*Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.*


# Developing A Forest Growth Monitoring Model Using Thematic Mappery Imagery

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**Abstrract**

Recently most investigations in satellite-based remotely sensed data has concentrated upon the biophysical characteristics of vegetation for large area, little attention has been given to the allometric relationship of tree and reflectance to the recorded pixel value. In this research crown width and/or canopy closure was associated with pixel value in terms of their surface-exposure to satellite sensors. Given the fact that planted-tree crown closure is correlated with their height and diameter at breast height (dbh) in early stages of the plantations, it is expected that a relationship exists between tree canopy closure, height, dbh and their associated reflectance-values. The proposed concept was tested in a case study for planted black spruce *(Picea mariana)* using Landsat Thematic Mapper (TM). Crown width, height, and dbh of planted trees were measured in an area of 30m X 30m, for every 2-year age intervals, from 0 to 21 years. Canopy closure, mean height, and dbh of each plot (with shrubs and herbs understory more than 60%) were plotted against their associated Digital Numbers (DN) for TM bands 4 and 5. An inverse-linear relationship between DNs and their associated canopy closure, height, and dbh were found in band 5 as $r^2$ = 0.863 and 0.941, respectively.

**Introduction**

Trees continuously add new growth onto their old structure. As their crowns expand, their height and dbh increase; thus, a relationship exists between tree crown width, height and dbh. Camopy closure will be estimated based on satellite data of crown reflectance; and in order to estimate height and dbh from the estimate of canopy closure, the relationship between crown width and/or crown projection area and height and dbh will be established from field data.

Conventional monitoring of plantation canopy closure, dbh and height using ocular field estimation and/or aerial photo interpretation, cannot provide a timely and cost effective assessment of the divergence between actual and expected plantation canopy closure, dbh, and height. This is because plantation inventories are only repeated every 5 years for early stage plantations (using only field data) and every 10 to 15 years for older plantations.

A problem associated with traditional plantation dbh and height growth models is that they are typically constructed and initialized using ground data. The cost of implementing ground-based assessment exercises is high and continues to increase, in some cases beyond the point of feasibility.

To remedy these problems, two concepts are drawn:

(i) the reflectance values, recorded by sensors, for a given tree species is a function of exposed canopy projection area (canopy closure) regardless of their age and density. (ii) a quantitative relationship exist between the tree canopy closure, height and dbh, as measured on the ground, and reflectance values as estimated from the satellite imagery. Finally, it can be postulated that while a relationship exists between satelite information (Digital numbers) and canopy closure in one hand and crown width and height and crown width and dbh in the other, it can be proposed that with the help of these relationships, it would be easy to estimate height and dbh from the data taken from the satelite.

**Background**

Honer (1972) proposed a density concept based on the crown width/height relationship. He concluded that there should be a family of lines representing the crown width/height relationship, with each line representing a given density condition. Relationship between crown width and dbh was investigated by many authors (Vezina, 1963; Sprinz and Burkhart, 1987; Farr et al. 1989; Gauvin et al. 1993). Oladi (1996) noted that relationship exists between crown width/height and crowm width/dbh.

The relation between crown width/dbh, crown width/ height, dbh/height, and clear bole length were studied as a function of height and dbh (Ek 1974). A regression technique was used and good relationship was found between crown width/dbh, crown width/ height, dbh/height.

Most forest attributes such as age class, species composition, Leaf Area Index (LAI), mean height, basal area, mean dbh, timber volume etc. over very large areas have been investigated by many researchers using remotely-sensed data. Correlation between the reflectance values in various TM bands and forest in different development stages is well known from the early plantation stages (Coleman et al. 1990, Fiorella and Ripple 1993) to the older forest stands (Poso et al. 1987, Cohen and Spies 1992). Pierce et al. (1992) and Franklin et al. (1992) used TM data to separate different forest cover types. They found that this sensor is able to provide adequate information to differentiate forest species. The utility of Landsat TM data to estimate coniferous timber volume for a mountainous mixed-conifer species was investigated by Gemmell (1995). He used both forest polygons and ground data to estimate timber volumes and reported sampling TM imagery in small areas (0.25 ha) was unsuitable for specifying the relationship between TM data and the forest information. A classification accuracy of 78% for forest polygon inventory was found. In addition, height and density were correlated with TM band 5 reflectance at r = 0.86 and 0.96 respectively.

