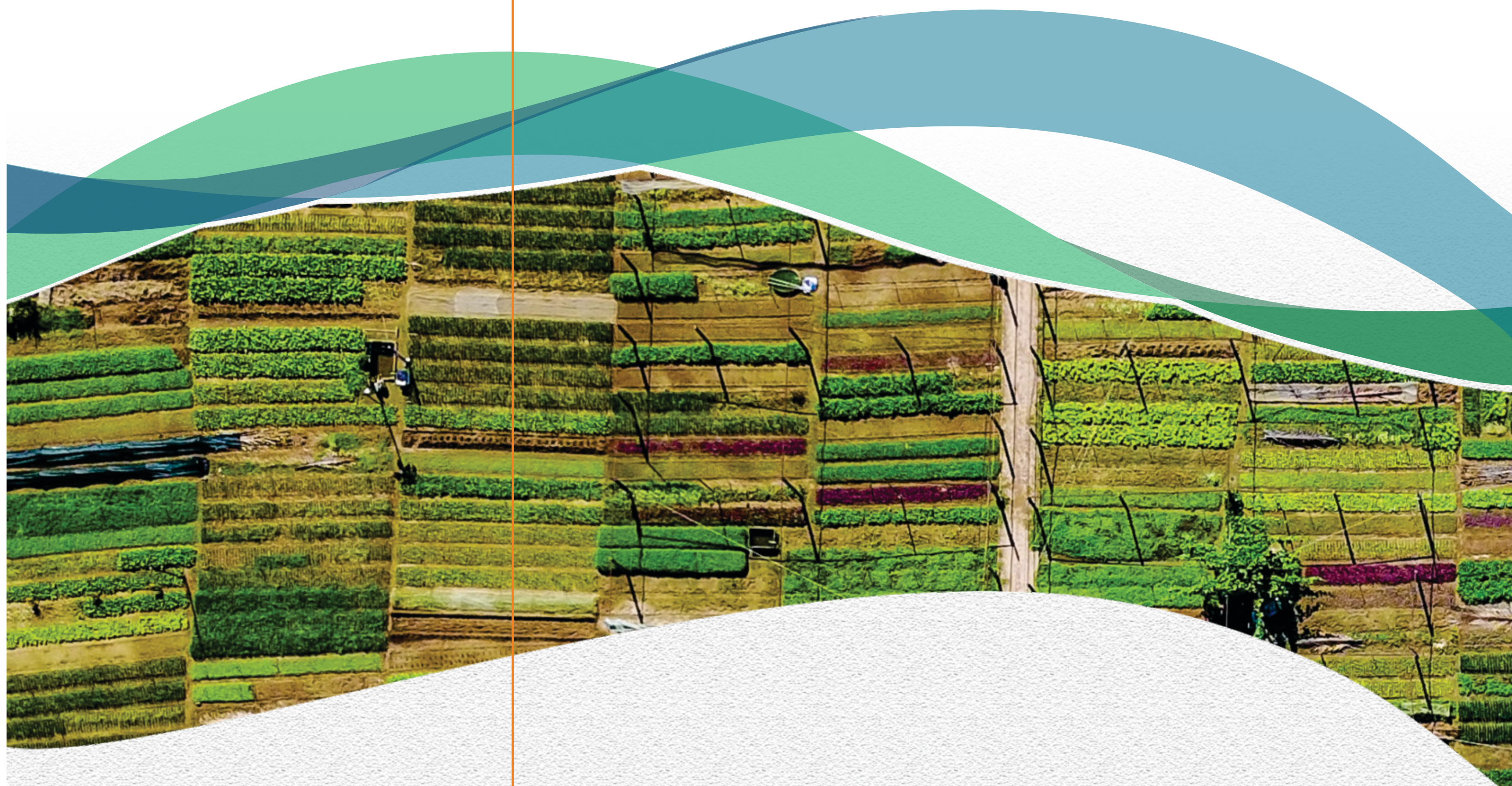
PROCEEDINGS OF THE 13TH INTERNATIONAL CONFERENCE ON

APPLICATION OF INFORMATION TECHNOLOGY IN AGRICULTURE ASIA-PACIFIC REGION

(APFITA 2022)

Application of Smart Technology for Achieving Sustainable Agriculture



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PREFACE

Warmly welcome to the 13th International Conference on Application of Information technology in agriculture Asia-Pacific Region (APFITA 2022), to be held on November 24-26, 2022 at the University of Engineering and Technology, Vietnam National University, Hanoi (VNU-UET)!

On behalf of the organizing committee, it is our pleasure to cordially welcome and invite you to the APFITA 2022 with the topic of "**Application of smart technology for achieving sustainable agriculture**", to be hosted by the University of Engineering and Technology, Vietnam National University, Hanoi (VNU-UET). This international conference is co-organized by APFITA (The Asian-Pacific Federation for Information Technology in Agriculture), INFITA (the International Network for IT in Agriculture, Food and the Environment), MARD (Ministry of Agriculture and Rural Development), Alliance Bioversity & CIAT and VIDA (Vietnam Digital Agriculture Association). In 2022, INFITA (the International Network for IT in Agriculture, Food and the Environment) board decided to organize the World Congress on Computer in Agriculture (WCCA) in conjunction with APFITA 2022 in Hanoi, Vietnam. The APFITA 2022 in Hanoi, Vietnam aims to bring together leading academic scientists, educators, students, engineers, researchers, government agencies and key actors from the private sector from all over the world to exchange and share the most recent innovations, and concerns, as well as discuss advanced technologies, trends, challenges, and solutions related to smart agricultural technology, to enhance the agricultural value chains and towards a sustainable agriculture. It also aims to provide an opportunity for postgraduate students (Masters and PhD) to present their research works and to interact with scientists and engineers in the research community and industry. This conference was supported by VNU Asia Research Center (ARC) from grants source by CHEY Institute for Advanced Studies and VNU University of Engineering and Technology.

As the Organizing committee of the Conference, we would like to express my sincere thanks to all sponsors, keynote/invited speakers, session chairs, committee members, authors, and participants to build this memorable and informative conference. We hope that this conference will give you a chance to learn about recent innovation, trends, concerns, practical challenges, and desired expertise in the field of Application of smart technology for sustainable agriculture.

Finally, it is a great and an honor to welcome you to an enjoyable program in the beautiful city of Hanoi. We hope that all of you will enjoy this special conference, take the opportunity to establish future international research collaboration and hope that you will have a great experience in your staying time in Hanoi, Vietnam.

APFITA 2022 Organizing Committee

VNU University of Engineering and Technology

PART A
FULLTEXT

THE SHOOT AND ROOT COMPETITION FOR CARBON ASSIMILATION IN THAI CASSAVA (*Manihot esculenta* Crantz of cv. Kasetsart 50)

Khongkhuntian, T.[1) *] and Ratttanaareekul, W.
1) King's Mongut University of Technology Thonburi, Thailand
Email: tanyarat.kho@kmutt.ac.th
* Corresponding author

ABSTRACT: It is well known that cassava shoot and root development are limited by carbon assimilation between shoot and root growth. Though the storage root appears two months after planting, leaf biomass appears to be the dominant investment. Normally, cassava plants should decrease their investment in shoots at 6 MAP. If the shoots have preference over tuberous root growth in the competition for carbon assimilates for too long, it will affect final yield. In our study, the KU50 variety showed root preference after 4 months of planting (MAP). Interestingly, the shoot and root competition of the KU50 variety still occurs even in the mid-stage (5-8 MAP) and late-stage (9-12 MAP) of the growth cycle, though it is not so obvious. Mid-stage fluctuation of biomass of root and shoot ratio can be up and down in the range of 5–10%, and late-stage root and shoot ratio are changed in the range of 3–5% depending on the plant age. The results of a field study with various water treatments also revealed that the carbon partitioning ratio between shoot and root biomass is a phenotypic trait in the KU50 variety, though environmental factors such as water stress had a minor effect on the so-called partitioning before 4 MAP. This trend is considered to be phenotypic traits which are heavily influenced by variety and will be a good key factor for plant breeding programs and estimation of harvesting time for most benefits for farmers.
Keywords*: Cassava, carbon assimilation partitioning, biomass.*

1. INTRODUCTION

Cassava, *Manihot esculenta* Crantz (Euphorbiaceae) is broadly planted in tropical and subtropical zones as it is a good source of starch, produced in its storage roots. The plant is a perennial plant, usually planted from stem cuttings. The storage root can be harvested in the first year, after 12 months, or in the second year if the location has a very short dry season, after 18 months (Ekanayake et al, 1998).

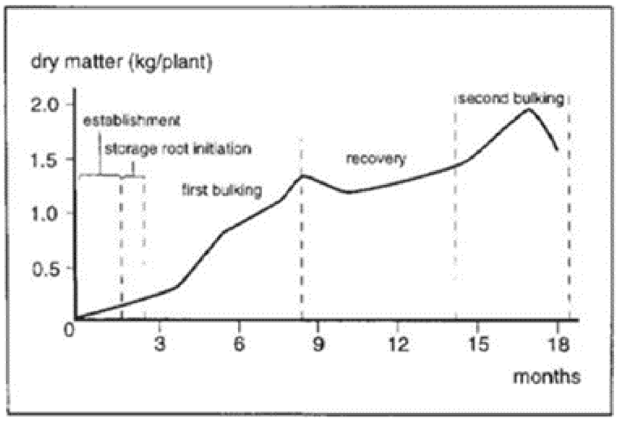

Figure 1. Growth pattern of a cassava plant from Ekanayake et al, 1998, p.10

Selecting cassava for higher yield and stress resistance is a goal to achieve more food security on a global scale. In Thailand, many varieties of cassava have been selected for morphological, structural, biochemical, and physiological traits that are suitable for the local microclimate and higher yield. Shorter harvesting time is also considered a desired trait in Thai cassava varieties (Malik et al., 2020); in Thailand, it is a common practice to harvest 9–12 months after planting (MAP).

Storage root yield is determined by crop growth and the partitioning of carbon assimilation between root and shoot. The source-to-sink carbon partitioning and carbon metabolism processes change throughout plant development and can affect the final root yield of cassava, along with various environmental factors, especially water and fertilizer. Cruz et al. (2003) work showed that N-deficiency can affect carbon assimilation. Photosynthetic rates decreased with increasing N-deficiency, suggesting a limited capacity for carbon export from source leaves under N-limitation. However, the decreased photosynthetic rate is associated with a decrease in reducing saccharide but not starch accumulation. In water stress cassava, growth of all plant parts decreased substantially. Sasiprapa et al. (2019) work in a field experiment at Kamphaeng Phet Province in 2015 showed that under the stress condition, the maximum net photosynthesis rate is lower than the non-stressed plant. At 6MAP, the period of photosynthesis is also affected by water stress, thus hindering the higher yield of storage roots. Interestingly, though the growth of all parts in water-stressed cassava is decreased, a study of Chiewchankaset et al., 2022 in KU50 and HN varieties showed that the stem and storage roots still maintained the starch concentration. The stems gradually lost starch during stress. Their work suggests that stem carbohydrate reserves are important in sustaining basal growth during a prolonged stress and providing reserves for regrowth upon resumed rainfall. Hence, suggesting the predominant genetic effect of the carbon partitioning strategy of each variety.

The objective of the study is to investigate the effect of water treatment, which is an environmental factor, on the carbon partitioning pattern of the Thai cassava variety in field experiments throughout the plant development cycle.

2. MATERIALS AND METHODS

The study was conducted in the Experimental Field in Klong Pong Learning Center for Agriculture, Technology Transfer and Management, Lam Nang Rong subdistrict, Non Din Deng District, Buriram Province, Thailand, at 14.242399972553267, 102.69374687196944(DDM) during February 2014-February 2015. The whole area used in this experiment is approximately 8 Rai. The precipitation during the whole crop cycle was 1131.1 mm.

Cassava, Kasetsart 50 (KU50) variety, is propagated using 20-25 cm long stem cuttings, taken from plants approximately 12 months old. The spacing is 0.8 meter by 1 meter apart along each row and across ridges. The experiment was conducted in split-plot designs, consisting of 3 treatments: supplementing the water to the field to maintain 50%FC, 75%FC, and 100%FC. Each treatment had two subplots. Each subplot was separated by at least two border rows.

Irrigation was carried out using drip irrigation systems, and water volume and schedule were determined using soil moisture sensors stress to supplement water in order to maintain the desired water level for each subplot independently. WATERMARK Soil Moisture Sensor-MODEL 200SS is used to measure soil moisture ranging from 0 (saturated) to 200 (dry) centibars and is collected periodically by WatchDog 1200 data loggers. Rainfall data was collected by the WatchDog 2900ET Weather Station that is located in the center of the field and collected by SpecWare Pro software. A 15-minute logging interval was set as the data collection frequency.

Fertilization was applied at the time of tilling with dried chicken manure at a dose of 500 kg/rai. The field was re-fertilized with complete fertilizer (15-7-18) a month after planting with a dose of 50 kg/rai. During the investigation, there were no major pests or diseases during the experiment.

Six plants per treatment were harvested every month until 12 months after planting (MAP) The plant samples were separated into total shoots (leaves, petioles, stems excluding stem cuttings), and total roots for dry biomass measurement.

3. RESULTS AND DISCUSSION

3.1. KU50 shoot investment in various stages and water treatments

The data set from each subplot showed differences in the value of biomass, which is an effect of the soil factor in the location of each replication. The trend is almost exactly the same. Moreover, the analysis of shoot dry biomass from 2 different plot replications shows that the shoot dry biomass remains steady after 4 MAP, in all water application differences (Figure 2). Considering cassava leaf life in KU50, which averages about 88 days (Phosaengsri et al., 2018), this may be the first batch of leaf fall that triggers the root biomass accumulation. According to Alves and Setter (2004), leaf expansion and development is about to halt even during water stress. Though the leaf can resume its vigor after re-watering, the development of the canopy was delayed. It is clearly shown that KU50 has reached the desired canopy within 4 months, keeps maintaining it and starts to show root investment preference after 4 MAP. This is evidently a variety characteristic as the result in the field shows that the difference in the shoot biomass in each water treatment is not significant in both fresh and dry biomass.

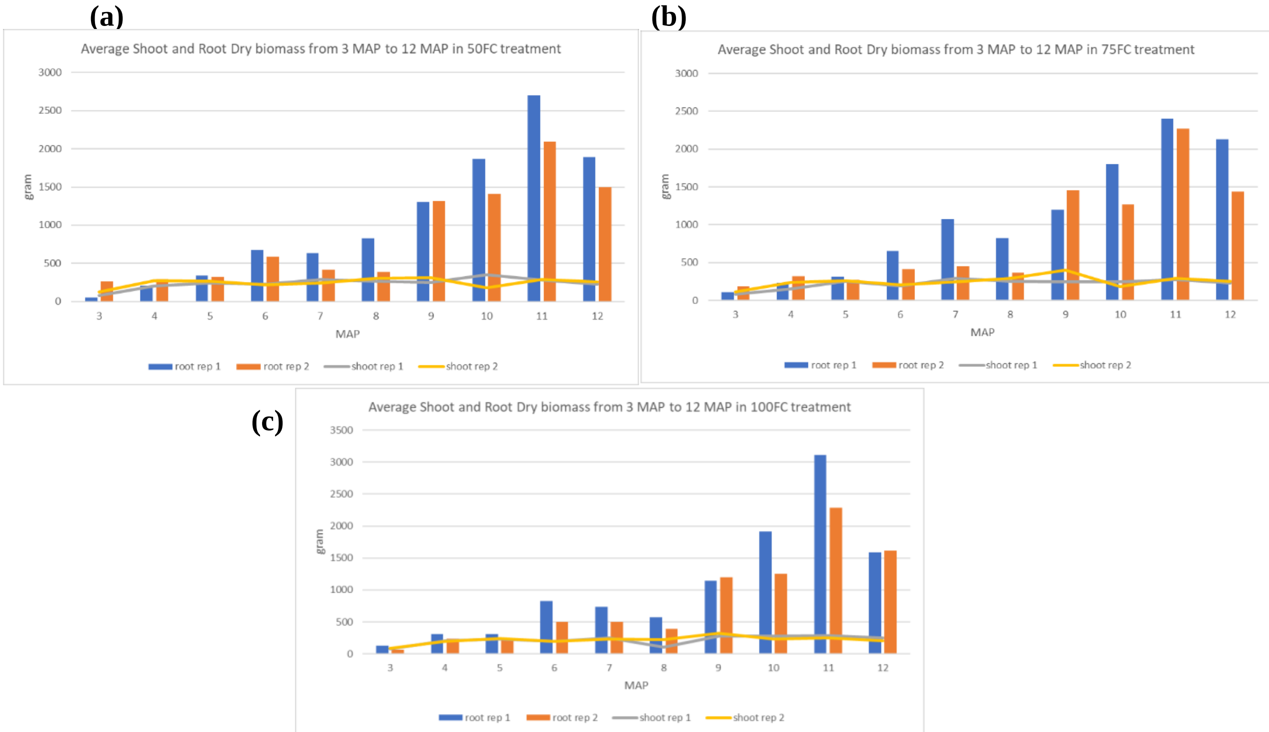

Figure 2. Averaged dry biomass from shoot and root in different water treatments of KU50. (a) 50%FC (b) 75%FC (c) 100%FC

3.2. Shoot-Root ratio of biomass in different stages and water treatments of KU50

Regarding all the different water treatments and obtained data, KU50 shows a slight fluctuation in root dry biomass accumulation in the mid-stage or the first bulking period in the same pattern, starting to increase in 5MAP, reaching the peak at 7MAP, then slightly decreasing in 8MAP. This phenomenon can be explained by the cassava leaf life in KU50, which averages about 88 days (Phosaengsri et al., 2018) and this may be the second batch to fall. Mid-stage fluctuations of biomass of root and shoot ratio can be up and down in the range of 5–10% of total biomass (Figure 3).

In the late-stage or recovery stage (8-12 MAP), KU50 starts the same pattern of fluctuation in root dry biomass as found in the mid-stage but with greater volume, starting with 9MAP, increasing to 11MAP, then dropping to 12MAP despite adequate water supplementation (Figure 2B, C). Compared to the total biomass, root and shoot ratios fluctuated from time to time in the range of 3–5%.

According to the growth pattern of cassava (Figure 1), at 8–14 months, the cassava goes into a recovery stage and the biomass is dropped in the first phase of the stage, then slowly but steadily increased. Chiewchankaset and her coworkers (2022) believe that the pattern of shoot-to-root carbon partitioning is both affected by genetics and the environment, depending on the response of varieties. The results of this experiment, on the other hand, clearly demonstrated that, at least in KU50, there is a pattern of fluctuation of shoot and root biomass from time to time during the 8-12 month of planting (Figure 2, 3), a phenotypic trait that is heavily influenced by genetics but less influenced by water feeding or plot location.

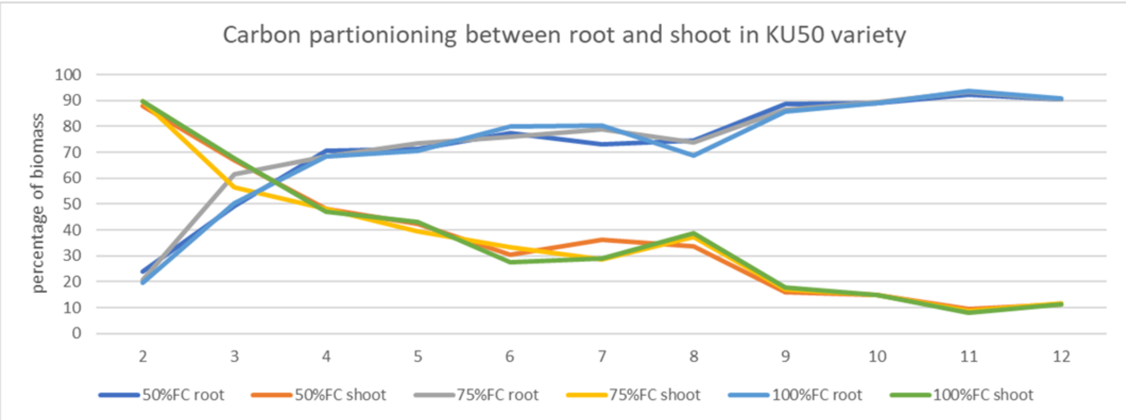

Figure 3. Changes in the dry biomass percentage of root and shoot at various developmental stages of Kasetsart 50 (KU50) in field experiments

4. CONCLUSIONS

This dynamic source-to-sink carbon partitioning trait in the late stage should be considered as a genetic potential characteristic of individual varieties for developing new high-yielding genotypes in cassava breeding programs. One of the important characteristics for cassava breeding when selecting a new variety is the Harvest Index (*HI*), which is measured in different stages (90, 180, and 270 days after planting; DAP, or 3, 6, and 9 MAP, respectively) to predict the fresh root yield (*FRY*). The *HI* was calculated by fresh root weight divided by the total fresh biomass (Barandica et al., 2016, Phosaengsri et al., 2019). Recently, Barandica and his colleagues (2016) consolidated phenotypic data from 14 years of cassava breeding and suggested that *HI* in the early stage was not as reliable as indirect estimation for *FRY* in the later stage. The result of the experiment also suggests that *HI* in 12MAP should be considered as another characteristic that is more reliable for a new variety selection. Moreover, from this knowledge, the practice of harvesting KU50 can be improved to estimate the time that carbon assimilation at the root is the highest, increasing benefits for farmers.

5. ACKNOWLEDGEMENT

This work was financially supported by the National Science and Technology Development Agency (NSTDA), National Research Council of Thailand and the Center for Translational Agriculture Research (CTAR), King Mongut's University of Technology Thonburi (KMUTT). The authors would like to sincerely thank members of the Center for Translational Agriculture Research (CTAR) and the Center for Agricultural Systems Biology (CASB) KMUTT for useful suggestions and comments.

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ANALYSIS OF DEFORMED WING VIRUS (DWV) INFECTION IN A BEEHIVE USING AUDIO RECORDINGS

Cheng-Chun Lee[1)], Hung-Jen Lin[1)], Mu-Hwa Lee[1)], Yun-Heng Lu[2)], An-Chi Liu[1,3)], and Joe-Air Jiang[1*)]

1) Department of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan
2) Department of Entomology, National Taiwan University, Taipei, Taiwan
3) BioEnergy Research Center, National Taiwan University, Taipei, Taiwan

* Corresponding author

ABSTRACT: Apiculture currently faces many difficulties, of which deformed wing virus (DWV) is regarded as one of the main hazards. To avoid the damage caused by DWV outbreaks, beekeepers must spend significant time and effort observing the health status of bee colonies, resulting in a substantial increase in production costs. To solve this problem, this study established an audio monitoring system to monitor the infection of DWV in the beehive. During the experiment, each bee colony was fed with 200 mL of 0.7M with 10^8 virus number/μL virus sucrose solution daily. Then, 4 bees from each hive were sampled every 2 days, and a real-time quantitative PCR was used to measure the DWV replication on a single bee. At the same time, the results of the real-time quantitative PCR were compared to the recordings from the real-time audio monitoring system for each beehive. This study then built a prediction model from the audio recordings of beehives to predict the level of DWV infection of the bee colony. The linear prediction model had an MSE of 0.062 and an MAE of 0.156 on the test set while the binary classification model achieved 97.8% of accuracy, demonstrating that the model accurately predicts most estimated qPCR values. With the audio monitoring system, beekeepers can grasp the infection level of DWV in the bee colony in real time, and take proper measures before the outbreak of DWV, thereby reducing economic losses caused by DWV infection.

Keywords: *Beehive, Honey Bees, Deformed Wing Virus, Real-Time Quantitative PCR, Audio Monitoring System.*

1. INTRODUCTION

As a pollinator, honey bees are essential to agriculture, and they pollinate many flowering plants. In 2006, a large number of bee colonies died in North America, and it's generally referred to as the colony collapse disorder (CCD). As of now, there is no conclusive explanation, but pesticides, viruses, malnutrition, or varroa mites could be responsible. A large number of bee colonies disappeared, causing not only a serious blow to the bee industry but also to many crops that were unable to pollinate.

It is currently only possible to determine whether bees are affected by pesticides or viruses by manually observing the state of their hives. Real-time monitoring of infection levels within a hive requires continuous monitoring and uninterrupted observation. It is impossible to achieve the above characteristics through traditional manual observation. Additionally, manual observation is time-consuming and labor-intensive, but it will also affect the natural activities of the colony as a whole.

DWV (deformed wing virus) is a common bee virus spread by Varroa mites and bees. Infected bees may display symptoms such as reduced wing size caused by DWV[3], which is transmitted by

Varroa mites. DWV-infected bees experience a dramatic reduction in lifespan and are evicted from the hive to avoid further infection within the hive.

In order to immediately grasp the impact of the virus infection on the status of bees, and to detect abnormalities as soon as possible to avoid huge losses in agriculture, this study collected audio data from the beehives by recording, and then analyzed the spectrum to create two prediction and classification models by using neural networks. The classification model determines whether the bees in the hive are infected with the DWV virus and whether the health status of the bee colony is abnormal through binary classification while the predictive model predicts the qPCR value. If possible, the beekeepers could be notified as soon as the situation occurs to reduce losses and prevent them before they occur.

2. MATERIALS AND METHODS

In this study, the western honeybee Apis mellifera (purchased from Hsinchu City Bee Farm - Abin Pure Honey) was used as the experimental subject and was raised in the National Taiwan University Insectarium, with a total of four hive boxes. Experiments were conducted between August 10, 2022 and August 20, 2022. 200 mL of 0.7M with 10^8 virus number/μL virus sucrose solution per hive were prepared and fed to the bees once a day for eleven days.

Figure 1. Experimental field

In this experiment, a Raspberry Pi 3B+ was used as the main computing unit and a microphone was used to record audio. After the device was protected, it was placed on the top of the beehive to collect the recording data in the beehive, and the recording files are divided into different files on a per-minute basis. A random sample of four bees were taken from each of the four beehives for each qPCR test. In the event, there is no detection or only one detection, the qPCR value for the day is set as not detected; if there is detection on the day, and the number of detected bees exceeds two, the average of the detected bees is calculated as the qPCR value for the day.

A qPCR measurement was conducted every two days during the experiment. Table 1 showed the qPCR results of four bees sampled from each beehive. Figure 2 illustrated a line graph of the qPCR results of each beehive during the experiment. In the first few days, no qPCR signal was detected, and the DWV virus was detected on the fourth day of the experiment. A linear regression analysis was performed on the data points with the number of days detected, and the regression line was used as an estimate of qPCR for audio data (Figure 3). MFCC (Mel-Frequency Cepstral Coefficients) were used for subsequent analysis of the audio data after enough data was collected.

Table 1. qPCR results

hive\d.p.i.	0	2	4	6	8	10
Hive 1					8.24766705	8.50328522
					8.14298999	9.11798455
					7.92472719	8.64805137
					8.16303454	9.54560148
Hive 2			7.85863573	7.77945449	8.53719935	
			7.82300099	7.74381974	8.25657574	9.03112486
			7.99894754	7.91976629	8.21648665	9.08012264
					8.02049556	9.64359702
Hive 3			8.17489408	8.09571284		9.11798455
			7.84304553	7.76386428	9.34788977	9.64359702
			8.10139742	8.02221618	9.94477173	9.03112486
					8.78390883	
Hive 4			7.94104108	7.86185983	8.07172051	8.23602464
			7.99894754	7.91976629	8.55501672	7.85072397
					8.68419267	8.03680945
			7.46765048	7.9576282		

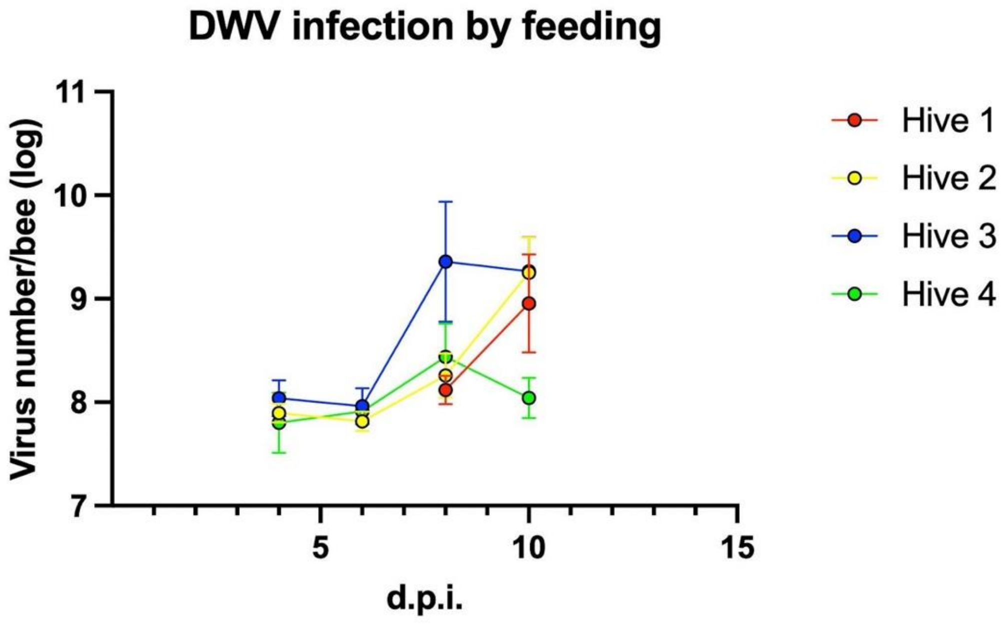

Figure 2. DWV infection by feeding, d.p.i. (days post infection) is the number of days elapsed, virus number/bee(log) is the log value of the qPCR value.

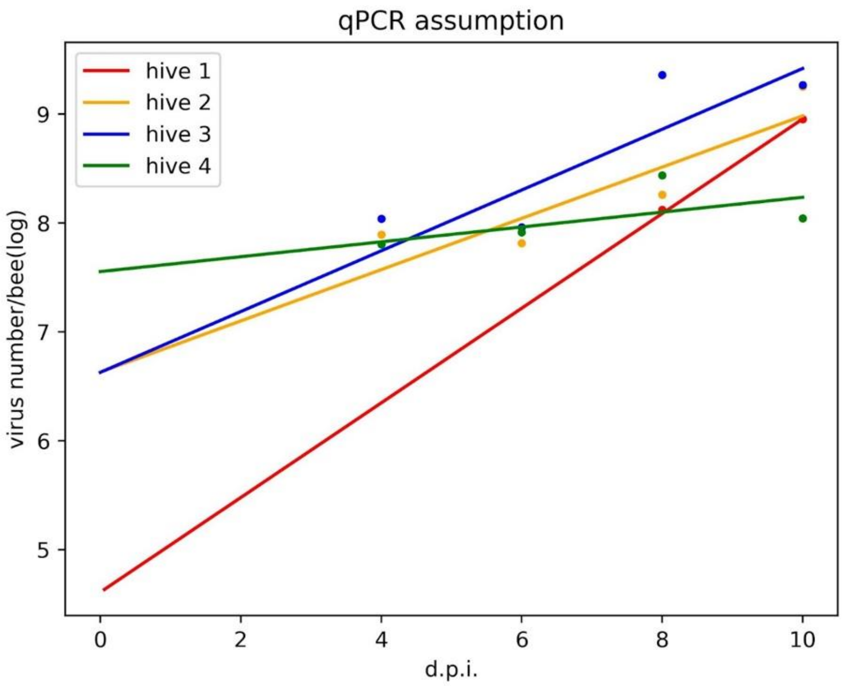

Figure 3. qPCR value assumption

It consists of two types of neural networks, one predicts the linear value of qPCR for DWV virus, and the other predicts whether DWV virus is present based on a binary classification.

As an activation function, the neural network uses a relu (rectified linear unit) function, followed by long-short term memory (LSTM) for sequence analysis, and finally two different methods for obtaining the predicted qPCR value and the binary prediction of infection or not. In this study, we developed a neural network prediction model that could be used to detect DWV virus infection in beehives. Figure 4 showed an overall diagram of the system architecture. Once the model is built according to the above steps, the system will extract the features of the audio data collected in real time with MFCC, and then use them to make predictions about the beehive's current state. Based on the prediction results of the model, the beekeeper could determine the current status of the beehive and react immediately if any abnormal conditions arise.

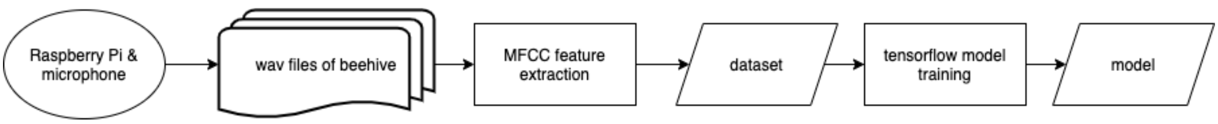

Figure 4. Experimental flow chart

3. RESULTS AND DISCUSSION

As for the dataset, MFCC-converted audio recordings from the beehive are used, and each beehive uses 11 days' worth of recordings. Of these, training sets make up 80%, test sets make up 20%, and validation sets make up 10% of training sets.

3.1. Linear prediction model

On the validation set, the linear prediction model had an MSE of 0.060 and an MAE of 0.152. As a result of the test set, the MSE was 0.062 and the MAE was 0.156. Figure 5 showed the predicted data points for the test set, demonstrating that the model accurately predicts most estimated qPCR values.

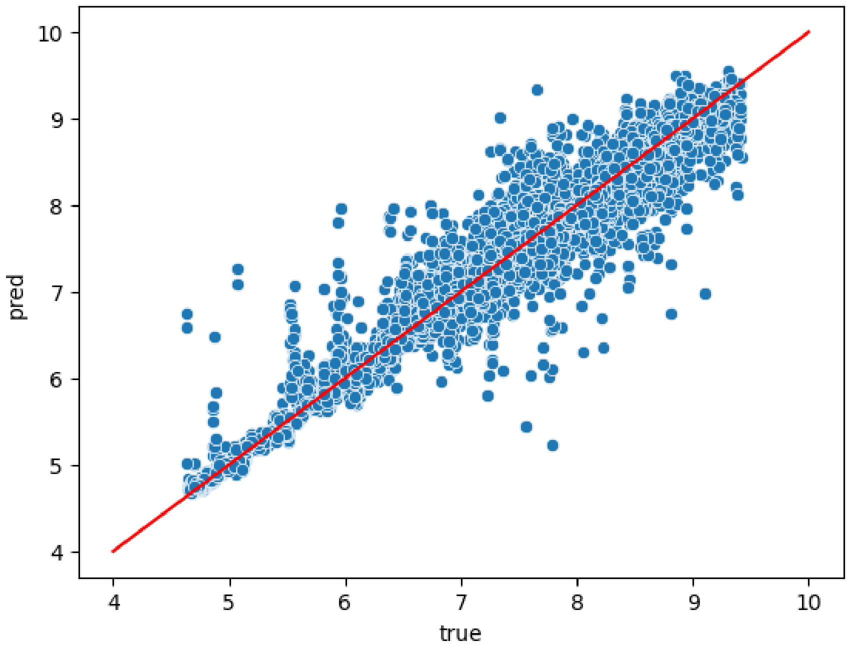

Figure 5. Linear prediction results of the test set

3.2. Binary classification model

As seen in figure 6, 97.89% of the data could be classified correctly using the binary model, and the f1-score is 0.9829, showing that this model is accurate for most abnormal conditions.

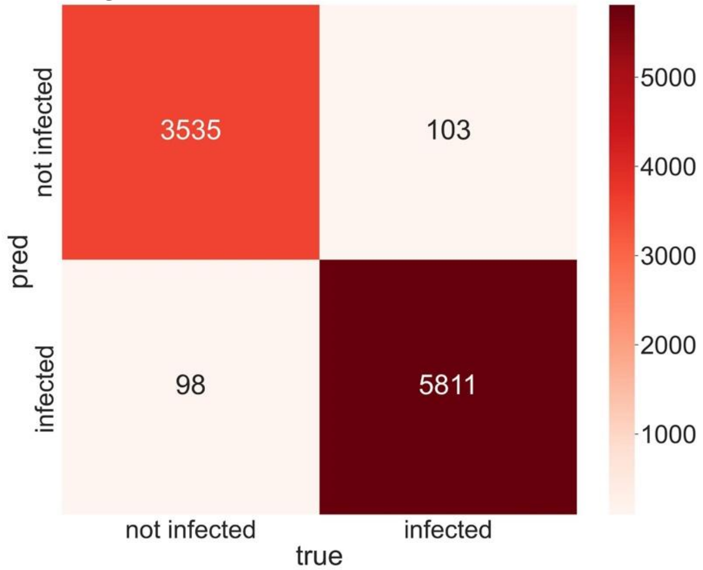

Figure 6. Binary classification results of the test set

4. CONCLUSIONS

It has been demonstrated that the neural network prediction models established in this system are quite effective and efficient, based on the results of the tests. This system greatly enhances the convenience of managing bee colonies and bee farms. By using this audio alarm system, bee farmers not only save a great deal of time and manpower, but they are also able to digitalise bee-related data, making it convenient to analyze different situations in the future, and it increases the generality and versatility of the model.

5. ACKNOWLEDGEMENT

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RESEARCH ON THE POSSIBILITY OF USING YEAST AND MYCORRHIZAL FUNGI TO RESTORE DROUGHT SOIL

Minh Thi Nguyen[1], Huong Thi Tu[1], Chau-Thuy Pham[2]

1) Faculty of Resources and Environment, Viet Nam National University of Agriculture. Trau Quy town, GiaLam district, Hanoi, Vietnam.
Email: NguyenMinh@vnua.edu.vn.

[2)] University of Engineering and Technology, Vietnam National University, Hanoi, 144 Xuan Thuy, Cau Giay, Hanoi, Viet Nam. Email: thuypc@vnu.edu.vn

* Corresponding author: Minh Thi Nguyen

ABSTRACT: Along with climate change, the area of dry land is increasing in the world and in Vietnam with different levels, leading to strong impacts on ecosystems and human life. A warming climate could make a third of the earth's surface dry. It is important, therefore, to find solutions for rehabilitation and drought soil using. The application of microorganisms in the environment is becoming more and more suitable to ensure environmental quality, yield and quality of agricultural products and especially contribute to soil improvement. The study was conducted for evaluation and selection of beneficial microorganisms: yeasts (capable of producing polysaccharide mucous membranes, good heat tolerance, high enzymatic degradation, ...) and mycorrhizal fungi, which establishment of symbiosis in plant and resistant to drought conditions. The combination of selected strains including yeast strains (Saccharomyces and Schizosaccharomyces) and strains of symbiotic mycorrhizal fungi (*Gigaspora decipiens* and *Dentiscutata nigra*) are applied to restore drought soil in pot experiment. The tested results showed that, using a combination of yeast and Arbuscular Mycorrhizae on mung bean (*Vigna radiata*) enhanced plant growth at all monitoring parameters compared to the control formula at the significant levels LSD5%: root length increased 42.10-80.06%; number of fruits increased by 61.29-85.71% in all experiments with different soil moisture (40%, 30% and 20%). Moreover, this inoculation also contribute improving soil properties and available nutrients (especially the increase in soil moisture by 32.96 to 38.86%) due to the synergistic effect of yeasts and Arbuscular Mycorrhizae; so could potential for practical applications to reclamation and using drought soil, adapt to climate change.

Keywords*:* *Climate change, Drought soil, Abuscular Mycorrhizae, Microbes combination, Yeast.*

1. INTRODUCTION

Along with socio-economic development, global climate change is becoming more and more complicated, leading to strong impacts on ecosystems and human life (Koutroulis, A. G., et al., 2019; Nordhaus, W., 2019). In addition to prolonged droughts and floods, dry land is becoming more and more serious with an increasing area (Cianconi, P. et al., 2020; Hoegh-Guldberg, O., et al., 2019). A warming climate could make a third of the earth's surface dry. It is estimated that 12% of land have experience drought by 2100 due to changes in rainfall (Yao, J., et al., 2020), but drought will occur over 30% of land if evaporation rates are higher due to climate change by increasing energy status and air humidity (Ministry of Agriculture and Rural Development, Vietnam 2014). In latest climate report, the Intergovernmental Panel on Climate Change (IPCC) warns that soil moisture will decrease globally and drought conditions in agricultural areas are at risk of worsening. That risk has been leading to a decline in productivity and crop output in arid regions with varying degrees in the world in general and Vietnam in particular.

A number of measures aimed at restoring dry soil have been applied in practice. Besides reasonable farming and irrigation measures, the use of chemical humectants such as PMAS-1 (Super absorbent polymer), ... also brings certain effects. However, these measures have some limitations such as high cost and environmental impact in different aspects. Therefore, the research and production of biological products with good moisture-retaining effect and drought-resistant ability to restore drought-stricken soil, ensure crop productivity and environmental quality is essential. and needs attention.

Yeast can form the mucous membranes structure which mainly polysaccharides formed from the condensation of monosaccharides through glucoside bridges, in addition, mucous membranes are composed of polypeptides and proteins. This membranes has the effect of reducing water evaporation, increasing the water holding capacity of the soil, maintaining soil moisture in terrain conditions without irrigation for a long time, contributing to improving the survival rate of plants (Abdulrhman et al., 2022; Ramya. P et al., 2021; Quin Xi et al., 2019). The Institute of Biotechnology (Vietnam Academy of Science and Technology) has successfully produced a biological product to keep soil moisture called Lipomycin-M. The main ingredient is the yeast strain *Lipomyces* PT7, an isolate from bare land in Ha Hoa district, Phu Tho province (2006), which has the advantage of being able to form mucous membranes in dry soil conditions to help reduce drainage, maintaining soil moisture in the absence of irrigation water for a long time, contributing to improving the survival rate of plants, good support for greening bare land and bare hills.

Besides, Mycorrhizal fungi have the ability to symbiosis on the host plant, which enhances root growth, increases nutrient absorption especially phosphorus, resulting in increased tolerance to adverse living conditions and disease resistance, thereby promoting plant vitality, stimulating plant growth and improving soil properties (Hao, Z.,et al., 2019; Campo, S.,et al., 2020; Adeyemi, N. O., et al., 2021) . There are also some studies on the use of symbiotic mycorrhizal fungi in the restoration of dry soil, such as using the biological product Mycorrhizae imported from the US. This product is produced from the endosymbiotic mycorrhizal fungus-Arbuscular Mycorrhizae (AM), which has the effect of increasing the growth and development of the roots, the ability to absorb nutrients and increasing drought tolerance,... However, the effect of these bioproducts are still limited in their mass application.

This study was caried out in order to find a solution to improve, restore and use dry land, ensure productivity, crop quality and protect the environment with the hypothesis of promoting the synergistic effect of yeast and symbiotic mycorrhizal fungi in dry soil restoration.

2. MATERIALS AND METHODS

2.1. Materials

The indigenous yeast and AM, Alluvial soil (in Gialam, Hanoi, Vietnam), peat, compost, nutrient (inorganic fertilizer NPK) and seeds were chosen for study to arm guarantee for AM and seedlings growth in pot experiment.

2.2. Estimate the biological activities of AM

The rhizosphere soil was processed to extract the resting spores i.e. extramatricular chlamydospores, using the modified method of wet-sieving and decanting suggested by Gerderman and Nicolson (1963). AM spores were counted under a dissecting microscope and collected individually using pipette with a finely extruded tip and fine forceps and separated into different groups based on their morphology, color, and type of hyphae attachment; then classified by Franke and Morton system (1988).

The sample of fresh roots was cleaned in 10% KOH, stained in 0.05% Trypan blue, and stored in lactic acid: glycerol (1:1, v/v). The AM colonization was assessing by using a magnifel-intersect method (McGonigle et al., 1990), where roots are observed at 200x magnification and arbuscules are quantified separately from vesicles and hyphae.

Soil chemical, physical and microbiological properties were determined according to general methods under Vietnamese Standard.

To investigate the effect of nutrient on the spore activities, spores were stored in water at 4°C until required, then surface-sterilized in chloramines T and streptomycin and washed 5 times in sterile water. Then, AM spores were put in 24 well plate (1 spore/ well; 10 spores/ solution, 2ml solution/well) and incubated at 25°C in the dark. The nutrient broth was extracted by mixed with sterile water (1:10 ratio) and the filtered solution was sterile by passage through a 0.2 μm Millipore membrane. The spore activities were observed follow four steps during the spore growth: Initial stage-new spore without hyphae (A type); next stage-spore with one hyphae (B type); development stage-extension of hyphae (C type) and mature stage-auxiliary cell attached of the hyphae (D type) with 3 levels (slight, moderate and extensive).

For enrichment of AM spores, the plants grew in a greenhouse during 2 months, were later harvest, and analyzed for mycorrhizal colonization and host plant growth. The mung bean seeds were sterilized in 10% NaOCl solution about 1 hour and rinsed thoroughly with de-ionized water and then germinated on moist filter paper in sterilized Petri dishes at 25^0C. The seeds germinated about 2 weeks, so seedlings were soon placed into the pots with 10 AM spores per one. Soil was passed through a 2 mm mesh sieve before using, autoclaved twice at 80^0C for 30 minutes.

2.3. Determination of mucinogenic ability (polysaccharite) of yeast strains

The yeast isolates were clarify by morphological method based on the taxonomy key of Kreger-van Rij (1984). The ability to produce mucous membranes of yeast strains was evaluated through the results of measuring the viscosity of yeast cultures. Yeast strains were cultured on Hansen liquid medium on a shaker at 160 rpm for 72 h, then measure by using Brookfield viscometer (USA). Proceed to select the parameters for the machine: shaft type S61, rotation speed 100 rpm. Viscosity value is meaningful when the helix rate of the flow reaches from 10 to 100. Take 25ml of yeast culture into the measuring tube, install the measuring tube on the rack and fix it with screws. Set the time to record the results as 2 minutes.

2.4. Determination of enzyme activity by diffusion method on agar plates (William, 1983)

Using Hansen medium supplemented with 2% starch, gelatin and CMC substrates, respectively, for determination of amylase, protease and cellulose enzyme activities of yeast. Aspirate 0.2 ml of the culture into the agar well, put the petri dish in the refrigerator for 6 h to allow the enzyme to diffuse on the agar plate, then put it in the incubator at 28ºC for 48 h and then stain it with lugol solution, after appearing the clear zone, measure the diameter.

2.5. Quantification of IAA by Salkowski's method

Yeast was grown in Hansen medium supplemented with 0.1% tryptophan, shaken at 200 rpm at 30^0C for 48 h. The culture was then collected and centrifuged at 5500 rpm for 5 min.

Aspirate 1ml of the clear solution obtained after centrifugation into a test tube containing 2ml of Salkowski's reagent, and as a control, 1ml of liquid medium that has been centrifuged without microorganisms added to 2ml of reagent. Shake well, leave in the dark for 20 minutes. Colorimetric by spectrophotometer at 530 nm. The OD index was compared with the standard plot to calculate the amount of IAA in the culture. IAA content is in µg IAA/ml.

Build IAA standard curve by using 10 volumetric flasks numbered in order from 0 to 10 with tube 0 as negative control, IAA content of the flasks in increasing order is 0, 5, 10, 20, 30 , 40, 50, 60,70, 80, 90 µg IAA/ml.

The standard curve equation has the form: $Y = a. X + b$, where X is the concentration of the sample (µg/ml), Y is the optical absorbance (OD 530 nm). The content of IAA equivalent to IAA in the sample is according to the formula: $X = (Y-b)/a$.

2.6. Evaluation of pathogen resistance of yeast strains

Using the method of co-culture on petri dishes, the same conditions between the microorganisms to assess the resistance to diseases and harmful agents. The pathogens used are *Fusarium oxysporum* causing wilt disease on tomato plants and *Phytophthora infestans* causing late blight on potato and tomato plants.

Cultivate yeast on 9ml of specialized medium solution on a shaker at 150 rpm. After 72 h, the culture solution was evaluated for disease resistance. Measure the clear zone appear after co culturing yeast on pathogen petri dish in 48h.

2.7. Test experiment

The experiment seri consist of 12 treatments with 5 replications with 5 plants/pot. Each pot holds 5kg of alluvial soil.

- Control: use the amount of fertilizer according to intensive farming (0.2g Urea; 0.07g super phosphate; 0.3g KCl/pot)
- Treatments using yeast preparations (10ml of preparation mixed with 50ml of clean water) fertilize 10ml/pot from the time the plant shows real leaves.
- Treatment using AM inoculum with 10g of inoculant/pot from the time the plant has real leaves
- Treatment using preparations from yeasts and AM: 10ml of yeast inoculum and 10g of AM preparation/pot from the time the plant has real leaves

Table 1. Experiment treatment

STT	Treatment	Soil moisture (%)	Bioproducts
1	CT1	40	Control without inoculum
2	CT2	40	Yeast
3	CT3	40	AM
4	CT4	40	Yeast and AM
5	CT5	30	Control without inoculum
6	CT6	30	Yeast
7	CT7	30	AM
8	CT8	30	Yeast and AM
9	CT9	20	Control without inoculum
10	CT10	20	Yeast
11	CT11	20	AM
12	CT12	20	Yeast and AM

Growth and development on mung bean plants: plant height, root length, number of fruits, leaf area, etc. Were measured directly. Soil properties before and after the experiment were analysis by American book protocols seri No 5.

The results were statistical analysis by IRRISTAT 5.0 program.

3. RESULTS AND DISCUSSION

3.1. Drought soil properties in Phuc Dong commune, Ha Tinh province

Based on the distribution of arid soil in Huong Khe district, Ha Tinh province, the soil sampling area and the root zone of fruit trees in Phuc Dong commune was chosen for study. The properties of soil samples in the sampling area of Phuc Dong commune were analyzed and the results are presented in Table 2.

Table 2. Soil properties in Phuc Dong commune

Parameters	Result
pH	4.39
Moisture (%)	13.23
OC (%)	0.76
N (%)	0.16
Total postassium (%)	1.01
Total phosphorous (%)	0.09
P_2O_5 (mg/100g soil)	9.12
K_2O (mg/100g soil)	9.66
Total dissolved salts (%)	0.091

The investigated results show that the soil in the sampling area has low pH (acidic soil); low total organic matter content; total nitrogen, phosphorus and potassium were moderate; available phosphorus and potassium content was in poor level; soil moisture very low, which are characteristic of drought soil. Therefore, research to restore and use drought land in this area is essential.

3.2. Isolate the yeast and Arbuscular Mycorhizae

Some fruit soil and flower were chosen for sampling because saccharose content high, which suitable for yeast development. From 8 samples of rhizosphere soil of fruit trees, 7 samples of flowers was got 75 yeast isolates including 51 isolates from fruit tree soil, 24 isolates from flowers. Yeast strains are quite diverse in morphology, size, and are predominant in the soil of fruit trees.

Table 3. Yeast isolates from soil and flower

Sample	Plant source	Yeast isolate
Root zone soil	Grapefruit	10
	Banana	3
	Sapodilla	6
	Guava	9
	Apple	8
	Papaya	5
	Sugar cane	6
	Litchi	4
Flower	Hibiscus	12
	Five-colour	5
	Chrysanthemum	2
	frangipani	2
	Jasmine	3
Total		75

From 7 soil samples, 19 isolates of symbiotic Arbuscular Mycorrhizae (AM) were collected. Depending on the type of host plant and the land in which it lives, the AM number as well as the morphological and size characteristics of AM strains are also different. In which, the highest number of mycorrhizal strains were isolated on *Eleusine indica* Gaertn (7 isolates); at least on *Bidens pilosa* (4 isolates) and the majority of mycorrhizal isolates on alluvial soil (12 isolates).

Table 4. Arbuscular Mycorrhizae isolates from rhizophere soil

Sampling location		AM isolates
Gia Lam	*Eleusine indica* Gaertn	4
	Echinochloa colona	3
	Bidens pilosa	2
	Artemisia vulgaris	3
Huong Khe	*Eleusine indica* Gaertn	3
	Bidens pilosa	2
	Artemisia vulgaris	2
	Total	19

3.3. Biological characteristics of selected yeast and mycorrhizal strains

In general, 6 selected yeast strains have high ability in polysaccharide mucous production, enzymatic activities, phosphorous decomposition, production of growth promoter – IAA (Indol acid acetic), adaptability to wide pH and temperature range, plant disease resistance and high antibiotic tolerant (Table 5.) Therefore, they could apply potential for producing of biological products to restore and use dry land.

Table 5. Biological characteristics of selected yeast strains

No	Label	Growth time (h)	Viscosity (mPa.s)	Clear zone (cm)				IAA (µg/ml)	Adaption			Resistance (cm)		Classify
				Starch	Protein	Xenlulose	P		t°(°C)	pH	antibiotic (mg/l)	Fus	Phy	
1	1B3	24	1.51	0.1	2.2	-	-	4.22	20-45	4-8	1000	0.9	0.6	*Saccharomyces* 1B3
2	1B5	24	1.59	2.2	2.9	3.2	0.3	4.12	20-50	4-8	1000	0.5	0.3	*Saccharomyces* 1B5
3	1HX4	24	1.50	3.2	2.2	3.2	0.1	3.84	20-50	4-8	1000	0.5	0.6	*Saccharomyces* 1HX4
4	3BN	24	1.49	3.2	2.4	1.9	0.1	4.09	20-50	4-8	800	0.6	0.8	*Saccharomyces* 3BN
5	3PG1	24	2.82	-	1.6	3.1	0.1	7.35	20-50	4-8	800	0.6	0.6	*Schizosaccharomyces* 3PG1
6	3V1	12	1.61	0.1	1.6	2.0	0.1	6.85	20-50	4-8	1000	1.4	0.4	*Saccharomyces* 3V1

Note:(-) No activity ; Fu (Fusarium oxysporum); Phy (Phythophthora insfestan)

The AM spores were quite diverse in shape, color and size. Most spores are spherical, nearly spherical, but some spores are oblong or irregular. The spores have different colors and sizes range from 210 - 380 µm. AM strains have different distribution. The symbiotic mycorrhizal fungi that can be distributed in many different lands are better able to survive and adapt to the environment. This result is also completely equivalent to the research results of Nguyen Thi Minh (2014) on the morphological characteristics and size of AM strains isolated in the alluvial soil of the Red River Delta.

Table 6. Characteristics of selected mycorrhizal fungal strains

Label	Sampling location	Shape	Colour	Size (µm)	Germination rate (%)	Clarify
AM1	Gialam	Spherical, near spherical, some irregular	Clear white to light dark green	290-380	80	*Scutellospora* sp 1
AM4	Gialam	Spherical to near spherical	Clear white to creamy white	270-320	90	*Gigaspora decipiens*
A1	Gia Lam, Huong Khe	Spherical, near spherical, some elongated	Light yellow brown to dark brown	300-380	80	*Gigaspora* sp2
A2	Gia Lam, Huong Khe	Spherical, near spherical	Yellow brown turns black	210-310	90	*Dentiscutata nigra*

Four AM strains with good characteristics were chosen to continue test experiments on inoculum to host plants (Table 6). The symbiotic mycorrhizal fungus is characterized by an obligatory symbiosis with the host plant roots, and depending on the host plant, the symbiotic ability of the mycorrhizal fungus is also different. Legume nodule bacteria have the ability to self-assimilate nitrogen, promoting the establishment of a symbiotic relationship of mycorrhizal fungi with plants, so mung bean was selected as host plant. When inoculating plants, strains of AM capable of enhancing the growth and development of the host plant as well as being able to penetrate the root of the host plant and produce many new spores will have high vitality, good growth and development ability (Nguyen Thi Minh et al., 2014).

The results of Table 7 showed that the growth of host plants was different between the experimental treatments. In 4 treatments with mycorrhizal fungi, the growth of host plants was higher than that of the control treatment (no mycorrhizal infection) at all monitoring parameters at a significant error level of LSD5%. In which, the plant height in the mycorrhizal treatments was 1.08 - 4.4 cm higher than the control (equivalent to 6.46 - 26.33%) and the root length also increased from 1.35 - 2.64cm (equivalent to 44.55 - 87.13%). At the same time, the biomass in the mycorrhizal treatments was also higher than that of the control, with an increase of 0.56 - 0.78g/plant in stem weight and 0.07 - 0.11g/plant in root weight. All four parameters were highest in the treatment infected with *Dentiscutata nigra* (A2) (Table 7).

Table 7. Effects of mycorrhizal inoculation on growth of mung bean (after 30 days of experiment)

Parameter Treatment	Plant height (cm)	Root lengh (g/plant)	Stem weight (g/plant)	Root weight (g/plant)
1. Control (No AM)	16.71	3.03	0.99	0.09
2. *Scutellospora* sp1 (AM1)	17.79	4.39	1.55	0.16
3. *Gigaspora decipiens* (AM4)	19.93	5.04	1.72	0.18
4. *Gigaspora* sp3 (A1)	18.89	4.77	1.65	0.16
5. *Dentiscutata nigra* (A2)	21.11	5.67	1.77	0.20
$LSD_{5\%}$	0.05	0.03	0.03	0.02
CV%	0.1	0.3	1.0	5.1

Thus, the treatment of mycorrhizal fungi has the effect of enhancing the growth and development of the host plant and depending on the infected mycorrhizal strains, the growth and development are also different.

Figure 1. *Biomass of Mung beans after 30 days of experimental planting*

In addition, in the treatment with higher infection rate and number of spores, the establishment of symbiosis in the host plant will be better (Nguyen Thi Minh et al., 2014).

The results indicated that: in all treatments for AM, the degree of root infection and the number of spores produced were higher than the control at a significant error of LSD5%, demonstrating the establishment of symbionts and their spore reproduction was superior to that of the untreated control.

The level of mycorrhizal infection and spore produced were highest in the treatment with Dentiscutata nigra (A2) (reaching 17.78% root length, 27 spores/100g soil) and the lowest in the treatment with Scutellospora sp1 (AM1) (reaching 9.53% root length, 16 spores/100g soil) (Table 8).

Table 8. The growth of mycorrhizal fungi on mung beans (at 30th day)

Parameter Treatment	Root infection (% root length)	Spore No/100g soil
1. Control (without AM)	1.32	3.33
2. *Scutellospora* sp1 (AM1)	9.53	16.10
3. *Gigaspora decipiens* (AM4)	15.45	24.09
4. *Gigaspora* sp3 (A1)	12.11	19.63
5. *Dentiscutata nigra* (A2)	17.78	27.06
$LSD_{5\%}$	0.13	1.23
CV%	0.6	3.9

It is clear that mycorrhizal fungi affect the growth and development of plants and the formation of symbionts. The AM strain has a higher degree of root infection and the number of spores produced, the better in the growth and development of the plant and vice versa. This result is also completely consistent with previous results on AM by Nguyen Thi Minh et al. (2014). The results showed that the presence of mycorrhizal fungi had a positive effect on the growth and development of the plant, especially in terms of root weight and the level of root infection. This is explained by the fact that AM mycorrhizal fungi live symbiotically in the root of plants, expanding the absorptive area of the roots. When the mycorrhizal mycelium develops strongly, the rate of root infection increases, increasing the ability to take advantage of nutrients from the soil to provide plants, create conditions for plants to growth.

Among the 4 selected AM strains, the *Dentiscutata nigra* (A2) and *Gigaspora decipiens* (AM4) showed superior efficiency on host plants and had higher application potential than other strains. Therefore, those AM strains with 6 strains of yeast were selected to produce bioproduct for inoculation of plants growth on drought soil.

3.4. Effect of bioproduct on plant under drought conditions

Monitoring results (Table 9) suggested that after 60 days of experiment, all growth and development indicators of mung bean plants were used with yeast preparations (CT2, CT6, CT10), symbiotic mycorrhizal fungi AM (CT3, CT7, CT11), yeast and AM (CT4, CT8, CT12) were higher than those without inoculum (CT1, CT5, CT9) at all 3 soil moisture levels (40%, 30% and 20%) in significant error level LSD5%. In particular, the effectiveness of the treatment of using yeast and AM inoculants on the growth parameters of the plants was superior. The root length increased 42.10 - 80.06%; the number of fruits increased 2.4-3.8 fruits/tree (increased 61.29-85.71%) compared to the treatment without inoculants in all experiments with different soil moisture (40%, 30% and 20%). Other hand, the rate of diseases decreased by 8.34-13.35% compared to the control.

This result is equivalent to the research results of Nguyen Thi Minh et al (2014), Vu Quy Dong et al. (2015),… They report that AM have great ability to save water for irrigation, increase nutrient absorption, resulting plants have higher vigor, reduce the rate pathogen, and have the ability to withstand adverse conditions of the environment. When mycorrhizal fungi were present in the soil, the growth and development parameters of plants such as plant height and leaf area increased compared to soil without mycorrhizal fungi.

Table 9. The growth of mung bean plant after 60 days of experiment

Parameter / Treatment	Plant height (cm)	Root length (cm)	Fruit No/plant	Leaf area (cm^2/plant)	Pathogen rate (%)
CT1	42.54	8.74	6.20	78.89	20.03
CT2	44.44	11.12	7.80	83.03	15.05
CT3	44.46	12.16	7.83	83.62	11.67
CT4	46.48	12.42	10.05	88.69	6.64
$LSD_{5\%}$	0.52	0.17	0.91	2.34	4.32
CV (%)	0.9	1.0	8.3	2.0	13.5
CT5	29.50	6.42	3.62	76.32	15.03
CT6	31.60	8.34	5.10	80.22	13.38
CT7	31.62	9.44	5.08	80.58	13.53
CT8	33.24	11.56	6.63	86.42	6.68
$LSD_{5\%}$	0.27	0.19	0.76	2.07	6.46
CV(%)	0.6	1.6	11.0	1.9	18.8
CT9	26.56	5.32	2.81	70.82	18.36
CT10	28.22	7.32	3.85	74.13	13.35
CT11	28.42	8.30	4.06	74.71	13.32
CT12	30.40	10.34	5.23	81.57	4.98
$LSD_{5\%}$	0.40	0.16	0.91	2.63	6.54
CV (%)	1.0	1.5	16.7	2.5	17.6

Figure 3. Experiments with yeast and AM inoculant on mung beans under different drought conditions

3.5. The effectiveness of yeast and AM on drought soil improvement

The bioproduct from yeast and AM in addition to stimulating the growth and development of plants, the activity of microorganisms (yeast and mycorrhizal fungi) in the bioproduct also has the ability to retain soil moisture, metabolize insoluble compounds into soluble, at the same time improving soil properties.

The test experiment results indicated that, all 3 bioproducts (yeast; AM; yeasts and AM) tended to contribute to soil improvement at all three different soil moisture levels. In particular, using bioproduct made from both yeast and AM given the best effect.

Soil moisture increased from 32.96 to 38.86%, especially, the content of available nutrients has increased, available Phosphorous content increased by 57,59-62.89%, available posstasium increased 33.24-47.85% compared to the treatment without inoculants. The results of increasing soil moisture holding capacity by combination of yeast and AM of this study are higher than to the effectiveness of Lypomycin-M with water retention 8-12% for some crops (Tong et al., 2005).

Table 10. Soil properties before and after experiment

Treatment	pH	Độ ẩm (%)	OC (%)	N (%)	K_{TS} (%)	P_{TS} (%)	P_2O_5 (mg/100g)	K_2O (mg/100g)	Yeast (CFU/g)	AM spore/100g
Before experiment	6.78	40.11	1.16	0.23	0.16	1.36	1.94	6.98	1.05×10^5	15
CT1	6.73	47.62	1.17	0.24	0.16	1.37	1.94	6.97	1.95×10^6	22
CT2	6.77	54.27	1.16	0.25	0.17	1.39	2.12	7.68	3.05×10^7	46
CT3	6.75	54.13	1.17	0.25	0.17	1.39	2.83	8.16	4.99×10^7	193
CT4	6.69	63.32	1.18	0.27	0.19	1.40	3.16	10.32	7.21×10^8	279
CT5	6.65	49.68	1.16	0.20	0.14	1.35	1.93	6.95	1.71×10^6	18
CT6	6.66	52.03	1.16	0.20	0.15	1.36	2.07	7.69	1.95×10^7	77
CT7	6.63	53.11	1.17	0.21	0.15	1.37	2.68	8.25	2.71×10^7	157
CT8	6.67	55.97	1.17	0.22	0.17	1.39	3.08	9.87	5.62×10^8	229
CT9	6.58	28.95	1.15	0.18	0.13	1.31	1.91	6.89	1.02×10^6	16
CT10	6.59	34.76	1.16	0.18	0.13	1.32	2.03	7.91	2.65×10^7	26
CT11	6.60	34.80	1.18	0.19	0.14	1.32	2.47	8.95	2.65×10^7	106
CT12	6,.2	40.20	1.19	0.20	0.15	1.35	3.01	9.18	4.43×10^8	198

More over, the density of useful microorganisms (yeast and AM) in the treatment of using yeast and mycorrhizal fungi also tended to increase compared to the control without inoculum, even using yeast or AM only. This is due to promoting the synergistic effect of both yeast and mycorrhizal symbionts in the soil, converting nutrients to provide for microorganisms, and contributing to soil improvement and ensuring the yield and quality of crops. This result is also consistent with the research results of Abdulrhman et al., 2022; Ramya. P et al., 2021; Quin Xi et al., 2019 using yeast in drought stress and semiarid land; Nguyen Thi Minh et al., 2014 and Vu Quy Dong et al., 2015 using AM to promote plant growth.

The study results expressed that the application of yeast and AM not only stimulates the growth and development of plants, but also tends to positively improve soil environmental factors (humidity, exchange nutrients, ...), enhance the resistance of plants to adverse conditions.

4. CONCLUSIONS

Six yeast strains belonging to Saccharomyces and Schizosacchromyces varieties with high polysaccharide production ability and 2 AM strains with good biological activity and strong symbiosis on host plants to produce bioproducts for inoculation of plants in drough soil. The tested results showed that, using a combination of yeast and Arbuscular Mycorrhizae on mung bean (*Vigna radiata*) enhanced plant growth at all monitoring parameters compared to the control formula at the significant levels LSD5%: root length increased 42.10-80.06%; number of fruits increased by 61.29-85.71% in all experiments with different soil moisture (40%, 30% and 20%). Moreover, this inoculation also contribute improving soil properties and available nutrients (especially the increase in soil moisture by 11.25-15.70%) due to the synergistic effect of yeasts and Arbuscular Mycorrhizae; so could potential for practical applications to reclamation and using drought soil. The application of microorganisms in the environment, therefore, is becoming more and more suitable to ensure environmental quality, yield and quality of agricultural products and especially contribute to soil improvement.

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MODELING THE IMPACT OF LOW LIGHT INTENSITY ON STORAGE ROOT DEVELOPMENT USING CASSAVA-OPENSIMROOT MODEL

Nattharat Punyasu[1)], Johannes A. Postma[2)], Saowalak Kalapanulak[1,3)], Jittrawan Thaiprasit[3)], Tobias Wojciechowski[2)], and Treenut Saithong[1,3,*)]

1) Bioinformatics and Systems Biology Program, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bang Khun Thian), Bangkok, Thailand
2) Institute for Plant Sciences (IBG2), Forschungszentrum Jülich, Jülich, Germany
3) Center for Agricultural Systems Biology, Systems Biology and Bioinformatics Research Group, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi (Bang Khun Thian), Bangkok, Thailand
* Corresponding author, Corresponding Author's contact: treenut.sai@kmutt.ac.th

ABSTRACT: Light intensity is one of the major factors that determine the amount of carbon substrate yielded from photosynthesis. Plants exposed to unfavorable light intensity always show less CO_2 fixation and a decrease in plant dry weight. In cassava, low light intensity was reported to affect not only above-ground plant development but also storage root (SR) formation. However, the insightful study of carbon assimilation and allocation resulting in lowered SR production is not yet present. For this purpose, Cassava-OpenSimRoot (MeOSR), a functional-structural plant model (FSPM) developed in our laboratory, was employed to simulate cassava plant growth as well as SR development under different light intensity conditions. Simulation suggested that photosynthesis under a low light environment generated less photoassimilate, then lowered the overall carbon budget for plant development. The limiting carbon substrates first affected shoot growth and later led to insufficient carbon allocated for storage root bulking. The results were corresponding to the simulated root architecture that showed smaller numbers of thickening roots and shorter lateral roots under the low light condition. Our simulated results also showed that an insufficient carbon budget at the early stage of plant development has a large impact on cassava storage root formation. Modeling crop growth via MeOSR enabled us to investigate the dynamics of shoot-root carbon partitioning under variable light conditions and its effect on overall plant growth and SR formation.

Keywords: *Carbon allocation, Cassava, Functional-Structural Plant Model, Light intensity, Storage root development.*

1. INTRODUCTION

Cassava is an ideal staple crop to secure food sufficiency under the threat of climate changes. It can survive and provide reasonable production in a marginal semi-arid environment (El-Sharkawy 2006). Nonetheless, cassava starchy root yield varies largely with the exposed surrounding conditions (Bakayoko et al. 2009; De Souza et al., 2017). Cassava grown under low light intensity or shade condition was observed to form storage roots later than usual and finally have low production (Okoli and Wilson 1986). Jorge and colleagues reported that low light intensity (PPFD = 101 µmol s^{-1} m^{-2}) reduced the survival rate of *in vitro* plants to 30%-70% with minimal root dry mass and numbers at 35 days after culture (Jorge et al., 2000). Since the optimal light intensity is required for plant photosynthesis and also CO_2 fixation, the low light intensity was hypothesized to cause abnormal growth of plants by affecting the assimilated carbon budget for the whole organismal development.

Understanding how the plant maintains carbon balance and distributes carbon to sink organs, especially under low carbon income situations, is essential to improve storage root formation which determines the final harvesting yield.

Crop growth modeling helps extend the current understanding of carbon assimilation and allocation underlying plant development in various exposed environments. It simulates daily growth (e.g., biomass) according to the physiology of plants and the environment of exposure. OpenSimRoot (Postma et. al., 2017) is a crop growth modeling platform that allows not only the simulation of carbon used for biomass production but also root system structure. The platform has been applied to study growth and development in plenty of crop species, and recently in cassava (Cassava-OpenSimRoot model (MeOSR); Punyasu et al. (manuscript in preparation)). This model conceptually simulates carbon balance based on four processes, including (1) carbon uptake from photosynthesis, (2) carbon allocation for organ growth (i.e., leaves, stems, fibrous, and storage roots), (3) carbon cost for respiration, and (4) carbon cost for root exudation.

Here, the effect of light intensity on cassava storage root development was investigated regarding carbon assimilation and partitioning for either shoot or root growth using MeOSR model. The model mimicked the varying light conditions by setting the average daily light intensity (PAR) to 2000 μmol/cm^2/day for the low light condition and to 4000 μmol/cm^2/day for a typical light condition. The simulation was performed to investigate the growth of plants up to three months old. This work allows us to gain more insights into the influence of light intensity on carbon assimilation and shoot-root carbon partitioning in altering plant growth and SR formation.

2. MATERIALS AND METHODS

The MeOSR model (Punyasu et al. (manuscript in preparation)) was employed to simulate cassava plant growth under varying light conditions. The model was first parameterized to fit with the measured growth phenotype of field-grown cassava plantation. In a normal condition, the average daily light intensity (PAR) was set to be 4000 μmol/cm^2/day, and in the low light intensity condition, it was downed to 2000 μmol/cm^2/day. The daily growing biomass for each plant part was simulated to reflect the modeled carbon assimilation and partitioning within plants.

3. RESULTS AND DISCUSSION

3.1. Simulation of cassava plant growth

Simulation of MeOSR showed that the reduction in solar input had significant effects on both shoot and root growth. The low light intensity affected the amount of carbon harvested from photosynthesis (Figure 1A). The reduced carbon budget for plant growth first affected the amount of carbon allocated for shoot development (i.e., leaf and stem), beginning at 40 DAPs (Figures 1 (B-D), and Figure 1G). Then, the lower leaf area led to a more pronounced deficiency of the assimilated carbon and subsequently limited carbon allocated for root growth (Figure 1G). The circumstance obviously delayed storage root bulking (at 50 DAPs, Figure 1F), but only little effect was observed in the growth of fibrous roots (Figure 1E). The growth rate of fibrous roots was reduced by 19 %, whereas that of tubers showed approximately 3-time higher reduction (63 %) at 84 DAPs. The finding results were similar to the study from a field experiment where cassava plants were exposed to 32% of solar input at 50-84 DAPs (Aresta and Fukai 1984). The delay in storage root bulking could finally lead to a decrease in the storage root yield. These results demonstrated that the low carbon availability under low light intensity limited shoot growth and was subsequently lacking in carbon substrate for storage root bulking. The impact of low light intensity on the transition of developmental stages was also found in Arabidopsis where low light intensity prolonged the juvenile vegetative phase (Xu et. al., 2021). Interestingly, we found that cassava plants allocated carbon to root growth more than shoot under low light intensity (Figure 1G) which might be a sort of plant response to stress. This simulation highlighted the physiological characteristics of cassava that tended to reserve carbon in the below-ground storage roots during stressful conditions. In cassava literature, a study also showed that lack of solar radiation at an early age made a greater effect on the growth of storage roots compared to shoot development (Fukai et al., 1984).

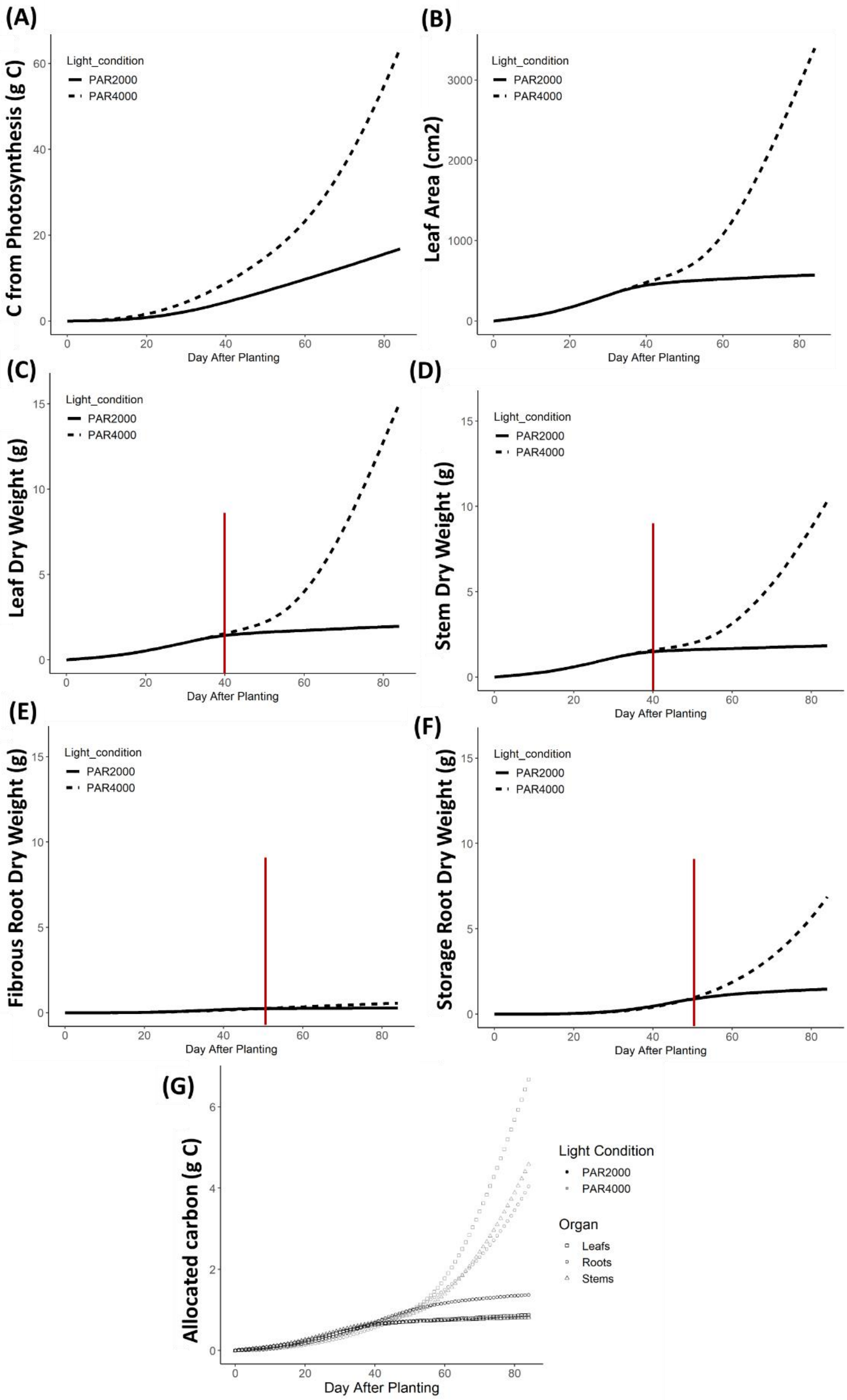

Figure 1. Simulation of carbon assimilation and allocation in cassava plants grown under low (PAR2000, solid line) and normal (PAR4000, dot line) light intensity. Red lines marked where the effect of light conditions was first observed in the simulated growth of the plant.

3.2. Simulation of root system structure

Root systems structure of the growing cassava plants were envisaged according to the distribution of root dia meter and length. The simulation showed that the lower carbon harvested under the low light condition affected both characters of the root structure. Corresponding to the carbon balance model, the root architecture system of cassava simulated under low light conditions had fewer numbers with smaller diameter sizes of thickening roots (Figure 2A). Moreover, fibrous roots were found relatively shorter in this condition (Figure 2B). The simulated root structure up to three months after planting demonstrated that the limited carbon harvested from photosynthesis constrained SR formation and also later development.

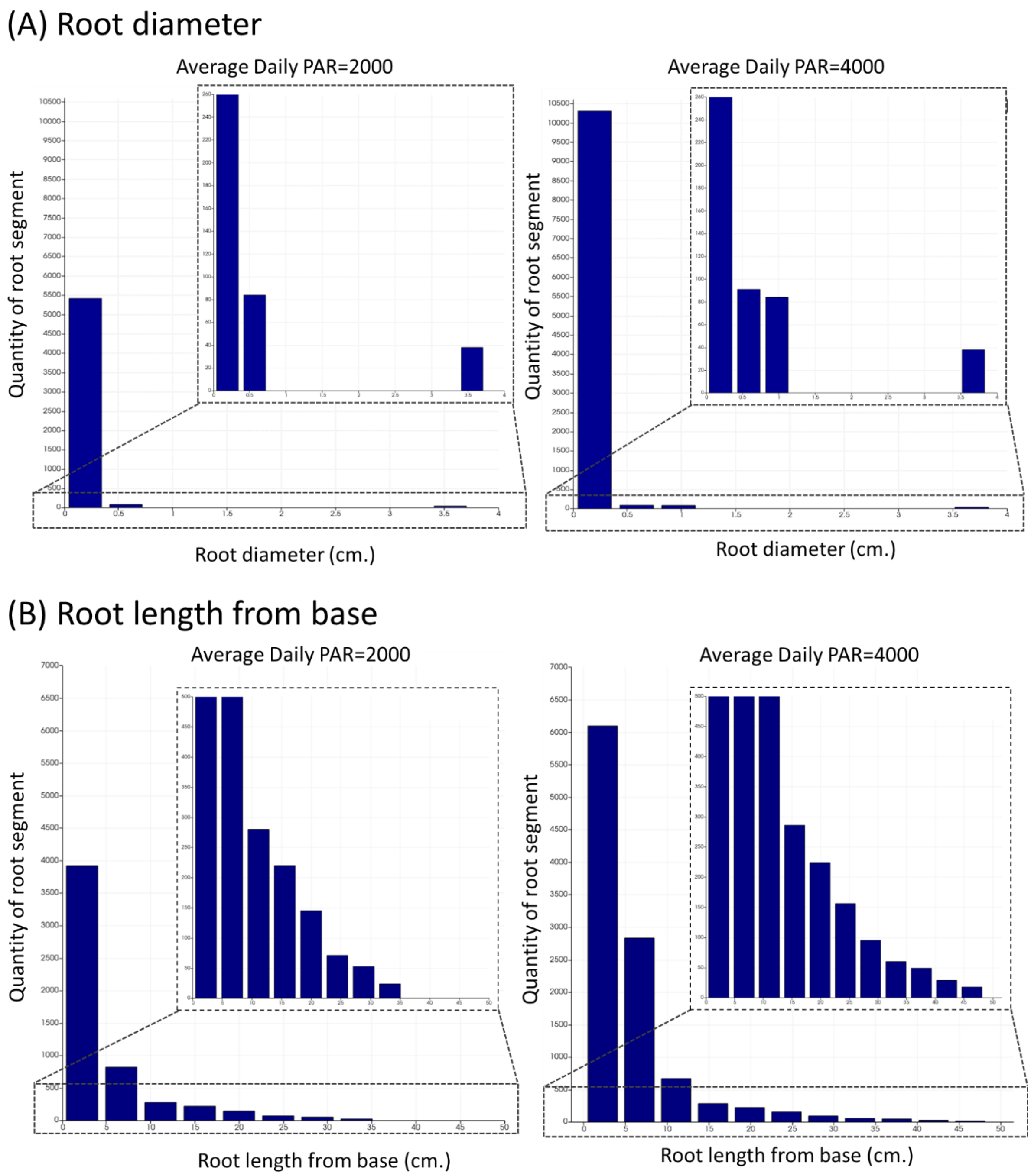

Figure 2. Simulation of cassava root system under low (PAR 2000 µmol/cm^2/day, left panel) and normal (PAR 4000 µmol/cm^2/day, right panel) light intensity conditions, (A) histogram of root segment diameter (centimeter) and (B) histogram of root segment length (centimeter).

4. CONCLUSIONS

The computational model simulation allows us to fill in the missing link of the response of carbon assimilation and allocation under low light intensity, and the limiting cassava plant growth and storage root formation. The simulated results highlighted the dynamic changes in carbon partitioning under the restricted carbon supply. The simulation of the 3D root system supported the finding influence of low light intensity in limiting carbon allocated for storage formation, as shown by distinct root length and root diameter distribution between plants simulated under the light intensity conditions. Overall, this work gained insights into the source of cassava plant growth in response to low light intensity.

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SCALABLE ENERGY HARVEST FOR IOT AND ROBOTICS IN FIELDS

Masayuki Hirafuji

The University of Tokyo/ Field Phenomics Research Laboratory, Japan
hirafuji@evolution-lab.com

ABSTRACT: In sensor networks at farms, a certain amount of energy to get and send one sample of information such as phenotypes is required, and total energy to create big data becomes enormous. We have developed a photovoltaic system that can respond immediately to such diverse power needs and can be easily installed, moved, and removed. It consists of five solar panels and its shape is cube or rectangular. We have used it to create agricultural big data in farms for several years. As power consumption increased, e.g., in edge computing, the battery voltage often dropped, and sensing stopped. The amount of power generated varies with latitude, weather, and season, solar panel orientation, and the rate at which battery voltage drops is also highly dependent on battery capacity. Even if the amount of electricity generated matches the power needed, a large-capacity battery is required to provide power even in cloudy or rainy weather, increasing costs. Due to the difficulty of predicting long-term weather, it is difficult to determine in advance the optimal configuration of solar panel size and battery capacity. To adaptively approach its optimal configuration in fields, detailed time-series data on electricity generated, battery voltage, and power consumption are needed. So, we have conducted a long-term operational test of the photovoltaic system. The results show that the charging current to the battery is highly dependent on the power consumed etc. In order to make the data easily accessible to everyone and to enable long-term storage, these measured data were posted by the IoT device to a SNS (Twitter) and automatically graphed by the agent (Twitter bot). Since SNS data may disappear suddenly, the data was backed up by another cloud service. In the future, we plan to use Web3 services to store the data semi-permanently.

Keywords*: Energy harvest, Sensor network, Big data, IoT, Web3.*

1. INTRODUCTION

For sensor networks in farms, a certain amount of energy to get and send one sample of information such as phenotypes is required, and total energy to create big data (TB class) becomes enormous. In the 20 years of operation of the sensor network using Field Servers (Hirafuji et al., 2002) to date, outages have often been caused by power shortages (Figure 1). Automatic operation of drones in fields require a larger amount of electricity. Recently, electric tractors such as MONARCH (the MK-V electric tractor, 2022) are available, and require 9.6kW for charging. So, for robotics farms in future, KW-scale or MW -scale energy harvest will be required. Conventional solar power plants are suitable for such large-scale energy harvest. However, equipment of energy harvest in farms must be easily installed, moved, and removed. For example, in Japan, the Agricultural Land Law prohibits the construction of permanent facilities such as solar power plants on farmland. On the farmland with crop rotation, the equipment must be moved every year.

As for sensor networks, there are many kinds of small-scale energy harvesting methods such as kinetic energy (vibration, sound, wind and hydro) and thermal power generation have been tried (e.g., Gilbert et al., 2008; Elahi, et al., 2020). However, all these energy sources are not practically useful for diverse use cases in agriculture. For example, hydropower is limited to areas such as near irrigation canals. Vibration energy harvesting is too small to collect data such as 3D/high-resolution/multi-spectrum imagery. Thermal energy harvesting is not scalable due to the small amount of electricity in room temperature. Wind power generation can generate large amounts of energy, but it is costly and cumbersome to install large wind turbines in the field. Solar power has an advantage called Swanson's Law. Swanson's law is "the price of photovoltaic modules drops 20 % for every doubling of cumulative shipped volume" (Swanson's Law provides green ray of sunshine for PV, 2022). Moreover, cost performance of semiconductor devices is decreasing exponentially known as Moor's low. As the results, prices of solar panels have been decreasing exponentially. We have developed a photovoltaic system (Solar Cubicle) that can respond to various demands.

2. PRACTICAL PROBLEMS

The amount of electricity generated varies with latitude, weather, and season, solar panel orientation, and so on. The rate at which battery voltage drops is also highly dependent on battery capacity. Even if the amount of electricity generated matches the power needed, a large-capacity battery is required to provide power even in long-term cloudy or rainy weather, increasing costs.

Due to the difficulty of predicting long-term weather, it is difficult to determine in advance the optimal configuration of solar panel size and battery capacity. To adaptively approach its optimal configuration, detailed time-series data on electricity generated, battery voltage, and power consumption are needed. So, we have conducted a long-term operational test of the photovoltaic system, which were integrated with Field Servers (Figure 1). This installation method reduces the exclusive area of the solar panels and allows the size and stacks of solar panels to be increased according to the power requirements. However, the poles must be buried deep in the ground to prevent them from collapsing in strong winds of Typhoon, and if there are rocks or illegal dumping materials in the ground, holes must be dug with a power shovel or an auger drill (Figure 2). Field Servers can perform Wi-Fi spots by Wi-Fi mesh network or WDS network. Large solar panels are needed to maintain always-connected long-distance communication service. The installation work for such service's energy harvest is more extensive (Figure 3).

On the other hand, if only a small amount of data is collected intermittently, a compact Field Server with small solar panels can be configured using LPWA and power-saving circuits, but if more sensors are used or the number of measurements is increased, power shortages are likely to occur (Figure 4). In such cases, it is difficult to increase power generation for the structure.

(1) Single stack solar panel (2) Double stacks solar panels (3) Triple stacks solar panels

Figure 1. Solar panels integrated with the Field Servers. As camera resolution increased and the volume of communications grew, multiple solar panels were installed with the Field Servers.

Figure 2. If the ground is hard due to gravel or industrial waste, a power shovel or other excavating equipment is needed to dig a deep hole.

(1) Installed with a pole (2) Installed on a desk (3) With a wind turbine(4) Installed in Himalaya (6500m)

Figure 3. Larger solar panels and wind turbines were required for radio relay stations and surveillance.

(1) Four 2W-solar panels (2) Three 3W-flexible solar panels (3) Two 3W-flexible solar panels

Figure 4. Examples of power-saving Field Servers with real-time clock and LPWA/4G/Wi-Fi for intermittent operation were deployed in large-scale farms. Only small data could be sent by small electricity generated.

3. EASY & SCALABLE ENERGY HARVEST

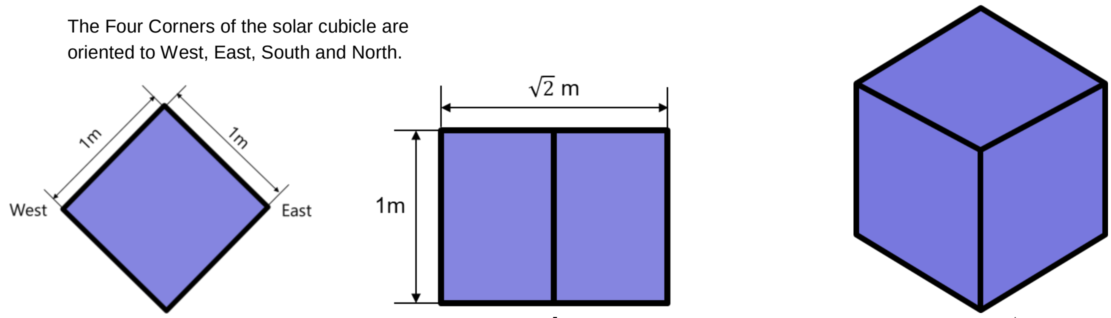
We proposed a photovoltaic system (Solar Cubicle) that can respond immediately to diverse power needs and can be easily installed, moved, and removed (Hirafuji et al., 2019). The Solar Cubicle consists of five solar panels and its shape is cube or rectangular. We have used it to create agricultural big data in farms for several years, and confirmed the Solar Cubicles were deployed easily. It can provide enough electric power for different use cases (Figure 5). The theoretical power generation of a Solar Cubicle is between 100% and173% of power of a solar panel, when arranged as shown in Figure 6. However, the operational details of how each solar panel generates electricity were unknown.

If all solar panels are connected in series, it is easy to find out when there is a disconnection between solar panels, but it cannot be higher than the maximum input voltage of the charge controller. Since the back-to-back solar panels do not receive direct sunlight at the same time, those two panels were connected in series. These two pairs of solar panels in series connection and the solar panels on the top (ceiling) were connected in parallel. Currents and voltage of the solar panels, battery voltage, charging current, and load current (energy consumption) were measured. The measured data was automatically posted to Twitter and further graphed by a Twitter bot so that the raw data and graphs could be viewed on Twitter.

(1) 150W panel type with a DSLR camera sensor (2) 150W panel type with 2 DSLR cameras (3) 150W panel type with 3 DSLR cameras (4) 12W panel type with a TDR soil moisture

(5) The testing field (DATA-FARM) for energy harvest, field plant phenotyping, metaverse contents and robotics farming in Sarabetsu village, Hokkaido, Japan

Figure 5. Quick deployments of Field Servers with high power consumption devices and the Solar Cubicles.



150W solar panel (1m x 1m) 150 x √2 ≒ 212 [W] 150 x √3 ≒ 260 [W]
(1) Top View of the Solar Cubicle (2) View from the sun at sunset/sunrise (3) View from the sun on the best case

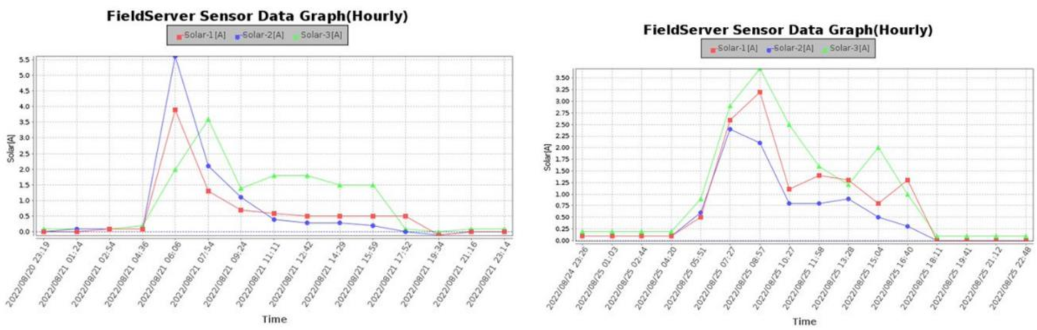
Figure 6. Theoretical power generations of the Solar Cubicle located on the optimal direction.

4. RESULT & DISCUSSION

At the testing field, Sarabetsu DATA-FARM shown in Figure 5-(5), we grow soybeans (*Glycine max*) for field phenotyping. Many types of Solar Cubicles were deployed to supply electricity for phenotyping equipment such as high-resolution camera and assimilation chamber to measure photosynthetic rate. Simultaneously, we are improving the Solar Cubicles measuring data such as charging current and battery voltage.

Let's evaluate performance of the 150W type Solar Cubicle, which is indicated by the arrow in Figure 5-(5). The peak times of the generated current of the solar panels are different (Figure 7). Therefore, the total power generation is stable from sunrise to sunset. The time-series data of normalized electricity generated and normalized solar radiation shows that electricity generated is relatively large when solar radiation is low and relatively small when solar radiation is high. This may be due to the charge controller charging the battery while avoiding overcharge and overdischarge (Figure 8). The relationship between battery voltage and charging power shows a large variance (Fighure 9-1). Battery voltage fluctuates with power consumption and solar radiation. So, the charging current to the battery is highly dependent on the power consumption etc. This complex relationship is analogous to the relationship between photosynthetic rate and solar radiation. Figure 9-2 shows relationship between normalized electricity generated of the 150W type Solar Cubicle and normalized photosynthetic rate of soybeans. As such diverse data is accumulated, it may become possible to accurately estimate photosynthetic rates from them. In order to make the data easily accessible to everyone and to enable long-term storage, these measured data were posted by the IoT device to a SNS (Twitter) and automatically graphed by the agent (Twitter bot) as shown Figure 7. Since SNS data may disappear suddenly, the data was backed up by another cloud service (Twilog). In the future, we plan to use Web3 services to store the data semi-permanently.

When the battery is fully charged, the charge controller does not charge the battery to protect it, and the generated power is released as heat. Therefore, we should find alternative applications to utilize the energy generated so that it is not wasted. The proposed energy harvest system with Field Servers can be used as a micro data center, which can be deployed in fields to use PCs, GPUs, hard disks, etc. In near future, the micro data center can be utilized as distributed storage and distributed computation nodes for Web3 such as PoW (Proof of Work) and PoS (Proof of Storage). It works fully in daytime, and halts at night (Figure 10).



2022/08/21 2022/08/25

Figure 7. Charging current of solar panels. Solar 1 (red line) is pair of southeast/northwest solar panels, Solar 2 (blue line) is northeast/southwest solar panels, and Solar 3 (green line) is top solar panel.

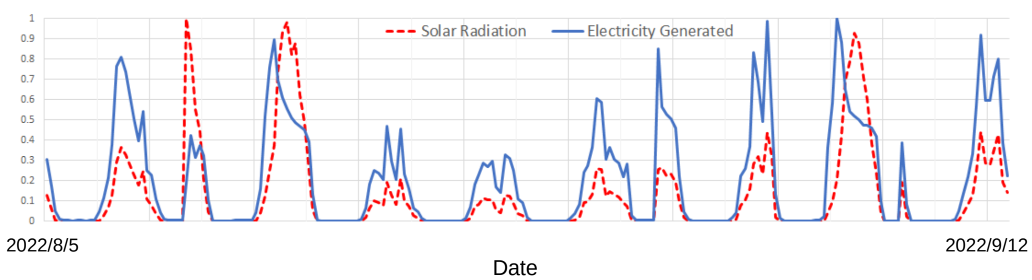
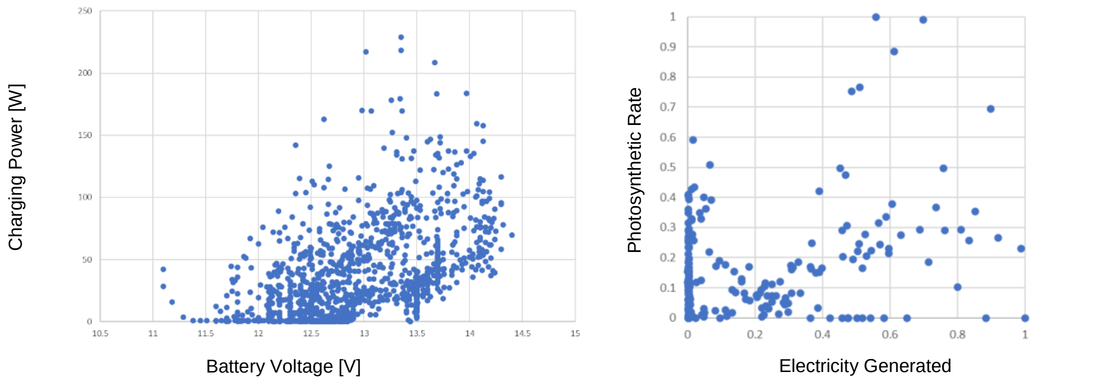


Figure 8. Normalized solar radiation and electricity generated from 2022/8/5 to 2022/9/12.



(1) Relationship between charging power battery voltage and charging power of 150W type Solar Cubicle.

(2) Relationship between normalized electricity generated of the 150W type Solar Cubicle and normalized photosynthetic rate of soybeans

Figure 9. Relationship amongst battery voltage, charging power and photosynthetic rate

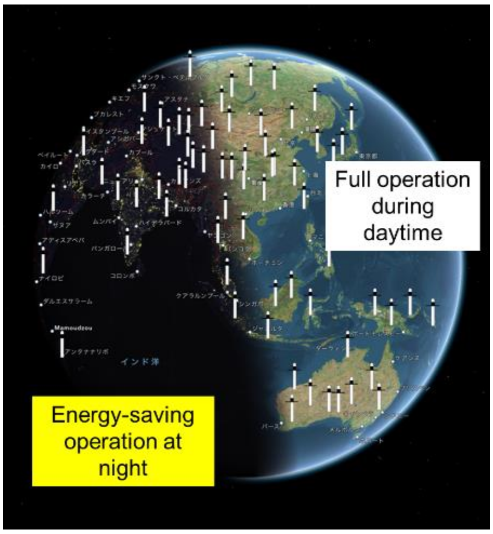


Figure 10. Field Servers with the Solar Cubicles can work as distributed storage/computing nodes for Web3 services.

5. CONCLUSION

We proposed a scalable energy harvest system that consists of a cube/rectangular body with five solar panels, which can stand on its own, and generated power is scalable depending on the size of the solar panels. This system can withstand wind and rain for long-term. In addition, the small footprint is minimal and can generate power stably from sunrise to sunset. Batteries and IoT devices stored inside are protected from the external environment, such as solar radiation.

6. ACKNOWLEDGEMENT

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APPLICATION OF DIGITAL TECHNOLOGY AT COOPERATIVE LABA BANANA ĐẠ K'NÀNG, LAM DONG, VIETNAM

Pham Thi Hanh[1, *)], Abdul Jamal[2)]

1) Vietnam Women's Academy, Vietnam. E-mail: hanh.pham@hvpnvn.edu.vn, Mobile: +84939013689
2) The New College (University of Madras), India

* Corresponding author

ABSTRACT

The article clarifies the theoretical basis of digital technology, digital transformation in economics; Cooperatives economies. In particular, experience in applying digital technology at Cooperative Laba Banana Đạ K'Nàng, Lam Dong, Vietnam. Identifying a number of issues of digital technology application of Cooperative Laba Banana Đạ K'Nàng and serving state management, including the advantages and disadvantages of cooperatives implemented. The author mainly uses a systemic approach; methods of analysis and synthesis; methods of comparison. Findings: Advantages of digital technology application in Cooperative Laba Banana Đạ K'Nàng: (i) Electronic Traceability System, (ii) Application of Digital Technology, (iii) High demand for digital technology application. Cons: (1) Not focusing on the application of technology to production and operation activities, (2) Data management and updating activities reported to state management agencies encountered a lot of inadequacies, (3) Setting up digital technology systems individually, not in the general ecosystem. Pick up the digital technology system in the general ecosystem from production to operation and administration,... They all need to be digitally implemented. The need to apply digital technology in production and business activities of cooperatives is great, the state needs to show its role in developing and implementing special policies in the management and updating of reporting data to create big data in agriculture.

Keywords: *Digital Technology, Cooperatives, Vietnam.*

1. INTRODUCTION

The terms "digital economy", "digital technology" are mentioned by default, but do not appear in any of Vietnam's digital economic development policy documents or long-term mainstream studies for a long time. Previously, Vietnam's text mainly used the terms IT - Information Technology and ICT - Information and Communication Technology. This study examines digital technology systems, digital technology in the field of economics, and experience in applying digital technology at the cooperative Laba Banana Đạ K'Nàng, Lam Dong, Vietnam. Especially, in the context of the prolonged COVID - 19 epidemic, the application of digital technology to production and business activities is very necessary. By using digital technology in the production and business of agricultural cooperatives, women have been able to improve their economic power.

The most basic forms of the context "digital" are often used in the same terms as "digitalization" and "digital transformation." These terms also represent the main application of digital technology in economics. Digital transformation is associated with business model transformation. Data exchange, data creation, data analysis, and data adjustment with processable information are the necessary and important competencies to master the digital transformation (Schallmo, Williams, and Boardman, 2017). Table 1.

Presenting key terms related to the application of digital technology in the socio-economic sector drawn from the studies conducted.

Table 1. Terms related to digital transformation

Terminology	Meaning (according to previous studies)
Business Model	Interaction with suppliers, customers, partners demonstrates the principle of creating value for the business.
Digitization	The technical process by which the same information (signal) is converted to digital form.
Digitalization	The application of digital technology in social processes is call technology.
Digital Business Model	The optimization of resources, characterized by othorpaedicity and convergence of experience, platform and content.
Digital Technology	It is a coordinated factor in innovation, creating fundamental changes to the business.
Digital Innovation	The process of innovation is the constant discovery of new ways of combining.
Digital Transformation	Enhanced (data) exchanges with (unrelated) partners create striking changes in how change occurs in every aspect of the business.
Digital Enterpreneurship	Take on the risks turned by digital transformation to prepare for business and exploit opportunities.

Source: Bican and Brem, 2020.

Bican and Brem (2020), propose a framework of elements of the digital business model as shown in figure 1. Accordingly, businesses use digital technology to optimize the use of resources, forming a digital business model, which is the foundation for stimulating digital innovations.

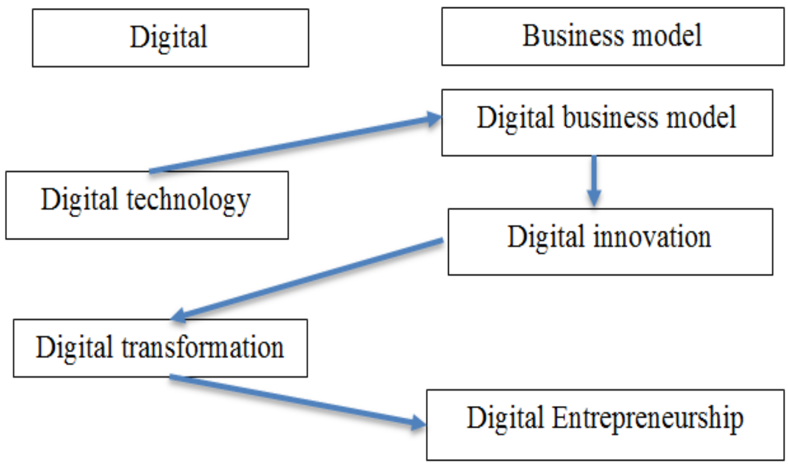

Figure 1. Elements of the digital business model

Source: Bican and Brem, 2020.

Cooperatives are a type of collective economy with a history of formation and development spanning nearly 200 years, starting in England with the ideological foundation of Robert Owen to create the first cooperatives in 1821. Since then, the theory of cooperatives has continued to be developed by many well-known thinkers in Britain, France, Germany and capitalist countries, which have strongly influenced the formation of the cooperative building movement in most countries and set the stage for the science of cooperatives to be taught, Research at universities.

Marxism-Leninist views on cooperatives have a decisive influence on the development of cooperatives in socialist countries. In his works, Lenin affirms the objective existence of the cooperatives, affirming the nature of the cooperative stemming from the "cooperation" between people and people; the cooperative must be on the basis of voluntary, self-conscious participation and the interests of the participant. Lenin also clearly distinguishes cooperatives from enterprises and affirms to support, have priority for investment and incentives for cooperatives development.

President Ho Chi Minh's thoughts and views on cooperatives are a drawing of the theory and experience of Western countries at the forefront of cooperative development, combined with Eastern values and cultures and presented in the work "The Way of Destiny". He explained the nature of the cooperatives in a simple, easy-to-understand way "Cooperatives are like contributing rice to blow rice together to get rid of waste, labor is much fun"; The one who specifies: *"Nuclear, the center of the cooperative is the member; members cooperate with each other for practical interests and maintain their independence; the member is the true purpose of the cooperatives, which is the goal that the cooperatives must serve; cooperatives are means to serve members, must ensure the benefit to the members - the cooperative is the member who is the owner"; those who are not members shall not benefit from cooperatives; All members are equal in all decisions of the cooperatives."*

Ho Chi Minh's view of cooperatives has many similarities with the international perception of cooperatives and remains intact to this day when he distinguishes cooperatives from commercial enterprises or charities: cooperatives are different from trade associations for their own profit, Jointly beneficial cooperatives. Cooperatives are not the same as charities because they are destroyed without making them; Cooperatives have to spend, have made, only help people in the Society but help equally, in a way that is "Destiny", everyone helps that everyone is helped. He also pointed out that the cooperative model is popular and thorough when established, but the organization of the cooperatives must ensure self-awareness, voluntariness, autonomy and efficiency. Ho Chi Minh's thought on cooperatives is inherited, developed and perfected by the Party in line with the Party's collective economic reform line. However, in the period of 30 years of renovation (since 1986), the concept of cooperatives in our country also has points that are not fully in line with the concept of cooperatives according to the popular international model. This assessment can be verified by studying relevant legal documents: Including **the Law on Cooperatives of 1996**, **the Law on Cooperatives of 2003, the Law on Cooperatives of 2003, the Law on Cooperatives 2012,** the International Cooperative Union (ICA), the International Labour Organization (ILO)," Tran Quang Tien (2015).

2. MATERIALS AND METHODS

The study mainly uses the following methods: System approach: The application of digital technology is a process that closely binds the processes, stakeholders and policies of the State. The system approach helps to see the problem objectively and comprehensively. The analysis and synthesis method is used in the whole research process to analyze scientific research works on digital technology, cooperatives, and digital technology application at Cooperative Laba Banana Đạ K'Nàng, Lam Dong, Vietnam. From analyzing and synthesizing the experience of applying digital technology at Cooperative Laba Banana Đạ K'Nàng, Lam Dong, Vietnam, the study will analyze the problems that can be done and exist in the process of applying digital technology in this cooperative under state management. The comparison and comparison method is used to support the conclusion of digital technology lessons at Cooperative Laba Banana Đạ K'Nàng, Lam Dong, Vietnam, in the context of promoting the application of digital technology and the digital economy today.

3. RESULTS AND DISCUSSION

Step 1. Planting trees

Planting method: 1.5m from the row, 1.5m from the tree, plant sole, followed by a 3m walkway, then to the next double row. Planting pit size: 50 cm x 50 cm x 50 cm.

Planting season: Bananas are planted all year round, but it is best to plant when the soil is moist enough or at the beginning of the rainy season, the plant grows well for a high survival rate. The farmer determines the time of ripening, harvesting but chooses the planting time suitable to the conditions of active water irrigation.

Seedlings: Seedlings are tissue transplant varieties, Laba banana seedlings transplant tissue with the advantage of strong growth, high uniformity, and disease cleanliness, making simultaneous harvesting convenient for good cultivation for export. Choose seedlings that reach a height of 20 cm or more and have 4-6 leaves. Banana varieties are important factors, if not selected corretcly they will affect yield and quality of bananas when sold. Place the seedlings down the hole, then install the rest of the mixing soil, creating a mound about 30 cm high to hold water.

Step 2: Take care

Spraying probiotics: After planting seedlings, dilute 1 liter of probiotics with 500 liters of water spray it on the whole stem, spray once a week. When the flowers have been blooming for 10 weeks, once a week for the plants that are preparing for harvest.

Care, watering: Watering: At the stage of seedlings, depending on the weather, the planting time adjusts the amount of irrigation water accordingly. Banana trees are only planted once a day, mature plants are watered 3 times a week or always maintain soil moisture is always maintained between 70-80%. It is recommended to plant windshields around the garden to limit leaf tearing that reduces banana yield. When the banana plant is in great need of water, it is necessary to pay attention to watering and adequate fertilization so that the banana grows well.

Fertilizer: The nutritional requirements of large banana trees, require a lot of new fertilizer for a high yield. The soil must be more organic, humus content in the soil is high. Depending on the fertility of the soil, the ability for the yield of the plant to have the appropriate amount of fertilizer for each root, in addition to the symptoms of lack of stool manifested on the plant, can increase or decrease.

Figure 2. Model of watering bananas.

Source: Cooperative Laba Banana Đạ K'Nàng, 2021.

Pruning leaves: Old and sick leaves will die and hang from trees, which are home to many pests. It is necessary to cut these leaves with a sharp knife, usually at the same time as pruning the buds. This will reduce diseases caused by leaf spots and other pests. At the same time, it increases the growth capacity of the side buds. Cut off all the leaves hanging from the trees and the leaves to less than 50% of the healthy leaf area and place between rows of bananas. If the area of leaves is more than 50%, it should not be removed but only cleaned.

Cut off male flowers and manage the age of banana chambers: Male flowers, also known as banana corn, are usually removed in a position about 10 cm below the last fruit and simultaneously with the fruit chamber sack. Dispensing with male flowers tends to increase the size of the bottom bounces and the volume of the fruit chamber. It is possible to break male flowers by hand, but it is best to use a sharp knife. At this time, the combination of fruits pruning or even fruits does not meet the requirements of the consumer market. Such pruning will increase the length of the remaining fruits and shorten the time from ripening to harvesting. It is required to cut the bud when the flower blooms for 6 to 7 days, and at the same time, tie the color cord (change the color of the wire each week) and record how many wires have been tied to the chamber, then proceed to the chamber. The banana chamber is usually covered with plastic bags. This type of chamber bag is used to keep the ball beautiful, free from pests, and promote the fruit's growth, especially in cold conditions. The fruit sack often increases the size of the fruit and shortens the time from the chamber to the harvest. At the same time, it increases the commercial value and makes bananas grown for export.

Figure 3. Banana chamber cover technique.
Source: Cooperative Laba Banana Đạ K'Nàng, 2021.

Against falling trees: To limit falling when the tree has fruit, use 2 piles to cross together in the shape of an X to support the neck of the banana chamber, 2 pile legs, and a prosthetic body standing on 3 legs. Use a single-end nylon rope tied above the prosthetic stem to the neck of the other end banana chamber tightly to the base of the banana tree next to or across the next trunk to keep the banana tree upright, limiting the chance that the storm wind topple the tree.

Step 3: Harvest

Harvesting standard: Measure the magnitude of the fruit in the middle of the top banana; if it reaches 43 mm, then harvest.

Harvest method: Place the transport trough under the harvested banana tree, cut down the trunk, and cut down the chamber. Then they put the banana chamber in the trough carefully. Only one banana chamber is put into a trough, which is transported carefully so as not to scratch the banana. Only a maximum of 24 chambers can be transported at once.

Step 1 to Step 3: Each banana tree will be fitted with an electronic chip. The deployment of electronic chips for each banana tree stump will help the technical departments of the cooperative and its partners in Japan jointly monitor the growth process as well as the traceability of the laba banana tree. From there, the partner will ask the garden owner to take care of the order properly, making sure the order is good.

Figure 4. Laba banana of the cooperative Laba Banana Đạ K'Nàng electronically mounted chip monitoring of growth and for traceability
Source: Cooperative Laba Banana Đạ K'Nàng, 2021.

Step 4. After harvest

Bananas will be born after harvesting:

+ Qualified banana bouncing must be free of scratches, diseased mushrooms, fruits, green peel, smooth skin, and old enough and it must also reach 9-10 fruits prer kg , will be cleaned, disinfected> Dried on the fan> tray, packed, stamped> transferred to cold storage> Export.

+ Bananas that do not meet the above standards will be cooked by the Ripening Machine: Because the harvested banana is a green banana for export, to sell fresh bananas, it is necessary to ripen them and supply them to supermarkets, convenience stores ... for powdering or drying, then packing and stocking for distribution.

4. RESEARCH LIMITATIONS AND FUTURE RESEARCH DIRECTION

The study has focused on the experience of applying digital technology at Laba Banana Cooperative, without comparing production and business performance through statistics and analysis over time. Therefore, this is a problem that can continue to be studied with the application of digital technology in cooperative Laba Banana Đạ K'Nàng in the future.

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USING RASTERIZED WEATHER DATA TO IMPROVE THE ACCURACY OF AGRICULTURAL YIELD AND HARVEST PERIOD INFERENCE MODELS: A CASE STUDY OF SHORT-TERM VEGETABLES

Chih-Wei Kuan [1,*)], Tien-Yin Chou, Mei-Ling Yeh and Chin-Huang Hsu

1) Feng Chia University, Taiwan
will@gis.fcu.edu.tw
* Corresponding author

ABSTRACT: A good inference model will help the sustainable development of agriculture, especially the prediction of agricultural yield and harvest period of agricultural products. For short-term vegetable agricultural products, effectively estimating the harvest period of individual production areas will be able to estimate the overall agricultural product quantity, and then achieve a balance between agricultural production and agricultural product prices, and achieve the goal of sustainable agriculture. In recent years, with the development of AI, many excellent models for estimating agricultural yields or prices have been published. However, these models all require very important weather information, and the data of weather station in different countries are also different. In Taiwan, not all farmland areas have corresponding weather station, which will also affect the accuracy of model predictions. This study integrates the weather data of Taiwan over the past 30 years, and uses the rasterized weather data of 1 km as the input for various model weather information. We apply several agricultural product forecasting models to compare the accuracy between the traditional method that closest to the weather station and our method that using rasterized weather information. The experimental results show that the inference model is closer to the actual yield after excluding the shocks caused by man-made or special events. As a more accurate model for farmers or agricultural data scientists, our research method in this paper provides a better and more reliable method.

Keywords: *Agriculture, Raster, Forecasting model, Yields.*

1. INTRODUCTION

In recent years, AI (artificial intelligence.) has developed rapidly and its technology is mature, and more and more applications in agriculture. Many papers or studies use AI for yield forecasting or price forecasting in agriculture. How to control the balance between crop yield and agricultural product prices will be the goal of sustainable agricultural development. In the stage of developing various AI prediction models, the weather information of the farmland is very important, and the accuracy of the weather information will affect the accuracy of the model prediction. The weather monitoring stations currently built in Taiwan are not evenly distributed, and the distances between the weather stations and the farmland are also different. In the past, the closest distance method was used to collect the weather information of the farmland as training parameters for the AI model. However, the predictions made by the farmland far away from the weather station will be inaccurate. Therefore, this study will use the weather data of 1km raster as the weather parameters of various AI models, and use the short-term crops-vegetables as the research crops. The target object is compared, and the differences between various AI models between the traditional closest distance method and rasterized weather data are compared. In addition to the comparative charts, this study also designed a simple interface for farmers to use as one of the reference sources for short-term vegetable crops when their fields are fallow or converted.

2. MATERIALS AND METHODS

This study assumes that the parameters of various AI models are fixed constants, and excludes erroneous data under the influence of various human and policy factors, and selects weather data as the variable parameters of model. The rasterized weather data and research methods used are described below.

2.1. Weather Data

The traditional method of obtaining weather data is to use the closest distance method as the weather station information of the farmland, and then the accuracy of the model will be affected when the distance is too far. Therefore, this study attempts to integrate the Central Weather Bureau(CWB), the River Management Office, Water Resources Agency(WRA), and the Environmental Protection Bureau(EPB). and other weather data, and using the 1KM rasterized location information released by National Science & Technology Center for Disaster Reduction(NCDR), the weather information in the past 30 years corresponds to the locations of 30,000 grids across Taiwan as the basic weather data for this study. As shown in

Figure 1, the table data is the location data of the whole Taiwan 1 km grid, and each grid records the detailed coordinate range. We integrated the weather station data of the CWB, WRA, and EPB, and matched the collected weather data to the corresponding grid locations, as shown in

Figure 2. The data recorded in the table includes the past 30-year daily maximum temperature, daily minimum temperature, daily average temperature, daily cumulative rainfall, and solar radiation.

	ID	LAT	LON	LAT_MAX	LON_MAX	LAT_MIN	LON_MIN
1	ZTReAD_3792	21.89809	120.86288	21.9070731528412	120.872561700224	21.8891068471588	120.853198299776
2	ZTReAD_3639	21.89821	120.84283	21.9071931528412	120.852511708374	21.8892268471588	120.833148291626
3	ZTReAD_3793	21.91669	120.86301	21.9256731528412	120.872692964248	21.9077068471588	120.853327035752
4	ZTReAD_3640	21.91681	120.84296	21.9257931528412	120.852642972407	21.9078268471588	120.833277027593
5	ZTReAD_3489	21.91693	120.82294	21.9259131528412	120.832622980567	21.9079468471588	120.813257019433
6	ZTReAD_2898	21.91734	120.74277	21.9263231528412	120.752453008445	21.9083568471588	120.733086991555
7	ZTReAD_2751	21.91746	120.72272	21.9264431528412	120.732403016605	21.9084768471588	120.713036983395
8	ZTReAD_3794	21.93527	120.86316	21.9442531528412	120.872844228262	21.9262868471588	120.853475771738
9	ZTReAD_3641	21.93539	120.84311	21.9443731528412	120.85279423643	21.9264068471588	120.83342576357
10	ZTReAD_3490	21.93551	120.82306	21.9444931528412	120.832744244598	21.9265268471588	120.813375755402
11	ZTReAD_3341	21.93563	120.80301	21.9446131528412	120.812694252766	21.9266468471588	120.793325747234
12	ZTReAD_3193	21.93573	120.78296	21.9447131528412	120.792644259573	21.9267468471588	120.773275740427
13	ZTReAD_2899	21.93595	120.74289	21.9449331528412	120.752574274548	21.9269668471588	120.733205725452

Figure 1. 1km^2 Rasterized Location Data.

