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Integration of Leaf Water Content Index (LWCI) and Enhanced Vegetation Index (EVI) for Stress Detection of Rice Plant Using Landsat 8 Satellitte Imagery

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Abstract

Rice is the main staple food for Indonesian society. Almost 95% of Indonesians consume rice. Along with the increasing population in Indonesia, the level of rice consumption each year has increased. But on the other hand, the amount of paddy fields has decreased due to the development of settlements and industry. Consequently, the business of fulfilling rice consumption needs should prioritize agricultural intensification method. This agricultural intensification program requires good supporting data. One of the supporting data required is a plant health condition that can be represented in data on rice stress levels. Monitoring the stress level of rice plants can be done using remote sensing methods based on satellite imagery. One of them is Landsat-8 satellite imagery with certain algorithm. In this research, a modification algorithm of Rice Paddy Stress Index (RPSI) was obtained by integrating Leaf Water Canopy Index (LWCI) and Enhanced Vegetation Index (EVI). LWCI is used as a representation of water content in vegetation and EVI is used as a representation of the greenish level of plants associated with chlorophyll content. Plants that experience a decrease in health will decrease the content of chlorophyll and water. The results of this study indicate that in 2015 planting season 2 in Kendal Regency there are 1696.26 ha of rice fields indicated experiencing stress and 3493.85 Ha of rice fields have a potential stress. The result of validation test shows that RPSI algorithm method has 75% accuracy for determining rice stress level.

1. Introduction

Rice is a plant that is widely cultivated in Indonesia. Indonesia's population consumption of rice reaches 102 kg per capita per year. This is considered by the Ministry of Agriculture to be of high consumption. Even almost double the world rice consumption which is only 60 kg per capita per year. In Asia, Indonesia's rice consumption is the highest. The high rate of national rice consumption because rice is an inseparable part of the national food culture [1]. Fulfillment of rice consumption is increasing, it is necessary to increase rice production.

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Increasing rice production can be done by diversifying agricultural land and intensifying agricultural land. However, at this time the printing of new agricultural land is very much unable to compensate for the conversion of agricultural land that is turned into residential and industrial areas. Therefore the best way to increase rice production at present is by agricultural intensification. To carry out this program, good plant health management is needed. One of the supporting data needed is the condition of plant health which can be represented in the data of stress levels of rice plants.

Plant health data can be seen from the level of plant stress. This plant stress can be caused by pests or decreasing the content of important substances (caritenoid, nitrogen, chlorophyll and water). In general, low stress plants will have a high productivity possibility. Spatial identification of plant stress is also needed to overcome the decline in plant health which is closely related to nutrition and pest prevention.

Conventional plant stress detection requires a long time and adequate effort. Whereas the need for plant stress data is needed quickly and continuously to support the analysis of the level of fertility and crop production results. This requires a technology that can be used to detect chlorophyll content of leaves quickly and efficiently. Remote sensing methods can provide solutions for rapid detection of plant stress over large areas. Moreover, the development of remote sensing technology has now developed quite rapidly.

Several remote sensing methods can be used to detect stress of rice plants. One way is to utilize various combinations of vegetation indexes. However, at this time there is no algorithm that is really quite precise for the identification of rice plant stress levels. Therefore this objective research will modify the algorithm by integrating Leaf Water Content Index (LWCI) and Enhanced Vegetation Index (EVI) into Rice Paddy Stress Index (RSPI) with Landsat-8 satellite imagery. LWCI is used as a representation of water content in vegetation and EVI is used as a representation of the level of greenness of plants associated with chlorophyll content. Plants that have decreased health will experience a decrease in chlorophyll and water content.

Leaf Water Content Index (LWCI) is an index that shows the moisture content of the leaf canopy. [2] utilizes LWCI with Landsat TM imagery for mapping forest vegetation. This LWCI is formulated as follows:

$$LWCI = G\ x\ \frac{-log[1-(NIR-SWIR)]}{-log[1-NIR-SWIR]} \quad (1)$$

Where G is the soil index which is usually for canopy vegetation areas worth 1, then NIR is a reflectant in the Near Infrared channel (0.8-1.4 μm) and SWIR is a reflectant in the Shortwave Infrared channel (1.4-3μm).

