Korean J. Ecol. 18(2) : 243~253, 1995

Seral Changes in Environmental Factors and Recovery of Soil Fertility 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 환경요인의 변화와 토양 비옥도의 회복

이 규 송 · 김 준 호
서울대학교 자연과학대학 생물학과

ABSTRACT

Seral changes in environmental factors and recovery of soil fertility during abandoned field succession after shifting cultivation were investigated in eastern Kangwon-Do, Korea. Relative light intensity of herb and shrub layer decreased gradually until 50 years and increased slightly thereafter. Amount of litter and nutrients derived from it were depicted as a parabola form showing the gradual increment during the first 50 years and slight decrease thereafter. Organic matter, pH value, total-N and Mg of soil were plotted as an early depletion-mid pinnacle form showing the extreme depletion during the first 10 years, abrupt increase in about 20 or 50 years and gradual decrease thereafter. Ca, Al, Mn and Na of soil were depicted as a pinnacle form showing the peak in about 20 or 50 years. Thickness and field capacity of soil increased gradually, but K and total-P did not show any tendency as succession proceeded. The soil fertility, overall capacity of soil nutrients and water for plant growth, was plotted as the early depletion-mid pinnacle form.
Key words: Abandoned field, Fertility, Light intensity, Litter, Recovery, Soil, Succession

INTRODUCTION

Shifting cultivation was well known as an anthropogenic disturbance leading to vegetation denudation, soil erosion and flood in Korea. Therefore, the projects for the rehabilitation and greening in shifting cultivation areas were carried out by the Korean government from 1960s to 1970s (Ho 1975, Lee *et al.* 1979). At present, the mosaic lands composed of croplands, plantations and abandoned fields were observed in the eastern Kangwon-Do, where shifting cultivation was extensively carried out once.

Clements (1916) pointed out the importance of action and reaction during succession, and Tilman (1985) proposed the resource-ratio hypothesis that dominant plant species change along gradient of soil nitrogen versus light during succession. Odum (1969) proposed a model stressing that as ecosystems developed their ability to retain nutrients increased. Vitousek and Reiners (1975), however, argued against biomass increment hypothesis, saying that the ability to hold nutrients was greater in immature watershed ecosystems than in mature ones. It was found out that the former was true in P conservation within ecosystems but the later was true in N conservation during succession (Vitousek 1977, Grimm 1987). In old-field succession, nutrients such as P, Ca and K declined by leaching during the first 10 years (Odum *et al.* 1984). Almost all the litter was contributed by the overstory in hardwood forests and 3/4 of nutrients in the litter was composed with N, Ca and K (Goez *et al.* 1972). Aweto (1981) developed soil fertility index, defined as overall capacity of soil to supply nutrients and water for plant growth during abandoned field succession.

