Tropentag, October 6-8, 2009
"Biophysical and Socio-economic Frame Conditions for the Sustainable Management of Natural Resources "

Model for Estimation of *Acacia senegal* Volume from NDVI

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Introduction

The total wood consumption in Sudan in 2000 (including fuel wood, charcoal, poles, locally produced saw logs/sawn wood and imported sawn wood) was 22.6 million m³ (FNC, 2000; and FAO, 2002). The total annual input (allowable cut) was about 11 million m³ in the area north of 10º latitude that was inventoried in 1995. Without taking the growing stock in the wood-surplus south into consideration, there is an annual wood deficit of more than 11.6 million m³. Therefore, measuring the size and complexity of forest canopies over large areas would enable scientists to better understand these environmental processes. However, the basic need in any planning exercise is to have a well-defined database to arrive at a decision for any development activity incorporating all limiting and de-limiting factors so as to understand their correlation and interaction. In this regards there is a need to adopt quick and cost-effective methodologies for forest inventories which allow for both the assessment of the total forest biomass and for potential fuel wood. In this regard, the study was conducted in Nabag reserved forest in Southern Kordofan state in the Sudan during 2007-2008. The aim was to provide quick tools for estimation of *Acacia senegal* stand volume from satellite imagery using Normalized Difference Vegetation Index (NDVI). The study used stratified sampling design to collect the field data, and TERRA ASTER L1b image band 1, 2 and 3N to produce the NDVI map. Afterwards, the average stand volume for each sample plot has been calculated and correlated with the NDVI values for the same location using ERDAS Imagine program. Finally, the SPSS program has been used to produce an algorithmic model for estimation of the stand volume of *Acacia senegal* from the NDVI value.

Material and Methods

For most inventories of woody vegetation, sample intensity usually defined to achieve an allowable error based on the total volume (McCoy, 2005). In this context, initially, the study site was divided into several strata with regard to their spectral reflectivity with the help of supervised clusterization using ERDAS Imagine software (Fig. 1). Then the sample plots were assigned randomly to each stratum. Accordingly, stratified random sampling design was selected to locate the Ground Control Points (GCPs) and collection of the field data. The sample size was defined to be 0.36 ha calculated from Justice and Townshend (1981) formula (McCoy, 2005) and CRS sample size calculator (CRS, 2009). The Townshend formula indicates that a site dimension is estimated from the image pixel size and the locational accuracy of image registration as follows.

$$A = P\,(1+2*l)$$

"*Where: A = Minimum site dimension, P = Single pixel dimension (30 meter) and L = Estimated locational accuracy in number of pixels (represents the residual error of image registration and resampling which was 0.5)".*

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The CRS calculator calculates the sample size in referral to the confidence level and confidence interval. With regards to this, at confidence level of 95%, the confidence interval has found to be 29 and 95. Hence, the sample size was calculated to be 11 hectares and the total number of sample plots was found to be 31 sample plots (11/0.36).

For each sample plot a diameter at breast height (DBH) for ten *Acacia senegal* trees and a height for at least 3 of them have been measured and recorded. Then after the average stand volume for each sample plot was calculated using the equation bellow.

$$V = \pi * d^2/4 * h*ff$$

Where: V= Volume, d=diameter, h= height, π= 3.1415 and ff= form factor (from Sudan Forest National Corporation.

Concerning the TERRA ASTER image it has been calibrated and reprojected to the UTM zone 35 and Spheroid and Datum WGS 84. The image then entered in the ERDAS Imagine program and an NDVI map was produced (Fig. 2). Afterwards, the sample plots were located on the NDVI maps and the pixel value for each one was recorded. Due to similarity in the NDVI values of the sample plots only ten sample plots were used in the formulation of the model. As the area of the sample plot was 0.36 ha, each sample was including 16 pixels, hence the total number of pixels was 160, and the average value has been used in the model. Finally, the recorded NDVI values correlated with the sample averages volumes and the model has been produced.

