Channeling agriculture innovation transfer from universities and research centre to vocational high schools: Lesson learned from Indonesia

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ABSTRACT

SEAMEO BIOTROP has been assigned by the Ministry of Education and Culture of the Republic of Indonesia to revitalize secondary vocational high school in agriculture for the last three years. There were three main programmes, i.e. fruit tree gardening, food security, and establishment of teaching factory. The activities include: training, field implementation, and supervision. There were 46 schools have been selected for the implementation of fruit tree gardening, and 80 schools have been involved in the food security and teaching factory programmes. This has been a successful programme, where the capacity of the head masters, teachers, and students have been improved. SEAMEO BIOTROP has not only transferred innovation developed by the Centre, but also involved universities (IPB University) and agriculture research centre (Orange and Sub-tropical Fruit Research Centre under the Ministry of Agriculture) in implementing the programme. Most of the partner schools have implemented the technology introduced by SEAMEO BIOTROP and partners institution in their schools and the surrounding farms. SEAMEO BIOTROP scientists have developed an application to monitor the progress of the schools and also to sustain long distance consultation. The programmes have shown that secondary vocational high schools in agriculture have potential to be developed as transfer technology hub in agriculture for their surrounding communities/farmers. Skill development in industry 4.0 in the area of agriculture could also be introduced to selected schools in the future.

Keywords: BIOTROP, Fruit, Garden, Industry 4.0, School, SEAMEO, Vocational

INTRODUCTION

SEAMEO BIOTROP has succeeded in establishing the School Garden Programme in Indonesia, which was initiated in March 2016 as part of SEAMEO College Research 6: A Participatory Action Research on School and Community-based Food and Nutrition Programme for Literacy, Poverty Reduction and Sustainable Development with funding support from the Japan Fund for Poverty Alleviation through the Asian Development Bank. Lesson learned from the programme, was that technology transfer to schools from a research and development centre like SEAMEO BIOTROP, is more effective compares to direct transfer to the community. Implementation of the transferred technology to schools is more sustainable than to the community. If a model is established in a school, operated by student and supervised by skillful teachers, the model could become the learning object of not only students, but also the surrounding community, especially parents of the students.

Following the successful implementation of the School Garden Programme, SEAMEO BIOTROP also launched another programme called Establishment of School Fruit Garden for Education, Production, Genetic Conservation, and Entrepreneurship in Agriculture Vocational School in Indonesia (SMARTS-BE) in February 2018 during its 50th-anniversary celebration. The SMARTS-BE Programme (also known as Non-Seasonal-Fruit Garden Programme) was an initiative of the Secretary-General, Ministry of Education and Culture (MoEC) of Indonesia, Dr Didik Suhardi, who has a deep concern on the low rate of fruits consumption by Indonesians and the high amount of imported fruits can be found easily in Indonesian markets. He instructed SEAMEO BIOTROP to collaborate with schools, especially the Agricultural Vocational Senior High Schools to establish a non-seasonal-fruit garden in the schools' areas. The programme is aimed to support the learning process to improve knowledge of students on fruit and proper fruit tree cultivation in the schools. The selected schools should have enough land to produce fruits on a commercial scale, in order to allow students to manage fruit production commercially (maintaining quality, harvesting, grading, packaging, and marketing). Vocational Senior High Schools in Agriculture joining this programme are distributed across Indonesia up to sub-district level; therefore, the schools could be encouraged to conserve and cultivate their local fruit species and varieties. Another objective of the programme is also to develop entrepreneurship atmosphere in the schools (production and selling of fresh fruits, processed products, and high-quality seedlings).

SEAMEO BIOTROP's SMARTS-BE programme is part of the implementation of the Center's programme thrust number two, i.e., Sustainable Management of Intensively Used Ecosystems/Landscapes and the commitment of the Centre to implement priority 4 of the SEAMEO 7 priority areas, i.e., Promoting Technical and Vocational Education and Training (TVET). The Agricultural Vocational Senior High Schools could play a significant role in disseminating knowledge and mature technology on fruit trees cultivation, production, and processing to the surrounding communities/farmers. The schools could also become the hubs for technology transfer from SEAMEO BIOTROP (i.e., together with its partner universities and research centres) to the community. Once established, the school fruit gardens programme could become a demonstration or reference model for communities to learn best practices on fruit gardening at their convenient time guided by students and supervised by well-trained teachers. In the long run, the programme is expected to increase fruit production in Indonesia.

Besides SMARTS-BE programme, SEAMEO BIOTROP has also be assigned by the Directorate of Technical and Vocational Education to train and supervised Vocational Senior High Schools in Agriculture in Indonesia to support food security and teaching factory programmes. With this programme, SEAMEO BIOTROP could transfer more expertise to the vocational schools, not only limited to fruit gardening.

This paper would present the transfer technology from SEAMEO BIOTROP, as a research and development centre, to Vocational Senior High Schools in Agriculture in Indonesia and other SEAMEO member countries. The paper also present skill development in industry 4.0 in the area of agriculture that has been introduced to selected schools, smart agriculture technology development at SEAMEO BIOTROP that later could also be transferred to the vocational schools in the future.

