Detection Phase Growth of Paddy Crop Using SAR Sentinel-1 Data

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Abstract. Paddy growth monitoring is necessary conducted to ensure successful the harvest and production of paddy. The monitoring can be done by using satellite data, both optical and radar data, which can cover a large area and time observation frequency for seasonal crops, such as paddy. In tropical area, cloudy day usually happen, so that problems can’t be handle with optical data. Utilization of radar data that can penetrate the cloud condition can solve the problem, either as a complement of optical data or used alone to monitor the growth phase of paddy. The research was conducted to investigate the capability of Sentinel 1 SAR multi temporal data to detect the growth phase of paddy crop. The research was done in paddy fields belong to Sang Hyang Sri, Subang, West Java during the planting season of 2017. The results found that SAR data in dual polarization (HV, VV), and both combination can be used to detect paddy phase, such as early planting, vegetative, generative, and bare condition after harvesting.

1. Introduction
The Remote Sensing Application Center, LAPAN has the task of carrying out research and development on the use of remote sensing data related to spatial information on natural resources, as well as product information derived from satellite remote sensing data. Research activities and model development for monitoring the growth phase of paddy crops have been built since 1997 by using Landsat imagery and have been used to monitor paddy crop area on the island of Java. Along with Landsat 7 status, which is SLC-Off, from 2005 to 2010, a 250 m resolution MODIS Terra image was used to monitor the phase of paddy crop growth in P Java. Furthermore, it was developed throughout the Indonesian territory, so that it could be operated by BBSDLP in the Integrated “Katam” System since 2015. The use of satellites with optical sensors to monitor the growth phase of paddy is limited because it is affected by weather conditions and cloud coverage, especially in tropical countries such as Indonesia. Cloud coverage in Indonesia in the September to November period was 60 % greater (Eastman et al, 2011) [1]. In addition, the paddy crop season in the Western Region of Indonesia is generally conducted in October - March which is the rainy season, so that remote sensing data with active sensors or radar is an alternative as a complement or substitution of optical sensor remote sensing data.

Based on the background above, the study was conducted to identify paddy crop phases using Sentinel-1 radar (SAR) data.
2. Methodology

2.1. Research sites
The research was conducted in the paddy fields of Subang Regency and its surroundings, especially in the paddy fields of PT Sang Hyang Sri, Sukamandi, Subang, West Java Province. The location of the paddy field is shown in Figure 1.

![Research Location in the Paddy Field of PT Sang Hyang Sri, Sukamandi, Subang, West Java.](image)

2.2. Data and Research Methods
The data used in this study are SAR Sentinel 1 Path 149 / Frame 613, from May to October 2017. The stages of processing and analysis of Sentinel-1 images to detect paddy crop phases presented in Figure 2. For an analysis of the appearance of land cover around paddy fields, a visual analysis of Landsat and Sentinel-1 images was carried out at the same time, namely the image on July 19, 2017. Although only 2 data polarization, VH and VV, but from Sentinel 1 data can be generated by RGB composite images such as natural natural color by creating a synthetic channel VV / VH ratio on the blue layer. Whereas the detection of phenology of paddy crop growth refers to the method that has been done using Landsat 8 satellite imagery, so that the Normalize Difference Polarization Index (PI = 1 - NDPI), where NDPI = (VV-VH)/(VV+VH)) or the Polarization Ratio Index (RPI=VH/VV) can be used. The phase of paddy crop is determined by changes of RPI from 2 different recording dates in sequence. Positive changes indicate the vegetative phase, whereas negative changes indicate the generative phase. Validation test was done by overlaying the confusion matrix between the results of the model with the paddy crop phase in the paddy field area of PT Sang Hyang Sri whose planting schedule was known and some result of field survey.

3. Result and Discussion
Analysis of Sentinel-1 imagery was carried out to identify the condition of paddy fields as well as the paddy phase, if only using one image only would be able to identify water, vegetation and bare only. The condition of the vegetation is not immediately known whether it is in the vegetative or generative
phase, but by using several multi-time images (16 daily for Landsat 8), at least 2 data, the paddy phase will be known [2-3]. The vegetative phase is characterized by changes in the level of greenness increasing (positive), on the contrary the generative phase is characterized by a decrease in the level of greenness (negative), because the leaves have fallen or yellowed. Digitally changes in the increase and decrease in the greenish level of leaves can be detected by changes in the Vegetation Index (EVI) of optical satellite data such as Landsat 8. Based on the RGB composite image the appearance of the colors of water objects, vegetation and open land (note the marked circle) such as residential areas are not much different between the RGB composite image of Sentinel-1 data (see Figure 3). The appearance of the image shows that the body objects of the dominant color are dark blue to bright, green to yellow for vegetation and reddish brown, orange, magenta for open land objects. Interesting conditions are shown by variations in the color of open land in paddy fields after harvest (bare phase), besides there are bright magenta colors, some are dark green.