The NDVI is a simple numerical indicator which assess whether the target under observation contains active green vegetation or not. The NDVI value is calculated from the red (R) and the near infrared (NIR) spectral reflectance measurements. The NDVI values vary between -1.0 and +1.0. The low values of NDVI (0.1 and below) correspond to barren areas of rock, sand or snow. The moderate value (0.2-0.3) represents shrub and grassland, while a high value (0.6-0.8) indicates temperate and tropical rain forests (John & David; 1999).

Results and Discussion

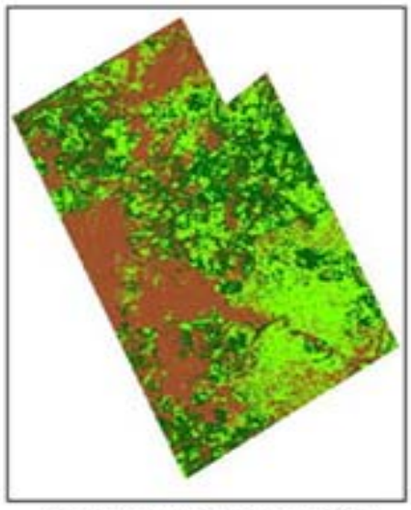
The total number of trees used for the stand volume calculation and model elaboration was 425 trees with an average of 42.5 trees per sample plot (Table, 1). The average volume per sample plot was found 0.082 m^3. Concerning the satellite data the sample plots were located in the NDVI map with the help of their coordinates. With refer to the NDVI value range it has been found that the barren area and rock occupy the range < 0.0, the shrubs and rangeland had a value ranges from 0.0-0.19 and the forest land > 0.2 NDVI value. Afterward, the average NDVI value for the pixels covered by each sample plot has been recorded (Table 1). Notice that it has been found in one of the sample plots, that the average value of the NDVI was less than that of the forest category range.

As the study is was carried out in nearly pure *Acacia senegal stand* which is used for gum Arabic production and when reach the rotation used for building purpose. Therefore, the study concentrated on the usable part of the tree (Breast Height which is more than 1.3 meter). Accordingly, the study used the volume calculated at this level which is referred as stand volume. The study supposed that the forest stand has nearly the same growth conditions such as pure sand soil, nearly same rainfall amount per year and free of disease and attack with insects and other factors that affect the NDVI values.

Afterwards the study used the SPSS statistical program to test the best relationship between the average stand volumes obtained from the sample plots and the average NDVI values calculated from the map. The test was started generally with all possible correlations and tested about ten such as linear, logarithmic, inverse, compound, cubic, exponential, etc. The results showed that the logarithmic function was the best (Fig. 3).

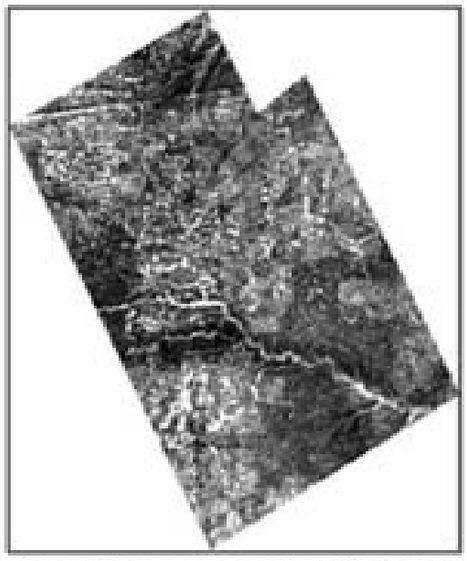
Table 1: Sample Plot Mean Volume and NDVI

Sample #	Coordinate		Total # trees	Total volume/m³	Mean Volume/ m³	Mean Pixel NDVI Value
1	12° 33" 41.4'N	29° 55" 27.5'E	22	0.59	0.04	0.2
2	12° 33" 33.5'N	29° 55" 25.7'E	11	0.70	0.04	0.2
3	12° 32" 26.4'N	29° 55" 26.7'E	70	2.68	0.17	0.26
4	12° 32" 12.7'N	29° 55" 27.3'E	53	1.80	0.11	0.2
5	12° 32" 08.7'N	29° 55" 40.4'E	53	1.63	0.10	0.2
6	12° 32" 06.2'N	29° 55" 47.7'E	60	2.60	0.16	0.22
7	12° 33" 34.9'N	29° 55" 05.7'E	47	0.42	0.03	0.2
8	12° 32" 26.7'N	29° 55" 39.8'E	48	1.01	0.06	0.2
9	12° 32" 06.6'N	29° 55" 47.8'E	39	1.53	0.10	0.2
10	12° 33" 31.2'N	29° 55" 54.3'E	22	0.23	0.01	0.17