Then, Enhanced Vegetation Index (EVI) is one of the development of vegetation index which is an integration of SAVI and ARVI. EVI (Enhanced Vegetation Index) is more resistant to the influence of atmospheric aerosol composition and the influence of soil color variations. In order to withstand atmospheric distortion, EVI uses blue light channel information. The EVI algorithm is also designed to have a better sensitivity to very green (fertile and dense) regional images [3]. The EVI is formulated as follows:

$$EVI = G * \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + C_1 * \rho_{Red} - C_2 * \rho_{Blue} + L} \quad (2)$$

Where L is the nonlinear alignment of the leaf canopy. C1 and C2 are aerosol coefficients, each valued at 6 and 7.5,. G is a gain factor of 2.5 and ρNIR, RED, BLUE are reflectance values of NIR, red and blue channels. EVI is more responsive for the determination of canopy structure including Leaf Area Index (LAI), canopy type, plant physiogonomy and canopy architecture. With the water canopy content factor and the green conditions of the plants a combination of EVI and LWCI into RPSI is expected to be used to identify stress levels of rice plants.

2. Methods

2.1. Study Area

This research was conducted in Kendal Regency with 2015 test data. Kendal Regency is one of the districts that is a national food buffer. Of the total land area in Kendal District, 76.12% is used for agricultural business (rice fields, dry fields, and ponds). According to the 2015 Central Java Food Crop Statistics data [4] mentioned that in Kendal District there were 2,056 Ha of rice fields experiencing drought and 1,055 experiencing puso or crop failure.

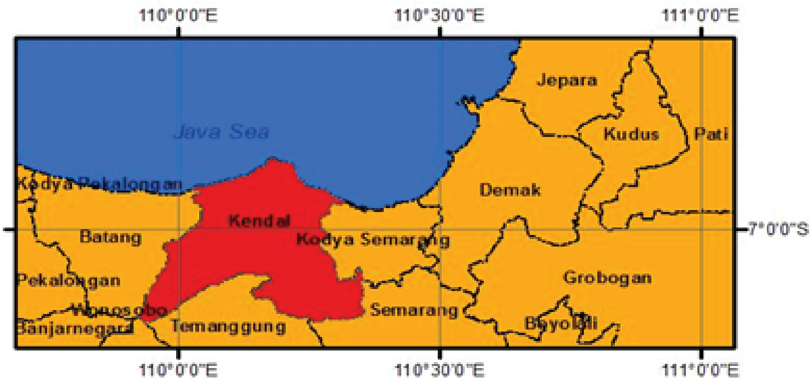

Figure 1: Study area in Kendal Regency.

2.2. Materials

Some data that used in this study are:

1. 2 scene landsat 8 imagery path: 120 row: 065
   (a) Date: 29 may 2015
   (b) Date: 14 June 2015
2. Indonesian base map, scale 1: 25.000
3. Sample point of crop stress

2.3. Landsat 8 Satellitte Data Processing Method

The landsat 8 data imagery that used have L1 level. Actually it has been terain corected but in this study we still corected using indonesian base map to certain the accuracy. Then the image is done radiometric calibration process. Radiometric calibration to obtain TOA reflectance done through two phases, the first phase is the conversion of DN values into spectral values radians, and the second phase is the conversion value of the spectral radiant into spectral reflectance values (Kustiyo, 2014) with a correction phase angle of the sun to obtain a corrected TOA reflectance value. After TOA (Top of Atmosphere) reflectance were obatained, then LSWI and EVI were calculated using TOA reflectance. The LSWI and EVI imagery is clipped using vector paddy field rice that obtain from landuse map BAPEDA Kendal.