	LAT	LON	RECORD_DATE	MAX_T	MIN_T	T	RAIN	SOLAR_RADIATION
1	21.89809	120.86288	1900-01-01	0	0	0	0	0
2	21.89809	120.86288	1980-01-01	24.02	21.76	22.49	0	203.47
3	21.89809	120.86288	1980-01-02	23.51	22.33	22.89	0	187.98
4	21.89809	120.86288	1980-01-03	23.41	22.22	22.92	0	202.51
5	21.89809	120.86288	1980-01-04	22.81	19.74	21.96	0.1	210.91
6	21.89809	120.86288	1980-01-05	20.11	18.78	19.47	0.09	195.38
7	21.89809	120.86288	1980-01-06	21.69	19.8	20.94	0	161.52
8	21.89809	120.86288	1980-01-07	20.9	18.35	19.09	0.07	181.63
9	21.89809	120.86288	1980-01-08	21.35	18.78	20.27	0.01	121.31
10	21.89809	120.86288	1980-01-09	21.72	19.29	20.63	0.3	131.03
11	21.89809	120.86288	1980-01-10	20.51	18.89	19.66	0.04	220.12
12	21.89809	120.86288	1980-01-11	22.33	19.8	20.96	0.04	202.24
13	21.89809	120.86288	1980-01-12	23.85	20.48	22.07	0.01	211.47

Figure 2. 1 km^2 Rasterized Weather Data.

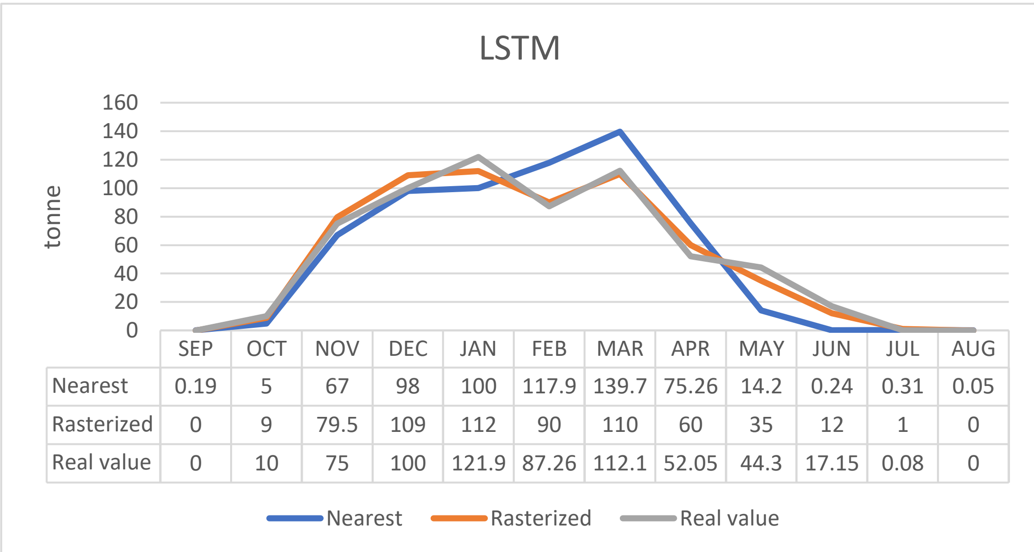
2.2. Research Methods

After confirming that the weather data is processed by rasterization, the weather information obtained by each farmland will be more accurate than the traditional closest distance method. This study will list three more commonly used models for crop yield prediction, and compare the traditional methods respectively. The difference between the closest distance method and rasterized data and the actual yield is used to verify the feasibility of this research method. These three methods are LSTM (Long short-term memory), ARIMA (Autoregressive Integrated Moving Average model), GREY (Grey Model). This study chooses a short-term leafy vegetable - broccoli in Kaohsiung, and compares the actual production of broccoli in the Kaohsiung market in the past year. Three different forecasting models are used to verify whether the rasterized data can improve the accuracy of each model.

3. RESULTS AND DISCUSSION

3.1. Research Result

In this study, the models made by LSTM, ARIMA, and GREY based on the nearest-distance weather station data and rasterized weather data, respectively, compare the actual production to verify whether the accuracy has been improved, as shown in Figure 3, Figure 4, and Figure 5. Excluding the months when broccoli was not produced in August, September, and October. In other months, the performance of these three models in rasterized data is closer to the actual production than the nearest weather station data. The experimental results show that regardless of the model, when using the rasterized data of the past 30 years as the data for training the model, the predicted output is closer to the actual output.



	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Nearest	0.19	5	67	98	100	117.9	139.7	75.26	14.2	0.24	0.31	0.05
Rasterized	0	9	79.5	109	112	90	110	60	35	12	1	0
Real value	0	10	75	100	121.9	87.26	112.1	52.05	44.3	17.15	0.08	0

Figure 3. Comparison Chart with Nearest and Rasterized Weather Data based on LSTM.

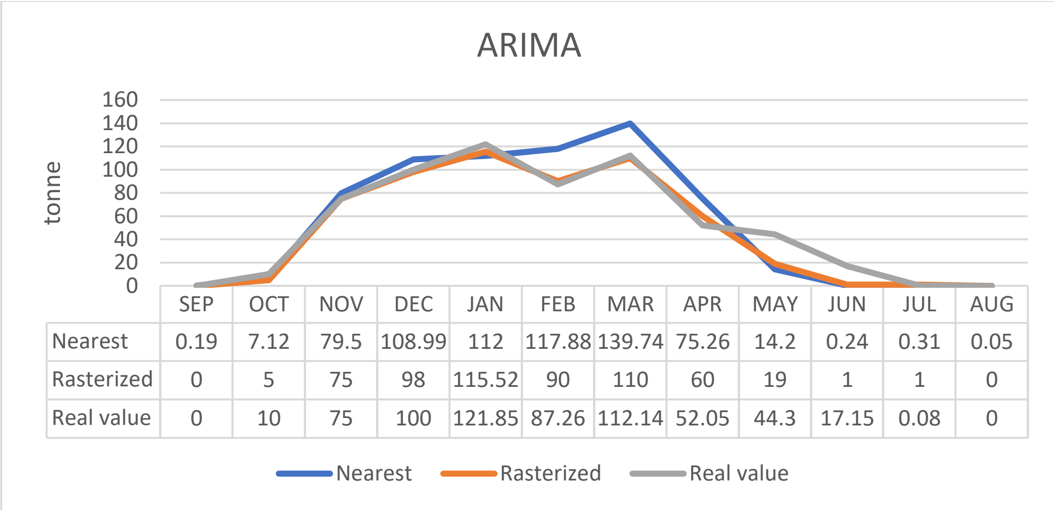


Figure 4. Comparison Chart with Nearest and Rasterized Weather Data based on ARIMA.

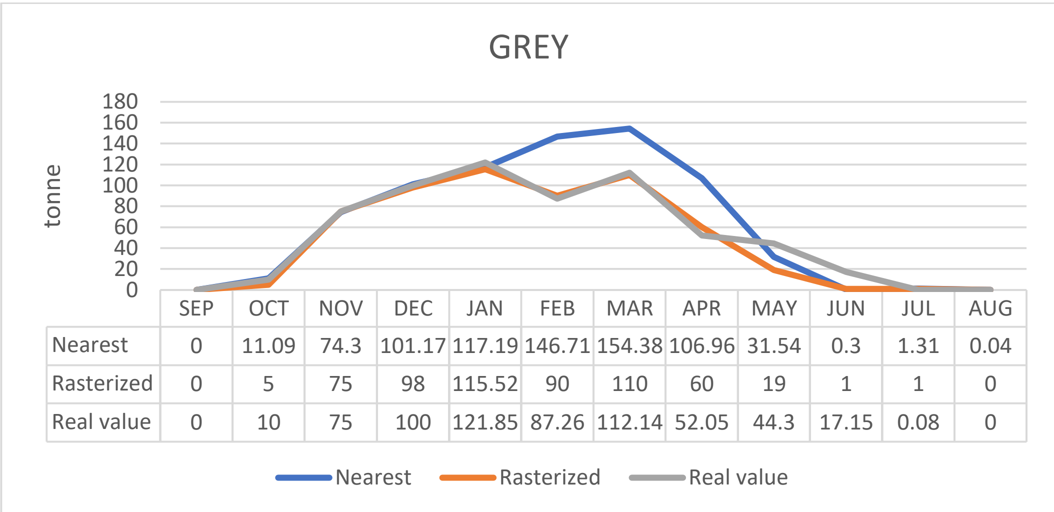


Figure 5. Comparison Chart with Nearest and Rasterized Weather Data based on GREY.

In addition to the above-mentioned yield prediction, this paper also estimates the growth period of different crops based on the collected weather data, as shown in **Figure 6**. The rasterized spatial location and weather data can be integrated into the grids. Farmers can click to display the forecast of growth period, including forecast information such as vegetative growth period, flowering period, fruiting period, and harvesting period.

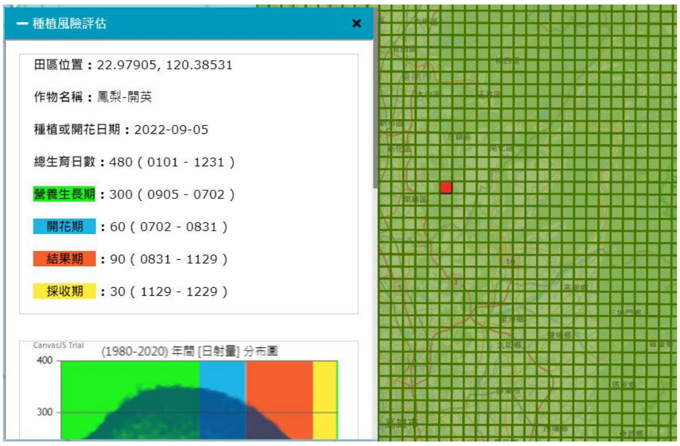


Figure 6. To Provide the Harvest Period of Crop with Rasterized Weather Data.

3.2. Interactive User Interface

In addition to the above-mentioned three different models to verify the feasibility of rasterized weather data, this study also designs a simple interface that allows farmers to choose different types of vegetables to grow according to their needs, as shown in **Figure 7**. Then select the location of the planting, and according to the rasterized data corresponding to the location, as shown in **Figure 8**. Then fill in the expected planting date and planting area to predict the model as shown in **Figure 9**. Finally, the prediction results as shown in **Figure 10** are obtained. The model will give the recommended vegetable types according to the conditions, and provide farmers with options when they switch to crops.

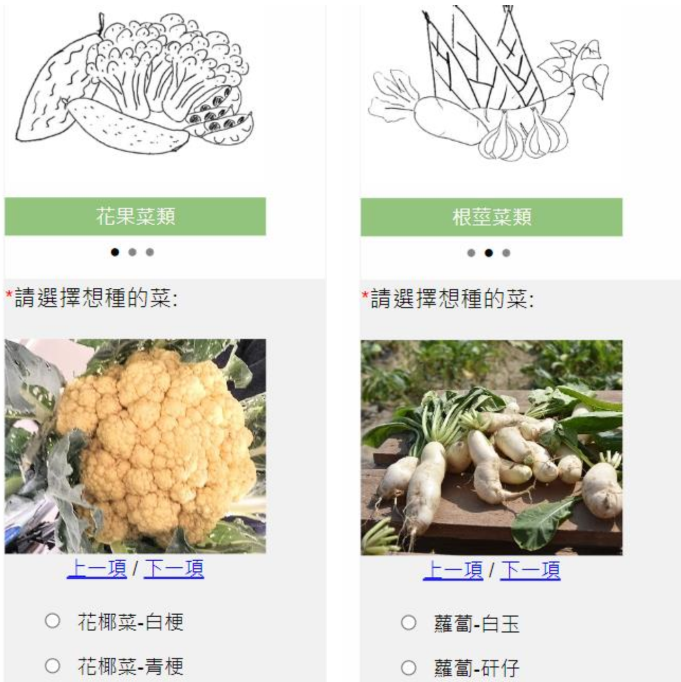


Figure 7. Choose different kinds of short-term vegetable according to farmers' needs.

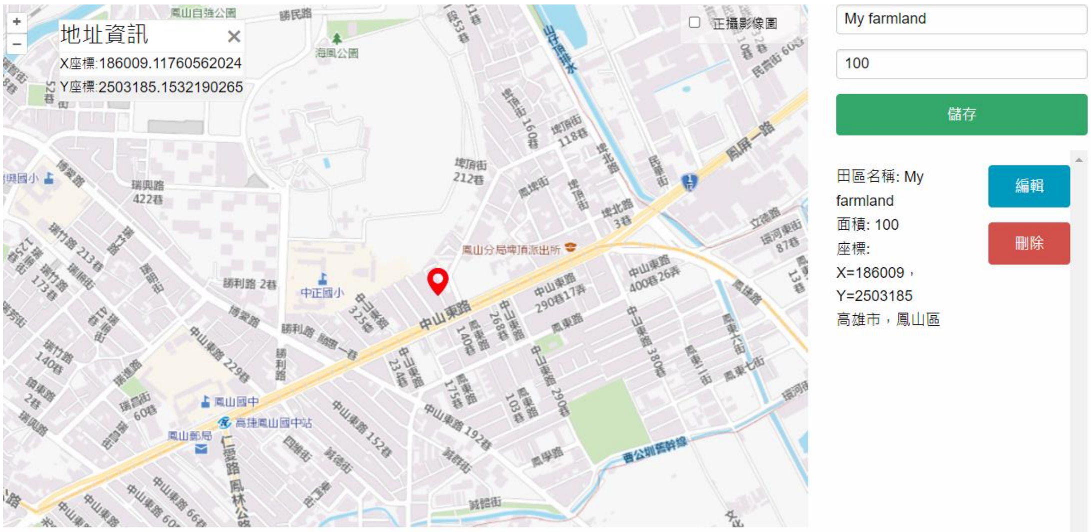


Figure 8. Choose Farm Location by Simple GIS Map.

Figure 9. Fill in the planted area and the expected yield.

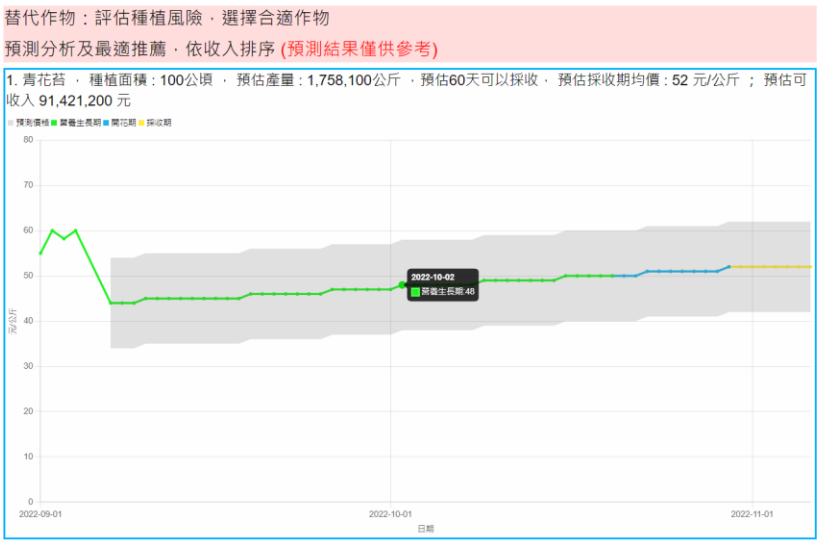


Figure 10. Forecast Harvest Period and Yield.

3.3. Discussion

This study uses rasterized weather data to improve the accuracy of the prediction model, but the research targets are all short-term vegetable crops, and the suitability of long-term woody crops has not yet been compared. In addition to the daily maximum temperature, minimum temperature, average temperature, rainfall, and solar radiation in the weather data, other conditions such as wind speed and soil conditions are the key factors affecting yield, and this part will also be the focus of continued research in the future.

4. CONCLUSIONS

This research uses the 1km rasterized weather data to compare three different forecasting models. The experimental results show that the predicted results of the three models are closer to the actual production value when the rasterized weather data is used. The method is an effective method, which can improve more accurate prediction values for various prediction models. This research also uses this method to implement a simple page, which provides farmers with simple information to get the suggested information as a reference for farmers to plant.

5. ACKNOWLEDGEMENT

Part of the data of this research come from Agriculture Bureau of Kaohsiung City Governoment, Central Weather Bureau, National Science & Technology Center for Disaster Reduction. During the implementation of the research, we would like to express our special thanks to the officers of these inisitutes for their great help and participation in the discussion of research techniques, so that the results of this research can be combined with practical application project, and can really provide farmers to utlize this function.

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ESTIMATING OF CROP COEFFICIENT FROM WATER CONSUMPTION IN *Manihot esculenta Crantz of cv.* Kasetsart 50

Rattanaareekul W.[1) *] and Khongkhuntian T.[2)]

1) King Mongkut's University of Technology Thonburi, Thailand
warakorn.rat@kmutt.ac.th / Chom Bueng, Ratchaburi 70150, Thailand

* Corresponding author

ABSTRACT One of the values that is required to manage irrigation of crops efficiently is crop coefficient (Kc). Kc is the coefficient for growing crops to reach full potential under the optimum condition for fertility and water in soil. Kc is already known to be species and cultivar specific. The objective of this research was to use the adapted version of the lysimeter method with indirect measurement of water consumption for Kc estimation in Kasetsart 50 (*Manihot esculenta Crantz of cv. KU50*) at the 3 distinct growth stages; in the initial stage (0 - 30 DAP), middle stage (31 - 150 DAP) and end stage (151 - 180 DAP) of the growth cycle. The experiment plot was designed the tank using sealed cement block as the basal structure, amount of water applying in drip irrigation was determined by soil moisture sensors in 30 cm and 60 cm from soil surface and dripping rate. The results showed the average Kc value generated for the different growth stages were: 0.6696_{Init} which was gradually increased to 1.6576_{Mid} in middle stage and slightly decreased at the end of middle stage and then Kc was sharply decreased to 0.7927_{end} in end stage. The estimation of Kc values of KU50 were higher compared to FAO Penman-Monteith in all 3 growth stages, but this research could report the first specific value of Kc in the Thai variety of cassava.

Keywords: *Cassava, Crop coefficient.*

1. INTRODUCTION

Knowledge of Kc is essential for crop water requirement (evapotranspiration) evaluation, which is useful for efficient agricultural water management and irrigation scheduling. The Food and Agriculture Organization Irrigation and Drainage Paper No 56 (FAO 56) on crop evapotranspiration (ETc) approach is considered as a global standard method so that the estimated values are appropriate for agricultural applications. According to the FAO 56, the reference crop evapotranspiration (ETo) represents the effect of meteorological parameters on water balance calculated from the FAO Penman-Monteith equation.
The water balance is the concept that presents equivalent water in a water cycle system. The water balance equation is a mathematical description to estimate the mass of water between the inflow (input) water and outflow (output) water into the crop root zone at some period of time (Zhang et.al, 2002, Sutcliffe, 2004, Byeon, 2014; Mohajerani et al., 2021, Davie, 2008). In the root zone, water is added from irrigation (I), rainfall (P) as the input water, some part of the water is lost by surface runoff (RO) and flows through soil by deep percolation (DP). upward flow by capillary rise (CR), horizontal flow by subsurface (ΔSF). If all fluxes other than evapotranspiration (ET) can be assessed, the evapotranspiration can be deduced from the change in soil water content (ΔSW) over a time period:

$$ET = I + P + RO - DP + CR \pm \Delta SF \pm \Delta SW \qquad (1)$$

Because of difficulty accessing true values of some fluxes such as subsurface flow, deep percolation and capillary rise from a water table. The soil water balance method can usually only give ET estimates over long time periods. (Allen et.al, 1998).

Basically, weighing lysimeters was used to directly measure both ETc and ETo. Kc was automatically estimated from the FAO 56 equation (Allen et al., 1998, Ko J et al., 2009). Although the lysimeter method is well known to measure Kc. Size and weight vary with tree species measured, making Kc measurements of shrubs and fruit trees costly and requiring too much space for plants like cassava. Because of the mechanical and electrical components of the lysimeter for high resolution, that causes increasing cost (Fisher, 2012). Due to a variety of environmental factors and cassava types, the Kc value can fluctuate. The accuracy of Kc, for high frequent irrigation, influences the performance of growth as well as productivity. The aims of this research were to calculate temporal crop coefficient value (Kc) by actual crop evapotranspiration (ETc) estimation and the reference crop evapotranspiration (ETo) calculation based on the water balance approach.

2. MATERIALS AND METHODS

2.1. Location

A12 x 12 m^2 plastic greenhouse plot experiment was used in Chom Bueng district, Ratchaburi province in the west of Thailand. For the cassava cultivation area of Chom Bueng district, there is clay loam soil texture, soil pH (H2O): 8.42 and low-organic, EC content (1.12%). In Ratchaburi province, the average rainfall is around 1,000 to 1,200 millimeters per year, the maximum temperature of 36 °C (April-May) and daily average temperatures around 27 °C. Chom Bueng district is one of the drought areas in Thailand, where it is the lowest recorded rainfall in Thailand. This research was conducted in the span of 6 months from December 2017 (dry season) to June 2018 (wet season).

2.2. System design and Plot treatments

The system was designed based on free drainage of a non-weighing lysimeter system which is used for actual evapotranspiration measuring by recording the amount of precipitation, amount of water lost from soil and amount of water lost from evapotransipiration (Bryla et.al, 2010, Bhat et.al, 2020). Design factors involved in lysimeter were considered of soil depth and disturbance, soil thermal modifications and drainage. Plot treatment was considering soil thermal fluctuation and price of material. The tanks were designed using cement as the basal structure, then, the precast concrete well ring system was assembled to create the tank. To avoid the root structure disturbance of cassava and soil temperature and depth, we designed the overall height of the tank to be approximately 80 cm. The tank consists of 2 precast concrete well rings (diameter 100 cm with height approximately 40 cm and one well base chamber with the same diameter placed on even ground, attached to one 0.5-inch drainage pipe with a valve. The inner walls and the bottom of the tank were mortar lining to prevent water leakage. In the meantime, bottom lining was applied with a slight slope (approximately 2 degrees) for better drainage. The cassava variety used in this experiment was Kasetsart 50 (Manihot esculenta Crantz of cv. KU50).

2.3. Data collection

Real-time weather information was collected by air temperature, relative humidity, rainfall, wind speed and direction, wind chill, dew point sensors of WatchDog 2900ET Weather Station that are located in the center of the plastic greenhouse area. The four AA alkaline batteries are weather stations powered for 10-months. An AUX port to the USB-to-3.5 mm.-Stereo-Plug Adapter was used to transfer data via SpecWare Pro software. A 15-minute logging interval was set as the data collection frequency. WATERMARK Soil Moisture Sensor-MODEL 200SS was used to measure soil moisture tension from 0 (saturated) to 200 (dry) centibars. WatchDog 1200 data loggers with up to 4 external sensor ports were used for 2 soil moisture sensors that automatically record in 15 minute measurement interval. The weather data was used to estimate ETo by FAO Penman-Monteith Equation.

$$\mathrm{ETo} = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (2)$$

Where ETo is reference evapotranspiration (mm day^{-1}), R_n is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m^{-2} day^{-1}), T is mean daily air temperature at 2 m height (°C), U2 is wind speed at 2 m height (m s^{-1}), e_s is saturation vapour pressure (kPa), e_a is actual vapour pressure (kPa), e_s-e_a is saturation vapour pressure deficit (kPa), Δ is slope vapour pressure curve (kPa $^0C^{-1}$) and γ is psychrometric constant (kPa $°C^{-1}$)(Allen et.al, 1998).

2.4. Measurement

Monitoring the water balance in the tank, initially, the water is applied to dry soil in the tank to obtain water holding capacity saturation. The amount of water usage and the initial soil water potential data were recorded before starting the experiment. Soil moisture sensors at 30 cm depth were used to monitor the water status in the tank daily. Soil water potential data was automatically recorded using a data logger to maintain a steady water level in the soil. Irrigation water is applied periodically on the face of the tank to achieved the desired soil water potential and the volume was recorded, while excess water is collected from the bottom through a drainage pipe, to estimate the volume of overall water loss between each irrigation. At the end of the experiment, the volume of water was applied again until the water holding capacity of soil reached saturation to balance the initial use of water to prepare the soil.

2.5. Calculate the reference evapotranspiration and the crop evapotranspiration

Crop evapotranspiration (ETc) can be calculated from meteorological data directly integrating the crop resistance, albedo and air resistance factor into the Penman-Monteith approach. The FAO Penman-Monteith method is used for the estimation of the standard reference crop to determine its evapotranspiration from the hypothetical grass reference surface, which is estimated from the evaporation loss from a water surface of pan evaporation.

$$ETc = Kc \times ETo \tag{3}$$

Where ETc is crop evapotranspiration (mm day^{-1}), Kc is crop coefficient (dimensionless), ETo is reference crop evapotranspiration (mm day^{-1}). (Allen et.al, 1998).

On the other hand, the mean daily climate parameters of WatchDog 9200ET were used to estimate ETo, according to Equation 2.

2.6. Calculate the root zone soil water storage

In the case of this research, the root zone water balance equation was adapted from the Allen et al. equation (Equation 1.) that is used to calculate the amount of the root zoon soil water storage in tanks, expressed as:

$$ET = I \pm \Delta SF \tag{4}$$

Where ΔS is the change in root zone soil water storage over the time period of interest, I is the irrigation, E is direct evaporation from the soil surface, T is transpiration by plants, for the horizontal flow, rainfall (I), runoff (RO) and deep drainage out of the root zone (DP and CR) were zero as there is no leakage.

3. RESULTS AND DISCUSSION

Due to the differences in evapotranspiration depending on the growth stages, cassava is small, Kc value is small in the initial stage and then cassava grows until fully developed in the middle stage. In the end stage, a cassava reaches physiological maturity. The 3 stages of growth: the initial stage, middle stage, and end stage were used to determine the value interval of ETc values, which were obtained from the water balance monitoring in the tank, and ETo values, which were estimated from the FAO Penman-Monteith equation. Based on these estimation methods (Figure 1), it was found that ETo value gradually increased at every stage over the 6-month period of planting. In the first month, ETo value was 3.04

mm.month^{-1} and decreased to 3.00 in the second month. In the third month, fourth month, fifth month, and sixth month, they increased to 3.02, 3.07, 3.13 and 3.21 mm.month^{-1}, respectively. On the other hand, the calculation results from Equation 3 indicated that during the initial stage, ETc value was 2.04 mm.month^{-1}. The amount of crop evapotranspiration per month was relatively stable. From the first month to the third month and from the third month to the fourth month, there was a sudden increase in water consumption as a result of the rapid self-development of cassava plants and the values were relatively stable during the fourth month and fifth month (middle stage). After the fifth month, ETc value declined sharply as a result of the transpiration rate, because the cassava plants began to shed their leaves (end stage).

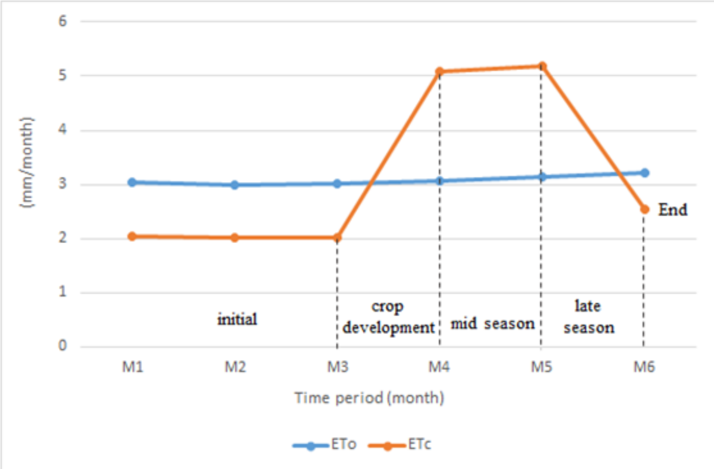

Figure 1. Schematic showing ETo and ETc curve with four crop stages

The results, calculated by The FAO Penman-Monteith method, using the aforementioned ETo and ETc values, can generate the average Kc value for the different growth stages were: 0.6696_{Init} (during month 1 – month 3 or at day 0 - day 105) which was gradually increased to 1.6576_{Mid} in middle stage (from day 4 to 5 or at day 135- day 195) and slightly decreased in the end of middle stage and then Kc was sharply decreased to 0.7927_{end} in end stage (in the 6th month or at Day 225- day 255) as in Figure 2.

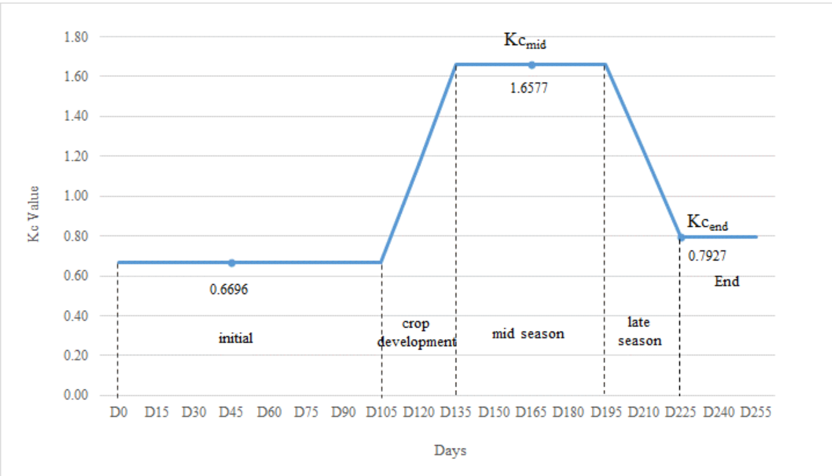

Figure 2. Schematic showing Kc curve with four crop stages and three Kc values

Table 1. Comparison between monthly crop coefficient from FAO and research result.

Crop Stage	FAO Kc ($mm.month^{-1}$)	Research result Kc ($mm.month^{-1}$)
Initial stage	0.3	0.6696
Middle stage	0.8	1.6576
End stage	0.3	0.7927

Table 1 shows the estimation of FAO indicates Kc will escalate rapidly during the middle stage, and fall significantly from the middle stage to the end stage; Kc values were 0.3, 0.8, and 0.3. By comparing the calculated Kc values with FAO Kc values, it showed twice-increasing values, from 0.3 to 0.6696, from 0.8 to 1.6576, and from 0.3 to 0.7927 during the initial stage, middle stage, and end stage, respectively. In consequence, Kc values are advantageous for irrigation planning as optimum water efficiency, which is available for use in the Thai variety of cassava.

4. CONCLUSIONS

This is the first report of Kc values for growing KU50 in the west of Thailand which provides data on temporal crop coefficient values. In the initial, middle and end stages of plant growth produced different temporal crop coefficients. However, this value was 2 times higher than the FAO Kc value in all 3 growth stages due to the cassava type differences and environmental conditions. Kc value obtained from this report was suitable for irrigation scheduling in the Thai variety of cassava. Therefore, it is recommended that the cassava should be referred to as this KC value for irrigation management.

5. ACKNOWLEDGEMENT

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RECORDING SOUNDS OF *Bemicia Tabaci* ON AN ARTIFICIAL LEAF

Fumina Utsumi[1)], Tadashi Ebihara[2,*)],
Naoto wakatsuki[2)] and Koichi Mizutani[2)]

1) College of Engineering Systems, University of Tsukuba, Japan
Category – (Student)
2) Faculty of Engineering, Information and Systems, University of Tsukuba, Japan
Contact: ebihara@iit.tsukuba.ac.jp
* Corresponding author

ABSTRACT: Whiteflies, particularly the *Bemisia Tabaci*, are difficult-to-control pests that transmit plant virus diseases that cause fatal damage to tomatoes and other horticultural crops. To establish effective control methods for whiteflies, it is necessary to understand their biology. Whiteflies are known to use sound to communicate between males and females during mating behavior. However, the reality of acoustic communication during the entire life cycle of whiteflies remains unclear in many cases. In conventional measurement environments, whiteflies are released onto plants to record the sound of communication, however, because the environment changes over time due to plant growth and mortality, long-term measurement has not been feasible. Therefore, this study aims to create an artificial leaf suitable for whitefly keeping and stable over time and to clarify whether the sound of whitefly emergence can be recorded there. An artificial leaf was prepared by dripping sap from mashing cucumber leaves between two pieces of Parafilm. Furthermore, a measurement system was constructed in which the artificial leaf was stretched over the top of a paper container and a microphone was placed outside to measure the communicating sound. Five whiteflies were released into the container with an artificial leaf, and the sound of communication was measured for one hour in an anechoic chamber. As a result, the communication sound was successfully recorded. In the future, the artificial leaf will be improved to keep whiteflies for a long period, to clarify the communication of whiteflies.

Keywords*: Whitefly, sound recording, artificial leaf.*

1. INTRODUCTION

Whiteflies are agricultural pests that damage crops such as cucumbers and tomatoes. Whiteflies proliferate explosively in horticultural facilities, cause damage from sooty rot caused by the nectar they excrete, and can transmit more than 300 plant viruses, including tomato yellowing disease, Gilbertson *et al.* (2015). Whiteflies are known to communicate using microscopic sounds, Kanmiya (1996), and have pesticide resistance that varies by species and biotype, Nauen *et al.* (2002), Horowitz *et al.* (2005). However, effective control of whiteflies requires an understanding of their biology, yet much remains unknown.

In this study, we focus on the acoustic biology of whiteflies. In previous studies, whitefly emergence sounds were recorded using cucumber leaves for about 6 hours, Nakabayashi *et al.* (2017). However, this means that the sound of whitefly outbreaks has only been measured for a short period. One of the reasons why the sound of whitefly has not been measured over several days is that it is challenging to keep whiteflies and plants stable for a long time. For example, acoustic measurements have conventionally been conducted by releasing whiteflies on cucumber leaves, Nakabayashi *et al.* (2017), however, long-term stable experiments have not been realized because plant leaves wilt and die immediately. On the other hand, artificial leaves with a parafilm membrane have been used as a stable rearing environment for whiteflies in the field of diet study of whiteflies, Zhou *et al.* (2017). However, it is still not clear whether the sound generated by whiteflies released on these artificial leaves can be measured. Hence, in this study, we create an artificial leaf and perform that the sound of whiteflies can be recorded on an artificial leaf.

2. MATERIALS AND METHODS

2.1. Artificial Leaf

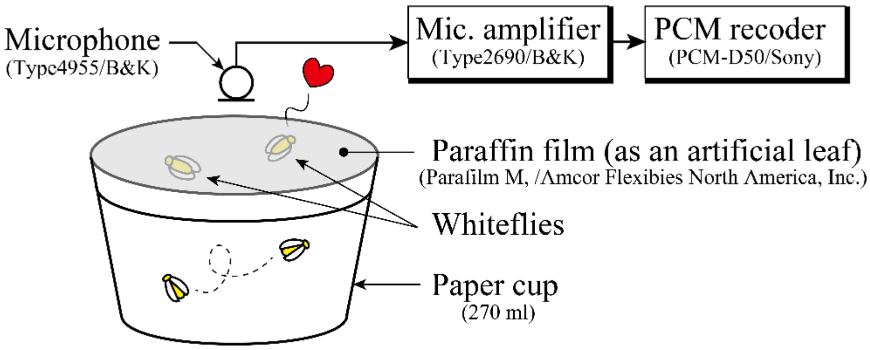

Figure 1. Sound recording system of whiteflies on artificial leaf.

In this study, the artificial leaf was created by dripped sap obtained by grinding cucumber leaves between two sheets of paraffin film. Specifically, a sheet of paraffin film (Parafilm M, Amcor Flexibles North America, Inc.) was stretched over a 90 mm diameter paper cylinder and tensioned. Then, the sap obtained by mashing cucumber leaves with a mortar and pestle was dripped onto the film surface. Finally, the sap was dripped and spread between films by stretching another film over the film with sap. In the following measurement, we put five whiteflies (*Bemisia tabaci*, biotype Q1) in the paper container covered with the paper cylinder.

2.2. Measurement System

The experimental system for measuring the sound of whiteflies on the artificial leaf is shown in Figure 1. A low-noise microphone (Type 4955, B&K) was placed over the artificial leaf at a distance of 5 mm from the film surface. The measured sound was then amplified by a conditioning amplifier (Type 2690, B&K) and stored on a PCM recorder (PCM-D50, SONY). Sound recording was performed in an anechoic chamber (temperature: 27.9^{0}C, humidity: 71%) for 1 hour. To observe the behavior of whiteflies, a camera (MX-P2, ELMO) was placed over the artificial leaf.

Whitefly sounds were picked up semi-automatically from the recorded signals by signal processing. Specifically, the recorded sound was bandpass filtered (transmission bandwidth: 150-450 Hz), and pulled whose pressure exceeded 0.02 mPa were extracted as candidate sounds. Finally, a worker separated the whitefly sounds from other noises (e.g., the flying sound of whiteflies) by listening to the candidate sounds.

3. RESULTS AND DISCUSSION

Figure 2 is a photograph of the artificial leaf used in this study. We observed whiteflies on the artificial leaf visually. As a result, we found that whiteflies were move around the artificial leaf (they fly immediately even when they land on the artificial leaf), different from the natural leaf condition (they tend to stay on the leaf once they landed).

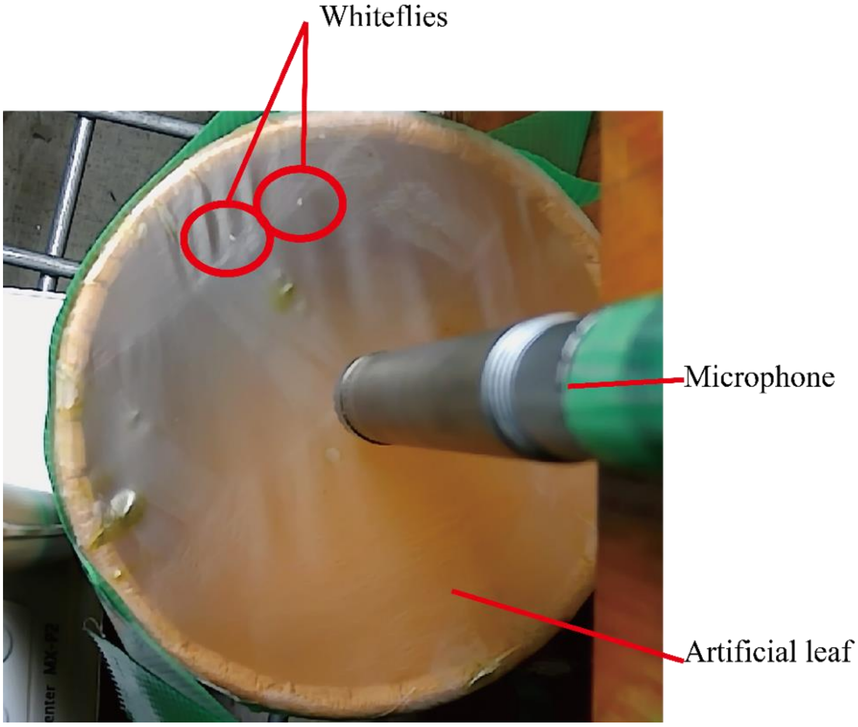

Figure 2. Photograph of two whiteflies on artificial leaf.

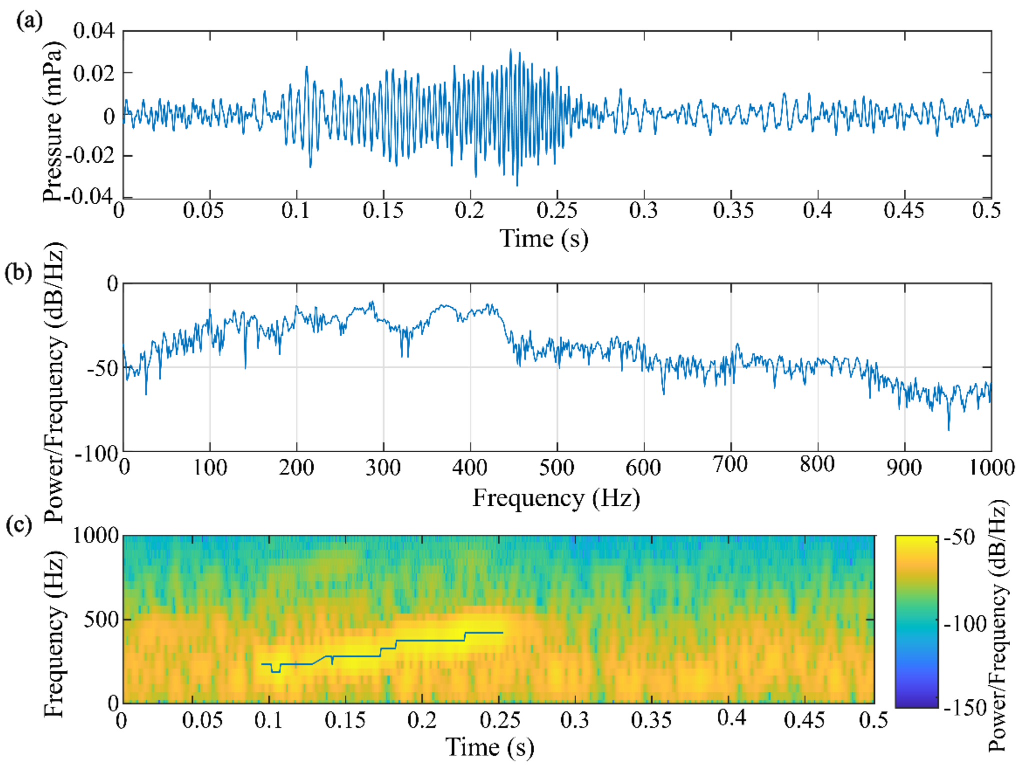

Figure 3. Experimental results; (a) recorded sound of whiteflies, (b) spectrum and (c) spectrogram of recorded sound.

However, we succeeded in recording 25 sounds of whiteflies in 1-hour of measurement. Figure 3(a) shows an example of the recorded sounds. As shown in the figure, the amplitude of the recorded sound was about 0.03 mPa and the signal length was about 0.15 s. Figure 3(b) shows the spectrum of the recorded sound. As shown in the figure, it can be seen that the whitefly sounds have a frequency bandwidth of 200 – 400 Hz. Furthermore, focusing on the spectrogram (time-frequency representation of the signal) of the recorded sound, it was found that the frequency of the signal was swept from 200 to 400 (Hz). These characteristics are in good agreement with the whitefly sounds recorded on cucumber leaves. Therefore, the obtained results suggest that the whitefly sound can be recorded even on the artificial leaf.

However, we also found that the recorded sound of whiteflies on the artificial leaf was much smaller than that on the actual leaf. Specifically, the sound pressure of the recorded sound of whiteflies on cucumber leaves was 1.5 mPa, Nakabayashi *et al.* (2017), which is 50 times larger than that on the artificial leaf. One of the reasons considered is the differences in physical properties between paraffin film and leaves, such as the presence or absence of rigidity.

4. CONCLUSIONS

In this study, we created an artificial leaf and performed that the sound of whiteflies could be recorded on an artificial leaf. An artificial leaf was created by dripping sap obtained by grinding cucumber leaves between two sheets of paraffin film. Five whiteflies were put on the artificial leaf, and sound recording was performed in an anechoic chamber for 1 hour. As a result, we succeeded in recording 25 sounds of whiteflies. Furthermore, the amplitude and time-frequency characteristics of the recorded sounds were found to be in good agreement with the whitefly sounds obtained on cucumber leaves. These results suggest that whitefly sounds can also be recorded on the artificial leaf.

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TECHNOLOGICAL TRANSFORMATION IN AGRICULTURAL SECTOR OF PUDUCHERRY UNION TERRITORY, INDIA

Pham Thi Hanh A[1,*], Abdul Jamal B[2)], Yasmeen Sultana C[3)], Ratna Vadra D[4)]

1) Vietnam Women's Academy, Vietnam.
E-mail: hanh.pham@hvpnvn.edu.vn, Mobile: +84939013689
2) The New College (University of Madras), India
E-mail: abduljamal@thenewcollege.edu.in
3) Pondicherry University, Puducherry, India
4) IMT, Ghaziabad, India

* Corresponding author

ABSTRACT

Agriculture, with its allied sectors, is unquestionably the largest livelihood provider in India, more so in the vast rural areas. Additionally, it makes a sizeable contribution to the Gross Domestic Product. For all-encompassing rural development, sustainable agriculture is crucial in terms of food security, rural employment, and environmentally friendly technologies like soil conservation, sustainable natural resource management, and biodiversity protection. India has experienced a green revolution, a white revolution, a yellow revolution, and a blue revolution in agriculture and related fields. Technology in agriculture can be used in different aspects of agriculture such as the application of herbicide, pesticide, fertilizer, and improved seed. Over the years, technology has proved to be extremely useful in the agricultural sector. Presently, farmers are able to grow crops in areas where they were thought could not grow, but this is only possible through agricultural biotechnology. The objective of the study is to analyse the technological transformation and its impact on agricultural sector in Puducherry Union Territory of India in economic perspective. This research work is based on descriptive and investigative analysis. The present study is put together with the help of both primary and secondary data. Primary Data has been collected from the selected Taluks with the help of pre-determined and well-structured interview schedule consultation with the help of academicians, planners, policy makers and experts in the field. During the course of the survey, only 750 samples could be collected. The overall objective of the study is to analyse the technological transformation and its impact on agricultural sector in Puducherry Union Territory in economic perspective. Present study shows the respondents' perceptions of the importance of the attributes that are considered to be significant in determining agricultural transformation in Puducherry Union Territory of India.

Keywords: *Innovative Technology, Cultivational Practices, Technological Transformation.*

1. INTRODUCTION

India is developing nation with a strong agricultural base. Agricultural account for 24 per cent of the Gross Domestic Product (GDP) and provides livelihoods to 58 per cent of country's population. Agriculture in India provides a living for the bulk of the population and should never be overlooked. Agricultural production has increased, despite the fact that its proportion to GDP has decreased to less than 20% while other sectors' contributions have expanded at a higher rate. Agriculture technology mostly relates to the development of machines that aid in farming. Agricultural technology is one of the most revolutionary and influential sectors of contemporary technology in India, driven by the basic need for food. These agricultural tools have dramatically enhanced farm output while also altering how people are employed and food is produced around the world. The tractor is the most common piece of agricultural machinery. Agriculture which has gone through lot of transformations has also been subject to various stresses. Constraint of availability of land, water and other natural resources added more to the already declining state of art. Most importantly dereliction in aspects relating to policy changes and natural scarcities multiplied the misfortunes. When the demand for agricultural products both for consumption and agro based industries increased, it's potential to meet up to the growing demand was a big challenge. Soil conservation, water preservation and sustainable agricultural production became the need of the hour concepts. Therefore, this research work is formulated keeping this view in mind the objectives and research questions are framed. On the other hand, adaptation of better irrigational facilities like sprinklers and drip system enhanced optimal and efficient usage of water resources.

2. STATEMENT OF THE PROBLEM

Over the years, the agricultural sector has not received as much attention as other sectors in services and manufacturing. It still contributes 15 per cent in the total export figure of India. Besides, Indian agriculture is unquestionably characterized by an extremely wide diversity in technology employed and in attendance still past areas covered by conventional agricultural practices with single cropping pattern. Similarly, there are relatively modern and mechanized operations in many states of the country, which also rely on substantial use of fertilizers, pesticides and vast quantities of water. It made a noticeable shift from area expansion to yield improvement, wherever possible, in order to the meet the growing demand for agricultural products, particularly food. As a consequence of this change, the energy consumption in agricultural sector has increased the size of output. It is pertinent to note that the structure of energy consumption has also changed substantially with a huge shift from animal and human labour towards tractor intended for farming operations, and electrical energy and diesel are largely used for groundwater irrigation. The impact of technology adoption can be studied in terms of extent of cultivation of high yielding variety of crops, application of NPK fertilizers (Nitrogen, Phosphorous, and Potash (Potassium)), application of pesticides and mechanization of agriculture in terms of tractors and power tillers use, and use of machines and equipment in various stages of cultivation of crops. The technology adoption in agriculture could be studied in terms of energy consumption behaviour. The energy devised from each input is measured on the basis of standard norms. The energy components include both traditional technology and modern technology.

3. OBJECTIVE

The overall objective of the study is to analyse the technological transformation and its impact on agricultural sector in Puducherry Union Territory of India in economic perspective.

4. METHODOLOGY

This research's influence is based on data collection and examination. This research is detailed and in-depth. This study uses primary and secondary data. Puducherry is chosen for study. Primary data was obtained from the selected Taluks with the support of academicians, planners, policymakers, and field specialists. Three taluks have enough farmland, thus they're agriculturally rich. This district's marketing of agricultural products, irrigational facilities, climate, employment, and income-generating amenities allow farmers to adopt new technologies. The study examines land use, cropping patterns, and cultivation methods. Based on severe cases, maximum variances, and maximum similarities. Published and unpublished resources provide secondary data. Handbook of Statistics on Indian Economy, Economic Survey, Government of India, Statistical Yearbook, Central Statistical Organization (CSO), Ministry of Commerce and Industry, Ministry of agriculture, Reserve bank of India bulletins, Books, Research articles, magazines and periodicals, Government Official Websites, etc.

Usage of modern agricultural technology

Modern agriculture uses robots, temperature and humidity sensors, aerial photos, and GPS. Cutting-edge equipment, robotic systems, and precision agriculture may make businesses more successful, efficient, safe, and environmentally friendly.

Modern technology increases farmers' production and income. Modern technology increases farmers' production and income. It's vital to analyze the sorts of technology accessible and how respondents in the research area use them. Table 1 shows the area's modern agriculture technologies. Table 1 shows the agriculture technique employed by Puducherry Union Territory respondents. 18% of respondents employed both traditional and modern land preparation approaches. 22.67% of respondents utilized traditional seed technology, 54.13% used modern, and 23.20% used both. 20.53 percent of respondents utilized traditional manures, fertilizers, and insecticides, 26.40 percent used modern, and 53.07 percent used both. 25.7% of respondents employed traditional harvesting techniques, 54.4% used modern, and 20.5% used both. 27.73% of respondents employed both traditional and contemporary technology. Over 72% of respondents employ contemporary technology to prepare farmland. 70% of the samples employ contemporary transportation such as trucks, tractors, and minivans to convey harvest produce from the land to residential areas and ultimately to market. Traditional technology still dominates sowing, manure, fertiliser, pesticide, and harvesting.

Table 1. Usage of Modern Agricultural Technology

Particulars	Traditional Technology	Percentage	Modern Technology	Percentage	Both	Percentage
Land preparation technique	165	22.00	450	60.00	135	18.00
Seeds used	170	22.67	406	54.13	174	23.20
Manures, fertilizers and pesticides	154	20.53	198	26.40	398	53.07
Harvesting Technique	188	25.07	408	54.40	154	20.53
Mode of Transport	164	21.87	378	50.40	208	27.73

Source: Computed from primary data, 2022

Influencing factors for agricultural transformation

Several factors influence the transition from conventional to advanced agriculture. Size of land, farmers' economic status, and other variables affect modernization. Table 2 shows Puducherry Union Territory respondents' agricultural transformation factors.

Table 2 indicates how respondents view the importance of agricultural transformation in Puducherry Union Territory. Nearly 48.27% of respondents stated non-farm employment has a large impact on agricultural transformation in the study area, 32.08% said it has a little impact, and 18.93% said it has no impact. 55.73% of the samples said the price of agricultural products had a large impact on agricultural transformation in the study area, 32.67% said it had a moderate impact, and 11.60% stated it had no impact. 51.87% of respondents stated agriculture had a major part in agricultural transformation, 31.6% said it played a minor role, and 16.5% said it played no role. 48.67% of respondents said agricultural policy and innovation were largely responsible for agricultural transformation, 31.07% believed somewhat, and 20.27% did not believe at all. Nearly 51.87 percent of respondents said real estate operations that limit cultivable land were largely responsible for agricultural change, 29.47% said it was somewhat, and 18.67% answered not at all. Land ownership and irrigation had a large role in agricultural transformation for 68.27% of respondents, a minor part for 18.67%, and no involvement at all for 13.07%. Similar empirical validation was observed in package and other qualities, with most respondents knowledgeable of agricultural change.

Table 2. Influencing factors for Agricultural Transformation

Particular	Great Extent	Percent	Some Extent	Percent	Not at all	Percent
Non-farm employment	362	48.27	246	32.80	142	18.93
Price for the products	418	55.73	245	32.67	87	11.60
Cultivation practices in the area	389	51.87	237	31.60	124	16.53

Particular	Great Extent	Percent	Some Extent	Percent	Not at all	Percent
Agricultural policy and innovation	365	48.67	233	31.07	152	20.27
Real estate	389	51.87	221	29.47	140	18.67
Land possession and irrigation	512	68.27	140	18.67	98	13.07

Source: Computed from primary data, 2022

Usage of Modern Techniques in Cultivational Practices

In India, modern farming techniques have made their way into the country's agricultural practices. As a result, it's critical to examine the public's perception of the use of modern techniques on the identified samples in the research area.

Table 3. Usage of Modern Techniques in Cultivational Practices

Particular	Very High	%	High	%	Med.	%	Low	%	Very	%
Usage of Tractors	426	56.80	245	32.67	45	6.00	22	2.93	12	1.60
Drones	418	55.73	223	29.73	32	4.27	64	8.53	13	1.73
Inorganic fertilizer	422	56.27	266	35.47	31	4.13	21	2.80	10	1.33
Chemical pest control	420	56.00	241	32.13	55	7.33	26	3.47	8	1.07
Crop rotation	432	57.60	234	31.20	42	5.60	32	4.27	10	1.33
Intensive tillage	405	54.00	270	36.00	29	3.87	28	3.73	18	2.40

Source: Computed from primary data, 2022

Table 3 depicts the respondents' differing perspectives on the use of modern techniques in the study area. Table 3 shows how respondents in Puducherry Union Territory feel about the use of modern technology in farming. In terms of tractor usage, nearly 56.80 percent of respondents rated it as very high, 32.67 percent as high, 6 percent as medium, 2.93 percent as low, and 1.60 percent as very low. In the case of agricultural drones, nearly 55.73 percent of respondents thought it was very high, 29.73 percent thought it was high, 4.27 percent thought it was medium, 8.53 percent thought it was low, and 1.73 percent thought it was very low. On the use of inorganic fertiliser, nearly 56.27 percent of respondents thought it was very high, 35.47 percent thought it was high, 4.13 percent thought it was medium, 2.80 percent thought it was low, and 1.33 percent thought it was very low.

In terms of viewpoint on chemical pest control, nearly 56 percent of respondents thought it was very high, 32.13 percent thought it was high, 7.33 percent thought it was medium, 3.47 percent thought it was low, and 1.07 percent thought it was very low. In terms of crop rotation, nearly 57.60 percent of respondents thought it was very high, 31.20 percent thought it was high, 5.60 percent thought it was medium, 4.27 percent thought it was low, and 1.33 percent thought it was very low. When it came to intensive tillage, nearly 54 percent of respondents thought it was very high, 36 percent thought it was high, 3.87 percent thought it was medium, 3.73 percent thought it was low, and 2.40 percent thought it was very low. As a result of the above table, it can be deduced that the majority of the respondents in the study area believe that the majority of modern methods have been largely utilised. Crop rotation and intensive tillage are also thought to be more popular among respondents in the study area. Furthermore, the analysis revealed that respondents were concerned about the rising cost of inputs, which magnifies the cost of input in the study area.

5. TEST OF HYPOTHESES

Null Hypothesis: H_o: There is no significant relationship between use of innovative technology and socio-economic conditions of sample respondents in the Puducherry Union Territory of India.

Table 4. Descriptive statistics

	Mean	Min	Max
Use of innovative technology	38.2	12	48
Income (Rs)	32.2	09	38

Source: Computed from primary data, 2022

Table 5. One-way ANOVA -
Difference test between the work life balance of different age groups

Work Life Balance	Sum of Squares	Degrees of freedom	Mean Square	F – Value	Sig.
Between Groups	601.712	21	200.571	1.382	0.003
Within Groups	54689.278	729	153.013		
Total	65290.990	485			

Source: Computed from Primary data, 2022

The one-way ANOVA was used to see if there was a significant relationship between the use of innovative technology and the socioeconomic conditions of the study area's identified samples. The calculated F value is 1.382, which is greater than the p value of 0.003 at the 5 percent level of significance, according to the ANOVA results. Because the F value is greater than the P value, it can be assumed that a significant relationship exists between the use of innovative technology and the socioeconomic conditions of the recognized samples across the study area. The null hypothesis is thus rejected, while the alternative hypothesis is accepted.

6. SUGGESTIONS

- Crop rotation is an important requirement in this area. Farmers must concentrate on self-sufficiency in terms of the crops or grains grown, lowering the cost of procuring grains for their own needs.
- The cultivable area must be increased using a variety of methods and government incentives. The key is to ensure that not only better food is produced, but also that the ecological balance is maintained.
- Agriculture-based industries, horticulture-based industries, based industries, and mineral-based industries all have potential in the study area.

7. CONCLUSION

Agricultural technology is one of the most revolutionary and influential sectors of contemporary technology in India, driven by the basic need for food. The overall objective of the study is to analyse the technological transformation and its impact on agricultural sector in Puducherry Union Territory of India in economic perspective. Present study shows the respondents' perceptions of the importance of the attributes that are considered to be significant in determining agricultural transformation in Puducherry Union Territory. The impact of technological transformation on agricultural productivity was investigated in a study on the impact of technology on cultivational practises and productivity. It has also attempted to comprehend the farmers' perspectives on the use of technology in their farming practises. The goal of the research was to figure out how technology affects people's living standards. Through the analysis, it was attempted to demonstrate that there is a significant relationship between the use of technology and people's socioeconomic conditions. The study also attempted to demonstrate the link between agricultural output and the productivity of agricultural workers. The analysis also reveals that farmers have a generally positive attitude toward the use of innovative advanced technology. It's also worth noting that the study found a significant difference in revenue between the pre- and post-reform periods. However, the study also found that there is considerable reluctance among farmers to adopt farming as their primary occupation, which could be due to a lack of sufficient revenue that other sectors tend to attract. As a result of the study, it has been concluded that a significant technological transformation is required to revive this already dying industry.

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INDIVIDUAL POSTURE ESTIMATION OF SWINE FROM PIGGERY VIDEOS USING TRANSFER LEARNING

Hiroki Ichikura[1)], Tadashi Ebihara[2,*)], Naoto Wakatsuki[2)], Yuka Maeda[2)], and Koichi Mizutani[2)]

1) Graduate School of Science and Technology, University of Tsukuba, Japan
2) Graduate School of Science and Technology, University of Tsukuba, Japan
Contact: ebihara@iit.tsukuba.ac.jp
* Corresponding author

ABSTRACT: Improving the efficiency of swine health management is one of important issues in the swine industry. Currently, pigs are managed in groups (approx. 20 pigs per group), and the health of pigs are judged based on visual observation. However, detection of unhealth pigs from visual signs of sickness or weakness relies on the skills of the piggery worker. To address this issue, the authors are aiming to establish a new health management system that does not rely on manpower by constructing a visual monitoring system for early and efficient detection of pig health problems. In this paper, we report the results of estimating the posture of a group of pigs from videos using artificial intelligence (AI). To monitor a swine group using a single video camera, it is necessary to take the pigpen from the top. However, the AI for estimating the posture of animals cannot analyze images taken from the top of the pig pen as they are, because the AI assumes that the animals are taken from the side. Therefore, we applied transfer learning to "AnimalPose," an AI for estimating the posture of quadrupeds, using images of a pig group taken from the top. As a result, the AI with transfer learning successfully estimated the posture of a group of pigs from an image taken from the top of a pigpen.

Keywords: *Pig pen, monitoring, image processing, AI, transfer learning.*

1. INTRODUCTION

In recent years, as the average number of pigs raised per pig farmer has been increasing, there has been a demand for more efficient and labor-saving swine herd management. In particular, early detection of infected pigs is important because swine influenza – one of the infectious diseases of pigs – is highly infectious and contagious. Thus, the health management of swine herds in swine production facilities is one of the most important tasks. Currently, the health status of farmed pigs is confirmed by farm patrols, inspections, and screening of production performance. If digital technology can be utilized to objectively and in real-time ascertain the health status of pigs on farms, it is expected to save labor and improve the efficiency of swine health management.

As initial symptoms of swine influenza infection, an increase in the frequency of sneezing and coughing and decreased activity have been reported. Therefore, a swine monitoring system that records sounds in a pig pen using a microphone and detects sneezing sounds with high accuracy with aid of signal processing, Mito *et al*. (2019). Although this method can separate sneezing sounds from other noises with high accuracy, it has not yet been able to detect sneezing sounds for each pig. Detection of individual pigs by recording videos of a pig pen and using deep learning has also been reported by

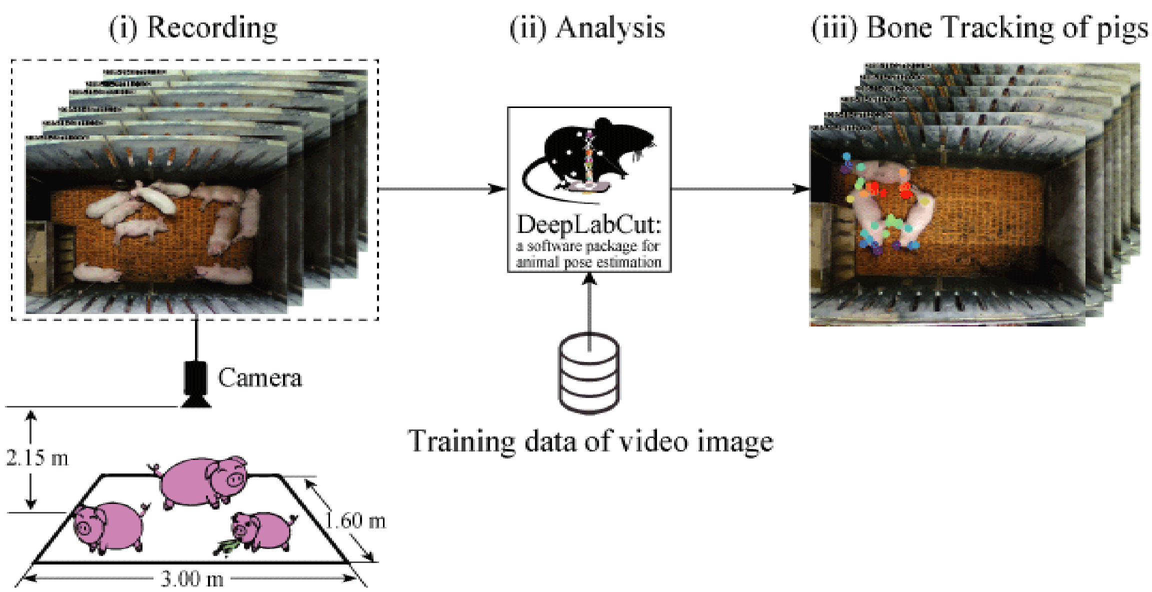

Figure 1. Monitoring system of pig pen using videos.

Nasirahmadi et al. (2019). Although this method can detect the location of each pig from videos taken in a pig pen with 20 to 30 pigs, estimation of various behaviors such as walking and eating has not been achieved yet.

Experimental Site	Swine Research Instite, Japan Agricultural Cooperative
Number of Pixels	800 × 600
Learning Rate	0.0001
Number of Test Data	190 (three pigs is 95. ten pigs is 95.)
Number of Epoch	1,000
Minibatch Size	8
Number of Annotated Images	40 (three pigs is 20. ten pigs is 20.)

In this study, we manage to realize automated and efficient swine health management by monitoring sneezing behavior and the activity of pigs from a video of the pig pen with aid of deep learning. In this paper, we establish a system to detect the posture of individual pigs from videos of a pig pen. We utilize an algorithm for estimating the animal skeleton and transition learning. We will consider whether it is possible to detect the posture of each pig from videos of the pig pen.

2. MATERIALS AND METHODS

2.1 Monitoring system of pig pen

Figure 1 shows a proposed monitoring system of pig pen. The workflow of the proposed system is as follows; (i) a video of a pig pen is recorded by a video camera, (ii) the recorded video is input to a software package for animal pose estimation [DeepLabCut, Mathis *et al.* (2018)], and (iii) computed skeleton made of numbers of keypoints (*e.g.*, left ankle and right ankle) are output. Note that since the proposed system needs to handle videos taken from the top of the pig pen to monitor the pigs with a single camera, transition learning is applied to DeepLabCut to estimate the posture of the pigs from the recorded videos.

2.2 Experimental environment

Table 1 shows the experimental environment. We recorded videos of the pig pen at the Swine Research Center, Japan Agricultural Cooperatives in 2016. Two types of pig pen – a pig pen with 3 and 10 pigs – are recorded using a video camera with a resolution of 800×600 pixels (SANAWA, CMS-010BK) for 8 hours, simultaneously. Note that the video camera was placed at a height of 2.15 m from the floor of the pig pen. 190 test data were then input to the animal pose estimator to compute a skeleton consisting of a large number of keypoints. Prior to the experiment, a transition learning of DeepLabCut was conducted using 40 annotated images that were also obtained in the same environment. The performance of the proposed method was evaluated by creating a confusion matrix.

3. RESULTS AND DISCUSSIONS

Table 2. Confusion matrix of the proposed system when (i) three and (ii) ten pigs are in cage.

(i) Confusion matrix of three pigs

True class \ Predicted class	True	False
Number of labeled parts	645	147
Number of unlabeled parts	186	102

(ii) Confusion matrix of ten pigs

True class \ Predicted class	True	False
Number of labeled parts	1293	869
Number of unlabeled parts	894	544

(ii) Bone tracked result of ten pigs

(i) Bone tracked result of three pigs

Figure 2. Output of DeepLabCut(computed skeleton made of numbers of kepoints) when (i) three and (ii) ten pigs are in cage.

Figure 2 and Table 2 show the experimental results. Figure 2(i) and 2(ii) show the detected skeletons and keypoints of 3 and 10 pigs, respectively. As shown in the figure, the proposed system successfully detects the skeletons of each pig and output its keypoints. Table 2 shows the confusion matrix of the proposed system. Here, we focus on the true positive rate (TPR) and false positive rate (FPR), which indicate the accuracy of detecting the correct label. In this experiment, the TPR and FPR of the proposed system monitoring 3 pigs were 0.81 and 0.35, respectively, while those of the proposed system monitoring 10 pigs were 0.59 and 0.37, respectively. These results indicate that the proposed system can accurately detect pig skeletons when there are 3 pigs in the cage, and the accuracy decreases as the number of pigs in the cage increases. One of the reasons consided is that the overlap of pigs increases as the number of pigs in the case increases, resultting in a large detection error.

4. CONCLUSIONS

In this paper, we established a system to detect the posture of individual pigs from videos of a pig pen. An algorithm for estimating the animal skeleton (DeepLabCut) and transition learning were employed. We considered whether it is possible to detect the posture of each pig from videos of the pig pen through experiments. As result, the proposed system could accurately detect pig skeletons when there are 3 pigs in the cage, and the accuracy decreased as the number of pigs in the cage increased. One of our future works include improvement of detection accuracy by extending the training data and increasing the number of training sessions.

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PROPOSED DESIGN SMART SUPPLY CHAIN SYSTEM FOR VERTICAL INTEGRATION OF OIL PALM INDEPENDENT SMALLHOLDER GROUP

Kursehi Falgenti *, Yandra Arkeman , Khaswar Syamsu and
Erliza Hambali

IPB University, Indonesi
*) gekfalgenti@apps.ipb.ac.id

ABSTRACT: Independent smallholders (ISH) play an essential role in Indonesia's oil palm agroindustry. The Fruit Fresh Bunch (FFB) supply channels from ISH farmers are more conventional and complex than plasma and company farmers' supply channels. Meanwhile, the Crude Palm Oil (CPO) derivative products market has dramatically changed. The allocation of high-quality CPO for high-value derivative products such as biodiesel has increased sharply. The sustainable index of biodiesel development is shallow. The importers have begun implementing traceability parameters to ensure that CPO derivative products come from sustainable sources. The transformation of the FFB supply chain helped ISH contribute more to producing high-quality CPOs for high-value derivative products. The main objective of this research is to propose a smart FFB supply chain design. This research focuses on analyzing business processes along the supply chain and reengineering the FFB supply chain operations into a smart supply chain. The development of ISH FFB smart supply chain using artificial intelligence (machine learning for plantations classification and fuzzy inference system for optimization of FFB segregation and weigh) and blockchain for traceability. The chosen technology supports the vertical integration of the ISH group with the public Palm Oil Mill (POM) of Palm Co and the upstream high-value CPO derivative industry.

Keywords: *Artificial intelligence, blockchain, independent Smallholder, Smart Supply Chain, vertical integration.*

1. INTRODUCTION

Indonesia is the world's largest producer of Crude Palm Oil (CPO), but CPO export performance, CPO productivity, and Indonesian CPO commodity prices are lower than Malaysia (Hudori, 2016). The supply of FFB from independent smallholders (ISH) plays an essential role in the palm oil agro-industry, making Indonesia the world's largest CPO producer. All FFB supplies from ISH sales channels end up at the public Palm Oil Mill (POM), but not many ISH sell FFB directly to public POM. The FFB supply channel from ISH is more complex than FFB supply from plasma and company farmers. Before reaching the public POM, FFB is traded by several parties as intermediaries. The extended supply chain makes the public POM unable to identify the location of the plantation and the name of the independent oil palm smallholder who owns FFB.

The European Union (EU) only imports from reliable sources (Goggin & Murphy, 2018) to ensure that imported products are safe for health; therefore, the source of raw materials from FFB as raw materials for CPO derivative products must be traceable. They only import high-quality CPO derivative products from plantations and POM with RSPO certification.

In addition to export purposes, another high-value palm oil derivative product is biodiesel. Domestic demand for CPO as raw material for biodiesel is increasing along with the mandatory B30 biodiesel program for non-PSO, industry, and power plants. Public POM, part of the biodiesel supply chain, currently produces more CPOs to be sent to refineries to be processed into biodiesel. For just three years, there has been an increase in biodiesel production. In 2017, Indonesia's biodiesel production was only 4.7 Million KL, increasing to 8.6 Million KL in 2020 (Bayu, 2021).

Although Indonesia has succeeded in developing biodiesel energy, the sustainability index of Indonesia's biodiesel development is low (Papilo et al., 2018). One of the causes of the low sustainability index of biodiesel development is that there is no traceability system for FFB as a biodiesel raw material. To increase the sustainable index of biodiesel, as a part of the biodiesel supply chain, ISH must have an ISPO certificate. The Directorate General of New, Renewable Energy and Energy Conservation (EBDTKE) compiled Indonesian Bioenergy Sustainability Indicators (IBSI) (Hambali et al., 2019) and started implementing them downstream to ensure sustainable bioenergy development. The development of the FFB traceability system upstream needs to be well planned to increase the sustainability index of biodiesel development.

The demand for CPO for biodiesel production has increased sharply and changed the structure of the CPO market. Meanwhile, the government intervened in the CPO market by issuing a Domestic Market Obligation (DMO) policy to guarantee a CPO quota for cooking oil. EU markets require quality and traceability of CPO derivative products. All upstream FFB supply chain stakeholders must collaborate to transform ISH's FFB supply chain to support the traceability of CPO derivative products for export purposes and the traceability of biodiesel raw materials. The conventional ISH FFB supply chain will find it challenging to respond to these market changes. Advanced technology for smart decision-making to improve operational effectiveness.

Heterogeneous and complex supply chain processes link intra-organizational and inter-organizational processes. With the support of advanced technology, these complex business processes can be managed (Rejeb, Keogh, and Treiblmaier, 2019). A Smart Supply Chain (SSC) can build interconnectivity, facilitate data collection, real-time communication, intelligent decision making, and processes that efficiently and effectively serve customers (Potter & O'Reilly, 2014). The capabilities of SSC can be implemented to support the transformation process in the ISH FFB supply chain and to facilitate vertical integration between ISH groups and public POM and downstream CPO derivative products industry.

This study proposes a smart supply chain system for ISH. With the support of a smart supply chain, vertical integration between ISH groups and public POM can improve the performance of the Indonesian palm oil industry facing the challenges of market changes downstream.

2. MATERIALS AND METHODS

2.1. Smart supply chain

Business competition in the digital economy era encourages organizations to adapt and transform. Digital transformation, with the support of information technology, makes it easier for organizations to collaborate and share information. The transformation is not only in the organization's internal but also in the supply chain. Actors in the supply chain need to collaborate to improve supply chain performance. Information Technology (IT) has been confirmed to be essential in improving supply chain management performance (Hahn 2019).

In contrast to conventional ICTs that only support coordination and information sharing, advanced technology more broadly strengthens communication, control, collaboration, cooperation, connection, and cognition along the supply chain. These six aspects are essential in achieving operational excellence (Mangla et al., 2020). Advanced technologies driving digital transformation in the era of the industrial revolution 4.0 include; the Internet of Things (IoT), cloud computing, big data, simulation, augmented reality, additive manufacturing, Horizontal and vertical system integration, Autonomous robot, and Cyber security (Alcácer & Cruz-Machado, 2019).

Supply chain digital transformation is a complex task. Three features must be considered in dealing with this complexity: 1) horizontal integration through the value chain, 2) vertical integration and networking of manufacturing or service systems, and 3) end-to-end engineering of the entire value chain (Wu et al., 2016). Vertical integration requires intelligent interrelated relationships and digitization of business units at various hierarchical levels in the organization (Ustundag & Cevikcan, 2018). On the other hand, horizontal integration creates holistic value across organizations to enrich the product life cycle using information systems, financial management, and efficient material flow. Horizontal and vertical integration enables real-time data sharing, resource allocation productivity, coherent business units, and accurate planning. End-to-end engineering assists the product development process by integrating digital technology by considering customer requirements, product design, maintenance, and recycling (Wang et al., 2016).

The results of previous research, transformation with the support of information technology in the supply chain using the virtual supply chain concept (Chou, Marion, and Wang 2003). In the era of industry 4.0, the concept developed into a smart, intelligent, and digital supply chain. The concepts of smart supply chain and intelligent supply chain are innovations supported by advanced technology in operating activities in the Supply Chain Operation Reference (SCOR). Smart supply chain (SSC) development makes product and service customization more agile and flexible (Liu et al. 2021). SSC can build interconnectivity, facilitate data collection, real-time communication, intelligent decision-making, and efficient and effective customer service processes (Potter & O'Reilly, 2014). Several studies with the concept of smart supply chain and intelligent supply chain in supply chain operational activities that have been carried out include; cloud computing for cost optimization on supply chain channels (Li, 2020); AI and big data in the delivery process (Constant-Nicolalde, Guerra-Terán, and Pérez-Medina 2020). Researchers have analyzed and proposed various types of advanced technologies to build SSC. The work of designing a smart FFB supply chain for oil palm ISH requires technology that is suitable for the operational problems of the upstream supply chain to help deal with market changes downstream, as discussed above.

2.2. Method

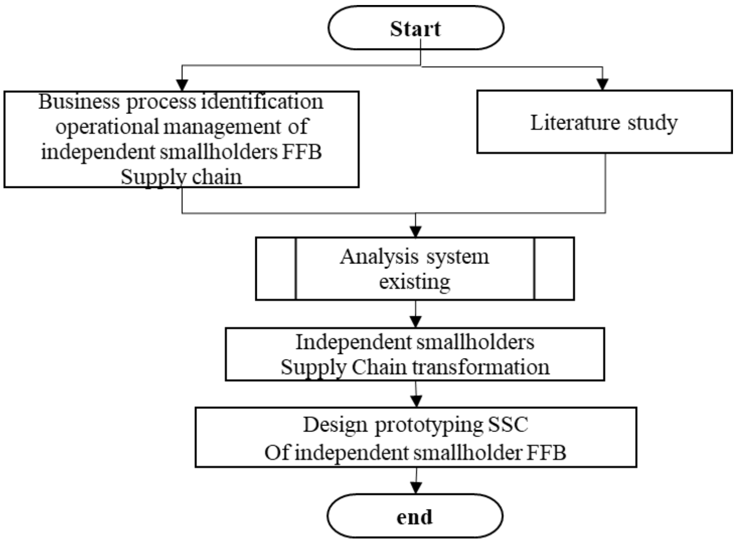

Figure.1: Research Flow Chart

Building a smart supply chain starts with identifying the operational business processes of the FFB supply chain management and the actors involved. Based on the current condition of the ISH FFB supply chain, the next step is to analyze advanced technology that is suitable to overcome supply chain operational problems and implement these advanced technologies to support the operational management transformation process for ISH FFB procurement. The transformation starts by identifying business processes along the supply chain and reengineering the FFB supply chain operations into a smart supply chain. These stages can be seen in Figure 1.

3. RESULTS AND DISCUSSION

After the problems in the FFB supply chain for ISH are described in the introduction, then to deal with market changes, this section discusses the transformation of the FFB supply chain for ISH with the support of advanced technology.

3.1. Classification of Farms using machine learning.

The first stage of the transformation is the identification of smallholders' farms and the classification of ISHs' farms. The identification of the farm based on the farmer's name, address, and map of the farms has been carried out by the Indonesian Palm Oil Farmers Union (SPKS). SPKS has mapped 1291 farmers and 1,756,696 hectares of ISH plantations (datasawit.com). Strengthening Palm Oil Sustainability (SPOS) in Indonesia has also identified 17,589 planters, and 24,388,704 ha of plantations have been identified for STDB application (sawitrakyat.or.id). The next step is to classify

ISH farms based on the level of implementation of sustainability. Attributes from the economic, social, environmental, and institutional aspects were selected to produce trusted farms with a high level of sustainability, potential farms with a moderate level of sustainability, and fewer potential farms with a low level of sustainability. The attributes selected were based on data from the Diagnostic Study of Smallholder Oil Palm Plantations in several locations in Rokan Hulu Regency by the Oil Palm Workers Union (SPKS) (Uwin 2016). The selected attributes for further exploration can be seen in Table 1.

Table 1. Sustainability attributes of ISH oil palm farms classification model

No	Economics	Socials	Environments	Institutional
1	Farms Area (Ha)	Gender of farm owner	Land Type	organization member
2	Age of mature plant (years)	The origin of the farmer	Land clearing method	Farmer Partner
3	Amount of fertilization per year	Farmer education	Topography	
4	FFB Buyer	Other jobs	Land conversion	
5	Number of mature plan	Land certificate	Previous land status	
6	Seed Sertificate	Social Security	House–farm distance	
7	Number of trucks	Number of workers		

The complex task of multi-attribute classification and lots of farm data is more effective with machine learning (ML) methods. Machine learning automatically improves the capabilities of computer systems through experience (Jordan and Mitchell, 2015). Conventional machine learning spends much manual work at the pre-processing data stage, algorithm selection, and hyper-parameter settings. Various kinds of auto-machine Learning (Auto-ML) methods have been proposed by experts to produce an end-to-end machine learning pipeline (Tuggener et al. 2019).

3.2. FFB segregation in public POM with BAS and FIS

POM, with a large production capacity of >= 90 Tons/Hour, is supported by two weighing terminals. Internal FFB with external FFB is weighed at different terminals. This smart supply chain design has two weighing terminals for weighing FFB for high-quality CPO production and FFB weighing for standard quality CPO production. Weighing for high-quality CPO production is supported by a weighing scheduling system using the Block Appointment Scheduling (BAS) method.
The scheduling of each session is set for a different type of FFB. Not all trucks are entered in the service register with the BAS scheduling system. ISH trucks from trusted farms and Trucks from companies' plantations are registered through BAS System. FFB shipments with quality control ensure that FFB is scheduled to be weighed immediately after harvest. Delivery of FFB directly from the farm to POM without intermediaries. Scheduling with quality control for the production of high-quality CPO. Unscheduled trucks for standard-qality CPO can arrive at any time with FIFO method.

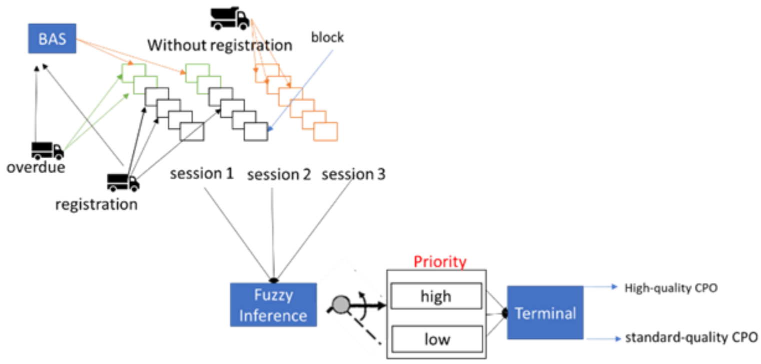

Figure 2. FFB truck weighing priority and segregation model

Fuzzy Inference System (FIS) is an application of fuzzy logic theory (Zadeh 1988) suitable to control FFB truck weighing services at public POMs that receive FFB from various sources ranging from company plantations, from cooperatives, intermediaries and ISH. Delivery times also vary due to the location of the farms in many places. FFB segregation to produce CPO with various quality. The rules in FIS segregation of ISHs' FFB are as follows (figure 2);

Input: Arrival status (registration and on time, registration and late, no registration)
Type of sender (trusted farms, potential farms, less potential farms)
Truck capacity (large, medium, small)

Outputs:
Service priority (high (high-quality CPO), low (standard quality CPO))

3.3 Traceability system using Blockchain and smart contracts

Blockchain technology is an essential technology in the supply chain transformation. Blockchain offers immutability, auditability, and provenance. It makes it more powerful, and several parties collaborate in a transparent ecosystem (Akyuz and Gursoy 2020). All these capabilities have not been found in the previous technology. Smart contracts and blockchain integration can increase the business process of supply chain operation to be more accurate, valid, transparent, secure, and efficient. The smart contract is a small program stored in the blockchain, and it works when information conditions in a determined contract are fulfilled. Automatically, the smart contract sends a determined data source, including the cause (the trigger) of the occurrence. Technology consortium blockchain hyper ledger fabric and smart contract were chosen to build a traceability system for high-value CPO derivative products such as biodiesel and CPO derivative products for export purposes to European countries. This traceability system is the most crucial part of the smart supply chain of ISH FFB (Figure 3).

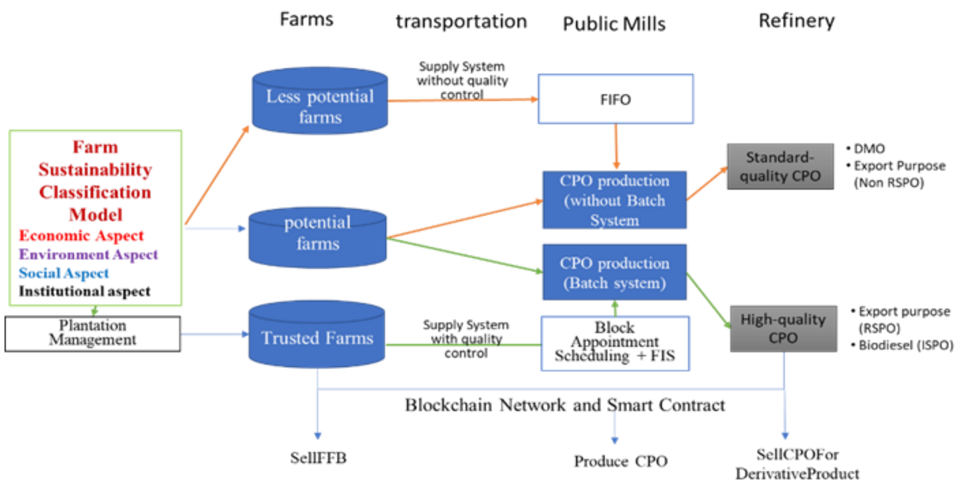

Figure 3. Smart Supply Chain of ISHs FFB

4. CONCLUSIONS

As the world's largest palm oil producer, CPO export performance, CPO productivity, and Indonesian CPO commodity prices should be much better than in Malaysia. To improve the performance of the national palm oil industry, the Government of Indonesia has integrated all government-owned oil palm plantations into Palm Co. This horizontal integration makes Palm Co the largest palm oil company in the world. With a land area of 700.000 ha, In 2026, it will produce 1.8 million tons of CPO. The vertical integration of ISH will increase Palm Co's performance. This integration is supported by ISHs' FFB smarts supply chain. This smart supply chain makes it easier to share real-time data. This integration will also facilitate the development of a traceability system for high-value CPO derivative.

5. ACKNOWLEDGEMENT

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IMPLEMENTATION OF AN AUTOMATIC LACEWING EGG TRANSFER SYSTEM

Yung-Chun Chuang[1)], Hung-Jen Lin[1)], Jen-Cheng Wang[2)], An-Chi Liu[3)], Mu-Hwa Lee[1)], and Joe-Air Jiang[1,*)]

1) Department of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan
2) Department of Computer Science, National Taipei University of Education, Taipei, Taiwan
3) Bioenergy Research Center, National Taiwan University, Taipei, Taiwan

* Corresponding author: jajiang@ntu.edu.tw

ABSTRACT: Lacewings (*Mallada basalis*) are important natural enemies in biological control. They are omnivorous and eat a large amount of food. Since they can play an important role in pest control, researchers began to develop lacewing rearing methods. In manual lacewing rearing, the eggs are transferred to isolated rearing microplates manually, and the process is time-consuming. The labor costs are accounted for 60 percent of the total production costs. In this study, automatic rearing techniques are developed, which can transfer eggs automatically to reduce labor costs. The automatic control system is built to place eggs onto isolated rearing microplates. Such an automatic transfer method is designed to reduce positioning error. The experimental results show that the r square between the targeted points and the actual landing points is 0.999. The average time required to automatically transfer eggs to 96 wells is 689.5 s and the standard deviation is 12.3 s, whereas the average time for the manual transfer is 762.0 s and the standard deviation is 123.3 s. The automatic lacewing egg transfer system can therefore replace manual egg transfer methods while significantly improving the operating efficiency.

Keywords: *Automatic Rearing System, Biological control, Egg Transfer System, Mallada basalis.*

1. INTRODUCTION

The lacewing, also known as *Mallada basalis*, is a biological control insect that is incredibly important and is the natural enemy of a wide variety of pests. Lacewings consume small insects that are widespread in the field, such as aphids and whiteflies, as their food source(Hewlett et al., 2019; Pappas et al., 2007). In the 1950s, scientists started looking into the technique of manually rearing lacewings due to the positive influence it brought to biological control (Finney, 1948). The cost is the most significant obstacle in promoting lacewings in pest control. Research has found that the cost of rearing lacewings was 1.6 times higher than simply using pesticides (Chen & Chao, 2020). The labor cost of lacewing rearing accounted for roughly 60% of the overall production cost when traditional techniques of breeding lacewings were employed (Chuang, 2022), so the production cost of lacewings remained high and it would be very difficult for lacewing products to replace pesticides in any ways.

Egg washing and egg transplantation are two tasks that must be completed to manually rear lacewings successfully, and the tasks must be repeated multiple times. First, eggs that are laid by imagoes are soaked in a solution containing diluted sodium hypochlorite to remove the egg stalks (Bezerra et al., 2014). Next, the eggs are filtered using a stainless steel filter, and then they are left to dry out and moved onto isolated rearing microplates(Hewlett et al., 2019). The diameter of a lacewing egg ranges from 0.5 mm to 1 mm. The eggshell is highly delicate; during the process of egg retrieval, there is a high probability that the eggshell would rupture owing to improper treatment, and the egg retrieval would fail as a result(Nordlund & Correa, 1995). Thus, manual egg retrieval is quite time-consuming and difficult. To summarize, the practice of manually retrieving eggs not only requires intensive labor but also lowers egg-hatching rates. As a result, it is necessary to develop an automatic transfer system for the purpose of egg transfer.

This research proposes an automatic lacewing egg transfer system. A motion control card moves a three-axis mechanical plate to the position of eggs, and a dispensing needle is used to retrieve eggs and places them in the isolated rearing microplates. Such movements continue until all eggs are transferred.

2. MATERIALS AND METHODS

2.1. System architecture

Figure 1 presents a diagram of the system's hardware architecture. The computer sends a signal to activate the motion control card using the Recommended Standard 232 (RS-232). The motion control card uses a digital signal to control the three-way valve. The air in the three-way valve travels through the vacuum generator, the throttle valve, and the dispensing needle. The computer also sends a command to the motion camera via the USB-A port, and the camera transmits back an image that it has acquired after it received the command. Both direction signals and pulse signals are responsible for controlling the four drivers and one linear actuator via the A/B signal line. All of the data collected is sent to a server for data storage.

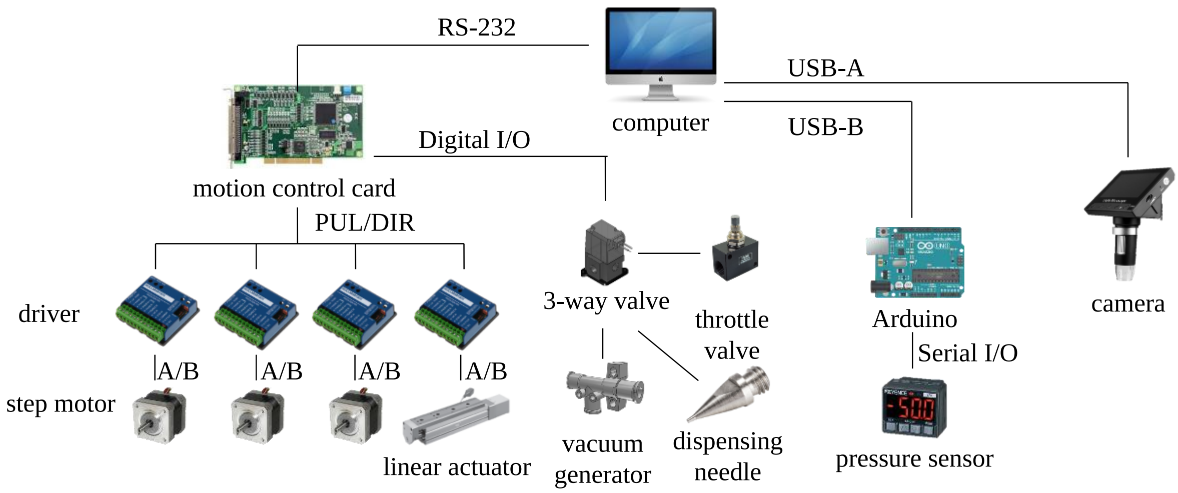
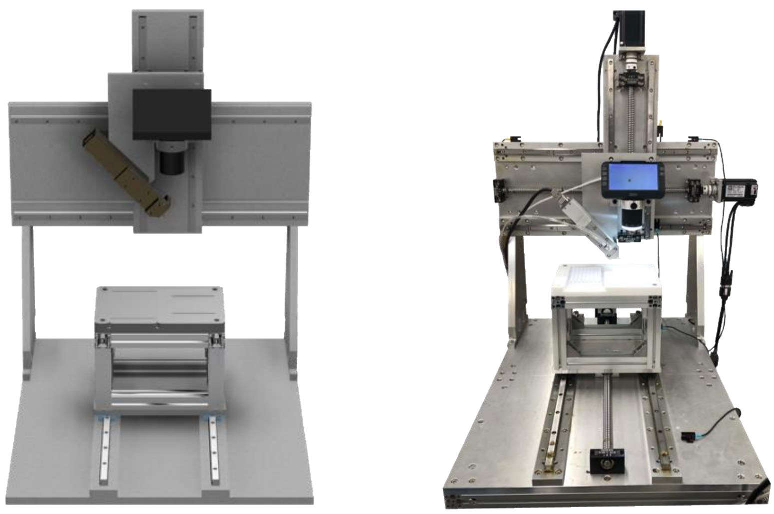


Figure 1. Hardware architecture of the proposed egg transfer system.

Figure 2 shows the proposed transfer system. An aluminum frame was used to hold the devices and components mentioned above. The devices and components in the proposed system were lightweight, so an aluminum frame, though less strong than a frame made of stainless steel, was selected as the main material to conduct the whole system.



(a) (b)

Figure 2. Proposed egg transfer system. (a) Simulated system. (b) Real constructed system.

A flow chart of the system operations is presented in Figure 3. The process of egg transfer is described as follows. First, a folder for image storage is named and established. The three-axis movements are calibrated to ensure that the three-axis motor can move to its original position. A preview image is taken by the camera. The motor is moved to the suction plate, and the camera remains activated. Second, the image of an egg is obtained, and the coordinates of the center point of the egg are collected. Third, the image of a single egg is cropped for further analysis. Fourth, the needle is moved to the center point of the egg, and the egg is sucked by the needle and transferred to an isolated rearing microplate. The image of the rearing microplate is utilized to determine whether the transfer process should end. If an empty grid on the microplate is found in the image, the process of the egg transfer continues and a new image will be taken until all grids are found to be occupied.

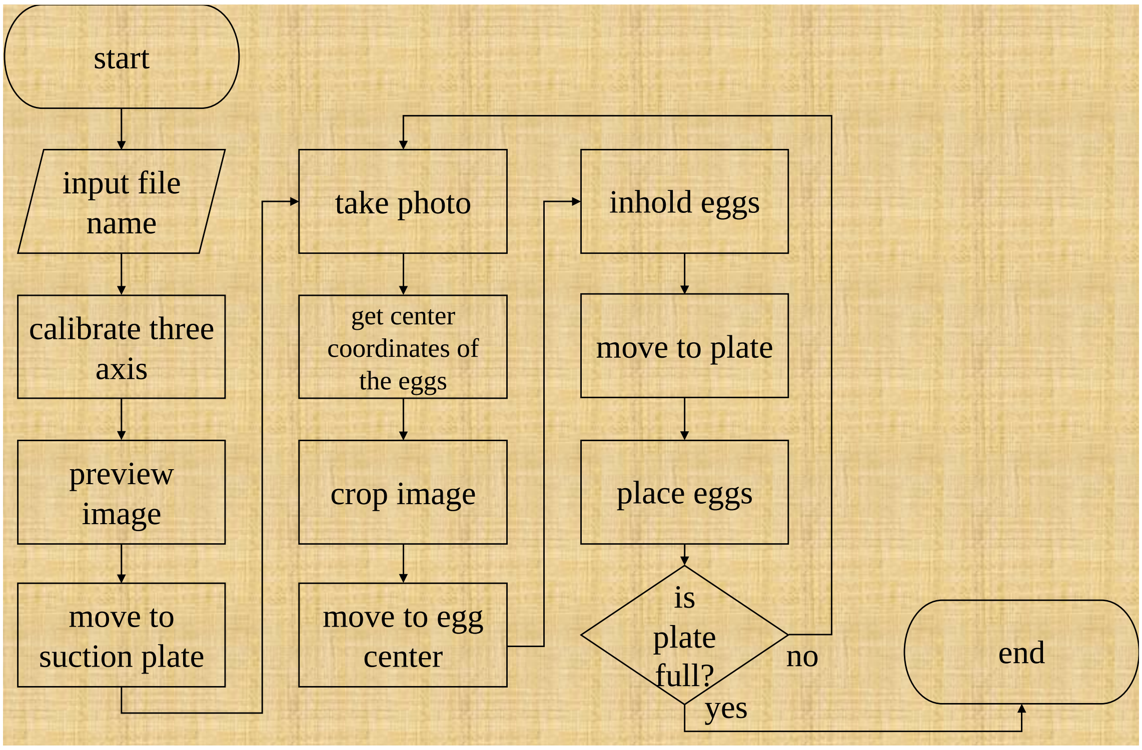


Figure 3. System flow chart.

2.2. Experiments

Two experiments were conducted to examine the efficiency of manual and automatic lacewing egg transfer. The first experiment was set up to investigate the time required for eggs to be manually transferred. An operator moved eight microplates of eggs, each microplate holding 96 eggs. The time required for transferring each microplate of eggs was recorded and compared to the time required for the automated egg transfer. The experiment was conducted in June 2022, and it was repeated three times.

The second experiment aimed to examine the placement precision of the automatic transfer system. In this experiment, the eggs were scattered on the 17 x 9 grids of a microplate, and they were transferred to a targeted grid one by one. Then the distance between the actual landing point and the targeted point was measured. In June 2022, this experiment was conducted and repeated three times.

3. RESULTS AND DISCUSSION

Table 1. depicts the outcomes of the first experiment. The shortest time for the manual transfer is 630.7 seconds, the longest time is 1,000.3 seconds, and the average time is 762.0 seconds. There is a significant difference between the time required for the manual and automatic transfer. The shortest time required for the automatic transfer is 663.7 seconds, the longest time is 701.7 seconds, and the average time is 689.5 seconds. The speed of transferring eggs through the automatic transfer method is, on average, 9.5% faster than that through the manual method. In addition, the standard division for the time required for the manual transfer and the automatic transfer is 123.3 and 12.3 respectively. This shows that the amount of time required to transfer eggs is quite consistent when using the proposed automatic egg transfer system. Thus, experimental results have suggested that the proposed automatic transfer system is more stable and efficient than the manual egg transfer.

Table 1. Transfer time between the manual and automatic transfer.

plate	1	2	3	4	5	6	7	8	Mean	SD
manual	1000.3	824.3	690.7	740.0	849.7	711.3	630.7	649.3	762.0	123.3
automatic	699.0	694.7	680.3	696.3	701.7	690.0	663.7	690.3	689.5	12.3

The experimental results of the positioning precision experiment are illustrated in figure 4. As can be seen from the figure, the distance ranges from 0 to 1000. The targeted point is positively and linearly correlated with the actual landing point. The regression line for the targeted and actual landing points is expressed as

$$y = 1.0004x-1.4379 \tag{1}$$

where x represents the targeted point, and y represents the actual landing point. The value of the r-square is 0.999, indicating that the two sets of data are highly correlated. Generally speaking, the greater the moving distance, the greater the deviation between the targeted and actual landing point, but this is not the case when the proposed egg transfer system was tested. There is sufficient evidence to support that the proposed transfer system is reliable and stable.

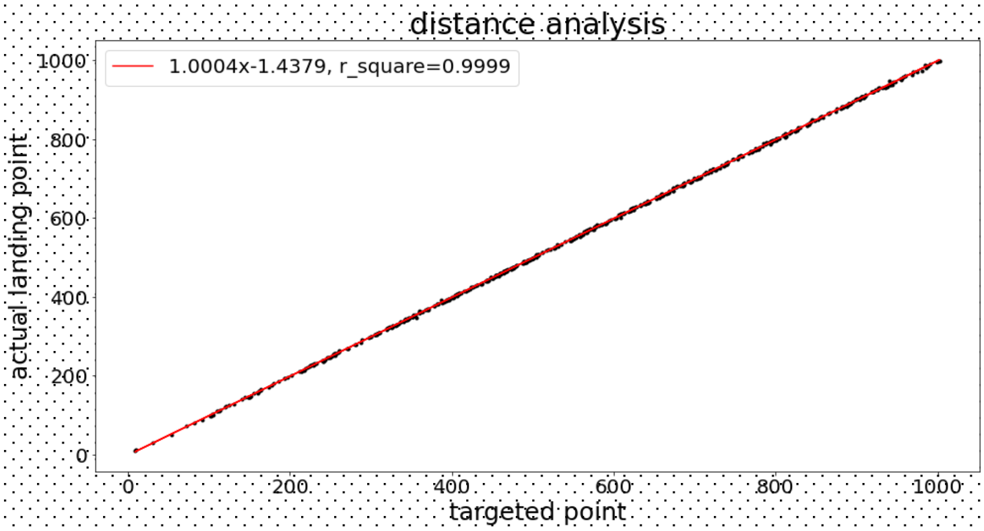


Figure 4. Distance analysis results.

4. CONCLUSIONS

This study proposed a system that can automatically transfer lacewing eggs to rearing areas. Such a system can solve the issues related to manually rearing lacewings. The proposed system transfer lacewing eggs onto a 96-well microplate with an average speed of 689.5 seconds, which is 9.5% faster than employing a manual approach. Additionally, the r-square for the regression model that involves the targeted points and the actual landing points is 0.999, indicating that this system can accurately move eggs to a targeted area. The proposed automatic transfer system is therefore a promising option to replace manual transfer methods.

5. ACKNOWLEDGEMENT

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THE APPLICATION OF THERMAL IMAGING TECHNOLOGY IN THE HEALTH MANAGEMENT OF DAIRY COWS

Kuo-Hua Lee[1, *]), Jih-Yi Chen[1]), Yi-Hsin Yeh[1]), Jen-Wen Shiau[1]), Tsair-Fwu Lee[2]), and Chao-Chien Chen[3])

1) Livestock Research Institute, Council of Agriculture, Executive Yuan, Taiwan
khlee@mail.tlri.gov.tw
2) National Kaohsiung University, Taiwan
3) Smartagri Integration Service Co Ltd.

* Corresponding author

ABSTRACT: In this study non-invasive thermal imaging was used to measure the temperature of dairy cows accurately and quickly for the assessment of their state of health. There were 25-35 milking cows in this trial. Three dual-lens infrared thermography were mounted two meters in front of the passageway leading to the milking bays. The thermal image resolution was 384 x 288 pixels, and the temperature range was -20°C to +150°C. A visible light lens was used to identify the eye socket and udder of cow, and the thermal lense was focused to automatically detect the temperature of the eye socket or udder. The temperature data was recorded by a computer management software system. When the temperature of the cow exceeds the threshold set, the red warning light will light up immediately. The results showed that the average thermal image temperature of the eye socket of a cow was 37.2 ± 1.1^{0}C (n=2,270), and the average temperature of the eye sockets of a cow with fever was 39.3 ± 0.5^{0}C (n=641). The average thermal image temperature of the udder of a cow was 36.1 ± 0.9^{0}C (n=2,367), and the average temperature of the udder of a cow with mastitis was 39.6 ± 1.2^{0}C (n=477). These results showed that thermal imaging technology could be used to monitor the health of dairy cows and was potentially very useful for the dairy industry.

Keywords: *Thermal image, infrared, dairy cow, fever, mastitis.*

1. INTRODUCTION

Body temperature monitoring provides opportunities for early screening, diagnosis and treatment, so that a sick cow can be quickly restored to health and productivity. Although handheld rectal thermometers are the most commonly used method for the measurement of body temperature, they are uncomfortable for the cow, and also take time and effort. Infrared thermography (IRT) is a tool that is being used increasingly with farm animals due to the growing interest of society in animal welfare [1]. This technique detects the heat irradiated by the body surface and decodes it into body temperature, to determine a relationship to the state of health of the animal [2]. Research has shown that the orbital, udder and urogenital regions permit quick evaluation of the state of health of an animal in a non-stressful manner [3,4,5]. In addition to being non-invasive, it is also very easy to apply. Furthermore, many studies have reported that the eye is the best region for measuring body temperature as is the udder temperature for mastitis detection in dairy cows [6-8].

Our research team conducted body temperature tests on 52 Holstein-Friesian cows in 2016. We compared rectal temperature with the temperature around the eyes measured with an infrared camera. We found that the average temperature around the eyes (38.1^{0}C) was reasonably close to the rectal temperature (38.6^{0}C). The study, published in the Ministry of Science and Technology Agriculture Special Issue (https://web.most.gov.tw/sd_ebook/530/sd-530.pdf), verified that the temperature around the eyes can indeed be representative of the rectal temperature in dairy cattle.

The challenge facing dairy farmers in the southeastern United States is heat stress and the strains that cause heat stress in lactating dairy cows [9]. Taiwan, has a subtropical climate and high temperatures and humidity for 4-6 months of the year, and the resulting heat stress is hard on lactating dairy cattle. The occurrence of bovine mastitis, reproductive disorders and bovine epidemic fever is a serious issue for dairy farmers in Taiwan. An early warning of symptoms that will allow prompt health action will reduce the huge economic damage that can be caused by such diseases is a priority. Many systems have been proposed for the automatic monitoring of dairy cattle, but most of them require sensors to be placed on the cow's body. This can cause discomfort and become a burden to the animal [10].

An automated long term non-contact body temperature detection method is proposed that combines infrared thermal imaging technology for the eye temperature and udder skin surface temperature monitoring of dairy cows.

2. MATERIALS AND METHODS

The cow images (RGB) and thermal images were taken from Holstein-Friesian cattle raised in the dairy farm of the Livestock Research Institute, COA. There were 25-35 milking cows in this trial. One dual-lens IRT was installed at a height of 2.2 m above the milking entrance of the passageway and two dual-lens IRTs were installed 2.0 m in front of the passageway, (see Figure 1). The thermal image resolution was 384 x 288 pixels, and the temperature range was -20^{0}C to +150^{0}C. A visible light lens was used to identify the eye socket and udder of cow, and the thermal lenses were focused to automatically detect the temperature of the eye socket and udder. The experiment was conducted during the milking time of the cow, which was 04:30 AM to 04:30 PM every day. The temperature information was recorded by the computer management software system (see Figure 2). The data collection was completed from October 2021 to August 2022. The image tag content includes: (1) images of eye sockets; (2) thermal images of eye sockets; (3) images of udders; (3) thermal images of udders. The image is first identified to find the correct eye socket or udder area. Then used the deep learning and image recognition methods to find and confirm the eye socket or udder in the color RGB image. Then focus on the eye socket or udder area, read the color level of this area in the corresponding infrared thermal image, and then convert an average temperature. When the temperature of the cow exceeds the threshold set, the red warning light will light up immediately.

Specifications of the photographic infrared cameras (see Figure 3) used in this trial. The infrared thermal imager was IP56 and it's lens was made of germanium glass, which is waterproof and dustproof. The shell was a metal frame, which had the functions of anti-collision and corrosion resistance. Detection temperature range -20^{0}C to +150^{0}C, accuracy ±0.3^{0}C, resolution 384 x 288 pixels. Thermal image viewing angle 78^0 × 29^0; minimum working distance 0.5 m; image update rate 30Hz; thermal Sensitivity < 50mk; spectral range 8-14μm; image format JPEG. The maximum resolution of the visible light camera used was 1920 x 1080 at 30fps; image viewing angle 78^0 × 29^0. The adopted IRT device was calibrated inside the factory, and the control unit of the device could accurately record the voltage level. For emissivity, the IRT lens was kept 1 m from the subjects and targeted at the heads, and without altering the materials and light exposure, the emissivity was set to 0.95. For the environmental factor, this was excluded to reduce negative influences on the IRT temperature.

3. RESULTS AND DISCUSSION

3.1. Thermal measurement of the temperature of the eye socket

When milking cows (25-35 heads) in the milking entrance, the IRT automatically identify the cow's eye socket and udder, then measure the temperature of the eye socket and udder, and immediately data processing and displayed on the management system (see Figure 4). The results showed that the thermal image temperature of the eyes could be reliably detected, collected and analyzed. In this study, 2,911 images of eye sockets were collected. The average eye socket temperature was 36.4 ± 2.0^{0}C (n = 2,168), and the average temperature of the eye socket of a cow with fever was 40.0 ± 0.5^{0}C (n = 12). Church et al (2014) suggested that the lacrimal caruncle or ocular surface in the orbital region of cattle was a sensitive thermal window due to characteristically high vascularization. The thermal image temperature of the eye socket was relatively constant and close to the rectal temperature, unlike that of the chest, abdomen or rump. Our research team conducted body temperature tests on 52 Holstein-Friesian cattle in 2016 and we compared the rectal temperatures of the cows with those measured with an infrared camera. We found that the average temperature around the eyes (38.1^{0}C) was close to the rectal temperature (38.6^{0}C). Bleul et al (2019) suggested application of IRT in animals to detect infectious and febrile states. During an infectious response, body temperature increases due to the presence of IL-1 and PGE2-alpha. This increase can be detected in thermal images. Automated IRT could also assist in diagnosing complex respiratory disease in calves. In this line of research, Schaefer et al (2019) evaluated 65 dairy calves weighing ~220 kg, exposed to standard transport and industrial practices. IRT detected and associated higher temperatures with clinically diagnosed respiratory diseases in the animals. Schaefer's study also showed that thermal imaging cameras could reliably detect the presence of fever and early detection could make treatment more effective. The application of IRT for the detection and monitoring of diseases involving fever is likely to become more widely used and shows promise of becoming a great tool.

3.2. Thermal measurement of the temperature of the udder

In this experiment, twoIRTs were installed at the milking entrance to measure the temperature of the udders (see Figure 3). There were 2,844 images of udders were collected. The results showed that the average temperature of the udder of normal cows was 36.1 ± 0.9^{0}C (n=2,367), and the average temperature of the udder of cows with mastitis was 39.6 ± 1.2^{0}C (n=477). The justification for using the udder region in IRT is based on the fact that mastitis is characterized by bacterial colonization of the mammary gland which generates a local inflammatory response due to the presence of proinflammatory cells. This causes a secretion of prostaglandin, histamine, and interleukins which trigger vasodilatation of the mammary capillaries, increasing the temperature of the region by 1.5^{0}C. In an experimental model of induced mastitis in six bovines using IRT, Hovinen et al (2008) identified an increase of 1.5^{0}C in the temperature of the skin of the mammary gland, which they were able to associate with other signs of inflammation, such as increases in somatic cell counts and rectal temperature.

Figure 1. The dual-lens IRTs installed at the milking entrance and automatically measured the temperature of the eye sockets and udders.

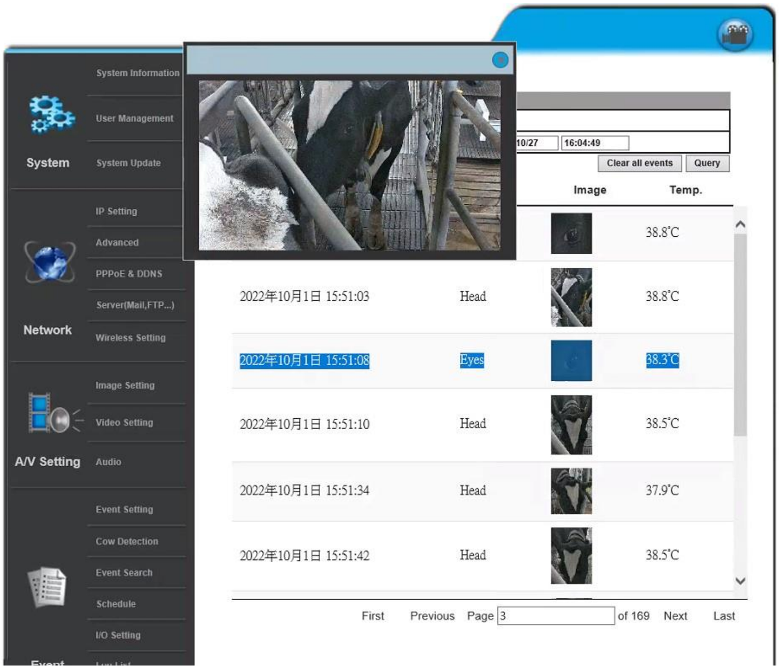

Figure 2. The cattle images and temperature information were recorded by the computer management software system.

Figure 3. A photographic infrared thermal camera.

Figure 4. The infrared thermal cameras could automatically identify and detect the temperature of the eye sockets (upper left 37.9^{0}C and lower left 39.5^{0}C) and udder (upper right 37.9^{0}C and lower right 37.2^{0}C) of dairy cows.

4. CONCLUSIONS

These results showed that the infrared thermal imager and identification system installed at the entrance to the milking passage in a dairy farm milking shed, can automatically detect the temperature of eye sockets and udders. This shortens the time it takes to measure the temperature, which usually involves the use of a rectal thermometer, as well as some discomfort both to the animal and the person using the thermometer. While the method can quickly detect any deviation from a normal temperature, further research on the accuracy and correlation with various dairy cow diseases is still required. However, the results showed that thermal imaging technology can be applied to monitor the changes in eye socket and udder temperature of dairy cows, which is a check for fever and mastitis prevention, and was potentially very useful for the dairy industry.

5. ACKNOWLEDGEMENT

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VISUALIZATION OF ACTIVE SITES ASSOCIATED WITH ROS ACTIVITY OF COMPOUNDS BY MORGAN FINGERPRINT

Masayuki Kogoshi[1,2,*], Nobutaka Kitahata[3], Kazuyuki Kuchitsu[4], Hideyuki Mizuno[5] and Takamitsu Kurusu[6]

1) Suwa University of Science, Japan
gh21701@ed.sus.ac.jp/ 5000-1 Toyohira, Chino City, Nagano Prefecture, Japan
2) National Agriculture and Food Research Organization, Japan
3) The University of Tokyo, Japan
4) Tokyo University of Science, Japan
5) Suwa University of Science, Japan
6) Suwa University of Science, Japan
* Corresponding author

ABSTRACT: Pesticides have become an integral part of modern life and are widely used to protect agricultural land. However, the frequency of pesticide development has been decreasing annually. Reactive oxygen species (ROS) play multiple beneficial roles as signaling molecules at low concentrations, whereas at high concentrations, ROS and related redox-active compounds cause cellular damage, indicating that ROS modulators have the potential to function as pesticides. For efficient prediction of ROS production from chemical compounds, we studied a method for visualizing active sites associated with the ROS activity of compounds using the Morgan fingerprint (MFP) technique. As a dataset for the analysis, we used ROS production data from cultured plant cells treated with approximately 10,000 compounds. The MFP was used to represent the structural features of molecules as mathematical objects. We constructed 512 type-fingerprint datasets based on numerical values. We found 78 data points that were highly correlated with ROS production and identified the structural parts of the compounds that contribute to ROS activity in plant cells. Additionally, we determined the structural parts of compounds that contribute to ROS production. Using this system, we modified the substructures of the compounds to create new structures that were predicted to exhibit high ROS production. The increase in ROS production in the created compounds was confirmed using a support vector machine. These results suggest that ROS activity in plant cells correlates with both thiophene and pyrimidine backbone structures, and the visualisation technique using MFP is effective for predicting the ROS activity of compounds.

Keywords: *Reactive oxygen species (ROS), pesticide, fingerprint, visualisation*.

1. INTRODUCTION

Pesticides have become an integral part of modern life and are widely used to protect agricultural land. However, the frequency of pesticide development has been decreasing annually, and a new research method that is different from the conventional visual selection method is required (Kraehmer et al., 1991). One reason is that the conventional visual selection method is time-consuming and expensive for discovering potential pesticide candidates.

Reactive oxygen species (ROS) are partially reduced or excited forms of atmospheric oxygen that are considered to play a dual role in plant biology (Mittler, 2017). ROS play multiple beneficial roles as signaling molecules capable of regulating diverse metabolic pathways and for gene expression in response to stress at low concentrations. Conversely, at high concentrations, ROS and related redox-active compounds cause cellular damage and necrosis through oxidative stress, indicating that ROS modulators have the potential to function as pesticides with novel modes of action.

Recently, a screening method has been developed to select ROS modulators using ROS production in plant cells as an index and determining the suitability of the selected compounds as pesticides (Kurusu and Kuchitsu, 2017). To increase the scale and reduce costs, in silico screening based on the ROS activity prediction of a group of compounds via learning is required. Furthermore, there are diverse sources of ROS production in plant cells, but there is insufficient knowledge regarding the relationship between ROS activity and compound structures.

It has been reported that a combination of fingerprinting and regression-based machine learning can be used to determine and visualise the sites of compounds that correlate with ligand-binding activity (An et al., 2013). By using data regarding ROS activity and secondary structures of approximately 10,000 chemical compounds, we attempted to visualise the correlation between ROS activity and secondary compound structures using both MFP and support vector machine (SVM) techniques. In the future, we expect to improve the accuracy of *in silico* screening based on the prediction of ROS activity via machine learning.

2. MATERIALS AND METHODS

2.1. Dataset

For the analysis, we used a dataset comprising ROS production data from cultured plant cells treated with 9,991 chemical compounds. We arbitrarily selected 1,000 compounds and used them for final verification (dataset B), and the remaining 8,991 compounds (dataset C) were classified into five types according to the amount of ROS production. Common logarithmic values of ROS production ($\log_{10}$ROS) were classified into five categories: ≥5, ≥4 and <5, ≥3 and <4, ≥2 and <3, and others. To eliminate data bias during learning, approximately 100 cases were selected from dataset C and used in dataset A.

2.2. Morgan fingerprints (MFP)

MFPs have been used to exploit the structural features of compounds via machine learning. They comprise 'circular substructures', which count substructures that are at a certain distance from the atom; for the analysis performed in this study the radius was set to 2. MFP contains a vector of hundreds to thousands of dimensions that represents the presence or absence of various substructures in a molecule with 0 or 1, respectively, and similar molecules are represented by similar vectors. The code for visualising the bit array of the MFP was first released in the 2018 open-source RDKit update (RDKit: open-source cheminformatics software).

