Korean J. Ecol. 19(4) : 305~320, 1996

Biomass Changes of a Human-influenced Pine Forest and Forest Management in Agricultural Landscape System

Hong, Sun-Kee[*] and Nobukazu Nakagoshi

Department of Environmental Studies, Hiroshima University,
Higashi-Hiroshima 739 Japan

인간간섭하의 소나무림의 현존량변화와 농촌경관시스템내에서의 산림관리

홍 선 기[*] · 中越信和

일본 히로시마대학교 종합과학부 환경연구과

ABSTRACT

It is necessary to obtain information about the productivity of the human-influenced forest and to understand the consumption of biomass resources in secondary forest in order to examine the resource flux by human activity in rural landscape. Thus the aims of this study were to elucidate the biomass and their use of secondary *Pinus densiflora* forests and to discuss sustainable utilization of secondary forests in rural landscape system. This study was carried out in Yanghwa-ri, Kongjugun, Chungcheongnam-do, central Korea. The changes of growth rate and aboveground biomass of a pine forest for 2 years were analyzed to understand forest management regimes in rural pine forests. Through allometric equations deduced from 25 sample trees, biomass was estimated. The biomass increase of pine forest was approximately 16.36 t/ha/yr in the unexploited stand and 12.24 t/ha/yr in the exploited stand. These were nearly equal to those of natural pine forests in central Korea. This result proved that human-influenced pine forest in rural landscape as well as the natural one has high potentiality to provide forest products. Making graveyard in forest-land was the important disturbance and land-use which currently occurring in rural landscape in the study area. Finally, we presented some forest management for sustainable and positive uses of secondary forests as one of the local energy resources in terms of the holistic landscape-ecological view.

Key words: Agricultural landscape system, Biomass, Growth rate, Human activity, Pine forest

---

[*] Current address: Department of Biology, Seoul Women's University, Nowon-Ku, Seoul.
E-mail : *pinehong@soback.kornet.nm.kr*

INTRODUCTION

The estimation of plant biomass (standing crop) and net primary production (NPP) is fundamental to understanding processes in forest ecosystems, because all food chains in the ecosystem begin with plant materials. The change of biomass, moreover, provides an important measure of total human activity for energy use (Odum and Turner 1991). Changes in biomass and NPP may also be used to assess successional trends and dynamics in different forest ecosystems after human or natural disturbances (Shidei and Kira 1977, Peet 1981, Knight 1991, Tadaki 1991).

Many studies about plant biomass or productivity have been concerned with the management and utilization of forest as one of the natural resources. Recently, sustainability in a broad sense has become an issue in the world resource management (*e.g.* Turner 1993), especially for forest landuse (Noss 1993). Such studies reflect the fact that sustainable utilization of limited natural resources must be appropriate in socio-economic terms while minimizing ecological damage (Zonneveld 1990, Hobbs and Saunders 1993). Forest clearance by human activity also gives diverse habitats for species colonization, nutrient movement, water flux, and other ecological interactions between landscape elements (Burel and Baudry 1990). For these reasons, many recently emerged studies concerning biomass, productivity and forest-cutting are closely related with the causes of human-nature complex (Franklin and Forman 1987). Human activity, therefore, must be considered as one of components influencing forest ecosystem or landscape (McDonnell and Pickett 1993), especially in a secondary vegetation.

Recently scientists have begun to study biomass and NPP of various forest ecosystems to obtain accurate information on commercial timber production and renewable energy sources in Korea. Red pine (*Pinus densiflora*) is one of the representative tree species of the secondary forest in Korea (Rim *et al.* 1991), and it has played an important role in sustainable production of plant materials such as timbers, fuels and organic fertilizer for agriculture (Kim *et al.* 1981, Nakagoshi and Rim 1994). Several papers on the biomass and productivity of pine forests are now available (Kim and Yoon 1972, Lee 1985, Lee *et al.* 1985, Kim *et al.* 1988, Park and Kim 1989, Park and Lee 1990, Lee and Park 1991). These reports, however, deal with natural forests that occupy only a small part of the total forest cover in Korea. There are few studies on secondary pine forests which have been sustained under the traditional management or human exploitation in Korea.

To estimate forest economic prospect, it is necessary to obtain information about the productivity of the human-influenced forest and to understand the consumption of biomass resources in the secondary forest. Thus the aims of this study were to elucidate the biomass and their use of secondary *Pinus densiflora* forests and to discuss sustainable utilization of secondary forests in rural landscape system.

METHODS

Study area

The investigated area lies in Yanghwa-ri, Kongju-gun, Chungcheongnam-do, Korea (lat. 36°23′ N, long. 127°12′ E) (Fig. 1). The annual mean temperature and precipitation are 12.2 ℃ and 1,319mm, respectively, in Taejon near Yanghwa-ri. In terms of thermal climate condition, the area is located in the southern part of the deciduous broad-leaved forest zone (Yim and Kira 1975).

A small section of the farm village, Yanghwa-ri lies in a basin surrounded by the mountainous ranges of Mt. Kyeryong (845m above sea level) including a part of the national park. The soil was mainly derived from granite, and generally is poor in soil nutrients. The forest covers 458.5 ha of the whole area of 773 ha, and consists mostly of private pine forest. Cultivated field and residential areas cover 230.1 ha of the whole section (Hong *et al.* 1995). The harvesting operation for the estimation of biomass was carried out in the experimental forest of Chungnam National University, Puyo near Yanghwa-ri (Fig. 1).

