DEVELOPMENT OF SPATIAL DECISION SUPPORT SYSTEM
FOR VILLAGE BASED NATIONAL RICE PRODUCTION
(PHASE 1: DEVELOPING BASELINE OF SPATIALLY-EXPLICIT
DYNAMIC MODEL)

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EXECUTIVE SUMMARY

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. 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.

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. 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. 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.
The research entitled “Development of Spatial Decision Support System for Village Based National Rice Production (Phase 1)” has succeeded in addressing several important information on the physiological responses of rice to different fertilizer doses, environmental effects (weather) and cropping patterns on the three selected varieties. The dynamics of LAI are generally uniform, experiencing an increase in LAI until it reaches a maximum vegetative growth stage at 47 days after planting, and then decreases towards harvest time. The similar and consistent response is shown by NDVI which is derived from the Sentinel-2 imagery. NDVI has significant response to the fertilizer dosage treatment. A higher fertilizer dosage gives a higher NDVI value, especially in the early stages until maximum vegetative stage. However, cropping patterns and varieties cannot be distinguished through this NDVI value.

Drone imagery demonstrated its potential to differentiate cropping patterns and varieties. The index values generated using the Red and Green channels show the similar pattern as the NDVI generated using the Sentinel-2 image. Further processing is required to produce an empirical formula that represents the spatio-temporal relationship between signature reflectance and plant characteristics-based drone imagery.

The interaction of soil plants and the environment, including weather is a dynamic process and may not be explained by simple regression analysis, and its proven by this research. Understanding plant physiological responses and interaction of soil plants and the environment can be addressed by integrating remoted sensed data with spatially explicit crop dynamics model. This is the ultimate goal of this research which is expected to be achieved at phase 3 of research activities.
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1. INTRODUCTION

1.1 Background

Rice has become a staple food source in Indonesia, as evidenced by statistical data from the amount of rice consumption in 2018 reached around 29.57 Million Tons. Based on these data the determination of the paddy field area is an important aspect in determining the sustainability of food security. According to data from (Kementerian Pertanian, 2018) the area of paddy fields continues to change every year, in 2016 the area of paddy is 8,187 million hectares while in 2017 is 8,162 million hectares due to the dynamics of paddy plant growth tends to occur in a short time, so that monitoring of paddy is needed in near-real-time.

One of the method that is used in determining whether a land belongs to the paddy field or not is to use Remote Sensing approach. (Dong, et al., 2016) has mapped the paddy field area in Northeast Asia with the Remote Sensing approach using Landsat 8 Satellite Imagery. Paddy field mapping has also been carried out by (Cai, et al., 2019) using the time series Sentinel 1-2 image to obtain paddy field map in the Dongting Lake area in Hunan Province, China and field survey data that used to validate the accuracy of paddy field map.

Every object on earth has a different spectral reflectance, even in one variety of paddy can have different wavelengths that can be influenced by the variety, age, density, to the level of health / greenness of the plant. Spectral Signature identification is a method of Remote Sensing. According to (Vaesen, et al., 2001) there are several approaches in identifying Spectral Signature such as RVI, NDVI, PVI, WDVI and LAI. Based on the approach it is expected that using Spectral Signature can classify paddy to the level of species, age, and health.

Monitoring and forecast local crop production are critical steps in addressing food security problems at a global scale. The combined effects of a changing climate, growing population, soil loss, as well as the natural variability of weather, require methods that provide a timely and accurate assessment of crop growth and production (Huang, et al., 2019). Crop growth and production model are urgently needed to dynamically simulate crop phenology, leaf area index, biomass, water use and grain yield formation in response to variations in genotype, environment and management, as well as their interactions (de Wit, et al., 2015).

A DSS is an information system that supports a user in choosing a consistent response for a particular problem in a reduced time frame (Hamouda, 2011). DSS are computer-based systems, built in order to solve multi-scenario problems by analyzing the feasibility of each scenario in a short time in order to provide a near optimum solution among them. A DSS may also be applicable for multiple problems and the possible solutions may or may not integrate aspects of sustainable development (Mannina, et al., 2019).

Precision agriculture is one approach that can be used in overcoming problems in agriculture. The purpose of precision farming itself is to minimize (spending costs,
time, and the spread of pests and diseases), optimize the use of resources effectively and efficiently, and maximize the harvest from agricultural land. As stated by (Zhang & Kovacs, 202) precision agriculture (PA) is the application of geospatial techniques and sensors (e.g., geographic information systems, remote sensing, GPS) to identify variations in the field and to deal with them using alternative strategies. According to that statement, the need for geospatial techniques that is integrated with information systems will be used as a tool to deliver information from government level to farmer group level.

The advance of technological development in agriculture is not impossible to develop an agricultural information system that can help various problems that occur in agricultural land, currently has developed several information systems about rice farming such as IPB Digitani (IPB University), SIMOTANDI (Rice Plantation Monitoring Information System) from the Ministry of Agriculture, KATAM (Integrated Planting Calendar) which contains information related to the planting calendar developed by the BALINGBANGTAN (Agricultural Research and Development Agency) (Balitbangtan, 2015). This research is expected to build an information system that can be a tool for its users in terms of overcoming problems that arise in paddy agriculture in form of Web-GIS and Mobile App.

1.2 Research Framework

The goal of the overall (3 years) proposed research is to build and operate SIPANAS (Sistem Informasi Manajemen Padi Nasional), a Spatial Decision Support System for Village Based National Rice Production.

The 3-year research framework to achieve the goal is presented in Figure 1. The development of information systems will be divided into 3 (three) main stages. First stage is collecting basic data that will be obtained from the results of the analysis, field measurements, field survey, and some data obtained from government agencies. Second stage is the construction of several analytical models such as crop and field status baseline, spatial-explicit dynamic model and DDS for crop and field management model. Third stage is building the information system itself by integrating the results of the model that will be made in the previous stage and will be displayed in the form of Web-GIS and Mobile App as a product in the delivery of information.

1.3 Problem Statement

In Indonesia, the management of paddy fields still uses conventional methods, which is still based on the interpretation or fundamental knowledge of each farmer. Therefore, it needs an information system that can help each farmer in determining the management of paddy plants based on the level of need of the paddy.

1.4 Research Objectives

The general objective of this research is to develop spatial decision support system for village based national rice production (SIPANAS, Sistem Informasi Manajemen Padi Nasional). The specific objectives of this study are:
1. Identifying Paddy plantation to the level of the variety, age and health level based on the spectral signature reflectance of the paddy (1st year),

2. Developing a baseline rice growth and development model (1st, 2nd year),

3. Building a spatial-explicit dynamic model, in order to get (e.g. growth, yield, water balance, nutrient status and pest and disease) (1st, 2nd year),

4. Building a model to determine DSS for precision crop and field management (e.g. crop and field management, fertilizer management, water management, pest and disease management, CSA (Climate Smart Agriculture), adaptation/mitigation option and GHG (Greenhouse Gas) inventory) (2nd year).

