

VARIABILITY OF FOREST MENSURATION INDICES IN CLIMAX TROPICAL FORESTS (AT THE EXAMPLE OF LAOS)

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PHILIPCHUK, A.N. 1993. Variability of forest mensuration indices in climax tropical forests (at the example of Laos). Mean volumes and their variability were calculated for the principal forest vegetation formations widely represented in Laos (evergreen, semi-deciduous and pine tropical forests). For calculations data of the ground study of 2000 sample plots were used. The values of the calculated indices vary within wide ranges, the variability of volumes being maximal in deciduous and semi-deciduous formations. Within the forest vegetation formation the most stable is the ratio of the exploitable to the total volume. This index can be used for the estimate of the total volume of the trunk timber in the mensuration of tropical forests.

Key words: Tropical forest - variability - volume - sample plot - forest inventory - forest stand

PHILIPCHUK, A.N. 1993. Pembolehubahan petunjuk sukatan hutan di klimaks hutan-hutan tropika (sebagai contoh Laos). Isipadu purata dan pembolehubahannya telah dikira untuk pembentukan tumbuhan hutan utama yang banyak terdapat di Laos (hutan-hutan malar hijau, separa meluruh dan pain tropika). Untuk perkiraan, data dari kajian tapak 2000 plot sampel telah digunakan. Nilai petunjuk yang dikira berbeza dalam julat yang besar, pembolehan isipadu didapati tertinggi dalam pembentukan meluruh dan separa meluruh. Diantara pembentukan tumbuhan hutan yang paling stabil ialah nisbah usahasil berbanding jumlah isipadu. Petunjuk ini boleh digunakan untuk membuat anggaran jumlah isipadu batang kayu dalam sukatan hutan-hutan tropika.

Introduction

Variability of forest mensuration indices, mean volume of the forest stand per *ha* in the first place, is the necessary parameter for the substantiation of the sampling volume in forest inventory carried out with the statistical method (FAO 1981, Vries 1986). It is especially important for an inventory in tropical forests (Zeide 1980). Difficult access and large expenditures of money and labour needed for the ground work call for reliable determination of the sampling volume at the stage of the forest inventory project preparation. Data about the degree of variability of timber volumes per *ha* make it possible to achieve the necessary accuracy of forest mensuration indices with minimal expenditures.

Materials and methods

Study area

The study area is located in the central part of Laos and occupies the territory of three provinces: Khammouan, Saravane and Savannakhet, where large areas of climax tropical forests untouched by economic activities (Figure 1) have been