The standard regression coefficients of the linear support vector regression model were used to indicate the contribution of each component (bit) of the MFP vector of a chemical compound to the property value ($\log_{10}$ROS). A value *Ai* that integrates the contributions of the substructures towards a certain atom *i* was calculated using the following equation:

$$A_i = \sum_{n=1}^{N} \left(C_n \times \frac{1}{f_n} \times \frac{1}{x_n} \right) \qquad (1)$$

Where f denotes a list of MFPs containing one or more i in the atoms constituting the backbone substructure, and f_n (n = 1, 2,... N) denotes the number of each substructure in the chemical molecule. C_n and X_n denote the contribution of each MFP component and r number of atoms in each substructure, respectively. Each atom was coloured with different shades of red or blue, based on the strength of its positive or negative impact on ROS production, respectively.

2.3. Visualisation of active sites associated with ROS activity of compounds

Considering the small amount of data available for machine learning, we used a linear SVM and applied the Boruta model (Kursa, 2010) to improve its artificial intelligence accuracy. This model includes a feature extraction technique that selects the MFP vector components that contribute

gh21701@ed.sus.ac.jp / 5000-1 Toyohira, Chino City, Nagano Prefecture, Japan

significantly to inference. According to the Boruta model, we ranked the variable importance using random forest and then eliminated the variables with low correlation to physical properties. GridSearchCV from the Scikit-learn library was used to optimise the hyperparameters of the linear SVM.

3. RESULTS AND DISCUSSION

3.1. Visualisation of active sites associated with ROS activity of compounds via MFP

We constructed 512 type-fingerprint datasets based on numerical values. Figure 1 shows the top 10 standard regression coefficients of the linear support vector model that contribute to the physical property values (bits) of the MFP components (Figure 1a) and structures with high MFP contributions (Figures 1b–d). Consequently, we discovered 78 data points that were highly correlated with ROS production and identified structural parts of the compounds that contribute to ROS activity in plant cells.

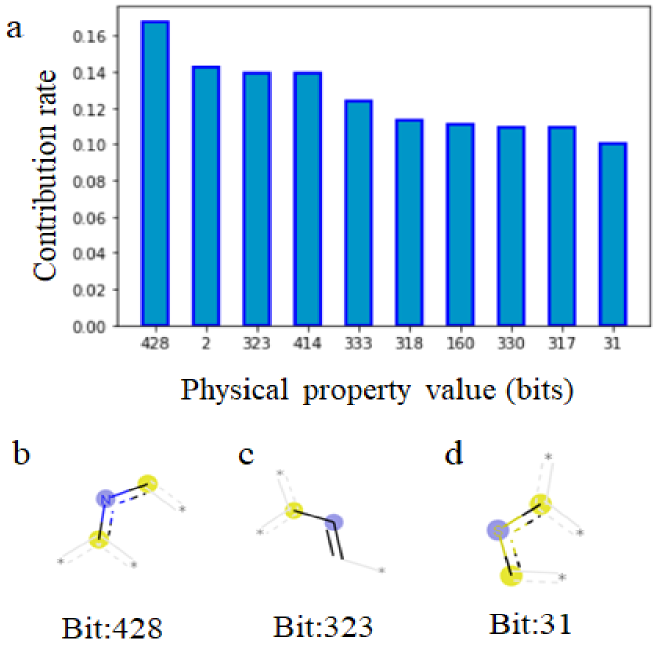
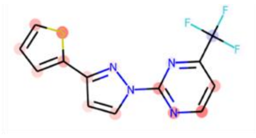
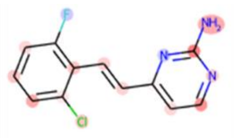


Figure 1. Standard regression coefficients of the linear support vector model. (a) Top 10 standard regression coefficients. A positive value indicates a positive contribution to $\log_{10}$ROS. (b–d) Structural diagrams showing high MFP contributions. The bit number indicates the physical property value (bit) of the MFP component.

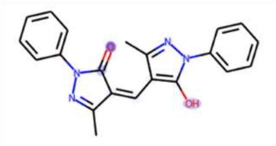
Figure 2 shows the representative chemical compounds visualised via MFP. The experimental data revealed that these compounds exhibited high ROS activity in plant cells (Figures 2a and b). The trifluoromethyl group (CF_3) attached to the benzene ring negatively contributed to the ROS activity, as shown via the MFP visualisation in Figure 2a. In contrast, the amino group (NH_2) attached to the benzene ring positively contributed to ROS activity (Figure 2b). To confirm the reliability of the MFP-based visualisation technique, changes in ROS activity were examined by replacing the CF_3 group in compound (a) with NH_2. As expected, its ROS activity increased from 5.7 to 6.3 (Figures 2a and d). These results suggest that the visualisation technique using MFP is effective in predicting the ROS activity of compounds in plant cells.



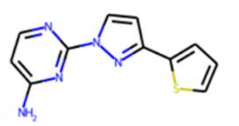
(a) FC(F)(F)c1ccnc(-n2ccc(-c3cccs3)n2)n1
(Measured $log_{10}ROS$ 5.74)



(b) Nc1nccc(/C=C/c2c(F)cccc2Cl)n1
(Measured $log_{10}ROS$ 5.59)



(c) CC1=NN(c2ccccc2)C(=O) /
C1=C¥c1c(C)nn(-c2ccccc2)c1O
(Measured $log_{10}ROS$ 1.45)

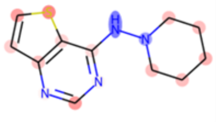


(d) Nc1ccnc(-n2ccc(-c3cccs3)n2)n1
(Predicted $log_{10}ROS$ about 6.3)

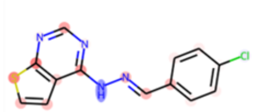
Figure 2. Representative structures of chemical compounds visualised using MFP. (a and b) Chemical compounds with high ROS activity in plant cells. (c) Chemical compound with low ROS activity in plant cells. (d) A novel chemical compound wherein the trifluoromethyl group (CF_3) of the compound shown in (a) is replaced with an amino group (NH_2). Each atom is coloured with different shades of red or blue, based on the strength of its positive or negative impact on ROS production value ($log_{10}ROS$), respectively.

3.2. Chemical structures strongly correlated with ROS activity in plant cells

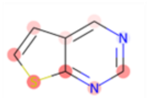
As shown in Figures 1b and d, a thiophene ring (bit:31) and part of the pyrimidine ring (bit:428) were effective for inducing ROS activity that was visualised via MFP. Figures 3a and b show two compounds with thieno [2,3-d] pyrimidine structures containing thiophene and pyrimidine rings. The experimental data revealed that these compounds exhibited high ROS activity in plant cells, and high values were also detected in SVM predictions (Figures 3a and b). Next, we determined the sites in these compound structures that were strongly correlated with ROS activity. The thieno [2,3-d] pyrimidine structure was observed to be effective in ROS production (Figures 3c–e). In the future, we will continue to investigate the partial structural conversion that contributes to the increased ROS activity.



(a) C1CCN(CC1)NC2=NC=NC3=C2SC=C3
(Measured $log_{10}ROS$ 5.15)
(Predicted $log_{10}ROS$ about 4.91)



(b) C1=CC(=CC=C1/C=N¥NC2=C3C=CSC3=NC=N2)Cl
(Measured $log_{10}ROS$ 4.42)
(Predicted $log_{10}ROS$ 5.33)



(c) C1=CSC2=NC=NC=C21
(Predicted $log_{10}ROS$ about 4.47)

(d) C1=CSC=C1
(Predicted $log_{10}ROS$ about 4.47)

(e) C1=CN=CN=C1
(Predicted $log_{10}ROS$ about 3.49)

Figure 3. Chemical compounds containing the thieno [2,3-d] pyrimidine structure visualised using MFP. (a and b) Compounds with a thieno [2,3-d] pyrimidine structure that show high ROS activity in plant cells. (c–e) show the thieno [2,3-d] pyrimidine structure, thiophene ring, and pyrimidine ring, respectively. Each atom is coloured with different shades of red or blue, based on the strength of its positive or negative impact on ROS production value ($log_{10}ROS$), respectively.

4. CONCLUSIONS

We created a program that visualises the basis of the SVM prediction results using MFP. Based on the visualisation of the predictions, we changed the partial structures of compounds and determined the inference values that indicated that the modified compounds increased ROS production. Furthermore, the thieno [2,3-d] pyrimidine structure was shown to be strongly correlated with ROS activity in plant cells (Figure 3), indicating that the visualisation technique using MFP is effective for predicting the ROS activity of compounds in plant cells. It has been reported that some compounds containing a thieno [2,3-d] pyrimidine structure demonstrated antibacterial and antiviral properties (Ma et al., 1995). The development of new herbicides using substituted thienopyrimidine derivatives was also reported (Ota et al., 2007).

Overall, ROS activity in plant cells correlates with both thiophene and pyrimidine backbone structures, and the visualisation technique using MFP is effective for predicting the ROS activity of compounds. In the future, this system is expected to contribute to improving the accuracy of in silico screening based on the prediction of ROS activity via machine learning, and the proposed system may be a useful tool for developing new pesticides based on ROS activity.

5. ACKNOWLEDGEMENT

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AN ELECTRIC ASPARAGUS HARVESTING ROBOT ARM

Shao-Hsiang Yeh[1)], Cheng-Yu Chueh[1)], Cheng-Chun Lee[1)],
Joe-Air Jiang[1,*)]

1) Department of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan

* Corresponding author: jajiang@ntu.edu.tw

ABSTRACT: In Taiwan, asparagus is a cash crop with a price of more than TWD 100 per kilogram and is harvested twice a year. As the agricultural population ages and labor is in short supply, it is necessary to develop automatic, labor-saving harvesting devices. An electric asparagus harvesting robot arm was developed in this study. The robot arm featured a 5-degree of freedom. The software driver used for controlling the robot arm was iRUBY. The gripper jaw served as the end effector of the robot arm, capable of shearing the asparagus. An industrial PC computed the optimal path of the robot and controlled all the processes of harvesting asparagus. After being repeatedly tested 150 times in an hour, it was found that the average time for the asparagus harvesting robot arm to trim an asparagus shoot was about 25 seconds. When the battery of the robot was in full charge, the robot arm could operate over 100 times. The robot arm could also be equipped with computer vision to improve the accuracy of autonomous harvesting of asparagus to reduce labor shortages and human fatigue.

Keywords*: Autonomous harvesting robot, Asparagus, Robot arm.*

1. INTRODUCTION

Asparagus is a high-value cash crop, and farmers in Taiwan apply the mother-stalk cultivating method to grow asparagus, which is pretty different from the methods used in other countries. Such a method is able to grow asparagus with better quality, creating higher economic values with a price of more than TWD 100 per kilogram. Asparagus is harvested twice a year. Nevertheless, this method requires hard work, often causing occupational injuries to farmers. In recent years, due to labor shortage and higher labor costs, many studies have focused on developing automatic, labor-saving devices for harvesting asparagus. This study proposes to use a robot arm to automatically harvest asparagus to solve the problems associated with manual harvesting.

2. MATERIALS AND METHODS

2.1. Robot Arm

The proposed robotic arm, attached to a harvesting machine, featured 5 degrees of freedom, using the cartesian coordinates as the control reference in the three-dimensional space. There were X, Y, and Z axes respectively. And the first axis of the robot arm was parallel to the z-axis used for rotation. The second axis was equipped with a metal reducer, which was responsible for the ascending and descending movement of the third, fourth and fifth axes, which were the main harvesting components. The top and bottom of the second axis were equipped with a laser sensor for the function of calibrating the origin point of the robot arm. As the machine was turned on, the robot arm started to calibrate the origin point. When the second axis reached either the top or the bottom as the end position, the laser sensor would send a signal to the robot arm to halt, protecting the device from damage. The entire second axis was structurally strengthened, the slide rail was equipped with a dust cover, and the gear parts were also sealed dustproof. Therefore, dust and gravel would not hinder the harvester when it was deployed to the actual field. The end effector on the fifth axis was the grip used to perform the task of asparagus picking. A HIWIN XEG-C1 electric gripper jaw was selected, which had a length of 239.5mm and a width of

125mm. The blades were mounted on top of the gripper jaw to cut off asparagus. There was a sponge under the blades, so the blades would not damage asparagus when they were gripped and removed. During the harvesting process, the harvester followed the trail in the asparagus field. When an asparagus shoot was detected, the robot arm would move to a standby harvesting point and prepare to clip the shoot. Such a design was to avoid irregular points along the trail stopping the robot arm, resulting in the robot arm being unable to reach asparagus shoots. The movement range of the robot arm was based on the rows where asparagus shoots grew during the harvesting process. The robot arm first moved along the Z-axis direction and lifted an asparagus shoot vertically while avoiding touching or hurting other asparagus plants and their tender stem. Then the robot arm moved along the X-axis and Y-axis directions.

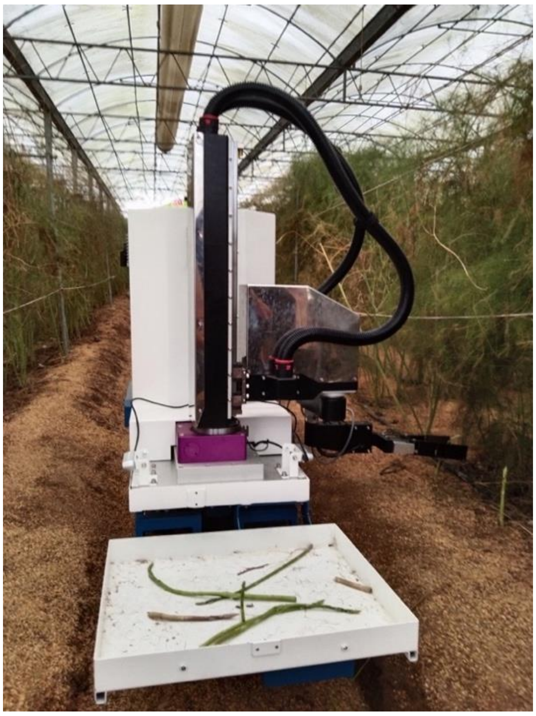

Figure 1. Electric asparagus harvesting robot.

2.2. The Control of the Robot Arm

After the positions of asparagus shoots were determined, the position information was sent to an industrial computer to convert into corresponding coordinates. The converted coordinates were input into the programming software iRuby to transmit the control signal to the driver board of the server to control the robot arm. The harvested asparagus shoots were placed in an asparagus basket.

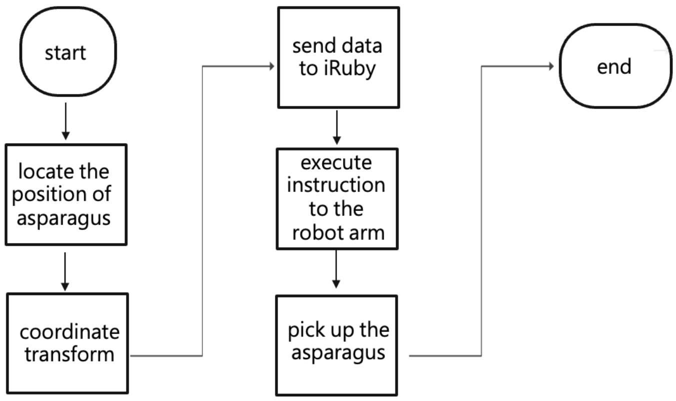

Figure 2. The flow chart of the robot arm that harvests asparagus shoots.

2.3. Repeatability and Accuracy of the Robot Arm

An experiment was conducted to examine the Repeatability and Accuracy of the proposed robot arm. This experiment was carried out at Precision Machinery Research & Development Center in Taichung on September 30^{th}, 2022. Using the FARO/Vantage-E laser tracker to test the repeatability and accuracy of the robot arm. The type of measurement is based on the movement of a reflector along the laser beam emitted from the laser light source as shown in Figure 3. The testing method measures five points situated on a diagonal plane of an imaginary cube followed by ISO 9283:1998. There are five test positions from P1 to P5, and the measurement consists of 30 measuring cycles.

Figure 3. The repeatability measurement tested by laser tracker

2.4. Stability of the Robot Arm

An experiment was conducted to examine the stability of the proposed robot arm. This experiment was carried out in an asparagus field supervised by the Tainan district agricultural research and extension station in Chiayi from August 7^{th} to 11^{th}, 2022. The measured width of the asparagus field furrow was 50 cm, the depth was 30 cm, and the distance between the asparagus plant and the harvester was about 60 cm. The experiment of harvesting and clipping asparagus shoots was repeated 15 times, and the results were recorded.

2.5. Operation time of the Robot Arm

The time required to complete the whole harvesting process was examined. The tasks required to complete in the harvesting process included a position command that contained coordinates being sent from the industrial computer, the robot arm reaching the standby point the harvester moving to the standby point, picking up the asparagus shoot and removing it, and placing the asparagus shoot in the basket. The experiment was also repeated 15 times and the results are recorded.

2.6. Operation Time and the Voltage of the Harvesting Machine

The computer connected to the harvester machined showed the total voltage of the harvesting machine. When the harvesting tasks were performed for a period of time, the voltage of the machine would drop. This experiment examined the relationship between the voltage drop and the operation time of the robotic arm.

3. RESULTS AND DISCUSSION

3.1. Repeatability and accuracy result of the Robot Arm

As Table 1 showed the accuracy and repeatability of the five-point from P1 to P5. The maximum standard deviation of positioning accuracy was 1.64, and the maximum standard deviation of repeatability is 1.38.

Table 1. measurement results of the positioning accuracy and repeatability.

measuring point	positioning accuracy(mm)	Repeatability (positioning precison)(mm)
P1	0.80	1.29
P2	1.43	1.17
P3	1.31	1.38
P4	1.64	1.38
P5	0.57	1.19

The result of the measurement shows that the accuracy of the standard deviation of the robot is no more than 2 mm. Therefore, the accuracy of the robot arm is enough to pick asparagus in the field.

3.2. Stability of the Harvesting

In the experiment, the robot arm was able to successfully perform harvesting tasks nine times, and the success rate of harvesting was 60%. As asparagus shoots grew, the depths of asparagus plants changed, which made the robot arm unable to effectively and accurately locate different asparagus plants.

3.3. Time required for the Harvesting

The shortest time for the robot arm to complete the whole harvesting process was 47 seconds, and the longest time was 62 seconds. The average time was 56.5 seconds, and the standard deviation was 5.01 seconds. The variations in the harvesting speeds were largely caused by the difference in the position of each asparagus plant. Therefore, the movements distances between the asparagus plant and the robot arm varied, resulting in time differences.

3.4. Operation Time and the Voltage of the Harvesting Machine

After the asparagus harvesting machine was fully charged, the monitor attached to the machine showed that the voltage was 52V. The voltage dropped after the harvesting operation began. The voltages under continuous operation are shown in Table 1.

Table 2. voltage dropping when the electric asparagus harvesting robot operated (per minute).

ΔV/min	**51.3～50 V**	**50～48 V**	**48～46 V**		
average (ΔV)	0.005	0.008	0.01	total average(ΔV)	0.0077
standard deviation(ΔV)	0.0009	0.0045	0.0026	total standard deviation(ΔV)	0.0018

The rates of the voltage drop were calculated using the following intervals: 51.3 V-50 V, 50 V-48 V, and 48 V-46 V. The harvesting machine functioned normally when its voltage was higher than 46 V. After operating for one hour, the voltage of the machine dropped by 0.46V. Given that the voltage for the fully charged machine was 52 V, it was estimated that the machine could continuously operate for 13 hours.

4. CONCLUSIONS

The asparagus harvesting machine developed by this study is estimated to be able to operate continuously for 13 hours, so it can help achieve the goals of labor-saving harvesting and reduce the chances of occupational injuries caused by harvesting asparagus shoots every season. The experimental results also point out the need for improvement. In future studies, to find a suitable method to calibrate the zero point of the robot arm, a depth camera will be attached to the left and right sides of the machine to perform image recognition of asparagus plants. It is expected that the combination of image recognition and the proposed robotic arms is able to create a fully automated asparagus harvester.

5. ACKNOWLEDGEMENT

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FACTORS AFFECTING ON PROCESS INNOVATION IMPLEMENTATION IN JAPANESE AGRICULTURAL CORPORATIONS

Nguyen Thi Ly[1)], and Teruaki Nanseki[2,*)]

1) Vietnam National University of Agriculture, Vietnam
E mail: nguyenly@vnua.edu.vn. Contact Details: Faculty of Economics and Rural Development, Vietnam National University of Agriculture, Trau Quy town, Gia Lam district, Hanoi, Vietnam
Category – (Delegate)
2) Kyushu University, Japan

* Corresponding author: nanseki@agr.kyushu-u.ac.jp

ABSTRACT: The growing number of corporations is trending in Japanese agriculture cause of easier in their business development as well as it is a chance in implementing agricultural innovations. However, the studies that investigated the factors associated with the types of innovation are limited, especially in process innovation, of which digital agriculture technology is a trigger, among the Japanese agricultural corporations. Therefore, this study aimed to identified factors associated with the implementation of a process innovation that is new or significantly improved production processes, delivery methods, and activities that support them in a Japanese agricultural corporation by using a Probit model to analyze a national survey of 324 corporations. The results showed that 47.8% (n=155) of the corporations implemented the process innovation. The results also found that the corporations with a higher number of regular employers tend to perform the process innovation. The corporations targeted their sale amount at 1.5 times and 1.8 times compared to their current sale amount tend to perform the process innovation. Besides, the corporations were flowers and foliage plants and the mixed types tend to implement the process innovation compared to the rice corporations. However, the factor that hindered the process innovation implementation of the Japanese agricultural corporation was the number of experience years joining in the agricultural activities of these corporations. In addition to this, corporations with annual sales amounts from 1000 -2000 million yen tend to less implement the process innovation compared to the corporation with an annual sale amount of fewer than 30 million yen. The corporations at the stage of recession and the 2nd mature tend to less implement the process innovation compared to the corporations at the first starting stage. Based on these findings, it is considered that a higher target promotes the process innovation, but long experience and mature stage hinder the process innovation. These may imply that digital agriculture technology has a larger impact on process innovation in agricultural corporations with less experience at the startup stage.

Keywords: *Japanese agricultural corporation, process innovation implementation, a micro-data analysis.*

1. INTRODUCTION

An agricultural corporation is expected to be more efficient and profitable way in their operation in the situation of Japanese agriculture that faced aging farmers and lack of successor (Nanseki, 2021, Clever et al., 2014). Agricultural corporation is a general term for corporations engaged in agriculture such as land-use agriculture such as rice cultivation, institutional horticulture, and livestock farming. Organizational forms are broadly divided into joint-stock companies and partnerships based on the

Companies Act, and agricultural cooperative corporations based on the Agricultural Cooperatives Act (Clever et al., 2014; Ministry of Agriculture Forestry and Fisheries (MAFF), 2021). The number of agricultural corporation in Japan increased steadily by 13% to 31,000 in 2020 compared to five years ago (MAFF, 2021). This increasing trend of agricultural innovation made a change in the agricultural structure (Nanseki, 2022). Also it creates an opportunity to implement innovation that contribute to overcome the lack of farmers challenge for improving agricultural productivity (MAFF, 2016). However, the interesting question of policymakers, as well as scholars on factors, shed light on the innovation implementation in the agricultural corporation is unfolding. There is only Nguyen et al. (2022) attempt to unfold the factors associated with product innovation in Japanese agricultural corporations but those with process innovation, that are promised with a trigger digital agricultural technologies, are still in form of a question. Therefore, this study aims to identify factors associated with the process innovation implementation of Japanese agricultural corporations.

2. MATERIALS AND METHODS

2.1. Data

This study used the raw data of the survey of “Questionnaire on Business Development and Innovation in Agricultural Corporation Management” that was conducted in 2019 via a mailing method. The total questionnaires were sent to 2,885 Japanese agricultural corporations in whole Japan. These corporations found their names on websites such as the Japan Association of Agricultural Corporations or relevant literature by using a professional search. Finally, 505 corporations were completed the questionnaire and the primiliry result of this survey was published in Nanseki (2021). Moreover, this study focused on the process innovation implemented by Japanese agricultural corporations that are defined as new or significantly improved production processes, delivery methods, and activities that support them. In here, new or significantly improved" refers to something new to the corporation and is new to the market that the corporations joined in. Process innovations were divided into three categories: (1) Implemented a new or significantly improved production process; (2) Introduced new or significantly improved delivery and distribution methods; and (3) Implemented new or significantly improved systems and mechanisms to support production processes and delivery methods. According to Nanseki (2021), the implementation rate of these categories was 33.7% (n=170), 11.9% (n=60), and 9.9% (n=50), respectively. However, the number of valid observations with available data for all variables using in this study was 324.

2.2. Empirical model to estimate factors associating with process innovation implementation

As a lot of studies research on adopting new technologies in agriculture, logit and probit models are preferred to use. This study used the probit model to determine whether a corporation implemented process innovation as equation (1):

$$Y^* = \beta_0 + X\beta \quad + e, \tag{1}$$

$$with\, Y = 1\; if\; Y^* > 0\; and\; Y = 0\; if\; Y^* \leq 0.$$

In which, Y* is an unobserved or latent variable, and Y is an observed variable of Y*. Y=1 if the corporation implemented process innovation that means that the corporation implemented at least one category of process innovation and 0 otherwise. X is a set of explanatory variables. It includes: (1) Type of corporation (Limited company, stock company; agricultural producers' cooperative corporation and others); (2) own land that corporations certified; (3) Region that corporations located; (4) age of corporation (in years); (5) agricultural years of corporations (in years); (6) background of corporation; (7) Regular employees (in persons); (8) annual sales of corporations; (9) profit margin; (10) growth stage; (11) sale target; (12) profit margin target; (13) main product of the corporation; (14) self-evalution in new product and technology development; (15) self-evaluation of impact of Japan join in overall evaluation on the corporation; (16) to (24) are characteristics of the representative of the corporation including age, educational background, and non-agricultural experience. β represents a set of estimated parameters, and *e* is a standard normal distribution.

3. RESULTS AND DISCUSSION

3.1. Main characteristic of process innovation implementation in Japanese agricultural corporation

The descriptive result showed that there was 47.8% (n=155) of Japanese agricultural corporations among 324 surveyed corporation implemented at least one of three categories of process innovation. In detailed, the implementation rate of implemented a new or significantly improved production process, introduced new or significantly improved delivery and distribution method and implemented new or significantly improved systems and mechanisms to support production processes and delivery methods are 37.7%, 12.0%, and 10.8%, respectively. This implied that the corporation concentrated more in implementing a new or significantly improved production process than in the rest two categories.

3.2. Factors associated with process innovation implementation

Factors associating with process innovation implementation in Japanese agricultural corporation were shown in Table 1. The process innovation implementation means that the corporation implemented at least one category of process innovation. The value of a Chi-squared likelihood ratio with 69 degree of freedom was 111.40 and was significant at 1%. It implies that the current estimated model was better than the null model without explanatory variables. Moreover, the correctly classified of the estimated model was 72.96%. It means that the current estimated model predicted correctly 72.96% of observed samples.

Table 1. Factors associating with process innovation implementation

No	Variables	Coef.		Std. Err	z	P>|z|	[95% CI]	
1	Type of corporation (1 = Limited company is the base group)							
	2 = Stock company	-0.042		0.229	-0.180	0.855	-0.491	0.407
	3 = Agricultural producer's cooperative corporation	-0.475		0.349	-1.360	0.174	-1.160	0.209
	4 = Others	0.000	(empty)					
2	Own land (Dummy)	0.083		0.333	0.250	0.804	-0.570	0.735
3	Region (1 = Hokkaido is the base group)							
	2 = Tohoku	0.153		0.658	0.230	0.817	-1.137	1.442
	3 = Kanto	-0.187		0.681	-0.270	0.784	-1.521	1.147
	4 = Hokuriku	-0.361		0.696	-0.520	0.604	-1.726	1.003
	5 = Kinki and Tokai,	-0.096		0.697	-0.140	0.890	-1.462	1.270
	6 = Chugoku and Shikoku	-0.564		0.658	-0.860	0.392	-1.854	0.726
	7 = Kyushu and Okinawa	-0.683		0.652	-1.050	0.295	-1.960	0.595
4	Age of corporation (years)	-0.006		0.010	-0.670	0.504	-0.025	0.012
5	Agricultural experience of corporation (years)	-0.007	*	0.004	-1.940	0.052	-0.014	0.000
6	Background of corporation (1= Is a farmer established a corporation only one member/single corporation is the base group)							
	2 = A farmer jointly established cooperation with other members	-0.053		0.263	-0.200	0.840	-0.569	0.463
	3 = A farmer established the corporation in collaboration with non-farmers and companies from other industries.	0.458		0.536	0.850	0.393	-0.593	1.509

	4 = A non-farmer entered agriculture as an individual and established a corporation.	-0.498		0.480	-1.040	0.300	-1.439	0.443
	5 = The company mainly deals in a separate/different business, but it has entered agriculture as a new business.	-0.500		0.418	-1.200	0.232	-1.318	0.319
	6 = The parent/main company or group company has established a new corporation and entered agriculture.	0.300		0.414	0.730	0.468	-0.511	1.112
	7 = Others	-0.293		0.507	-0.580	0.562	-1.286	0.699
7	Regular employees (persons)	0.019	**	0.008	2.410	0.016	0.004	0.034
8	Annual sales (1 = Less than 30 million yen is the base group)							
	2 = 30 - 50 million yen	0.105		0.420	0.250	0.803	-0.718	0.928
	3 = 50 - 100 million yen	-0.287		0.368	-0.780	0.434	-1.008	0.433
	4 = 100 - 300 million yen	-0.489		0.369	-1.330	0.185	-1.213	0.234
	5 = 300 - 500 million yen	0.177		0.522	0.340	0.735	-0.846	1.199
	6 = 500 - 1000 million yen	-0.230		0.619	-0.370	0.710	-1.443	0.983
	7 = 1000 - 1500 million yen	-2.156	***	0.700	-3.080	0.002	-3.528	-0.783
	8 = 1500 - 2000 million yen	-1.551	*	0.857	-1.810	0.070	-3.231	0.129
	9 = from 2000 million and above	-1.145		0.909	-1.260	0.208	-2.927	0.637
9	Profit margin (1 = 0% (Break-even) is the base group)							
	2 = 1-5%	0.320		0.330	0.970	0.332	-0.326	0.965
	3 = 5-10%	-0.366		0.367	-0.990	0.320	-1.086	0.355
	4 = 10-15%	0.365		0.415	0.880	0.379	-0.449	1.179
	5 = 15-20%	0.533		0.548	0.970	0.331	-0.542	1.607
	6 = From 20% and above	1.007		0.908	1.110	0.267	-0.772	2.786
	7 = Deficit	-0.232		0.370	-0.630	0.532	-0.957	0.494
10	Growth stage (1 = Starting is the base group)							
	2 = Growing	-0.399		0.374	-1.070	0.286	-1.132	0.333
	3 = Mature	-0.698		0.426	-1.640	0.102	-1.533	0.137
	4 = Recession	-1.631	***	0.583	-2.800	0.005	-2.774	-0.489
	5 = 2nd starting	-0.389		0.445	-0.870	0.383	-1.261	0.484
	6 = 2nd growing	0.518		0.460	1.120	0.261	-0.384	1.419
	7 = 2nd mature	-1.359	*	0.715	-1.900	0.057	-2.761	0.042
	8 = 2nd recession	0.000		(empty)				
	9 = Others	-0.633		0.769	-0.820	0.410	-2.140	0.873
11	Sales target (1 = Remain as the current is the base group)							
	2 = 1.2 times	0.219		0.331	0.660	0.508	-0.430	0.867

	3 = 1.5 times	0.681	*	0.371	1.840	0.066	-0.046	1.407
	4 = 1.8 times	1.829	**	0.779	2.350	0.019	0.302	3.355
	5 = 2.0 times	0.161		0.427	0.380	0.705	-0.675	0.997
	6 = Above 2.0 times o less than 3 times	0.554		0.525	1.060	0.291	-0.475	1.584
	7 = From 3 times and above	0.691		0.543	1.270	0.203	-0.373	1.755
	8 = Decreasing	0.000	(empty)					
	9 = There no target	0.000	(empty)					
12	Profit margin target (1 = 0% (Break-even) is the base group)							
	2 = 1-5%	0.094		0.475	0.200	0.844	-0.837	1.025
	3 = 5-10%	-0.091		0.474	-0.190	0.848	-1.020	0.838
	4 = 10-15%	0.212		0.508	0.420	0.677	-0.784	1.208
	5 = 15-20%	0.112		0.544	0.210	0.837	-0.955	1.178
	6 = From 20% and above	0.734		0.633	1.160	0.246	-0.506	1.974
	7 = There is no target	0.000	(empty)					
13	Main product (1 = Paddy rice is the base group)							
	2 = Wheat	0.000	(empty)					
	3 = Beans and coarse cereals	0.000	(empty)					
	4 = Open ground vegetable	0.562		0.397	1.420	0.156	-0.215	1.340
	5 = Facility vegetable	-0.476		0.373	-1.270	0.203	-1.208	0.256
	6 = Flowers and foliage plants	1.362	**	0.540	2.520	0.012	0.304	2.421
	7 = Fruiter	0.220		0.398	0.550	0.580	-0.560	1.000
	8 = Mushroom	-0.274		0.635	-0.430	0.666	-1.519	0.970
	9 = Livestock production	0.654		0.424	1.540	0.123	-0.178	1.486
	10 =Mixed	0.884	**	0.350	2.520	0.012	0.197	1.570
	11 = Others	0.320		0.374	0.850	0.393	-0.414	1.053
14	Self-evaluation	0.115		0.091	1.270	0.205	-0.063	0.294
15	FTA participation	0.066		0.095	0.690	0.488	-0.120	0.251
16	Age of representative	0.001		0.090	0.010	0.995	-0.176	0.177
17	High school	-0.503	**	0.223	-2.260	0.024	-0.939	-0.066
18	Vocational school	-0.069		0.330	-0.210	0.835	-0.715	0.578
19	Educational institution	0.219		0.340	0.640	0.520	-0.448	0.885
20	Junior college	-0.132		0.426	-0.310	0.758	-0.967	0.704
21	University	0.086		0.252	0.340	0.733	-0.407	0.579
22	Graduate school	-0.224		0.553	-0.410	0.685	-1.307	0.860
23	Other type of education	0.607		0.692	0.880	0.380	-0.749	1.963
24	Non-agricultural experience	0.011		0.060	0.180	0.861	-0.107	0.128
	Constant	-0.069		1.276	-0.050	0.957	-2.569	2.432

Source: Nanseki, 2021; n = 324; $1~109 yen (in 2019 from https://www.stat-search.boj.or.jp/ssi/cgi-bin/famecgi2); Note: ***, **, and *: Statistically significant at 1%, 5%, and 10% respectively; log likelihood = −156.900; Chi-squared likelihood ratio (69) = 111.40***; pseudo-R^2 = 0.2620; correctly classified = 72.96% (a) In Probit model 17 observations were not used because these 17 observations belonged to the categories that predicts failure/successful perfectly.

The results showed that the number of regular employees, the annual sale target, main product of the corporation have a positive sign of estimated coefficients. It means that these factors tend to foster the process innovation implementation among Japanese agricultural corporation. In detailed, the coefficient of regular employees was 0.019. It implies that the corporations with a higher number of regular employers tend to perform the process innovation. The results also found that the coefficient of the annual target sale at 1.5 times and 1.8 times compared to their current sale amount were 0.681 and 1.829. It means that the corporations targeted their sale amount at 1.5 times and 1.8 times also tend to perform the process innovation compared to their current sale amount. This result is consistent to the finding of Nguyen et al. (2022) who found that the corporation also tend to implement the product innovation when they targeted their sale amount at 1.5 times to 1.8 times compared to their current sales. This implies that the targeted sale amount at the certain level can be a motivation for the agricultural corporation implemented the innovation at their farms. Besides, the coeffient of the flowers and foliage plants and the mixed corporation were 1.362 and 0.884. It also showed that the corporations had flowers and foliage plants accounting for at least 60% of the annual sales and the corporations had an annual sale with a variety of products without products amount sale equal to or larger than 60% of the total amount of sale of that corporation, called the mixed corporations, tend to implement the process innovation compared to the rice corporations.

However, some coefficients were found negatively belonged to agricultural experience of corporation, annual sales of categories of 1000 - 1500 million yen and 1500 - 2000 million yen, recession and 2nd mature growth stages and high school. It means that these factors hindered the process innovation implementation of the Japanese agricultural corporation. In specific, the longer experience years joining in the agricultural activities these corporations tend to less implement process innovation. The reason might be the data was collected in three years previous the survey time and the experienced corporations have been already implemented process innovation earlier. In addition to this, corporations with annual sales amounts from 1000 -2000 million yen tend to less implement the process innovation compared to the corporation with an annual sale amount of fewer than 30 million yen. The corporations at the stage of recession and the 2nd mature tend to less implement the process innovation compared to the corporations at the first starting stage. In addition to, the representative of the corporation got high school educational level also tend to hinder the process innovation implementation.

4. CONCLUSIONS

Agricultural corporations becomes an important component of changing the Japanese agriculture structure to overcome aging farmers and lack of successors to operate efficiently and profitably. Also, the innovation implementation have been promising to bring more productivity for the Japanese agriculture. However, the question on which factors driving the process innovation implementation in the Japanese agricultural corportions was unanswered. Therefore, this study found the answer for this question. First, this study found that 47.8% of the Japanese agricultural corporations implemented the process innovation in their farms. The implementation rate of each components of the process innovation was different. Moveover, more the number of regular employees, 1.5 times to 1.8 times higher targeted annual sale compared to the current amount of sale, and flowers and foliage plants and the mixed corporations tend to implement the process innovation. However, the corporations with more experiencing in agricultural activities, got an annual sales of the 1000 - 2000 million yen, stand at the recession and 2nd mature growth stages and their reprentative graduated high school level tend to hinder the process innovation implementation.

Based on these findings, it is considered that a higher target annual sale promotes the process innovation, but long experience and mature stage hinder the process innovation. These may imply that digital agriculture technology has a larger impact on process innovation in agricultural corporations with less experience at the startup stage.

5. ACKNOWLEDGEMENT

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ANALYSIS OF SAR TEMPORAL BACKSCATTERING VARIATION FOR DIFFERENT CROPS USING SENTINEL-1A DATA

Shaik Salma[1,*], Aishwarya V[2] and B.M. Dodamani[3,*]

1) National Institute of Technology Karnataka, Surathkal, India
2) National Institute of Technology Karnataka, Surathkal, India
3) National Institute of Technology Karnataka, Surathkal, India
Email: s.salma4268@gmail.com and bm.dodamani@gmail.com
* Corresponding author

ABSTRACT: Timely assessment of agricultural crops is necessary for continuous monitoring of crop growth at different stages. It is important to monitor crop growth continuously at both spatial and temporal variability. The present study focuses to investigates the ability of C-band Sentinel-1A dual-polarized datasets for temporal backscattering profile extraction to distinguish different crops. The study was carried out in the Hunsur region of Mysore District, and the considered crops for the study are Cabbage and Pumpkin. The Sentinel-1A Ground Range Detected data products (VH and VV polarization) are acquired in the year 2021 from January to December with a 12-day time interval. Temporal backscattering profiles have been plotted according to crop growth stage, from initial ploughing to harvesting stage. For cabbage crop, the backscattering range for VH polarization varies from -18.095 dB to -14.388 dB and for VV polarization it varies from -9 dB to -1.6 dB for VV. The peaks for cabbage crops are observed at the mature stage and at the cupping development stage for VH and VV respectively. For pumpkin crop, backscattering peaks are observed at early vegetative stages in both polarizations due to the development of fruit with the backscattering range of -17.99 dB to -13.13 dB for VH and -9.19 dB to -4.61 dB for VV polarization. The study reveals that the temporal analysis of the crops was consistent with the crop calendar obtained from the field study, and concluded that, in VH polarized backscattering profile, the crops showed significant backscattering ranges concerning crop growth stages. Whereas, in VV polarization, the extracted backscattering profile at the peak stage of the crop is overlapping with the urban profile due to the multiple scattering interaction.

Keywords: *Temporal backscattering analysis, Sentinel-1A, SAR, agricultural-crops.*

1. INTRODUCTION

Monitoring the crops is required to understand crop acreage, yield estimation, biophysical parameter extraction, and other agricultural applications. The conventional method of crop monitoring is very difficult and time-consuming. The invention of remote sensing made it easy to monitor cropping practices. For precise monitoring of crops, high spatial and temporal resolution sensors are required. Remotely sensed optical and Synthetic Aperture Radar (SAR) microwave imagery of moderate to high resolution with high temporal availability has been used. SAR microwave data can be utilized in agriculture in the following applications: Crop type and growth stage identification, cropping patterns and area statistics, and mapping yield loss due to crop flooding (Bégué et al., 2018; Jiankum Guo et al., 2005; Karjalainen et al., 2008), and has proved as a very effective technique in agricultural monitoring.

For agricultural applications, images need to be acquired frequently to monitor critical crop growth stages (Karjalainen et al., 2008). The phenology changes can be monitored by the varying backscatter response since, volume scattering changes as the crop structure changes. Information on crop age (in terms of days), planting date, and harvesting date are required for implementing management practices.

Phung et al., (2020) developed an algorithm to predict the planting date, harvesting date, and rice age using Sentinel-1 SAR data with the predicted and actual dates were in good correlation. The geometric structure of crops, dielectric properties of crop canopy, and underlying background soil vary significantly with crop phenological stages (Xie Qinghua, 2021). The accuracy of crop identification and area estimation can be increased by having a better understanding of the crop and the underlying soil characteristics that influence the radar backscatter throughout the growing season, and by evaluating the multitemporal SAR data for crop identification. Useya and Chen (2019) used Sentinel-1 GRD products to map the small-scale farms in Zimbabwe using Random Forest (RF) and K-means classifiers. Post classification combined all the classes corresponding to a plot to identify the crop rotation practiced within the plot. Crop rotation can be identified by the temporal analysis of NDVI values over agricultural land (Jiankum Guo et al., 2005). The extracted NDVI time series for croplands shows the crop phenology information and the temporal changes help in the identification of crop rotation.

Crop phenology information is a prominent characteristic of crop identification. Temporal responses of polarimetric observables over different crop types showed a high sensitivity to crop growth and phenology. Kumari et al., (2019) delineated early and late growing soybean crops using a knowledge-based decision rule classifier and support vector machine (SVM) classifier. Before the SVM method, the images are classified using a fuzzy C-mean clustering algorithm to extract pixels for training samples and are later used as input for SVM. Kumar et al., (2017) used crop parameters for the classification of SAR data using a RF, SVM, Artificial neural network (ANN), and Liner regression (LR). In comparison to SVM, ANN, and LR algorithms, the RF method produced more accurate results and it demonstrates the capability of Sentinel -1A SAR data to monitor agricultural practices. SAR backscatter varies for different landcover classes and in crops depending upon geometry, biomass, and dielectric properties. SAR polarizations can show differences in crop's backscatter at various crop growth stages. The sequential crop classification images aid in the identification of crop rotation patterns in an agricultural region. Time series analysis examines backscatter values at various crop stages. The present study focuses on the crop discrimination in terms of SAR backscattering intensity using the temporal backscattering analysis of dual polarized SAR data.

2. STUDY AREA AND DATASETS

The study site is located in an agricultural area near the Hunsur city of Mysore district, Karnataka, India with the total geographical area of the study site is 44.6 sq. km. The location map and satellite image of the study site is shown in Figure 1. It receives moderate rain during the monsoon season (Gangadhara and Subash 2017). The crops cultivated in the area include paddy, ginger, turmeric, cabbage, tomato, red chillies, pumpkin, and tobacco. For the study, the crops considered are cabbage and pumpkin, and the crop period is mentioned in Table 1.

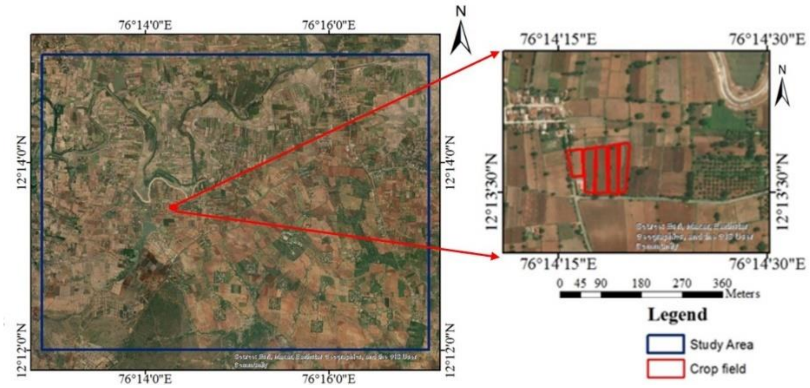

Figure 1. Study area location Map

Table 1. Selected crops growth period in number of days

Crop	Start period	End period	Crop period (days)
Cabbage	January 2021	June 2021	120
Pumpkin	July 2021	January 2022	125

2.1. Data products

Synthetic Aperture Radar (SAR) has helped in obtaining crop information irrespective of meteorological conditions with its transit signal (Crockett, 2013). Sentinel-1 SAR C-band imagery is widely used in crop monitoring applications. The European Space Agency (ESA) provides Sentinel-1 data products for free in the ESA's Copernicus portal (https://scihub.copernicus.eu/dhus/#/home). The data has inherent noises and requires pre-processing to suppress the unwanted noise and distortion, and enhance the image features. The data specifications has been noted in Table 2.

Table 2. Sentinel-1A GRD data specifications

Polarization	VV, VH (dual-pol) (vertical transmitter with vertical and horizontal receiver)
Mode used	Interferometric Wide Swath mode
Wavelength	5.6cm (C-band)
Revisit time	12 days
Spatial resolution	5x20m
Incidence angle	20^0 - 47^0 covering wide swath

3. METHODOLOGY

3.1. Pre-processing

The pre-processing workflow majorly includes applying the orbit file, thermal and border noise removal, calibration, speckle filtering, multi-looking, terrain geocoding, and conversion of linear to decibel scale, and is carried out in the SNAP toolbox. Initially, the orbit file is applied to obtain the accurate position of the SAR image. Low-intensity noises caused by the background energy of SAR receivers are removed by the thermal noise removal tool. The border noise removal tool removes the low-intensity noise and invalid data on image edges. The original SAR images are not radiometrically corrected by default, backscattering would be more at the mid-range when compared to near and far swath. The calibration tool normalizes the pixel intensity and scales them to the backscattering coefficient (sigma-naught) value. A 5x5 refined Lee filter is used to remove the speckle noises. The multi-looking tool converts the ground range pixels to square pixels. Range-Doppler terrain correction is applied to rectify the geometric distortions. In this step, VH and VV polarization are separately stacked and pre-processed. Finally, the obtained image in linear scale is converted to backscattering intensity (decibel scale) values. The pre-processed image is then clipped to an area of interest using geo-coordinates of the shapefile.

3.2. Classification and temporal analysis

Crop classification helps in identifying crops from other land cover classes. This helps in the identification of crop type, mapping cropped areas, and estimating yield. Supervised classification methods like random forest, support vector machine, and maximum likelihood classifier gives high classification results (Clemente et al., 2020; Hütt et al., 2016). In this study, random forest (RF) classifier is used for crop classification. A random forest classifier, a supervised classification algorithm is used for both classification and regression (Breiman, 2001). A random forest is a set of tree predictors in which each tree is based on values of a random vector sampled independently. Pre-processed SAR images are imported into Google Earth Engine (GEE) as image assets. The training samples digitized in Google Earth Pro are exported as a KML (Keyhole Markup Language) file and later converted as vector data in the GIS application. These vector data are imported into GEE as table assets. Classification trails are performed with 100 to 500 decision trees. A decision tree with high performance in crop classification is chosen.

During the crop phenological stages, backscatter energy from the crops is affected by their dielectric properties and soil parameters. The temporal analysis gives information on crop growth stages according to the changes in backscatter values over a crop period. Backscatter values tend to increase or decrease during ploughing, transplanting, tillering, vegetation, and harvest stages. The temporal behavior of cabbage and pumpkin are investigated in this study. From the classified maps, polygon geometry is created over the crop fields. The mean backscatter values from the geometry are considered for temporal analysis. The SAR images are stacked and a temporal backscatter profile is generated.

4. RESULTS AND DISCUSSION

Sentinel-1A SAR images of VH and VV polarization are calibrated to sigma nought to represent the backscattering coefficient. The selected crops with their crop period along with the crop growth stages, including the acquisition dates of Sentinel-1A data for monitoring is mentioned in Table 3. The cabbage crop period is observed from 18 January 2021 to 23 June 2021, and the pumpkin cropping is observed from 05 July 2021 to 01 Jan 2022. By using the RF classifier, the overall accuracy assessment for classified images and percent identification of cabbage fields in the study area is shown in Figures 2 (a) and 2 (b) respectively, for both VH and VV polarizations. The variation in overall accuracy assessment using RF classifier and percent identification of pumpkin crop in the study area is shown in Figure 3 (a) and 3 (b) respectively. Over the considered period for the analysis, good overall accuracy has been achieved in both the VH and VV polarizations, with higher accuracy in VV than VH polarization. Whereas, for percent identification of crop pixels, both VH and VV polarizations has achieved a similar trend, but the temporal backscattering values for crops has been varied significantly with higher disparity for both the selected crops.

Table 3. Crop calendar with Sentinel-1A data acquisition dates

Crop	Crop period	Data acquisition dates	Crop stage
Cabbage	120 days	18 and 30 January 2021	Ploughing
		11 and 23 February 2021; 07, 19, and 31 March 2021	Seedling & Cupping
		12 and 24 April 2021; 06 and 18 May 2021	Early heading & flowering
		30 May 2021; 11 and 23 June 2021	Mature & Harvest
Pumpkin	125 days	05, 17, and 29 July 2021; 10 August 2021	Pre-cultivation stage & field ploughing
		22 August 2021; 03, 15, and 27 September 2021; 09 October 2021	Seedling, germination & growth of vines
		21 October 2021; 02, 14, and 26 November 2021; 08 December 2021	Flower & Fruit development
		20 December 2021	Harvest

Temporal backscattering profiles have been plotted according to crop growth stage, from initial ploughing to harvesting stage. The backscattering trend of VH and VV polarization for cabbage growth stages is shown in Figure 4 (a). Ploughing process digs and turns over the uppermost soil to bring nutrients to the surface. This land preparation technique creates roughness in the soil and high backscattering is observed in January. During the seedling and cupping stage, a gradual increase in VH polarization is observed while inconsistent increases and decreases are observed in VV polarization. As the biomass increases the backscattering values were seen gradually increasing. The peaks for cabbage crop are observed at the mature stage and at the cupping development stage for VH and VV respectively, and hence the high backscattering values were observed. During harvest, the backscattering values increase indicating roughness in the field. VH polarization shows a consistent increase and decrease in backscattering values in each crop growth phase. After harvest on 11 June 2021, VV polarization shows a consistent high backscattering due to the double-bounce scattering effect. For cabbage crop, the backscattering range for VH polarization varies from -18.095 dB to -14.388 dB and for VV polarization it varies from -9 dB to -1.6 dB for VV.

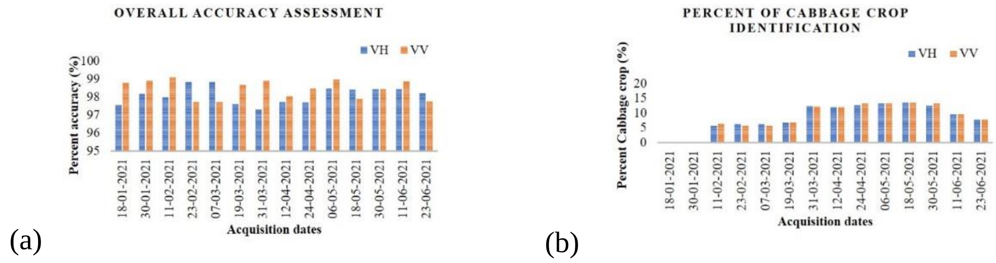

Figure 2. (a) Overall accuracy assessment and (b) Percent identification of cabbage crop fields

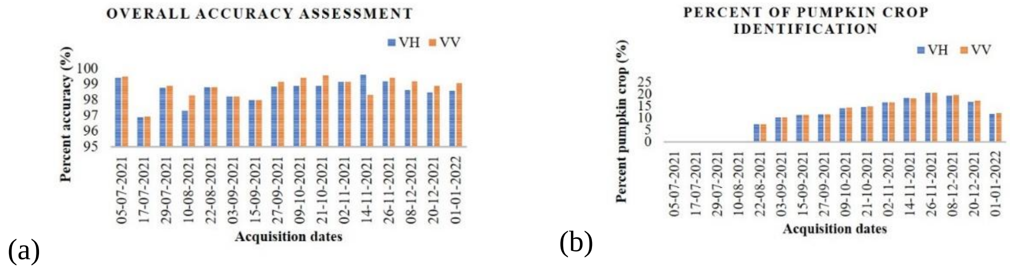

Figure 3. (a) Overall accuracy assessment and (b) Percent identification of pumpkin crop fields

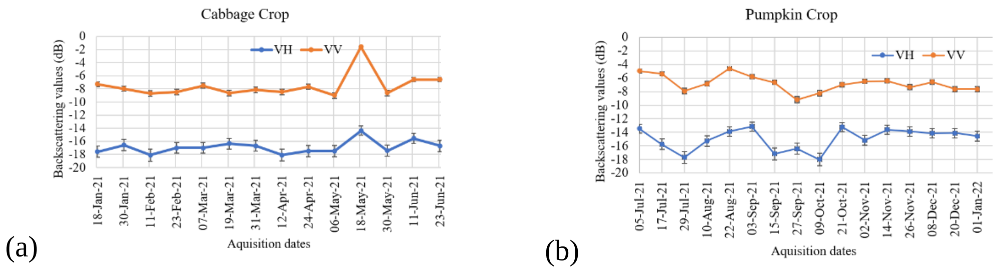

Figure 4. Backscattering trend analysis (a) cabbage crop (b) pumpkin crop

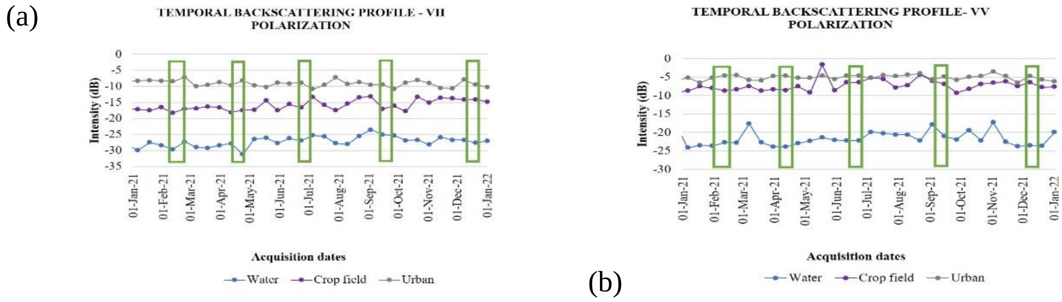

Figure 5. Temporal backscattering of crop variation with urban and water classes (a) VH polarization (b) VV polarization

The temporal analysis could demarcate the pumpkin crop with their backscattering trend in each growth phase, and is shown in Figure 4 (b). VH and VV polarization backscattering profile for pumpkin crop is very distinct throughout the crop period. Pre-cultivation techniques and ploughing of fields are performed in July 2021. From 29 July 2021, the backscattering values increase steadily in both VH and VV polarization. This is the seedling and germination stage of the pumpkin crop. A drop in backscattering is observed from 15 September 2021 to 09 October 2021 which is during the pumpkin vine growth. The backscattering values continue to increase in the flowering and fruit development stage. The backscatter values fall after 20 December 2021 when the pumpkins are harvested. For pumpkin crop, backscattering peaks are observed at early vegetative stages in both polarizations due to the development of fruit with the backscattering range of -17.99 dB to -13.13 dB for VH and -9.19 dB to -4.61 dB for VV polarization. For both the crops, in VV polarization, the extracted backscattering profile at the peak stage of the crop is overlapping with the urban backscattering values due to the multiple scattering interaction. The urban backscattering values in the study area varies in the range of -10.2 dB to -6.7 dB for VH polarization and the range varies from -5.7 to -4.2 for VV polarization respectively, and is shown in Figures 5 (a) and 5 (b). The crop classification and temporal analysis of the cabbage crop were consistent with the crop calendar obtained from the field study.

5. CONCLUSIONS

The present study reveals that, even though there is a variation in classification accuracy in VH and VV polarizations, the percent identification of crop pixels depending on the crop growth stages were similar. In the cabbage crop, from cupping development to the mature stage, the identification of pixels remains significant, whereas, in the pumpkin crop the crop pixel identification is gradually increasing from the initial stage and reaches maximum at the peak and mature stage of fruit development. From the temporal backscattering trend analysis, the peak backscattering intensity were observed at the cupping and mature stage of the cabbage crop, and at the early vegetative stage for the pumpkin crop. From the trend analysis, it is concluded that the backscattering intensity values of crop fields shows significant consistency with crop growth stages in VH polarization than in VV polarization. In VV polarization, the extracted backscattering profile at the peak stage of the crop is overlapping with the urban profile due to the multiple scattering interaction of vertical wave polarization.

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CLOUD-BASED SIMULATION OF PRECISION FEEDING SYSTEM FOR PIG HEALTH MANAGEMENT

Xuan-Truong Nguyen [1], Linh Manh Pham [1,*]

1) VNU University of Engineering and Technology, 144 Xuan Thuy, Cau Giay, Hanoi, Vietnam.
* Corresponding author: linhmp@vnu.edu.vn

ABSTRACT: Quantifying livestock health is essential before it can be implemented in livestock and management strategies. Precision livestock farming will help improve the quality of livestock, save costs and reduce waste to the surrounding environment. Among the livestock, pigs are seen as the main source of human food, accounting for the largest proportion of the food people have consumed. The improvement of livestock quality not only increases the demand for food without residues of antibiotics and chemicals but it also helps ensure the welfare of livestock. Furthermore, developing healthy pig production is one of the elements of ensuring national food security. In the world today, the precision feeding system (PFS) is applied to analyze and give the correct amount of feed for each pig in a pigsty, but the investment and operating costs are very high. In this paper, we present a method to calculate cumulative feed intake (CFI) based on data pre-processed from a precision feeding system. In which CFI is an important characteristic for assessing animal health by the amount of feed it receives, the feed intake of the pig will deviate from the target trajectory but, once the perturbing factor is over, the pig will strive to increase its feed intake through compensatory feed intake to rejoin the target trajectory of CFI. Moreover, we develop a cloud tool to simulate voluntarily eating activities of growing-finishing pigs thereby helping agricultural researchers or institutions not have to invest large sums of money on real equipment.

Keywords: *Precision Livestock Farming, Precision Feeding System, health, cloud simulation*.

1. INTRODUCTION

The industrial revolution 4.0 is having a strong impact on the agricultural development model in the world. The trend of agricultural development in general and the livestock industry in particular in countries, especially in developed countries [1], is currently shifting to a new model. Smart livestock farming has become an unstoppable trend of world agriculture. Precision feeding is one of the areas of smart husbandry using modern multidisciplinary technologies including information technology, mechanics, electronics, automation, biotechnology, etc.

A precision feeding system (PFS) includes automatic feeders linked to a computer system to exploit the data collected from the individual animals and the amount of food they receive daily as well as a number of data obtained from environmental sensors. The data processed and calculated based on mathematical functions to make predictions, warn farm managers or perform feed mixing that directly affects each individual animal.

The pig farming in the world in general and Vietnam in particular are facing many challenges such as climate change and the spread of epidemics. In addition, the development of society and the improvement of people's living standards increases the demand for food without residues of antibiotics and chemicals as well as ensuring the welfare of animals. In addition, ensuring a healthy pig production is one of the elements of ensuring national food security. To meet the above challenges as well as to develop pig production sustainably, one of the important factors that need to be enhanced is the resistance and resilience of the animal. A healthy animal has greater resistant and resilient that is more resistant to perturbation such as extreme environmental conditions or epidemics, will use less antibiotics and thus have better welfare. However, the resilience and recovery under farm environment conditions is a complex and difficult to evaluate. One of the main reasons for the difficulty in evaluating this indicator is its dynamics over time. It is also because of this dynamics that in the past, methods of evaluation were invasive based on the sampling (hormones, anti-biotic agent...) does not delivery high performance. Therefore, our paper consists of two contributions: (1) focusing on building a process to pre-process data collected from the precision feeding system to detect perturbation on growing-finishing pigs; (2) modeling voluntarily eating activities of pigs and uploading the model to the cloud simulation tool for doing remote experiments. (1) Data is added in set, each set in a csv file as input to run simulations on GAMA to calculate CFI curve simulation. The rest of the paper is organized as follows. In Section 2, the materials and methods of simulation of precision feeding system are provided. In Section 3, we highlight results and a few discussions. Finally, we conclude in Section 4.

2. MATERIALS AND METHODS

2.1. General description of methods

Perturbations such as heat stress or environmental pollution have a transient effect on pigs, leading to changes in feed intake. However, the cause of a perturbation is not always be known in advance, but consequences for the animal's performance can be observed. Due to the rapid development in on-farm monitoring technologies, the precision feeding system uses RFID chips [2], data is created to analyze and give the exact amount of feed for each individual pig in a pigsty. With this system, individual pigs are precisely fed and monitored according to a pre-set nutritional route, so that data for each pig can be recorded in detail. Furthermore, feed intake was one of the first noninvasive and measurable characteristics affected by perturbations. Besides, the cost to operate a precision feeding system is very high, can reach tens of thousands of USD, the feasibility is not high and causes financial difficulties for research centers with small and medium scale.

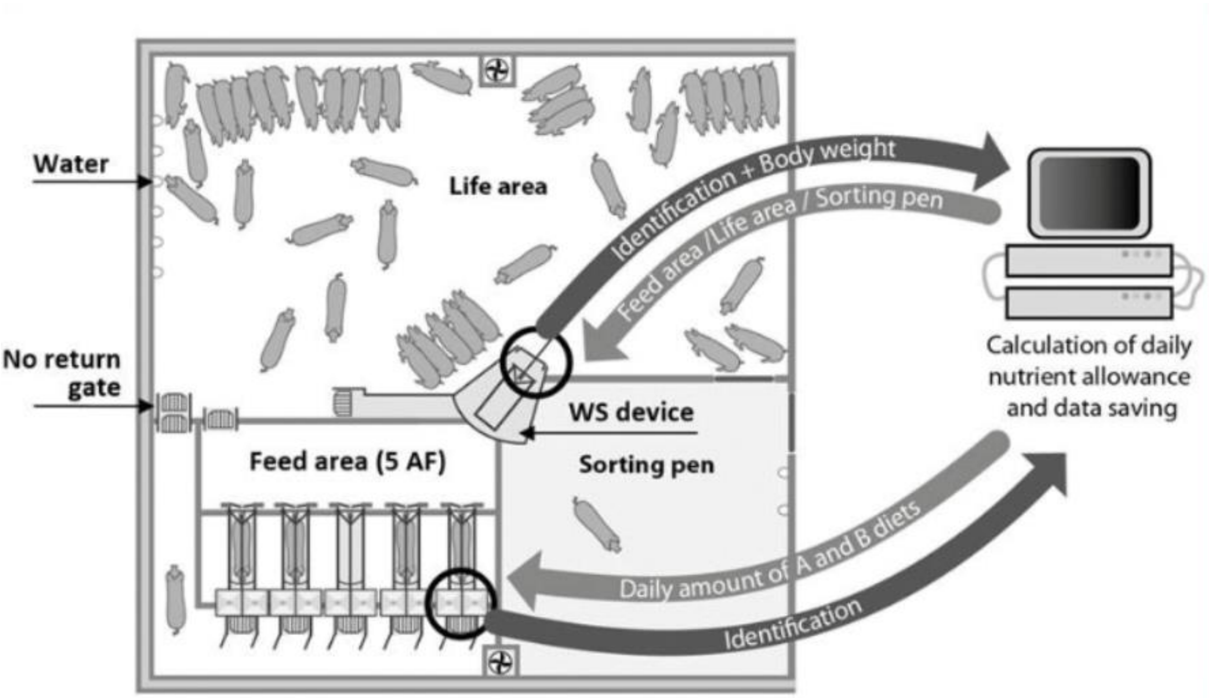

Figure 1. PFS system model [9]

The process of data analysis and assessment based on this non-invasive method requires the collection and process of big data regarding each individual pig, consisting of two main steps [3-4]. The first is to estimate the target trajectory curve of the feed intake. Deviations of feed intake observed from this target trajectory represent potential consequences of perturbation, and a classification process was performed to identify the most significant deviations. The second step is to quantify the animal's response in terms of resistance and resilience. In summary, this procedure is based on two model components: one that estimates the target trajectory of feed intake and the other that characterizes the perturbation given in [5] Nguyen-Ba et al.

GAMA is a simulation platform, which aims at providing field experts, modellers, and computer scientists with a complete modelling and simulation development environment for building spatially explicit multi-agent simulations. It has been first developed by the Vietnamese-French research team MSI (located at IFI, Hanoi, and part of the IRD/SU International Research Unit UMMISCO) [6].

Daily feed intake data will be used as a source to detect disturbances. Data is usually collected from an agriculture facility using precision feeders. The feeder scans the animal to identify the pig using the RFID tag and calculates the amount of feed for each meal. The data is then sent to the computer and stored for later calculations. Our study uses the data set from Nguyen-Ba et al. The data is processed and then put into the simulation on the GAMA tool to create a model of a barn consisting of large individuals combined with a system for precise pig troughs that allows monitoring of each individual pig along with the amount of feed. like a real farm models.

2.2. Precision feeding system simulation in the cloud

2.2.1. Building a precision feeding system simulation application on GAMA platform

From a file summarizing a herd of pigs at Le Magneraud farm (Charente-Maritime, France), we have separated each pig into separate data set and added them to the system. Each file includes 5 columns corresponding to 5 fields of each pig, 114 rows corresponding to 114 days that the system recorded the data of pigs from 69 to 182. The ID is a number representing the identity of a pig; Age is the date of age; Feed Intake is the daily amount of feed that an individual pig; Weight is the weekly weight of each pig; Cumulative Feed Intake is the total feed intake from the start of each individual pig. The herd of pigs that we use in this system includes 20 swines with 20 different database files with corresponding IDs, specifically each animal is depicted in Figure 1.

Age	Feed Intake	Weight NA	Weight	CFI
69	1.916	25	25	1.916
70	1.947	NA	25	3.863
71	1.337	NA	25	5.2
72	2.696	NA	25	7.896
73	1.945	NA	25	9.841
74	2.592	NA	25	12.433
75	2.56	NA	25	14.993

Figure 1. Data input

All these files are added to a list of matrices to prepare input data for the system. This list has 20 matrices, each of which has 2 dimensions. Horizontal is only the data corresponding to each row in a file representing pigs in the database. Vertical is the process of collecting each column corresponding to a field in the database. Each matrix will correspond to an added csv file.

Simulation in GAMA language with the input of 20 pigs mentioned above, the system will simulate the process of each pig being fed a certain amount of feed in the smart feeder. The pig will grow according to the amount of feed it is fed. Feed intake data and barn environment data can be collected from two main sources: (1) reliable data sources are available from farms that have implemented precisionfeeding systems; (2) simulated data source. (1) These data sources must be preprocessed to filter out the data of pigs raised and monitored in the same batch. These data sources must be preprocessed to filter out the data of pigs raised and monitored in the same batch (those born on the same farm and with approximately the same birthday). Each cycle (round) of the simulation corresponds to 3 hours of life of the pig herd, whereby we have 8 cycles corresponding to 1 day, 56 cycles corresponding to 1 week, we have 2 ways to run the simulation: Method 1: Run simulation with simulated data for a pig instance. Run with at least 24 (hours) / 3 * 30 (day) = 240 cycles to collect individual pig data after at least 1 month. Output (output) will be a list of csv files corresponding to each pig after each emulator run. Method 2: Run the simulation with input data, so, at least to run all the given database, we need to run GAMA with the number of cycles: (last age – first age + 1) * 24 (hours) / 3 + 1 = (182 – 69 +1) * 8 + 1= 913 cycles. Output (output) will be a list of csv files corresponding to each pig after running the emulator. After each simulation, the system will automatically record the data of each pig in the output directory.

2.2.2. Put the simulation on the cloud.

The current simulation is running on local environment, so monitoring and usage are limited. Bringing simulations to the cloud makes it possible to perform remote monitoring or test research, regardless of complex settings or environments. We use 1 server to install GAMA platform, the source code that simulates the PFS above will be downloaded by the user from the Website and stored on the server that installs GAMA. When the user manipulates and executes the simulation command, the system will automatically connect to the GAMA server and proceed to run the application source code like when the user runs on the desktop environment. The work is conducted through the headless GAMA mechanism. The data such as simulation results will be processed and returned to display on the user interface (Figure 2).

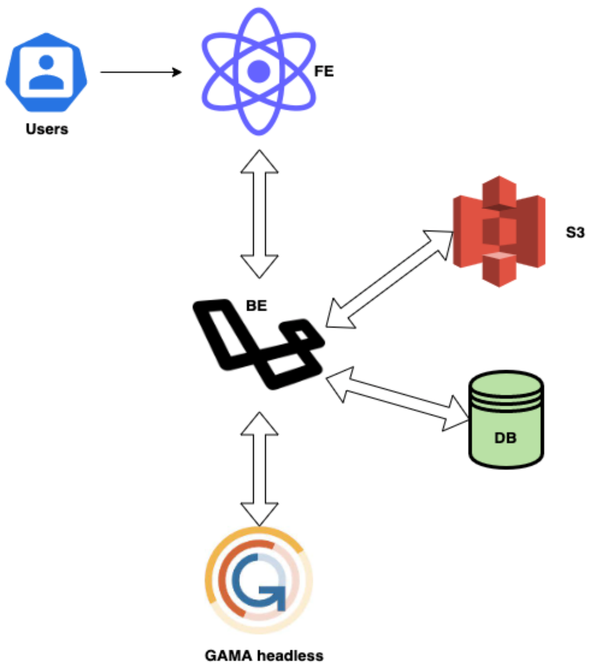

Figure 2. System overview model

In GAMA's headless mode these scripts all take 2 arguments: test file and output. The input parameter file is the simulation-output.xml file containing the test and output parameters, the output snapshot folder path is the result folder containing the snapshots during the simulation. After completing the simulation of the PFS on the GAMA desktop platform and the Restful API system to serve the user's actions and connect to the GAMA server, we proceed to build the user interface in order to users can easily use the system without having too many technical skills such as API or GAMA. The technology used is ReactJS [7].

3. RESULTS AND DISCUSSION

We have successfully run a simulation of precision feeding system on the Website. The backend is built on the Laravel framework, which is structured on top of Docker to optimize deployment and installation environments. The source code backend has also been integrated with GAMA along with the Java running environment, which is JDK [8]. Users can run the simulation just through simple operations, when starting the simulation, the user can set custom parameters. Figure 3, 4 is a simulated result of the whole herd in the barn scale on the Website. The feeding system will include 5 troughs, each trough is for 1 animal at a time. When the pig enters the trough, the RFID chip attached to the pig will send to the computer system the pig's ID and the pig's nutritional and CFI route/curve.

The simulation will include the interface screens:

- Main_display: represents the screen when simulating (Figure 3)
- Info_display: indicates the screen of pigs with ID
- CFI_comparison: Bar chart showing comparisons between CFIs of pigs (Figure 4)
- Weight_display: represents the histogram weight of each pig (Figure 5)
- CFI_display: represents the graph of the CFI curve of each pig (Figure 6)
- Weight_comparison: bar graph showing comparison between weight columns (Figure 7)

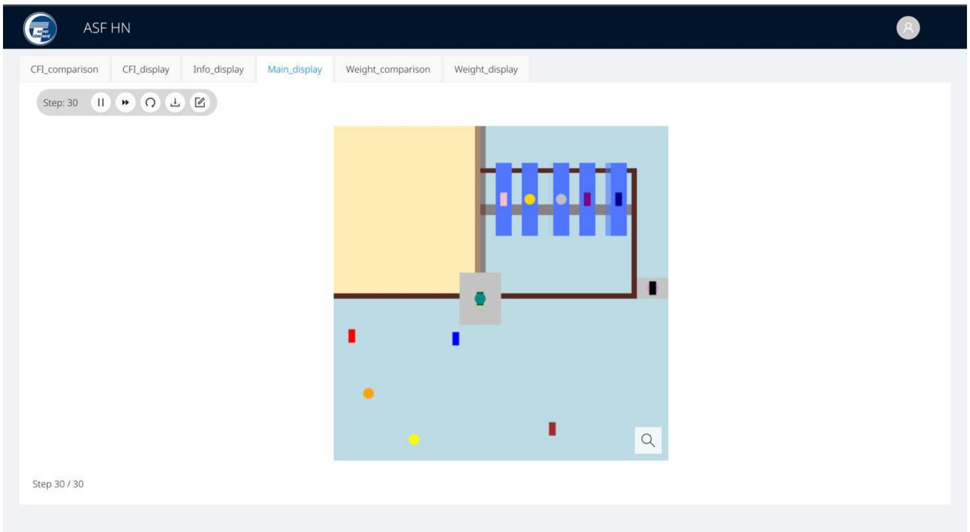

Figure 3. Main_display screen outputs

Figure 4. CFI_comparison screen outputs.

Figure 5. CFI and Weight_display screen outputs

Figure 6. CFI_display screen outputs

Figure 7. Weight_comparison display screen outputs

4. CONCLUSION

The recent development of monitoring technologies offers new opportunities for livestock management. We have developed an application that simulates the precision feeding system using the GAMA simulation platform, the application has a user-friendly interface, convenient for users, and run the simulation with high optimization ability to help everyone, who understands how feeding systems work, save money on investments in research and testing.

5. ACKNOWLEDGEMENT

The authors would like to acknowledge Asia Research Center, Vietnam National University, Hanoi (ARC-VNU) and CHEY Institute for Advanced Studies (CIAS) [grant number CA.20.9A] for financial supports.

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DETECTION OF WHITEFLIES AND VEINS ON LEAVES BY CAPTURING IMAGE UNDER CONTROLLED LIGHTING

Hirotaka Obo[1)], Tadashi Ebihara[2, *)], Yuka Maeda[2)], Naoto Wakatsuki[2)] and Koichi Mizutani[2)]

1) Graduate School of Science and Technology, University of Tsukuba., Japan
2) Faculty of Engineering, Information and Systems, University of Tsukuba, Japan
Contact: ebihara@iit.tsukuba.ac.jp
* Corresponding author

ABSTRACT: Whiteflies (*Trialeurodes vaporariorum*) are agricultural pests that damage crops such as tomatoes and cucumbers. Counting the number of whiteflies is commonly used to confirm the effectiveness of whitefly control methods. However, it is challenging for workers to count whiteflies visually since whiteflies are very small (approximately 1 mm in length) and live on the underside of leaves. Therefore, this study proposes a method of whitefly bio-detection using image processing. Although whiteflies and plant leaves are clearly different in color, it is challenging to count the number of whiteflies from pictures taken by a camera. Many image processing methods directly illuminate the object being photographed; however, it was found that when whiteflies on leaves are photographed with lighting, the light reflects off the leaves, and the brightness of the image is not flat, which becomes a barrier for automatic detection. On the other hand, when whiteflies are photographed in indirect lighting (ambient light), it was found that whiteflies could successfully be detected very clearly using only the classical method with the RGB and HSV model. In the experiment, whiteflies on the underside of a leaf were photographed for a long period, decomposed into its RGB and HSV color space components, and thresholded. Thresholding was carried out using Otsu's method, which automatically determines the threshold level. As a testing arena, we used cucumber and green perilla leaves. From experiments, it was found that the whiteflies on cucumber and green perilla leaves could successfully be detected by blue (B) and value (V), etc. Furthermore, leaf veins were detected by hue (H) and saturation (S), although not perfectly. This image processing method has the potential to be applied not only to whiteflies but also to other insects and to plant studies.

Keywords: *Whitefly, Bio-detection, Insects counting, Thresholding, Image processing.*

1. INTRODUCTION

Whiteflies (*Trialeurodes vaporariorum*) are agricultural pests that damage crops such as tomatoes and cucumbers. Whiteflies are capable of transmitting more than 300 plant viruses, Gilbertson *et al.* (2015). Whiteflies have a short life cycle, and some biotypes are resistant to pesticides, Nauen *et al.* (2002). Therefore, novel detection and control methods that utilize the ecology of whiteflies have been considered, e.g., Nishijima *et al.* (2019), Nakabayashi *et al.* (2017), and Sato *et al.* (2020).

Counting the number of whiteflies is commonly used to confirm the effectiveness of whitefly control methods. However, it is challenging for workers to count whiteflies visually since whiteflies are very small (approximately 1 mm in length) and live on the underside of leaves. Hence, this study proposes a method of whitefly bio-detection using image processing.

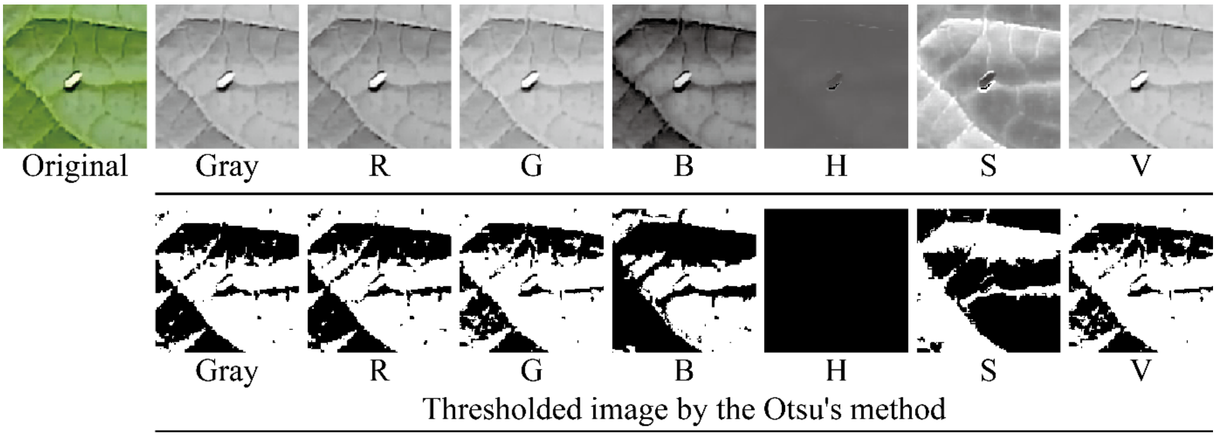

Figure 1. Image of a whitefly on a leaf is decomposed into several color components. This figure indicates that leaves and whiteflies cannot be easily separated by thresholding.

Although whiteflies and plant leaves are clearly different in color, it is challenging to count the number of whiteflies from pictures taken by a camera. Figure 1 shows an example of image of a whitefly on a leaf. As shown in the figure, whiteflies and leaves are not clearly separated by thresholding. Previous studies for automatic detection of whiteflies from images have also reported that it is difficult to distinguish between whiteflies and leaf veins depending on the shooting conditions, Udo *et al.* (2017).

In this paper, we focus on the shooting conditions of whiteflies and propose a method to separate whiteflies and plant leaves by controlling the brightness of the light. In addition, we manage to detect the shape and position of leaf veins in the images. This study contributes to the automation of whitefly bio-detection.

2. MATERIALS AND METHODS

2.1. Lighting method for thresholding

This paper proposes a lighting method suitable for whitefly image detection. Conventionally, whiteflies could not be bio-detected by the thresholding method. It is assumed that when whiteflies on a leaf are photographed with lighting, the light reflects off the leaf, and the brightness of the image is not flat, making detection difficult. Therefore, a method using indirect light (ambient light) on the leaf was compared to the conventional method.

2.2. Experimental setup

The experimental environment is shown in Fig. 2. A camera (MX-P2, ELMO) was used to take close-up images of whiteflies (*Bemisia tabaci*, Q1- biotype) on the underside of the leaf. Two types of light sources were used: a room light and a desk light. The back plate of the equipment prevents light from illuminating the surface of the leaf. The sensitivity, exposure time, and focal length of the camera were kept constant for all shootings. Two types of leaves, cucumber and green perilla, were used as a testing arena. The leaf was fixed in front of the camera using a jig. The illuminance on the floor of the room was 150 lx when only the room light was turned on.

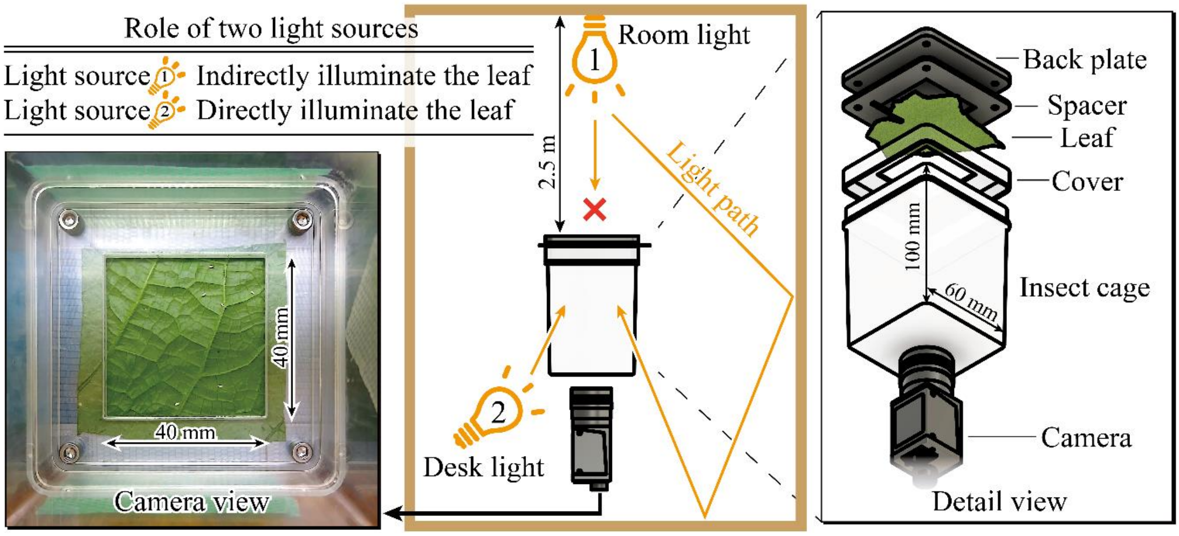

Figure 2. Schematic diagram of the experimental setup. Images of whiteflies on a leaf are captured. The light source is controlled to determine the optimum conditions for capturing images.

2.3. Image processing

We would like to describe the image processing used in this study. First, a total of 6 hours of video was taken under different leaf and light conditions, from which 40 images were extracted. The images were trimmed so that the entire leaf was zoomed in on. Then, the images were decomposed into its RGB and HSV color space components. For thresholding, general method (Otsu's method) was used to determine the appropriate threshold value for the entire leaf (40 mm × 40 mm). Finally, the threshold values were used to generate a black-and-white image, and features were extracted to detect whitefly bodies.

3. RESULTS AND DISCUSSION

Table 1 summarizes the experimental conditions and the resulting figures.

3.1. Testing on a cucumber leaf

Experimental results using cucumber leaves are shown in Figs. 3 and 4. As shown in the figures, whiteflies were not well detected in any of the color components when the leaf was directly illuminated. We also see that light was reflected on the surface of the leaf. On the contrary, when indirect light (ambient light) was used, whiteflies were successfully detected (R, G, B, Gray, and V components). Furthermore, leaf veins could be detected (H and S components).

3.2. Testing on a green perilla leaf

Experimental results using green perilla leaves are shown in Figs. 5 and 6. Although slightly different from the cucumber results, whitefly bio-detection was generally successful in green perilla leaves when indirect (ambient) light was used (especially the B component). Leaf veins were also detected (H and S components), although not completely due to noise.

Table 1. Experimental conditions of Figures

Leaf	Cucumber	Cucumber	Green perilla	Green perilla
Room light condition	ON	ON	ON	ON
Desk light condition	ON	OFF	ON	OFF
Illuminance of leaf underside	1,500 lx	20 lx	1,500 lx	20 lx
Figure of result	**Figure 3**	**Figure 4**	**Figure 5**	**Figure 6**

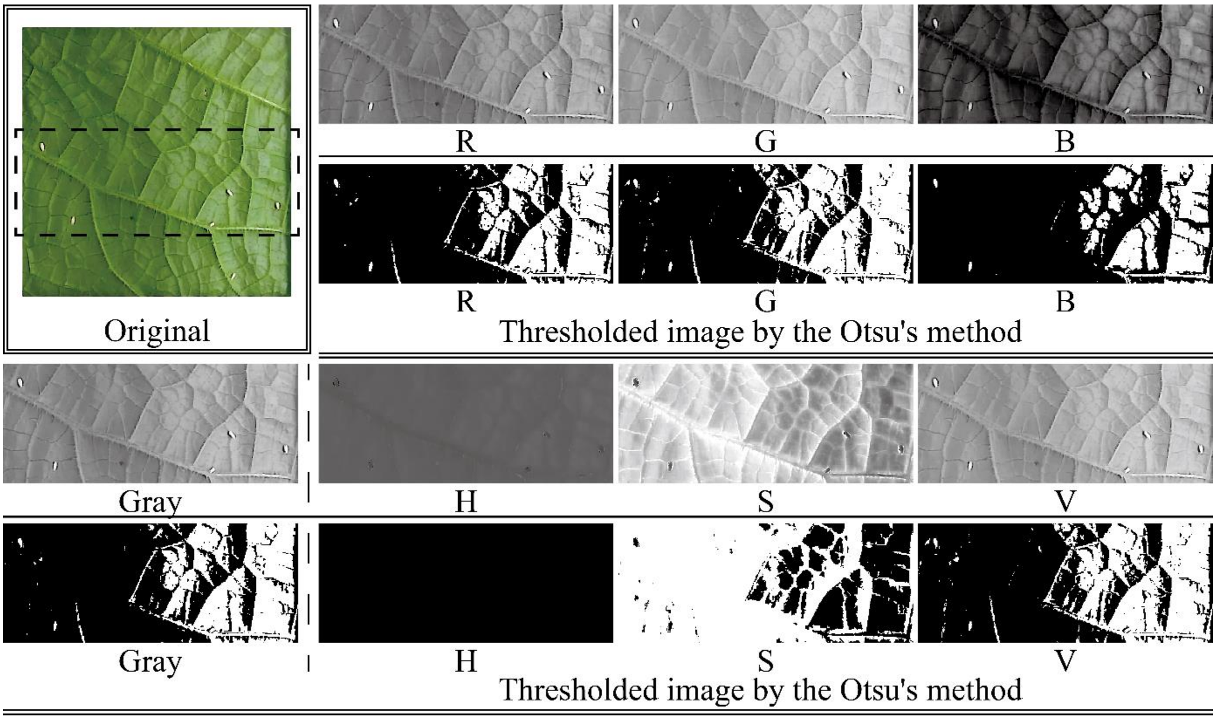

Figure 3. [Cucumber leaf, 1500 lx] Image of experimental results. The cucumber leaf was directly illuminated using a desk light. The decompositions of color spaces are also shown. In addition, the images were thresholded. Whiteflies and leaf veins are visible in the image.

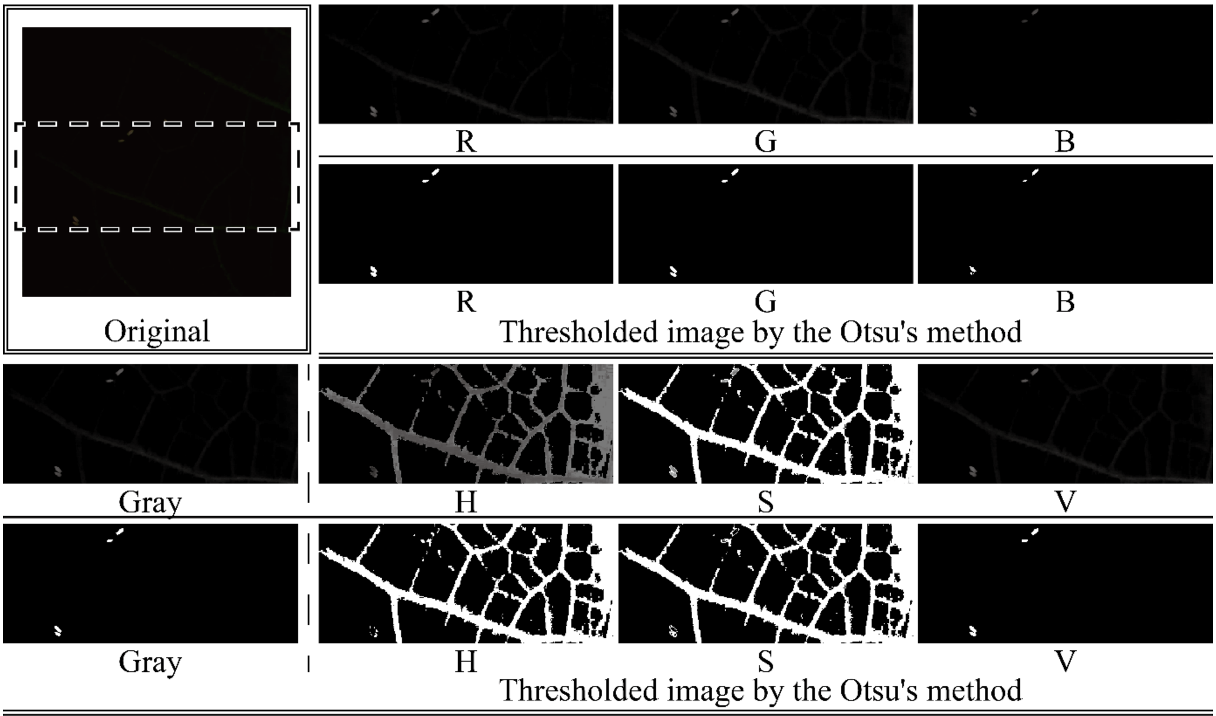

Figure 4. [Cucumber leaf, 20 lx] Image of experimental results. The cucumber leaf was indirectly illuminated using a room light. The decompositions of color spaces are also shown. In addition, the images were thresholded. Whiteflies and leaf veins are visible in the image.

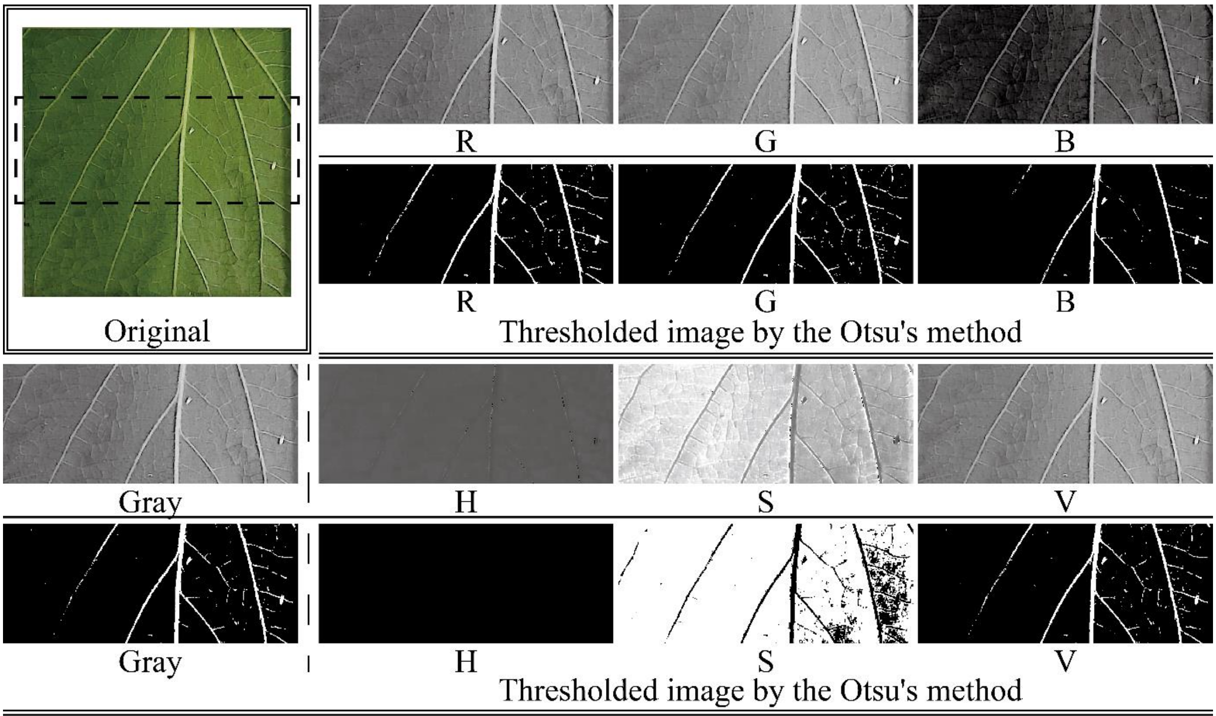

Figure 5. [Green perilla leaf, 1500 lx] Image of experimental results. The green perilla leaf was directly illuminated using a desk light. The decompositions of color spaces are also shown. In addition, the images were thresholded. Whiteflies and leaf veins are visible in the image.

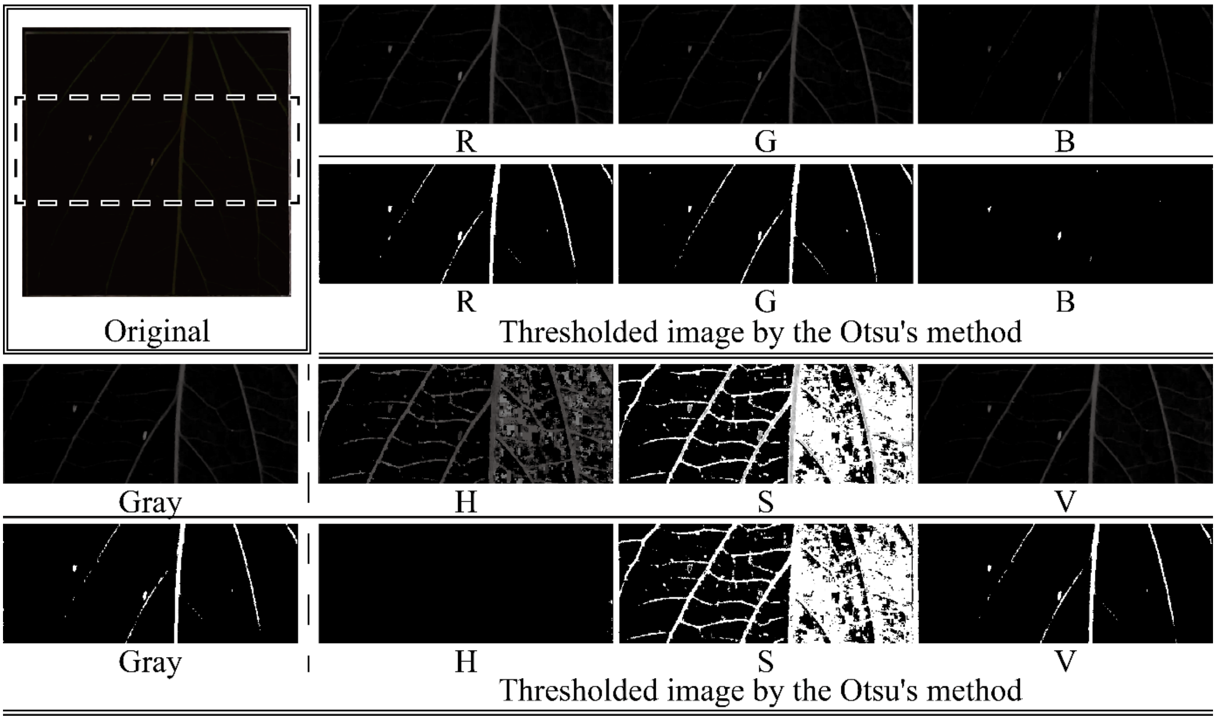

Figure 6. [Green perilla leaf, 20 lx] Image of experimental results. The green perilla leaf was indirectly illuminated using a room light. The decompositions of color spaces are also shown. In addition, the images were thresholded. Whiteflies and leaf veins are visible in the image.

3.3. Discussions

As described in 3.1 and 3.2, whitefly bio-detection was successful on cucumber and green perilla leaves when indirect (ambient) light was used. The Otsu's method was indicated to be sufficiently useful as a threshold determination, although it is a classical method. However, we found that the optimal color component for whitefly bio-detection depends on the leaf type. In addition, the proposed method was also able to detect the shape and location of leaf veins in the image.

4. CONCLUSIONS

In this paper, we focused on the light source and proposed a method to separate whiteflies and leaves by controlling the brightness of the light. Whitefly bio-detection was successfully achieved in both cucumber and green perilla leaves when indirect (ambient) light was used. However, the optimal color component for whitefly bio-detection depends on the leaf species. Furthermore, the proposed method also detected the shape and position of leaf veins in the images. This study contributes to the automation of whitefly bio-detection. This image processing method has the potential to be applied not only to whiteflies but also to other insects and to plant studies.

ACKNOWLEDGEMENT

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IMAGE PERCEPTUAL RECOGNITION AS A RESEARCH ON AUTOMATIC BODY CONDITION SCORE OF DAIRY COWS

Yi-Hsin Yeh[1, *]), Szu-Han Wang[1]), Tsung-Yi Lin[1]), Jen-Wen Shiau[1])

1) Livestock Research Institute, Council of Agriculture, Executive Yuan, Taiwan
yihsin@tlri.gov.tw

ABSTRACT: In the dairy farm of the Hsinchu branch of Livestock Research Institute Council of Agriculture Executive Yuan, a study was carried out on the automatic perception and recognition of the body condition score of 20 dairy cows. Set up a camera next to the dairy cow walking channel, shoot the image of the dairy cow hip area from the left rear of the dairy cow at an angle of about 45 degrees and a height of about 190 cm twice a day, and use the software to automatically identify the image characteristic values between the ilium and ischial, and then automatically give the body condition score (BCS). Compare with the traditional observer to make the BCS judgment score of the dairy cow with the naked eye (V font ≤ 3, U font >3, flat U font ≥ 4). The results of 240 scoring studies show that the rate of using image perception to accurately determine the body condition of dairy cows is 95% (228 times), higher than 80.4% (193 times) of traditional observers. Therefore, automatic scoring of dairy cow body condition score may replace traditional observers as an indicator of dairy cow body condition measurement and scoring.

Keywords: *Body Condition Score, Dairy Cow, Image Recognition.*

1. INTRODUCTION

The idea of the body condition score (BCS) has started to prevail in America as of the 1970s. In 1982, Wildman et al. first standardized the BCS scoring system. In 1994, Ferguson et al. provided the use of better practices for the assessment of BCS in Holstein dairy cows (Hsieh and Chuang, 2014).To date, BCS has been used extensively as an important indicator in evaluating the nutritional status and energy reserves of dairy cows. It is important to note that a BCS is determined by the amount of body fat or lack of body fat, not the physical size of the cows (Chen, 2021).

In addition, the monitoring of the body condition of cows represents an indispensable part in farm management. This is especially important during calving to early lactation of cows, as the cows enter a state of negative energy balance (NEB) around calving to early lactation, if they do not attain a reasonable BCS at various lactation stages or dry period, problems during calving may very likely take place or the cows may develop post-partum metabolic diseases such as fatty liver, ketosis, milk fever, mastitis, foot disease, displaced abomasum or even breeding difficulties, etc. (Li,1983). Professionally trained cow BCS observers can assess the body condition of cows and assign a BCS just by the naked eye; they instantly and conveniently evaluate if the cows have acquired sufficient energy intake through BCS. On the downside however, this method of manual scoring is more subjective and a long time is required for the training of professional BCS observers, to be able to carry out relevant scoring (Li , 2002). Although the determination of BCS is slightly subjective, it can assign a fatness score for different age groups without being affected by the physical size, milk yield, health status, or other factors of cows. It is a method of more convenience, easy performance, and low cost for evaluating if the energy is balanced in cows (Hsieh, 2014).

To solve the subjective factor issue in manual scoring and the long training time problem of BCS observers, this study planned to recognize and measure the body shape of dairy cows through visual measurement technology via image recognition technology and in compliance with the BCS determination standards. This study subsequently performed categorization according to acquired characteristics, and built a system determining very thin, thin, normal, fat, very fat, and thereby building an automated "measuring system for the body shape of dairy cows" to determine the BCS of dairy cows as an indicator in monitoring their health.

2. MATERIALS AND METHODS

The professionally trained BCS observers will stand approximately 45 degrees behind the cows and examine by the naked eye the cows' hip area in between ala ossis ilium and tuber ischii and conduct body condition scoring. Cows with a V shape are determined as ≤ 3.0, cows with a U shape are determined as > 3.0, and cows with a flat U shape are determined as ≥ 4.0. This study replaces the naked eye with a camera, and conducts image recognition through the YOLOv4 algorithm, in the hope of setting up an artificial intelligent "measuring system for the body shape of dairy cows."

2.1. Measuring system for the body shape of dairy cows.

Changes of BCS in cows can be used as the basis for determining the association between diet and nutrient digestion and utilization of cows. The BCS application time points are 1) 7-8 weeks before calving; 2) 3 weeks before calving; 3) before peak of lactation. The scores are 1-5, with 1 being very thin, 2 being thin, 3 being normal, 4 being fat, and 5 being very fat. On average, a score 1 of BCS is approximately 8% of the body weight (i.e., approximately 50-60kg), and 5-6 months of time is required for every 1 score point increment (Chang, 1984). This study has in March 2022 used the lactation barn of the dairy farm of Hsin-Chu Branch, Livestock Research Institute, Council of the Agriculture Executive Yuan as the test field for conducting automated BCS testing on 20 Holstein cows and compared the results of the automated scoring using image perception recognition system to that of the traditional scoring by the observers.

At the beginning of the study, to compare with results of professional BCS observers standing behind cattle at an angle of approximately 45 degrees and to avoid harming the cattle due to the low height of installation, the body shape measuring system equipment was stationed behind the exit of the milking passage for cows. The camera was installed approximately 45 degrees to the rear left of the cows, at a height of 190 cm. The camera had a resolution as high as 2592 × 1520 and color capturing at 0.08 lux and was IP66 certified for international protection marking. It was primarily used for acquiring body shape characteristic information of the dairy cows. During the twice-daily milking times (morning and afternoon), the camera automatically took images of the cows' hip shape in between ala ossis ilium and tuber ischii when they passed the milking passage. The images then entered the image processing server for operational analysis. In total, data were collected from 20 lactating dairy cows for a period of seven months. After the dairy cattle body shape database and identification model training, the plan is to conduct research from various perspectives and heights based on the preliminary results.

Figure 1. Establishment of image recognition annotation data for cow hips (V, U, flat U).

2.2. YOLOv4 Image Recognition.

This study utilizes the recognition algorithm of small sample learning, coupled with the camera capturing of the shape of the cows' hip in between ala ossis ilium and tuber ischii when they enter the milking passage (Kannadaguli, 2020). There are two steps in the recognition of the hip area of cows: detection and recognition. The YOLOv4 algorithm is used in detecting the hip area of dairy cows. It is primarily done by lots of image categorization and data annotation, offering the computer basic knowledge in understanding human beings' way of recognizing the characteristics of the image content. The recognition model trains MobileNetV2 with small sample learning algorithm and utilizes online triplet loss for implementation (Narayanan et al., 2021).

YOLOv4 consists of Input, Backbone, Neck, and Prediction. Of all, the Neck layer splits the three output feature maps into 19*19 (32 times), 38*38 (16 times), and 76*76 (8 times), which correspond to detecting small objects, medium objects, and large objects, respectively. It then combines and integrates features of different layers. After that, determine the three annotation results (V, U, flat U) according to the BCS scoring standards.

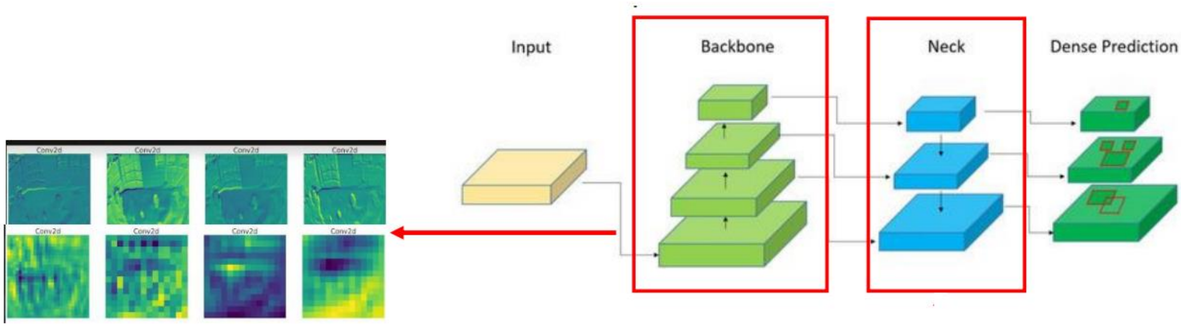

Figure 2. Establishment of basic recognition technology knowledge by YOLOv4 through large quantity image categorization and data annotation

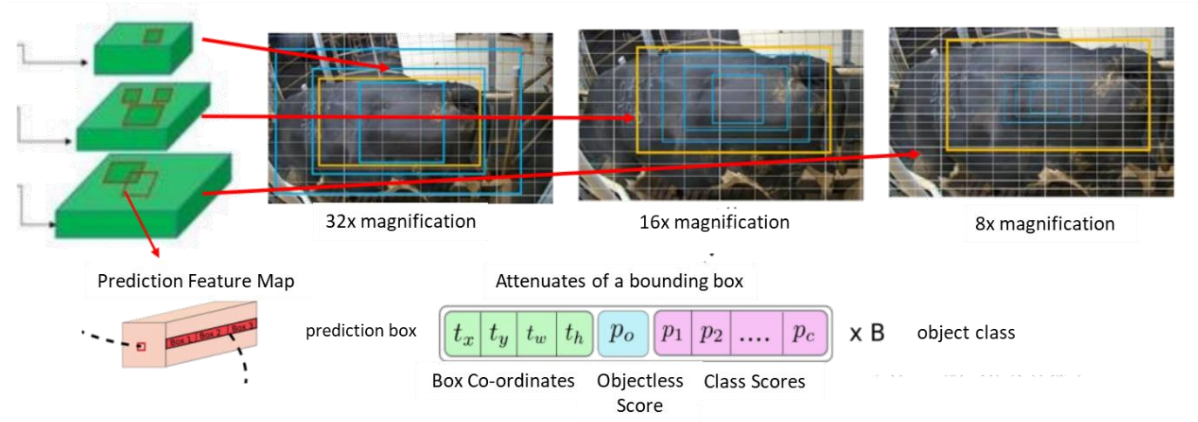

Figure 3. Determination of the three annotation results byYOLOv4 based on the BCS scoring standards.

3. RESULTS AND DISCUSSION

3.1. The results of body shape measurement and recognition of dairy cows.

This study conducted automated BCS testing on 20 Holstein cows and, from March−October 2022, accumulated 3,555 data points.

Figure 4. Establishment of image recognition annotation data for cow hips (V, U, flat U).

Table 1. Scoring in simulation of BCS expert's point of view.

BCS Score	1	2	3	4	5
type	very thin	thin	normal	fat	very fat

In simulation of BCS expert, divide the body condition of dairy cows into 5 levels, with scores 1-5, which are very thin, thin, normal, fat, very fat, and through the measuring system of the body shape of dairy cows, determine the BCS, as in figure 5, a score of 3.0 has been determined by the system, the hip shape is V type, which is categorized as normal.

Figure 5. BCS scoring in simulation of BCS expert's point of view.

3.2. YOLOv4 Image Recognition results.

A camera set was stationed behind the exit of the milking passage at approximately 45 degrees to the rear left of the cows and a height of 190 cm. The camera set was used for detection of the hip area and recognition of the body shape of dairy cows and for subsequent scoring. During the test period (2022.03.21−2022.10.11) and after 300 scoring results, the findings from scoring using the automated measuring system were compared to the on-site scoring results of the observers. To use 2022/5/21 results as an example, 20 cows were measured as testing benchmarks, which were initially scored by an expert BCS; results of the automated measuring system for the body shape of dairy cows (accuracy rate: 95%) and the on-site scoring results of the observers (accuracy rate:85%) were then compared (Table 2).

Table 2. Cow body shape recognition results (2022.05.21)

No.	Cow ID	Scoring results rated by experts	Recognition results by automated system	Scoring results rated by on-site observers	Category
1	108907	3.50	3.50	3.50	normal
2	108920	4.00	4.00	4.25	fat
3	104723	3.00	3.00	3.00	normal
4	106107	2.25	2.25	2.25	thin
5	106110	3.25	3.25	3.25	normal
6	107811	4.00	4.00	4.00	fat
7	107821	3.00	3.00	3.25	normal
8	108915	3.75	3.75	3.75	normal
9	108923	3.00	3.00	3.00	normal
10	108919	3.50	3.50	3.50	normal
11	109456	4.00	4.00	4.00	fat
12	109459	3.50	3.50	3.50	normal
13	104726	4.25	4.25	4.25	fat
14	104715	4.00	4.00	4.00	fat
15	106111	3.00	3.00	3.00	normal
16	109458	3.50	3.50	3.50	normal
17	107830	3.25	3.25	3.25	normal
18	109451	3.75	3.75	3.75	normal
19	103020	2.25	2.50	2.50	thin
20	107812	3.00	3.00	3.00	normal

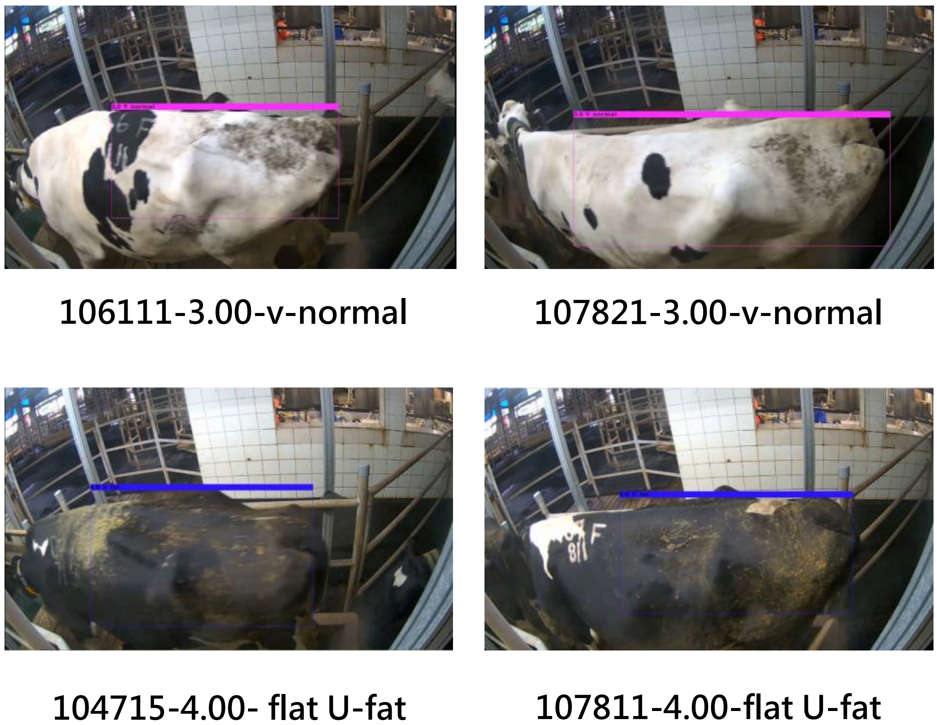

Figure 6. Scoring results from using the automated measuring system for the body shape of dairy cows.

After 300 scoring results using the image perception for recognition, the accuracy rate of the automated system was 95.3% (number of times: 286), whereas the accuracy rate of the on-site BCS observers was 80.3% (number of times: 241). The scoring results indicate that the automated system using image perception recognition achieves a higher precision and accuracy rate than do the on-site observers (Table 3). Additionally, the image perception recognition can also digitize the former scoring results, which can be used as indicators for measurement and scoring of the body shape of dairy cows in the future.

Table 3. Scoring in simulation of BCS expert's point of view.

Test date	Number of tested cows	Number of correct scores	
		Automated scoring method	on-site observers
03/21	20	18	14
04/01	20	17	16
04/11	20	19	15
04/21	20	18	16
05/01	20	20	15
05/11	20	20	15
05/21	20	19	17
06/01	20	19	18
06/11	20	19	17
06/21	20	20	16
07/01	20	19	17
07/11	20	20	17
08/11	20	19	17
09/11	20	20	15
10/11	20	19	16
Total	300 (A)	286 (B)	241 (C)
Accuracy rate		95.3% (B / A)	80.3% (C / A)

4. CONCLUSIONS

The systemized and long-term application of image perception recognition for scoring the body shape of dairy cows will accumulate and form a considerable database of body shape scoring results. This can lead to the development of automated body shape detection and scoring services that help in the usual monitoring and observation of dairy farmers, allowing better management in the feeding and nutrition of cows. Concluded by the results of this study, that the image perception recognition technology can be utilized as a tool for scoring body shape of cows, and at the same time objectively determine the body shape change differences in cows. As a result, coupling the image perception automated recognition technology with adjusted farm feed and formula can effectively control the excessive changes in the BCS of cows, and will help the farmer improve the physique of cows to increase their ability to reproduce and reduce the loss from culling.

5. ACKNOWLEDGEMENT

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MODELING CARBON METABOLISM IN THE DEVELOPING STORAGE ROOTS OF RAYONG 9 CASSAVA VARIETY UNDER DIFFERENT WATER CONDITIONS

Porntip Chiewchankaset[1)], Jittrawan Thaiprasit[1)], Saowalak Kalapanulak[1,2)]
and Treenut Saithong[1,2, *)]

1) Center for Agricultural Systems Biology (CASB), Systems Biology and Bioinformatics Research Group, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi (Bang Khun Thian), Bangkok, Thailand
2) Bioinformatics and Systems Biology Program, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bang Khun Thian), Bangkok, Thailand

* Corresponding author E Mail: treenut.sai@kmutt.ac.th

ABSTRACT: Global climate changes alter seasonal period and cause unusual variation in daily temperature and humidity. The circumstance directly affects water availability for crop growth and subsequently reduces final production. Studies in cassava show that irrigated plantation could alleviate the impact of the variable environmental exposures and could also rise storage root (SR) yield under a favorable condition. It demonstrates a closed link of water availability condition to plant carbon metabolism and biomass production. As hypothesized, we here investigated carbon assimilation and carbon conversion in developing storage roots of Rayong 9 cassava variety grown under the different water regimes (WR), relatively drier (WR1) and wetter (WR2) conditions based on soil matric potential. Constraint-based metabolic model was developed to simulate carbon conversion towards root biomass biosynthesis in responsible of the higher yield of SR dry weight and starch content in WR2 condition. Simulation showed that carbon flux partitioning in root metabolism at 8-month-old plants differed between water conditions. Plants in WR2 condition showed higher total photosynthesis which yielded more amounts of sucrose for storage root development. The simulated results also showed the difference in balance of apoplasmic (via invertase) and symplasmic (via sucrose synthase) sucrose transports in these conditions. The more active carbon flux through sucrose synthase reaction at the late stage of SR development observed in WR1 may reflect the response of carbon metabolism to the relatively dry condition. This insightful understanding of metabolic response to water conditions has moved another step forward to the optimized irrigation practice in cassava precision farming.

Keywords: *Carbon assimilation, Cassava, Constraint-based metabolic model, Crop yield, Water availability.*

1. INTRODUCTION

Climate changes are root of almost all of the challenging problems in this century. The impacts on world population are not only on environmental concerns, such as natural disasters, but also on food security. Alteration and fluctuation of seasonal period, precipitation pattern, and daily temperature directly affect water availability for agriculture (Sabbaghi et al., 2020). It was predicted that water resource will decrease by at least 15% in 2045, based upon a broad range of climate scenarios simulated via positive mathematical programming. The circumstance will result in decrease of crop production, such as wheat, barley, alfalfa, sugar beet, onion, and cucumber, between 2.41% and 59.95% (Shayanmehr et al., 2022). Comparing to the major food crops such as rice, maize, and sorghum, cassava is considered as a well-adaptive crop species to variable climatic condition. Nonetheless, cassava root yields were also reported to be significantly affected under water deficit conditions (Raji and Byju, 2020).

Cassava (*Manihot esculenta* Crantz) is one of the most important starch crops whose underground roots contain starch up to 70-90% of dry weight matter. Starchy roots of cassava are the main carbohydrate source feeding millions of people in tropical regions across Africa, South America, and Asia (Raji and Byju, 2020). Though cassava is able to survive under unfavorable conditions, its production is unstable and cannot cope with the growing demand. To secure crop productivity, cultivation management has been researched together with cassava genetic improvement. Rayong 9 is one of the high yielding cassava varieties that is grown extensively in various parts of Thailand. Its storage roots contain high percentage of starch in dry weight matter, which is suitable for ethanol production and a broad range of industrial applications (Vongcharoen et al., 2018). Rayong 9 cassava plant produces at least 1.5-fold SR production in the irrigated field (Mahakosee et al., 2019). The influence of water availability on plant growth is mostly described based on the physiological responses, but limited extent on carbon metabolism inside plant which is more directly related to crop yield. In water deficiency condition, cassava plants tend to reduce transpiration rate by quickly closing stomata and reducing leaf canopy. The new leaves developed under the condition always smaller which affect effectiveness of light interception during photosynthesis. This systematic response brings to reduction of photosynthetic rate and finally decrease in storage root yield (El-Sharkawy, 2007).

