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Developing an Operational Method for Assessing Forest Resources in *Abu Haraz* Reserved Forest in Kordofan, Sudan

Hassan Elnour Adam[a]*

[a]Technical University of Dresden, Institute of Photogrammetry and Remote Sensing, Germany

Abstract

Forest resources in Sudan play different roles in characterizing the ecological and environmental changes as indirect benefit and satisfy a wide range of needs for the rural population (food, shelter, energy, income). The area under forest reserve is five million hectares, which is equivalent to 2.2% of the total area of the country. Forests in Sudan contribute to 82% of the total energy consumption in the country. Due to decline in forest resources in Sudan and the expected bad consequences, quantifying and appraising of the existing resources and their sustainable management is needed. The aim of the research is to develop an operational method to assess the forest resources in *Abu Haraz* natural reserved forest in Kordofan using cluster sampling method. *Abu Haraz*, which is selected as the study area, is the biggest natural reserved forest in Kordofan and located in low rainfall woodland savannah. Six systematic cluster sampling were used and distributed in the forest with equal distances. Each cluster covers an area of 60 ha, and includes 25 circular sample plots. Tree parameters such as tree specie, diameter, height and crown diameter were collected from trees with dbh $\geq$ 7 cm. Step-wise regressions was used for developing the operational equations of tree species. Results showed that the reserved forest is dominated by two species, *Albizza amara* and *Lannea humilis* with 34% and 46%, respectively. The density of the trees is found to be of 37 trees ha^{-1}, volume is 24.13 m^3 ha^{-1} and basal area is 2.25 m^2 ha^{-1}. 72% of the growing stock is found in diameter class between 27 -31cm. Two equations were developed for the dominant species using volume as dependent variable and height and diameter at breast height as dependent variables. The sampling error and intracluster correlation coefficient error were found to be ±10% and 0.07, respectively. The study concludes that the forest is under heavy pressure of local use so management plan must be formulated in order to reduce the degradation of the area.

Keywords: Forest reserve, Cluster sampling, Step-wise regression, *Abu Haraz*,

Introduction

Forest resources in Sudan play different roles in characterising the ecological and environmental changes as indirect benefit and satisfy a wide range of needs for the rural population (food, shelter, energy, income) (Mahir, 1996) . The area under forest reserve is five million hectares,

* Contact addresses: Hassan Adam, Gerokstr. 38/403, 01307 Dresden, Germany
E.mail: Hassan_adam@hotmail.com

which is equivalent to 2.2% of the total area of the country. Forests in Sudan contribute to 82% of the total energy consumption in the country (FAO, 2003). In Fact, the population is increasing, available resources are limited, and the population exerts great pressure on the forest for fuel wood, charcoal, construction, grazing of animals and agriculture expansion. These resulted in the destruction and losses of most of the reserved forest. Due to decline in forest resources in Sudan and the expected bad consequences, quantifying and appraising of the existing resources and their sustainable management is needed.

Forest inventors are conducted to obtain unknown information about the natural resources to assist the local forest managers for proper and scientific forest management plan. One of the main problems of forestry in Sudan is the lack of quantified data, which can help to demonstrate the virtual role that forest plays in protecting the environment (Badi *et al*., 1989). The main causes of forest destruction in Kordofan State are the rain-fed agriculture expansion and illicit felling. *Abu Haraz* reserved natural forest now under intensive pressure from surrounding human population through agricultural encroachment, so it needs more efforts to get involved in managing and conserving the existing land resources.

The aim of this research is to develop an operational method to assess the forest resources *in Abu Haraz n*atural reserve forest in Kordofan using cluster sampling method.

Material and Methods

Study area

Abu *Haraz* forest, which is selected as the study area, is the biggest natural reserved forest in Kordofan and located in low rainfall woodland savannah, and under the protection and administration of Forest National Corporation (FNC). The forests cover an area of 4.900 ha. The forest plays an ecological and environmental role in the area.

Sampling techniques

Forest measurements are taken to provide information on the species, quantity, size quality and distribution of the forest component. Cochran (1977) noted that for large forest areas, sampling could provide all the necessary information at much lower costs with reliable results than total enumeration.

The sampling was carried out with the classic systematic cluster sampling method in a camp unit. Six clusters were designed and distributed in the forest with the camp in the centre of each cluster (60 ha). Cluster sampling has been used with success in tropical forest in remote areas (Hush, 1971). Sampling units selected the concentric circular sample plots with two radii (17.84 m & 5 m). 25 circular sample plots were systematically located in each cluster with distance of 200x100m between each one and another. The total inventoried area is equal to 15 ha.

The tree parameters were measured in each sample plots by 100% enumeration for all trees with DBH $\geq$ 7cm includes DBH, tree height, tree species, crown diameter and natural regeneration.

The form factor (ff) for the volume calculation used as 0.4 (Adam, 1998).

