Seasonal Assessment of Rice Planting and Growing Cycle in North Aceh, Indonesia: A SAM Approach on Sentinel-2 Satellite Imagery

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Abstract

Observing the growing season and planting are essential to maintaining the sustainability of rice plants and food availability in the region. Conventionally, the observation and monitoring of rice plants are carried out manually by direct observation in the field. Those activities do indeed take time and are costly. Therefore, the utilization of medium-resolution satellite imagery is an alternative way to monitor the growing season of paddy fields in the rice production center of North Aceh. North Aceh is one of the leading rice production centers in the country; monitoring the planting season and growth cycle of paddy rice are essential aspects of maintaining rice production. Conventionally, mapping and assessing plant growth in plant morphology can be known by regularly monitoring every season. One way to monitor changes in the growing season for future predictions, even though time has passed, is to use satellite imagery. This study aims to map the area and phase level of rice plant growth in Aceh rice production centers in the North Aceh regency. Spectral Angle Mapper (SAM) on Sentinel-2 imagery to map the spatial distribution of paddy fields in different phases of the rice growing season from 2019 to 2022. Growth parameters were extracted with index vegetation series to evaluate the image's ability to provide information on the rice plant growth stage from Sentinel-2 imagery. To estimate the phase rate of rice growth, spectral angle mapper analysis on Sentinel-2 images has been piloted to assist in estimating the growth phase in each season and its spatial distribution. The mapping of rice plants' growing season and growth showed differences in area distribution for the districts observed in the wet, vegetative, generative, and dry fallow phases in 2022. SAM algorithms produced different data on the growth phase of rice plants.

Keywords: *Paddy-Rice, Growing Cycle, SAM, Sentinel-2 Imagery*

1. Introduction

In recent years, monitoring the Earth's surface has been made possible by developing several modern Earth Observation systems that continuously provide large amounts of satellite data, one of which is the Sentinel 2 satellite data (Agency, 2012). Sentinel 2 data is one of the data used in remote sensing systems that can be used to monitor rice crops (Talem and Hailu, 2020).

Rice is one of the most important food crops; more than 50% of the world's population consumes it as a staple (IRRI, 2006). More than just food, rice is considered an important sector to support the national economy and maintain food stability (Redfern and Azzu, 2012). Determination of the area, beginning and end of the growing season, and growth rate of rice plants can be done with remote sensing technology. Remote sensing is an efficient technique for mapping areas relatively cheaply compared to manual observation and mapping.

Remote sensing technology has entered a new era where high-resolution imagery has been produced for various mapping purposes and to assess land cover characteristics on the Earth's surface, especially for high-resolution imagery (Bakara, 2014). However, the availability of data is limited. Medium-resolution satellite imagery can be used to substitute the use of high-resolution imagery. Using high-resolution imagery can make observing the parameters in mapping land and crop growth cycle easier, especially food crops such as rice. However, for extensive observations, using medium-resolution imagery such as Sentinel-2 can also help obtain information on the area of rice plants (Ali et al., 2021).

In the medium to high-resolution images, the texture, colour, and shape of objects in the image are almost the same as the appearance on the ground (Earth's surface), but the variation in growth can be distinguished by the spectral angle mapper approach (Kruse et al., 1993; Sugianto, 2005), and utilizing vegetation indexes, namely by formulating and combining reflection spectra in bands or channels produced by satellite images.

Rice is an important food crop that has become the staple food of more than half of the world's population. In Indonesia, rice is the primary commodity in supporting people's food. Indonesia, as a country with a large population, faces challenges in meeting the population's food needs. Therefore, food security policy is the main focus of agricultural development. According to the data (BPS, 2020). The rice harvest area in 2020 was 10.66 million hectares, a decrease of 20.61 thousand hectares or 0.19 percent compared to 2019, which was 10.68 million hectares. Rice production in 2020 amounted to 54.65 million tons of dry-milled grain, an increase of 45.17 thousand tons or 0.08 percent compared to 2019 which amounted to 54.60 million tons of GKG—especially for Aceh, rice consumption in 2019 reached 139 kg/capita/year, while nationally only 83.40 kg/capita/year. Aceh is one of the provinces that consume rice is high per capita per year.

