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Mapping of Invasive Species *Acacia Decurrens* in Part of Mount Merbabu National Park Using Prisma Hyperspectral Imagery

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Abstract: Mount Merbabu National Park (TNGMb) is a forest area in the Mount Merbabu. Management and planting changes have caused many changes to the types of plants in TNGMb. *Acacia decurrens* is an invasive species and its presence in TNGMb can result in a decrease in the diversity of native vegetation types. This research aims to (1) map the distribution of *Acacia decurrens* plants in TNGMb using PRISMA hyperspectral imagery with the Spectral Angle Mapper (SAM) and Spectral Information Divergence (SID) methods. (2) determine and test the level of accuracy of mapping *Acacia decurrens* plants in TNGMb using PRISMA hyperspectral imagery. Classification results were carried out using the SAM and SID methods on PRISMA images. The best A. decurrens mapping results were SAM classification at a maximum angle of 0.3 radians with PRISMA Imagery. The distribution of *Acacia decurrens* in the TNGMb area is in the southwest and northwest. The best accuracy test results were from mapping *Acacia decurrens* with PRISMA images with an accuracy test value of 56.36%.

Keywords: *Acacia decurrens*, PRISMA Hyperspectral, Spectral Angle Mapper (SAM), Spectral Information Divergence (SID)

INTRODUCTION

Mount Merbabu National Park (TNGMb) is in Central Java Province. This forest area was recognized by the Dutch East Indies Government as a forest area before Indonesian independence. After Indonesia became independent, this forest area was managed by the Government of the Republic of Indonesia with several management changes. In central Java, Mount Merbabu has been recorded as the most recent distribution area of the species but research in this area is limited (Kurniawati, 2017). In 2004, "Decree of the Minister of Forestry Number 135/Menhut-II/2004 was issued regarding changes in the function of Protected Forest Areas and Natural Tourism Parks in the Mount Merbabu Forest Group" so, it was designated as the Mount Merbabu National Park (TNGMb). Based on official legal provisions, the TNGMb area is strengthened by "Decree of the Minister of Forestry Number SK.3623/Menhut-VII/KUH/2014 concerning the Determination of the Mount Merbabu National Park Forest Area covering an area of 5,820.49 hectares in Semarang Regency, Boyolali Regency and Magelang Regency, Province Central Java". The decision was made on May 6, 2014. Said to have high diversity if the community is composed of many species with the same species abundance and almost the same (Astuti, Murningsih, & Jumari, 2018). Forest fires in Mount Merbabu National Park that occur almost every year are a serious almost every year is a serious problem, especially in the dry months. Recorded in the last ten years, between September 2014 and September 2019, there have been 4 large fires (Hadi, Mukti, & Widyatmanti, 2021). Mount Merbabu National Park (TNGM) is one of the natural attractions for Central Java Province which is at an altitude of 3,142 meters above sea level located in three districts namely Semarang, Magelang and Boyolali Regencies (Kartika, Utomo, & Tambotoh, 2023).

Management and planting changes in the TNGMb area have caused many changes to the types of plants in TNGMb. There are even several parts where people are allowed to carry out intercropping and *cemplongan* planting. One of the plants planted in TNGMb is *Acacia decurrens.* The *Acacia decurrens* plant originates from New South Wales, Australia, specifically in the Greater Blue Mountains area, and was brought to Indonesia during the Dutch colonial era. Such high dominance could threaten the stability of the ecosystem in the TNGMb area (Untoro, Hikmat, & Prasetyo, 2017). The *Acacia decurrens* plant has benefits for the forest products industry. This is caused by the excess of invasive species invasive species which is triggered by the nature of the invasive species themselves, including having ability to grow quickly, and mature (Putri, Lestariningsih, & Ramadhani, 2024).

