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Analysis of Inter-Species Association and Covariation in a Natural Deciduous Forest

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天然闊葉樹林에서의 樹種間 相關關係와 共變異關係의 分析[1]

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ABSTRACT

Utilizing chi-square test statistics, inter-species association and covariation were analyzed for the 37 woody plant species in a deciduous forest dominated by *Quercus mongolica* and *Q. variabilis*. within 50 temporarily established 20 m×20 m square quadrats, the association for each pair of species was presented based on the presence-absence parameters. *Acer palmatum* had significant positive association with *Acer mono* and *Kalopanax pictus*, but negative association with *Pinus densiflora*. Other positively associated species pairs were *Prunus sargentii-Macckia amurensis*, *Quercus serrata-Kalopanax pictus*, *Symplocos chinensis* var. *pilosa -Euonymus oxyphyllus*, and *Ulmus davidiana* var. *japonica-Lindera obtusiloba*. The covariation for each pair of species was evaluated based on the quantitative measures, density and basal area. Overall results showed that the association and covariation values among species generally agreed with each other. Because covariation was calculated by density and basal area of the tallied species in the sample plots, the number of species pairs of covariation tended to be greater than those of association. Especially, *Pinus densiflora*, considered to be pioneer species in the successional stage, had negative covariation with most of climax species.

These ecological information could be applied to silvicultural practices, such as ecosystem classification, establishment of mixed hardwood forest, and tending operations for marking crop trees and desirable species.

Key words : *Deciduous forest*, *inter-species association*, *inter-species covariation*, X^2 *test*.

要　約

신갈나무와 굴참나무가 優占種인 闊葉樹林에서 출현하는 37가지 木本植物에 대한 樹種間 相關(association)關係와 共變異(covariation)關係를 X^2 檢定을 이용하여 分析하였다. 50개의 20 m×20 m 正方形 標本區內에서 각 樹種의 出現・非出現이 媒介變數가 되는 相關關係를 分析한 결과, 단풍나무는 고로쇠나무 및 음나무와 高度(α=0.01)의 正의 相關關係를 갖고 있으나, 소나무와는 高度의 負의 相關關係를 갖고 있었다. 졸참나무와 음나무, 참회나무와 노린재나무, 노린재나무와 다릅나무, 다릅나무와 산벚나무, 그리고 생강나무와 느릅나무는 상호 正의 相關關係가 있는 것으로 나타났다. 각 樹種의 密度와 胸高斷面積으로 비교된 共變異의 分析 결과는 相關關係와 매우 부합되는 바가 많았다. 더우기 標本區에 生存하는 樹種의 個體數와 胸高斷面積이 媒介變數가 됨으로써 相關關係보다는 共變

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異關係를 맺고있는 樹種들의 雙이 많은 것으로 나타났다. 특히 遷移의 初期 혹은 中盤段階 樹種인 소나무는 대부분의 遷移 後期 樹種 혹은 極盛相 樹種들과 負의 共變異關係가 있는 것으로 판단되었다.

이러한 生態學的인 情報들은 生態界 分類, 闊葉樹 混肴林 造成, 그리고 미래목 선정등의 保育작업에 응용할 수 있을 것이다.

INTRODUCTION

A natural forest community is an aggregation of living organisms having mutual interactions among themselves and interrelationships with their surrounding environment. The distribution, the abundance, and the interaction of plant species are influenced by those biotic and abiotic factors that exist in the community.

In the natural deciduous forest of temperate region, assemblage of various woody plant species is an ecological product of such concepts by one way or another. The occurrence or nonoccurrence of a species in a particular area seems to be somewhat related to the occurrence of another species. We are interested here in investigating how a certain pair of tree species are growing in the same area and avoiding each other. This affinity of occurrence or repulsion of two species is so called interspecies association(Pielou, 1977 ; Greig-Smith, 1983 ; Schluter, 1984 ; Ludwig and Reynolds, 1988).

