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Seral Changes in Floristic Composition during Abandoned Field Succession after Shifting Cultivation

Lee, Kyu Song and Joon-Ho Kim
Department of Biology, Seoul National University

화전 後 묵밭의 식생 천이 진행에 따른 종조성의 변화

이 규 송 · 김 준 호
서울대학교 자연과학대학 생물학과

ABSTRACT

Seral changes in floristic composition during abandoned field succession after shifting cultivation was investigated in eastern Kangwon-Do, Korea. According to the DCA ordination based on the floristic composition, sere of the dominant species was shown as follows: *Digitaria sanguinalis, Persicaria* spp., *Commelina communis* etc. in the annual stage (0~1 years); *Erigeron* spp., *Artemisia* spp., *Rubus crataegus* etc. in the *Erigeron-Artemisia* stage (2~6 years); *Pinus densiflora, Salix* spp., *Miscanthus sinensis, Arundinella hirta* etc. in the shrub - earlier tree stage (10~25 years); *P. densiflora, Quercus mongolica, Spodiopogon sibiricus* etc. in the mid-tree stage (25~50 years); *Q. mongolica, Tripterigium regelii, Lespedeza maximowiczii, Carex siderosticta* etc. in the later tree stage (50~80 years). In mid-tree stage, size-frequency distribution of *P. densiflora* was plotted as a platycurtic curve and that of *Q. mongolica* as a reverse J-shaped curve, which meant *P. densiflora* was thinned through interspecific competition and *Q. mongolica* was regenerated by itself in the later tree stage.

Key words: Abandoned field, Floristic composition, *Pinus densiflora, Quercus mongolica,* Shifting cultivation, Succession

INTRODUCTION

Abandoned fields, called old-fields, are distributed world-wide and thus allow comparison of studies from various geographical regions. A great numbers of studies on the old-field succession have been conducted in United States and other countries (Osboronova *et al.* 1990).

In USA, Oosting (1942) and Bazzaz (1968) studied the general successional trends in North Carolina and Illinois. Keever (1983) pointed out the underestimation of land use history and seed availability for explanation of variation in mechanisms of old-field succession among and within regions in a retrospective view of it for the last 35 years in North Carolina. Monk (1983) discussed the relationship between life form and species diversity in relation to some succession theories in Georgia. Schafale and Christensen (1986) reported the importance of chance factors such as seed rain and localized disturbance in vegetational variation among old fields.

Olson (1987) studied the effects of dispersal mechanisms as the species characteristics determining the different tree species' colonization success in sites with the different properties during abandoned field succession in Sweden. Osboronova *et al.* (1990) observed some basic temporal patterns, and tested several hypotheses of successional theory at the population, community or ecosystem level in the successional development in Czechoslovakia.

Hayashi (1977, 1984) described 4 stages of sequence characterized by the growth form and ecological characteristics of the dominant species in secondary succession of herbaceous communities in Japan. Although the abandoned field successions after shifting cultivation in Korea were investigated by several workers, these studies were focused on the earlier successional stages (Lee *et al.* 1979, Lee 1981, Kang 1982, Ok 1984).

The purpose of this study is to elucidate the seral changes of floristic composition during abandoned field succession after shifting cultivation in eastern Kangwon-Do, Korea.

STUDY SITES

Study sites were selected, within an area of 10 km from north to south and 5 km from east to west, in Chinbu-Myon, Pyongchang-Gun, Kangwon-Do, Korea (37° 30′~37°35′ N, 128°30′~128°35′ E) (Fig. 1). Criteria of site selection, and climatic and geological characteristics were described by Lee (1995) and Lee and Kim (1995). Several environmental factors during abandoned field succession in the sites were described by Lee and Kim (1995).