Plot environment and soil properties

The field study was carried out from 1991 to 1993. An exploited stand, a pine forest including graveyards, was selected in Yanghwa-ri (Fig. 2). An unexploited stand (no graveyard and abandoned from human activity for approx. 3 years) was also selected near the exploited stand. A 20×50 square meter quadrat plot was set up in each stand (Fig. 2), and a tree census for all woody stems over 3m in height was carried out in both plots.

The relative light intensities were measured through hemispherical photography using a fisheye lens (Nikkor Auto f=1:2.8, 8mm) (Madgwick and Brumfield 1968). Total illuminance was estimated by overlaying a grid on the hemispherical photographs of a forest canopy. It is then possible to estimate the percentage reduction of illuminance by

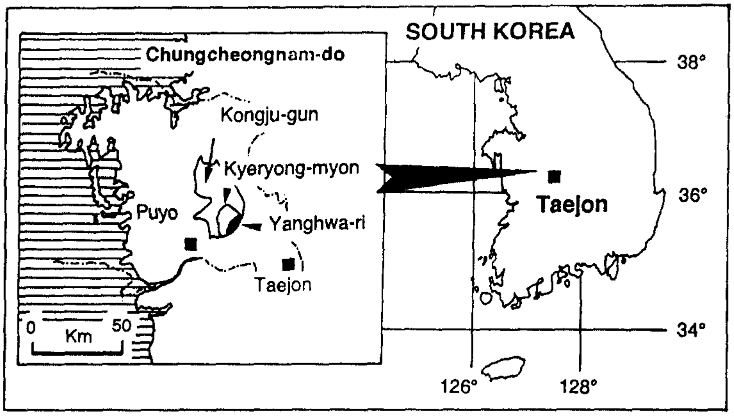

Fig. 1. Locations of Yanghwa-ri and Puyo and the investigated areas.

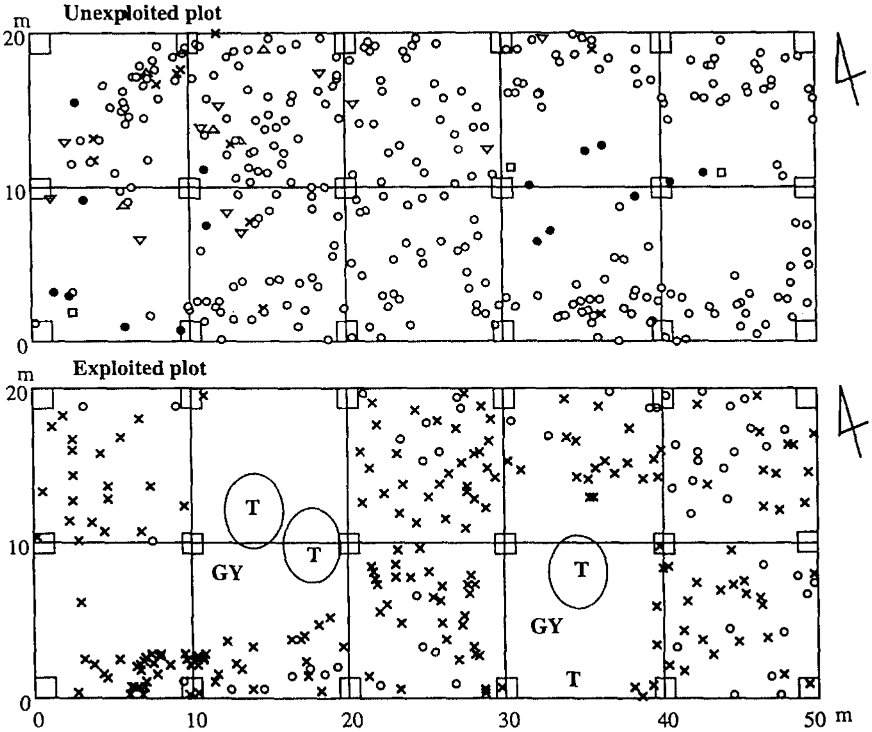

Fig. 2. The distributions of main trees over 3m in height in both pine forests in Yanghwa-ri. Open circle; original *Pinus densiflora* in 1991, Cross; damaged *Pinus densiflora* in 1993. Closed circles; *Pinus rigida*, Triangle; *Alnus firma*, Reverse triangle; *Robinia pseudoacacia*, Small box; *Quercus variabilis* in 1991. Plus; damaged stem of those species in 1993. Big boxes are measuring sites of soil properties and RLI*p*. GY and T mean graveyard and tomb, respectively.

counting the segments that are clear and those which are obstructed (Anderson 1964).

To examine the soil properties, eighteen soil samples (each of 200g) of A horizon under the organic horizon (including surface litter and fermentation layers) were ramdomly sampled in each pine stand (Fig. 2). The pH was determined in a 1:2.5 soil:water suspension using a glass electrode assembly. Total nitrogen and organic carbon contents were determined by the micro-Kjeldahl method and loss on ignition. The ratio of the weight of organic carbon to the weight of total nitrogen in the soil (C/N ratio) was obtained by dividing the percentage of organic carbon by the percentage of total nitrogen.