**PROCEDURES**

Using aerial photographs of study area, selected plantation stands were stratified into units of homogeneous height, crown closure, and density. Two-year age interval stands were identified and were assigned and marked on the maps of 1: 12 500 scale. Within 26 plantation stands, a sampling intensity of 10 plots for every 2-year age interval (3 to 21 years) was selected. Each sample plot encompassed an area of 90m X 90m. Each plot was subdivided into 9 square subplots (30m X 30m - the size of a TM pixel). One subplot was the primary unit of data collection. Plots were distributed 90 m (three TM pixels) apart from each other in a systematic fashion.

In order to determine the canopy closure of each subplot, the density of each subplot was calculated and crown width, total height and diameter at breast height (dbh) of the planted trees were measured. Landsat image was atmospherically and geometrically corrected. For geometric correction, Image to Vector Ground Control Points Collection (GCIV) was used.

**RESULTS AND DISCUSSION**

**Crown Width ,Height and Dbh Relationship**

There was a strong linear correlation between crown width (dependent) and height of black spruce (independent; Fig. 1, $R^2 = 0.94$)

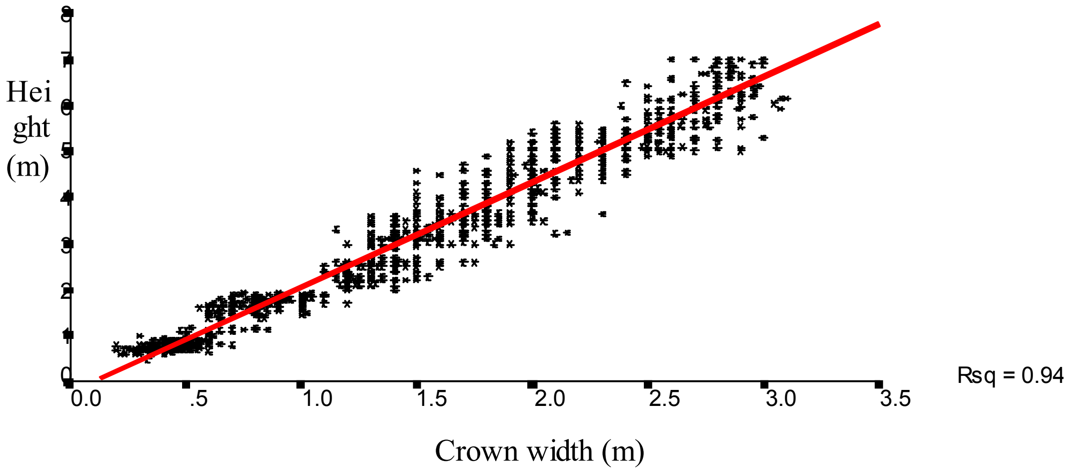


Fig. 1 Scatter plot of height vs. crown width overlaid with the fitted line.
Height = - 0.223 + 2.2 * Crown width

Dbh was measured on trees 7 years or older. There was a strong correlation between dbh and crown width of black spruce (Fig. 2, $R^2 = 0.92$)