2.4. Development of Rice Plant Stress Index (RSPI) Methods

The level of stress of rice plants in this study was obtained with the Rice Plant Stress Index (RPSI). The RPSI index is obtained by integrating LWCI and EVI where LWCI is used to identify stress as seen from the moisture and leaf biomass level, and EVI identifies stress as seen by the greenness of the leaves. The LWCI and EVI indexes are combined by averaging between the two. This is done on a basic basis because rice in the initial phase has a low level of greenness, but water in this phase will be needed. Whereas if the phase rises (greenness also rises to the generative phase) then the water demand will not be as much as the initial phase. This basic complementarity between water level and greenness is used in preparing the RPSI. The RPSI equation used is as follows:

$$RSI = [1 - \left(\frac{EVI + LSWI}{2}\right)] \quad (3)$$

This rice stress identification method is intended for rice plants in the vegetative and reproductive phases. In the Ripening phase where the rice leaves have begun to dry out, it is difficult to distinguish between those who are stressed and those who are not. Therefore identification with this method requires growth phase data which is identified by the NDVI method according to Sari's research [5].

This method is applied to the imagery data for May 2015 in Kendal district. The results of the processing of the RSPI method are then used to identify stress of rice plants. Field data from the results of the drought and plant hopper disaster survey were used as the basis for the validation test of this RPSI method.

3. Result and Discussion

3.1. Result of LWCI and EVI transformation

In this research, LWCI is used as the approach of plant moisture stress. The results of the transformation of the LWCI value based on the data processing carried out, obtained a range of values between -0.351 to 0.985. The results of the distribution of LWCI values can be shown in Figure 2(a).

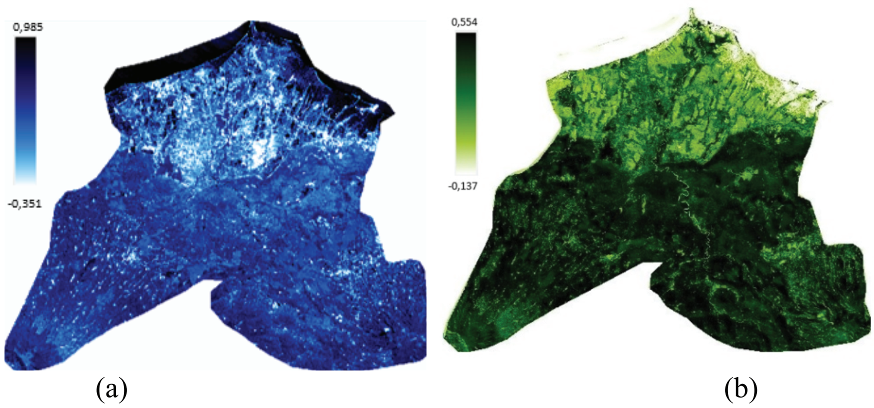

Figure 2: Result Of LWCI Transformation From Landsat 8 Imagery (a) And . Result Of LWCI Transformation From Landsat 8 Imagery (b).

The results of the LWCI transformation show that vegetation land in northern Kendal has a lower LWCI value. This can show the level of moisture in the vegetation in the north lower than the south. This lower level of moisture can be indicated by the presence of moisture stress. However, it is also possible that land in the north is undergoing a phase of reproductive rice growth and fallow phase. Where in this phase rice plants tend to be dry (for reproduction) and without plants accompanied by dry soil (for fallow phase).

The EVI index in this study was used to show the level of greenness of plants. This green value is used as a tool to identify the level of health that is associated with the level of plant stress. The greener rice plants are assumed to have better health. But this also has to consider the growing phase of rice because at different phases it certainly has a different normal range of greenness. The results of the EVI index value in the Kendal region on May 29, 2015 are in the range of -0.137 to 0.554. The distribution of EVI values can be seen in Figure 2(b).

The results of the EVI transformation show that the southern part of the area dominated by forests has EVI values in the range of 0.4 to 0.55 while in the northern part associated with rice fields and gardens the value of EVI increases. While in the sea area EVI values can be seen below 0 which indicates no vegetation.