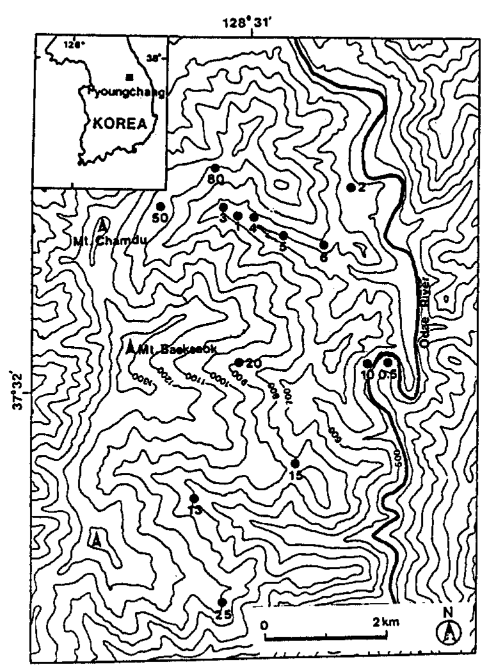

Fig. 1. Map showing the study sites. Numerals stand for the years since abandonment after shifting cultivation.

METHODS

Vegetation was analyzed separately in herb and woody layers during growing season from 1992 to 1994. Twenty 0.5 m × 0.5 m quadrats in herb layer and five 5 m × 5 m quadrats in woody layer were established in each abandoned field. Floristic composition, frequency, coverage and above-ground biomass in herb layer, and floristic composition, shoot density and basal area in woody layer were recorded. Three 10 m × 10 m quadrats in 50 year-old abandoned field and two 20 m × 20 m quadrats in 80 year-old abandoned field were added in consideration of tree height. From the vegetation data, relative coverage (RC), relative frequency (RF), relative biomass (RB), relative density (RD), relative basal area (RBA) and importance value (IV = RC + RF + RB in herb layer, IV = RD + RBA in woody layer were calculated. DCA was performed by CANOCO program in order to predict the direction of abandoned field succession (Ter Braak 1987).

RESULTS

Seral changes in herb species

In DCA ordination carried out for the data of 64 herb species with over 1 in importance value (IV) in each abandoned field, eigenvalues of axis I and II were 0.858 (47%) and 0.584 (32% of total variance), respectively. Older abandoned fields were lacated at the right part of the axis I, and younger ones were located at the left part of the axis I (Fig. 2A). The dominant species in abandoned field succession were divided into 4 groups: *Digitaria sanguinalis*, *Persicaria fauriei*, *Persicaria nodosa*, *Commelina communis*, *Echinochloa crus-galli* and *Panicum bisulcatum* in the annual stage (group A; 0~1 years); *Erigeron*

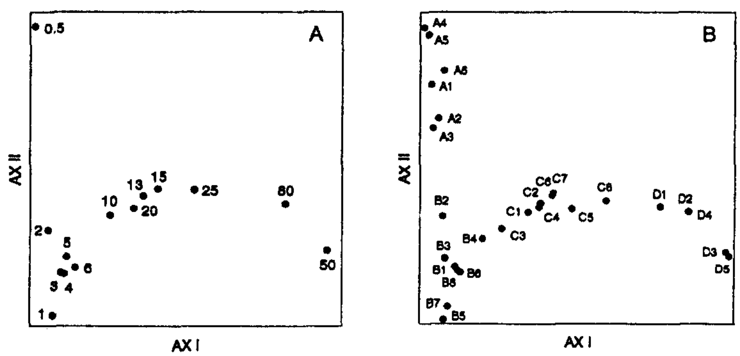

Fig. 2. DCA ordination of 14 abandoned fields (A) and 27 dominant herb species with importance value > 15 in each field (B) based on the data matrix of 64 herb species occurred in 14 fields.

Group A : A1; *Digitaria sanguinalis*, A2; *Persicaria fauriei*, A3; *Commelina communis*, A4; *Persicaria nodosa*, A5; *Echinochloa crus-galli*, A6; *Panicum bisulcatum*,

Group B : B1; *Erigeron annuus*, B2; *Persicaria blumei*, B3; *Erigeron bonariensis*, B4; *Oenothera odorata*, B5; *Alopecurus aequalis* var. *amurensis*, B6; *Artemisia princeps* var. *orientalis*, B7; *Stellaria media*, B8; *Artemisia feddei*