The rice plant consists of several phases during its growth. In the early phases of growth, the condition of paddy fields is dominated by water. Then the vegetative growth phase is characterized by the denser leaves of rice plants so that they cover the rice fields. In the generative phase, the dense leaf state is replaced with yellow rice grains, while in the fallow phase, the field condition becomes fallow for some time before replanting the following season.

This study aims to map the spatial distribution of the growth phase in the 2022 planting season on paddy fields in rice production centers in North Aceh Regency. As an effort to apply technology that can be used periodically in mapping the area of rice fields, this research can be used to monitor rice plants on a broader scale if it has been found that *spectral signature is* the standard from the sample location studied.

2. Methodology

This research was conducted in North Aceh District. North Aceh Regency is located at 4° 43'17.64" to 5° 15' 45.904" North and 96° 47' 12.979" to 97° 31' 0.104" East. Location of research conducted sampling region of interest (ROI)-selection of training locations and *spectral library selection* for each growth phase at the selected site. The results are included in the image analysis as *a training set point* in sub-district areas where rice plant area cover is dominant in the appearance of satellite images. The study was conducted from February to May 2022.

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The research method was processing analysis on Sentinel 2 images—and field surveys to determine the *ground control point* (GCP). The image analysis results map the distribution of rice plants in the North Aceh district. The SAM approach analyzed the growing season cycle and plant growth. Descriptive methods with field surveys and secondary data collection are the main activities in analyzing supervised classification results and multi temporal analysis of images at the study site.

2.1. Spectral Angle Mapper (SAM)

The SAM classification algorithm uses pixels in the corrected image and compares them with spectral references at the same dimensional angle. These reference spectral values are called *Endmembers*. The image used in classification with the SAM method is first converted into an *at-surface reflectance* value. The decision-making of this classification is based on the spectral angle formed by a pixel against a spectral reference value in a feature space (Yuhas et al., 1992; Kruse et al., 1993).

$$\alpha = \cos^{-1} \frac{\Sigma XY}{\sqrt{\Sigma(X)^2 \, \Sigma(Y)^2}} \quad (1)$$

α = an angle is formed between the reference spectrum and the image spectrum
X = image spectrum
Y = spectrum reference

SAM classification recognizes objects based on mean and specific spectra (classes of objects). The average spectrum is the average value of the entire spectrum that arises from the reference object. In the classification process, if the spectral angle of the identified pixel has a degree value less than the mean spectrum, then the pixel is grouped into a predetermined class. Conversely, if the spectral angle of the identified pixel has a greater degree value, then the pixel is unclassified (non-target class). If a pixel belongs to two different classes, it will simultaneously be grouped into the class with the closest spectral angle.

A spectral library is a set of data related to a series of spectral reflections in the wavelength range between 400 nm-2500 nm, resulting from reflected electromagnetic waves captured by sensors. The spectral Library is obtained from field measurements and hyperspectral images and is used as a reference in image analysis (Sugianto and Rusdi, 2017).

Spectral libraries are obtained from field measurements or satellite imagery and developed as a reference in image analysis. *The spectral Library* is extracted from unique pixels at each growth phase from peak reflections of different wavelengths at specific times, such as red to near-infrared wavelengths, as indicators of differences in the same vegetation image (Nuarsa, 2014). The spectral Library that is built in rice plants consists of spectral rice plants in each growth phase. The growth prediction model and rice production estimation were developed by combining spectral Library with biophysical conditions/parameters of rice plants, including leaf area, leaf height, number of tillers, wet and dry weight, N uptake, and yield components (sweet potatoes).