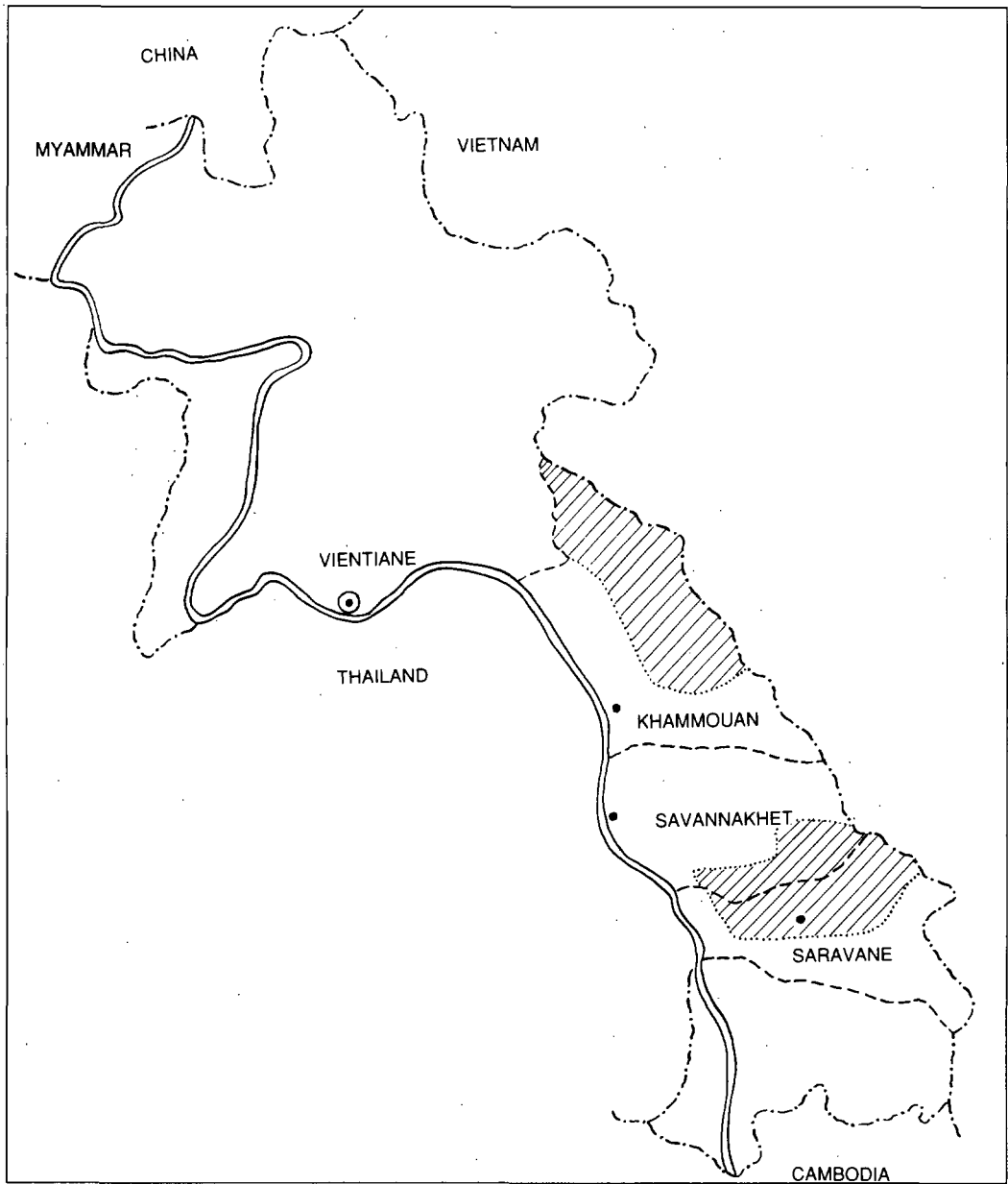


Figure 1. Location of the study area

preserved. The distinguishing feature here is the low population density and difficult access to most of the forests.

The climate in the region is monsoon, sub-equatorial. There are two climatic seasons in a year: hot and humid (from May to October), and cool and dry (from November to April). Mean annual air temperature is 25°C. The minimum temperature is about 7°C in the mountain regions of northeast Khammouan, the maximum temperature exceeds 40°C. In the mountain regions the seasons are not so well pronounced. Here, even in the dry period, the precipitation is enough for evergreen vegetation. Mean annual precipitation in the mountains is 4000 mm, and in the valley, 2500 mm. About 80 to 90% of the annual precipitation takes the form of heavy tropical showers during the hot season. On the whole, the climate of the region is quite typical for the border of tropical and subtropical zones, and has no anomalous deflections.

The study area in the province Khammouan by its relief is mountainous. The terrain is heavily rugged, with a deeply cut river system, the overfalls of ground elevations make up 200 to 300 m km⁻¹. Protracted slopes with the steepness of 225° to 40° dominate. Watersheds with outlets to the surface of rock outcrops are well pronounced. Maximum heights reach 1000 m above sea level. In provinces Saravane and Savannakhet, the study area is located on the plain.

On the study area tropical light-brown forest soils are most common. The valleys of river terraces have tropical podzolic-sand soils.

In Laos, evergreen, deciduous, semi-deciduous and pine tropical forests vegetation formations are widely represented (Bochkov *et al.* 1984, 1986). Large tracts of evergreen tropical forests are located on mountain slopes and plateaus (Figures 2, 3), and small plots on river banks and along springs in the valley. Evergreen forests are characterized by a great diversity of the species composition and multi-storeyed composition of the canopy. The upper storey is represented by high trees (35 to 40 m); its crown closure does not exceed 25%, the second storey consists of trees with height of 25 m and it is also not dense. The third storey as a rule consists of trees which never reach the upper storey, and forms the closed canopy without "windows". Tree crowns adjoin each other and are interlaced by lianas (Figure 4). In this storey and in the shrub storey young growth of tree species is widely represented. The lowest storey consists of plants having the height of several centimetres to 1 m. It is represented by seedlings of tree species, grasses and ferns. Main tree species are represented by the genera *Anisoptera*, *Hopea*, and *Parashorea*.

