CORRELATION ANALYSIS OF VEGETATION INDICES WITH CANOPY CLOSURE USING WORLDVIEW-2 IMAGERY

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Abstract. Canopy closure is the one of biophysical surrogate in forest ecosystem modelling. It represents the structural characteristics and can be used as forest productivity indicator. The aim of this research is to assess the utilization of Spectral Vegetation Indices (SVI) to estimate canopy closure in forest environment using World View 2 imagery. The research area is a part of forest located in Banyuwangi District. This research review some of vegetation indices such as Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), Ratio Vegetation Index (RVI) and Difference Vegetation Index (DVI). As a modelling input and verification data, we use a set of field samples that collected from some distinct area with homogenous and heterogeneous vegetation. The expected result of this research is the most optimum vegetation index that can used for canopy closure estimation in the forest environment.

1. Introduction

Tree cover mapping has been recognized by the scientific community as an important task in studies focused on land surface and atmosphere interaction (Jingfeng 2014). It is a core variable to understanding the fluxes between land surface and the lower boundary of the atmosphere, such as exchanges of radiation, heat, carbon, and Water (Gordon 2008). Therefore, the availability of accurate and up-to-date spatial information on the tree cover fraction and on its spatiotemporal patterns is essential to understanding the role of trees in regulating these land surface-atmosphere fluxes. Consistent and comprehensive tree cover information at high temporal and spatial resolutions is required to support more detailed studies on the effects of bio-geophysical impacts of vegetation cover change.

Canopy cover refers to the proportion of the forest floor covered by the vertical projection of the tree crowns. This is analogous to the use of the term ‘cover’ by ecologists to refer to the proportion of the ground area occupied by the above ground parts of plants. Canopy closure measurements integrate information over a segment of the sky hemisphere above one point on the ground. Ideally the entire sky hemisphere should be assessed, although the segment measured varied with the instrument used. Indeed, on steep slopes, light may arrive from angles lower than the horizontal. Measures of canopy cover assess the presence or absence of canopy vertically above a sample of points across an area of forest (Jennings et al. 2008).

The main objective of this research is to develop a remote sensing-based approach that is effective methodologies to demonstrate the direct role of the forest cover in regulating local land surface geophysical properties of bio (Godinho et al. 1999).The high-resolution global map of tree cover is produced by Hansen et al. (2013) recently widely used in a variety of scientific research, including those focused on understanding the dynamics of Earth's biophysical systems (Alkama and Cescatti 2009). Thus, in order to overcome the limitations and uncertainties of these data, the first objective of

this study was to develop an approach to accurately estimate the percentage of canopy cover at the pixel level with the Worldview-2 vegetation index (Godinho et al. 1999).

2. Material and Method

2.1 Study area

The study area is in the east part of Bangsring Village, Wongsorejo Subdistrict, Banyuwangi Regency, East Java Province (figure 1). Bangsring Village (between 114º 23' 10" - 114º 25' 06"and 8º 04' 45" - 8º 06' 45") is located about 20 km north of Banyuwangi, with 55.26 km^2 wide and elevation gradient from sea level is about 37 m. The temperature range from 24 to 26˚C (BPS Banyuwangi 2016). Field surveys was conducted on 18-23 July 2016. The study area is partly forest area that managed by the Perum Perhutani, called the Watudodol forest. The Watudodol forest was dominated by teak stand.