Acacia decurrens plant is a tree that has fast growth and can grow after forest fires occur (Moore, 2002). *Acacia decurrens* can adapt to new environments so it has the potential to become an invasive species. The invasion that occurs can threaten the existence of the natural ecosystem found in TNGMb (Purwaningsih, 2011). The *Acacia decurrens* plant has the characteristic of being able to grow to the adult phase and reproduce in less than two years. According to Purwaningsih (2010), the dominance of *Acacia decurrens* in TNGMb has caused a decrease in the diversity of native vegetation types. *Acacia decurrens* in TNGMb is invasive because it flowers all year round and its seeds are resistant to forest fires. Thus, the participatory mapping process in this activity is in line with the concept of participatory in general (Ayuningtyas, 2022).

Hyperspectral images have a narrow range with a large number of channels. One use of this narrow range is to detect special physiological characteristics, structures, and even species (Niphadkar & Nagendra, 2016). The hyperspectral image used in biodiversity mapping to species mapping is *Precursore Iper Spettrale della Missione Applicativa* (PRISMA). This research is about mapping the invasive plant *Acacia decurrens* using PRISMA hyperspectral imaging.

LITERATURE REVIEWS

1. PRISMA Hyperspectral Imagery

PRISMA (Hyperspectral Precursor of the Application Mission) Hyperspectral Image is images that has high spectral resolution and distinguish objects based on spectral response. It consists of 100-200 channels with a narrow range (70-400 nm). The narrower the spectral range, the easier to distinguish specific spectral characteristics. Therefore, species-level identification can be carried out using hyperspectral remote sensing response bases. PRISMA mage which is owned by ASI *(*Agenzia Spaziale Italiana) was launched on March 22 2019 on the rocket VEGA (Vettore Europeo di Generazione Avanzata). Invasive species control using hyperspectral remote sensing is considered more efficient than conventional methods because it is able to present wide spatial coverage, multi-time, and multi-channel. Multiple Endmember Spectral Mixture Analysis (MESMA) is required in the spectral unmixing process because the distribution of Acacia decurrens communities is smaller than the spatial resolution of PRISMA Hyperspectral imagery (Sulistyarini, A., & Arjasakusuma, 2023).

Table 1. PRISMA image characteristics

Parameter	VNIR	SWIR	Panchromatic
Spectral range	400-1010 nm	920-25050 nm	400-700 nm
Spectral resolution	≤ 12 nm	≤ 12 nm	-
Number of bands	66	171	1
SNR (signal to noise ratio)	200 in the range 0.4-1.0 µm	200 in the range of 1.0-1.75 µm 100 in the range of 1.95-2.35 µm	240
MTF (Modulation Transfer Function)	0.8	> 0.7	> 0.2
Spatial resolution	30m	30m	5m
Pixel size	30 x 30 m	30 x 30 m	6.5 x 6.5 m
Width of sweep	30km	30km	30km

Source: www.eoportal.org

2. Characteristics of the Invasive Species Acacia Decurrens

Acacia Decurrens is an invasive species that grows quickly or is difficult to control with a high level of dominance causing disruption to natural habitats and threatening ecosystem stability in the Mount Merbabu National Park Area.

Invasive species are species that widely affect their habitat, environmental damage, and can live in their new habitat, and become a nuisance to biodiversity, ecosystems, socio-economics, and human health. The development of invasive species tends to be rapid and able to adapt well to new environments.

Figure 1. Physiology of *Acacia decurrens* plants and flowers (Personal documentation, 2024)