Deciduous forests grow on plain dry sites, spread in the provinces of Saravane and Savannakhet, and are practically not found in the province of Khammouan (Figure 5). The stands as a rule are one-storeyed, seldom two-storeyed, with height of about 25 m, and are very sparse. Main species are: *Dipterocarpus tuberculatus*, *D. obtusifolius*, *Pentacme siamensis*, *Terminalia tamicutosa*. In general, deciduous forests are considered to have been formed in the tropical zone under the influence of anthropogenic factors. The study of *Dipterocarpus* stands has not



Figure 2. Evergreen forest, sparse "window" on the stream



Figure 3. The author on the clearing with diameter of 15 to 20 m in the evergreen forest, the clearing is the result of dominant tree dieback



Figure 4. Very often the movement in the evergreen forest is possible only by the cut lines

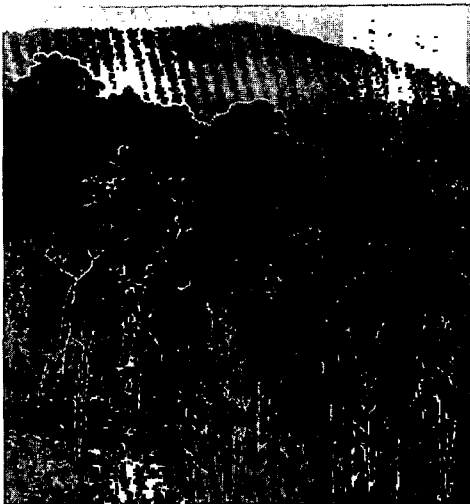


Figure 5. In some places the boundary of the deciduous and evergreen forest is quite well pronounced

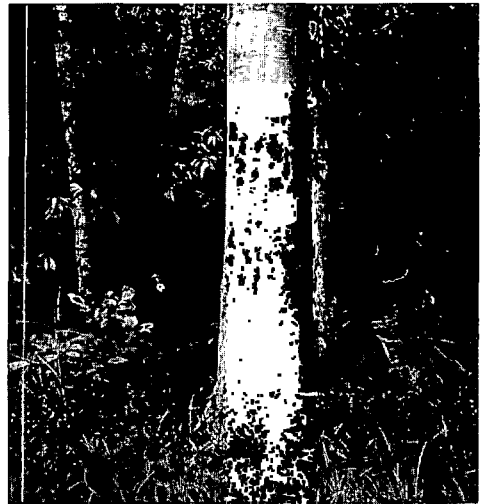


Figure 6. Semi - deciduous forest

confirmed it. Part of the preserved tracts in the provinces of Saravane and Savannakhet does not appear to have any economic impact and, according to our estimates, can be classified as climax.

Semi-deciduous forests (mixed) are located on the border of evergreen and deciduous forests. The upper storey is represented by evergreen species, the lower storeys consist of deciduous and evergreen trees. Species of both formations are characteristic (Figure 6).

Pine forests are made up by two types of tropical pines: *Pinus khasya* and *P. merkussii*. They grow only in the province of Khammouan on the mountain plateau Nakai and gentle mountain slopes (Figure 7). The stands are distinguished by high productivity. Mean height reaches 35 to 40 m; there are some trees which are more than 45 m high, with the $D_{1,3}$ being up to 2 m. On some sample plots the total volume makes up 1200 $m^3 ha^{-1}$.