FRUIT TREE GARDEN PROGRAMME (SMARTS-BE PROGRAMME)

Overall planning of the programme has been conducted by SEAMEO BIOTROP's scientist, supported by experts from IPB University in early 2018, and subsequently, a SMARTS-BE team was set up. The working area for implementing the programme was divided into six clustered areas that cover region across Indonesia, from Sumatera in the West to Papua in the East. One coordinator was assigned for each cluster area, and they were responsible for preparing the proposal for activities in their respective regions.

There are several activities conducted in all areas, including 1) selection of target schools in each cluster; 2) setup coordination with the selected schools; 3) capacity building training for Head Masters, Teachers, and Student representatives from each school on fruit trees cultivation and fruit processing; 4) identification of the source of seeds and seedlings; 5) distribution of seeds and seedlings to schools; 6) planting; and 7) monitoring and evaluation.

FOOD SECURITY AND TEACHING FACTORY PROGRAMME

Different from SMARTS-BE programme, in the Food Security and Teaching Factory programmes, SEAMEO BIOTROP planned and offered training programmes that could be delivered to Vocational Senior High Schools in Agriculture. The Directorate of Technical and Vocational Education facilitated the communication between SEAMEO BIOTROP and the vocational schools. Skills that were agreed to be transferred to the vocational school teachers are: tissue culture technique, production and processing of edible mushrooms, hydroponic, aquaponic, cultivation and processing of lemon, cultivation and extraction of plant essential oils, processing of essential oil to become various products, and soymilk production.

The mechanism was that vocational schools free to choose what skills they want ed to be trained at SEAMEO BIOTROP. After attending the training for several days, the teachers would return to their respective vocational schools to implement their skills. Later, experts from SEAMEO BIOTROP visited the vocational schools to supervise and evaluate the implementation of the technology transfer. The experts helped the teachers to solve the problems so that the technology could be applied successfully.

SELECTION OF VOCATIONAL SCHOOLS

SEAMEO BIOTROP has collaborated with the Directorate of Technical and Vocational Educationl of MoEC to select priority schools across Indonesia. Of the 36 schools recommended by the Directorate, only 30 schools were finally selected as target schools in 2018. Six more vocational schools were selected to join the programme in 2019, while continuously monitoring and supervising the old group of vocational schools. Those vocational schools were chosen based on the availability of horticulture teaching activity, land for cultivation, fruit processing unit, competence teachers, the experience of the schools on fruit gardening, and school location.

The schools joining the Food Security and Teaching Factory programmes, were directly selected by Directorate of Technical and Vocational Education. There were 40 schools selected in 2018 and attend the training at SEAMEO BIOTROP. In 2019 the number was double to become 80 vocational schools. The vocational schools came from 27 provinces in Indonesia.

TRAINING PROGRAMME

SEAMEO BIOTROP in collaboration with the Research Centre for Orange and Sub-tropical Fruits (Balitjestro), in Batu-Malang, East Java, Indonesia had successfully conducted a training course for Head Masters, Teachers, and Students representatives from each vocational school from 31 July to 3 August 2018. This activity was officially opened by HE Prof. Dr Muhajir Effendy, MAP the former Minister of Education and Culture of Indonesia, who was also the President of the SEAMEO Council. The training was followed by training on fruit processing in collaboration with IPB University in Bogor, West Java, Indonesia.

Training programmes on tissue culture technique, production and processing of edible mushrooms, hydroponic, aquaponic, cultivation and processing of lemon, cultivation and extraction of plant essential oils, processing of essential oil to become various products, and soymilk production have been conducted at the laboratories and units of SEAMEO BIOTROP.

FIELD IMPLEMENTATION IN INDONESIA

Following the completion of soil sampling and analyses obtained from the target schools, a total number of 13,500 fruit tree seedlings from various species and varieties had already been distributed to those schools and several other vocational schools nearby SEAMEO BIOTROP. With guidance from their respective SMART-BE area coordinator, teachers who had learned and practiced from the training course started to cultivate the seedlings in their school's yard. The respective coordinator for each clustered area then conducted supervision, monitoring and evaluation by actively visiting each school to ensure the schools have planted and maintained the seedlings correctly. As part of the programme, each school was obliged to write a manual to plant a specific species of fruit trees thrive in their field. These manuals were then compiled and documented by SEAMEO BIOTROP's SMART-BE team.

As part of the SMART-BE programme, SEAMEO BIOTROP through its tissue culture laboratory has studied the mass propagation of wild edible fruits from Indonesian forests, namely matoa (*Pometia pinnata*) and tropical chestnut (*Castanopsis argentea*). These species have been successfully propagated using tissue culture technique. The seedlings produced through tissue culture would be distributed to the schools when ready.

To implement this SMART-BE programme, SEAMEO BIOTROP has received additional funding from the MoEC on top of its regular funding to run programmes and activities. Simultaneously, MoEC via the Directorate of Vocational Senior High School has also provided funding directly to the schools that participated in the programme. With the presence of fruit garden as a teaching model and as a teaching factory for fruit processing and entrepreneurship classes, this programme may have significant impacts on improving teaching programmes in the schools, both for teachers and students to enhance their knowledge and skills in horticulture; particularly, in subjects related to fruits production and processing.

SMARTS-BE programme potentially could be implemented in other SEAMEO Member countries facilitated by SEAMES, SEAMEO Centers in the respective countries, and respective government. SEAMES could assist in promoting the idea to the Ministry of Education of the SEAMEO Member countries, while SEAMEO Centers as partners could facilitate SEAMEO BIOTROP to explore potential collaboration with relevant ministries, universities, research centres, and private companies to jointly conduct the planning, training course, implementation, and supervision of the programme.