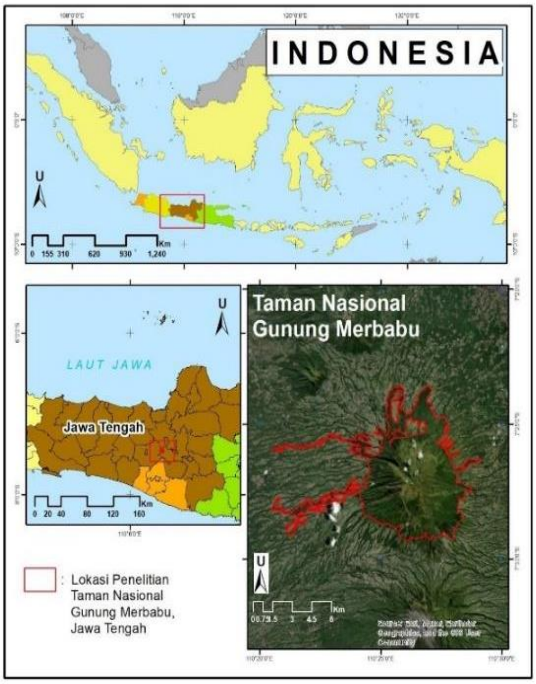
RESEARCH METHODS

This research is divided into several main stages, namely data preparation, data processing, and validation tests. The research stages can be seen in the flow diagram in Figure 3. The method used in this research is guided classification using the Spectral Angle Mapper (SAM) and Spectral Information Divergence (SID) methods.

1. Research sites

The research location is in the Mount Merbabu National Park Area (TNGMb) geographically located at 110° 32'E –110° 48'E and 7° 38' South Latitude –7° 48' South Latitude with an altitude of 600 – 3142 meters above sea level.

Figure 2. Research Location



2. Data processing

The data processing stages consist of: Channel Selection, PRISMA Image Masking, Initial Classification, Spectral Library Processing, Spectral Angle Mapper (SAM) Classification, and Spectral Information Divergence (SID) and Accuracy Test.

3. Spectral Angle Mapper (SAM)

Spectral Angle Mapper (SAM) is a pixel-based classification method. The SAM algorithm determines the similarity between two spectral reflections by calculating the spectral angle between them. The smaller the angle formed the closer and more similar it is to the reference spectral. Angles that exceed the threshold become angles that are not included in the classification.

4. *Spectral Information Divergence* (SID)

Spectral Information Divergence (SID) classification algorithm is a classification method that uses divergence measures to compare object pixels with a spectral reference in classifying objects (Salghuna & Pillutla, 2017).

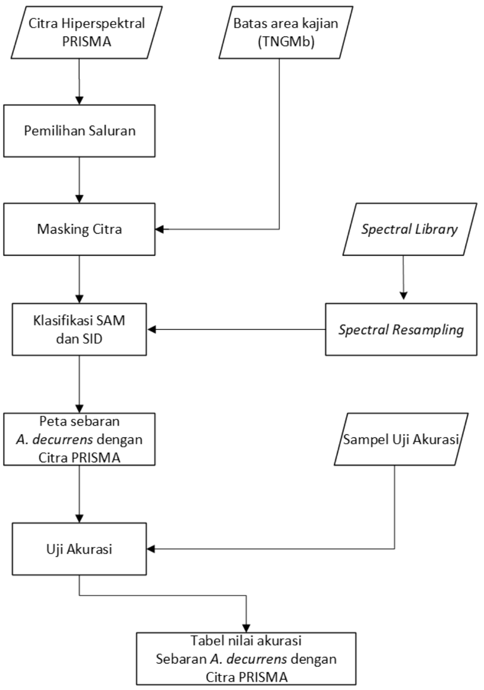
The difference between the reference pixel and the analyzed pixel determines the divergence value; similar pixels have small divergence values. SID is a pixel-based classification algorithm originating from information theory, used to describe materials (Chang, 2000). According to (Rahmandhana, Kamal, & Wicaksono, 2022) , the accuracy of species mapping using SID is higher than using the SAM algorithm.

5. Accuracy Test

Accuracy tests are carried out to measure the accuracy of the classification results with the results of observations in the field. The confusion matrix method was used in this research to test the level of accuracy of *Acacia decurrens* mapping. Accuracy using the confusion matrix is calculated by user accuracy, manufacturer accuracy, and overall accuracy.

Accuracy tests are carried out based on the classification process carried out. This accuracy test aims to differentiate between the classification of *A. decurrens* and non - *A. decurrens plants.* From the results of the Canonical Correspondence Analysis (CCA), Acacia decurrens, at the seedling stage, appears to coexist with other groundcover species such as Alangium javanicum and those from the Araliaceae family (Sutomo, 2019).