The species association is detected entirely by the presence and absence data of species in the collection of sampling units, resulting in being positive, negative, or absent. However, if the sample contains quantitative measures of species, for example, density, basal area, or biomass, additional information can be obtained compared to that of species associtation itself. The abundance data may have the tendency to increase and/or decrease together between two species. It is referred to as inter-species covariation(Ludwig and Reynolds, 1988). The procedure for examining species covariation is based on such abundance data, depending on whether or not the abundance data of two species covary.

Presumably, the association and covariation between two tree species in the forest community exist because of one or more among three main reasons. They are 1) same habitat selection, 2) similar environmental requirements, and 3) intrinsic interaction(Hubalek, 1982). Nevertheless, we are tend not to explain the possible underlying reasons why the association and covariation might occur, but to test statistical significance of those correlations in this study, which would be served as preceding information to generate suitable hypotheses to explain such complex ecological patterns. Practical considerations will be discussed with outcoming information as well.

THE STUDY AREA

The study area is located on Yongwha Mountain (38° 02' north latitude, 127° 45' east longitude) in Whacheon-Gun, Kangweon-Do. Vegetation type is classified to a temperate broad-leaved deciduous forest, dominated by *Quercus* species.

The climate of the study area is typically continental with summer rainfall and winter drought. Annual precipitation at the meteorological station in Chuncheon, about 12 km away from the study area, has been recorded in excess of 1200 mm, which is characterized by localized torrential downpour in summer, mainly in June, July, and August. The mean annual temperature has been 11.2℃, with cold season means(average for December, January, and February) of -0.3℃ to 3.5℃ and worm season means(average for June, July, and August) of 26.4℃ to 32.1℃.

The landscape is hilly to mountainous with exposed ridges and steep slopes up to 40°. Approximate elevation ranges from 200-600 m above mean sea level and aspects are various. The area is highly dissected by many small streams flowing between ridges of various width.

The soils of the study area have been weathered from igneous and metamorphic rocks, primarily granites and gneisses. They are chiefly well-drained and slightly acid brownish soils. Surface soil textures range from loamy sand to loam, and those of subsoil are commonly high in clay, generally identified to sandy clay loam. The structure of subangular blocky is prevalent.

METHODS

Data Collection

In order to analyze inter-species association and covariation, plot sampling techniques were utilized. During 1989 growing season, vegetation data were collected on 50 temporarily established 20 m×20 m (0.04 ha) quadrats evenly distributed with reference to 1 : 25,000 topographic map of the study area. It has been reported that the outcome of association and covariation among species is largely dependent on the size and shape of the sampling unit (Greig-Smith, 1983 and Kershaw, 1961). On the reference of Westhoff and Maarel (1978) and Mueller-Dombois and Ellenberg (1974), and according to the vegetation type of temperate deciduous forest, the size of 0.04 ha and square shape were adopted to lessen the dependence.

All woody plant species greater than 2.0 cm DBH in the sample plots were tallied, and DBH and total height were measured to the nearest 1.0 cm and 1.0 m, respectively. Botanical nomenclature of the species followed Lee (1982).

Even though not carried out the analysis, herbaceous plants were recorded, and site data included slope position, gradient, aspect, elevation, and estimates of soil properties.

Data Analysis

The procedure for analyzing inter-species association is based on the occurrence or non-occurrence of species in the collection of 50 sample plots. Each pair of species has the number of sample plots within which 1) both species present, 2) one but not the other, and 3) neither species presents. The number of all possible pairwise species combination that can be computed according to the equation S(S-1)/2, where S is the number of species to be analyzed (Agnew 1961). This information provided both the test and measure of inter-species association of the study forest. The chi-square test statistic was employed to test the null hypothesis of independence, which indicates no association between a certain pair of species. The test statistic was computed as

$$X^2 = \Sigma \frac{(\text{observed value-expected value})^2}{\text{expected value}}$$

Three association measures, the Ochiai Index (Ochiai, 1957), the Dice Index (Dice, 1945), and the Jaccard Index (see Brower and Zar, 1977), recommended by Hubalek (1982), were also calculated to review association conditions. Three association indices are identically characterized by 0.00 at "no association" and 1.00 at "absolute association".

