Evaluation of structure
in *Pinus halepensis* M. stands in North Greece

TSITSONI TH.*, KARAMANOLIS D.**, STAMATELOS G.***, GKANATSAS P. *

* Laboratory of Silviculture, School of Forestry & Natural Environment, Aristotle University of Thessaloniki, 540 06, Thessaloniki, Greece; Tel. +30 31 998904: Fax +30 31 998881
** Laboratory of Forest Management and Remote Sensing, Aristotle University of Thessaloniki, 540 06, Thessaloniki, Greece; Tel. +30 31 998959: Fax +30 31 998897
*** Laboratory of Forest Biometry, Aristotle University of Thessaloniki, 540 06, Thessaloniki, Greece; Tel. +30 31 998958: Fax +30 31 998861

Abstract

The Principal Component Analysis (P.C.A.) is a multivariate technique useful in the description and the revealing of relations between variables in a great number of data. The structure of *Pinus halepensis* forests by P.C.A. was studied. The method was applied in silvicultural data of *Pinus halepensis* forests in Kassandra Peninsula. Sampling was done on 49 plots spreaded over of the peninsula. By the analysis of a total of 12 initial variables it was found that the first 6 principal components,«new variables», interpret almost 83% of the total variance. It was also found that the first component, which explains 29.6%, affects the configuration of stand structure.

Keywords: Principal Component Analysis, Pinus halepensis forests, Structure data

1.Introduction

This research studies, by the Principal Component Analysis, the structure of stands of *Pinus halepensis,* the dominant tree species in Mediterranean forest ecosystems.

In the Mediterranean region *P. halepensis* and *P.brutia* occupy an area of 6.8 millions ha, which is bigger than the rest of all other forest species (Quezel, 1986). In Greece *P. halepensis* occurs in Peloponnisos, Sterea Hellas, Epirus, Chalkidiki, Volos, Aegean and Ionean islands (Fig.1). This species prefers high values of mean annual temperature and resists even the prolonged summer drought period, so it may be considered as an index species of Mediterranean climate regions of Greece in the zone of Quercetalia ilicis.

In this zone wildfires are, however, an integral part of the Mediterranean environment (Naveh, 1974; Trabaud *et al.*, 1985) and they make *P. halepensis* more competitive against the rich shrubby vegetation of exceptionally flammable species composing its understorey (Dafis,1986,1987; Wagner, 1970; Tsitsoni, 1991). So, the structure of the forest ecosystems in these regions is affected by wildfires.

In natural situations the description of objects and conditions or the comprehension of various events presuppose a great number of variables. Vidyakin (1991) asserts that the most informative method involves indices. Other researchers, Kravtsov and Milutin (1985) and Chernodubov (1993), consider that success is only achieved by studying a complex of traits and making use of multivariate analysis. Especially in the forestry research it is often necessary to study the joined variability of a great number of correlated variables, which are measured in randomly selected sampling units (Van

Laar,1991). Cases of applying the Principal Component Analysis in forestry were provided by Jeffers (1967) and many other cases in the forest - environmental research by Liu and Keister (1978), Kalkstein (1981), and Pregitzer and Barnes (1982).
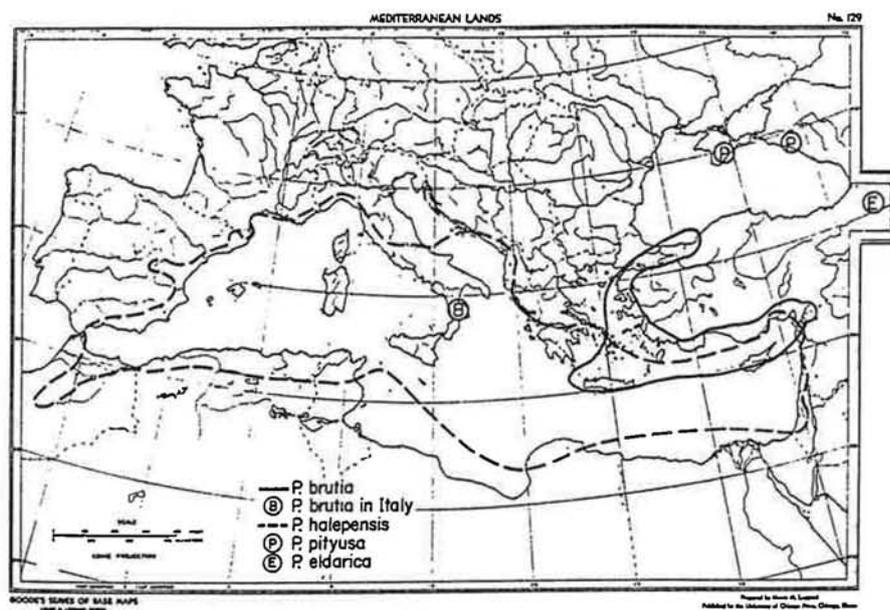

