

# **YIELD TABLE OF CARNARIUM ALBUM ROEUSCH PLANTATION FOREST IN LANG SON, BAC GIANG AND QUANG NINH PROVINCES**

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## Signs:

- A: Age of forest tree (year)
- CNS: Productivity level (1, 2, 3)
- Dg: Mean diameter of the forest stand (cm)
- Hdo: Mean Height of the dominant layer (of 20% of the highest trees in the forest stand (m)
- Hg: Mean height of the forest estate (m)
- Nht: Present density (tree/ha)
- Nopt: Opimal density (tree/ha)
- Stbq: The area of the canopy is the average of the forest trees (m<sup>2</sup>)
- Vbq: The average volume of the forest tree in the forest estate (m<sup>3</sup>)
- Vsp: The mean product volume of the forest tree with small-end diameter of 6cm (m<sup>3</sup>)
- M: Yield of the forest stand (m<sup>3</sup>/ha)
- Msp: The yield of timber products with smal-end diameter of 6cm (m<sup>3</sup>/ha)
- Z<sub>M</sub>: Annually mean growth on yield (m<sup>3</sup>/ha/year)
- Δ<sub>M</sub>: Mean growth on yield (m<sup>3</sup>/ha/year)
- P<sub>M</sub>: Growth rate on yield (%)

# GENERAL INTRODUCTION ON WHITE CARNARIUM FOREST YIELD TABLE

## 1. Forest yield table

Carnarium forest yield table is a comprehensive table of the process of growth and increment of Carnarium forest species in the provinces of Lang Son, Bac Giang and Quang Ninh. This Table for management and production of plantation forest includes:

- Determine productivity level of Carnarium plantation forest
- Estimate productivity and production of Carnarium plantation forest at present
- Estimate the yield of Carnarium plantation forest through business cycle
- Define measures for thinning to improve the yield for business purposes: Time for thinning, thinning density, optimal density.

Hence, it can be found that the yield table is not only a table for recording the growth of forest trees, the forest estate, but also a tool to manage plantation forest business activities effectively.

## 2. Users of materials

With requirements of forestry plantation practices at present, farmers are involved in the planting and tending of the forests, with the support of forestry technical staff. Therefore, yield tables are used by different target groups according to their tasks:

- **For farmers:** Tables used to determine and forecast production of plantation forests. Therefore, for use of the yield table, simple instructions are prepared so that farmers can look up the table to determine the most basic parameters onf the production of plantation forest.
- **For technical staff and forestry managers:** It is also used to identify and forecast the targets of productivity, production and measures for maintenance of plantation forests. However, its use can apply in two ways: i) Look up the Table to determine the values of the production; ii) Use the ready-made program to manage and monitor the production of plantation forests.

## 3. Structure of materials includes

Carnarium tree species in three provinces are planted in different circumstances, therefore, the productivity and production will vary, and hence, the production is predicted to follow the levels of productivity. Therefore, the establishment and use of the yield table of Carnarium plantation forests in this area includes 2 parts:

- Part I: The table of productivity level of Carnarium plantation forest and instruction for use.
- Part II: The table of production of Carnarium plantation forest and instructions for use.

# PART I: THE TABLE OF THE PRODUCTIVITY LEVEL OF CARNARIUM PLANTATION FOREST

## I. INTRODUCTION OF PRODUCTIVITY LEVEL TABLE OF CARNARIUM FOREST

Carnarium forest trees in the project area are established in different local conditions and circumstances, so the productivity and the production also vary. Therefore, to assess and forecast the production of this species, it needs to divide the productivity level.

Division of the productivity level is understood as classification of the objects into relatively identical units, this work should be carried out in the first step in the yield forecast process.

The table of productivity level will help to:

- Classify and evaluate the productivity of the present forests
- Forecast the productivity and yield of the above-mentioned plant species according to specific conditions.

So, it can be said that the table of the productivity level is a tool for classification of forests in terms of productivity and production.

In fact, plantation forest productivity depends much on ecological and human factors. Each unit of yield classification is the combination of affective factors. However, for simpler, in yield science, the science in people look for indicators reflecting fully the factors which affect on the production and use it as a basis for division of productivity level. In this case, the target of average height of the dominant layer (Hdo) is used as a basis for division of productivity level for Carnarium plantation forest in 3 provinces of Lang Son, Bac Giang and Quang Ninh provinces.

## II. METHOD FOR ESTABLISHMENT OF PRODUCTIVITY LEVEL

### Data collection for establishment of productivity level table on the ground

*Average height of the dominant layer (Hdo) was used as the target for distribution productivity level of Carnarium plantation forest:* Because the Carnarium plantation forests in the provinces have different soil conditions and also have different planting density like with other tree species, while (Hdo) objectively reflects the productivity of forests and not affected by thinning of the lower layer, or density, therefore, it is used for establishment of productivity level in this case. Hdo is calculated in average from the height of about 20% of the highest trees on 0.1 hectares.

