森林科學硏究 第15號 : 1~9, 1999
J. For. Sci., Kangwon Nat'l Univ., No. 15 : 1~9, 1999

The Estimation of Tree Form Index for Major Canopy Species in the Natural Deciduous Forest.

Ji Hong Kim[1)] and Hee Moon Yang[1)]

天然闊葉樹林 主要 上層 林冠 樹種의 林木 形質 指數 推定

金知洪[1)] · 梁熙文[1)]

ABSTRACT

Noticing the intrinsic growing habit variations of hardwood species which is indigenous to the natural deciduous forest, eighteen tree species in overstory were selected for comparative evaluating tree form so as to develop the tree form index(TFI). Selected six tree form attributes were arbitrarily divided four assessment criteria and given appropriate scores. Eighteen tree species were undergone corresponding scores, converted to percentage base, and estimated TFI by the summation of the six scoring values. Cluster analysis was carried out to review which attribute would have been shared among species based on dissimilarity of scores for each pair of species in 18×6 data matrix.

The result showed that *Populus davidiana* had the highest TFI value of 80.8 and *Carpinus cordata* had the lowest TFI value of 46.3. The species which received more than 70 of TFI are *Populus davidiana*, *Betula costata*, *Fraxinus mandshurica*, and *Ulmus davidiana* var. *japonica*, characterized by the advantage of straight and longer bole, the narrower crown, and the thinner branch. On the contrary, such species as *Sorbus alnifolia*, *Prunus sargentii*, *Acer mandshuricum*, *Juglans mandshurica*, and *Carpinus cordata* received less than 60 of TFI, characterized by the disadvantage of the crooked or forked stem, the wider or deeper crown, and the thicker branch. In the dendrogram produced by cluster analysis, arbitrary value of Euclidean distance 10 divided eighteen species into four distinctive groups, and the typical characteristics of each group were discussed.

Keywords : Natural deciduous forest, Canopy tree, Tree form index, Cluster analysis

---

1) 강원대학교 산림과학대학 : College of Forest Sciences, Kangwon National University, Chunchon, 200-701, Korea

요 약

천연활엽수림에서 자생하는 활엽수종 고유의 생장 특성을 감안하여, 18개 주요 상층 임관 구성 수종을 대상으로 임목 형질을 평가하는 한 방편으로서 林木 形質 指數(tree form index; TFI)를 추정하였다. 선정된 6개의 형질 속성을 4개의 급수로 나누고, 임목 개체의 전반적인 형질에 미치는 영향력을 고려하여 합당한 점수를 부여하였다. 18개 수종에 대하여 속성 별로 점수를 부여하고 百分率로 환산한 후, 각 점수를 합하여 임목 형질 지수를 산출하였다. 각 쌍의 수종별 점수 차이와 18×6 行列을 바탕으로 集落分析(cluster analysis)을 시도하여 수종별로 어떠한 속성들이 공통적인가를 검토하였다.

연구 결과, 임목 형질이 가장 좋은 수종은 TFI 수치 80.8을 기록한 사시나무로 파악되었고, TFI 수치 46.3을 기록한 까치박달나무는 임목 형질이 가장 좋지 않은 수종으로 분석되었다. 70점 이상의 비교적 높은 지수를 획득한 상층 임관 수종들은 사시나무, 거제수나무, 들메나무, 느릅나무 등으로서, 통직하고 완만한 수간, 높은 枝下高, 좁은 樹冠, 가는 가지 등의 특성을 갖는 장점을 지니고 있었다. 반면에, 60점 미만의 낮은 지수를 얻은 수종들은 팥배나무, 산벚나무, 복장나무, 가래나무, 까치박달나무 등으로서, 굽었거나 기울어진 수간, 낮은 枝下高, 넓은 수관, 굵은 가지 등의 성격을 갖는 경향이 있었다. 집락분석 결과에 의한 分類圖에서 Euclidean 距離係數 임의의 값 10은 연구 대상 수종들을 4개의 뚜렷한 樹種群으로 분류하였고, 각 수종군에 대한 임목 형질 특성을 검토하였다.

I. INTRODUCTION

The recent forestry profession in Korea has taken a growing interest in the management and production of the natural deciduous forest, considering ecological implication and increasing hardwood demand. Since the natural deciduous forest is characterized by complicated and diverse stand structure and function, it is required to develop appropriate silvicultural information and technology for the management of the forest. Accordingly, high diversity of tree species in the natural deciduous forest has imposed multi-species and multi-layer uneven-aged stands on our timber management scheme for the forest. However, all of the composed species are hardly able to be managed at once. The better and more desirable tree species are selected to establish the forest for hardwood production partially in terms of tree form.