Figure 1. Geographic spreading of Pinus halepensis and Pinus brutia in Mediterranean region and in Greece (Mirov, 1967)

The aim of this research is to study how much site and stand factors of the *P. halepensis* forests contribute to the formation of the structure in order to apply a rational management of similar forests ecosystems. For this purpose it was used the P.C.A. analysis because this method is very important for the analysis of biological and environmental problems where strong correlation appear among many variables because the significant biological problems are multivariate (Jeffers,1967).

2. Study area

The region of Kassandra Peninsula was selected for studying the *P. halepensis* structure because this species reaches its optimal growth in this region (Dafis, 1987) and forms beautiful forests which ought to be conserved.

The research was conducted at the state and community forests of the Kassandra Peninsula which is located 60 Km south-eastern of Thessaloniki and occupies an area of about 35,000 ha. According to the climatic data of the meteorological station of the Forest Service in Kassandra (1975 - 1990) the mean annual rainfall is 560 mm while the mean annual temperature goes up to 16.5° C (mean max. 39.4° C, mean min. 4.6° C). The vegetation of the area consists of the characteristic Mediterranean floristic components, dominated by *P. halepensis*. It belongs to the Quercetalia ilicis zone. Geologically it shows a relative homogeneity since the dominant rocks are marls, cobble sand, and marl limestone.

3. Methods

In order to study the stand structure 49 sample plots of 20x25 m^2 (Dafis, 1969) were taken, with the long side parallel to the levelling curves. In every plot all trees - with diameter over 4 cm - were numbered, measured for their diameter, height, crown length and classified according to the IUFRO system (Leibundgut, 1959; Matthews, 1989) with respect to the social position of the trees and the quality of the stems. In order to have a more complete ecological interpretation for every sample plot the following data were registered: elevation, exposure, slope, and age (all measured trees of even-aged stands have been classified in age classes 10-20, 25-35, 40-50,60-80 years). Also, from the structural data, the mean height of the 100 highest trees per ha, the basal area (G) and the index (G X h) were measured.

The data mean dominant height, basal area/ha, (G X h), mean crown length, ground cover, number of trees/ha, age, stem quality, vitality, slope, exposure, altitude above see level were analysed with the Principal Component Analysis, a multivariate technique in which a number of related variables are transformed to set of uncorrelated variables (Dunteman, 1989; Jackson, 1991).

For the P.C.A. the statistical package SPSS/PC version 5.0 was used (Norusis, 1994).

4. Results and discussion

The structure of *P. halepensis* stands is mostly even-aged, occurring after fire. Furthermore, there are some group-selective stands which are the result of a constant pressure of grazing and irregular clear cuttings (Tsitsoni, 1991).

Table 1 contains the initial statistics for each factor. The total variance explained by each factor is listed in the column labelled *Eigenvalue*. The next column contains the percentage of the total variance attributable to each factor. The last column, the cumulative percentage, indicates the percentage of variance attributable to that factor and those that precede it in the table. Several procedures have been proposed for determining the number of factors to use in a mode. One criterion suggests that only factors accounting for a variance greater than 1 (eigenvalue greater than 1) should be included. Table 1 shows that 67.5% of the total variance is attributable to the first four factors which have eigenvalue greater than 1. Although this is the default criterion in the SPSS Factor Analysis procedure, it is not always a good solution (Tucker et al., 1969).

Figure 3 is a plot of the total variance associated with each factor. The plot shows a distinct break between the steep slope of the large factors and the gradual trailing off, which is called **scree**, of the rest of the factors.

Table 1. The initial statistics for each factor

Factor	Eigenvalue	Variance	
		%	cum %
1	3.54928	29.6	29.6
2	2.07285	17.3	46.9
3	1.40397	11.7	58.6
4	1.07311	8.9	67.5
5	.95327	7.9	75.4
6	.90439	7.5	83.0
7	.67644	5.6	98.6
8	.48952	4.1	92.7
9	.35121	2.9	95.6
10	.28974	2.4	98.0
11	.22830	1.9	99.9
12	.00789	.1	100.0