The quantitative measures of species abundance, density and basal area in this study, were subjected to the evaluation of inter-species covariation. The use of correlation coefficients to measure the relative intensity of covariation in each pair of species abundance data was presented in addition to the species association. The positive covariation between two species indicates that when the abundance of one species increases in a sample plot that there is a corresponding increase in abundance in that sample plot by the other species. On the other hand, the negative covariation means that for the increase in one, there is the decrease in the other. Pearson product-moment correlation and Spearman rank correlation were employed for the analysis, and the test was taken for the hypothesis that a significant correlation existed.

All required mathematical and statistical procedures, and computer programs were followed by Ludwig and Reynolds (1988).

RESULTS

Species Composition

Dominated by *Quercus mongolica* and *Q. variabilis*, 37 woody plant species (23 tree species and 14 shrub species) were tallied from the sampling procedure. Table 1 shows relative density, relative frequency, relative coverage (on the basis of basal area), and importance value for each species by the method of Curtis and McIntosh (1951). More than 75% of importance value was occupied by five dominant tree species. It can be noticed that the forest lies under the way of progressing succession procedure. The evidence could be adduced by the appearance of small sized climax species, such as *Acer mono*, *Acer palmatum*, *Macckia amurensis*, *and Tilia amurensis*. Even though quantitative measure

Table 1. Species composition and their ecological measures in the study forest.

Species	Relative Density(%)	Relative Frequency(%)	Relative Coverage(%)	Importance Value(%)
Quercus mongolica (Q.M)*	35.76	13.20	41.20	30.05
Quercus variabilis (Q.V)	25.10	13.20	34.40	24.33
Styrax obassia (S.O)	14.30	11.37	6.97	10.88
Pinus densiflora (P.D)	3.20	7.40	7.34	5.98
Fraxinus rhynchophylla (F.R)	4.67	10.05	2.80	5.84
Lindera obtusiloba (L.O)	6.40	8.40	1.18	5.30
Ulums davidiana (U.D)	4.30	7.67	1.49	4.48
Quercus serrata (Q.S)	0.62	2.90	0.97	1.49
Prunus sargentii (P.S)	0.67	2.91	0.61	1.39
Acer palmatum (A.P)	0.73	2.30	0.50	1.17
Acer mono (A.M)	0.39	2.10	0.50	0.99
Kalopanax pictus (K.P)	0.39	2.11	0.29	0.93
Symplocos chinensis (S.C)	0.62	2.11	0.06	0.92
Euonymus oxyphyllus (E.O)	0.17	2.43	0.02	0.87
Maccikia amurensis (M.A)	0.39	1.85	0.19	0.81
Rhododendron schlippenbachii (R.S)	0.31	1.32	0.03	0.55
Rhododendron mucronulatum (R.M)	0.20	1.05	0.03	0.42
Rhus chinensis (R.C)	0.25	0.79	0.10	0.38
Morus bombycis (M.B)	0.20	0.79	0.09	0.35
Prunus padus (P.P)	0.14	0.79	0.08	0.33
Rhus trichocarpa (R.T)	0.08	0.79	0.01	0.29
Tilia amurensis (T.A)	0.25	0.26	0.28	0.26
Cornus controversa (C.C)	0.06	0.53	0.08	0.22
Corylus heterophylla (C.H)	0.08	0.52	0.03	0.21
Betula davurica (B.D)	0.06	0.26	0.18	0.16
Phellodendron amurense (P.A)	0.11	0.26	0.10	0.15
Juglans mandshurica (J.M)	0.03	0.26	0.16	0.14
Staphylea bumalda (S.B)	0.06	0.26	0.01	0.11
Cornus walteri (C.W)	0.03	0.26	0.04	0.11
Quercus aliena (Q.L)	0.06	0.26	0.01	0.10
Callicarpa dichotoma (C.D)	0.03	0.26	0.02	0.10
Lespedeza bicolor (L.B)	0.03	0.26	0.00	0.09
Quercus acutissima (Q.A)	0.03	0.26	0.00	0.09
Euonymus alatus (E.A)	0.03	0.26	0.01	0.09
Magnolia sieboldii (M.S)	0.03	0.26	0.00	0.09
Aralia elata (A.E)	0.03	0.26	0.00	0.09
Sorbus alnifolia (S.A)	0.03	0.26	0.00	0.09
Brillouin's Diversity Index 0.8200 ; Evenness 0.5229				