5. Developing an information system as a means of delivering information for each stakeholder from government level to farmer groups level (3rd year).
Figure 1 Research Roadmap for Spatial Decision Support System for Village Based National Rice Production (SIPANAS)
1.5 Expected Output

The study on developing spatial decision support system for village based national rice production (named: SIPANAS) is divided into three phases, which are expected to be carried out within three consecutive years. In accordance with above specific objectives, each phase is expected to:

Phase 1: produce empirical formulas which represent spatio-temporal relationships among signature reflectance with growth and development stages, macro nutritional and health status of rice. Those empirical formulas with field (soil) and environmental status/information are required in developing baseline of spatially-explicit dynamic model. The study on developing spatial decision support system for village based national rice production (called SIPANAS).

Phase 2: produce validated spatially-explicit dynamic model with DSS capability to support crop and field management.

Phase 3: produce SIPANAS, a web-GIS and mobile apps platform which integrates spatially-explicit dynamic model and DSS for precision crop and field management.

1.6 Research Scope

The stages in building a precision agricultural information system are divided into several sections, which can be seen in Figure 1. Each part of this research section has a link to achieve the main goal of building a development of spatial decision support system for village based national rice production precision agricultural information system.

In the early stages of research, observations will be made in the form of mapping paddy fields for the research location, designing and making experimental plots with variety parameters, nutrient input and recording and analyzing the spectral characteristics of rice plants during one cycle of growth and development. Field observation data will be processed and evaluated to produce a baseline empirical formula for the development of SIPANAS.

The next stage is to build an information system prototype using Web-GIS technology and Cellular Applications which will be used as tools in collecting field data obtained from farmers (e.g. location, area, planting date, variety, management, planting density, fertilizer application rate and cropping calendar/pattern).

The next stage of this research is processing, in this section, an analysis model will be developed to determine the basic status of crops and land. This basic information is needed in developing a spatiotemporal dynamic model of rice crops. The next stage of the system is the future decision which will be built in the form of DSS for precision agriculture to help farmers make decisions in rice field management. Processing and future decision stages will be carried out in the second year of research. The final stage of this research is the finalization of the information system by integrating the system itself with the model created in the previous stage, which is expected to be completed in the second or third year of the research process. The
framework in the development of a precision agricultural information system is presented in Figure 2.

![Diagram](image)

**Figure 2** Precision agriculture information system framework
2. **BENEFITS AND IMPORTANCE OF RESEARCH**

In general, the results of this study are expected to be useful to support precise and intelligent rice field management. The SIPANAS information system developed will also be useful for farmers in managing paddy fields using near-real-time information. Furthermore, the results of this study (SIPANAS) can be accessed and used by stakeholders from the government level to the farmer group level as a tool in managing and utilizing spatial agricultural resources more optimally.

This Phase 1 research is a crucial step to produce an empirical formula that represents the spatio-temporal relationship between signature reflectance and growth and development stages, macro nutrient status and health status of rice plants. Empirical formulas with land (soil) and environmental status / information are needed in developing a spatial-explicit baseline dynamic model for rice. This Phase 1 research is important to be carried out as part of the development of a precision agricultural information system in Indonesia, which will be packaged in a Spatial Decision Support System for Village-Based National Rice Production which will be called SIPANAS.
3. METHODOLOGY

3.1 Time and Location
The research was started in March / April 2020 as the implementation of Phase 1 Research in 2020. The focus of Phase 1 in this research is to produce an empirical formula that represents the spatio-temporal relationship between signature reflectance and stages of growth and development, macro nutrient status and health status of rice plants. The empirical formulation is based on data from field research.

The location of the field research is in Pasir Kaliki Village, Rawamerta District, Karawang Regency, West Java. The location selection was based primarily on its suitability for planting rice in the research period until the end of November 2020.

3.2 Data and Tools
3.2.1 Required Data
Data that used in this research will be obtained from several sources such as Google Earth, ESA (European Space Agency), BIG 9 (Geospatial Information Agency), BMKG (Meteorology, Climatology and Geophysics Agency) and primary data obtained from field measurements. The data needed in this research is presented in Table 1.

<table>
<thead>
<tr>
<th>Data</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESA (European Space Agency)</td>
<td></td>
</tr>
<tr>
<td>- Sentinel 2</td>
<td>Vegetation index temporal analysis</td>
</tr>
<tr>
<td>Field Measurements</td>
<td></td>
</tr>
<tr>
<td>- Location Survey</td>
<td>Validate satellite imagery approach</td>
</tr>
<tr>
<td>- Spectral reflectance</td>
<td></td>
</tr>
<tr>
<td>Drone Imagery (RGB)</td>
<td>High resolution imager</td>
</tr>
<tr>
<td>Data Cuaca</td>
<td>Basic data</td>
</tr>
<tr>
<td>Farmer Contribution Information/Data</td>
<td>Basic data</td>
</tr>
<tr>
<td>- Location</td>
<td></td>
</tr>
<tr>
<td>- Area</td>
<td></td>
</tr>
<tr>
<td>- Variety</td>
<td></td>
</tr>
<tr>
<td>- Management/cultural practice</td>
<td></td>
</tr>
<tr>
<td>- Planting density</td>
<td></td>
</tr>
<tr>
<td>- Fertilizer application rate</td>
<td></td>
</tr>
<tr>
<td>- Cropping calendar/pattern</td>
<td></td>
</tr>
<tr>
<td>BIG</td>
<td>Basic data</td>
</tr>
<tr>
<td>- Administrative boundary</td>
<td></td>
</tr>
<tr>
<td>- DEMNAS</td>
<td></td>
</tr>
<tr>
<td>Kementan/ATR</td>
<td>Basic data</td>
</tr>
<tr>
<td>- Paddy field map</td>
<td></td>
</tr>
</tbody>
</table>
3.2.2 Required Tools

In order to achieve the expected results, some software and hardware are needed for data acquisition, processing and analysis. The list of software and hardware used in this research are shown in Table 2.

Table 2 Required tools

<table>
<thead>
<tr>
<th>Tools</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td></td>
</tr>
<tr>
<td>- ArcGIS 10.5</td>
<td>Spatial data analysis</td>
</tr>
<tr>
<td>- R studio</td>
<td>Statistical data analysis</td>
</tr>
<tr>
<td>- Microsoft Excel</td>
<td>Digital number vegetation analysis</td>
</tr>
<tr>
<td>- ArcGis Server</td>
<td>Service control</td>
</tr>
<tr>
<td>- PostgreSQL</td>
<td>Data storage</td>
</tr>
<tr>
<td>- ArcGis Online</td>
<td>Web-GIS</td>
</tr>
<tr>
<td>- AppStudio for ArcGis</td>
<td>Mobile App</td>
</tr>
<tr>
<td>- Ocean Optics</td>
<td>Spectrophotometer data processing</td>
</tr>
<tr>
<td>- AgiSoft Photoscan</td>
<td>Drone image processing</td>
</tr>
<tr>
<td>Hardware</td>
<td></td>
</tr>
<tr>
<td>- Garmin Geo-Explore</td>
<td>Point data acquisition</td>
</tr>
<tr>
<td>- Spectrophotometer</td>
<td>Acquisition of spectral signature reflectance</td>
</tr>
<tr>
<td>- Drone</td>
<td>High resolution image (RGB)</td>
</tr>
</tbody>
</table>

3.3 SIPANAS Development Roadmap

The roadmap for the development of the SIPANAS information system is divided into 3 (three) main stages (Figure 3). The first is collecting basic data that will be obtained from field observations and measurements, and secondary data obtained from agencies / institutions. Second is the development of several analytical models such as baseline status of crops and fields, spatial dynamics models of rice plants and DSS for management of paddy fields and rice crops. Then the third is to build an information system by integrating the results of the model created in the previous stage and displayed in the form of Web-GIS and Cellular Applications as products in delivering information.
Figure 3 Research Roadmap for Spatial Decision Support System for Village Based National Rice Production (SIPANAS)
3.4 Spectral Characteristics Analysis of Rice Crops

Analysis of the spectral characteristics (spectral signature reflectance) of rice plants is a step to obtain the reflection value in the wavelength range of 340 - 900 nm with an interval / channel that is denser than the satellite image channel / band. The results of these spectral measurements were used in the actual analysis of the Vegetation Index (VI) of each experimental plot observed during the growth and development cycle of rice plants.