From the above and for the additional reason that the curve of Figure 2, changes its inclination at point 6 (0.9), we set 6 factors, which explain greater rate of the total variance (the 83%), to be further analyzed and discussed.
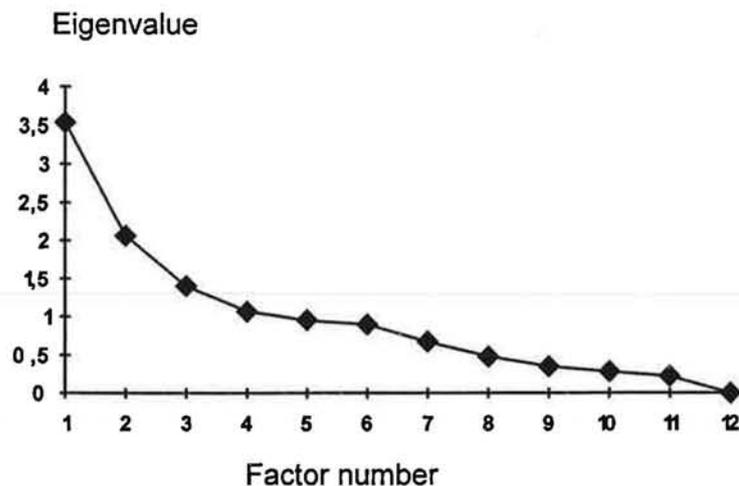

Figure 2. Screen plot

The explanation of factors was done by the method of diminishing classification taking into account only the variables which had a value greater than 0.5 (Table 2). The rotation of factors axes was implemented by the rectangle rotation (varimax) method. In Table 2 the variables are explained by every factor, and the rates of explanation of each variable are shown. Therefore, it results from this table that the factors in succession explain the following variables:

The **first factor** is characterised by the variables Gxh, mean dominant height, basal area and mean crown length, which identify the factor «volume characteristics».This factor explains 29.6% of the variation.

The **second factor** is determined by the variables ground cover and number of stems/ha, which identify the factor «density of vegetation» and interpret 17.3% of variation.

The **third factor** (variance 11.7%) is characterised by the variables age and stem quality.

The **fourth factor** is determined by the variable vitality and explains 8.9% of the variation.

The **fifth factor,** characterised by the variables slope and exposure, explains 7.9% of the variation.

The **sixth factor** (variance 7.5%) is determined by the variable elevation.

The total variation of the six components reaches 83.0%.

Table 2. The Factor Matrix shows the correlation between variables and factors after the orthogonal rotation (Varimax)

Variable	Factors					
	1	2	3	4	5	6
Gxh	:95321	-.08431	-.03716	-.15087	.06834	-.00356
Mean highest height	.89691	-.05132	-.13406	.03983	.06206	-.01514
Basal area/ha	.86291	-.09141	-.2622	-.24129	.11431	.00335
Mean crown length	.77172	.06131	.04948	.33873	-.04883	-.04074
Ground cover	-.04096	.87927	.03875	.21632	.14638	.02450
Number of stems/ha	-.07454	.70901	.43158	-.18146	-.16827	.08874
Age	.10106	-.12997	-.83851	.08063	.19389	.12951
Stem quality	.00310	.14595	.74786	.46378	.13194	.21146
Vitality	-.03991	.06328	.05603	.89032	.03177	.00394
Slope	-.01464	-.13984	.14031	-.14177	-.85523	.23458
Exposure	.37172	-.38614	.02650	-.33618	.59795	.22493
Above see level	-.04146	.06205	-.00628	.01856	-.12501	.94833

5. Conclusions

On the basis of this study it is established that: When studying the structure of *P. halepensis* stands, it is advisable to make use of the multivariate approach with P.C.A. as this method is the most informative one. From the volume characteristics, which have to be studied first, the most important contributions are the variation in mean dominant height, basal area and mean crown length, which account for 29.6% of the variation. These variables seem to be those, which are affected by site quality, so the silvicultural measures should be different in each site. The second factor is the density of vegetation and accounts for 17.3% of the variation, which mainly is influenced by human activities. Physiographic variables seem to play a small role in the structure of *P.halepensis* stands as they explain only the 15.4% (7.9%+7.5%) of the stand structure variation.

The above data can be used for the application of a rational management of *P.halepensis* forests, conducted ecologically (via the above method) based on the management goals set out by silvicultural research in the area (Tsitsoni, 1991).

For the area under research the silvicultural purpose is to create forests, which, besides the main management objective (wood production), should also implement other purposes as well (resin production, apiculture, soil protection and water production), since they are appropriate as multiple use forests (Tsitsoni, 1991). For the estimation of the structure of *P.halepensis* forests, except the factors were drown out by P.C.A., one should also take into account the following factors (Lamprecht, 1977; Leibundgut, 1982; Dafis, 1990):

-The increase of population which increasingly affects the use of wood and reduces the provisions of it (Steinlin 1980).

- The current industrial and technological development which increase the economic interest of the forests, contributing many times to the development of the region.
- The social functions of the forest which have a great significance today.