Figure 3. Research flow diagram



RESULTS AND DISCUSSION

This research uses 2D-level PRISMA images recorded on May 3, 2022. The 2D level images on PRISMA have been radiometrically corrected (*Top of Atmosphere*), atmospherically (*Bottom of Atmosphere*), and have been orthorectified.

The use of hyperspectral imagery such as PRISMA imagery also requires consideration of the number of channels used. In this study, channel selection is based on the observed wavelength requirements, especially for vegetation objects that are sensitive to the near-infrared channel and show reflection variations in the visible channel. Besides considering wavelength, it is also important to consider the image conditions on each channel. The channels used must have low or minimal noise levels.

The selection of channels that are free from noise is done visually. The required wavelength range is from the blue channel to the near-infrared, from 406 nm to 849 nm for a total of 51 channels. PRISMA image that has gone through the initial stages of data processing as seen in Figure 4.

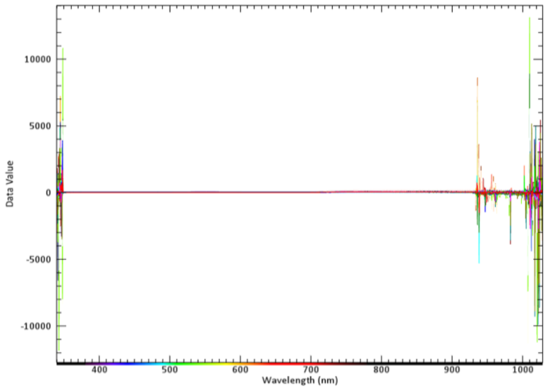
Figure 4. PRISMA image after the *masking process*

The endmember data used in this research comes from field endmember extraction carried out using a JAZ VNIR spectrometer by Sulistyarini in 2023. This spectrometer has a spectral range from 339.581421 nm to 1028.441772 nm (Sulistyarini, 2023).

The total endmember samples used were 46, consisting of 15 Acacia samples, 7 Cinchona samples, 3 Pine samples, 3 Pine samples, 9 Puspa samples, and 9 Savannah samples. Each type of vegetation is measured at three angle variations, from the right, left, and in front of the recorded object. In addition, samples were taken from vegetation with different relative ages to examine differences in the spectral response of each vegetation.

Figure 5 shows the spectral reflection curve from spectrometer measurements before processing. It can be seen that there is *noise*, especially at wavelengths less than 400 nm and around 900 nm. To overcome this, a spectral resampling process needs to be carried out."

Figure 5. Spectral reflection curve of initial data from spectrometer measurements

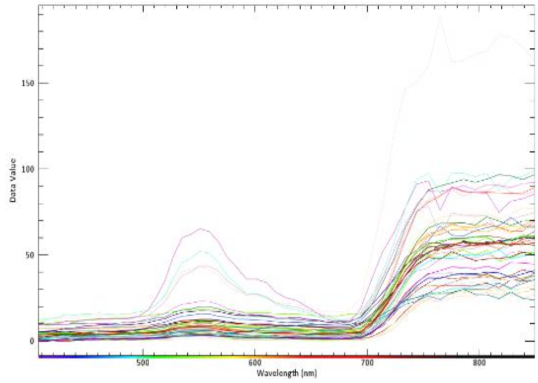


The spectral reflection pattern has been subjected to *spectral resampling* is seen in Figure 6. The spectral reflection pattern that is visible is the highest reflection seen in the near-infrared channel, the reflection that tends to be low is in the blue channel. This pattern occurs because the infrared channel reflects the greatest energy when it hits objects in the form of vegetation. *Spectral resampling* will produce spectral data from a spectrometer that has the same spectral resolution as the image used.

In the PRISMA image, the wavelengths used are 400.133331 nm to 849.883911 nm. These wavelengths are the in the blue, green, red and near-infrared channels. The *spectral resampling* process is carried out using image *files* as input in the *spectral resampling process*. The image used is an image that has been stacked at this wavelength.

The spectral reflection patterns from *the endmembers* , which initially amounted to 46 data, have undergone an optimization process to select the most representative *endmembers* . This process is known as Spectral Optimization and produces 30 *endmembers* that are considered optimal for use as input data in the SAM and SID classification processes.

