International Journal of GEOMATE, Oct., 2019 Vol.17, Issue 62, pp. 101 - 106
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.62.8782
Special Issue on Science, Engineering & Environment

SPATIO-TEMPORAL ANALYSIS OF RICE FIELD PHENOLOGY USING SENTINEL-1 IMAGE IN KARAWANG REGENCY WEST JAVA, INDONESIA

*Supriatna[1], Rokhmatuloh[1], Adi Wibowo[1], Iqbal Putut Ash Shidiq[1], Glen Putra Pratama[1,] and Laju Gandharum[2]

[1]Dept. of Geography, Faculty of Mathematics and Natural Sciences, University of Indonesia; [2]Agency for The Assessment and Application of Technology, Indonesia

*Corresponding Author, Received: 28 Dec. 2018, Revised: 26 Feb. 2019, Accepted: 10 Mar. 2019

ABSTRACT: The paddy is an important food crop for Indonesian people. It has become the primary staple food and the most gradually increased crop regarding its productivity. It recorded in 2015 that national production for paddy field was 15.13% produced by West Java province. With the national food security issues, monitoring in rice field growth becomes important to give some baseline information regarding the provision of staple food. The phase begins when the rice is planted in the ground and ends when the rice is ready for harvesting. Rice phenology divided into five classes, namely, land preparation, early vegetative, late vegetative, generative, and harvesting. One of the effective ways in monitoring is through rapid measurement using a remote sensing system, in this case, Sentinel-1 Synthetic Aperture Radar (SAR). The objective of the study to implement Sentinel-1 image in a spatiotemporal analysis of the rice field phenology. Sentinel-1 images at the C-Band are capable of monitoring rice phenology. The study aims to provide a spatial and temporal assessment of rice phenology in Karawang using Sentinel-1 images. As results, in northern irrigation area, the paddy is grown quickly even it receives water last compared to southern and middle Karawang irrigation areas. Furthermore, we found that the rice phenology phase distribution in Karawang does not follow the irrigation pattern. Rice in northern irrigation areas have the lowest backscatter values. The temporal analysis shows that rice reaches the harvesting stage quicker in dry season compared to the rainy season with the same backscatter values.

Keywords: Rice field, Phenology, Sentinel-1, Spatiotemporal analysis

1. INTRODUCTION

Rice phenology defined as the changes that occur within the rice from the moment rice is planted in the ground and proceeds to grow during the harvesting stage [1]. According to the Agency for the Assessment and Application of Technology Indonesia, rice phenology divided into five stages which are land preparation, early vegetative, vegetative stage, generative, and harvesting. The information on rice phenology can assist the rice planting farmers in their decision-making process, especially in the period where climate change affects the production of rice. Rice crop monitoring is always necessary, but there is a challenge in understanding the dynamics of phenological stages and providing accurate and timely information due to the large farming area [2, 3]. The costly, time wasting and labor consuming issues in this study can be addressed using remote sensing technology. Remote sensing imagery is useful in many applications, especially for obtaining land-cover information at lower cost and lesser time [4, 5, 6].

Information of plant's phenology related with a biophysical and biochemical attribute. Those attributes were affecting the reflectance spectrum of the plant and changes in the spectrum can be detected by remote sensing imagery [7]. Both optical sensors such as MODIS [3], Landsat [8], and SPOT [9], and radar sensors such as RADARSAT [10], ALOS PALSAR [11] and TanDEM-X [12] were useful to detect biophysical attribute and monitor phenology of the rice crop. The Synthetic Aperture Radar (SAR) image has been widely used to identify rice phenology due to the capability to provide cloud-free data. [13] find that three different dual *polarimetric* SAR image shows similar behavior in rice phenology monitoring. Sentinel-1 *polarimetric* images in the C-Band are capable of monitoring rice phenology [1, 14, 15, 16]. Then this research used the Sentinel-1 *polarimetric* image for identifying the Rice Phenology.