To ensure the sustainability of the programme, SEAMEO BIOTROP will allocate budget to maintain communication, and frequent visits to the participating schools. SEAMEO BIOTROP would also promote the schools to become a reference school in the province to extend the programme to other schools and community, and also to support corporate social responsibility (CSR) programmes of nearby state and private companies.

Since the beginning, SMARTS-BE programme has been a bridge of communication and collaboration among the participated Agricultural Vocational Senior High Schools. Communication among schools and with SMARTS-BE team was done using a social media group. Exchange visits and knowledge sharing among schools had also been accelerated since the establishment of the programme.

Through the corporate social responsibility (CSR) programme, two schools had successfully established a link to support their SMARTS-BE programme implementation, the first one is from a state forestry company based in East Java Province, and the second one is from a gold mining company based in Papua Province, respectively. With those supports, the schools could plant more fruit tree seedlings.

The vocational schools teachers attending various training course at SEAMEO BIOTROP have implemented their skills. A WhatsApp group was established to facilitate communication between participants and instructors, and also SEAMEO BIOTROP Board of Directors. This communication platform is important to monitor the progress of the implementation of technology at schools and to help the teachers should there is any problems.

TRANSFER TECHNOLOGY TO OTHER SEAMEO COUNTRY

Technology transfer has also been conducted by SEAMEO BIOTROP to other SEAMEO member countries, especially Cambodia for hydroponic and edible mushroom production, and Brunei Darussalam for hydroponic and food processing (soymilk production, mungbean juice, and ginger sweet). While hydroponic has become a skill to teach at the university (Royal University of Phnom Penh) in Cambodia, in Brunei Darussalam it has generated entrepreneurship among students and help the spread of hydroponic practices in the country.

SMART MONITORING

The SMARTS BE Monitoring System is the applications based spatial technology, developed and used to monitor and evaluate the SMARTS BE program with vocational schools throughout Indonesia as members of the programme. Utilization of geo-location information be able to represent objects comprehensively to answer rapid and accurate of the data needs.

The SMARTS BE Monitoring System application was developed in webgis and mobile (android) based platforms. Objectives of the SMARTS BE Monitoring System consist of build a geodatabase network between schools that are members of the SMARTS BE, Implemented precision agriculture mastermind in order to improve the competence of educational staff in perfecting and aligning the curriculum towards the industrial revolution 4.0 and Integration of fruitless agricultural crops with independent learning systems and oriented towards local fruit resources.

The architecture of the SMARTS BE Monitoring System consists of 3 (three) main parts of the application, database and connections between the two applications. Details of architecture of the system, presented in the image below.

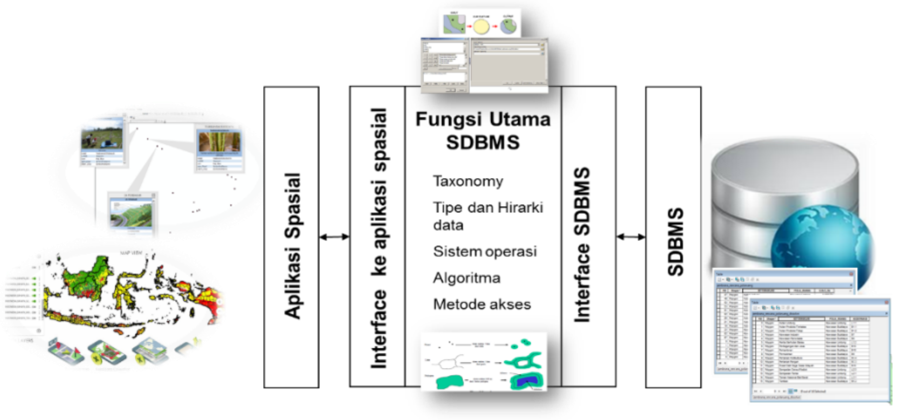


Figure 1. Architecture of SMARTS BE Monitoring System

The next stage of developing the SMARTS BE Monitoring System is expert system based on data and information that is collected from all members of the SMARTS BE.

So that the SMARTS BE Monitoring System will become an integrated application and become a one stop system in fruitless season development in Indonesia.

FURTHER DEVELOPMENT OF SMART AGRICULTURE

According to the Food and Agriculture Organization (FAO), global demand for primary food (staple foods) will grow by 60% in 2050 as a result of demographic growth and changes in welfare and income levels (FAO, WFP and IFAD, 2012). This increasing global demand is confronted with the uncertainty of sufficient food supply mainly due to global climate change which also correlates with the development/change of biological enemies such as plant pest and diseases. In response to this problem, there is a need to increase agricultural production, efficiency in farming inputs, and proper use of technology and agricultural management systems that are designed towards sustainable agriculture. Hence, the adoption of information technology and mechanization in agriculture in the form of climate smart agriculture is a mandatory since it allows cultivation activities and agricultural inputs to be adequately managed following the needs of plants, soil conditions and the environment. Smart agricultural technology combined with data-based precision agriculture will elevate more productive and resilient agriculture (Ryu, Yun, Miao, Ahn, Choi, & Kim, 2015).