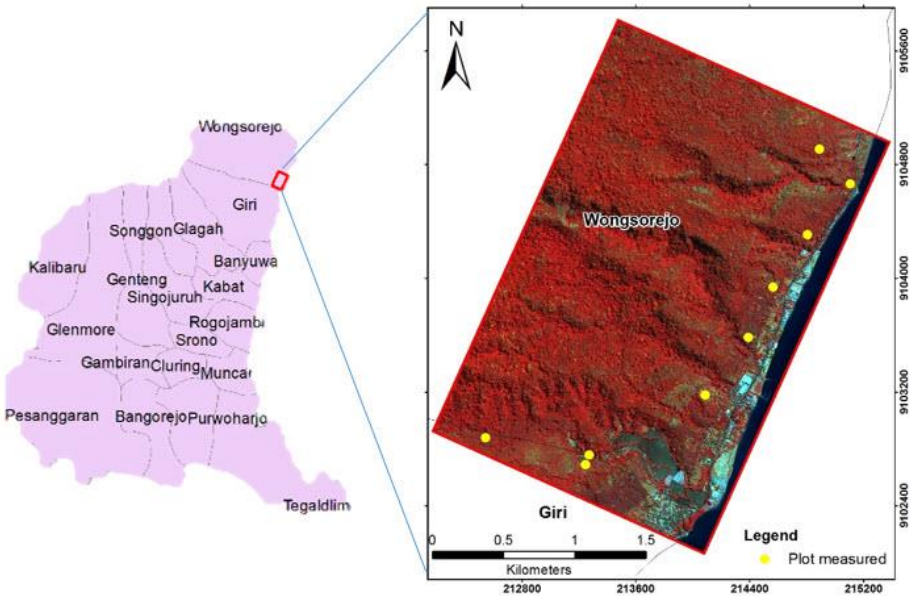

Figure 1. Study area in Bangsring village, Banyuwangi regency

2.2 Image Datasets

Imagery used for this study is a Worldview-2 that consisting 8 multispectral bands (4 standard colors: red, blue, green, near-IR and 4 new colors: red edge, coastal, yellow, near-IR2) at 2 m spatial resolution and 0.5 m panchromatic band. The image data was acquired on 5 July 2015. The image was corrected for atmospheric spectral radiance (W/cm^{2}sr.nm) and reflectance using the ENVI 4.8 software.

Vegetation indices were used in this study consist of Normalized Difference Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), Ratio Vegetation Index (RVI), and Difference Vegetation Index (DVI). The Normalized Difference Vegetation Index (NDVI) is the most commonly used VI, as it enables to eliminate topographic effects and variations in the sun illumination angle, as well as other atmospheric elements such as haze. NDVI images, in contrast to ratio, have normal distributive (Rouse et al. 1974).

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \quad (1)$$

The Soil-Adjusted Vegetation Index (SAVI) is intended to minimize the effects of soil background on the vegetation signal by incorporating a constant soil adjustment factor L in the denominator of the NDVI equation. The L factor chosen depends on the density of the vegetation (Huete 1988).

$$SAVI = \frac{(1+L)(NIR-R)}{(NIR+R+L)} \quad (2)$$

The Ratio Vegetation Index (RVI) is constructed as a ratio, problems of variable illumination as a result of topography are minimized. The range for RVI extends from 0 to infinity. The ratio value less than 1.0 is taken as vegetation while value greater than 1.0 is considered as non-vegetation area (Birth 1968).

$$RVI = \frac{NIR}{R} \quad (3)$$

The Difference Vegetation Index (DVI) multiplies the slope with the near-infrared band and then subtracts the red band. It results in positive values indicating vegetation, zero indicates bare soil, and negative values indicates water (Richardson 1977).

$$DVI = NIR - R \quad (4)$$

2.3. Data Collection

Hemispherical photography (also fisheye or canopy photography), estimates potential solar radiation and characterizes plant canopy using photographs taken looking upward through an extreme wide-angle lens which approaches or equals 180-degrees. The theory of hemispherical photography represents the common theory of most indirect optical methods for canopy cover estimation in its purest form, since the photographs contain the optical information in its highest resolution, while other devices often use lower resolution information.

The measurements are performed on a grid of 10m x 10m resolution to cover an area of 0.25 ha. At least 9 measurements along this regular spaced grid are obligatory and measurements carried out on the center swath and the edge of the plot. For practical reasons, a measurement height of 1.5m for photographs is defined. This height should avoid disturbances by lower shrubs or installed litter fall or deposition samplers which may disturb the light sphere or point of view. The location of each measurement point has to be documented by relative X, Y coordinates. The origin is the lower left measurement point, the adjustment of the system is north to south and east to west. If another metric coordinate system is already established, the respective coordinates may be submitted instead. Deviations from the fixed measurement grid may be necessary in some cases in order to avoid interference with other measurements.

2.4. Statistical Methods

Statistical analysis used to know the correlation between the pixel numbers of vegetation indices with leaf area index. Ten samples of canopy cover from field measurement directly correlated with the pixel number based on coordinates. The output of this analysis is equation represents the correlation. Variable dependent symbolized as y, in this case is canopy cover value that would be modeled. Pixel value of each samples symbolized as x and correspond with constant value a. As linear equation, there is independent value c. If the equation has a positive value, it means the correlation is strengthening each other linearly. But if there is minus equation, the variable dependent and independent has a opposite correlation. Another value resulted from this statistical analysis is r value. This value represent strength of correlation of dependent and independent variable. The equation resulted used to model the canopy cover value using vegetation index band as input.