Drones will be used to acquire realtime data on rice plants during the period of growth and development until harvested in a wider coverage of rice fields. The results of the Vegetation Index (VI) analysis from the drone data will be validated using the VI data obtained from the VI analysis obtained from the Sentinel-2A image. The spectral value of Sentinel-2A is assumed to be the VI value that is closest to the actual rice plant because it uses the NIR wavelength. The process of analyzing the spectral characteristics of rice plants is shown in Figure 4.

![Figure 4 Spectral signature reflectance analysis](image)

The multispectral camera's remote sensing imaging technology uses green, red, red edge, and near infrared waves to capture visible and invisible figures of plants and vegetation (DroneZon, 2020). The electromagnetic wavelength is divided into filters using several instruments that are sensitive to wavelengths, including the frequency of human vision. Spectral classification of multispectral drones is shown in Table 3.
Table 3 Multispectral drone wavelength. Source: (adminjogjasky, 2018)

<table>
<thead>
<tr>
<th>Drone Multispectral Band</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>450-520</td>
</tr>
<tr>
<td>Green</td>
<td>520-600</td>
</tr>
<tr>
<td>Red</td>
<td>600-690</td>
</tr>
<tr>
<td>Near Infrared (NIR)</td>
<td>750-900</td>
</tr>
</tbody>
</table>

3.5 Spatially Explicit Crop Dynamic Model

3.5.1 Sub Model of Crop Growth and Development

Growth and development of rice grown as an annual from seed begin with the germination of seed and ends with the formation of grain. During that period, growth and development of the rice plant can be divided into two phases: vegetative and reproductive.

These two phases deal with growth and development of different plant parts. Growth and development of rice are a continuous process rather than a series of distinct events. The vegetative phase deals primarily with the growth and development of the plant from germination to the beginning of panicle development inside the main stem. The reproductive phase deals mainly with the growth and development of the plant from the end of the vegetative phase to grain maturity. Both phases are important in the life of the rice plant. They complement each other to produce a plant that can absorb sunlight and convert that energy into food in the form of grain. The vegetative and reproductive growth phases are subdivided into groups of phonological stages. The vegetative phase consisted of four stages: (1) emergence, (2) seedling development, (3) tillering and (4) internode elongation. Similarly, the reproductive phase of growth is subdivided into five stages: (1) pre-booting, (2) booting, (3) heading, (4) grain filling and (5) maturity (Vanderlip & Arkin, 1997; Warrington & Kanemasu, 1983; de Vries, et al., 1989).

![Figure 5 Tahap – tahap perkembangan tanaman (Handoko, 1992)](image)

Growth and development of rice influences by environmental condition, especially water availability, temperature, solar radiation and soil fertility (Vanderlip & Arkin, 1997), (Warrington & Kanemasu, 1983), (van Heemst, 1986) and (de Vries, et al., 1989) introduced heat unit/thermal unit concept. This concept assumed rice crop development rate is proportionally with temperature. The relation of development stage/phase and temperature is expressed:
where, $TU_s$ : thermal unit at stage, $s$
$T$ : average daily temperature ($^\circ$C)
$T_o$ : base temperature ($^\circ$C); for rice crop = 15 $^\circ$C

Then if development stages are divided into four phases proportionally as shown in Figure 6, then rice crop development stages can be calculated as follow:

$$S_t = \sum_{i=1}^{4} s_{i.t-1} + \max \left( 0, \min \left( 0.25, \frac{T-T_o}{TU_s} - \frac{3}{4} \right) \right)$$

Rice crop growth is resultant product of photosynthesis activities. Leaf of plants absorb some part of solar radiation, called Photosynthetic Active Radiation (PAR) which is part of light solar radiation spectrum around 400 – 700 nm of wavelength. This PAR is about 50% of solar radiation received on top plant canopy. The crop ability to convert solar energy into dry matter is called Light Use Efficiency (LUE). LUE describes amount of biomass increase per total absorbed radiation, and it’s stated by the following equation:

$$dW_p = LUE \cdot Q_{int}$$

where, $dW_p$ : dry matter of plant organ increase (kg m$^{-2}$)
$LUE$ : light use efficiency coefficient
$Q_{int}$ : absorbed solar radiation (MJ m$^{-2}$ day$^{-1}$)

$$Q_{int} = Q_0 - Q_0 e^{-k \cdot LAI}$$

where, $Q_{int}$ : absorbed solar radiation (MJ m$^{-2}$ day$^{-1}$)
$k$ : extinction coefficient of canopy ($\approx 0.5$)
$Q_0$ : net solar radiation incident upon the uppermost canopy (MJ m$^{-2}$ day$^{-1}$)
$LAI$ : leaf area index = f (vegetation index derived from drone imagery)

Figure 6 describes rice crop growth and development dynamics process as function of environmental factors.
Figure 6 Forester diagram of rice crop growth and development (Handoko, 1992)

3.5.2 Rice Crops Dynamics Water Content and Land in Rice Fields

Spatial and temporal variation of paddy field water content is expressed by soil water balance formula as follow:

\[ \theta_i = \theta_{i-1} + If_i - Ro_i - ET_i - Pc_i \]  \hspace{1cm} (5)

where, \( \theta_i \) : soil water content (mm) at day-\( i \)
\( \theta_{i-1} \) : previous soil water content (mm)
\( If_i \) : infiltration (mm) at day-\( i \)
\( Ro_i \) : surface run-off (mm) at day-\( i \)
\( ET_i \) : evapotranspiration (mm) at day-\( i \)
\( Pc_i \) : percolation (mm) at day-\( i \)

The infiltration can be calculated as follow:

\[ If_i = P_i + Ig_i - Ro_i \]  \hspace{1cm} (6)

where, \( If_i \) : infiltration (mm) at day-\( i \)
\( Ro_i \) : surface run-off (mm) at day-\( i \)
$P_i$ : precipitation (rainfall) (mm) at day-i