Currently, the terms smart agriculture and precision agriculture have been used interchangeably (Fiehn, Schiebel, Avila, Miller, & Mickelson, 2018); (Suakanto, Engel, Hutagalung, & Angela, 2016). Precision agriculture is a combination of strategy, methodology, and technology for cultivating land with crops. The development and implementation of precision agriculture technology enable farmers to handle and manage the spatial variability of agricultural land efficiently. It can be achieved by utilizing information and communication technology, remote sensing, geographic information systems and navigation systems (GPS applications) that have developed rapidly to support agricultural activities (Aubert, Schroeder, & Grimaudo, 2012); (Fountas, Wulfsohn, Blackmore, Jacobsen, & Pedersen, 2006). Precision agriculture includes studies and efforts to manage spatial and temporal variability of land that can affect crop production (yields). This definition is coherence with the opinion of (Zhang, Shi, Jia, Seielstad, & Helgason, 2010) that precision agriculture focuses on efforts to regulate amount and accuracy of input in line with land conditions and the actual needs of plants. Precision agriculture includes on-farm activities such as land management and crop cultivation, and off-farm, such as the provision of superior seeds, transportation of products and warehousing. Precision agriculture requires that every agricultural activity, both on-farm and off-farm, is carried out correctly, in the right location, on time, in the right amount and the proper method (Gebbers & Adamchuk, 2010).

Precision agriculture is a revolution in agriculture field that was driven by world food needs that continue to rise due to human population growth, improving welfare and income of the people. It is also driven by the scarcity of agricultural land because it competes with the need for space for housing and human activities, which in turn triggers more studies and efforts to improve the quality of the agricultural system to be more efficient, more profitable and sustainable (Zhang, Hao, & Sun, 2017). In implementing the precision agriculture system, it requires a systematic monitoring of agricultural activities and efficient techniques so that it can be done intensively to monitor any changes that occur in crops. Managing agricultural inputs through sustainable management system such as using the right size and quantity of materials and tools/facilities, on-time handling, proper location and methods includes processing, planting, fertilizing, pest and disease handling and fuel uses, will guarantee not only the sustainability of agricultural activities but also environment (Mulla, 2013); (Gebbers & Adamchuk, 2010); (Khanal, Fulton, & Shearer, 2017).

Integration of GIS Technology, Remote Sensing and Information Technology can be used to monitor agricultural activities in a landscape through spatial-temporal computing models. With this model, monitoring of sub-unit scale of field activities can be carried out and can provide appropriate recommendations at each location depicted on the map/image. As the evolution of remote sensing, many models have been developed and used in agriculture. Several models have shown their capability to map and monitor spatial distribution of crop yields based on spectral information and topographic characteristics, soil characteristics, and meteorological data (Kersebaum, Lorenz, Reuter, Schwarz, Wegehenkel, & Wendroth, 2005). Some other monitoring models come up with the ability to map of the physiology of vegetation due to water stress (Moran, Inoue, & Barnes, 1997); (Gago, et al., 2015); (Veysi, Naseri, Hamzeh, & Bartholomeus, 2017), to map of nitrogen deficiency (Schlemmer, et al., 2013), to map of potential biomass (Machwitz, et al., 2014); (Bendig, et al., 2015), to map of pest and disease attacks (Sankaran, Mishra, Ehsani, & Davis, 2010) and to map of weed distribution within horticultural plants (Usha & Singh, 2013).

Another application of remote sensing in agriculture perspective is create a yield prediction map by using spectral formulas (Lobell, 2013) which led to further research to integrate those above mentioned models into spatially-explicit dynamic model which allows monitoring of agriculture using remote sensing data.

1. Assimilation of remote sensed data into spatially explicit dynamics model for rice yield and food sufficiency prediction

Real-time information on the status of rice production is one of important factors in the formulation of strategic decisions by farmers (producers), private sector, and government. For instance, timely information and accurate estimation of the distribution and development phases of rice plants, yield potential and harvest area are very crucial in the management of agricultural inputs such as fertilizer and irrigation, supply chain strategies, including import and export (Mosleh & Hassan, 2014); (Sakamoto, Van Nguyen, Ohno, Ishitsuka, & Yokozawa, 2006); (Gumma, Nelson, Thenkabail, & Singh, 2011). In addition, spatial planting lag is influenced by differences in paddy field types, geographical factors, and weather conditions. Those factors will cause variation in harvesting time and harvested area, which ultimately determines the dynamics of food supply and food sufficiency in certain districts, cities and throughout the country (Hartrisari, Imantho, & Suyamto, 2013); (Sari, Ismullah, Sulasdi, & Harto, 2010).

The interaction of soil plants and the environment, including weather, is a dynamic process and may not be explained by simple regression analysis. (Hartrisari, Imantho, & Suyamto, 2013) had integrated remoted sensed data with spatially explicit crop dynamics model to predict harvest time and rice production by regencies in West Java (Figure 1). Other significant research output by this study was a prospect of food sufficiency per district as one critical input in determining rice import's policy and its distribution (Figure 2, 3).