* The abbreviation are applicable to all the other tables.

was not included, commonly present herbaceous plant species were *Syneilesis palmata*, *Boehmeria tricuspis*, *Osmorhiza aristata*, *Astilbe chinensis* var. *davidii*, *Scutellaria fauriei*, *Clematis heracleifolia*, *Aconitum pseudo-laeve* var. *erectum*, *Carex* spp., *Panicum* spp., and *Pteridium aquilinum* var. *latiusculum*.

The Brillouin's species diversity index of 0.8200 was also presented in Table 1. The value of Brillouin's diversity index generally increases as the number of species increases, and as the number of individuals per species varies widely among species. Compared to another research of the index of more than 2.5000 by Kim(1989) in more stable and complex natural forest community of Mt. Chumbong, in a viewpoint of ecological structure, the study area had much less species diversity index and evenness values. High dominance of few species and low species diversity indicate that the study forest is considered to be less mature and far below to the steady state in terms of ecosystem development (Odum, 1969).

Inter species Association

On the basis of presence-absence data of the species in 50 sampling units, the pair combinations of species association for 13 woody plant species were shown in a matrix form of Figure 1. Since *Quercus mongolica* and *Q. variabilis* occurred in every plot, they should not be included the species matching process, considered as intermediate ones. The species tallied in less than 5 sample plots were omitted for the test. The sign of '+' indicates positive association, and that of '−' means negative. Eight pairs of species were significantly associated positive or negative with each other at $\alpha<0.05$ level.

Acer palmatun had significant positive association with *Acer mono* and *Kalopanax pictus*, but negative association with *Pinus densiflora*. Other strong positively associated species pairs were *Prunus sargentii-Macckia amurensis*, *Quercus serrata-Kalopanax pictus*, *Symplocos chinensis* var. *pilosa-Euonymus oxyphyllus*, and *Ulmus davidiana* var. *japonica-Lindera obtusiloba*. The overall trend of species association pattern was somewhtat similar to the results in Mt. Gyeryong by Song(1985) and in Mt. Chumbong by Yun, Han and Kim(1987).

Using the computer program of Ludwing and Reynolds(1988), test statistics, chi-square values, and association indices were calculated and tabulated in Table 2 for significantly associated eight pairs of species. Serving as the index of overall species association, the variance ration(VR) of 2.51, greater than 1, indicates that the species in the study forest commonly exhibit a positive association. In addition, W, test statistic is 125.72 and falls beyond the range of X^2 values 34.8-67.5, when sampling units are 50. This supports the positive association among selected species as being statistically significant at $\alpha<0.05$.

Three admissible indices were also calculated to measure the degree of association between pairs of species. The association between *Lindera obtusiloba* and *Ulmus davidiana* var. *japonica* had the highest value of indices. The interpretation of the indices are based on 0.00 at no association and 1.00 at maximum association. However, the indices indicate only the degree of association and do not provide test for association as X^2 test does.