Group C : C1; *Miscanthus sinensis*, C2; *Arundinella hirta*, C3; *Artemisia iwayomogi* C4; *Patrinia scabiosaefolia*, C5; *Lysimachia clethroides*, C6; *Patrinia villosa*, C7; *Onoclea sensibilis* var. *interrupta* C8; *Spodiopogon sibiricus*

Group D : D1; *Syneilesis palmata*, D2; *Ainsliaea acerifolia*, D3; *Carex siderosticta* D4; *Disporum smilacinum*, D5; *Dryopteris crassirhizoma*

Table 1. Correlation coefficients between environmental factors and stand scores of DCA ordination based on herb species data matrix in abandoned fields

Environmental factors	Correlation coefficients		Environmental factors	Correlation coefficients	
	Axis I	Axis II		Axis I	Axis II
Altitude	0.799***	−0.048	Soil pH	0.328	0.206
Slope	−0.195	−0.257	Organic matter	0.881***	0.001
Aspect	0.170	−0.384	Field capacity	0.909***	−0.002
RLI† (Herb layer)	−0.699**	−0.076	Soil N	0.880***	−0.010
RLI† (Shrub layer)	−0.911***	−0.036	Soil P	−0.370	−0.069
Litter depth	0.620*	−0.206	Soil Ca	0.532*	0.097
Litter dry weight	0.840***	0.002	Soil Mg	0.542*	0.232
Soil depth	0.725**	0.341	Soil K	−0.035	0.365
Gravel content	−0.086	0.178	Soil Al	0.689**	0.081
Sand content	0.707**	−0.339	Soil Na	0.069	0.112
Silt content	−0.782***	0.226	Soil Mn	0.552	−0.088
Clay content	−0.152	0.608*			

* significant at 5 % level, ** at 1 % level, and *** at 0.1 % level

† relative light intensity

annuus, *E. bonariensis*, *Artemisia princeps* var. *orientalis*, *A. feddei*, *Oenothera odorata*, *Persicaria blumei*, *Alopecurus aequalis* var. *amurensis* and *Stellaria media* in the *Erigeron-Artemisia* stage (group B; 2~6 years); *Miscanthus sinensis*, *Arundinella hirta*, *Spodiopogon sibiricus*, *Artemisia iwayomogi*, *Patrinia scabiosaefolia*, *P. villosa*, *Lysimachia clethroides* and *Onoclea sensibilis* var. *interrupta* in the shrub or earlier tree stage (group C; 10~25 years); *Syneilesis palmata*, *Ainsliaea acerifolia*, *Carex siderosticta*, *Disporum smilacinum* and *Dryopteris crassirhizoma* in the later tree stage (group D; 50~80 years) (Fig. 2B). Axis I scores of herb ordination were positively correlated with altitude, litter accumulation, soil depth, sand content, organic matter, field capacity, total-N and Al of soil, but were negatively correlated with the relative light intensity (RLI) and silt content. Axis II scores of herb ordination were positively correlated with clay content (Table 1).

Seral changes in woody species

In DCA ordination carried out for the data of 27 woody species having ≧ 5 in IV in each abandoned field, eigenvalues of axis I and II were 0.726 (48%) and 0.442 (29% of total variance), respectively. Older abandoned fields were located at the right part of the axis I, and younger ones were located at the left part of the axis I (Fig. 3A). The dominant species in abandoned field succession were divided into 3 groups: *Rubus crataegifolius*, *Spiraea prunifolia* var. *simpliciflora*, *Sorbaria sorbifolia* var. *stellipila*, *Spiraea salicifolia*, *Salix gracilistyla*, *Rhus chinensis*, *Salix purpurea* var. *japonica* and *Acer ginnala* in the *Erigeron-Artemisia* stage (gro A); *Pinus densiflora*, *Salix hulteni*, *Fraxinus rhynchophylla*, *Maackia amurensis*, *Betula davurica* and *Lespedeza cyrtobotrya* in the shrub or earlier tree stage (group B); *Quercus mongolica*, *Tripterigium regelii*, *Lespedeza maximowiczii*, *Symplocos chinensis* for.

