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Effects of Stratification on Reducing the Number of Sample Plots and Increasing Inventory Accuracy in Mixed uneven-aged Forest Stands

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ABSTRACT: After sampling in an area of 1300 hectare, variables were classified based on their correlation. The use of basal area brings greater precision in plannings rather than stand volume. The number of sample plots in the sampling without stratification is much more than needed. If qualitative stratification of the stands is carried out before inventory, the accuracy of data increases while the number of sample plots is reduced. The exclusive use of a stratification variable and using the information obtained from it for judgment and planning of other variables cause to deviation of the results. For identification and analysis of stands structure, the use set of number of trees per hectare, De'liocort coefficient, percentage of the total number of industrial tree species, the shape of distribution curve in diameter classes, statistical comparison for the distribution of the number of trees in diameter classes between the present and optimal conditions lead to more accurate results.

Keywords: Stand volume, structure, basal area, stratification, Hyrcanian forests, high forest.

INTRODUCTION

Sampling, as can be deduced from its name, is reliable only within a defined confidence range. In addition, forestry planning is dependent on the information obtained from the field survey and description of stand and habitat. On the other hand, natural overt and covert relations among the elements in forest ecosystems as well as their extent, diversity and changes in time and space cause that the experts' eyes and memory and others involved in producing data do not have the capacity to maintain their integrity. Therefore, describing the stand and habitat do not make the planners needless of inventory.

The possibility of quantitative processing, grouping results, and reconstruction of quantitative data in mathematical and graphics environments, are among the sampling capabilities.

Thus, if sampling is designed and implemented with the precise methods having the ability to retrieve locations (on the ground, maps and computers), it will have a valuable role in increasing the accuracy and improving the use of information obtained from description. Classification (stratification) is among the ways to facilitate and improve the use of information collected in sampling and description with a large volume. Thus, while reducing the amount of costly and cumbersome operations, the accuracy and diversity of available information is increased.

Forest structure is one of the important criteria for evaluation, comparison and judgment about the forest stands condition and their classification. Study of the forest structure is the expression of two properties:

- Identifying or introducing the components of an overall set,

-The correlation, type and relationship among the components,

Therefore, the structure is studied when the frequency of quantities including basal area, stand volume, number of trees, height of the trees, cover and stratum are investigated in terms of diameter and age classes along with the type and contribution of each factor in the two-way or multiple relationship of the components (Daniel,1979; Nyland,1996).

In the present study, among the parameters mentioned above, the frequency of tree in diameter classes was investigated.

By performing this research project, the hypothesis of positive effects of grouping data based on variable on increasing statistical accuracy, improved data processing, and increased use of information to introduce forest stands were investigated.

Also, after reviewing proper classification indicators and relationships within and among the types based on the structure of uneven-aged forest stands, the applied directory of typology was proposed.

Accordingly, the main objectives of the study include:

-Examining the statistical relationship among variables and data obtained from sampling

-Determining the quantitative and qualitative variables obtained from sampling to be used for separating the types.

-Comparison of two sampling methods: without and with classification in terms of the accuracy and efficiency to present the features of forest stands.

-Determining the number of sample plots to estimate the quantitative parameters and describe silvicultural indicators.

-Providing a suitable method for applying the indicators presented in the studies related with uneven-aged forest stand structure; in other words, providing a preliminary list and practical guideline of structure typology in the mixed uneven-aged forest stands under the same conditions of the area of study in this research project.

In order to planning a number of forest management plans or projects (FMPs) in the Hyrcanian forests during two decades (1955-1975), general classifications have been already used based on knowledge, experience and existing facilities; however, the purpose of most of them was to separate the lands based on land use on a large scale and separation of large management units.

In 1958, the first comprehensive inventory of the forests of northern Iran was conducted within four years using aerial photos scale 1: 5,000 and 1: 10,000 and 1: 55,000 (Vafaiinejad, 1995). In this project, the southern lands of the Caspian Sea were divided into forest and non-forest types.

In 1973, the revision plan of the mentioned project was conducted using the Probability Proportional to Prediction method (Rasaneh, 2001). During 1968-1973, the Romanian experts, after initial studies in the Neka Zalem Rood FMPs, divided the forest area into three types including production, reclamation and protection forests (Anonymous. 1984). The implementation of this type of classification is very effective where the FMPs has been successful. In the mentioned plan, the data obtained from statistics and habitat sites description and analysis were mainly based on phytosociology and the frequency of trees along with other basic studies for detailed description of habitat. In this FMP, the data were converted to the map of extensive areas to have the ability of spatial analysis.