	Acer mono	Acer palmatum	Euonymus oxyphyllus	Fraxinus rhynchophylla	Kalopanax pictus	Lindera obtusiloba	Macckia amurensis	Pinus densiflora	Prunus sargentii	Quercus Serrata	Styrax obassia	Symplocos chinensis var. pilosa
Acer mono												
Acer palmatum	⊕											
Euonymus oxyphyllus	-	-										
Fraxinus rhynchophylla	+	+	+									
Kalopanax pictus	+	⊕	-	-								
Lindera obtusiloba	+	+	+	+	+							
Macckia amurensis	+	+	+	-	+	+						
Pinus densiflora	-	⊖	+	-	-	-	-					
Prunus sargentii	-	-	-	-	+	+	⊕	+				
Quercus Serrata	+	+	-	-	⊕	+	+	-	+			
Styrax obassia	+	+	+	+	+	-	+	-	-	+		
Symplocos chinensis var. *pilosa*	+	-	⊕	+	-	+	⊕	-	-	-	+	
Ulmus davidiana var. *japonica*	+	-	-	-	-	⊕	+	+	-	-	+	+

Fig. 1. Complete X^2 matrix for 13 woody plant species in the study area (+ ; positive association, − ; negative association, ⊖ or ⊕ : significant association at<0.05). *Quercus mongolica* and *Qvariabilis* occurred in every plot, considered as intermediate species.

Table 2. Inter-species association indices and test statistics for significantly associated species in the study area.

VR=2.51(Index of overall association)
W, Test statistic=125.72

Species Pair	Association Type	X^2 Value	Association Indices		
			Ochiai	Dice	Jaccard
A.P-A.M	++	12.78	0.589	0.588	0.417
A.P-P.D	−−	8.89	0.063	0.054	0.028
A.P-K.P	++	12.78	0.589	0.588	0.417
Q.S-K.P	++	9.10	0.533	0.526	0.357
E.O-S.C	++	10.25	0.535	0.533	0.364
S.C-M.A	++	10.25	0.535	0.533	0.364
M.A-P.S	+	5.86	0.456	0.444	0.286
L.O-U.D	+	4.43	0.712	0.712	0.533

+, ++ : Significant positive association at $\alpha=0.05$, $\alpha=0.01$, respectively
−− : Significant negative association at $\alpha=0.01$

Inter-species Covariation

As in previous chapter, the species association was based entirely on presence-absence data and was tested for independence in the co-occurrence of pairs of species. However, since our sample contained quantitative measures of species density and basal area, covariation among major tree species was tested by the statistical method of Pearson's and Spearman's correlation. In order to examine the question of covariation for each pairwise combination of twelve major tree species, the Pearson and Spearman correlation coefficients were computed and summarized for species density and basal area in Tables 3 and 4, respectively.

Out of the 66 covariation pairwise combinations on density basis, seven correlations were significant using the Pearson correlation, and eleven with the Spearman correlation at $\alpha<0.05$ level. The highest positive Pearson correlation was recorded by 0.566 between *Acer palmatum* and *Kalopanax pictus*, and Spearman correlation by 0.622 between the same pair of species(Table 3).

Out of the 66 covariation pairwise combinations on the basal area basis, nine correlatiobns were significant using the Pearson correlation, and eight with Spearman correlation at $\alpha<0.05$ level. The highest Pearson correlation was recorded by 0.653 between *Acer palmatum* and *Kalopanax pictus*, and spearman

Table 3. Pearson (uper-right tringle) and Spearman (lower-left tringle) correlation coefficients for 12 major tree species on the basis of density.