Growth rates of trees

The growth rates of the trees were estimated in the same site where population structure of pine was examined previously (Hong *et al.* 1993). A census of trees above 3m in height was carried out in Oct., 1993 in the same way as in Oct., 1991. Forest managements like cutting of stems and branches, or collection of litters to the plots and pines was recorded through this second tree census. Annual change of $D^2 \cdot H$ data derived from diameter at breast height (DBH) and tree height (H) was used for measuring of relative growth rate (RGR) in this study.

Measurement of biomass

Estimation of pine biomass was carried out according to the following procedures. The felling operation was carried out in Aug., 1992 according to standard sampling methods (Kim and Yoon 1972, Kim 1976, Lee and Park 1986, 1991, Park and Kim 1989, Park and Lee 1990). Twenty-five sample trees of *Pinus densiflora* were selected at random in the pine forest of the University forest of Puyo near Yanghwa-ri (Table 1).

Each sample tree was felled at 10cm height above ground surface, and the trees were divided into the following four components: bole, branch, foliage and cone. The boles were cut into 1m long logs. The fresh weight of the sample was determined by weighing and

Table 1. Data of sample trees of *Pinus densiflora* for estimation of allometric equation of biomass shown in Table 2

No.	DBH(cm)	H(m)	Dry weight (kg)						
			Cone	Foliage	Live branch	Dead branch	Bole-wood	Bole-bark	Total
1	3.10	4.63	<0.01	0.06	0.15	0.03	0.54	<0.01	0.87
2	3.85	7.22	0.02	0.19	0.08	0.05	1.53	0.03	2.00
3	3.98	4.98	<0.01	0.21	0.16	0.04	0.96	0.01	1.41
4	4.00	7.09	<0.01	0.13	0.10	0.04	1.57	0.03	2.01
5	4.15	4.50	–	0.12	0.24	0.05	0.79	0.01	1.29
6	6.60	6.80	0.01	0.31	0.49	0.12	2.69	0.04	3.67
7	6.95	6.12	<0.01	0.36	1.14	0.05	2.47	0.04	4.20
8	7.50	7.60	<0.01	0.63	1.11	0.12	5.08	0.11	6.67
9	9.38	7.60	0.03	0.82	1.28	0.19	7.12	0.13	8.85
10	9.70	7.60	0.02	0.97	1.08	0.19	7.06	0.10	9.33
11	10.50	7.80	0.06	1.00	3.00	0.15	8.64	0.15	11.96
12	10.75	9.80	0.03	1.05	1.65	0.50	9.91	0.14	12.85
13	12.45	9.20	0.11	1.14	2.36	0.87	12.77	0.20	16.49
14	13.60	9.80	0.15	2.44	4.49	0.08	11.53	0.19	18.33
15	14.95	10.90	0.06	1.48	5.46	0.93	19.28	0.24	26.17
16	15.60	9.90	0.06	0.89	4.01	0.99	14.87	0.24	45.08
17	16.50	8.00	0.14	1.92	8.22	2.64	19.22	0.32	29.95
18	17.90	10.70	0.08	4.14	9.28	1.92	25.80	0.38	39.87
19	19.35	70.90	0.20	1.55	9.51	1.60	25.49	0.37	53.25
20	19.50	7.60	0.22	1.81	6.21	2.60	23.45	0.60	31.12
21	20.50	7.60	0.26	3.06	11.46	1.24	22.01	0.62	33.73
22	21.60	7.80	0.17	1.47	16.11	1.02	25.80	0.49	40.66
23	22.80	7.60	0.25	9.92	19.69	1.95	32.02	0.62	56.69
24	23.50	10.00	0.33	8.78	22.07	0.93	40.42	1.00	64.44
25	25.25	6.70	0.15	1.36	18.87	0.80	37.51	0.53	52.31

summing each component. A 1.5 to 2.5cm thick discs from every 1m section of bole stem and samples of other components were taken to Chungnam National University, Taejon. About 20 to 25% by weight of each individual tree component was sampled for dry weight analysis in the laboratory. Root samples could not be taken because of the hard rock surrounding the root system. For branches, live and dead branches were separated. All sampled components were put in paper bags and dried at 80 to 90℃ until their weight became constant. Dry weights of each component were directly used in the calculation of the biomass of original tree individuals.

Estimation of above-ground biomass

The biomass of the forest stand was calculated by allometric equations (Ogawa *et al.* 1968, Whittaker and Woodwell 1968, Zavitkovski 1976) based on local experience in Korea (Kim and Yoon 1972, Kim 1976, Lee and Park 1986, 1991, Park and Kim 1989, Park and Lee 1990). The generalized equations used in those studies were following two types:

$$\log Wt = a + b \log D^2 \cdot H \quad (1),$$

$$\log Wt = a + b \log D + c \log H \quad (2),$$

where Wt is oven dry weight of each component in kg, D is diameter at breast height in cm, H is tree height in m, and a, b, and c are parameters.

Estimations of above-ground biomass of *Pinus densiflora* forest were accomplished in several mature pine plantations and natural forests using equation (2) (Lee and Park 1986, 1991, Park and Kim 1989), and in secondary forests using equation (1) (Kim and Yoon 1972, Park and Kim 1989).