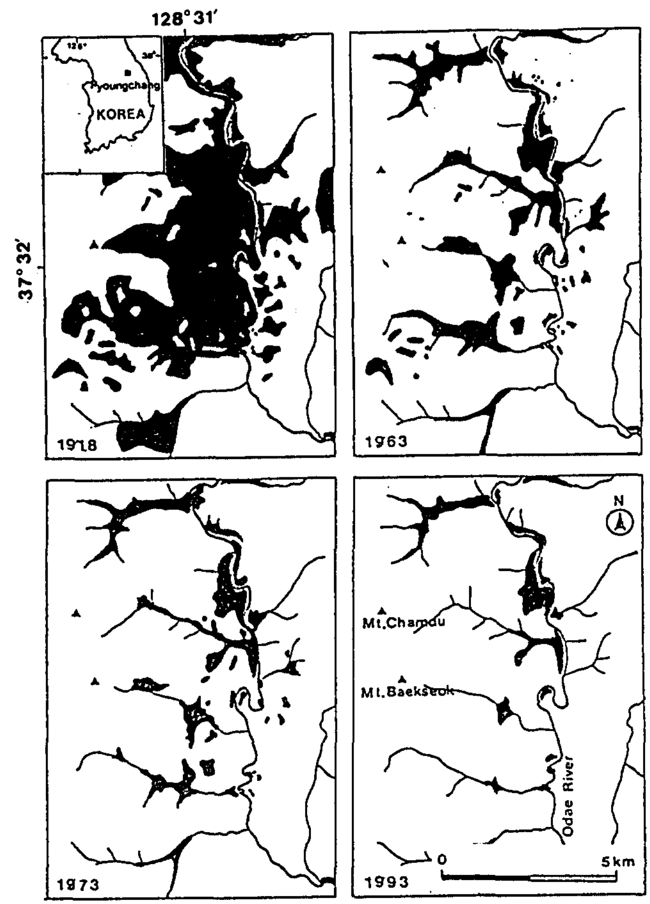

Fig. 1. Changes of cropland area by shifting cultivation in the study area during 1918~1993. Black area indicates cropland by shifting cultivation.

The purpose of this study is to investigate the seral changes of environmental factors such as light intensity, soil physicochemical characteristics and litter characteristics, and to examine the recovery of soil fertility during abandoned field succession after shifting cultivation.

STUDY SITES

This study was carried out in Chinbu-Myon, Pyongchang-Gun, Kangwon-Do, Korea (37°30′~37°35′ N, 128°30′~128°35′ E). Mean annual temperature and annual precipitation were recorded as 6.3℃ and 1,894 mm, resretctively, at Taegwallyong Meteorolo-

Table 1. Altitude, aspect, slope, area and surrounding vegetation of the study sites

Site(YR)	Altitude(m)	Aspect(°)	Slope(°)	Area(m×m)	Surrounding Vegetation
0.5	430	−	0	30×80	cultivated field
1	630	−	0	20×80	mixed scrub in valley
2	590	40	19	20×60	cultivated field
3	650	180	6	150×70	*Pinus plantation*
4	590	190	33	80×50	*Pinus and* Larix plantation
5	530	220	40	70×50	*Pinus* plantation
6	550	140	19	70×80	*Pinus* plantation
10	420	60	32	30×40	old-field, mixed scrub in valley
13	800	80	20	30×50	*Pinus* forest, mixed scrub in valley
15	860	20	10	30×50	*Quercus mongolica* forests
20	890	170	25	20×40	mixed forest in valley
25	990	110	17	50×40	*Quercus mongolica* forests
50	930	110	10	100×100	*Quercus* forests, *Pinus* plantation
80	950	180	5	100×100	*Quercus mongolica* forests

gical Station located at 25 km NE from the study sites. This area shows the climatic characteristics of cold-temperate broad leaved deciduous forest region (Yim and Kim 1983).

Fig. 1 shows a change in cropland area from 1918 to 1993, decreasing after the cessation of the shitting cultivation in the study area. Table 1 represents characteristics of topography and surrounding vegetation of the 14 abandoned fields studied.

METHODS

Abandoned fields aged from 0.5 to 80 years after shifting cultivation were carefully selected in consideration of altitude, aspect, slope, area and surrounding vegetation as described by Lee (1995). Light intensity on surface of the ground of inside and outside of vegetation was determined with a quantum sensor (Cat. No. 550) of quantum meter (Ramsden 550).

Five soil samples were collected from 1~5 cm depths, after removal of litter and top 1 cm soil in each abandoned field. The soil samples were air-dried and then passed through a 2 mm mech sieve for determination of soil texture, field capacity, pH value and organic matter, and through a 1 mm mesh sieves for determination of nutrient content. The thickness of soil and litter layer, soil texture, field capacity, pH value, content of organic matter, total-N, total-P, extractable K, Ca, Mg, Al, Mn and Na of soil and litter were determined by the method described by Lee (1995).