Therefore two forest forms should be suggested to the research region:

i. Economic forests with ecological management for multiple use (wood production, resin production, apiculture, soil protection and water production).

ii. Forests for outdoor recreation, located along the coasts where there is a great touristic interest. For these forests a special significance must be given for the maintenance of ecological stability and the improvement of the aesthetic value.

6. Bibliography

Chernodubov, A. I. (1993).The stucture of *Pinus sylvestris* L. in the Insular Pine Forests of The South Russian Plain. Silva Genetica 43(4) : 186-189.

Dafis, S. (1969). Site research in Beech forests. Sci. Ann. of Agric. For. Sch., Thessaloniki, 13 : 1-48 (in Greek).

Dafis, S. (1986). Forest Ecology. Giahoudis-Giapoulis, Thessaloniki, 443 pp. (in Greek).

Dafis, S. (1987). Ecology of *Pinus halepensis* and *Pinus brutia* forests. In: Hellenic Forestry Society (Editor), Proceedings of the 1st Scientific Meeting of Hellenic Forestry Society on *Pinus halepensis* and *Pinus brutia* forests, Chalkida, Sept. 30-Oct 2, 1987. Thessaloniki, 17-25, (in Greek).

Dafis, S. (1990). Applied Silviculture. Giahoudis-Giapoulis, Thessaloniki, 258 pp. (in Greek).

Jackson, J.E. (1991). A User's Guide to Principal Component. John Wiley &Sons. Inc., N.Y. 569 pp.

Jeffers, J.N. (1967). Two Case Studies in the Application of Principal Component Analysis. Appl. Statist. 16(3): 225-236.

Kalkstein, L. S. (1981). An Improved Technique to Evaluate Climate-southern Pine Beetle Relationships. Forest Sci. 27(3): 579-589.

Kravtsov, V. A. and Milutin, L. I. (1985). Population analysis with the help of the multimeasured methods. General Biology Journal 46(4) : 557-564.

Lamprecht, H. (1977). Der funktionell Bestimmte Waldbau. Allgem Forstzeitschrift 34.

Leibundgut, H. (1959). Ueber Zweck und Methodik der Struktur und Zuwachsanalyse von Urwaeldern. S.Z.F. 3:111-124.

Leibundgut, H. (1982). Die natuerliche Waldverjuengung. Ver. Paul Haupt Bern und Stuttgart.

Liu, C. J. and Keister, T.D. (1978). Southern Pine Stem Form Defined Through Principal Component Analysis. Can. J. For. Res. 8:188-197.

Matthews, J.D. (1989). Silvicultural Systems. Oxford University Press, New York, 264 pp.

Mirov, N.T. (1967). The Genus Pinus. The Ronald Press Company, New York, 602 p.

Naveh, Z. (1974). Effects of Fire in Mediterranean Region. In: Kozlowski T.T. and Ahlgren C. E. (Editors), Fire and Ecocystems, Academic Press, New York, 401-434.

Norusis, M. J. (1994). SPSS Professional Statistics 6.1 SPSS Inc., Chicago, Illinois, U.S.A.

Pregitzer. K. S. and Barnes, B.V. (1982). The Use of Ground Flow to Indicate Edaphic Factors in Upland ecosystems of the McCormick Experimental Forest, Upper Michigan. Can J. For. Res. 12:661-672.

Quezel, P. (1986). Les pins du group «halepensis». Ecologie, Vegetation, Ecophysiology. Options Mediterraneennes. C.I.H.E.A.M., Marseille, 1986-1.

Steinlin, H. (1980). Die gegenwaertige Holzversorgung Europas. S. Z. F., 1:1-29.

Tucker, L. R. (1971). Relations of factor score estimates to their use. Psychometrika, 36:427-436.

Trabaud, L., Michels, C. and Grosman J. (1985). Recovery of burnt *Pinus halepensis* Mill. forests II. Pine reconstitution after wildfire. For. Ecol. Manage., 13:167-173.

Tsitsoni, Th. (1991). Stand structure and conditions determining natural regeneration after fire in the Allepo pine forests of Kassandra Peninsula (Chalkidiki, Greece). Ph.D. Thesis. Thesssaloniki , 150 pp. (in Greek with English abstract).

Van Laar, A. (1991). Forest Biometry. Univ. of Stellenbosch. Stellenbosch, 590 pp.

Vidyakin, A. I. (1991). Index valuation of the *Pinus Sylvestris* populations structure signs. Forest Management 1 : 57-62.

Wagner, C. E. (1970). Fire and Red Pine. In: Proceedings of the 10th Annual Tall Timbers Fire Ecology Conference Fredericton, N. Brunwick, 211-219.