In 1974, the Stedler Herter Company did an inventory of the Gilan forests (North West of Iran) using a total of ten blocks. Each block included one or more watersheds, divided into several compartments (about 2,000 ha) and sub-compartments (400-600 ha) (Vafaiinejad, 1995). The inventory was performed based on four indicators as follows:

Separation of forest and non-forest lands, the condition of forest stand degradation, the condition of crown and height of trees, forest canopy (density).

During 1974-1976, inventory was performed on networks with dimensions of 100*200, 200*200, and 150*200 m, based upon natural conditions and the type of strata with variable plot sizes.

After 1978, further inventory was carried out on a network with dimensions of 175 × 200 m, and sampling plots with an area 700 m^2 with systematic random sampling.

In 1985, the comprehensive plan for northern forests of Iran with the aim of revising FMPs was placed on the agenda of the FRWO with following headlines:

Identifying watersheds in terms of FMPs, biological resources (forest and rangeland), socioeconomic and hydrometeorological characteristics, soil, geological and forest road construction. After initial studies and estimating the number of samples in each watershed and implementation of inventory, forests were divided into four categories in terms of standing volume per hectare as follows:

Less than 100 m3, between 101-200 m3, between 201-350 m^3, more than 350 m3 per hectare.

In the study project mentioned, after dividing the northern forests to 103 watersheds, the sampling plots were established on strips with a distance of five km in the direction of contour lines and each 250 m (a total of 144 north-south strips). The distribution of sampling plots was systematic random. The results of this project were published in 1989 (Anonymous. 1989). Since the aim of sampling in this project was not to separate the forest stands, therefore, the data was only applied in large-scale and general knowledge of the forest, and in terms of time, they were reliable up to 10 years after operation.

Amani and Hassani (1997) studied the typology of beech mother in evenaged and unevenaged stands and provided a detailed instruction. The results of case studies on forest stand structure are presented in some research projects (Amini, 2007, Eslami, 1997).

MATERIALS AND METHODS

A. Natural and geographical characteristics

The study area is located in the forests of northern Iran, south of Sari, section 5 of the Neka Zalem Rood FMP with an area of about 1,300 hectares and an altitude of 100-340 m a.s.l. (Fig. 1).

Fig. 1. Location map of the study in South of Sari city.

Maximum, minimum and average slope are 80%, 5%, and 30-35%, respectively. The general aspect of the study area is northern, so that 43% of the land is located in northern slopes, 10 percent in the Northeast, 17 percent in the Northwest, 19 percent in the West, and 3% in intermediate slopes. The soil type is brown forest soil.

The forest type is mixed broadleaf, unevenaged high forest. The dominant tree types are beech-hornbeam and hornbeam-beech. Beech and hornbeam form over 28% and 27% of the number of trees. The frequency of basal area for beech and hornbeam is reported to be 34% and 29%, and totally 85% for industrial species (Amini, 2001, Anonymous 1984).

The meteorological data are provided based on the data from the nearest synoptic station at an altitude of 300 meters above sea level with a 27-year period. The average annual rainfall is 1500 mm; the average temperature in the coldest months of the year i.e December, January, February and March is 7.6 °C with an average monthly rainfall of 124 mm in the mentioned months; the average temperature in the hottest months of the year ie June, July, August and September is 22.6°C with an average monthly rainfall of 95 mm in those months.

The most important reason for choosing this area for this research includes: a) No silvicultural operations, regeneration, and planned exploitation have been implemented until inventory. b) This forest includes most of the different conditions in the mid-elevation forests of Mazandaran and could be an example for the implementation of pilot typology project.

Methods

The fundamental parts of this research include:

-Systematic random sampling at 150*200 m sampling net system in plots at 10 R area.

-Correlation among different variables and calculating the number of sample plots required to estimate basal area, stand volume, and number of trees with sufficient statistical accuracy.

-Data classification with different indicators and the proposed inventory model in the classified forest.