$Ig_i$ : irrigation (mm) at day-i

Water losses through evapotranspiration is calculated by using Penman-Monteith’s method (Van Lier, et al., 1999; Smith, 1992). This method is recommended by FAO as a best standard for evapotranspiration calculation. The advantages of the Penman-Monteith Method can be applied globally without additional parameters and it has been calibrated with several types of lysimeters (Allen, et al., 1998). In accordance to Penman-Monteith’s method, reference evapotranspiration ($ET_0$) is calculated:

$$ET_0 = \frac{0.408\Delta(Rn-G) + \gamma \frac{900}{T+273} U_2 (e_s-e_a)}{\Delta + \gamma (1+0.34U_2)}$$

(7)

where, $ET_0$ : reference evapotranspiration (mm/day)

$Rn$ : net solar radiation (MJm$^{-2}$ day$^{-1}$)

$T$ : temperature ($^\circ$C)

$G$ : flux density of soil surface = 0.1(T$_i$ – T$_{(i-3)}$) (MJm$^{-2}$day$^{-1}$)

$U_2$ : wind speed (m/second)

$(e_s-e_a)$ : water vapor pressure deficit (kPa $^\circ$C$^{-1}$)

$\Delta$ : slope/gradient of water vapor pressure curve (kPa $^\circ$C$^{-1}$)

$\gamma$ : psychometric constant (kPa $^\circ$C$^{-1}$)

$$\Delta = \frac{2504 \exp \left(\frac{17.27 T}{T+237.3}\right)}{(T+237.3)^2}; \text{ dan } \gamma = 0.00163 \left(\frac{P}{\lambda}\right)$$

(8)

where, $\gamma$ : psychometric constant (kPa $^\circ$C$^{-1}$)

$P$ : psychometric constant (kPa)

$\lambda$ : laten heat of evaporation = 2.45 MJ kg$^{-1}$

$P$ is calculated as function of elevation ($z$), as follow:

$$P = 101.3 \left(\frac{293-0.0065z}{293}\right)^{5.26}$$

(9)

Saturated ($e_s$) and actual ($e_a$) vapor pressure are calculated with the following formula:

$$e_s = e_0(T) = 0.611 \exp \left(\frac{17.27 T}{T+237.3}\right)$$

(10)

$$e_a = e_0(T_{BB}) - \gamma_{asp} (T_{BK} - T_{BB})P$$

(11)

where, $\gamma_{asp}$ : Aspiration Asman constant (0.0008)

$P$ : atmosphere pressure (kPa)

$T_{BK}$ : dry bulb thermometer ($^\circ$C)

$T_{BB}$ : wet bulb thermometer ($^\circ$C)
Reference evapotranspiration ($ET_0$) is defined as the rate of evapotranspiration from no water limitation large surfaces and densely overgrown with uniform height grass (8-15 cm) and albedo 0.23 (Allen, et al., 1998). Evapotranspiration is consisted evaporation and transpiration. Maximum water losses through evaporation at paddy field is calculated as follow:

$$E_m = ET_0 \cdot e^{-k \cdot LAI}$$  \hspace{1cm} (12)

where, $E_m$ : maximum evaporation (mm day$^{-1}$)

$k$ : extinction coefficient of canopy ($\approx 0.5$)

$ET_0$ : reference evapotranspiration (mm day$^{-1}$)

$LAI$ : leaf area index = f (vegetation index derived from drone imagery)

Water losses through evaporation is happened on top (surface) layer only. Actual evaporation then is calculated by the following equation:

$$Ea_i = Em_i \cdot \frac{SWC1_i}{FC1_i}$$  \hspace{1cm} (13)

where, $Ea_i$ : surface layer actual evaporation at day-i (mm day$^{-1}$)

$Em_i$ : maximum evaporation (mm day$^{-1}$)

$SWC1_i$ : soil water content at layer 1 at day-i (mm day$^{-1}$)

$FC1_i$ : saturated water content (field capacity) at layer 1

Water losses through transpiration from each layer is then calculated by the following equation:

$$Tr1_i = Tm_i \cdot \left( \frac{SWC1_i - WP1}{FC1_i - WP1} \right)$$  \hspace{1cm} (14)

$$Tr2_i = Tm_i \cdot \left( \frac{SWC2_i - WP2}{FC2_i - WP2} \right)$$  \hspace{1cm} (15)

$$Tm_i = ET0_i - Em_i$$  \hspace{1cm} (16)

where, $Tr1_i, Tr2_i$ : transpiration from layer 1 and 2 at day-i (mm day$^{-1}$)

$Tm_i$ : maximum transpiration (mm day$^{-1}$)

$Em_i$ : maximum evaporation (mm day$^{-1}$)

$SWC1_i, SWC2_i$ : soil water content at layer 1 and 2 at day-i (mm day$^{-1}$)

$FC1, FC2$ : saturated water content (field capacity) at layer 1 and 2

$WP1, WP2$ : water content at permanent wilting point at layer 1 and 2

Thus, actual transpiration of paddy field is expressed:

$$Ta_i = Tr1_i + Tr2_i$$  \hspace{1cm} (17), SWC > WP

$$Ta_i = Tm_i$$  \hspace{1cm} (18), SWC ≥ FC
Furthermore, water losses through percolation ($P_c$) will occur when $\text{SWC}_1 > \text{FC}_1$:

$$P_c_i = \text{SWC}_1 i - \text{FC}_1$$

And water losses through sub surface drainage ($D_r$) will occur when $\text{SWC}_2 > \text{FC}_2$:

$$D_r_i = \text{SWC}_2 i - \text{FC}_2$$

3.5.3 Plant Nutrition Dynamics

Rice crop production sustainability is depended on proper management practices including putting more organic matter plus liming and using inorganic fertilizer (Fegeri & Balligar, 2001; Fenning, et al., 2005; Yan, et al., 2007; Sukristiyonubowo, et al., 1993; Whitbeard, et al., 2000). Previous researchers reported that rice crop responses to fertilizers was vary depending on varieties, soil, climate, and cultural practices (Min, et al., 2007; Cho, et al., 2012; Fegeri & Balligar, 2001). Previous studies also reported that nutrient uptake depends on variety, cultural practices, nutrients supply, and climate (Sukristiyonubowo, et al., 2016; Singh, et al., 2001).

Those studies were proven that soil and crop nutrient dynamics depended on environmental factors such weather, soil physics and chemical condition, pH and additional nutrient supplies. Figure 8 shown the dynamics of soil and rice crop N
nutrient status. Nutrient status on paddy fields are also vary since soil physics and chemical condition, pH and even micro climate at any locations are totally different.

Nutrient status will be approached by greenness index of rice crop. Since nutrient status will vary following the growth and development of rice, thus temporal and spatial variety will be address by coupling drone data and crop nutrient model.