*Collect data to establish table the productivity level (Hdo) as follows:*

- Data collected at local level: Including 3 provinces of Lang Son, Bac Giang and Quang Ninh with 10 districts.
- In each site condition and at different age, conduct to measure the height (Hdo) and repeat it at least 3 times. The site condition consists of the factors: soil type, topographical location, climate, slope degree....
- At each point, measure the height of 20% of the highest trees (Ho) over 0.1ha. Determine the highest tree through visual and measure the height of the trees with height measuring equipment with an accuracy of 0.1m
- Also record the targets of forest estate, ecology and human related
- Number of enumerated points = number of site conditions x number of ages x 3 times of repetition. As a result of this, 221 inventory points have been collected and the height of 1105 dominant trees have been measured.
- Collected data are evenly laid on all Carnarium plantation forests at age of 1-10 in different localities and site conditions.

**Table 1: Localities and data collected for establishment of the productivity level table**

Localities	Number of inventoried points (Hdo/A)	Number of trees with measured height Hdo
<b>Lang Son Province</b>	<b>38</b>	<b>190</b>
Cao Loc District	9	45
Loc Binh District	5	25
Dinh Lap District	3	15
Chi Lang District	21	105
<b>Bac Giang Province</b>	<b>169</b>	<b>845</b>
Luc Nam District	17	85
Luc Ngan District	64	320
Son Dong District I	21	105
Son Dong District II	67	335
<b>Quang Ninh Province</b>	<b>14</b>	<b>70</b>
Dong Trieu District	8	40
Tien Yen District	6	30
<b>TOTAL</b>	<b>221</b>	<b>1105</b>

**Data processing and establishment of productivity level table**

Basing on inventory data to calculate the average and create a set of the data including the target of Hdo in average, age by localities and forest estate elements, ecology and human interfere (results in appendix 1).

Using SPSS software to code variables and to explore the factors affecting the productivity and production of Carnarium in local research areas through analysis of each step multi-variable model. Calculate the average height of Hdo for each survey site, create a ser of data of Hdo by age (A).

SN of inventory site	Average Ho (m)	Age (A)
1		
2		
.		
n		

Modelization of the relationship Hdo/A under the form of appropriate growth function. Results from exploring of appropriate model by software SPSS and Statgraphics Plus showed that Schumacher function has coefficient to determine the highest R2 and theories through the center of point cloud Ho/A.

$$\text{Function Schumacher: } Hdo = a.exp(-b.A^{-m})$$

Productivity classification: How to proceed:

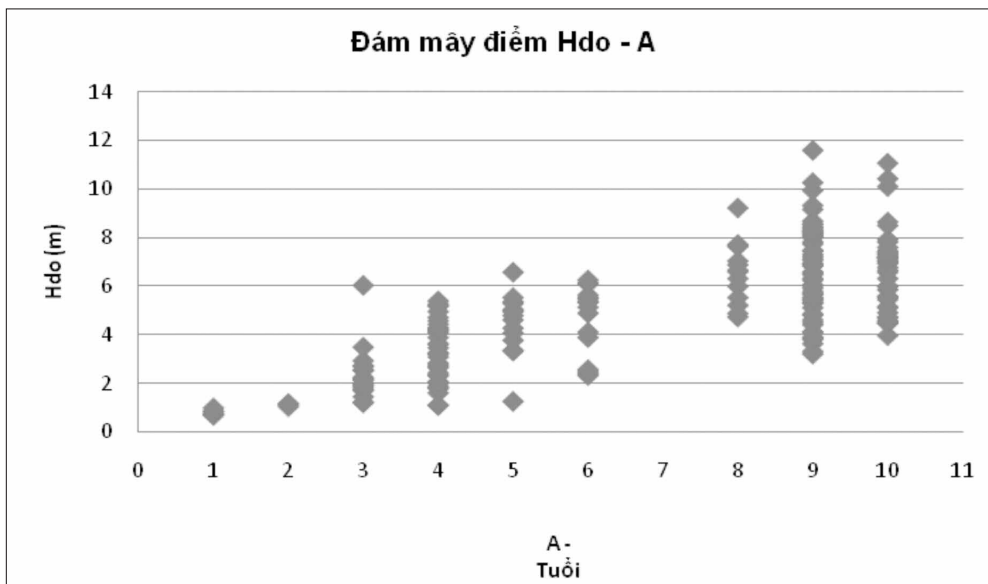
- Select age of basic Ao for considering changes of Hdo: This age is selected as 9 years old with a lot of observations and is the time that different forest stands have a different distribution of the height Hdo (observe on the diagram with cloud points Hdo/A, the cloud turns the fan)

- Determining the productivity levels: Based on changes of Hdo, divided number of levels into 3 levels of productivity. Level I: Well, Level II: Medium and III; Bad.
- Calculate Hdoi for each level of productivity i at age Ao: = At age Ao= 9, divide the range of change of Hdo by 3 levels for distance (Ho) for each level (K):

$$K = \frac{Hdo\ max - Hdo\ min}{3}$$

- Results from inventory showed that at Ao = 9, Hdo changes from 3.2 - 11.6m, in the scope of 8.4m, so the distance between the level K = 2.8m
- Calculuate model Hdoi /A for each productivity level: From model general established Hdo/A, using method Affill to determine the parameters (ai) of the model for each level:

$$ai = Hdoi\ exp\ (b.A^{-m})$$



### III. TABLE OF PRODUCTIVITY LEVEL OF CARNARIUM FOREST

#### 3.1 Relationship between Hdo with ecological factors, human activities - factors affecting productivity, production of Carnarium plantation forest.