The methods used for each of these cases are as follows:

Initial identification. After initial identification of the study area, field visits were performed to assess the compliance of research operations with natural characteristics of the mentioned area. Then, this area was determined on topographic map, scale 1:25000, and an inventory net (grid) was designed at 200*150 m according to the map scale. The rectangle length of the net (grid) was in an east-west direction. Then, the inventory net and sample plots at 10 R (1,000 m²) area were established on the vertices of the net (grid) in a circular shape with a radius of 17.84 m. In each sample plot, the data of all trees with a diameter at breast height more than 7.5 cm, habitat site characteristics, and control trees were recorded. In each sample plot, the closest tree to the plot center and the thickest tree within the plot were recorded as control trees for the stand height curve and equation. The data were entered in the SPSS software, and processing and calculation were conducted for each sample plot, total sample plot inscribed in a compartment and for the whole forest.

B. Data preparation and processing

Diameter classes. After the data of diameter at breast height for each tree were entered into the computer, the diameter classes were formed and called the median of each class (10, 15, 20 ...). Then, the frequency in each diameter class was obtained by counting. In those studies where more than one sample plot was required, the mean frequency in sample plot was recorded for each diameter class as the number in diameter class at different levels (compartments, type, forests).

Grouping of tree species. In the FMPs, developed for the forests of northern Iran, trees are grouped (classified) into two general categories (classes): fuel wood species (Iron wood, Persimon, Caucasian walnut) and other industrial species and the next plans and steps are designed and tracked similarly. Therefore, where group comparisons were necessary, trees were classified into fuel wood species and industrial groups depending on the type of species, and date were analyzed separately. Moreover, in more detailed studies, industrial species such as beech, hornbeam and other industrial species were investigated separately.

Calculation of basal area. To calculate the basal area, the cross section of each tree was calculated by the geometric relationship of (?*d2/4), where d is the value of diameter at breast height. Then, the total cross section of trees in each sample plot (plot) was the basis for subsequent calculations. With regard to the area of each plot (1000m2), by applying the coefficients of area on the mean and total basal area of the sample plots located in a compartment or a type, and also the sample plots whose basal area is extracted, the basal area per hectare was calculated.

Calculation of tree volume and standing volume. For volume calculations, the common method in the forestry projects in northern Iran was used.

The volume of beech and other species was obtained from the beech volume table (Anonymous, 1985) and Volume tables with Formclass (Anonymous, 1970), respectively. Since in the revision plan (project) of the study area, new tariffs were prepared for different species and the results of this research project should be compared and linked with the results of FMPs, therefore, in the present study, volume calculations were performed with reference to the above mentioned tariffs (Anonymous, 1984).

Data classification and comparison. All data obtained from inventory operations as well as the data obtained from the processing of primary data could be classified into two groups as follows:

-Non-quantitative or non-ordinal data (Non-Parametric) including aspects and the tree dominant type.

- Quantitative or ordinal data (parametric) includes all variables whose data are inherently ordinal, having the capability of any classification based on their values.

After preliminary statistical calculations (including maximum, minimum, mean, variance and cv %), it was observed that some data had very high and abnormal cv% due to the lack of replication and huge difference among the quantities recorded. Therefore, the use of these variables in the forest quantitative classifications, even if having a silvicultural value, is not possible and advisable. Therefore, they were excluded from quantitative evaluations and were used in the qualitative classifications. In contrast, there were variables whose cv% was low, having no classification capability. These variables were also excluded from quantitative classifications (further analysis).

C. Matrix correlation among the variables

In order to reducing the number and variety of variables, whether the data were collected at the beginning of the study or obtained by processing in later stages, all data were organized as follows (Loetsch, 1964 and Smith, 1996):

Respective data of forest stand characteristics

-Statistical indices (total, mean) in each sample plot for diameter, volume, basal area, and number of trees collected for 20 tree species,

-The percentage of industrial species, firewood species and canopy cover,

-Dominant type based on each of the three variables: standing volume, number and basal area of trees,

-Diversity of tree species,

-Reduction coefficient of the number of trees in the diameter classes or De'liocort coefficient (q) (Banan, 1964)

Respective data of control trees characteristics. Statistical indices (mean and total) for 20 species, including: volume, basal area, diameter at breast height, tree height, and slenderness ratio (h*100/d) (Namiranian, 2006)

Respective data of habitat characteristics containing: aspects (8 groups), altitude (m), slope (%).