3.2. Growth Stage of Rice Identification

The EVI index in this study was used to show the level of greenness of plants. This green value is used as a tool to identify the level of health that is associated with the level of plant stress. The greener rice plants are assumed to have better health. But this also has to consider the growing phase of rice because at different phases it certainly has a different normal range of greenness. The results of the EVI index value in the Kendal region on May 29, 2015 are in the range of -0.137 to 0.554. The distribution of EVI values can be seen in Figure 3.

Rice growing phase is a biophysical element that is very important in the identification of rice fields, especially for the identification of health and stress of plants. The growth phase factor greatly determines the state of rice plants, because if the growth phase is different then the normal limits for water requirements and greenness are also different. In this study the identification of rice growing phases using NDVI based on the method used by [5]. Mapping of the growth phase is done by cutting the image first for paddy fields based on Kendal Regency BAPEDA data. Furthermore, the value of the growth phase is classified by class as in Table 1.

From the results of the NDVI classification as shown in Table 1, the distribution of spatial distribution of rice growing in Kendal Regency on May 29, 2015 is shown in Figure 3.

Table 1: Range Of NDVI Classification For Growth Stage Of Rice.

Growth Stage	Range of NDVI	Difference of NDVI t and NDVI t-1
1	0,210 - 0,310	> 0
2	0,311 - 0,476	> 0
3	0,477 - 0,597	> 0
4	0,598 - 0,671	> 0
5	0,672 - 0,700	> 0
6	0,682 - 0,699	< 0
7	0,619 - 0,681	< 0
8	0,511 - 0,618	< 0
9	0,356 - 0,510	< 0
Fallow (Bera)	0,156 - 0,355	≤ 0

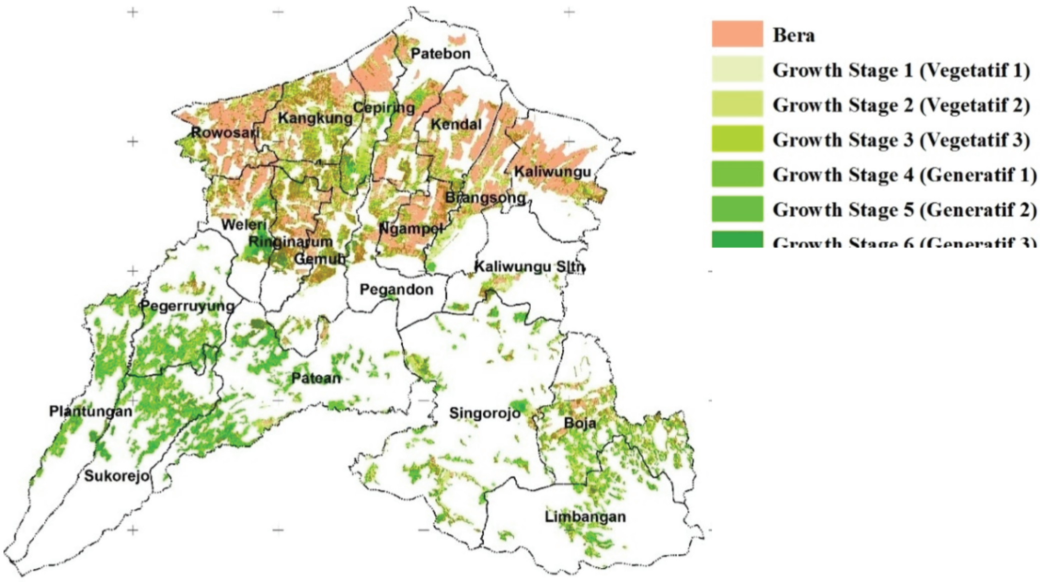

Figure 3: Growth stage map of rice in Kendal (29 Mei 2015).