Soil fertility index (SFI) was calculated by the following equation:

$$SFI = (Eld/Hld + Efc/Hfc + Eom/Hom + Etn/Htn + Esc/Hsc) \times 100$$

Where *Hld, Hfc, Hom, Htn* and *Hsc* represent the highest value of litter amount, field capacity, organic matter, total-N and cation content (sum of Ca, Mg, K and Al) of soil among 14 abandoned fields, respectively, and *Eld, Efc, Eom, Etn* and *Esc* represent those in each abandoned field, respectively.

RESULTS

Relative light intensity

Relative light intensity (RLI) was higher under shrub layer than under herb layer through seral stages, and it decreased gradually from 0.5 to 50 years and increased slightly thereafter (Fig. 2).

Litter

Thickness of litter layer and litter amount per unit area were plotted as a parabola form showing the gradual increment during the first 50 years and slight decrease thereafter (Fig. 3). Increasing rate of litter thickness was faster than that of litter amount for the first 10 years, which may be due to sparse accumulation of the stem debris of *Erigeron* and *Artemisia*. Content of N, P and K in litter were the highest in annual stage (0~1 yr abandoned fields), and decreased gradually as succession proceeded except for N (Fig. 4).

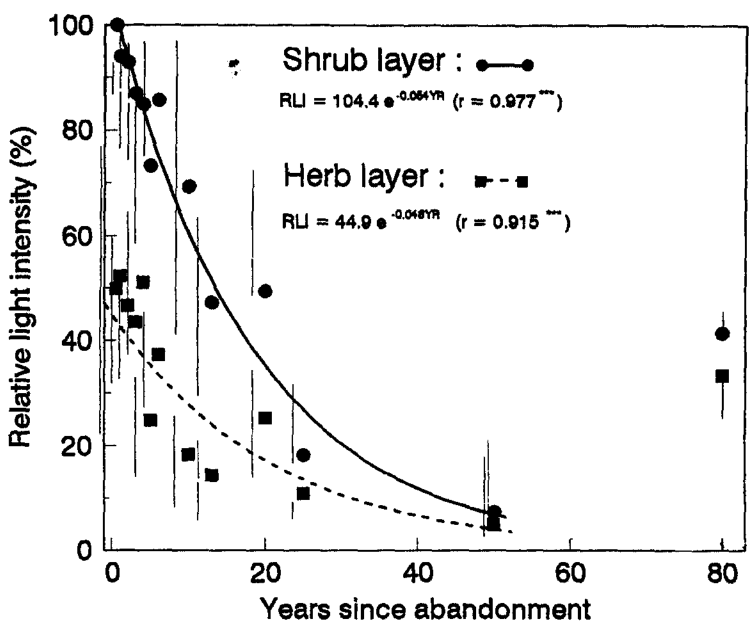

Fig. 2. Seral changes in relative light intensity of shrub and herb layers as succession proceeds in abandoned fields. Regression analysis was conducted during the first 50 years.

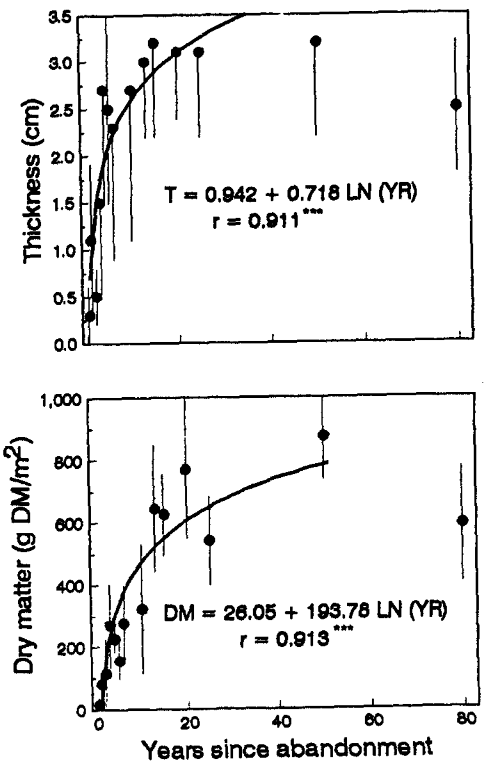

Fig. 3. Seral changes in thickness and dry matter of litter during abandoned field succession. Regression analysis was conducted during the first 50 years.