Then, the correlation test was performed among all variables.

D. Classification based on the dominant species

To classify the sample plots the measures took place as follows:

Initially, the mean and total value of each classification criteria including stand volume, number of trees, and basal area of trees were calculated for each of the sample plots.

Then, each sample plot was named based on the type of dominant species and for each of the classification criteria. In this way, each plot was classified three times and each time based on one of the mentioned criteria i.e. stand volume, number of trees or basal area. The sample plots with the same name were placed in one group. Then, the groups were compared using mean comparison test (One-way Duncan 95%), ANOVA, and consistency test of data distribution in diameter classes (Wilcoxon test).

E. Studying the stand structure

To evaluate and compare the structure of uneven-aged forest stands, there are several methods based on the frequency of trees in diameter classes, each is dependent on its own special indicators (Smith, 1996, Loetsch, 1964, Zeid, 1995, Amini, 2001). Based on objectives, this type of study could be done at different scales such as compartment, type, or the entire forest (Amini, 2001).

In this research project, a set of methods introduced was used to investigate the structure as follows:

-The use of numerical indices: calculation and comparison of the numerical indices for the existing (current) and optimal conditions such as total or mean number of trees, the percentage of number of industrial species compared to the total number, De'liocort coefficient (Banan, 1964).

-The use of frequency distribution table for the number of trees in diameter classes,

-Comparison of current and optimal conditions using the chi-square, Wilcoxon and Kolmogorov-Smirnov tests (Namiranian, 2006),

-Comparison of distribution histogram for the current and optimal conditions (Amani, 1997),

-Simultaneous comparison of visual curves with the results of statistical analysis of the current and optimal distribution

F. Calculating the number of plots required

Designing a sampling system is very important in detailed introduction of the population. In this regard, the number of sample plots is considered as one of the main factors.

$$N = (Sx2\ \%)/\ (E2\ \%) \qquad \ldots(1)$$

In this research project, the number of plots for forest inventory was examined using the equation (1) (Zobeiri, 2002), Where Sx% is the standard deviation of the study variable among 430 sample plots with an error of 7%.

RESULTS

A. Correlation test among variables

After the inventory of the entire forest, quantitative and qualitative variables were separated and groups were formed. According to the obtained results, among the variables studied, three factors, basal area, number of trees and stand volume had more capability (potential) to show the correlation. Therefore, in most stages of processing, these three parameters were used.

B. Effect of classification based on the main variables

Grouping sample plots based on the dominant tree: with the aim of grouping the sample plots based on one of the mentioned variables and calculating on the basis of other variables, the following results were deduced (Table 1):

Table 1: Effects of stratification and separable groups based on the frequency of main variables.

Dominant species	**Stratification Variable**	**Dominant Species**								
		Beech			**Hornbeam**			**Other Industrial Species**		
		Stratification Variable								
		No of trees	Stand Volume	Basal Area	No of trees	Stand Volume	Basal Area	No of trees	Stand Volume	Basal Area
Hornbeam	Number of trees	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Stand Volume	*	*	*	ns	ns	ns	ns	ns	ns
	Basal Area	ns	ns	ns	ns	ns	ns	ns	ns	ns
Other Industrial Species	Number of trees	ns	ns	ns	ns	ns	ns	ns	ns	ns
	Stand Volume	ns	ns	ns	ns	*	*	ns	ns	ns
	Basal Area	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fuel wood Species	Number of trees	*	*	*	*	ns	ns	ns	*	ns
	Stand Volume	*	*	*	ns	*	*	ns	*	*
	Basal Area	*	*	*	ns	ns	ns	ns	*	*

* = Significant difference at ($P<0.05$), (ns) = no significant difference at ($P<0.05$)

a) The mean values of stand volume, number of trees and basal area in the forests whose dominant species were firewood species showed a significant difference (P<0.05) compared to the forests whose dominant species was beech.
b) The mean values of stand volume in the forests whose dominant species was beech showed a significant difference (P<0.05) compared to the forests whose dominant species was hornbeam.
c) The mean values of stand volume in the forests whose dominant species was hornbeam showed a significant difference (P<0.05) compared to the forests whose dominant species were firewood or other industrial species.
d) The mean values of stand volume and basal area in the forests whose dominant species were other industrial species showed a significant difference (P<0.05) compared to the forests whose dominant species were firewood species.
e) The mean values of stand volume in the forests whose dominant trees are fuel wood species showed a significant difference (P<0.05) compared to the forests whose dominant trees were other industrial species (except beech and hornbeam). Also, a significant difference (P<0.05) was recorded for the mean values of number of trees in the forests whose dominant species was hornbeam.