Tree form, including the shape and size of the crown and the bole, may be considered to be conspicuous attributes to judge the quality of tree, of which each segment is affected in its development by a number of genetic and environmental factors. It is obvious that the general conformation of the crown and bole of a particular tree depends not only upon species, variety, and age, but also the composition, density, site quality, and disturbance antecedents of the stand where the tree is growing. Differently from most of coniferous species which develop single undivided spirelike stem showing excurrent crown form, hardwood species, however, breaking up their stem into a series of lateral branches resulting in unequal development of the crown of a multiple stemmed tree, exhibit deliquescent crown form. It is because deliquescent species are presumed to be phototropic growing toward the direction where there is more light on the crown.

The ideal tree form from an economic point of view is a straight stem that is nearly cylindrical, has minimum taper from base to crown, and has no protruding branch stubs or other defects. By changing the stand density it is possible to improve the rate at which trees are as such favorable conditions. The hardwood species, however, tend to have inherent characteristic tree form in uncontrolled and unregulated natural forest, being able to be compared with each other which one is more desirable or not in term of tree quality for timber production. In Korean natural deciduous forests early successional tree species tend to grow faster and have more desirable tree form for timber production than those of late successional or climax stage(Horn, 1971; Kim, 1993).

The purpose of this paper is to evaluate the quality of inherent tree form for various hardwood species growing in the natural deciduous forest, so as to provide fundamental information for selecting species and establishing managerial criteria in the management of the natural deciduous forest.

Ⅱ. MATERIALS AND METHODS

Noticing the intrinsic growing habit variations of hardwood species which is indigenous to the natural deciduous forest, eighteen tree species in overstory were selected for comparative evaluating tree form so as to develop the tree form index. Even though At least five individuals for each species were sampled for its replication, the most number of samples were 46 individuals in *Ulmus laciniata*. The data were collected mainly in Gariwang-san area, and some few data were from the Experimental Forest of Kangwon National University and Gari-san area.

It is well known that crown and bole forms are largely influenced by the stand density. Nevertheless, since the forests in which this study was carried out were fully occupied canopy and seldom varied in terms of stand density, the authors were able to free from density dependent variables occurring in crown and bole forming process.

Selected six tree form attributes were arbitrarily divided four assessment criteria and given appropriate scores(Table 1). The approach is the summation of the scoring values of corresponding grade for six attributes in the vector of each species. The raw score sums were obtained in this way on a potential scale of 0 to 75. To express these value as tree form index, the sums were converted to percentage of the maximum possible value. The analysis between species and six attributes yielded 18×6 data matrix. Introducing Euclidean distance which was used to measure dissimilarity of obtained scores between each pair of species(Pielou, 1984), the cluster analysis was conducted to classify distinctive species groups. The actual algorithm was based on the generalized clustering procedure by Lance and Williams(1966). Multivariate Statistical Package(MVSP ver. 2.2) which was developed by Kovach(1995) was utilized for the cluster analysis.

Table 1. The basis of score application on the assessment criteria for six tree form attributes

Tree form attributes	Grades	Assessment criteria	Scores
Bole straightness(BS)	Ⅰ	straight or crooked ≤10°	15
	Ⅱ	crooked 11 - 20°	10
	Ⅲ	crooked 21 - 30°	5
	Ⅳ	crooked ≥31°	0
Tree declination(TD)	Ⅰ	≤10° of declination	15
	Ⅱ	11 - 20° of declination	10
	Ⅲ	21 - 30° of declination	5
	Ⅳ	≥31° of declination	0
Crown width(CW)	Ⅰ	<⅓ of total height	12
	Ⅱ	½ - ⅓ of total height	8
	Ⅲ	⅔ - ½ of total height	4
	Ⅳ	>⅔ of total height	0
Bole height(BH)	Ⅰ	>⅔ of total height	15
	Ⅱ	⅔ - ½ of total height	10
	Ⅲ	½ - ⅓ of total height	5
	Ⅳ	<⅓ of total height	0
Branch angle(BA)	Ⅰ	≤60° of branch angle	9
	Ⅱ	61 - 70° of branch angle	6
	Ⅲ	71 - 80° of branch angle	3
	Ⅳ	≥81° of branch angle	0
Branch interval(BI)	Ⅰ	≥2m of branch interval	9
	Ⅱ	1 - 2m of branch interval	6
	Ⅲ	0.5 - 1m of branch interval	3
	Ⅳ	≤0.5m of branch interval	0

Ⅲ. RESULTS AND DISCUSSION

1. Tree Form Index(TFI) Estimation

Eighteen major canopy hardwood species were selected for the study. Table 2 shows the number of sample trees, mean DBH, and mean height for each species. *Juglans mandshurica* had the largest mean DBH of more than 37cm and *Phellodendron amurense* had the smallest mean DBH of less than 18cm. *Populus davidiana* had the tallest individual trees showing more than 20m high, and *Carpinus cordata* had the mean height of less than 13m. Indicated by

Table 2. The number of sample trees and mean diameter and height for 18 hardwood species.