SPP.	Q.M	Q.V	A.P	A.M	Q.A	S.O	F.R	M.A	P.D	K.P	P.S	U.D
						Pearson Product-Moment Correlations						
Q.M		0.110	-0.279	-0.319*	-0.219	-0.157	0.044	-0.281	0.249	-0.218	0.116	0.001
Q.V	0.141		-0.251	-0.169	-0.032	-0.034	0.025	-0.104	0.130	-0.153	0.141	0.318*
A.P	-0.324*	-0.303		0.190	0.113	-0.016	-0.175	0.370*	-0.200	0.566**	-0.064	-0.123
A.M	-0.327*	-0.078	0.469**		-0.001	0.028	-0.215	0.120	-0.247	0.219	-0.033	-0.117
Q.A	-0.245	-0.042	0.151	0.105		-0.103	-0.148	0.045	-0.127	0.123	-0.080	-0.168
S.O	-0.176	-0.015	0.096	0.066	0.002		0.256	0.164	-0.319*	0.012	-0.140	0.186
F.R	0.103	0.155	-0.184	-0.165	-0.111	0.363*		-0.050	0.107	-0.203	-0.083	0.084
M.A	-0.333*	-0.090	0.165	0.120	0.193	0.185	0.018		-0.197	0.482**	0.193	0.053
P.D	0.164	0.212	-0.384*	-0.389*	-0.130	-0.252	0.033	-0.251		0.197	0.108	0.282
K.P	-0.226	-0.186	0.622**	0.329*	0.252	-0.038	-0.247	0.252	-0.283		0.034	-0.110
P.S	-0.049	0.006	-0.101	0.009	0.039	-0.115	-0.062	0.361*	0.046	-0.023		0.351*
U.D	-0.114	0.100	-0.163	0.014	-0.203	-0.143	0.003	0.088	0.275	-0.067	0.350*	
						Spearman Rank Correlation						

* : Significant at $\alpha=0.05$
** : Significant at $\alpha=0.01$

Table 4. Pearson (upper-right tringle) and Spearman (lower-left tringle) correlation coefficients for 12 major tree species on the basis of basal area.

SPP.	Q.M	Q.V	A.P	A.M	Q.A	S.O	F.R	M.A	P.D	K.P	P.S	U.D
					Pearson Product-Moment Correlation							
Q.M		-0.212	-0.127	-0.398*	-0.025	-0.242	0.346*	-0.078	-0.198	-0.214	-0.248	-0.203
Q.V	-0.207		-0.220	-0.078	-0.093	-0.016	0.089	-0.173	-0.117	-0.169	-0.010	-0.055
A.P	-0.179	-0.212		0.221	0.298	0.051	-0.047	0.476**	-0.116	0.653**	-0.091	-0.081
A.M	-0.402*	0.046	0.493**		-0.088	0.200	0.323	-0.051	-0.102	0.530**	-0.085	-0.034
Q.A	0.043	-0.015	0.147	0.130		-0.022	-0.109	0.382*	-0.065	0.322*	-0.070	-0.090
S.O	-0.342*	-0.040	0.263	0.250	0.147		0.357*	-0.006	-0.104	0.112	0.150	0.138
F.R	-0.251	0.126	0.084	0.228	-0.090	0.402*		-0.088	-0.135	0.087	0.146	0.021
M.A	-0.184	0.067	0.160	0.136	0.215	0.151	0.027		-0.105	0.548**	0.100	0.103
P.D	-0.057	-0.191	-0.431**	-0.402*	-0.086	0.174	-0.123	-0.200		-0.128	0.028	-0.032
K.P	-0.209	-0.133	0.558**	0.292	0.401	0.199	-0.074	0.190	-0.227		-0.093	-0.037
P.S	-0.110	0.100	-0.0117	0.097	0.040	0.044	-0.023	0.374*	0.120	0.027		0.224
U.D	-0.265	-0.053	0.023	0.093	-0.074	0.022	0.022	0.257	0.150	0.045	0.296	
					Spearman Rank Correlation							

* : Significant at $\alpha=0.05$
** : Significant at $\alpha=0.01$

correlation by 0.588 between the same pair of species (Table 4).