C. The number of sample plots required

The estimation of number of sample plots in the forestry projects in northern Iran is done based on the standard deviation of stand volume. In other words, in equation 1, X is the tree volume.

Table 2: Results of estimating the number of plots required.

Stratification Variable	Estimation Variable	Species	Standard Deviation (%)	Plots number for	
				Each Species	All Species
Basal Area	Volume (M^3 per Ha.)	Beech	32	85	119
		Hornbeam	38	118	
		Other industrial	45	166	
		Fuel wood Sp.	44	154	
	Basal Area (M^2 per Ha.)	Beech	31	78	98
		Hornbeam	34	92	
		Other industrial	40	129	
		Fuel wood Sp.	40	129	
	Trees Number (No per Ha.)	Beech	39	123	128
		Hornbeam	40	129	
		Other industrial	41	136	
		Fuel wood Sp.	40	129	
Trees Number	Volume (M^3 per Ha.)	Beech	30	73	122
		Hornbeam	40	129	
		Other industrial	46	170	
		Fuel wood Sp.	44	154	
	Basal Area (M^2 per Ha.)	Beech	22	68	99
		Hornbeam	36	105	
		Other industrial	41	136	
		Fuel wood Sp.	38	117	
	Trees Number (No per Ha.)	Beech	37	111	128
		Hornbeam	45	166	
		Other industrial	41	136	
		Fuel wood Sp.	37	111	
Stand Volume	Volume (M^3 per Ha.)	Beech	33	88	118
		Hornbeam	37	111	
		Other industrial	44	154	
		Fuel wood Sp.	50	201	
	Basal Area (M^2 per Ha.)	Beech	32	85	101
		Hornbeam	33	88	
		Other industrial	39	123	
		Fuel wood Sp.	45	166	
	Trees Number (No per Ha.)	Beech	41	136	129
		Hornbeam	38	117	
		Other industrial	41	136	
		Fuel wood Sp.	39	123	

However, in this study, according to the obtained results of grouping of sample plots as well as the results of correlation test, the three variables of stand volume, basal area and number of trees per hectare were used for each of the dominant species including beech, hornbeam, other industrial species, and wood species and also for total species. Therefore, the obtained results make it possible to do the forest classification based on one variable, while the estimation of number of plots could be done based on another variable. For example, when forest is classified based on the frequency of basal area per hectare in order to estimate the volume per hectare, a number of 85 plots will have sufficient accuracy (Table 2).

The weighted average frequency of sample plots was used to calculate the average number of sample plots required for the beech, hornbeam, other industrial species, and wood species. The results of the number of sample plots needed for the study area are shown in Table 2. The content of this Table is set so that forest classification could be performed based on a variable and the number of sample plots could be estimated based on another variable with a maximum error of seven percent. Based on these results, the maximum number of plots needed to estimate each of the following variables is as follows: Stand volume: 122, basal area: 101, number of trees: 129, all variables: 116 sample plots. If forest classification is done based on the number of trees and the volume of other industrial species is required, a number of 170 sample plots will have sufficient accuracy.

In summary, the volume, basal area and number of trees could be estimated with acceptable accuracy for the study area in this research project with a maximum number of 130 sample plots,. However, in random systematic method without classification 415 plots were sampled.

The results based on the indicators of structure

D. Comparison of compartments structure based on quantitative indicators

Statistical indicators including tree density per hectare, the percentage of industrial trees to the total number of trees, and the De'liocort coefficient under two spatial classifications are presented in Table 3.

Table 3: Statistical indicators under two spatial classifications.