Figure 6. *Endmember* data spectral reflectance curve concerning the PRISMA image wavelength

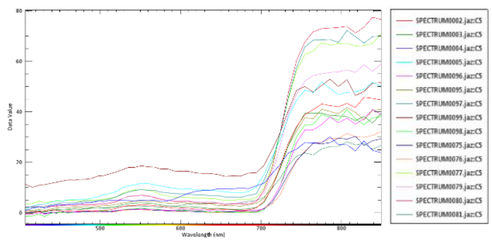


A decurrens in the endmember data reflection curve of PRISMA image extraction have high reflectance at wavelengths of 690 nm to 800 nm, which is the near-infrared channel in PRISMA images. The spectral reflectance pattern *of A. decurrens* varies depending on the age type.

This variability is influenced by the health condition of the leaves, leaf width, and chlorophyll content in the leaves. Figure 7 shows that the spectral reflection pattern *of A decurrens* generally has a similar curve shape, the data values give a different response at each reflection point.

CCA analysis showed that temperature and light density was positively correlated with *A. decurrens* abundance. This study showed that the IAPS invasion in MMNP was correlated with the eruption of Mount Merapi (Sunardi, Sulistijorini, & Setyawati, 2017).

Figure 7. Spectral reflectance curve of *A. decurrens endmember data* from PRISMA image extraction

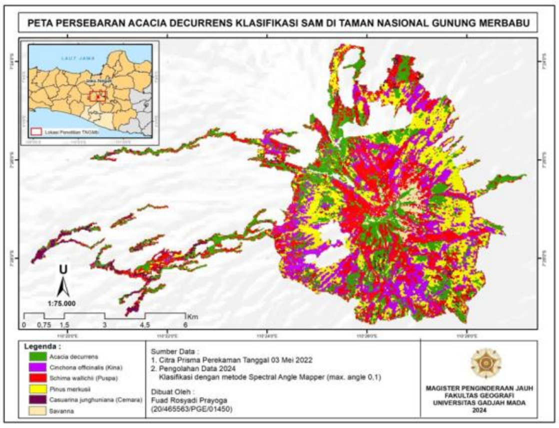


1. *Spectral Angle Mapper* (SAM) Classification

Classification of the distribution of *A. decurrens* was carried out using the *Spectral Angle Mapper* (SAM) method using PRISMA Imagery. Figure 8 displays the classification results based on spectrometer *endmember data* on PRISMA images using the SAM method at a maximum angle of 0.1 radians. On the map, the dominance of the vegetation class can be seen in the *Schima wallichii* (Puspa) plants which are evenly distributed throughout almost the entire TNGMb area. The next dominant plants are *A. decurrens* , *Cinchona officinalis* (Kina), and Pinus merkusii. *Casuarina junghuhniana* (Cemara) is more common in the outer areas of TNGMb and does not appear to dominate.

The distribution of vegetation that looks *underestimated* is the Savanna plants which should be at the top of Mount Merbabu but do not appear to dominate that part. Classification using the SAM method at a maximum angle of 0.1 radians shows the existence of unclassified TNGMb areas. Therefore, it is necessary to vary the maximum angle to obtain optimal classification results, namely at a maximum angle of 0.2 and 0.3 radians.

Figure 8. Distribution map *of A. decurrens* Classification SAM max. *angle* 0.1



The results of classifying the distribution of *A. decurrens* using the SAM method with a maximum angle of 0.2, as seen in Figure 9, show a similar spatial distribution for each vegetation type with the SAM method at a maximum angle of 0.1 radians. The dominant vegetation is the *Schima wallichii* (Puspa) plant. The apparent difference is a reduction in unexplained classifications. In Figure 10, the results of classifying the distribution of *A. decurrens* using the SAM method with a maximum angle of 0.3 shows a spatial distribution that is similar to the previous SAM method map. On this map, the unexplained classes are decreasing. Therefore, visually, classification using the SAM method with a maximum angle of 0.3 shows optimal results.