After a statistical test of these two equations, the estimation of biomass of pine forests was compared by using the allometric equation (1) which had a larger coefficient of determinant (r^2) to the estimation of the total aboveground biomass than that of equation (2) (Table 2). The biomass of other tree species was also estimated by equations introduced from the following studies: *Pinus rigida* (Kim 1976) and other broad-leaved tree species (Forestry Research Institute 1987).

RESULTS

Stand characteristics of *Pinus densiflora* forest

Tables 3 and 4 present an analysis of the stand characteristics of *Pinus densiflora* populations in Yanghwa-ri. The stand age was about 18.9 years old in the unexploited plot and 27.1 years in the exploited plot. The tree density of the plots, 1,730 and 2,350 stems/ha reflects a vigorous regeneration of pine forest in the investigated area. An analysis of the age and size structure of the plots offers some information about the regeneration pattern. Those pine forests were regenerated about 40 years ago and then sustained their stand characteristics by means of forest management (Hong *et al.* 1993).

There is management regime in or around the forests. Under this old tradition, the graveyard was constructed in a private forest (Fig. 2). Owners of graveyard manage the surrounding of the graveyard ground by traditional forest practices, and then the harvested plant material is used for fuel and green manure. This management often influences the regeneration efficiency of the undergrowth under the pine canopy.

Table 2. Allometric regressions for sample trees of *Pinus densiflora* in Yanghwa-ri. Equation: $Wt=a(D^2 \cdot H)^b$ where Wt is oven dry weight of each component in kg, D is DBH in cm, and H is tree height in m

Tree components	a	b	r^2
Cone	0.000087	0.913	0.795*
Foliage	0.003793	0.804	0.860*
Dead branches	0.000533	0.940	0.820*
Live branches	0.000959	1.136	0.937*
Bolebark	0.000273	0.912	0.962*
Bolewood	0.021727	0.870	0.989*
Total	0.026424	0.901	0.989*

* $p<0.001$ in F-test in ANOVA.

Table 3. The traits of *Pinus densiflora* populations in two plots in Yanghwa-ri

Plots	Tree density	Age Mean±SD	Tree height Mean±SD	DBH Mean±SD	Sum of growing stock ($D^2 \cdot H$)
Unexploited	2350	18.9±3.5	4.2±0.8	6.8±3.1	607077.3
Exploited	1730	27.1±3.7	6.4±1.8	11.1±5.2	1936708.1

* All data of *Pinus densiflora* is counted over 3m in height per 1ha.

The good light of sparse forest gives a chance for the light-demanding plants such as *Lespedeza cyrtobotrya, Rhododendron mucronulatum, Carex humilis* and *Miscanthus sinensis* var. *purpurascens* to grow on the forest floor (Table 4). The *Pinus densiflora* forests in this area, therefore, are in an early successional stage (Hong *et al.* 1995).

The C/N ratio was about 31.5 and 39.1 in the unexploited plot and the exploited plot, respectively. Compared to the mean values for the whole pine forest of Korea (Rim *et al.* 1991), our data are low. It means that total nitrogen of soil in the study area is less than

Table 4. General features of plots surveyed in Yanghwa-ri. RLI*p* is a relative light intensity measured by hemispherical photography

		Unexploited	Exploited
Soil properties	pH	4.24±0.10*	5.10±0.16
	C/N(%)	31.47±14.35	39.08±5.12
Light condition	RLI*p* (%)	39.3±5.3	42.2±4.8
Herb layer	Height (m)	0.7±0.1	0.5±0.2
	Dominant plant	*Lespedeza,* *Carex,* *Smilax,* *Robinia,* *Miscanthus*	*Zoysia,* *Quercus,* *Lespedeza,* *Carex*
Litter layer	Coverage (%)	38.0±14.4	43.3±12.5

* Mean±SD

that of other regions. It is due to the low decomposition of soil organic matter by microbes induced from dry soil (Miller and Donahue 1990). In general, a granite soil tends to have high pH. Compared to the natural pine forest (Lee and Park 1991), the values of pH in both plots are less acidic. Such soil properties may result from a poor forest floor derived from the irregular disturbance on the forest floor through practices such as litter raking and weeding. The soil pH in the exploited site including many gravemound, especially, was less acidic than that of unexploited site, possibly because of the mixture of calcium carbonate in soil when the mound was constructed.

Growth rate of *Pinus densiflora* forest for 2 years

Relative growth rate (RGR) of pine population was estimated from the census data of all trees in different years. Fig. 2 shows a distribution map of pine forests in Yanghwa-ri. Loss of biomass was found in both pine plots. Natural thinning of young pines under the canopy occurred in the unexploited plot. The main cause of biomass loss in the exploited plot was the removal of trees by human, for example cutting, felling and destruction by heavy machine to construct a new graveyard. When new graves were constructed, plants were cut down besides well-grown and good shaped pines. Table 5 shows growth rate of dominant tree species in pine forests for 2 years.