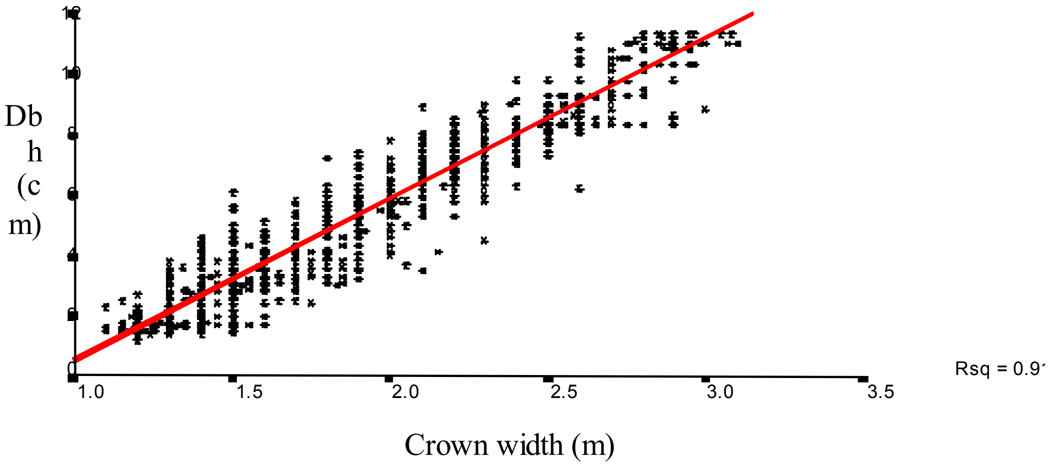


Fig. 2 Scatter plot of dbh vs. crown width overlaid with the fitted line.
Dbh = - 4.769 + 5.315 * Crown width

**Canopy Closure, Height and Dbh Relationship**

Canopy closure is an indication of the ground area occupied by a vertical projection of widest portion of trees' crowns. The canopy closure was calculated from crown width (CW) as:

$$\text{Canopy Closure} = (CW/2)^2 * \pi$$

There was a strong correlation between canopy closure and height of black spruce before canopy closure (Fig. 1, $R^2 = 0.95$).

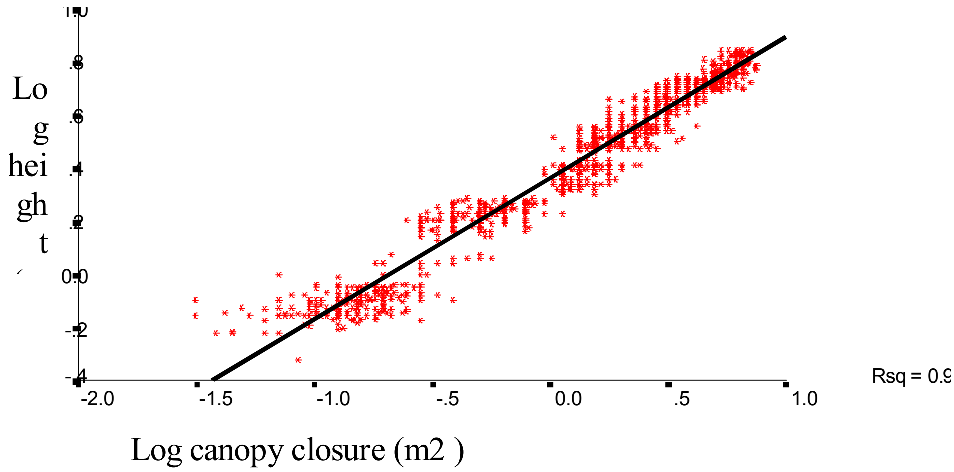


Fig. 1 Scatter plot of height vs. canopy closure overlaid with the fitted line.
LOG Height = - 0.363 + 0.531 * LOG CPA

There was a strong correlation between dbh and canopy closure area of black spruce $R^2 = 0.91$; Fig. 2).