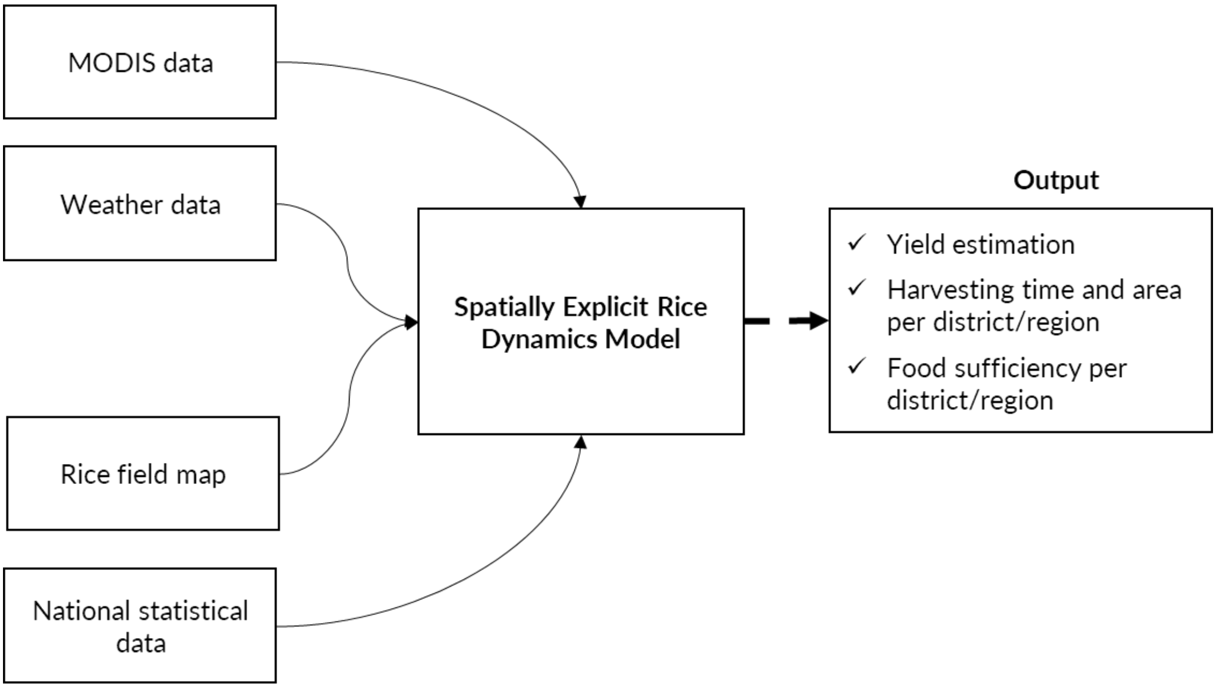


Figure 1. Framework of integration of remote sensed data into spatially explicit rice dynamics model for prediction of harvest time and area, yield and food sufficiency in West Java (Hartrisari, Imantho, & Suyamto, 2013).

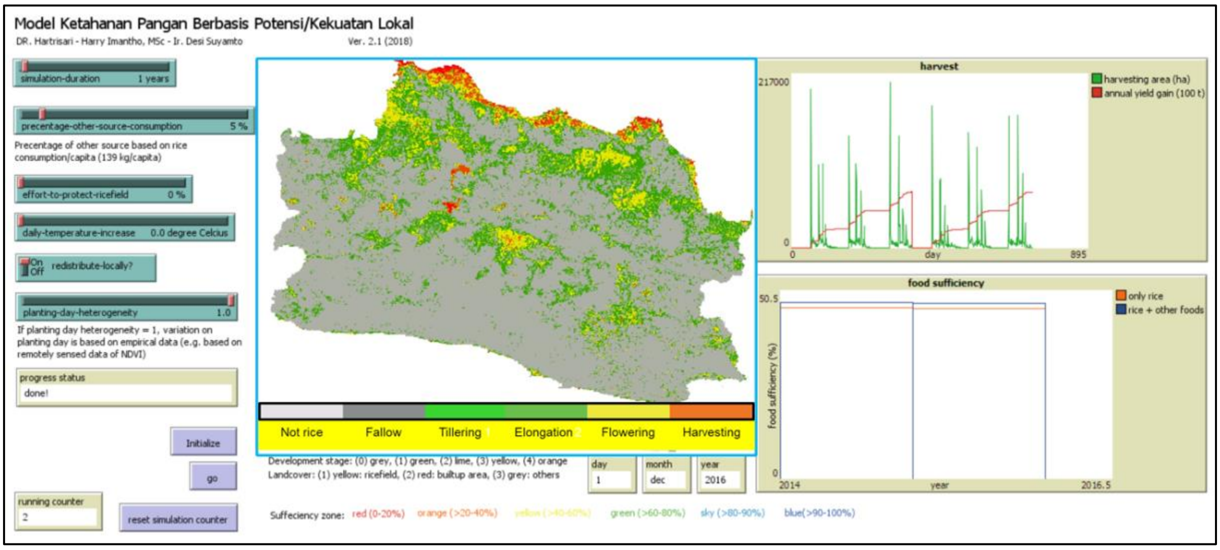


Figure 2. Daily dynamics simulation of standing crop based on MODIS planting lag for harvest time and area, yield and food sufficiency in West Java (Hartrisari, Imantho, & Suyamto, 2013).