Results from the analysis and exploration of the relation Hdo by age A with all ecological, forest factors and human activities, with the method of selected regression, it showed that the production of Carnarium forest in 3 provinces depends much on the land factor and level of tending. These factors cause impact at the level of  $P < 0.05$  according to the model:

$$Hdo = 4.890 + 0.670A - 1.093\ Do\ good\ soil - 0.343\ Tending$$

$$\text{With } N = 221, R = 0.860, Fr = 134.123 \text{ with } P < 0.00$$

So, here it showed that planting of Carnarium forest needs to pay attention to soil index and investment to tending activities.

### 3.2 Table on the productivity level of Carnarium plantation forest

Using norm of Hdo to devide the productivity level. Firstly, model Hdo/A average is established:

$$\ln(\text{Hdo}) = 7.38861 - 7.72465 * A^{-0.15}$$

with N = 221, R = - 0.838, Fr = 516.088 with P < 0.00

$$\text{then: Hdo} = 1617.456 \exp (- 7.72465 A^{-0.15})$$

Divided into 3 levels of productivity, defined indicator Hdoi for each level of productivity and limited at survey age A0 = 9. With changes Hdo in each level is K = 2.8m

**Table 2: Height Hdo indicates for 3 levels of productivity and limitation**

Prodcutivity level	Ao (age)	Hdoi (m)
<b>Level I (Good)</b>	<b>9</b>	<b>10.2</b>
Limit	9	8.8
<b>Level II (Medium)</b>	<b>9</b>	<b>7.4</b>
Limit	9	6.0
<b>level III (Bad)</b>	<b>9</b>	<b>4.6</b>

On the basis of Hdoi at age Ao = 9, determine the model Hdo / A for each yield level by the method Affill:

$$\text{Hdoi} = \text{ai} \exp (- 7.72465 A^{-0.15})$$

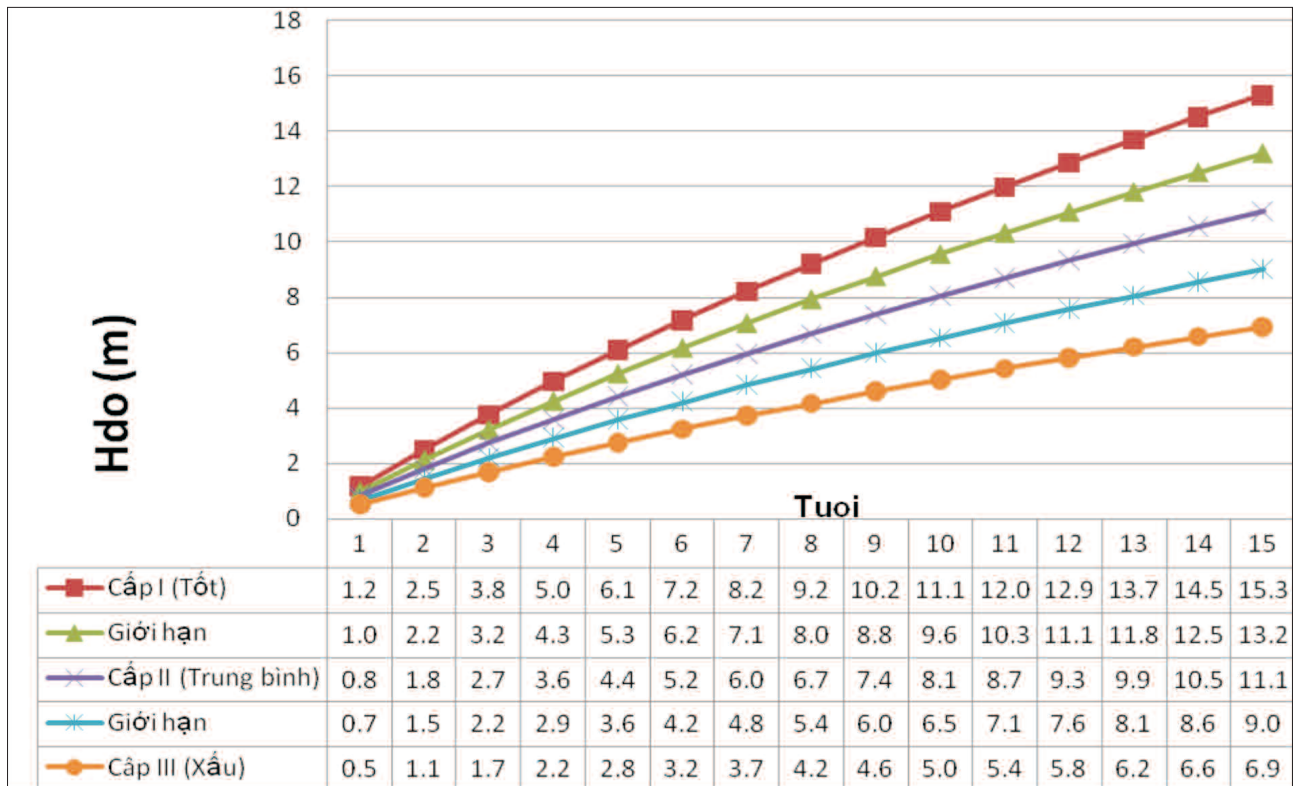
With one parameter (ai) at each level of productivity and limit of level as follows:

**Table 3: Parameter ai by the productivity and limitation levels**

Productivity level	Parameter ai by productivity level
<b>Level I (Good)</b>	<b>2631.758</b>
Limit	2270.987
<b>Level II (Medium)</b>	<b>1910.216</b>
Limit	1549.445
<b>Level III (Bad)</b>	<b>1188.674</b>

Basing on the model Schumacher for each productivity level and limit, establish a table of productivity level for Carnarium forest.