3.3. Identification of Rice Sress Level using RSPI

The level of stress of rice plants in this study was carried out with the Rice Plant Stress Index (RPSI) previously described. The classification of rice stress levels in this study was based on [2] and [6]. In his research, [2] used LWCI for the analysis of vegetation health levels with a stress limit of 0.15. Whereas [6] uses EVI for health analysis of wheat with a healthy limit on EVI value of 0.1. Based on two previous studies, the stress range was integrated from LWCI and EVI so that the RSI stress limit value was (1- (0.10 +0.15) / 2) or 0.87. To detail the stress level in the range 0.82 - 0.87, it is classified as potential stress, range 0.7 - 0.82 is classified as no stress, and the range 0.5 - 0.7 is classified as very healthy. This stress mapping of plants considers the phase of growing rice, where most of the potential stress of rice both drought and plant pests generally occur in the vegetative and generative phases. In the reproductive phase it is more stressful because of attacks on the grains of rice and in the fallow phase there is no possibility of stress because the fallow phase is a resting phase without plants. So the study in this research phase used for stress analysis is the vegetative and generative phases. For fallow and reproductive phases because the leaves are dry, stress will be detected. Therefore in this study an RPSI data overlay and growth phase were carried out. So that in the fallow phase there is no stress automatically. The results of the spatial distribution of stress levels in Kendal Regency on 29 May 2015 can be seen in Figure 4.

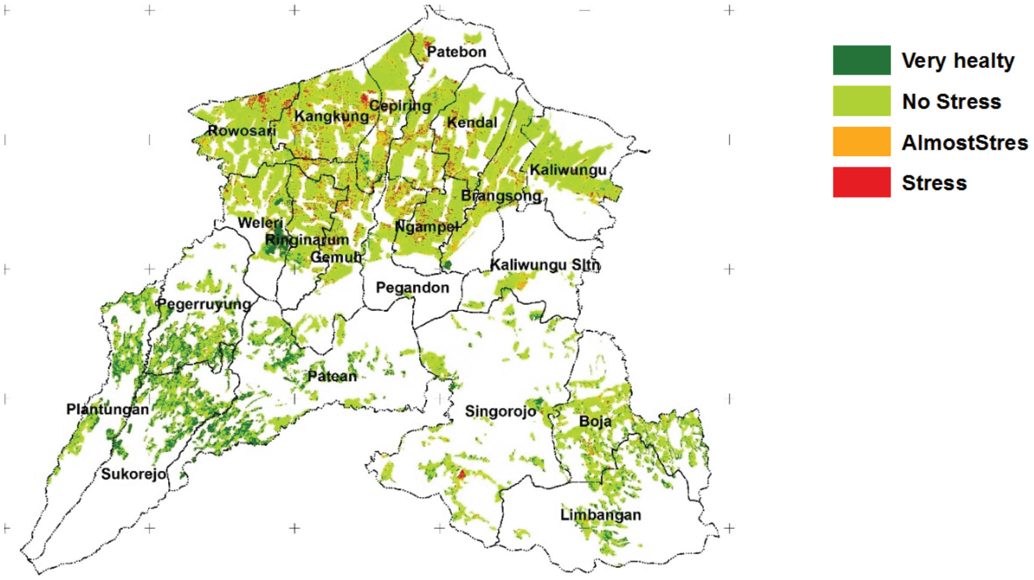

Figure 4: Stress Identification Map of rice in Kendal (29 Mei 2015).

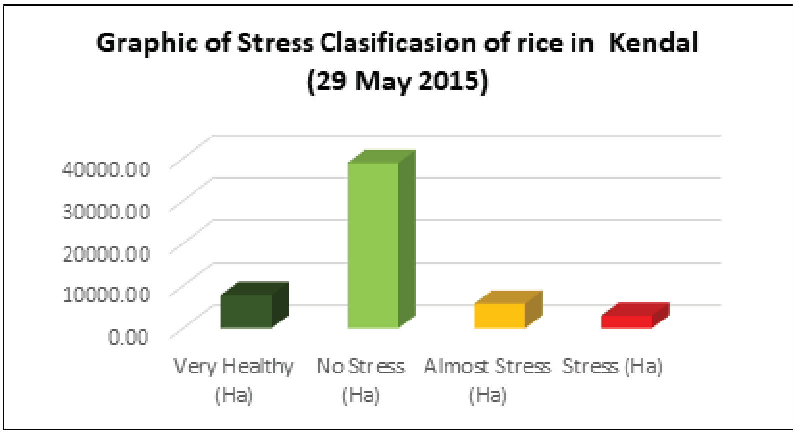

Figure 5: Graphic of Stress Clasificasion of rice in Kendal (29 May 2015).