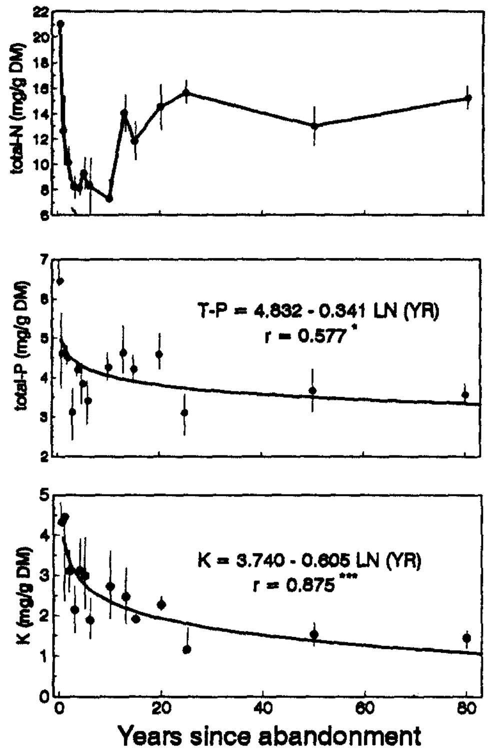

Fig. 4. Seral changes in concentration of total-N, total-P and K in litter during abandoned field succession.

Amount of total-N, total-P, K, Ca, Mg, Al, Mn and Na in litter layer per unit area were depicted as a parabola form (Fig. 5). These nutrients in the later stages increased as much as 2 to 4 folds of those in the earlier stages (0.5~10 years).

Soil

pH value, organic matter, content of total-N and Mg in soil layer were depicted as an early depletion-mid pinnacle form showing the extreme depletion between 5 and 10 years, abrupt increase in about 20 or 50 years and gradual decrase thereafter (Figs. 6 and 7). Content of Ca, Al, Mn and Na were depicted as a pinnacle form showing abrupt increase in about 20 or 50 years and gradual decease thereafter (Fig. 6). K and total-P in soil fluctuate in the earlier stages and then became stable in the later stages (Fig. 6). Soil thickness and field capacity increased linearly as succession proceeded but the later showed early depletion during the first 10 years (Fig. 7). Sand content was depicted as a parabola form, and silt content was depicted as the reversal form of sand content (Fig. 7). Soil texture was sandy loam until the first 13 years, and loamy sand thereafter (Fig. 7).