Graph on the relation between Hdo/A and 3 productivity levels and level limit

Table 4: Table on productivity level of Carnarium plantation forest

Age	Productivity level (Value is the mean height of the dominant forest layer Hdo (m))				
	Level I (Good)	Limit	Level II (Medium)	Limit	Level III (Bad)
1	1.2	1.0	0.8	0.7	0.5
2	2.5	2.2	1.8	1.5	1.1
3	3.8	3.2	2.7	2.2	1.7
4	5.0	4.3	3.6	2.9	2.2
5	6.1	5.3	4.4	3.6	2.8
6	7.2	6.2	5.2	4.2	3.2
7	8.2	7.1	6.0	4.8	3.7
8	9.2	8.0	6.7	5.4	4.2
9	10.2	8.8	7.4	6.0	4.6
10	11.1	9.6	8.1	6.5	5.0
11	12.0	10.3	8.7	7.1	5.4
12	12.9	11.1	9.3	7.6	5.8
13	13.7	11.8	9.9	8.1	6.2
14	14.5	12.5	10.5	8.6	6.6
15	15.3	13.2	11.1	9.0	6.9

## IV. PRODUCTIVITY CLASS TABLE

Materials and tools for use of Yield Table

For use of Productivity Class Table, It needs to prepare:

- Height measurement tape: Height measurement device Sunnto or Blumbleiss, if trees are at small age, 1.0 m poles can be used.
- Diameter Measurement Tape: If a perimeter measurement tape is used to find out the diameter or diameter clamp is used, then, history of plantation forest, ages, planting density, thinning process, tending,.. should be taken into account.

### 4.1 Use of productivity level

To use the productivity level, it should conduct:

- Productivity levels are determined through the average height of the dominant layer (Hdo), so in each forest plot, the height of the dominant trees needs to be measured. About 20% of the highest trees in 0.1 hectares (Hdo) needs to be measured.
- To calculate the dominant average height Hdo and referring to the age of the forest stand, look up the table of productivity level (Table 4) to determine the level of productivity. In case, the forest has not yet been established but the production needs to be estimated, then, the productivity level can be determined through the plantation forests in the area with similar site conditions.

Table of Productivity level is established into 3 levels:

- Level I: Good
- Level II; Average
- Level III: Bad

In the Table, the upper limit line of Level I and lower limit of level III, which means that if average Hdo at one age lying on the upper limit line of Level II, then it will belong to Level I and if lying below the lower limit of level II it will belong to Level III and clearly that if Hdo lying between the lower limit and upper limit of level II then it will belong to level II.

For example, a forest plot aged  $A = 8$ , value of mean Hdo measured in average is 8.5m, then, such forest plot belongs to level I, the level that provides the best production..

So to define the productivity level, just only measure a number of the highest trees in a plantation forest plot, however, if height measuring devices are used, then, they will guide the people how to use it properly.

## PART II: YIELD TABLE OF CARNARIUM PLANTATION FOREST.

### I. INTRODUCTION OF CARNARIUM YIELD TABLE

Yield Table consists of indicators of growth, mean increment of the forest trees and forest stands. Therefore, in the process of table establishment, the relationship between mean growth rate by age at different productivity level has been studied. The Table of Carnarium species consists of:

- The Table is established by productivity level. Therefore, before using the Table, the productivity level of plantation forest should be defined.
- On each productivity level, there will be a corresponding yield table

Table is used to determine the productivity and yield at present time and also to predict it for a certain time in the future. The yield indicators include growth indicators of the average trees, productivity values, and the production of products with at least diameter of 6 cm.

In addition, it also provides an optimal density at different time and over the productivity level so as to recommend proper time for plantation and tending, at the same time to forecast time suitable for management of plantation forests such as time for tending, exploitation at mature age.

In addition, the relationship of mean increment and forest estate is modeled therefore, a simple program should be applied for technical staff and managers who can forecast and monitor plantation forest areas with the help of the computer.

### II. METHOD FOR ESTABLISHMENT OF CARNARIUM YIELD TABLE.

#### 2.1 Establish growth and yield table for average trees in the forest stand

Growth, productivity, products from a forest stand are a combination of growth, production, products of all trees in the forest. For even-aged plantation forest stand, the curves of distribution of trees by diameter, height and volume are asymptotic to the distribution of the stands, therefore, growth values, products of the average trees in the forest stand such as diameter (Dbq), average height (Hbq), average volume (Vbq), volume of the small-end products with diameter of 6 cm (VSP) can be used to find out the forest stand.