2. Macro nutrient status retrieval by using Sentinel-2 data for oil palm precision fertilizer dosage recommendation

Indonesia is the world's largest palm oil producer and exporter. In accordance to The Central Bureau of Statistics Indonesia (BPS), in 2018, it's production reachs 47,6 million tons Crude Palm Oil (CPO) or 12.5% increased compare last year production. This increase was supported by about 12,76 million ha of oil palm plantation (Indonesian Oil Palm Statistics, 2019). The production in the future is predicted become higher, because the demand for source of fats and oil and biofuel is still growing (Comte, Colin, Whalen, Grünberger, & Caliman, 2012). However, this can lead to limitation of available land for oil palm plantation.

Fertilizer management and application highly affect oil palm productivity. Good fertilization management benefited to the plantation environment, maintain crop health and increase yields. Good fertilization management is also prerequisite for the sustainability of oil palm (Goh & Teo, 1998). According to (Goh & Teo, 1998), one of the steps of effective fertilizer management is to assess the nutrient requirements for the growth and yields targets and prevent the deficiency occur. The common method that has been used widely to detect the nutrient in oil palm is the Kjeldahl method. Although this method is simple, but it is time-consuming, destructive and costly, especially for large area plantation (Rendana, Rahim, Lihan, Idris, & Rahman, 2015).

Several studies were proven that integration of remote sensing and information technology produced many models such as crop yields monitoring model based on spectral information and topographic characteristics, soil characteristics, and meteorological data (Kersebaum, Lorenz, Reuter, Schwarz, Wegehenkel, & Wendroth, 2005), nitrogen deficiency's prediction model (Schlemmer, et al.,

2013) and model for potential biomass (Machwitz, et al., 2014); (Bendig, et al., 2015). (Kaliana, Seminar, Sudradjat, & Rusiawan, 2019) had integrated Sentinel-2A data and nutrient empirical model to retrieve near real time macro nutrient status (Nitrogen, Phosphor and Kalium) with satisfying results. The determination coefficient of developed models is 92% for N, 90% for P and 85% for K. Figure 3 and 4 show the output of spatial decision support system for oil palm precision fertilizer dosage recommendation.

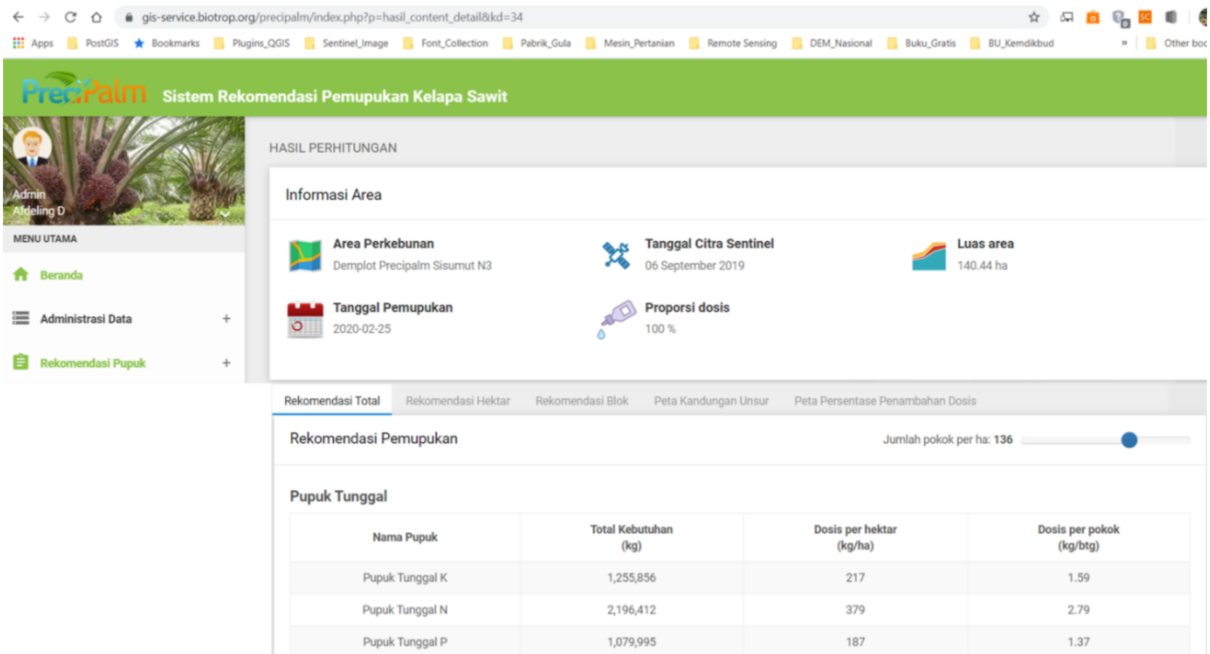
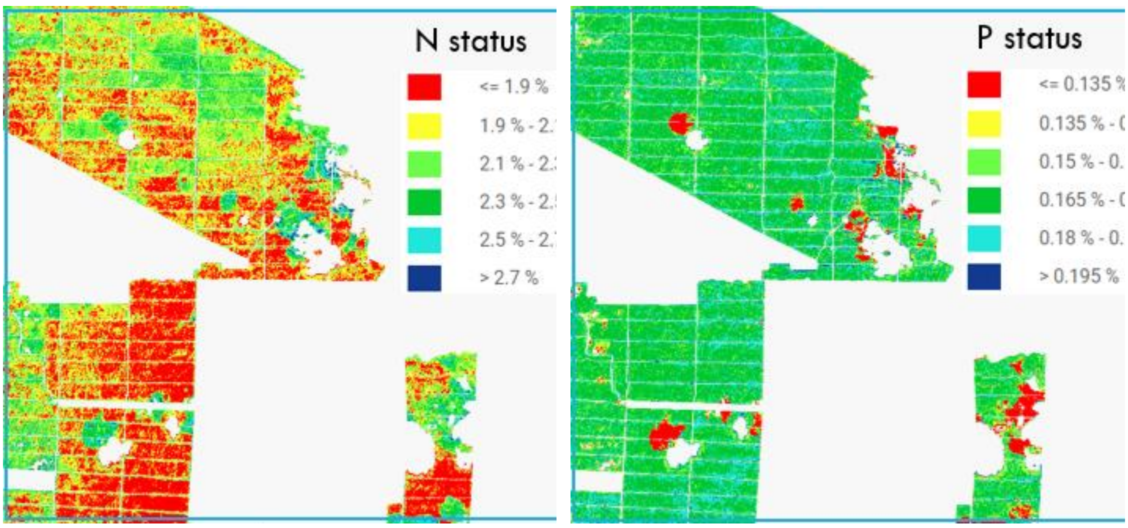