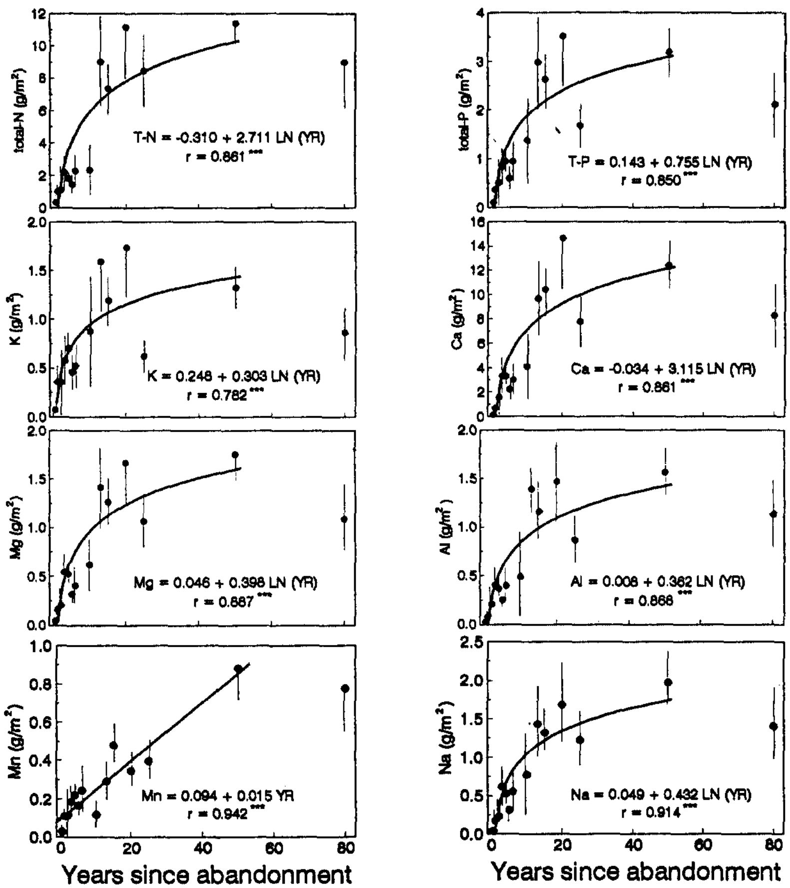

Fig. 5. Seral changes in the amounts of total-N, total-P, K, Ca, Mg, Al, Mn and Na content in litter per unit area during abandoned field succession. Regression analysis was conducted during the first 50 years.

Soil fertility

The soil fertility index (SFI) was depicted as an early depletion-mid pinnacle form showing the extreme depletion during the first 10 years, abrubt increase in about 50 years and gradual decrease in 80 years (Fig. 8).

DISCUSSION

In the foregoing data, decreasing relative light intensity (RLI) through the seral stages is one of the most important factors causing succession (Tilman 1985, Hester *et al.* 1991). Slight increase of the RLI from 50 to 80 years may be due to self-thinning of canopy of *Quercus mongolica*, which is the dominant species in 80 year-old abandoned field (Lee 1995).