Constraint-based metabolic model (CBM), an effective approach for investigating metabolic complexity, was originally developed to study metabolism underlying growth and development of microorganisms, and has recently been applied to gain more insights into metabolic responses to environmental conditions of plants (Baghalian et al., 2014; Perez-Garcia et al., 2016). CBM model of cassava, rMeCBM, is constructed in 2019 to investigate carbon utilization in metabolism of high and low yielding varieties (Chiewchankaset et al., 2019). The model is successful to simulate the differences in carbon conversion towards biomass biosynthesis that underlie the phenotypic yield. Herein, we employed rMeCBM to study carbon assimilation and conversion of developing storage roots in response to the different water conditions. The study was investigated based on Rayong 9 plants, a commercially important cassava variety, grown in experimental field with varying water regimes (WR): dry (WR1) and wet (WR2) conditions on the basis of soil matric potential was used in this study. The knowledge obtained from this study will lead to a better understanding of metabolic response to water conditions that is essential for further improvement of irrigation practice in cassava precision farming.

2. MATERIALS AND METHODS

2.1. Constraint-based metabolic model of carbon assimilation in cassava storage roots

Carbon conversion in metabolism of the developing roots under the different water conditions was modelled using rMeCBM model, the constraint-based metabolic model of carbon assimilation in cassava storage roots (Chiewchankaset et al., 2019). The model described carbon utilization towards biomass production through seven sub-metabolic pathways, i.e. starch and sucrose biosynthesis pathway, respiration pathway, pentose phosphate pathway, cell wall biosynthesis pathway, amino acid biosynthesis pathway, fatty acid biosynthesis pathway, and nucleotide biosynthesis pathway. In the model, carbon conversion was simulated through 468 reaction fluxes related to 393 metabolites and three cellular compartments (cytosol, mitochondria, and plastid). All simulations were performed using COBRA Toolbox 2.0.6 (Schellenberger et al., 2011) in MATLAB (The MathWorks, version R2019b) and the large-scale linear programming using the GNU Linear Programming Kit (GLPK; glpkmex-2.4-precom-win-glpk-4.20).

2.2. Simulation of carbon assimilation in the cassava storage roots under different water conditions

Carbon metabolism in storage root was simulated using sucrose from photosynthesis as the main carbon substrate. Sucrose uptake rate for storage root growth ($mmol_{sucrose}\ gDW^{-1}_{SR}\ day^{-1}$) was calculated from leaf photosynthesis, leaf area, and plant dry weight in similar manner to Chiewchankaset et al. (2019). Biomass equation was derived from the molecular composition of the developing storage root, including carbohydrate, sucrose, glucose, fructose, starch, protein, amino acids, lipid, fiber, cellulose, and xylan. The model was optimized to satisfy maximal growth rate of storage roots under the studied conditions. All physiological data and biomass composition of Rayong 9 cassava variety were taken from the field plantation at the Field Crop Research Station at the Division of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand during December 2015 to December 2016 (Mahakosee et al., 2019, and in-house study). In brief, the experiment was laid out in a randomized complete block design consisting of two water treatments with three replicates. The crop was maintained at near field capacity by using a mini-sprinkler system to enhance good crop establishment. After the first month, two different water regimes were applied and the actual soil water content was measured using watermark probe (Watchdog 1645, PCE group, PCE Germany, Meschede, Germany) at 40 cm depth throughout the study period.

3. RESULTS AND DISCUSSION

3.1. Effects of water availability on cassava storage root yield and starch content

Rayong 9 is a high yielding cassava variety that shows well response to soil water status. Growing Rayong 9 cassava plants in the two different water availability regimes (WR1 and WR2) led to significantly different storage root yield and root starch content, especially at final harvest (~ 11 months after planting (MAP), Figure 1).

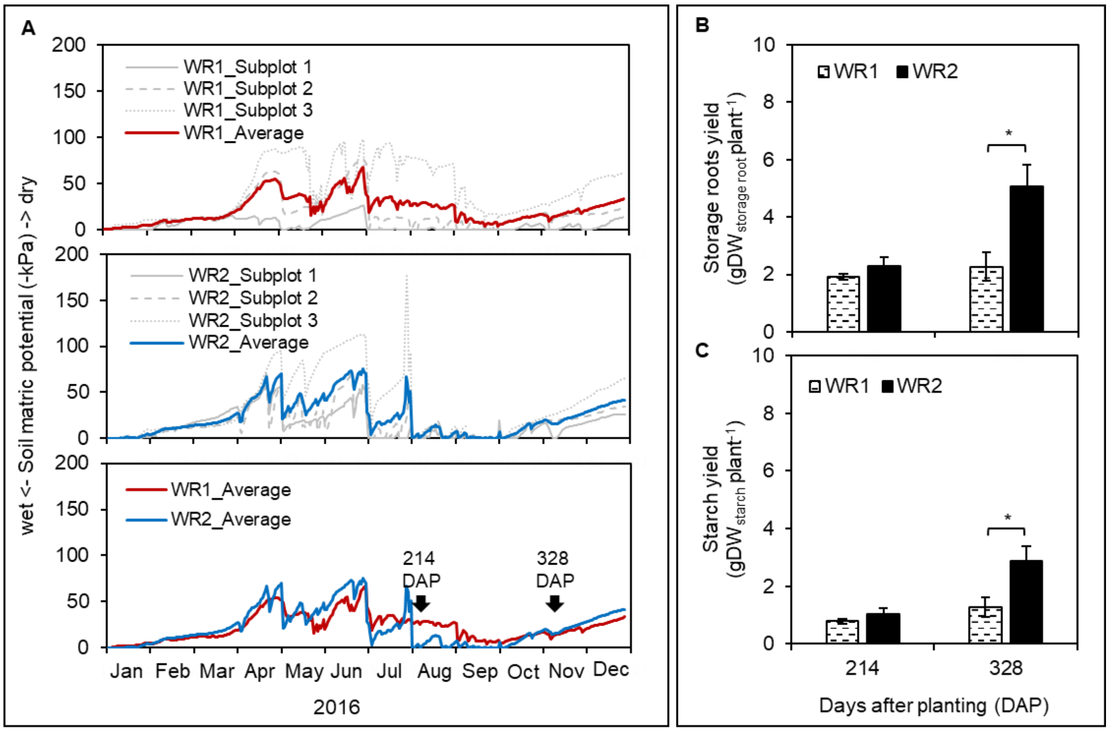

Figure 1. Soil water profile of cassava field experiment and crop growth yield. (A) The average soil matric potential of WR1 (drier) and WR2 (wetter) during December 2015 to December 2016. (B) Storage root yield and (C) root starch yield of Rayong 9 plants at 214 and 328 days after planting (DAP). Data are shown as means ± SE (n = 4 for storage root yield and n = 3 for starch yield), and the significant difference based on one-sided student's t-test ($p \leq 0.05$) is denoted as asterisk (*).

Average soil matric potential of WR1 and WR2 were comparable throughout cultivation period, with the largest different at the late stage of root development (eight MAP, from August 2016) (Figure 1A). At the early growth stage (~ 1-5 MAP, January – May 2016), both water conditions were subjected to low soil water content, whereas during the late growth stage WR2 was likely wetter than WR1. The results showed that storage root yield from WR2 condition were slightly higher at 214 DAP, and that were increased to 2.23-times greater at 328 DAP (Figure 1B). Similar results were also observed in root starch content (Figure 1C). The response of Rayong 9 cassava variety to water availability in soil was explained physiologically by Mahakosee et al. (2019). Their work suggested that plants limit leaf canopy development as exposed to drought at the early plant ages. Once more water available, plants generate new leaves and expand leaf size during late developmental stage. This extensive canopy development might increase total photosynthesis of plants that is hypothesized to yield higher photoassimilate translocated for root growth as well as starch production.

3.2. Carbon flux partitioning in metabolism of developing root under WR1 and WR2 conditions

Carbon assimilation towards SR development under WR1 and WR2 conditions was studied through rMeCBM model simulation. The study reflected the differences in carbon assimilation and metabolism according to (i) the total photosynthetic rate, (ii) the specific sucrose uptake rate for storage root metabolism, and (iii) the simulated fluxes of carbon conversion to biomass production.

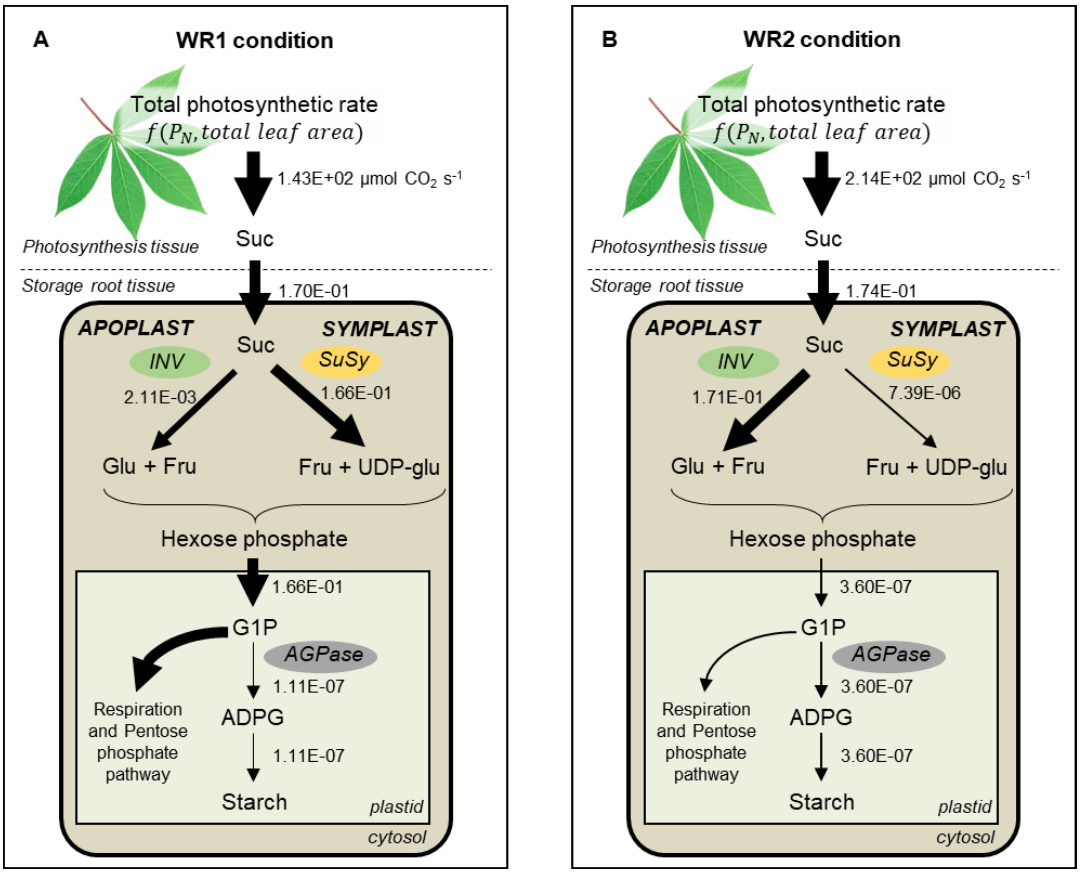

Figure 2. Simulation of carbon flux partitioning in metabolism of developing storage root of Rayong 9 cassava variety under (A) WR1 and (B) WR2 conditions at 214 days after planting. The thick arrows denote the dominant fluxes. The unit of carbon reaction fluxes in storage root tissue is day^{-1}. Metabolite abbreviations is defined as follows: ADP-glucose, ADPG, fructose, Fru; glucose-1-phosphate, G1P; glucose, Glu; sucrose, Suc; UDP-glucose, UDP-glu. Enzyme abbreviations is defined as follows: ADP glucose pyrophosphorylase, AGPase; invertase, INV; sucrose synthase, SuSy.

At 214 DAP, the total photosynthetic rate of plants in WR2 (214 μmol CO_2 s^{-1}) was higher than that in WR1 (143 μmol CO_2 s^{-1}) by 1.50 times, suggesting more photoassimilates available for plant growth under well-water condition (Figure 2). The specific sucrose uptake rates, which refer to velocity of carbon supply to root metabolism per mass of SR produced, were found not different between the conditions, while the distinction appeared at carbon flux partitioning in root metabolism. Under WR1 condition, sucrose was mainly metabolized through symplasmic pathway as shown high flux of sucrose hydrolysis into glucose and UDP-glucose by sucrose synthase related reaction (Figure 2A). In contrast, sucrose was more actively translocated via apoplastmic pathway in WR2 plants, where sucrose was predominantly broken down into glucose and fructose by invertase related reaction (Figure 2B). The high activity of sucrolytic reaction in WR1 condition is corresponding to studies of drought stress response in plants, including cassava (Zhao et al., 2015), soybean (Du et al., 2019), and grape berry (Zhang et al., 2006). Huang et al. (2021) showed that sucrose synthase gene family in cassava storage root was up-regulated in drought condition. The results also predicted high reaction flux of ADP glucose pyrophosphorylase in WR2 plants, approximately by 3.24 times, which would describe the greater starch yield of plant in this condition (Figure 2). Similar results were observed in potato tubers that the activity of ADP glucose pyrophosphorylase was inhibited under drought condition (Geigenberger et al., 1997). These findings were consistent with the simulation of plant metabolism at 328 DAP (data not shown) when clearer yield different was observed.

4. CONCLUSIONS

In summary, this study demonstrated the effects of water condition on the carbon assimilation, carbon conversion for root biomass, and storage root yield in developing storage root of high-yielding cassava variety through the model simulation. The results highlighted the differences in carbon assimilation, regarding sucrose translocation and conversion pathways, which would lead to the low storage root yield and starch content in the relatively drier condition (WR1). The sucrose synthase was more active in WR1 that may reflect the response of carbon metabolism to more drought condition. This insightful understanding of metabolic response to water conditions could help improve the precision of the current irrigation practice in cassava farming.

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A REVIEW OF GEOPHYSICAL APPLICATIONS IN AGRICULTURE AND THEIR POTENTIAL IN VIETNAM

Huong Phan[1],*, Phong Nguyen[2], Kha Tran [3], Tung Nguyen[2]

[1]Hanoi University of Mining and Geology, Vietnam
E Mail / phanthienhuong@humg.edu.vn
[2]Vietnam Petroleum Institute, Vietnam
[3] Institute of Marine Geology and Geophysics, Vietnam academy of science and technology, Vietnam

* Corresponding author

ABSTRACT: Geophysical methods are effective tools for soil characterization and monitoring because they allow prediction of soil properties from measured geophysical parameters. Despite their notable advantages including rapid data acquisition, large data coverage, high data density and inexpensive survey implementation, the geophysical methods have been getting little attention in Vietnam so far. This article gives an overview of popular geophysical methods being applied in agriculture of several countries in the World to characterize and monitor soil properties. The main applications of each method are summarized and related publications are given for reference. A preliminary experiment of the most popular method, Ground Penetrating Radar, was carried out by the authors to reveal that although geophysical methods are very potential applications in agriculture, a great challenge of applying them in Vietnam is the lack of reliable techniques to accurately infer soil properties from measured geophysical parameters, which can be very noisy and have no explicit relationship with them.

Keywords: *Geophysics, geophysical methods, precision agriculture, soil properties, soil monitoring, soil characterization.*

1. INTRODUCTION

Geophysical methods, traditional tools for studying deep earth properties, in recent years have been actively applied in agriculture to utilize their significant strengths, such as quick measurement, easy deployment, high data density and low operational cost. With the help of geophysical methods, maps of soil properties in vast areas can be created and updated regularly to assist land management, plantation optimization and farm planning. Several techniques for geophysical data analysis have been established and widely applied to determine soil properties (Besson et al., (2013); Blanchy et al., (2020); De Benedetto et al., (2012); Donohue et al., (2013); Jadoon et al., (2015); Grote et al., (2010); Huang et al., (2016); Keller et al., (2017); Moghadas et al., (2019); Wong et al., (2009).

In Vietnam, however, soil properties are still solely measured by sample analyses in laboratories which are time consuming, expensive, and hence leading to sparse data points. Apparently, little attention has been given to geophysical applications in agriculture in spite of their effectiveness. Trung et al., (2008) and Thu et al., (2012) are probably the only two articles found on Vietnamese public domain that tried to use electrical method to predict the high salinity of underground water in a northern Vietnam coastal plain area.

With that background, this article gives an overview of the most common geophysical methods being applied in agriculture over the World and describes a preliminary experiment implemented at Agricultural Academy testing ground aiming to evaluate the potential application of these methods in Vietnamese agriculture.

Corresponding author E Mail: phanthienhuong@humg.edu.vn

2. GEOPHYSICAL METHODS AND THEIR APPLICATIONS IN AGRICULTURE

2.1. Geophysical methods

The applications of geophysical methods in agriculture have been previously described and reviewed by several authors (Romero- Ruiz et al., (2018), (2021); Pradipta et al., (2022)). Table 1, modified from Pradipta et al., (2022), summarizes the most popular methods, their measured physical parameters and the soil properties that can be inferred from them. Related original publications are also given for reference.

Geophysical Methods	Physical parameter	Applications	References
Ground-Penetrating Radar **(GPR)**	Propagation velocity (v) of EM waves	Soil moisture measurement	Zhou et al., (2019); Lu et al., (2017)
		Monitoring SM variabilities	Barca et al., (2019); Zhou et al., (2019); Klotzsche et al., (2018); Jonard et al., (2013); Cavallo et al., (2016)
		Spatial variations of clay content	De Benedetto et al., (2012);
		Identifying the compacted layer	Muñiz et al., (2016); Akinsunmade et al., (2019)
		Delineation of soil and bed rock	Nováková et al., (2013);
		Identifying humous and non-humous layers	Winkelbauer et al., (2011);
Electromagnetic Induction **(EMI)**	Bulk electrical conductivity (σ)	Soil moisture variations	Blanchy et al., (2020); Moghadas et al., (2019);
		Monitoring SM variabilities	Barca et al., (2019); Moghadas et al., (2019);
		Identification of clay, silt, and sand/gravel	Heil et al., (2012); De Benedetto et al., (2012);
		Soil organic matter mapping	Rentschler et al., (2020);
		Soil salinity distribution	Jadoon et al., (2015);
		Detection of soil compaction	Schmäck et al., (2021);
Electrical Resistivity **(ER)**	Resistivity (Ω)	Soil moisture variations	DeJong et al., (2020);
		Identifying root water uptake	Vanella et al., (2018);
		Soil-bed rock delineation	Cheng et al., (2019);
		Identification of compacted zones	Besson et al., (2013);
		Characterization of regolith	Gourdol et al., (2018);

		Soil structural change after compaction	Keller et al., (2017); Besson et al., (2013);
Spectral Gamma	Gamma ray energy (MeV)	Clay content and soil quality	Ameglio, (2018);
		Soil moisture variations	Sunori et al., (2021);
		Soil salinity distribution	Viscarra Rossel et al., (2007);
		Total soil organic carbon and cation exchange capacity	Kassim et al., (2021);
Seismic	seismic velocities (v_p and v_s)	Detection of compacted soil	Romero-Ruiz et al., (2021); Donohue et al., (2013);

2.2. Geophysical applications in agriculture

Ground-Penetrating Radar method

Ground-Penetrating Radar method (GPR) is a method of non-destructive electromagnetic wave reflection, high frequency electromagnetic wave, commonly used for high-resolution near-ground studies. Antennas transmit high-frequency electromagnetic waves from a few tens of MHz to several GHz into the soil, part of the energy reflect back to the antenna at the boundary of the two layers which have different dielectric permeability. The change of electromagnetic wave energy tells the nature of the medium it passes through. GPR method has been widely applied in agriculture to predict soil layers, soil compaction and soil moisture (Muñiz et al., (2016); Akinsunmade et al., (2019); Nováková et al., (2013).

Electromagnetic induction method

Electromagnetic induction (EMI) method measures selected components of an electromagnetic (EM) field forming in the soil by induction caused by an artificial EM field. The characteristics of the induced EM field is linked with the subsurface electrical resistivity. The measured apparent conductivity (ECa) after being corrected gives the soil conductivity vertically at varied depths. The soil conductivity data in turn can be further processed to indicate different soil properties such as the amount and type of clay content, the moisture variations, the bulk density, or the salinity distribution (Huang et al., (2016).

Resistivity method

This method measures soil's resistivity which also dependent on other properties such as porosity, moisture content, structure and architecture of the soil (Samouëlian et al., (2005). For example, the DC resistivity of the soil depends on the mineral salt concentration of the water in the pore or the total dissolved mineralization, so the method can be used to evaluate soil salinity or to define the salty – pale boundary of the aquifer (Romero- Ruiz et al., (2018).

Gamma method

Gamma ray emission originates from spontaneous radioactive decay and it does not depend on any other objective or subjective case. The activity of radioactive isotopes depends on soil geochemistry so the gamma activity can be used to predict organic content, clay content, as well as other geochemical soil elements (Viscarra et al., (2007).

Seismic method

The seismic method measures the seismic wave and their propagation velocities through the subsurface from the source to receivers. Since seismic wave partly reflects at each soil boundary, the seismic method can be used to map subsurface soil boundaries. It can also be used to predict the soil porosity and density which control the propagation velocities. The main disadvantage of seismic method is that it is expensive and requires bulky equipment to be implemented. Although not as popular in soil monitoring as other geophysical methods, in certain circumstance, the seismic geophysical method still can be applied to provide valuable information on soil properties (Pradipta et al., (2022).

3. EXPERIMENTAL APPLICATION OF GEOPHYSICAL METHODS FOR SOIL PROPERTY PREDICTION IN VIETNAM

Acknowledging the importance of geophysical applications in soil characterization, the Ministry of Science and Technology has funded an experimental project to predict soil properties from geophysical parameters using technology of industry 4.0. As a part of the project, a GPR survey line was carried out in the Agricultural Academy experimental field (Figure 1a) and the acquired data have been processed by filtering the noise but apparently the resulted cross section is still noisy (Figure 1b). In this section, the horizontal axis is the distance in meters, the vertical axis is time on one side and depth on the other side. Three soil boundaries can be interpreted as colored lines in the section. The first boundary is sub-horizontal and has a depth of about 30 cm, the shallowest part of the boundary is about 25 cm while the deepest part is about 35 cm. The soil layer between the first and the second boundaries has an average thickness of 20 cm with the thinnest interval of 15 cm and the thickest interval of 25 cm. The third layer has the thickness ranged from 15cm to 40cm. Below the third boundary, some coherent features can still be observed but they are difficult to interpret due to excessive noise level.

Other soil properties besides the boundaries cannot be calculated at this stage of the project because they require modeling of GPR data together with actual lab measured data points for calibration (Winkelbauer et al., (2011), Zhou et al., (2019), Barca et al. (2019), that are not currently available.
It is worth noting here that geophysical parameters and soil properties are interdependent but inexplicitly. Therefore, careful data processing techniques and sophisticate modeling algorithms are crucial to receive accurate information of soil characteristics. This is probably the main reason why the geophysical methods have not been applied for soil characterization and monitoring in Vietnam.

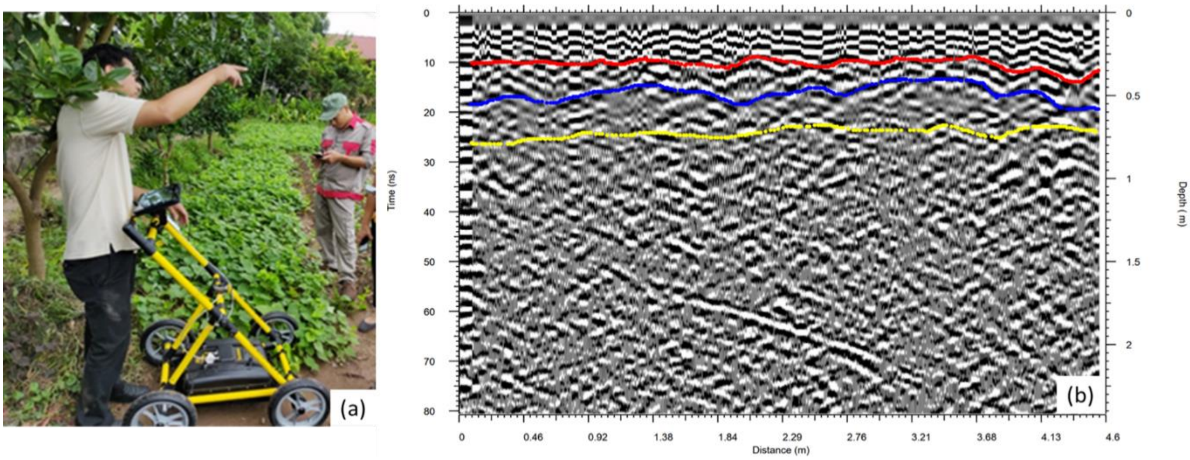

Figure 1. A trial application of GPR to predict subsurface soil layers implemented in the experimental field of the Agricultural Academy using Geoscaner equipment (a) and the resulted cross section with interpretation (b).

4. SUMMARY AND CONCLUSION

The review has demonstrated that geophysical methods are useful tools for soil characterization and monitoring. They have proven effective in soil property studies thanks to the several advantages, including rapid data acquisition, high data density, large data coverage with inexpensive implementation.
The main challenge is that soil properties cannot be directly indicated by measured geophysical parameters, instead they are inferred from them by sophisticate data analysis and data modeling techniques, that are not readily available in Vietnam. This is probably the main reason why geophysical methods have not been applied for agricultural purposes in the country so far.

A preliminary experiment of GPR method reveals that the data can be useful but need a lot of processing effort to reduce the great amount of contaminated noise. A combination of varied suitable geophysical methods and the use of industry 4.0 technologies can be a solution to provide more reliable information about soil properties (Sunori et al., (2021).

5. ACKNOWLEDGEMENT

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IDENTIFICATION OF EARLY AND LATE BLIGHT ON POTATO LEAVES USING DEEP LEARNING

Quoc-Anh Hoang[1, *)] and Hoang-Anh The Nguyen[2)]

1) University of Engineering and Technology, Viet Nam
hoangquocanhrb@gmail.com
2) Vietnam – Korea Institute of Science and Technology, Vietnam
anhnth@most.gov.vn
*****Corresponding Author: Quoc-Anh Hoang, hoangquocanhrb@gmail.com
Hoang-Anh The Nguyen, anhnth@most.gov.vn

ABSTRACT: Potato is one of the popular foods of Vietnamese people and some countries in the world. As with other food crops, diseases can seriously affect the yield and quality of the harvest. Therefore, in addition to disease prevention, early detection of diseases on plants can somewhat reduce the impact of diseases and farmers can offer timely solutions. Therefore, in this paper, we propose a disease identification software system based on potato leaf images using deep learning network and a mobile robot system. Camera is mounted to the mobile robot system that allows us to collect potato leaf images in the potato filed real-time. We test the proposed system on a public dataset and collect results on late blight, healthy and early blight with IoU metrics of 0.92, 0.92 and 0.93, respectively.

Keywords: *Leaf Disease, Deep Learning, Segmentation, Classification.*

1. INTRODUCTION

Potato is a familiar food in Vietnam as well as in some countries around the world. They are rich in potassium. In addition, potatoes also contain phosphorus, magnesium, calcium, sodium, iron, zinc, Vitamin C, just to name a few. However, potatoes can be affected by many diseases, reducing the quality and quantity of produce made with potato. This reduction is partly due to lacking measures for identification of diseases on potatoes.

Currently, in Vietnam, identification of diseases on potato leaves is still mostly done manually. With a large farming area, this can take time and effort from farmers. In addition, the symptoms of the disease may appear similar or identical that makes it difficult to recognize if the leaves are just inspected manually. Farmers often identify diseases by experience rather than based on scientific basis.

The proposed method uses deep learning to classify two common diseases on potato leaves based on images captured from a mobile robot system. There are a number of works relevant to this work could be found in the literature. This paper use [1] as base, Rizqi *et al.* (2020) used VGG16 [2] to classify four types of diseases in potato plants based on leaf conditions, their accuracy is 91%. Prajwala *et al.* (2018)[3] used Convolutional Neural Network model to identify tomato leaf diseases. The dataset was obtained from Plant Village, their accuracy from 94% to 95%. Both papers did not use segmentation method to separate the ground from the leaves images. Mohanty *et al.* (2016) [4] used AlexNet and GoogLeNet to identify 14 plant species and 26 diseases, their model has an accuracy of 99.35% on the test set. When experimenting with images taken under other conditions, their model achieved an accuracy of 31.4%.

McCool *et al*. (2017) [5] traded the accuracy and complexity of the model to learn lightweight models that can be applied to robots. This model applies to the weed classification problem and achieves accuracy greater than 90% with a processing speed from 1.07 to 1.83 frames per second.

2. MATERIALS AND METHODS

The proposed method in this paper consists of three main parts: a mobile robot that can move at common potato growing terrains (e.g. potato fields), a deep learning model capable of classifying potato leaf diseases (early blight, late blight and healthy leaves) (Fig. 1) based on images taken from the mobile robot, a software to help farmers monitor and control the robot remotely.

2.1. Data Acquisition

The data are taken from the "New plant Diseases Dataset" from Kaggle - an online community platform for data scientists and machine learning enthusiasts [https://www.kaggle.com/datasets/vipoooool/new-plant-diseases-dataset]. This dataset is collected from a potato plantation in Malang, Indonesia (Fig. 1). The data included 2391 late blight disease photos, 2391 early blight photos, and 2262 healthy photos leaf (7044 total) (Table 1).

Figure 1. Healthy, early blight and late blight

Table 1. Number of leaves.

	Train	Validation	Test
Healthy	1824	228	210
Late blight	1939	242	210
Early blight	1939	242	210

The downloaded original data set is used for the classification problem. In addition, a copy of the above dataset is labeled and adds noise (ground, surrounding leaves, etc.) to the segmentation problem (Fig. 2).

Figure 2. Image after adding background

2.2. Segmentation

The image taken from the robot can include the soil, so we have to preprocess the leaf region to make it separate from the soil image region. That split leaf image will be the input for the classification phase. There are many models for segmentation problems: PSPNet [6], HRNet [7], etc. with a large number of parameters and complex architecture. In this paper, the segmentation model used is UNet [8].

The architecture of Unet resembles the letter U, which explains its name. This architecture consists of 3 parts: contraction (encoder) bottleneck and expansion (decoder). The contraction part is made up of multiple blocks. Each block consists of two layers of CNN (Convolutional Neural Network) with a kernel size of 3x3, followed by a layer of 2x2 max pooling. The number of kernels or feature maps doubles every block, so this architecture can learn complex features efficiently. The layer in the lowest position mediates between the layers in the contraction and expansion part. It uses 2 3x3 CNN layers, followed by 1 with 2x2 up convolution.

2.3. Classification

After passing through the segmentation phase, images of potato leaves become input for classification. The deep learning model used here is VGG16 that consists of 16 layers, 13 convolution layers (2 convolution-convolution layers, 3 convolution-convolution-convolution layers) all have a 3×3 kernel, after each convolution layer is max pooling downsize to 0.5, and 3 layers fully connected.

2.4. Communication from mobile robot to server

In order for farmers to be able to receive images as well as control robots at long distances, we select the method of transmitting signals and images using Firebase (Fig. 3). In this communication manner, the robot sends an image to Firebase and server gets that image for further processing.

Alongside with communication, an interface is developed to display the captured foliage image. In this work, we use PyQt and Qt5 Designer tools because of their ease of use and convenient combination with image receiving and processing.

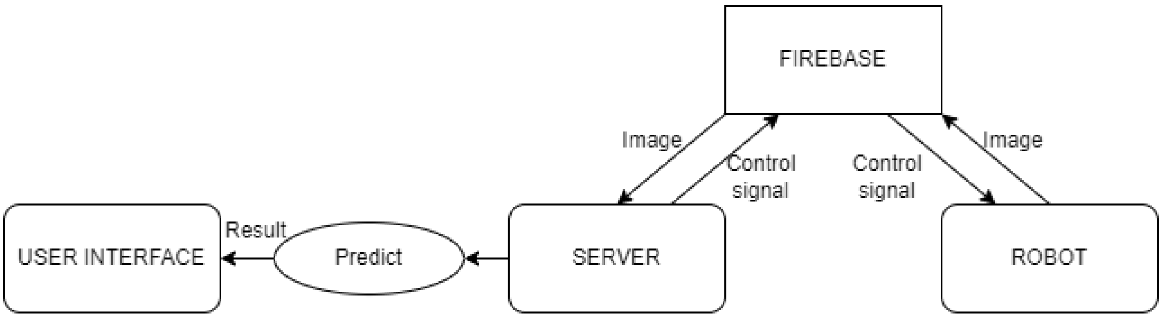


Figure 3. System diagram

2.5. Mechanical construction

The robot developed in this work has two main functions that are picture taking and movement. So, the main frame, motor, camera, electrical source are the main parts of it. For the outdoor potato field or greenhouse operating environment, chain wheels might be more suitable so that the robot can move easily.

The main parts of the robot include an embedded computer Raspberry pi 4, Pi camera, robot frame (Fig. 4), Arduino uno R3, four motors, driver, crawler, and battery power.

Figure 4. Raspberry pi 4, pi camera (internet), and robot frame

3. RESULTS AND DISCUSSION

The training process consists of two parts: segmentation and classification.

3.1. Segmentation

At the segmentation phase, the model was trained with a learning rate of 0.001, the batch size is 8, the maximum number of epochs is 300, the number of classes is 1 for 1 leaf class, the optimization algorithm is RMSprop, the loss function is SmoothL1Loss with parameter beta = 1.0 (figure 5, 6).

$$L = \{l_1, ..., L_N\}^T \quad (1)$$

$$l_n = \begin{cases} 0.5(x_n - y_n)^2/beta, & if\ |x_n - y_n| < beta \\ |x_n - y_n| - 0.5 \cdot beta, & otherwise \end{cases} \qquad (2)$$

$$l(x, y) = mean(L) \qquad (3)$$

The model was trained on Google Colab with a virtual computer that has the following configuration Tesla T4 GPU 15 GB, 12 GB RAM, Intel (R) Xeon (R) CPU 2.20GHz.

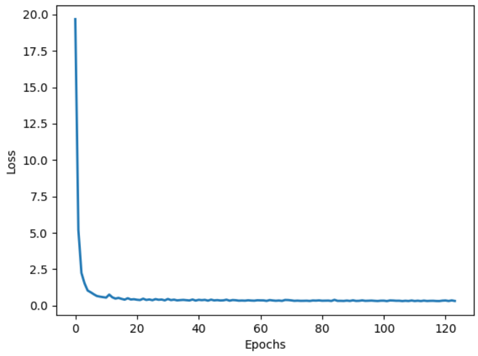


Figure 5. Segmentation training loss

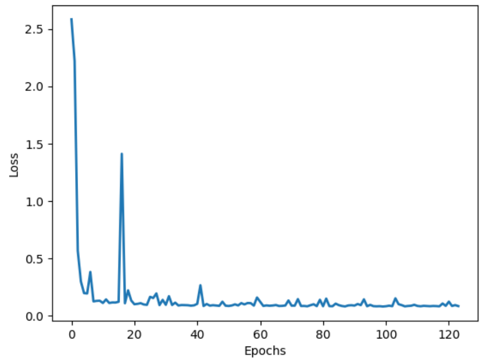


Figure 6. Segmentation validation loss

The metric for segmentation model in this paper is IoU (Intersection over Union) which is defined as:

$$IoU = \frac{TP}{(TP + FP + FN)} \qquad (4)$$

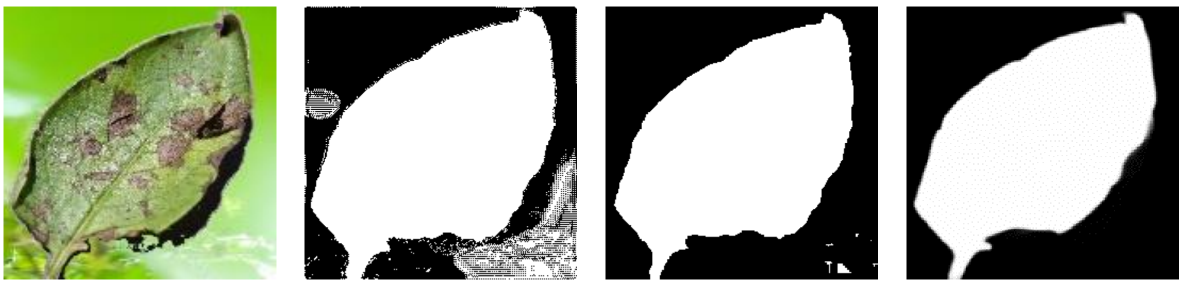
In which, TP, FP and FN represents for True Positive, False Positive and False Negative, respectively.

The IoU metric result after testing on test data (Table 2)

Table 2. IoU metric result of segmentation

	Late blight	Healthy	Early blight
IoU	0.91669	0.922017	0.929805

After the image is passed through the segment model, the result is still not very good because of residual small parts outside the actual leaf. Therefore, we use erode method in Opencv with kernel size equal 5 to filter out the unnecessary residuals. Result is shown in Fig. 7.



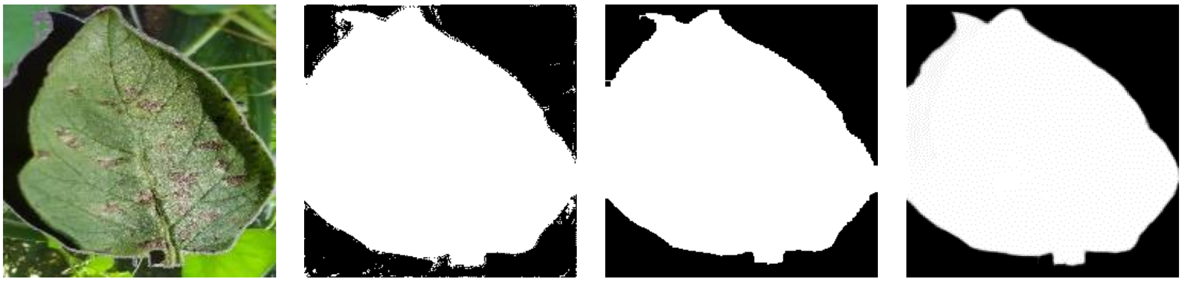


Image | Predicted | Predicted and erode | Ground Truth

Figure 7. Result of segmentation model

3.2. Classification

The image is resized to 256x256. The CNN model was trained with a learning rate of 0.001, batch size of 8 and the maximum number of epochs of 200. The number of classes is 3 corresponding to 3 states of leaves (late blight, early blight, healthy). The optimization algorithm is RMSprop. Lastly, the loss function is Cross Entropy Loss which is defined as follow:

$$Loss = -\frac{1}{output\_size}\sum_{i=1}^{output\_size} y_i.\log \hat{y}_i + (1-y_i).\log(1-\hat{y}_i) \qquad (5)$$

Similar to the segmentation phase, the classification model is trained on the Google Colab environment.

For the model to quickly converge, instead of training from scratch, I use the transfer learning method from the original vgg16 model that was learned through the ImageNet dataset. Replace the last number of classes of the model with 3 (corresponding to 3 leaf states). With that, I froze the convolution layers and update the weights only on the fully connected and classified layers. The basis for implementing this method is that the original model has learned to get good features from large datasets. Results of classification are illustrated in the below figures (Fig. 8, 9, 10, 11) and tables (Table 3, 4):

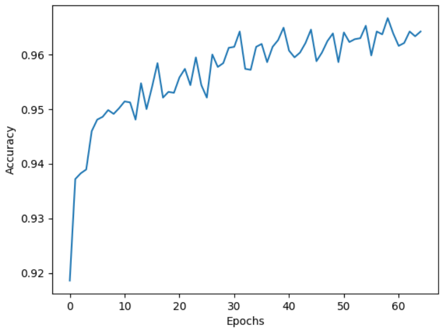


Figure 8. Classification training accuracy

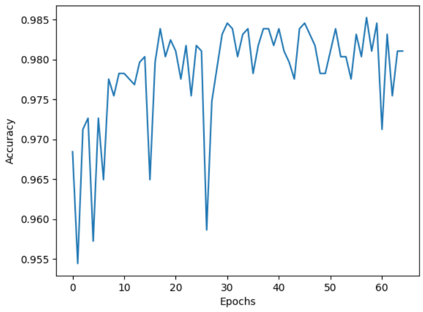


Figure 9. Classification validation accuracy

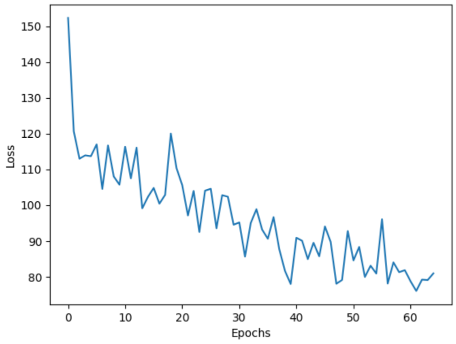


Figure 10. Classification training loss

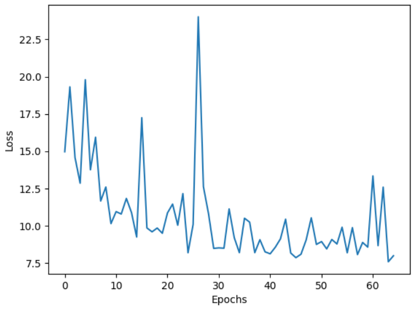


Figure 11. Classification validation loss

Table 3. Confusion matrix.

		Predict		
		Early blight	Late blight	Healthy
Real	Early blight	**206**	4	0
	Late blight	0	**205**	5
	Healthy	1	2	**207**

Table 4. Classification result.

	Early blight	Late blight	Healthy
Precision	**0.995**	0.9716	0.976
Recall	0.981	0.976	**0.986**

Finally, the classification accuracy on three classes of potato leaves is approximately **98.098** % on testing data. The final result (potato disease) is shown on the right side of the interface, in Fig. 12, this is *Early blight.*

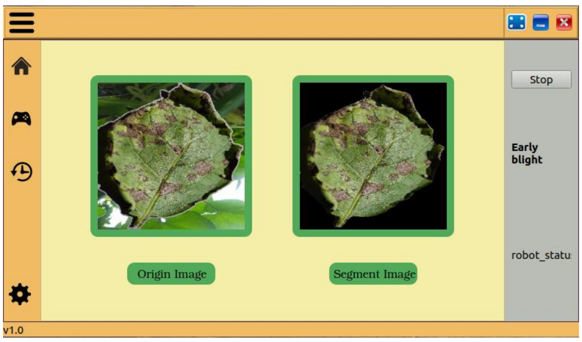


Figure 12: Display result on app

4. CONCLUSIONS

The results obtained from this experiment can assist farmers in controlling and detecting early wilt and late wilt of potatoes, helping to increase yield and quality of obtained potatoes. However, it still takes more time to deploy, evaluate and collect more data so that the model can learn many new features. The total time to infer one leaf is about five seconds: three seconds to send and receive an image from robot to Firebase and from Firebase to server, two seconds to predict leaf disease. The server has the following configuration: Intel(R) Core (TM) i3-8130U CPU 2.20GHz, 8GB RAM and no GPU. The final average IoU of the segment model is approximately 92.3%, and the accuracy is 98.098%. The accuracy achieved is greater than 90% partly because the photo of the potato leaves was taken under the same environmental conditions (light, humidity, temperature...). Accuracy may drop a bit when testing with different shooting conditions. This model can be applied to training with new disease datasets. In the future, we will test the proposed system with new large-scale potato leaf datasets and collect more results on the potato fields.

5. ACKNOWLEDGEMENT

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MODELING AN INTEGRATED HALAL ENTERPRISE RESOURCE PLANNING SYSTEM FOR TRACEABILITY OF THE FROZEN MEAT PRODUCT

Verry Surya Hendrawan[1, *)], Taufik Djatna[2)], Yandra Arkeman[2)] and Khaswar Syamsu[2)]

1) IPB University, Indonesia
ipbvshendrawan@apps.ipb.ac.id
2) IPB University, Indonesia
* Corresponding author

ABSTRACT: In the recent days, consumer concern about the integrity of the halal products grows rapidly along with consumer awareness of the importance of buying and consuming halal products. In Indonesia itself, where the majority of the population is Moslem, ensuring the halal status and thayyib level of a product is crucial. Frozen meat is a commodity that is prone to contamination and adulteration, so it has the potential to become non-halal during its product handling in the whole supply chain. Although it is mandatory for the frozen meat circulated in Indonesia to have halal certification, it is still important for consumers to know where the frozen meat they buy comes from, when was the cow is slaughtered, who was the Juleha (halal slaughtered person), where was it slaughtered, how was it transferred, how was it stored etc. An effective traceability system is needed to be able to let the consumers are fully aware of what happened to the frozen meat along the supply chain, especially to address the consumer concerns regarding the integrity of halal status and thayyib level of the food. This study aims to analyze and design an Integrated Halal Enterprise Resource Planning (ERP) information system that integrates all business processes, which include i.e.: raw material procurement, raw material receipt and storage in warehouses, manufacturing (production process), finish product storage in warehouses, and finally to deliver the product to the customers. This also includes the processing for the account payable and account receivable. All modules are developed in Odoo. The system modeling method used is UML (Unified Modeling Language) to describe the functional, logical, and physical architecture. The results showed that; (1) Halal ERP can store and process frozen meat halal information properly to ensure the traceability, and (2) UML method can provide modeling according to system requirements.

Keywords: *Halal, Thayyib, ERP, UML.*

1. INTRODUCTION

There are growing concerns about the integrity of Halal food and the traceability of products along the supply chain (Tan et al., 2022). Especially in Indonesia where the majority of the population is Muslim. Halal is an object, commodity, or activity that is permitted to be used, consumed, or carried out, per the Islamic religion. The opposite of halal is haram, which means prohibited from being used, consumed, or carried out. In comparison, *thayyib* means 'good,' which indicates the grading.

Frozen meat is one of the commodities that is prone to contamination, so it has the potential to become non-halal during handling in the supply chain. 40% of national beef consumption needs in Indonesia are satisfied through importing the frozen meat. The most significant volume of frozen meat imports came from Australia and Brazil, and a small portion from the United States. Those three countries have met the requirements of the international halal standard HAS23000 and the national halal product assurance standard BPJPH (Halal Product Assurance Organizing Agency). However, it is still crucial to ensure that imported frozen meat maintains its halal status and level of thayyib along the supply chain (Hijrah et al., 2021; Jannah & Al-Banna, 2021; Mazhar & Bajwa, 2018). The increasing public awareness drives an increasing demand for clarity of information regarding, for example; the origin of the cattle, when and at which TPH (animal slaughter place) they were slaughtered, juleha certificate (halal slaughter attendant), and others (Rashid et al., 2018; Rashid & Bojei, 2018; Zainuddin et al., 2020)

An effective traceability system is needed so that consumers know what happens to the frozen meat along the supply chain. To address consumers' concerns regarding food integrity, halal food businesses need to rethink their conventional supply chains and leverage new technologies (Rejeb et al., 2021).

With an ERP system, all business processes can be integrated to a single system. Not only for procurement process, but also another supply chain processes including production. By integrating these processes with the Halal concept applied, it can be considered as a guarantee of Halal integrity throughout the whole food supply chain processes (Zahra et al., 2019).

The number of studies that discuss ERP integration in halal traceability is still limited, most research does not discuss ERP as a whole, and only discusses part of the processes in ERP. The research that has been done by Vanany et al., (2019), which discusses halal internal traceability using ERP at the Chicken Meat Processing Company. According to Vanany et al., (2019), there are several halal tracing points within the Chicken Meat Processing Company that need attention, namely in the purchase process, receiving raw materials, storing raw materials, manufacturing processes, and storing finished products. Another research that has been done by(Fathi et al., 2019), only discussed halal ERP in the Sales module, then similar research was also carried out on the scope of the manufacturing ERP module (Khanfar et al., 2021).

2. MATERIALS AND METHODS

2.1. Research Framework

This research consists of two stages to achieve the research objectives. The first section is the analysis section which begins with a needs analysis to identify stakeholder needs and model business processes. The second stage is the development of an integrated ERP system design. At this stage, several sub-stages have their own design results. In the first sub-stage, we start by translating the results of the previous analysis into the functional/operational architecture of the system, the logical architecture and the next sub-stage is the development of the physical architecture using class diagrams.

2.2. Requirement Analysis

Requirements are descriptions of how a product/system behaves. There are several types of requirements classification, such as; user requirements, which are a high-level abstract of what users need, and system requirements, which means a detailed description of what the system is supposed to do (Soares et al., 2007). Needs analysis is the first stage needed in developing a system. In this study, a needs analysis was carried out based on previous research data on halal supply chain authentication and discussions with relevant stakeholders to obtain stakeholder needs. Stakeholder requirements are obtained by identifying the business processes that are usually carried out in the frozen meat supply chain.

System Requirements Analysis is illustrated with a system entity diagram that contains several important components that affect and form the system as a whole (Wasson, 2016). The system developed will contain acceptable and unacceptable inputs and outputs, along with stakeholders, roles, resources, internal and operational constraints, threats, and opportunities. This analysis will be input in the design process to get the expected system design.

2.3. System Design

The system design in this study developed a design with three system level designs to obtain a comprehensive design. These design levels complement each other and will be used as input in the next stage of system development (Pearce & Friedenthal, 2013). The design stages consist of functional architecture, logical architecture, and physical architecture.

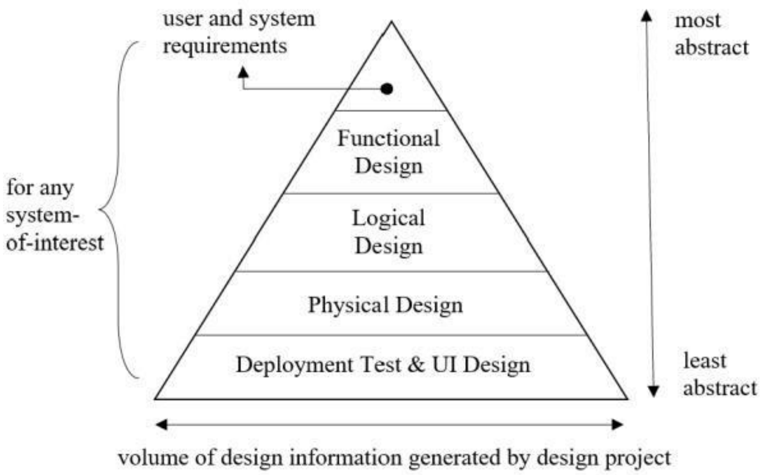


Figure 1. System design abstraction stage (Pearce & Friedenthal, 2013)

The functional architecture of the system is to describe the functionality and performance related to operational requirements. The functional architecture, which represents the problem space (what the system should do), is at the highest (abstract) hierarchical level, regardless of the technical solution (Fernandez & Hernandez, 2019).

Logical architecture is an intermediate abstraction between functional architecture and physical architecture. Logical architecture components represent abstractions of physical solutions. A component of a logical system thus defines functions, properties, and interfaces that are common to various physical design alternatives (Fernandez & Hernandez, 2019).

The physical architecture represents a specific technical solution. In the perspective of design development with technology-based systems, there are several focuses (stages) in the development of physical architecture, namely: (1) database design specifications, (2) software specifications, and (3) user interfaces (Whitten & Bentley, 2015).

3. RESULTS AND DISCUSSION

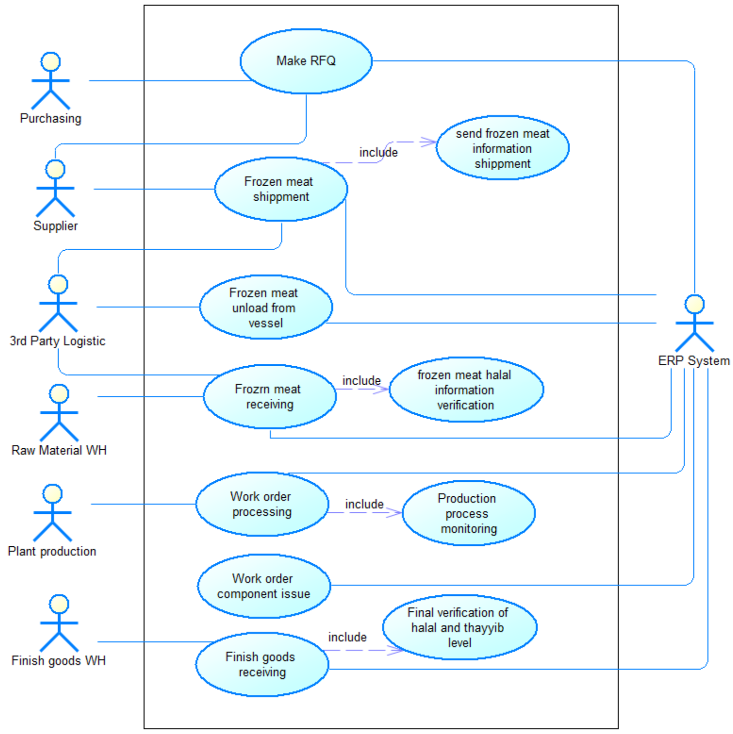
3.1. Requirement Analysis

The developed system aims to create an effective ERP system for traceability of halal frozen meat. The system requires acceptable input such as halal certificate number, origin of the meat, where it was slaughtered and what processes have been passed. Thus, users are able to access a detailed traceability information of frozen meat to ensure product halalness. Several stakeholders are involved in this system, starting from raw meat suppliers, transportation parties, and frozen meat processing factories. In this system, these three stakeholders play a role in the implementation of an effective traceability system. This technology provides an opportunity to provide a transparent ERP system to ensure traceability of frozen meat.

3.2. Design System Architecture

In the functional architecture, use case diagrams are used to explain the general functions that occur in the business process. The actors involved in the halal ERP system consist of frozen meat suppliers, transportation parties, and frozen meat processing factories.

Figure 1. Halal ERP use case diagram



In the use case diagram, it is described that there will be a mechanism where data will be integrated starting from the process from the frozen meat supplier to verifying the halalness of the frozen meat to the storage process in the finished product warehouse. With comprehensive data integration, it will facilitate the traceability process to ensure the halalness of frozen meat products.

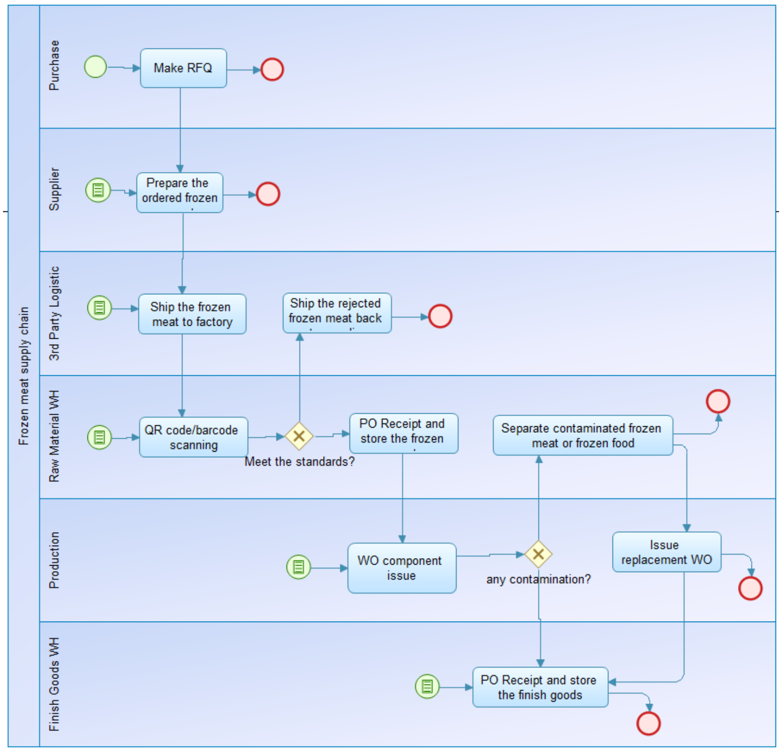


Figure 2. BPMN Diagram for ERP Halal

The following is the result of the BPMN diagram to describe the business process or logical architecture of a halal ERP system. In the BPMN diagram, the two gates serve as checkpoints for halal status and thayyib levels of frozen meat and frozen food. Suppose there is contamination or counterfeiting that changes the halal status. In this case, product separation and investigation is carried out to ensure the problem is properly isolated and resolved.

This BPMN diagram has six actors, ten tasks, and two gates. The six actors are purchasing, suppliers, 3PL (third party logistics), Warehouse of raw materials, Production, and Warehouse of finished goods.

The process will be initiated starting from preparing frozen meat for shipment, sending frozen meat to the factory, scanning barcodes or QR codes, up to Work Order Acceptance to receive Work Order according to quality standards in Finish Good Warehouse.

As for the two gateways consist as follows; (1) whether based on results; (1a) barcode and QR code scanning and (1b) random sample laboratory testing, so that frozen meat can be accepted at Raw Materials Warehouse, (2) based on the results (2a) barcode and QR code scanning, and (2b) sensor readings, and (2c) random sample laboratory test, then frozen food can be accepted at Finish Good War ehouse.

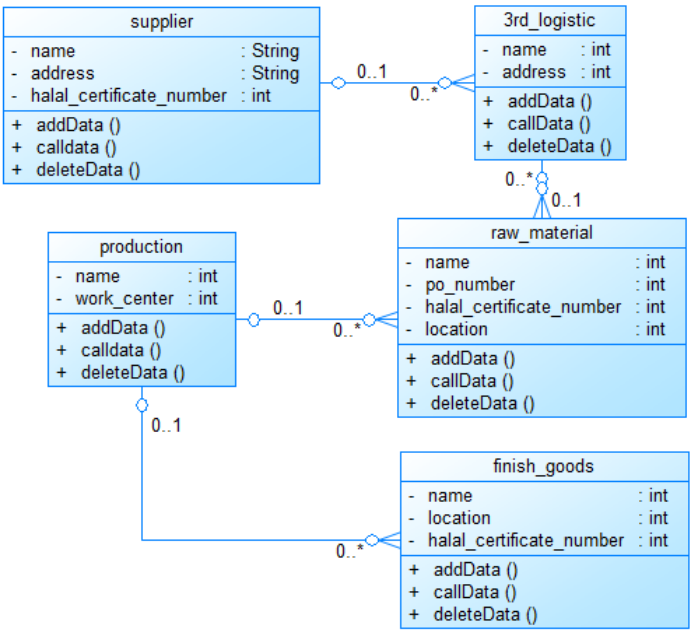


Figure 3. Class Diagram for ERP Halal

In the physical architecture, we use class diagrams to explain the database structure of the halal ERP system. Each class in the class diagram describes the tables in the ERP database. Based on the class diagram, we can see that in the raw_material and finish_goods classes there is a halal_certificate_number attribute, this attribute will later determine whether frozen meat products can be verified as halal or not by searching the data from the supplier to the data in the finish_goods class whether the data that appears is valid or not.

3.3. Report Tabulation

The integrated ERP system model that is built must be able to integrate all recorded data and produce standardized and customized reports, especially regarding the involvement of halal status and thayyib level at every critical point.

Table 1. List of reports generated by the ERP system, complete with the halal status and level of *thayyib* of frozen meat and frozen food products. Note: CR: Comprehensive Report, SR: Summary Report, ER: Exception Report, HR: History Report, PR: Predictive Report, PR: Predictive Report, STR: Status Report.

Reporting	Frequency	Reporting Type	Report User	Resource Report	Qualitative Data	Quantitative Data	Formula
1. PO Status Report	On demand	CR + HR + STR	Production Planning and Inventory Control (PPIC), Purchasing, WH, Accounting	Purchasing	Supplier Profile	Total PO qty., PO due date., Received PO., PO receipt date	Outstanding PO qty. = Total PO qty. - Received PO qty.
2. PO Receipt Report	On demand	SR + HR + STR	PPIC, Purchasing, Raw Material WH/ RM-WH, Accounting	Purchasing	Supplier ProfileRM-WH Profile	Total PO qty., PO due date., Received PO., PO receipt qty., PO Receipt date	Received PO qty. = Total PO qty. - Outstanding PO qty.
3. Halal Certificate Report	Daily	CR + HR + STR	All	RM-WH, Production, Finish Good WH/ FG-WH	Supplier Profile, Trucking Company Profile, RM Transit WH Profile, RM-WH Profile, Work Center Profile, FG-WH Profile	Contaminated PO, Trucking Contamination, Raw Material Contamination, WO Adulteration Finish Good Contamination	Certificate existence? Yes or No Adulteration existence? Yes or No
4. Raw Material WH Status Report	On demand	CR + STR	PPIC, Purchasing, RM-WH, Production	Raw Material WH	Supplier Profile, Trucking Company Profile, Raw Material Transit WH Profile RM-WH Profile, Work Center Profile	Total PO qty., PO due date., Received PO., PO receipt date Inventory Location Report	Raw material WH Inventory qty. = PO Receipt qty. – WO Component Issue qty.
5. WO Release	Daily	CR + HR + STR	PPIC, RM-WH, Production	PPIC	Work Center Profile	Standard Processing Time, Available Hour	WO Release qty. = Total outstanding WO qty. – Received WO qty.
6. WO Picklist	On demand	SR + STR	PPIC, RM-WH, Production	PPIC	Work Center Profile, RM-WH Profile	Standard Processing Time, Available Hour	WO Picklist qty. = BOM x WO Release qty.
7. WO Receipt	On demand	CR + HR + STR	Finish Good WH, Production, Customer Service (CS), Sales, Marketing	Finish Good WH	Work Center Profile, RM-WH Profile	Standard Processing Time, Available Hour	WO Receipt qty. = Total outstanding WO qty. – WO release qty.

8. Yield Report	On demand	SR + HR + STR	RM-WH, Production, FG-WH, Customer Service (CS), Sales, Marketing	RM-WH, Production, FG-WH	All	Supplier Profile, Trucking Company Profile, Raw Material Transit WH Profile Raw Material WH Profile, Work Center Profile, Finish Good WH Profile	Contaminated PO = Trucking Contamination + Raw Material WH Contamination Contaminated WO = WO Adulteration + WO Contamination Contaminated SO = Finish Good WH Contamination % of (Contamination = Contaminated PO + WO + SO qty.)/Total SO qty.

4. CONCLUSIONS

This research has analyzed and designed an integrated ERP-based halal traceability system, including; suppliers, procurement, transportation, warehouse and manufacturing, to check halal status and thayyib level. This study also succeeded in developing the proposed integrated ERP modeling architecture, which shows that; (1) ERP is able to manage the main functions for the integration of all recorded data, and (2) the UML method can provide modeling according to system requirements.

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DETECT OF VULVA SIZE BY AI TECHNOLOGY OF HEAT PERIOD IN SOW

Shen Chang Chang [1, *], Chia Ying Chang [2] Chao Wei Huang[3], Jenn Rong Yang[1] And Shao Yu Peng[4]

1) Livestock Research Institute, Council of Agriculture, Executive Yuan / Kaohsiung Animal Propagation Station, Taiwan.
2) National Pingtung University of Science and Technology/ Bachelor Program in Scientific Agriculture, Taiwan
3) National Pingtung University of Science and Technology/ Department of Tropical Agriculture and International Cooperation, Taiwan
4) National Pingtung University of Science and Technology/ Department of Animal Science, Taiwan
*Corresponding author: macawh@mail.tlri.gov.tw

ABSTRACT: This study was to investigate the changes in vulva size of sows before and after heat period in sow. It was understood those changes to develop the automated equipment and automatic warning system in the future in sow. The experiment used 26 crossbreed sows (LY and YL), including gilts and sows. The results showed that the length, width, and area of the vulva were having an increasing trend 4 days before and after heat. The system adopted an AI-based image processing technique to detect the vulva size of sows. The system used a one-stage object detector, the most representative models are YOLO. The equipment have RFID, camera, tag and large number of GPUs. The camera with 2.8 - 12 mm zoom lens is installed at 1.5 meters high from the ground, which is used to capture 0.8 m2 full size of the shed area. The results showed that the accuracy rates of the length and width of the vulva of sows after image recognition were more than 90%. The intelligent sow estrus monitoring system was established by the collection of basic data on the sow's heat behavior and the degree of swelling of the vulva, and then the image recognition system was used to measure the height and width of the sow's vulva. According to the heat behavior of the sows on the day of estrus was more frequent and the time is longer, it was judged when the sows entered the stable mating period and had the behavior of looking for boars. This system could increase the success rate of sow mating, reduce feeding costs, accurately know the optimal mating time and shorten days open of sows and thereby improving the production efficiency of pig farms.

Keywords: *Image recognition, Vulva, Heat, Sow.*

1. INTRODUCTION

There is a significant demand for the input of manpower in the pig farms of Taiwan; however, the entrance of young people into the industry has not been seen today. With a worsening situation of lack of manpower, mechanical and electronic equipment have been installed in the pig farms to reduce manpower and increase the accuracy of the observed values. Besides, incorporating intelligent technology and automation equipment represent the current trend in animal husbandry; by incorporating technology in farms, it not only increases the industrial output value but also permits the intelligent technology to be more in line with on-site farm work operations, introducing more breakthroughs and development with more possibilities in the discipline of feeling management. Whether or not sow mating has been successful poses a direct impact on the feeding cost and its economic efficiency. When the mating success rate is increased and the open days are reduced, the income can be increased and the feeding cost can be decreased, therefore, it is crucial to precisely know when is the best mating time (Tur, 2013).

Shen Chang Chang, macawh@mail.tlri.gov.tw

Sows are animals that are in estrus all year round and the period from estrus to mating represents a crucial stage. The sows' estrus cycle lasts from 16 to 25 days, with an average of 21 days, which may differ according to factors such as species. Sows will be in estrus approximately 3 to 10 days post weaning, with an average of 5 days. When sows are in estrus, their vulva will redden and swell, have a standing reflex, secrete mucus, their ears will prick and will be seeking boars, etc. (Signoret., 1970). When a certain concentration is reached by the blood follicle-stimulating hormone (FSH) and luteinizing hormone (LH) levels in sows, through the circulatory system, the ovarian estradiol (E_2) progesterone (P_4) secretion levels will be affected, which will then promote the development of ovarian follicles, that are later ruptured to release eggs (Williams, *et al*., 2017). Noguchi, *et al.* (2010) indicated that 2-3 days before ovulation, the blood E_2 concentration of sows will attain a peak. Whereas after ovulation, the blood P_4 concentration will increase gradually, with the blood E_2 concentration gradually decreasing. The swelling, reddening, and mucus secretion of the vulva of sows, are associated with ovarian E_2 production (Soede, *et al.*, 1998). Lee, *et al.* (2019) suggested that during estrus, the increase in ovarian E_2 secretion has caused an increase in the internal pudendal artery blood flow, which leads to the swelling and temperature increase of the vulva.

Before ovulation, there will be a large amount of ovarian E_2 secretion, which will cause swelling, reddening and mucus production of the vulva. Although there will be vulva swelling for sows during estrus, unswelling of the vulva and closed labia are signs to the naked eye that a sow is not in estrus, in addition, when one applies pressure to the sow's back or touch its genital, the sow will immediately run away. During estrus, the sow will display several conditions obviously, including a standing reflex, a pudendal closure that is not tight, darkening of labia, swelling of vulva and mucus discharge, etc. Professional pig farmers can tell if a sow is in estrus according to particular standards which are of higher accuracy; however, more manpower and time are required. After mating with the boar, the sperms will require to undergo the capacitation process, therefore, a suitable time for mating will be 12 hours before the ovulation of the sow. That being said, the estrus cycle also differs with the seasons, pig age and species. The swelling of the vulva and its temperature change is used to tell if a sow is in estrus. These indications are used to remind the breeding personnel of the sows' conditions so that they can tell as to the best time for the pigs to mate and thereby increase the mating success rate.

2. MATERIALS AND METHODS

2.1 Animal experimental design

This study used 26 crossbred sows (YL and LY crossbred sows), including gilts and sows, for collection of images of changes in vulva swelling for data analysis.

2.2 Image recognition system

We used the 1080P camera in our real time identification system. The identification system based on yolo v4, the input image size was 608 × 608, and all database had total 8496 images (4868 images with white pig and 3628 images with black pig). Training data used random selection 70% in each part of our database, and others was testing data. The ground truth had 4 class which was white pig vulua, with pig back, black pig vulva, and black pig back. The training parameters are set as follows: Epoch = 80, minibatch size = 4; learning rate = 0.001. We got the box loss = 0.1379, object loss = 0.0061, class loss: 0.002, and total loss = 0.114 when we used up the training after 152 hours on GPU 3080Ti. In the detection, the frame rate about 10 FPS on the same computer, then based on this real time identification system, we didn't use tracking algorithm.

This system is with regard to pig behavior and parturition detection. SSD (Single Shot MultiBox Detector) is primarily used in this system for image recognition of the pig's body and hips and the piglet behavior, for subsequent analysis of the parturition behavior. Throughout the image recognition process, the adjusted image is first inputted to the CNN layer for the acquisition of feature map, a series of different sizes of feature maps will then be created by SSD and each feature map will be drawn with several anchor points. Making each anchor point the center, a score is obtained through evaluation with different ratios and sizes of boxes. Next some of the most likely bounding boxes and scores indicating whether or not there are objects are obtained. Then through ROI pooling map the acquired coordinates to the series of feature maps and divide them into sections of equal quantity for max pooling, to obtain proposal feature maps of the same size and determine the pig part as the image recognition learning model.

3. RESULTS AND DISCUSSION

Soede, et al.(1994) indicated that sows will show signs of estrus 4 to 5 days post weaning. The period of estrus is 54 ± 15 hours. 3 ± 11 hours after estrus, the blood concentration of E_2 of sows will reach a peak. But the time from the blood E_2 concentration peak to LH peak is 11 ± 5 hours, and the time from the blood E_2 concentration peak to ovulation is 41 ± 4 hours. Noguchi, et al. (2010) indicated that 2-3 days before ovulation of sows, the blood E_2 concentration will reach a peak. After ovulation, the P_4 concentration will increase gradually, with the blood E_2 concentration gradually decreasing. The swelling, reddening and mucus secretion of the vulva of sows are associated with ovarian E_2 production (Soede, *et al.*, 1998). There is a significant difference in the length of the sows' vulva before and after estrus, the longest length is observed on the second day post estrus. There is a significant difference in the width of the sows' vulva before and after estrus, but no significant difference in the width of the vulva is observed after estrus. 2 days before estrus to estrus, the blood E_2 concentration of sows reaches a peak. Lee, et al. (2019) indicated that during estrus, the increase in the ovarian E_2 secretion has caused an increase in the internal pudendal artery blood flow, which led to the swelling and temperature increase of the vulva.

Therefore, this study utilizes the image recognition system to collect data on the vulva changes of sows before and after estrus and as verified, this recognition technology can be utilized to conduct measurement on the vulva of the sows; the accuracy rate for vulva length and width measurements are 93.8% and 92.4, respectively. The swelling on the vulva can be used as indicator to tell if a sow is in estrus, which helps in determining the best time for the pigs to mate and thereby increasing the mating sucessing rate.

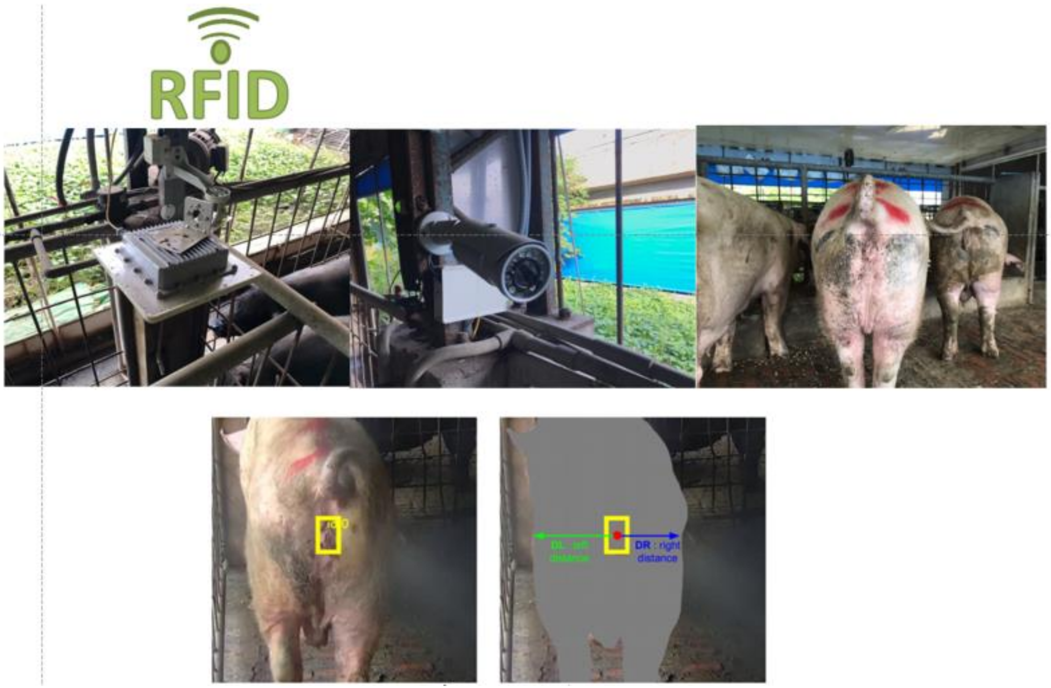

Figure 1. Equipment of image recognition system in sow pen.

4. CONCLUSIONS

Through this image recognition technology, measurements of vulva length and width have been conducted during pregnancy and the results have been verified to be 93.8% and 92.4% accurate, respectively. Through this technology, whether or not a sow is in estrus can be monitored, which can be referred to as the time to mate the pigs or not to increase the mating success rate.

5. ACKNOWLEDGEMENT

The authors would like to thank colleagues in the Kaohsiung Animal Propagation Station, COA-LRI in Taiwan, for managing the sow.

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DEVELOPMENT OF AN AUTOMATED CARE SYSTEM FOR MOTH ORCHIDS (PHALAENOPSIS SPP) IN GREENHOUSES

Chi Tran Nhu[1)], Toan Le Ngoc[1)], Phu Nguyen Dang[1)], Hien Le Thi[1)],
Bao Anh Hoang[1], Chieu Le Van[2)], and Van Nguyen Thi Thanh[1, *)]

1) VNU – University of Engineering and Technology, Vietnam
2) VNU – University of Science
trannhuchi@vnu.edu.vn

ABSTRACT: Phalaenopsis orchids are the popular commercial orchid and bring great economic value to farmers. However, most of them are now being cared manually based on human labor. In this paper, an automated care system was proposed to develop for phalaenopsis orchids based on the IoT platform. The system includes 4 main blocks: sensors, center processing, actuator and communication. The basic parameters of the environment, including air temperature and soil moisture are read and analyzed by a programmable logic controller (PLC) through the sensor block. Based on the pre-programmed control algorithm, PLC can control the peripheral devices in the actuator block to make a suitable environment for the growth of phalaenopsis orchids. Besides, a software interface on computer and a web interface on the server are also built to control and monitor remotely the system. The experimental results showed that the environmental parameters such as air temperature and soil moisture in the greenhouse were kept stable at the preset range even though the parameters outside the greenhouse were changed over time. The response time of the system for actions from users was quite short, less than 1 second for all control methods. The system was then experimented with some phalaenopsis orchids. The results showed that new roots started to appear after 15 days and the root length are 25 mm and 50 mm after 30 days and 45 days, respectively. More slowly, the new leaves appeared after 30 days and grew up to 30 mm in size after 45 days. The growth of plants is the same as that of manual care on the farms. With achieved results, the system proved its potential to replace the human for caring automatically phalaenopsis orchids but still ensure the growth of plants and bring many benefits to users.

Keywords: *Moth orchids (Phalaenopsis spp), automated care system, greenhouse, IoT platform.*

1. INTRODUCTION

Orchidaceae is a large family, with 20,000–30,000 species of orchids, specifically 600–800 genera and 25,000–35,000 species. Orchids are from a few millimeters and grams to several meters in size. They are soft, fragile and herbaceous or can be hard and almost petrified [1]. For about 100 years, growing orchids was considered as a hobby of the rich, but the introduction of Dendrobium Pompadour proved to be a step forward. The turning point also brought about the popularity of orchid farming in Thailand. In 1966, only a small amount of cut orchids were exported from Thailand to several European countries, but within a decade the country had achieved its status as the world's leading producer and exporter of orchids, which continues to hold its position as the world's main orchid exporter. In 2012, Thailand's total cultivated area was 7,420 acres with a yield of 2,403 kg/acre and export of cut flowers was $2.1 billion 63.6 billion to 148 countries and crop exports to 160 country (17.8 million USD). Also in 2012, an estimated 46% of orchid production was consumed domestically and 54% was exported [2].

In Vietnam, in recent years, phalaenopsis orchids have been consumed very strongly. According to the Taiwan Phalaenopsis Production Association (China), in 2018, Vietnam was one of the countries with the largest import turnover of Phalaenopsis orchids from Taiwan, after the US and Japan. the whole of the Netherlands. From 2014 to 2018, the number of Vietnamese phalaenopsis orchids imported from

Taiwan increased from more than 5.3 million USD to more than 16.6 million USD, equivalent to more than 382 billion VND. The highest growth rate in the world with 39%, higher than both Japan and the US. Not only importing flowers from Taiwan, Vietnam also imported more than 3.2 million plants from China, estimated to be worth more than 137.6 billion VND. In the North alone, in 2019, there were only about 27 businesses and farmers producing phalaenopsis, of which the most concentrated were Hanoi and Quang Ninh province, accounting for about 57% of the area with an output of about 3 million plants. Compared to the potential of the region, the above figure is still very modest. It is forecast that the consumption of Phalaenopsis orchids in Vietnam will increase sharply in the coming years. Meanwhile, the amount of domestically produced goods is still limited and has not kept up with the needs of the market. The production of phalaenopsis orchids still has many difficulties and limitations such as lack of copyright, lack of initiative in seedling sources, large investment capital, lack of information on domestic and foreign markets. Besides, the caring systems in Vietnam are still manual, the farm scale is not large. The caring stages are still significantly dependent on workers. This is a difficulty to scale up the farm.

Nowaday, “Internet of Things” (IoT) is a highly promising line of technology, capable of providing many solutions towards agricultural modernization [3]–[6]. Data from the sensors are read and transferred to the central processor. The data is then analyzed and indicates the necessary changes to the system, so that the human factor is minimized. In this article, an IoT system was proposed and developed to control and monitor environmental parameters in greenhouse. When there is a change beyond the stable level, the central processor PLC will automatically adjust the parameters through sensor and actuator system. The next section presents in details the materials and methods of the system. Experimental results and discussion are presented in section 3. Finally, conclusions are given in section 4 of the paper.

2. MATERIALS AND METHODS

2.1. Materials

The brain of the system was a Programmable Logic Controller (PLC S7-1200, Siemens, Germany). The air temperature sensor (PT100) with the temperature range from -5 to 170 degree, soil moisture sensor (SM2801M) with working humidity from 5 to 90%RH and LED growth light were purchased from Amazon. The heating lamp was a type of filament lamp form Rang Dong JSC (Vietnam). Pump, fans, profiled aluminum bars and mica sheets were purchased from a local electronic shop.

2.2. System Design

The proposed system was divided into 4 main blocks: sensors, controller, actuator and communication, as shown in Fig. 1. All were integrated inside a mini-greenhouse built using profiled aluminum bars and plexiglass for demostrating the working of the proposed system. Control block used a PLCS7-1200 to collect the environment parameters from the sensors. Based on the threshold values set by users, some peripheral devices were activated to make a suitable environment for the growth of moth orchids. The fan and heating lamp can adjust and maintain the temperature inside the mini-greenhouse within the allowable range. A mini-pump was used to supply water when soil moisture was lower than the designated level. Besides, a growth light and a fan were used to support the photosynthesis of plants. The growth lamp only had the wavelengths of 633 nm and 433 nm corresponding to the red and blue lights could stimulate plant growth, while a fan helps to exchange air between the inside and outside of the mini greenhouse. Besides, a graphical user interface and a web interface were built to control and monitor remotely the system. They were developed using Windows Control Center software (WinCC) from Siemens (Germany). In addition, the data was also saved on the database, so users can evaluate easily the performance of caring process.

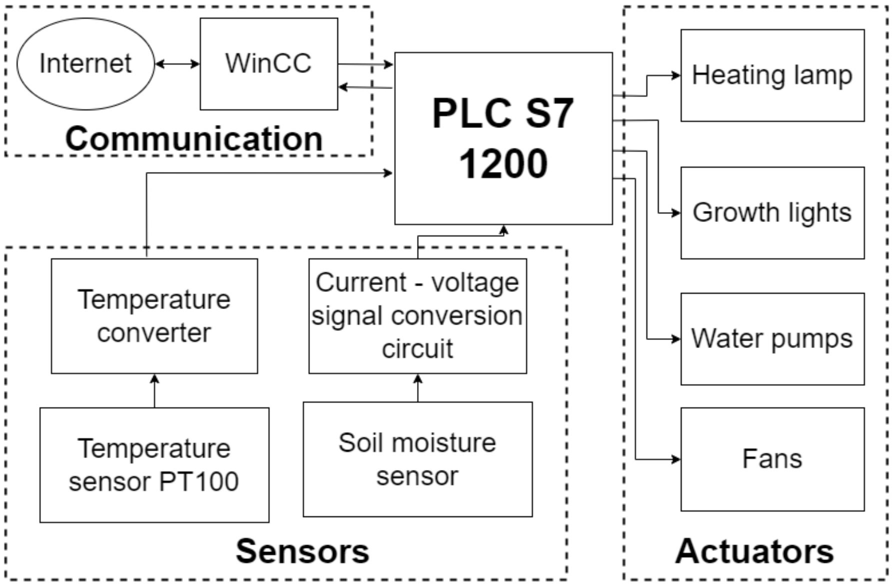
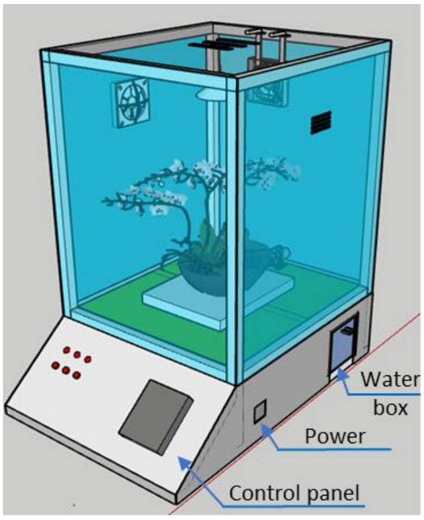


Figure 1. Block diagram of the proposed system

For the mini-greenhouse, it was designed by a computer aid design software (Solidworks 3D graphical software from, SOLIDWORKS Corp.), as show in Fig. 2 (a). The mini-greenhouse consisted of 2 main parts with the overall dimension of 650 mm x 420 mm x 670 mm. The bottom part with the dimension of 650 mm x 420 mm x 130 mm contains the entire control system as mentioned above, a power supply and a water box providing to the plants. The front of the frame was the control panel including the buttons and indicator lights for on-site control and monitoring purposes. The upper part of greenhouse was a large space for plant samples with the dimension of 520 mm x 420 mm x 540 mm. This part includes the sensors, peripheral devices and a tray of orchids in the middle of part. Both the parts were fabricated by profiled aluminum bars and mica sheets. The white mica sheets were used to protect the control system inside the bottom part, while the upper part was surrounded by transparent mica sheets to make it easier for users to observe the growth of plants from outside, as shown in Fig. 2 (b). Besides, the layer between two parts where places the tray was made by a green mica sheet with barriers at the surrounding edges to prevent water from overflowing to the control system inside the bottom part.



(a)

(b)

Figure. 2. System design. (a) The 3D design of proposed system on software; (b) The system after fabrication

2.3. Control Algorithm

There was a control algorithm developed and integrated into the industrial controller, PLC. There were two control modes: manual and automatic in the program. In manual mode, users can turn on/off directly peripheral devices through buttons on the control panel of system or on software interface. In automatic mode, the peripheral devices were controlled based on the values read from the sensors, as shown in Fig. 3. The heating lamp or fan was activated when the air temperature read from PT100 sensor was lower or higher permissible temperature range, while the pump was turned on when the soil moisture was lower the setting threshold. Besides, the growth was on during the day for 12 hours, from 6 AM to 6 PM for plant photosynthesis.

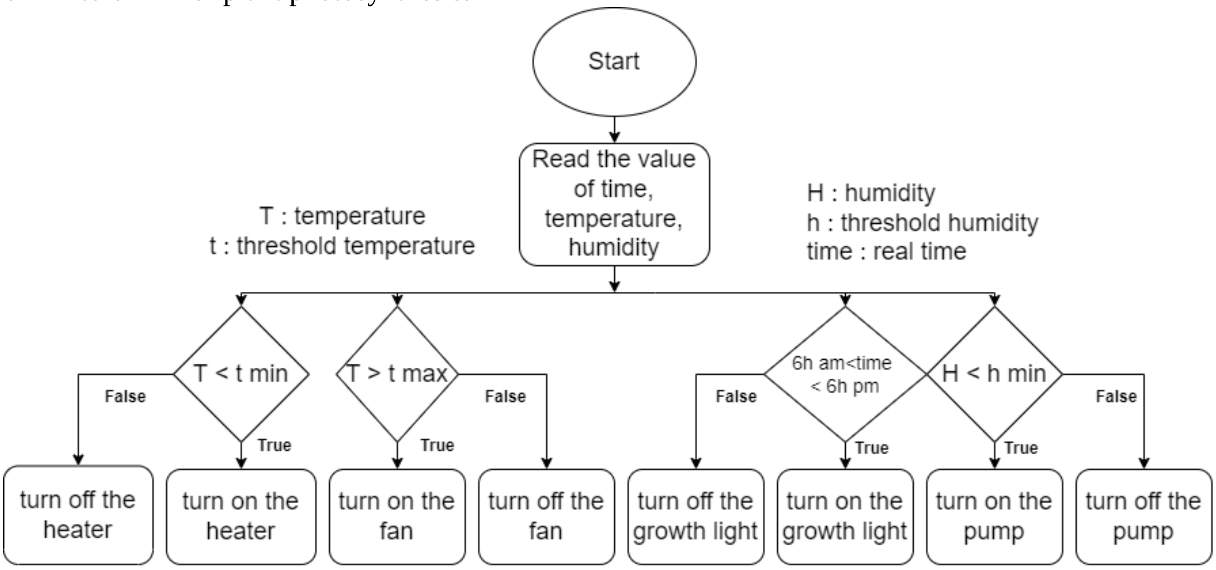


Figure. 3. Control algorithm

3. EXPERIMENTS AND RESULTS

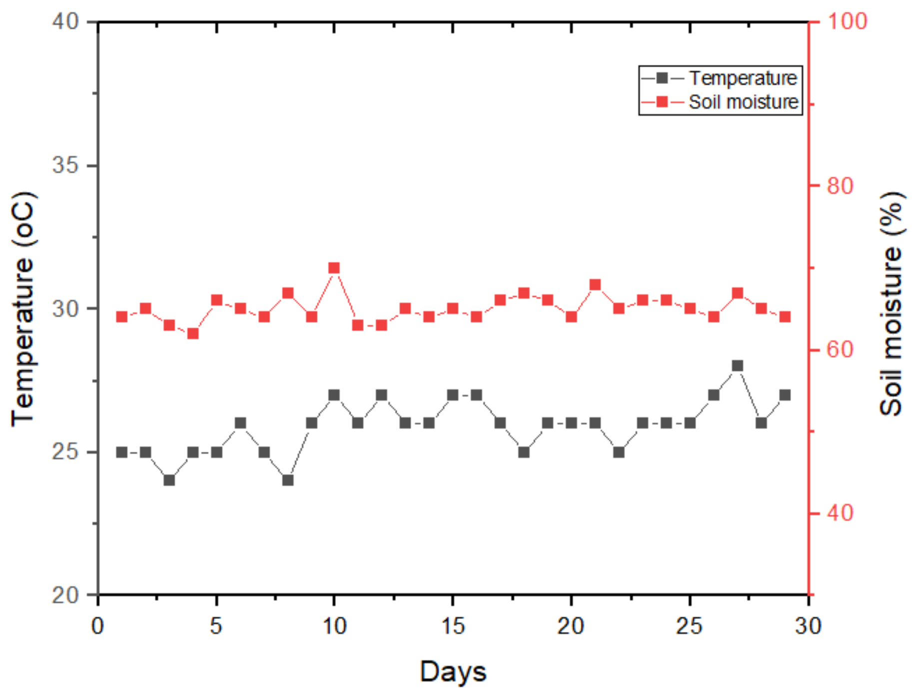
3.1. Experimental Setup

After being built, the mini-greenhouse was placed in the laboratory to evaluate the performance of the system. Firstly, the environment inside the greenhouse was investigated to evaluate the response of the system to the change of the external environment. After that, the system was experimented with some baby orchids (phalaenopsis spp) for 45 days to compare to with standard growth rate. There were some parameters setup in the system, including the temperature range from 25ºC to 27ºC, the soil moisture ranges from 62% to 72%. These parameters were suitable for the growth of orchid plants.

3.2. Response Investigation of System

Environmental parameters inside the greenhouse was investigated before the plants were grown. The results show that the temperature inside the greenhouse was quite stable in the setting range, from 25ºC to 27ºC even though the outside temperature changed significantly from 19ºC to 30ºC, as shown in Fig. 4. It is clear that the fan or heating lamp were activated when the temperature inside the greenhouse increased or decreased beyond the allowable thresholds. The results also proved the system's ability to maintain the desired temperature in the greenhouse suitable to orchid plants. Similarly, the soil moisture was also investigated to evaluate the response of pump. The result shows that the soil moisture was controlled at setting range from 62% to 70%, as shown in Fig. 4.

Figure. 4. Environment parameters inside the greenhouse: Air temperature and soil moisture



Besides, the response time of the system for different forms of stimulation was also evaluated, as shown in Table 1. The results indicate that the response time was the fastest (almost immediately) when users pressed a button to turn on/off one of peripheral devices, while the response time through Wi-Fi wireless communication was the slowest, with the average response time of 1 second. The experiments for different methods were performed 10 times and averaged.

Table 1. The response time of the system for different control methods

Control methods	**Response time**
Control panel	immediately
Software interface on PC with wire communication	0.483 s
Software interface on PC with wireless communication	1 s
Web interface with wireless communication	0.67 s

3.3. The growth of orchid inside the greenhouse

There were 6 baby orchid plants added into the greenhouse to monitor the growth of them for 45 days. The results show that the plants grew well in the environment condition of the greenhouse, as shown in Fig. 5. After 15 days, the new roots start to appear. They were 25 mm and 50 mm in length after 30 days and 45 days, respectively. More slowly, the new leaves were only appeared after 30 days and have the length of 30 mm for the next 15 days. This growth rate is similar to the plants that are cared manually in farmers.

(a)

(b)

(c)

Figure. 5. The growth of orchild plants in the proposed system. (a) The original plants. (b) After 30 days. (c) After 45 days.

4. CONCLUSIONS

This report presented an automated care system for moth orchids (phalaenopsis spp) in greenhouses using the IoT platform. The system included 4 main blocks and integrated inside a mini-greenhouse built based on profiled aluminum bars and mica sheets. The experimental results showed that the proposed system could make a suitable environment for the growth of orchid plants. The response time of the system was quite fast for different control methods. The orchid plants experimented inside the system showed the great growth with the appearance of new leaves and roots after 15 days and 30 days, respectively. After 45 days, the length of new roots increased to 50 mm while the length of new leaves rose by 30 mm. The achieved results proved the potential of the proposed system in caring automatically moth orchids, enhancing productivity and reducing production costs, so it can bring many economic benefits to users. In addition, by using industrial controllers and sensors, it is easy to apply the proposed system to big farmer in the future.

5. ACKNOWLEDGEMENT

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DEVELOPMENT OF AN IOT SYSTEM FOR AUTOMATED HYDROPONIC SPINACH (*Spinacia Oleracea*) GROWING

Chi Tran Nhu[1)], Phu Nguyen Dang[1)], Chung Tuong Duy[1)], Hien Le Thi[1)], Khanh Nguyen Le[1)], Tung Bui Thanh[1)] and Van Nguyen Thi Thanh[1, *)]

1) VNU – University of Engineering and Technology, Vietnam
trannhuchi@vnu.edu.vn

ABSTRACT: In this report, an automated hydroponic spinach growing system was proposed and developed based on the IoT platform. The system consists of three main blocks: sensors, control and communication. The hydroponic growing medium data (i.e EC and pH) from sensors is read and processed by an embedded system before being transferred to a center controller through Modbus TCP industrial communication. Data and the status of the system are stored automatically on a server via internet communication. They can be observed and controlled remotely through a software interface on PC or smartphones. A program for controlling of growing medium for three development stages of spinach (microgreens, baby and adult leaves) has built. Experimental results with spinach plants showed that the parameters of root length, the number of leaves, leaf and stem length for the plant group automatically cared by the proposed system (testing plant group) increased significantly in comparison to the plant group cared manually (control plant group) after a week in the same conditions of air environment and light. For the testing plant group, root length, the number of leaves and leaf length rose by 102%, 11 and 33%, while the figures for the control plant group were only 49%, 10, and 26%. In addition, there were much more new roots appeared in the testing plant group than in the control plant group after that time. This indicates that the proposed system can shorten considerably the harvest time of the plant and bring great economic value to farmers.

Keywords: *IoT system, spinach, hydroponic growing medium.*

1. INTRODUCTION

Nowadays, agricultural lands are already declining in Vietnam and many countries in the world. This happens due to the conversion of agricultural land into industry and settlement purposes. There are several root causes of this conversion, including economic and social phenomena, the limitation of land resources, population growth, and economic growth [1]. In urban areas, agricultural technology has developed rapidly and often called urban farming or urban agriculture. Urban farming/urban agriculture is one powerful solution to deal with the dwindling agricultural land. Urban agriculture uses the unused or empty land in urban areas, such as rooftops, balconies, terraces, or even on the walls of buildings to to cultivate agriculture. One of the farming techniques commonly used in urban farming is hydroponics. Hydroponic cultivation is planted by utilizing water and do not use soil as medium of its planting with emphasis on the needs fulfilment of nutrients for the plants. Hydroponics is derived from Greece, in which "hydro" means water and "ponous" means work [2]. The hydroponics technique can overcome the problems of agricultural land area in urban areas. Hanna Norén *et al.* compared the quality and performance of new integration modeling systems to conventional soil-based farming for Arabidopsis thaliana [3]. Results showed that hydroponics produces greater yields than soil-based farming. In particular, the number of leaves and stem length are both roughly 2 times as long, while the leaf biomass is around 5 times larger.

In a hydroponic farming system, the water will be used continuously and just diminish because of evaporation by the sun or by the photosynthesis process of plants. Therefore, the system needs to be supplied water continuously to ensure the growth of plants. Besides, the hydroponic systems also require particular care in controlling water temperature, water level, acidity (pH) of the nutrient solution, and higher densities of nutrient solution [4]. However, the control process still uses in the manual methods and depends on human labor. For instance, farmers or owners of hydroponic farming systems have to spend a lot of time to adjust the density level of the nutrient solution, which is done at least once a day. If the density of nutrients is too high or too low, they will add water or nutrients into the system. This is a big inconvenience for caring plants in a large scale. It can increase production costs and reduce crop yield. To solve this problem, research groups are applying technology to agriculture to develop the field of smart agriculture [5], [6]. One of them is Internet of Things (IoT) system, a cutting-edge technology movement that links and communicates electronic instruments and tools with one another over the Internet, including computers, cell phones, cars, refrigerators, televisions, and so forth [7].

In this paper, we propose to develop an IoT system for growing automatically hydroponic spinach, a popular vegetable in Vietnam with a good source of vitamin C, calcium, iron, phosphorus, salt, and potassium as well as beta carotene (pro vitamin A) [8]. The proposed system can control the temperature, relative humidity, pH level, the inflow and outflow of water and the amount of nutrient solution in a hydroponics system. The experimental results with some real spinach plants proved the potential of the system in growing automatically plants and opens up applicability in large farms.

2. MATERIALS AND METHODS

2.1. Materials and Components

Programmable Logic Controller (PLC) was a type of S7 1200 series with CPU 1214C DC/DC/DC (Siemens, Germany). An embedded system based on Arduino UNO KIT and Ethernet Shield W5100 was utilized for data acquisition purpose. SHT20 temperature and humidity sensor (DFROBOT), pH sensor (Analog Meter Pro Kit V2, DRFROBOT) and EC sensor (EC DFRobot Gravity) were all purchased from Amazon. Also, some common materials and components were purchased from local chemical and electronic shops.

2.2. System Design

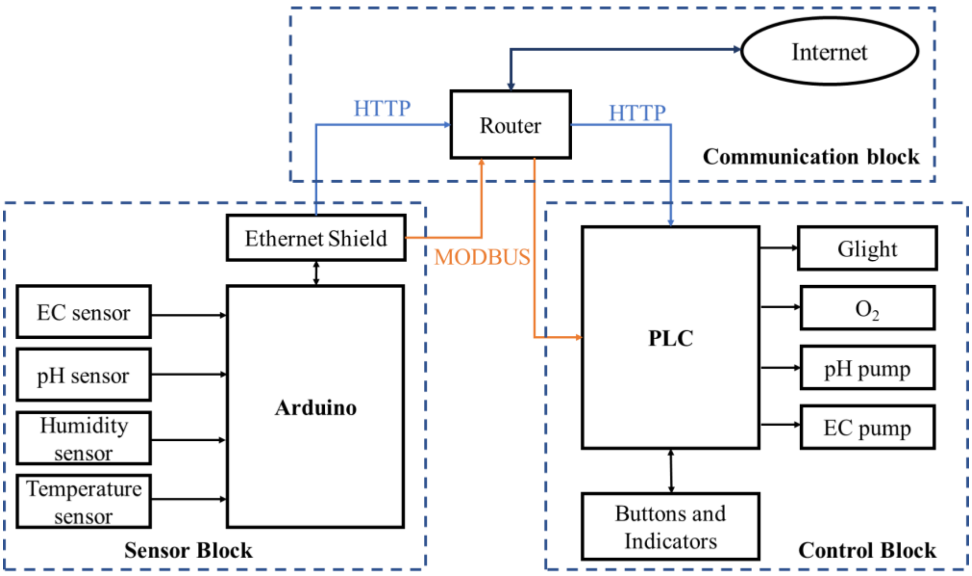


Figure 1. Block diagram of the proposed system

The system are divided into three main blocks: sensor, control and communication, as shown in Fig.1. In the sensor block, there were four types of sensors used in the system to read the data from environments. pH sensor and electrical conductivity (EC) sensor were used to monitor the nutritional parameters in the liquid, while humidity and temperature sensors were employed to check the air environment in the environment space. The data from the sensors were read and saved by Arduino UNO R3 KIT before being transferred to the control block and the internet through Ethernet Shield and Modbus communication. In the control block, PLC S7 1200 was the central controller, it could control peripheral devices such as pumps and growth light (Glight) based on the read parameters from sensors or from the controlling signal. Besides, peripheral devices can also be controlled directly by a panel contained buttons outside the system. Finally, the communication block contains a Wi-Fi router connected to the internet. This router read the data from the sensor block as well as the status of the system from the control block and transfer them to the server for remote monitoring. Besides, the router played a role as the mediator to connect between the sensor block and the control block through Modbus TCP protocol.

2.3. Control algorithm

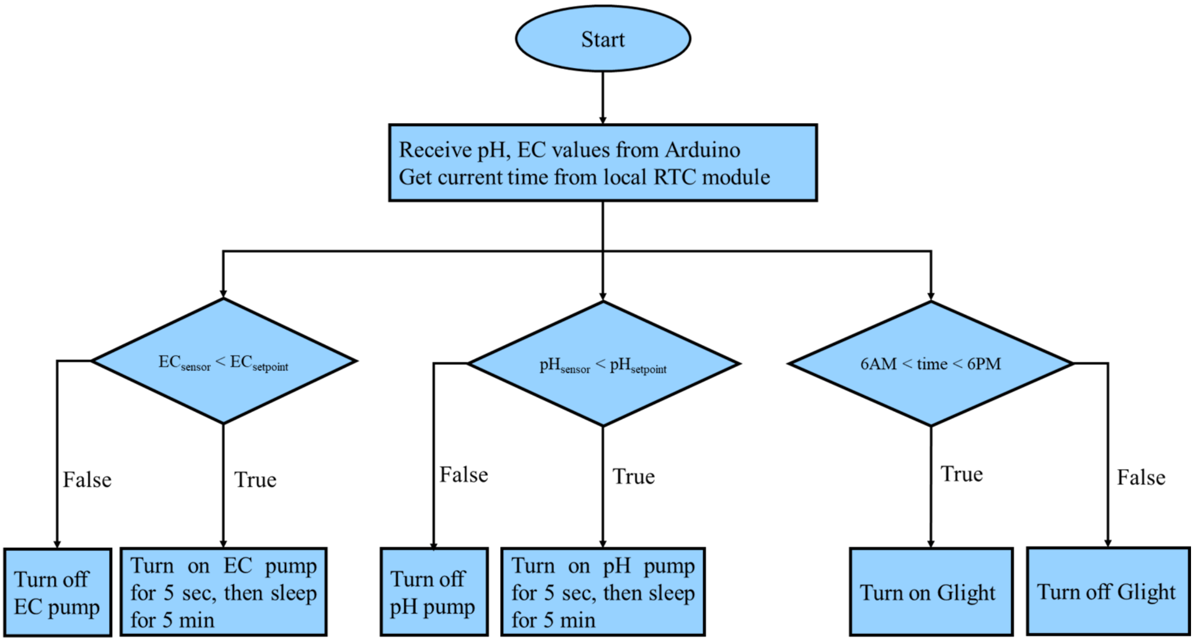


Figure 2. The control algorithm of proposed system

In the system, the sensor block can be regarded as an IoT node. This node was in charge of reading the data from sensors and then transferred to the central controller through Modbus TCP communication, a variant of the MODBUS family of simple, vendor-neutral communication protocols intended for supervision and control of automation equipment. Using Modbus in this system brings many advantages of accuracy, reliability, transmission distance and scalability. There are two operation modes established in the system: manual and automatic. In the manual mode, users can control directly peripheral devices through a control panel outside the system or graphical user interface on web page. The status of the devices was exhibited through LED indicators. For the automatic mode, peripheral devices were controlled based on the environmental parameters read from the sensors to make the suitable environment for spinach plant care. The control algorithm for automatic mode was depicted in Fig. 2. Firstly, PLC read the data of environment parameters from IoT node and current time. Following this, these parameters were compared to the threshold values of pH and EC in the memory. When the real parameters from the sensors were less than the threshold values, this means there is a lack of nutrients in the solution provided to plants. So, the pump system would be activated for 5 second to add nutrients into the system. The pump time of 5 seconds for nutrient was optimal time investigated before to make sure that the parameters were at the suitable range. Because it takes time for the nutrients to diffuse into the entire solution, so if continuous pumping and measuring can make the parameters go out of the appropriate range and affect spinach growth. To increase the diffusion rate of the nutrients in the solution, an aquarium air pump was used. Other than that purpose, it also provide more oxygen for plant roots to breathe and prevent root rot and death. In addition, the grow light was on for 12 hours, from 6h am to 18h pm, providing artificial light source for plant photosynthesis.

3. EXPERIMENTS AND RESULTS

3.1. Experimental setup

The proposed system was integrated in a mini greenhouse constructed of aluminum profile and mica sheets, as shown in Fig. 3. The below part of greenhouse with the size of 650 mm x 400 mm x 131 mm contained the control system mentioned above, while the upper part with the size of 540 mm x400 x 520 mm consisted of a hydroponic tank with spinach plants, sensor probes and the pipelines from pumps and the growth light. There were two hydroponic tanks placed inside the system, a tank for automatic care mode with the proposed system and a control tank for manual care mode with the sampling cycle of 3-days on time using portable measuring devices. Placing both tanks inside the system aim for making sure the same conditions of air temperature, humidity and the light for two care modes. This is important to evaluate properly the performance of the propose system. Each tank was placed four small spinaches with similar age. These spinaches were selected from a seedling nursery with good conditions such as pest-free, hardy. Besides, water level and nutritional contents (pH and EC parameters) in both tanks were the same before plants were cultivated. Moreover, an IP camera from Hikvision was also used to observe remotely the growth of plants during the experiment.

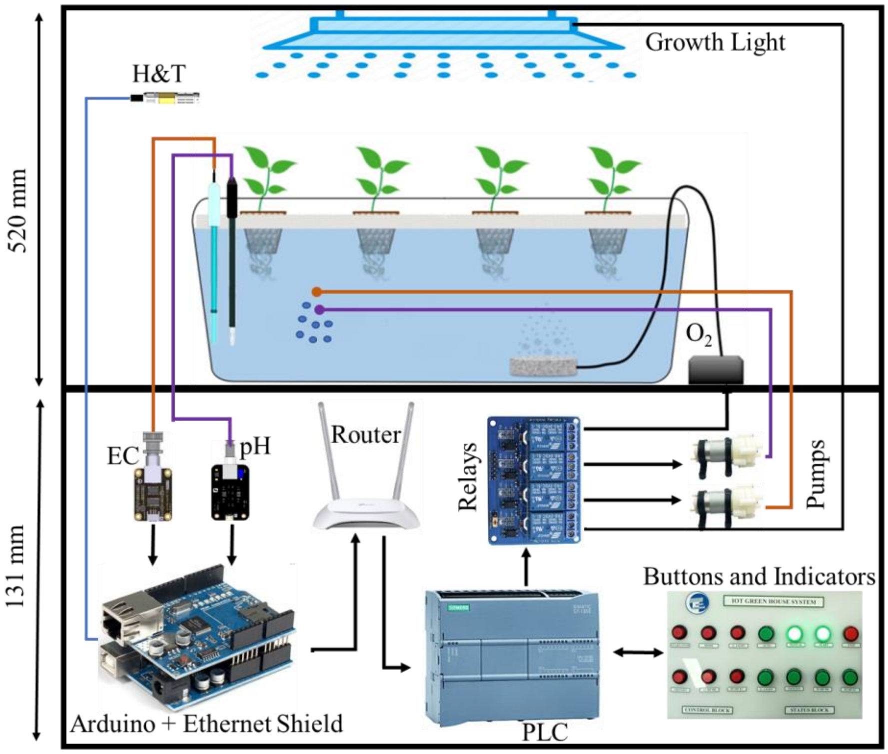


Figure 3. Experimental setup

3.2. Sensor calibration

PH and EC sensors play an important role in the system because the returned results from them are the two key parameters to evaluate the nutritional content in the liquid. However, since the probes of the sensors were always placed in the liquid and in direct contact with the liquid in the tanks, they can be surface denatured after a certain time leading to the error in measuring results. Therefore, it is necessary to recalibrate the sensors periodically after a period of use. To enhance the accuracy, quadratic Lagrange interpolation polynomial was used in the calibration process of both sensors, as described in Eqs.1 and 2. Besides, a portable multifunctional device (Oakton PCTSTestr™ 50) was also employed to assist in the construction of the calibration curve. For pH sensor, there were three the solutions with pH values of 4, 7 and 10 used to determine the fixed points on the graph. Following this, the calibration curve was built through Lagrange interpolation polynomial, as shown in Fig. 4 (a). It is easy to determine pH value based on the ADC value read from the sensor. Similarly, the calibration line for EC sensor was also built using three solutions with EC values of 406, 705 and 1006 µS/cm, combined to Lagrange interpolation polynomial, as shown in Fig. 4 (b).

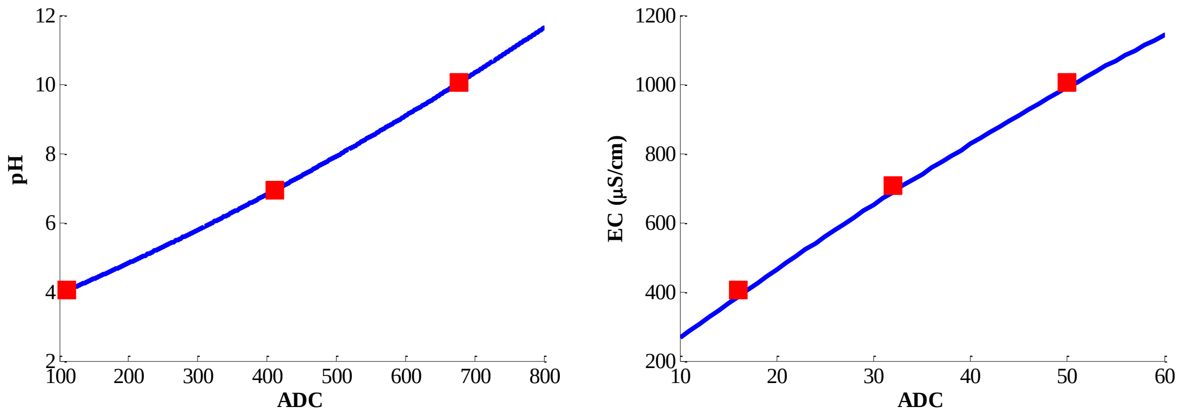
Lagrange interpolation polynomial:

$$L_n(x) = \sum_{k=0}^{n} p_n^{(k)}(x) y_k \quad (1)$$

with

$$p_n^{(k)}(x) = \frac{\prod_{i=0, i \neq k}^{n} (x - x_i)}{\prod_{i=0, i \neq k}^{n} (x_k - x_i)} \quad (2)$$

Where $L_n(x)$ the target expression, n is the order of polynomial, in this case it is set to 2, x is ADC value read from the sensors and y_k is pH or EC value of calibration sample corresponding to ADC value x_i.



(a) (b)

Figure 4. Calibration lines for pH sensor (a) and EC sensor (b) based on Lagrange interpolation polynomial.

3.3. Investigation of the proposed system for spinach

As mentioned above, a group of four baby spinaches were grown in the tank under automatic mode (testing group) and another group was grown in the tank under manual mode (reference group). They were taken care for seven days before being taken out to compare the growth, as shown in Fig. 5. It is clear that spinaches grew rapidly and their morphology changed significantly in size, number of leaves, leaf length and root length.

For the total number of leaves, both groups of plants show the increase in the number of leaves, as detailed in Table. 1. On average, there were eleven new leaves formed in the testing group, whereas the figure for the reference group was ten. Besides, the leaf length was also evaluated. The results show that the leaf length increased around 33% in the testing group, while the leaf length of the manual care plants only rose about 26% after seven days (Table. 1). Overall, the number and quality of leaves in testing group were better than reference group after they were taken care for seven days.

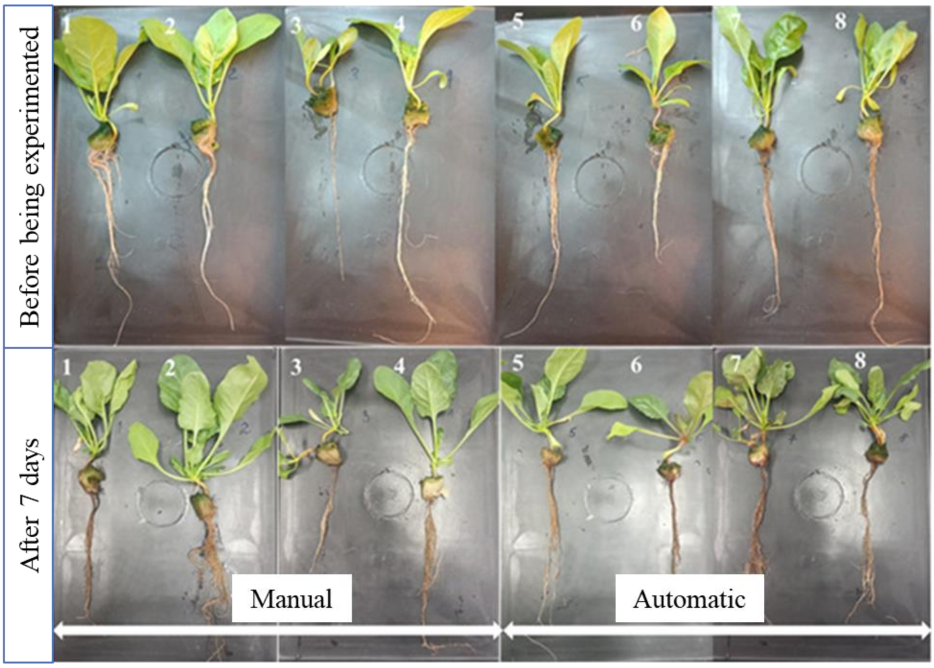


Figure 5. The growth of plants after 7 days

Table 1. The average increase of some parameters on the two plant groups

Parameters	Automatic group	Manual group
Total number of new leaves	11	10
Leaf length	31%	26%
Root length	102%	49%
New roots	Yes	No

For root morphology, the results show that the increase percentage of root length in testing group was twice as high as that of reference group (Fig. 6 (a) and Table 1). In addition, many new roots appeared clearly in the testing group while it is less in the reference group after seven days, as show in Fig. 6 (b).

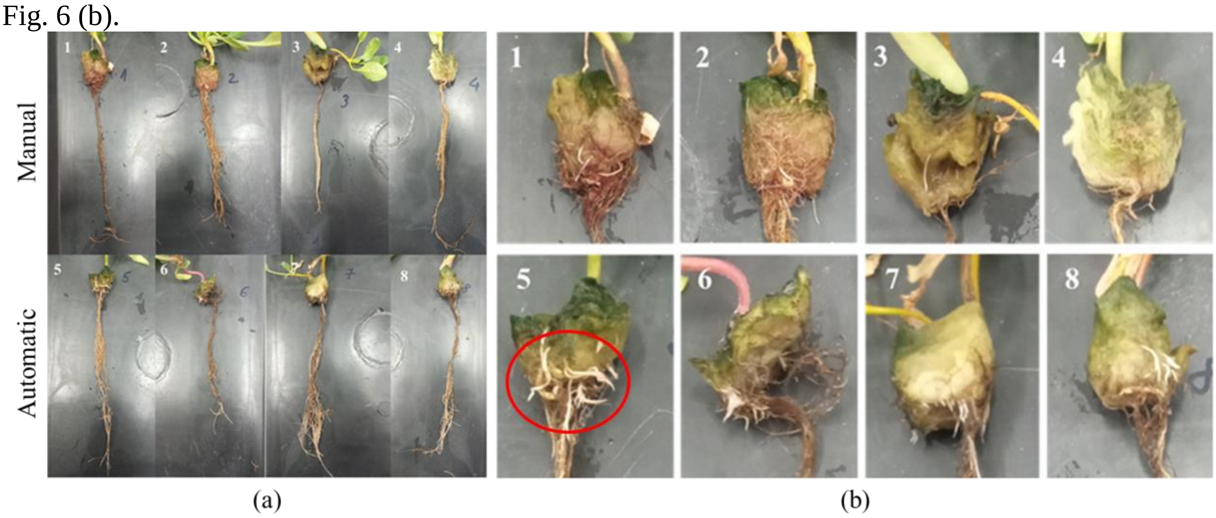


Figure 6. The changes of root morphology in two plant groups after 7 days. (a) The length of roots; (b) the appearance of new roots.

Similar results were also observed in two plant groups after 30 days (harvest), as shown in Fig. 7. In brief, the obtained results confirmed that the spinach group taken care automatically grew better than the manual care group. Because the proposed system always ensured a suitable environment for the growth of spinaches.

Figure 7. Plant morphology after 30 days

4. CONCLUSIONS

This paper presented the development of an IoT system for automated hydroponic spinach (Spinacia oleracea) growing. The parameters of hydroponic and air environment were read and analyzed by an Arduino UNO KIT through sensors before being transferred to the controller using Modbus industrial communication. Based on read data, the controller activated peripheral device to make the suitable environment for the growth of plants. Besides, Lagrange interpolation polynomial was also applied to enhance the accuracy of calibration process. Experiments were conducted for two spinach plant groups, including the testing plant group and the control group. The results showed that the parameters of the number of new leaves, leaf length and root length in the testing plant group were higher significantly than those in the control plant group after 7 days. Especially, the new roots in the testing plant group were appeared more early than the control plant group. Similar results were confirmed after 30 days or at adult stage. With achieved results, the proposed system proved the great performance in caring spinach plants and also show its potential to apply to large farms in the future.

5. ACKNOWLEDGEMENT

This work has been supported by VNU University of Engineering and Technology under project number CN21.17.