Figure 9. Distribution map *of A. decurrens* Classification SAM max. *angle* 0.2

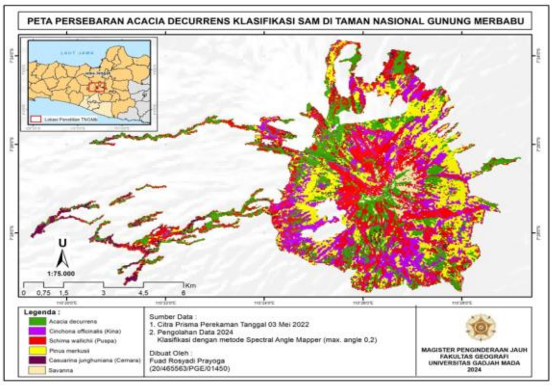
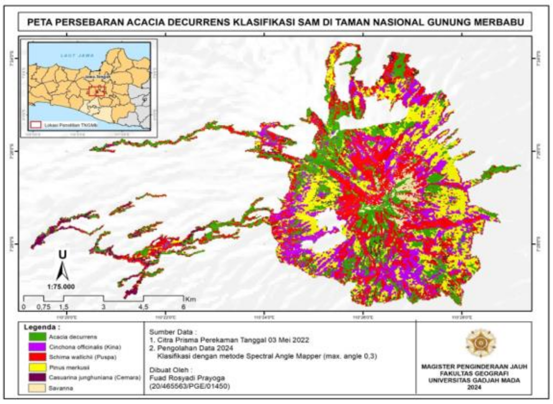


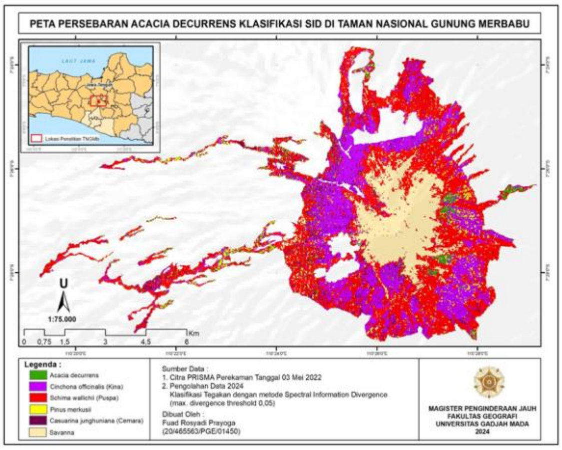
Figure 10. Distribution map *of A. decurrens* Classification SAM max. *angle* 0.3



2. Classification (*Spectral Information Divergence*) SID

The next classification uses the SID method with *endmember data input* from the spectrometer. In this classification, we also tested three variations, namely the maximum divergence threshold *of* 0.05, 0.10, and 0.15.

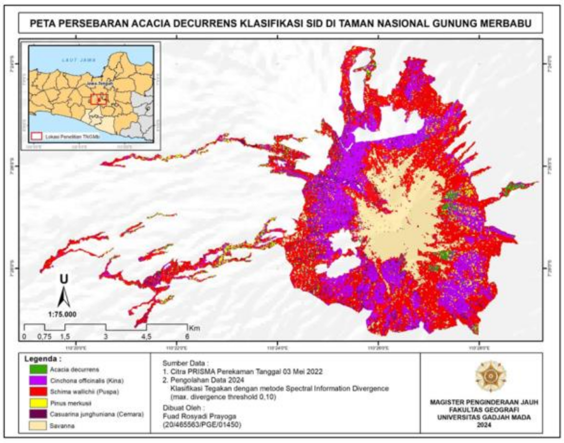
Figure 11. Distribution map *of A. decurrens* Classification SID max. *divergence threshold* 0.05



The distribution map of *A. decurrens* is classified using SID with a maximum difference limit of 0.05, as seen in Figure 11. The results of this map show the distribution of Savanna plants that dominate the peak area of Mount Merbabu.