Established Model of growth, products of average trees in the forest stand (Dbq, Hbq, Vbq, VSP) is related to age (A) and the factors affecting on the growth and productivity level and indicated through the mean height of the dominant layer (Hdo).

Establishment of the growth model and products of average trees in the forest stand is an important part in establishment of yield table.

#### 2.2 Collect data for establishment of the growth model and products of average trees in the forest stand

Data collection should follow to the following order:

- i. Determine number of places with average trees to be inventoried in the forest stand: Inventory of average trees in the forest stand should be conducted on the divided productivity levels and by ages throughout the business cycle and will be repeated. Total inventory sites in 3 provinces are 73 sites.
- ii. Determine the productivity level of the inventoried forest stand: Use of Table on Productivity levels:

- Measure 20% of the highest trees on 0.1 hectares and then, calculate average Hdo
- Look up at Table Hdo corresponding to A, determine the level of the productivity of the forest stand.

iii. Determine average trees in the forest stand: Measure systematically by rows about 20% of number of the trees over 0.1 hectares (No of trees). Each tree, diameter at  $D_{1,3}$  should be measured. Average diameter of the forest stand (DG) is the diameter corresponding to the trees having mean cross sections (gbq):

$$gbq = \frac{\sum gi}{n} = \frac{\pi/4 \sum Di^2}{n}$$

$$Dg = 2 \sqrt{\frac{gbq}{\pi}} = \sqrt{\frac{\sum Di^2}{n}}$$

iv Analytic of average trees of the forest stand: At each point, 5 trees should be analyzed, total analytic trees is 365 trees. Fell and collect data of analytic trees including measuring of the radius of the canopy by 4 directions Rt). Indicators to be collected including:  $D_{1,3}$ , L (length); 4 diameters Doi (tree trunk is divided into 5 equally parts), measure diameter from the stump (Doo), at 1/5 L is  $D_{o1}$ , at 2/5 L is  $D_{o2}$  until to 4/5 L is  $D_{o4}$ , the indicators of Doi is used to calculate exactly the volume of average trees (Vbq); Define the location of the diameter of small end of the product as 6cm (Dn), measuring the length of the tree from the cut stump to Dn having Ln, this is a basis to calculate the volume of the product of the average tree (VSP).

**Table 5: Table for collection of data in the sample plot and analytic of average trees in the forest stand.**

Location	No of sample plots	No of analytic trees
<b>Lang Son province</b>	<b>20</b>	<b>100</b>
Cao Loc Ditric	2	10
Loc Binh District	1	5
Dinh Lap District	6	30
Chi Lang District	11	55
<b>Bac Giang province</b>	<b>53</b>	<b>265</b>
Luc Nam District	10	50
Luc Ngan District	17	85
Son Dong I District	16	80
Son Dong II District	10	50
<b>Quang Ninh province</b>		
Dong Trieu District		
Tien Yen District		
<b>TOTAL</b>	<b>73</b>	<b>365</b>

### 2.3 Data processing and establishment of growth model, products of average trees in the forest stand

From the analytic data of average trees an each point, consolidate to calculate the average values for each point. From that establishment of growth model, the product of average trees.

Steps to conduct:

- i) Calculate the average indicators and fill in the following Table:

**Table 6: Synthetic Table of the indicators of average trees in the forest stand.**

Average indicators	Point 1	Point 2	.	.	.	Point 73
Dg (cm)						
Hg (m)						
Hdo (m)						
St bq (m <sup>2</sup> )						
Vbq (m <sup>3</sup> )						
Vsp (m <sup>3</sup> )						
A (year)						
N (tree/ha)						
Productivity Level						

How to calculate the indicators in the above-mentioned Table:

- Dg, Hg: average of the analytic trees of each point
- Hdo: Value of dominant average height at each point determined through 20% of the highest trees.
- Stbq: Average canopy Area of analytic trees at each point, the area of the canopy of each tree is calculated by canopy radius measured from 4 directions (Rti)
- Vbq: is the average volume of the average trees in the forest stand at each point. The volume of each average tree is calculated by the formula by dividing the tree into 5 equal segments, each section has a length as L/5:

$$Vbq = \frac{\pi L \cdot 10^{-4}}{80} \{ (D00 + D01)^2 + (D01 + D02)^2 + (D02 + D03)^2 + (D03 + D04)^2 + (D04 + 0)^2 \}$$

VSP is the volume of average product of the analytic trees at each point, with a given small-end diameter, way of calculation is to gather the volume of all segments towards the small-end diameter of 6 cm.

- A, N, the productivity level: Are indicators of age, density, productivity level at inventory point.

ii) Building growth models, products of average trees of the forest stand:

The criteria of growth depends on 3 main factors i.e age of the forest stand(A), productivity level indicated through Hdo and present density (NHT).

However in the Canarium planted areas with clear density blank, so there is no relationship between growth indicators with the density, growth of average trees here is independent with the current density.

Regression Models are traced, found and estimated in the software of Statgraphics Centurion XV according to multiple linear regression model.