Data analysis

Methods of data analysis include volume computation, regression function and intracluster correlation coefficient (equation 1 & 2). The step-wise multiple regressions were used for fitting volume functions for the whole trees and the dominated individual tree species.

$$S^2 = \frac{(n-1)S_b^2 + n(M-1)S_w^2}{nM-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\rho = \frac{S_b^2 - S^2}{(M-1)S^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where:

ρ	intracluster correlation coefficient
S_b^2	Variance between clusters
S_w^2	Variance within clusters
S^2	Total variance of clusters
M	Number of elements per cluster
n	Number of clusters sampled
N	Number of clusters in the population

Results and Discussion

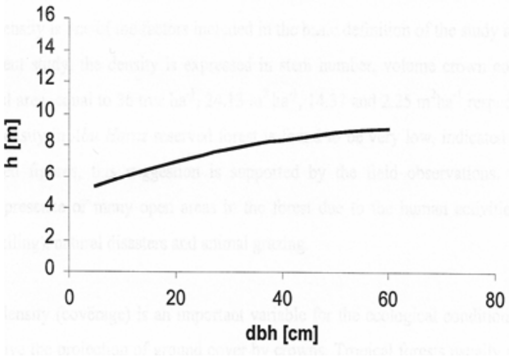
The study showed that the forest is characterised by uneven distribution of tree and low biodiversity. *Abu Haraz* reserved forest is dominated by two species, *Albizza amara* (*Arad)* and *Lannea humilis* (*Leyon) with* 34% and 46%, respectively. The rest of the forest is covered by other ten tree species.

The volume of the stocked wood and the basal area in the forest are 24.13 24.13 m^3 ha^{-1} and 2.25 m^2ha^{-1}, respectively, which is rather low. However, the number of trees is 36 $treeha^{-1}$ which also rather low due to the removal of all big trees. And 72% of the growing stock is found in diameter class between 27 – 31cm.

Stand height curves for the two dominant trees were generated using non-linear regression equations. The equation used the height as dependent variable and DBH as independent variable. Three equations were applied to select the most fitted one. These equations are parabola function, logarithmic function and exponential function.

Exponential function was fitted for stand height of *Lannea humilis* tree (Fig. 2), and the Parabola function is fitted to the stand height curve of *Albizza amara* tree (Fig. 1).

The crown coverage, which an important variable for the ecological condition in the forest, was found very low (14.37%).



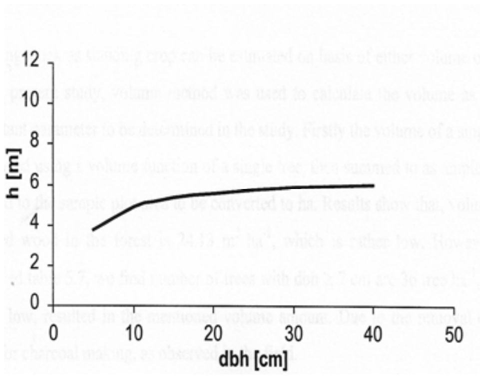


Fig. (1) Stand height curve of *Albizza amara*

Fig. (2) Stand height curve of *Lannea humlis*

Different approached (methods) were developed for equation construction, which have a common purpose of producing simple and accurate statement of volume in relation to the measured parameters. In this study equation method was used because it's widely used in forest resources inventories to measure volume. Numerous tree volume equations based on the regression approach have been developed for the two dominant tree species. The step-wise multiple linear regression techniques is the main method used in analyzing the data to develop best- fitted model for volume functions

Derivation of the mathematical function of the *Albizza amara* volume is based on 238 measured standing trees. The best selected and fitted model for *Albizza amara* with regression coefficient is presented in equation (3).

The selected equation model for *Lannea humils* is based on 247 measured standing threes, and presented in equation (4).

$$V = 0.111+17.05BA+H^2+DBH-H \quad \ldots\ldots(3)$$

$$V = 0.136+17.95BA+H^2- DBH+H \quad \ldots\ldots(4)$$

Where:

V	Volume
BA	Basal area
H	Tree height
DBH	Diameter at breast height

The analysis results showed in figure (5) indicates that there is no difference in the variance trend as a function of plot spacing. Therefore increase in distance between plots will cause no changes in the variance, but increase the cost and time. Therefore its better to use the short distances between plots in the cluster sampling.

The sampling error and intracluster correlation coefficient error were found to be ±10% and 0.07, respectively.

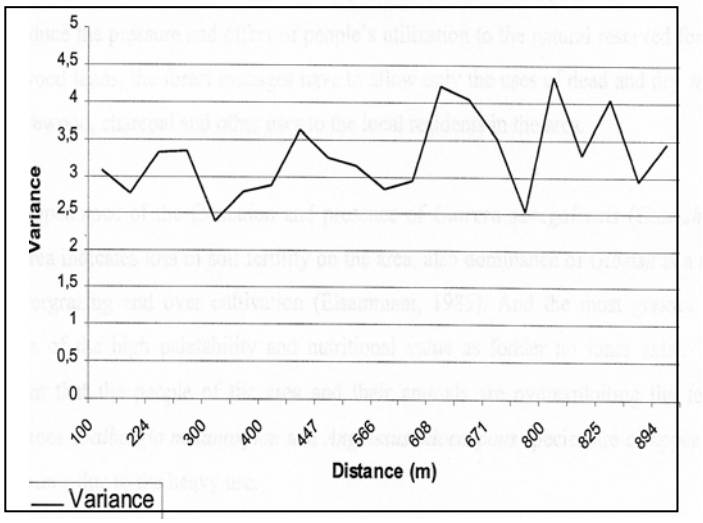


Fig. (3) Variance versus plot spacing in meters

Conclusions and Outlook

Disturbances in the forest are limited to seasonal grazing, forest activities (fuel wood, charcoal making and local construction material) and agricultural activities. Natural regeneration was found extremely very low due to the grazing and accident fires.

The study concluded that, a management plan for *Abu Haraz* reserved forest should be established to increase the productivity of the resources and to reduce the degradation of the forest. Also, use of recently innovated and developed charocal burning stoves should be encouraged through production and distribution in the area.

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