Factor	Basis for comparing	Mean	Min	Max	Variation (Cv%)
Trees Number (No per Ha.)	Compartments	187.07	117.15	246	15.7
	Diameter Classes	9.56	0.53	55.71	91.42
Percent of Indus. Sp. to All Trees	Compartments	71.33	39	100	24
	Diameter Classes	-	-	-	-
D’ Liocourt Fator	Compartments	1.34	0.95	1.69	12.7
	Diameter Classes	1.33	0.13	7.9	74.4

Evaluation and comparison of the compartments structure by integrating the indicators. Separation of mixed uneven-aged forest stands structure according to each of the indicators evaluated separately is not enough (Amini, 2000, Amini, 2001). These indicators include the tree density, the percentage number of industrial species to the total number of trees, simultaneous comparison of visual curves with the results of statistical analysis of the current and optimal distribution, the De'liocort coefficient …

According to the obtained results, ten structure conditions could be separated in the study forest. The summary of this integration is presented in Table 4.

-In some forest stands, the tree density exceeds the minimum threshold; however, its distribution is not desirable in the diameter classes (green color in the column of number of trees per hectare).

-Some forest stands have a minimum density and the distribution of number in diameter classes is optimal but the percentage of industrial species to the total frequency is not optimal.

-Some forest stands have a minimum density and optimal distribution and the percentage of tree frequency to the total frequency is optimal; however, the available distribution showed a significant difference compared to the control distribution.

Table 4: Classification of compartments based on independent and integrated indicators of structure.

No of Group	Conditions	Indus. Sp. To All Trees (%)	Trees No	D'Liocourt	Chi Sq&Obser	Chi Sq	Compar No
1	The best conditions	78	191.1	1.39	1	ns	110
		84	176.3	1.24	1	ns	116
		84	165.5	1.24	1	ns	121
		94	168.5	1.13	1	ns	125
2	The indicators of structure are appropriate but the percentage of industrial species is lower than minimum	65	166	1.35	1	ns	106
		51	183.9	1.36	1	ns	118
		66	182.8	1.31	1	ns	119
		48	174.3	1.18	1	ns	144
3	Indicators of structure are appropriate, and there will be no significant difference with optimal distribution if a diameter class is omitted	74	171.8	1.24	2	*	102
		85	176	1.36	2	*	115
		83	165	1.21	2	*	122
4	Tree density and D'Liocourt coefficient are appropriate, the percent of industrial trees is lower than minimum, if a diameter class is omitted there will be no significant difference with optimal distribution	71	190.9	1.22	2	*	111
		64	213.7	1.28	2	*	97
		65	201.8	1.36	2	*	117
		39	215	1.4	2	*	128
5	Tree density, D'Liocourt coefficients, and percentage of industrial trees are appropriate, showing significant difference with optimal distribution	77	233.3	1.4	3	*	148
		100	196.7	1.31	4	*	150
6	Tree density and percentage of industrial trees to the total number of trees are appropriate but D'Liocourt coefficient is inappropriate, showing significant difference with optimal distribution	80	206	1.14	4	*	96
		83	246	1.49	3	*	103
		100	201.4	1.59	4	*	105
		85	213.3	1.51	4	*	123
		95	166.7	0.95	4	*	124
		84	212.5	1.11	4	*	126
		74	195	1.96	4	*	151
7	Although by omitting a diameter class, there is no significant difference with control distribution, in spite of appropriate density, D'Liocourt coefficient and the percentage of industrial trees are not desirable.	71	210	1.55	2	*	100
		52	183	1.51	2	*	120
		52	183.7	1.49	2	*	131
8	The percentage of industrial trees and D'Liocourt coefficient are inappropriate, showing no significant difference with optimal distribution	48	215.7	1.42	3	*	89
		62	225.7	1.58	3	*	101
		58	244.3	1.48	3	*	108
9	Density is sufficient and D'Liocourt coefficient is appropriate, the percentage of industrial trees is less than optimal, showing a significant difference compared to control distribution	71	174.3	1.17	4	*	114
		71	215.7	1.17	4	*	129
		66	165.7	1.36	4	*	109
10	Other conditions that cannot be integrated with any of the above mentioned groups	44	146.7	1.34	4	*	95
		100	122.5	1.41	4	*	104
		56	163.8	1.45	4	*	112
		42	152	1.59	1	*	113
		62	162	1.18	1	*	130
		98	117.2	1.02	4	*	149

In the chi-square column: ns: no significant difference with optimal distribution, *: significant difference with optimal distribution

-In those forest stands that there is a minimum tree density, well distributed among diameter classes, and there is an optimal percentage of industrial species to the total frequency, showing no significant difference compared to the control distribution, it can be concluded that the best condition existed at the time of inventory.