Nitrogen status one of nutrient that has high correlation with greenness index of rice. An experimental plot will be designed to reveal the correlation and derive empirical model on calculating macro nutrient (N, P and K) from drone multispectral data. Empirical model of baseline (actual) crop nutrient status will be generated using statistical method. Several activities in generating empirical model of baseline crop nutrient status is drawn in Figure 9.
Estimation of additional fertilizer needed by crop based on macro nutrient content (N, P, K) on rice crop leaves and macro nutrient content on soil obtained from previous phase. This baseline fertilizer demand is calculated by the following equation:

\[
VN = \left( \frac{CN}{LN} \right) . VN_R \\
VP = \left( \frac{CP}{LP} \right) . VP_R \\
VK = \left( \frac{CK}{LK} \right) . VK_R
\]

where, \( VN, VP, VK \) : additional N, P, K needed by crop  
\( CN, CP, CK \) : critical level of N, P, K on crop (% dry matter)  
\( LN, LP, LK \) : nutrient (N, P, K) content based on multispectral data (% dry matter)  
\( VN_R, VP_R, VK_R \) : previous/optimum recommendation fertilizer dosage (kg ha\(^{-1}\))

### 3.6 Field Experiments

#### 3.6.1 Experimental Design

Field experimentation will be conducted to facilitate measurement of rice spectral signature according to variation of variety, planting technique, and rate of fertilizer. These three factors are considered as treatments, and will be implemented in the field experiment using research design of randomized complete block design (RCBD). The treatments in the RCBD is arranged as the following:
1. Rate of fertilizer application (F) as main block, consisting three levels:
   a. F1-At recommended level according to (Permentan No.40/Permentan/OT.140/4/2007, 2007)
   b. F2-At 30% higher than the recommendation
   c. F3-At 30% lower than the recommendation
2. Planting technique (P) as sub-main block, consisting three levels:
   a. P1-Jajar Tegel. Jajar Tegel is a method of planting rice seedlings at the same distance, for example 25 cm x 25 cm, resulting in a population of 160,000 clumps per ha.
   b. P2-Jajar Legowo 2: 1 (single seed technique), and generally denoted as 25 x 12.5 x 50. Jajar Legowo 2: 1 is done by planting rice seeds in two rows parallel blocks at a distance between rows 25 cm and a distance in rows of 12.5 cm. The distance between blocks is twice the distance between the rows within the block (eg 50 cm). Jajar Legowo 2: 1 produces a population of 213,300 bushels per ha.
   c. P3- Jejer Manten (double seed technique). Jejer Manten, denoted as 30 x 5 x 30, is a method of planting rice seeds 30 cm apart. At each planting point, plant two seedlings at a distance of 5 cm between the seedlings. Jejer Manten produces a population of around 189,350 clumps of rice per ha.

![Diagram](image.png)
3. Rice variety (V) as the main sub-blocks representing the three most common varieties planted by farmers in the research location, namely:
   a. V1-Variety 1 (Ciherang Bima)
   b. V2-Variety 2 (Inpari 32)
   c. V3-Variety 3 (Pandan Wangi)

   Each treatment has three levels, so there are 27 treatment combinations (namely: 3x3x3). If each treatment will be repeated 3 (three) times, it will produce 27x3 = 81 experimental units (plot). By considering that the characteristics of each plot will be associated with one Sentinel 2 image pixel, the area per plot is 10 m x 10 m = 100 m², so an area of 8100 m² is required. At the field experiment location, the distribution of the plot positions will be adjusted to match the pixel distribution of Sentinel 2 images.

   During the study, all research plots received sufficient irrigation water. Weeds and plant pests are controlled manually or chemically as needed.
3.6.2 Observation and Measurement

Observations and measurements will be carried out to obtain plant, soil, and environmental parameter data.

Observation of plant parameters includes growth and development. Growth parameters include, among others: leaf area, plant height, number of tillers, weight of seeds / plant, crop yield per plot (tonnes / ha).

Observation of plant development includes observing and measuring from emergence to seed maturity. Panicle initiation was identified as when the panicle appeared as a 1.0 - 1.5 mm long white hairy cone on the main stem. Flowering is identified as when the stamens are visible. Ripe seeds are identified as the time when 10-15% of grain in panicles is still green.

The nutritional status of the plants and the color of the plants (especially the canopy / leaves) will also be measured and observed regularly. The measurement of the nutritional status of the plants will be carried out using chemically appropriate methods. Meanwhile, plant color measurements will be measured using a leaf chart (BWD) and other methods including using drones.

Observations of soil parameters include: soil nutrient status (N, P, K, Mg) and soil physical characteristics (density, soil texture, soil moisture content at the point of permanent wilting and field capacity).

Observations of environmental parameters include: weather conditions (solar radiation, minimum maximum temperature, relative humidity, wind speed, rainfall). Weather conditions are measured live at the test site using an automatic weather station (AWS).

Measurements and observations were made at specific time intervals depending on the temporal resolution requirements for data analysis. For example, the measurement / observation of weather data is daily (daily), crop data every 5 or 10 days (taking into account the temporal resolution of image acquisition by Sentinel 2), soil physics once during the experiment, soil and plant nutrient status twice during the experiment at the vegetative and generative stages.

3.6.3 Field Survey

Field surveys will be conducted to obtain data / information on cultural practices in the study area at the village / district level. The survey will use a questionnaire as an instrument, with farmer respondents and agricultural officers. Data / information collected in the field survey includes: rice field location, rice field area, varieties, management / culture practices, planting density, dosage of fertilizer application, and calendar / cropping pattern.

3.6.4 System Information Prototype

The system information prototype is the first step in the development of the overall system, by involving users (farmers) so that farmers can contribute directly to system development. The system is designed as a means of collecting data from farmers directly, targeted to be built in the first year of research. The data obtained will be used at a later stage in making agricultural models to be developed. The system information prototype framework is shown in Figure 10.
Figure 10 Framework of system information prototype

- Location
- Area
- Planting date
- Variety
- Management/cultural Practice
- Planting density
- Fertilizer application rate
- Cropping calendar/patter
4. RESULTS AND DISCUSSION

4.1 Description of Experimental Plots on Research Areas

Experimental plots were made according to the treatment, namely the fertilization dose (F) as the main plot, and variety of varieties (V) and planting technique (P) as subplots. Each treatment was repeated three times. The combination of these treatments resulted in 81 plots with each plot size ± 10m x 10m. This size was chosen so that one experimental plot accurately represented 1 pixel of the Sentinel 2 image. Thus, setting the orientation of each plot in the research field duplicates the arrangement of pixels in the Sentinel-2 image. (Figure 11).

![Figure 11 The appearance of the experimental plot on Sentinel-2 imagery](image)

The distribution of plots on the research area can be seen in Figure 13-15. Fertilization doses (F1, F2, F3) were the main plot, with subplots are varieties (V1, V2, V3) and planting techniques (P). Visually, it can be seen that the distribution of the experimental plots in the research area can accurately duplicate the pixel arrangement of the Sentinel-2 image.
Figure 12 Distribution of plots based on fertilizer dosage (F1 = red, F2 = Blue, F3 = green) as the main plot

Figure 13 Division of sub-plots on F1 plots with each combination of treatment varieties (V) and planting techniques (P)
Figure 14 Division of sub-plots in plot F2 with each combination of treatment varieties (V) and planting techniques (P)

Figure 15 Division of sub-plots in plot F3 with each combination of treatment varieties (V) and planting techniques (P)
This research also uses drones. The number of pixels contained in the drone aerial photo for 1 pixel in the Sentinel-2A image is ± 153227 which can be seen in Figure 16 below.