The backscatter classification method is used to classify rice phenology according to backscatter values. Karawang Regency is chosen as the study area because it is one of the top rice producers within the West Java Province. West Java province is the largest rice producer in Indonesia, especially Karawang Regency. Based on the national statistic report, in 2014-2015, rice production has been reduced from 11,085,544 to 10,856,438 tons from [17]. From the report, it is possible to acknowledge that efforts to maintain food security in West Java Province are necessary. Northern, Middle, and Southern Karawang areas are observed using spatial analysis according to the irrigation pattern [18]. Temporal analysis observes the rice phenology during the dry season and the rainy season. This research aims to provide a spatial and temporal assessment of rice phenology in Karawang according to Sentinel image analysis.

2. METHODS

To answer a spatial and temporal assessment of rice phenology in Karawang using Sentinel-1 images, starting from image acquisition and field data collection. We also used the Geographic Information System to manage image and filed data.

2.1 The Study Area

Karawang Regency located on 107° 2’-107° 40’ east and 5° 56’-6° 34’ south (Figure 1). It is an administrative region located in the coastal area, adjacent to the Java sea, especially in the northern part. Karawang Regency chosen as the study area because it is one of the top rice producers within the West Java Province. According to the statistical data of West Java Province, the production of paddy field in Karawang reached 1,180,817 tons in 2015. It was the second largest producer after Indramayu regency (1,233,785 tons).

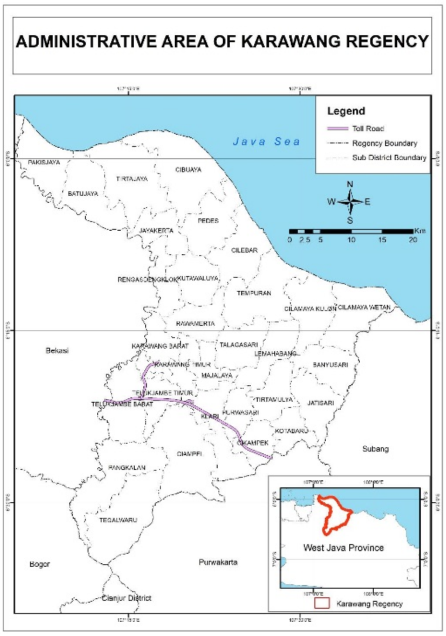

Fig.1 Study area

Rice paddies observed in this study are rice paddies planted in rice fields that grow in a cycle of three main periods which are planting period, growing period, and harvesting period. Five classes are taken from these three main periods according to literature study on Sentinel-1 backscatter values which are land preparation, early vegetative, late vegetative, generative, and harvesting/ripening. Spatial analysis approach is used to achieve a spatial pattern of the rice growth phase, and temporal analysis is used to achieve a temporal pattern of the rice growth phase. Figure 2 explains the conceptual framework of this research.

