

Forest Condition Analysis Based on Forest Canopy Closure With Remote Sensing Approach

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ABSTRAK

Analisis Kondisi Hutan Berdasarkan Tutupan Kanopi Menggunakan Pendekatan Remote Sensing. Pengurangan luasan hutan masih menjadi problem di Indonesia teristimewa untuk Pulau Jawa dengan kondisi populasi penduduk yang terpadat. Untuk mengetahui seberapa jauh perubahan kawasan Gunung Papandayan terhadap fungsi bentang ekologisnya maka dicoba analisis satelit SPOT 2 tahun 2008 dengan standart koreksi pada level 2A. Prosesing data satelit dilaksanakan dengan melakukan pengukuran awal meliputi radiometri, geometri, dan koreksi topografi untuk memisahkan bentuk bentang penggunaan berupa hutan dan atau lainnya. Penutupan kanopi dicatat menggunakan foto digital dan dianalisis menggunakan perangkat lunak RGBFisheye. Hasil penelitian dapat ditunjukkan bahwa kawasan Papandayan terdiri dari kawasan hutan terbuka (10-40%), semi tertutup (40-70%) dan tertutup (>70%). Hasil analisis juga dapat dihitung seluas 16,846 ha. Sebagian hutan merupakan hutan semi terbuka (49,38% atau 8983 ha) yang terdiri dari 3604 tapak sedangkan hutan terbuka terdiri dari 15,07% (2741 ha) dan tersusun 16450 tapak.

Kata kunci: Kondisi hutan, tutupan kanopi, photograph, Gunung Papandayan.

INTRODUCTION

Tropical rain forests have a variety of ecological functions, such as carbon storage. Hydrologic cycle is one important part of the ecological functions of tropical rain forest. In addition, tropical rain forests also serve as a refuge of living marine resources as they provide habitat for endemic animals and plants (Montagnini & Jordan 2005). However, the widespread transfer of forest land into agricultural land, residential & industrial, has caused extensive reduction and fragmentation of forests which in turn may affect ecological functions of forests

(FWI / GFW 2001). Current forest condition in Indonesia is very worrying. Deforestation has become a threat to the majority of forests in Indonesia, especially in Java which has a high population density. Indonesia as a whole has lost more than 20 million ha of its forest cover between 1985 and 1997 the average deforestation rate reached 1.7 million ha per year. Forest land in Java itself in the perspective of space has been fragmented into patches of patch-like farm fields, gardens, fields and residential and industrial. Land use to meet human needs such as agricultural land and the fields will continue to increase the rate of defores-

tation and forest fragmentation inherent in the nature reserve and national parks. If this activity continues to adversely impact on the ecological functions of forests as described previously (FWI/ GFW 2001).

Some studies, for example Zuhri & Sulistyawati (2007) and Wickham *et al.* (2007), shows that the use of land around the forest is one factor that can influence the occurrence of disturbances on forests, especially from human activities. Therefore, in forest conservation efforts, it is important to study the existence of a forest in the spatial or spatial perspective, including a look at the position between the forest land-use forms in the vicinity. One technology that can be used to conduct spatial analysis of forest landscape and its surroundings quickly and accurately is remote sensing. In principle, this technology allows users to identify landscape structure within a broad spatial scale. Remote sensing technology, when combined with geographic information system (GIS) can facilitate data management, data processing and presentation of data in spatial or in forms that are easy to be understood and used for forest management purposes.

The Mount Papandayan volcano area is one area that still has a fairly extensive forest areas, and includes the conservation area is the Mount Papandayan Natural Reserve. Various ecological functions are still stored in these forests, including as a store of carbon. It is known that in the year 1994 till 2001 the volcano area, capable of storing carbon stocks reach 2,771,575 Mg C (Sulistyawati *et al.* 2006). This area is

one of the remaining conservation areas in Java with a variety of problems as a conservation area in it, including the problem of deforestation (Whitten *et al.* 2007). Illegal logging and land clearing and plantation agriculture is still a threat in some corners of the forest area in this region. Natural factors, namely the eruption that occurred in 2002, also became the cause of damage to some forest areas in the volcano area. Seeing these conditions it is necessary to attempt to determine the extent to which these disturbances have affected the structure and quality of forests in the volcano area spatially.