The trees of the unexploited plot showed a large RGR in Yanghwa-ri. Nitrogen-fixing trees such as *Robinia pseudo-acacia*, *Alnus firma*, and alien *Pinus rigida* showed a higher height growth than that of *Pinus densiflora*. The light conditions of the unexploited plot may contribute to the good growth of oaks. Light availability in forest canopy is the most important growth factor for mature trees (Oliver and Larson 1990) as well as seedlings and saplings (Grime and Jeffrey 1965). Thus both pine forests in Yanghwa-ri contain appropriate places for growth of the above-mentioned woody plants as well as pines which

Table 5. A dynamics of growth rates of main trees in *Pinus densiflora* forests for 2 years in the study plots

Plots	Main trees[1]	Propor -tions[2] (%)	DBH (cm, Mean±SD)		Height (m, Mean±SD)		RGR of $D^2 \cdot H$ (Mean±SD)
			91'	93'	91'	93'	
U	Pd	83.1	7.02±2.99	7.94±3.38*	4.27±0.84	4.81±0.83*	0.08±0.05
	Pr	9.6	9.49±2.30	11.11±2.74*	4.46±0.70	5.35±0.67*	0.11±0.05
	Af	6.4	6.22±8.55	6.72±8.38^{NS}	5.09±2.87	6.25±3.01***	0.13±0.13
	Rs	0.6	2.75±1.09	3.68±1.18*	3.89±0.98	4.49±1.03**	0.17±0.14
	Qv	0.3	3.67±1.09	4.83±1.27^{NS}	4.07±0.91	4.67±1.20^{NS}	0.15±0.12
E	Pd	100.0	12.99±4.90	13.89±5.17*	6.92±1.45	7.82±1.55*	0.06±0.02

[1] All tree species over 3m in height. [2] These proportions are counted by growing stocks ($D^2 \cdot H$) of main tree over 3m in height. *; $p<0.001$, **; $p<0.01$, ***; $p<0.05$, NS; not significantly different in t-test. U and E mean Unexploited and Exploited plot, respectively. Pd; *Pinus densiflora*, Pr; *Pinus rigida*, Rs; *Robinia pseudoacacia*, Af; *Alnus firma*, Qv; *Quercus variabilis*.

demand for sunlight.

Only well grown good-shaped pines remained in the exploited plot in 1993 and they showed a smaller RGR than the unexploited plot in spite of open forest condition. This is probably due to the aging of these old pines left for aesthetic beauty around new graveyards and to soil water stress.

Changes of biomass

The allometric relationship between $D^2 \cdot H$ and the dry weight of each component of pines was derived from data obtained from sample trees (Table 2). The coefficient of de-

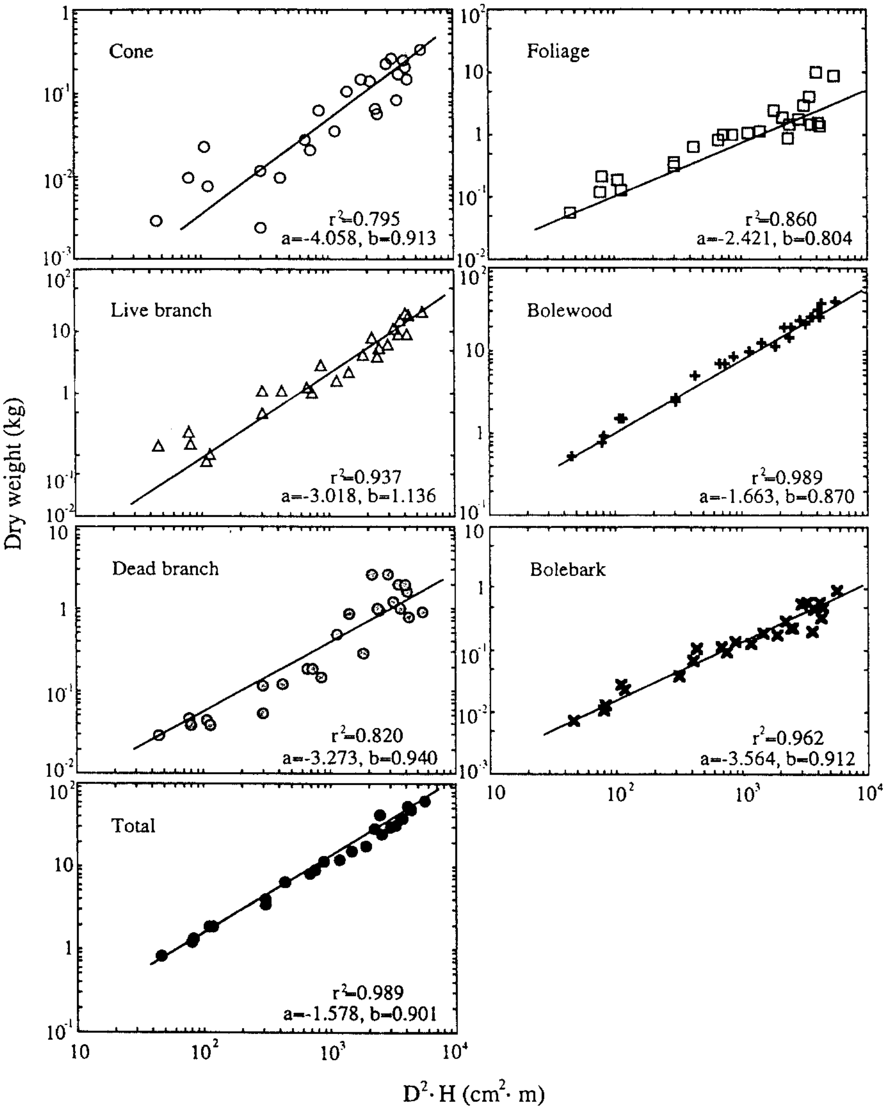

Fig. 3. The relationships between dry weight of tree components and $D^2 \cdot H$ of sample trees.

termination (r^2) of allometric regression for cones was lower than those of the other components (Fig. 3), but this low r^2 shows a similar trend to the previous studies in Korea (*e.g* Kim and Yoon 1972, Park and Kim 1989).