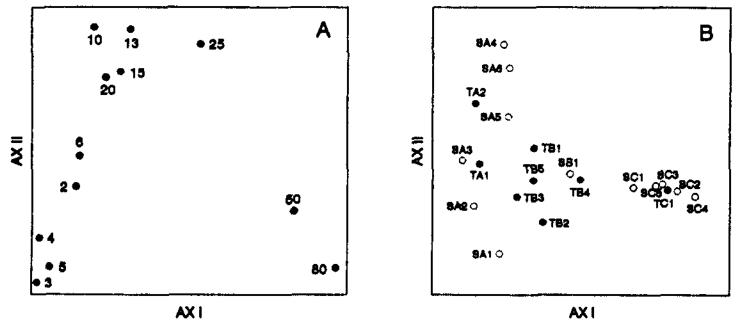

Fig. 3. DCA ordination of 12 abandoned fields (A) and 20 dominant woody species ≧ 10 in IV in each field (B) based on the data matrix of 27 woody species occurred in 12 fields.

Group A : Shrub - SA1; *Rubus crataegifolius*, SA2; *Spiraea prunifolia* var. *simpliciflora*, SA3; *Sorbaria sorbifolia* var. *stellipila*, SA4; *Spiraea salicifolia*, SA5; *Salix gracilistyla*, SA6; *Rhus chinensis*.

Tree - TA1; *Salix purpurea* var. *japonica*, TA2; *Acer ginnala*.

Group B : Shrub - SB1; *Lespedeza cyrtobotrya*.

Tree - TB1; *Pinus densiflora*, TB2; *Betula davurica*, TB3; *Salix hulteni*, TB4; *Fraxinus rhynchophylla*, TB5; *Maackia amurensis*.

Group C : Shrub - SC1; *Tripterygium regelii*, SC2; *Lespedeza maximowiczii*, SC3; *Symplocos chinensis* for. *pilosa*, SC4; *Aristolochia manshuriensis*, SC5; *Stephanandra incisa*.

Tree - TC1; *Quercus mongolica*

Table 2. Correlation coefficients between environmental factors and stand scores of DCA ordination based on woody species data matrix in abandoned fields

Environmental factors	Correlation coefficients Axis I	Axis II	Environmental factors	Correlation coefficients Axis I	Axis II
Altitude	0.742**	0.159	Soil pH	0.189	0.715**
Slope	−0.565	−0.122	Organic matter	0.813**	0.079
Aspect	−0.069	−0.652*	Field capacity	0.894***	−0.034
RLI† (Herb layer)	−0.507	−0.569	Soil N	0.791**	0.166
RLI† (Shrub layer)	−0.810**	−0.317	Soil P	−0.206	−0.381
Litter depth	0.375	0.449	Soil Ca	0.396	0.633*
Litter dry weight	0.690*	0.372	Soil Mg	0.481	0.492
Soil depth	0.737**	0.198	Soil K	−0.148	0.395
Gravel content	−0.133	0.245	Soil Al	0.573	0.555
Sand content	0.664*	0.439	Soil Na	−0.181	0.724**
Silt content	−0.676	−0.428	Soil Mn	0.342	0.277
Clay content	−0.132	−0.216			

* significant at 5 % level, ** at 1 % level and *** at 0.1 % level
† relative light intensity

pilosa, *Aristolochia manshuriensis* and *Stephanandra incisa* in the later tree stage (group C) (Fig. 3B). Axis I scores of woody species ordination were positively correlated with the altitude, soil depth, organic matter, field capacity and soil total-N, but were negatively correlated with the relative light intensity and silt content. Axis II scores were positively correlated with pH and Na in soil (Table 2).