Overall results show that the covariation values among species generally agreed with two different quantitative measures and correlations. However, we may be able to recognize several abrupt disagreement between density and basal area basis in Pearson product-moment correlation. These pairs of species were *Quercus mongolica* vs. *Fraxinus rhynchophylla*, *Quercus variabilis* vs. *Ulmus davidiana* var. *japonica*, *Quercus serrata* vs. *Macckia amurensis*, and *Pinus densiflora* vs. *Styrax obassia*.

There are two different kinds of disagreement. One is high values of Pearson correlation by density basis and low values of the correlation by basal area basis(for example, *Pinus densiflora* vs. *Styrax obassia*), and the other is exactly reverse type of correlation values(for example, *Quercus mongolica* vs. *Fraxinus rhynchophylla*). This is mainly because of distributional pattern of each pair of tree species, which is appeared from the disparity of size and number of trees between two species, i.e., small number of large diametered trees or large number of small diametered trees. If one species has totally different distributional pattern from the other species', we may have different covariation correlation in accordance with computation process based on the quantitative measurement, density or basal area.

DISCUSSION : PRACTICAL IMPLICATIONS

The main thrust of ecological activity with consideration to forestry has been directed not only toward the identification and classification of forest ecosystems but also toward the silvical substantiation of findings of ecology and their application to silvicultural practice. In addition, it is recognized that stand structure is important in various goods and services of forests, so most categories of forester should be familiar with a basic knowledge of community structure, Recently, Probst and Crow(1991) have emphasized on the practical importance of the diversity of inter-species interactions and have suggested sound ecological management of natural resource, including the forest. Most forest managers are well aware of antagonistic or harmonious interactions between their crop trees and some of the other species. But the full significance of inter-species relationships for the composition and productivity of the forest community is not always recognized. Recognition of practical implication of the inter-species relationships and how we can influence them makes the possibility of applying these interrelationships to our advantage. The authors suggest some practical implications which are derived from inter-species association and covariation information in the management of natural broad

-leaved forest communities.

The correlations obtained from association(Fig 1) and covariation(Table 3 and 4) may be graphically represented in the form of a two-dimensional spatial arrangement of species(Agnew1961 ; Welch 1960 ; DeVries 1953). A pair of species highly positively correlated are positioned close to one another. The arrangement of species mainly reflects positive correlations, making several groups of species, supposed to be growing and distributed together. These correlated groupings of major species represent distinctive forest communities. This information can be adopted to a method of ecosystem classification in natural forest cmmunities of which has a characteristic response to resource management. Even though not included this study, related to environmental requirements of the species in the group, the efficiency of ecosystem classification will be enhanced.

We have well known definite advantages to the establishment and management of single species plantations. However, single species plantations have serious disadvantages, most of which are ecological, and the high rate of hardwood plantation failure may be attributable in part of monoculture (Von Althen 1979 ; Schlesinger and Williams 1984). If more than two species are planted in mixture, we may have some advantages, such as growth compensation among species, reduction of damage from insects and diseases, high value for wildlife habitat, and better aesthetic appearance(Von Althen 1988).

The matter of choice of species mixed should be considered to their degree of adaptability to the site conditions. In addition, the arrangement of mixture must also be viewed as that of an assemblage of species, representing some ecological attributes of natural stand structure and function. If we discover some mutual attraction or affinity for coexistence among tree species, it is essential to utilize and employ such ecological and silvicultural information in practice. It means that the establishment of hardwood mixed plantations could be based on the information derived from inter-species association and covariation. This is also applicable to tending operations to improve productivity and to regulate stand structure in natural forests. Such silivcultural prescription as selection of desirable species and crop trees in natural stands might be made by using the results of inter-species association analysis. Crop trees or species, with which the other species have negative association and/or covariation, will be released to enhance stand composition and productivity. Proposed operation is considerably close to realize maintaining the natural conditions as well as pursuing economic effectiveness.

It must be apparent that the ecology of forest ecosystem involves a variety of topics which are valuable to forest resource managers. Much of the value is associated with a full understanding of forest structure and function. Rational management of natural resources should be closely related to the ecological characteristics of the resources.

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