![Figure 16](image)

Figure 16 In 1 pixel of the Sentinel-2A imagery, there are ± 153227 pixels in the drone aerial photo imagery

### 4.2 Weather Conditions During Research

The weather conditions during the study are presented in the following table. During the study, there were only 13 rains, with a total rainfall of 78.8 mm. Even so, plants do not experience water shortages because there is a good supply of water from irrigation.

<table>
<thead>
<tr>
<th>Description</th>
<th>CH (mm)</th>
<th>V_angin (km/hour)</th>
<th>Tmax (°C)</th>
<th>Tave (°C)</th>
<th>Tmin (°C)</th>
<th>RHmax (%)</th>
<th>RHave (%)</th>
<th>RHmin (%)</th>
<th>RGlobal (MJ/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.9</td>
<td>1.0</td>
<td>32.0</td>
<td>27.4</td>
<td>23.6</td>
<td>95.2</td>
<td>84.7</td>
<td>68.0</td>
<td>10.9</td>
</tr>
<tr>
<td>Maximum</td>
<td>29.7</td>
<td>1.8</td>
<td>33.8</td>
<td>29.0</td>
<td>26.3</td>
<td>98.0</td>
<td>93.9</td>
<td>80.0</td>
<td>13.3</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.0</td>
<td>0.4</td>
<td>27.9</td>
<td>25.0</td>
<td>20.6</td>
<td>90.0</td>
<td>77.2</td>
<td>55.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>78.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>962.7</td>
</tr>
</tbody>
</table>

While the daily values during the study for several weather elements are presented in the following Figure.
4.3 Growth

The development of three rice varieties for the three main stages is presented in the following Table. The data show that Inpari-32 has a longer harvest life than the IR-69 and Pandan Wangi varieties.

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Thermal heat unit (°C day) for Varieties with Base Temperature (Tb) = 17°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IR-69</td>
</tr>
<tr>
<td>Planting - Maximum Tillers</td>
<td>365,5</td>
</tr>
<tr>
<td>Maximum Tillers - Flowering</td>
<td>192,0</td>
</tr>
<tr>
<td>Flowering - Harvest</td>
<td>301,6</td>
</tr>
<tr>
<td>Planting - Harvest</td>
<td>859,1</td>
</tr>
</tbody>
</table>
4.4 Leaf Area Index

Leaf area index (LAI) charts for all treatment combinations are presented in the following Figure. The dynamics of LAI are generally uniform, experiencing an increase in LAI until it reaches a maximum at the maximum vegetative growth stage, and then decreases towards harvest time. Meanwhile, the characteristics of LAI need to be further analyzed to see their response to the treatment of fertilizer doses, varieties, and planting techniques.

4.4.1 Leaf Area Index Based on Fertilizer Dosage

[Graph showing LAI on the combination of fertilizer treatment on cropping patterns P1 and V1 variety]

[Graph showing LAI on the combination of fertilizer treatment on cropping patterns P2 and V1 variety]
LAI on the combination of fertilizer treatment on cropping patterns P3 and V1 variety

LAI on the combination of fertilizer treatment on cropping patterns P1 and V2 variety

LAI on the combination of fertilizer treatment on cropping patterns P2 and V2 variety
LAI on the combination of fertilizer treatment on cropping patterns P3 and V2 variety

LAI on the combination of fertilizer treatment on cropping patterns P1 and V3 variety

LAI on the combination of fertilizer treatment on cropping patterns P2 and V3 variety
4.4.2 Leaf Area Index Based on Planting Patterns

LAI on the combination of cropping pattern treatment of the dose of fertilizer F1 and V1 variety

LAI on the combination of cropping pattern treatment of the dose of fertilizer F1 and V2 variety
LAI on the combination of cropping pattern treatment of the dose of fertilizer F1 and V3 variety

LAI on the combination of cropping pattern treatment of the dose of fertilizer F2 and V1 variety

LAI on the combination of cropping pattern treatment of the dose of fertilizer F2 and V2 variety
LAI on the combination of cropping pattern treatment of the dose of fertilizer F2 and V3 variety

LAI on the combination of cropping pattern treatment of the dose of fertilizer F3 and V1 variety

LAI on the combination of cropping pattern treatment of the dose of fertilizer F3 and V2 variety
4.4.3 Leaf Area Index by Variety

LAI on the combination treatment of varieties of F1 fertilizer dosage and P1 cropping pattern
LAI on the combination treatment of varieties of F1 fertilizer dosage and P2 cropping pattern

LAI on the combination treatment of varieties of F1 fertilizer dosage and P3 cropping pattern

LAI on the combination treatment of varieties of F2 fertilizer dosage and P1 cropping pattern
LAI on the combination treatment of varieties of F2 fertilizer dosage and P2 cropping pattern

LAI on the combination treatment of varieties of F2 fertilizer dosage and P3 cropping pattern

LAI on the combination treatment of varieties of F3 fertilizer dosage and P1 cropping pattern
4.5 Spectral Characteristics

4.5.1 Vegetation Index based on Sentinel-2 Imagery

The vegetation index was obtained from the results of NDVI calculations using Sentinel-2A imagery taken from the post-planting phase (18 July 2020) to harvest (01 October 2020 for varieties V1 and V3, while for V2, harvest fell on 06 October 2020). In that time span, there are some satellite image data that cannot be analyzed because they are constrained or obstructed by clouds. Therefore, from that timeframe, the data can be used only on 18 July 2020, 28 July 2020, 07 August 2020, 17 August 2020, 27 August 2020, 06 September 2020 and 16 September 2020. Furthermore, the calculation results are presented graphically for see NDVI's response to treatment.
4.5.2 NDVI’s Response to Treatment based on Fertilizer Dosage

The average NDVI response (Y axis) during the experimental period (X axis) based on fertilizer dosage treatment (F1, F2, F3) on various combinations of cropping patterns (P1, P2, P3) and varieties (V1, V2, V3) is presented in the following figure.

Based on the NDVI graphic display, it can be seen that NDVI gives a visually more significant response to the fertilizer dosage treatment. A higher fertilizer dosage gives a higher NDVI value, especially in the early stages to the maximum vegetative stage.

Combination of fertilizer dosage treatment on cropping patterns P1 and V1 variety

Combination of fertilizer dosage treatment on cropping pattern P2 and V1 variety
Combination of fertilizer dosage treatment on cropping patterns of P3 and V1 variety

Combination of fertilizer dosage treatment on cropping patterns of P1 and V2 variety

Combination of fertilizer dosage treatment on cropping patterns P2 and V2 variety
Combination of fertilizer dosage treatment on cropping patterns of P3 and V2 variety

Combination of fertilizer dosage treatment on cropping patterns P1 and V3 variety
Combination of fertilizer dosage treatment on cropping patterns P2 and V3 variety

Combination of fertilizer dosage treatment on cropping patterns of P3 and V3 variety

4.5.3 NDVI’s Response to Treatment based on Planting Patterns

The average NDVI response (Y axis) during the experimental period (X axis) based on cropping pattern treatments (P1, P2, P3) on various combinations of varieties (V1, V2, V3) and fertilizer doses (F1, F2, F3) is presented in the following figure.