3. Result and Discussion

3.1 Hemispherical Photo Processing

Canopy closure samples are analyzed by calculate the proportion of black area and white area from each photo taken. Photo that captured with terrestrial photography using hemispherical lens processed to be a black and white mode. The black portion of image represents the shadow due to canopy closure and the white portion is open sky. In some case, there are clear sky so the contras between

open sky and shadow can separated easily. But in other hand, the presence of clouds makes we have to use an additional processing. The additional processing is divide the image to CMYK mode to make a threshold and separate the black portion and white portion objectively. Every cyan and blue objects defined as black by increasing the saturation to maximum value. The object that consist red, green, yellow portion or lowered to a minimum saturation. The percentage of closure calculate the ratio of total pixel black portion and total pixel of image.

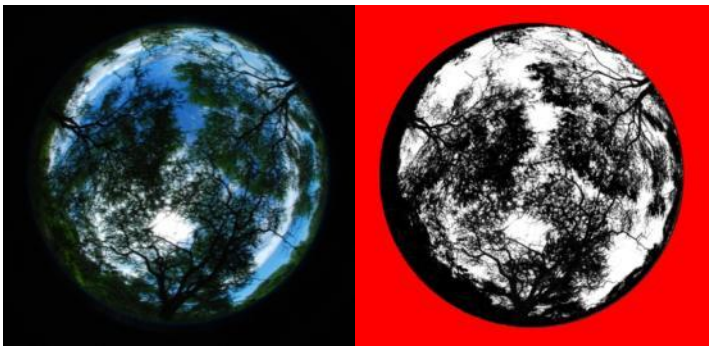

Figure 2. Example of the hemispherical photo before (left) and after processing (right) to calculate the canopy closure (Laboratory analysis 2016).

Canopy measurement can be conduct by direct measurement using densitometer, cajanus tube, hemispherical photography and oscular estimation (Kohornen et al. 2006). This research use the sampling plot method and hemispherical photography to derive the Gap Fraction, Canopy Openness, Canopy Closure, and Canopy Cover (CaCo) Index information. The result of hemispherical photography analyzed using Gap Light Analysis (GLA). The result of this analysis shown on table 1.

Table 1. Result of Gap Light Analysis (GLA)

Plot Number	Gap Fraction Of Selected Area %	Part Of Hemispherical. Taken By Camera %	Cut Level Between Black And White Pixels (1-254)	Canopy Openness %	Canopy Closure %	Canopy Cover (Caco) %	Modif. Caco Index %
28	13,48	94,26	86	14,86	85,14	62,25	63,66
38	6,60	94,26	70	7,14	92,86	71,05	76,99
97	31,71	94,26	127	34,44	65,56	37,34	38,75
51	11,64	94,26	65	12,74	87,26	64,87	67,42
136	41,17	93,48	81	44,67	55,33	28,43	26
103	11,98	93,48	73	12,52	87,48	59,33	69,31
130	29,19	93,48	65	31,60	68,40	39,91	41,73
72	4,30	93,48	66	4,25	95,75	70,77	83,24
16	30,67	93,12	200	30,87	69,13	42,96	53,65

Based on the result calculation of GLA, the highest value from canopy cover is 95,75% and the lower value is 55,33%. At the canopy closure value range from 75% to 100% dominate by heterogeneous vegetation like secondary forest that have succession. The homogenous vegetation dominate by *Tectonagrandis* that older than five years. The plantation among the trees is 4x4 m so that canopy crown very dense and before wither process. At canopy closure value between 75% to higher than 55% are dominated by homogenous vegetation (*Tectonagrandis)* that has been withered. It also has difference of age among the tree so gap fraction among tree increased. The dominant factor of canopy closure value are space of tree, leaf width, age, deciduous vegetation characteristics and type of canopy crown.

