# **Development of Forest Cover Density Mapping Methodology**

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#### Abstract

Forest cover density is one of the most useful parameters to consider in the planning and implementation of rehabilitation program. This study is development of bio-physical analysis model for obtaining of Forest Canopy Density (FCD) using LANDSAT TM data image analysis. The four key components of FCD model are viz. vegetation, bare soil, thermal and shadow. The initial and medium stages of this study was implemented under the research project of International Tropical Timber Organization (ITTO).

# **1. Introduction**

As generally applied in forestry, conventional RS methodology is based on qualitative analysis of information derived from training areas (i.e. ground-truthing). This has certain disadvantages in terms of the time and cost required for training area establishment, and the accuracy of results obtained. In this new methodology, forest status is assessed on the basis of canopy density. The methodology is presently identified as the Forest Canopy Density Mapping Model, or for short the FCD Model. Unlike the conventional qualitative method, the FCD Model indicates the growth phenomena of forests which are quantitative analysis. (Shown in Fig. 1) The degree of forest density is expressed in percentages: i.e. 10% FCD; 20%; 30%; 40% and so on. FCD data indicates the intensity of rehabilitation treatment that may be required. The method also makes it possible to monitor transformation of forest conditions over time including degradation. Additionally, it can assess the progress of reforestation activities.

The Forest Canopy Density (FCD) Mapping and monitoring Model utilizes forest canopy density as an essential parameter for characterization of forest conditions. FCD data indicates the degree of degradation, thereby also indicating the intensity of rehabilitation treatment that may be required.

The source remote sensing data for FCD model is LANDSAT TM data. The FCD model comprises bio-physical phenomenon modeling and analysis utilizing data derived from four (4) indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI). It determines FCD by modeling operation and obtaining from these indices.

The canopy density is calculated in parentage for each pixel. The FCD model requires less information of ground truth. Just for accuracy check and so on.

FCD model is based on the growth phenomenon of forests. Consequently, it also becomes possible to monitor transformation of forest conditions over time such as the progress of forestry activities. The application tests were implemented in this area. The evergreen forests are in the islands of Luzon (Philippines) and Sumatra (Indonesia); and for monsoon (subtropical deciduous) forests in Ching-Mai (Thailand) and Terai (Nepal).



Fig. 1 Analysis by conventional (left) and FCD (right) methods

#### 2. Characteristics of Four Prime Indices

The indices have some characteristics as below. The Forest Canopy Density Model combines data from the four (4) indices. Fig.1.2.3 illustrates the relationship between forest conditions and the four indices (VI, BI, SI and TI). Vegetation index responses to all of the vegetation cover such as the forest, bushes, scrubs and grassland. Advanced vegetation index (AVI) reacts sensitively for the vegetation quantity compared with NDVI. Shadow and thermal index increases as the forest density and vegetation quantity increases respectively. Black colored soil area shows a high temperature. Bare soil index increases as the bare soil exposure degrees of ground increase. These index values are calculated for every pixel. Fig.2 shows the characteristics of four indices compared with forest condition.

Note that as the FCD value increases there is a corresponding increase in the SI value. In other words where there is more tree vegetation there is more shadow. Concurrently, if there is less bare soil (i.e. a lower BI value) there will be a corresponding decrease in the TI value. It should be noted that VI is "saturated" earlier than SI. This simply means that the maximum VI values that can be recorded appear earlier in the analysis. This happens because the VI captures data from the total bio-mass, regardless of the density of the trees or forest. On the other hand, the SI values are primarily dependent on the amount of tall vegetation such as trees which cast a significant shadow. Table.1 shows combination characteristics between four indices.



Fig. 2 The characteristics of four prime indices of the forest condition

Indices	Hi- FCD	Low-FCD	<b>Grass Land</b>	<b>Bare Land</b>
AVI	Hi	Mid	Hi	Low
BI	Low	Low	Low	Hi
SI	Hi	Mid	Low	Low
TI	Low	Mid	Mid	Hi

Table.1 Characteristics combination between major four indices

# 3. Calculation of Four (4) Indices

# 3.1 Advanced Vegetation index (AVI)

When assessing the vegetation status of forests, the new methods first examine the characteristics of chlorophyll-a using a new Advanced Vegetation Index (AVI) that is calculated with the following formulae.

# B1-B7: TM Band 1-7 data

B43=B4-B3 after normalization of the data range.

CASE-a	B 43 < 0	AVI=0
CASE-b	B 43 > 0	AVI = ((B 4 +1) x (256-B3) x B 43) <sup>1/3</sup>

#### 3.2 Bare Soil Index (BI)

The *value* of the vegetation index is not so reliable in situations where the vegetation covers less than half of the area. For more reliable estimation of the vegetation status, the new methods include a bare soil index (BI) which is formulated with medium infrared information. The underlying logic of this approach is based on the high reciprocity between bare soil status and vegetation status. By combining both vegetation and bare soil indices in the analysis, one may assess the status of forest lands on a continuum ranging from hi vegetation conditions to exposed soil conditions.