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DRAGON FRUIT DETECTION AND COUNTING USING CONVOLUTIONAL NEURAL NETWORK

Truong-Son Nguyen[1)], Minh-Trien Pham[1)] and Cong-Hoang Quach[1,*)]

1) VNU University of Engineering and Technology, 144 Xuan Thuy, Cau Giay, Hanoi, Vietnam

* Corresponding author
quachconghoang89@gmail.com

ABSTRACT: Dragon fruit is among the tropical fruits contributing relatively high export value to Vietnam. However, beside Vietnam, many other countries have invested in expanding the production of this fruit. This means Vietnam needs to take essential measures to improve the production process and ensure quality control for this fruit. As a result, this study has put forth the application of mobile system for detection and counting dragon fruit to address the yield estimation challenge. The proposed system could be integrated into an unmanned aerial vehicle or mobile robot. RGB-D images and Global Positioning System (GPS) data - inputs of the system are collected by stereo camera and the GPS device respectively. Initially, RGB images are fed to a convolutional neural network (CNN) model for detecting fruits. Then, the obtained fruits are tracked and counted across frames, using the Hungarian algorithm and the Kanade-Lucas-Tomasi feature tracker. At the same time, the fruit's relative position is estimated using fusion data from RGB images, depth images, and GPS. The outputs of proposed system are the number of fruits and their 3D positions in scanned areas. The developed structure was deployed and optimized for embedded device, using a custom dataset of 12,000 dragon fruit images and TensorRT frames. The accuracy of optimized model was evaluated by comparing with ground-truth human-annotated visual counts. The results show that at 30 fps, the experimental system achieves high efficiencies of 91.1% accuracy in fruit detection and 90% accuracy in fruit counting.

Keywords: *Dragon fruit, Convolutional Neural Network, TensorRT, Hungarian algorithm.*

1. INTRODUCTION

Dragon fruit, also known as *pitaya*, is the fruit of several different species of tropical climbing plants of the genus *Hylocereus*, family *Cactaceae*. Although *pitaya* is native to the tropical regions of North, Central, and South America, it is now grown worldwide for commercial value. Moreover, dragon fruit does not require cultivation, has high drought tolerance, is easy to adapt to light intensity and high temperatures, tolerates many different soil salinities, and is beneficial to human health [1], [2], [3]. Dragon fruit is widely grown in more than 20 tropical and subtropical countries, such as the Bahamas, Bermuda, Indonesia... and Vietnam. This fruit has become the most profitable crop for Vietnamese farmers. Vietnam has the largest dragon fruit growing area in Asia and it is grown in 63/65 provinces of the country, mainly two species of dragon fruit, *Hylocereus undatus* (white flesh) and *H. polyrhizus* (red flesh) [5]. Vietnam is the main exporter of dragon fruit worldwide due to high global demand. However, the cultivation of dragon fruit in Vietnam is still backward and has not met the quality requirements for fastidious markets such as Europe.

In recent years, the application of advanced technologies in agriculture has gain significant attention, opening a new development direction for agriculture, namely precision agriculture. Typical among them is the problem of estimating crop yields in precision agriculture. One of the most interesting problems is estimating the yield of crops, especially in the task of detecting and counting the number of fruits. In addition, the trend of building agricultural applications using remote sensing is increasingly popular because of labor saving and high flexibility. Therefore, in this paper, we propose a mobile system that allows us to identify ripe and unripe dragon fruit based on the machine learning model, give the number of dragon fruit and their 3D positions in the scanning area. It could be integrated into an unmanned aerial vehicle or mobile robot.

The rest of the paper is organized as follows. In Section 2, a detailed description of the system is provided. In Section 3, we describe techniques for dragon fruit and experiment in real environment. We conclude in Section 4 with a discussion of future research directions.

2. SYSTEM DESCRIPTION

In terms of system inputs, we use two inputs, which are images from a stereo camera and high-precision Global Positioning System (GPS) from a Real-time Kinematics (RTK) module. The obtained data is processed on an small embedded computer to ensure system flexibility.

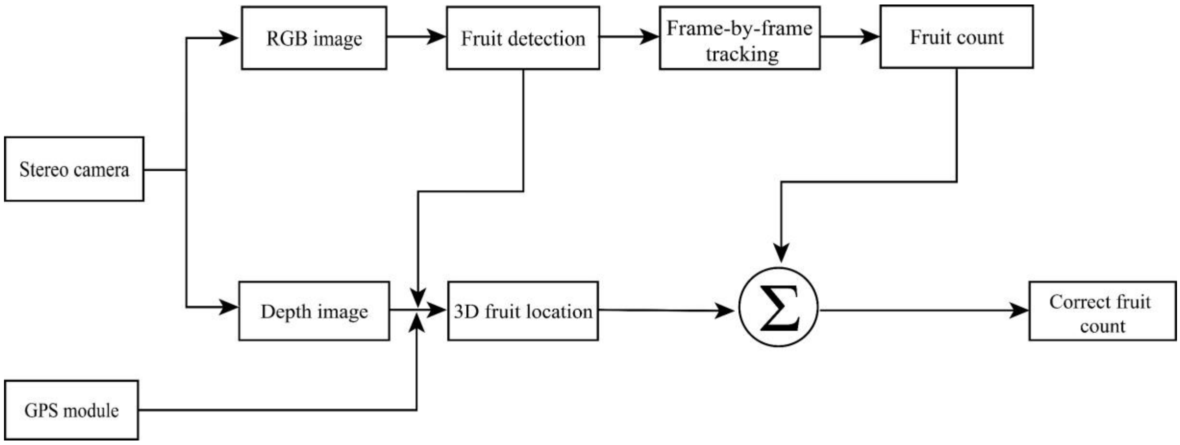

Figure 1. The data processing pipeline

Accurate automated fruit counting can enable growers to determine storage and labor needs prior to harvest. This is an important problem that we focus on solving in this system. Our fruit counting approach consists of two steps, fruit detection followed by fruit tracking. The overview of the system is shown in Figure 1.

2.1. Fruit detection

In this system, to ensure compactness, we use YOLOv5 model for fruit detection task. This is a popular and highly compatible machine learning model. YOLO (You Only Look Once) or YOLOv1 is a single shot detector in which a fully convolution neural network converts the input image to a tensor of scores for object detection [6]. The prediction of class probabilities and bounding box coordinate form the final feature map in a single forward pass-through CNN makes YOLO one of the fastest objects detection methods. In this study, YOLOv5 was used for detection tasks because this version was improved with Focus layers, that reduced required CUDA memory, reduced layer, increased forward propagation, and backpropagation [7].

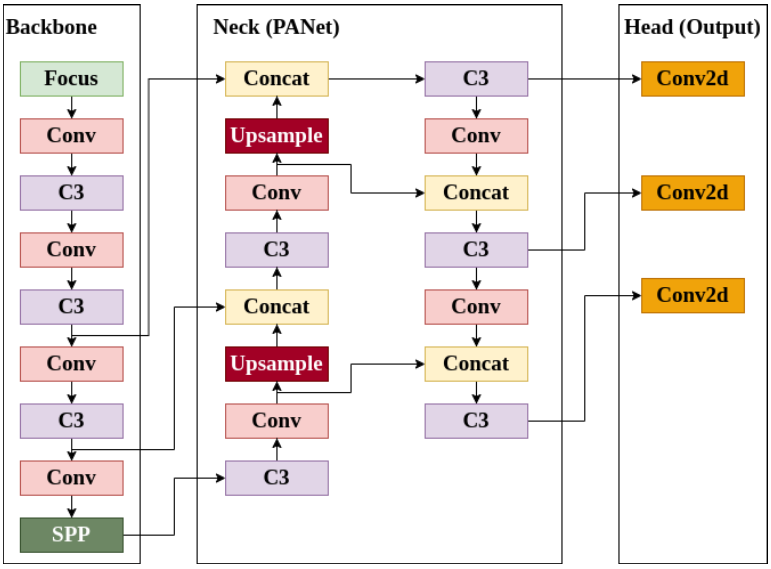

Figure 2. YOLOv5 Architecture

'Conv' refers to 'convolution layer' and 'Concat' to 'concatenation layer'. C3 is composed of three convolution layersand a module cascaded by various bottlenecks. Spatial pyramid pooling (SPP) is a pooling layer that is used to remove the fixed size constraint of the network. Upsample is used in upsampling the previous layer fusion in the nearest node. Concat is a slicing layer and is used to slice the previous layer. The last 3 Conv2d are detection modules used in the head of the network.

After model training, we also improve the inference speed of model by using TensorRT with NVIDIA device. TensorRT is a machine learning framework that is published by NVIDIA to run inference that is machine learning inference on their hardware (in this study, we use Jetson AGX Xavier). TensorRT is highly optimized to run on NVIDIA GPUs. It is the fastest way to run a model now. The job of TensorRT is to take a pre-trained model and 'compile' it into an 'engine' that runs fast. The speed of improvement depends on the model itself and the setting used for compilation.

2.2. Fruit counting

As the module scans trees, it is important to produce a running count to estimate fruit yield from farms. To do this task, we have created a fruit counting algorithm based on the Hungarian algorithm and the Kanade-Lucas-Tomasi feature tracker [8]. We compute the optical flow of image descriptors over subsequent frames to estimate camera motion. After that, this information is used to maintain track of fruits that have previously been recognized in earlier frames. The fruit tracking algorithm uses the anticipated camera motion between frames to anticipate where fruits seen in earlier frames will be. To make sure previously discovered fruits are not repeated, these detections are compared with fruits found in the present frame by using Hungarian algorithm.

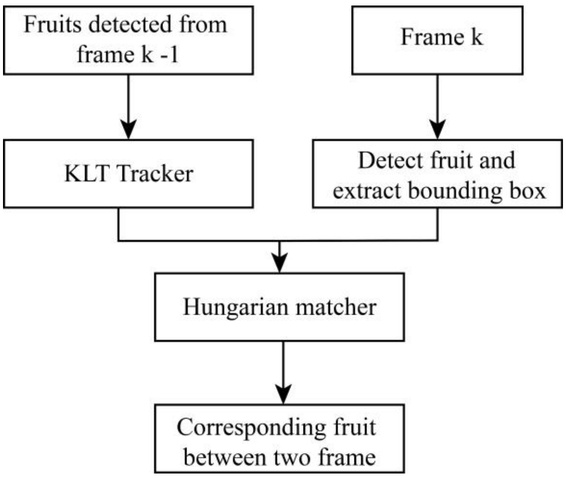

Figure 3. Fruit tracking frame to frame

An initial count of the fruits in an image sequence will be given by the earlier detection and tracking steps. However, this counting method is still vulnerable to fruits that are duplicate counted because during camera movement some fruit may disappear and appear to interrupt tracking. This count can be further rectified by localizing the fruit in 3D.

To get the information about the 3D position of the fruit, we use the information from the fruit detection results on the RGB image combined with the depth information from the stereo camera. After the fruit is detected, the fruit position will be represented by the center of the bounding box. From the depth information, we calculate the fruit position relative to the camera. This position is converted to a global coordinate system using highly accurate GPS information from RTK.

The 3D fruit locations can be now used to correct the initial fruit count. We can delete the first fruits that were double counted. Not every fruit is tracked in every frame they appear in due to occlusion and illumination change. So, some fruits that are originally monitored, then lost, and then discovered and tracked once more at a later frame, will be counted as different fruits, and appear twice in our initial count. After localizing these fruit tracks in 3D, we can quickly identify these fruits that were double counted because they would be near together.

3. RESULTS AND DISCUSSION

In this section, we present the dataset used to train the machine learning model and test the system in real dragon fruit farm.

3.1. Dataset

The dataset sources still provide little information on agricultural products because each country's climate and surroundings are so unique. To increase the stability and accuracy of the model, photos of dragon fruit were gathered for the study from farms, packaging facilities, and an image processing facility with the proper lighting. The database includes pictures taken from a variety of shooting angles. The collected data set includes two labels of ripe dragon fruit and unripe dragon fruit with a total of 12000 images. Images were collected by camera and LabelImg software was used for labeling. For training we split the data into three parts: 1000 photos are used for testing, 9500 images are used for training, and 1500 images are used for validation. To verify the model's accuracy in the real environment, random images from the image-processing chamber were selected as the test data. The collection of data on dragon fruit is also a meager contribution to this study because there are so few sources of information on agricultural items. Some situations result in model training that is overdone. In this study, data augmentation techniques such as image rotation, gamma correction, and scale were employed to extend the model's database size and improve the model's training accuracy while preventing overtraining.

Figure 4. Data samples. '1' refers Ripe dragon fruit and '0' refers Unripe dragon fruit

We have conducted YOLOv5 machine learning model training on this dataset. Figure 5 below show confusion matrix of model with test data with accuracy is 94%.

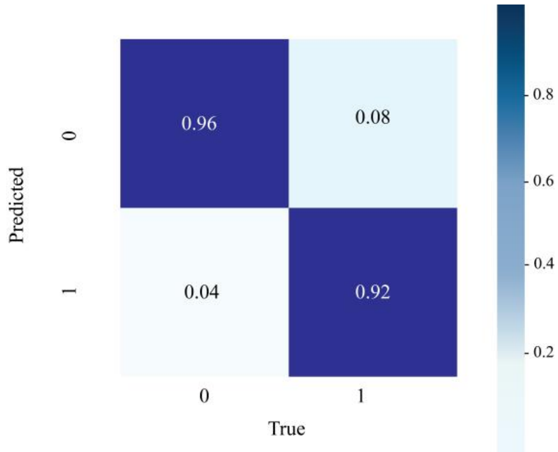

Figure 5. Confusion matrix of YOLOv5 model

a. b.

Figure 6. Detection result: a. Origin label, b. Predict label

After performing model optimization using TensorRT, the average accuracy of the model dropped to 91.1% with FP16 and 82.3% with INT8 with ripe dragon fruit.

3.2. Experiment

In this section, we show the results of using our dragon fruit dataset in real-world conditions. Based on this result, we conduct an experiment on the fruit detection and fruit counting algorithm on a dragon fruit farm. In order to test the system in a real environment, we built a small hardware model that can be held in the hand as shown in Figure 7. This module can be fully optimized for robots or UAVs.

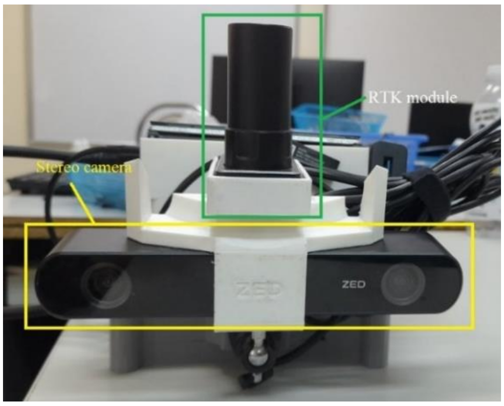

Figure 7. Hardware sample

In experiment, we used a stereo camera with resolution is 1920x1080 as input images of system. The depth information is obtained from RGB images by Semi-global matching algorithm [9]. Our system uses the FP16 model and achieved a processing speed of 40 fps. However, after applying the fruit counting algorithm, the processing speed dropped to 30 fps.

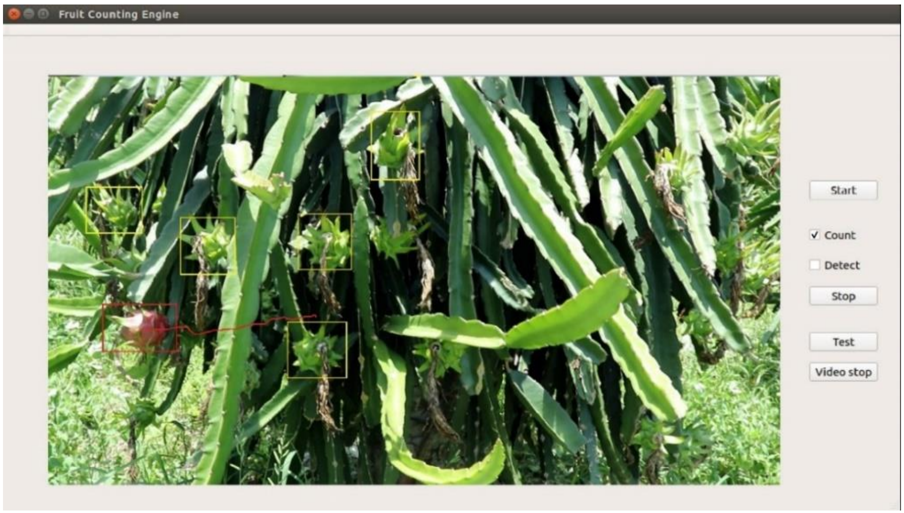

Figure 8. Ripe dragon fruit tracked

We conducted an experiment on a dragon fruit field with an area of 0.5ha. The dragon fruit trees are planted 2 meters apart. In total, there are 120 trees in 10 rows and 273 ripe dragon fruits. We only select ripe fruits to include in the counting algorithm, this will reduce the processing complexity. The tracking result shown in Figure 8.

Table 1. Result of experiment

Measure	Ground truth	Ours module	Accuracy
Number of fruits	273	246	90%

The results show that at 30 fps, the yield prediction system achieves 90% accuracy in fruit counting.

3.3. Discussion

In this study, the system's fruit counting task worked quite well, but there were still some problems with light conditions and tree branches. In sunny weather conditions, tracking with optical flow will be less accurate. This also affects the depth estimation of the stereo camera.

4. CONCLUSIONS

This paper proposes a systematic procedure for precision agriculture, particularly for dragon fruit in Vietnam. We developed data analysis and visualization methodologies to help growers obtain actionable information from acquired data, and interpret them for efficient farm management, especially in the two tasks of dragon fruit detection and counting. System has been tested in real conditions. Our system can be easily integrated with remote sensing platforms such as UAV or AGV. Moreover, with this system, we can apply to many different types of objects based on the characteristics of the obtained data. Because of this, growers have more freedom to select the best method of use. Our solution can quickly map a farm when installed on many UAVs. It is useful for applications that require quick results.

Our future work will be to integrate more spectrum and thermal imaging sensors to be able to add functions for plant health assessment. These data will be applied in productivity management problems as well as irrigation system management.

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EMPLOYING BARCODE ON VELVET ANTLER TRACEABLE SUPPLY CHAIN IN TAIWAN

Hsiao-Mei Liang[1, *)], Shann-Ren Kang[1)] and Pei-Mei Chen[2)]

1) Kaohsiung Animal Propagation Station, Livestock Research Institute, Council of Agriculture, Executive Yuan, Taiwan
Email / hlliang@mail.tlri.gov.tw
2) Department of Animal Industry, Council of Agriculture, Executive Yuan, Taiwan

* Corresponding author

ABSTRACT: This project is the first traceability information system for velvet antler production in Taiwan. Adjustments were made to the traceability system and its additional functions in accordance with the development of the deer breeding industry, which appealed to deer farmers and incentivized their continued usage of the system. Also, low-cost and easy-to-use 2D barcodes were adopted as the carrier of information on the velvet antler supply chain. Deer farmer can use the cell phone to scan the 2D barcode on individual deer fence, input production data about the deer, and update the data to computers and servers through the internet. That data is then stored and converted through the servers, and posted on the Taiwan Deer Farm website. Deer farmers can also load deer production data into 2D barcodes that can be exported as 2D barcodes that are unique to their farms and can be attached to the product or the packaging of the velvet antler. In addition, the Taiwan Deer Park website was developed alongside the system to collect various production data on deer. Not only does the website disclose deer production data to consumers by providing them with the information contained in the barcodes but a national velvet antler labeling system is also included to allow the National Velvet Antler Labeling Committee to examine the accuracy of the registration information. Through the certification of the National Velvet Antler Label, we can ensure the quality of velvet antlers, enhance consumer confidence in the safety and quality of velvet antlers, and also increase the accuracy of inputting information from deer farmers and willing on usage of the system.

Keywords: *Barcode, Velvet Antler, Traceability.*

1. INTRODUCTION

The concept of traceability started around 1987 with the ISO specifications, which was mainly applied to control quality management in manufacturing industries (Ene, 2013). However, in 1989, milk was contaminated with dioxin in Belgium, and in 1998, dioxin contamination was found in animal feed materials imported from Brazil in Germany and the Netherlands, and dioxin residues were detected in meat and cow's milk after animals consumed unclean feeds with dioxin residues (Malisch 2000), and in 1986, Mad cow disease occurred in the UK, but contaminated animals continued to be slaughtered and sold to consumers until 1996, when it was confirmed that Mad cow disease could be transmitted to humans, and major food safety incidents such as Creutzfeldt-Jacob disease (CJD) continued to occur, while these series of agricultural contamination and animal disease events caused consumer fears about meat safety (Monte and Gargi, 2018). For the purpose of establishing a food safety system, the EU was the first to define in 2002 in the EU General Food Law (EU General Food Law, 2002) traceability as the ability to trace and follow a food, feed, food-producing animal or substance intended to be or expected to be, incorporated into a food or feed, through all stages of production, processing and distribution. Many countries, such as the United States, Japan, and Romania have enacted legislation and started to establish traceability systems for food and agricultural products (Ene, 2013). In 2007, Taiwan enacted and enforced the "Agricultural Production and Certification Act" to promote traceability, and in 2015, established the Directions Governing the Management for Taiwan Agricultural

Products Traceability to achieve transparency of production information through public traceability of production information to enhance the product safety responsibility of producers, ensure the safety of agricultural products, and increase consumer confidence in local consumption. At present, the livestock and poultry products with traceability in Taiwan include ground chicken, white meat chicken, goose meat, meat duck, chicken egg, duck egg, processed duck meat, processed duck egg, processed chicken meat, processed chicken egg, processed goose meat, pork, beef and cow's milk, etc., among which traceability is fully implemented for beef.

Because velvet antlers contain high concentrations of insulin-like growth factors and growth factors that promote the activation of cells such as epidermis, neuronal cells, cell transformation, and epithelial cells (Barling *et al.* , 2005; Francis and Suttie, 1998; Feng *et al.* , 1997; Wolfgang *et al.* , 2010; Lai *et al.* , 2007; Clark *et al.* , 2006; Yang *et al.* , 2012), and rich in amino acids and minerals (Fu et al., 2007), have been widely consumed by consumers for health maintenance in recent years. According to the 2020 agricultural annual report, the number of deer in captivity was 17,105, the velvet antler production was 28,684 kg, and the value of velvet antler production reached $703,818,000, accounting for 0.14% of the total value of agricultural products, indicating that the deer farming industry has the potential to develop into a refined livestock industry. Velvet antlers are the main economic product of the domestic deer farming industry, mainly supplied as health food. In the face of frozen velvet antlers in the international market and increasing imports of velvet antler products, it is necessary to establish a safe and traceable velvet antler supply chain to provide safe and high quality velvet antlers, strengthen domestic consumer confidence, and differentiate from imported products. Therefore, the goal of this program is to build the first velvet antler supply chain traceability system in Taiwan and apply 2D barcode to link the whole production chain information to build a pragmatic and widely-used traceability system.

2. MATERIALS AND METHODS

Target users of the system: consumers and deer farms with a valid certificate of compliance for deer inspection by the animal disease control centers of the county and city governments.

The choice of traceability label: Because of the benefits of low cost, mature technology, and easy operations, as well as the characteristics of representing text, graphics, large capacity, high reliability, data security and anti-counterfeiting, and easy modification of data, (White *et al*, 2007), the 2D barcode is chosen as the mobile carrier for this program. Another consideration is that the 2D barcode can be linked to the traceability system of the Council of Agriculture as the industry develops in the future, so that it can be used more extensively.

System plan: this program builds a supply platform with a 2D barcode series of velvet antler production chain. The system plan is shown in Figure 1. Deer in the deer farms have their individual proprietary barcodes. After scanning the barcode by cell phone, deer farmers can directly maintain the production data on the cell phone page, including species characteristics, gender, date of birth, parent animals, velvet antler production records, vaccination treatment, feed sources, etc. These data will be uploaded to computers and servers, which can be stored and converted to reveal the production information of deer on the Taiwan Deer Park website, and the production data can be loaded into the 2D barcode and exported to the deer farm's proprietary 2D barcode, which can then be posted on the product or velvet antler packaging bag.

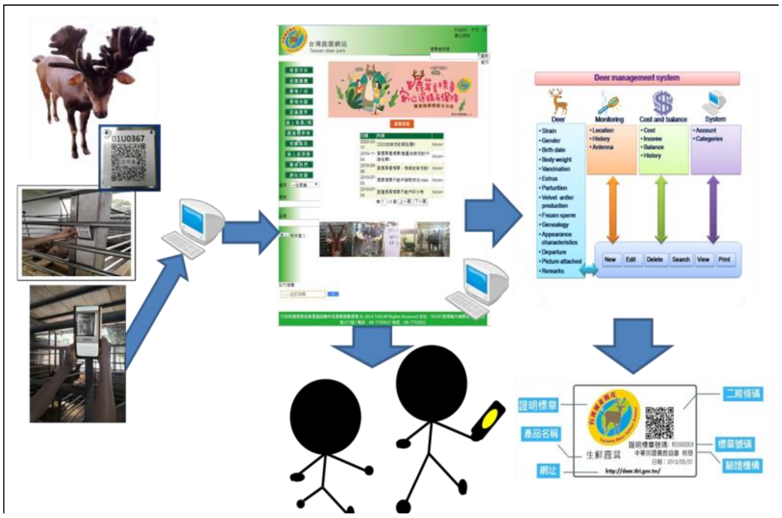

Figure 1. System plan flow

System design: the Taiwan Deer Park website was designed to collect various production data on deer. Not only does the website disclose deer production data to consumers by providing them with the information contained in the barcodes but a national velvet antler labeling system is also included to allow the National Velvet Antler Labeling Committee to examine the accuracy of the registration information. Through the certification of the National Velvet Antler Label, we can ensure the quality of velvet antlers and the recognition of deer farmers and consumers and increase the data accuracy and system usage. The system architecture of Taiwan Deer Park website and the national velvet antler label are shown in Figure 2 and Figure 3.

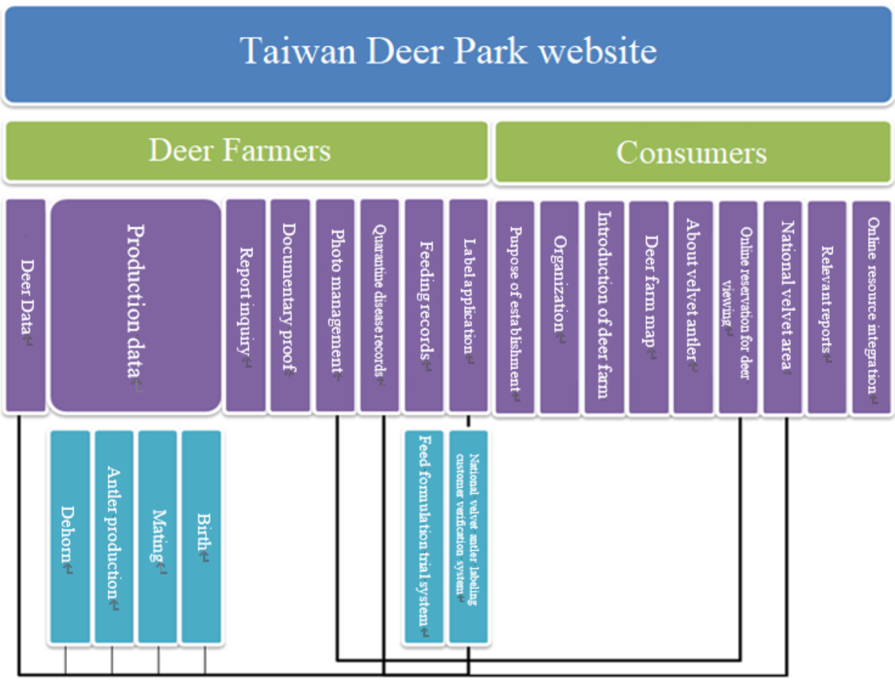

Figure 2. System design architecture

INCLUDEPICTURE "https://kmweb.coa.gov.tw/files/IMITA_Gallery/166/e7874d0e33_m.jpg" * MERGEFORMATINET INCLUDEPICTURE "https://kmweb.coa.gov.tw/files/IMITA_Gallery/166/e7874d0e33_m.jpg" * MERGEFORMATINET INCLUDEPICTURE "https://kmweb.coa.gov.tw/files/IMITA_Gallery/166/e7874d0e33_m.jpg" * MERGEFORMATINET Figure 3. Taiwan velvet antler logo and text

3. RESULTS AND DISCUSSION

In order to construct a traceability system for velvet antler supply chain, UHF RFID technology was introduced in 2016 for deer farm management operations (Liang *et al*., 2016). Deer are tagged with UHF RFID ear tags, and the RFID reader antenna is installed in the deer barn to read the information. When the deer with RFID ear tags pass through the deer barn passage, the information in the RFID ear tags can be read automatically by the RFID reader antenna, so that the operators can quickly know the deer's identity through this method, and there is no need to confirm the deer's identity manually at close range. At the same time, if the deer is in the breeding room of the deer barn, the handheld RFID reader can be used to quickly identify the deer within the reading area. In addition to reducing the operating time and inconvenience of identifying deer, the main purpose of developing deer production management information system is to apply to deer farming management. The system mainly provides basic information about deer, such as antler production records, birth records, cost analysis and other farming management information. The above information is recorded electronically through the system function, so that the operators can understand and analyze the deer data, and understand breeding and antler production status of the deer through the records, and improve the quality and efficiency of the deer farm as a reference. The application of RFID technology in deer production and operation can have a considerable benefit, with actual benefits both from the production side and the sales side for future promotion and application, but in real practice, because the costs of RFID reader and RFID ear tag are too high, the willingness for deer farmers to participate is not high. Therefore, this program makes correction based on the previous experience and adopts the lower-cost 2D barcode, and the 2D barcode is designed to link with the national velvet antler label, so that the deer farmers are more willing to use the 2D barcode and widely use it to promote their own deer farms (Figure 3).

Figure 3. Deer farmers use 2D barcode to promote their deer farms

Figure 4. 2D barcode can be scanned by a cell phone to output for a printout of the deer's proprietary ID card

The key to the success of the velvet antler traceability mechanism and information system is the continuous use and construction of deer production data by deer farmers. Therefore, the focus of this program is to improve the efficiency of deer farmers in using the system to create data. The program applies the lower-cost 2D barcode and designed a proprietary barcode for deer, and built a mobile sign to allow the barcode to move with the deer as they are moved to different fences, allowing deer farmers to enter information at the deer fences without having to search through numerous deer pages or return to the computer desk in the management room to create data. The input data can be printed as deer identification data, which becomes a deer-specific ID card (Figure 5), providing simple, clear and real-time information for consumers. This convenient approach really attracts the young deer farmers of the second generation to invest in the digitalization of the deer industry and improves the efficiency of data entry.

4. CONCLUSIONS

The program built the Taiwan Deer Park website through the traceability system, allowing the public to identify information about the origin of velvet antler products for purchase, and plans and executes it according to the operating habits and practical needs of deer farmers to help deer farmers to manage, promote and market velvet antlers in a computerized manner, and increase the willingness of deer farmers to join the system and increase its utilization rate by adding value to the national velvet antler label. Since deer farmers participating in the program must have a certificate of compliance for tuberculosis inspection of the deer by the animal disease control centers to join the program, and with the increase in the number of inspected deer in the country, the number of deer farms providing quality and safe velvet antlers in the country will grow. This program brings out the transparency of velvet antler production information and adjusts the system design according to the development of deer farming industry to attract deer farmers to participate in digitalization. Although the deer farming industry is currently focusing on the sale of velvet antlers, with the development and expansion of the deer farming industry in the future, this information system will be extended to the processing side and the sale side, and will be widely applied to the end products throughout the domestic velvet antler production, sale and supply.

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PRELIMINARY RESEARCH FOR AN AUTOMATIC MONITORING AND ANALYSIS SYSTEM FOR INTERNATIONAL PLANT PEST EPIDEMICS

Jiun-Ting Chen [1)], Ming-Shu Yuan [1,*)], Chun-Nan Chou [2)],
Hui-Wen Wang [2)], and Yi-Tzu Wenig [2)]

1) Shih Hsin University, Taipei, Taiwan, R.O.C.
juanems@mail.shu.edu.tw
2) Bureau of Animal and Plant Health Inspection and Quarantine, Council of Agriculture, Executive Yuan, Taipei, Taiwan, R.O.C.

ABSTRACT This research seeks to build an “International Plant Epidemic Automatic Detection and Analysis System” in response to climate change and frequent international trade. The system uses web crawlers and automatic semantic analysis to explore the web pages of important international organizations and scientific literature databases. After collecting information about pest epidemics, public opinion, and its associated prevention and management, the data will be disassembled and stored in categories to speed up the efficiency of data collection and analysis, to support generation of epidemic warnings. This research begins with a preliminary study on important quarantine pests of recent concern, and it is expected that the results could be used as a reference for future system planning and development. This article describes the preliminary research underpinning the structure of the “International Plant Epidemic Automatic Detection and Analysis System” through database design and system function scenario design to provide a reference for future system development.

Keywords: *Plant Epidemic Automatic Detection, automatic semantic analysis, pest epidemic, management information.*

1. MOTIVATION AND OBJECTIVES

This study analyzes worldwide plant epidemics, a major environmental problem, identifies and analyzes the key problems, and devise solutions.

1) Problem analysis

In response to climate change and frequent international trade, there is a need to attend closely to epidemic status, prevention, and management of quarantine pests of concern in Taiwan on a regular basis, as well as the likelihood of epidemics involving emerging pests of international concern, so that appropriate precautionary and management measures can be taken in a timely manner.

Quarantine pests of concern in Taiwan include more than 1,500 species of fungi, bacteria, insects, mites, nematodes and weeds. Because of the difficulty of collecting information manually about epidemic status and the management of individual pest species, this study deployed web crawlers and automatic semantic analysis to collect information on the status, public opinion, prevention, and management of pest epidemics from important global organizations and scientific databases. The results present a preliminary insight into the epidemic status of important quarantine pests of concern.

2) Proposing solutions

This study deployed web crawlers and automatic semantic analysis in lieu of manual searchers to gather information on the status, public opinion, prevention, and management of pest epidemics.

2. LITERATURE REVIEW

Burgeoning developments in international trade and communication have drastically increased the quantity and types of agricultural imports and exports. Although consumers have a wider variety of agricultural product options, but there is also an increased risk of foreign invasion from harmful species such as red fire ants, lychee stink bugs, fall armyworms, etc., which cause environmental, ecological, and economic damage. In light of this risk, the government enacted on April 22, 1999, the Quarantine Requirements for the Importation of Plants or Plant Products into the Republic of China, which summarizes the export countries, host plants, and relevant import quarantine regulations for quarantine pests. The information therein enables the public and plant and animal plant protection or quarantine officers to query and understand more about quarantine regulations.

To allow the quarantine authority to fully control the types of plants approved for entry to Taiwan as well as the progress of the epidemic status in the export country, the import quarantine regulations have been analyzed, consolidated, filed, and queried. Additionally, a database has been established to maintain the relevant articles for public query. The database is also an important reference that facilitates the implementation of quarantine measures. The Bureau of Animal and Plant Health Inspection and Quarantine, Council of Agriculture, Executive Yuan has entrusted Prof. Min-Shu Yuan of Shih Hsin University (2019, 2020) to continuously review the list of plants approved for entry (including 8,502 botanical names, 4,567 Chinese names, etc.);analyze and file data pertaining to the List of Enterable Plants or Plant Products under Precautionary Requirements (including 476 botanical names, 480 Chinese names, 44 pest names, their quarantine requirements, etc.) and the List of Prohibited Plants (including 521 botanical names, 517 Chinese names, 152 pest names, etc.) outlined in the Quarantine Requirements for the Importation of Plants or Plant Products into the Republic of China; and establish a query system on the list of plants approved for entry and their quarantine requirements so that the public and quarantine offers can query the list of plants approved for entry and their quarantine requirements. In addition, a plant quarantine and pest epidemic status database was created in 2019, so that the Bureau of Animal and Plant Health Inspection and Quarantine can collect and archive the entire epidemic data, provide a reference for risk assessment, and enact quarantine regulations to prevent the invasion of foreign plant diseases and insect pests, and contain any outbreaks (Yuan, 2021). On the basis of the established plant quarantine and pest epidemic status database, three tasks as part of the program have been carried out as follows:

1) Maintaining and updating the basic information (including the scientific names and taxonomic ranks) of 742 pest and plant entries in the plant quarantine and pest epidemic status database.

2) Creating a new database function for generating pest risk assessment profiles. This function allows users to query information by entering pest species, hosts, and distribution into the pest database, and to store and edit the contents of multiple query results. A risk assessment summary can be generated to save the time for manual collection, comparison, and filing.

3) Designing an automatic knowledge retrieval system for scientific and technological studies on plant epidemics. In 2021, the system's main function was automatic searching of English-language abstracts. Users select keywords specifying the country, symptoms, area of disease, transmission, and botanical names for comparison, and an abstract on the key points of a study can be quickly generated so that epidemic prevention personnel can readily grasp the epidemic status outlined in studies abroad.

The Bureau of Animal and Plant Health Inspection and Quarantine have also entrusted Prof. Ya-Chun Chang of National Taiwan University and Prof. Wen-Ling Deng of National Chung Hsing University in a program on the analysis and development of quarantine techniques on the global epidemic status of important quarantine viruses and bacterial pests. The program also covered the analysis and study of the scientific names and classifications (including the family and genus) of viruses and the scientific names, hosts, and distribution of bacterial pests outlined in the list of pests in Article 10 of the Quarantine Requirements for the Importation of Plants or Plant Products into the Republic of China – Part B, Quarantine Requirements for Enterable Plants or Plant Products under Precautionary Requirements (Chang and Deng, 2018). The data could serve as an important reference for the inventory tasks in this study.

3. SYSTEM DEVELOPMENTAND OBJECTIVES

The objectives of this study include: 1. Selecting, as preliminary sources, four key epidemic information websites: 1) FAO, 2) CABI, 3) Plant Disease Journal, 4) Global Plant Protection News. 2. Using web crawlers to regularly consolidate information from these epidemic information websites, as well as using keyword extraction technology to analyze and identify the quarantine pests of concern in Taiwan, and automatically generating the analytic graphs required by the Bureau of Animal and Plant Health Inspection and Quarantine.

The work tasks and implementation steps include: 1) Querying the need to crawl through the epidemic information websites and planning the functions of the web crawlers. 2) Examining the structures of the target websites and performing data analysis. 3) Developing a web crawler program to collect website information on a regular basis. 4) Developing a screening program to remove website noise. 5) Creating an automatic epidemic status report generation function. 6) Developing an interface for the maintenance and management of quarantine pests of concern. 7) Comparing the web crawler results about the quarantine pests of concern. 8) Generating weekly graphical reports about the distribution of pests. 9) Collecting relevant studies.

4. SYSTEM DEVELOPMENT

This section describes the system development process, including the system overview and system coding principles in the early phases of system development. The list of system requirements is consolidated based on the user needs, and the data analyzed by the system, including database design and system scenarios are further described as well.

The system mainly uses web crawlers to retrieve information from news websites, online forums, and social media. Stealth technology was used to reduce the probability of crawlers being blocked. Afterwards, text mining was used to index and extract important lexical features and associations. Lastly, the analysis results are presented visually. The system development procedure is shown in Figure 1.

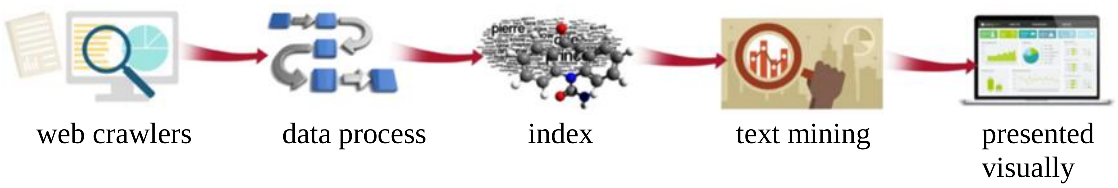

Figure 1. System development procedure.

The system functions include system management and the management of various roles including system settings, listing reports, data sources, website management, retrieval programs, retrieval servers, and scheduling-related management functions. The coding format for identifying the requirements and functional items in this system is DEAP-12-34-5678, in which 1) DEAP is the English language code of the program. 2) The 12th codes that consist of AM, AF, EF, EM, and NE, represent analysis management functions, analysis function requirements, retrieval management functions, retrieval function requirements, and non-functional requirements, respectively. 3) The 34th code is the module code. 4) The 5678th code is a serial number. The system functions in the early phase of development, including data retrieval and the functions of the analytical platform, are summarized in Table 1.

Table 1. Summary of the data retrieval and analytical platform.

No.	Code	Function name	Content
1	DEAP-AM-01	System function management	Add, modify, and delete system operation functions
2	DEAP-AM-02	Role management	Add, modify, and delete role information and the access
3	DEAP-AM-03	User management	Add, modify, and delete system users

4	DEAP-AF-01	Personal data management	Add or modify personal information and password
5	DEAP-AF-02	Settings for issue analysis	Set the program name and description, manage program members, select the issue analysis channel, edit issues, edit issue-related items
6	DEAP-AF-03	Lists of data	View details based on the channel type, analysis target, and time
7	DEAP-AF-04	Issue analysis reports	Extract important features and lexicon based on the analysis targets, so as to generate an analysis report
8	DEAP-EM-01	Source website management	Manage the retrieval websites and channels
9	DEAP-EM-02	Retrieval program development	Set the relevant retrieval task parameters
10	DEAP-EM-03	Retrieval server management	Configure the retrieval delivery server
11	DEAP-EM-04	Retrieval scheduling management	Set retrieval task scheduling period

The data analysis on entity relationships covered system function items, system users and roles, as well as system-related programs and program-related information, system and related keywords, system-related servers, main programs, program-related issues, and program dimensions, program server information, related program servers, related channels, user operation records, and also records the system keywords and user keywords. The entity relationships within the data analysis subsystem is diagrammed in Figure 2:

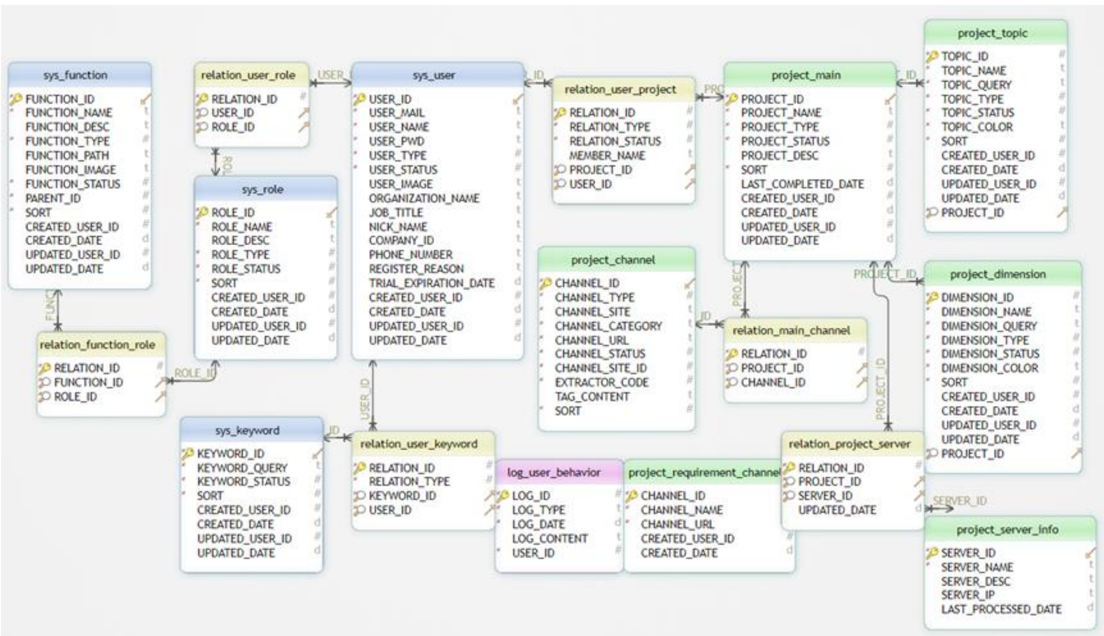

Figure 2. Entity relationships within the data analysis subsystem.

Data retrieval included setting the data source in the retrieval program, as well as the data crawler functions and scheduling settings.

During data retrieval, the configuration file was first read and then the browser was activated, the source code was parsed, and all content URLs and the content page links within were extracted based on the URLs. Data was extracted from forums and news websites. The data retrieval process is shown in Figure 3:

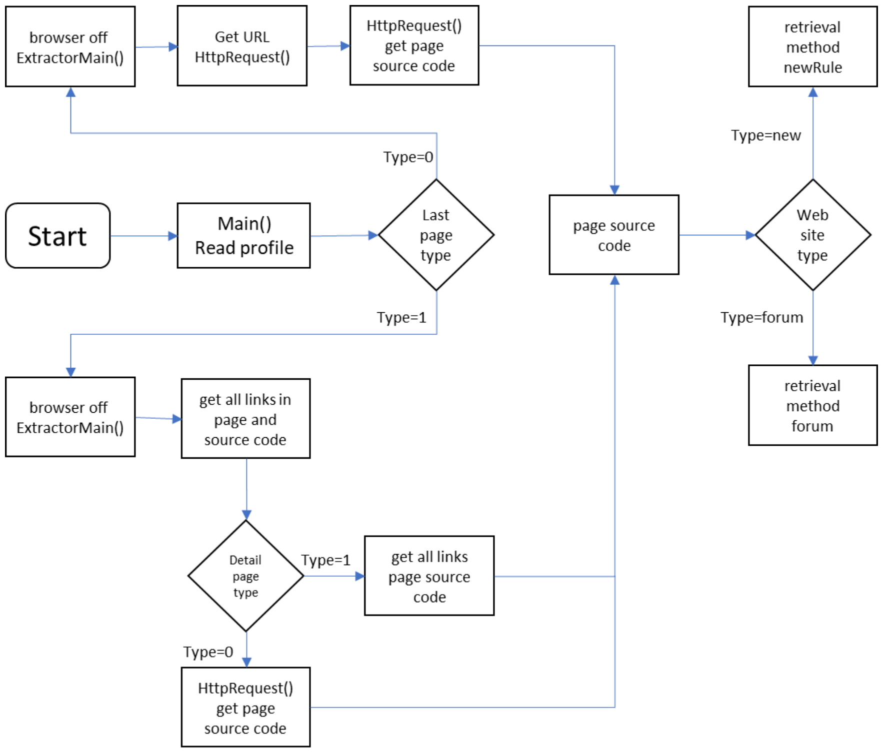

Figure 3. Data retrieval process.

The information retrieval dispatch tasks were performed through an information retrieval platform. After going online through a proxy server, the crawlers sent back the original webpage code, and the data was stored in a database after cleansing. The process is shown in Figure 4.

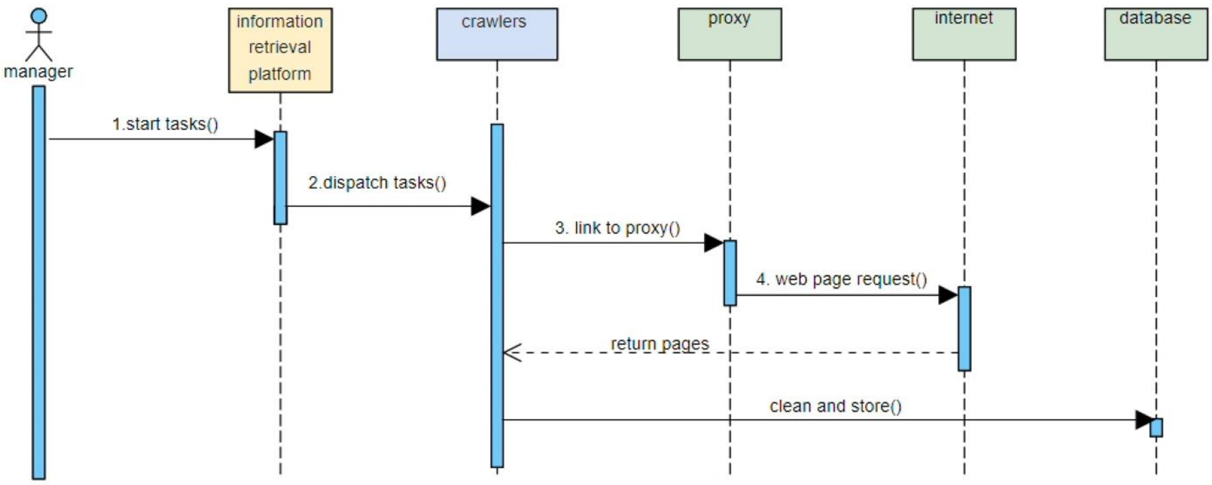

Figure 4. Data retrieval sequence.

5. CONCLUSIONS

This study performs a preliminary needs analysis and generates a report on epidemic detection. The target websites included FAO-Desert Locust Zone, CABI, Plant Disease Journal, Global Plant Protection News. Epidemic data on 11 emerging pests were collected, including ToBRFV, TYLCV, ToMMV, PCFVd, CLVd, TASVd, TPMVd, TCDVd, Schistocerca gregaria, Spodoptera frugiperda, and Eriosoma lanigerum. The collected data was first disassembled, and a pest epidemic status and distribution report was generated based on the country of origin. The preliminary results show that our approach can save significant time relative to manual data collection, and provide a reference for the development of future precautionary mechanisms. In the future, in addition to strengthening the accuracy of automatic research and analysis results based on user feedback, we shall gradually accumulate our research experience and subsequently develop semantic research and analysis techniques for pest hosts, methods of transmission, and other related information. The application of web crawlers and automatic semantic analysis can replace manual information collection on the status of and public opinion on pest epidemics, as well as providing precautionary measures and meeting the long-term objectives of adjusting border quarantine management measures.

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IMPACTS OF READ LENGTH AND MUTATION ON CIRCULAR RNA DETECTION METHODS FROM PLANT CLIP-SEQ DATA

Manh Hung Nguyen[1], Viet Phuong Hoang[1], Cong Tien Phan[1],
Trung Nghia Vu[2] and Ha-Nam Nguyen[3*]

1. University of Engineering and Technology, Vietnam National University, Hanoi, Vietnam
21025075@vnu.edu.vn, 19020052@vnu.edu.vn, 20020266@vnu.edu.vn
2. Karolinska Institutet, Sweden
TrungNghia.Vu@ki.se
3. Vietnam Institute for Advanced Studies in Mathematics, Vietnam
nhnam@viasm.edu.vn

* Corresponding author

ABSTRACT Circular RNA (cicrRNA) is a group of non-coding RNAs with covalently closed structures bringing a variety of biological functions in not only animals but also plants. Recent studies have shown the potential roles of circRNAs in stress responses, growth and development of plants. Sponging with RNA-binding proteins (RBP) is a known biological function of circRNAs which can be investigated by the technology of cross-linking and immunoprecipitation followed by sequencing (CLIP-Seq). Generally, traditional circRNA detection methods designed for high-throughput RNA-sequencing (RNA-Seq) data are applicable to the CLIP-Seq data. However, different from the RNA-seq, the CLIP-Seq consists of several unique characteristics such as single-end reads, largely variant read length, and experimental mutation which can hinder the circRNA detection methods. The impacts of these factors on the methods' performances have not been properly investigated. To address this issue, in this study, we provide a rigorous assessment of five popular circular RNA detection methods applicable to CLIP-Seq data. Particularly, different settings of read length variation and mutations are applied to generate the simulated datasets for evaluation. We further evaluate these methods using two different CLIP-Seq datasets of Arabidopsis thaliana. The results show that the heterogeneity of read lengths and mutations of the CLIP-Seq data can deteriorate both sensitivity and precision of the circRNA detection methods.
Keywords: *Circular RNA, CLIP-Seq.*

1. INTRODUCTION

Circular RNA (circRNA) is a type of non-coding RNA with a covalently closed-looped structure based on a linking bond between 3' and 5' ends (Chen, 2016). The special structure of circRNA makes its distinctive behavior from other RNA molecules, for example, a longer existence in cells by not being affected by exonuclease digestion agents (Enuka et al., 2016). Several fundamental functions of circRNA have been discovered such as miRNA/RBP sponge, involved in transcriptional regulation, and binding with specified proteins to create RBP (Chen, 2016). CircRNA research has been conducted widely in human and mammal tissues and organisms. Studies about circRNA in plants in recent years are mainly found in typical model species, such as Arabidopsis thaliana and Oryza sativa (Lai et al., 2018). Some circRNA functions in plants have been reported, for example, the sponging function in leaf-senescence (Liu et al., 2017) and involvement in sophisticated pathways of plants to respond to stress conditions (Wang et al., 2017). However, the detection of circRNAs in plant cells is still challenging due to their low level of expression, which requires a high sequencing depth for improving sensitivity.

Sponging with RNA-binding proteins (RBP), a known biological function of circRNAs, can be investigated by the combination of cross-linking and immunoprecipitation followed by sequencing (CLIP-Seq). CLIP-Seq is one of the most striking protein-centric approaches to investigate RNA-protein interaction, focusing on a specific RBP to discover associated RNAs by high throughput sequencing (Licatalosi et al., 2008). Most of the CLIP-Seq experiments are interested in the interaction of mRNAs. However, the investigation of interacting RNAs has expanded to some non-coding types of RNAs, showing the interaction between lncRNA and RBPs. With the instance of circRNAs, RBP-circRNA interactions are profiled from public datasets (Zhang et al., 2020), while finding circRNA's role on an important protein, AGO, is executed (Li et al., 2017). Different CLIP techniques are used to optimize capturing the binding site of the interaction. Evolving from original high throughput sequencing (HITS-CLIP), iCLIP can precisely identify the binding nucleotides by hard cutting at the binding sites (König et al., 2010). Photoactivatable ribonucleoside-enhanced CLIP (PAR-CLIP) is another CLIP version which causes a specified mutation exactly at the binding site of the transcript (Hafner et al., 2010). CLIP variants improve the finding of binding sites; however, they reduce the quality of sequencing results with randomly truncated reads (iCLIP) or particular mutated sites (PAR-CLIP). These technical issues can significantly impact on CLIP-Seq data, for example increasing the number of mutations in the read sequences as well as the variation of read length.

This study aims to evaluate the effect of these factors including read-length diversity and mutation rate on the performance of circRNAs detection. Five recent advanced bioinformatics circRNA detection methods applicable to CLIP-Seq including CIRCExplorer, find_circ2, UROBORUS, Clirc, and CircScan are chosen for the assessment. The evaluation will be performed on simulated datasets and two real CLIP-Seq datasets of Arabidopsis thaliana plant.

2. MATERIALS AND METHODS

2.1. Circular RNA detection methods

Five circular RNA detection methods have been chosen to investigate the impact of CLIP-Seq characteristics on detection performances. Three of them including CIRCExplorer (Zhang et al., 2014), find_circ2 (Memczak et al., 2013), and UROBORUS (Song et al., 2016) are recent advanced circRNA detection methods from RNA-Seq data which can run with single-end reads of CLIP-Seq, two remaining tools are methods developed for CLIP-Seq data including Clirc (Zhang et al., 2020) and CircScan (Li et al., 2017). CIRI2 (Gao et al., 2018), a wildly-used RNA-Seq method is not included in this study due to its inability to handle short CLIP-Seq reads (<=50 bp). It is worth noting that the majority of CLIP-Seq data have short reads (Nguyen et al., 2022).

Find_circ2 (Memczak et al., 2013) removes all aligned reads from BWA-MEM alignment results to achieve unmapped reads for further circRNA detection. The unmapped reads are extracted to 20-nucleotide anchors at two ends and aligned again to figure out anchor positions as well as annotate circular RNA splicing. Other conditions like GU/AG splice sites and a maximum of two mismatches are also included to discard suspicious breakpoints.

CIRCexplorer (Zhang et al., 2014) is a tool that detects circRNA from RNA-seq reads supporting TopHat/TopHat- Fusion or STAR. Unmapped reads extracted from STAR are separated from multiplied sequence reads and individually mapped to the reference genome and realigned in reverse order to work out BSJ reads. Known gene annotations are also supplied to limit mispositioning errors.

UROBORUS (Song et al., 2016) identifies junction reads from back-spliced exons based on TopHat and Bowtie. Unmapped reads from TopHat have trimmed 20 bp at both sites to form an artificial PE seed in FASTQ file format. PE seed is then mapped to the genome with a maximum of 2 bp mismatching by Tophat. The result is divided into two cases: balanced mapped junction (BMJ) reads and unbalanced mapped junction (UMJ) reads. Other filters and alignments are implemented to detect plausible BSJ reads.

CircScan (Li et al., 2017) implements alignment to genome and transcriptome by calling Bowtie2 aligner. Unmapped reads are searched and broadened to generate full read mapping to identify back-splicing junctions based on information about donor and acceptor anchors. The match bonus and mismatch penalty are estimated in the scoring schema of the alignment step. With PAR_Clip samples, the T to C mutations resulting from crosslinking of photo-reactive nucleoside 4-thiouridine is considered as a match and bonus 1. Junction reads scoring more than 20 aligned with a single location and overlapped at least one read are retained. Junction sequences are then suffered 1000 times and scored continuously to ensure the false discovery rate <5%.

Clirc (Zhang et al., 2020) creates a combined index library from linearized circRNA sequences and linear transcripts employing Gsnap. Clip-Seq data are mapped concurrently to both compositions of the above library. Reads mapped idiosyncratically to circRNAs adapting alignment requirements of mismatch rate and coordinate elongation are separated for the next step. Finally, some filters are enforced to point out RBP-bound circRNAs.

2.2. Datasets

Simulated CLIP-Seq data

We utilize the Circall-simulator of the previous study (Nguyen et al., 2021) to generate a single-end read sample with the read length of 50bp and denoted as Sample O. Particularly, we collect linear RNAs and 11,165 exonic circular RNAs (which are divided them into two sets of tandem RNAs and circRNAs in the ratio of 30% vs 70%) of the HELA cell-line (Nguyen et al., 2021) for the simulation.

To generate the simulated datasets with variable read lengths, we collect the read length information from the real CLIP-Seq human dataset used in a recent study (Nguyen et al., 2022) and trim the reads of sample O accordingly. Specifically, 21 heterogenous CLIP-Seq samples with the primary read length of 50bp are collected, then ordered by their read-length mean. The read-length mean of a sample can be used to measure the loss of information in that sample (compared to the sample if all reads have fixed 50bp read length). The lower read-length mean indicates that more information is missing from the sample. Next, the read-length information of the samples at the first-quartile, median and third-quartile of the read-length means across 21 samples is used as the pre-defined read-length distribution to simulate three samples called A, B, and C, respectively. For each of these samples, the reads of sample O are randomly trimmed (by removing the right-most sequence) following the corresponding pre-defined distribution of read lengths. The information on mean and dominant read lengths of the simulated samples is provided in Table 1.

To generate the mutated versions of these above-simulated datasets, we mimic the mutation “T to C”, a typical feature of PAR-CLIP. Specifically, for each sample O, A, B and C (wild-type version) we randomly replace 2% of nucleotide T with nucleotide C across all reads to generate the corresponding mutated version.

All sequencing data are generated and aligned using the reference genome and transcriptome of UCSC hg19 Homo sapiens.

Table 1. Read-length information of the wild-type simulated datasets. Columns “Mean” and “Dominant” indicate the read-length mean and the read length with the largest proportion (in the parentheses).

Sample name	Mean	Dominant
A	34.96	41 (45,93%)
B	36.10	42 (47.18%)
C	37.05	40 (68.70%)
O	50	50(100%)

Real CLIP-Seq data

Plant CLIP-Seq data has been collected from 2 CLIP-Seq studies on Arabidopsis thaliana (Meyer et al., 2017; Zhang et al., 2015). Both samples are collected from Arabidopsis thaliana seedlings and processed with two different techniques: iCLIP (6 samples) and HITS-CLIP (2 samples). Different replicants from a sample are concatenated to improve sensitivity performance. Specified adapters of two protocols are removed from raw sequencing data using *cutadapt* (Martin, 2011). Arabidopsis thaliana genome and annotation version TAIR10 are used in alignment and detection steps.

2.3. Evaluation metrics

Generally, we use the metric set of Sensitivity, Precision and F1 to measure the performances of the circRNA detection tools, as shown in Equation (1), (2), and (3), respectively.

$$\text{Sensitivity} = \frac{Number\ of\ true\ positive\ Circular\ RNA}{The\ total\ number\ of\ true\ Circular\ RNA} \quad (1)$$

$$\text{Precision} = \frac{Number\ of\ true\ positive\ Circular\ RNA}{The\ total\ number\ of\ Circular\ RNA\ \det ected} \quad (2)$$

$$\text{F1} = 2 \text{ x } \frac{Precision \cdot Sensitive}{\text{Pr}ecision + Sensitive} \quad (3)$$

With simulated datasets, the ground truth of circRNAs of each sample is used for the evaluation. For the Arabidopsis thaliana experimental datasets, due to the lack of validated circRNAs of the sample, we collate the method results with the circRNAs of Arabidopsis thaliana reported from plantCircBase (Chu et al., 2017).

3. RESULTS AND DISCUSSION

3.1. Impacts of the read-length variation

Table 2 presents the influence of the variation of read lengths in CLIP-Seq on circRNA detection performance using three wild-type simulated datasets. For the trimmed samples, the read trimming can reduce the information of the potential back-splicing junction (BSJ) supporting reads, consequently reducing the performance of all methods in comparison to the results of the original sample. With CircExplorer, the trimmed samples reduce almost all detected circRNAs from the untrimmed sample (from 2040 in Sample O to 0/0/76 in Sample A/B/C), making severe drops in sensitivity. UROBORUS detects the least circRNAs in Sample O (1193 circRNAs found); however, unlike CircExplorer, this tool remains approximately 1/3 of the circRNA detected in trimmed samples. All remaining methods report the top number of circRNAs across all samples. In general, both sensitivity and precision are significantly decreased by the read-length variation and proportional to the level of loss of information. This also makes the F1 score follow the same trend, decreasing in samples C, B and A in the same order. Two CLIP-Seq methods Clirc and CircScan generally outperform the RNA-Seq methods. Among RNA-Seq methods, only Find_circ2 is comparable with the CLIP-Seq methods.

In summary, various read lengths in one sample have considerable effects on all detection methods, and more seriously in CircExplorer and UROBORUS. In this simulation study, Clirc obtains the best performance across all data samples.

Table 2. Performance on untrimmed/trimmed datasets. (CE: CircExplorer, FC2: Find_circ2, UR: UROBORUS, CL: Clirc, and CS: CircScan)

Method	Untrimmed Sample O				Trimmed Sample A			
	#found	Sen.	Prec.	F1	#found	Sen.	Prec.	F1
CE	2040	0.227	0.869	0.36	0	-	-	-
FC2	4375	0.442	0.789	0.566	2257	0.172	0.679	0.274
CL	5393	0.552	0.8	0.653	3919	0.314	0.715	0.437
CS	4122	0.438	0.831	0.574	2705	0.22	0.724	0.337
UR	1193	0.132	0.863	0.228	461	0.037	0.707	0.07
	Trimmed Sample B				Trimmed Sample C			
	#found	Sen.	Prec.	F1	#found	Sen.	Prec.	F1
CE	0	-	-	-	76	0.006	0.75	0.013
FC2	2473	0.192	0.691	0.3	2702	0.209	0.689	0.321
CL	4105	0.332	0.722	0.455	4203	0.339	0.719	0.461
CS	2893	0.236	0.727	0.356	3050	0.249	0.727	0.37
UR	530	0.042	0.702	0.079	609	0.049	0.724	0.093

3.2. Impacts of the mutations

The impact of mutation on detecting performance is analyzed by comparing the performances of the mutated samples vs corresponding wild-type samples. Figure 1 (a) presents the shift of sensitivity and precision between mutated and wild-type versions of sample O. Considerable but consistent drops in precision can be witnessed among five reported results (8%-12%), while corresponding sensitivities also decline but with more diverse amplitudes of two distinctive groups (3%-6% from CircExplorer/UROBORUS and 10%-12% from CircScan/Find_circ2/Clirc).

Three trimmed samples A, B and C observe a similar trend; however, the magnitude of change is narrower, see Figure 1(b). Specifically, the precision of most methods, except CircScan, decreases. The precision loss is approximately 1% in most instances of Clirc and Find_circ2; while precision from CircScan is mostly stable in Sample B and Sample C, and even increases slightly in Sample A (0.5%). For sensitivity, a downward trend appears with Find_circ2, Clirc and CircScan, with around 1.2%-2% decreases. Both sensitivity and precision of UROBORUS remain in all instances. CircExplorer only reports circRNAs in Sample C with a similar trend to UROBORUS result.

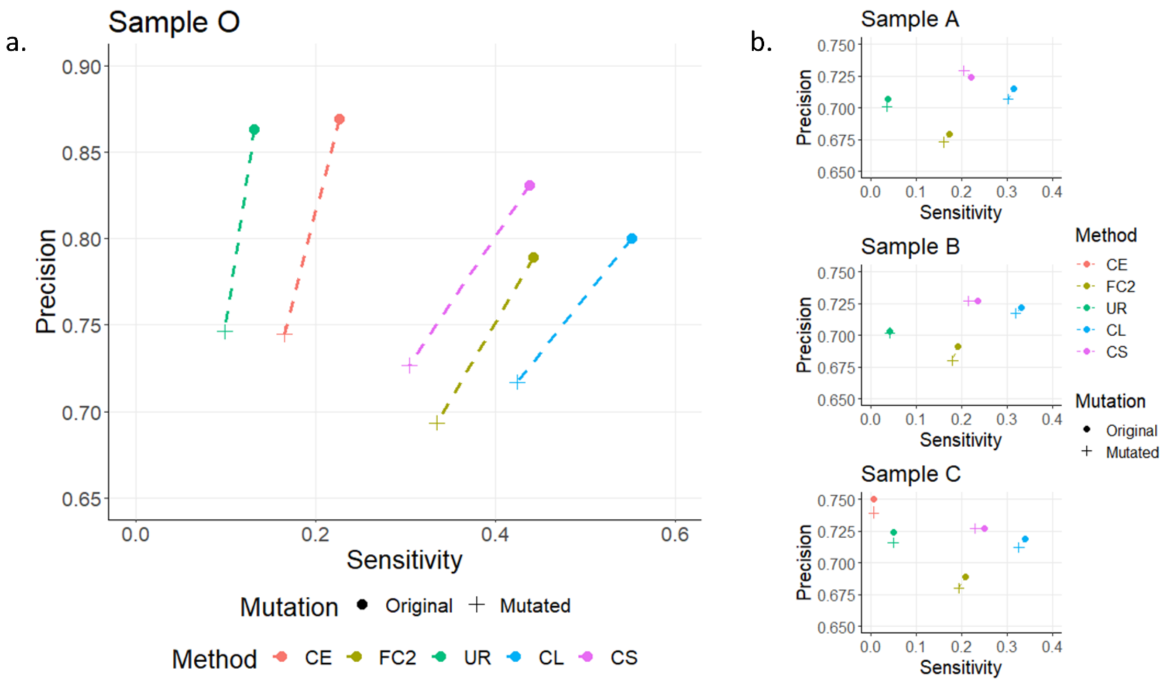

Figure 1. Impact of mutation on Sensitivity and Precision in sample O and three trimmed samples A, B, and C. In each plot, a dot denotes the performance on the wild-type version of a sample, while a cross denotes the performance on the corresponding mutated version of the sample. (CE: CircExplorer, FC2: Find_circ2, UR: UROBORUS, CL: Clirc, and CS: CircScan.)

3.3. Arabidopsis thaliana experimental datasets

Table 3 shows the detection results of eight CLIP-Seq samples from two studies about Arabidopsis thaliana, with six iCLIP samples and two HITS-CLIP samples. The results of CircScan and UROBORUS are missing due to the crash of Bowtie2 alignment. Since there is no "ground truth" information on circRNAs as in the simulation study, we validate the circRNA candidates by using a "golden set" of circRNAs of Arabidopsis thaliana which are extracted from PlantCircBase (Chu et al., 2017). Most detection methods report a tiny number of circRNAs, except Find_circ2; and most of the reported instances do not appear in the "golden set". Only two samples of 7GFP_LL24 and 7GFP_LL36 show PlantCircBase's circRNA with a consistent result from Clirc. Find_circ2 reports a vast number of circRNAs; however, most results cannot be found in PlantCircBase, so highly false positive, which is consistent with the previous study (Nguyen et al., 2022).

Table 3. Performances on Arabidopsis thaliana datasets.

Protocol	Sample	Method	#found	in "golden set"	Protocol	Sample	Method	#found	in "golden set"
iCLIP	7GFP_LL24	CE	0	0	iCLIP	GFP_LL24	CE	0	0
		FC2	543	1			FC2	27	0
		CL	36	1			CL	2	0
	7GFP_LL36	CE	48	2		GFP_LL36	CE	0	0
		FC2	0	0			FC2	30	0
		CL	168	5			CL	1	0
	RQ_LL24	CE	0	0	HITS-CLIP	SRR517963	CE	0	0
		FC2	47	0			FC2	1305	0
		CL	3	0			CL	97	0
	RQ_LL36	CE	0	0		SRR517964	CE	0	0
		FC2	14	0			FC2	49	0
		CL	2	0			CL	11	0

4. CONCLUSIONS

In this study, we assess the effects of some CLIP-Seq data's characteristics on the performance of five circRNA detection methods and investigate the results of these methods in several plant datasets from Arabidopsis thaliana. We consider the impact of heterogeneous short read length and particular mutations observed from CLIP-Seq techniques by simulation. For plant CLIP-Seq data, we collect eight samples from two different CLIP-Seq techniques to check for the ability to detect circRNAs. The result shows that both read-length variation and mutations can significantly impact the precision and sensitivity of the tools. The CLIP-Seq method Clirc performs well against other methods in both simulated and real datasets. For the Arabidopsis thaliana experimental datasets, there is little overlap between detected circRNAs and the "golden set" from the public database, which is consistent with the previous benchmark study (Nguyen et al., 2022). A larger sample set and independent validation work are needed for validation, which is out of the scope of this study.

5. ACKNOWLEDGEMENT

Not applicable.

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ICT BASED PARTICIPATORY WATER GOVERNANCE SYSTEM TO IMPROVE PERFORMANCE OF CANAL IRRIGATION SECTOR IN INDIA

Deepak B. Hiremath[1] and Sanjay Chaudhary[2*]
1) School of Engineering and Applied Science, Ahmedabad University, India
deepak.hiremath@iet.ahduni.edu.in
2) School of Engineering and Applied Science, Ahmedabad University, India
sanjay.chaudhary@ahduni.edu.in

ABSTRACT: In India, canal irrigation is one of the important sectors of irrigation. The Planning Commission of India in its report in 2017, states that over 2950 Billion Rupees of investment by the government in Medium and Major irrigation scheme in infrastructure development across the country. Even after these enormous investments into the sector there has been a growing dissatisfaction among the stakeholder especially the farming sector due to the disarray in services provision. The paper seeks to find the reasons for this growing dissatisfaction and problems propose a solution. The main cause of the this is lack of communication and transparency among the stakeholder viz. Water User Associations (WUA), Irrigation Department (ID), and finally the farmers on matters such as quantity and distribution of water in the irrigation system especially between head and tail. There has been no feedback mechanism to ensure water has been delivered to the farmers or the maintenance of the infrastructure provided to them. On the other hand, there is no accountability if payments have been made by farmers to the Irrigation Department. Lot of money and efforts has been spent in developing the infrastructure, but the service aspects have completely been ignored. This can also be attributed to the lack of manpower in the sector. The government has started the digital India initiative to bring transparency into various sectors. This paper tries to bring out how ICT can help to bring back transparency, accountability and trust into the system by proposing a water governance farmer centric model which incorporate crowd sourcing technics to minimize the communication gap between the stake holders. The system also addresses one of the major concerns of the Irrigation Department of estimating the water requirement given the number of farmers willing to take-up water from the canal system for a particular season well in advance so that the Irrigation Department can plan more accurately.

Keywords: *Service Provision, Information and Communication Technology (ICT), Canal Irrigation, Water Governance System, Water User Association (WUA).*

1. INTRODUCTION

In India, where most rainfall is received between June-September (Southwest monsoon) and October-December (Northeast monsoon), irrigation sector assumes importance for both agriculture and drinking water purposes. The government has spent over Rs. 2950 billion on infrastructure development of Major and Medium irrigation projects Planning Commission (2011). These investments have helped India to expand the Major and Medium Irrigation System. A detailed analysis of the irrigation sector reveals that its performance falls far below expectation. The sector suffers from many problems including poor maintenance, deteriorating physical structures, low recovery of project costs, underutilization of created potential, tail end water deprivation, uncontrolled water delivery, soil salinity, siltation, water logging, disintegration of indigenous irrigation institutions and most importantly poor quality of irrigation services.

Dr. Sanjay Chaudhary, Professor and Dean of Students, School of Engineering and Applied Science, Ahmedabad University, GICT Building, Central Campus, Navrangpura, Ahmedabad, Gujarat 380009

The revenue receipts generated by water sales were not able to even cover the operational and maintenance (O&M) costs, Meinzen-Dick et al. (2002).

Almost 70 percent of the budget was spent on salaries of employees which left only 30 percent for actual repair and maintenance of infrastructure, Swain et al. (2008). During the past two decades, many of the states have undergone numerous reforms to address these issues and improve the system's performance. Under these reforms, emphasis was placed on facilitating farmers' participation in irrigation management (Participatory Irrigation Management), both by under externally aided irrigation development and agricultural intensification programs through state government initiatives, Planning Commission (2011). This led to the formation of WUA. The International Water Management Institutes defines Water User Association as *a non-profit organization that is initiated and managed by the group of water users along one or more hydrological sub-systems regardless of the type of farms involved. These are the potential members of the WUA, who pool financial, material, technical and human resources for the operation and maintenance of the irrigation and drainage system within their jurisdiction for the benefit of all the members.* States have laid emphasis on decentralization of water management and empowering water users to set up WUAs. The functions of the WUAs are to take over the responsibility of O and M of irrigation system at the distributary level (tertiary level), distribution of water and collection of water fees from the users Phadnis et al. (2012). The amendment of the National Water Policy in 2002, National Water Policy (2002) led to setting up of many WUAs across states. The general perception of the government in many states was that devolution of powers through formation WUAs was the only way to improve the irrigation systems across the country in terms of O and M as well as improve revenue generation. This view was supported by NGOs, policy makers and funding agencies. Keeping these objectives in mind more than 63167 WUAs covering around 14.62 million hectares were formed, Nair (2012).

The reason for underperformance of the canal irrigation sector primary focuses on "Vicious Circle" of irrigation systems, which states that irrigation charges proposed on the farmers are very low, as a result cannot even cover the O & M costs of the schemes. This leads to overall poor performance of the system especially in service provision sector resulting in dissatisfaction of farmers. As the farmers are dissatisfied with the services provided by the department, they end up paying even lower fees or do not pay at all. This widens the gap for the financial resource required for O & M and leads to deterioration of infrastructure creating a vicious circle of low-cost recovery, poor maintenance of infrastructure, inadequate and unreliable water supply, inefficient and corrupt institutions, unwillingness of the farmers to pay due to poor services and low-cost recovery. Another reason why the cost of recovery is very low is, the irrigation fees charged by the government in many states is very low. The cost of recovery is greater than the cost of the fees itself. Various studies across India on the functioning of WUAs have concluded that most problems arose from the devolution of powers which caused flaws in the functioning of WUAs current systems. The notion that participatory irrigation management (PIM) was the best resolution to tackle the present problems of the irrigation sector seemed to be a misconception. One can assume at best, that decentralization of irrigation systems through establishment of WUAs have produced mixed outcomes, Swain (2008), Parthasarathy (2000), Parthasarathy (2011), Pant (2008), Bhatt (2013), Reddy et al. (2005), Marothia (2005). The only effective solution to the problem is improving the recovery of irrigation fees from farmers to improve the overall effectiveness of the system, Malik (2014).

From the above discussion there are two major problems which need to be addressed

1. How to break the Vicious circle within the existing policy paradigm?
2. To bring in transparency and accountability among all stakeholders.

It is evident that the irrigation sector is facing a major crisis when it comes to service provision of irrigation water, and it appears that improving this sector is the only solution to break the circle. Currently the government is encouraging the use ICT applications in many of its sectors, to bring improvement in service provision facilities by increasing the efficiency and simultaneously bringing in accountability and transparency into them. Surprisingly, in the irrigation sector there is hardly any evidence in this regard. Information and Communication technology can play a vital role in the following fronts of the irrigation sector:

- Monitoring the WUA (water distribution)

- Improving communication between various stakeholders
- Transparency
- Collection of Irrigation Service Fees
- Operations and maintenance
- Fund allocation
- Feedback/ grievance redressals system

This paper tires to develop a farmer centric water governance system, targeted to improve the service provision of the canal irrigation system in respect to the above-mentioned fronts by bringing in more accountability and transparency between the various stakeholders viz. WUA, Irrigation Department (ID), and farmers. The proposed system integrates various services like collection/payment/tracking of irrigation service fee, information dissemination like alerts on water delivery, crop recommendation, weather alerts and feedback mechanism for farmers using crowd sourcing techniques. The system is designed to help advance estimation of water requirement for the Irrigation Department and reduce the dependency the on paper trail and manpower which the sector is already suffering from.

2. CURRENT SCENARIO ON USE OF TECHNOLOGY IN THE CANAL IRRIGATION SECTOR

The use of ICT in irrigation sector for service delivery is mostly applicable in the Western economies like USA, European countries, etc. where the average land holding are between 300-400 hectares which are very different from Indian context. In Spain, about 70 percent of the water resources are managed with the help of ICT based technology. Various technologies which are used to improve the performance of management tasks in WUAs are Geographical Information System, Web and mobile applications, Supervisory Control and Data Acquisition System and Decision Support Systems. The key enhancements in WUAs management performance were a more equitable and efficient allotment of water, water traceability, and increasing the management transparency, which in turn lead to decrease in vandalism and conflicts. The web and mobile based services helped farmers participate more into the water management process, Soto-Garcia et al. (2013). In Egypt, the Korean Trust Fund helped in setting up of a management information system (MIS), which effectively enhanced the efficiency of planning and operation of irrigation and drainage services. The idea was to benefit poor small land holding farmer by providing reliable irrigation services. ICT use in the canal irrigation sector in India is still at a nascent stage. The few projects which have been initiated are at pilot stages, which are yielding mixed results. Majority of the projects in India are focused on automation of canal irrigation systems. For example, the Chambal project in Madhya Pradesh funded by UNDP and Khadakwasla project based in Maharashtra, the pilot project conceived as one unit, integrating telemetry, communication, computers and decision support software to improve system operations. It covers the operation of the New Mutha Right Bank canal and its distributaries, Mandavia (1999). The Rajasthan Agricultural Drainage (Rajad) project is a pilot project where four remote monitoring sites have been selected. Data is transmitted to the CAD office for monitoring and control. A head regulator gate on one of the distributaries which was of the slide type and manually operated has been replaced by an automatic gate. The pilot project is implemented by CAD authorities of the Chambal and Indira Gandhi Naher projects in consultation with Canadian experts, Mandavia (1999). The Sardar Sarovar project in Gujarat, the Narmada canal conveyance and delivery system of up to 8.5 cumecs designed discharge capacity has been planned and designed to be operated on the controlled volume operational method with remote monitoring and control system for its operation, Mandavia (1999). The Tungabhadra project in Karnataka, executed on the right bank high level canal up to the Karnataka-Andhra Pradesh state border. In this task, four agencies are associated and have executed the pilot project Mandavia (1999). Andhra Pradesh has used

Geographic Information System and Information Technology Enabled Services ITES for facilitating WUAs in preparation of participatory action plans and day to day availability of canal water and planning its use. The Canal Network Flow Monitoring System (CNFMS) captures the water release data from the designated mobile at regular intervals that are sent by SMS by the designated field engineer and stored in the central database server, Burton et al. (2014). Besides Maharashtra, where the State Water Resource Department in collaboration with WIPRO has designed a web portal, which allows online bill payment in addition to offering information on various schemes by the government. There is hardly any evidence from any other state in India that has even come close in developing citizen-based service delivery systems for the farming community. Even that system is more concerned in helping the Irrigation Department track real time water availability status of various reservoirs and dams cross the state, Hiremath (2016). An SMS based information delivery system was started at Visnagar district, Dharoi Dam project by Development Support Centre, Ahmedabad provided farmers information related to number and schedule of water release. In Madhya Pradesh, the engineer-in-chief had complied mobile numbers of 4000 farmers who were situated in the tail end of various canal irrigation systems. Random calls would be made by engineer-in-chief to the farmers to verify if water reached their fields, Hiremath (2016). From the above examples, apart from a few exceptions; majority of the focus is on automation of canal/dams, mostly remote monitoring of water resources in dams or automated gate control. Use of technology for citizen centric models is hardly evident in the country. Apart from SMS and manual call based examples there has not been much integration of technology for monitoring, feedback and water governance based example. Maharashtra started a water portal which gives option for online payment of fees, provides information about the various schemes and addresses grievances but there is hardly any evidence of the usage. The portal is very generic which caters to the WUA more than the water users (citizens) as such. There is no evidence of decision support system for farmers' benefits and live monitoring of whether water is reaching the farmers field or not.

3. OBJECTIVES

The following objectives which were kept in mind while designing the governance system:

- Design an ICT based water governance system that improves accountability, transparency and services to all its stakeholders viz. WUA and Irrigation Department.
- Help the Irrigation Department by estimating the potential water requirement in advance for a particular season.
- Develop a feedback mechanism for the water users so that the WUAs and Irrigation Department can resolve issues faster and precisely.

4. WATER GOVERNANCE SYSTEM: METHODOLOGY AND DESIGN

The primary actors involved in the system are viz. WUAs, Farmers, Taluka, District, State Irrigation Department, State and Central government and Funding Agencies. This model is based on a hub and spoke model of technology-based project implementation. The Hub which is the central unit of the system is controlled by the various Irrigation Department at district/state/central level. The spokes are the WUAs level which help the hub for implementation of various functions such as collection of irrigation service fee, registration of farmers (members), help in estimation of the total water demand based on cropping pattern and area under irrigation under their command. The WUAs also help in conflict resolution and maintenance of canals. A group of WUAs will be under command of a taluka or district which they lie in. The State governments can monitor the performance and functioning of both WUAs and the lower-level irrigation departments. This system interface is through web and mobile based applications as illustrated in Fig. 1. The core of the system consists of functionalities such as member registration system, irrigation service fee collection, information dissemination system, water requirement and fee estimation, and grievance, monitoring and feedback system. The system gives provision to extend its present scope to additional components such as crop recommendation system, fund allocation, resourcing allocation etc. The farmers/ water users can register themselves using unique member ID's; where all the information about the farmer regarding farm details and crops are procured and store in a database which help creating a centralised repository. This will help in improving the water estimation for the irrigation department. The water estimation process can be integrated with various hydraulic water distribution models to help automate the whole process. The information dissemination system helps farmers get information about the irrigation schedule and is integrated with the meteorological department database to help provide weather related information to the farmers. The various modules and their interactions are elaborately discussed in the subsequent sections.

4.1. Member Registration

Registration of water user into a common database is one of the primary goals of the system. An individual unique ID for identification purposes is required. In the proposed system, after surveying about 150 farmers along Almatti Right Bank in Bagalkot district, 100 percent farmers had Aadhar card (Unique Identification Number for citizen of the country). The proposed system uses the existing Aadhar based technology for unique ID registration at the WUA. This will lessen the requirement of registration and help to link various other details like bank account details, crops grown, land owned/leases into the system. Aadhar can be scanned to directly access the system database for the WAU or Irrigation Department to know the pending dues and other irrigation related details of the farmer/member.

4.2. Water Requirement and Irrigation Fee Estimation

After discussion with officials at Dharoi irrigation scheme in Gujarat and Almatti Right Bank irrigation scheme in Bagalkot district of Karnataka, one of the primary concerns of the Irrigation Department was their inability to estimate the total seasonal water requirements. This was because farmers tend to ignore giving information regarding their water demands, about crops and total area they intend to cultivate for the season. The system will partially be able to resolve this matter. During the registration, the farmer details about the crop and area are taken into consideration at the beginning of the season. The total estimated land along with crop details from each WUA will be made available to the Irrigation Department for that particular command area. This will help the department get a better estimate of water requirement across the command area in much shorter time frame than the conventional method of paper based estimation and verification. This is mostly possible as most states in the country collect Irrigation Service Fee (ISF) at the beginning on the season. Once the land requirements are in the database it is possible to approximately estimate the ISF collection from a particular area for a particular season based on farmers' registration details at the time of payment of ISF and historical farming patterns. A part of the problem can be addressed using various simulation models which the Irrigation Department uses to calculate water requirement based on various factors like water level in the dam and area to be irrigated in the command area, length of canal etc. using existing models such as integrated reservoir-based canal irrigation model (IRCIM), Optimal Allocation of Canal Water Through OPTALL Model, etc. Additional features can be added to the existing frame like prediction models for scenario analysis like Soil and Artificial Neural Network Model (ANN), Water Assessment Tool (SWAT), etc., based on forecasts given by the meteorological department. The system can give various scenarios, based on various rainfall estimates, which can help the farmers and irrigation departments take decisions on what to grow and how much of water can be provided to the farmers under various rainfall scenarios.

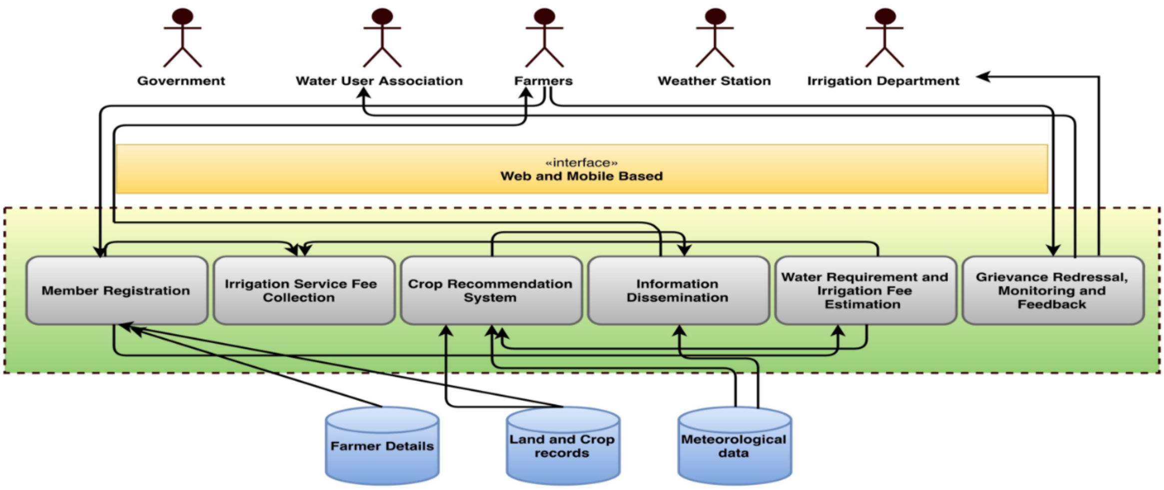

Figure 1. System Architecture

4.3. Irrigation Service Fee (ISF) Collection

A major problem faced by both WUAs and the Irrigation Department is tracking and collection of payment of the ISF from the farmers. The ISF collected as compared to the estimated by the government is only 14.6%, 3iNetwork (Inde). (2011). The two reasons which can be attributed are low irrigation fee and second low recover. The lack of collection of irrigation service fee is a major reason for the irrigation sector to under performance. One of the biggest problems is the paper trail in collection ISF from farmers. In states like Gujarat and Uttar Pradesh the assessment of ISF is done by the Irrigation Department and collection is done by the Revenue Department and in states like Maharashtra and Madhya Pradesh assessment and revenue collections are done by the Irrigation Department with about 6-10 levels of bureaucracy needed to clear the assessment and collection, Nair et al. (2012). The system once incorporated can reduce this paper trail along with reduction in leakage of ISF during collection by increasing transparency. There is a huge bureaucratic paper trail required for irrigation service fee collection and assessment by Irrigation and Revenue Departments. Digitalization of this process can reduce both time and paper trail drastically. Bank account linkages and other payment gateways/payment options will be made available to stakeholders. The system, as explained in the previous section is linked through Aadhar which acts as a unique identity. Once the farmers are registered into the system, the WUA and the ID can track they payments made by the farmers and their dues.

4.4. Information Dissemination System

Absence of or poor communication from Irrigation Department about water release schedules/dates, quantity and frequency of water supply per season and maintenance work updates is another key problem for farmers and WUAs. SMS based updates system is one important way to address this issue. The system provides the Irrigation Department and WUAs amenities to send SMS reminders to its members. Apart from the primary use SMS based integrated system can be used by the WUA's and Mete-orological department to provide relevant information like crop recommendations and weather update.

4.5. Grievance Redressal Monitoring and Feedback System

The lack of feedback mechanism from farmers is another issue. There is hardly any system in place where the farmers can lodge official complains related to irrigation issues. Many times, farmers are either at the mercy of the Irrigation Department officials or WUAs to address the complaint. Even if complaints are lodged there is no process to track if the issue have been solved. There are many complaints related to water distribution especially the head and tail issues of a command area. There is no definitive method to trace whether water is delivered to the farms in the tail end of canals. A feedback/grievance system integrated into the current system helps identify problems farmers face and helps the WUA and Irrigation Department to target their efforts to solve the issues promptly. This will also help in increase reliability of the system and help concerned government authorises to know the status of each underlying departments performance. The proposed system integrates crowd sourcing techniques to solve this issue. Crown sourcing is defined by Oxford dictionary as follows: Crowd sourcing is "*the practice of obtaining information or input into a task or project by enlisting the services of a large number of people, either paid or unpaid, typically via the Internet*." The system consists of a mobile based SMS application server to record the feedback of the farmers in terms of water delivery. The day water is released, the farmers in a particular area will send feedback by just typing 0 for yes for water being delivered and 1 for no in case water has not been delivered. The system will track the area which the farmer has send the response from (information related to location and address is stored in the database at time of registration along with mobile number), Fig. 2. If, there are large number of responses from an area about water being not delivered, corrective action can be taken immediately. Similarly, complaints related to maintenance and lack of delivery of water can be tracked easily in this system. Fig. 3, illustrates lodging an online complaint of farmers directly at the WUA and how their complaint can be tracked using the system. This is also applicable for farmers who cannot or are not able to file complains directly though mobile devices or do not own mobiles though their Aadhar numbers. A specialized app isn't designed for this purpose as most farms which from the ground level studies illustrated that they use mostly very simple mobile phone mostly for the purpose of communication and do not have internet based services.

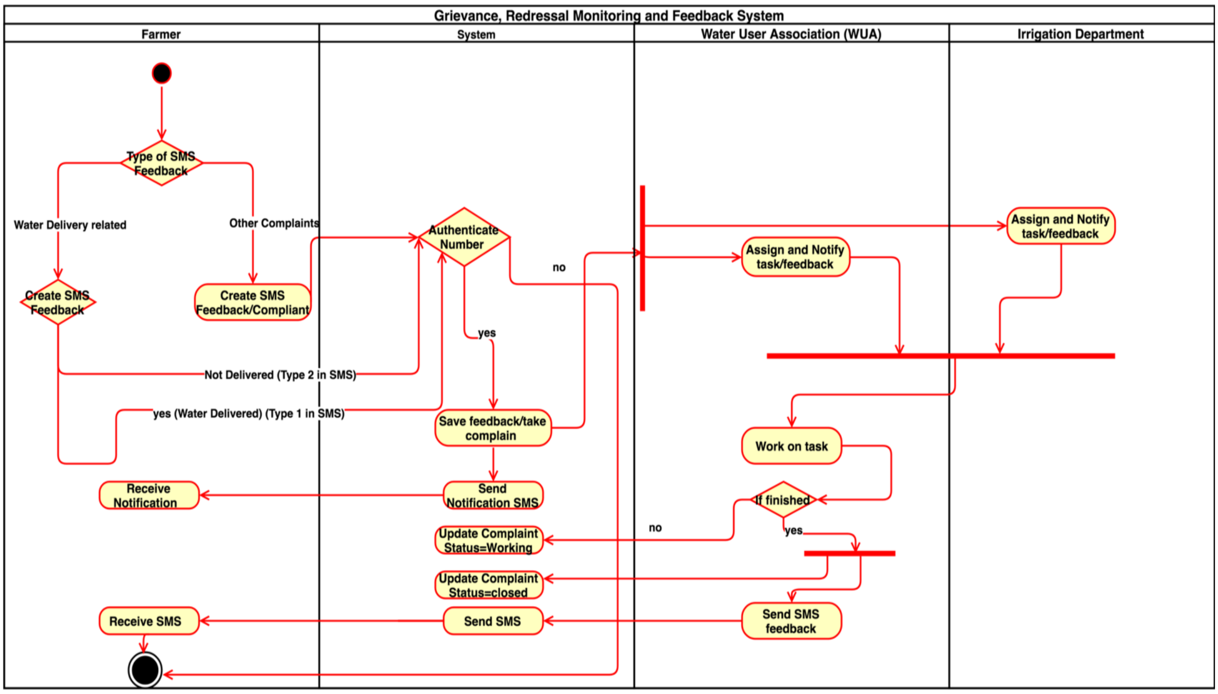

Figure 2. Grievance, redressal, monitoring and feedback system (SMS Based)

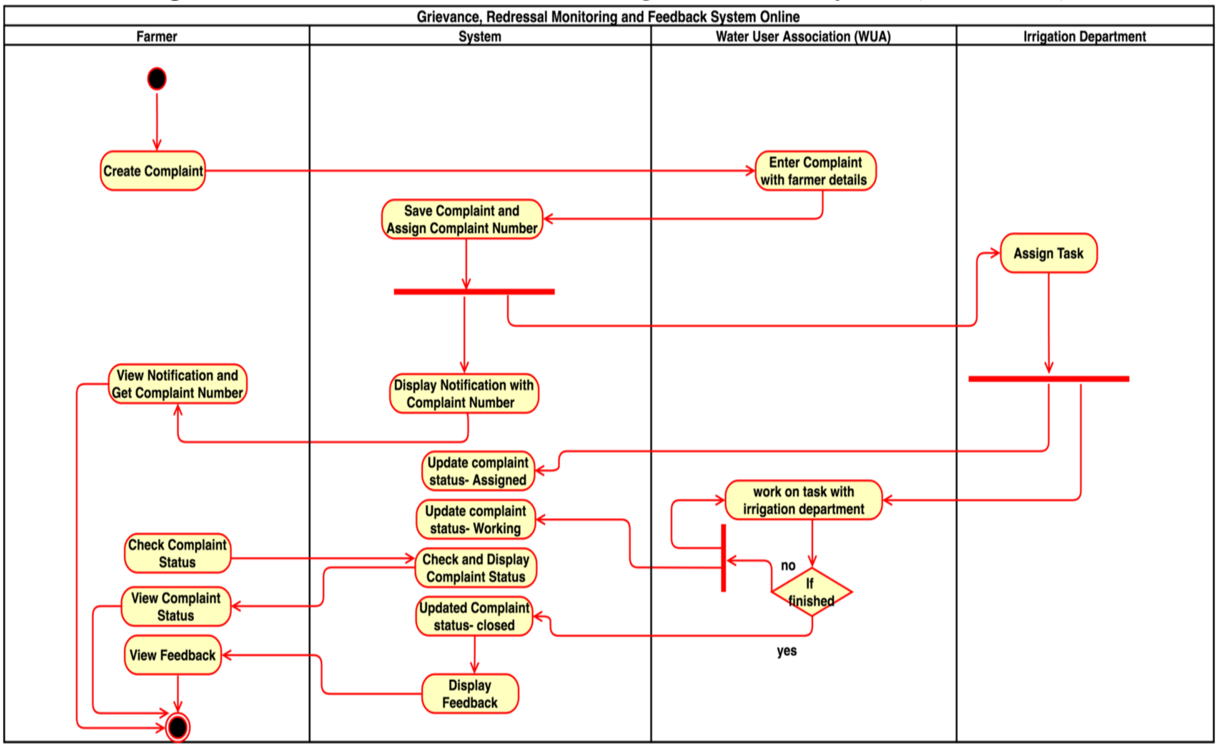

Figure 3. Grievance, redressal, monitoring and feedback system (Online)

4.6. Additional Modules

Resource Allocation

Resource allocation in terms of expansion of canal command area in order to increase the irrigation potential is one of the objectives of the WUAs. The WUA can propose to Irrigation Department, areas where the canal irrigation potential can be increased. This can be done by first mapping out irrigation potential created area vs. irrigation potential utilized. Various other water sources in the command area like borewells, tube wells, open wells, tanks, etc, will also help the Irrigation Department and government planners to decide which areas are high priority areas for expansion of canals. Spatial data can be used for mapping though remote sensing and GIS.

Fund Allocation

Several central government and state government funds are allocated for various purposes to WUAs, and district irrigation departments to implement various projects such as maintenance of canals in the command area under the control of the WUA. Tacking and distribution of these funds become essential. The centralised governance system can help in distribution and allocation of funds to WUAs directly instead of the tedious process of WUAs going to the Irrigation Department officials. The government can keep a tract of the work progress and how and where exactly these funds are being utilized.

5. ICT APPLICATION

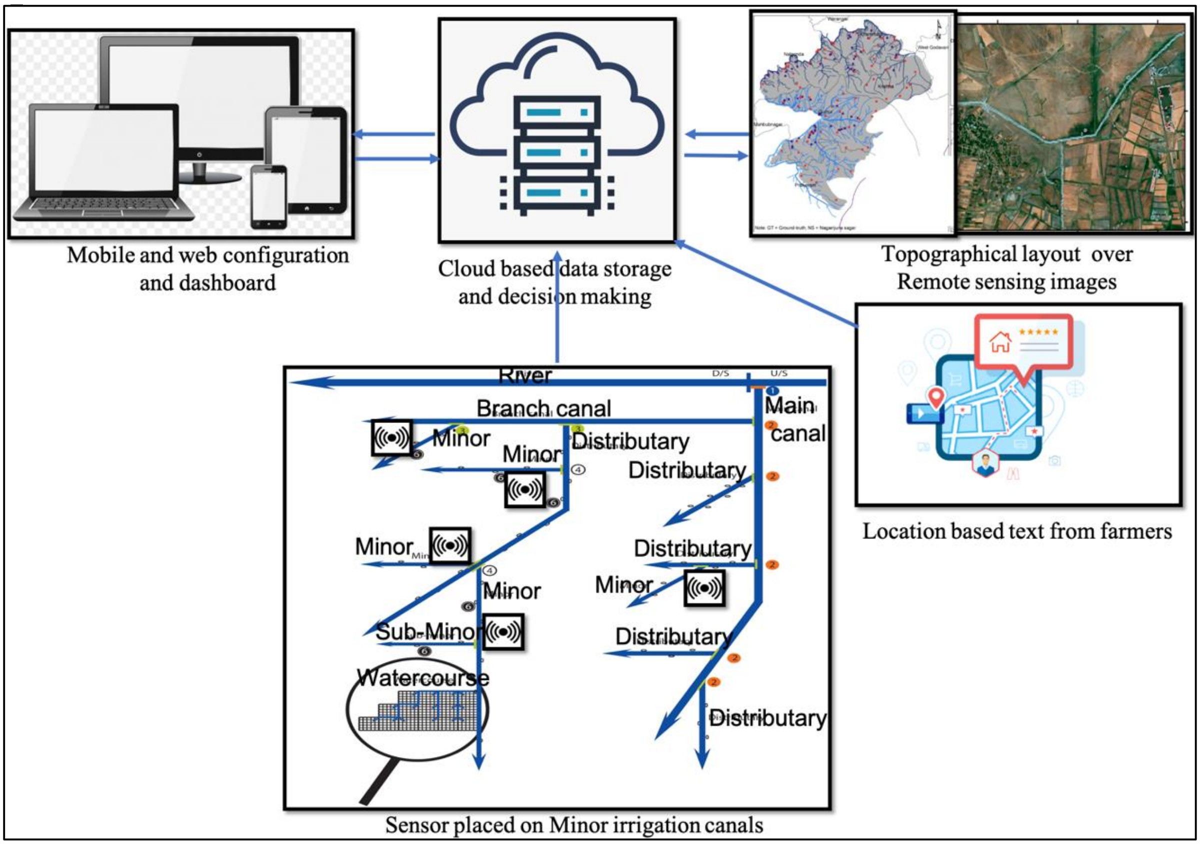

Figure 4. ICT Implementation

The system implementation must take part at various levels across the canal irrigation system. The process of water detection and dissipation needs to be automated. Even though most canals have sensors across the main water outlets (main branch and distributaries) to measure the flow, most of the minor branches of the canal system across the country do not have them. Water flow sensor needs to be installed at the minor branch of the canal which are under the WAUs control. The agriculture farms belonging to the farmers can be marked in the command area to which the canal supplies water. The territory of each WAU is also marked. This is done by overlaying on topographic sheet using GIS to pinpoint the exact location of the water supply across the area. Existing topological maps of command area of the canal are used for this purpose. The command area of the canal are georeferenced based of features viz. canals, roads, farms drainages, WUA boundaries and other water bodies which are converted to GIS shape files and are overlaid on ground images of the area. Canal network data structures are important to assess the water distribution and reach to various farms. Various canal IDs are assigned to branches of the canal. The sensors location is also overlayed on the map. Similarly farm id will also be provided to help track the distribution. The various farmers land will be linked to the mobile numbers of the farmer and instant feedback regarding the same can be recorded. This will help to figure out the water distribution in the area. The database which is underlying the GIS application is also used to capture other application information such as payments and feedback made by the farms which is in the command area (Fig.4).

6. CONCLUSIONS

The aim of the research is to try to break the vicious circle of poor performance of the irrigation sector by technological interventions. The primary goal is to improve service delivery to farmers by involving all the major stakeholders (Irrigation Department, WUA and farmers). The proposed design is an attempt to partially solve existing problems by focusing on improving service delivery. The proposed water governance system with the help of crowd sourcing techniques will bring in accountability into the existing system by its monitoring and instant feedback processes related to water delivery services. The system addresses one of the major concerns of the Irrigation Department of estimating the water requirement given the number of farmers willing to take up water from the canal system for a particular season well in advance so that the Irrigation Department can plan more accurately. The model is an attempt to incorporate information and communication-based water governance application in the irrigation sector so as to improve the performance especially service delivery sector which has been totally ignored due to many reasons including lack of manpower. The applications can help in improving the communication between various stake holders and bring in more transparency especially between the farmers and the Irrigation Department. The digitalization is mainly focused at the WUA level as it is the institutional interface between the farmer and Irrigation Department (Government).

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USING IMAGE RECOGNITION TECHNOLOGY FOR PADDY RICE (*Oryza sativas* L) SEED GERMINATION TESTING

I-Cheng Chen[1, *)], Jo-Ping Cheng[1)], An-Qin Xu[2)], Shi-Jie Luo[2)] and Kuo-Yi Huang[2)]

1) Taiwan Seed Improvement and Propagation Station. COA, Taiwan
ICChen@tss.gov.tw
2) Department of Bio-Industrial Mechatronics Engineering, National Chung Hsing University, Taiwan ROC.
* Corresponding author

ABSTRACT: This study presents a novel machine vision-based automatic sorting system for paddy rice seedlings. The system comprises an inlet–outlet mechanism, machine vision hardware and software, and a control system for sorting seeds according to quality. The proposed method uses an artificial neural network classifier to estimate the geometry of seedlings and to classify seedlings as “good” or “not good” (NG). The system shows 86.0% consistency from 6,335 seedling images, but 11.6% of the seedling images could not be identified correctly and needed to be re-checked.

Keywords: *Image recognition, germination, paddy seeds.*

1. INTRODUCTION

In 2018, the official seed testing laboratory of Taiwan processed more than 1,500 seedlings. Paddy Rice (*Oryza sativas* L) was the main crop tested and the seed germination tests were conducted manually by well-trained inspectors. Since the tests are time and energy consuming and the results may also be affected by fatigue, an image recognition system has been devised to assist in the seed testing task.

2. MATERIALS AND METHODS

2.1. Materials

A new kind of container was designed for growing the seeds as shown in Figures 1 and 2. One seed is put in each cell, and it is covered with an acrylic sheet. The seedlings are germinated for 10 days (first count date for domestic testing) at a growth chamber temperature of 20-30^{0}C.

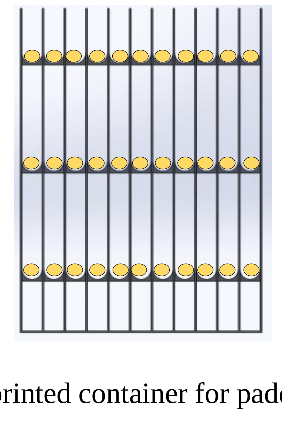

Figure 1. The 3D- printed container for paddy seed germination.

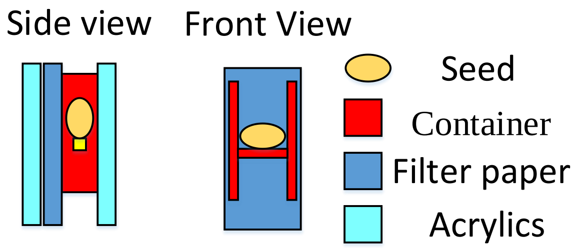

Figure 2. Seed in each schematic diagram.

2.2. System structure

The device consists of a platform scanner, an Arduino, and a personal computer (Figure 3).

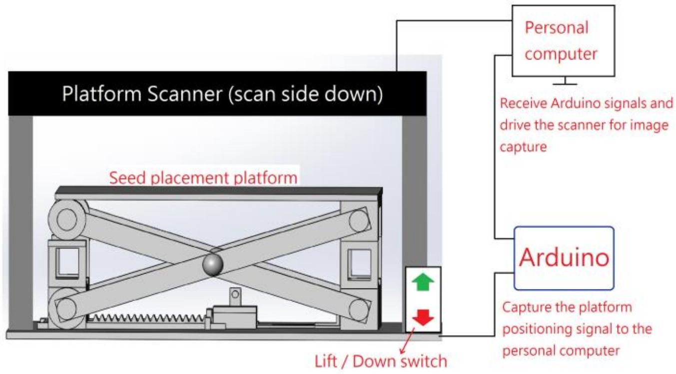

Figure 3. The image recognition system for paddy rice seedling evaluation.

2.3. System operation flow chart

System operation is as follows. The seed growth plate is placed on the lift platform. The Up button is pressed to raise the platform to its operating position. The Arduino sends a scanner start signal to the control system after the platform has reached the anchor point, and the system starts the image capture process. After image capture has been done, an identification routine is used to recognize the seedlings. After the seedlings have been identified, the drop button is pressed, moving the platform down, and the seed growth plate can be removed. This identification process is repeated for each set.

2.4 Classifier

The computer program analyzes the gray level of the R/G/B layer of the raw image. It sorts the raw image into seed, root, shoot and coleoptile (Figure 4). In this system, the artificial neural network classifier recognizes four paddy seedling features: root length, root width, shoot length, and shoot curvature. These four selected characters were used to check the performance of the artificial neural network classifier using 4,494 recorded seedling images. By 2018 a total of 6,335 seedling images analyzed by the computer program had been checked against the results obtained by 3 trained analysts.

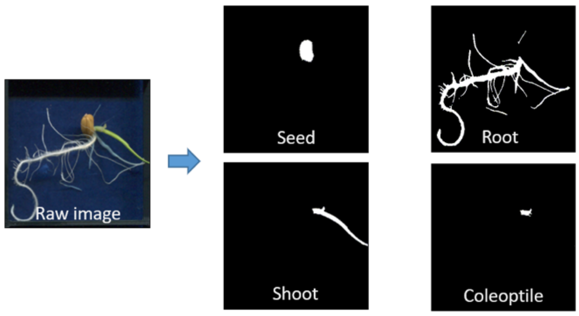

Figure 4. The seedling image features

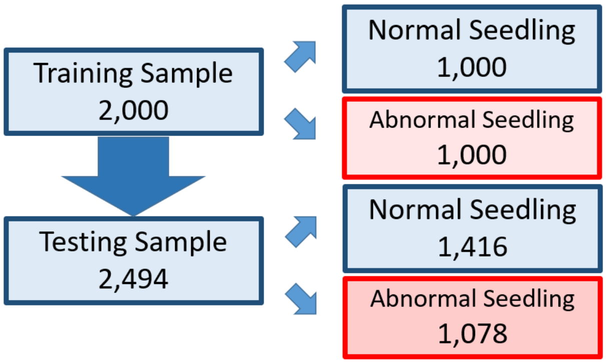

Figure 5. Seedling images for training the artificial neural network classifiers.

3. RESULTS AND DISCUSSION

Normal seedlings evaluated by a human expert and the computer program show similar values of four selected characters. Lower root length, root width and shoot length shows that the root and shoot system formation of abnormal seedlings are relative slow; high shoot curvature shows the shoot of abnormal seedlings are more crooked (Table 1). The consistency of 6,335 seedling images was 86.0% (Table 2). A total of 734 seedlings images (11.6%) were defined manually as having feature extraction errors (Table 3) which included feature extraction errors for the root, environmental errors and others (Figure 6).

Table 1. Root length, root width, shoot length, and shoot curvature of normal and abnormal seedlings identified by 3 trained analysts and the computer program.

	Root Length (mm)	Root Width (mm)	Shoot Length (mm)	Shoot Curvature
Normal Seedlings - Manual	28.58 ± 9.68	1.16 ± 0.51	16.27 ± 6.10	1.25 ± 0.39
Normal Seedlings - Computer program	28.84 ± 9.59	1.12 ± 0.51	17.82 ± 5.09	1.25 ± 0.28
Abnormal Seedlings - Computer program	5.63 ± 2.14	0.17 ± 0.01	5.43 ± 2.79	2.19 ± 1.10

Table 2. Consistency of evaluation by humans compared with that of the computer program.

	consistency - normal seedling	consistency - abnormal seedlings	consistency - all seedlings
percentage (%)	82.4	91.1	86.0

Table 3. The causes of feature extraction errors.

	Feature extraction error of root	Environmental error	Other
number	501	133	100
(%)	7.91	2.10	1.58

Figure 6. Some examples images with feature extraction errors.

4. CONCLUSIONS

The artificial neural network classifier processes seedling evaluation using four main characters, and shows 88.8% consistency compared with human evaluation. Analysis of 6,335 images showed 86.0% consistency, but 11.6% of the seedling images could not be correctly identified and needed to be re-checked. The correlation of germination rate between this system and reference method (BP) still needs to be confirmed. The utilization of space on the germination plate also needs to be improved.

5. ACKNOWLEDGEMENT

We would like to thanks the funding support for this project from Council of Agriculture, Executive Yuan, Taiwan (ROC).

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USING THE DNDC MODEL TO ASSESS THE IMPACT OF CLIMATE CHANGE ON CROP PRODUCTION AND GREENHOUSE GAS EMISSION IN CENTRAL TAIWAN

Jenn-Kuo Tsai[1)], Chong-Yi Liao[2)], Ming-Chieh Lin[1)], Chi-Ling Chen[1,*)], Chih-Feng Chiang[1)], Hung-Yu Dai[1)], Dah-Jing Liao[3)], Hong-Shu Wu[3)], Rei-Chang Wang[4)], Chin-Shing Chang[4)], and Ai-Hua Yang[4)]

1) Taiwan Agricultural Research Institute, COA, Executive Yuan (TARI), Taiwan
*Chiling@tari.gov.tw
2) Taichung District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan, Taiwan
3) Chiayi Agricultural Experiment Branch, Taiwan Agricultural Research Institute, Council of Agriculture, Executive Yuan, Taiwan
4) Tainan District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan, Taiwan

* Corresponding author

ABSTRACT: Global observations and the scale of recent disastrous events show that climate change is continuing and has enormous effect on the state and function of the agro-ecosystem. The aim of this study was to assess the impact of climate change on the production of rice and peanuts as well as greenhouse gas emission in central Taiwan using the DNDC (Denitrification-Decomposition) model. Calibration of the model was done using data collected from 16 agricultural sites from 2009 to 2021. Climate change was simulated under conditions of mean annual warming of 0.015 to 0.037°C and CO_2 concentration increases from 2 to 6 ppm over the past 10 years. The simulation results predicted that the yield of rice (variety: Tainan No. 11) would show a gradual annual increase in yield of around 5 - 15% under variable weather scenarios due to an enriched CO_2 concentration. The peanut yield (variety: Tainan No. 14) will also show a slight annual increase due to both warming and CO_2 concentration. However, the predicted yield would fluctuate between 600-3,000 kg ha^{-1} due to a change in the rainfall pattern. Since peanut planting and growth is vulnerable to rainfall change, the fluctuation of yield on the clay soil of the Chiko Branch Farm would be higher than on the sandy soil of the Yuinlin Branch Station. The results revealed that climate change might have a more serious effect on the production of upland crops than paddy rice. The adaptation strategies should be evaluated and applied to mitigate the impact by practical steps such as no-tillage or higher furrows and so on. The emission of greenhouse gases will rise with climate change and although crop residue removal can help to reduce emissions, it also leads to reduced production and soil carbon storage.

Keywords: *Climate Change, Crop Production, Greenhouse Gases Emission, DNDC model.*

1. INTRODUCTION

As the impact of climate change increases, production in the agricultural ecosystem continues to change under the influence of many dramatic environmental fluctuations (Arora, 2019). The crop model can be verified using data integration and parameter calibration to simulate growth and predict production based on the collection of production information and environmental factors. The impact of global warming and climate change on crop growth can be attenuated by the adjustment of crop management, fertilizer application, water use, soil physicochemical properties, etc. (Adams et al, 1990) and the best cultivation methods and adjustment strategy can be chosen to ensure a sufficient and high-quality food supply. Since the DNDC (Denitrification-Decomposition) crop model can be applied to different crop systems (Li, 2007; Zhao et al, 2020; Jiang et al, 2021), it is very helpful for the simulation of agro-ecosystem crops in diverse systems such as exist in Taiwan. The aim of this study was to assess the impact of climate change on production and greenhouse gas (GHGs) emission in paddy rice and peanut crops in central Taiwan using the DNDC model.

2. MATERIALS AND METHODS

2.1. Observations and Field Data Collection

To assess the impact of climate change on the production of rice (variety: Tainan No. 11) and peanut (variety: Tainan No. 14), as well as GHGs emission in central Taiwan. The planting period is early spring for 1st rice and early autumn for 2nd rice or peanut. The daily meteorological data, soil data, management data, and yield data with different fertilizer input was collected as follows: 1) the Chi-Ko Branch Farm (the CK site) and Yuin-Lin Branch Station (the YL site) of long term ecological research (LTER) from 2009 to 2019; 2) Thirteen paddy rice fertilizer experimentation sites around Taiwan were selected in 2012; 3) two sites for peanut cultivation by the Taiwan Agricultural Research Institute (TARI) from 2018 to 2021, see Figure 1. The eddy covariance (EC) system was used to measure methane (CH_4) emission at the CK site and TARI. The fertilizer used included chemical fertilizer and manure. Mean data collected over half an hour were used to estimate the emission from each crop.

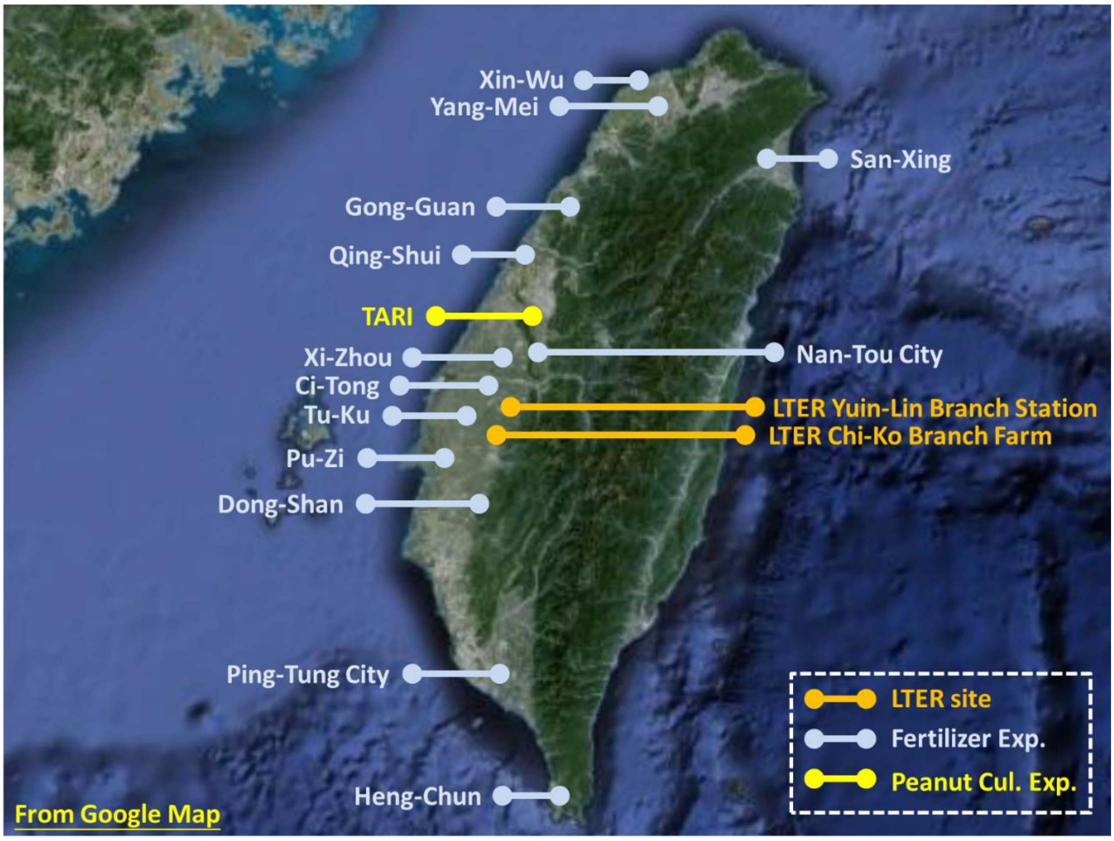


Figure 1. Data collection for the DNDC model around Taiwan.