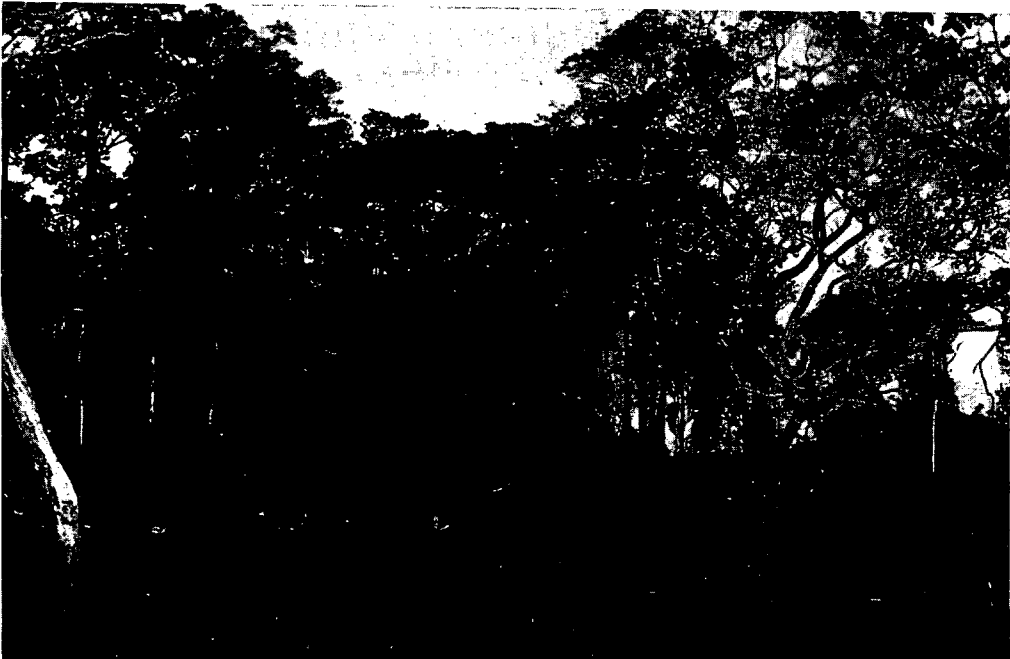


Figure 7. Boundary of the pine forest tract

Data collection

The experimental materials are represented by data from sample plots laid by the Laos - Soviet expedition during the forest inventory of 1981 to 1983 (Table 1). The studies were carried out in the Eastern part covering 200,000 ha (1226 sample plots) in the province of Khammouan and 150,000 ha (876 sample plots) in the provinces of Saravane and Savannakhet.

Sample plots on the inventory area were located systematically on the cut lines. The distance between the lines was 2 to 4 km, between the centers of the sample plots on the lines 500 m. Sample plots were circular plots with a constant

Table 1. Distribution of sample plots by provinces and forest vegetation formations (numbers)

Forest vegetation formation	Province	
	Khammouan	Saravane, Savannakhet
Evergreen forest	785	225
Semi-deciduous Forest	83	541
Deciduous forest	4	197
Pine forest	267	-
Total	1139	963

radius, and consisted of four sub-plots of different sizes (0.001, 0.01, 0.1 and 0.25 *ha*) with a common centre and radii of 1.79, 5.64, 17.84 and 28.21 *m* respectively. On the smallest plot the undergrowth and self seeding of valuable tree species were taken into account. On the next plot a complete counting of trees with the D_{123} of 10 to 29 *cm* was done. On the plot of 0.1 *ha* trees with the diameter of 30 to 59 *cm*, and on the plot of the maximal size, trees with the diameter of ≥ 60 *cm* were counted. Ground mensuration was done using standard methods (FAO 1981, Husch 1982).

When mean volumes were determined, all trees having the diameter of ≥ 10 *cm* were taken into account, that is data obtained on three sample plots beginning with the radius of 5.64 *m* were used. The volume of stems was determined for the commercial forests and total parts of trees using available local volume tables for evergreen, deciduous and pine forests separately.

Sample plots were formed into groups by each forest vegetation formation. Within each formation classes of the slope steepness with the interval of 5° were singled out. The analysis of the obtained results did not reveal significant differences in this feature (Philipchuk 1987) and later all sample plots were grouped into two classes according to the landscape conditions: mountain height above sea level of ≥ 600 *m* (Khammouan province), and plain of < 600 *m* (Saravane and Savannakhet provinces). For each group the following indices were calculated:

- $M_{od}, m^3 ha^{-1}$ - mean total volume of the stand;
- $M_k, m^3 ha^{-1}$ - mean commercial volume of the stand;
- $\frac{M_k}{M_{od}}, \%$ - ratio of the commercial volume to the total volume;
- $\frac{M_{od}}{V_{od}}, \%$ - variability of the total volume;
- $\frac{M_k}{V_k}, \%$ - variability of the commercial volume;
- $\frac{V_{k/od}}{V_{od}}, \%$ - variability of the ratio of the commercial to the total volume.