The spectral Library is one of the parameters and inputs in the SAM classification process. Spectral Library is information about the characteristics of the reflection or emission of electromagnetic waves from the spectral reflectance of each recorded object. Spectral libraries that have a more significant number of channels are assumed to be able to classify with Higher Accuracy.

3. Results and Discussion

The result of mapping of rice field of North Aceh comprises for all districts of North Aceh Regency, resulting various spatial distribution of rice field in the region. North Aceh Regency has the most extensive rice field area in Aceh Province. Baktiya District has the largest area of rice fields compared to other districts in North Aceh Regency, with an area of 5,221.74 Ha or 13.94 percent. The districts with the smallest rice field area in North Aceh Regency are Lapang District and Nisam Antara District. Details and extent of other rice fields based on sub-districts in North Aceh Regency can be seen in Table 1 and Figure 1.

Table 1.
Distribution of Plant Area per District in North Aceh

District		Area	
		ha	%
1	Baktiya	5,221.74	13.94
2	Baktiya Barat	2,203.58	5.88
3	Banda Baro	819.85	2.19
4	Cot Girek	212.31	0.57
5	Dewantara	270.98	0.72
6	Geureundong Pase	121.27	0.32
7	Kuta Makmur	1.298.18	3.47
8	Langkahan	907.49	2.42
9	Lapang	379.15	1.01
10	Lhoksukon	3,988.48	10.65
11	Matang Kuli	1,200.97	3.21
12	Meurah Mulia	1,763.21	4.71
13	Muara Batu	1,350.46	3.61
14	Nibong	695.69	1.86
15	Nisam	1,614.53	4.31
16	Nisam Antara	6.23	0.02
17	Paya Bakong	1.132.47	3.02
18	Pirak Timu	787.56	2.10
19	Sawang	1,979.07	5.28
20	Seunuddon	1.745,07	4.66
21	Simpang Keuramat	411.76	1.10
22	Syamtalira	918.00	2.45
23	Syamtalira Aron	1,174.76	3.14
24	Syamtalira Bayu	1,283.77	3.43
25	Tanah Jambo Ayee	2,985.11	7.97
26	Tanah Luas	2,360.55	6.30
27	Tanah Pasir	615.56	1.64
TOTAL		37,447.79	100