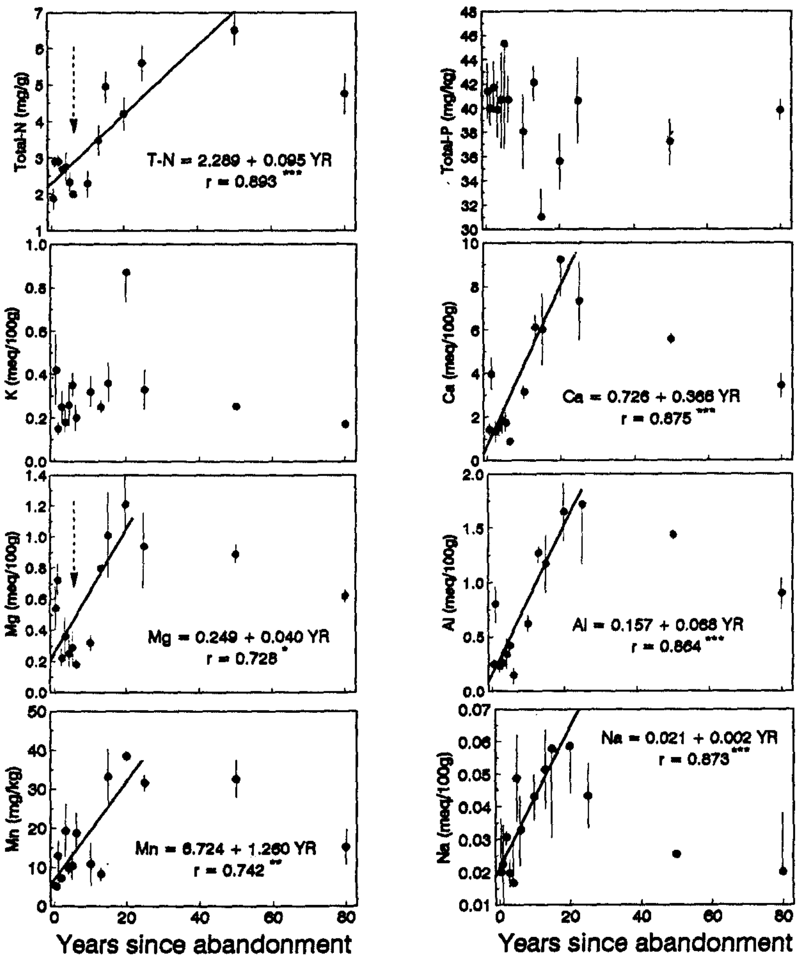

Fig. 6. Seral changes in total-N, total-P, K, Ca, Mg, Al, Mn and Na in soil during abandoned field succession. Regression analysis of total-N was conducted during the first 50 years, and those of Ca, Mg, Al, Mn and Na during the first 20 years. Small dotted arrows of total-N and Mg represent the decline in the earlier stages.

Vitousek and Reiners (1975) and Borman and Likens (1979) insisted that the nutrient incorporation capacity by vegetation was greater in the earlier stages than in the later ones. The same was true in the abandoned field succession in this study because dry matter of litter acccumulated with a parabola form during succession and the most important nutrients such as total-N, total-P, K, Ca, Mg, Al, Mn and Na derived from litter also represented a parabola form (Fig. 3 and Fig. 5). Decrease in litter thickness, litter amount and amount of nutrients in litter layer per unit area in 80 years may be due to the fact that litter decomposition of *Q. mongolica* growing 80 year-old abandoned field was slower than that of *Pinus densiflora* growing in 50 year-old abandoned field (Lee 1995).