Four sample plots laid in deciduous forests (Khammouan province) were excluded from calculations as the results obtained in four sample plots cannot be considered reliable.

Results

Productivity of climax tropical forests growing in the mountain and plain conditions cannot be reliably determined. The most productive formation under conditions of Laos is the pine forest (Table 2). Mean volume is $405 \text{ m}^3 \text{ ha}^{-1}$, the share of commercial timber is 57%. Pine forests of Laos are far more productive than wild but secondary stands of *Pinus khasya* growing under similar conditions on the territory of Vietnam. According to the data of Uibric *et al.* (1984), mean volume of pine stands in the province Lam Dong makes up $200 \text{ m}^3 \text{ ha}^{-1}$. The variability of the basal areas per *ha* (the variability of the mean volume is in this case higher) makes up 92%. It is indicative of the decisive anthropogenic impact on the degree of variability of forest mensuration indices, which must be taken into account when the inventory project is being prepared in regions subjected to the anthropogenic - technogenic influence.

Inventory of pine stands under conditions of Laos is not very difficult. Forest tracts have distinct boundaries which makes it possible to extract them by space and aerial photographs at the stage of the inventory project preparation. The minimal, as compared to other formations, index of the volume variability allows the sampling volume in the inventory to be reduced, and the variability of the

Table 2. Mean values and variation of volumes by forest vegetation formations

Indices	Evergreen forest	Semi-deciduous forest	Deciduous forest	Pine forest
$M_c, \text{ m}^3 \text{ ha}^{-1}$	$\frac{133^*}{132}$	$\frac{114}{36}$	$\frac{-}{26}$	$\frac{235}{-}$
$M_t, \text{ m}^3 \text{ ha}^{-1}$	$\frac{277}{261}$	$\frac{263}{202}$	$\frac{-}{76}$	$\frac{405}{-}$
$\frac{M_c}{M_t}, \%$	$\frac{47}{50}$	$\frac{40}{42}$	$\frac{-}{34}$	$\frac{57}{-}$
$V_c, \%$	$\frac{56}{43}$	$\frac{73}{62}$	$\frac{-}{87}$	$\frac{47}{-}$
$V_t, \%$	$\frac{47}{40}$	$\frac{61}{52}$	$\frac{-}{69}$	$\frac{40}{-}$
$V_c/t, \%$	$\frac{29}{23}$	$\frac{34}{33}$	$\frac{-}{43}$	$\frac{19}{-}$

*In the numerator - values for the province Khammouan, in the denominator - values for provinces Saravane, Savannakhet.

ratio of the commercial to the total volume (which is 19%) makes it possible to give up ground measuring of the total height of trees.

There is a regular reduction of the stands' productivity from the evergreen to the semi-deciduous and deciduous formations. The ratio of the commercial to the total volume has a lesser degree of variation in the evergreen formation (29 and 23% for mountain and plain regions respectively) than in the semi-deciduous (34 and 33%) and deciduous (43%) formations. As a whole the variability of the total volume per *ha* by forest vegetation formations in Laos changes from 40 to 70%: this index increases with the decrease of the absolute value of volumes.

Conclusions

In Laos considerable areas of climax tropical forests which are a unique object of the study have been preserved. Complete absence of economic influence or a very low degree of it is present in forest stands having their natural state. Forest tracts of the study area are excellent samples of the main formations of the climax tropical forests of southeastern Asia and reflect their structure.

The study results have shown that forest stands of the study area are distinguished by considerable productivity which is very close to the productivity of the temperate zone forests, and in some cases even exceeds it. About 50% of the timber volume is of commercial value.

The most productive forest vegetation formation in the study area is the pine forest, then (in the order of decreasing mean volumes per *ha*) the evergreen, semi-deciduous and deciduous forests.

The variability of mean and commercial volumes per *ha* in climax tropical forests is considerably lower than in the secondary forests subjected to anthropogenic impact. The least values of variability of volumes are reported to be in clear or simple (by composition) stands. The influence of the relief on the value of the volume variability has not been noticed.

The ratio of the commercial volume to the total is rather a stable parameter in the forest vegetation formation. The variability of this index is twice less than the variability of the initial indices: commercial and total volumes.

The obtained results are of practical interest for the preparation of inventory projects in tropical forests, and give a good view of the natural parameters and their relationships which can be used as the basis for forest management.

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