3.2 Vegetation Indices Analysis

Four generic vegetation indices used to emphasize the vegetation characteristic, in this case canopy closure and canopy coverage. RVI is a simple ratio between NIR band and Red band. Its pixel value range from 0 until 14, 07. The spectral characteristic red an infrared spectrum are sensitive with water based object. As the result, the region that has a high wetness appears dark due to the absorption in both of spectrums. The vegetation tone looks vary due to the characteristic of water content in their leave. NDVI image value range is narrow from -1 until 1 but due to the normalization by sum of NIR and red band value. Canopy density, especially in vertical thickness has a maximum influence to the tone. The dense vegetation has a high value starts from 0.637 until maximum value 1. It is make a sense because leave structure reflect both of those band and doesn't depend on the condition vegetation. The image of DVI has a uncontrolled value that range from -0,046 until 0,343. It has a great contrast but doesn't consistence with the characteristic of vegetation. Different with the other generic VI, SAVI is the advance one that design to minimize the effect of soil reflectance. However, the value doesn't represent the canopy or vegetation characteristic.

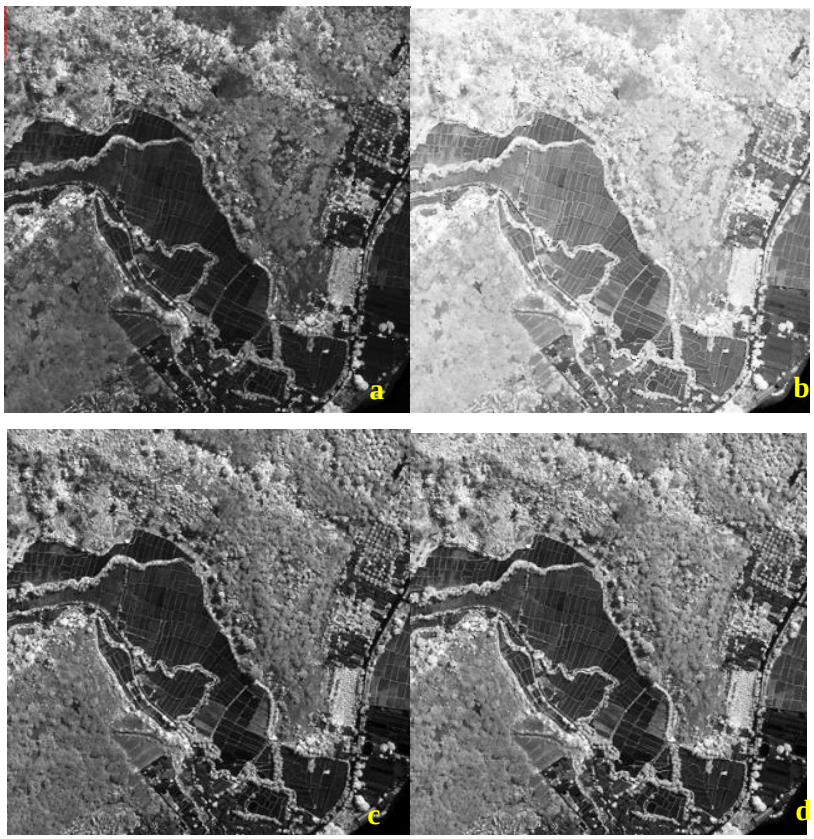

Figure 3. Image of vegetation indices; (a) RVI, (b) NDVI, (c) DVI and (d) SAVI

Each samples of canopy closure correlated with the five generic Vegetation Indices (VI) based on geographic coordinates recorded. The recapitulation of the VI pixel value and canopy closure shown in table 2. Linear regression analysis used to know how the correlation between those phenomenon and how straight is it. Based on this analysis, Ratio Vegetation Index (RVI) has the highest value coefficient of determination (R^2) with 0,7136. The correlation of each VI is positive that mean increase of canopy closure would be follow with the VI value rising. NDVI is in the second position with 0,687 follow by SAVI and DVI with 0,5048 and 0,3891.

Table 2. Pixel value of each VI and percent of canopy closure measured in field

Plot Number	RVI	SAVI	NDVI	DVI	% Closure
4	3,54	0,20	0,48	0,09	86,12
10	5,54	0,27	0,66	0,12	93,27
28	6,29	0,28	0,67	0,13	94,67
35	3,70	0,25	0,50	0,13	81,99
38	3,79	0,21	0,51	0,09	76,05
42	5,19	0,25	0,64	0,11	94,24
43	6,56	0,32	0,70	0,16	70,78
47	6,87	0,35	0,72	0,18	66,16
48	5,02	0,25	0,63	0,12	96,17