	Samples	DBH(cm)	Height(m)
Acer mandshuricum (AZ; 복장나무)	18	31.8±10.5*	17.1±1.5*
Acer mono (AM; 고로쇠나무)	19	22.7±10.7	16.7±1.9
Betula costata (BC; 거제수나무)	33	25.8± 7.3	19.6±1.8
Betula schmidtii (BS; 박달나무)	5	34.0± 7.2	19.0±1.2
Carpinus cordata (CC; 까치박달나무)	10	21.4±12.5	12.7±3.3
Cornus controversa (CO; 층층나무)	22	27.0± 6.0	17.1±1.8
Fraxinus mandshurica (FM; 들메나무)	23	32.8± 7.2	20.1±2.1
Fraxinus rhynchophylla (FR; 물푸레나무)	11	22.9± 5.9	17.2±2.4
Juglans mandshurica (JM; 가래나무)	8	37.4± 8.9	17.6±2.4
Kalopanax pictus (KP; 음나무)	16	34.1± 7.1	18.8±2.0
Phellodendron amurense (PA; 황벽나무)	5	17.8± 5.1	14.8±2.2
Populus davidiana (PD; 사시나무)	5	29.0± 2.6	20.4±1.4
Prunus sargentii (PS; 산벚나무)	5	25.8± 4.8	16.4±1.2
Quercus mongolica (QM; 신갈나무)	13	32.6±13.7	18.1±2.1
Sorbus alnifolia (SA; 팥배나무)	5	32.2± 8.9	16.8±1.3
Tilia amurensis (TA; 피나무)	7	24.0± 5.5	16.1±2.6
Ulmus davidiana var. *japonica* (UD; 느릅나무)	5	22.6± 6.6	16.2±1.5
Ulmus laciniata (UL; 난티나무)	46	30.7± 9.1	18.7±1.8

* Mean±Standard deviation

the values of standard deviation in Table 2, the mean height of sample trees for each species was less variable than the mean diameter of them. It is because the individual sample trees were taken in overstory layer, and site quality of the study area was fairly high enough to support selected species. Therefore, as trees are getting old, height growth may reach the plateau of sigmoid growth curve more earlier, but diameter increment may continue thereafter.

Taking into account of the distribution and size of diameter and height, leaving the discussion of wood quality and utilization matter not dealt in this paper, most of selected species retain satisfiable production potential as hardwood resources.

On the basis of the adopted assessment criteria for six tree form attributes(Table 1), eighteen tree species were undergone corresponding scores, converted to percentage base for convenient sake, and tree form index(TFI) was the summation of the six scoring values. Table 3 represents undergone scores for six tree form attributes and tree form index in the order of higher values of tree form index.

Table 3. The matrix of percentage values transformed from the average scores of six assessment criteria and tree form indices for 18 hardwood species.

	BS[1]	TD[1]	CW[1]	BH1	BA[1]	BI[1]	TFI[2]
Populus davidiana	20.0	20.0	14.6	12.8	5.4	8.0	80.8
Betula costata	18.2	18.6	12.8	10.1	11.5	7.3	78.5
Fraxinus mandshurica	17.9	19.1	10.9	11.4	10.0	7.5	76.8
Ulmus davidiana var. *japonica*	13.8	13.5	16.0	13.7	8.0	8.0	73.0
Phellodendron amurense	12.0	18.7	12.8	8.0	11.2	6.4	69.1
Fraxinus rhynchophylla	13.9	17.8	11.6	6.1	10.3	7.7	67.4
Tilia amurensis	17.3	20.0	9.6	9.3	7.2	3.2	66.6
Kalopanax pictus	12.5	19.2	9.7	8.3	8.5	6.8	65.0
Acer mono	12.3	17.9	10.4	10.5	8.6	4.4	64.1
Ulmus laciniata	14.6	18.1	9.5	4.8	9.7	6.6	63.3
Quercus mongolica	13.3	19.4	6.2	7.2	10.0	6.7	62.8
Cornus controversa	15.4	16.2	8.9	11.9	4.2	4.9	61.5
Betula schmidtii	13.3	20.0	5.3	6.7	12.0	4.0	61.3
Sorbus alnifolia	13.3	20.0	10.7	6.7	4.0	4.0	58.7
Prunus sargentii	10.7	13.6	7.8	6.7	8.8	9.4	57.0
Acer mandshuricum	9.2	16.5	6.2	6.4	7.6	6.7	52.6
Juglans mandshurica	6.7	14.7	5.3	8.2	6.5	8.0	49.4
Carpinus cordata	9.6	15.3	5.9	4.7	8.0	2.8	46.3