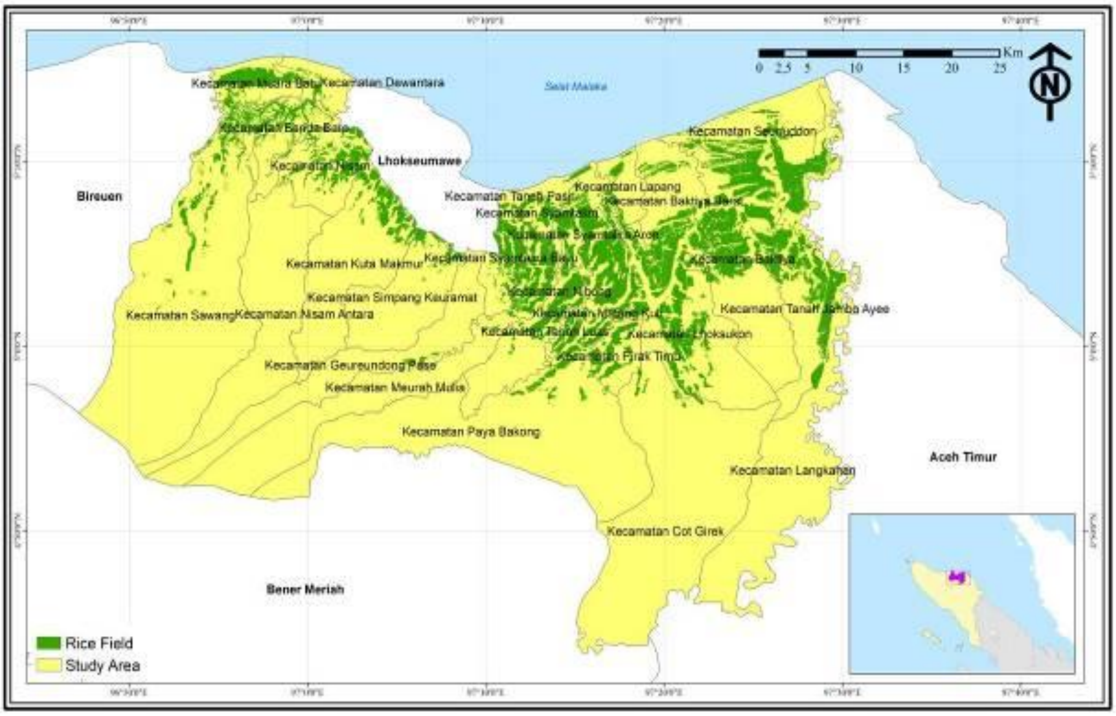

Fig. 1. Map of Rice Distribution in North Aceh Regency.

Before SAM analysis was carried out to obtain data on the growth phase of rice plants, Sentinel-2 image data was first analyzed to obtain reflectance values and patterns from the images used. Analysis of reflected patterns can be performed by looking at reflectance values at different wavelengths and bands. Analysis of the growth phase of rice plants using Sentinel-2 satellite imagery, where the bands used fit into a long-range wave with a wavelength of 10m spatial resolution band, i.e., the blue band (0.490 – 0.560 µm), green (0.560 – 0.665 µm), red (0.665 – 0.705 µm) and NIR (0.842 – 0.945 µm) (Figure 2).

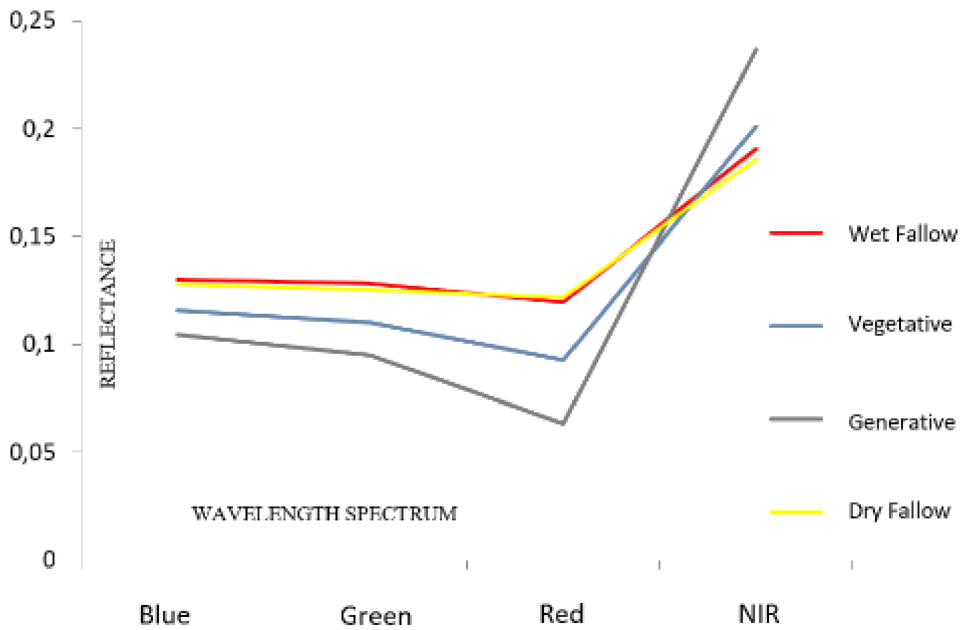

Fig. 2. Reflectance Value Compling to Wavelength Spectrum at Each Growth Phase

There is a significant difference in the reflectance value in each phase of rice plant growth. The higher the wavelength, the higher the reflectance value. In the blue, red, and green bands, the reflectance values are close together to produce a pattern that is formed stably. While in the NIR band, the reflectance value is higher than the other 3 bands, resulting in a pattern that tends to rise. Thus, the NIR band can distinguish the phases of rice growth.