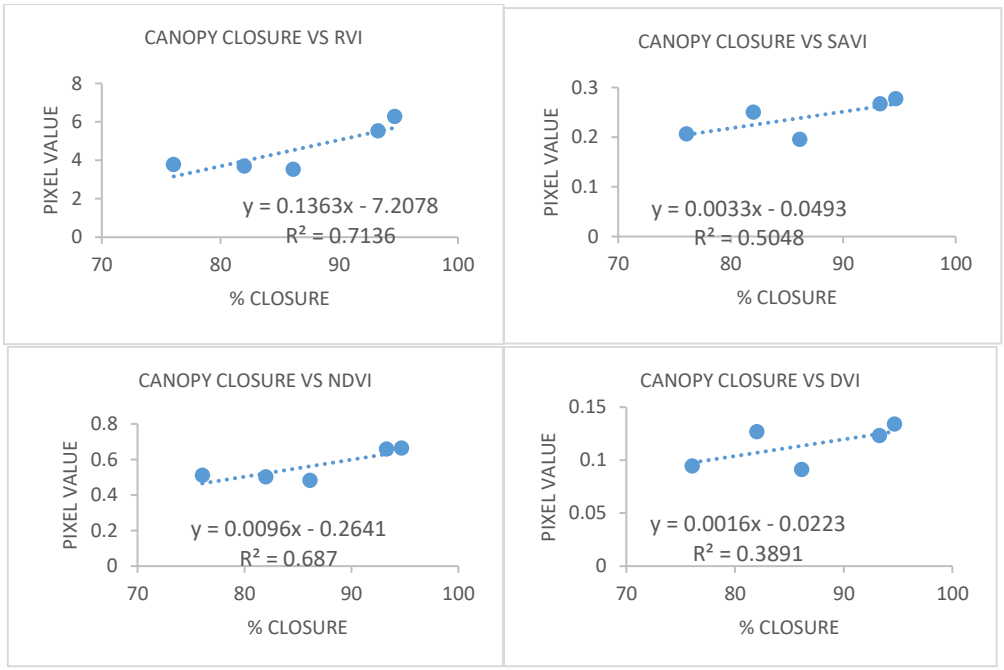

Figure 4. Equation and coefficient of determination of each VI related the canopy closure

3.3 Canopy Closure Model

The Worldview imagery used as main input to model the canopy closure. The equation derived from correlation analysis between VI and canopy closure used to representing the model image. The canopy closure estimated from each indices reaches the maximum value (100%). The fact is all of the model images shows that the maximum value located in the somewhere with low canopy structure.

In the research area deciduous plantation vegetation such as *Tectona grandis* that has its own community, there are no canopy in the second layer below its canopy. As the result the some special vegetation with high homogeneity has a moderate value. Utilization of hemispherical photography method for canopy closure measurement has a weakness that it cannot record the coverage of layer canopy and structure under the high vegetation, such as bush and bottom vegetation.

Table 9. The correlation of canopy closure estimated using model and field measurement. RVI has the best result

Vegetation Indices	Equation	R^2
RVI	y = -1,6031x + 230,36	0,9174
SAVI	y = 0,0223x + 75,342	0,2526
NDVI	y = -2,1105x + 289,12	0,8626
DVI	y = -0,5006x + 134,74	0,7529

The result of canopy modeling using vegetation indices are validated using field samples. RVI model is the most representative index to model the canopy closure with the coefficient of determination value 0,9174. NDVI also validated with a good coefficient of determination value 0,8626. DVI and SAVI has a poor coefficient of determination value, 0,7529 and 0,2526. Based on those analysis, we can infrared that SAVI can't represent the variation of canopy closure due the elimination of soil effect reflectance. The study area has a big variation of vegetation. Despite of all of the fact, domination of plantation vegetation like *Tectona grandis* that has falls period and make a soil reflectance increased influence the consistencies of the SAVI value. In other hand, RVI with the simple concept can represent these phenomenon because of it consistencies.

4. Conclusion

The conclusion of this research is the RVI is the best vegetation index that can used to model the canopy closure. It has a good positive correlation that defined from the coefficient of determination value that higher than 0,9. The factor that influence the result of modelling is the type of vegetation that dominated by plantation vegetation such as *Tectona grandis* and *Acacia nilotica* that has uniformity of canopy closure. The variation of canopy and vegetation structure under the top vegetation canopy cannot represented by the model effectively. It can occurred because the canopy closure sampling method using hemispherical photography cannot reach the closure of second layer vegetation canopy.

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