- ✓  $\text{Log}(Vbq) = -1.97024 - 8.80581 \cdot \text{sqrt}(CNS) \cdot A^{-0.7}$   $R^2 = 0.623$
- ✓  $\text{Log}(Stbq) = -2.60694 + 0.64793 \cdot \text{log}(A) + 1.36078 \cdot \text{log}(Hg)$   $R^2 = 0.552$
- ✓  $Hg = 1.8478 + 0.246448 \cdot \text{log}(A) \cdot Hdo$   $R^2 = 0.733$
- ✓  $\text{Log}(Dg) = -0.483092 + 1.29409 \cdot \text{log}(Hg)$   $R^2 = 0.887$
- ✓  $\text{Log}(Vbq) = -9.01565 + 1.78448 \cdot \text{log}(Dg) + 0.742927 \cdot \text{log}(Hg)$   $R^2 = 0.992$
- ✓  $Vsp = -0.00578811 + 1.04584 \cdot Vbq$   $R^2 = 0.984$

Where log is logarithm base e

The model is set up to estimate the average growth value of forest stand by age, the productivity level and identify mature age and optimal density

### III. THE CARNARIUM YIELD TABLE

#### 3.1 Process of the growth of the volume of average trees in the forests and mature age of Carnarium

Model of the relationship between the average volume of the forest stand by age and the productivity level is established as follows:

General model:  $\log(Vbq) = a - b \cdot \sqrt{\text{CNS}} \cdot A^{-m}$ , resulted in:

$$\log(Vbq) = -1.97024 - 8.80581 \cdot \sqrt{\text{CNS}} \cdot A^{-0.7} \quad R^2 = 0.623$$

Replace productivity levels (CNS) of 1, 2, 3 then it will give a growth model of Vbq for each level, from here, two important periods can be estimated according to the growth function of Schumacher:

- Age reaching at the maximum capacity:  $A1 = (bm/(1+m))(1/m)$  is the period that forest trees grow fastest. the annually increment rate reaches at maximum. Thinning should be applied at this time in order to raise the production and shorten the business cycle.
- Quantity mature Age =  $A2 = (bm)(1/m)$  is the time that forest trees have the highest average growth rate. At this time, logging is required to get the highest yield per unit area.

**Table 7: Age reaching the maximum productivity and mature in quantity of Carnarium in 3 productivity levels**

Productivity level	Age reaching the maximum productivity	Mature Age in quantity
1	6	13
2	10	22
3	14	29

Based on the determined level of productivity of forest plots, forecast the time needed for tending and the time for main exploitation of Carnarium.

#### 3.2 Model of optimal density of Carnarium

Based on the established relationship between the area of average tree canopy (Stbq) with age (A) and average height (Hg), in which Hg has a close relationship with the criteria indicating productivity level Hdo; then, optimal density (Nopt) of Carnarium can be forecasted in case of pure plantation.

$$\log(\text{Stbq}) = -2.60694 + 0.64793 \cdot \log(A) + 1.36078 \cdot \log(\text{Hg}) \quad R^2 = 0.552$$

with Hg determined through Hdo in the Model:

$$\text{Hg} = 1.8478 + 0.246448 \cdot \log(A) \cdot \text{Hdo} \quad R^2 = 0.733$$

$$\text{Nopt} = 8000 / (\exp(-2.60694 + 0.64793 \cdot \log(A) + 1.36078 \cdot \log(\text{Hg})))$$

Through the productivity level Table to determine A, Hdo, then determine corresponding Hg and using the Model to determine Nopt following A and the productivity level.

**Table 8: Optimal density of Carnarium by age in 3 productivity levels**

A (year)	Nopt/ha by productivity level		
	I	II	III
8	2176	2933	4303
9	1729	2363	3549
10	1405	1943	2977
11	1165	1626	2533
12	981	1381	2182
13	838	1187	1900
14	724	1032	1669
15	632	906	1479

To define the optimal density, it needs to determine the productivity level and age of the forest plots. Such above model is established under the condition of pure plantation, presently, the forest plots in the Table established site are mixed and clearly planted, therefore, not reaching the optimal density. Therefore, this Model is only used to establish new forests or to support to thinning operation of the forest stands in the future.

### 3.3 Carnarium Yield Table by the productivity level

Use of the results from modelization of the growth process, products from the average trees of the forest stand by the productivity level to establish the yield table. The table is established for each productivity level.

Values of the average trees by age and productivity level are determined basing on the models:

- ✓ Mean height:  $H_g = 1.8478 + 0.246448 \cdot \log(A) \cdot H_{do}$ , correlative to A and  $H_{do}$  of the productivity level table, determine  $H_g$  by age and productivity level.
- ✓ Mean diameter:  $\log(D_g) = -0.483092 + 1.29409 \cdot \log(H_g)$ , correlative to  $H_g$  by age and productivity level, inferably corrective  $D_g$ .
- ✓ Average volume of the forest stand:  $\log(V_{bq}) = -9.01565 + 1.78448 \cdot \log(D_g) + 0.742927 \cdot \log(H_g)$ , coorelative to  $D_g$ ,  $H_g$  by age and productivity level, define coorelative  $V_{bq}$
- ✓ Volume of the products of average trees  $V_{sp} = -0.00578811 + 1.04584 \cdot V_{bq}$ , coorelative to age, productivity level, it can calculate coorelative  $V_{sp}$ .