The results of the four classifications determined indicate that there is Kendal Regency's agricultural land which is quite potentially experiencing stress. This can be proven by the area of stressed land which is 1696.26 ha or in other words 5.26% of the total area of Kendal Regency, and 3493.85 of potential stress or 10.83%. While 22880.89 ha did not experience stress or in other words 70.95% of the total land area of Kendal Regency and 4179, 61 ha were categorized as very healthy or at 12.96%. For a clearer classification diagram can be seen in Figure 5.

3.4. Validaton of RSPI Method

This accuracy test was conducted to determine the accuracy of the RPSI method in identifying stress levels of rice plants. This accuracy test is done by comparing the facts of the field with the mapping data. Thus it can be seen what level of accuracy and also how much the level of error. The results of this accuracy test are outlined in the form of a convusion matrix. This accuracy test was conducted at 16 points spread in 7 districts. Consists of Kaliwungu, Brangsong, Pegandon, Gemuh, Kangkung, Cepiring and Patebon Districts. The distribution of 16 points can be seen in Figure 6.

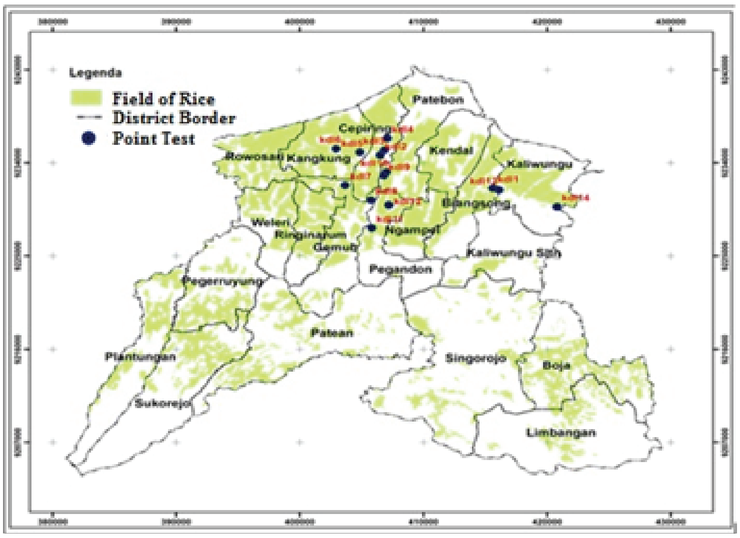

Figure 6: Spatial distribution of validation test points.

At the 16 points found 3 conditions of rice fields, namely no stress, potential stress and stress. From the 16 fact field conditions, there are some that are suitable and there are also some that are not in accordance with the survey data. The results of convusion matrix of validation test can be seen in table 2.

Based on the stress validation test above it can be seen that the accuracy of the classification of the stress level of rice plants using RSPI obtained an overall accuracy of 87.50%.

Table 2: Convusion Matrix of Validation Test.

	Tidak ada Stress	Potensial Stress	Stress	Total
No Stress	3	1	0	4
Almost Stress	0	6	1	7
Stress	0	0	5	5
Total	3	9	4	16
overall accuracy (%)	87.50			

4. Conclussion

1. The Rice Stress Index (RSI) can be developed on Landsat 8 satellite images by integrating the Enhanced Vegetation In-dex (EVI) and Leaf Water Content Index (LWCI)

2. The accuracy of the Rice Stress Index (RSI) in identifying rice stress levels with Landsat 8 imagery shown from the results of validation with overall accuracy of 87.5%. This value has shown that this method is quite effective for the identification of rice stress in paddy fields.

Acknowledgments

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