Forest canopy closure is one important parameter in providing the effect of several ecological processes in a forest ecosystem and is a key variable in several studies on the modeling of forest protection, forest management and planning. Canopy cover can also be used as indicators of forest condition in knowing the extent of its density, other than that it is also used as an indicator in estimating the density of stands, to calculate leaf area index (LAI), various indices of vegetation, habitat analysis and in estimating the composition of forest vegetation (Korhonen *et al.* 2006). In addition the canopy closure is one of the parameters used to define the term 'forest' with 'other vegetation areas' (Paletto & Tosi 2009). One use of identification data based on the condition of the forest canopy cover this in the future can be developed to determine the condition of the forest (forest health), forest conservation, disaster management and evaluation in conducting forest management in the volcano area (Prasad *et al.* 2010).

This study also explored the use of digital photography as a simple method to obtain the level of canopy closure (CC) in a forest. In this study, canopy closure is defined as an area of tree canopy cover is projected horizontally at the soil surface, and expressed as a percentage of land covered by such projections (Escobar *et al.* 2005). Satellite remote sensing technology is a technology that is often to perform analysis of canopy cover, where the assumptions used is any change in the forest canopy closure is reflected in the canopy structure as described in the satellite image (Prasad *et al.* 2010). This research aimed to detect the land cover around Mount Papandayan and to analyze forest condition using remote sensing approaches and parameters of canopy cover as a determinant of the existence and condition of the forest landscape perspective contained in the Mount Papandayan volcano area.

MATERIALS AND METHODS

This research was conducted at the Mount Papandayan and surrounding area, located within the administration area of Kabupaten Garut and Kabupaten Bandung, West Java, Indonesia. With the study area boundaries are determined by arbitrary which in 7° 8' 25.277" LS until 7° 23' 20.944" LS and 107° 39' 41.167" BT to 107° 48' 36.304" BT with a total study area covers 36,963 hectares. This area consists of natural forests and forest plantations. Regions volcano has an altitude 2,638 meters above sea level. General location of steep topography, hilly, mountainous and has a steep cliff.

According to climate classification the area of Mount Papandayan is concluded as climate type B with annual rain fall up to 3,000 mm, average air temperature 10C and air humidity between 70-80% (Ulumuddin 2004).

METHODS

Satellite imagery used in this research is the SPOT 2 satellite imagery, with the date of acquisition June 20, 2008. SPOT satellite image data was the main data to extract thematic information on land cover. The data supporting for spatial data was digital elevation model (DEM) which contains information on the altitude. This DEM data is the supporting data to make ortorectification SPOT satellite imagery.

Software used to perform processing satellite image data that is ER Mapper 7.0 and ERDAS Imagine 9.1. Meanwhile, to perform spatial analysis and GIS data used the software ArcGIS 9.3. Other software used in this study was RGBFisheye which is a software for image processing hemispherical photographs.

In this study, the SPOT image data used consisted of two scenes, where the area of the Mount Papandayan volcano is located on the border between the two scenes, so to get the image area done first study combining the two images (mosaic image) and make selection in the study area the Mount Papandayan area. The process of merging the images using ER Mapper 7.0 software.

SPOT image data that is used already experiencing radiometric and geo-

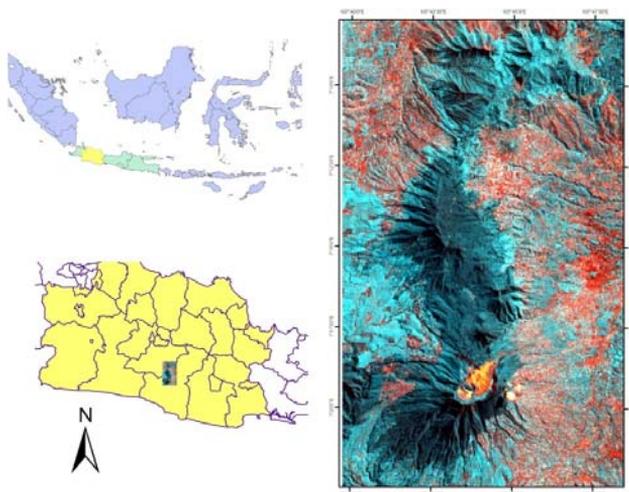


Figure 1. Location of Study Area (Source: SPOT Image 2008).

