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Estimation of Forest Variables using Remote Sensing and GIS: Case Study of Nabag Forest-South Kordofan, Sudan

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ABSTRACT

Acacia senegal (gum Arabic tree) is one of the most important economic species in the Sudan and constitutes a large part of the forest stand in the country specially in Kordofan state. The gum Arabic tree in study area was facing a lot of endanger factors such as desertification, domination by invader natural species, illicit falling and week management plans. Therefore, there was a need for reliable estimate and update of information and condition regarding the tree management in sustainable bases. This study used remote sensing and GIS techniques together with field inventory to estimate the gum tree volume parameter. The study used ASTER L1b satellite imagery band 1, 2 and 3n for the year 2007 together with forest inventory. The procedure for forest variables estimate began with acquisition of the mentioned satellite imagery then registered, enhanced and subset. Afterwards, the subset was clustered into several strata using unsupervised classification ISODATA algorithm of ERDAS Imagine 9.1 software; and after with the help of the spectral profile tests and Principal Component Analysis (PCA), the image was clustered in to three classes. Afterward, the sample plots were selected randomly from the strata for collection of field data (diameter & height). With regards to remote sensing, the study used the Normalized Difference Vegetation Index (NDVI) to estimate the forest volume. The results showed that the volume produced from the NDVI was not significantly different from that calculated from the field data and what has been found in the literature. The study concluded that remotely-sensed data together with the field data were useful and effective in estimation of forest volume parameter in the study area and the NDVI was a good index for forest variable estimate. © 2012 Friends Science Publishers

Key Words: Forest; Volume; Estimate; Remote sensing; NDVI

INTRODUCTION

The state of forest resources in the Sudan can only be estimated from the National Forest Inventory (1998), some national surveys and from global ones such as World Bank (1979 & 1982), Sudan Energy Survey (1987), FAO (2000) and the Forest National Corporation (FNC) annual reports. One of the most common tools for forest resources estimate and update is the forest inventory. In forest inventory there are various variables and parameters necessarily to be measured. Some of these variables are dependently originated and others are independent. The dependent variables for instance are forest conditions and the independent variables are those such as volume, basal area, crown closure, etc. (Franklin, 2001). Volume and biomass are intricately linked to forest growth and much of same logic in developing remote sensing estimates of the parameters (Franklin & Luthen, 1995).

The study area is "Nabag Reserved Forest" which located in Northern Kordofan State in the Sudan with a centre coordinate of 12º 32' 26" N and 29º 55' 26" E. The forest was established in 1960 as *Acacia senegal* plantation for Gum Arabic production as main objective, besides soil reclamation and environmental conservation. The forest was growing in nearly pure sandy soil with low fertility. After some, while and due to shortage of rainfall, illicit felling and improper management plans, the forest cover has been degraded and its composition has been changed. Due to that, the tree species have been decreased and mixed with other natural species. In the recent years the Forest National Administration has tend to manage the stand in sustainable basis by restoring the forest plantation through direct seedling and Toungya agroforestry system. To fulfill that, it was highly needed to develop cost-effective and applicable information and data gathering methods. Therefore, as the tree volume is the most important variable in forest

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evaluation, this study was attempted to investigate the use remote sensing, Geographical Information System (GIS) techniques together with field inventory (Gemmell, 1995) to estimate the volume parameter of *A. senegal* and to develop models that could help in managing the forest stands in a sustainable basis.

The overall objective of the study was to develop method for estimation of forest variables using remote sensing and GIS that could help for forest policy implementation and management of *A. senegal* stands in a sustainable base.

MATERIALS AND METHODS

The study used ASTER L1b satellite imagery band 1, 2 and 3n (15 meter resolution) for the year 2007 together with forest inventory. The procedure for forest variables estimate began with acquisition of the mentioned satellite imagery then registered, enhanced and the study site has been subset. Afterwards, the subset was clustered into several strata using unsupervised classification ISODATA algorithm of ERDAS Imagine 9.1 software. Then with the help of the spectral profile tests and Principal Component Analysis (PCA), the image clustered in to three classes (Fig. 1). After that the sample plots were selected randomly from the strata for collection of field data such as diameter and height. The area of the sample plot has been calculated as 0.36 ha using the Townshend (1981) equation (1) below.