Figure 3. Web-based spatial decision support system for oil palm precision fertilizer dosage recommendation (Kaliana, Seminar, Sudradjat, & Rusiawan, 2019).



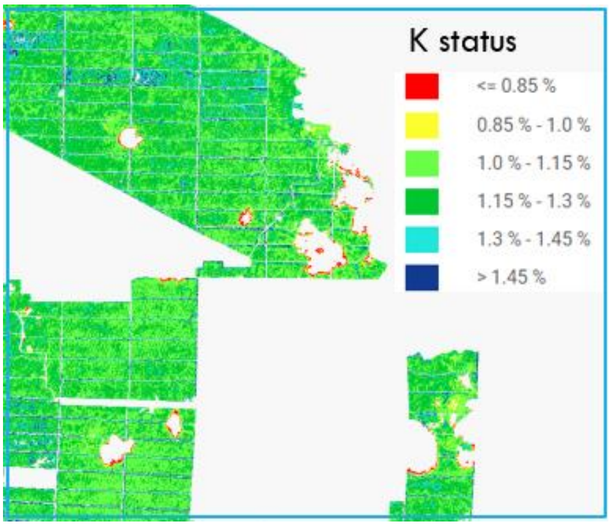


Figure 4. Near real time nutrient status retrieval as another output of web-based spatial decision support system for oil palm precision fertilizer dosage recommendation (Kaliana, Seminar, Sudradjat, & Rusiawan, 2019).

POTENTIAL COLLABORATION WITH TSUKUBA UNIVERSITY

SEAMEO BIOTROP could play a significant roles as technology transfer hub from universities and research centres, especially those related to agriculture. Best agricultural practices and new finding related to agriculture could be transferred from Tsukuba University to SEAMEO BIOTROP through a collaboration. The technology could then be transferred to schools in Indonesia and other SEAMEO member countries.

CONCLUSION

Research centres and universities are source of innovation and new technology. However, innovation and technology would not be useful for the community until it is implemented. Research centres and universities are mostly located in the central cities away from the users of the innovation and new technology, the farmers. In the meantime, Vocational Senior High Schools in Agriculture are mostly located up to sub-district that are closer to the farm and the farmers. The students are mostly the children of the farmers living nearby the vocational schools. Hence, this would be an effective way to transfer technology to the farmers. Transfer technology from research centres and universities to the vocational schools would enable to upgrade agricultural practices to adopt industrial 4.0 what is also called smart agriculture.

REFERENCES

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems* , 510-520.

Bendig, J., Yu, K., Aasen, H., Bolten, A., Bennertz, S., Broscheit, J., et al. (2015). Combining UAV-based plant height from crop surface models, visible, and near infrared vegetation indices for biomass monitoring in barley. *International Journal of Applied Earth Observation and Geoinformation* , 79–87.

Comte, I., Colin, F., Whalen, J. K., Grünberger, O., & Caliman, J. P. (2012). Agricultural Practices in Oil Palm Plantations and Their Impact on Hydrological Changes, Nutrient Fluxes and Water Quality in Indonesia. *Advances in Agronomy* , 71–124.

FAO, WFP and IFAD. (2012). *The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger.* Rome: FAO.

Fiehn, H. B., Schiebel, L., Avila, A. F., Miller, B., & Mickelson, A. R. (2018). Smart Agriculture System Based on Deep Learning. *Proceedings of the 2nd International Conference on Smart Digital Environment* (pp. 158-165). Rabat, Morocco: ICSDE'18.

Fountas, S., Wulfsohn, D., Blackmore, B. S., Jacobsen, H. L., & Pedersen, S. M. (2006). A model of decision-making and information flows for information intensive agriculture. *Agricultural Systems* , 192-210.

Gago, J., Douthe, C., Coopman, R. E., Gallego, P. P., Ribas-Carbo, M., Flexas, J., et al. (2015). UAVs challenge to assess water stress for sustainable agriculture. *Agricultural Water Management* , 9–19.

Gebbers, R., & Adamchuk, V. I. (2010). Precision Agriculture and Food Security. *Science* , 828–831.