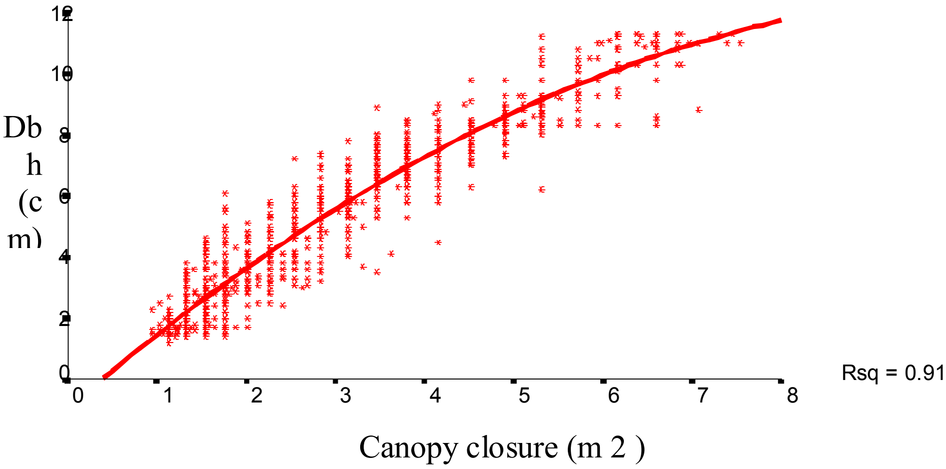


Fig. 2 Scatter plot of dbh vs. canopy closure overlaid with the fitted line.

**Canopy Closure and Remotely sensed data**

Mean crown closure of each subplot (30m X 30m) was calculated from crown width which were derived from field survey. The DNs in TM bands 4 and 5 were extracted for plantation ages of 1, 3, 5, 9, 11, 13, 15, 17, 19 and 21 years. The extracted DNs were plotted against their associated crown closure. Fig 1 shows an inverse-linear relationship ($R^2$ = 0.897) between DNs and their associated crown closure in band 5.

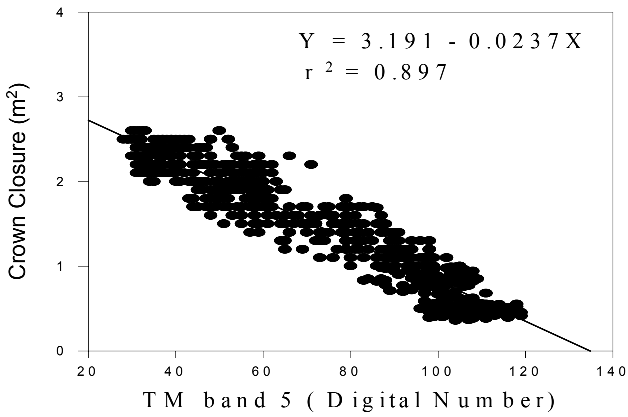


Fig. 1. Scatter plots and result of regressing crown closure on TM band 5. Each point represent mean crown closure of a 30m X 30m ground plot.

The visible region of the spectrum (0.4 to 0.7 *um*; TM band 1, 2, and 3) showed a narrower range of reflectance due to highly absorption of the plant leaves, where the energy is required for photosynthesis, than the near and middle-infrared (TM band 4, 5, and 7). TM band 4 was less sensitive to background reflectance than TM band 5 and the latter had a greater dynamic range of DNs. Canopy closure of each plot was calculated by multiplying the number of survived planted tree to crown closure. Fig 2 represents scatter plots of the canopy closure against their associated DNs. A comparison between Fig. 1 and Fig. 2 shows that there is slightly lower correlation between canopy closure and DNs than the mean crown closure and DNs (0.89.7 and 0.863 respectively). This differences may be due to variation between the number of survived planted trees in different plots.