In the area below, the *Schima wallichii* (Puspa) plant dominates all sides of TNGMb. Furthermore, the *Cinchona officinalis* (Kina) plant dominates almost all sides of the TNGMb area. However, *A. decurrens* , Pinus merkusii, and *Casuarina junghuhniana* (Fir) do not dominate and tend to be underestimated.

Figure 12. Distribution map *of A. decurrens* Classification SID max. *divergence threshold* 0.10



The distribution map *of A. decurrens* was classified using SID with a maximum difference threshold of 0.10, as seen in Figure 12. The dominance of *the Schima wallichii (Puspa)* plant can be seen in the middle to lower areas of Mount Merbabu National Park.

Figure 13. Distribution map *of A. decurrens* Classification SID max. *divergence threshold* 0.15

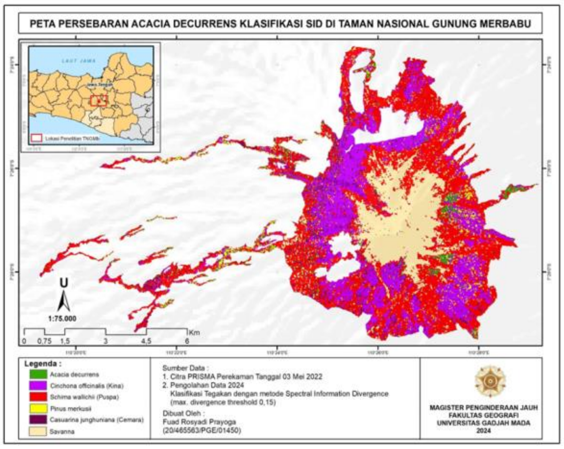


Figure 13 shows the distribution map *of A. decurrens* classified using SID with a maximum difference threshold of 0.15. The dominant plant on this map is *Schima wallichii* (Puspa), with visuals similar to the previous variation.

3. Accuracy Test

Accuracy test samples were carried out by taking field samples carried out on the official Mount Merbabu climbing route via Suwanting and the official Mount Merbabu climbing route via Selo. The Suwanting climbing route is located in Suwanting, Banyuroto Village, Sawangan District, Magelang Regency.

The Suwanting route is a narrow path, during field activities on the Suwanting route it is not possible to survey locations that are not on the side of the climbing route. Most of the route is also on the edge so the right and left sides are steep valleys where it is not possible to carry out surveys. The condition of the route when it rains makes it slippery and there is a flow of rainwater which makes it difficult to carry out field surveys. Rain conditions were also unable to reach the savanna vegetation during field surveys. The condition of the Suwanting climbing route is shown in Figure 14.

Figure 14. Condition of the climbing route via Suwanting

A. decurrens plants in the Suwanting route tend to be scattered and not grouped until they reach the Mitoh Valley which is located at an altitude of 2,127 meters above sea level. Plants associated with *A. decurrens* are pine, quinine, puspa, and shrubs. Some samples located under cloud cover in the PRISMA image cannot be used for accuracy testing. Field surveys on the Suwanting route were hampered by rainy weather during the day and the terrain of the climbing route did not allow making plots with a size of 1 pixel or 30x30 meters.

The official climbing route for Mount Merbabu via Selo is located in Suroteleng Village, Selo District, Boyolali Regency. The presence of *A. decurrens* on the Selo climbing route was found at the beginning of the climbing route, namely in the area behind the Selo Resort, Mount Merbabu National Park Hall.

There are several areas where *A. decurrens* dominate with interspersed Pinus, Kina, Puspa plants and the background of the stands is bushes as in Figure 15. The percentage of *A. decurrens* covered in one pixel is around 35% to 50%. Weather conditions are an obstacle in carrying out field surveys so the sampling that can be done does not reach the Savanna land cover on the Selo climbing route.

Figure 15. Condition of land cover around the Selo climbing route

The condition of the route in Selo makes it possible to observe the presence of *A. decurrens plants* on the side of the climbing route. The obstacle faced by field activities is rainy weather conditions during the day. There were 10 samples obtained.

Overall the number of samples is 55 samples. These samples were divided into classes *A. decurrens* and *Non-A. decurrens* . Based on the sample data, an accuracy test was carried out using a confusion matrix.