Goh, K. J., & Teo, C. B. (1998). Agronomic principles and practices of oil palm cultivation. In K. J. Goh, S. B. Chiu, & S. Paramananthan, *Fertilizer management in oil palm agnomic principles and fields practices* (pp. 241-318). Selangor, Malaysia: Agricultural Crop Trust (ACT).

Goh, K., Teo, C., Chew, P., & Chiuw, S. (1998). Fertilizer management in oil palm agnomic principles and fields practices.

Gumma, M. K., Nelson, A., Thenkabail, P. S., & Singh, A. N. (2011). Mapping rice areas of South Asia using MODIS multitemporal data. *Journal of applied remote sensing , 5* (1).

Hartrisari, H. H., Imantho, H., & Suyamto, D. (2013). *Decision Support System on Spatial Planning for Food Security* (1st ed.). Bogor: SEAMEO BIOTROP.

Indonesian Oil Palm Statistics. (2019). *Statistik Kelapa Sawit Indonesia 2018.* Jakarta: BPS.

Kaliana, I., Seminar, K. B., Sudradjat, & Rusiawan, D. I. (2019). Nutrient content prediction of leaves in oil palm plantation using Sentinel-2 satellite imagery. *International Symposium on Smart Agriculture for Environmentally and Consumer Friendly Food Production* (pp. 100-107). Taiwan: National Pingtung University of Science and Technology.

Kersebaum, K. C., Lorenz, K., Reuter, H. I., Schwarz, J., Wegehenkel, M., & Wendroth, O. (2005). Operational use of agro-meteorological data and GIS to derive site specific nitrogen fertilizer recommendations based on the simulation of soil and crop growth processes. *Physics and Chemistry of the Earth* , 59–67.

Khanal, S., Fulton, J., & Shearer, S. (2017). An overview of current and potential applications of thermal remote sensing in precision agriculture. *Computers and Electronics in Agriculture* , 22-32.

Lobell, D. B. (2013). The use of satellite data for crop yield gap analysis. *Field Crops Research* , 56–64.

Machwitz, M., Giustarini, L., Bossung, C., Frantz, D., Schlerf, M., Lilienthal, H., et al. (2014). Enhanced biomass prediction by assimilating satellite data into a crop growth model. *Environmental Modelling & Software* , 437–453.

Moran, M. S., Inoue, Y., & Barnes, E. M. (1997). Opportunities and limitations for image-based remote sensing in precision crop management. *Remote Sensing of Environment* , 319–346.

Mosleh, M. K., & Hassan, Q. K. (2014). Development of a remote sensing-based "Boro" rice mapping system. *Remote sensing , 6* (3), 1938-1953.

Mulla, D. J. (2013). Twenty five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. *Biosystems Engineering* , 358–371.

Rendana, M., Rahim, S. A., Lihan, T., Idris, W. M., & Rahman, Z. A. (2015). A Review of Methods for Detecting Nutrients Stress of Oil Palm in Malaysia. *Journal of Applied Environmental and Biological Sciences , 5* (6), 60-64.

Ryu, M., Yun, J., Miao, T., Ahn, I.-Y., Choi, S.-C., & Kim, J. (2015). Design and implementation of a connected farm for smart farming system. *IEEE Sensors* .

Sakamoto, T., Van Nguyen, N., Ohno, H., Ishitsuka, N., & Yokozawa, M. (2006). Spatio–temporal distribution of rice phenology and cropping systems in the Mekong Delta with special reference to the seasonal water flow of the Mekong and Bassac rivers. *Remote Sensing of Environment , 100* (1), 1-16.

Sankaran, S., Mishra, A., Ehsani, R., & Davis, C. (2010). A review of advanced techniques for detecting plant diseases. *Computers and Electronics in Agriculture* , 1–13.

Sari, D. K., Ismullah, I. H., Sulasdi, W. N., & Harto, A. B. (2010). Detecting rice phenology in paddy fields with complex cropping pattern using time series MODIS data. *Journal of Mathematical and Fundamental Sciences , 42* (2), 91-106.

Schlemmer, M., Gitelson, A., Schepers, J., Ferguson, R., Peng, Y., Shanahan, J., et al. (2013). Remote estimation of nitrogen and chlorophyll contents in maize at leaf and canopy levels. *International Journal of Applied Earth Observation and Geoinformation* , 47–54.

Suakanto, S., Engel, V., Hutagalung, M., & Angela, D. (2016). Sensor networks data acquisition and task management for decision support of smart farming. *International Conference on Information Technology Systems and Innovation.* Badung, Bali: ICITSI.

Usha, K., & Singh, B. (2013). Potential applications of remote sensing in horticulture—A review. *Scientia Horticulturae* , 71–83.

Veysi, S., Naseri, A. A., Hamzeh, S., & Bartholomeus, H. (2017). A satellite based crop water stress index for irrigation scheduling in sugarcane fields. *Agricultural Water Management* , 70–86.

Zhang, R., Hao, F., & Sun, X. (2017). The Design of agricultural machinery service management system based on internet of things. *Procedia Computer Science* , 53-57.

Zhang, X., Shi, L., Jia, X., Seielstad, G., & Helgason, C. (2010). Zone mapping application for precision-farming: a decision support tool for variable rate application. *Precision Agriculture* , *11*, 103-114.