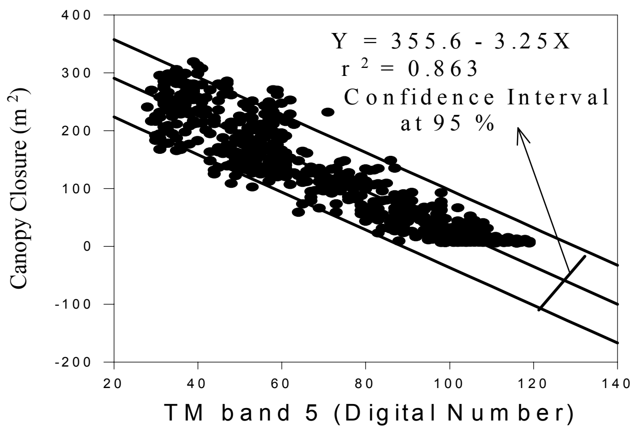


Fig. 2. Scatter plots and result of regressing canopy closure on TM band 5. Each point represents mean crown closure of a 30m X 30m ground plot.

Fig. 3 gives the result of linear correlation between DNs and mean height. There was a high inverse correlation between height and DNs in TM band 5 ($R^2$ = 0.941The inverse correlation between DNs and height is consistant with the finding of Gemmell(1995)·

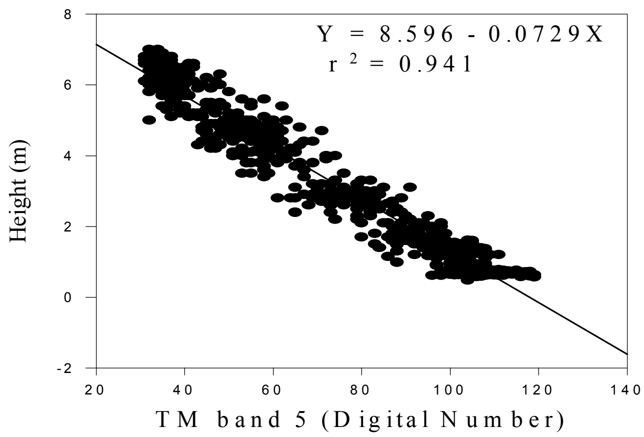


Fig. 3. Scatter plots and result of regressing height on TM band 5. Each point represents mean height of a 30m X 30m ground plot.

Fig. 4 presents an inverse correlation between DNs in band 5 and dbh ($R^2$ = 0.873) DNs in TM 5 have a higher correlation with the height than the dbh. This difference is consistent with the relationships between canopy closure where plotted against height and dbh $R^2$ = 0.87 and 0.77 respectively.)

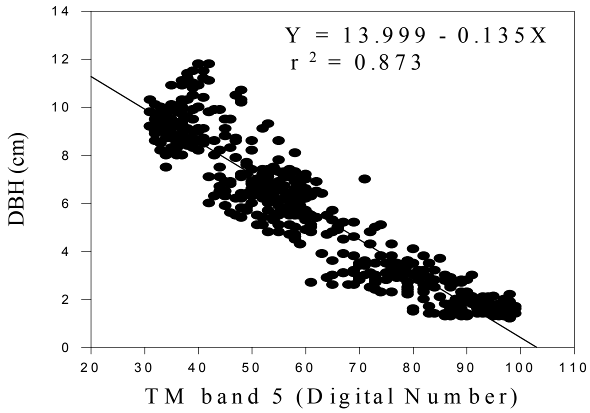


Fig. 4. Scatter plots and result of regressing DBH on TM band 5. Each represents mean DBH of a 30m X 30m ground plot.

## CONCLUSION

This study demonstrated that the TM imagery is a valuable data source for estimating canopy closure, height and dbh. In this initial investigation, canopy closure, height and dbh were successfully correlated with TM DNs and these attributes could thus be estimated from TM imagery. TM bands 1,2, and 3 were unsuitable for this purpose because of their small DNs range. TM band 5 had greatest DN range of the TM bands. This band revealed a higher correlation with canopy closure, height and dbh ($R^2$ = 0.86, 0.94, and 0.87 respectivel) than TM band 4.

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