Size-frequency distribution of the two tree species

Seedlings of *Quercus mongolica* invaded for the first time into 6 year-old abandoned field (Fig. 4). Seedlings and saplings of *Q. mongolica* in 13 and 15 year-old abandoned fields located in a ridge occurred much more than those in 10 and 20 year-old fields located in a valley. *Pinus densiflora* was the dominant species in the shrub or earlier tree stages, in which seedlings of *P. densiflora* were very abundant. In 50 year-old abandoned field, size-frequency distribution of *P. densiflora* was depicted as a platycurtic curve and that of *Q. mongolica* as a reverse J-shaped curve (Fig. 4). From these results, *P. densiflora* seemed to be thinned through interspecific competition in the mid-tree stage, while *Q. mongolica* to

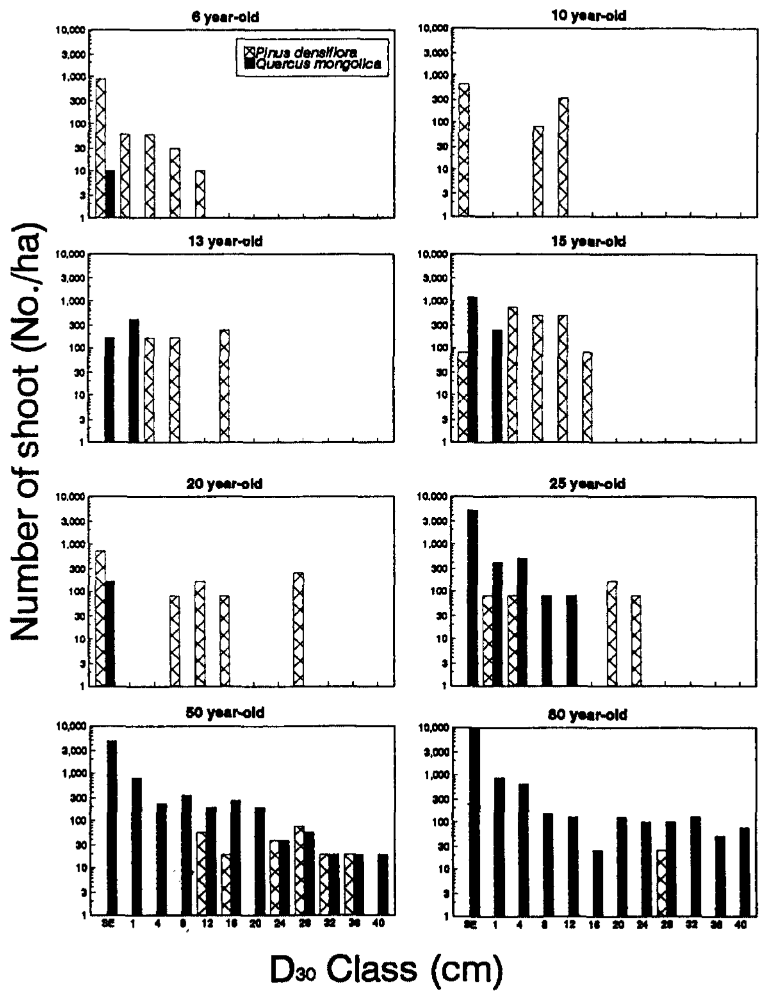

Fig. 4. Distribution of *Quercus mongolica* and *Pinus densiflora* by size class with age of abandoned fields.

be self-regenerating well in the later tree stage.

DISCUSSION

Although the abandoned field succession after shifting cultivation in Korea was investigated by several workers, these studies were focused on the earlier successional stages (Lee *et al.* 1979, Lee 1981, Kang 1982, Ok 1984). From the results of this study and the prior studies, seral changes in floristic composition during abandoned field succession after shifting cultivation in Korea may be synthesized as in Table 3. Park (1966) divided the grassland succession in Korea into 3 types, continental, transitional and maritime type, and classified the abandoned field succession after shifting cultivation as the transitional grassland type. Hayashi (1977, 1984) reported the sequence of dominants in secondary succession of herbaceous communities in Japan as follows; *Chenopodium-Digitaria-Ambrosia-Polygonum-Setaria* (pioneer stage) → *Erigeron-Oenothera* (winter annual stage) → *Artemisia-Solidago* (perennial herb stage) → *Miscanthus-Imperata* (perennial grass stage). This sequence was similar to that in this study.