Equation (1): $A = P (1+ 2*L)$.

[*Where, A=Minimum site dimension (sample size-one area dimension), P=Single pixel dimension (15 M-resolution) and L=Estimated locational accuracy in number of pixels (1.5)]*.

With regards to remote sensing, the study used the Normalized Difference Vegetation Index (NDVI) for forest volume estimate. NDVI is a simple numerical indicator that assess whether the target under observation contains active green vegetation or not. It is values are calculated from the RED and NIR spectral reflectance measurements of the satellite. The NDVI values vary between -1.0 and +1.0. The low values range between (0.1 & below) and correspond to barren areas of rock, sand or snow. The moderate values (0.2-0.3) represents shrub and grassland, while a high values (0.6-0.8) indicates temperate and tropical rainforests (John & David, 1999).

The parameters measured in the field were Diameter at Breast Height (DBH), Diameter at Root Collar (DRC), and Height (H); in addition to that the number of trees per sample plot were been recorded accordingly, the volume per each sample plot was calculated. After that the sample plots were located on the NDVI imagery using ARCGIS package of ESRI and the NDVI values corresponding to each sample plot were extracted. Modules were then developed to relate the field data and spectral response of the imagery. Finally, the models were used to predict the forest volume parameter based on NDVI value.

RESULTS AND DISCUSSION

According to (Table I), the study found that the average volume per sample plot was 1.32 m^3 and the average number of trees per sample plot was 42.5. While an average volume per single *A. senegal* tree is 0.031 m^3 and the average number of tree per hectare was 118.1 and hence the average volume per hectare was 3.7 m^3. The figures estimated for Nabag forest were nearly the same as that reported by (SRAAD, 1992) in its vegetation survey project that has been carried out 30 years ago (1987). It was reported that the average numbers of trees per ha was 53.41 tree and the average standing volume was 3.0 m^3. The difference could be referred to that they used in their calculation only the trees that has diameter or crown greater than 5 cm. However the number of trees in 2007 was greater than that of 1987, but the no difference showed in the term of volume.

The NDVI results showed a maximum positive value of 0.26 in the sample plot areas and minimum was 0.17 (Table II). This low NDVI values could be related to the morphological characteristics of *A. senegal* species and the season. The tree has small leaves with less greenness (the dominant NDVI factor) on November (the time of image acquisition). Also, the poor sand soil has less fertility and hence less green vegetation as shown in (Fig. 1).

With regards to the field inventory, the mean DBH has been calculated from the collected measurements while the H has estimated by an equation derived from the measured height samples (Equation 2).

Equation 2: $H= 1.936+0.109*DBH$

[Where, H=Height, DBH=Diameter at Breast Height, 1.936 & 0.109 are constants].

As a lot of DRC were included in the sample plots and in order to increase the efficiency of volume estimation, a relationship between DBH and DRC has been produced (Equation 3).

Equation 3: $DBH = a0*\exp(a1*DRC)$.

[Where, DBH: Diameter at Breast Height, A0 (constant) = 3.19. a1 (constant) = 0.15].

Note: the equation calculated at $r^2=0.35$].

Finally, a model has been developed for estimation of trees volume from NDVI (Model 1). The model is a logarithmic function elaborated from the mean sample NDVI and volume produced (Table II). The model has been selected from other models tested such as linear regression and inverse.

Volume = $a0+a1*\ln(NDVI)$.

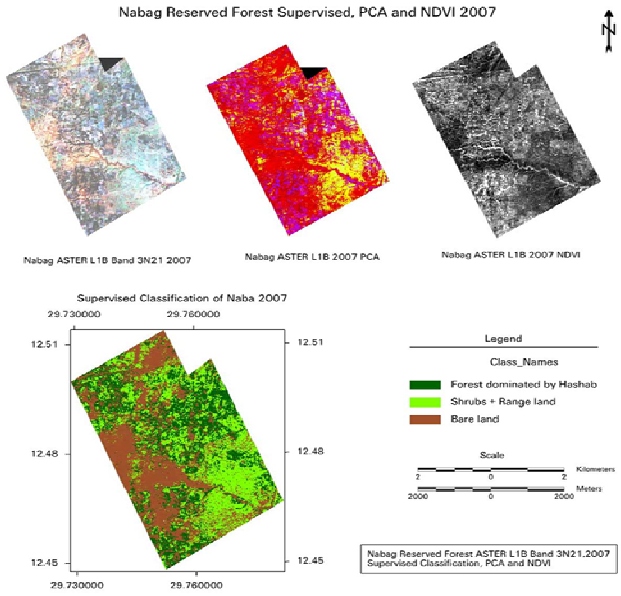
Where, A0=.420; A1=.750; ln=the natural logarithm; NDVI=Mean NDVI for sample plot of 0.36 ha.