metric correction 2A level, but because the study area is a mountainous region which has a very curvy contours, topographic correction was also done to further improve the quality of spatial data in the extraction of image and reduce the shadow effect due to topography of the study area very varied. Shadow effects greatly affect the result of interpretation, especially for mountainous areas, thus this process is needed for the study area in the volcano area.

Topographic correction process carried out by using the software ERDAS Imagine 9.1. Applications used in the software is in part based topographic normalization Minnaert constant. In principle applied in the normalization process involves several functions, and data as shown in Figure 2. One of the necessary data is elevation data obtained from the DEM, and data concerning the direction of sunlight coming to the angle sensor (solar azimuth & elevation) derived from SPOT imagery metadata. Prior to con-

ducting the topographic normalization using the software, changed the structure of image data prior to radians, and after normalizing the data structure is returned in the float data type and then used to perform spectral extraction in land cover land use classification.

Prior to the classification of vegetation cover information, beforehand to process visual images increased by adding a layer of vegetation index SPOT multi-spectral imagery and false color composite technique to facilitate the identification of each land cover. Then the image classification based discrimination is open forest (canopy closure 10% -40%) with levels of density is low disturbed and extracted; forest dense (40% -70%) with levels of density is medium average forest subjected to disturbance; and very dense forest (canopy closure > 70%) with levels of density is a very high and very dense forest, undisturbed intact patches, some area have high forest extracted once, now well protected and managed;

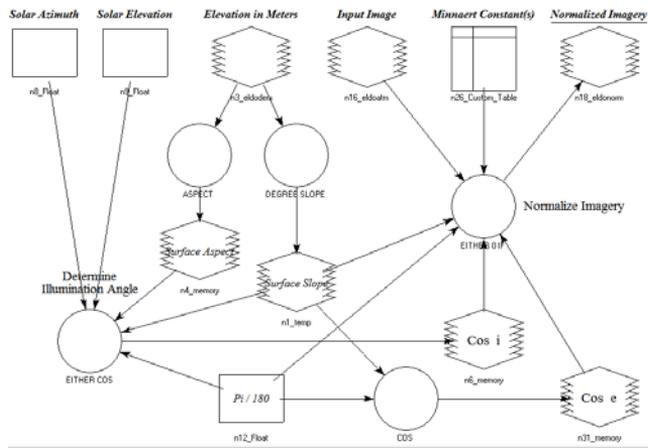


Figure 2.. Topographic normalization process (ERDAS Imagine).

shrubs or grasslands; Agricultural field or dry land; buildings; water bodies and other land cover. The basis of this classification based on land cover classification methodology of the FAO (1996) in the journal Forest resources assessment 1990.

Subsequent data processing, is extraction of spectral characteristics of the combination of the three channels owned by the SPOT satellite imagery was conducted in Terrestrial Ecosystems Analysis Laboratory-SITH ITB. The software used is ER Mapper 7.0. In this study, to perform detection algorithm approach was used in land cover classification of multispectral image. Type classification used is the supervised classification. In principle, supervised classification requires data from a field training site that provides an indication or characteristic of each land cover. There are 101 point training site that has been collected and a reference in the analysis of land use classification.