[1] Abbreviations from Table 1.
[2] Tree Form Index

The result showed that *Populus davidiana* had the highest TFI value of 80.8 and *Carpinus cordata* had the lowest TFI value of 46.3. Empirical field observation was largely supported by objective scoring assessment method used in this study. The species which received more than 70 of TFI were *Populus davidiana*, *Betula costata*, *Fraxinus mandshurica*, and *Ulmus davidiana* var. *japonica*, characterized by the advantage of straight and longer bole, the narrower crown, and the thinner branch. On the contrary, such species as *Sorbus alnifolia*, *Prunus sargentii*, *Acer mandshuricum*, *Juglans mandshurica*, and *Carpinus cordata* received less than 60 of TFI, characterized by the disadvantage of the crooked or forked stem, the wider or deeper crown, and the thicker branch.

The form of trees is determined by the differential elongation of buds and branches, and the expression of a particular growth habit is generally related to the phenomenon of apical dominance(Zimmerman and Brown, 1971). Apical dominance channels energy into rapid vertical growth at the correlative expense of lateral branching and canopy spread(Wells, 1976). TFIs of selected species were reflected these patterns of intrinsic growth and development habit. Most coniferous species and some hardwood species like *Fraxinus mandshurica*, *Betula costata*, and *Populus davidiana* in this study, of which main stem or leader outgrows the lateral branches beneath tend to give rise to the excurrent crown and the clearly defined central bole. Also it is an important option in the pioneering way of life because trees of high light requirement can attain a position in the canopy by strongly vertical, excurrent growth, thus diminishing the possibility of being suppressed and shaded.

However, in the majority of hardwood species, notably oaks, maples, walnuts, and many others, the lateral branches grow as fast as the terminal shoots, giving rise to the deliquescent growth habit where the central stem eventually disappears from repeated crooking and forking to form a large spreading crowns(Horn, 1971). In deliquescent trees where the terminal leader is often suppressed, its epinastic effect is lost and lateral branches tend to grow upward at many angles and lengths(Zimmerman and Brown, 1971). Consequently, the species such as *Juglans mandshurica*, *Carpinus cordata*, and *Acer mandshuricum* in this study, whose TFI value was fairly low tended to have crooked and/or forked bole, large and deep crowns, small bole height, and thick branches.

2. Cluster Analysis of Selected Species

Since eighteen species had different set of scoring data for six attributes, cluster analysis was carried out to review which attribute would have been shared among species so as to classify distinctive groups of species possessing similar tree form. Computing average dissimilarity of scores for each pair of species and/or cluster from 18×6 data matrix, the classification process was continued until eighteen species were agglomerated into a single all-inclusive cluster. In the dendrogram produced by pair group average method, arbitrary value of Euclidean distance 10 divided eighteen selected species into four distinctive groups(Figure 1).

Group I consists of *Juglans mandshurica*, *Prunus sargentii*, *Cornus controversa*, *Acer mandshuricum*, *Betula schmidtii*, and *Quercus mongolica*. The species of this group were associated with relatively poor tree quality with lower TFI on the average of 57.4. Since the species, including any other species in this study, have been growing and distributing in dense and fully occupied stand, so that they are presumed to have the restricted crown and maintain somewhat straight and clean bole (Zimmerman and Brown, 1971; Hocker, 1979). Nevertheless, the common concept of density dependent tree quality did not applied to these species. They are typified by crooked or forked stems with large volume of crowns and small clean bole height. Especially large diameter trees of *Juglans mandshurica* and *Quercus mongolica* have played the role of "wolf tree" in the study forest.