3.1. Paddy Crop Growth Identification
In general, identification of paddy crops in paddy fields using multi-temporal satellite data, such as Landsat 8 imagery is only global in nature, which can only identify water, vegetation and bares and
changes over time. Whereas crop age cannot be classified without knowing the planting schedule info. Based on experience, for identification of the water phase (from planting preparation) mixing can occur with the vegetative phase (paddy crops that have just been planted until the age of one week), making it difficult to distinguish. Besides being difficult to distinguish from the vegetative phase (initial), especially until the age of 1 week of crops, it turns out that the water phase is also often difficult to separate from the bare phase if the bare is in humid conditions. Therefore in this identification the phase of water mixing with paddy is 1 week old, while the bare phase in moist condition. Although there are difficulties as mentioned above, but by analyzing multi-time images associated with the age of the paddy, the mixing can be minimized.

Figure 3. Comparison between Composite Image of Sentinel 1 (left) and Landsat 8 on 19 July 2017

3.2. Extraction of Paddy Crop Growth Parameters
To find out how the growth of paddy crops gradually from planting to harvesting, multitemporal backscatter of SAR Sentinel-1 were used during paddy growth (on average 4 months) shown in figure 4. RGB Composite Image Results derived from a combination of SAR Sentinel-1 (VV-VH-VV / VH) data polarization are shown in Figure 5. As a reference for knowing the age of paddy crops, the PT Sang Hyang Sri paddy field area was used which had known the schedule of paddy crops in each Block. The results of spatial statistical analysis of Multitemporal SAR Sentinel-1 data from starting planting (June 1, 2017) which coincide with the receipt of data until harvest in a paddy block are shown in Figure 4 for VH backscatter, Figure 7 for VV backscatter and Figure 8 for the VH / VV ratio. Thus it can be seen that changes in paddy growth are based on changes in the scattering value of Sentinel-1 radar data every 12 days, both using a single backscatter and its ratio. Based on Figure 9 shows that during the flooding period and the spread of paddy crops (generally 3-2 weeks before planting) it appears that the backscatter value which was originally high (up to 0.225) decreased until planting and reached the lowest after 12 DAP. Then it rises to the top of the scattered tilapia at the age of paddy 86 - 90 DAP. Furthermore, it decreases not too sharp until harvest (120 DAP). The phenology of paddy growth based on backscatter is somewhat different from optical data, such as Landsat 8. Figure 3-6 shows the fluctuations in the backscattering value of HV from starting to harvesting and bare phase. Beginning with a relatively larger backscatter value when stocking (24 days before planting) which is dominated by water and soil mud. Then it decreases the initial
vegetative phase (24 DAP), then increases again through the maximum vegetative phase until the age of 108 DAP in the generative phase 2. Then the BS value decreases again until harvest (120 DAP). Later the backscattering value increases again in the bare phase. These findings indicate conditions that are somewhat different from the results of [3] research which do not explain the existence of fluctuations from before planting to the age of 20 Days after planting (DAP).

**Figure 4.** Composite Image of Sentinel 1, RGB(VV,VH,VV/VH) from May until September 2017

This HV backscatter fluctuation is more similar to the growth and development of paddy canopy with a special pattern that rises up to 108 DAP. The backscattering value is still increasing in the generative phase due to canopy roughness due to growing and drying of paddy grains. Different conditions are indicated by the backscattering value of VV which does not have a specific pattern like as paddy growth (see Figure 5). The backscattering value of VV is more fluctuating, which is rising and decreasing both in the vegetative and generative phases, so it is rather difficult to use the VV parameter to detect the phase of paddy crops. VV backscatter in fact makes it more sensitive to changes in crop wet conditions. This is shown by the appearance of a blue water body and variations on RGB VV, VH, VV / VH images. The backscatter fluctuations that are more similar to the profile
like as paddy growth are indicated by the ratio of VH / VV (RPI) or Polarization Index (PI = 1 – NDPI), as shown in Figure 6 which has a distinctive pattern. Phenology before planting to age 20 has a drastic decline in PI values from > 0.275 to 0.125 and then increases through the maximum vegetative phase of age 60-64 DAP (PI <= 0.425) to generative phase 1 (84 DAP) with PI <= 0.45, then decreases slightly during generative phase to PI value amounting to 0.25 during the harvest period (120 DAP). Furthermore, the PI value increases in bare phase with an PI value of around > 0.425.