For forest areas, prior to the classi-

fication required additional data that provide information of forest canopy closure in the study area. Due to determine an area known as the forests in this study is the minimum area of 0.05 to 1 hectare with tree canopy closure of more than 10-30 percent with trees potentially reach a minimum height of 2-5 meters (Sasaki & Putz 2009). For data collection was done in the field of forest canopy cover in the study area using hemispherical photographs. Digital data stored in JPEG format (pictures 3.2.b) and captured using a digital camera device single lens reflect Nikon D-90, with wide-angle lens is AF Nikkor fisheye 10.5 mm and has a angle of view lens reaches 180o . Technically, the image capture canopy done in good weather conditions, altitude of the camera 1.3 m above the ground, and use a tripod to help stabilize the camera holder as shown in Figure 3a. Exposure settings used in the automatic mode to reduce the possibility of overexposure.

Data collection was done by random sampling at the edges and middle of the

forest. Performed three times in one footprint repetition of data acquisition, and the distance between each footprint of more than 30 m to improve the accuracy of the data. In each footprint making geographic location data were recorded using a GPS Garmin 60CSX with a minimum of error between 3 to 8 meters. Canopy images were analyzed using a RGBFisheye program to extract percent canopy cover. The software is developed by the Gifu Faculty of Applied Biological Science, Japan, and can be obtained online from <http://www.gifu-u.ac.jp/~ishidam/RGBFisheye.htm>. Any data obtained were recorded and tabulated by the program Microsoft Excel 2007.

Results from the classification of areas with different patches of land cover including forest land cover with a canopy closure certain who then made a calculation amount, size, and shape of patches that correlated with the inventory data in the field. Mapping land cover and forest area of forest canopy closure in the region this volcano requires processing using software Arc GIS 9.3.

RESULTS

By using a supervised classification technique, the type of land in the volcano area consists of tea gardens, settlements or buildings, fields / plantations, grass / shrub, craters, waters and forests area. From Figure 4.A shows that the forest is the most dominant land cover (16,847 hectares or 44.38%). The forest area is continuous with each other extends from the north and south of the study area so that it can be considered as one big patch.

Landcover fields and plantations are the second largest land cover after forest (10,026 hectares or 27.12%). This land cover is divided into various size patches, which accounted for 1,488 with different size and spread in almost all regions, but quite a lot which is located adjacent to the forest. The type of grass or shrub land is land cover with the dominant shrubs and herbaceous life forms the extent of 4,832 hectares (13.07%). This land type appear scattered in several parts of the study area, especially on the edge of the woods, and some also appear in the interior forest.

Forest land cover in this study differentiated the condition based on physical parameters of the tree canopy closure (Figure 4.B). Class is open forest with canopy closure between 10% - 40%, class dense with forest canopy cover between 40% - 70%, and the class very dense forest with canopy cover between 70% - 100%. Open forest has a number of patches reached 16,450 patch and only have a total area of 2,741 hectares (15.07%). While the dense forest has a total area of forest area reaches 8,983 hectares (49.38%), with a patch that were identified totaling 3,604 ha. Then, very dense forest has a total area of 6,467 ha (35.55%) and 5,554 the number of patches. From some of these statistics can be seen that the forest dense is the most extensive land cover classes compared to two other forest canopy cover land. This dense forest was dominated forest area of southern and northern Mount Papandayan forest.

From the data in Table 1 shows that a dense forest with forest canopy cover

is 40% -70% of land cover classes of the most extensive forest canopy closure compared with other forest canopy closure classes. This dense forest was dominated forest area of southern and northern forest Mount Papandayan Area. Very dense forests are more numerous in the middle of the study area, with a still fairly large proportion of which is approximately 35.55% of the total area of forest. Whereas open forest has the smallest proportion than the two other forest class, ie approximately 15.07% of the total area of forest.