In more detailed steps, qualitative classifications such as the dominant type could be used beside the quantitative classifications.

Study of structure based on dominant type (qualitative variable). In order to reduce the number of criteria and variables and a more detailed study on the arrangement of groups, the following types were formed: beech, fuel wood species, hornbeam and other industrial species. Mean comparison (one way-Duncan) was performed among the types with the dominance of mentioned species based upon the three variables and results confirmed a significant difference among the study groups. Therefore, this type of grouping could be applied along with the classifications done using quantitative indicators.

E. The effects of changes in geographic aspects on main variables

Since normally the border of the project area, series, and compartments is determined based on silvicultural criteria (indicators), relying on the relative homogeneity of geographical units of FMP, the effects of habitat factors such as geographical direction on difference among groups is declined.

In other words, in this classification method, the effects of habitat variables on silvicultural properties become weak. Therefore, reduced number of groups and inclusion of plots in four groups (four geographical directions) increase the number of observations in each group and remove the variations among groups. Therefore, if there is an urge or necessity to use this indicator for the classification of low forest area units, geographical directions had better be classified into eight groups, so that the differences become more pronounced.

The reasons described above indicate the reduced effects of geographical directions; therefore, the effects of changes could be attributed to other variables and a variety of forest classifications could be tested with more confidence.

DISCUSSION

In natural uneven aged broadleaf forests, various types could be separated by combining different conditions and indicators. To judge the current condition of forest, there are different indicators with which the evaluation criteria could be converted to quantities comparable to each other. Therefore, appropriate indicators should be selected based on the objective of study.

According to the results, there is a very strong correlation between basal area and stand volume ($R > 0.95$). Therefore, in planning programs, basal area could be used rather than stand volume. The advantage of this replacement is that systematic errors resulted from measuring tree height, distribution of control trees in diameter classes, shape coefficient, volume table, and so forth are removed from estimation. Thus, with one measurement and the shortest calculation, the data (information) needed for planning are obtained with greater speed and accuracy.

It should be noted that this procedure is only related to the planning stage and the possibility of change in other processes of measuring the trunk volume after logging requires further researches.

The forests whose conditions are similar to the study area in this research project could be classified based on the variables evaluated with showing a significant difference among the groups ($P<0.05$).

Therefore, using silvicultural measures (stand volume, basal area, number of trees) based on the dominance of one species or a group of species (E.g. industrial species, fuel wood species) and in combination with measures resulting from the application of mathematical equations and statistics (D'Liocourt coefficient, distribution in diameter classes), it is possible to separate and classify the stands and set a careful planning in accordance with the specifics of each with an appropriate confidence interval.

Different local conditions of habitat sites lead to several conditions; therefore to facilitate the introduction and future investigation and planning, forest stands could be separated by quantitative indicators of density and distribution for each variable per unit area and distribution in diameter classes.

In those forest stands that there is a minimum tree density, well distributed among diameter classes, and there is an optimal percentage of industrial species to the total frequency, showing no significant difference compared to the control distribution, it can be concluded that the best condition existed at the time of inventory.

To estimate the number of plots needed, where a smaller area of forest is under planning, the use of CV% of the main variables (stand volume, number of trees, …) or a combination of them reduces the number of plots and increases the accuracy of the data.

CONCLUSION

The use of classification method in the forests similar to the study area in this research project will have a significant impact in reducing the volume and costs of operations, compared to what is usual (common) in no classification method in which vast areas are sampled. The increased accuracy of operations is among the findings of this issue.

Therefore, the possibility of increasing the area of sample plots is provided to get more detailed information closer to nature as well as access to the variables having lower contribution in no classification method.

SUGGESTIONS

1) Separation and integration of common units of habitat sites and forest based on soil characteristics, geology, aspect, elevation, climate, silvicultural, characteristics and potentials of each individual unit.
2) Changes in sampling method from random systematic to stratified random systematic sampling.
3) Description of compartments before sampling in order to separate the types and independent units in terms of existing and future conditions.
4) The use of integrated information obtained from statistics and description to separate the existing structure of stands.
5) Preparing the type maps for the spatial relationship of the silvicultural units in describing the compartments and updating them
6) Using multivariate indicators rather than relying on volume in estimating the sample size and its area.
7) Using basal area rather than stand volume in silvicultural planning of FMPs.

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