Based on the opinion of Nuarsa (2014), rice-planting objects have a high level of sensitivity in the red band and near-infrared (NIR). Chlorophyll pigments on leaves will absorb light on the red channel. However, near-infrared rays are scattered by the internal sponge mesophyll on the leaf structure, which causes the reflectance value in the near-infrared (NIR) wave spectrum to be higher than the visible wave spectrum (blue, red, green).

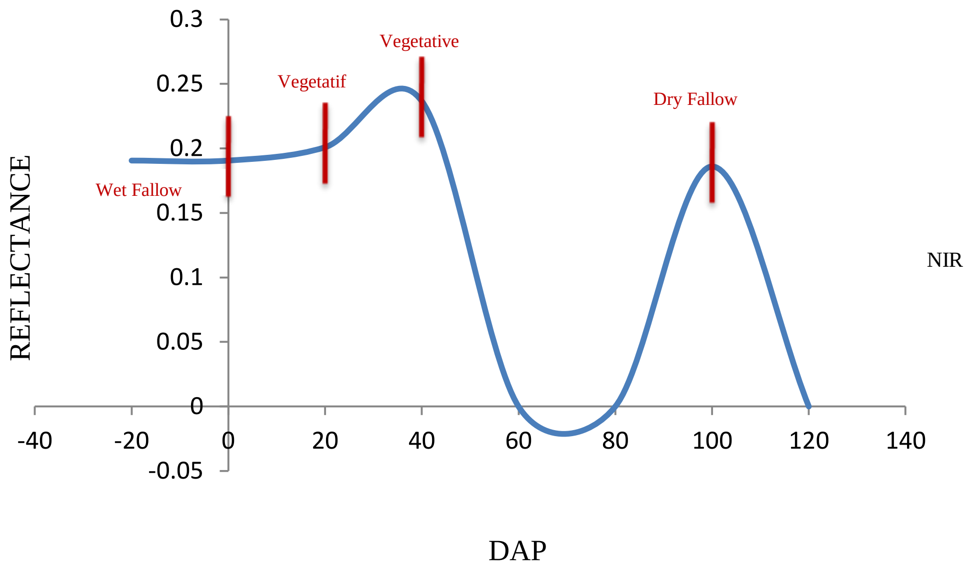

Fig. 3. The Relationship between Reflectance Value and Growing Periods (Days After Planting, DAP)

Based on the results of the analysis of Sentinel-2 image data and field survey data to produce data on the phase and area of rice plants using the SAM method to produce four phases, namely wet, vegetative, generative, and dry fallow phases. Details of the data from SAM analysis can be seen in Table 2 to Table 5 and Figure 3 to Figure 7.

Table 2.
SAM Analysis Result for January 2022.

Growing Phase		Area (ha)	(%)
1.	Vegetative	15,668.92	41.84
2.	Generative	8,195.31	21.88
3.	Wet Fallow	4,263.49	11.38
4.	Dry Fallow	9,326.30	24.90
	TOTAL	37,454.01	100