Most of the open forest patches more easily found spread on the area of

forest edge. This is in accordance with the Lele *et al.* (2007) stating that the open forest is more often found on the edges resulting from the fragmentation of the dense forest. Edge of the dense forest area is the location of vulnerable and more susceptible to interference than the forest interior areas (Forman 1995). In this study, not only found in open forest on the edge of the forest, but also identified in the area of forest interior. This is apparently because of interference originating from human activities like illegal logging has also been reaching the forest interior. Apart from illegal logging, natural factors such as a fallen tree due to

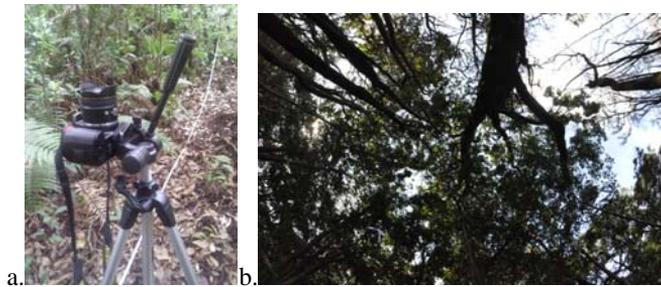


Figure 3. a) Photograph hemispherical device., b) the image of the canopy closure (private collection).

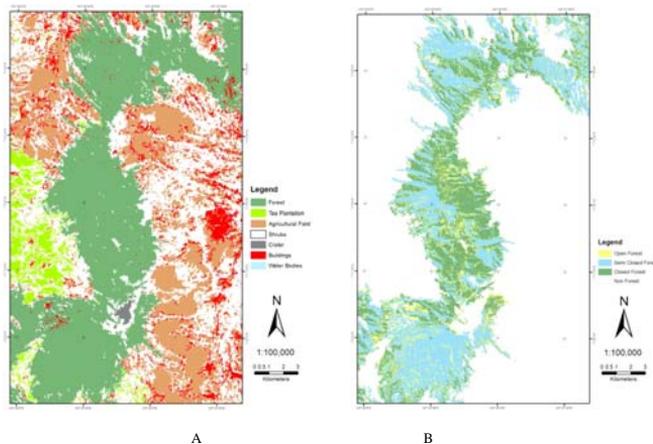


Figure 4. Distribution of land cover (A) and forest conditions Mount Papandayan (B).

age and disease can lead to open areas with low canopy cover.

DISCUSSION

Of the eight classes of land cover which can be identified and classified, forest land cover is the most dominant. The total area of forest cover reached 16,847 hectares or 44.38% of the total area. The forest area is continuous with one another extends from the north and south so it is considered as a single patch. Agricultural land use is the second largest land use after forest area, reaching 10,026 hectares or 27.12% of the total area. But this is divided land cover patches, which accounted for 1,488 with different size and spread in almost all regions. When the note Figure 4 in the pre-

vious section, in the region agricultural fields are often found in areas bordering the forest.

The type of grass or shrub land is the dominance of land cover with shrubs and herbaceous life forms (Table 2). Type of land has an area of 4,832 hectares and covers 13.07% of the overall study area. The distribution of land type of grass and bushes seemed scattered in several parts of the study area, especially on the edge of the forest, and some also appear in the interior forest.

From Figure 4, shows that the majority of forest areas in the study area is directly adjacent to the land cover that has a very high level of human activity such as a agricultural field, tea plantation, and settlements. Tea plantation land cover is more concentrated in the west

Table 1. Patch Size of Each Class of Forest Canopy Closure.

Canopy Closure Class	Patch Size		
	Area (hectare)	Number of patches	% Area
Open Forest (10%-40%)	2,741	16,450	15.07%
Dense Forest (40%-70%)	8,983	3,604	49.38%
Very Dense Forest (70%-100%)	6,467	5,554	35.55%

Table 2. Landcover classes in the Mount Papandayan area.

No.	Landcover Class	Area (hectare)	% Patch Area	Number of Patch
1	Forest	16,847	44.38%	1
2	Shrubs	4,832	13.07%	2,384
3	Agricultural fields	10,026	27.12%	1,488
4	Water Bodies	13	0.04%	1
5	Buildings	3,655	9.89%	4,827
6	Tea Plantation	1,884	5.10%	301
7	Crater	121	0.33%	22
	Total	36,963	100.00%	9,028

and borders directly with forest land cover, one of which is the region's tea estates of PTPN VIII. Agricultural fields located in the vicinity of forest are popular for farm produce some agricultural commodities such as potatoes, cabbage, and carrots and has a wide coverage area. Residential buildings and land cover population is scattered in the region. There are approximately 4,827 patches of land cover were identified as residential buildings and residents. Landcover class residential land or buildings is that there are directly created by human infrastructure such as villages, urban, and industrial areas so that a very high level of human activities on these land cover classes and can provide the potential damage to the forest at the forest edge areas.