The bolewood occupied about 70% of the total biomass, and the total biomass to $D^2 \cdot H$ showed a significantly higher coefficient of determination ($r^2=0.989$, Table 2). These results were also similar to the previous studies of *Pinus densiflora* forests in Korea (Lee and Park 1986, 1991, Park and Kim 1989). Both bolebark and dead branches such as necromass also showed statistically high coefficients of determination in bolebark, 0.962, dead branches, 0.820.

Table 6 shows the changes of biomass for 2 years in each forest. The total aboveground biomass of the unexploited forest was 90.29 t /ha 1991 and it increased to 122.90 t /ha in 1993. Biomass of the exploited forest was 181.75 t /ha in 1991 and 206.19 t /ha in 1993. The main increase in biomass of pine was in the bolewood. The mean annual biomass increase of bolewood for 2 years was 10.68 t /ha /yr and 5.72 t /ha /yr in each site. These are 67 and 76% of the biomass increase of total aboveground in each site.

Table 6. Change of biomass of *Pinus densiflora* forests in Yanghwari during two years

Trees	U (2350 stems /ha)			E (1730 stems /ha)		
	1991	1993	t /ha /yr	1991	1993	t /ha /yr
Pinus densiflora						
Cone	0.32	0.43	0.05	0.88	1.21	0.17
Foliage	7.24	9.53	1.15	10.15	12.24	1.05
Live branch	13.19	19.65	3.29	31.57	40.41	4.42
Dead branch	2.26	3.14	0.44	6.59	7.52	0.47
Bolewood	61.04	82.41	10.68	129.82	141.26	5.72
Bolebark	0.98	1.34	0.18	2.74	3.55	0.41
Others*	5.26	6.40	0.57	–	–	–
Total aboveground	90.29	122.90	16.36	181.75	206.19	12.24

* Others are total biomass of *Pinus rigida, Robinia pseudoacacia, Alnus frma* and *Quercus variabilis.*

DISCUSSION

Heterogeneous structure and biomass of rural pine forest

Construction of graveyards in pine forests is one of forest-use in the rural landscape in Korea (Kamada and Nakagoshi 1993, Hong *et al.* 1995). Traditional harvesting of plant materials is then carried out around graveyards in private forests. Plant materials such as twigs, branches and litters in forests had been collected and used for a fuel for traditional heating system, "Ondol" and for farmyard manure (Kim *et al.* 1981, Nakagoshi and Rim 1994).

Such periodical forest disturbance influences vegetation processes and tree growth and fosters a vertically and horizontally heterogeneous structure of rural pine forests. The open forest created by this forest management, moreover, allows colonization of the light-demanding plant species. Although the canopy is composed of pine, the lower tree layer is mainly composed of light demanding plants such as oaks, and nitrogen-fixing trees, *e.g. Alnus firma* and *Robinia pseudo-acacia* even in the exploited forest. Few saplings occurred under the pine canopy in the exploited forest. A short grass *Zoysia japonica* covered the graveyard ground to prevent soil erosion on the grave mounds. Planting is severely restricted in the graveyard.

According to Kim *et al.*(1981), forest products of 9.6 t/yr per farm house had been consumed for energy and agriculture in the mountainous region in Korea. This value, however, did not include the cutting of plants for constructing graveyards. Biomass of 34.31 ton was removed from the exploited plot during this study by constructing graveyards and following human activities. If we assume that there are two graveyards per 0.1ha as in the exploited plot (Fig. 2), then approximately 1.71 ton of biomass is exploited for space of one graveyard.

Compared to nearly old natural pine forests in Korea (Kim and Yoon 1972, Lee and Park 1986), our results show larger values of biomass. These data, however, are similar to that of warm- and cool-temperate lowland pine forests in Japan (Tadaki 1991). In case of the natural pine forest in high mountainous range (*e.g* Lee 1985), they have a stable state with density, stand age and high productivity (Lee and Kim 1989). Their productivity will also decrease, if their stable ecosystem is collapsed by environmental conditions such as water and nutrient stress. In contrary, pine forests in rural landscape, however are mainly secondary forests originated from human activity. Anthropogenic disturbance on pine forest (*e.g* excluding competition with *Quercus* spp.) has given a chance to maintain the ecological characteristics of secondary pine forest from environmental change (Hong *et al.* 1995). Therefore, pine forests with a high density (1,730 to 2,350 stem/ha) and young stand age (18 to 29 year old) sustained by human activity might show a high biomass increase. Although forest disturbance such as construction of graveyards and fuel collection may continue, biomass increase of pine forest will be continued in Yanghwa-ri.