![Figure 5. Comparison Paddy Growth Profile between VH (left) and VV Backscatter of SAR Sentinel-1](image)

![Figure 6. Paddy Growth Profile based on Polarization Index (PI = 1-NDPI) of Backscatter SAR Sentinel-1](image)

### 3.3. Relationship Between PI Backscatter SAR Sentinel-1 and Paddy Age

The profile of paddy growth from before planting, when planting to harvesting and bare phase in detail can be known by extracting the value of backscatter in blocks of paddy field which is known when early planting and harvesting in the area of PT Sang Hyang Sri, Subang. Sampling was carried out based on the dominant rice variety in paddy fields in P Java, Sumatra, Sulawesi and most of the territory of Indonesia was the Ciherang variety. The output of each polarization backscatter of the PI Index is presented in Figure 5. Furthermore, the growth model can be made so that it can be known more precisely at what age the PI value starts to increase again between 12-24 DAP, when the PI
reaches peak values, and a decline before harvest in the generative phase 2 as shown by PI Multitemporal in Figure 6. To separate the PI range that overlaps between phases, the model is separated during ages before planting up to 24 DAP and thereafter. The regression analysis of the relationship between PI and the age of paddy crops is shown in Figures 7. The identification of the paddy phase needs to be carried out continuously for the purpose of monitoring paddy growth until harvest, whether it is good / normal or not. So it is not a momentary activity like the usual classification for mapping the paddy fields, as other writers have done, including using ENVISAT-ASAR data in Vietnam[4]; using L Palsar canal in [5]; using TerraSar-X in India [6]; used canal X and C SAR data in the Philippines [7]; used Landsat 8 data in Vietnam [8]; and using Sentinel-1 in the Indramayu area, West Java [9]. The classification method for the operational purposes of monitoring the paddy phase continuously and covering a large area is not effective if it cannot be done automatically. In addition, the spectral response from optical data and radar backscatter which is used as a reference for training areas can change the range of values in different periods or seasons. The identification of the paddy crop phase will be easier and faster to do if using biophysical parameters using an index that is in line with the phenology of paddy crop growth itself. In the phase before planting which is dominated by water to the initial vegetative at 19 DAP, the vegetative phase to the maximum, the generative phase and bare of paddy crops have special characteristics that can be detected by a range of index values. Maspiyanti F., et al. [10] conducted a paddy phase classification using Hyperspectral data with good results. The scarcity of Hyperspectral data does not allow the method to be carried out for the operational purposes of monitoring the paddy crop phase.

![Figure 7. Corelation between PI Polarization with Paddy age from sowing phase until early vegetative (19 DAP)](image-url)
Figure 8. Correlation between Polarization Index (PI) with Paddy age from 20 DAP until Harvest

Based on the model produced during the sowing period, initial preparations that are dominated by water up to 24 DAP mixed can be seen that the lowest PI value occurs at the age of 19 DAP, and the maximum value occurs at the age of 84-90 DAP. Furthermore, the crop phase and paddy age can be produced in more detail using the value of the Sentinel-1 PI Index data scattering ratio based on these 2 models. An example of the results is presented in Figure 9 with the results validation of 70% compared to the information on the paddy phase in the PT Sang Hyang Sri paddy field block.

Figure 9. Spatial Distribution of Paddy Age on 19 July 2017 based on SAR Sentinel-1 Data

4. Conclusion and Suggestions
Based on the results of quantitative analysis of backscattering (BS) values for each Sentinel-1 SAR Polarization data, namely VH, VV and Polarization Index (PI=1-NDPI), where NDPI = (VV-VH)/(VV+VH), so the PI parameters are better used, because changes during paddy growth are closer to phenology growth and development of paddy crops which were separated into 2 models before and
after the age of 19 DAP. Further research will be carried out to verify and validate models using different dates and varieties and be implemented for different areas.

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