2.2. Model Verification, Validation, and Evaluation

Paddy rice model verification was done using the DNDC (Version 9.5) parameters calibrated using field data collected at the CK and YL sites from 2009 to 2013 and the paddy rice fertilizer experiments carried out around Taiwan in 2012. Validation for suitability analysis of the model was carried out using the field data collected at the CK and YL sites from 2014 to 2019. In addition, peanut model verification was done using the DNDC model parameters, calibrated with the field data collected at the CK and YL sites from 2009 to 2013, and the peanut cultivation experiments in TARI from 2018 to 2021. Furthermore, peanut model validation for suitability analysis was conducted using the field data collected at the CK and YL sites from 2014 to 2019. The slope, the y-intercept, Pearson's correlation coefficient (r), Nash-Sutcliffe efficiency (NSE), and percent bias (PBIAS) were used to evaluate the feasibility of the model in accordance with Moriasi et al, (2007).

2.3. Collection of Future Climate Change Scenarios

The Taiwan Climate Change Projection Information and Adaptation Knowledge Platform (TCCIP) of the Ministry of Science and Technology (MOST), show three meteorological scenarios which downscale to a 5 x 5 km grid using statistical downscaling, included baseline (BS), RCP4.5, and RCP8.5. BS, RCP4.5, and RCP8.5 were estimated based on different warming scenarios, with an annual increase rate of atmospheric CO_2 concentration of 3.41, 1.86, and 6.54 ppm yr^{-1}.

3. RESULTS AND DISCUSSION

3.1. Weather Change Observed by Long-Term Monitoring in Central Taiwan

Meteorological data collected from the YL site from 1987 to 2021 showed the number of days with an average air temperature >30°C is increasing year by year and days with mean air temperature <15°C were more frequent, see Figure 2A. Figure 2B shows the monthly rainfall pattern from 2007 to 2021 at the CK site. Occasional extremely heavy rainfall, which could even prevent planting, occurred between June and November. In addition, our results showed that rainfall during the growth period had an impact on peanut yield. When rainfall exceeds a certain critical value, the yield was reduced, see Figure 3. Records show this above-average rainfall caused muddy fields and made cultivation very difficult in 2012, 2017, and 2018. An abnormal rainfall pattern in November also raised the cost of harvesting. It is clear that excessive temperature and heavy rainfall has a significantly negative impact on the average peanut yield (Lekhnath and Ramesh, 2013). Pollination will also be affected by heavy rain during the flowering period. The high soil moisture from heavy rain can make the plants leggy, increase their susceptibility to pests and disease, and cause pod rot (Frank, 1974).

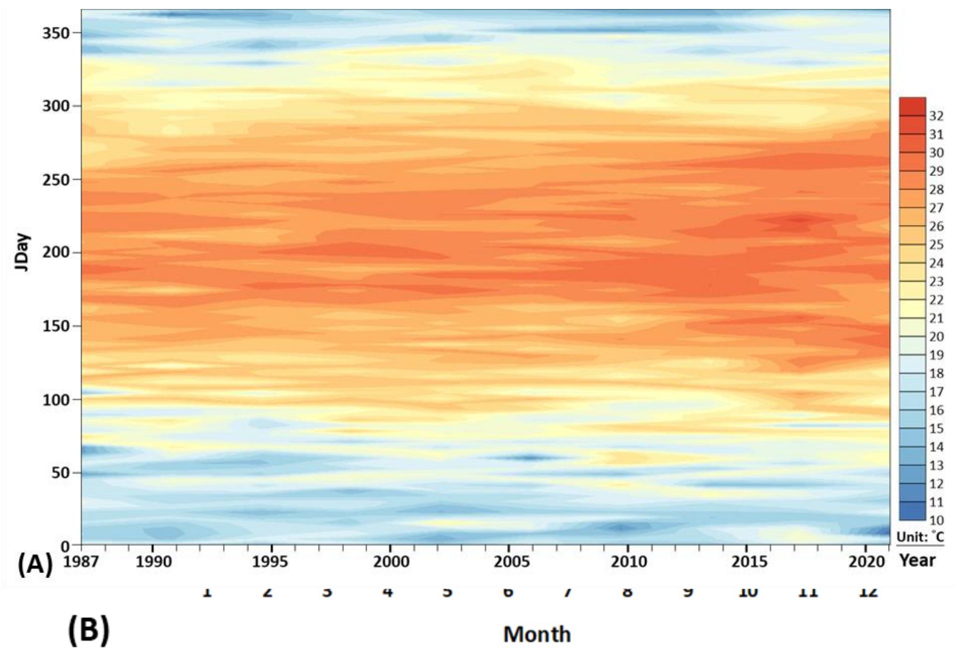


Figure 2. Long-term meteorological data. (A) daily average temperature change from 1987-2021 at the YL site, and (B) monthly rainfall pattern from 2007 to 2021 at the CK site.

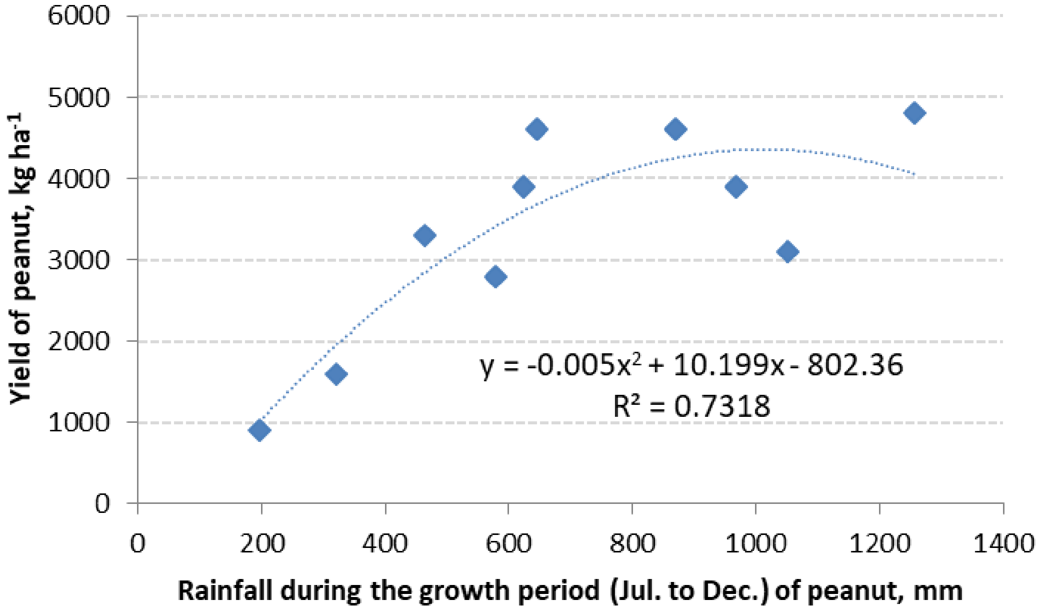


Figure 3. The relationship between the 2nd peanut yield and the total rainfall during the growth period (July to December) at the CK and YL sites.

3.2. Crop Parameter Identification

The results of paddy rice and peanut model verification and validation are shown in Figures 4 and 5 clearly demonstrating that the DNDC model can be applied in the simulation of rice and peanut growth.

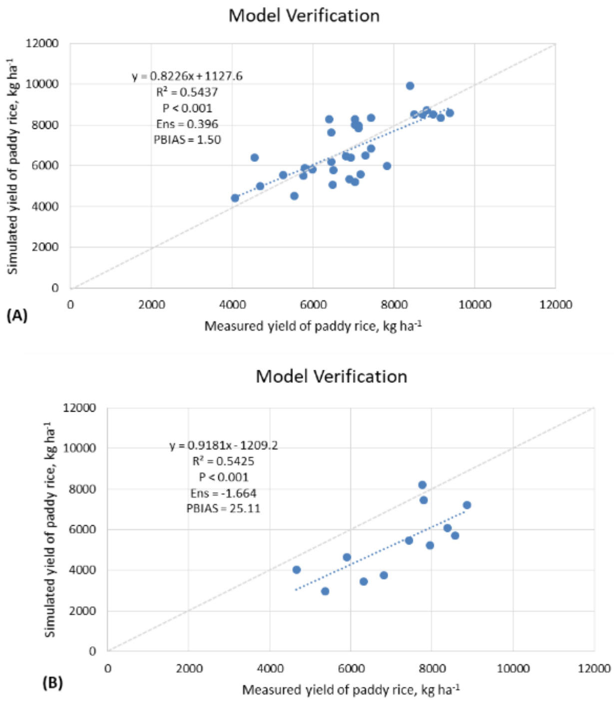


Figure 4. DNDC Paddy Rice Modeling Results. (A) model verification, (B) model validation.

3.3. Impact of Climate Change on Crop Production

The DNDC modeling shows that paddy rice and peanut yields might increase in future decades, see Figure 6. The simulation results predict that the enriched CO_2 concentration will result in a gradual rise in the annual yield of rice (Tainan No. 11). The increase will be around 5-15% under the scenario of variable weather. The annual peanut (Tainan No. 14) yield will also increase due to warming and CO_2 enrichment. Crop yields vary greatly among experimental sites, but less among scenarios. But changes in the rainfall pattern might affect both practical agricultural operations and crop production, especially in upland crops. Fluctuations at the CK site which has clay soil will be higher than at the sandy YL site, see Figure 6D. Higher furrows are recommended.

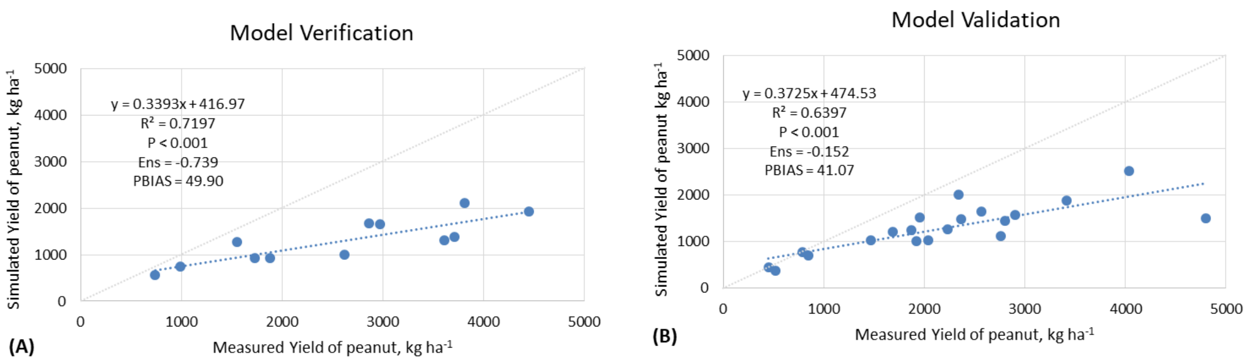
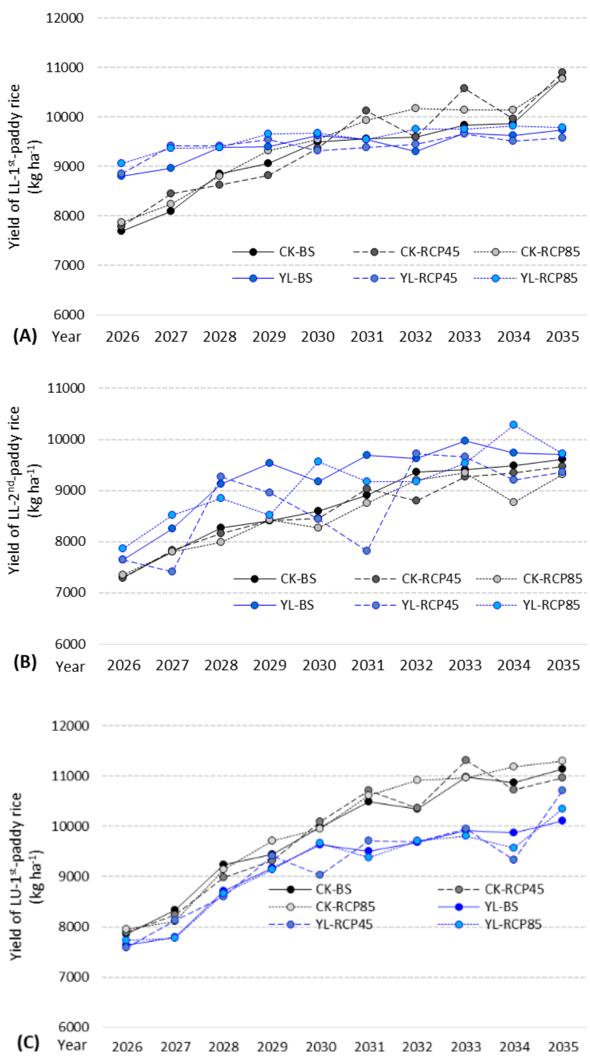


Figure 5. DNDC Peanut Modeling Results. (A) model verification, (B) model validation.



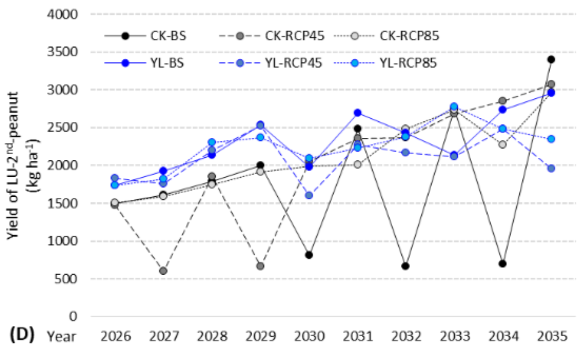


Figure 6. Simulated paddy rice and peanut yield in central Taiwan in the DNDC model. (A) 1st paddy rice at LL, (B) 2nd paddy rice at LL, (C) 1st paddy rice at LU, (D) 2nd peanut at LU.

3.4. Model Verification for CH_4 Emission at Paddy Fields

The results of the relationship between observation and simulation of CH_4 emission are shown in Figure 7. Although the simulated CH_4 emission was not fitted to the 1:1 line, the emission trend was clearly simulated. However, more data should be collected for better parameter identification.

3.5. Impact Simulation on GHGs emission under climate change

CH_4 and N_2O emissions both increase with climate change, see Figure 8. The CH_4 emissions from rice fields were higher than those from peanut fields, which may be because the CH_4 in paddy fields is mainly produced by bacterial activity under anaerobic conditions caused by irrigation or flooding of the soil by rainwater (Yagi et al 1996). Consequently, the CH_4 emissions resulting in higher fertilizer inputs (HI) are higher than that of less input (LI). In addition, the N_2O emission in LI was lower than that from HI treatment, see Figure 8, which is consistent with previous studies (Chen et al, 2016). This shows a trend towards a yearly increase coupled with climate change, despite some inter-annual oscillation.

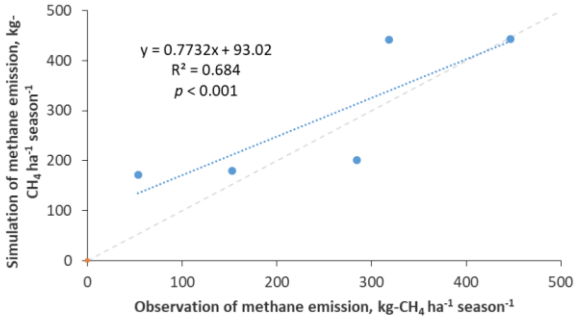
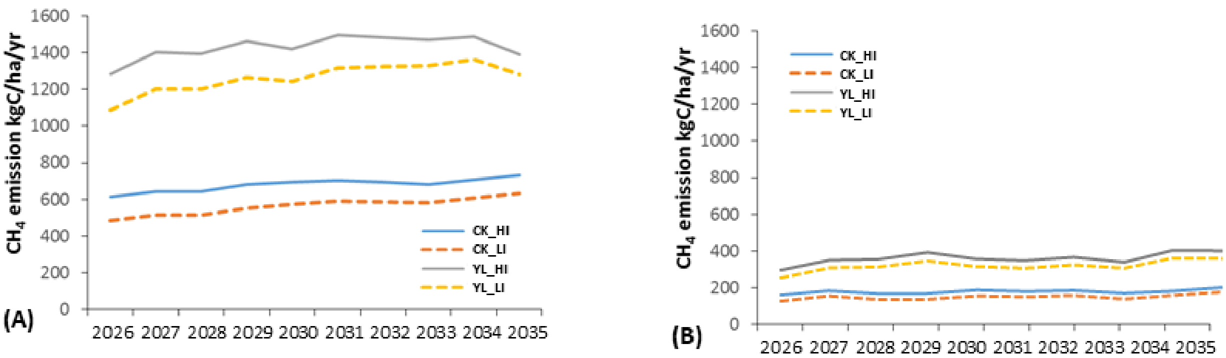


Figure 7. The relationship between observation and simulation of CH_4 emission.



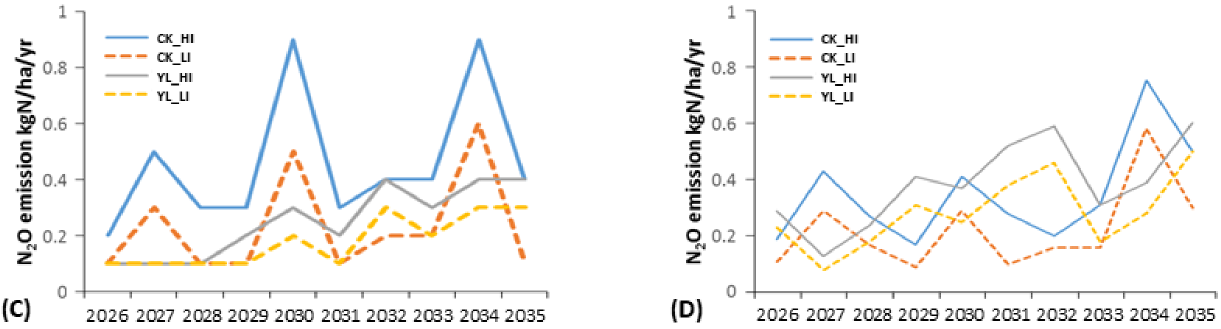
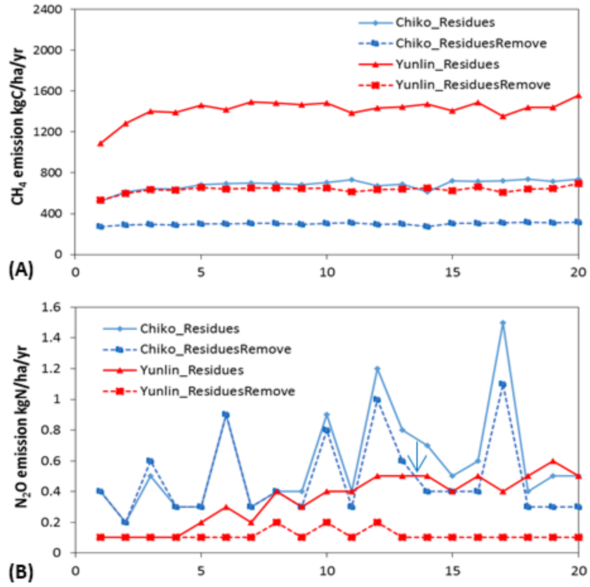


Figure 8. The impact of climate change on GHGs emissions by DNDC model simulation. (A) CH_4 emission at LL, (B) CH_4 emission at LU, (C) N_2O emission at LL, (D) N_2O emission at LU.

3.6. Simulation on GHGs emission and yield by rice straw removal

Although the crop residue removal can reduce these emissions, it will lead to lower production and soil carbon storage, see Figure 9, which is consistent with previous studies (Miura, 2003; Qiu, 2009). In addition, soil organic carbon (SOC) increased with the proportion of rice straw residue. This shows that rice straw retention in the fields has a negative impact on the mitigation of greenhouse gas emissions, but a positive impact on soil carbon sequestration (Qiu et al 2009). Furthermore, retention of the straw seems to increase the yield slightly. Yang (2015) also shows that increasing the SOC content in the first 10 years increased crop yield which reached stability after 10 years of planting.



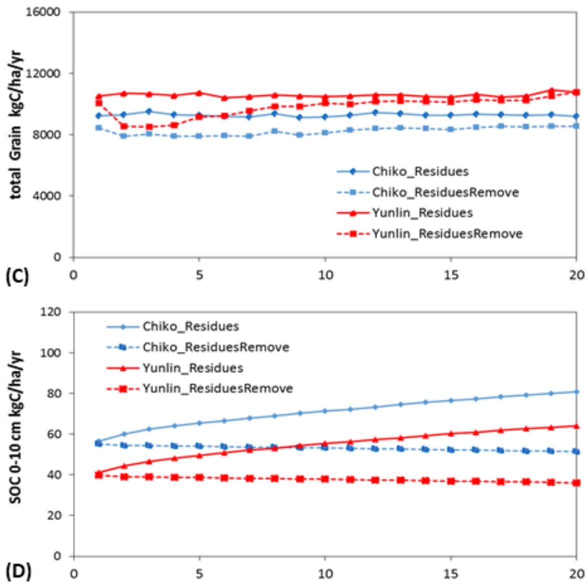


Figure 9. Simulation on GHGs emissions and yield by rice straw removal for the next 20 years. (A) CH_4 emission, (B) N_2O emission, (C) yield, and (D) SOC of 0-10 cm soil.

4. CONCLUSIONS

The results of model simulation reveal that the crop production and CH_4 emission simulated are highly correlated with measured data. However, the simulated peanut yield was lower than the measured data, and the simulated emissions were higher than the measured data. The parameters still need to be adjusted for application in Taiwan. Rice and peanut yields are affected by climate change, especially high temperature and uneven rainfall. The fluctuations in yield of peanuts cultivated in clay soils is higher than those in sandy and loam soils under climate change. Higher furrows are recommended to mitigate the impact of heavy rainfall. The GHGs emission will become higher with climate change. Although the crop residue removal can reduce GHG emission, it also leads to reduced production and less soil carbon storage.

5. ACKNOWLEDGEMENT

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MeTRN 1.0: AN INTEGRATIVE DATABASE FOR RECONSTRUCTING TRANSCRIPTIONAL REGULATORY NETWORK IN CASSAVA (*Manihot esculenta* Crantz)

Nattawet Sriwichai[1)], Trenut Saithong[1,2)] and Saowalak Kalapanulak[1,2,*)]

1) Center for Agricultural Systems Biology (CASB), Systems Biology and Bioinformatics Research Group, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi (Bang Khun Thian), Bangkok, Thailand
2) Bioinformatics and Systems Biology Program, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bang Khun Thian), Bangkok, Thailand

* Corresponding author

ABSTRACT: Transcriptional regulation is a crucial biological process for controlling gene expression in a living cell. To comprehend it, several genome-wide experiments and computational approaches have been applied to unravel the complex system. Comparing to other eukaryotes, a multi-cell organism like plant obtains a specific transcriptional regulation by distinctive transcription factors (TFs) containing plant-specific DNA binding domain such as TCP, NAM, EIN3, DUF573. The unique transcriptional regulation in plants is vital to explore specially in cash crops like cassava. Cassava (*Manihot esculenta* Crantz) is an important starchy tuberous crop serving millions of people worldwide. In this work, a genome-scale transcriptional regulatory network of cassava, called *Manihot esculenta* Transcriptional Regulatory Network (MeTRN), was reconstructed using three systems biology approaches including template-based, reverse engineering-based, and *cis*-regulatory element analysis-based methods. The constructed MeTRN contains 4,812,519 interactions of 33,006 genes (99.92% of annotated protein-coding genes in the genome) and 2,116 TF genes from 64 TF families in cassava genome version 6.1 in Phytozome database. MeTRN has combined transcriptional regulations from PlantRegMap and extended the landscape of regulatory region to distal promoter up to 2 kb from translational start site resulting in 11 times higher numbers of interactions than PlantRegMap. Additionally, a user-friendly search for finding a set of regulatory proteins controlling all target genes functioning in a particular metabolic pathway is provided. The MeTRN is available for public access at https://bml.kmutt.ac.th/MeTRN.

Keywords: *cassava, database, transcriptional regulation network.*

1. INTRODUCTION

Transcriptional regulation is the main biological process to control eukaryotic gene expression by the sequence-specific DNA-binding proteins, called transcription factors (TFs) or regulators. Those proteins recognized specific DNA sequences of 5-16 base pairs on the promoter of gene target called *cis*-regulatory elements or TF binding sites (TFBSs) (Yu et al., 2016). TFs control gene transcription for cellular and developmental processes. Interestingly, plants, which are sessile organisms, have evolved a robust response system for sensing and responding to environmental cues (Lehti-Shiu et al., 2017). Plant genomes are significantly larger and contain more TF-coding genes than those of animals and fungi. (Rodriguez-Mega et al., 2015). The TF families in plants have shared among eukaryotes and some of them are distinct, including 21 plant-specific TF families (Lehti-Shiu et al., 2017).

A network of TFs regulating target genes explored through high-throughput experiments and computational methods enabled us to understand the global regulation of cell development and responses to environmental changes in a systematic view as the transcriptional regulatory network

(TRN) (He & Tan, 2016). Several computational approaches have been applied to reconstruct TRN in the plants. A template-based method was applied to infer the unknown TF-target gene interactions from the known interactions in well-studied organisms via homology-based approach (Romero et al., 2022). Reversed engineering approach was applied to infer the transcriptional regulation based on gene co-expression analysis. This approach has been successful for unraveling transcriptional regulation in plants, including Arabidopsis, rice, and cassava (Khampoosa et al., 2014; Ueda et al., 2020; Wirojsirasak et al., 2019). However, transcriptome data with multiple data points was required for proposing TRN under specific conditions. A *cis*-regulatory element analysis has been proposed to identify putative TFs controlling a target gene by scanning known TFBSs on a promoter of target gene query (Tian et al., 2020; Yilmaz et al., 2011). Recently, to reconstruct highly confidential TRN the integrative computational approaches have been employed for example in rice (Wilkins et al., 2016). AGRIS and PlantRegMap databases provided the collection of interactions between gene and its regulators to understand plant transcriptional regulatory systems (Tian et al., 2020; Yilmaz et al., 2011). However, a few studies have been focusing on transcriptional regulation of tuberous root crops, especially cassava.

In this work, TF-target gene interactions were extensively reconstructed from three computational-based approaches, including template-based, *cis*-regulatory element analysis, and reverse engineering to infer the genome-wide transcriptional regulatory network of cassava (MeTRN). Herein, 4,812,519 transcriptional interactions among 33,006 genes including 2,116 TF genes were provided and led to the largest resource for investigation of transcriptional regulation in cassava, the important crop for the tropical area because of its starchy tuberous roots, the main carbohydrate resources for over half a billion people around the world, especially in Africa and Asia. Unraveling the transcriptional regulation in cassava will unlock the bottleneck for genetic modification and precision-biomarker identification vital for a marker-assisted plant breeding for improving new cassava cultivars with desired properties e.g., high starch yield and disease resistance.

2. MATERIALS AND METHODS

2.1 MeTRN construction

MeTRN was constructed based on cassava genome version 6.1 in Phytozome database by using three computational approaches, including template-based, *cis*-regulatory element analysis, and reverse engineering-based. For template-based method, TRN of *A. thaliana* from AtRegNet v2016.08 (Yilmaz et al., 2011) was used as the template to transfer its transcriptional regulation to cassava based on homology searching of a paired gene via reciprocal best hit (RBH) BLASTp (E-value < 10e-10, identity ≥ 60%, and query coverage ≥ 60%). Furthermore, the MeTRN was reconstructed based on *cis*-regulatory element analysis by using two criteria, (1) putative TFBSs on the promoter of a target gene in the range of 2 kb from translational start site without gene overlapping were predicted using PlantPAN v2 (Chow et al., 2016), then their TF-binding genes from the reference organisms were transferred to cassava genes via homology-based approach using above criteria, and (2) transcriptional interactions between TF and target gene of cassava from PlantRegMap (Tian et al., 2020) were included in MeTRN. Lastly, the MeTRN was constructed from reverse engineering approach via gene co-expression analysis of high fluctuation gene across conditions (SD ≥ 70 percentile) and gene-gene association (absolute Pearson correlation coefficient > 0.9 and p-value < 0.05) using three microarray datasets of *A. thaliana* under diurnal circle (GSE11708, GSE3416, and GSE6174) and two microarray datasets of cassava under storage root development (GSE25813 and FG804688-FG807563). TF genes and their families were assigned from PlantTFDB v5 (Jin et al., 2017) and inferred from PlantPAN v2 (Chow et al., 2016) via orthologous gene transferred from *A. thaliana* with RBH BLASTp with the same criteria mentioned above. Moreover, TF gene IDs version 1.1 in PlantPAN were transferred to version 6.1 with RBH BLASTp (E-value < 10e-10, identity ≥ 80%, and query coverage ≥ 80%). Cassava genes annotated their function in metabolic pathways based on CassavaCyc v8.0 (Hawkins et al., 2021) were included in MeTRN.

2.2 Web application development

MeTRN-API was built on top of the FastAPI framework for developing APIs with Hypercorn ASGI web server written in Python 3 to access the MySQL relational database and provide data via a representational state transfer (REST) application programming interface (API). The MeTRN website was developed with a responsive web design that was suited for display on any devices using Bootstrap v5.1 framework. A table, graphical chart, and biological network were rendered via GridJS, ChartJS, and VisJS libraries respectively. Custom HTML and JavaScript were created to connect the API backend for searching and showing the results.

3. RESULTS AND DISCUSSION

3.1 Characteristics of MeTRN database

The genome-wide transcriptional regulatory network of cassava (MeTRN) was reconstructed from three systems biology approaches, template-based, reverse engineering, and cis-regulatory element analysis, resulted in 4,812,519 interactions of 33,006 genes (covered 99.92% of protein-coding genes in cassava genome). Most interactions (98.82%) were predicted from cis-regulatory elements analysis based on the 2,000 bp upstream region of each target gene. It provided all potential physical binding (direct interaction) between TF and specific nucleotide sequences on a promoter of target gene. On the other hand, indirect interactions between TFs and target genes from template-based and reverse engineering were demonstrated in Figure 2B. In addition, 2,116 TF genes were classified into 64 families based on DNA-binding domains including 12, 5, 8, and 27 TF families in land plant-specific, Virdiplantae, Viridiplanae shared with few eukaryotes, and common eukaryotes, respectively (Lehti-Shiu et al., 2017). The number of TF genes in each TF family was presented in Figure 2C. The genome-scale transcriptional regulation of cassava has been provided as the user-friendly website, MeTRN (Figure 1).

3.2 The extended cassava transcriptional regulations in MeTRN compared with PlantRegMap

Transcriptional regulation of cassava in terms of interactions between TF genes and their target genes in MeTRN were compared with those in PlantRegMap, cis-regulatory element analysis approach for transcriptional regulation prediction (Tian et al., 2020). MeTRN provided 11 times more interactions between target genes and regulators than PlantRegMap (Figure 2D). In addition to PlantRegMap, MeTRN considered the transcriptional regulation in a distal promoter region up to 2,000 base pairs in

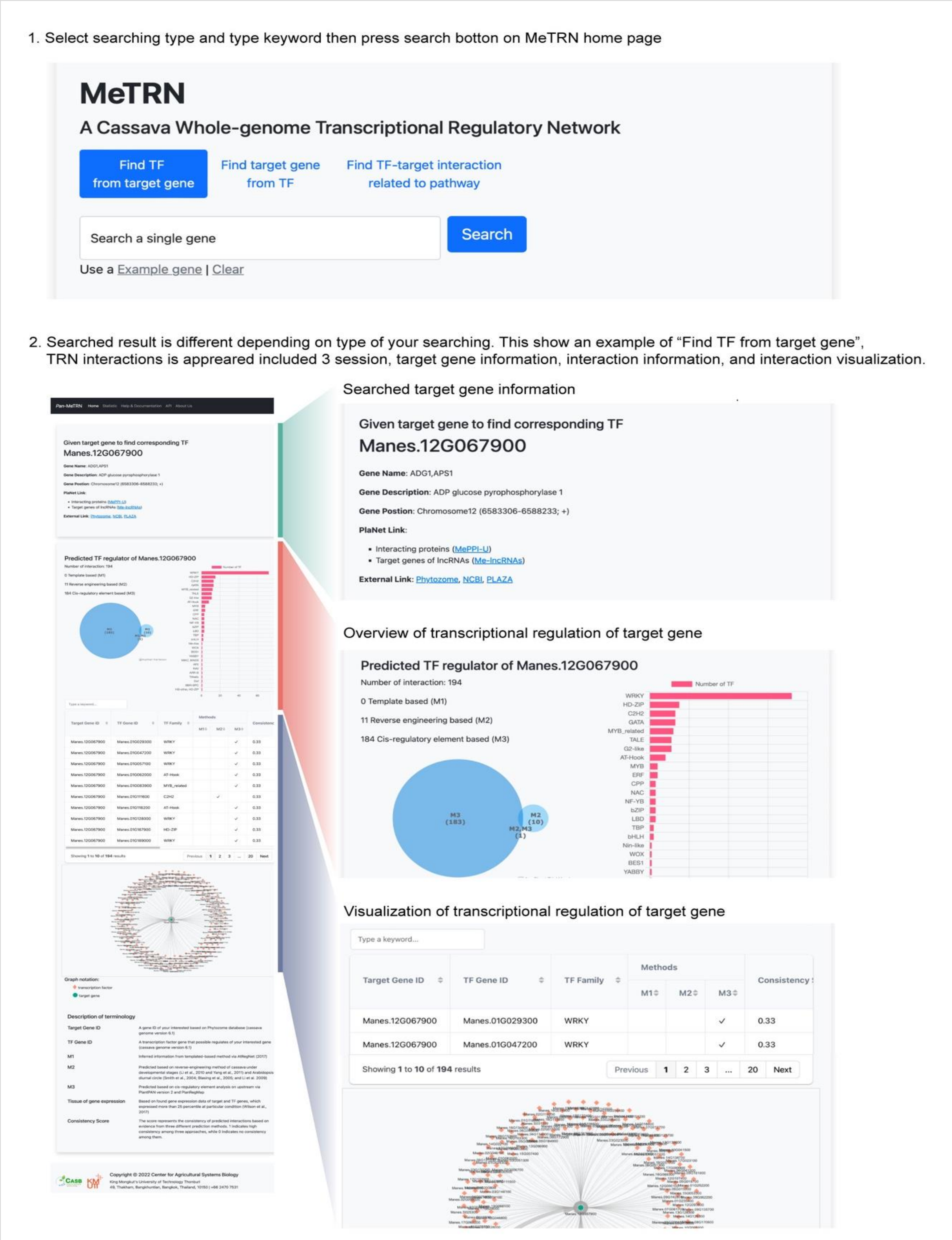
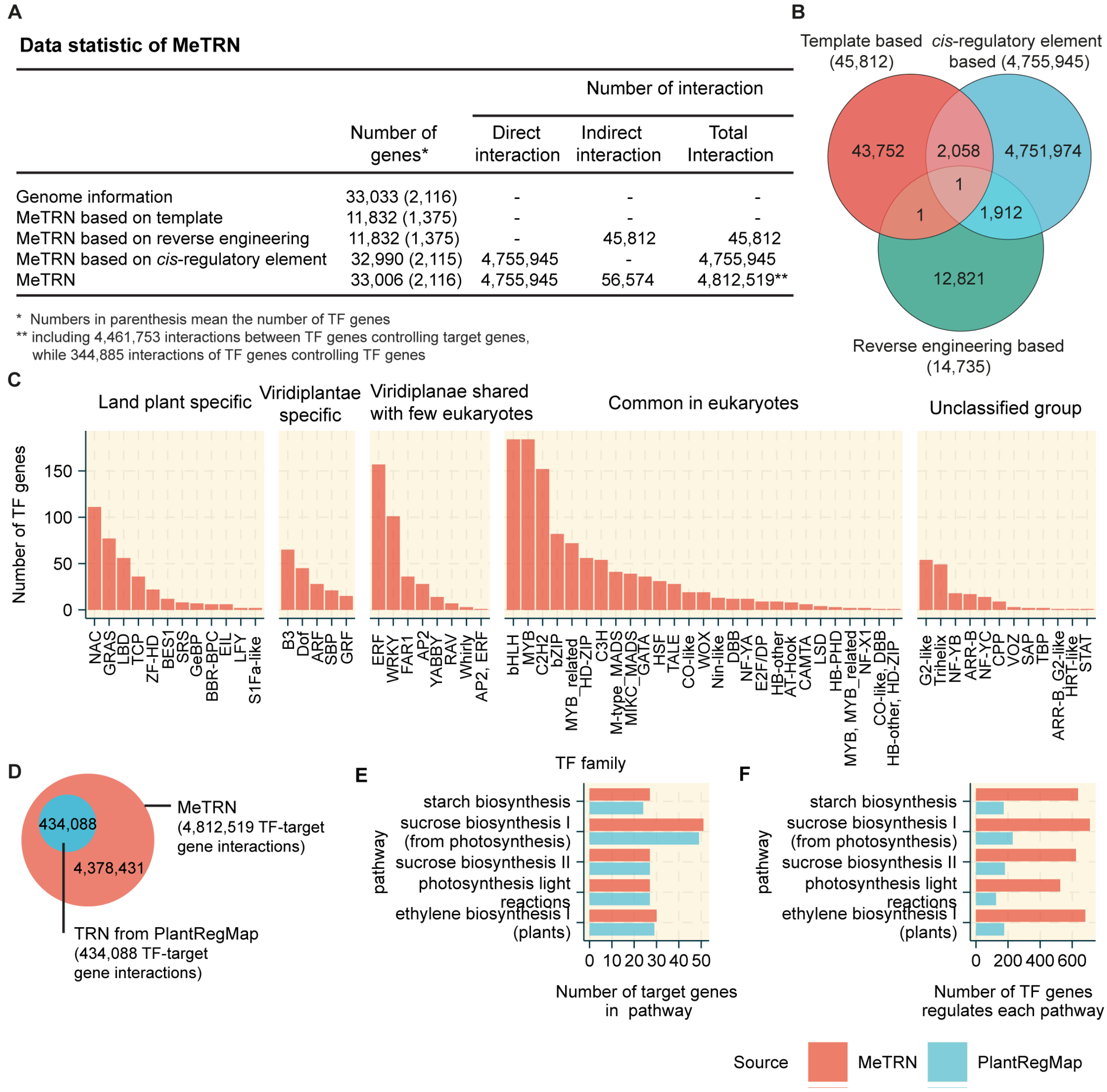


Figure 1. The MeTRN 1.0 website and example of searched results for putative TFs controlling one target gene, *APS1*, as a query. The list of putative TFs and graph visualization of transcriptional regulation are demonstrated.

The upstream sequences from the translation start site. Nevertheless, PlantRegMap considered only TFBSs on the core and proximity promoter of a gene (-500 to +100 bp from transcriptional start site) (Jin et al., 2017; Tian et al., 2020). Moreover, applying both template and reverse engineering-based techniques resulted in additional 11 TF genes in MeTRN, including 8, 2, and 1 TF genes from the AT-Hook, TBP, and C2H2 families, respectively. MeTRN expanded transcriptional regulation of target genes in several important metabolic pathways of cassava as shown in Figure 2E-F).



Data statistic of MeTRN

	Number of genes*	Number of interaction: Direct interaction	Indirect interaction	Total Interaction
Genome information	33,033 (2,116)	-	-	-
MeTRN based on template	11,832 (1,375)	-	-	-
MeTRN based on reverse engineering	11,832 (1,375)	-	45,812	45,812
MeTRN based on *cis*-regulatory element	32,990 (2,115)	4,755,945	-	4,755,945
MeTRN	33,006 (2,116)	4,755,945	56,574	4,812,519**

* Numbers in parenthesis mean the number of TF genes
** including 4,461,753 interactions between TF genes controlling target genes, while 344,885 interactions of TF genes controlling TF genes

Figure 2. Data statistic of MeTRN. **A**, number of genes and interactions in MeTRN. **B**, comparison of transcriptional regulation in MeTRN based on template, reverse engineering, and *cis*-regulatory element-based method. **C**, the number of TFs in each TF family, 2,116 TF genes were classified into 64 TF families within four groups based on evolution including land plant-specific, *Viridiplantae* specific, *Viridiplanae* shared with few eukaryotes, common eukaryotes, and unclassified. **D**, Venn diagram demonstrating the overall cassava transcriptional regulation comparison between MeTRN and PlantRegMap. **E** and **F,** demonstrated cassava transcriptional regulation comparison between MeTRN and PlantRegMap in five metabolic pathways, including starch biosynthesis, sucrose biosynthesis I, sucrose biosynthesis II, photosynthesis light reaction, and ethylene biosynthesis I in term of numbers of target genes and TF genes in each metabolic pathway.

3.3 Application for searching potential transcriptional regulators controlling target genes or target genes of interested TF genes

It is a time and cost intensive experiment to examine the physical interaction between TFs and their target gene's promoters such as yeast one hybrid (Y1H) method. MeTRN is a straightforward database that assists plant molecular biologists for identifying candidate TFs that might control the interested target genes. For example, the transcriptional regulation of 1-aminocyclopropane-1-carboxylic acid synthase 6 (*MeACS6*; Manes.01G057800) in ethylene biosynthesis pathway was demonstrated as a case study. The outcome revealed 125 anticipated regulator genes from template-based, reverse engineering, and *cis*-regulatory element analysis. With high confident predictive results from both reverse engineering and *cis*-regulatory element analysis method, five TFs in the C2H2 family were proposed for controlling *MeACS6* at the transcription level (Figure 3A).

3.4 Application for searching potential transcriptional regulators controlling a set of genes in a particular interested metabolic pathway: a case study for ethylene biosynthesis pathway

To identify the key regulators controlling enzymatic genes in the ethylene biosynthesis I metabolism, the MeTRN provides 4,906 TF genes regulating enzymatic genes for ethylene production. After eliminating interactions with consistency scores more than 0.66 (putative interactions from at least two approaches), 10 TF genes were proposed to control ethylene production in cassava. Three TF genes may control the genes encoding for methionine adenosyl transferases, five TF genes may regulate genes encoding for 1-aminocyclopropane-1-carboxylate synthases, and two TFs may control the 1-aminocyclopropane-1-carboxylate oxidases gene (Figure 3B). MeTRN database offers a useful guidance for candidate TFs controlling an interested target gene. The computational screening process is vital before performing a time and cost intensive experimental work.

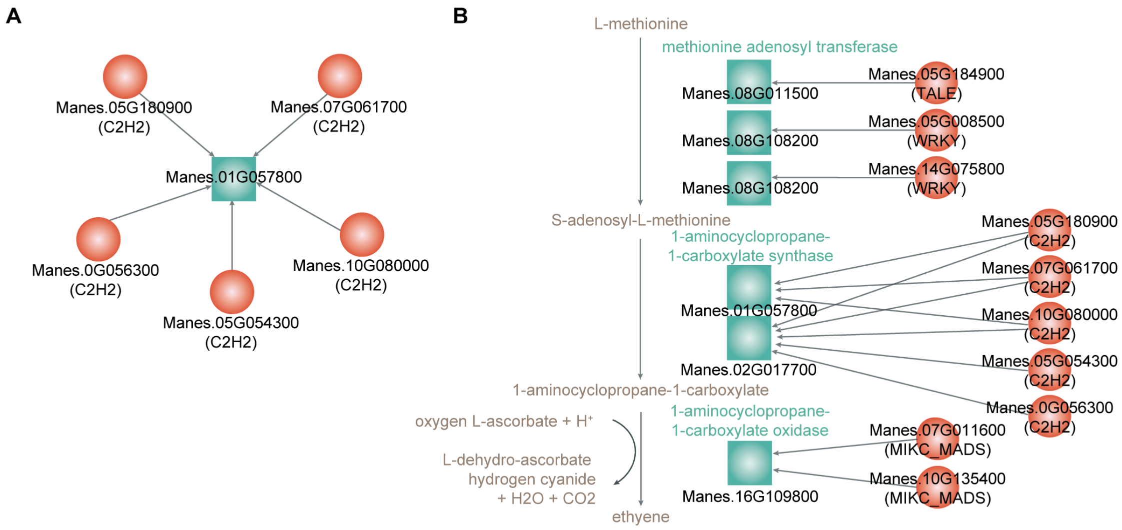


Figure 3. Demonstration of MeTRN applications including two main applications. **A**. TFs controlling an interested target gene. **B**. identification of key regulators controlling a set of genes functioning in each metabolism: a case study in ethylene biosynthesis pathway.

4. CONCLUSIONS

MeTRN has been provided a valuable resource of transcriptional regulation in cassava. This database allows users to search for regulators controlling target genes or find a set of regulators controlling a set of target genes functioning in each metabolic pathway. Unraveling the transcriptional regulation in cassava will unlock the bottleneck for genetic modification and precision biomarker identification for a marker-assisted breeding program to improve new cassava cultivars with desired properties, namely high starch yield and disease resistance.

5. ACKNOWLEDGEMENT

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APPLICATION OF ELECTROCHEMICAL SENSOR SYSTEM IN DETECTING WHITE SPOT SYNDROME VIRUS: A REVIEW

Linh Huynh Thi-Thuy [1,2*)], Nha Vo Quang [1)], Cuong Ngo Xuan [1)], Thuan Nguyen Duy [1)], Loc Do Quang [3)], Tung Bui Thanh [2)], Phu Nguyen Dang [2)], Trinh Chu Duc [2)]

1) School of Engineering and Technology, Hue University, Vietnam
2) University of Engineering and Technology, Vietnam National University, Vietnam
3) University of Science, Vietnam National University, Vietnam

*Corresponding author: Huynh Thi Thuy Linh, email: thuylinh@hueuni.edu.vn, 01 Dien Bien Phu, Hue province, Vietnam

ABSTRACT: Viral white spot shrimp disease caused by white spot syndrome virus (WSSV) has had a negative impact on the aquaculture industry, especially on the shrimp farming industry. Up to now, there have been no vaccines and treatments for WSSV. Therefore, early detecting and diagnosing of diseases in farmed shrimp are necessary to limit the great economic losses caused by this disease. In the paper, we show the white spot disease situation in some locations in Vietnam, especially in Thua Thien Hue province where the disease occurs every year. In addition, we review the electrochemical method for detecting white spot disease virus in shrimp. From that, the electrochemical sensor system is proposed to develop for the early detection of white spot disease in shrimp.
Keywords: *Electrochemical sensor, detecting WSSV, potentiostat, real-time detection.*

1.INTRODUCTION

The shrimp industry plays an important role in aquaculture. However, the shrimp industry's growth is impacted by disease episodes resulting in billions of dollars in loss annually [1]. White spot shrimp disease is caused by White spot syndrome virus (WSSV) which is considered one of the most lethal viruses in aquaculture. After 5-7 days of infection, the mortality rate is up to 100% [2]. WSSV was initially discovered in Taiwan and spread quickly worldwide [3]. Up to now, there have been no vaccines and treatments for WSSV [4].

Therefore, the early detection of WSSV is of great interest to many researchers to protect aquaculture farms [5]. There are many diagnostic methods that have been used to detect WSSV such as PCR – Polymerase Chain Reaction [6], both one-step and nested PCR [7], insulated isothermal PCR – portable devices [8], LAMP PCR – Loop-mediated isothermal amplification PCR [9], immunological quick test [10], [11], ELISA – Enzyme Linked Immunosorbent Assay [12], DNA microarray [13] are the popular methods. Besides these, real-time PCR [14], [15], [16] is the quantitative method that gives highly accurate results. However, this test is quite expensive and requires many steps, professional technicians as well as expensive equipment and laboratories.

Recently, numerous research has shown that electrochemical methods have been applied in many fields, from physics, medicine, to biology. Based on advances in microelectronic and microengineering, modern sensing systems are more and more small, sensitive, selective; lower production, and maintenance costs [17]. For these reasons, the electrochemical biosensor has been a useful direction in providing a sensitive, specific, and rapid method to detect WSSV in water before stocking ponds and to monitor the WSSV spread during shrimp cultivation [18]. Real-time virus detection like that helps control on-site the spread of WSSV at shrimp farms without adequate testing facilities [19]. Nevertheless, these studies only focused on the functionalization of the sensor surface for WSSV detection, which is only a part of the electrochemical system. Meanwhile, the electronic part is also a very important part of the signal supply and the corresponding measurement system for that signal.

Not only the world, but Vietnam is also affected, so in this paper, WSSV infection in shrimp farming in Vietnam was evaluated in recent years, particularly in Thua Thien Hue province where the disease occurred yearly. Then electrochemical sensor system for WSSV detection was proposed that is suitable for the economy and characteristics of local farmers.

2. WSSV SITUATION IN VIETNAM

2.1. Epidemic situation

As a coastal country, Vietnam has great potential for marine economic development. In particular, brackish water shrimp is one of the popular cultured species because it brings high economic value to the people. It was found that Vietnam shrimp exports in February 2022 increased sharply by 43% in volume and 57% in value over the same period in 2021 [20]. In which, whiteleg shrimp (scientific name is Litopenaeus vannamei) production was estimated at 25.5 thousand tons, up 6.3% over the same period last year; Black tiger shrimp (scientific name is Penaeus monodon) reached 14.2 thousand tons, equal to the same period last year [21].

Also a coastal province of Vietnam, in the first 6 months of 2021, the brackish water shrimp farming area in Thua Thien Hue province was estimated at 757 ha, up 4.8% over the same period. In particular, the area of black tiger shrimp farming was 360 ha, an increase of 3.4%; whiteleg shrimp farming area reached 346 hectares, up 5.5% over the same period. The output of brackish water shrimp reached 2503 tons, up 7.0% over the same period last year [22].

The data has shown that the shrimp farming industry in Vietnam in general and Thua Thien Hue, in particular, is developing very quickly. However, recent studies show that disease in aquaculture has currently been a major challenge for the sustainable development of the aquaculture industry [23]. Especially, the white spot disease in shrimp caused by the white spot syndrome virus has had no specific treatment, spread at a high level, and caused mass death [24], heavy damage [25].

According to a source from the Vietnam Department of Animal Health, in the first 6 months of 2021, white spot disease occurred in 121 communes of 46 districts, towns in 17 provinces, and cities with a total area of damage caused by the disease of more than 859 hectares, accounting for 1.38% of shrimp farming area in epidemic communes. More importantly, in Ha Tinh province, the shrimp farming area with white spot disease accounted for 85.11% of the total shrimp farming area [26].

In the past 3 years, in Thua Thien Hue province, the disease occurred mainly in Quang Phuoc, Quang An commune in Quang Dien district. The infected area in 2019, 2020, and 2021 was 13.50 ha, 37.90 ha, and 33.48 ha, respectively (Figure 1) [27].

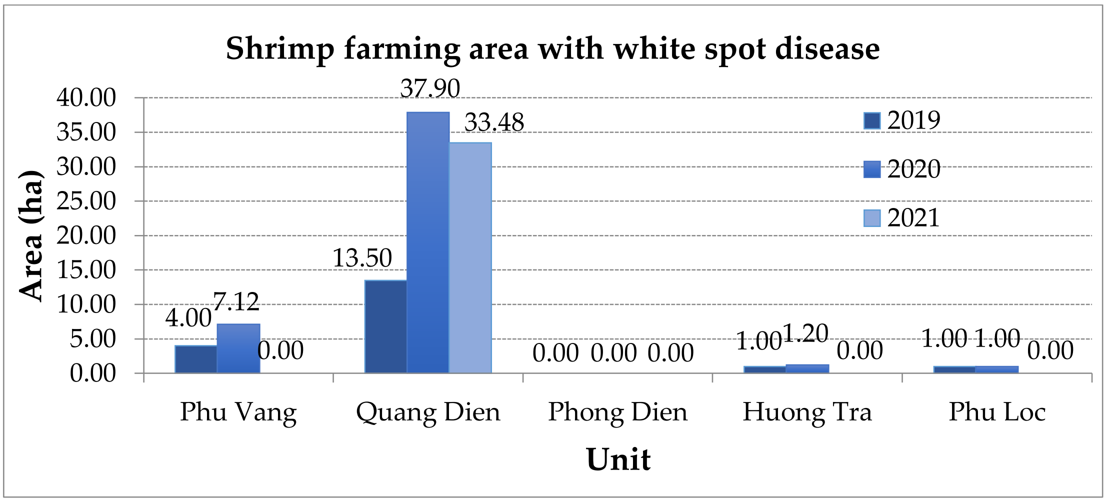

Figure 1. Statistics on disease situation in Phu Vang, Quang Dien, Phong Dien, Huong Tra, Phu Loc districts from 2019 to 2021

In 2021, Thua Thien Hue had a farming area of over 5368 hectares, of which the shrimp farming area is 1639 hectares with about 1 billion shrimp seed stock, and a large number of crabs, fish and other species. However, the epidemic occurred from the end of March 2021 and spread quite quickly. In 2021, there were 76.74 hectares affected by diseases, of which white spot disease mainly was 33.48 ha, environmental impact was 43.26 ha [28]. It can be seen that the rate of diseases caused by WSSV is up to 43.62%.

Also in 2021, samples were taken and tested for 5 kinds of diseases including WSSV (White Spot Syndrome Virus), MBV (Monodon Baculovirus), IHHNV (Infectious Hypodermal and Hematopoietic Necrosis Virus), TSV (Taura Syndrome Virus), AHPND (Acute Hepatopancreatic Necrosis Disease) in all infected shrimp ponds and farming areas. Results were returned within 24 hours. Of the 242 samples tested, 49 were WSSV-positive, 32 were MBV-positive, 20 were IHHNV-positive, 20 were TSV-positive, and 20 were AHPND-positive (Figure 2) [28]. Then, diseased shrimp ponds and canals were treated with chemicals to destroy pathogens; Drains of diseased shrimp ponds were closed and people around the area were informed to take preventive measures. In addition, the government controlled and monitored the environment of the farming areas and informed them on the mass media.

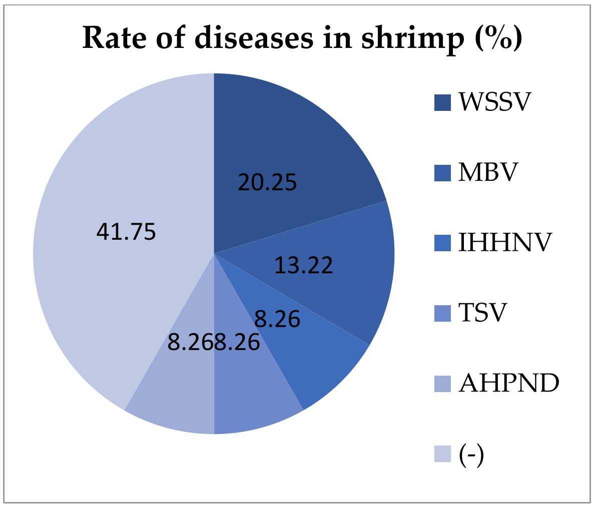

Figure 2. Percentage of diseases in shrimp in Thua Thien Hue province in 2021. WSSV accounted for the highest percentage

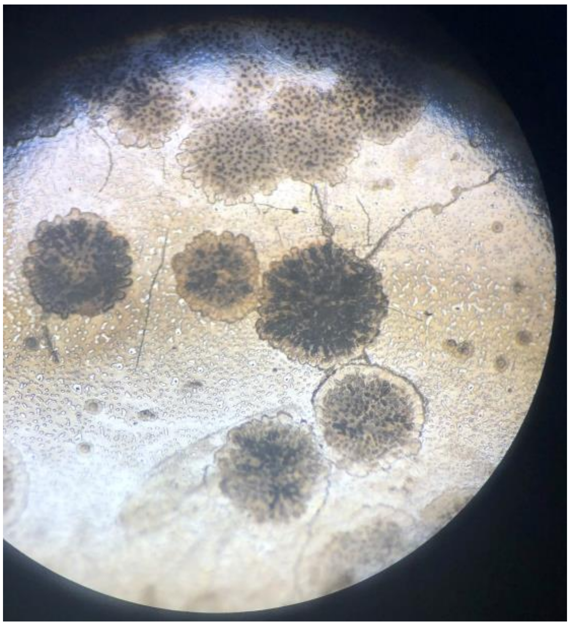

Figure 3. White spot shrimp template

Figure 3. is the shell of shrimp head (45-day old) with positive PCR results for WSSV examined under the microscope, objective 4x (samples were taken from the Veterinary disease diagnosis and

treatment station, Thua Thien Hue Sub Department of Livestock Production and Animal Health). When spots appeared as shown in figure 3, shrimp died in the entire shrimp farming area. Farmers needed to harvest and treat diseased shrimp and ponds according to the instructions of local Sub Department of Livestock Production and Animal Health. Time change seasons of the year (about April-May) is the time that epidemics often appear. Beside this, Thua Thien Hue is a locality characterized by erratic weather, complicated epidemics, a polluted environment, and spontaneous farming without biosecurity which are risk factors for disease recurrence and spread in aquaculture, especially in the hot season.

2.2. Practical methods of detecting WSSV

In fact, individual farms in the world and also in Vietnam have detected the disease by clinical diagnosis or laboratory diagnosis [29]:

- Clinical diagnosis: Based on typical symptoms and lesions of diseased shrimp. The disadvantage is that not knowing the exact cause of the disease and detecting the disease late cause serious economic losses.

Figure 4. External expression of shrimp infected with WSSV, many white spots on the head shell of shrimp

- Laboratory diagnosis: Collect real samples, test with PCR molecular biology test method. However, to implement this method, farmers need to send test samples of suspected infected shrimp to the testing center - which is fully equipped with the necessary equipment and technical staff to conduct a diagnosis and confirm the cause. It is far away from the shrimp farming area. As a result, shrimps can die in mass due to not being handled in time, thereby causing serious economic losses to farmers.

Figure 4 are samples of shrimp infected with WSSV brought to the testing facility by the farmer, at the same time shrimp in the pond also died in mass. The head shell had many round white spots.

The above analysis indicates that white spot disease occurs every year in Thua Thien Hue province. The extent of damage caused by the white spot virus is indisputable and the serious problem is that the disease development occurs too quickly, when farmers realize the external manifestations of the disease, the farmed shrimp may die for a short time later. Apart from real-time PCR, there is no other technology to detect the disease early, causing serious damage to shrimp farmers. To solve this urgent problem, it is necessary to apply modern technology to the rapid and on-site detection of diseases caused by WSSV.

3. ELECTROCHEMICAL SENSOR IN WSSV DETECTION

3.1. Proposal system

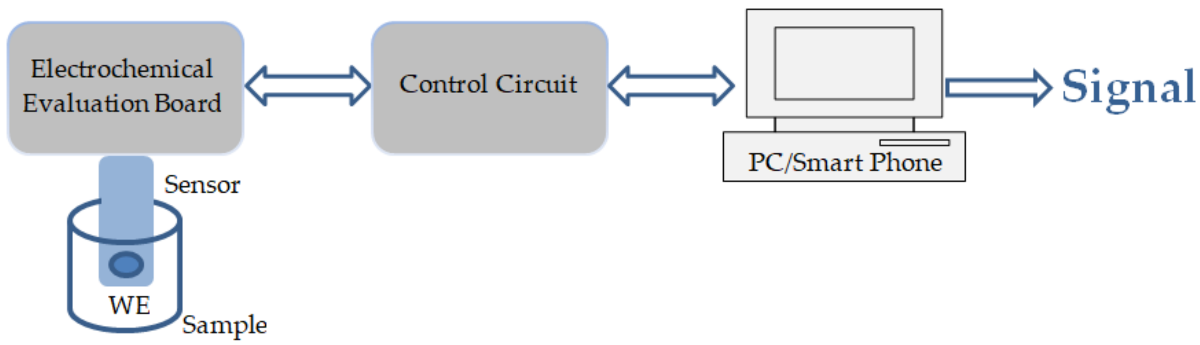

Figure 5. The block diagram of the electrochemical biosensor system

An electrochemical biosensor is an application of an electrochemical sensor, which integrates a biosensor and an electrochemical signal converter. It consists of 3 main parts [17]:

(i) Biological recognition element: detects targets that need to be identified specifically.

(ii) Transducer: converts biological signals into measurable electrical signals.

(iii) Signal processing system: converts the measured signals into readable signals and outputs the necessary information.

The transducer is an electrochemical measuring system - Potentiostat. For the system to be used directly at shrimp farms, it needs to have the main requirements: portable, easy to use, low in cost, specific to WSSV. Electrochemical evaluation boards (AD5940ELCZ), Control circuit (Arduino Uno or ESP8266 for wifi connection) and Control software for signal processing (Matlab) are proposed to use. The block diagram of the electrochemical biosensor system is shown in Figure 5.

The WSSV viral envelope consists of at least 35 different proteins of which VP28 and VP26 account for approximately 60% [30]. Therefore, antibody VP28/26 has been used to functionalize the sensor electrode surface [19][31]. When WSSV binds to the sensor electrode (binding between protein VP28/26 in virus envelop and antibody VP28/26 mounted on electrode surface), the non-conductive virus particles coat the conductive surface, increasing the electrical resistance. From there, a standard curve representing the relationship between the percentage change in the impedance and the corresponding virus concentration is constructed. The electrode functionalization procedure [32] is shown in Figure 6. This is also the Biological recognition element of an electrochemical biosensor.

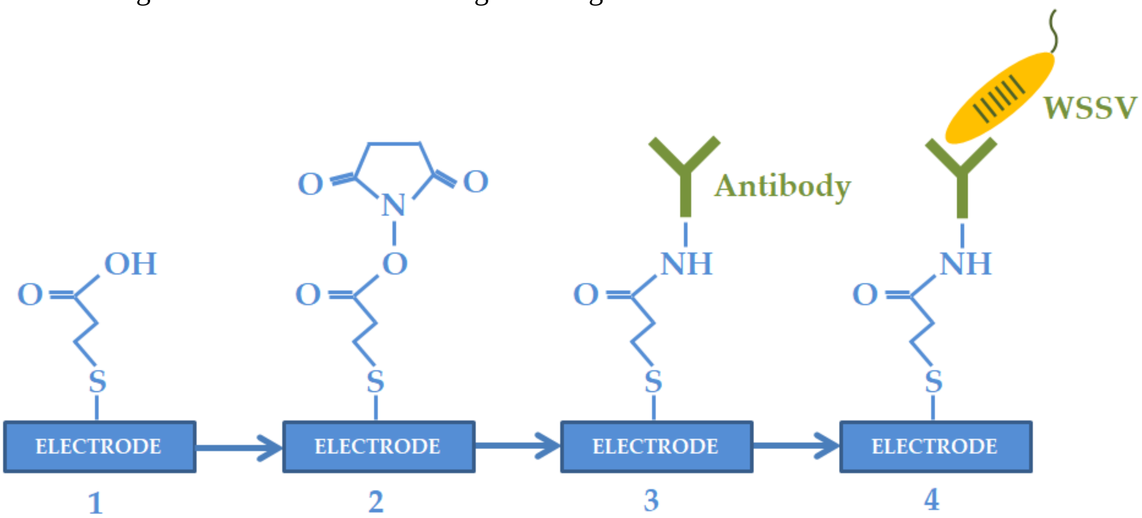

Figure 6. The electrode functionalization procedure: 1. Make a self-assembled monolayer; 2. Activate carboxyl; 3. Bind antibodies; 4. Link Antibody – WSSV

In Figure 7, EIS (Electrochemical Impedance Spectroscopy) response was recorded before and after making a SAM (self-assembled monolayer) on the surface of the gold electrode in the presence of $Fe(CN6)^{3-/4-}$ 5mM in KCl 0.1M at a frequency range between 0.1 Hz and 10^5 Hz. Screen-Printed Electrode is used to measure on Metrohm Autolab system. Experimental results show that the diameter of the semicircle in the EIS spectrum increases significantly after binding SAM (SAM electrode) to the BARE electrode.

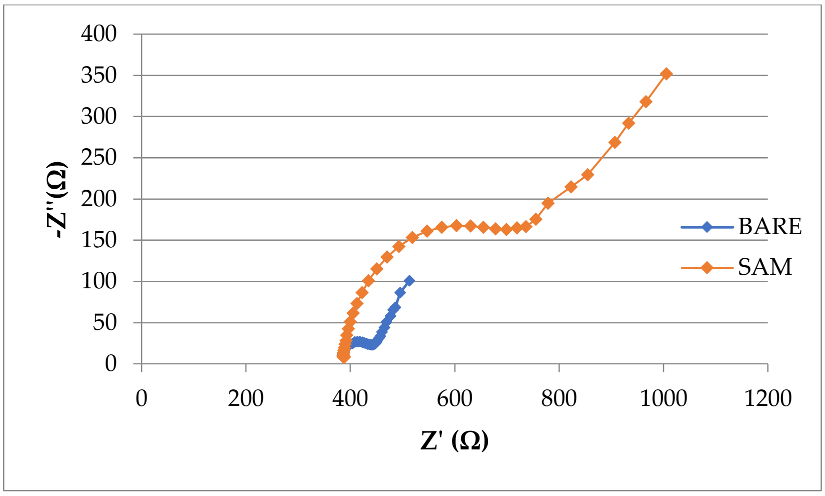

Figure 7. EIS response of BARE electrode and SAM electrode

3.2. Development prospects of electrochemical method

Of the causes of white spot disease, shrimps infected with viruses cause the most severe loss. For the white spot virus disease on shrimp, there is currently no treatment method, mainly using disease prevention and anti-epidemic measures such as monitoring batches of broodstock, collecting water and pond bottom sediment samples to test if in doubt; treating water, ponds, tanks, tools, breeding areas; harvesting diseased shrimp for destruction according to the guidance. Parallel to preventive measures is diagnosing the disease by clinical or laboratory diagnostic methods.

Due to the inability to return the analysis results early, it is difficult for farmers to come up with effective solutions such as harvesting immediately or continuing farming or carrying out treatment measures depending on whether shrimp are infected with WSSV. As a result, shrimp can die in mass due to not being handled in time, thereby causing serious economic losses.

Compared with PCR diagnostic methods, the electrochemical sensor device has a simple structure, easy to use, suitable for monitoring and early warning of WSSV virus on-site for shrimp farms where complex, modern equipment and professional technicians are not provided. In addition, the electrochemical sensor is simple to design and develop structure; the working electrodes, counter electrodes, and comparison electrodes are all integrated into a small chip, which helps to reduce the volume and mass of the sample that needs analysis.

Therefore, the development of sensor system for the purpose of early detection and real-time monitoring of white spot disease on shrimp at the farm is an extremely necessary work, bringing high economic efficiency to shrimp farmers. Figure 8 shows the overview of the proposed system for the early detection of white spot disease in shrimp.

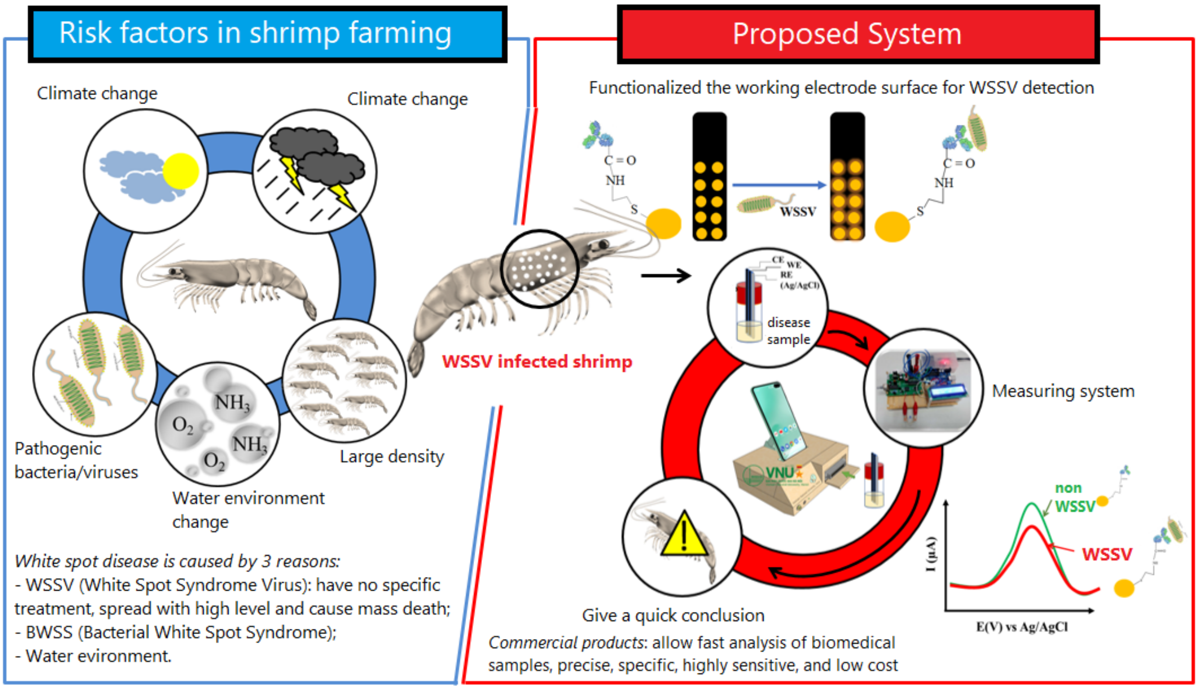

Figure 8. Overview of the proposed system for early detection of white spot disease in shrimp

However, the challenge is to apply microelectronics and microsensor technologies in the process of building the system in order to obtain the signal with high stability and accuracy. The electrochemical biosensor is also a new technology that has not been applied much locally. This is the calculation that is solved in our next studies.

4. CONCLUSIONS

White spot shrimp is the most dangerous disease that causes serious damage to shrimp farmers and the aquaculture economy. However, this disease has not received much research attention because it has been only found in aquaculture countries. Technically, there are numerous papers not only providing solutions for detecting white spot virus in shrimp with the sensor but also showing that this sensor has been successfully tested for other shrimp pathogenic viruses, opening up flexible application possibilities for it in the near future. Besides, using the electrochemical method is very suitable for on-site detection and early diagnostics of WSSV. In the next research, a complete electrochemical biosensor system having the function of detecting and quantifying WSSV from farmed shrimp can be developed, and the proposed device can act as a real-time monitoring system for timely virus detection.

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A QUANTITATIVE APPROACH OF PAN SHARPENED OUTPUT WITH HIGH-RESOLUTION UAV DATA AND SATELLITE IMAGERY

C. Das[1], P.Jena[1], F. Dutta[1] and B. K. Handique[1,*]

[1]North Eastern Space Applications Centre, Department of Space, Government of India
Email – bkhandique@gmail.com
* Corresponding author

ABSTRACT: There have been notable studies in improving information extraction through pan-sharpening of multi-resolution satellite data. The availability of very high-resolution data from UAV (Unmanned Aerial Vehicle) platforms has provided better scope for fusion with satellite data for various applications, including detailed mapping and monitoring of crops. Imageries from Sentinel-1 and Sentinel-2 satellites and high-resolution UAV multispectral data were fused to study the improvements in classifying field crops. Color Normalized (CN) Brovey Pan-Sharpening algorithm was used for fusion of individual bands from satellite as well as UAV data. Best fused data have been considered with minimum RMSE for further classification. It is observed that NIR band performed best among all the UAV multispectral bands. K-NN (K Nearest Neighbor) and DT (Decision Tree) supervised classifiers were used for segmentation and classification of fused data. DT gave higher accuracy of 70.75% for the fused data of Sentinel 2 and 68.87% for the fused data of Sentinel 1. Our study reveals the compatibility of UAV multispectral data with the Sentinel-1 and Sentinel-2 for fusion resulting in better crop discrimination.

Keywords: *UAV, Pan-Sharpening, Segmentation and Crop classification Accuracy assessment.*

1. INTRODUCTION

Agriculture is an important sector of the Indian economy and provides livelihood to a majority of the population. Acquiring timely and reliable agriculture information is crucial to the establishment of related policies and plans for food security, poverty reduction and sustainable development. Since its inception in the 1960s, Remote Sensing has opened up a plethora of options for exploration and innovations in various domains. In the past two decades it has been widely used as a powerful tool for rapid, accurate and dynamic agriculture applications (Shanmugapriya et al., 2019). European Space Agency (ESA)'s Sentinel operational satellites have set a new paradigm for remote sensing applications (Berger et al., 2012). Sentinel 1 works on the microwave range (Torres et al., 2012), whereas Sentinel 2 works on visible EMS (Drusch et al., 2012). The Remote Sensing community is diligently investigating these medium spatial and wide spectral resolution sensors to enhance the quality and betterment of the study. However, the constraints *viz*., relatively low and fixed spatial and temporal resolution, cloud occlusion, high equipment costs etc. of the space-borne sensors pose a serious threat to the frequent monitoring of agricultural activities. Because of this, UAVs equipped with multiple imaging sensors, autopilots and GPS systems are becoming a valuable and competitive tool for augmenting traditional space-borne and aerial RS approaches (Rokhmana, 2015; Deng et al., 2018).

UAVs provide high spatial, temporal, and spectral resolution imageries at low-cost in a flexible manner in terms of flight configurations such as observation angles, flight routes, for which UAVs are fast developing and offer a powerful technological strategy for many agricultural applications, including crop status mapping, crop yield prediction, diseases detection, weed and pest management rapidly and non-destructively.

Pan-sharpening is a technique that enhances low-resolution data and maintains the integrity of data for better image analysis (Jagalingam and Hegde, 2015; Jenerowicz et al., 2017). Studies suggested that fusion of high-resolution UAV multispectral data with coarse satellite images gives better enhancement for crop differentiation and analysis of crop stages up to a significant level of accuracy (Vivone et al., 2015). The present study focuses on integrating the optical and microwave satellite images (Sentinel-1 and Sentinel-2) with UAV data. The effectiveness of these fused products in distinguishing crops using multiple classification algorithms on small and fragmented land is also investigated.

2. MATERIALS AND METHODS

2.1. Study Area

The study village named Bandia is located in Darrang district of Assam state in the north eastern part of India (26^{0}26'57.22"N and 92^{0}3'7.02"E).

Maize, the main crop grown during the Rabi (winter) season, plays an important role in the rural economy. Rice, jute, mustard and seasonal vegetables are also cultivated in the study area.

2.2. Methodology

Three different types of datasets, viz., Sentinel 1 (SAR), Sentinel 2 (Multispectral) and UAV (Multispectral) were used for this study. The dual-camera system (Red Edge MX and Red Edge MX Blue) integrated into the UAV, gives 10 synchronized bands.

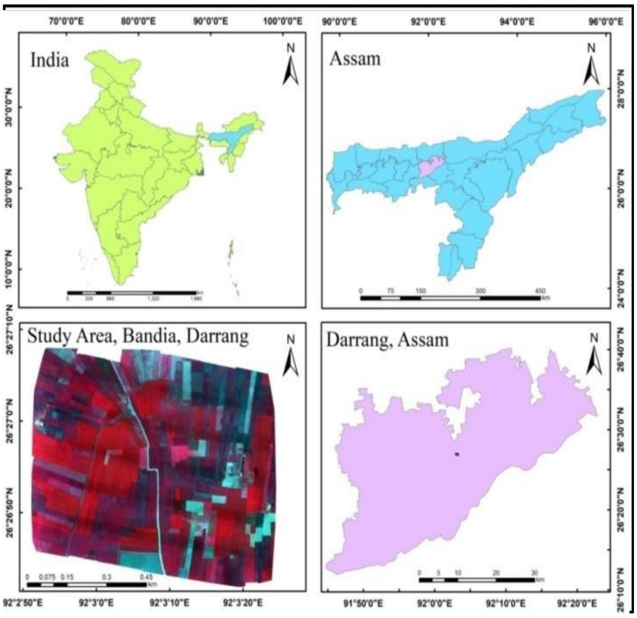


Figure 1. Location Map

The flights were taken about 120m above the ground with an equivalent ground sample distance (GSD) of 8.8 cm per pixel and the data capturing speed was 1 frame per second. To ensure the consistency in the dataset, UAV survey was scheduled on the same date of Sentinel pass. The SNAP toolbox was used to pre-process the Sentinel 1 and Sentinel 2 data (Filipponi, 2019). The UAV images were processed through the Pix4D mapper software (Pix4D SA, Switzerland) to obtain geo- rectified, orthomosaic reflectance data. The dual polarized Sentinel-1 SAR (VV and VH) and three Sentinel-2 multispectral bands (Green, Red and NIR) having 10m spatial resolution were fused (Color Normalized Brovey Pan-Sharpening) with 8.8cm UAV data. Root Mean Square Error (RMSE) was then calculated to determine the acceptability of the output (Jagalingam and Hegde, 2015), based on which the fused product with lowest RMSE were chosen for crop discrimination.

To delineate different crops, object-based image segmentation were employed on the fused data,followed by employing multiple classification approaches, *viz.* Support Vector Machine (SVM), Random Forest(RF), Bayes Classifier (BC), K Nearest Neighbor (KNN) and Decision Tree (DT) algorithms. The segmentation and classifications were executedthrough e-Cognition 9.0 software. It was found that KNNand DT produced better results, which were analyzed for accuracy assessment. The detailed methodology followed is illustrated in Figure 2.

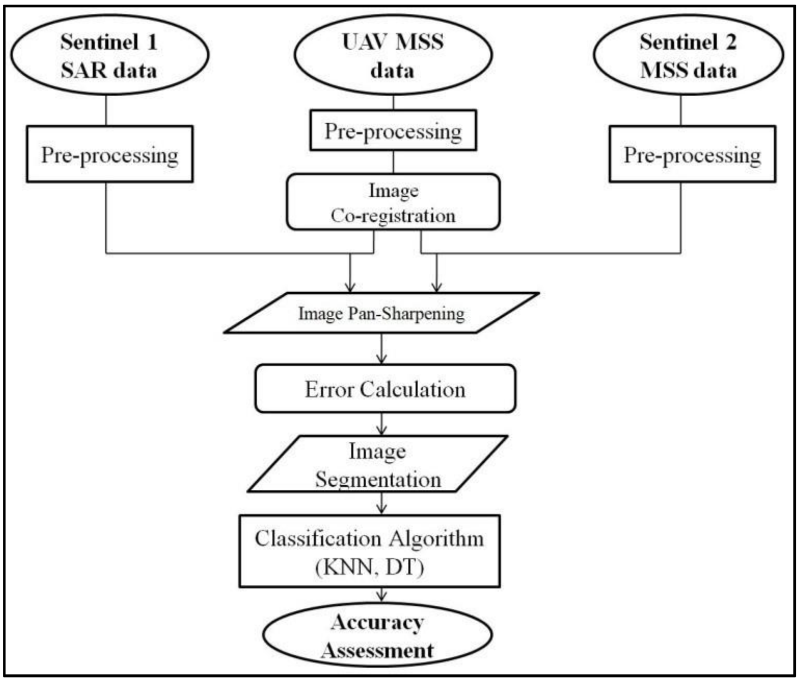


Figure 2. Methodology Flowchart

3. RESULTS AND DISCUSSION

3.1. Fusion of Sentinel images with UAV multispectral data

Figure 3(a) and 3(b) demonstrate the error analysis of the fused data product between Sentinel (Sentinel-1 SAR & Sentinel-2 multispectral) images and UAV 10 band multispectral data. Among all the output, the fusion of satellite images with UAV-NIR band (λ: 842nm) revealed to have the highest accuracy in maintaining the integrity of the raw data. Hence, for subsequent analysis, we considered the UAV-NIR based fusion with Sentinel datasets, the output of which is depicted in Figure 4 & 5.

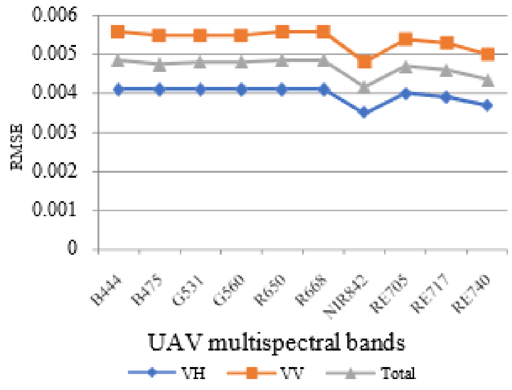


Figure 3(a). RMSE of the pan sharpened output of UAV with SAR data

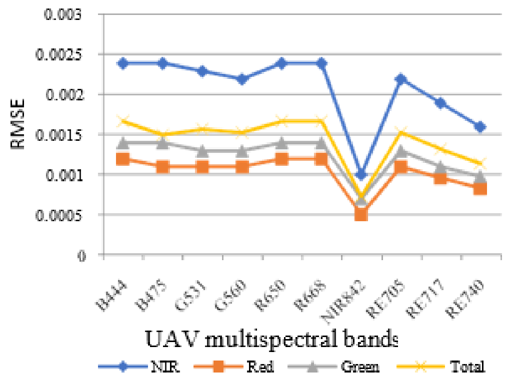
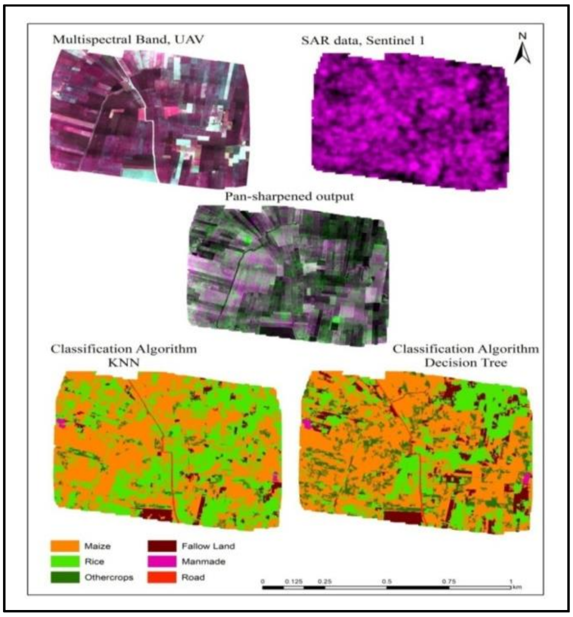


Figure 3(b). RMSE of the pan sharpened outputof UAV with multispectral data

3.2. Image Classification

The results of image classification on fused data are shown in Figure 4 & 5 and Table 1. It was observed that both the classification algorithms performed better in UAV-NIR & Sentinel-2 Multispectral fused data (UAV-S2) as compared to UAV-NIR & Sentinel-1 SAR fused product(UAV-S1). Between the classifiers, DT outperformed KNN with overall accuracy of 70.75% in UAV- S2 and 68.87% in UAV-S1. Relatively lower accuracy in KNN was attributed to misclassification, as the classifier considers the dataset's nearest or adjoining training values to analyze input characteristics (Zhang et al., 2018). In the current exercise, some fallow lands are fallen in rice category, since both the fields were water-logged at the time of image acquisition. It was also noticed that the reflectance of maize at early growth stage has similar signature with transplanted rice in upland situation that reduced the classification accuracy of KNN over DT. On the other hand, DT supports automatic feature interaction that generates a model or tree to determine the target class with respect to the training samples (Al-Obeidat et al., 2015), which in turn resulted in better classification with higher accuracy. Similar advantage of DT classification algorithm over other supervised algorithms was also observed by Sharma et al. (2013) and Mishra et al. (2017).



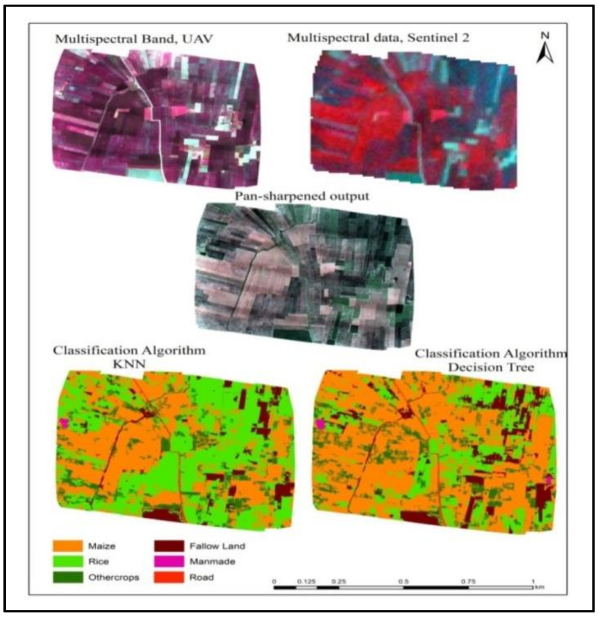


Figure 4. Classified output of Sentinel 1-UAV

Figure 5. Classified output of Sentinel 2-UAV

Table 1: Overall Accuracies and Kappa Coefficient Values of Classified Outputs

Classified Output	Classification Algorithm	Overall Accuracy(%)	Kappa
Fused S1-UAV	KNN	66.98	0.55
	DT	68.87	0.57
Fused S2-UAV	KNN	68.87	0.57
	DT	70.75	0.60

4. CONCLUSIONS

The study aimed to find the best suitable bands for pan-sharpening output and check the compatibility of the data (Sentinel 1 and Sentinel 2) for fusion with UAV multispectral data and its applicability for post-processing. Of all the classifiers used, KNN and DT delivered satisfactory output. We found the DT classifier the best fit for the fused data analysis, considering the producer and user accuracies and Kappa coefficient values. Sentinel 2 multispectral pan-sharpened output gave better results in conserving the data integrity. Also, Sentinel 1 pan-sharpened output performed satisfactorily well for crop discrimination. Our attempt to fuse the Sentinel 1 data with UAV multispectral data bear good promise for the discrimination of crop grown in *kharif* (monsoon) season.

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APPLYING THE LONG SHORT-TERM MEMORY METHOD TO SIMULATE THE STAND GROWTH OF PLANTATIONS AFTER THINNING AND MODEL EVALUATION

Shyh-Chian Tang[1, *)], Jiunn-Lin Wu[2)], Yi-An Chen[2)], Han-Ching Hsieh[1)]
and Wei-Hsuan Chen[1)]

1) Taiwan Forestry Research Institute, Council of Agriculture, Executive Yuan. Taiwan, R.O.C.
stantang@tfri.gov.tw
2) Department of Computer Science and Engineering, National Chung Hsing University. Taiwan, R.O.C.

* Corresponding author

ABSTRACT: Thinning operations play an important role in plantation management since economic and ecological benefits exist. The forest managers should realize the prediction of plantation growth after different thinning regimes. With the remarkable process of artificial intelligence (AI) in recent years, there are various methods to simulate a nonlinear stand growth model. The management risk could be reduced by exact prediction of tree growth. In this study, the AI deep learning technique (Long short-term memory, LSTM) was applied to predict the stand growth of thinning permanent plots of Taiwan red cypress (*Chamaecyparis formosensis*) and Taiwania (*Taiwania cryptomerioides*). The plots are located in the Forest Conservation and Management Administration, Veterans Affairs Council, and Taiwan Forestry Research Institute, Council of Agriculture. The LSTM module was developed based on the Recurrent Neural Network (RNN) method. And it was found suitable to deal with time series issues. For the Taiwan red cypress plantations, the reserved basal areas after thinning were 8, 11, 15, and 21 m^2/ha, and the DBH and tree height were investigated for trees 9 to 35 years old. On the plots at Taiwania plantations, the reserved basal areas were 28 and 32 m^2/ha. The investigated trees ranged from 20 to 39 years old. Using the above LSTM method, the modules for DBH vs. tree age, tree height vs. tree age, and tree height vs. DBH could be constructed. The Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) were applied to evaluate the model performance. The results demonstrated that the prediction models showed good credibility. And that there is potential in using the AI technique to predict the stand growth. It could be the future reference for stand management and thinning programming.

Keywords: Deep *Learning, Stand Growth, Taiwan red cypress (Chamaecyparis Formosensis), Taiwania (Taiwania Cryptomerioides), Thinning Regime.*

1. INTRODUCTION

Thinning operations play an important role in tending measures of forest management. Outside of increasing the benefits of intermediate income, increasing timber production, enhancing domestic timber supply, and the self-sufficiency rate, it can promote tree growth, carbon sequestration, and plantation biodiversity (Su et al., 2015; Chiu et al., 2017; Chen and Yen, 2018), and enhance plantations health. Taiwan red cypress (Chamaecyparis formosensis) and Taiwania (Taiwania cryptomerioides) are two precious and important conifer plantation species. Their rotation ages are up to 80 years. It is vital to adjust stand density and increase intermediate income. Furthermore, suitable thinning operations can add to carbon sink processes in forest land and is, therefore, beneficial to counter climate change.

In forest unit management practice, predicting the stand stock after thinning correctly to reduce management risk is important. Artificial intelligence (AI) has recently been widely applied in fields including sound, image recognition, biomedicine, forestry, etc. (Liang et al., 2021). Compared with the traditional statistical regression method, premised hypothesis limits apply less to AI methods. This study attempted to use the Long Short–Term Memory method (LSTM), which belongs to deep learning, to stimulate and predict the stand growth after thinning. The model performance was evaluated to verify the simulation result.

2. MATERIALS AND METHODS

2.1. The plot description and database

Two permanent conifer species plot databases are applied in the study. The site description was as follows. The Taiwan red cypress plantations are located in the Forest Conservations and Management Administration, Council of Veterans Affairs, Executive Yuan. The plantations were built in 1982 and have four thinning treatments, including 8, 11, 15, and 21 reserved basal areas. The Taiwania plantations are located in the Taiwan Forestry Research Institute, Council of Agriculture, Executive Yuan. The plantations were built in 1979 and have two thinning treatments, including 28 and 32 reserved basal areas. The investigated intervals for the plots were from one to five years.

2.2. Modeling of deep learning for stand growth

There were exploding and vanishing gradients problems existing in the traditional Recurrent Neural Network (RNN). In order to solve the long-time series issues, the Long Short–Term Memory (LSTM) was submitted by Hochreiter and Schmidhuber. The LSTM included four new elements: Memory cell, Forget gate, Input gate, and Output gate (Hochreiter and Schmidhuber, 1997; Hsu, 2021). The structure and formulas are as follows.

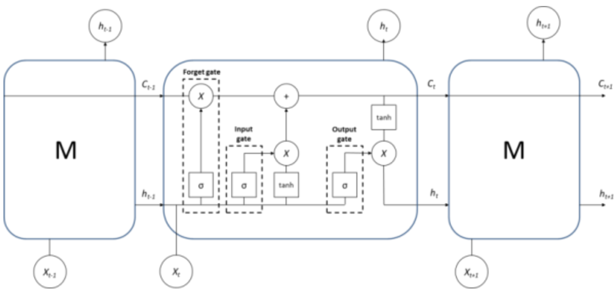

Figure 1. Structure diagram of LSTM

Forget Gate

$$f_t = \sigma(W_f \cdot [x_t, h_{t-1}] + b_f) \quad (1)$$

h_{t-1}: Output of the previous layer x_t : Input of Series data σ : Utility function
w,b : Parameter

Input Gate

$$i_t = \sigma(W_i \cdot [x_t, h_{t-1}] + b_i) \quad \widetilde{C_t} = \tanh(W_c \cdot [x_t, h_{t-1}] + b_c) \quad C_t = f_t \times C_{t-1} + i_t \times \widetilde{C_t} \quad (2)$$

i_t : Output of the utility function tanh : Activation function $\tilde{C}_t$: Output of tanh
C_t : Candidate output

Output Gate

$$o_t = \sigma(W_o \cdot [x_t, h_{t-1}] + b_o) \quad h_t = o_t \times \tanh(C_t) \quad (3)$$

o_t : Candidate value by the utility function h_t : Output of this layer

Performance evaluation of the model

The Mean squared error (MSE) and Mean absolute percentage error (MAPE) were used to evaluate the model performance. The formulas were as follows.

$$MSE(y,\hat{y}) = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y})^2 \qquad MAPE(y,\hat{y}) = \frac{\sum_{i=1}^{n}\left|\frac{y_i-\hat{y}_i}{y_i}\right|}{n} \times 100 \qquad (4)$$

y_i=Observed data $\hat{y}$= Prediction data n= Obertved times

3. RESULTS AND DISCUSSION

3.1. LSTM model construction

The LSTM models are based on the data of permanent plots of the Taiwan red cypress and Taiwania plantations after thinning. The DBH and tree height data were trained separately. In order to avoid the problem of overfitting, the Dropout mechanism was added so that training errors could be monitored. If errors could not be reduced effectively, training would be terminated in advance. The training datasets of the two conifer species for different thinning intensities included DBH vs. stand age, tree height vs. stand age, and DBH vs. tree height. The results are illustrated in figures 2 to5.

The results of the deep learning models well simulated the characteristics of tree growth. Python could be well used to code and simulate the DBH and tree height for different thinning strategies.

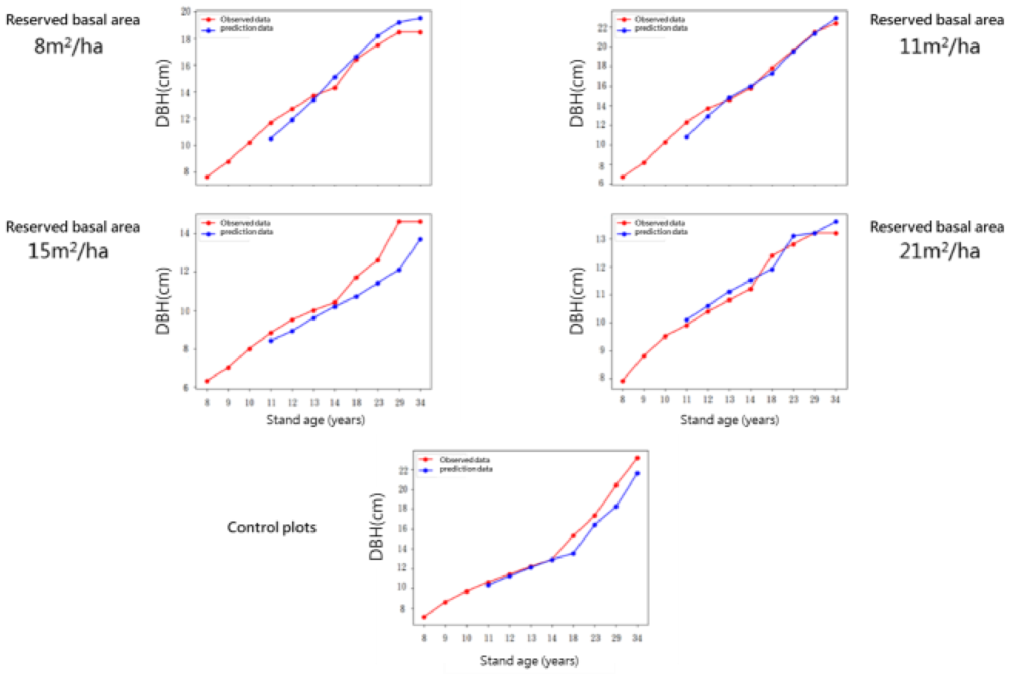

Figure 2. The prediction curves constructed by LSTM DBH model for Taiwan red cypress plantations vs. observed curves for different thinning intensities.

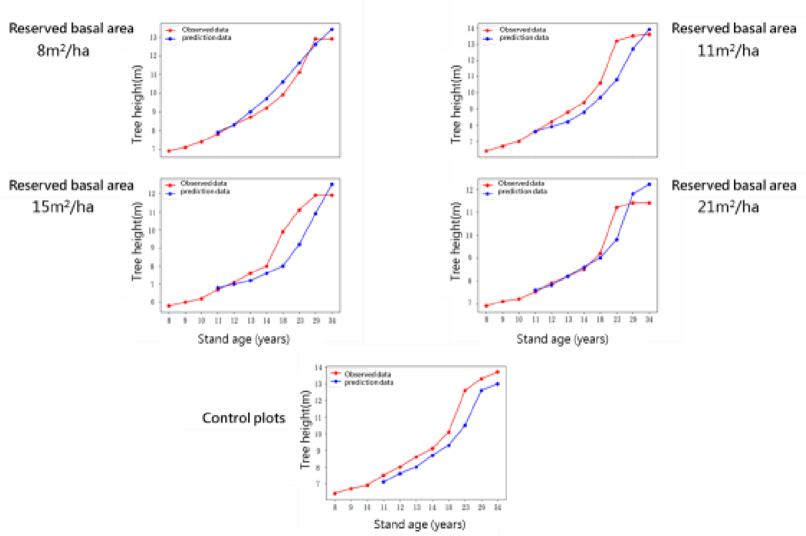

Figure 3. The prediction curves constructed by LSTM Tree height model for Taiwan red cypress plantations vs. observed curves for different thinning intensities.

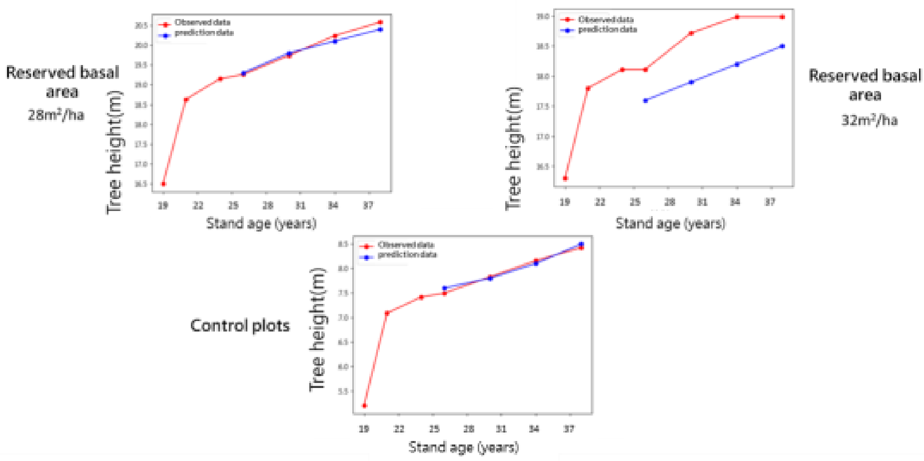

Figure 4. The prediction curves constructed by LSTM Tree height model for Taiwania plantations vs. observed curves for different thinning intensities.

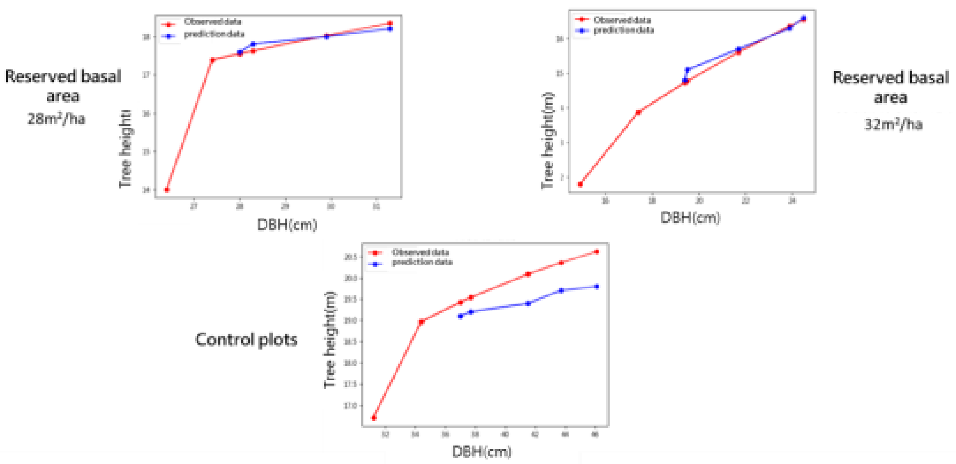

Figure 5. The prediction curves constructed by LSTM DBH – Tree height model for Taiwania plantations vs. observed curves for different thinning intensities

3.1. Performance evaluation of modelling

The MSE and MAPE were calculated for different LSTM models for the Taiwan red cypress and Taiwania to verify the model's effectiveness. The data was separated to train and validate the dataset in advance. If the MAPE value of the validated dataset was less than 10%, it meant that the constructed models had reliable simulation results. Tables 1 and 2 show that all the MAPE values of the validated dataset for the two species were less than 10%. Meaning the prediction models are found to be reliable in simulating the tree growth after thinning.

Table 1. Growth prediction model performance evaluation of Taiwan red cypress plantations.

	Reserved basal area (m^2/ha)	8		11		15		21		Control plots	
	Dataset type	Training	Validation	Training	Validation	Training	Validation	Training	Validation	Training	Validation
DBH growth model	MAPE	14.08	7.98	9.92	3.68	8.70	3.44	8.73	3.46	8.57	3.75
	MSE	16.67	8.11	5.19	1.62	5.21	0.54	3.94	0.45	3.06	0.58
Tree height growth model	MAPE	10.37	5.09	9.30	4.55	9.81	5.28	9.37	3.82	7.69	3.31
	MSE	2.36	0.49	1.65	0.92	2.20	0.96	1.91	0.33	1.46	0.49
DBH vs. tree height model	MAPE	11.47	5.15	10.14	5.25	9.37	6.30	8.40	5.83	10.74	7.06
	MSE	2.52	0.91	1.98	0.92	1.77	0.68	1.32	0.96	2.07	0.76

Table 2. Growth prediction model performance evaluation of Taiwania plantations.

	Reserved basal area (m^2/ha)	8		11		Control plots	
	Dataset type	Training	Validation	Training	Validation	Training	Validation
DBH growth model	MAPE	8.89	3.31	7.69	2.80	7.07	3.50
	MSE	25.29	3.55	11.64	1.88	5.51	1.05
Tree height growth model	MAPE	7.63	1.28	3.47	3.13	2.46	1.73
	MSE	3.43	0.11	0.71	0.40	0.28	0.21
DBH vs. tree height model	MAPE	2.61	0.82	1.19	0.42	2.18	0.67
	MSE	0.47	0.37	0.09	0.01	0.26	0.18

3.3. Simulation of stand attributes

The stand attributes such as DBH, tree height, and forest stock for different thinning strategies and ages could be simulated by constructing LSTM models. Furthermore, the stand's carbon sink could be calculated by using the methodology of IPCC (Intergovernmental Panel on Climate Change). Tables 3 and 4 illustrate the simulation results for DBH, tree height, forest stock, and carbon sink under different thinning regimes and ages for Taiwan red cypress and Taiwania plantations.

Table 3. Predictions for different thinning intensities for Taiwan red cypress plantations.

Reserved basal area (m^2/ha)	Stand age (yr)	Stand density (stands/ha)	Average DBH (cm)	Average tree height (m)	Forest stock (m^3/ha)	Carbon sink* (ton/ha)
8	15	1,150	15.8	9.6	98.0	33
	25	1,050	18.9	11.7	156.0	53
11	15	1,600	15.7	8.6	120.6	41
	25	1,500	19.4	10.6	212.7	72
15	15	2,300	15.2	8.9	168.1	57
	25	1,950	20.4	10.3	297.1	100
21	15	3,850	14.4	8.5	241.2	81
	25	2,020	16.1	9.4	175.0	59

*Calculated with the IPCC method.

Table4. Predictions for different thinning intensities for Taiwania plantations.

Reserved basal area (m^2/ha)	Stand age (yr)	Stand density (stands/ha)	Average DBH (cm)	Average tree height (m)	Forest stock (m^3/ha)	Carbon sink* (ton/ha)
28	20	740	32.6	17.9	500.4	128
	30	693	38.6	19.4	712.1	182
	40	640	46.2	20.6	1,000.4	256
	50	590	52	21.3	1,208.0	309
	60	545	55.6	22	1,317.7	337
32	20	863	16.1	12.8	101.8	26
	30	788	21.6	15.5	202.6	52
	40	712	25.1	17	271.1	69
	50	636	28	17.6	312.0	80
	60	568	29.3	17.8	308.6	79

*Calculated with the IPCC method.

4. CONCLUSIONS

The study attempted to apply deep learning LSTM techniques to simulate the stand growth after thinning. The analyzed data were collected from permanent plots of the Taiwan red cypress and Taiwania plantations. The MAPE method, for which the values were all less than 10%, illustrates that the models constructed by including DBH vs. age, tree height vs. age, and tree height vs. DBH have good simulation effects. The results of deep learning LSTM models conform to actual tree growth characteristics. The models were compiled by using Python to predict the stand's DBH, tree height, stand volume, and carbon sequestrations for different tree ages under different thinning regimes. The results could be used to develop a Decision Support System (DSS) to enable forest farmers and management units

5. ACKNOWLEDGEMENT

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ADVANCES, OFFICIAL SUPPORTS AND PERSPECTIVE OF SMART AGRICULTURE DEVELOPMENT IN CHINA

Li Dongpo*
(School of Economics and Trade, Hunan University of Technology and Business,
Changsha 410205, China)

ABSTRACT: Smart agriculture uses new generation technologies, such as the Internet of Things, big data, artificial intelligence, cloud computing, and blockchain to further refine and improve the intelligence of agricultural production. China considers smart agriculture as an important engine to promote high-quality agricultural and rural development. This study reviews the latest advances of smart agriculture as well as the challenges and official supports of smart agriculture. The study then summarizes the opportunities of smart agriculture and forecasts the future perspective of agricultural technology. Finally, the study offers suggestions for the acceleration of agricultural and rural development using high-quality smart technologies. The study's findings confirm that smart agriculture has become an important part of the national economy, although it is still in its infancy. Both the national and regional authorities of China have introduced policies favoring the development of smart agriculture. This has resulted in its high popularization, with perfect industrial chains and many large-scale enterprises involved in increasing the country's self-sufficiency in production and technology. While these policies have several positive effects on rural telecommunication and technology, smart agriculture faces certain constrains in terms of R&D capability, fiscal investment, farmer capacity, and talent training. By taking appropriate measures for these weak areas under unified planning, the agricultural and rural economic growth of China can be accelerated using high technologies.

Key words: *China, Advance, Official Support, Perspective, Smart agriculture.*

1. INTRODUCTION

Compared with the United States (US), Australia, and most European Union (EU) countries, China has a larger number of farmers, but lower scale of agricultural management. The average size of a farmland in the US is over 200 hm^2, with an average area of over 113 hm^2 per farmer. In the EU, 82% of farms are over 20 hm^2, 52% of them over 100 hm^2 in area. In contrast, 95% of Chinese farms are less than 3.4 hm^2 in area, and these account for over 80% of the total national cultivated land (Zhao, 2021). In recent years, with the acceleration in urbanization, China's rural population is showing a trend of reduction, an aging labor force, and an increase in per capita cultivated land area. The small scale and limited capacity of farmers constrain their production efficiency and profitability. Smart agriculture is an important measure to solve these problems by confronting the diminishing advantage of population-driven economic growth and the resources and environment constraints (Laurens *et al*., 2019). Smart agriculture is gaining popularity with its significant economic impacts reflected in increasing crop output, reducing labor intensity, and expanding farm size (Charania and Li, 2020). For instance, large-scale smart production management in Beijing could reduce the labor, water, fertilizer, and medicine use by 55%, 25%, 31%, and 70%, respectively (Zhao *et al*., 2021). It can also help promote smart technologies and maintain sustainability in agriculture (Hassina *et al*., 2020). Policies promoting smart agriculture have been proposed by the Communist Party of China's (CPC) central committee and the State Council in their annual *Central No. 1 Document* since 2012. Smart agriculture has become a component of China's modern agriculture following their 14th *Five-Year Plan (2021–2025) for National Socioeconomic Development* and *the Outline of Long-Term Objectives by 2035* adopted by the National People's Congress on March 11, 2021. A variety of other official documents have been issued to promote smart agriculture in China.

Many studies have focused on smart agriculture in China from the technical perspective, including climate-smart (Wang *et al.*, 2018; Tong *et al*., 2019; Liang *et al*., 2021), internet (Zheng *et al*., 2022), and cloud (Yang *et al.*, 2022) services. The other topics considered vary from general status and practice to path selection and policy suggestions, economic effects, and international comparison. Using macro statistical data and a national survey, Song (2020) and Cao *et al.* (2021) reviewed the features, problems, and promotion strategies of smart agriculture in China. In the context of rural revitalization, Zhao *et al*. (2021) summarized the macro demand for high-quality science and technologies and the strategies and route of China to reach its smart agriculture development goal by 2035. Liu *et al*. (2021) examined the impact of smart agricultural production investment (SAPI) announcements on shareholder value using sampled data of 118 listed companies in China from 2010 to 2019. Ma *et al*. (2020) explored the smart agriculture path of China in a comparative analysis with Japan.

In summary, few studies have comprehensively reviewed the policy framework of smart agriculture in China integrating the present status, perspective, and policy suggestions. This study tries to fill the research gap in this regard as follows. Section 2 summarizes the definition and components of smart agriculture from the perspective of Chinese academics, discusses the extension rate and domestic industry chain. Section 3 reviews the national policies for the promotion of smart agriculture in China. Section 4 examines the opportunities and problems of smart agriculture and the countermeasures suggested. Section 5 concludes the study, presenting the major findings and promotion features of smart agriculture in China.

2. SMART AGRICULTURE ADVANCES

2.1. Definition and components of smart agriculture

2.1.1 Concept and features of smart agriculture

Smart agriculture originated from the agricultural informatization of developed countries after their industrialization and agricultural mechanization. This can be traced back to the soybean disease diagnosis system of plant/DS invented by the University of Illinois in 1978 (Michalski *et al.*, 1982). According to a research report on smart agriculture development in China released by CAICT and CARD (2021), smart agriculture is a new agricultural production mode and comprehensive solution deeply integrating new generation information technology with decision-making, production, circulation, and trading.

Chinese scholars summarize smart agriculture into the following five features (Kang *et al*., 2019; Song 2020; Cao *et al*., 2021): (1) Digitization of information perception. Smart agriculture applies big data in decision making for agricultural production and management, using information acquisition technologies such as Internet of Things (IoT) and 5S, i.e., remote sensing technology (RS), geographic information system (GIS), global positioning system (GPS), digital photogrammetry system (DPS), and expert system (ES).Thus, man, machine, and things are connected in different processes to automatically perceive and accurately identify various agricultural elements, information, and environments. (2) Scientific management of decision-making. This is carried out with a highly integrated model using big data, machine learning, and artificial intelligence (AI), among other technologies. This model promotes personalized services such as quantitative analysis and investment in agricultural management. (3) Intelligent control. An intelligent network integrates AI and IoT to promote the automatic, intelligent, and unmanned operation of equipment. (4) Precision investment. A quantitative decision-making model helps to accurately optimize the resource allocation in each agricultural process and improve investment efficiency through reduced costs and consumption. (5) Personalized information service. A big data platform supplies diversified information for the benefit of agricultural business entities. Smart agriculture is a new business model and industry that will reshape the production, supply, and industrial chain. Thus, smart agriculture has great potential in the field of high-quality, efficient, green, and safe development (CAICT and CARD, 2021).

2.1.2 Components of smart agriculture

The fields suitable for smart agriculture in China and other countries include precision production, economic benefit accounting, food safety, and electronic commerce. Smart agriculture forms a closed loop that starts with complete and accurate data acquisition. Thereafter, a network provides a pipeline for the flow of data, taking scientific and accurate analysis as the core, and accords efficient execution by the end of the closed loop (CAICT and CARD, 2021).

Smart agriculture mainly uses next generation information and communication technologies (ICTs), represented by the following elements (Fig. 1). (1) Big data: A database on temperature, air humidity, wind speed, wind direction, sunshine, precipitation, crop growth, irrigation and fertilization, field management, disasters, soil characteristics, and facilities useful for mining and analyzing the relationship between variables and optimizing agricultural production (Huang *et al*., 2018). (2) IoT: An information aggregation platform based on the interconnection of various sensors, radio frequency identification (RFID), and other electronic terminals. Its core component and foundation are still the internet, but it highlights the automatic interconnection between terminals and business applications (Yang, 2019). (3) ICT: The general name for all communication equipment such as computers, network hardware, satellite system, and various services and application software for video conference, distance education, and so on. It provides great potential for better management of big data and efficiency improvement of agricultural production and business (Zhang *et al.*, 2016). (4) Data mining: A process to determine the general and essential relationship between variables using statistical theories and methods through empirical analysis of large volumes of data (Xiang, 2019). (5) Cloud computing: A network formed by the interconnection of multiple computer terminals. Huge data computing tasks are decomposed into several small programs, which are processed and analyzed by different servers, and then fed back to users through the network (Yang *et al.*, 2022).

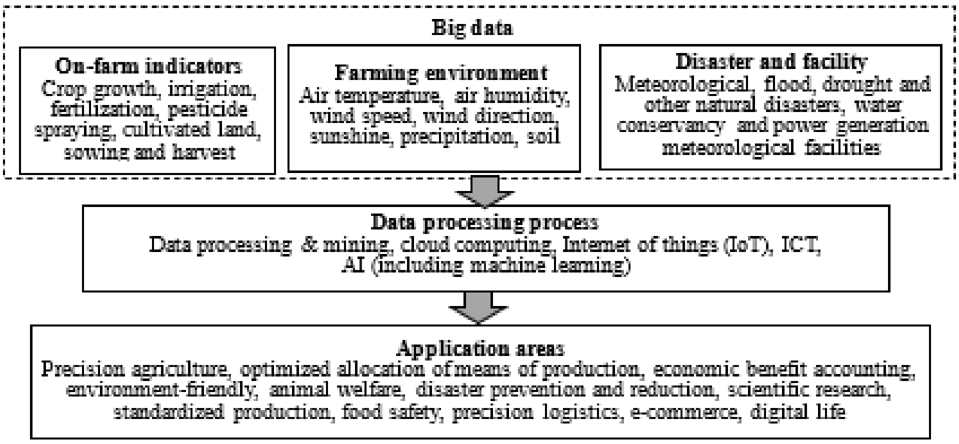

Figure 1. Components and application fields of smart agriculture.

Source: summarized and drawn by the authors

2.2. Smart agriculture practices in China

2.2.1 Extension to regions and sectors

China's smart agriculture started in the 1980s. Although China's smart agriculture is backward compared with that of some leading countries, it is developing rapidly in recent years. Several new generation technologies such as IoT, sensor and remote monitoring, wireless transmission, big data, and AI have been applied to agriculture. Through automation, digitalization, networking, and intellectualization, smart agriculture has improved the agricultural management and production efficiency of China. According to an estimation of the Qianzhan Industry Research Institute (QIRI)[1], the potential market size of China's smart agriculture has increased from US$13.7 billion in 2015 to US$26.8 billion in 2020, representing an annual growth rate of 14.3% (Fig. 2). China's smart agriculture includes four typical application scenarios. From the market share released by the QIRI (2019), they are data platform services (40%), UAV plant protection (35%), automatic agricultural machinery (10%), and fine breeding (15%). The 2015 and 2020 agricultural GDP of China were US$977.3 billion and US$1127.3 billion, respectively. Thus, in 5 years, the share of smart agriculture in China increased by one percent, from 1.4% to 2.4%. This indicates that China has a large potential for smart agriculture.

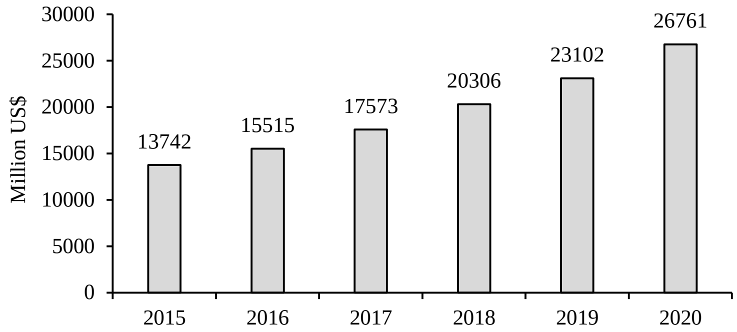

Figure. 2. Market size of smart agriculture in China from 2015 to 2020.
Source: https://www.qianzhan.com/analyst/detail/220/190513-8c89e13f.html

2.2.2 Smart agriculture industry chain

China's smart agriculture has formed a relatively perfect industry chain. The upstream chain consists of integrated circuits, satellite navigation systems, and sensors, whose components are manufactured mainly using nonferrous metals, monocrystalline silicon, and electronic ceramics. The midstream chain includes data platforms, UAV plant protection, automatic machinery, and smart breeding, while the downstream chain involves the processing of plant and animal products (Fig. 3).