The above-mentioned mean increment indicators are independent with the density as all the density of all forest stands is very clear, therefore, there is no relationship or linkage to forest tree growing. Density variation (N) by age and productivity level: The density is ranged between 300 – 1.500 trees/ha, each level is 200 trees away from each other.

Values of increment, products from forest stands and growth are calculated as follows:

- ✓ Volume of the forest stand/ha:
- ✓ Volume of the products with small-end size of 6cm:
- ✓ Annual increment volume:  $ZM = MA - MA-1$
- ✓ Mean increment volume:  $\Delta M = M/A$
- ✓ Growth rate:  $PM\% = ZM / M$

## **IV. USE OF CARNARIUM YIELD TABLE**

### **4.1. Cases using the Yield Table**

For forest growers, Yield Table should be used in the following cases:

- Need to forecast economic efficiency through the production before deciding forest establishment.
- Need to evaluate the productivity of present forest plots that does not take in too much effort to survey comprehensively.
- Need to forecast production at the end of business cycle to forecast economic efficiency
- Determining the optimal density and thinning in each period.
- Define the time when thinning operation should start to to improve production
- Define the business cycle, age for effective exploitation for each productivity level

These are important values for forest owners to make a correct decision in selecting investments for forest establishment and application of silvicultural measures

### **4.2. Materials and tools are used for yield table:**

For use of the yield table, it needs to prepare:

- Height measuring device as Sunnto or Blumbleiss, if trees are still young. Poles with 0.1m intervals can be used
- Diameter measuring tapes: Perimeter measuring tapes or claspers should be used.
- Plantation forest history to know age, planting density, thinning process, tending...
- Computers, in case of using production forecasting programme on the computer

So it is found that using the Table, only simple tools are required, cheap and can be used by farmers. Technical staff can use ready-made program installed to predict the productivity and production on the computer.

### **4.3. How to use the Yield Table**

To use the Yield Table, the following steps should be conducted:

#### ***i) Define the criteria of the current forest stand:***

- Determining the age of the forest stand: Based on, plantation forest history
- Define the level of productivity of the forest stand that needs predict the production.:
  - The efficiency level is determined through the average height of the dominant layer, so the height of the dominant trees should be measured. Number of trees to be measured is about 20% of the highest trees on 0.1 hectares (Hdo)
  - Calculate the average height of the dominant trees Hdo and linking to the age of the forest stand, looking up at the productivity level Table, and then it will determine the level of productivity. In case of no forest is established, but it needs to know production needs to want the output, you can determine the efficiency levels through the forests in areas with established local conditions.



So defining the productivity level, just measure some highest trees in the plantation plots, but if height measuring devices are used then it should guide the people how to use it.

- Determining the density of the forest stand (N / ha): a lot of a size of 400m<sup>2</sup> (20x20m) can be established or 6-trees method is applied or by counting number of trees by rows and converting to ha.

**ii. Look up the Yield Table, optimal density and yield**

Based on the information of the forest plot, using different tables to define mature age, optimal density and yield

- *Use of the table to define mature age:* Based on the productivity level, determine the time needed for thinning (age reaching at the maximum productivity) and age for main exploitation (Mature age in quantity) for forest plots.
- *Use optimal density Table:* Use the density optimization: Based on the productivity level, age of the forest stand, define  $N_{opt}$  as a basis for thinning operation..
- *Use of Yield Table by productivity level:* Including the steps:
  - Select the productivity-level Table
  - Based on the current age or age to forecast and corresponding it can forecast the target for average growth of the forest stand, increment and growth of the forest stand and wood products with small size of small stop of 6cm

In case of the density not matching with the value in the Table (200 trees away from each other), it may be calculated simply as follows: Determine the values of the average growth  $D_g$ ,  $H_g$ ,  $V_{bq}$ ,  $V_{sp}$ ; then calculate the values for the forest stand:  $M = V_{bq} \times N$ ;  $M_{sp} = V_{sp} \times N$  with a simple hand pocket calculator.

#### **4.4. How to use simple programs to forecast production of White Carnarium plantation forest**

From the relationships between the average grow models of the forest stand, canopy growth, density, linking these functions in Excel program to easily determine the present production and forecast potential production on the calculator. This tool is set up for technical staff in the management process and supporting to farmers.

Click here to open [White Carnarium Planation Yield Forecast Program](#)

The Program is established in a simple form including 3 Sheets in Excel:

- Sheet 1: Enter information input
- Sheet 2: Models
- Sheet 3: Information of forest production

Users simply enter input data in **Sheet 1 "Enter input data"**, then the program automatically calculates and turns out the results of production at present as well as at the time of forecasting in **Sheet 3 "information on forest production"** Information in Sheet 2: "Models" are the parameters of the entered growth models, no need to change. Sheet 2 and 3 are locked to prevent from any change, the users just only enter data in sheet 1, results of forecasts should be printed in sheet 3.