Table 2. Confusion matrix for accuracy test of A. decurrens classification results using the SAM method (max angle 0.3 radian) on PRISMA Image

	A. decurrens	Non-A. decurrens	Total	Users' Accuracy	Commission's Error
A. decurrens	17	18	35	48.57 %	51.43 %
Non-A. decurrens	6	14	20	30 %	70 %
Total	23	32	55	Overall's Accuracy	
Producer's Accuracy	73.91 %	56.25 %		**56.36 %**	
Omission's Error	26.09 %	43.75 %			

Accuracy test results for the distribution of *A. decurrens* using the SAM method (maximum angle 0.3 radians) as in Table 2. A total of 17 *A. decurrens samples* matched the classification results and field survey results with *a User's Accuracy value* in the *A. Decurrens class* of 48.57%. *Producer's Accuracy* value in class *A. Decurrens* 73.91%. The results of the classification of *Non - A. decurrens* contained 14 samples that matched the results of the classification and the results of the field survey, for an overall accuracy of 56.36%.

The results of the accuracy test for the distribution of *A. decurrens* using the SID method (*max divergence* 0.15) on PRISMA Image are presented in Table 3. The overall accuracy of this classification is 38.18%. In the *A. decurrens class,* there was only 1 suitable sample between the classification results and the results in the field. *Users' Accuracy* value in class *A. Decurrens* 2.86%. *Producer's Accuracy* value in class *A. Decurrens* 100%. For *Non-A class. The corresponding decurrens* between the classification results and the results in the field were 20 suitable samples. The low level of accuracy in SID classification on PRISMA images shows that the *A. decurrens classification results* tend to be underestimated. Meanwhile in *Non-A class. decurrens, the Schima wallichii (Puspa)* class dominates the classification results using the SID method.

The accuracy test values for the SAM method and SID method are better than the SAM method. The distribution of variations in vegetation types using the SAM method also looks better compared to the SID method. The SID method can differentiate Savanna vegetation types better when compared to the SAM method. However, overall both methods were not able to produce maximum accuracy test values.

This is because the types of vegetation in TNGMb are heterogeneous and their distribution tends to be random. So the number of pure pixels that can be identified is only small. Apart from that, the ideal and good condition of endmember data will also influence the results of accuracy test values from mapping the distribution of *A. decurrens*.

Table 3. Confusion matrix for accuracy test of A. decurrens classification results using the SID Method (max divergence 0.15) on PRISMA Image

	A. decurrens	Non- A. decurrens	Total	Users' Accuracy	Commission's Error
A. decurrens	1	34	35	2.86 %	97.14 %
Non- A. decurrens	0	20	20	0 %	100%
Total	1	54	55	Overall's Accuracy	
Producer's Accuracy	100%	62.96 %		**38.18 %**	
Omission's Error	0 %	37.04 %			

CONCLUSION

Gunung Merbabu National Park (TNGMb) is a conservation area with a high level of biodiversity (Siregar & Musadri Asbi, 2020). The best results of mapping *A. decurrens with PRISMA Imagery using the SAM and SID methods were SAM classification at a maximum angle of 0.3 radians*. The distribution of *A. decurrens* in the TNGMb area is in the southwest and northwest.

The accuracy of test results using the SAM method weas 56.36%. The SAM and SID methods have a relatively low level of accuracy for mapping *A. decurrens* in Mount Merbabu National Park, this is due to the presence of heterogeneous vegetation so that only a few pixels are pixels with only one type of vegetation.

Reading maps (and interpreting maps) for geographers is a very urgent activity in an effort to tap, extract and recognize the geospatial data side (Kumalawati, Riadi, & Febriyan, 2020).

Indonesia urgently needs an effective and implementable plant conservation strategy, in accordance with the conditions and characteristics of its geography, biodiversity and high level of endemicity (Widyatmoko, 2019).

At the planning level, community participation is consultative; the role of national park managers tends to be dominant in planning and designing activity programs while the community only participates in these activities by getting incentives (Sadono, 2013).

THANK YOU NOTE

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