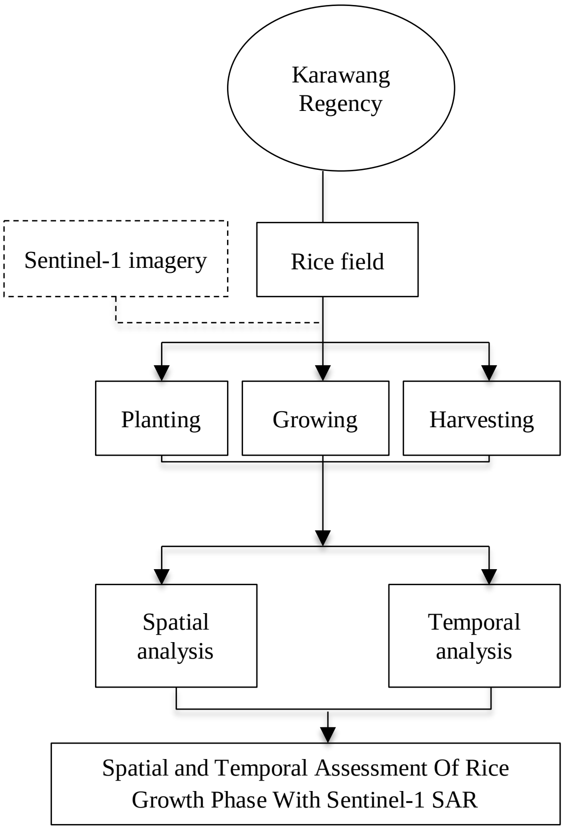

Fig.2 The conceptual framework

Image masking was performed on both Sentinel-1 images to separate rice fields from other land cover types in Karawang Regency. Pre-processing of Sentinel-1 SAR images includes radiometric calibration to adjust pixel values so that they represent backscatter, radiometric terrain flattening to smoothen rough surfaces caused by topographic differences, speckle filtering to remove image noise that causes spatial patterns that are not uniform, and geometric terrain correction to register geographic coordinates on the Sentinel-1 image. Decibel values are used to create samples for phenology classes based on literature study which is then validated using field survey. List of data used in this research can see in Table 1.

Table 1 Data used in the study

Information	Data Format	Source
Sampling area for rice phenology	Field photos and GPS coordinate	Field Survey (22 June 2017 and 13 November 2017)
Rice phenology	Planting calendar (2016-2017) Sentinel-1 SAR Image	Tabular data from Ministry of Agriculture European Space Agency
The spatial pattern of rice planting	Area Survey Sampling (June 2017)	Agency For The Assessment And Application Of Technology (BPPT)
	Standard Rice Crop Field Map (2012)	Ministry Of Agriculture

Maximum likelihood classification is then used to classify the Sentinel-1 image into five classes. Reference data which consists of GPS coordinates and field photos are used to create training areas of each rice phenology for the maximum likelihood classifier. Each phenology has 1 point with a size of 1 pixel used to create a training area and the total number of points collected in this research are 78 points meaning the number of pixels used to create training areas for both Sentinel-1 images pixels used from previous research in Table 2.

Table 2 Rice phenology backscatter values in Indramayu Regency

Acquisition Date	Backscatter Value VH Polarisation	Rice Phenology
7 February 2016	-18	Land Preparation
19 February 2016	-19	Land Preparation
02 March 2016	-22	Early Vegetative
14 March 2016	-21	Vegetative
26 March 2016	-17	Late Vegetative
25 May 2016	-13	Generative and Harvesting
30 June 2016	-19	Land Preparation
24 July 2016	-20	Vegetative

Source: Agency for the Assessment and Application of Technology Indonesia (BPPT), 2016

3. RESULT AND DISCUSSION

Backscatter classification of 22 June and 13 November 2017 Sentinel-1 SAR images produced five classes of rice phenology which are land preparation, early vegetative, late vegetative, generative, and harvesting. Land preparation phase has the lowest area percentage in Karawang rice field with 14% of the area on 22 June. Harvesting phase during 22 June shows the highest percentage of the area which is 57% in Karawang rice field. Rice phenology during 13 November 2017 has the lowest area percentage of 17% for late vegetative, and harvesting phase as the highest with 31% of the area. Spatial information on rice phenology in Karawang regency saw in Figure 3.

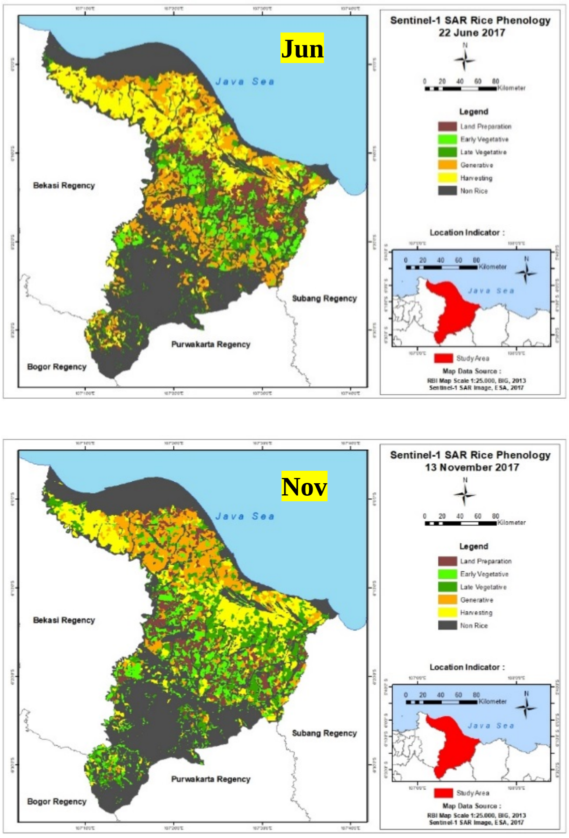

Fig. 3 Maximum likelihood classification for rice planting stages on 22 June and 13 November