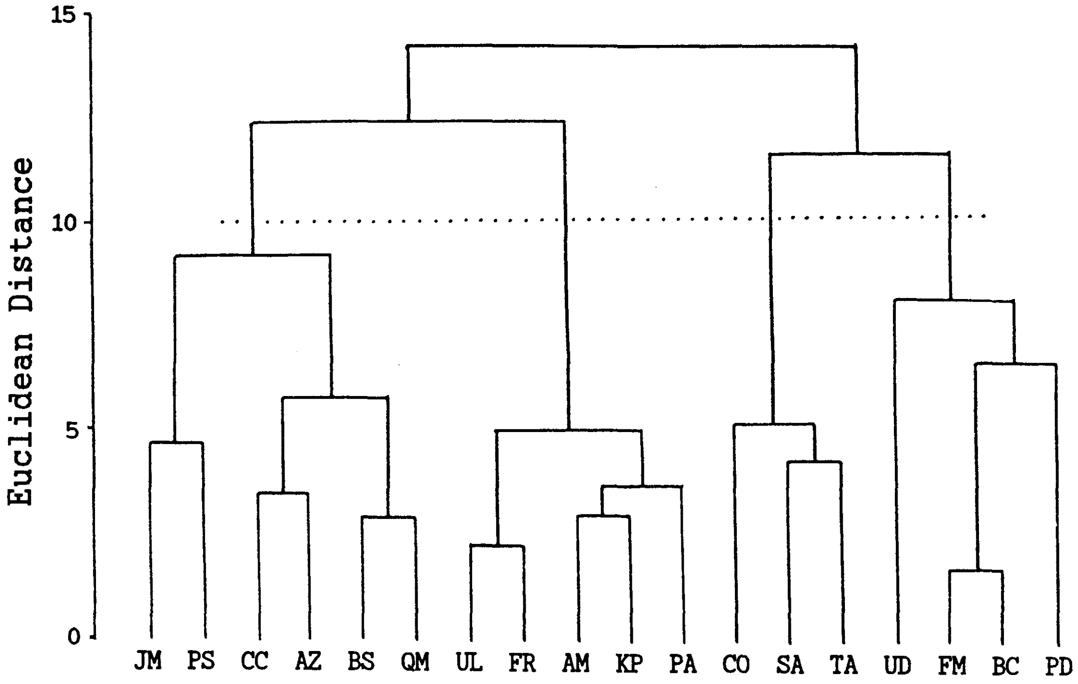

Fig 1. The dendrogram of the scoring relationship for eighteen tree species. The cluster formed by using pair group average method. The Euclidean distance value of 10 resulted four species groups. Letter codes for species are from Table 2.

Group Ⅱ consists of *Ulmus laciniata, Fraxinus rhynchophylla, Acer mono, Kalopanax pictus, Phellodendron amurense.* The characteristics of these species are intermediate between group Ⅰ and group Ⅳ. The average TFI was estimated as 65.6. It may be possible for these species to improve tree form quality by establishing extremely dense stands, then the thinning treatment can accelerate diameter growth rate to produce good hardwood timber.

Group Ⅲ consists of only three species, *Carpinus cordata, Sorbus alnifolia,* and *Tilia amurensis,* appearing to be an outlier, more close linkage to the group Ⅳ in the cluster. This group was distinguished by the relatively narrower branch interval. These species obtained average TFI value of 57.2.

Group Ⅳ consists of *Ulmus davidiana* var. *japonica, Fraxinus mandshurica, Betula costata, and Populus davidiana.* Species which belong to this group have the highest TFI than those of any other groups. All of them are above 70 of TFI on the average of 77.3. The species of this group retain the advantage in terms of external tree quality with the attributes of the large proportion of straight and perpendicular stems, the small amount of crown volume, and upright thin branches. These species are more likely characterized by apical dominance growing habit, consequently exhibiting excurrent tree form, presumed pioneer and/or early successional components under the way of secondary succession after various kinds of disturbances(Wells, 1976; Kim, 1993).

LITERATURE CITED

1. Hocker, H. W., Jr. 1979. Introduction to Forest Biology. John Wiely & Sons, New York. 467pp.
2. Horn, H. S. 1971. The Adaptive Geometry of Trees. Princeton Univ. Press. 144pp.
3. Kim, J. H. 1993. The estimation of climax index for broadleaved tree species by analysis of ecomorphological properties. J. Kor. For. Soc.82(2): 176-187
4. Kovach, W. L. 1995. M.V.S.P.: Multivariate Statistical Package. version 2.2. Kovach Computing Service.
5. Lance, G. N. and W. T. Williams. 1966. A generalized sorting strategy for computer classification. Nature 212:218.
6. Pielou, E. C. 1984. The Interpretation of Ecological Data : A Primer on Classification and Ordination. John Wiely & Sons' New York. 263pp.
7. Wells, P. V. 1976. A climax index for broadleaf forest : an N-dimensional ecomorphological models of succession. Central Hardwood Conference Proceeding. pp131-176.
8. Zimmerman, M. H. and C. L. Brown. 1971. Trees. Structure and Function. Springer-Verlag, New York. 336pp.