Based on the NDVI graphic display, it can be seen that the different cropping patterns do not give NDVI responses which are visually significantly different.
Combination of cropping pattern treatment of F1 fertilizer dosage and V1 variety

Combination of cropping pattern treatment of F1 fertilizer dosage and V2 variety
Combination of cropping pattern treatment of F1 fertilizer dosage and V3 variety

Combination of cropping pattern treatment of F2 fertilizer dosage and V1 variety

Kombinasi perlakuan pola tanam terhadap dosisi pupuk F2 dan varietas V2
Combination treatment of cropping patterns on the dose of fertilizer F2 and V3 variety

Combination of cropping pattern treatment of fertilizer dosage F3 and V1 variety
Combination treatment of cropping patterns on the dosage of F3 and V2 variety

![Graph showing NDVI response to treatment based on variety.](image)

Combination treatment of cropping patterns on the dose of fertilizer F3 and V3 variety

4.5.4 Varietas NDVI’s Response to Treatment based on Variety

The average NDVI response (Y axis) during the experimental period (X axis) based on the treatment of varieties (V1, V2, V3) at various combinations of fertilizer doses (F1, F2, F3) and cropping patterns (P1, P2, P3) is presented in the following figure.

Based on the NDVI graphic display, it can be seen that different varieties do not respond to NDVI which is visually significantly different.
Combination of variety treatment on F1 fertilizer dosage and P1 cropping pattern

Combination of variety treatment on F1 fertilizer dosage and P2 cropping pattern

Combination of variety treatment on F1 fertilizer dosage and P3 cropping pattern
Combination treatment of varieties to the dose of fertilizer F2 and cropping pattern P1

Combination of variety treatment on F2 fertilizer dosage and P2 cropping pattern
Combination of variety treatment on F2 fertilizer dosage and P3 cropping pattern

Combination of variety treatment on fertilizer F3 dosage and cropping pattern P1

Combination of variety treatment on F3 fertilizer dosage and P2 cropping pattern
Combination of variety treatment on F3 fertilizer dosage and P3 cropping pattern

4.6  RGB Vegetation Index based on RGB Drone Imagery

The vegetation index is obtained from calculations using aerial photographs taken from the post-planting phase (18 July 2020) to before harvest (01 October 2020 for V1 and V3 varieties, while for V2, harvest falls on 06 October 2020). From that timeframe, the data analyzed were on 18 July 2020, 28 July 2020, 07 August 2020, 17 August 2020, 27 August 2020, 06 September 2020, 16 September 2020 and 26 September 2020.

4.6.1 Vegetation Index based on Fertilizer Dosage

The average response of the vegetation index (Y axis) during the experimental period (X axis) based on fertilizer dosage treatment (F1, F2, F3) on various combinations of cropping patterns (P1, P2, P3) and varieties (V1, V2, V3) is presented in the following Figure.

Combination of fertilizer dosage treatment on cropping patterns of P3 and V3 variety
4.6.2 Vegetation Index based on Planting Pattern

The average response of the vegetation index (Y axis) during the experimental period (X axis) based on cropping patterns treatment (P1, P2, P3) at various combinations of fertilizer doses (F1, F2, F3) and varieties (V1, V2, V3) is presented in the following Figure.

Combination of cropping pattern treatment of fertilizer doses on F1 and V2 variety

4.6.3 Vegetation Index based on Variety

The average response of vegetation index (Y axis) during the experimental period (X axis) based on the treatment of varieties (V1, V2, V3) at various combinations of fertilizer doses (F1, F2, F3) and cropping patterns (P1, P2, P3) are presented in the following Figure.

Combination of variety treatment on F1 fertilizer dosage and P3 cropping pattern
In general, RGB drone images can produce different vegetation indexes in response to fertilizer treatment, planting techniques, and varieties. The visual index was seen to be higher in the treatment of higher fertilizer doses, in the row row planting technique, and in the Pandan Wangi variety. This may be related to the drone pixel size which is much smaller than the Sentinel-2 image pixels, so that the drone image is able to capture differences in spectral reflection characteristics in paddy fields with different treatments given.
5. CONCLUSION

Some conclusions based on data that have been processed and analyzed are as follows:

1. The orientation of the experimental plot or plot in the research area duplicates the pixel arrangement in the Sentinel-2 image.
2. Weather conditions during the study were generally sunny or slightly cloudy and only rained 13 times, with a total rainfall of 78.8 mm. Even so, plants do not experience water shortages because there is a good supply of water from irrigation.
3. The development of the three rice varieties shows that Inpari-32 has a longer harvest life than IR-69 and Pandan Wangi varieties.
4. The dynamics of LAI are generally uniform, experiencing an increase in LAI until it reaches a maximum at the maximum vegetative growth stage, and then decreases towards harvest time. LAI characteristics need to be further analyzed to see their response to the treatment of fertilizer doses, varieties, and planting techniques.
5. NDVI graphic display from Sentinel-2 image shows that:
   a. NDVI gave a visually more significant response to the fertilizer dosage treatment. A higher fertilizer dosage gives a higher NDVI value, especially in the early stages to the maximum vegetative stage.
   b. The difference in cropping patterns did not give NDVI responses which were visually significantly different.
   c. Different varieties did not respond to NDVI which was visually significantly different.
6. RGB drone images can produce differences in vegetation indices in response to fertilizer treatment, planting techniques, and varieties. Visually, the vegetation index was seen to be higher in the treatment of higher fertilizer doses, on the technique of planting rows of tiles, and in the Pandan Wangi variety.
7. Further processing is required to produce an empirical formula that represents the spatio-temporal relationship between signature reflectance and plant characteristics, plant and soil macro nutrient status and environmental conditions as a baseline for a spatial-explicit dynamic model of rice plants.
6. TEAM LEADER AND RESEARCH MEMBERS

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7. REFERENCES


8. ANNEX

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EDUCATION, PROFESSIONAL WORK AND EXPERTISE

Impron is an agrometeorologist by education. Impron obtained his Bachelor in Agrometeorology from Bogor Agricultural University (IPB University), Indonesia; Master of Agricultural Science from University of Melbourne, Australia; and PhD from Wageningen University, The Netherlands. His doctoral thesis “A Greenhouse Crop Production System for Tropical Lowland Conditions” was based on greenhouse climate modeling and field experimentation of protected crop (tomatos) production inside plastic/screen greenhouses.

Impron is a lecturer at the Department of Geophysics and Meteorology, Bogor Agricultural University on the subjects of Climatology, Agricultural Meteorology/Climatology, and Agriculture Simulation and Modelling. As a lecturer, he also supervises research and thesis for undergraduate, master, and doctoral students.