The biomass of undergrowth was poor in the exploited pine forest in Yanghwa-ri because of the intensive cyclic harvesting of biomass for fuels and farmyard manure and the management of surrounding graveyard. However, analysis of light conditions and the relative growth rate of trees implies that light plays an important role in growth. If proper management of upper-layer plants, moreover, is continued, an active recruitment of pine will be sustained. Canopy gaps created after disturbance provide early succcessional plants with different regeneration strategies with opportunities to colonize in the forest. Moderate disturbance by human activity, therefore, is indispensable to sustain favorable habitat for the local native plants of rural forests, especially of the early successional pine forest.

At the present, early successional plants in the secondary forest show a high growth rate because of these intensive forest management. However, if those management activities are decreased, succession of pine forest will be progressed rapidly. Consequently, pine-dominated vegetation will gradually change to hardwood forest like *Quercus* in the next stage (Lee 1989, Hong *et al.* 1995).

Forest land-use and resource management in agricultural landscape system

The dependence on plant resources has continued in rural Korea in spite of the rapid increase of gas, electricity and nuclear power as alternative energy sources (Nakagoshi and Rim 1994). According to statistics (The Forestry Administration 1991), the proportion of firewood to total forest product is increasing from approximately 165,000 ton or 16.5% in 1976 to 271,000 ton or 20% in 1991, although annual production of forest product is drastically decreasing from about 5 million ton in 1976 to 1.4 million ton in 1990. It imply that the forest-use like fuel production, thus, is still continued in Korea.

According to The Science and Technology Agency, Japan, the primary productivity needed from the forests is 2 t/person/yr in Korea, which is similar to that of Japan (The Science and Technology Agency 1992). The forest utilization rate as indicated by the percentage of total production from forest (firewood and timber, etc.) to primary productivity of all forests is, however, 75% in Korea and 10% in Japan. Kim *et al.* (1981) provided a more detailed breakdown related to rural energy in Korea. A farm family has consumed 3,363 kg/yr of plant materials harvested from the rural forest including stem, branch, leaf and undergrowth for cooking and heating. They have also consumed 3,526 kg/yr of the forest materials to feed livestock. Electricity, gas, and fossil energy are used for cooking and heating in urban regions, but in rural regions, forest materials are still partly used for compost and firewood. Therefore, the traditional reliance on forest resources in ordinary life is comparatively high in Korea.

Since secondary pine forests cover 399.5 ha (51.6%) of Yanghwa-ri village (Hong *et al.* 1995), we could estimate the total aboveground biomass, 42,584 to 77,491 tons from the present biomass data. Consequently, we can assume that forest biomass of 29.6 t/ha/yr to 38.5 t/ha/yr per a farm house is available for local energy resource in Yanghwa-ri. If forest products of 9.6 t/yr/farm are consumed for energy and agriculture in the rural village (Kim *et al.* 1981), our data show that farmers in Yanghwa-ri can easily get sufficient forest resource to provide sustainable local energy. In the case of pine forests in Yanghwa-ri, both of cyclic utilization of by-products and artifitial disturbance on vegetation stimulated regeneration of woody plants and sustained their productivity increases. It also indicates that if proper management is sustained, the sustainable utilization of forest resource as local energy is possible.

The total area of graveyards in Kyeryong-myon was 198 ha (0.34% of a total area) in 1990 (Hong *et al.* 1995), and 2.6 ha in Yanghwa-ri. However this area is now expanding year by year (*e.g.* 5.8% increase from 18.8 ha to 19.9 ha from 1989 to 1990). Nearly one percent of total land cover of Korea is occupied by graveyards, but the use of forest products during construction and cleaning of the graveyard is not sustainable. Some recent studies on forest productivity have focused on complete utilization of the forest resource as an alternative energy source (Kim *et al.* 1988, Lee 1985, Park and Kim 1989). When the productivities of the pine species that mainly make up the secondary forest in Korea are compared, the exotic *Pinus rigida* and a hybrid *Pinus rigida* x *P. taeda* show relatively smaller biomass than *Pinus densiflora*. It suggests that *Pinus densiflora* plays an important economic role in forest resources better than other exotic pines. The secondary pine forest in rural area, moreover, shows a high productivity. It means that rural pine forest has a high economic potentiality in local forest resources in Korea in the future.

Recently, landscape ecology is emerging as multi- (or inter-) disciplinary notion to integrate current ecological hierarchy. This concept is very appropriate for the forest land-use and management strategies where integration of multidisciplinary idea is needed at a landscape-scale in order to create the total ecological and human systems like agricultural landscape system (Zonneveld 1990). We think that these landscape ecological concept is also needed for land-use and conservation of forest to create ecologically-functioning secondary forest.

The development of advanced forest management together with improvement of traditional management is a way in which the protection of biodiversity and ecological functions of secondary forests sustainable forestry (Kirby 1988, Noss 1993). Finally, we suggested that the traditional and human-directed managements which control the forest succession is constantly required to maintain the heterogeneity in community and landscape structure that provides various habitats for local biota.

ACKNOWLEDGEMENTS

We are grateful to Prof. Ho-Kyung Song at the Department of Forestry of Chungnam National University, Taejon for giving information on this study. We also thank to cooperated researchers in CNU and Hiroshima University, and to Prof. Young-Deuk Rim of Inchon National University of Education. Special thanks are due to Dr. Keith J. Kirby of the Nature Conservancy Council, Peterborough, UK and two anonymous reviewers for their helpful comments on this manuscript. This research was partly supported by funding of the Japan Society for the Promotion of Science (JSPS) to HSK.