Other land cover in the form of the crater and the water body does not dominate the study area. Water body is defined as areas dominated by coverage of water such as sea, lakes, and rivers. There is only one patch of land cover waters, ie Lake Ciharus located on the north, with total area of approximately 13 hectares. While the crater area which is dominated by rock the rest of eruptions in 2002, identified with a total area of 1.21 km² in the middle area of study. Crater region located in the southern part of study area and categorized as still active crater with an active hot sulphur activity.

Most of the open forest patch mainly found scattered evenly in the edge of forest land cover. This statement supported by Lele *et al.* (2007) in which open forest most likely to be found in the edge supposedly caused by conversion of fragmented dense forest. One reason as why

this could happen, is because the edge is having a higher level of disturbance compared to forest interior, so there is high number of conversion from dense forest into open forest.

In this research, open forest not only could be found in the edge of the forest, but also identified in the interior part of the forest inside the Papandayan Natural Reserve. This supposedly caused by high level of disturbance in this area, especially from human activity such as illegal logging which still could be found during the time of research (Figure 5a). Besides illegal logging, natural factor such as fallen tree could cause an open area with a low canopy closure (Figure 5b).

The most potential disturbance occurred in the mountain forest area was from human activity, although there is also disturbance caused by natural activity such for example volcanic eruption (Figure 5c and d). Mount Papandayan is one of the active volcanoes in Java, in 2002 the eruption from this volcano has expand the diameter of the crater to even larger size than before. Volcanic eruption is one form of disturbance caused by nature. The disturbance resulted from lava and cloud would give an extreme physical transformation (Figure 5c)

Vulcanic dust is a product from vulcanic eruption which gives instant effect on the surrounding ecosystem supposedly because with even the slightest layer of dust, vulcanic ashes could cover the leaf surface of plant and halt the process of photosynthesis. In the area surrounding the crater of Mount Papandayan, area in the impact of vulcanic eruption has low canopy cover

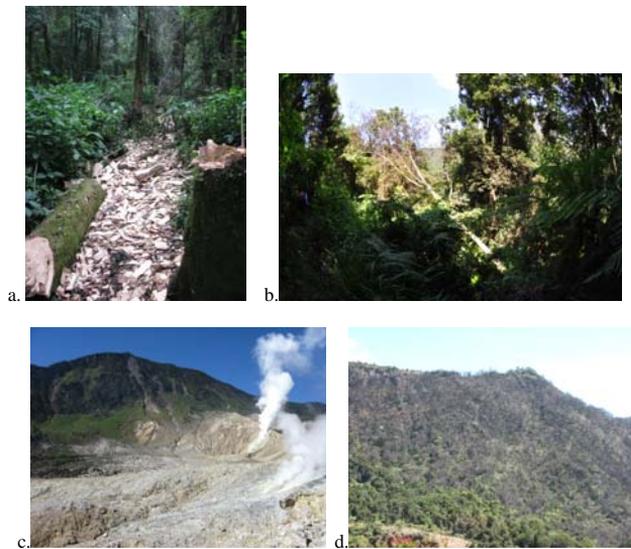


Figure 5. Examples of interference received by the forest of Mount Papandayan.

because the hot cloud and thick cover of volcanic ashes that cover ground surface. Forest surrounds the crater appear to be dry and have a dark brown coloration from far away as been shown in figure 5d. These damaged forests has a relatively low canopy cover compared than forest with no disturbance.

CONCLUSION

Land cover in the area of Mount Papandayan was tea plantation; buildings, Agricultural plantation, grass/bush, crater, water body, and forest, with forest as the most dominant land cover (44.38% or 16,847 ha).

Forest land cover in the area of Mount Papandayan mostly dominated by dense forest canopy cover class which was comprised of 49.38% from total area size of area study.

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