### Sheet 1: Enter inputs in this Sheet

#### Sheet 1: Enter inputs in this Sheet

Input information	Enter input data
Species	Carnarium
N/ha (Present density (tree/ha))	900
A (Present age (Year))	11
Ho (m) (Dominant layer height of 20% highest trees in the forest stand.)	14.0
A + n (Time desired forecasting production at certain age) (year)	15
Ndb/ha (Density at the time of forecasting (tree/ha) (after thinning))	900

### Sheet 2: Models

(Not change in this Sheet)

#### Sheet 1: Enter inputs in this Sheet

#### Devision of productivity level

General model:  $H_{oi} = a_i \cdot \exp(-b \cdot A^{-m})$

Productivity level	$a_i$	$b$	$m$
I	2631.758	7.72465	0.15
Limit	2270.987		
II	1910.216		
Limit	1549.445		
III	1188.674		

#### General mean volume growth

**General model**

$$\log(Vbq) = -1.97024 - 8.80581*\sqrt{CNS}*A^{-0.7}$$

Parameter	a	b	m
Value	-1.970	8.806	0.7

**Mean growth in the forest stand**

Models	Paramete		
	a	b1	b2
$Hg = 1.8478 + 0.246448*\log(A)*Hdo$	1.84780	0.24645	
$\log(Dg) = -0.483092 + 1.29409*\log(Hg)$	-0.48309	1.29409	
$\log(Vbq) = -9.01565 + 1.78448*\log(Dg) + 0.742927*\log(Hg)$	-9.01565	1.78448	0.74293
$Vsp = -0.00578811 + 1.04584*Vbq$	-0.00579	1.04584	

Log: logarit neper

**Optimal density**

General model:

$$Nopt/ha = 8000 / \text{Exp}(-2.60694 + 0.64793*\log(A) + 1.36078*\log(Hg))$$

Parameter	a	b1	b2
Value	-2.60694	0.64793	1.36078

**Sheet 2: Models**  
(Not change in this Sheet)

**Sheet 1: Enter inputs in this Sheet**

<b>Present</b>	
Type of information	Present forest yield
Characterisitics of the present forest stand	
Species	<b>Carnarium</b>
Age of stand (year)	<b>11</b>
N/ha (tree/ha)	<b>900</b>
Ho (Dominant layer mean height, m)	<b>14.0</b>
Productivity level	<b>1</b>
Important time	
Age reaching maximum productivity (thining)	<b>6</b>
Age matured in quantity (main harvest)	<b>13</b>
Mean growth in present forest stand	
Dg (cm)	<b>12.3</b>
Hg (m)	<b>10.1</b>
Vbq (m <sup>3</sup> )	<b>0.060</b>
Vsp (m <sup>3</sup> )	<b>0.057</b>
Density	
Optimal density (Nopt tree/ha)	<b>983</b>
Need thinning or not	<b>No</b>
N (thined trees/ha)	<b>0</b>
Production in present forest stand	
M (m <sup>3</sup> /ha)	<b>54</b>

<b>Forecast</b>	
Type of information	Present forest yield
Characterisitics of the present forest stand	
Species	<b>Carnarium</b>
Age of stand (year)	<b>15</b>
N/ha (tree/ha)	<b>900</b>
Ho (Dominant layer mean height, m)	<b>15.3</b>
Productivity level	<b>1</b>
Important time	
Age reaching maximum productivity (thining)	<b>6</b>
Age matured in quantity (main harvest)	<b>13</b>
Mean growth in present forest stand	
Dg (cm)	<b>15.5</b>
Hg (m)	<b>12.1</b>
Vbq (m <sup>3</sup> )	<b>0.103</b>
Vsp (m <sup>3</sup> )	<b>0.102</b>
Density	
Optimal density (Nopt tree/ha)	<b>632</b>
Need thinning or not	<b>Yes</b>
N (thined trees/ha)	<b>268</b>
Production in present forest stand	
M (m <sup>3</sup> /ha)	<b>93</b>

Msp (m <sup>3</sup> /ha)	<b>0.103</b>
Δm (m <sup>3</sup> /ha/year)	<b>0.102</b>
<b>Production of forest stand after thinning</b>	
M thinning (m <sup>3</sup> /ha)	<b>632</b>
Msp thinning (m <sup>3</sup> /ha)	<b>Yes</b>
M after thinning (m <sup>3</sup> /ha)	<b>93</b>
Msp after thinning (m <sup>3</sup> /ha)	
Δm (m <sup>3</sup> /ha/year)	

Msp (m <sup>3</sup> /ha)	<b>92</b>
Δm (m <sup>3</sup> /ha/year)	<b>6.2</b>
<b>Production of forest stand after thinning</b>	
M thinning (m <sup>3</sup> /ha)	<b>28</b>
Msp thinning (m <sup>3</sup> /ha)	<b>27</b>
M after thinning (m <sup>3</sup> /ha)	<b>65</b>
Msp after thinning (m <sup>3</sup> /ha)	<b>64</b>
Δm (m <sup>3</sup> /ha/year)	<b>4.3</b>

## REFERENCES

- 1) Vu Tien Hinh (2005), *Forest Yield*, Agriculture Publishing House, Ha Noi.
- 2) Bao Huy (2002), *Scientific research for Teak business and production (Tectona grandis Linn)*, Ministry of Education and Training.

**Annex 4: Results of the Regression Model on relationship between average factors of the forest stand - Treated in Statgraphics Centurion XV**