Impron has involved in projects/researches related to agrometeorology and climate change themes (such as climate change vulnerability assessment, climate change adaptation and mitigation, capacity building, and development of climate responses strategies and climate proofing). Impron also involved in various field surveys as methodology expert with clients from government institutions and state-own enterprises.
**EDUCATION**

<table>
<thead>
<tr>
<th>University/Location</th>
<th>Degree/Study program</th>
<th>Graduated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wageningen University/ Wageningen, The Netherlands</td>
<td>Doctor/ Agriculture and Environmental Sciences</td>
<td>2011</td>
</tr>
<tr>
<td>University of Melbourne/ Melbourne, Victoria, Australia</td>
<td>Master of Agricultural Science/ Crop science</td>
<td>1994</td>
</tr>
<tr>
<td>Bendigo College of Advance Education/ Bendigo, Victoria, Australia</td>
<td>Associate Diploma/ Scientific Instrumentation</td>
<td>1989</td>
</tr>
<tr>
<td>Bogor Agricultural University/ Bogor, West Java, Indonesia</td>
<td>Bachelor (Sarjana)/ Agrometeorology</td>
<td>1987</td>
</tr>
</tbody>
</table>

**TRAINING/WORKSHOP**

<table>
<thead>
<tr>
<th>Institution – Time - Location</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICSEA–BIOTROP–GCTE 7-22 Oct. 1997-Bogor, Indonesia</td>
<td>Modelling Global Change Impacts on Tropical Landscape and Biodiversity</td>
</tr>
<tr>
<td>ICSEA–BIOTROP–GCTE 5-20 Nov. 1996 - Bogor, Indonesia</td>
<td>Modelling Impacts of Global Change on Rice and Crops in Southeast Asia</td>
</tr>
<tr>
<td>GIZ–GAPCC–IMACC 11-17 Apr 2013 - Bogor, Indonesia</td>
<td>ASEAN Regional Multipliers and Advisors: Integrating Climate Change Adaptation into Development Plans and Investments (Climate Proofing)</td>
</tr>
</tbody>
</table>

**WORK EXPERIENCES**

<table>
<thead>
<tr>
<th>Institution:</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Bogor Agricultural University (IPB) – Bogor – Indonesia</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep 2016</td>
<td>Now</td>
<td>Head of Postgraduate Study Program</td>
<td>Master of Science in Information Technology for Natural Resources Management (<em>MSc in IT for NRM</em>). A joint postgraduate program by SEAMEO BIOTROP and Bogor Agricultural University (IPB University)</td>
</tr>
<tr>
<td>Dec 2013</td>
<td>Sep 2016</td>
<td>Head of Postgraduate Study Program</td>
<td>Graduate Studies in Applied Climatology Master and Doctoral (Program Studi Pasca Sarjana Klimatologi Terapan S2/S3), Department of Geophysics and Meteorology.</td>
</tr>
<tr>
<td>Dec 1995</td>
<td>Now</td>
<td>Lecturer</td>
<td>Subjects: Climatology, Agricultural Meteorology, Agricultural Simulation Modeling</td>
</tr>
<tr>
<td>Ags 1997</td>
<td>June 2000</td>
<td>Secretary</td>
<td>Department of Geophysics and Meteorology.</td>
</tr>
</tbody>
</table>
### Institution:
Mercu Buana University – Jakarta – Indonesia

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep 1994</td>
<td>Sep 1997</td>
<td>Lecturer</td>
<td>Subjects: Climatology, Water Management</td>
</tr>
<tr>
<td>Sep 1994</td>
<td>Sep 1997</td>
<td>Vice Dean</td>
<td>Vice Dean III for Student Affair</td>
</tr>
</tbody>
</table>

### Institution:
BIOTROP – Impact Center for Southeast Asia (ICSEA)

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2000</td>
<td>Des 2002</td>
<td>Deputy Head</td>
<td>Deputy Head should take activities including:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Provide assistance to ICSEA head</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Maintain day-to-day activities in the operation of ICSEA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Provide guidance to the ICSEA staff in operating the centre</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Representing ICSEA Head when He/She is in absent</td>
</tr>
</tbody>
</table>

### RESEARCH/CONSULTANCY RECORD

### Institution:
Individual Contract

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2016</td>
<td>Nov 2016</td>
<td>Climate Change Adaptation Expert</td>
<td>Formulation of Climate Change Vulnerability Assessment and Adaptation, to support project “Institutional Strengthening of Local Government for Integrating Climate Change Adaptation in Local Development Plan (Adaptation Project) in the Regency of Gorontalo” This project is lead by Transformasi Foundation in cooperation with Climate Change Task Force- Gorontalo Regency. Indonesian Climate Change Trust Fund (ICCTF) funds the project.</td>
</tr>
</tbody>
</table>
### June 2014 - Sep 2014

**Climate Change Expert**

Formulation of “Indonesia National Strategy on Article 6 of the United Nations Framework Convention on Climate Change (UNFCCC)”.

Collaboration: The Indonesia Council for Climate Change (DNPI) - Japan International Cooperation Agency (JICA)

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### 2011 - 2015

**Expert/Consultant/Source Person**

Involved in projects:

1. Development of Climate Change Disaster Mapping for Provinces of West Sumatera and Bengkulu (Pengembangan Peta Kebencanaan Berbasis Perubahan Iklim di Propinsi Sumatera Barat dan Bengkulu).

2. Development of Child-Centered Climate Change Vulnerability Assessment in Surabaya City.


### Institution:

**Individual Contract**

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
</table>
   Collaboration: The Indonesia Council for Climate Change (DNPI) – PT Sucofindo (2013)

5. Socialization and Study of Response of Communities in Supporting National Plan in Reducing Greenhouse Gases Emission (Sosialisasi dan Kajian Respon Masyarakat dalam Rangka Mendukung Rencana Pemerintah |
<table>
<thead>
<tr>
<th>Year1</th>
<th>Year2</th>
<th>Role</th>
<th>Projects Involved</th>
</tr>
</thead>
</table>
| 2010  | 2011  | Expert/Consultant/Source Person | Involved in projects:  

**Institution:**  
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
</table>
| 1st Oct 2012 | 31st July 2013 | Senior Advisor on Climate Response Strategies and Climate Proofing | In Project: ASEAN-German Programme on Response to Climate Change (GAP-CC)  
Responsibilites:  
1. Providing professional advice to partners and cooperating with important stakeholders  
2. Innovation and knowledge management an communication of innovation to a broad target group  
3. Implement Monitoring and Evaluation of Project’s Progress |

**Institution:**  
UNDP

<table>
<thead>
<tr>
<th>From</th>
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</thead>
</table>

**Institution:**  
Bogor Agricultural University (IPB University) – Bogor – Indonesia

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
</table>
| March 2011 | Nov 2012    | Researcher (Leader) | Research on "Evaluation of Drought Resilience Technology for Rice Cultivation Through a Participatory Approach" under the theme "Improving Research Excellence on Agricultural Adaptation" with activity "Increasing the


| Nov 1998       | Mar 1999      | Researcher (Member) | Research on homegarden as a complex agro ecosystem facing global change: study on microclimate at some homegarden types in Indonesia (case at DesaSukatani, Sukaraja Subdistrict). |

**Institution:** JICA- CRESCENT

<table>
<thead>
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<th>Position</th>
<th>Brief Job Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 2000</td>
<td>Dec 2000</td>
<td>Consultant (Member)</td>
<td>Study for Improvement of Irrigation Management and Empowerment of Water User’s Association for Enhancement of Turnover Program.</td>
</tr>
</tbody>
</table>

**LIST OF SELECTED PUBLICATIONS**


PROFESSIONAL SOCIETIES:

Member of The Society of Agricultural Meteorology of Indonesia (PERHIMPI).