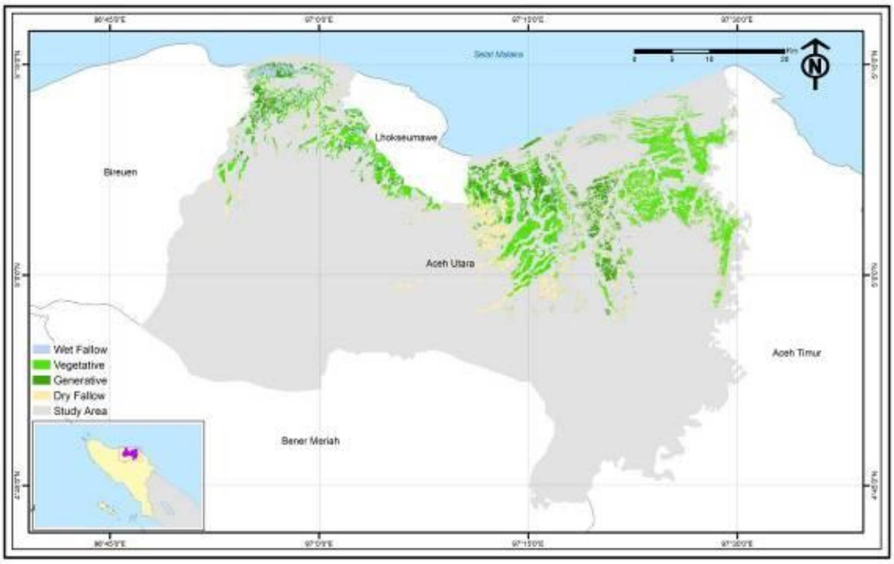

Fig. 4. SAM Result for January 2022.

Table 3.
SAM Analysis Result for February 2022.

	Growing Phase	Area (ha)	(%)
1.	Vegetative	7,982.53	21.31
2.	Generative	17,123.97	45.72
3.	Wet Fallow	6,309.89	16.85
4.	Dry Fallow	6,037.61	16.12
	TOTAL	37,454.01	100

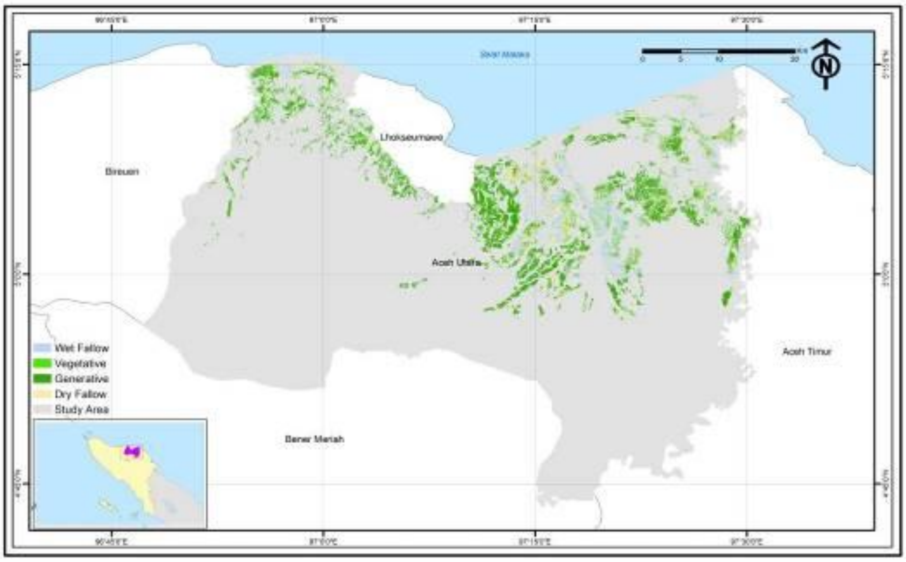

Fig. 5. SAM Result for February 2022.

Table 4.
SAM Analysis Result for April 2022.

	Growing Phase	Area (ha)	(%)
1.	Vegetative	10,645.14	28.42
2.	Generative	9,301.25	24.83
3.	Wet Fallow	10,793.74	28.82
4.	Dry Fallow	6,713.88	17.93
	TOTAL	37,454.01	100