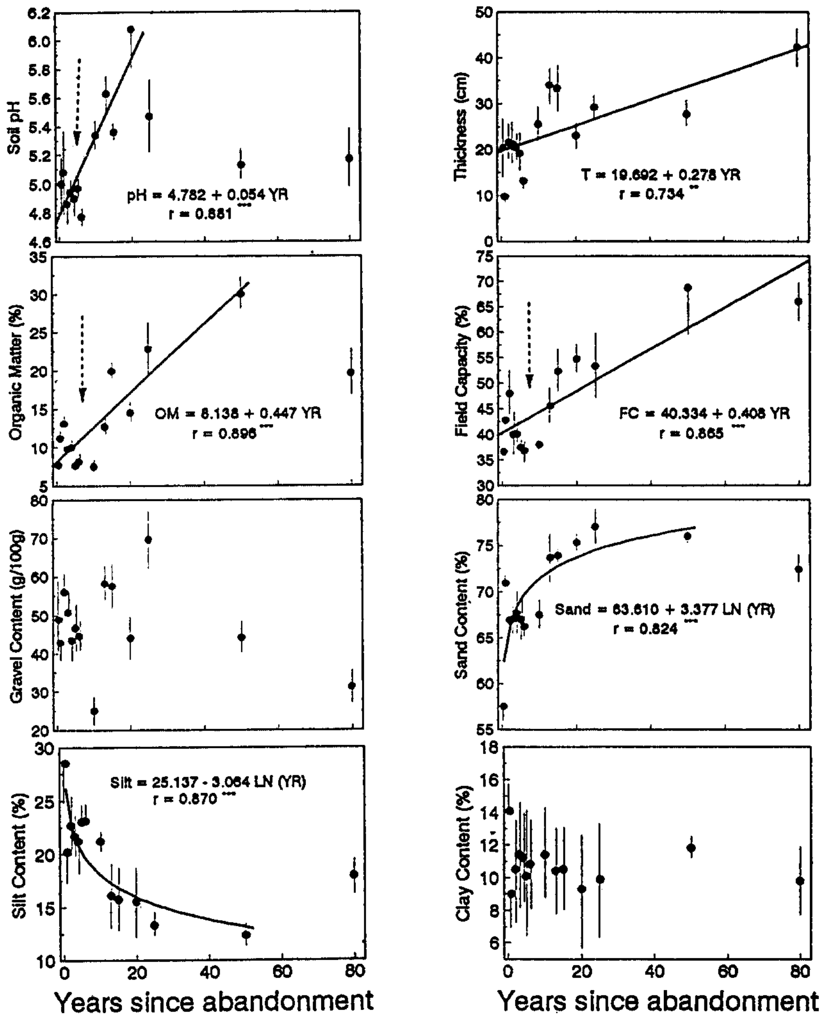

Fig. 7. Seral changes in pH, thickness, organic matter, field capacity, gravel, sand, silt and clay contents in soil during abandoned field succession. Regression analysis of soil pH was conducted during the first 20 years, and those of organic matter, sand content and silt content during the first 50 years. Small dotted arrows of soil pH, organic matter and fied capacity represent the decline in the earlier stages.

Although litter accumulated rapidly in the earlier stages, organic matter, field capacity, soil fertility index, total-N and Mg in soil declined temporarily (Fig. 6 and Fig. 7). It can be explained with the rapid development of herbaceous communities showing the vigorous nutrient uptake by weeds from top soil and much leaching from soil caused by insufficient retention of nutrients in the soil layers (Odum 1960, Aweto 1981, Odum *et al.* 1984). If nutrient uptake by vegetation was less than nutrient supplied by both mineralization of organic matter and atmospheric input, disturbance such as shifting cultivation could allow

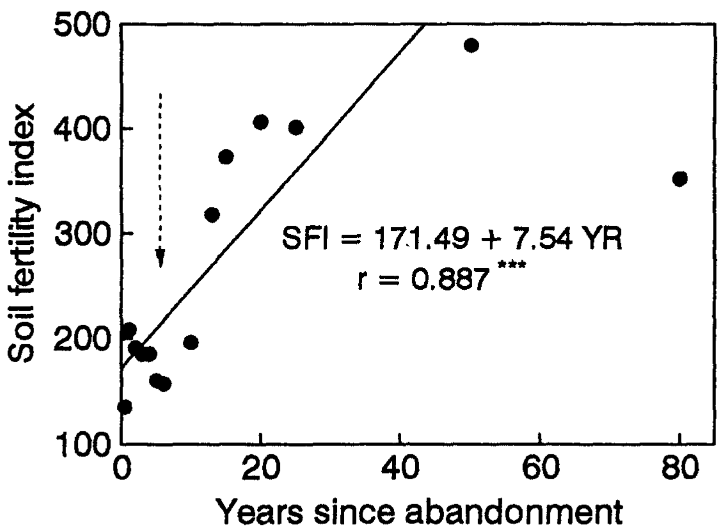

Fig. 8. Recovery of soil fertility index during abandoned field succession. Small dotted arrow in the earlier stages represents the decline.

the rapid nutrient loss from organic matter and soil as shown in the early depletion-mid pinnacle form (Likens *et al.* 1970). Capacity of nutrient retention in soil is closely related to the amount of organic matter (Vitousek and Reiners 1975). Soil organic matter with the early depletion-mid pinnacle form affected on total-N of soil and field capacity, and furthermore, on overall capacity of soil nutrients and water for plant growth (Figs. 7 and 8). Despite temporary depletion in the earlier stages, soil organic matter was very important to plant growth in the middle stages. Johnson and Swank (1973) found out that leaching of Ca and Mg was less in 14-year-old pine watershed than in 50 to 60 year-old hardwood watershed, and they explained such difference to higher productivity of younger pine. Vitousek and Reiners (1975) proposed the biomass increment hypothesis that after the disturbance nutrient retention capacity became the highest when community production was maximal. The nutrient amount of soil was smaller in the later stages when biomass was maximal than in the middle stages.