Nabag Forest Classified 2007

Fig.1



Nabag Reserved Forest NDVI 2007

Fig.2

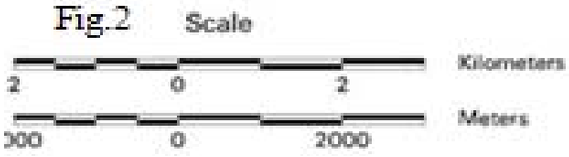


Figure 1 to the left: supervised classification of the TERRA ASTER satellite imagery of 2007 of the study area.

Figure 2 to the right: shows the NDVI map of the TERRA ASTER satellite imagery. The color represents the NDVI value that ranges from -1 to +1. The brighter the color the higher the NDVI value and vice versa the darker one.

Finally, the logarithmic model for estimation of *Acacia senegal* stand volume from NDVI value has been formulated as shown in the equation below:

Volume = a0 + a1* ln(NDVI)

Where: a0 and a1 are constants' driven from the calculation; a0= 0.420, a1= 0.750, ln= the natural logarithm and NDVI= mean NDVI value for the sample plot.

"It has to be considered that this model has been elaborated for Acacia senegal grown in pure sand soil in semi-arid land at gum Arabic belt of the Sudan"

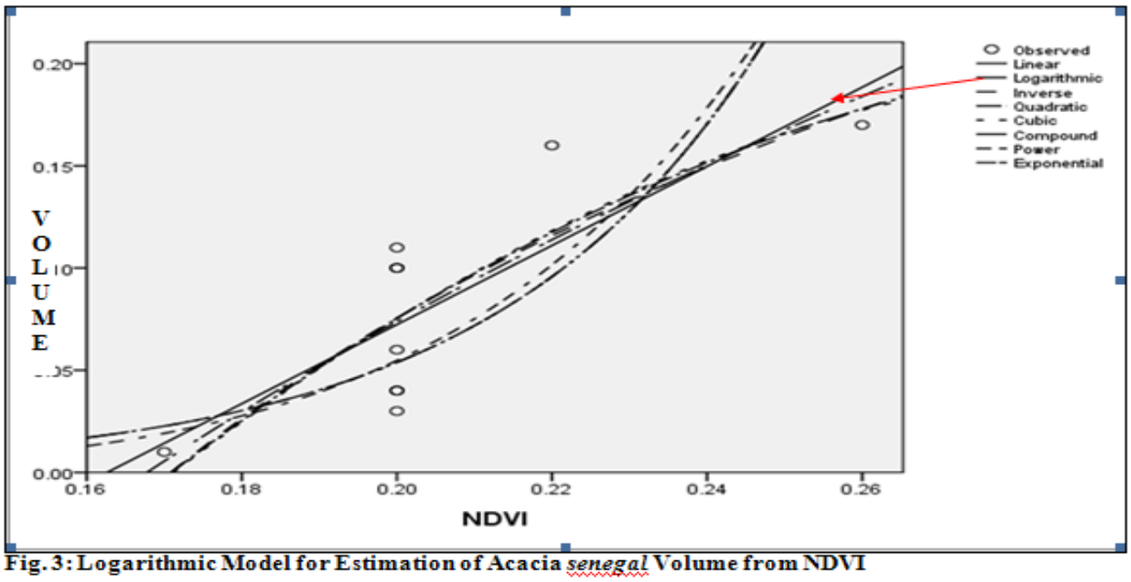


Fig. 3: Logarithmic Model for Estimation of Acacia *senegal* Volume from NDVI

Conclusion

This model has been elaborated for estimation of stand volume of *Acacia senegal (gum Arabic tree)* from an NDVI value using medium resolution satellite imagery, and for species grown in semi-arid land, nearly pure stand dominated by sand soil and has annual rainfall ranging between 250-400 mm.

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