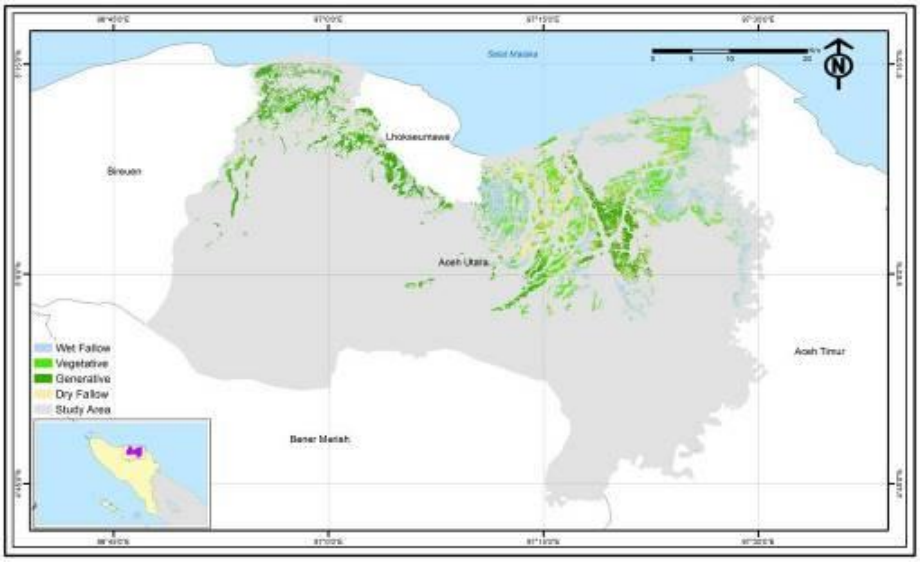

Fig. 6. Analysis Result for April 2022.

Table 5.
SAM Analysis Result for May 2022.

	Growing Phase	Area (ha)	(%)
1.	Vegetative	13,489.72	36.02
2.	Generative	5,781.28	15.44
3.	Wet Fallow	11,217.61	29.95
4.	Dry Fallow	6,965.40	18.60
	TOTAL	37,454.01	100

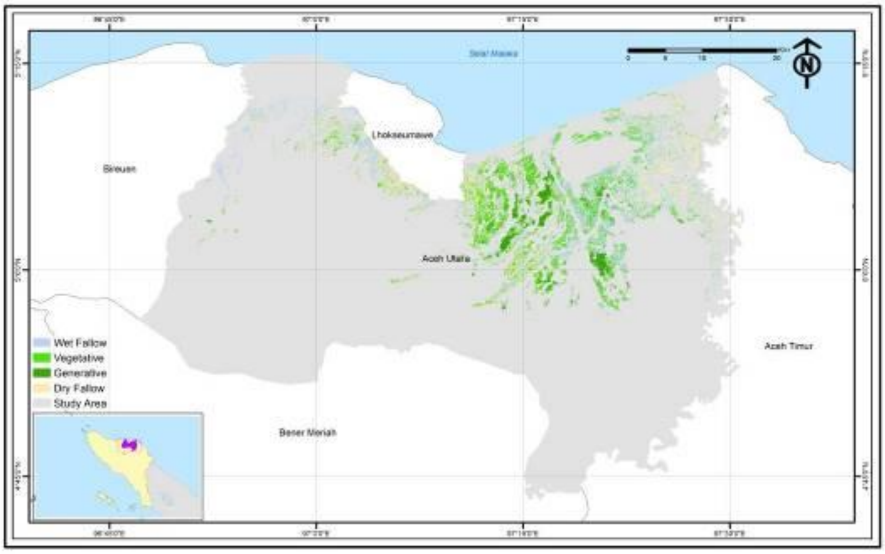

Fig. 7. SAM Result for May 2022.

4. Conclusion and Recommendations

The results of Sentinel-2 image processing using the SAM algorithm in North Aceh Regency obtained four phases of rice plants: vegetative, generative, wet fallow, and dry fallow phases. The image processing results produce plant area in each growth phase for January, February, April, and May 2002 with different spatial distributions of area for each growth phase. January 2002 was dominated by the vegetative phase, February was the generative phase, and April and May were dominated by the vegetative. This result shows there is not even a growing season in the region. The accuracy test results show the level of accuracy of SAM classification has an accuracy level with different values, SAM, which has a value range of 40% - 70%.

5. Acknowledgments

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