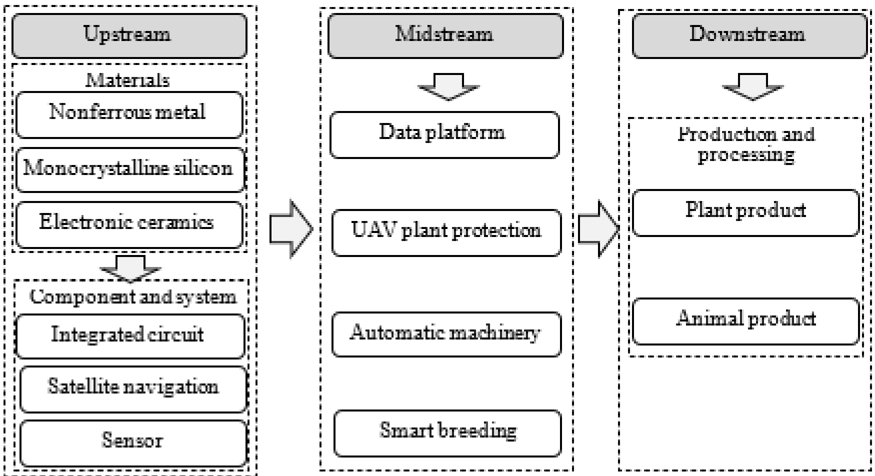

Figure 3. Schematic diagram of China's smart agriculture industry chain.
Source: https://bg.qianzhan.com/trends/detail/506/2111009-d9290910.html

[1] "Qianzhan" means "foresight" in Chinese. This listed institute was founded in 1998 at Tsinghua Campus, Beijing. It is committed to providing enterprises, governments, and research institutes with forward-looking advisory and solution reports in the fields of industrial application, planning, layout, upgrading and transformation, segmentation, and big data.

From Table 1, China's domestic enterprises provide the necessary products and technical support for the spread of smart agriculture in China in all sectors. Many of these enterprises are listed companies, such as CHC, Hi-Target, Hwali Create, SMIC, HIK Vision, and New Hope Group. While several of these enterprises were established around 2000, some such as COFCO Corporation, a time-honored state-owned enterprise group, were established in the 1940s, and others such as UML-Tech were new companies registered in the middle of the 2010s. The favorable policies of China prompted several traditional planting and breeding enterprises such as COFCO and Wens to adopt smart agriculture. In addition, many modern internet enterprises with smart technology have actively entered this field. For example, the internet giant NetEase started smart pig raising in 2009. It used modern technology to remotely monitor the physical condition, food intake, and excretion of pigs to provide them with a high-quality and comfortable living environment and produce delicious and safe pork (QIRI, 2021).

Table 1. Representative products suppliers of smart agriculture in China

	Sector	Representative supplier (Year of establishment, headquarter location)
	Satellite navigation	BdStar (2000, Beijing), CHC (2003, Shanghai), Hi-Target (1999, Guangzhou), Hwali Create (2001, Beijing)
	Integrated circuits	SMIC (2000, Shanghai), TSMC (1987, Taiwan), SK hynix (1987, Korea)
□	Sensors	HIK Vision (2001, Hangzhou), Dali technology (2001, Hangzhou), Goertek (2001, Weifang)
	Nonferrous metal	Xinjiang Joinworld (1958, Urumqi), Wanfang aluminum (1996, Jiaozuo)
	Monocrystalline silicon	TJSemi (1988, Tianjin), Longi (2001, Xi'an), Jinglong (1996, Xingtai)
	Electronic ceramics	Kyocera (1959, Japan), CCTC (1970, Chaozhou)
	Data platform	Haixinhuaxia (2008, Beijing), Aoko (2009, Beijing)
	UAV plant protection	DJI (2006, Shenzhen), XAG (2007, Guangzhou)
□	Automatic machinery	UML-Tech (2014, Beijing), ComNav (2014, Shanghai)
	Smart breeding	NetEase (1997, Guangzhou), Tequ (1997, Chengdu), Wens (1983, Yunfu)
	Plant product	COFCO Corporation (1949, Beijing)
□	Animal product	Deep Agriculture AI (2015, Nanjing), New Hope Group (1982, Beijing &. Chengdu)

Source: summarized by the authors, https://bg.qianzhan.com/trends/detail/506/211009-d9290910.html

3. CONSTRAINTS AND OFFICIAL SUPPORT

3.1. Bottlenecks of smart agriculture development

3.1.1 Less sustainability and independence of most smart agricultural projects

The R&D of smart agriculture takes a long period because it must cross several disciplines such as digital technology, agronomy, meteorology, and geography. Moreover, smart agriculture projects require continuous investment and face relatively greater technical and investment risks, making them less attractive to social funds. According to Cao *et al*. (2021), almost 50% of smart agriculture enterprises found the start-up construction costs too high, while 33% found the maintenance costs even higher, making it difficult for them to even recover their original investment. Furthermore, although the number of patent applications related to smart agriculture in China was the highest in the world, China faces a low rate of converting smart agriculture research achievements into field application. Some studies pursue the academic novelty and cutting-edge nature of the study or are guided by the criteria of article publication and project assessment, and do not fully consider the practical needs and acceptability. Moreover, China lacks independent innovation in key technologies such as crop growth modeling and production control software. Smart planting platforms, both in the field and facility of agriculture, are still in the early stages of commercialization. Several models and software were imported from institutions in the Netherlands, the US, Israel, and other countries (CAICT and CARD, 2021). Most smart agriculture pilot projects focus on the transmission and display of information, and do not deeply integrate with agriculture or have the means to solve the practical problems (Song, 2020).

3.1.2 Insufficient and unbalanced fiscal investment

By having greater social than economic benefits for a long period, smart agriculture in China has made it obligatory for the government to invest and promote it. However, because of limited budgets and awareness, the government at all levels have relatively insufficient funds for investment in smart agriculture. According to the information center of the Ministry of Agriculture and Rural Affairs, the county-level[2] financial investment in agricultural and rural informatization in 2020 accounted for only 1.4% of the national financial expenditure on agriculture, forestry, and water affairs. Of the 2703 county-level administrative regions sampled for monitoring and evaluation, 535 regions, accounting for 20.2% of the sample, did not have financial investment for agricultural and rural informatization; 22% of the regions still have neither administrative department nor public institution, such as an information center to undertake information work. This indicates the urgent need to improve the institutional and personnel capacity of smart agriculture (MARA, 2021b). In addition, the funds earmarked by the government for smart agriculture tend to support platform construction, especially those with large visual screens. According to the Chinese government's procurement website, of the 709 local government procurements relating to smart agriculture during the period 2014–2020, 268 were used for platform construction. These platforms have highly similar functions and poorly meet the needs of smart agriculture (CAICT and CARD, 2021).

3.1.3 Farmers lack the foundation to extend smart agriculture

At present, owing to the low profitability of agriculture, most young and middle-aged people seek employment in other industries. Thus, the elderly and women constitute the main labor force of agriculture and the demand for new agricultural technologies is insufficient. The multiple cropping index of cultivated land has decreased and many farmlands have been abandoned. Rural land transfer lacks orderly guidance, and this affects the scale enlargement of agricultural management. More than 98% of agricultural business entities are household farms; these account for 90% of the agricultural labor and 70% of the cultivated land (CAICT and CARD, 2021). The small scale of household farms makes them less profitable and incapable to adopt new information technologies. Since 2016, the average net profit per unit area of the three major grain crops, wheat, rice, and corn, has remained negative when labor cost is included. In 2019, the average output per labor was equivalent to only 4% in Israel, 5% in the US, 15% in the EU, and 17% in Japan (Zhao *et al*., 2021). The high costs are generally not affordable for most farmers, and this, along with the technical thresholds, constrains the promotion of smart agriculture. Therefore, smart agriculture is generally applied to some high-value cash crops, with only a few economically strong enterprises exploring its small-scale application.

3.1.4 Smart agricultural talent-training system yet to be established

The *Outline of Digital Rural Development Strategy* and the *Digital Agriculture Rural Development Plan (2019-2025)* have a series of arrangements to train digital agricultural talent. Since 2018, the Ministry of Education has approved the proposal of more than 10 agricultural universities to set up undergraduate majors in areas such as AI, data science, and big data technology and the establishment of 15 majors in smart agriculture, 6 majors in agricultural intelligent equipment engineering, and 2 majors in smart animal husbandry science and engineering. However, this is insufficient to meet the social demand for professional talent, and most studies are still in the stage of exploration and theoretical research. In a survey by Cao *et al*. (2021), nearly 60% of the business entities estimated that the largest obstacle to agricultural informatization as shortage of talent. More than 80% of the enterprises have a

[2] China has five administrative divisions, central, provincial, municipal, county, and township, of which the county and township are generally classified as rural areas.

demand gap for smart agricultural talent, of which the demand for technical talent is the largest, accounting for 59.3%. Among them, 62.9% found it difficult to recruit excellent talent, while 14.8% found this very difficult. In addition, the information technology skills training for farmers and new agricultural business entities is insufficient, with 40% of business entities saying that they lacked professional skills guidance. Thus, China's interdisciplinary smart agricultural talent training base and academic platform are yet to be fully established, implying a great demand for smart agricultural application and management talent.

3.2. Official Supports on Smart Agriculture Promotion

In China, the CPC Central Committee and the State Council jointly issue their annual *Central No. 1 Document* specifying the key issues to be solved with priority every year. In 2012, the document proposed the promotion of precision agriculture technology. The following years saw the document specifying more relevant terms and preferential policies favoring the rapid extension of precision agriculture technology. In 2015, the document adopted "intelligent agriculture" with necessary technological breakthrough. In 2016, it proposed the vigorous promotion of information technologies such as internet plus, IoT, cloud computing, big data, and remote sensing. Since 2017, the document has been using the term "smart agriculture"[3] regarding rural revitalization, rural e-commerce, and other post-2018 promotion measures (Table 2). The background is that the 19th CPC National Congress held in October 2017 put forward the goal of rural revitalization.

Table 2. Topic and contents relating to smart agriculture in the *Central No.1 Document* jointly issued annually by the Central Committee of CPC and the State Council of China in January to February.

Year	Topic of the No. 1 Document and contents relating to smart agriculture
2012	*Accelerating the innovation of agricultural science and technology to continuously enhance the supply capacity of agricultural products*: to accelerate research on cutting-edge technologies to achieve major independent innovation achievements in information communication and **precision agriculture**.
2013	*Accelerating the development of modern agriculture and further enhancing the vitality of rural development*: to develop **agricultural information services** with emphasis on information collection, accurate operation, remote digitalization and visualization, meteorological prediction and forecasting, and disaster warning.
2014	*Comprehensively deepening rural reforms and accelerating agricultural modernization*: to build an information and mechanization technology system focusing on the **IoT and precision equipment**, promote the R&D of new industrial especially facility agriculture and intensive processing.
2015	*Strengthening reform and innovation to speed up the construction of agricultural modernization*: to make major breakthroughs in **intelligent agriculture**, agricultural machinery and equipment.
2016	*Implementing the new development concept, speeding up agricultural modernization, and the building of all-round well-off society*: to implement key projects of **intelligent agriculture**; to promote **smart meteorology and remote sensing**; Internet plus; updating agriculture through Internet^{+}, IoT, cloud computing, big data and remote sensing.
2017	*Deepening the agricultural supply-side structural reforms and accelerating the cultivation of new driving forces for agricultural and rural development*: to implement **smart agricultural projects** and promote the demonstration of **the IoT and smart equipment**; to promote **smart meteorology** and disaster monitoring.
2018	*Implementing the rural revitalization strategy*: vigorously promote digital agriculture, implement smart agriculture, and promote **IoT pilot demonstration** and **remote sensing** technology applications.
2019	*Giving priority to improving the work on agriculture, rural areas and farmers*: to foster a number of technological innovation forces, and promote independent innovation in **smart agriculture**.

[3] Here, "intelligent agriculture" and "smart agriculture" are used to differentiate the two Chinese terms of "智能农业" and "智慧农业". The main difference is that "intelligent agriculture" emphasized the industrialization of agricultural production under relatively controllable environment and conditions (Yang, 2019: 11).

2020	*Promoting the key work in agriculture, rural areas and farmers to ensure the realization of all-round well-off society on schedule*: to build agricultural and rural big data center, promoting the application of **IoT, big data, blockchain, AI, the 5G mobile communication network, and smart weather forecasting**.
2021	*Comprehensively promoting rural revitalization, accelerating agricultural and rural modernization*: to promote **smart agriculture**, establish **big data** system, and deepen the integration with **new generation IT**.
2022	*Key work of comprehensively promoting rural revitalization in 2022*: to support the construction of **smart grain depots**, R&D and application of high-end **smart machinery**, and develop **smart environmental controlling**.

Source: summarized by the authors

In January 2019, the Ministry of Agriculture and Rural Areas and the Office of the Central Network Security and Information Technology Commission jointly released the *Digital Agriculture and Rural Development Plan* 2019–2025. This plan defined the specific objectives and key tasks, and scheduled the smart transformation of agriculture and rural areas from the perspectives of resources, production and management, public service, and governance. In May 2019, the Central Committee of the CPC and the State Council issued the *Outline of Digital Village Development Strategy* proposing to complete rural digitalization by the middle of the century, specifying their phased goals and plans.

The central government's specific policies on the spread of smart agriculture must be implemented through the relevant ministries and commissions. The Ministry of Agriculture and Rural Affairs has a key role in promoting smart agriculture from the following aspects: (1) Implementing key projects: By September 2021, their targets include 9 provinces and 426 projects demonstrating IoT, 100 digital pilot projects, 210 digital demonstration bases, and 120,000 informatized machinery. (2) Special subsidies: The Guidance on Agricultural Machinery Purchase Subsidy 2021–2023 was issued jointly with the Ministry of Finance in March 2021. This increased the subsidy rate for some products to 35% and stipulated that the machinery excluded can be subsidized through special pilot or appraisals. A special project was set up to promote R&D, demonstrate and promote smart machinery, and form an innovative consortium of leading machinery enterprises. (3) Construction of informatization standards: A technical committee for agricultural informatization standardization established in 2016 included four working groups for big data, IoT, network information security, and e-commerce. A *standard system for agricultural informatization* (provisional) was formulated, and two standards, *the basic metadata of agricultural information* and *technical specification for agricultural data sharing,* were officially released. (4) Data sharing: Since 2016, big data and data sharing have been promoted in 21 province-level regions, with big data centers constructed for eight agricultural products such as rice, soybean, oil, and cotton. An online market information platform for staple agricultural products was established in 2017. This provided large amounts of authoritative, timely, and machine-readable data. (5) Talent training: Since 2015, 100 million farmers have been trained nationwide in smart phone application skills. Fourteen e-commerce courses have been held after 2018 covering a total of 1500 trainees (MARA, 2021a).

4. PERSPECTIVE OF SMART AGRICULTURE IN CHINA

4.1. Development with high speed and quality

4.1.1 Promoting continuously enriched and improved policies

In China, the government provides strategic guidance, rule-making, and policy support considering the specific advantages and actual conditions of various regions. The central government issues increasing plans, guidelines, opinions, and schemes to the local governments and updates them to promote smart agriculture in terms of infrastructure, e-commerce, and information services. Through standard construction and public service improvement, the government guides and encourages multiple market entities to participate in and improve the evolving system of smart agriculture, which is closely integrating with rural vitalization and digitalization of the national economy. Furthermore, China has declared to achieve its carbon emission peak and neutralization goals by 2030 and 2060, respectively. On October 24, 2021, the State Council issued the country's action plan for carbon peak by 2030, which included a plan for agriculture in 10 key sectors to promote green and low-carbon growth. Smart agriculture provides a feasible path to change the traditional mode through digital transformation and dynamically obtain resource information, support intelligent, and accurate management. Thus, it supports the precise utilization of resources, improves production efficiency, and reduces carbon emission.

4.1.2 Rapidly developing rural telecommunication to consolidate the foundation

With the fast and steady deployment of infrastructure, China has roughly realized full internet coverage of its rural areas. Since 2015, the Ministry of Industry and Information Technology and Ministry of Finance have jointly implemented six universal telecommunication service pilot projects supporting the construction of more than 50,000 4G base stations with optical fiber in 130,000 villages, with about 1/3 of the facilities deployed in rural areas. By May 2021, more than 99% of the villages had access to optical fiber or 4G network, thus giving China the world's largest optical fiber and 4G network. During this period, the construction speed and scale of China's 5G network ranked first in the world, with an accelerating spread to rural areas. By the end of 2020, China had at least 718,000 5G base stations and over 200 million 5G terminals (CAICT and CARD, 2021). The rapid spread of new generation high-speed networks to rural areas could thus lay the foundation for smart agriculture in terms of hardware facilities, public interest, and skills.

4.1.3 Rapidly increasing capacity of new generation information technology

With agricultural modernization and informatization becoming a key topic in the *Central No. 1 Document* after 2015, an increasing number of enterprises and scientific institutions have been investing in smart agriculture, significantly accelerating the transformation of achievements. According to the China National Intellectual Property Administration (https://pss-system.cnipa.gov.cn), 134 patents related to smart agriculture, internet agriculture, and agricultural informatization have been registered by August 2021. The World Intellectual Property Organization (WIPO) reported that 2064 patent applications related to smart agriculture were registered in China by August 2021; this was ranked first in the world. The number of patents in the major sectors were as follows: management and control (661), growth and breeding (580), monitoring and detection (304), information collection (276), picking and processing (64), e-commerce logistics (45), agricultural decision-making (35), and social services (26).

4.2. Suggestions to accelerate the promotion of smart agriculture in China

4.2.1 Improve the quality of general development plans

At present, the governments at all levels continue to issue plans for smart agriculture promotion, but there are problems of unclear objectives and measures, and convergence of policies in different regions (Zhao, 2020). (1) National plans should focus on financial support and R&D in key technologies, clarify the objectives of smart agriculture at each stage, such as every five years, and decompose the responsibilities to different departments and regions (Cao *et al.*, 2021). (2) Local plans should formulate schemes in combination with the national arrangements and regional resource endowment. (3) The plans should gradually guide, considering the basic position of the market in resource allocation and the leading role of enterprises in technical R&D and promotion (Song, 2020). (4) The plans should be formulated in combination with the goals of carbon emission peaking and neutralization, with focus on smart technologies promoting energy conservation and green development in agriculture and rural areas. (5) Specific paths should be planned for different entities with focus on promoting the effective connection between small farms and modern agriculture, optimizing the scales to improve the managerial capacity of family farms, supporting cooperatives, and leading enterprises along with other large-scale entities to build modern agricultural parks (Zhao *et al*., 2021).

4.2.2 Increase the amount and efficiency of fiscal support

(1) Provide policy subsidies to enterprises that produce, manufacture, promote, and apply key smart agriculture technologies and products under the subsidy policy for purchase of agricultural machinery. (2) Strengthen the guiding role of finance, taxation, and insurance to attract private capital to smart agriculture infrastructure construction through loan interest discounts, finance guarantees, and other policies (Zhao, 2020). (3) Increase the support for projects set up jointly by production, teaching, and research institutions to ensure that financial funds are used more efficiently for scientific research

and agricultural production through direct connection between the market, enterprises, and farmers.

4.2.3 Identify the key technologies and promote independent research

Key technologies have the following aspects. (1) Smart service: new generation agricultural visual human-computer interaction and adaptive agricultural cloud service. (2) Smart decision-making: Agricultural big data and computational intelligence, support decision-making system, and knowledge model and algorithm. (3) Smart control: High-end plant protection UAV, smart equipment for harmless treatment of dead livestock and poultry, agricultural robot, postpartum treatment, and circulation equipment control of agricultural products. (4) Information perception: Agricultural product quality information perception, environmental information perception, agricultural machinery sensor, and life information perception (Zhao *et al.*, 2021).

The promotion measures could be as follows. (1) Update the laws, regulations, and policies related to investment, credit access, taxation, and intellectual property rights protection. (2) Rely on the national key R&D program of China[4] and the innovation fund for technology-based firms[5] to guide enterprises to participate in the R&D of smart agriculture. (3) Integrate the market mechanisms and specific projects in R&D, demonstrate and apply key smart technologies and products, encourage service-oriented enterprises to engage in agricultural businesses in market report and digital finance forms, and guide the smart transformation of agricultural enterprises (CAICT and CARD, 2021).

4.2.4 Improve the education, training, and technology promotion system

(1) Strengthen the information technology training for farmers: Use highly popularized information means such as smart phone Apps, social network sites (SNS), and webcasts to improve farmers' cognition and interest in smart technology, and supplement this through offline training activities to remove the constraints of conventional production (Wang, 2020). (2) Create a multiple-subject cultivation system: Following the government or industry association initiatives, collaborate with the education, research, and technology institutes in promoting smart skills in rural areas by providing platforms, personnel, and resources. (3) Cultivate skills in school education: Innovate the curriculum, teaching material, and methods of courses to ensure that students obtain digital skills. Furthermore, promote the vocational education system by increasing the enrollment of students and create smart technology-related courses to meet the needs of agricultural production and management (CAICT and CARD, 2021). (4) Create conditions for all types of talents to participate in smart agriculture: Establish cooperatives, information platforms, and other institutions and supplement them through preferential measures, such as low-interest loans and tax reliefs to facilitate entrepreneurship and social services, and popularize smart technologies in agriculture and rural areas (Song, 2020).

5. CONCLUSIONS

The government of China has issued a series of policies at the national and regional levels for the promotion of high-quality agricultural development, rural revitalization, and green and low-carbon development and to accelerate the spread of smart agriculture, which has attracted the attention of many scholars. In recent years, China is witnessing a rapid increase in its smart agriculture market scale, technology, R&D, and promotion, and the industrial chain has begun to take shape. However, smart agriculture confronts constraints from poor project independence and sustainability, unbalanced and inefficient financial support, weak economic and knowledge base of farmers, and a lagged talent training system. With the support of consistently improving policies, popularization of the rural telecommunications industry, and the continuous enhancement of information technology and R&D

[4] This was established in 2015 and managed by the Ministry of Science and Technology to fund major studies of social welfare as well as the development of key technologies and products relating to the core industrial competitiveness, the overall independent innovation ability, and national security.

[5] This was established with the approval of the State Council in 1999 and managed by the Ministry of Science and Technology under the supervision of the Ministry of Finance. It gives full play to the guiding role of financial funds and channel social funds and other innovative resources to support the development of science and technology-based small and medium-sized enterprises through free subsidies, loan discount, and capital investment (http://innofund.chinatorch.gov.cn/english2/index.shtml).

capacity, the overall perspective of smart agriculture in China appears optimistic. From academic findings, smart agriculture in China can be further promoted through better overall planning, increased efficiency of financial investment and R&D of independent technology, and an improved training and technology promotion system.

China's mode to promote smart agriculture depends on the overwhelming ratio of small-scale farms, relying on government policies and investment to increase the participation of large enterprises. It also focuses on the digital village, carbon peak and neutralization to gradually improve the farmers' professional quality, managerial scale and the utilization efficiency of agricultural resources and rural ecological environment. The huge agricultural and rural economy of China and its ever-changing production and R&D practices provide a broad space for further qualitative and quantitative studies, summarizing the modes and effect, popularizing the experience, and deepening the follow-up analyses of smart agriculture.

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A STUDY ON THE DEVELOPMENT OF AQUACULTURE MOBILITY MANAGEMENT TOOLS

Chao Chien Chen[1,*], Chi Yuan Lin [2], Yu Xin Wang [2] and Yu Jun Wang [2]

1) Shih Hsin University Department of Communications Management ,Taiwan
Email:mark@smartagri.com.tw
2) Fisheries Research Institute , COA, Taiwan

* Corresponding author

ABSTRACT: Learning to cultivate a competitive and self-sustainable aquaculture industry is one of the biggest challenges that Taiwan is currently facing. Therefore, it is necessary to set forward-looking and strategic technological research and development measures, strengthen the research and development of aquaculture production automation as well as factory technology and equipment, innovate aquaculture technology, and reduce production costs. The literature review reveals that more and more companies are trying to better their management and operations to enhance their competitiveness through mobility management. In addition, according to the 2021 CIO Study, operational efficiency is the most important goal for organizations, far more than any other, among the many indicators that signal improvement in the effectiveness with which organizations are run. Relevant studies have also confirmed that mobility management can indeed bring benefits to enterprises, such as strengthening employees' work learning and training results and effectively assisting employees in completing their work tasks. Therefore, it is the aim of this study to develop suitable application tools for smart aquaculture and the digital transformation of the aquaculture industry.

Keywords: *Aquaculture Fisheries, Action Management, Digital Transformation.*

1. INTRODUCTION

As Taiwan is located in a subtropical region, the weather and environmental conditions are uniquely suited for aquaculture development, and the coast is a spawning ground for many economic aquatic organisms, leading to a rich production of fish, shrimp and shellfish fry. In addition, there are 40,000 hectares of shallow waters along the coast of Taiwan, and no less than 30,000 hectares of beaches and tidal flats, which provide good breeding grounds for the development of aquaculture.

However, the traditional aquaculture industry is facing the challenges of aquaculture epidemics, high feed costs, aging of the workforce, experience gap, industry transformation, and sustainable environmental development, etc. Therefore, it is beginning to attract IoT (Internet of Things) related enterprises to develop various management solutions that combine big data with the demand for smart aquaculture, hoping to address the problems faced by the aquaculture industry (Hung, Jia-Mei, 2018) . IoT has widespread applications, and real-time information, intelligence, and preventive maintenance are the top three requirements for IoT applications (COIT, 2021).

At the same time, with the prevalence of mobile technology and the development of related applications and systems becoming more and more complete, many foreign companies are actively investing in promoting mobile applications within their enterprises and expect smartphones and tablets to assist employees in improving their work performance (Dimension Data, 2015). Therefore, this study aims to combine IoT devices to develop mobile management tools for aquaculture fishery, providing aquaculture operators with viable options for digital transformation.

Chao Chien Chen, mark@smartagri.com.tw

2. MATERIALS AND METHODS

The environmental pollution, resource wastage, and low production efficiency brought about by the traditional aquaculture model have become factors limiting the development of the aquaculture fishery. To resolve this problem, it is necessary to transform towards efficient ecological precision and smart aquaculture (Li, Dao-Liang, 2018). The literature also confirms that the use of industrialized and smart systems can facilitate the vertical expansion and deep integration into the field of aquaculture and fisheries, and further empower the aquaculture industry to make informed decisions, improve the level of smart aquaculture, and increase the contribution rate of aquaculture (Li, Hai-Tao, Wang, Hsin-An, Feng, Yan, and Lan, Chang-Chieh, 2017).

According to the results of the "2016 Taiwan Enterprise IT Trend Survey" conducted by Business Next Magazine, nearly 80% of enterprises in Taiwan indicated that they will definitely or probably go mobile in the future and also emphasized that the trend of multiple devices (smartphones and tablets) will definitely compel enterprises to face the demand of going mobile (Business Next, 2015). Enterprise mobility is the promotion of enterprises to allow employees to use enterprise systems through wireless mobile technology (*e.g.,* smartphones or tablets) (Consoli, 2012).

However, an enterprise's mobility strategy should provide employees with a single integrated, easy-to-use application and consistent user experience, and enable them to understand the goals and benefits of mobility. The employees must also possess the relevant knowledge and skills, in order to promote the acceptance of mobile technology in assistance to work duties, and in turn, enhance work performance (Forrester Research, 2015; Lu, Yueh, & Lin, 2015; Yueh, Lu and Lin, 2016). Many companies also indicate that the introduction of mobile technology into work assistance and learning training can effectively improve the efficiency of information communication and retention, and it is also very helpful for the improvement of management processes, which can clearly demonstrate that the introduction of mobile technology can effectively improve organizational performance (Lu, M.S., Lin, W.C. and Yueh, X.P., 2017).

Therefore, in this study we hope to develop mobile management tool applications (app) to provide aquaculture operators to use, we hope that we can improve the production management efficiency of aquaculture operators through effective application of apps. The envisaged app environment is described as follows:

2.1. App Software and Hardware Environment

Table 1. Software Environment Itemized List

Software Environment	Major Items	Secondary Items
Application System Database Host Servers	Operating System (OS)	Linux Ubuntu 20.04 LTS Linux Ubuntu 18.04 LTS (Database Host) App Service Deployment via Docker Service
	Database	Microsoft SQL Server 2019
Push functionality	Google Firebase Account	Google Firebase Cloud Messaging (FCM)
App Listing and Web Services	Apple Store IOS Listing	Apple ID Account Apple Developer Program Paid License
	Google Play Android	Google Account Google Play Developer Account (Google Play Console)
	Domain Name Service (DNS)	ainurture.com.tw
User-end	Operating System (OS)	Any operating system that supports the installation of a web browser
	Browser	Google Chrome (recommended), Microsoft Edge, Firefox, Safari

	App	Android, IOS
Development and maintenance tools	Integrated Development Environment (IDE)	Visual Studio Code
	Microsoft SQL Server data maintenance	SQL Server Management Studio (SSMS) or Azure Data Studio

Table 2. Hardware Environment Item List

Hardware	Operating System (OS)	Specifications
Website and Application Service Hosting	Linux Ubuntu 20.04 LTS	Processor: 2 Core or more Memory: 4 GB or more Hard disk space: 80 GB or more
Database	Linux Ubuntu 18.04 LTS or Windows Server 2019	Processor: 2 Core or more Memory: 4 GB or more Hard disk space: 80 GB or more

3. RESULTS AND DISCUSSION

3.1. Mobile Management Features

Industry information: To aid aquaculture operators to quickly grasp the pulse of industry intelligence, this study uses keywords such as fishery, culturing, aquaculture, and fishermen as search targets, and develops a system that automatically searches the Internet for relevant aquaculture and fishery news information, and then presents the fishery-related industry news feed on the app.

Expert Knowledge: In order to provide fishermen and aquaculture operators with a professional knowledge inquiry and consultation services, this study has also developed an expert knowledge module on the app, which is mainly divided into two types of functions, namely, aquaculture knowledge and fishery Q&A, and the contents are linked to the official website of the Fisheries Research Institute of the Council of Agriculture for synchronized updates. Therefore, fishermen and aquaculture operators can obtain the latest fishery-related knowledge resources immediately. They can also leave their inquiries on the app and the app will assist in matching with experts and scholars to respond, providing a channel for professional consultation.

Market Price Reporting: The market report is connected to the official website of the Taiwan Aquaculture Development Foundation and includes daily single-species multi-market quotes from Keelung, Toucheng, Su'ao, Tainan, Xingda Harbor, Kaohsiung, Ziguan, Penghu, Donggang, Xingang, Hualien and other production markets, as well as consumer markets such as Taipei, Sanchong, Hsinchu, Taoyuan, Miaoli, Taichung, Changhua, Puxin, Puli, Chiayi, Dounan, Jiali, Sinying and Gangshan. The app provides the latest quotes for fishery products for today and the past three months. The quotes are divided into upper price, middle price, lower price and average price, which are presented in a graphical chart on the app. Fishermen and aquaculture operators can click on the price column below the line chart block to display individual market information.

Aquaculture Monitoring: The app can be connected to water quality detection devices, such as water temperature, reduction-oxidation, dissolved oxygen, water conductivity, salinity, etc. The app provides users with real-time data to monitor the water quality of their aqua farms, so that they can make quick judgments and adjustments to avoid losses. In terms of app presentation, the weather block presents the real-time weather forecast for the past week and the real-time water quality monitoring status of each aquaculture area is provided at the bottom of the weather block, so that users can slide left and right to monitor more water quality sensing data. The monitoring data is color-coded to alert the fishermen, with blue being the safety value, yellow being the warning value, and red and pink being the danger values, allowing the fishermen to quickly learn of the latest information at a glance.

Production Management: According to the requirements of the Taiwan Good Agricultural Practices (TGAP) – Aquaculture, the production process of agricultural products with traceability systems set by the Council of Agriculture, the app provides farmers with real-time records of daily feeding status, including fish fry records, baiting records, medication records, etc. New records can be added by clicking on the + icon at the bottom right of the app. Through this research tool, we can help fishermen to apply for traceability certification of agricultural products.

3.2. IoT device connectivity

This study developed a mobile management tool for aquaculture fishermen, which can be connected to water quality detection devices, such as water temperature, reduction-oxidation, dissolved oxygen, water conductivity, salinity, etc., and used as data analysis applications. All five devices use HTTP API communication to request and respond to data, and the protocol specifications are as follows:

Table 3. Communication Protocols

HTTP Method	POST
Parameters	id(request account)
	pws(account password)
	data_type(device data type)

Table 4. Description of the Device Data

Device data type (data_type)	Equipment description
water temperature	water temperature sensor
redox potential	redox potential
dissolved oxygen	dissolved oxygen meter
water conductivity	water conductivity meter
water salinity	salinity meter

In addition to interfacing with water quality detection devices, we also provide data synchronization scheduling services to automate the scheduling process so that the device data can be synchronized with the RawData database and then, after sorting the original data from the devices through conversion services, the values of each water quality detection device can be queried through the management platform.

The data from a single device contains one or more sensor data, thus before conversion, we need to set the name of the field of the original response data corresponding to each sensor, and then provide conversion service to convert and match the data values.

4. CONCLUSIONS

The traditional aquaculture industry in Taiwan is facing the problems of aging workforce, high feed cost, and industry experience gap, so the application of IoT technology and equipment and information system will effectively help the aquaculture industry to upgrade and advance the digital transformation of the industry. Through the mobile management app developed by the Fisheries

Research Institute, we hope to provide the aquaculture industry with simple tools for production management and grasp of timely information. Therefore, it is suggested that relevant government agencies and units can conduct promotion seminars to guide aquaculture operators to implement the Aquaculture Mobile Management app developed by the Institute, and then complement the tool with government subsidies for aquaculture operators to purchase water quality monitoring IoT devices. Subsequently, the API developed by the Institute can be connected with water quality monitoring IoT devices to meet the production management needs of aquaculture operators for real-time information, intelligence and preventive maintenance.

In the future, this study can further explore the results and benefits of the aquaculture industry after the implementation of the Aquaculture Mobile Management app and analyze the value-added benefits of the mobile management APP on production process optimization and transformation, and efficiency and quality improvement, which can serve as a reference for other aquaculture operators to implement various applications, in the hope of driving Taiwan's aquaculture industry to gradually move towards the goal of digital transformation.

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EFFECT OF LIGHT EMITTING DIODES (LEDS) ON SHOOT GROWTH AND FLOWERING OF *DENDROBIUM OFFICINATE* KIMURA ET MIGO *IN VITRO*

Phan Xuan Binh Minh[1*], Ha Thi Dung[1], Do Minh Ngoc[2]

1) Center for Experimental Biology, National Center for Technological Progress, Viet Nam
2) High School for Gifted Students, Viet Nam National University, Viet Nam

* pxbminh@gmail.com

ABSTRACT: *Dendrobium officinate* Kimura et Migo is known as a valuable medicinal species belonging to the family of Orchidaceae. According to studies, the stems and flowers of this species contain various bioactive components such as polysaccharides, bibenzyls, phenanthrenes and flavonoids. Since a long time, they have been used in traditional medicine in many Asian countries and nowadays this species is cultivated on a large area for medicine and nutritious food. This study has conducted to evaluate the effect of light-emitting diodes (LEDs) with blue and red on shoot growth and flowering of *D.officinate* explants grown *in vitro*. The *completely random design* (CRD) design was used as the experimental design includes 6 treatments: Fluorescent lighting; 100% blue LED lights; 70% blue LED lights and 30% red LED lights; 50% blue LED lights and 50% red LED lights; 30% blue LED lights and 70% red LED lights; 100% red LED lights with photosynthetic luminous flux density (PPFD) light intensities of 50 µmol/m^2/s photons. As a result, blue LEDs light influenced positively on shoot multiplication and weight. Meanwhile, red LED lights helped shoot taller and flower earlier. After 8 weeks of culture the 100% blue LED lights experiment, the result was that the shoot multiplication rate and the average fresh weight of them reached the highest at 5.45 shoots/ explant and 562.17 mg respectively compared to at 3.23 shoots/sample and 416.27 mg of the 100% red LED lights. However, their average height was lowest at 3.08 cm compared to at 4.34 cm of the 100% red LED lights. After 24 weeks of culture, the 100% red LED lights experiment got the highest flower bloom rate with 51.43%, compared to 0% flower bloom rate of the 100% blue LED lights and control. These results are not only applied in the production of *D. officinate in vitro* culture, but also in the artificially cultivation of this species.

Keywords: *D. officinate, Flowering, In vitro culture, Light Emitting Diodes, Shoot growth.*

1. INTRODUCTION

Dendrobium officinate Kimura *et* Migo, a species of orchid for beautiful flowers, is used in traditional medicine in many Asian countries such as China, Viet Nam, Japan… Over decades, about 190 compounds have been isolated from *D. officinale* and these modern pharmacological effects can be mentioned as hepatoprotective, lowering blood sugar and fighting fatigue, stomach ulcers and even cancer (Tang et al., (2017)).

According to research by Wen et al (2018) polysaccharide is one of the main bioactive components that exhibits multiple biological effects in *D. officinale*, including glucose, mannose, galactose, xylose, arabinose and rhamnose with different molar ratios and types of glycosidic bonds. Today, in China, *D. officinale* has been cultivated under artificial conditions on a scale of industry and studies on materials and conditions for in vitro culture of *D. officinale* have also been published by Chen et al. (2014). In Viet Nam, *D. officinale* is also propagated by tissue culture is also known as grown under artificial conditions, the results of *in vitro* propagation of *D. officinale* were published by Son et al. (2014) and

Luan et al. (2021). However, the research results on light conditions in *in vitro* propagation of *D. officinale* was still limited.

Replacing light-emitting diodes (LEDs) by fluorescent lighting in vitro plant propagation is a good solution because the advantages of LEDs are long operating lifetimes, low heat, low energy consumption, high light intensity and high photoelectric conversion efficiency. Furthermore, LEDs emit wavelengths that match the absorption spectra of different plant species so it can effectively promote plant growth (Li et al., (2018). These benefits make LEDs become a suitable lighting device for the energy-saving needs of plant tissue culture and plant seedling (Rehman et al.2017). Mohidul et al. (2017), suggested that plants exposed to different LED wavelengths could induce the synthesis of bioactive compounds and antioxidants, then improve the nutritional quality of the plants. Similarly, LEDs increase nutrient content, reduce microbial contamination, and alter postharvest ripening of fruits and vegetables and agricultural products treated with LEDs can benefit human health due to their good nutritional value and high antioxidant properties. Wen et al. (2018), showed the research result that blue LEDs and red LEDs light had an effect on the index of growth, flowering and flower development of *D.officinale* in vitro: Red LEDs light helps plants to grow taller and flower earlier while blue LEDs light leads to larger stem diameter and thicker leaves.

2. MATERIALS AND METHODS

2.1. Materials

Plant materials: *D. officinale* shoots (1-1.5 cm length) were previously initiated from healthy mature plants through segments and shoot tips culture at the laboratory of Center for Experimental Biology, National Center for Technological Progress.

In vitro shooting medium composed: ½ MS medium with different of organic nutrient 20 g/l sucrose, 8 g/l agar, 10% coconut water, 100 g/l banana homogenate, 100g/l potato extract and 2g/l benzyladenine (BA) ; pH of medium is 5.5. (Murashige T., Skoog F., (1962), Chen et al. (2014)). *In vitro* rooting medium composed: Rooting media were prepared similarly to shooting media in which BA component was replaced by 5mg/l naphthaleneacetic acid (NAA).

Light quality setting: An LED light fixture (a rectangle consisting of 240 small lamps 120 cm× 5cm; voltage: 220v/50Hz) was constructed by Rang Dong Light source & vacuum flask joint stock company. The LED fixture could emit blue, red light according to design scale.

2.2. Experimental design

The Completely Randomized Design (CRD) was used as the experimental design, which consisted of six treatments, including:

1. FL (control): broad wavelengths at 400–700 nm.
2. 100% blue LED lights with a wavelength of 460 nm.
3. 70% blue LED lights with a wavelength of 460 nm and 30% red LED lights with a wavelength of 660 nm.
4. 50% blue LED lights with a wavelength of 460 nm and 50% red LED lights with a wavelength of 660 nm.
5. 30% blue LED lights with a wavelength of 460 nm and 70% red LED lights with a wavelength of 660 nm.
6. 100% red LED lights with a wavelength of 660 nm.

Culture conditions: All treatments were maintained at $23^0C \pm 2^0C$ under 12h of light a day, under six different light treatments at 50 µmol/m^2/s photon

2.3. Statistical analysis

The experiments followed a completely randomized block design. Each experiment was repeated three times. Observations on the number of shoots, length and fresh weight of shoots, rooting rate, number of roots, length of roots, flowering rate of plantlets, length and fresh weight of plantlets were recorded after 8 weeks of culture. All data were recorded as the mean number of three replicates at least with standard deviations. The results were analyzed for variance using the IRRISTAT 5.0 statistical analysis package. The difference between the means was tested by a least significant difference at P 0.05 ($LSD_{0.05}$).

3. RESULTS AND DISCUSSION

3.1. Effect of LEDs on shooting *D. officinale*

Determining the LED lighting conditions suitable for the growth and development of *D. officinale* shoots is an issue that needs to be investigated during *in vitro* culture in order to create an *in vitro* complete process for *D. officinale*. Results obtained after 8 weeks of culture in 6 different light treatments are shown in Table 1.

Table 1. Effect of different light treatments on shooting *D. officinale* after 8 weeks cultured *in vitro* shooting medium.

Treatments	No. shoots/explant	Shoots length (cm)	shoot fresh weight (mg)
100% Blue	5.45^{a}	3.08^{f}	562.17^{a}
70% Blue and 30% Red	5.26^{ab}	3.26^{e}	537.82^{b}
50% Blue and 50% Red	4.78^{b}	3.82^{c}	513.45^{c}
30% Blue and 70% Red	4.27^{c}	4.04^{b}	487.39^{d}
100% Red	3.23^{cd}	4.34^{a}	416.27^{f}
$LSD_{0.05}$	0.36	0.21	21.65

Note: $LSD_{0.05}$ is the minimum error at the allowable level of 5%; The different letters (a, b, c...) shown in the columns represent remarkable differences at the LSD level.

It can be seen that the growth and development of D. officinale shoots were not only influenced by medium components and growth regulators but also significantly influenced by lighting conditions. Under blue LED lighting conditions, shoots are stimulated to become fatter. Under 100% blue LED lights the average number of shoots per sample is the highest with 5.46 buds, about 1.2 times the control and 1.7 times the 100% red LED lights. As for red LED lighting conditions, they develop in length: in the formula of 100% red LED lights, the average length of them is 4.34 cm, 1.2 times more than the control and 1.4 times more than that of the 100% blue LED lights. To support for this, the results of Wen Tao et al. (2018) studies about the effects of blue LED lights and red LED lights on D. officinate in greater plantlet dry mass, larger stem diameter and thicker leaves can be mentioned (W. Moreover, that of Dao Quoc Hung et al. (2021) also showed that Dendrobium anosmum Di Linh Taly which was evaluated by in vitro culture under light-emitting diodes with blue and red combination (LED BR 30:35) had the percentage of PLB producing shoots at 38 –42%, compared to 10% of that under fluorescent. Through many studies, the light formula consisting of 70% blue LED lights and 30% red LED lights was confirmed to be appropriate conditions for the growth and development of shoots.

3.2. Effect of LED on root formation, growth and flowering of *D. officinate*

D. officinate shoots after 8 weeks of culture *in vitro* shooting medium were transferred to in vitro rooting medium and placed under 6 different light quality treatments. Effect of different light quality treatments on root, growth and flower *D. officinale* plats is shown through the criteria in Table 2 and Table 3.

Table 2. Effect of different light treatments on rooting of *D. officinale* after 16 weeks cultured *in vitro* shooting medium.

Treatments	Rooting rate (%)	Root number/plats	Root length (cm)
Fluorescent	80.73^{e}	4.56^{c}	1.64^{d}
100% Blue	99.47^{a}	5.45^{a}	1.08^{f}
70% Blue and 30% Red	96.26^{b}	5.06^{b}	2.26^{e}

50% Blue and 50% Red	95.58^{bc}	4.78^{bc}	2.52^{c}
30% Blue and 70% Red	90.12^{c}	4.27^{cd}	3.04^{b}
100% Red	84.87^{d}	3.23^{d}	3.34^{a}
$LSD_{0.05}$	2.62	0.36	0.21

Note: $LSD_{0.05}$ is the minimum error at the allowable level of 5%; The different letters (a, b, c...) shown in the columns represent remarkable differences at the LSD level.

Table 3. Effect of different light treatments on growing and flowering of *D. officinale* after 16 weeks cultured *in vitro* rooting medium

Treatments	Flowering rate (%)	Length of plats (cm)	Fresh weight of plats (cm)
Fluorescent	0	4.64^{bc}	836.22^{c}
100% Blue	0	4.08^{d}	983.21^{b}
70% Blue and 30% Red	12.14^{d}	4.26^{c}	945.78
50% Blue and 50% Red	21.27^{c}	4.82^{b}	907.13^{cd}
30% Blue and 70% Red	38.57^{b}	5.04^{ab}	881.72^{d}
100% Red	51.43^{a}	5.23^{a}	856.38^{e}
$LSD_{0.05}$	3.56	0.41	21.65

Note: $LSD_{0.05}$ is the minimum error at the allowable level of 5%; The different letters (a, b, c...) shown in the columns represent remarkable differences at the LSD level.

The results of Table 2 show that lighting conditions (blue LED lights and red LED lights) also affect the formation and development of roots: blue LED lights promote rooting and number of root of *D. officinate* shoots while red LED lights make roots grow longer than shoots. Under 100% blue LED lights, the rooting rate reached 99.47%, compared to 14.69% of 100% red LED lights and 18.74% of 100 fluorescent and the average number of roots per was 5.45, about 1.69 and 1.20 time higher than under 100% red LED lights and fluorescent light respectively.

However, this lighting conditions limited root growth with the average root length of 1.08 cm while the figures at 100% red LED lights and fluorescent lighting conditions were 3.34 cm and 1.64 cm. Therefore, 50% blue LED lights and 50% red LED lights are suitable lighting conditions for rooting of *D. officinale*. Similarly, in 2021, Dao Quoc Hung et al.'s research on *Dendrobium anosmum Di Linh Taly* showed that under 45% blue LED lights and 55% red LED lights the number of roots per shoot was 3.67–5.16, significantly more than under fluorescent light (1.95 roots per shoot) and root length was 3.42 –4.14 mm, compared to 2.97 mm under fluorescent light.

The differences in flowering rate, length and fresh weight of *D. officinate* in vitro plants in the 6 light quality treatments are shown in Table 3. red LED lights stimulated flowering of *D. officinale*: under be removed 100% red LED lights, the flowering rate was the highest at 51.43% while under that of both 100% blue LED lights and fluorescent lighting, the results were 0%. For explanation, Wen Tao et al. (2018) suggested that red LED lights promoted sugar transport from leaves to stems and stem tips, thereby promoting flowering. In addition, the combination of red LED lights and blue LED lights is proven to have a beneficial effect on the growth and quality of plants because red light can stimulate the growth of plants and blue LED lights can help plants have better photosynthesis, thicker leaves and fatter body. So, the appropriate lighting conditions for the growth and development of shoots should be are 50% blue LED lights and 50% red LED lights.

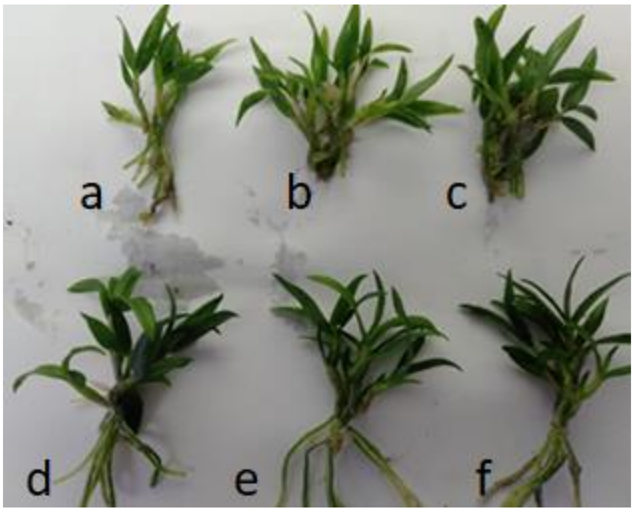

Figure 1: *D. officinate* after16 weeks cultured *in vitro* under different light treatments: (a) Fluorescent; (b) 100% Blue; (c) 70% Blue and 30% Red; (d) 50% Blue and 50% Red; (e) 30% Blue and 70% Red; (f) 100% Red

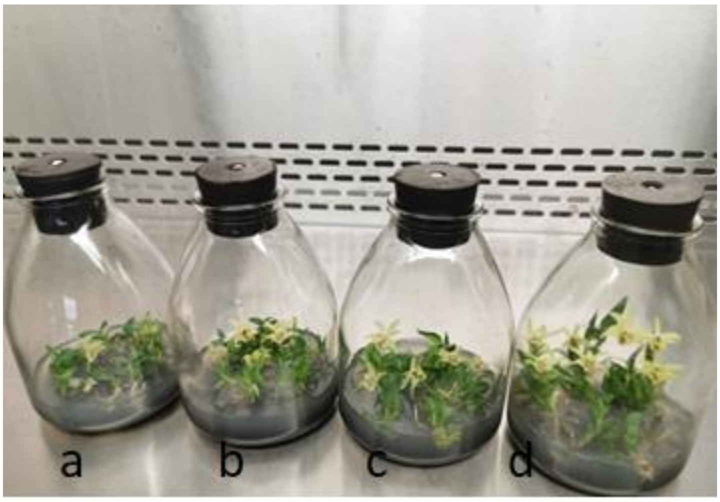

Figure 2: *D. officinate* ater 24 weeks cultured *in vitro* under different light treatments (a) 70% Blue and 30% Red; (b) 50% Blue and 50% Red; (c) 30% Blue and 70% Red; (d) 100% Red

4. CONCLUSIONS

The results showed that the specific wavelength of the LED greatly influences the growth characteristics of *D. officinal*. Under the red LED lights shoots maximized in length, promoting early flowering and root length but the lowest bud induction occurred. Meanwhile, bud induction, fresh weight and root formation of shoots developed best under the blue LED lights. Depending on the stage of shoot growth *in vitro* culture, the most appropriate lighting condition is chosen. During the rapid multiplication rate, it is necessary to push the induction and development of shoots to suitable lighting conditions of 70% blue LED lights and 30% Red LED lights, result after 8 weeks was that the shoot multiplication rate 5.26, average fresh weight and average length of shoot was 537.82 mg and 3.26 cm. In the plantlets stage, it is necessary to promote rooting and complete development of plantlets, so the appropriate lighting conditions are 50% blue LED lights and 50% Red LED lights, result after 24 weeks was that rooting plats rate 95.58%, root number/ plats 4.78, average length of root 2.52 cm, flowering plats rate 21.27% average fresh weight and average length of plats was 907.13 mg and 4.82 cm.

5. ACKNOWLEDGEMENT

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AGRICULTURAL INNOVATION AND DIGITAL FARMING: IMPACT, RISK AND PERSPECTIVE

Teruaki NANSEKI[1,*)]

3) Kyushu University, Japan
nanseki@agr.kyushu-u.ac.jp, info@nanseki.org

* Corresponding author

ABSTRACT: Agriculture needs innovation to be sustainable just like any industry. One of triggers of innovation is technology progress such as digital farming which is the hot issue in research, business, and policy, in present. It is obvious that digital farming technology has impacts on farming and agriculture by promoting innovation. Some impacts have positive effects on farming, but some impacts have negative effects under certain condition. Furthermore, digital farming increases some kinds of risks by using them in farms as same as any technology. In this paper, impact and risk of digital farming, as well as perspective, are discussed based on our comprehensive research on agriculture innovation in Japan. The results show that product innovation is most implemented and process innovation follows it. A good example of process innovation is digital farming in the context. In term of potential for growth, the technologies related to the automation, and support of both farm work and business management appear at the top of the list. It is worth noting that areas related to business management were shown to have a high likelihood of use both in the future and a high potential. The results also show that the main factors affecting cost-effectiveness can be broadly classified into: 1) system and robot utilization rates, 2) milk and crop yield enhancing effects, and 3) technical difficulties related to robot technology development. Furthermore, the risks associated with digital farming can be categorized into: 1) loss of data and know-how, 2) monopolization of data and intellectual property by platform enterprises, 3) excessive disclosure of data and confidential information, 4) electric power supply instability and production halts, 5) loss of diversity and vulnerability to unexpected environmental changes due to standardization of production, and 6) loss of human technical skills due to automation of production.

Keywords: *Agricultural Informatization, Agricultural Digitalization, Japanese Agricultural Corporation, Policy Implication.*

1. INTRODUCTION

Japanese agriculture with some characteristics such as the total farmland area continued a slow downward trend in recent years. In 2015, the total farmland area decreased by 22 thousand hectares from the previous year to 4,496 thousand hectares (Ministry of Agriculture, Forestry and Fishery (MAFF, 2016)). Moreover, total agricultural output continued a downtrend after a peak in 1984, before increasing in 2015 and reaching 9.3 trillion yen in 2917 (MAFF, 2019). In 1984, rice accounted for the largest share (33.5%), followed by livestock (28.1%) and vegetables (16.8%). In 2017, however, livestock output accounted for the largest share (35.1%), followed by vegetable output (26.4%), and rice output (18.7%). This indicates a major ranking change in the Japanese agricultural structure. The number of farms also is continuing a downward trend, stood at 1.377 million in 2015 and fell from 2.009 million in 2005. However, the number of corporation farms has increased steadily year by year. The number of corporation farms increase to 18,857 in 2015 from 12,511 in 2010, and 8,700 in 2005.

* Professor, Faculty of Agriculture, Kyushu University, Motooka 744, Fukuoka 819-0395, Japan

Japanese agriculture is characterized by an aging population. Therefore, innovation and digital farming are promised to solve the aging population as well as to bring growth in agriculture.

This paper provides an overview of the current status and trends in innovation and digital farming in Japan. Section 2 shows the implementation of agricultural innovation and the constraining factors. Section 3 empirically clarifies the potential of digital farming technology as one of the important driving force of agricultural innovation. In section 4, we discuss the benefits and risks of digital farming by drawing on the findings of previous studies.

In the related literatures, the term "digital agriculture" is sometime used. In this paper, when we focus on the industry digitized, digital agriculture is used. When we on the farming or farm digitized, digital is used in stead of "digital agriculture". This paper is basically based on Nanseki (2022).

2. CURRENT STATUS AND CHALLLENGES OF AGRICULTURAL INNOVATION

2.1. Status of innovation implementation and its determinants

In this section, we discuss the status of innovation implementation and its driving factors, based on the results of an original questionnaire survey (for details, see Nanseki 2021). Figure 1 shows the rate of innovation implementation by innovation type (OECD 2005). The innovation with the highest rate of implementation among respondents was "starting to produce and sell new or significantly improved goods", which is related to product innovation (41.9%), followed by "introducing new or significantly improved production processes", which is related to process innovation (33.7%), "developing new marketing channels", which is related to marketing innovation (27.5%), and "introducing new methods and procedures concerning transfer of competencies and assignment and organization of work" (19.4%). By contrast, innovations with the lowest rates of implementation were "introducing new methods and procedures concerning external relations with other companies and organizations", which is related to organizational innovation (5.7%), and "introducing new pricing strategies", which is related to marketing innovation (5.7%).

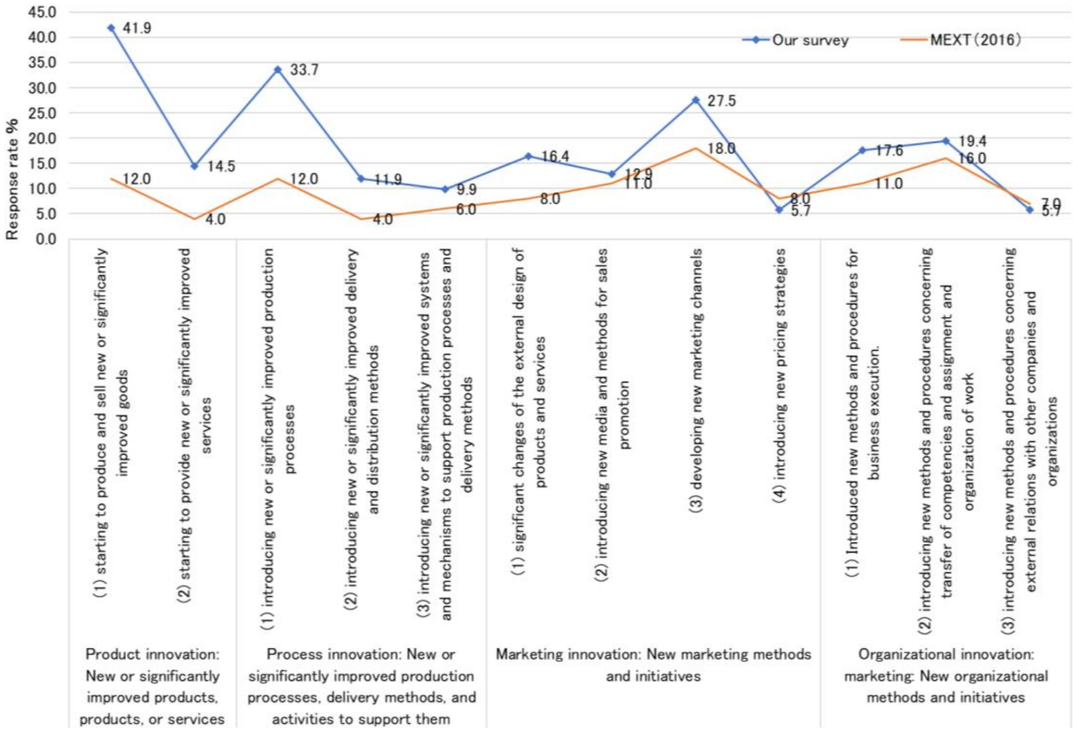

Figure 1. Implementation of innovation in farm management (Source: Translated from Nanseki (2022))

The rate of innovation implementation varies depending on product types, sales volume and so on. Nguyen et al. (2022) performed an analysis of the factors driving product innovation implementation among agricultural corporations by using a probit model. The results imply that: (1) corporations might require suitable annual sales to innovate; (2) innovating farms aim to grow and set high targets; (3) innovations are stimulated by hight self-evaluation in new product and technology development. Therefore, these factors should be considered to promote product innovation in Japanese agricultural corporations. The results of process innovation are presented by Nguyen and Nanseki (2022) at APFITA 2022.

2.2. Constraining factors in agriculture innovation

In the survey, the respondents were asked to rate the degree of constraint hindering the implementation of agricultural innovation on a 4-point scale: 1) "severely constrained", 2) "somewhat constrained", 3) "slightly constrained", and 4) "not constrained at all". The factor most frequently cited by respondents who answered "severely constrained" was "lack of qualified personnel" (14.7%), followed by "lack of internal funds" (9.6%), and "lack of good ideas" (8.0%). The factor most frequently cited by respondents who answered "somewhat constrained" was "lack of qualified personnel" (37.8%), followed by "limitations concerning one's own company's technical capabilities and know-how" (24.3%), and "lack of internal funds (i.e., coming from the respondents' companies/business groups)" (22.3%). The factor most frequently cited by respondents who answered "slightly constrained" was "demand for new products/services" (39.9%), followed by "difficulties in finding the necessary cooperating partners and institutions" (34.4%), and "little or no competition in the target market of the respondents' companies" (34.0%).

3. CHARACTERISTICS OF DIGITAL FARMIG AND FACTORS TO ITS ADOPTION

3.1. Future growth potential of digital farming

In recent years, the increasing use of information and communications technology (ICT) in the agricultural sector is driving significant advances in research and development and practical application of smart farming technology that combines ICT and robot technology (RT) with farming technology. These technologies can be broadly classified into data collection and measurement, automation and robotization of work, and business management. In the following of the paper, these are generically referred to as digital farming technologies.

Figure 2 shows the "future growth potential" of digital farming technologies as well as current and future use . Here, "future growth potential" (expressed in points) is calculated as the difference between "future utilization/planned efforts" and "current utilization" (expressed in percentage). The technology with the highest "potential for growth" is "automation and robotization of crop cultivation mechanical tasks (e.g., plowing, fertilization, pest control, including the use of drones, harvest, etc.)" (51.4 points). This was followed by "measurement of crop status (e.g., leaf color, pest, etc.), using drones and satellites" (47.2 points), "agricultural machinery with operation assist control (e.g., straight-ahead assist control, etc.)" (44.7 points), "automatic detection and notification of anomaly information (e.g., temperature, humidity, soil moisture, livestock estrus/body temperature, etc.)" (41.1 points), "formulation of management strategies and business plans (e.g., using personal computer (PC) simulations)" (37.3 points), and "automatic measurement of product quality (e.g., milk and meat quality of livestock, sugar and acid content of crops, etc.)" (36.2 points).

As can be seen from the above, at the top of the list are technologies related to the automation and support of farm work and business management (e.g., business and production information management). It is worth noting that areas related to business management such as "management strategies and business planning" were both shown to have a high likelihood of use in the future and a high potential for growth. This shows that these areas remain critical.

3.2. Factors in the adoption of digital farming technology

Mi et al. (2022) analyzed the factors contributing to the adoption of digital farming technology by using negative binomial models. The results are summarized as following. corporate form, eligibility to own farmland, sales target, profit target, major product, self-evaluation of ICT utilization and information management, and educational background of representatives as the potential determinants of technologies adoption by Japanese agricultural corporations. Specifically, regarding sales and profit targets, corporations aiming to increase their sales by 1.2 times the current value or raise their profits by 15%–20% of the current margin in the next 5 years were likely to adopt more technologies than those aiming to maintain the current status. Moreover, the self-valuation of ICT utilization and information management positively affected technology implementation. Finally, in terms of corporate representatives' characteristics, those who graduated from specialized schools and vocational colleges were more likely to adopt the technologies.

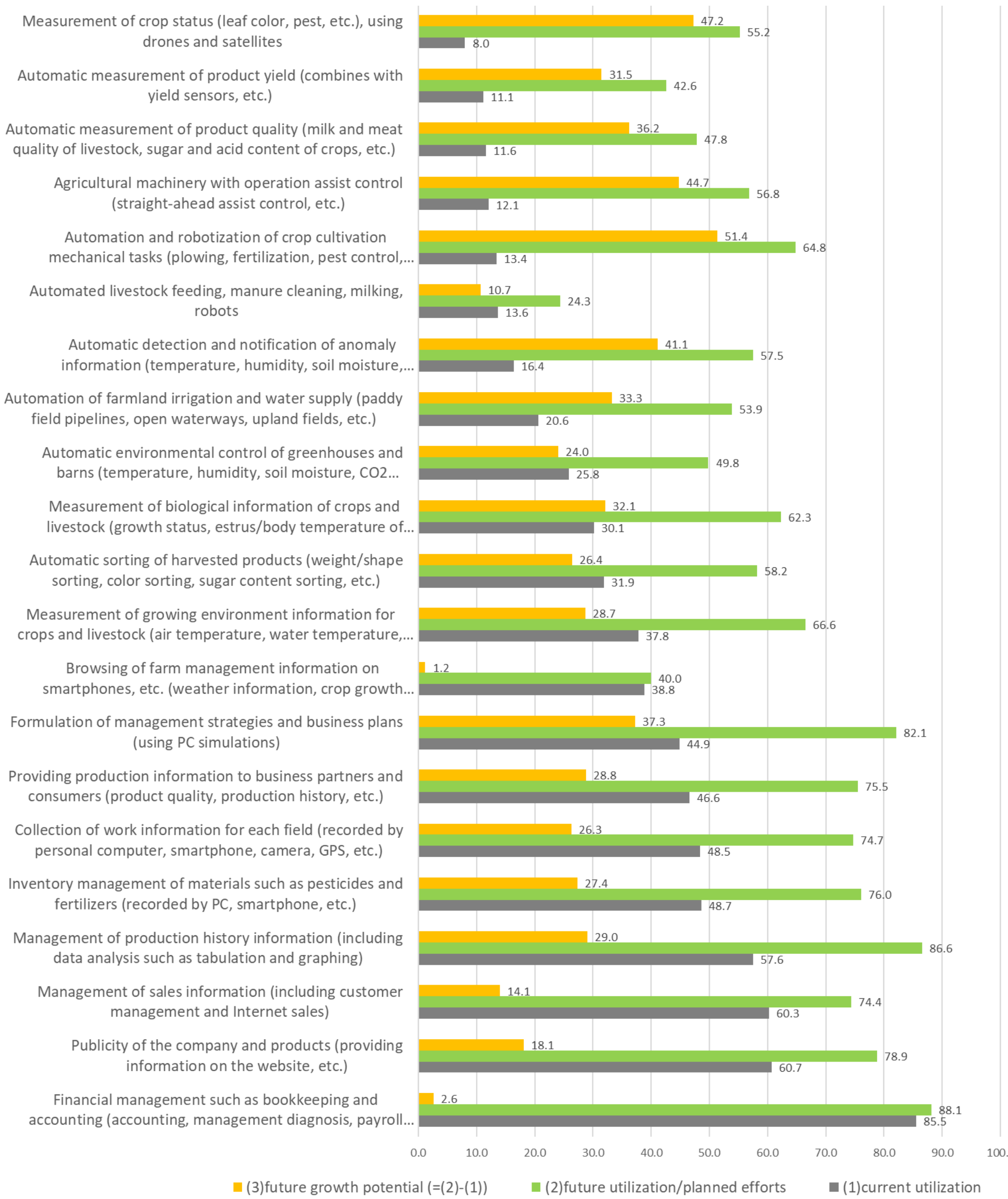

Figure 2. Future growth potential, future and current utilization of digital farming technology

Source: Translated from Nanseki (2022)

4. EFFECTS AND RISKS OF DIGITAL FARMING

Our society holds high expectations for innovation as a means to solve various problems and issues we face every day. As such, mass media and books tend to focus only on the positive side of innovation (e.g., beneficial effects, advantages, etc.). However, all changes have also a negative side (e.g., harmful effects, disadvantages, risks, etc.) Therefore, this section discusses both risks and effects of digital farming. In this study, agriculture using ICT and RT is referred to as digital farming.

4.1. Effects of digital farming by product types

In dairy farming, where work automation is most advanced, the practical use of robots have become widespread for most tasks. By contrast, in rice farming, where work automation is still at a relatively early stage, robots are in the process of being used for some tasks. These differences may be due to different crop characteristics and differences in cost-effectiveness related to the introduction of digital farming technology. The main factors affecting cost-effectiveness can be broadly classified into: 1) system and robot utilization rates, 2) milk and crop yield enhancing effects, and 3) technical difficulties related to robot technology development.

(1) System and robot utilization rates

In Japan, rice is usually planted from April to June and harvested from August to October, following a seasonal pattern. By contrast, in dairy farming, major tasks such as milking, feeding, and cleaning are the same 365 days a year and are rarely performed based on specific seasonal patterns. For this reason, the utilization rate of robots that can automate specific tasks varies greatly. Furthermore, Nanseki (2022) used an optimum farming plan model to analyze the effect of the potential use of agricultural robots with the same work capacity as that of humans, on the expansion of cultivation areas, assuming an advanced rice farm of 100 ha or more. The results of the study showed that, even assuming the use of fully unmanned robots, the scale expansion of the cultivation area did not reach 10%. In other words, in rice farming, which follows seasonal patterns, the scale expansion effect of the use of specialized robots for specific tasks is limited.

(2) Milk and crop yield enhancing effects

In dairy farming, the introduction of milking and feeding robots contributed to an increase in milk yield. In contrast, the use of agriculture robots in rice farming, such as unmanned tractors, rice transplanters, and combine harvesters is primarily aimed at labor saving and is generally not expected to lead to an increase in crop yields. However, automatic water level controllers can be used to increase crop yields as well as for labor saving purposes.

(3) Technical difficulties related to robot technology development

Dairy farming activities take place mainly in the barn, which makes task standardization easier to implement. On the other hand, in rice farming, which is mainly done outdoors, working conditions may vary depending on the land and weather conditions, making process standardization more difficult to achieve than in indoor work. This may act as a disincentive to the practical application of robot technology, and even if technical issues were solved, it may still lead to increased costs of robot manufacturing. The development of general-purpose robots that can perform various tasks with the same level of precision and speed as skilled workers will accelerate, in the future, the introduction of robot technology in rice farming. This, however, is not likely to happen anytime soon.

It is worth noting that ICT cost-effectiveness depends not only on the product types but also on the farm's business scale. In fact, ICT tends to become more cost-effective as business scale increases. Therefore, a virtuous circle can be expected in which ICT is implemented on a larger business scale leading to further management improvements and efficiency (Nanseki, 2017).

4.2. Risks of digital farming

As mentioned above, digital farming is expected to bring labor saving benefits to farmers (e.g., decrease working hours in dairy and rice farming) and effectively increase farm yield (e.g., increase milk yield per cow in dairy farming). Meanwhile, the introduction of digital farming aims to automate farm work by collecting and using vast amounts of data and information related to agricultural production and management through the use of ICT and RT. The risks associated with digital farming can be categorized into: 1) loss of data and know-how, 2) monopolization of data and intellectual property by platform enterprises, 3) excessive disclosure of data and confidential information, 4) electric power supply instability and production halts, 5) loss of diversity and vulnerability to unexpected environmental changes due to standardization of production, and 6) loss of human technical skills due to automation of production. The information about risks associated with the first three aforementioned points were sorted out with reference to DLG (2018).

(1) Loss of data and know-how

While human skills are inherent to a person's capabilities, technology and know-how which can be converted to visual and digital data can, technically, be easily distributed. Once data is recorded and analyzed, and converted to know-how and systems protected by intellectual property, unauthorized data distribution and leakage can easily occur at almost no cost. In order to avoid this, it is necessary to establish legal safeguards against data leakage as well as promote research, development and dissemination of data leakage prevention technology.

(2) Monopolization of data and intellectual property by platform enterprises

Various data related to farm businesses are commonly measured via networks and stored and processed in cloud systems. Very often, companies providing sensors and systems claim the right to use and analyze the collected data and information free of charge. Depending on the terms of use agreement, the intellectual property rights (or part of them) derived from the analysis of data may belong to the companies providing these sensors and systems rather than to the farm's owners. Compensation and rights of usage of data and information related to farm management as well as infringement of rights and the impact on the value of data may pose major challenges for the future. In order to prevent and resolve this contentious issue, legal arrangements should be introduced concerning the attribution of intellectual property rights derived from the collected data and its analysis and the allocation of compensation.

(3) Excessive disclosure of data and confidential information

The value chain of agricultural products from production to consumption involves a multiplicity of stakeholders (e.g., farm managers, distributors, retailers, consumers, and companies providing sensors and systems). Various discussions have been made about what kind of information these stakeholders should be required to disclose.

For example, in industrial production, disclosure of detailed information about production history, which sometimes is treated as confidential, is not common. By contrast, in farm businesses, disclosure of detailed information about production history may be required. This also applies to data disclosure required by the government such as those related to policy support for farming (e.g., subsidies, etc.). In order to address these issues, legal arrangements concerning the scope of data disclosure should be established.

(4) Electric power supply instability and production halts

A large number of digital technologies essentially requires a stable supply of electric power. Therefore, instability or interruption of power supply due to natural disasters, accidents, or malfunctions would have a significant impact on farm work as well as production management, and hence posing a risk for farm businesses.

For example, if the milking robot cannot operate due to a blackout, the cows may develop mastitis, which could, in the worst case scenario, lead to death. In a plant factory, if the nutritious solution and artificial light essential for growing crops cannot be supplied due to an electric outage, the crops may be completely wiped out. A stable power supply is essential for digital farming, and instability or interruption of power supply may represent a major risk factor. To prevent this, it is necessary to secure backup power sources including private power generators. Therefore, in order to weigh benefits and risks of digital farming, a cost-effectiveness analysis is needed that also includes the additional costs of the aforementioned measures.

(5) Loss of diversity and vulnerability to unexpected environmental changes due to standardization of production

As robotization and automation of farm work progresses, production management in individual farms will become more standardized. This may prompt many farm businesses to adopt similar production management strategies in response to weather and other environmental changes, leading to a weakening of the ability of farmers to respond to unexpected environmental changes. In order to prevent and solve this problem, it is necessary to establish a system for the development of agricultural human resources, as shown in the next section.

(6) Loss of human specialized skills due to automation of production

The automation of farm work by robots and cultivation management by artificial intelligence (AI) and other means may make it difficult to improve and maintain the technical skills of agricultural workers.

The way to prevent and resolve this issue is to establish a system for the development of agricultural human resources that allows the deliberate and systematic acquisition, improvement, and preservation of specialized skills and technology. Specifically, the development of business entities that may act as social infrastructures involved in the acquisition, improvement, and preservation of specialized skills and technology is required.

5. CONCLUSIONS

Our study on agricultural innovation has revealed the following points: 1) Agricultural innovations may be implemented based on an appropriate business scale; 2) Agricultural corporations that are particularly good at setting sales and profit margin goals, have new technology development capabilities, as well as an amount of actual sales reaching a certain volume are those more actively engaged in innovations; 3) The agricultural technology with the highest growth potential, among those mentioned in this paper, is the automation and robotization of mechanical operations for crop cultivation (e.g., plowing, fertilization/pest control, including the use of drones, harvesting, etc.), while areas related to business management such as management strategy and planning show a high room for growth and will increasingly find wider application in farm businesses, in the future; 4) The introduction of digital agricultural technology is more actively supported by agricultural corporations (i.e., companies) that are run by younger people, operate on a large business scale in terms of the number of corporate officers, set profit margin goals, and have strong ICT utilization and information management capabilities. The above results indicate that reaching a certain business scale, setting one's own financial goals (e.g., profit margin goals), and identifying one's own company's strengths compared to competitors are common factors that may contribute to the introduction of new technologies such as digital farming and the implementation of innovations.

This paper also specifically highlights differences in cost-effectiveness of digital farming technologies based on product types and discusses how these differences may affect the adoption status of each crop. Finally, the paper specifically outlines various risks associated with the introduction of digital farming technology, and provides some example of measures to deal with such risks.

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DEVELOPMENT OF COST-EFFECTIVE MODEL PREDICTIVE CONTROL-BASED WATER IRRIGATION SYSTEM FOR FARMS

Hoai Son Nguyen *, Van Hieu Nguyen, Quyet Thang Cao,
Chau -Thuy Pham

University of Engineering and Technology, Vietnam National University, Hanoi, 144 Xuan Thuy, Cau Giay, Hanoi, Viet Nam

* Corresponding author: Email: sonnh@vnu.edu.vn

ABSTRACT: Irrigation is an important work in farming. Although irrigation technology is developing rapidly and widely applied, the application of smart technology in irrigation is still not widespread and has some limitations. In our study, we design an effective irrigation system for farms, which collects sensor data and optimize the amount of irrigation water based on model predictive control (MPC) method and real-time sensor data. In order to allow sensor devices and actuators installed at many distant locations to communicate with gateway via Lora communication, we design a communication protocol called Agrinet, which is bandwidth-efficient and secure. We implement the system and perform experiments to verify the operation of the system including hardware equipment, data communication and irrigation control. We also evaluate the performance of our system by simulation. The evaluation results show that our MPC-based irrigation method can improve the efficiency in water use compared with on/off irrigation method.

Keywords: *Irrigation system, model predictive control, cost-effective irrigation, Agrinet network protocol.*

1. INTRODUCTION

Adequate watering for plants is one of the essential factors for plant growth. Therefore, irrigation is an important work in farming. However, the traditional irrigation method based on experience is laborious and inefficient. Since the impact of climate change causes the amount of water at many places of the Earth to decrease gradually, these places may lack water for irrigation [1].

Although irrigation technology is developing rapidly and widely applied, the application of smart technology to water irrigation control is still not widespread and has some limitations. Currently, most of the commercial automated irrigation system offered by the market, are programmed to irrigate at time intervals for predefined periods of time. The irrigation schedule is defined off-line, and it is usually based on the user empirical knowledge on crop needs, soil characteristic and climatic factors. The realization of Internet of Things (IoT) allows many devices, including sensors and actuators, to connect and exchange data with each other. With the help of IoT technology, soil, water, and weather data can be collected in realtime using various kinds of sensors and water efficiency can be improved if these data are used to control crop watering [2].

Model predictive control (MPC) is a multivariable control strategy that uses a mathematical model to predict the time evolution of a system. The design objective of MPC is to optimize the future behavior of process output by computing a trajectory of the future control variable. MPC attracts a lot of attentions in water irrigation due to its advantages of effectiveness in multi-objective optimization, simple control algorithm and easy digital implementation [3-6]. These works often use a simple mathematical model to predict the change of soil moisture. However, since the change of soil moisture after irrigation depends on many parameters, the accuracy of prediction models is limited.

In this paper, we present a solution to solve the problems through the implementation of the following objectives:

- Develop an effective MPC-based irrigation control method which can save irrigation water amount but still maintain the level of water required by the crop. We utilize an ANN model to predict the change of soil moisture when irrigation is stopped.
- Design an irrigation system which can collect environment data using sensors and control crop watering based on MPC-based irrigation control method. We design a communication protocol called Agrinet, which is bandwidth-efficient and secure and can be applied in large farms to ensure accurate and efficient communication between devices.

We implemented the system to verify the feasibility of the system and perform simulation to evaluate the performance of irrigation control algorithm.

The rest of the paper is as follows. Section 2 will describe our proposed method. Section 3 shows the evaluation results of our system. Section 4 concludes the paper.

2. PROPOSED METHOD

2.1. System design

We design a water irrigation system for farms, which need to be watered efficiently for crops. We consider that each farm will be divided into areas, each of which grows a different type of crop. Our system includes three components (Fig. 1).

- Gateway installed in each farm which forwards sensor-actuator data to Server and forwards control command from Server to actuators.
- Sensors and actuators installed in each area of a farm. Sensors monitor environmental data and actuators turn on/off water pumps.
- Server which manages and processes information obtained sensor-actuator from farms and sends control command to actuators.

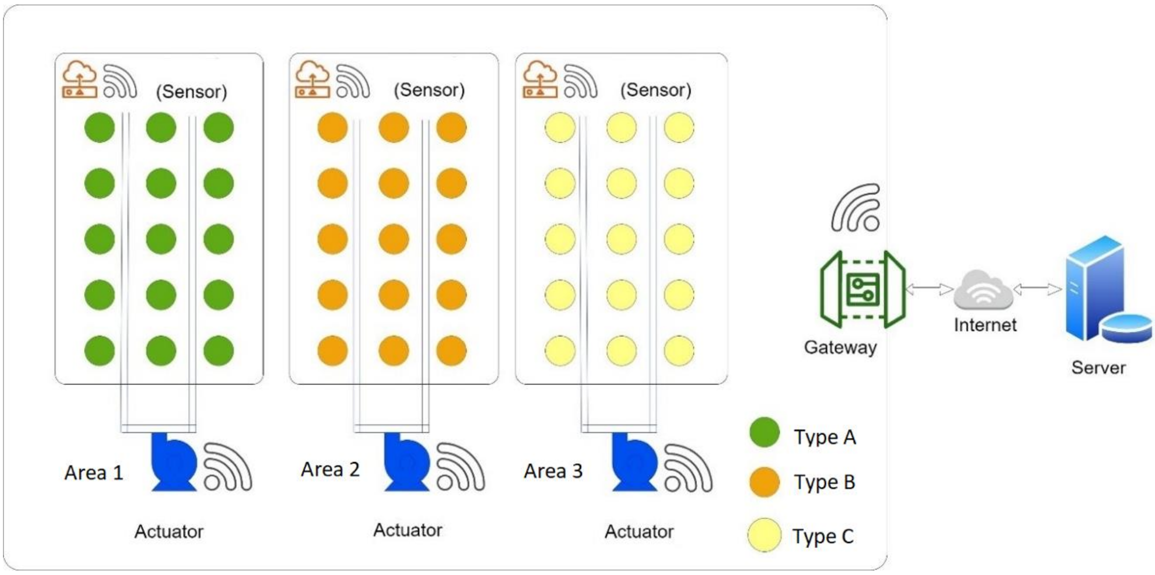


Figure 1. Overview of the proposed water irrigation system

The detailed design of the system is shown in Fig. 2. Since the distance between sensors/actuators and gateways may be far away, we use LoRa communication [7] for data exchange between Sensors/Actuators and Gateway and develop a protocol called AgriNet that enables device identification, reliable transmission, and packet encryption over LoRa. The detailed functions of AgriNet protocol are implemented as follows:

- Device identifier (ID): each device is assigned a 32-bit identifier. Source ID and destination ID are included in each packet sent between Sensors/Actuators and Gateway (Fig. 3).

- Reliable transmission: We use a "Stop-and-wait" approach to ensure reliable transmission. CRC-7 code is used to detect error in received data [8]. When a receiver receives an erroneous packet, it will not send any reply packet. If the sender does not receive a reply packet after a certain amount of time, it will resend the request packet.
- Packet encryption: AgriNet packet is encrypted by AES algorithm [9] to prevent eavesdropping.

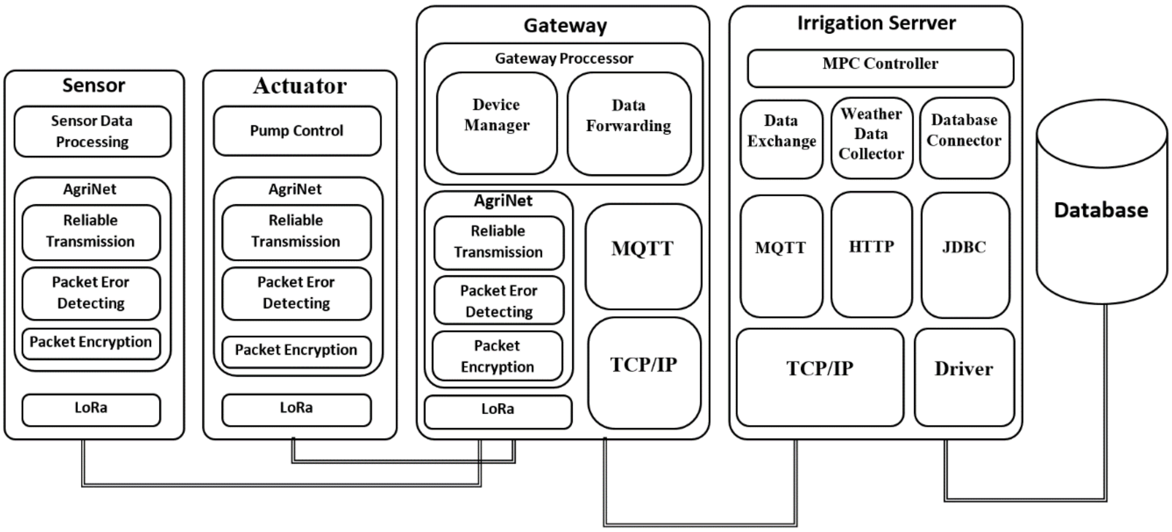


Figure 2. The detailed design of the proposed water irrigation system

AES

Source ID	Dest ID	Data	CRC
4B	4B	nB	1B

Figure 3. AgriNet packet structure

Server and Gateway communicate via MQTT broker using MQTT protocol. The server calculates the optimal amount of irrigation water for each area of farms using the model predictive control (MPC) method and sends control command to actuators via Gateway. Weather data is also collected to provide MPC controller the information of weather forecast.

2.2. MPC-based irrigation control

2.2.1. Effective soil moisture range

To satisfy the growth of plants, the amount of water stored by the soil must be kept in a range called effective soil moisture, which can be easily absorbed by plants. Excess of water or lack of water are both not good for plants to grow. The change of soil moisture depends on several factors such as water irrigation, plant's water absorption, water evaporation, soil water transport, ... [10] We need to control the amount of irrigation water to keep soil moisture within the effective soil moisture range.

After watering, the water evaporation rate increases quickly since the soil moisture in the soil surface layer increases quickly. Then the water will gradually move to the lower layer and the water evaporation rate gradually decreases. When the upper layer dries out due to evaporation, the water evaporation rate keeps almost unchanged [11].

In order to save irrigation water, we need to minimize the amount of water lost from soil due to water evaporation. Since water evaporation depends on various environmental parameters such as air temperature, air humidity, wind velocity, light intensity…, we need to avoid watering when water evaporation is high. Hence, we propose a model predictive control (MPC)-based irrigation method which can choose appropriate irrigation water amount and watering time at each time step to save irrigation water and keep soil moisture within an effective soil moisture range.

2.2.2. MPC-based irrigation control method

To calculate the appropriate water amount for each irrigation time, we utilize MPC-based irrigation method, in which the best irrigation plan will be calculated by Optimizer module based on soil moisture predictive model.

The Optimizer minimizes a cost function J, which is the total amount of irrigation water in *n+1*time steps:

$$J = minimize \left[\sum_{i=0}^{n} V_{water}[t+i] \right]$$

with the constraint that soil moisture must be kept within an effective humidity range. We can represent it through a mathematical expression

$$Th_l < M_{soil}[t] < Th_h \text{ for } \forall t \in [0,\ldots,n]$$

Here,

- n is MPC prediction horizon, which is defined as the number of time points considered in a time window
- $V_{water}[t]$ is the amount of irrigation water at time step *t*
- Th_l: Lower threshold of effective humidity range
- Th_h: Upper threshold of effective humidity range
- $M_{soil}[t]$: Soil moisture at time step *t* when the amount of irrigation water is (V_{water}[0], …,V_{water}[n])

The solution of the problem is the set of irrigation levels at equally spaced time steps. There are *(n+1)* such time corresponding to the present time and the next *n* time step in the future. If the scale *n* of the problem is not large, we can use exhaustive search method to find the optimal solution which satisfies the constraint of the problem.

After solving the solution, the MPC controller sends the value of irrigation water amount at the next-hour time to the actuator, which will control the pump for watering. This calculation will repeat again at the next time step.

In order to calculate soil moisture at time step *t*, we use 2 models:

- Linear regression model for calculation of the change of soil moisture when watering because the change of soil moisture when watering depends largely on water irrigation amount and the type of soil. The value of soil moisture when watering is then calculated using a linear function of irrigation water amount.

$$\Delta M_{soil} = \alpha . m_w$$

Here, ΔW_{soil} is the change of soil moisture when watering, m_w is the amount of irrigation water and α is a parameter which will be calculated based on linear regression model

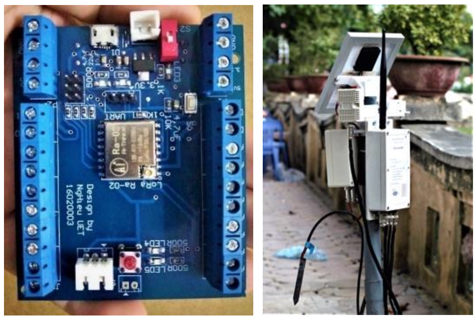
- Artificial neural network (ANN) model for calculation of the change of soil moisture when irrigation is stopped. In this case, the change of soil moisture depends on environmental factors such as current soil moisture, air temperature, air humidity, and light intensity.

3. Evaluation

3.1. Implementation

We have built the hardware for Gateway, Sensor, Actuator (Pump controller) to verify the operation of the system. (Fig. 4)

(a) Gateway



(b) Sensors

Figure 4. Gateway, Sensor and Actuator

We set up the experiments as shown in Figure 5. Sensor and Actuator are placed next to each other and near the soil to be watered. The sprinkler is placed around the sensor to evenly water the soil.

Firstly, we perform an experiment, which calculates the change in soil moisture value when watering. Each time watering, the soil moisture value measured by the sensor is recorded. The result is shown in Fig. 6. The change in soil moisture is linearly proportional to the amount of water irrigated. Here, the R-squared value of the train dataset is 0.9592.

Figure 5. Experiment to measure soil moisture in practice

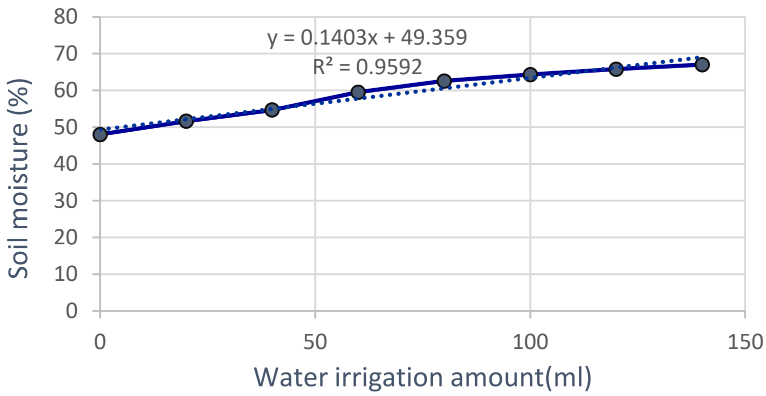


Figure 6. The change of soil moisture when watering

Secondly, we use the data set collected when watering a pot of soil placed outside, fully affected by temperature, air humidity, light in nature to build ANN model for calculation of the change of soil moisture when irrigation is stopped. Part of the data set is shown as Fig. 7.

After preprocessing the data set and using it as training data for ANN model, we get the Mean square error (MSE) between the actual value and the predicted value falls in [-2%, 6%] range, which is acceptable for the calculation of the change of soil moisture. We then verify our irrigation method through both simulation method and experimental method.

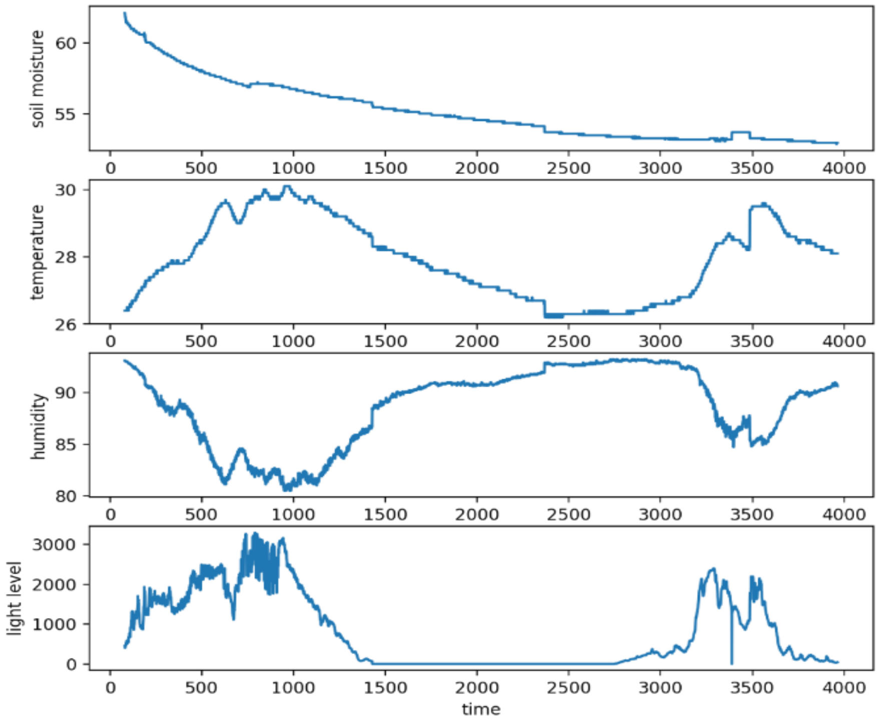


Figure 7. A data set collected when watering a pot of soil

3.2. Experiment result of MPC-based irrigation method

We perform experiment of MPC-based irrigation method with effective soil moisture range set from 60% to 70%. Figure 8 shows the experiment results. The soil moisture is maintained within effective soil moisture range. The system works normally without errors during the experiment. During the experiment, the pump turns on 4 times. The packet transmission delay between Sensors and Gateway via LoRa is 50ms. The exhaustive search method for finding the optimal solution of MPC-based irrigation method takes about 5 seconds.

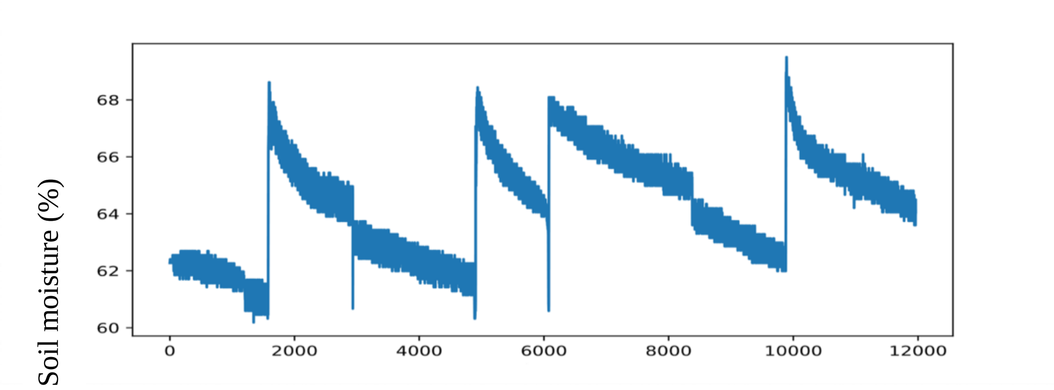
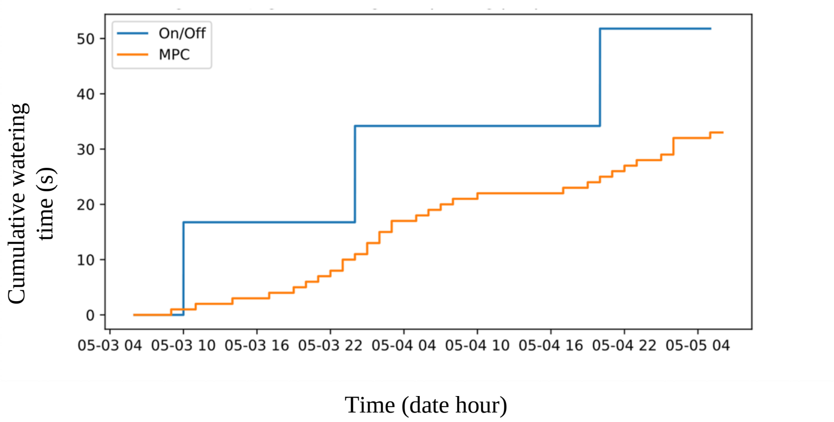


Figure 8. Experiment results of MPC-based irrigation method

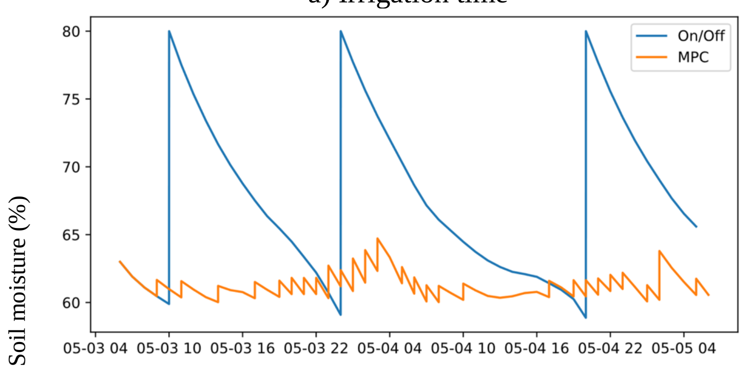
3.3. Sir on result of MPC-based irrigation method

We perform simulation to show the effectiveness of MPC-based irrigation method by comparing it with simple On/off irrigation method. In On/off irrigation method, the pump will start watering when soil moisture is lower than a lower threshold and stop watering when soil moisture is higher than a upper threshold. Effective soil moisture range is set between 60% and 80%. The change of soil moisture when watering and the change of soil moisture when irrigation is stopped are calculated based on two models mentioned above.

Figure 9 show the simulation results. In two-day simulation, the total watering time of MPC-based irrigation method is about 40% less than that of On/off irrigation method. It shows that our MPC-based irrigation method can save more water comparing with simple On/off irrigation method.



a) Irrigation time



b) Soil moisture

Time (date hour)

Figure 9. Simulation results of MPC-based irrigation method

4. Conclusion

In this paper, we have presented our proposed MPC-based irrigation method. Our proposed method predicts the change of soil moisture based on sensor data and ANN model and calculates appropriate irrigation water amount and watering time at each time step. Hence, our method can save irrigation water but keep soil moisture within an effective soil moisture range.

In near future, we need to improve the efficiency of our proposed MPC-based irrigation method by building more accurate prediction models for the prediction of soil moisture.

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A PRELIMINARY STUDY ON PRESENT STATUS OF ENERGY INPUT IN RICE PRODUCTION IN BRUNEI DARUSSALAM

M. A. Basunia[1,*)], A. M. K. Azizan[2)]

1) Universiti Teknologi Brunei, Brunei
ali.basunia@utb.edu.bn, Mechanical Engineering Programme Area,
Tungku Highway, Gadong BE1410, Brunei Darussalam
2) Former undergraduate student, Mechanical Engineering Programme Area,
Universiti Teknologi Brunei, Brunei

* Corresponding author

ABSTRACT: The **e**ffective energy consumption planning is necessary to achieve an ecologically, socially and economically viable sustainable crop production system. The energy input analysis is essential due to the increased energy demand. Therefore, the energy inputs for rice production by conducting a preliminary field study on the Wasan rice farm in Brunei Darussalam was evaluated. This was done through a visit to the farm and interviewed several farmers to collect the data related to energy consumptions in different stages of rice production. The total energy inputs per hectare for the size of lands 0.6, 1.1, 2.0, and 3.9-hectares were determined as 131,531.7, 141,241.9, 142,575.1, and 142,911.8 MJ/ha, respectively. The most significant energy contribute was by fuel energy, which accounted for 15,017.2, 24,120.5, 26,419.5, and 26,485.3 MJ/ha for 0.6, 1.1, 2.0, and 3.9-hectares of land, respectively. The manual energy inputs were the lowest as 3.92, 3.92, 5.88, and 3.92 MJ/ha, respectively, for the four sizes of land studied. The energy productivities were 0.3323, 0.8253, 0.4088, and 0.5098 kg/MJ respectively for the land sizes 0.6, 1.1, 2.0, and 3.9-hectares which shows the productivity is very low compare to energy input per hectare except for the land size 1.1 ha. So, there is need to increase the rice production per unit of land cultivated.

Keywords: *Energy input, rice production, specific energy, cropping intensity***.**

1. INTRODUCTION

Rice is the important staple food in Brunei Darussalam. The country has since devised a plan to become self-sufficient by farming rice rather than relying on imported rice. It is mentioned in "Brunei Darussalam's Voluntary National Review Report at the 2020 United Nations High-Level Political Forum" on "Sustainable Development Goal 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture" as Brunei Darussalam is committed to enhancing the country's food security by ensuring that citizens have access to a sufficient supply of safe, nutritious food at affordable prices (MFE, 2020). With a strong consumption pattern, 9.1% of rice is produced locally only (DoAA, 2021). Most rice is imported from Thailand. Hence, the Brunei Government had made initiatives to encourage the locals in rice farming because rice is the staple food in Brunei Darussalam. As part of Vision 2035, the government recently launched innovative agricultural initiatives that include developing infrastructure, expanding new lands, introducing new rice hybrids, developing hydroponic/aquatic phonetic technology, and improving post-harvest technology (Jonatan, 2015).

According to Kosemani and Bamgboye (2020), there were significant differences between three farms in Nigeria of different sizes regarding energy use and agronomic management, such as land preparation and transplant date. The average energy expenditure to produce rice in small, medium - and large farms, according to the study, amounted to 14,813.00, 14,543.00, and 14,067.00 MJ/ha. At the same time, the average yields were 6,695.00, 7,060.00, and 7,364.00 kg/ha, so the energy shares for small, medium-sized, and large farms were 6.58, 7.07, and 7.62, respectively (Kosemani and Bamgboye, 2020).

Rahman et al. (2015) made the opposing statement, claiming that larger paddy fields require more energy for land preparation. According to the study, the energy input per hectare for small, medium-sized, and large farms was 19,230.2, 20,757.7, and 24,460.7 MJ/ha, respectively (Rahman et al., 2015). As a result, it has been established that a larger paddy field necessitates more energy for land preparation.

A study by Kumar (2019) on small farms which are less than 1.00 hectares, medium farms are between 1.10 and 2.00 hectares, and large farms are greater than or equal to 2.00 hectares, stating that the average energy input per hectare for the preparation of small, medium, and large areas was 3,120.9, 5,718.1 and 7,882.7 MJ/ha. The use of energy per hectare increases proportionally to the size of the farm (Kumar et al, 2019).

Azizan (2022) reported that no study has been done related to energy utilization in different stages of rice production in Brunei Darussalam. So, there was a need to take at least a preliminary study to gain knowledge about energy consumption in rice production in Brunei Darussalam.

To thoroughly analyze the energy requirements of rice production means that specific or actual data is required. Therefore, field studies must compile a more comprehensive agricultural production energy database. In addition, all energy major and minor energy inputs are needed field operating energy data. As a result, this preliminary investigation was done with the limited field data by interviewing a limited number of rice-growing farmers due to Covid-19 under Wasan rice farm, which is the largest rice farm in in Brunei Darussalam. The objectives were to identify the forms of energy used in rice production, and to evaluate the energy utilization efficiency in different rice production activities in the study area.

2. MATERIALS AND METHODS

Data was collected by visiting several farmers at a paddy field owned by local farmers at Wasan which is situated in Pengkalan Batu. Inputs energy such as human or manual labour, machinery, seeds, fertilizers, fuel, chemical, irrigation water and electricity were considered. In terms of output energy, rice yield, straw, rice husk and rice bran was considered. The energy coefficients for different parameters has been shown in Table 1. The collected data were used to calculate the energy used in different rice production systems as described below.

2.1 Energy inputs

2.1.1 Calculation of direct energy input

(i) Human or manual energy (Ullah, 2009)

Human labor energy, $HL_E\ (MJ/ha) = H_T \times E_{HE}$ (1)

H_T = Total hours worked, h/ha, E_{HE} = Human energy equivalent, MJ/h.

(ii) Machinery energy (Kumar et al, 2019)

Machinery energy, $MECH_E\ (MJ/ha) = \sum_{i=1}^{n} T_{Mi} - E_{Mi}$ (2)

T_M = Machine operating time, h/ha, E_M = Machines' energy equivalents, MJ/h.

(iii) Fuel energy (Cherati et al, 2014)

Fuel energy, $FUEL_E$ (MJ/ha) = $Q \times CV$ (3)

Q = Amount of fuel used, L/ha, CV = Calorific value of fuel used fuel, MJ/L.

2.1.2 Calculation of Indirect Input Energies

(i) Chemical energy (Bhunia et al, 2021)

Chemical energy, $CHEM_E\ (MJ/ha) = (M_{MOP} \times E_{C\text{-}MOP}) + (M_U \times E_{C\text{-}U}) + (M_H \times E_{C\text{-}H})$ (4)

M = Amount of chemical applied to the field, kg/ha, E_C = Chemical energy equivalent, MJ/kg.

(ii) Fertilizer energy (Alipour et al, 2012)

Fertilizer energy, $FERT_E\ (MJ/ha) = (M_N \times E_N) + (M_P \times E_P) + (M_K \times E_K)$ (5)

M_N, M_P, and M_K = Amount of each type fertilizer applied to the field, kg/ha, E_N, E_P, and E_K = Energy equivalent of each type of fertilizer, MJ/kg
(iii) Seed energy (Bhunia et al, 2021)
Seed energy, $SEED_E\ (MJ/ha) = M_S \times E_S$ (6)
M_S = Amount of seed used for sowing, kg/ha, E_S = Seed energy equivalent, MJ/kg.

Table 1. Energy equivalent of inputs and outputs in rice production

Energy Source	Unit	Energy Co-efficient (MJ/Unit)	Reference
Direct Energy Use			
Manual Energy			
a) Human Labour	h	1.96	Ullah (2009), Kumar et.al, (2019)
Mechanical Energy			
a) Tractor - Disk Harrow	h	7.336	Kumar et.al, (2019)
b) Tractor - Power Tiller	h	6.693	Kumar et.al, (2019)
c) Transplanter	h	5.02	Kumar et.al, (2019)
d) Drone Sprayer	h	1.918	Maikaensarn and Chantharat (2022)
e) Water pump	h	1.75	Ullah (2009)
f) Combine Harvester	h	47.025	Ullah (2009)
Fuel Energy			
a) Diesel	ℓ	56.31	Cherati et al, (2014)
b) Petrol	ℓ	47.8	Cherati et al, (2014)
Indirect Energy Use			
Chemicals			
a) Nitrogen – N	kg	60.60	Bhunia et al, (2021); Alipour et al, (2012)
b) Phosphorus – P_2O_5	kg	11.10	Bhunia et al, (2021), Alipour et al, (2012)
c) Potassium – K_2O	kg	6.7	Bhunia et al, (2021), Alipour et al, (2012)
d) Potassium Chloride - MOP	kg	270.1	Ullah (2009)
e) Urea	kg	234.3	Ullah (2009)
f) Herbicide	kg	238	Bhunia et al, (2021), Alipour et al, (2012)
Water	m^3	1.02	Bhunia et al, (2021)
Electricity	kWh	11.93	Bhunia et al, (2021), Alipour et al, (2012)
Biological			
a) Seed	kg	14.7	Bhunia et al, (2021), Alipour et al, (2012)
Output Energy			
a) Paddy Rice	kg	14.57	Bhunia et al, (2021)
b) Rice Straw	kg	12.5	Alipour et al, (2012)
c) Rice Husk	kg	11.03	Lubis, (2018)
d) Rice Bran	kg	13.23	Sapwarobol et al, (2021)

(iv) Water energy (Bhunia et al, 2021)
Water energy, $WATER_E\ (MJ/ha) = V_W \times E_W$ (7)
V_W = Total amount of irrigation water applied to the field, m^3/ha, E_W = Energy equivalent of irrigation water, MJ/m^3.

(v) Electrical energy (Alipour et al, 2012)
Electric energy, $ELEC_E$ $(MJ/ha) = (Electricity\ used \times EE)/L$ (8)
Electricity used = Power consumption, kWh, E_E = Electrical energy equivalent, MJ/kWh, L = Land size, ha

2.2 Energy outputs

(i) Yield energy (Bhunia et al, 2021)
Yield energy, $YIELD_E$ $(MJ/ha) = M_Y \times E_Y$ (9)
M_Y = The yield rate, kg/ha, E_Y = The rice yield energy equivalent, MJ/kg.
(ii) Straw energy (Alipour et al, 2012)
Straw energy, $STRAW_E$ $(MJ/ha) = M_{ST} \times E_{ST}$ (10)
M_{ST} = The Rice straw amount, kg/ha, E_{ST} = The rice straw energy equivalent, MJ/kg.
(iii) Husk energy (Lubis, 2018)
Husk energy, $HUSK_E$ $(MJ/ha) = M_{HU} \times E_{HU}$ (11)
M_{HU} = Amount of husk, kg/ha, E_{HU} = Equivalent energy of rice husk, MJ/kg
(iv) Bran energy (Sapwarobol et al, 2021)
Bran energy, $BARN_E$ $(MJ/ha) = M_{BR} \times E_{BR}$ (12)
M_{BR}= Amount of rice bran, kg/ha , E_{BR} = Energy equivalent of rice bran, MJ/kg.

2.3 Energy Indicators

The energy ratio of inputs, which is the sum of the direct and indirect energy and outputs of the rice production system, and (grain and straw), was calculated after converting the respective units of inputs and outputs into energy units. These indicators can be determined by the equations (13) and (14).

Energy efficiency (energy ratio) = (Energy output, MJ/ha)/(Energy input, MJ/ha) (13)
Energy productivity = (Rice yield, kg/ha)/ (Energy input, MJ/ha) (14)

3. RESULT AND DISCUSSION

As indicated in Table 2, the direct input energy on all land sizes contributes less than 20% with the ratio increases with increasing land size with the lowest ratio of 11.82% on 0.62-hectare land. Indirect input energy contributes to more than 80% of all land sizes surveyed, yet the smallest land has the highest indirect input energy of 88.18% and it decreases as the size of the land increases.

Table 2. Calculated Energy Input

Input Energy (MJ/h)	Farm Size			
	0.62 ha	1.1 ha	2 ha	3.9 ha
Direct Input Energy				
Manual Labour	3.92	3.92	5.88	3.92
Mechanical Labour	542.592	542.9756	474.768	542.592
Fuel Energy	15,017.2	24,573.6	25,938.8	25,938.8
Total	15,563.71	25,120.5	26,419.45	26,485.312
Ratio	11.82 %	17.79 %	18.53 %	18.53 %
Indirect Input Energy				
Fertilizer Energy	588	588	588	588
Chemical Energy	13,086	13,086	13,038.4	13,324
Seed Energy	294	441	529.2	514.5
Water Energy	102,000	102,000	102,000	102,000
Electrical Energy	-	6.356	-	-
Total	115,968	116,121.4	116,155.6	116,426.5
Ratio	88.18 %	82.21 %	81.47 %	81.37 %

It was also observed that indirect energy consumption is more than direct energy consumption. The indirect input energy contributed more than 80% of the total input energy was also observed by

Kosemani and Bamgboye (2021). As for direct input energy, fuel energy has the highest energy contribution on all land. Meanwhile, water energy has the highest energy contribution for indirect energy consumption in all land. As for output energy, it was calculated and tabulated in Table 3. It is the energy calculated for rice yield, paddy straw, paddy husk and also rice brans for individual farm sizes respectively. The total input and output energies, and the energy productivity were summed together for each land size respectively (Table 4). Input energy increases with the increasing land size. The energy productivity is usually the measure of benefit gained from the unit of energy used. As for energy productivity for the farmers, the one with 1.1-hectare land has the highest value of 0.8253 kg/MJ. This means that the farm has produced big amount of yield than the others with the proportion of its land size and the input energy has been put into the rice farming. Therefore, farmers need to identify wasteful uses of energy to improve energy productivity.

Table 3. Output energy calculated

Output Energy (MJ/ha)	Farm Size			
	0.62 ha	1.1 ha	2 ha	3.9 ha
Rice yield	43,710	116,560	58,280	72,850
Paddy straw	26,250	70,000	35,000	43,750
Rice Husk	10,500	28,000	14,000	17,500
Rice Barn	1984.5	10,584	5292	3307.5

Table 4. Total input and output energy

Total	0.62 ha	1.1 ha	2 ha	3.9 ha
Input Energy (MJ/ha)	131,531.7	141,241.9	142,575.1	142,911.8
Output Energy (MJ/ha)	82,445.0	225,144.0	112,572.0	137,408.0
Energy Productivity (Kg/MJ)	0.3323	0.8253	0.4088	0.5098

4. CONCLUSIONS

The input energy increases proportionally according to land size, which is 131,531.7, 141,241.9, 142,575.048, and 142,911.812 MJ/ha, respectively. According to the findings, indirect input energy has made a greater contribution to rice farming in Wasan. The use of fuel from direct input energy and chemical energy from indirect input energy can be seen as the main contributors to input energy. The use of modern rice farming machinery also demonstrates that one's land can produce more rice yield – the use of spraying drones on 1.1-ha land results in a rice yield of 8000 kg/ha. This shows that the modern and efficient usage of modern rice farming machinery is important to reduce excessive energy input into the farm. After comparing the input energy values of rice farming at Wasan rice farm with the rice-producing country like Philippine (Kosemani and Bamgboye, 2021), rice production shows close similarity in the percentage of indirect and direct input energies. It was very difficult to compare the energy results with other rice producing countries as the farmer interviewed is four only. The government has launched an initiative to enlist the private sector as service providers for processes such as harvesting and land preparation, which would reduce the time traditionally required and increase total yield, in addition to fertiliser and pesticide subsidies.

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A GRADING EVALUATION SYSTEM FOR PEAR FRUIT APPEARANCE USING DEEP LEARNING METHODS

Kensuke Nakazawa[1, *)] and Tatsuya Yamazaki[2)]

1) Graduate School of Science and Technology. Niigata University, Japan
f21c039a@mail.cc.niigata-u.ac.jp
2) Faculty of Engineering, Niigata University, Japan

* Corresponding author

ABSTRACT: Appearance is one of the most important things for Le Lectier (pear) grading because this fruit is often used for gifts. Pear appearance grading depends on the appearance deterioration and its shape. Hereat the grading is usually defined by the authority, for example, the government of Niigata Prefecture in Japan. Therefore, pear farmers must evaluate and grade every pear through visual inspection. But this evaluation work has two problems: discrepant and inconsistent grading caused by subjective evaluation and the heavy workload of visual inspection. To solve these problems, we aim to develop an automatic grading system using computer vision for stability evaluation and load reduction. The proposed system consists of four steps: pear image capturing, detection of pear objects in the image, evaluation of appearance deterioration and fruit shape, and final grading by integrating the previous step evaluation results. In this paper, we elaborate on the second and third steps except for the fruit shape evaluation; namely, the detection of pear objects and the appearance deterioration are implemented by deep learning methods with semantic segmentation and object detection. We have collected pear images with various grading evaluations and experiments have been carried out to evaluate the proposed methods. The DeepLabV3+ model was used for semantic segmentation to detect pear objects. The experimental result was an Intersection over Union of 99.9% on the test set. Appearance deterioration detection uses object detection methods. In deterioration detection, the Faster R-CNN model was used to detect five kinds of appearance deterioration (damage and disease). The experimental result achieved a mean average precision of 51.0% on the test set. The processing time of the two steps was about 166.3 milliseconds per image on a machine with NVIDIA GeForce GTX 1080 Ti.

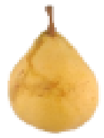
Keywords: *Deep learning, fruit grading system, image processing.*

1. INTRODUCTION

Grading of a kind of pear, Le Lectier (hereafter, referred to as pear simply), is based on mainly its appearance. Pear appearance grading depends on the deterioration of the pericarp and the fruit shape. The grading is usually defined by the authority, for example, the government of Niigata Prefecture in Japan, as shown in Table 1. Table 1 includes pear perspectives and criteria for classifying into three grades: Excellent, Brilliant, and Good. Examples of perspectives are shown in Figure 1; Alternaria has dense black points caused by bacteria (Figure 1 (a)), injury appeared by damage in farm work or shipping work (Figure 1 (b)), speckle is caused by dampness or bacteria (Figure 1 (c)), chemical has cork or ring caused by pesticide (Figure 1 (d)), and plane is caused by dampness (Figure 1 (e)).

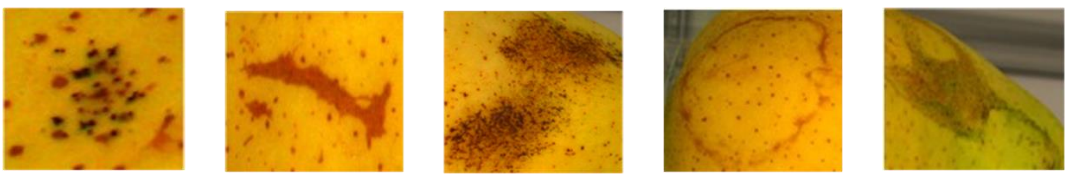
Currently, in the grading work, every farmer must evaluate and grade each pear through visual inspection. One of the largest issues in the visual inspection work is quantity. Some farmers yield tens of thousands of pears within a limited period because pears of the same variety are grown simultaneously. These pear fruits must be evaluated and graded in a short period. It is a heavy workload, and an automatic grading system using computer vision needs to be developed to alleviate their inspection work.

Table 1. Example of grading.

Perspective / Grading	Excellent	Brilliant	Good
Alteralia 	A discreet lump.	Some discreet lumps. (less than one third of surface and until three discreet lumps)	One valued less than Briliant that has worth as a product.
Injury and Speckle 	A discreet weak cork. (less than 10% of surface)	A discreet weak cork. (less than one third of surface)	One valued less than Briliant that has worth as a product.
Plane and Chemical 	Some weak stains. (less than 10% of surface)	Some weak stains. (less than one third of surface)	One valued less than Briliant that has worth as a product.

Development of the automatic grading system has another advantageous point. Pear evaluation work needs professional knowledge based on the farmer's skill and experience. Since each farmer's knowledge is different, their evaluation might be subjective and inconsistent grading may occur at the stage of shipping. On the other hand, the automatic grading system is expected to grade the pear fruits objectively based on the grading criteria defined by the authority.

In the previous work, we proposed an evaluation system for appearance deterioration that uses pericarp texture features and Convolutional Neural Networks (CNNs), Nakazawa et al. (2022). However, the proposed methods have two problems. The first problem is a limitation of the validity of the effect due to difficulty in the quantitative determination like a mean average precision (mAP) because the detection size is constant sizes. The second one is the computational speed of about 30 seconds per image, which is not fast enough to replace human evaluation work. This paper contributes to solving these problems and improving the accuracy and speed of the evaluation system for the appearance deterioration of pears. In this paper, we combine two models; one is DeepLabV3+ to segment pear region from the other region and the other is Faster Region-based Convolutional Neural Networks (Faster R-CNN) to detect appearance deterioration positions and classify them into 5 types shown in Figure 1. Improvement of accuracy and speed is verified by evaluation experiments, in which pear fruit images collected in cooperation with a farmer are used. The deterioration classes in the pear appearance images are annotated with the instruction of experts to datasets for train and validation.



a. alternalia b. injury c. speckle d. chemical e. plane

Figure 1. Examples of Appearance Deterioration.

2. Related Work

In the same way, as texture features were utilized in our previous method, Nakazawa et al. (2022), texture features are used in agricultural fields for plant disease classification by several research works. Texture features are one of the important characteristics of images that express visual brightness and tactile intensity. Kim et al. (2008), proposed a classification method for 5 diseases of grapefruit and normal ones using texture features and statistical software in their work. The result showed about 96.0%

classification accuracy. Arivazhagan et al. (2013), proposed a classification method for 2 or 3 diseases of 9 kinds of fruit leaves by using texture features and a model of the support vector machine. The results showed 87.66% average accuracy in 9 kinds of fruit leaves. Plant disease classification tasks using texture features have achieved high accuracy in a simple classification. However, our research objective is the detection of multi-appearance deterioration on the same pericarp image and grading evaluation of integrating its result. This section reviews agricultural evaluation works using CNN techniques.