Based on research conducted by [18] in Karawang Regency has an irrigation pattern that starts from southern Karawang near Jatiluhur Dam and ends at the northern parts of Karawang. Rice crops in Southern Karawang Regency receive water ahead of middle and northern parts of Karawang Regency. Sentinel-1 Classified Rice Phenology maps show that northern areas of Karawang reach harvesting stage quicker than middle and southern areas of Karawang Regency. Rice in central areas of Karawang reaches harvesting stage second quickest after Northern Karawang. Southern areas of Karawang have rice which reaches the harvesting stage at the slowest rate after northern and middle areas of Karawang Regency. Figure 4 is a sample area of Paddy Fields. Figure 4.a. Show the early vegetative stage, in this stage water bodies, is dominant on the paddy fields.

Fig. 4.a Early Vegetative Stage

Fig. 4.b Late Vegetative Stage

Fig. 4.c Generative Stage

Fig. 4.d Harvesting Stage

Figure 4.b. show the late vegetative stage, in this stage vegetation bodies, is dominant in the paddy fields. Figure 4.c. Show the generative stage, in this stage vegetation, covered the paddy fields. Figure 4.d. Show the harvesting stage, in this stage the yellow color is dominant on the paddy fields.

According to backscatter values in Southern Karawang irrigation areas, the pattern shows that backscatter is at it's highest in the land preparation phase and reduces in the early vegetative phase. After the early vegetative phase, backscatter values increase to -16 dB in the late vegetative phase, drops to -15 dB in the generative phase and rises to -13.3 dB when rice reaches harvesting stage. Backscatter pattern of rice phenology in Southern Karawang irrigation areas showed in Figure 5.

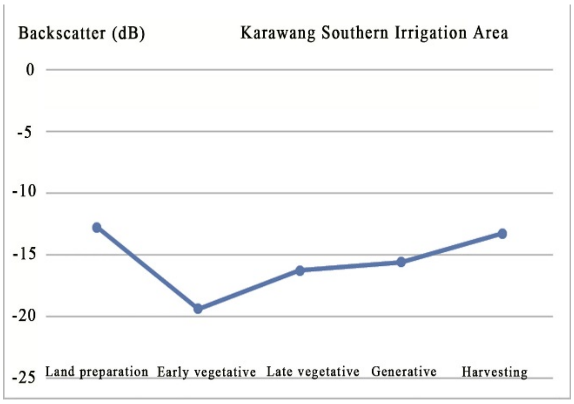

Fig. 5 Backscatter for each stage in the Southern Karawang irrigation area

Backscatter values of middle Karawang irrigation areas show a pattern where backscatter is at it's lowest when the rice plant is being prepared and increases to -14 dB when the rice grows to early vegetative stage. After the early vegetative stage, rice phenology backscatter drops to -17 dB in the late vegetative phase, increases in generative phase and reaches it is a peek at -11 dB when rice reaches harvesting stage. Backscatter pattern of rice phenology in middle Karawang irrigation areas can see in Figure 6.