#### $BI = [(B5+B3)-(B4+B1)] / [(B5+B3) + (B4+B1)] \times 100 + 100; 0 < BI < 200$

The range of BI is converted within 8 bits range

#### 3.3 Shadow index (SI)

One unique characteristic of a forest is its three dimensional structure To extract information on the forest structure from RS data, the new methods examine the characteristics of shadow by utilizing (a) spectral information on the forest shadow itself and (b) thermal information on the forest influenced by shadow. The shadow index is formulated through extraction of the low radiance of visible bands.

# $SI = [(256-B1) \times (256-B2) \times (256-B3)]^{1/3}$

#### **3.4 Thermal Index (TI)**

Two factors account for the relatively cool temperature inside a forest. One is the shielding effect of the forest canopy which blocks and absorbs energy from the sun. The other is evaporation from the leaf surface which mitigates warming. Formulation of the thermal index is based on these phenomenons. The source of thermal information is the thermal infrared band of TM data.

#### 4. The Procedure of FCD Model

The flowchart of the procedures for FCD mapping model are illustrated in Fig.1.2.4. Image processed results corresponding to the flow chart shows in Fig.3.



Fig. 3 Flow Chart of FCD Mapping Model

# 4.1 Noise Reduction; Clouds, cloud shadow and water area

Clouds have a higher irradiance value than ground data. Moreover, the amount of irradiance varies depending on whether the clouds are white, gray, black or combinations of different shades. These factors adversely influence statistical treatment and analysis of imagery data. Furthermore, cloud shadow can be confused with shadow cast by adjacent mountains. These problems can be minimized by creating a cloud shadow mask, using a histogram based on data derived from TM band 1, 2, and 3. Thereafter, a shadow mask of the mountain shadow area is formed at the ground level. This is done through parallel transformation of the mask of the cloud area. Water bodies create similar problems. Since water absorbs near infrared, water bodies should (and can) also be masked using a histogram of TM Band4.

## 4.2 Vegetation Density and Multi Vegetation Density Model; VD

It is the procedure to synthesize VI and BI by using principal component analysis. Since, VI and BI have high negative correlation. Then it is scaled between zero to hundred percent. Details in (Rikimaru, 1996)



# Fig.4 Concept of VD (Vegetation Density)

Consideration of the seasonal effects of forest conditions represented by leaf-shedding in the deciduous forest as the factors to affect the FCD analysis, study for upgrading of the FCD Model was carried out.

In the previous study of FCD model, the vegetation area was treated as a single component to compute the FCD-Single Model. In this study, the vegetation item is classified several groups , taking into forest considerations.



Fig.5 Concept of Model Area (Single Model, Multi Model)



Fig.6 VD Upper Level Threshold in Each



Fig.7 Transformation of VD in Each Model

## **4.3 Black Soil Detection**

SI data is extracted from the low irradiance area of each visible band. Where the soil is black or appears to be black due to recent slash-and-burn, low irradiance data may confuse shadow phenomenon with black soil conditions. This is because black soil usually has high temperature due to its high absorption rate of sun energy. But shadows lead to a decrease in soil temperature. By overlaying TI data and SI data this confusion can be avoided. Overlays are also useful when evaluating the relative irradiance of different parcels of land characterized by various shades of black soil.

## 4.4 Advanced Shadow Index; ASI

When the forest canopy is very dense, satellite data is not always be able to indicate the relative intensity of the shadow. Consequently, crown density might be underestimated. To deal with this problem, the new methods include those described below for determining the spatial distribution of shadow information. Details in (Rikimaru,1996)

#### 4.5 Scaled Shadow Index; SSI

The shadow index (SI) is a relative value. Its normalized value can be utilized for calculation with other parameters. The SSI was developed in order to integrate VI values and SI values. In areas where the SSI value is zero, this corresponds with forests that have the lowest shadow value (i.e.0%). In areas were the SSI value is 100, this corresponds with forests that have the highest possible shadow value (i.e. 100%). SSI is obtained by linear transformation of SI.

With development of the SSI one can now clearly differentiate between vegetation in the canopy and vegetation on the ground. This constitutes one of the major advantages of the new methods. It significantly improves the capability to provide more accurate results from data analysis than was possible in the past.

#### 4.6 Integration process to achieve FCD model

Integration of VD and SSI means transformation for forest canopy density value. Both parameter has no dimension and has percentage scale unit of density. It is possible to synthesize both indices safely by means of corresponding scale and units of each.

## $FCD = (VD \times SSI+1)1/2 - 1$

Fig.8 shows the procedure for forest canopy density (FCD) mapping model



Fig. 8 Procedure for Forest Canopy Density (FCD) mapping model

#### **5.**Conclusion

Forest Canopy Density model is one of the most useful parameters for forest monitoring. Conventional remote sensing methodology is based on qualitative analysis of information derived from study area i.e. ground truth information. This has certain disadvantages in terms of time and cost required for ground reference information collecting. FCD model is one the solution of it. But in the present status, for the optimize of model or verification of model results, it is still necessary the calibration test site. One of small test information site is under setting up at the Niigata prefecture , near by Nagaoka university of technology camps.

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