2.1. Object Detection

Object detection is a technique that deals with detecting instances of semantic objects of a certain class (such as humans, buildings, or cars) in images. In the agricultural field, the method is used for evaluation of plant disease diagnosis. Fuentes et al. (2017) proposed a tomato leaf disease detection method using Faster R-CNN. The result showed about 83.0% mAP for 9 kinds of leaf disease. In this work, high accuracy was achieved though the dataset with various resolutions and situations. Also, Fuentes et al. (2018) proposed `Filter Bank` using CNN to adapt each class after Faster R-CNN unit. The method improved mAP by 9.65% due to introducing `Filter Bank`. Saleem et al. (2020) proposed a method to detect 26 kinds of disease in 14 plants using the Plant Village dataset. The proposed method achieved 48.61% mAP by using Faster R-CNN. The Plant Village dataset includes 54,305 images of various types of plants.

2.2. Semantic Segmentation

Semantic segmentation is an approach to detect the belonging class of the object for every pixel. Mortensen et al. (2016) proposed a segmentation method to estimate the ratio of crops in mixed crop yield. The result of the proposed method showed 66.0% frequency weighted intersection over union (IoU) for 7 kinds of plant. Asad et al. (2020) proposed a segmentation method to spray herbicide accurately using U-Net. This method achieved 82.74% mAP for segmented weeds and soil. Tusubira et al. (2020) proposed a segment-based method to root necrosis scoring of cassava using U-Net. This work showed 90.0% mean IoU (mIoU) for test data. Kang et al. (2021) proposed a segmentation method to measure the ratio of roots in soil using DeepLabV3+. The result showed 98.75% IoU that segmented roots from the soil.

3. Proposed Method

In this paper, we propose a combined model of two semantic segmentation methods. The former takes the role of extracting the pear fruit region from the image and the role of the latter is the detection of deterioration positions in the fruit region and classification of the deterioration positions into 5 classes.

3.1. Pear extraction

In the former part, the DeepLabv3+ model, which was proposed by Chen et al. (2018), is used to extract the pear region. DeepLabv3+ is a semantic segmentation architecture that is an upgraded version of DeepLabv3 with several improvements, such as adding a simple yet effective decoder module to refine the segmentation results. With this method, every pixel is determined by whether it belongs to the pear region or not by learning. Finally, the pear region can be extracted from the original image.

3.2. Pear appearance deterioration detection

In the latter part, the Faster R-CNN model, which was proposed by Ren et al. (2015), is used to detect deterioration positions in the pear region and to classify each position. In general, Faster R-CNN has 2 stages detection process. In the first stage, a Region Proposal Network (RPN) considers whether anchors contain an object or not. In the second stage, the classifier network predicts class probability and bounding box (bbox) for each RPN. Though Faster R-CNN has a base net, which is a main neural network model, and it is usually a VGG net. In this method, the VGG net is replaced by ResNet as the base net.

4. Experimental Results

To verify the proposed method, evaluation experiments are carried out by using pear fruit images collected at a pear farm. In this experiment, the models in the proposed method have been trained and tested on a computer with an Intel(R) Xeon(R) CPU E5-2687W v4 3GHz and a GeForce GTX 1080 Ti.

4.1. Data description

In this experiment, 1204 pear fruit images in RGB, shown in Figure 2 (a) as an example, with a resolution of 2048 × 1536 pixels were used. These images were annotated with 119 images with the pear fruit region, that were used in pear extraction learning, as shown in Figure 2 (b). Also, we annotated 5 types of appearance deterioration as bbox for detection of appearance deterioration with experts' instruction, as shown in Figure 2 (c).

4.2. Pear extraction

For the learning of the pear extraction part, we split data into 100 images as train data and 19 images as test one. We have trained the DeepLabv3+ model with 25 epochs. The result shows 99.9% IoU for the pear fruit region. The computational time for the model inference is 56.1 ms per image.

4.3. Pear appearance deterioration detection

For the learning of Faster R-CNN, we divided data into 956 images as train data and 248 images as test data. We have trained the Faster R-CNN model with 25 epochs. The result shows 51.0% mAP for each deterioration. The computational time for the model inference is 98.6ms per image. The output images of the Faster R-CNN model are shown in Figure 3. They are a typical example of correct or incorrect classification for deterioration points. Figure 3 (a) shows the accurate detection of each deterioration in comparison with the expert instruction. On the other hand, though it seems that each deterioration is detected in Figure 3 (b) at the first glance, it includes incorrect recognition of deterioration. Since this was caused by inaccurate visual annotation by humans, data tuning in the annotation stage is needed to improve deterioration detection.

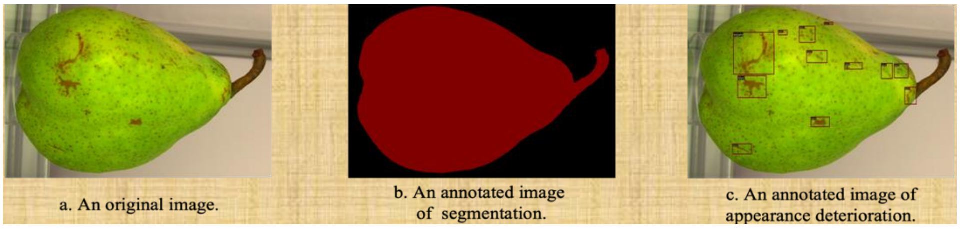
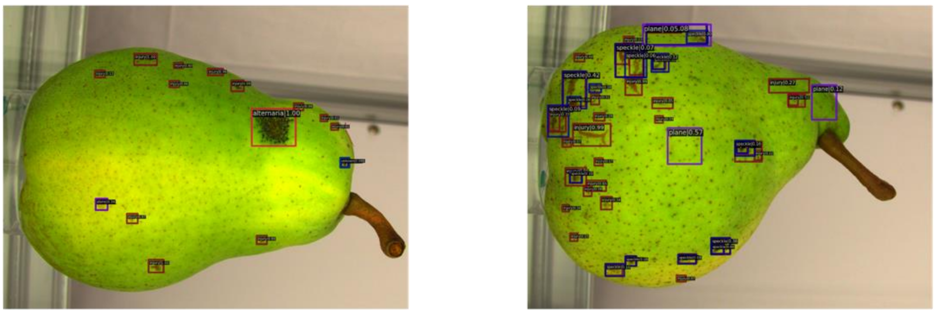


Figure 2. Examples of an original image and its annotated images.



a. An example of correct detection for annotation data. b. An example of incorrect detection for annotation data.

Figure 3. Result of deterioration detection. Each box label indicates the position of deterioration and confidence score.

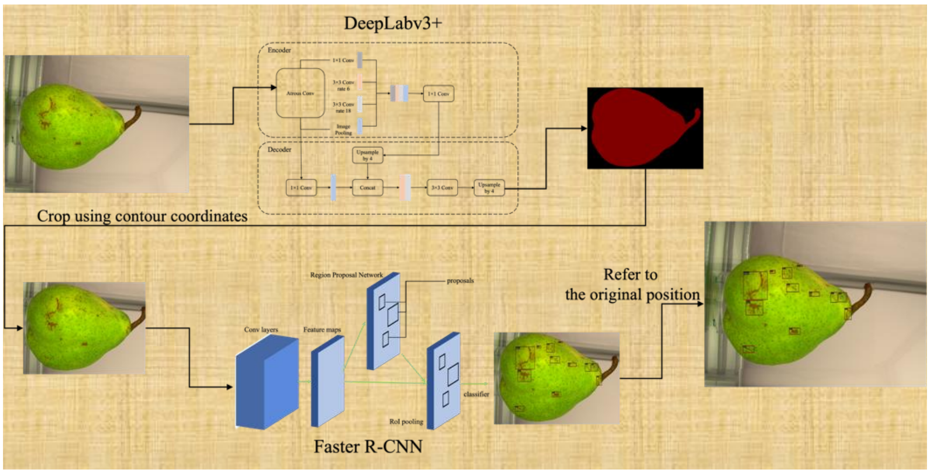


Figure 4. The proposed method workflow to evaluate pear appearance.

4.4. Combination of the models

The proposed model is a combination of DeepLabv3+ and Faster R-CNN. DeepLabv3+ extracts the pear area from the whole image and Faster R-CNN detects appearance deterioration in the extracted area. This workflow is shown in Figure 4. The computational time for an image in this workflow which combines the models is 166.3ms on average in the experiment.

5. CONCLUSIONS

In this paper, we presented an approach to evaluating the appearance deterioration of images of pears. The proposed approach consists of two combined semantic segmentation methods: object detection and deterioration detection methods. The object detection method was realized by the DeepLabv3+ model which was trained on a dataset of 100 images and evaluated on 19 images. On the other hand, the deterioration detection was implemented by the Faster R-CNN model which was trained on a dataset of 956 images and evaluated on 248 images. The experimental results showed that the proposed system could evaluate deterioration accurately. Furthermore, the speed of evaluation has been improved by smoothly combining two deep learning methods. Future work must improve the accuracy of appearance deterioration and consider the shape evaluation method.

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ISOLATION OF THE AMMONIUM AND NITRITE OXIDIZING BACTERIAL STRAINS FOR NITROGEN TREATMENT IN WATER POLLUTION

Nguyen Thi Tham[1, *)], Nguyen Ngoc Chinh[2)], Hoang Thi Bich Hong[3)]
and Pham Thi Huong[4)]

1) Ha Long University, Vietnam
nguyenthitham@daihochalong.edu.vn/ 258 Bach Dang street, Nam Khe ward, Uong Bi city, Quangninh province, Vietnam
2) Vietnam Academy of Science and Technology, Vietnam
3) Ha Long University,Vietnam
4) Ha Long University,Vietnam

* Corresponding author: nguyenthitham@daihochalong.edu.vn

ABSTRACT: The objective of this study was to isolate and purify the nitrifying bacterial from sludge and waste water in aquaculture system, soil at canteen area in Halong University and initially evaluate their ability to treat nitrogen in water. Nitrifying bacteria were isolated by serial dilution and agar plates and then purified by agar slant until obtaining axenic colonies. A total of six strains of nitrifying bacteria were isolated and purified from sludge samples, five strains of bacteria from waste water in the aquaculture area and three strains from soil in canteen area at Ha Long University for application in the treatment of nitrogen in water. The initial results for evaluation for ammonium nitrite treatment ability of isolates obtained by Sera kit test indicated bacteria strains capable of decomposing ammonium had high ability to nitrogen treatment, whereas bacteria strains with capable of decomposing nitrite had no clear sign of nitrogen treatment.

Keywords: *Bacteria isolation, nitrification, eutrophication, ammonium oxidizing, nitrite oxidizing.*

1. INTRODUCTION

Nowadays, water pollution has become an urgent global problem. One of the major water pollutants is nitrogen, which causes eutrophication in lakes, rivers, estuaries and coastal areas. It is caused by industrial, agricultural and human activities. The constant pollution of aquifers and the inappropriate use of water resources have increased the scarcity of water resources. The amount of wastewater generated annually has nearly doubled the concentration of fixed nitrogen in the biosphere, and large amounts of nitrogen exist in various water systems in the form of ammonium, nitrate and nitrite, which are toxic to living organisms, aquatic and environmental changes such as eutrophication. In agricultural activities, in aquaculture areas, there is often an excess of nitrogen in the ponds, affecting the growth, development and productivity of aquatic species (Moriarty et al,, 1997; Hargreaves et al., 1998).

Physical, chemical and biological methods have been developed over the past few decades for the treatment of wastewater and water in aquaculture ponds. An alternative to reducing nitrogen levels is to create treatment strategies using microorganisms to reduce nitrogen content in water. This is a measure with high economic efficiency, ease of use, safety, efficiency, and environmental friendliness.

One of these strategies is the use of nitrification, which is an aerobic process carried out by heterotrophic, gram-negative, non-spore forming microorganisms that are spherical, rod-shaped, or helical in shape snails (Spieck et al., 2005; Lin et al., 2007). Nitrification takes place in two stages: 1) oxidation of ammonium to nitrite, and 2) oxidation of nitrite to nitrate. Different species of microorganisms are involved in each of these stages. In this way, microbial bioremediation of water contaminated by nitrogenous compounds can be accomplished through the application of natural nitrifying and denitrifying microorganisms using inorganic nitrogenous forms or ammonium produced by human activities (Van de Graaf et al., 1995; Sahu et al., 2008). The search for specific microorganisms is important and necessary to determine their intrinsic ability for application in wastewater biological treatment strategies.

The objective of this study is to isolate and purify the nitrifying bacterial from sludge and waste water in aquaculture system, soil at canteen area in Halong University and initially evaluate their ability to treat nitrogen in water.

2. MATERIALS AND METHODS

2.1. Sampling method

The sampling tools are autoclaved and dried. For soil samples: Take 100 g of soil in 3 - 4 different locations (the end of the sewage drains of the canteen of Ha Long University) on an area of 100 m^2 by scraping the surface different soil layers 0 cm, 5 cm, 10 cm ... according to the vertical profile. Soil samples were placed in sterilized zip bags. The sample was mixed well, 10 g of soil was weighed to isolate ammonium oxidizing bacteria (AOB), and another 10 g of sample was taken to isolate nitrite oxidizing bacteria (NOB). Samples were suspended in a sterile conical flask with 90 mL in sterile liquid mineral medium. Stir well with a glass rod and shake on a shaker at 120 rpm for 30 min at room temperature, then voltex for 30 s and then allow to settle. Thus, we obtain a suspension with a dilution of 1:10. For slude samples: take the same as soil samples. Samples were taken in the aquaculture cement tank of Ha Long University.

Figure 1. Samples were taken in the aquaculture cement tank and end up the sewage drains of the canteen at Ha Long University.

For waste water samples: Take 100 ml of water at 3 - 4 different points in the aquaculture cement tank after the culture process of Ha Long University. Water samples were taken and mixed well into sterilized conical flasks. The returned sample was shaken well, and 10 ml was taken to isolate ammonium oxidizing bacteria (AOB), and another 10 ml was taken to isolate nitrite oxidizing bacteria (NOB). Samples were dissolved in a sterile conical flask with 90 mL in sterile liquid mineral medium.

The liquid mineral medium consisted of 0.1 g $MgSO_4$ x $7H_2O$, 13.5 g Na_2HPO_4, 0.7 g KH_2PO_4, 0.01 g anhydrous $FeCl_3$, 0.18 g $CaCl_2$ x $2H_2O$, 0.5 g $(NH_4)_2SO_4$ and 0.5 g $NaHCO_3$ (modified from Spieck and Bock, 2005) for the AOB, while for the NOB ammonium sulphate was replaced by 0.5 g of $NaNO_2$ (modified from Spieck and Bock, 2005); everything was dissolved in 1000 mL of distilled water, and final pH was adjusted to 7.5. Stir with a sterile glass rod and shake on a shaker at 120 rpm for 30 min at room temperature, then vortex for 30 s and allow to settle. We obtain a suspension with a dilution of 1:10.

2.2. Isolation and identification of native nitrifying bacterial consortia

Based on the growth observed in the count of nitrifying bacteria, isolation and purification of native bacterial consortia were carried out through reseeding in a minimal mineral agar medium with a composition of 0.66 g K_2HPO_4 x $3H_2O$, 1 g NH_4Cl, 2 g Na_2SO_4, 0.2 g $MgSO_4$ x $7H_2O$, and 15 g of Agar in 1000 mL of distilled water, adjusting the final pH to 7.5. The cultures were handled under the same growing conditions as those described for bacterial counts of nitrifying bacteria, and necessary reseedings were carried out until pure strains were obtained in a solid minimal mineral agar medium. The pure strains that were components of the native consortia were replanted in culture media of mineral minimal agar in an inclined tube, seeking to obtain sufficient growth for complete identification, and to keep them viable (Rodríguez et al., 2017).

To isolate microbial strains, a serial sample dilution method was performed. Take each 1 ml of suspension for each type of AOB or NOB bacteria (with a dilution of 1: 10) above and mix it into each test tube containing 9 ml of sterile liquid mineral medium to obtain a suspension with dilution is 1:100. Continuing in this way we will have the next dilution 1: 1000; 1: 10000. Depending on the number of microorganisms in the soil more or less, dilute to an appropriate concentration to create separate colonies. Using a sample of suitable dilution, aspirate 0.1 ml of the dilutions of each suspension to spread on a petri dish containing sterile medium of the same liquid mineral composition but supplemented with 15 g of agar. Then, these petri dishes were incubated at room temperature, after the bacteria have grown on the agar plate, observe and isolate pure colonies. The pure colonies will be preserved for further studies. Add 0.1 ml of the soil suspension at the dilution (10^{-5} or 10^{-6}) to the top of the solid medium in a petri dish. Immerse the strip in the alcohol beaker, ignite it on the flame for 30s, wait for it to cool, and wipe the droplet evenly on the surface of the agar medium.Turn the agar plate upside down, place it in the incubator at a suitable temperature (30 - 37ºC); After 1-2 days, observe the colonies on the agar plate with magnifying glass.

Obtaining pure strains of microorganisms: Using sterilized inocula, take a small amount of biomass of each separate colony, inoculate each test tube containing minimal mineral nutrient medium in inclined agar test tubes, and place in an incubator. have the right temperature. After a period of culture, check the purity of the microorganisms grown in each inclined agar test tube.

Checking the inoculum: Observe the growth of microorganisms through the inoculum on solid medium. If the inoculum has a uniform surface and color, it shows that the newly isolated variety is pure, keep it. If the inoculum is not homogeneous, discard.

2.3. Culturing method

The nitrate microorganisms were cultured in a closed system in a 500 ml conical flask sealed to protect against light and shaken at 120 rpm. The experiment was repeated 3 times. For microorganisms capable of oxidizing ammonium (AOB) cultured for 30 days and microorganisms capable of oxidizing nitrate (NOB) were cultured for 22 days. Every 8 days, 10 ml of the culture solution was taken for analysis (Rodríguez et al., 2017).

2.4. Analytical methods

Use the Sera test kit for qualitative and semi-quantitative assessment of pH, ammonium, and nitrite in aqueous media. The isolated bacterial strains were cultured in minimal mineral media and then transferred to culture for 3 days in wastewater samples contained in sterilized conical flasks collected from the outdoor aquaculture area, Ha Long University in the dark shaken 120 rpm, at room temperature. Each isolate was cultured in wastewater medium with 3 replicates and 1 control formula.

After 3 days, the water samples in the control formula and the water samples supplemented with isolated bacterial strains were evaluated for pH, ammonium and nitrite content in water by Sera test kit. Then, using ANOVA statistical analysis method of Microsoft Excel software with confidence $P<0.05$. The results presented include the mean ± standard error of the ammonium and nitrite data from each strain to determine whether the effect was due to bacterial action or to time.

3. RESULTS AND DISCUSSION

3.1. Bacterial isolation results from soil samples taken from the sewage drainage area of the canteen of Ha Long University

By isolating the spread, then turn the agar plate upside down and place it in an incubator at a suitable temperature (30 - 37ºC). After 1 - 2 days, the colonies observed were milky white, round in shape, flat, and 5 - 10 mm in diameter. Collection and selection of pure microorganisms: the biomass of each separate colony were inoculated on each petri dish containing minimal mineral nutrient medium in inclined agar test tubes by using sterilized rods, and place in the incubator at the appropriate temperature. The number of purified bacterial strains obtained was 03 (VK-CT1, VK-CT2 and VK-CT3) at the concentration of 10^{-3}, 3 at the concentration of 10^{-4}. Then, they will be selected to become identified and perform biological tests to remove nitrogen in wastewater.

Figure 2. Bacterial strains isolated from soil samples in the canteen area of Ha Long University on bacterial culture medium (addition of 15g agar).

3.2. Bacterial isolation results from waste water taken from aquaculture cement tank at Ha Long University

Observing colony morphology, the colonies were milky white, round, flat, whole, 1 - 4 mm in size. After the bacteria have grown on the agar plate, observe and separate the pure colonies. The obtained results show that the growth of microorganisms on slanted solid agar had uniform and uniform surface and color, proving that the newly isolated pure variety should be kept. Some test tubes showed fungal and heterogeneous cultures due to contaminated inoculation and no pure seed was obtained.The number of purified bacterial strains obtained was 05 colonies at 10^{-1} dilution. They were denoted as VK-NTS1, VK-NTS2, VK-NTS3, VK-NTS4 and VK-NTS5 respectively. Then, they were selected to become identified and perform biological tests to remove nitrogen in wastewater.

3.3. Bacterial isolation results from sludge sample taken from aquaculture cement tank at Ha Long University

For the isolation of bacteria capable of oxidizing ammonium, the same isolation method was used above. However, the diluent used was AOB, serial sample dilution was performed. After the isolation process, the resulting colonies have the following: Observing colony morphology, colonies were milky white, round, flat, whole, 1-5mm in size. After the bacteria have grown on the agar plate, observe and separate the pure colonies. The results obtained showed that all test tubes showed fungal and heterogeneous cultures due to contaminated inoculation and no pure seed was obtained. For the isolation of bacteria capable of oxidizing nitrite, the same isolation method was used above. However, the diluent used was NOB, serial sample dilution was performed. After the isolation process, the results obtained are as follows: Observing colony morphology, the colonies were milky white, round, flat, whole, with a size of 1 - 5 mm.

Figure 3. Bacterial strains were purified and cultured on slanted agar (supplemention of 15g agar).

The obtained results showed that the growth of microorganisms on slanted solid agar has uniform and uniform surface and color, proving that the newly isolated pure variety should be kept. Some test tubes showed fungal and heterogeneous cultures due to contaminated inoculation and no pure seed was obtained. The number of purified bacterial strains obtained was 06 lines. Then, they were selected to identify and perform biological tests to remove nitrogen in wastewater. The results from the table above show that all bacterial strains isolated on AOB and NOB selective media have similar morphology, most of the colonies are obtained with milky white, flat, round shape. raw, size from 1 to 10 mm.

This result obtained was compared with the research results of Rodrguez A. R. et al. in 2017. This group of authors isolated ammonium and nitrite oxidizing bacteria strains from soil, and their ability to use them in the denitrification of domestic wastewater and evaluated the nitrification capacity of different strains of autotrophic bacteria from soil from nearby domestic wastewater drainage sources. A total of seven nitrifying microorganisms were isolated and purified, including four *Streptomyces sp.*, one *Pseudomonas putida,* one *Sphingomonas sp*. and a strain of *Aeromonas sp*.

3.4. Results of testing the ability to treat nitrite and ammonium in water by isolated bacterial strains

Before conducting analysis, assessing the content of nitrite and ammonium in the water samples to be tested, the samples were measured pH by colorimetric method using Sera's test kit. After comparing the colors and comparing the table to evaluate the ammonium content and the corresponding pH, the results obtained are as follows:

Table 1. Analysis results of ammonium content and corresponding pH.

Sample	Replication	NH_4 content (mg/l)	pH						
			6	6.5	7	7.5	8	8.5	
Control		5	-	-	-	-	-	0.75	
Sample supplemented with bacteria capable of oxidizing ammonium	R1	1	-	-	-	0.02	-	-	
	R2	0.5	-	-	-	0.009	-	-	
	R3	0.5	-	-	-	0.009	-	-	NH_3
Sample supplemented with bacteria capable of oxidizing nitrite	R1	2	-	-	-	-	-	-	
	R2	2	-	-	-	-	-	-	
	R3	2	-	-	-	-	-	-	

The results in the table above showed that wastewater samples taken in aquaculture areas, the pH value was 8.5, corresponding to the ammonium content in wastewater of 0.75 mg/l. This was the threshold >0.5 mg/l, in the red range, so it was considered very toxic. This was the original control water sample with no bacteria added. This water sample was taken from the post-aquaculture discharge area. For 3 samples of experimental water added with bacteria capable of oxidizing ammonium, all obtained pH values in the range of 7.5. This indicated qualitatively that the wastewater sample contains bacteria that can lower the pH of the water, possibly because the bacteria in this water sample was capable of oxidizing ammonium, reducing the ammonium content in the water. Water should lower the pH. The corresponding measured ammonium content of 3 replicates at pH 7.5 measured 0.02 respectively; 0.009 and 0.009. Compared with the results table, the average data of ammonium concentration was 0.007 obtained in the safe area. This result indicated that initially the isolated bacterial strain was capable of oxidizing ammonium in wastewater.

4. CONCLUSIONS

A total of six strains of nitrifying bacteria were isolated and purified successfully from sludge samples, five strains of bacteria from waste water in the aquaculture area and three strains from soil in canteen area at Ha Long University for application in the treatment of nitrogen in water. The initial results for evaluation for ammonium nitrite treatment ability of isolates obtained by Sera kit test showed that for bacteria strains capable of decomposing ammonium had high ability to nitrogen treatment, whereas bacteria strains with capable of decomposing nitrite had no clear sign of nitrogen treatment. Future research should identify the isolated bacterial strains by molecular technology such as DNA bacteria extraction, gene sequencing with higher ammonium and nitrite levels, to find the maximum capacity of the isolated bacteria, and evaluate their potential use in wastewater treatment and application in other aquaculture systems.

5. ACKNOWLEDGEMENT

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A STUDY ON REAL-TIME WATER LEVEL RECOGNITION OF CCTV CAMERAS

Fu-Jen Chien[1, *)], Yao-Min Fang [2)], Tien-Yin Chou [2)]
and Thanh-Van Hoang [2)]

1) PhD Student / College of Construction and Department / Feng Chia University ,R.O.C Taiwan, Jeffrey@gis.tw +886-921999648Category – (Student)
2) Feng Chia University GIS Center Director,R.O.C Taiwan
* Corresponding author: jeffrey@gis.tw

ABSTRACT: In recent years, many important rivers have established water level stations to detect the water level. When a certain water level is reached, warning information will be sent to relevant units for subsequent measures such as bridge and road closures. However, with the recognition ability of AI images has been improved significantly, this research hopes to monitor water level by using the method of image recognition through CCTV images which can calculate the water level height More intuitively and further replace the original radar water level gauge or pressure water level gauge.

This study uses the current image segmentation of the image deep learning to segment the image of the water surface, and then uses the virtual water ruler which user draws to obtain the water level height by converting the water level height at the intersection of the water surface and the virtual water ruler.

In response to the concept of this study, it uses the Deeplab V3 algorithm provided by Google to obtain 500 images in the demonstration area in the morning, noon, and evening . It recognizes the image of the water level height every minute. The chart below shows the water level recognition next to the Lansheng Bridge in Wulai District in New Taipei City sponsored by the Water Resources Agency.

In this study, the water level height after image recognition was calculated separately in the morning, afternoon and evening. According to the statistics over a period , the accuracy rate of the water level detected by this study is as high as 83.5%, which is sufficient to replace related IoT devices effectively.

Keywords: *Deep learning, river water level.*

1. INTRODUCTION

With the water soaring during torrential rain, some bridges and roads need to be closed. Therefore, it is very essential to observe the relative water level at bridges. Radar wave water level gauge and pressure water level gauge can be used to observe the water level. However, the maintenance cost of these 2 instruments is increasing year by year, and the sensing value of the instruments might be abnormal, causing the disaster prevention unit to be unable to judge the local situation effectively. Thus, it is necessary to use CCTV Cameras to understand the actual situation. This study hopes to find the water level line through the image recognition river water level, and calculate the water level height through the method of virtual water ruler, method to achieve future warnings.

There are two kinds of literatures discussing the current CNN image recognition. Yan-De Li(2018) used the algorithm to point out “The difference between the predicted value and the actual value is less than 5 pixels (about 10 cm) as the accurate range, and the accuracy of water level identification within the accurate range is 98.2%”. In another article, Punyanuch (2020) focused on the accuracy of river identification in Japan, and the conclusion is that one camera 93% accuracy, multi Cameras 75.6% accuracy. These 2 articles both classify images by water level by object recoginition method the water level height can be calculated according to the current image matching method. This project uses Image Segmentation instead of image classification. It will try to find the water level line, and then match the water level line on the image to draw a virtual water level for calculating the real water level height. This study uses Image Segmentation instead of image classification to find the water level line, and then matches the water level line on the image to draw a virtual water level for the calculation to find the actual water level height.

In terms of research methods, this research hopes to compare and analyze the Google Deepak model and the HRNetV2+OCR model to identify the water level line through the current well-known model. Finally, to analyze the results through the accuracy comparison, which can be practically applied to recognize various river water levels in the future.

2. MATERIALS AND METHODS

2.1. PROPOSED METHOD

In this study, the water level identification is carried out in the Wulai area of Taiwan, which is a tourist attraction. When the typhoon and heavy rain came, the situation of closing bridges and roads had occurred.

First, we collect about 800 images during the day, evening and night. Each image will draw the water surface in the area, and establish a training dataset through searching for two images with high MIOU accuracy in recent years. Finally, we use various algorithms for training, taking 100 of them for verification, and then calculating the loss rate.

In addition, we prepare about 50 test data sets for empirical comparison, and then to use the virtual water ruler drawn on the picture to find the intersection of the water surface line and the virtual water ruler to calculate the actual water level for future practice.

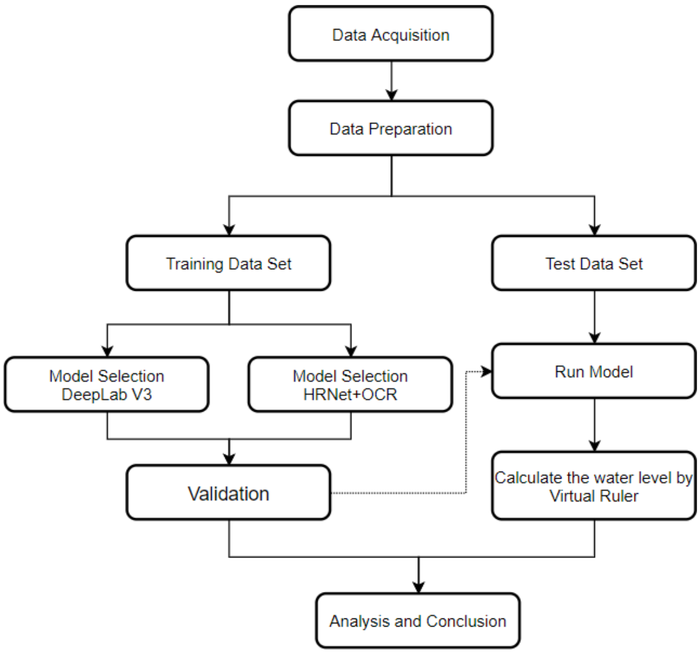

Figure 1. The overview of the proposed framework.

2.2. Model Selection

Semantic segmentation is an important guideline for identifying water surface images~~, and~~ it can integrate standard models (including comparative deep learning models) and network architectures (including comparative network architectures) applied to flooded road. The models include PSPNet , DeepLab, DANet, CFNet, etc., and network architectures cover VGG16, Inception, ResNet, and Xception. On the other hand, water-related texture features (ripples, splashes and raindrops, etc.) of the detection target can also be summarized. The texture feature is a kind of situational features to describe the surface properties of the scene corresponding to an image or its area. Texture cannot reflect an object essential properties because it is an object's surface property, and its features are often affected by several factors. When the resolution of the image changes, the texture features will have a relatively large deviation, and it is also affected by the lighting or reflection. Many literatures use the full connection condition to obtain the texture feature correlation randomly.

In order to know more accurate and applied models to surface models and architectures quickly, the score of each model becomes the secondary standard for reference. The scoring method is also called mean intersection over union (MIoU). The higher the score is, the more accurate the model will be.

The literature test samples considering the speed, accuracy and model are more in line with the actual interface image. Our team decided to use a proficient model and has been compared with MIoU. We adopted three models for analysis and comparison: the second model with DeepLab as the main axis and the HRNetV2+OCR model. Figure 2-5 is a line graph of MIoU for each semantic segmentation model in recent years.

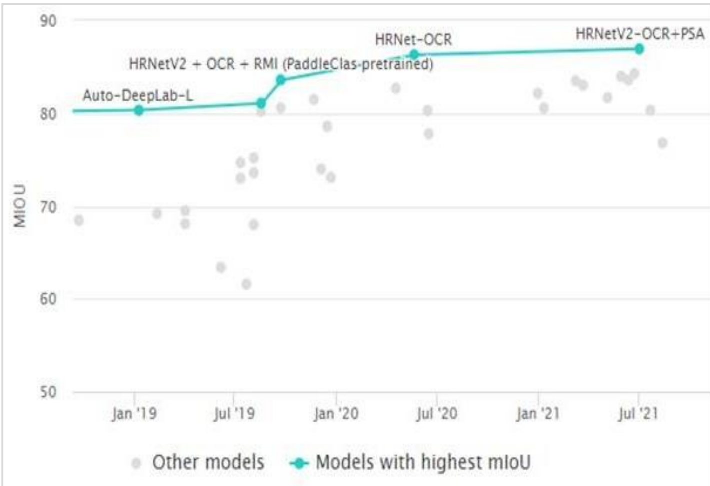

Figure 2. Image Segmentation Comparison with mIoU Index

2.3. Validation

To meet the actual model identification status, 100 images are reserved for verification, and the actual identification results determine the model to be applied to calculate the water level value. For DeepLabv3+ (Xception71 network) and HRNetV2-OCR (Ground Truth is labeled by people), the accuracy of the water level found by these two models is similar. In this study, it is found in the loss diagrams of each model (Figure 2-20) that in the same training sample, the training loss of DeepLabV3+ is faster and lower than that of HRNetV2+ OCR, so it is judged that DeepLabV3+ is more suitable for flooded areas.

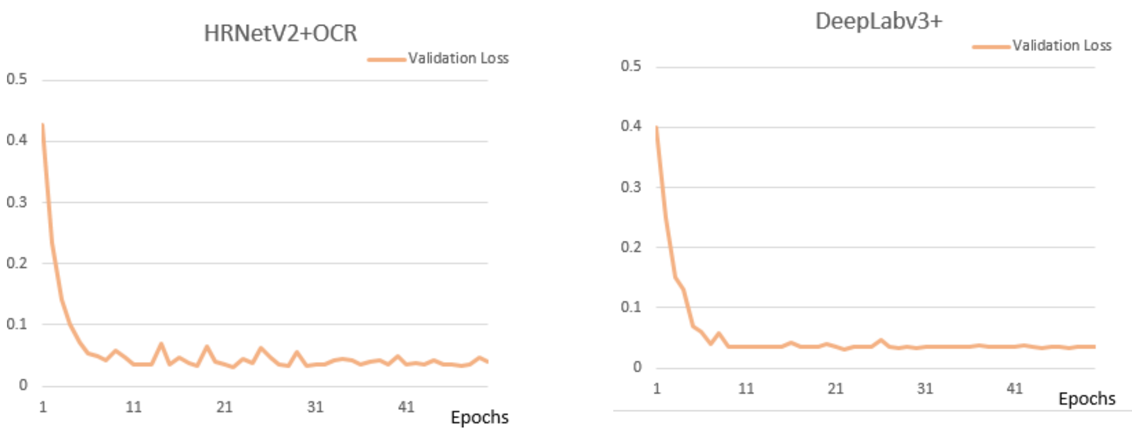

Figure 3. I Loss diagrams with mIoU Index

3. RESULTS AND DISCUSSION

3.1. Model Test

Based on the current 50 images and 1024*768 pixel of the identification size for calculation, its PA, MPA, MIOU accuracy indicators are as follows:

Table 1. Table layout. Captions for Tables are placed above.

Model	PA	MPA	MIOU
DeepLab V3	0.861	0.859	0.848
HRNetV2+OCR	0.848	0.835	0.821

3.2. Analysis and calculate the water level by Virtual Ruler

The following picture shows the water level height calculated by identifying the water surface range and a virtual water ruler. Accurate water surface recognition is used to assist in the calculation of the water level height, which is an effective method to replace the sensor. With the introduction of edge-operated cameras, it is believed that this technology will be used widely.

4. CONCLUSIONS

This study hopes to further calculate the water level height through water surface image recognition so the ability of water surface image recognition is very important. The accuracy of the recognition in this study is over 83.5%, which can meet the demand for water level height to a certain extent in practice. In the future, we will continue to optimize and explore the technology of automatically obtaining training samples for use in cameras with deep learning.

5. ACKNOWLEDGEMENT

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MULTI-HOUSE-BEE TRACKING SYSTEM BASED ON YOLOV5 AND DEEPSORT TECHNIQUES

Cheng-Yu Chueh[1)], Shao-Hsiang Yeh[1)], Hung-Jen Lin[1)], An-Chi Liu[1, 2)], En-Cheng Yang[3)] and Joe-Air Jiang[1, *)]

1) Department of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan
2) BioEnergy Research Center, National Taiwan University, Taipei, Taiwan
3) Department of Entomology, National Taiwan University, Taipei, Taiwan

* Corresponding author: jajiang@ntu.edu.tw

ABSTRACT: The division of labor among the western honeybees (*Apis mellifera*) is strict. The tasks performed by worker bees vary according to their age. A decrease in the number of field bees caused by environmental adversity will prompt the house bees to switch to field bees to ensure the survival of the colony. Currently, research has tried to understand the division of labor in the bee colony through manual counting and conducting statistical analysis, which is difficult to accurately determine the timing of duty changes for the house bees. To establish a novel research model, this study developed a long-term continuous image monitoring system that uses machine vision techniques to track individual bees over an extended period of time. Special observation boxes were used during the experiments, allowing the system to record continuous images with minimal disruption to colony growth. Multi-target tracking and image recognition are the two components of the image tracking process. The image recognition was achieved using a YOLOv5 model that detected the positions of house bees in the hive. Multi-target tracking used a DeepSORT model that assigned an individual ID to each house bee and then tracked its movements in consecutive images. A method of Multiple Object Tracking Accuracy (MOTA) was applied as an index to evaluate the system performances. The results showed that the tracking system has good performance, and the MOTA could be up to 93.7%. As a result of the proposed system, researchers are able to accurately determine the timing of house bee service transitions in subsequent research, as well as gain a greater understanding of the relationship between house bee service transitions and environmental challenges.

Keywords: *Multi-target tracking, Computer vision, YOLOv5, DeepSORT.*

1. INTRODUCTION

There is a strict division of work in the group composition of bees. A worker bee's division of labor is influenced by his or her age. As house bees, they are responsible for managing the hive during the former period. Later on, they are referred to as field bees. A field bee's division of labor is to search for food and water, while a house bee's division of labor is relatively complex, such as cleaning, feeding, building hives, and guarding. The ages and environments of worker bees have been shown to play an important role in the transformation of the division of labor. As a result of climate change, excessive pesticide hazards, food shortages, etc., worker bees of different ages perform different tasks [1]. Because the field bee population is reduced due to the inability to resist environmental adversity, the division of labor for the house bees is affected and the conversion to field bees [2] is accelerated in order to maintain the colony's balance. From the foregoing, it is apparent that task allocation and adjustment for the bee colony are not only related to the development of the bee age, but also to increasing environmental challenges.

As of right now, the research can only attempt to understand the state of the division of labor under different bee ages by means of manual counting and statistics [3]. In order to gain further insight into the timing of the changeover for the house bees and their adjustment ratios, continuous and uninterrupted observation is required. Manual observation and counting are, however, not capable of achieving this goal due to their time-consuming nature and high labor costs. Further, manual observation behavior will have a significant impact on the natural activities of the entire colony of bees.

Computer vision and deep learning have facilitated the detection and tracking of multiple targets in smart agriculture, and this technology has become an indispensable part of this field. The purpose of this research is to develop a long-term monitoring system for house bee tracking using YOLOv5 technology [4][5][6] to determine the position of the house bee, and to track the house bee's identity and trajectory using the DeepSORT algorithm [7][8][9]. As a result, it is expected to:

1. Establish an automated house bee detection hive for continuous video recording.
2. Detect the house bee and mark its center using the trained YOLOv5 model.
3. Calculate the multiple object tracking accuracy (MOTA) using the detection results from YOLOv5 in combination with the DeepSORT algorithm. Lastly, three videos of different nests and bee numbers were captured to demonstrate the general applicability of this tracking model.

2. MATERIALS AND METHODS

2.1. Design of an Automated House Bee Tracking Hive

As part of this study, an automated house bee tracking hive with an image monitoring system was set up. In this system, the house bees are able to track their location without causing any disturbance to the bee colony. Figure 1 illustrated the automated hive for tracking house bees that includes an observation box, a red light, and a camera.

The observation box was made of black acrylic sheets in order to block out external light sources, in accordance with the dark room environment of traditional beehives. Bees are prevented from striking the camera while the video system is recording video by the transparent acrylic plate inside the observation box. The back panel of the observation box has circular holes that correspond to the entrance and exit of a standard beehive.

Due to the dark environment of the observation box, the shooting of the camera system in the observation box is one of our greatest challenges. As well as ensuring that the system captures high-quality images, it is also important to consider whether the light source will change the behavior of the house bee, so certain restrictions are imposed on the light source selection. Studies indicated that bee colonies are unable to sense light with wavelengths greater than 650 nm, i.e., red light and near-infrared light [10]. A feature such as this is beneficial to the study of bee colony behavior in the hive, as it indicates that when red light is used as a light source, the impact on the colony of bees can be reduced. For this reason, we select the light source based on the red light (YG-5050-60D-R-A) and 4K high-speed camera (Sony, FDR-AX700) is the appropriate camera for capturing images.

Figure 1. The automated house bee tracking hive.

2.2. House Bee Tracking System

The research is primarily divided into two stages: multi-target detection using the YOLOv5 model and multi-target tracking using the DeepSORT model. Figure 2 shows the architecture diagram for tracking house bees.

The YOLOv5 model is a one-stage target detection model. A self-made house bee hive was used as the image source during the training process, and the 180 images obtained contain approximately 15,000 house bees. In accordance with a 3:1 ratio, the data was divided into training sets and validation sets. In the selection of model parameters, the input image resolution was adjusted to 640×640 pixels, the batch size was four, and a total of 200 iterations were conducted. Afterwards, the model was trained and its accuracy was evaluated. Lastly, the trained weights were input into the YOLOv5 detection model in order to identify the house bees. With the YOLOv5 model, the house bees were detected with bounding boxes, and the coordinates of their center point were obtained using geometric operations.

There are three components of the DeepSORT tracking model: the Kalman filter, the Re-identification (Re-ID) model, and the Hungarian algorithm. Based on the motion state of the target, the Kalman filter predicts and tracks the target's position, and the Re-ID model extracts the characteristic information of the target as the basis for prediction. This model can reduce the ID Switch situation during tracking by combining the motion state and feature information of the target. To mark the trajectory of the house bee in the continuous video, the Hungarian algorithm is used to match the detected position with the predicted position.

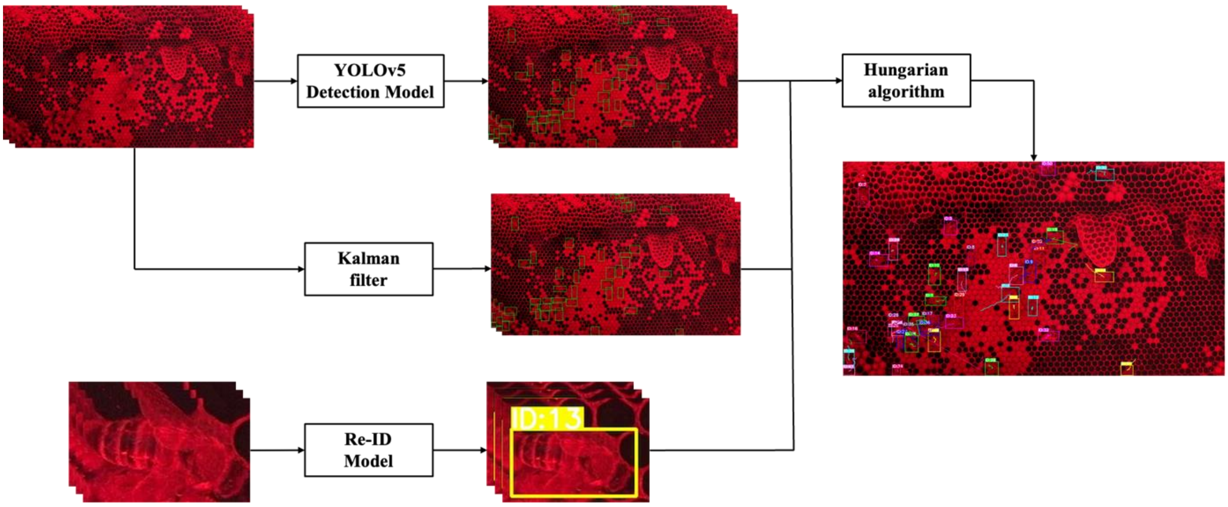

Figure 2. The architecture diagram of the house bee tracking.

2.3. Evaluation Method

2.3.1. YOLOv5 Model Evaluation

For the detection of house bees, this study uses Precision, Recall and Average Precision (AP) as the evaluation criteria of the detection model. As shown below, the formula is (1)(2)(3):

$$\text{Precision} = \frac{TP}{TP+FP} \quad (1)$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (2)$$

$$\text{AP} = \int_0^1 P(R)\,dR \quad (3)$$

where TP is true positive, FP is false-positive, and FN is false-negative. According to the confusion matrix, TP means the actual existence and the model prediction also exists; FP means the actual existence but the model prediction exists; FN means the actual existence but the model prediction does not exist. Therefore, Precision is the ratio of successful predictions among all predicted positive samples, and Recall is the ratio of correct predictions among all positive samples.

2.3.2. Multi-target Tracking Accuracy Evaluation

MOTA is used to evaluate the tracking of house bees, and the formula is presented in (4):

$$\text{MOTA} = 1 - \frac{\sum(FN+FP+IDS)}{\sum GT} \quad (4)$$

where GT is ground true, and IDS is identification switch. In the process of evaluating the tracking accuracy, MOTA considers the matching error of each frame in the video, including the number of FN, FP and ID Switch, and intuitively expresses the performance of the tracking model in object detection and trajectory tracking.

3. RESULTS AND DISCUSSION

3.1. Training Results for the YOLOv5 Model

A total of 180 images were captured in this study, and about 15,000 house bees were marked as the dataset for the YOLOv5 training model. According to Table 1, the training results for the model were satisfactory. Regarding the accuracy of Precision and Recall, it was known that there are still a small number of prediction errors, but the AP result reached an accuracy of 94.3%, indicating that the errors were all within a reasonable range. The model will be continuously improved and stabilized as more images are collected in future research.

Table 1. YOLOv5 model training accuracy.

Precision	94.8 %
Recall	88.9 %
AP	94.3 %

3.2. Evaluation of the Tracking System

To evaluate the accuracy of multi-target tracking, 240 frames of video were captured. Table 2 showed that the number of TP is greater than the number of FP and FN, which indicates that the prediction effect of this tracking model in the film is quite good. The accuracy of MOTA was as high as 93.7%, indicating that the system was not affected by matching errors, and the tracking model was still accurate despite some matching errors in FN, FP, and ID Switch shown in Table 3.

Table 2. Confusion matrix.

	Real Positive	Real Negative
Predicted Positive	TP = 9365	FP = 148
Predicted Negative	FN = 233	TN = 0

Table 3. Multi-target tracking accuracy.

ID Switch	224
MOTA	93.7%

3.3. Verification of The Extensive Usability for The House Bee Tracking System

For the purpose of verifying the stability and applicability of the tracking system, three honeycomb slices were removed from the traditional beehive and placed individually into the observation box. The results of model identification and tracking were shown in Figure 3. As demonstrated in the figure by the tracking results of the three honeycomb slices, the number of bee colonies and the background of the nests did not affect the accuracy of the detection model for house bees, and their location could be accurately determined. As far as multi-target tracking were concerned, all house bees on the three honeycomb slices could be identified and a trajectory map drawn by the tracking model. The integrated overall house bee tracking system achieved a good tracking effect, and it could also be widely applied to a variety of honeycomb slices.

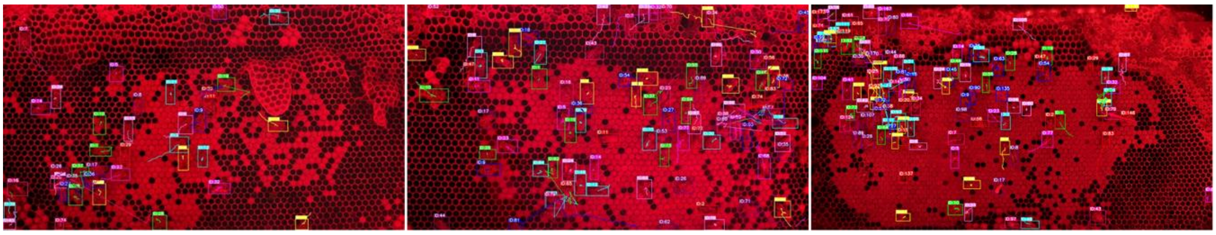

Figure 3. House bee tracking trajectory diagram.

4. CONCLUSIONS

In this study, an automated system for tracking house bees was developed. Through the design of the observation box, we overcame the problem of shooting in a dark environment and achieved a good balance between the quality of the images and the characteristics of the bees. For the internal tracking model, the AP evaluation of the YOLOv5 model was 94.3%, while the MOTA evaluation of the DeepSORT model was 93.7%. We further evaluated the model through the use of three different honeycomb slices to ensure its stability and broad applicability. It is clear from the above results that this automated house bee tracking system had a high level of accuracy and could be applied to a variety of honeycomb slices. It is also possible to use the dynamic tracking trajectory map in the future to establish a system that automatically classifies the behavior of the house bees through supervised learning. By using this system, researchers can establish continuous observations of the history of the division of labor in the house bees, and assess the relationship between the mechanism for division of labor and the external environment.

5. ACKNOWLEDGEMENT

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STABLE OBSERVATION OF WHITEFLIES USING ARTIFICIAL LEAF

Naomasa Urasaki[1)], Tadashi Ebihara[2, *)], Koichi Mizutani[2)],
Naoto Wakatsuki[2)], and Kenji Kubota[3)]

4) Graduate School of Science and Technology, University of Tsukuba, Japan
5) Faculty of Engineering, Information and Systems, University of Tsukuba, Japan
Contact: ebihara@iit.tsukuba.ac.jp
6) National Agriculture and Food Research Organization (NARO), Japan
* Corresponding author

ABSTRACT: Whiteflies are difficult-to-control insects that cause damage to tomatoes and other horticultural crops worldwide by transmitting viruses. The mechanism of the mating behavior of whiteflies (the relationship between their mating sounds and mating behavior) has been partially revealed. However, stable observation of whiteflies over several days is still challenging because both the whiteflies and leaflets began to die as soon as the leaflets were cut off for observation, and observation of whiteflies was available only a few minutes to several hours. Therefore, in this study, the use of an artificial leaf is considered to observe the behaviors of whiteflies stably. The artificial leaf was made by sandwiching a sucrose solution between two sheets of paraffin film. After colonizing the leaf with whiteflies, the behavior of whiteflies was successfully observed using a camera for over three days continuously. Because the artificial leaf was translucent, we also observed the mating behavior of whiteflies from the ventral side, which was previously impossible to observe. However, the survival rate of whiteflies was not enough (about 10% after three days), and improvement of the survival rate should be addressed in the near future.

Keywords: *Whitefly, courtship, monitoring, artificial leaf.*

1. INTRODUCTION

Whiteflies (*Bemisia tabaci*) are economic insect pest on various agricultural crops across the worldwide. Whiteflies are small (1-2 mm in length), and they easily invade horticultural facilities from the outside and multiply explosively (e.g., about 68 times per month), Yano (1981). Since whiteflies have the potential to transmit more than 300 plant viruses, Gilbertson *et al.* (2015), including tomato yellow leaf curl disease, they cause crop loss of vigor and abnormal coloration, Navot *et al.* (1991). The economic losses by whiteflies are significant, for example, damage to vegetables in Georgia, US, was estimated at US$132.3 million and $161.2 million in 2016 and 2017, respectively, Li *et al.* (2021).

However, control of whiteflies is still challenging. Although chemical control using pesticides works for whiteflies, a new biotype that is resistant to neonicotinoid pesticides (bio-Q type) has been reported, Nauen *et al*. (2002). Hence, a combination of multiple control methods including chemical control, biological control by introducing natural enemies of whiteflies, and physical control using insect screens or the yellow sticky sheets, has been considered.

In order to establish an efficient whitefly control system, it is necessary to understand the ecology of whiteflies. In this study, we particularly focus on the acoustic ecology of whiteflies. Whiteflies have been found to perform acoustic communication between males and females during mating, Kanmiya (2006) and Fattoruso *et al.* (2021). In addition, recordings and analysis of acoustic communication in whiteflies have revealed that communication sounds differ among biotypes, Nakabayashi *et al.* (2017), and Sato *et al.* (2021). However, long-term acoustical observations of whitefly colonies over the life cycle (development from egg to adult, approximately 14-40 days) have not been achieved because both whiteflies and plant leaves began to die as leaves are cut for observation. In addition, observing whiteflies on plant leaves (without cutting) did not result in stable plant growth, which becomes another barrier to stable observation. Hence, novel approach is necessary to investigate new acoustic ecology of whiteflies.

Therefore, in this study, the use of an artificial leaf is considered to observe the behaviors of whiteflies stably. After colonizing the leaf with whiteflies, the behavior of whiteflies is observed using a camera for over three days continuously. Because the artificial leaf is translucent, we also challenge to observe the mating behavior of whiteflies from the ventral side, which is previously impossible. In Chapter 2, we describe the artificial leaf and experimental conditions. In Chapter 3, we describe the experimental results with some discussions. In Chapter 4, we summarize the results and discuss future issues.

2. MATERIALS AND METHODS

2.1. Artificial leaf

Here we would like to briefly introduce the ecology of whiteflies and explain the details of artificial leaf.

(1) Most whiteflies are attracted by light.
(2) Whiteflies are parasitic on the underside of leaves.
(3) Whiteflies are easily attracted by static electricity when charged objects are nearby.
(4) Whiteflies feed on the vascular fluid of host plants.
(5) Whiteflies communicate with males and females during mating behavior by vibrating their leaf bodies.

Considering above ecologies, it is desirable if the artificial leaf meets the following conditions.

(a) The artificial leaf should be light-transparent.
(b) The artificial leaf should be static-resistant.
(c) The artificial leaf should contain rearing solution that can be sucked by whiteflies
(d) The artificial leaf should be vibrated by whiteflies.

Figure 1 shows the artificial leaf used in this work. First, paper cups with a volume of 270 ml were prepared as cages that were not light-transparent and did not generate static electricity. Then the opening of the paper cup was covered with a stretched paraffin film (Parafilm M series, Amcor Flexibles North America, Inc) as dummy leaves that was light-transparent. 0.5 ml of 15% sucrose solution was dropped onto the paraffin film, which was further covered with a stretched paraffin film. In this way, the sucrose solution was sandwiched between two sheets of paraffin film.

When whiteflies are released into a paper cup and the paraffin film is illuminated, the whiteflies are parasitized on the inside of the paraffin film. The whiteflies are expected kept for a long period of time by sucking the initial solution sandwiched between the paraffin film.

Figure 1. Artificial leaf fabricated in this study.

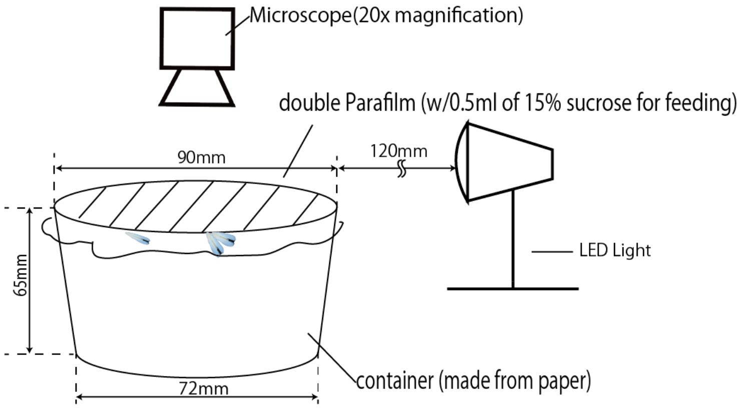

Figure 2. System for stable observation of whiteflies using artificial leaf.

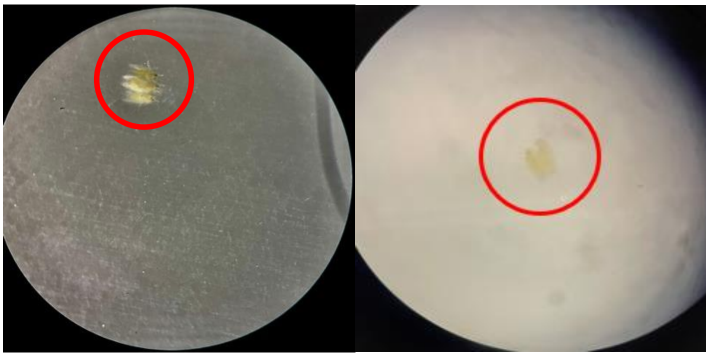

Figure 3. Ventral view of pairing seen during mating behavior of whiteflies.

2.2. Stable whitefly observation system using artificial leaf

Figure 2 shows the system for stable observation of whiteflies using artificial leaf. The artificial leaf (fabricated in 2.1), an LED light (makita, ML805), and a microscope (HOZAN, L-KIT543, 20x magnification) were set up in a dark room (Around 26℃). Approximately 100 whiteflies (*Bemisia tabaci*, bio-Q type) were released into a paper cup and the artificial leaf was illuminated from the side. Then the surface of the artificial leaf was observed with a microscope for three days.

3. RESULTS AND DISCUSSION

The ecology of whiteflies on the artificial leaf was successfully observed over a period of three days; Figure 3 shows an example of the observed mating behavior. Traditionally, the mating behavior of whiteflies can only be observed from the top side (the side with the wings) because the leaves are opaque. However, because the paraffin film is translucent, we were able to observe the mating behavior of the whiteflies from the bottom side. As shown in the figure, it was found that the abdomens of male and female whiteflies were close together during the mating behavior.

On the other hand, it was also found that the long-term breeding of whiteflies is challenging with the current artificial leaf. When the number of whiteflies surviving was counted, the survival rate was 10% after three days. One possible reason for this is that a 15% sucrose solution is not sufficient for whitefly feeding.

4. CONCLUSIONS

In this paper, the use of an artificial leaf was considered to observe the behaviors of whiteflies stably. After colonizing the leaf with whiteflies, the behavior of whiteflies was observed using a camera for over three days continuously. Because the artificial leaf is translucent, we were also challenged to observe the mating behavior of whiteflies from the ventral side, which is previously impossible. As result, the ecology of whiteflies on the artificial leaf was successfully observed over a period of three days. Furthermore, it was found that the abdomens of male and female whiteflies were close together during the mating behavior. However, the survival rate of whiteflies remained at 10% after three days, hence, the future challenge includes improving the survival rate of whiteflies on artificial leaf.

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PART B
ABSTRACT

FAWPREDICT: A DECISION SUPPORT SOFTWARE BASED ON WEATHER DATA FOR SMART USE OF PESTICIDES ON THE FALL ARMYWORM

Diep Thi Hoang[1)], Minh Tu Hoang[1)], Tran Thi Thu Phuong[2)]
and Minh-Trien Pham[1,*)]

1) VNU University of Engineering and Technology, Vietnam
Email: trienpm@vnu.edu.vn
2) Vietnam National University of Agriculture, Vietnam

* Corresponding author

ABSTRACT: Major challenges to maize crops worldwide have emerged with the proliferation of the fall armyworm (Spodoptera frugiperda) in recent years. To maintain the larvae density below the economic loss threshold, we need to implement multidisciplinary solutions using plant protection epidemiology, the Internet of Things, and data science methods to early detection, monitoring, forecasting, and making intelligent choices. In the traditional way of plant protection epidemiology, pheromone traps are hung up on the day of sowing; when 3-4 adults enter the trap, within 20 days, control is carried out. With this strategy, you'd have to spray a maize crop with pesticides four to five times as often, which is expensive and creates the issue of plant protection residues. In this study, we suggest using pheromone traps and the computational capabilities of data science to choose an optimal day to spray pesticides, hence reducing the total number of times pesticides need to be applied. To this end, we develop the FAWPredict software, which, given the input crop inspection date, the corresponding peak stage of worm (derived from traps), and inspection site, generates a prediction list of peak days for each stage in the next life cycle of the fall armyworms. The software automatically retrieves the next 30 days' weather forecast from the OpenWeatherMap API. At its core, the calculation is carried out by the degree-days formula which is based on our lookup table for the lower temperature threshold (t0) and the number of degree-days (K) for each life stage specifically built for the maize fall armyworm in Vietnam. With the forecast results, we advise farmers to only spray their fields once every maize crop when the FAW peaks are instar of ages 1-4. We provide FAWPredict as open source command line software at https://github.com/Imikaki/FAWPredict . The software may also be used with a user-provided lookup table for t0 and K that is tailored to the user's research object. FAWPredict helps to provide precise forecasts thanks to up-to-date weather information, which in turn reduces the need for pesticide spraying and eliminates the possibility of harmful residues.

Keywords: *Software, decision support, degree-days; fall armyworm; maize; peak forecast.*

MILKING ROBOT OF DAIRY CATTLE FARM COVER FOR LABOR SHORTAGE IN TAIWAN

Mingche Wu[1, *)], Renhao Hsieh[2)] , Jide Chen[3)] and Yienwei Hsieh[4)]

1) Taiwan Livestock Research Institute, Taiwan
mcwu71246@gmail.com
Digital infrastructure development and applications in agriculture
2) Lely Center Taiwan, Taiwan
3) Taiwan BouMatic, Taiwan
4) Taiwan DeLaval, Taiwan

* Corresponding author

ABSTRACT: Milk production of 2020 reached 437,155 tons from 560 dairy cattle farms with 112 lactating cows per farm and 7,040 liters of annual milk per cow in tropical Taiwan. The average annual incomes per farm was more than 20 million Taiwan dollar. The introduction of a milking robot in dairy cattle farm means the saving of at least of 8-hour workload a day to cover for labor shortage and reduce labor cost in Taiwan. The saved time make farm owner more freely to work and to have a quality life for young farmer. The milking robot with averaged price of 8.5 million Taiwan dollar, each one can milk 60 to 70 lactating cows per day. Lactating cows can produce milk in a healthy and stress-free assessment to the robot. The milking robot increases the number of milking times per day of each lactating cow and resulted in a higher milk yield production. The higher milk yield production means a higher income of farmer. Taiwan used three brands of milking robots in more than 10 farms and the first robot operated in 2017. Early results show that those on the milking robot choose to make 2.7 visits each day to be milked compared with twice daily milking on the traditional system. The average daily milk yield per cow has increased from 25 to 33 liters and resting time has lengthened by three hours daily, benefitting fertility. Most importantly, the saving of labor allows dairy farmers to arrange their time more flexibly, and the high quality and reliability of the milking robot leaves the dairy farmers with no worries. The capability and big data of robotic monitoring of individual cow has improved the efficiency of the farm management under precision farming and digital automation.

Keywords: *Robot, Dairy farming, Cattle*.

OPTIMIZATION OF CULTIVATION PLANS FOR AGRICULTURE IN TIDAL LANDS: A CASE STUDY OF HO CHI MINH CITY, VIETNAM

Nguyen Duc Vu[1, *], Long Dinh Nguyen[2], Nguyen Duy Liem[3] , and Nguyen Kim Loi[3]

1) Ho Chi Minh City Irrigation Department, Vietnam
E Mail: ndvu.snn@tphcm.gov.vn / Contact Details: 84 988 539 405
2) Faculty of Engineering, Dong Nai University, Vietnam
Email: dinhlonghcmut@gmail.com
3) Research Center for Climate Change, Nong Lam University, Vietnam
E Mail: nguyenduyliem@hcmuaf.edu.vn; ngkloi@hcmuaf.edu.vn

* Corresponding author

ABSTRACT: Agriculture in tidal lands has one of the important farming fields in agriculture of Ho Chi Minh city but has not yet been investigated and optimized for sustainable development. By impacting tidal flooding, strategy adaption and improvement of agriculture in tidal lands is very necessary and urgent at the current and the future under climate change. Our target is to predict optimal planting times for crops under flood and drought cycles, and more, we can select appropriate farming types including short term and long-term plans. Our approaches apply data processing method and propose a maximization problem of productivity of farming under planting time optimization based on an assumed database of tidal flooding analysis under climate change scenarios. Numerical results are shown to demonstrate the benefit of our proposed approaches and provided feasibility for real actions with a real database ready.

Keywords: *Agriculture in tidal lands, tidal flooding, optimization, planting time, climate change*

A NOVEL FRAMEWORK OF LANDSCAPE CROP-ECOLOGICAL MODELING

Tanh T. N. Nguyen [1) 2) 3) *]

1) An Giang University, Vietnam
Email: ntntanh@agu.edu.vn,
Address: 18 Ung Van Khiem St., Long Xuyen City, An Giang, Vietnam
2) Vietnam National University- Ho Chi Minh City, Vietnam
3) AgMIp-Vietnam, Vietnam

* Corresponding author

ABSTRACT: In a cropping system, plants grow in an ecosystem with abiotic and biotic factors. Thus, crop models should be designed regarding ecological structures and functions; however, this is a difficult task. Accordingly, this paper proposes a novel framework of landscape crop-ecological modeling (LCEM) for crop modeling. This framework includes ecological structures and functions of a crop system and works in a landscape scale. This type of spatial modeling considers the interactions of a plant to the other plants and surrounding environment, and versus. This new design allows multi-interactions in a crop system and then become flexible to support various needs of cropping decision changes. This paper also highlights challenges of LCEM and suggests strategies for working with LCEM.

Keywords: *Future crop modeling, LAE approach, crop decision-making, ecological modeling.*

RAPID TRAINING METHOD OF AGRICULTURAL SKILLS FOR TEMPORARY WORKERS

Dai Kusui[1, *], Hideo Shimazu[2] and Atsushi Shinjo[3]

1) NEC Solution Innovators, Ltd., Innovation Promotion Division, Japan
kusui@nec.com / 1-18-7 Shinkiba, Koto-ku, Tokyo 136-8627 Japan
2) NEC Solution Innovators, Ltd., Innovation Promotion Division, Japan
3) Keio University, Faculty of Environment and Information Studies, Japan

* Corresponding author

ABSTRACT: In agriculture, it is difficult to maintain the same number of employees in the off-season as in the busy season due to costs. Generally, farmers maintain the necessary number of employees during the off-season and hire temporary employees during the busy season. However, temporary workers are not engaged in farming throughout the year. Also, it is not always possible to hire the same persons every year. It is not certain that the persons hired this year will have the knowledge and experience for the target work. In addition, weather, farm, and crop conditions vary from year to year. The work must be adapted to this year's conditions. In order to work smoothly and at a consistent level in a limited time, it is desirable to instruct the temporary workers according to the conditions. In this paper, we propose the Rapid Agri-InfoScience learning model. The learning model is a model that, after narrowing down the work, limits the target to only "the crop of the moment" and learns how to make the decisions necessary to execute the work. Temporary workers can learn how to judge and work by limiting to the "situation at that time". The coach can create learning problems on the spot by limiting to the "situation at that time". Using the learning support system that implemented the model, experiments confirmed that the coach can create the problems and temporary workers can improve the quality of work. A professional instructor visually evaluated the quality of the temporary workers' work. Before learning, the temporary workers' work level was not up to the basic level. After learning, the temporary workers' work level was rated 60% higher than the basic level.

Keywords: *Training method, e-learning, master craftsmanship, agricultural work skills, temporary worker, part-time job.*

SITE SUITABILITY ASSESSMENT FOR TEA PRODUCTION USING SATELLITE REMOTE SENSING AND GIS IN BEAS BASIN, HIMACHAL PRADESH, INDIA

Sayanta Ghosh[1)], Renu Lata[2, *)] , K. C. Gouda[3)]

1) G.B. Pant National Institute of Himalayan Environment,
Himachal Regional Centre, Mohal, Kullu- 175126, Himachal Pradesh, India
Email ID-renu15_negi@yahoo.co.in , visittosayanta@gmail.com
2) CSIR Fourth Paradigm Institute, NAL Belur Campus, Bangalore, India

* Corresponding author

ABSTRACT: Tea has been cultivated and manufactured in the kanga valley, Himachal Paradesh since the middle of the 19th century. Even today almost 80 % of the total tea production in Himachal Pardesh is from Kangra district. Being one of the most important cash crop of India, tea cultivation has enough potential to boost up the economy of the other regions of Himachal Pradesh including Kullu district. Land suitability evaluation is important for assessing environmental limitations that inhibit higher yield and productivity in tea. Here, we have made an attempt to determine the suitable lands for sustainable tea production in the Beas basin of Kullu district using high resolution climate data from TerraClimate, phenological datasets from remote sensing, geospatial datasets of soil–plant biophysical properties and field survey. Sentinel-2 satellite data of 10 m resolution were processed to generate LULC as well as NDVI map. SRTM data of 30 m resolution were used to generate the elevation layer as well as watershed delineation map. Other vector and raster layers of edaphic, climatic parameters, and vegetation indices were processed in ArcGIS 10.8 software. Finally, suitability classes were determined using weighted overlay of spatial analysis based on reclassified raster layers of all parameters along with the results from Multi Criteria Decision Analysis (MCDA). The results of our study showed that only 165 km2 of land (5.32% of the total land) were in the highly suitable category. The proportions of moderately suitable, marginally suitable, and not suitable land categories for tea cultivation in the Beas basin were 7.23%, 49.68%, and 37.77%, respectively. Finally, a total of 19 and 27 potential sites (Panchayats) have been identified within highly suitable category and moderately suitable category respectively. The main outcome of the paper, we believe, will be helpful in analysing the scope of sustainable tea production which will be beneficial for elevating the local economy and livelihood sustainability of the district.

Keywords: *Tea Cultivation, Land suitability, Climate Data, Remote Sensing, GIS, Multi Criteria Decision Analysis (MCDA).*

OVERVIEW OF DEVELOPMENT STRATEGY AND POLICY INTELLIGENT AGRICULTURE IN VIETNAM

Pham Thi Tuyet Giang[1, *)]

1) Dong Thap University, Vietnam
E-Mail: tuyetgiang.luatk34@gmail.com
* Corresponding author

ABSTRACT: Agriculture is one of the three essential pillars contributing to Vietnam's promotion and socio-economic development. In recent years, the agricultural sector has suffered many negative impacts of climate change. In this situation, applying scientific and technical achievements and the requirements of digital transformation in agriculture have opened a new direction for Vietnam's agricultural industry. Promoting digital transformation toward intelligent agriculture is the optimal solution for the sustainable development of the farming industry to adapt to climate change. To operate and develop smart agriculture, Vietnam must develop and synchronously many answers, in which policy solutions and overall strategy development are considered important factors. Within the scope of the article, the author provides an overview of intelligent agriculture development strategies and policies in the context of the Fourth Industrial Revolution. Finally, some recommendations are proposed to build and perfect the policy framework to operate and develop intelligent agriculture in Vietnam.

Keywords: *Intelligent agriculture, sustainable development, agricultural policy.*

THE HEURISTIC DYNAMIC PROGRAMMING APPROACH FOR MULTI-CROP PRODUCTION SCHEDULING IN PLANT FACTORY

Dai Dinh Nguyen[1)], Chau Long Pham Huy[2)], Duy Khang Dao[3)], Khanh Le Nguyen[1,*)], Dong Do Duc[1,*)] and Minh-Trien Pham[1)]

1) VNU University of Engineerging and Technology, Vietnam
2) VNU University of Science High School for Gifted Students, Vietnam
3) St. George's Senior School, Canada
* Corresponding author: dongdoduc@vnu.edu.vn, nl.khanh@vnu.edu.vn

ABSTRACT: By controlling the temperature, humidity, lighting, nutrient supply, and other factors, the cultivation environment of plant factory is stable and delivers better produce quality. However, the drawback of this facility is high operation cost, therefore, how to schedule the cultivation plan to enhance the profit is an important issue. In our research, the object function of scheduling problem was formulated by considering the various practical operating conditions such as crop market value per unit and time, cleaning and maintenance period, rack-level modification… to target the maximum of revenue. Then, scheduling problem will be solved by mixed integer linear programming problem. However, to deal with the number of rack-level modification increases, this study further improved a heuristic algorithm, named Heuristic Plant Factory Scheduler with Dynamic Programming (HPFSDP), which applies a recursive technique to schedule crops rack by rack using Dynamic Programming. This approach provides better ease of implementation and modification compared with Heuristic Plant Factory Scheduler. As the results, the HPFSDP performs less computational time, especially when the number of rack-level or crops increased.

Keywords: *Plan factory, Crop scheduling, Mixed integer linear programming, Heuristic scheduler, Dynamic programming.*

THE IMPACT OF CLIMATE CHANGE ON THE DISTRIBUTION OF MAIZE IN TAIWAN

Yi-Ting Zhang[1, *] Wen-Chiao Wang[2] Horng-Yuh Guo[3] Tsang-Sen Liu[4]

1) Taiwan Agricultural Research Institute, TAIWAN, iting0707@tari.gov.tw, Assistant
2) Taiwan Agricultural Research Institute, TAIWAN
3) Taiwan Agricultural Research Institute, TAIWAN
4) Taiwan Agricultural Research Institute, TAIWAN

* Corresponding author

ABSTRACT: Face extreme weather, the impact of the new crown pneumonia epidemic, the Russian-Ukrainian war, and other sudden and uncertain emergencies causing turbulence in the international supply chain. The government of Taiwan encourages the cultivation of field corn to increase the domestic feed supply. Maize is the important food crop in the world and is a C4 plant that can use CO2 more efficiently and generate energy in water scarcity, such characteristics make C4 plants have a high anti-adversity advantage. Although the variety breeding of maize has been continuously improved, the basic crop water requirement and temperature requirement are still suitable in specific range. Heavy rainfall and continuous high temperature have a significant impact on crop cultivation. In the case of maize, high temperatures will affect flowering, and stagnant water will affect harvesting, which will affect yield. Based on the precipitation and temperature simulated by bcc-csm1-1 in the CMIP5 model, it is inferred that flint maize is suitable for planting regional changes in 2020, 2030, 2040 and 2050. The planting time of flint maize is from September to February of the next year in Taiwan. The average monthly temperature is 20-25 degrees, and the rainfall is less than 500mm as suitable planting conditions, and the areas prone to flooding are excluded. In the simulation analysis, temperature conditions have no significant impact on maize. The predicted rainfall in 2030 is too much in September, which will affect the root growth of maize during the germination period. Therefore, it is recommended to delay planting in October. In the future, meteorological disasters affecting food production may become normalized. Promote the planting of the right crops at the right time or at the right place, reducing agricultural damage and stabilizing production.

Keywords: *Maize, C4 plant, CMIP5.*

URBAN GREEN SPACE PHYTOSANITARY STATE ASSESSMENT WITH UAV MULTISPECTRAL VISUALIZATION

Stratulat T.[1, *)], Sacara V.[2)] , Volosciuc L.[1)] , Raileanu N.[1)],
Scerbacova T.[1)], Lungu A.[1)] , Crucean S.[1)] , Jalba S.[1)] and Curiev L.[1)]

1) Institute of Genetics, Physiology and Plant Protection, Republic of Moldova
tgs.05@mail.ru; l.volosciuc@gmail.com; nata.raileanu@gmail.com; tscerb@gmail.com;
andreilungu1004@gmail.com; stefan.ace681@gmail.com; happy_life2009@mail.ru;
2909loredana1994@gmail.com / +37322770447
2) Dron Assistance SRL, Republic of Moldova
sacara.vit@gmail.com

* Corresponding author: e-mail: tgs.05@mail.ru

ABSTRACT: Nowadays, more than 50% of the world's population lives in urban areas, and this number continues to increase. The presence of green spaces in cities is necessary to maintain the urban environmental health. The complex of diseases is one of the important factors of negative impact on the urban green sanitary state in Chisinau. Unmanned aerial vehicles (UAV) are modern and versatile tools with increased accuracy for detailed green spaces management. Despite their advantages, studies using UAV for the identification of physiological stress imposed on trees by biotic factors are infrequent. In this context, and considering the large areas that must be supervised, our study seeks integrated approach in assessing the sanitary state of green spaces by in-situ observation and remote-sensing in Chisinau. During spring-summer 2022, three study plots in three urban park zones were established. We used hyperspectral images obtained with UAV to detect outbreaks of tree diseases and classify them into different stages of infection. The harmful effects and impact of fungal pathogens causing damage to trees were estimated visually on the basis of the percentage of crown defoliation and discolouration of leaves or needles, from 0% (healthy tree) to 100% (dead tree), subdivided into six categories. The territory of 'Valea Morilor' park and 'Rischani Park' has been captured with 2300 individual images, covering 20 ha with an average resolution of 9,5 cm. After processing of the base products (multispectral images and Digital Surface Model), the NDVI models for the territories were created. Assessment of the health status of trees in urban green areas through in-situ observation and remote sensing using UAV technology was used for the first time in Moldova. The study showed that the implementation of this approach provides rapid and low-cost results, with good quality of the generated information.

Keywords: *Urban green spaces, unmanned aerial vehicles (UAV), phitosanitary status, classification.*

AUTOMATIC FEEDING SYSTEM FOR GREEN LACEWING LARVA

Yi-Ying Lai[1, *),]Hung-Jen Lin[1)], Jen-Cheng Wang[2)] , An-Chi Liu[3)],
Mu-Hwa Lee[1)] and Joe-Air Jiang[1,*)]

1) Department of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan
2) Department of Computer Science, National Taipei University of Education, Taipei, Taiwan
3) Bioenergy Research Center, National Taiwan University, Taipei, Taiwan

* Corresponding author: jajiang@ntu.edu.tw

ABSTRACT: Green Lacewings (*Mallada basalis*) are one of the most commonly used and commercially available natural enemies, because of its diversified intake and aggressiveness. However, the high cost of production is always the downside of releasing green lacewings in the field. To reduce the production costs, an automatic green lacewing larva feeding system was proposed. In the system, each larva was raised in a different cell to avoid cannibalism. The manual feeding was replaced by a three-axis machine and 40 vacuum suction cups, which could feed 40 cells automatically at the same time. The automatic feeding system also made sure that each larva was fed with the same amount of feeds of 10.10±1.63 mg. With the automatic feeding system, 400 larvae could be fed in 570 seconds, which reduced the labor cost associated with manual feeding and maintained the same amount of feeds for each larva

Keywords: *Automatic Feeding System, Green Lacewing, Natural Enemy*.

THE AUDIO MODEL FOR WESTERN HONEY BEES (*Apis mellifera*) BEING ATTACKED

Chao-Yang Chiu[1)], Yi-Ying Lai[1)], Hung-Jen Lin[1)], and Joe-Air Jiang[1,*)]

1) Department of Biomechatronics Engineering, National Taiwan University, Taipei, Taiwan
* Corresponding author: jajiang@ntu.edu.tw

ABSTRACT: In apiculture industries, it is common for beehives to be attacked by external enemies. The western honey bees (*Apis mellifera*) are the main species bred by beekeepers in Taiwan. Heavy casualties might occur, if they are attacked by external enemies such as vespidae. This also leads to the weakening of the whole colony and reduces the efficiency of collecting pollen from flowers, thereby causing economic losses to beekeepers. Since beekeepers have to manage a large number of beehives at the same time, it is necessary to develop a monitoring method that can allow beekeepers to instantly acquire information regarding a specific beehive being attacked by foreign enemies. In this study, an IoT-based system for beehive audio monitoring and warning was established. In this system, a microphone was placed in the beehive to collect the audio from the bee colony, and the collected audio data were transmitted to an embedded system (Raspberry Pi) that served as the end computing center. After analyzing the audio spectrograms, the center used a machine learning-based classification algorithm to determine whether the beehive was attacked by foreign enemies. The classification results and monitoring images were uploaded to a cloud to alert beekeepers in real time, which helps beekeepers take measures to reduce the risk of external enemy attacks.

Keywords: *Honey bee, Audio monitoring system, IoT.*

EFFECTS OF LED LIGHT INTENSITY AND CARBON DIOXIDE CONCENTRATION ON THE GROWTH OF SPINACH (*Spinacia oleracea* L.) IN CLOSED PLANT PRODUCTION SYSTEM

Duy Nhu Nguyen[1)], Quyet Huu Luong[1)], Khanh Le Nguyen[1,*)]
and Chau - Thuy Pham[*)]

1) University of Engineering and Technology, Vietnam National University, Hanoi,
144 Xuan Thuy, Cau Giay, Hanoi, Viet Nam

* Corresponding author: email: thuypc@vnu.edu.vn, nl.khanh@vnu.edu.vn

ABSTRACT: Plant factory (PF) is a vertical growing system which has been recently developed for indoor farming. This system's environment can be controlled to provide the optimal conditions for crop cultivation. Our research aimed to investigate the effects of light intensity and the carbon dioxide (CO_2) concentration on spinach's growth during vegetative stage in plant factory. Two experiments were conducted with different CO_2 concentration (500 and 800 ppm) in closed chamber. In each experiment, plants were hydroponically grown under three light intensities of 115, 140 and 160 µmol.$m^{-2}s^{-1}$. The values of light intensity was determined on the surface of growing beds and adjusted by changing the distance between growing beds and light fixtures. Growth's parameters including leaf number (LN), leaf length (LL), leaf area (LA), chlorophyll content (Chl), fresh mass (FM) and dry mass (DM) were determined at different growth stages (T30, T37 and T44 respectively to 30, 37 and 44 days after sowing). ANOVA analysis and non-parametric Kruskal analysis of variance were used to evaluate the statistical significance of the treatment effects. The results showed that, before 30 days old, the increase of light intensity was not significantly effected to the growth of plant. During later growing periods (30 days old afterward), the increase of light intensity remarkably boost up yield's related traits such as LN, FM and DM under air CO_2 condition. However, from 37 days old, the significant difference of growth indicators was not observed in the two treatments of higher light intensities (140 and 160 µmol.$m^{-2}s^{-1}$) under enriched CO_2 condition. It is suggested that, during latest growing period, the average light intensity of 140 µmol.$m^{-2}s^{-1}$ combining with elevating CO_2 concentration is an alternatively way to enhance spinach growth. The findings of this study could be helpful for growers to improve growing conditions for a better development of spinach in the indoor farming.

Keywords: *Plant factory, Light intensity, CO_2 concentration, Spinach, Growth indicators*

DETERMINANTS OF SMALLHOLDERS' ADOPTION OF INFORMATION AND COMMUNICATION TECHNOLOGIES FOR PRODUCTION AND MARKETING OF FLOWERS

Hoang Gia Hung[1, *], Nguyen Tien Dung[2] and Tran Thi Anh Nguyet[3]

1) University of Agriculture and Forestry, Hue University, Vietnam
Email: hoanggiahung@huaf.edu.vn ; 102 Phung Hung street, Hue city, Vietnam
2) University of Agriculture and Forestry, Hue University, Vietnam
3) University of Agriculture and Forestry, Hue University, Vietnam

* Corresponding author

ABSTRACT: Providing smallholders with more agricultural information and market opportunities is considered a crucial way to enhance their livelihood. Information Communication and Technologies can be significant forms of doing that. In order to foster smallholders' adoption of Information Communication and Technologies for production and marketing, it is important to understand factors that shape its adoption. However, little empirical research has considered determinants of smallholders' adoption of Information Communication and Technologies for production and marketing in Vietnam. this study examines factors that affect adoption of Information Communication and Technologies for production and marketing of flowers in Phu Vang district of Vietnam. A random sample of 150 was drawn from a total of 241 farmers. Descriptive statistics and inferential statistics were applied to analyze the data. The study found that the smallholders used mobile phones, televisions and internet connected computers as the common Information Communication and Technologies, and these were also effective Information Communication and Technologies for production and marketing of flowers. the smallholders used mobile phones, televisions and computers as the common Information Communication and Technologies, and these were also effective Information Communication and Technologies for production and marketing of flowers. Among the independent variables, gender, education level, type of household and community-based organization participation are significant determinants of smallholders' adoption of Information Communication and Technologies for production and marketing of flowers. Demographic and socio-technical characteristics of smallholders should be considered when promoting the smallholders' adoption of Information Communication and Technologies for production and marketing of agricultural produce in developing countries.

Keywords: *ICTs, adoptions, smallholders, determinants, Phu Vang, Vietnam.*

DETECTION OF LEAF DISEASES OF CINNAMON USING K-MEAN CLUSTER ALGORITHM WITH MOBILE APP

P.K.S.C.Jayasinghe[1]

1) Faculty of Technology /University of Ruhuna, Sri Lanka
subash@ictec.ruh.ac.lk

ABSTRACT: In Sri Lanka, cinnamon (Cinnamomum zeylanicum Blume) is extensively cultivated in some parts of dry zone, intermediate zone and wet zone on various soil types. In view of its industrial applications and medicinal properties, there is growing demand for true cinnamon in the world. Major drawbacks of cinnamon industry in Sri Lanka are low productivity and quality, poor value addition and inadequate and unsatisfactory extension services. Cinnamon is a hardy plant and therefore it is vulnerable to attack by a various insects and microbes. As the results of that, production of the cinnamon is getting low as current farmers don't have enough remedies for real time. It is reported that there are many diseases in leaf which could lead to make low production. Leaves of the cinnamon are very demand part of the tree as this is used to extract the leaf oil which is often used for flavoring toothpaste along with mint and eucalyptus oils and also use for remedial products like cleansers, oral rinses, topical skin applications and food product etc. Nowadays, the mobile phone has generated an opportunity for the farmers especially who are interested to receive relevant information related to weather, agro-technology, support services, market information. The use of mobile phone also keep them aware for identifying huge numbers of disease which are seen on leafy pants such as fungi, bacteria and viruses that might be affected by growing of the plant. This concept successfully applied to develop image processing algorithm to identify the leaf diseases of cinnamon with aid of mobile application. This study consisted of two stages, first stage was to classify the leaf disease using K-mean cluster technique and the second stage was to develop a mobile-based application. The images of diseases affected cinnamon leaves were acquired using high resolution digital camera under various conditions in several fields. The diseases of these leaf were basically identified with the help of plant pathologist. Then, several analytical techniques were used to classify the images based on expertise knowledge of plant pathologist. All these information were stored in a database. A client-server architecture was used to develop mobile application to retrieve plant leaf diseases by mobile phone (smart phone) in the field. The developed system will then compare the image inserted by the client with image stored in the database in the server-side. The extracts the features of query image compares the stored features and calculates a similarity value for each image using K-mena cluster algorithm. Then server responds to the image query by sending results to the client. Finally, disease with an acceptable accuracy will be detected and the client system (smart phone)will display the results as the output.

Keywords: *Mobile app, Cinnamon, K-mean clustering, Leaf diseases.*

LOW-COST AND FARMER-FRIENDLY METHOD FOR SURVEYING LOCAL ANIMAL RESOURCES: MONGCAI PIG BREED

Nguyen Quoc Trung[1], Nguyen Huong Giang[2], Nguyen Van Khoa[2], Nguyen Thi Thanh Mai[2] , Cao Thi Thu Thuy[2] , Nguyen Tien Duc[2] , Ngo Thanh Trung[3] , Tong Van Hai[2*]

1) Vietnam National University of Agriculture, Faculty of Biotechnology, Vietnam - nqtrung@vnua.edu.vn
2) Vietnam National University of Agriculture, Faculty of Biotechnology, Vietnam
3) Vietnam National University of Agriculture, Faculty of Veterinary Medicine, Vietnam

* Corresponding author

ABSTRACT: Mong Cai pig is an indigenous pig breed, which originated in Quang Ninh province, Vietnam, with the typical traits for the breed. There are many difficulties to evaluate the quality of this breed, as well as for farmers, in the selection process at present. We studied a farmer-friendly method based on common online platforms to survey and monitor Mong Cai pig genetic resources. A survey form was created on Google form based on the special traits of the Mong Cai pig breed, quantity traits, and some general information. All these categories were evaluated, and pictures of each individual were taken, then immediately filled on this online form. The information of each pig was instantly saved in excel format and cloud storage after the categories parameter and pictures are recorded. This method can be easily connected among farms then providing a useful database source for further analysis of the disease, inheritance, etc.

Keywords: *Database, Mong Cai pig, farmer-friendly, genetic resources, survey.*

MAXIMIZING THE PROFIT OF PIG FARMING UNDER THE HIGH COST OF FOOD SUPPLY CHAIN AND NEGATIVE VOLATILITY OF THE MARKET IN VIETNAM

Long Dinh Nguyen[1, *) , Dang Nguyen Dong Phuong[2)] , Le Hoang Tu[2)] ,
Phan Thi Ha[2)] and Nguyen Kim Loi[2)]

1) Faculty of Engineering, Dong Nai University, Vietnam
E Mail: dinhlonghcmut@gmail.com / Contact Details: +84 947 229 599
2) Research Center for Climate Change, Nong Lam University–Ho Chi Minh City, Vietnam
E Mail: phuong.dangnguyendong@hcmuaf.edu.vn, tu.lehoang@hcmuaf.edu.vn,
haphan0604@gmail.com; ngkloi@hcmuaf.edu.vn

* Corresponding author

ABSTRACT: Pig farming is one of the most important livestock accounting for a large proportion of agriculture in Vietnam. Under a degradation of the global market in the scarcity of raw materials and barriers to import and export sector, the livestock of pig farms has faced many difficulties in food supply chains and low selling prices. Farmers are no longer interested in restructuring pig herds in the current and the future, then the issue of food security will be a big problem. To deal with this issue, we propose mathematical models and optimization methods under the profit maximization problem of pig farming based on data analytics of the market and the procedure of pig raising. Our efficient mathematic approximation and low-complexity computations are investigated and implemented for solving the profit problem after deducting all livestock expenses. Our approach has been explicit and realistic description and fast deployment for solving the problem with widespread application in the swine industry. Numerical results are shown to demonstrate the benefit of our proposed approaches compared to conventional methods.

Keywords: *Pig farming, food supply chain, data analytic, optimization in agriculture, agriculture market.*

EXTENSION OF TRANSCRIPTIONAL REGULATOR RESOURCE IN CASSAVA BY MACHINE LEARNING BASED MODELING

Treenut Saithong [1,2,3 *)] , Bhukrit Ruengsrichaiya [2)] , Saowalak Kalapanulak [1,2,3)] , and Chakarida Nukoolkit [2,4)]

1) School of Bioresources and Technology, King Mongkut's University of Technology Thonburi (Bang KhunThian), Bangkok 10150, Thailand.
2) Bioinformatics and Systems Biology Program, School of Bioresources and Technology and School of Information Technology, King Mongkut's University of Technology Thonburi (Bang KhunThian), Bangkok 10150, Thailand.
3) Center for Agricultural Systems Biology, Systems Biology and Bioinformatics Research Group, Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi (Bang KhunThian), Bangkok 10150, Thailand.
4) School of Information Technology, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand.

* Corresponding author Email: treenut.sai@kmutt.ac.th

ABSTRACT: Transcriptional regulatory system of plant species is believed to be rather complicated and contains specific elements required for sessile organisms to survive under wide range of environmental conditions. The current findings of transcriptional regulatory cascade are always underestimated its complexity due to a lack of knowledge on the interactions of transcription factor proteins (TF) and the regulatory motifs in DNA, called TF binding sites (TFBS). This circumstance restricts our understanding into the response of plants to a particular exposed perturbation, which is a key prerequisite in the study pathway toward climate-adaptive plantations. To alleviate this limitation, Plant-DTI (Plant DBD-TFBS Interaction) is previously developed as a cutting-edge machine learning based tool for TF-TFBS prediction. The model was constructed from at least 1,241,314 interacting pairs of DNA binding domains (DBD) and TFBSs from experiments. The data coverage allows Plant-DTI to be able to predict gene targets of TFs up to half of the DBD types existing in plant species (30 TF families and 336 TFBSs). In this study, Plant-DTI model was exploited to study transcriptional regulation of sucrose synthase genes (SUS), a sucrolytic enzyme involving in carbon allocation and root biomass synthesis in cassava. There are 150 putative TFs were predicted for SUS1 gene, the majority of which are related to stress-response. The prediction was found consistent with the previous yeast one-hybrid (Y1H) study. These putative regulators enable us to connect the transcriptional response of SUS1 genes as well as their function to the exposed environments, and subsequently to better dealing with the surrounding influence. Taken together, this study demonstrates the advantage of big data and computational modeling to facilitate our moving towards the precise management in cassava farming.

Keywords: *Transcription factor (TF), Transcriptional regulation, Cassava, Machine learning, TF-TFBS interactions, Sucrose synthase.*

NEAR REAL-TIME MONITORING OF CASSAVA CULTIVATION AREA

Trong V. Phan [1,*], Louis Reymondin [1], Thibaud Vantalon [1], Erik Delaquis [2], Thuy T. Nguyen [1], Bandit Mienmany [2]

1) International Center for Tropical Agriculture (CIAT), Vietnam country office. c/o Agricultural Genetics Institute, Pham Van Dong, Bac Tu Liem, Hanoi, Vietnam.
2) CIAT, Lao PDR country office. c/o NAFRI, Dong Dok, Ban Nongviengkham, PO box 783

* Corresponding author: t.v.phan@cgiar.org, Tel: +842437576969 / +84904443123

ABSTRACT: Remote sensing technologies and deep learning/machine learning approaches play valuable roles in crop inventory, yield estimation, cultivated area estimation, and crop status monitoring. Satellite-based remote sensing has led to increased spatial and temporal resolution, leading to a better quality of land-cover mapping (greater precision, and detail in the number of land cover classes). In this work, we propose to use a long short-term memory neural network (LSTM), an advanced technical model adapted from artificial neural networks (ANN) to estimate cassava cultivation area in southern Laos. LSTM is a modified version of a Recurrent Neural Network (RNN) that uses internal memory to store the information received prior to a given time. This property of LSTMs makes them advantageous for time series regression. We employ Landsat-7/8 and Sentinel-2 time-series datasets and crop phenology information to identify and classify cassava fields using multi-sources remote sensing time-series in a highly fragmented landscape. The results indicate an overall accuracy of > 89% for cassava and > 84% for all-class (barren, bush/grassland, cassava, coffee, forest, seasonal, and water) validating the feasibility of the proposed method. This study demonstrates the potential of LSTM approaches for crop classification using multi-temporal, multisource remote sensing time series.

Keywords: *Cassava Mapping, Long Short-Term Memory (LSTM), Crop Classification, Deep Learning, Landsat-7/8, Remote Sensing, Sentinel-2, Multitemporal, Google Earth Engine.*

AGRICULTURAL PRODUCTS AND THE TRACEABILITY MODEL OF DAIMINH POMELO

Chu Anh Tiep[1*], Nguyen Thi Loan[1], Thieu Thi Phong Thu[1],
Tran Thi Thiem[1], Ngo Cong Thang[1]

1) Vietnam National University of Agriculture

* Corresponding author: catiep@vnua.edu.vn

ABSTRACT: Agricultural products are the daily fresh foods with a short expiry date. Its production condition is directly affected by weather such as temperature, rain and humidity. In addition, the farmers have limited access to management and information technology. Therefore, to do traceability for agricultural products, it needs the supports from state management agencies as well as the organizations from supply chain system. By many years of researching on the value chain of Dai Minh pomelo production, research team has obtained initial success in the construction of stamps and information for traceability, in using popular app for daily communication with the producer about the cultivation process and data management. Each household has their own QR code to trace the origin of pomelo with full information on production management and product quality, thus expanding the consumption market. Therefore, it increases the value of Dai Minh pomelo products and attracts many pomelo producers to do the same.

Keywords: *Agriculture products, food product, Daiminh pomelo, Qr-codes, traceability, value chain.*

THE DISASTER MANAGEMENT OF LARGE SCALE LANDSLIDE: A CASE STUDY OF DEBRIS FLOW EARLY RESPONDING SYSTEMS

Lok-Man Chiu [1*], Tien Yin Chou [2]) , Mei-Ling Yeh [2], Jau-Tung Wu [2] ,
Chen-Yang Lee [3], Hsiao-Yuan Yin [3], Yi-Chia Lin [3]

1) Geographic Information System Research Center, Feng Chia University, Taiwan, lawrence@gis.tw, 886-4-24516669 ext. 719
2) Geographic Information System Research Center, Feng Chia University, Taiwan
3) Soil and Water Conservation Bureau, Council of Agriculture, Taiwan

* Corresponding author

ABSTRACT: This paper studies the mechanisms of large-scale landslide management. It established early responding feedback mechanisms for the application in different scenarios. The paper started with the site descriptions of debris flow and large-scale landslides. It stated the fundamental differences between two types of disaster and followed by discussions of the uniqueness and necessity of large-scale landslide early responding mechanism establishment. With the current debris flow early responding systems as the evidence, this study clarified various important aspects in the early responding system. It includes the parameters of alerting area, monitoring equipment, data values, procedures of disaster prevention and evacuation. The clarifications can further shapes the workflows of large-scale landslide early responding system. Meanwhile, this paper studies references for the large-scale landslide responding parameters of specified monitoring rain gauge and on-site monitoring devices. A series of simulations have been carried out to discover the disaster factors and its data collection methods. Knowledge obtained was then contributed to the real-time data analysis development. Subsequently, disaster discussion-making center can generate alerting parameters, calculation formulas and associated responding signals (red or amber) according to its associated environmental factors. At the end of the study, the mechanisms of issuing and disarming alert system, as well as the principles of issuing alert system have been discussed.

Keywords: *Large scale landslide early responding systems, debris flow, large scale landslide.*

APPLICATION OF MACHINE LEARNING IN RICE BLAST DISEASES PREDICTION BASED ON WEATHER DATA

Yi-Ting Zhang[1, *] Chun-Jung Lai[2] Horng-Yuh Guo[3] Tsang-Sen Liu[4]

1) Taiwan Agricultural Research Institute, TAIWAN, iting0707@tari.gov.tw, Assistant Researcher
2) Taiwan Agricultural Research Institute, TAIWAN
3) Taiwan Agricultural Research Institute, TAIWAN
4) Taiwan Agricultural Research Institute, TAIWAN

* Corresponding author

ABSTRACT: Rice blast is a significant problem all over the world. Rice blast fungus spread rapidly and easily leading to large-scale infection under suitable weather conditions. It causes serious agricultural damage. Therefore, it is extremely important to study the relationship between climatic factors and rice blast. The environmental conditions for rice blast sporulation include: (1) Rainfall and dew make leaves moist (2) Relative humidity above 90% (3) Temperature between 20 and 28 degrees and obvious temperature difference (4) Excessive use of nitrogen fertilization fertilizer (5) Too dense of planting. Nowadays, the warning of rice blast in Taiwan is released by the temperature changing dramatically or farmers who have already found the disease. There is a time delay, although the farmers enhance the use of pesticides. Hence, it is not able to prevent crops from rice blast completely. In this study, the accuracy of rice blast detection is 85%. However, the identification of disease-resistant varieties has to be improved and it is easily confused with other diseases. In addition, the database of a symptom of rice blast at different growth stages is not enough. It is also necessary to establish the difference in crops during the growth continuously. The symptom of rice blast relies on expert recognition as well. The study is conducted by transfer learning because it is difficult to collect data which requires much time and effort for surveyors. Furthermore, different deep learning about object detection such as YOLO and SSD can be used for training according to the data collection. In the beginning, the probabilities of rice blast infection greater than 0.6 are chosen and it is provided with alertness and reports for users. Due to the difference in the growth stage, the development of rice blast is varied. The leaves that show similar symptoms of rice blast would be selected and the experts analyze the rice blast manually. The forecast model will be improved by collecting numbers of rice blast cases.

Keywords: *Rice blast, disease forecast, machine learning.*

TOMATO LEAF DISEASE DETECT AND CLASSIFY USING HYBRID DEEP LEARNING MODELS

Deepak Kumar[1, *)], Lokesh Malviya [2)] Sandip Mal[3)] and Bishwajit Roy[4)]

1) Department of CE NIT Patna-800001, Bihar India, decage007@gmail.com,
2) VIT Bhopal, University Madhya Pradesh, India,
lokesh.malviya2020@vitbhopal.ac.in,
9893096304, Research Scholar
3) VIT Bhopal, University Madhya Pradesh, India, sandip.mal@vitbhopal.ac.in,
7974537024, Assistant Professor
4) School of Computer Science, University of Petroleum and Energy Studies,
Uttarakhand-248007, India, bishwamail@gmail.com, 7870712932, Assistant Professor

* Corresponding author

ABSTRACT: In agriculture sector various innovations done with image processing. All such innovations help agriculturists to create early discovery and classification of leaf plant disease. Therefore, it is required to identify disease on plant leaves early in order to maintain health of plant. Physically it is difficult to identify with human eye as it cannot observe minute variations of infected part of the leaf. The main approach of the research is to detect the different diseases of tomato plant leaves by applying artificial neural network tool. Plant Leaves are utilized to decide the type of diseases that contaminates the crops. This paper proposes an identifying approach for tomato leaf diseases based on deep convolutional neural networks. Using a dataset of 11,000 images of diseased tomato leaves, the proposed deep convolutional neural network model is trained to identify the common tomato leaf diseases. With available dataset, the experimental results show that the proposed approach based on convolutional neural network achieved 94.72% overall accuracy.

Keywords: *Image Processing, CNN, Deep Learning, Classification, Plant Disease.*

THE APPLICATION OF UAV 3D AERIAL PHOTOGRAMMETRY IN TOUSHER BASIN, NANTOU, TAIWAN

Yi-Ting Zhang[1, *] Ting-Yun Ku[2] Hsin-Jen Hsu[3] Horng-Yuh Guo[4] Tsang-Sen Liu[5]
1) Taiwan Agricultural Research Institute, TAIWAN, iting0707@tari.gov.tw, Assistant Researcher
2) Taiwan Agricultural Research Institute, TAIWAN
3) Taiwan Agricultural Research Institute, TAIWAN
4) Taiwan Agricultural Research Institute, TAIWAN
5) Taiwan Agricultural Research Institute, TAIWAN

* Corresponding author

ABSTRACT: Tousher Basin is the largest peat soil area in Taiwan. The bottom of Tousher Basin is mostly agricultural area. It is also a flooded region in rainfall season. The properties of peat soil and the agricultural method made the flood more serious when it rains. According to previous research, UAV 3D aerial photogrammetry can be the low cost method instead of LiDAR. In this paper, the research method is to use UAV to take five pictures in five directions on every point in the research area to produce orthomosaic image, DSM/DTM and 3D model. The height of route of UAV was terrain follow to keep the fixed height from the land. The elevation of the bottom of basin is about 650 m, and the highest point on mountain range surrounding the bottom is 1008 m. The bottom of basin is the region which the height of route is 200 m. The slope region is terrain following to keep the same resolution and the width of pictures, and the height of route is 180 m. Therefore, the photogrammetry software can produce high resolution (5-10 cm/pixel) Digital Terrain Model (DTM) and 3D model of Tousher Basin for flood area simulation. Based on flood simulation result, the most seriously flooded region can be planed a flood detention basin park. Besides, the second seriously flooded region can be ornamental flower or cash crop farms. Irrigation channels in Tousher Basin can be designed based on the elevation data to drain flood more efficiently and keep a level of underground water to protect peat soil.

Keywords: *UAV, Aerial Photogrammetry, 3D modelling.*

LYCOPERSICON CROP LEAF DISEASE IDENTIFICATION USING DEEP LEARNING

Barkha M.Joshi[1,*] , Dr. Hetal Bhavsar[2)]

1) Computer Engineering Dept.
Sardar Vallabhbhai Patel Institute of Technology, Vasad, India.
2) Computer Science and Engineering Dept.
The Maharaja Sayajirao University of Baroda, Vadodara, India

* Corresponding author

ABSTRACT: Crop diseases pose a serious deathtrap to food safety, but their rapid disease diagnosis remains burdensome in many parts of the world due to the lack of the necessary foundation. These days deep learning models have shown better performance than hi-tech machine learning techniques in several fields, with computer vision being one of the most noticeable cases. Agronomy is one of the domains in which deep learning concepts have been used for disease identification on the different parts of the plants. Having a disease is very normal and common but prompt disease recognition and early avoidance of crop diseases are crucial for refining production. Though the standard convolutional neural network models identified the disease very accurately but require a higher computation cost and a large number of parameters. This requires a model to be developed which should be efficient and need to generate less no of parameters. This research work proposed a model to identify the diseases of the plant leaves with greater accuracy and efficiency compared to the existing approaches. The standard models likeAlexNet, VGG, and GoogleNet along with the proposed model were trained with the Lycopersicon plant leaf which is available in plant village. It has 9 categorical classes of diseases and healthy plant leaves. A range of parameters, including batch size, dropout, learning rate, and activation function were used to evaluate the models' performance or achievement. The proposed model achieved a disease classification accuracy rate of 93% to 95%. According to the findings of the accuracy tests, the suggested model is promising and may have a significant influence on the speed and accuracy with which disease-infected leaves are identified.

Keywords: *Convolution Neural Network, deep learning, crop diseases, Proposed model, Lycopersicon leaf disease identification.*

QUALITY CONTROL OF PRECIPITATION NETWORK IN NORTH CENTRAL PROVINCES OF VIETNAM

Le Kien Truc[1, *)], Pham Van Ha[2)], Phan Van Tan[3)] and
Nguyen Thi Nhat Thanh[4)]
1) University of Transport and Communications, Vietnam
2) Phenikaa University, Vietnam
3) VNU Hanoi-University of Science, Vietnam
4) VNU Hanoi-University of Engineering and Technology, Vietnam

* Corresponding author: lktruc.work@gmail.com

ABSTRACT: Precipitation is considered the most important parameter in agricultural weather. Most of the rain water is used to produce crops in agriculture. Ground measurement of precipitation is an essential input data for numerous operational applications such as quantitative precipitation estimation, weather forecasts and warnings, hydrological modelling and agricultural meteorology. Despite that, there are many different types of errors that can affect the monitoring quality of rain-gauges data. Therefore, the quality control process of rain-gauges precipitation data is very important for scientists, engineers and decision makers. In this study, an automated quality control process for rain-gauges measurement data from more than 200 stations in the North Central of Vietnam was proposed. Hourly rain-gauges data in periods of 2019-2020 were used for experiment and evaluation. Quality control process consist of three main steps: Gross check, temporal check and spatial check. Gross check is a preliminary check that each individual observation is satisfied in range of min and max value. In this paper, max value threshold was identified based on long-term historical rainfall data for each province. The gross check showed that 540 rain-gauges measurement points were detected as error. Temporal check is the second step that check the consistency between successive observation. A step change threshold was identified for each individual rain-gauge station base on the histogram analysis. The result showed that the outlier ratio detected by temporal check varies from 0.02 to 0.47% of total rain-gauges data. Spatial check is the thirst step that compare and individual station with some neighbor rain-gauges station. The result showed that the accuracy of spatial check depends on the radius of the neighbor stations. A combined threshold of a minimum of 3 stations and a maximum radius of 15km were proposed for spatial check. 1390 rain-gauges measurement outliers were detected by spatial check. Totally, 2431 outliers (approximately 0.1%) marked by automatic quality control procedure. The results of this study indicate the potential of applying an automatic quality control process to the network of rain-gauges stations in Vietnam and contribute to improving the quality of rain-gauges data before using it for further studies

Keywords: *Quality control, precipitation, rain-gauge, North Central, Vietnam.*

THE SPATIAL-TEMPORAL DYNAMICS OF SOIL SALINITY IN THE VIETNAMESE MEKONG DELTA

Nguyen Ngoc Mong Kha[1], Vo Quoc Tuan[*2] , Craig Poynter[3],
Susan Orgill[4], Dang Duy Minh[5], Jason Condon[3], Ben Stewart-Koster[6],
Chau Minh Khoi[5]

1) An Giang Department of Science and Technology, Vietnam
2) Department of Land Resources, Can Tho University, Vietnam
3) Charles Sturt University, Australia
4) Wagga Wagga Agricultural Institute, Australia
5) Department of Soil Science, Can Tho University, Vietnam
6) Griffith University, Australia

* Corresponding author:
Nguyen Ngoc Mong Kha; email: nnmkha@gmail.com
Vo Quoc Tuan; Email: vqtuan@ctu.edu.vn

ABSTRACT: Soil salinization is one of the most serious land degradation processes, increasingly prevalent in coastal areas of the Vietnamese Mekong Delta (VMD), where salinity intrusion has become a pressing issue. Understanding the farm-scale spatial distribution of soil salinity and its variation over time is important for management of agro-ecological landscapes. The main objective of this work is to map the spatial distribution of soil salinity and its variations from 2019 –2022. We obtained monthly soil samples (in a dry season) from the upper 20 cm at over 1000 sites in Soc Trang province and measured electrical conductivity (EC1:5, dS m-1) using Conductivity Meter. Sample sites were scattered across the sampling region, so aggregation and averaging of data to customized zones or administrative units were identified as potential options to represent seasonal variations. A hexagonal area of 10 square kilometers was chosen to represent monthly aggregated and averaged salinity data. The spatial variations in soil salinity were generated using ESRI's Tessellation function. These initial results provide an impression of the current rate and extent of recent change are an important precursor for more targeted sampling across the entire sampling area going forward. The results provide a scientific basis for seeking improved soil management techniques and profitable alternative crops to grow in the dry season under conditions of climate change.

Keywords: *Soil salinity, spatial distribution, climate change, Mekong delta.*

THE USE OF INDOOR PLANT AS AN ALTERNATIVE TO IMPROVE INDOOR AIR QUALITY

Do Cong Vinh, Nguyen Ba Trung, Nguyen Thi Cam Tu,
Nguyen Thanh Dat, Nguyen Thi Ngoc Anh* and Pham Chau Thuy*

University of Engineering and Technology, Vietnam National University, Hanoi, 144 Xuan Thuy, Cau Giay, Hanoi, Viet Nam

* Corresponding author: email: thuypc@vnu.edu.vn

ABSTRACT: Using plants to reduce and/or remove air pollutants, especially in indoor environment has been known as a promising green technology of environmental pollution treatment recently. This study initially developed an experiment which utilized sensors to evaluate the ability to absorb CO_2 and mixed volatile organic compounds (VOCs) of two indoor plants: aloe vera (Aloe barbadensis) and serpent tree (Radermachera Sinica). The study was carried out in a closed chamber made of transparent mica plastic with dimensions of 70 x 45 x 45 cm. Inside the closed chamber, a blower is installed for mixing and air conditioning, and a system of sensors for temperature, humidity, CO_2 concentration, VOCs to measure and control the air quality inside the chamber. The parameters of gas concentration, plant morphology, number of stomata and chlorophyll were determined before and after conducting the experiment. The study results showed that the concentration of TVOC was reduced by 52% after 15 hours in the presence of plants compared to the control samples by only 20% without the experimental plants. However, under conditions of lack of water and placed in an environment with high concentrations of polluted gases that inhibit respiration, the plant gradually loses its chlorophyll and the leaves turn yellow, the density of stomata is significantly reduced on the front and back of the leaves, even the happy tree loses its leaves. After 6 hours of testing, the plants began to change in morphology. Research has initially found out the principle of absorption of VOCs by indoor plants, as well as the effects of air pollutant on physiological processes of plants.

Keywords: *Indoor plant, sensor, carbon dioxide, volatile organic compounds, absorption.*

APPLICATION OF CHAMELEON SOIL WATER SENSOR IN WATER MANAGEMENT FOR UPLAND CROPS UNDER DROUGHT AND SEAWATER INTRUSION CONDITIONS IN THE MEKONG DELTA

Chau Thi Nhien[1, *)], Chau Minh Khoi[2)], Dang Duy Minh[2)],
Tran Duy Khanh[2)] , Cao Dinh An Giang[2)], Jason Condon[3)]
and Brooke Kaveney[3)]

1) Can Tho University, Vietnam
ctnhien@sobaclieu.edu.vn
2) Can Tho University, Vietnam
3) Charles Sturt University, Australia

* Corresponding author: ctnhien@sobaclieu.edu.vn

ABSTRACT: The Mekong River Delta (MRD) has faced an increase in freshwater scarcity and seawater intrusion, which are attributed to be caused by climate change. Therefore, studies on applying advanced farming techniques and soil management practices are needed to adapt to a resilient agricultural production. The Chameleon Soil Water Sensor System (CSWSS), which is a soil moisture sensor array connected to a Wi-Fi system to read, store and send data via the Virtual Irrigation Academy (VIA) website platform, was studied to improve water use efficiency for upland crops grown under drought and saline conditions. The studies were established in both greenhouse and field conditions. Maize, watermelon, and beetroot were grown in the treatments including regular and intermittent irrigation combined with different rates of salinity. The result showed that irrigation based on the CSWSS saved 45%, 52%, and 54% of the amount of irrigating water applied for the respective crops as compared with that used by the farmers while remaining the crop yields were not significantly different among the treatments which were set up in the greenhouse. On the other, the CSWSS treatment saved the amount of water irrigation compared with farmers' monitoring treatment. However, there were significantly different crop yields of beetroot and watermelon.

Keywords: *Chameleon, drought, saline, irrigating water.*

SUSTAINABLE FRUIT PLANTING AREAS UNDER CLIMATE CHANGE: A CASE STUDY OF KON TUM PROVINCE, VIETNAM

Nguyen Duy Liem[1, *], Le Hoang Tu[2], Hoang Ha Anh[3], Long Dinh Nguyen[4] , and Nguyen Kim Loi[2]

1) Faculty of Environment and Natural Resources, Nong Lam University – Ho Chi Minh City, Vietnam (email: nguyenduyliem@hcmuaf.edu.vn)
2) Research Center for Climate Change, Nong Lam University – Ho Chi Minh City, Vietnam (email:{tu.lehoang, ngkloi}@hcmuaf.edu.vn)
3) Faculty of Economics, Nong Lam University – Ho Chi Minh City, Vietnam (email: hoanghaanh@hcmuaf.edu.vn)
4) Faculty of Engineering, Dong Nai University, Vietnam (email: dinhlonghcmut@gmail.com)

* Corresponding author

ABSTRACT: Restructuring crops in inefficient industrial crop areas is a solution to improve agricultural land use efficiency and adapt to climate change. In this study, we presented GIS-based multi-criteria decisionmaking (GIS-MCDM) approach to evaluate land suitability for fruit crops, including both monocropping and intercropping in industrial orchards, considering sustainability dimensions (economic, social, and environmental benefits) under climate change in Kon Tum province, Vietnam. Ten selected criteria including economic (production value, added value, production efficiency), social (labor attraction, product consumption, access to capital, technical access), and environment (physical land suitability, soil erosion, nitrate loss) were created using field survey, maximum limitation method of FAO or hydrological model. Weight for each criterion was assigned using Analytic Hierarchy Process (AHP) depending on its relative importance in fruit planting in the study area through literature review. The sustainable map of fruit trees was generated using a weighted linear combination method in GIS and categorized into three sustainable classes namely, low, moderate, and high using quantile classification. The results show that in the baseline period, fruit trees had low, medium, and high sustainability. However, under the impact of climate change, most of the area is moderate sustainability by mid-century but will shrink by the end-century, leading to an increase in low sustainability. These findings could be useful to planners and decision-makers in land-use planning to prevent or reduce spontaneous fruit tree planting that may cause oversupply in the future.

Keywords: *Climate change, fruit crops, GIS-MCDM, land suitability evaluation, maximum limitation method.*

THE VEHICLE ROUTING PROBLEM WITH DRONES FOR FRESH AGRICULTURAL PRODUCTS

Quang Huy Vuong[1] , and Minh-Trien Pham[1,*]

1) VNU University of Engineering and Technology, Vietnam
trienpm@vnu.edu.vn

* Corresponding author

ABSTRACT: The delivery of fresh agricultural products is a significant challenge due to their perishability. In this paper, we address a real-life delivery of fresh agricultural products vehicle routing problem with drones (VRPD). The model considers the impact of the perishability as part of the overall distribution costs and explores the feasibility of deploying drones to the delivery. The model is constructed with mixed integer linear programming (MILP) optimization and the objective of this model is to minimize the quality deterioration value of agricultural products and the completion time i.e., the time at which all the vehicles are back to the depot, with the service of all customers carried out. The quality deterioration value is related to the deterioration rates, quantities, and delivery time of fresh agricultural products. We propose a heuristic approach to solve the problem. The results demonstrate that the utilization of drones and the proposed algorithm might reduce the delivery time and deterioration value of products significantly. Finally, the results also indicate that our proposed models provide an effective decisionmaking reference for logistics distribution enterprises.

Keywords: *Vehicle routing problem, Fresh agricultural products, Drone delivery, Mixed integer linear programming, Heuristic algorithm.*

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Experimental Zone for Agricultural Technology

Research activities of the Faculty of Agricultural Technology

Address: E3 Building, 144 Xuan Thuy Street, Cau Giay District, Ha Noi, Vietnam

Tel: (84) 024.37547.461; Fax: (84) 024.37547.460; Email: uet@vnu.edu.vn

NHÀ XUẤT BẢN
ĐẠI HỌC QUỐC GIA HÀ NỘI
16 Hàng Chuối – Hai Bà Trưng- Hà Nội

Tổng Biên tập: (024) 39714736
Hành chính: (024) 39714899
Biên tập: (024) 39714896
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