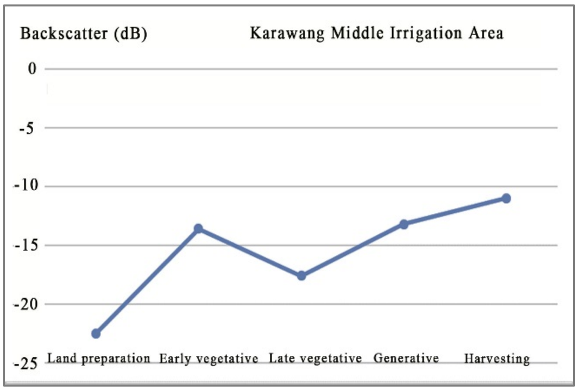

Fig. 6 Backscatter for each stage in the Middle Karawang irrigation area

Backscatter pattern of northern irrigation areas show that backscatter starts from -15.4 dB at the land preparation stage which then drops to -18.7 dB when rice reaches the early vegetative stage. Rice backscatter continues to drop when reaching the late vegetative stage and increases when rice reaches the generative stage. Backscatter values decrease from -15 to -16.2 when rice is ready for harvesting. Backscatter pattern of rice phenology in northern Karawang irrigation areas can see in Figure 7.

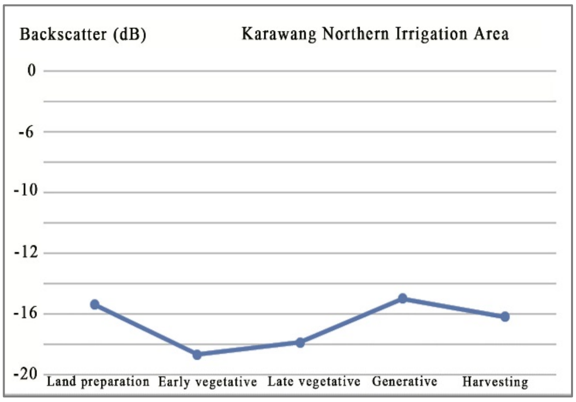

Fig. 7 Backscatter for each stage in Northern Karawang irrigation area

The result in three observed areas of Karawang Regency shows different backscatter pattern and value in each rice phenology phase. Although our results differ slightly from those of [1, 19, 20], it could nevertheless argue the site dependency factor is giving significant effect. This limitation became the underline issue when a SAR image-based method would like to propose for the large targeted area. Then a representative sample needed to achieve a good result.

Backscatter comparisons between dry season and rainy season show similar backscatter values from late vegetative phase to the harvesting phase. Differences in backscatter values seen in land preparation and early vegetative stage. Backscatter values are higher for land preparation stage in the rainy season compared to the dry season. Backscatter values are higher for the early vegetative stage in dry season compared to the rainy season. Comparison between backscatter values in the dry season and rainy season can see in Figure 8.

4. CONCLUSION

Rice phenology spatial pattern shows that northern irrigation areas grow rice which reaches the harvesting stage quicker compared to middle and southern irrigation areas. Backscatter values are the lowest for harvesting stage rice in northern irrigation areas and the highest in middle irrigation areas. Rice growth phase spatial pattern does not follow the irrigation pattern. The temporal pattern shows that rice reaches the harvesting stage quicker in the dry season compared to the rainy season with the same backscatter values. These findings add to a growing body of literature on to our understanding of rice phenology identification using SAR image.

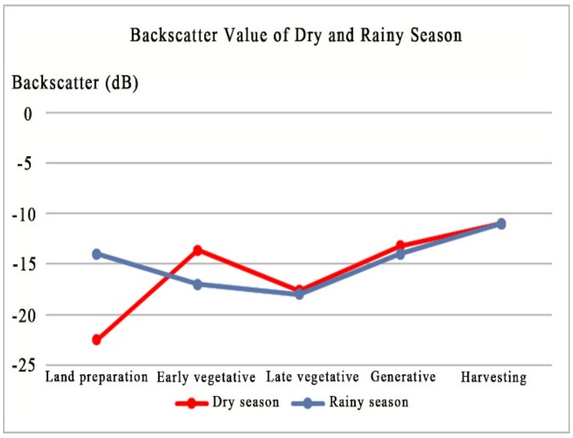

Fig. 8 Rice Phenology Backscatter Comparison Between Dry Season and Rainy Season

5. ACKNOWLEDGMENTS

This study is supported by the Ministry of Research and Higher Education, under the Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) or the Basic Primary Research for Higher Education Grant based on contract no: 382/UN2.R3.1/HKP.05.00/2018.