The first invasion of *Q. mongolica* was observed in the 3 year-old abandoned field in the prior study (Lee 1981), and also in the 6 year-old field in this study. The numbers of established seedlings and saplings of *Q. mongolica* were different among similarly aged aban-

Table 3. Seral change in dominant species in the abandoned field succession after shifting cultivation in Korea. These data were derived from this study and works by others (Lee *et al.* 1979, Lee 1981, Kang 1982, Ok 1984)

Stage (field age, year)	Dominant species
Annual stage (0 ~ 1)	*Digitaria sanguinalis, Persicaria* spp., *Commelina communis,* *Panicum bisulcatum, Alopecurus aequalis* var. *amurensis*
Erigeron - Artemisia stage (1 ~ 6)	*Erigeron* spp., *Artemisia* spp., *Oenothera odorata,* *Cassia mimosoides* var. *nomame, Rubus crataegus*
Shrub stage (6 ~ 15)	*Pinus densiflora, Salix* spp., *Lespedeza cyrtobotrya,* *Acer ginnala, Spiraea* spp., *Rhus chiensis,* *Miscanthus sinensis, Arundinella hirta, Patrinia scabiosaefolia*
Earlier tree stage (15 ~ 25)	*P. densiflora, Salix* spp., *L. cyrtobotrya, Quercus monolica,* *Fraxinus rhynchophylla, M. sinensis, Arundinella hirta,* *Spodiopogon sibiricus*
Mid-tree stage (25 ~ 50)	*P. densiflora, Q. mongolica, F. rhynchophylla,* *Lespedeza maximowiczii, Symlocos chinensis* for. *pilosa,* *S. sibiricus, Lysimachia clethroides*
Later tree stage (50 ~ 80)	*Q. mongolica, Trypterigium regelii, L. maximowiczii,* *S. chinensis* for. *pilosa, Aristolochia manshuriensis,* *Carex siderosticta, Disporum smilacinum,* *Ainsliaea acerifolia, Syneilesis palmata*

doned fields according to their topographic characteristics and surrounding vegetation (Fig. 4). *Quercus* spp. began to colonize in the 15 year-old field in Michigan, and growth rates of those seedlings were greater under previously established vegetation than on the bare ground (Harrison and Werner 1982). Although tree species dominated in the 40 year-old field because colonization and growth rates of those were very low in Illinois and Minnesota (Bazzaz 1968, Inouye *et al.* 1987), canopy of tree layer closed in the 20 year-old field in this study (Lee 1995). In the temperate forests, invading time of later successional species is a variable for the determination of succession rate (Horn 1976). The earlier and later successional species invade simultaneously after disturbance and successional pattern depends on their life cycles (Egler 1954). Leps (1991) insisted that role of chance affecting floristic composition decreased gradually as vegetation developed. In conclusion, succession rate in mountainous regions of eastern Kangwon-Do in this study with relatively small scale, abundant seed source from surrounding vegetation, nutrient rich soil and sufficient precipitation is more faster than that in the abandoned fields located in a plateau with large scale or nutrient poor soil in the United States.

요 약

강원도 평창군 진부면 일대에서 화전 후 묵밭의 식생 천이에 따른 종조성의 시간적 변화를 밝혔다. DCA ordination을 시행한 결과, 천이에 따른 주요 우점종은 1년생식물 단계 (0~1년차)에서 바랭이, 여뀌류, 닭의장풀 등이, 개망초-쑥 단계 (2~6년차)에서 망초류, 쑥류, 산딸기 등이, 관목-초기교목 단계 (10~25년차)에서 소나무, 버드나무류, 참억새, 새 등이, 중기교목 단계 (25~50년차)에서 소나무, 신갈나무, 큰기름새 등이 그리고 후기교목 단계 (50~80년차)에서 신갈나무, 미역줄나무, 조록싸리, 대사초 등의 순으로 바뀌었다. 중기교목단계에서 소나무는 신갈나무와의 경쟁으로 점차 도태되었고, 후기교목단계에서 신갈나무의 크기 등급 분포는 역 J자형을 나타냄으로써 신갈나무 순림이 지속될 것으로 추정되었다.

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