Model 1: Estimation of *A. senegal* Volume from NDVI.

Table I: Number of trees and volume per sample plots for Nabag forest

Sample #	Total # trees DBH	Mean DBH	Mean HDBH	Volume DBH	Total # trees DRC	Mean DRC	Mean HDRC	Volume DRC	Volume DBH+DRC
1	15	17	4.2	0.57	7	6.8	2	0.02	0.59
2	11	20.4	4.9	0.7	0	0	0	0	0.7
3	47	21.7	3.8	2.64	23	5.9	1.7	0.04	2.68
4	38	19.8	3.8	1.78	15	4.9	1.6	0.02	1.8
5	35	17.4	3.7	1.62	18	3.7	1.4	0.01	1.63
6	44	20.6	4.4	2.58	16	5.9	1.4	0.02	2.6
7	34	11.7	2.5	0.41	13	3.2	1.5	0.01	0.42
8	25	16	4.8	0.97	23	6.1	1.4	0.04	1.01
9	31	19.5	4.1	1.52	8	4.5	1.6	0.01	1.53
10	17	11.8	3.1	0.23	5	3.5	1.2	0.002	0.232
Mean	**29.7**	**17.6**	**3.9**	**1.30**	**12.8**	**4.5**	**1.38**	**0.02**	**1.32**

Fig. 1: Subset, classified and NDVI maps of the study area



CONCLUSION

The study concluded that ASTER satellite imagery was useful in estimate of forest variable in the study area. Also, it has been founded that an NDVI was a good indicator for forest volume variable estimate. From other side, the study recommends using medium satellite imagery for forest volume but with much as possible ground truth points.

Table II: Sample Plot Mean Volume and NDVI

Sample #	Coordinate		Total # trees	Total volume/ m^3	Mean Volume/ m^3	Mean Pixel NDVI
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

REFERENCES

FAO, 2000. *Food and Agriculture Organization*, pp: 140–479. The Global Forest Resources Assessment 2000 (FRA 2000): Main Report, FAO forestry paper

Franklin, S.E. and J.E. Luther, 1995. Satellite remote sensing of balsam fir forest structure, growth and cumulative defoliation. *Canadian J. Remote Sensing Environ.*, 21: 400–411

Franklin, S.E., 2001. *Remote Sensing for Sustainable Forest Management*. CRC Press, Boca Raton, Florida, USA

Gemmell, F.M., 1995. Effects of forest cover terrain and scale on timber volume estimation with Thematic Mapper data on rocky mountain site. *Remote Sensing Environ.*, 51: 291–301

John, W. and D. Herring, 1999. *Measuring Vegetation (NDVI & RVI)*. <http://earthobservatory.nasa.gov>, Accessed on 11.02.09

National Forest Inventory (NFI) Report, 1998. *Forest National Coorporation Libarary*. Khartoum, Sudan

SRAAD, Sudan Resource Assessment and Development Project, 1992. *First Interim Report: Sayed M. Hanafi and Azien E. Hassan.* Survey Department, Khartoum, Sudan

Sudan Energy, 1987. *Wood Energy/Forestry Project August 1987*. Household Energy Unit, Industry and Energy Department; Khartoum, Sudan

Townshend, J.R., 1981. *Prospect: A Comment on Future Role of Remote Sensing in Integrated Terrain Analysis.* Terrain analysis and remote sensing, George Allen and Unwin, London

World Bank, 1979. *Agricultural Sector Survey, 1836a-Su*. Washington DC

World Bank, 1982. *Investing for Economic Stabilization and Structural Change, 355a-SU*. February 16, Washington DC, USA

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