6. REFERENCES

[1] Nguyen, D. B., Gruber, A., & Wagner, W. (2016). Mapping rice extent and cropping scheme in the Mekong Delta using Sentinel-1A data. Remote Sensing Letters, 7(12), 1209-1218.

[2] Atzberger, C. (2013). Advances in remote sensing of agriculture: Context description, existing operational monitoring systems and major information needs. Remote Sensing, 5(2), 949-981.

[3] Onojeghuo, A. O., Blackburn, G. A., Wang, Q., Atkinson, P. M., Kindred, D., & Miao, Y. (2018). Rice crop phenology mapping at high spatial and temporal resolution using downscaled MODIS time-series. GIScience & Remote Sensing, DOI: 10.1080/15481603.2018.1423725.

[4] Ismail, M. H. & Jusoff, K. 2008. Satellite data classification accuracy assessment based on reference dataset. International Journal of Computer and Information Science and Engineering 2: 96-102.

[5] Shidiq, I. P. A., & Ismail, M. H. (2016). Stand Age Model for Mapping Spatial Distribution of Rubber Tree Using Remotely Sensed Data in Kedah, Malaysia. Jurnal Teknologi, 78(5), 239-244.

[6] Shidiq, I. P. A., Ismail, M. H., Ramli, M. F., & Kamarudin, N. (2017). Combination of ALOS PALSAR and Landsat 5 Imagery for Rubber Tree mapping. The Malaysian Forester, 80(1), 55-72.

[7] Kuenzer, C., & Knauer, K. (2013). Remote sensing of rice crop areas. International Journal of Remote Sensing, 34(6), 2101-2139.

[8] Dong, J., Xiao, X., Kou, W., Qin, Y., Zhang, G., Li, L., ... & Liu, J. (2015). Tracking the dynamics of paddy rice planting area in 1986–2010 through time series Landsat images and phenology-based algorithms. Remote Sensing of Environment, 160, 99-113.

[9] Upadhyay, G., Ray, S. S., & Panigrahy, S. (2008). Derivation of crop phenological parameters using multi-date SPOT-VGT-NDVI data: A case study for Punjab. Journal of the Indian Society of Remote Sensing, 36(1), 37.

[10] Choudhury, I., & Chakraborty, M. (2006). SAR signature investigation of rice crop using RADARSAT data. International Journal of Remote Sensing, 27(3), 519-534.

[11] Zhang, Y., Wang, C., Wu, J., Qi, J., & Salas, W. A. (2009). Mapping paddy rice with multitemporal ALOS/PALSAR imagery in southeast China. International Journal of Remote Sensing, 30(23), 6301-6315.

[12] Rossi, C., & Erten, E. (2015). Paddy-rice monitoring using TanDEM-X. IEEE Transactions on Geoscience and Remote Sensing, 53(2), 900-910.

[13] Watanabe T, Izumi Y, Tetuko J, Sumantyo S. Comparison of three compact-SAR modes through rice phenology monitoring. In Antennas and Propagation (ISAP), 2017 International Symposium on 2017 Oct 30 (pp. 1-2). IEEE.

[14] Lopez-Sanchez, J.M., Vicente-Guijalba, F., Ballester-Berman, J.D. and Cloud, S.R., 2014. The polarimetric response of rice fields at C-band: Analysis and phenology retrieval. IEEE Transactions on Geoscience and Remote Sensing, 52(5), pp.2977-2993.

[15] Chen, C.F., Son, N.T., Chen, C.R., Chang, L.Y. and Chiang, S.H., 2016. Rice crop mapping using Sentinel-1A phenological metrics. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 41, p.B8.

[16] Mansaray, L.R., Huang, W., Zhang, D., Huang, J. and Li, J., 2017. Mapping rice fields in urban Shanghai, southeast China, using Sentinel-1A and Landsat 8 datasets. Remote Sensing, 9(3), p.257.

[17] BPS – Agency for Statistic. 2015. Rice production report. Annual Report.

[18] Semedi., Siregar., Sanjaya. 2012. Rice Crop Spatial Distribution and Production Estimation Using MODIS EVI Case Study of Karawang, Subang, and Indramayu Regency. Bogor: Institut Pertanian Bogor.