적 요

강원도 평창군 진부면 일대에서 화전 후 묵밭의 천이에 따른 생육지 환경요인과 토양비옥도의 시간적 변화를 연구하였다. 상대광도는 50년차 묵밭까지 빠르게 감소한 다음 다소 증가하였고, 낙엽층의 발달과 낙엽에서 유리된 영양염류함량은 50년차까지 빠르게 축적된 다음 다소 감소하는 포물선형을 나타내었다. 토양의 pH, 유기물함량, 총-N 및 Mg 함량은 10년차 이내에서 감소한 후 20~50년차에서 급격히 증가한 다음 80년차에서 다소 감소하는 초기감소-중기첨탑형을 나타내었고, Ca, Al, Mn 및 Na 함량은 20~50년차에서 최대값을 보이는 첨탑형을 나타내었다. 토

심과 포장용수량은 지속적으로 증가하였고 총-P와 K 함량은 뚜렷한 경향성이 없었다. 식물생장을 위한 영양염류와 수분함량을 종합적으로 나타내는 토양비옥도는 초기감소-중기첨탑형을 나타내었다.

LITERATURE CITED

Aweto, A.O. 1981. Secondary succession and soil fertility restoration in south-western Nigeria. II. Soil fertility restoration. J. Ecol. 69: 609-614.

Bormann, F.H. and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York. 253p.

Clements, F.E. 1916. Plant succession: An analysis of the development of vegetation. Carnegie Inst. Fub. 242, Washington. D. C. 512p.

Grimm, N.B. 1987. Nitrogen dynamics during succession in a desert stream. Ecology 68: 1157-1170.

Goez, J.R., G.E. Likens and F.H. Borman. 1972. Nutrient content of litter fall on the Hubbard Brook experiment forest, New Hampshire. Ecology 53: 769-784.

Johnson, P.L. and W.T. Swank. 1973. Studies of cation budgets in the southern Appalachians on four experimental watersheds with contrasting vegetation. Ecology 54: 70-80.

Hester, A.J., J. Miles and C.H. Gimingham. 1991. Succession from heather moorland to birch woodland. I. Experimental alteration of specific environmental conditions in the field. J. Ecol. 79: 303-315.

Ho, U.Y. 1975. An analytical study of the problems involved in the project to rehabilitate the illegal field burning cultivators in Gangweon Do. Jour. Korean For. Soc. 28: 50-66.

Lee, K.S. 1995. Mechanisms of vegetation succession in abandoned fields after shifting cultivation in Chinbu, Kangwon-Do. Ph.D. Thesis. Seoul National University. 237p.

Lee, W.C., C.J. Kim and S.K. Chon. 1979. Studies on secondary succession at early stage in deserted land of shifting cultivation in Gangweon-do. Bulletin of the Korean Association for Conservation of Nature I: 145-166.

Likens, G.E., F.H. Bormann, N.M. Johnson, D.W. Fisher and R.S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecol. Monogr. 40: 23-47.

Odum, E.P. 1960. Organic production and turnover in old-field succession. Ecology 41: 34-49.

Odum, E.P. 1969. The strategy of ecosystem development. Science 164: 262-270.

Odum, E.P., J.E. Pinder III and T.A. Christiansen. 1984. Nutrient losses from sandy soils during old-field succession. American Midland Naturalist 111: 148-154.

Tilman, D. 1985. The resource-ratio hypothesis of plant succession. American Naturalist 125: 827-852.

Vitousek, P.M. and W.A. Reiners. 1975. Ecosystem succession and nutrient retension: a hypothesis. BioScience 25: 376-380.

Vitousek, P.M. 1977. The regulation of element concentrations in mountain streams in the northeastern United States. Ecol. Monorgr. 47: 65-87.

Yim, Y.J. and S.D. Kim. 1983. Climate-diagram map of Korea. Korean J. Ecology 6: 261-272.

(Received 29 April, 1995)