적 요

농촌경관에서의 인간활동에 의한 임산자원의 흐름을 살펴보기 위해서는 인간영향하의 산림에 대한 생산력과 이차림에서의 생물량자원의 소모에 관한 자료를 얻는 것이 무엇보다도 중요하다. 따라서 본 연구는 소나무이차림의 생물량과 그것의 이용상태를 살펴보고, 또한 농촌경관시스템에서의 이차림의 지속가능한 이용에 관해 논하는데 그 목적이 있다. 본 연구는 충청남도 공주군 양화리에서 실시되었다. 농촌소나무림내의 산림관리체계를 이해하기 위한 방법으로서 소나무림의 지상부현존량과 주요 구성수목의 성장률을 2년간에 걸쳐 분석하였다. 소나무 25개체를 시료

목으로 이용하여 상대생장식을 추출, 현존량을 추정하였다. 비교적 인간의 이용으로부터 방치된 임분은 매년 약 16.36 t /ha /yr, 관리림에서는 12.24 t /ha /yr의 현존량이 증가되었다. 이는 중부지역의 일부 자연림의 현존량 증가와도 유사한 결과였다. 이와 같은 결과는, 농촌경관에서 인위적 간섭을 받고 있는 소나무림일지라도 자연림과 마찬가지로 지속가능한 이용을 위한 산림자원으로서의 높은 잠재력을 갖추고 있다는 것을 의미한다. 산림내의 묘지조성은, 한국농촌경관에서 일상적으로 발생되는 인위적이고 전통적인 산림교란의 하나이고 또한 토지이용형태이다. 지역에너지자원의 하나로서 이러한 인간과 자연이 총체적으로 결합된 특징을 갖는 이차림의 지속가능하고 긍정적인 이용을 위한 관리전략을 경관생태학적인 관점에서 제안하고자 했다.

LITERATURE CITED

Anderson, M.C. 1964. Studies of the woodland light climate, I. The photographic computation of light conditions. J. Ecol. 52:27-41.

Burel, F. and J. Baudry. 1990. Hedgerow network pattern and processes in France. *In* I.S. Zonneveld and R.T.T. Forman (eds.), Changing Landscapes: An Ecological Perspective, Springer-Verlag, New York. pp. 99-120.

Forestry Research Institute. 1987. Forest inventory report. Seoul, Korea, 289p (in Korea).

Franklin, J.F. and T.T. Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. Landscape Ecology 1: 5-18.

Grime, J.P. and D.W. Jeffrey. 1965. Seedling establishment in vertical gradients of sunlight. J. Ecol. 53:621-642.

Hobbs, R.J. and D.A. Saunders. (eds.). 1993. Reintegrating fragmented landscapes-Towards sustainable production and nature conservation. Springer-Verlag, New York. 332p.

Hong, S.-K., N. Nakagoshi and M. Kamada. 1995. Human impacts on pine-dominated vegetation in rural landscapes in Korea and western Japan. Vegetatio 116:161-172.

Hong, S.-K., N. Nakagoshi and K. Nehira. 1993. Trends of *Pinus densiflora* populations under the traditional regimes of forest management in the rural landscapes of Korea and Japan. Ann. Bot. 51:5-20.

Kamada, M. and N. Nakagoshi. 1993. Pine forest structure in a human-dominated landscape system in Korea. Ecol. Res. 8:35-46.

Kim, J.-B., K.-W. Lee and C.-S. Kim. 1981. A studies on the energy in the rural region. Korea Rural Economic Institute, Seoul. 256p. (in Korean)

Kim, J.-H. 1976. Studies on the productivity and the productive structure of the forests. Ⅲ. Comparison between the productivity of *Pinus rigida* and of *Pinus rigitaeda* plantation. Korean J. Bot. 19:85-91. (in Korean with English summary)

Kim, J.-H. and S.-M. Yoon. 1972. Studies on the productivity and the productive structure of the forests. 2. Comparison between the productivity of *Pinus densiflora* and of *Quercus mongolica* stands located near Choon-Chun City. Korean J. Bot. 15:71-78 (in Korean with English summary)

Kim, K.-D., J.-H. Yun, Y.-G. Chung, K.-N. Lee and J.-W. Park. 1988. Stand structure and growth characteristics of four tree species in central region of Korea. J. Korean Forest Energy 8:41-53 (in Korean with English summary)

Kirby, K.J. 1988. Conservation in British woodland-adapting traditional management to modern needs. *In* H.H. Birks, H.J.B. Birks, P.E. Kaland and D. Moe (eds.), The Cultural Landscape-Past, Present and Future. Cambridge University Press, Cambridge. pp. 79-89.

Knight, D.H. 1991. Pine forests: A comparative overview of ecosystem structure and function. *In* N. Nakagoshi and F.B. Golley (eds.), Coniferous Forest Ecology from an International Perspective, SPB Academic Publishing, The Hague, pp. 121-135.

Lee, C.-S. 1989. A study on the succession of pine forests damaged by pine gall midge. Dissertation. Seoul National Univ. 106 p.

Lee, C.-S. and H.-E. Kim. 1989. Ecological study for natural regeneration by selfsown of *Pinus densiflora* forest. J. Agr. Sci., Chungbuk National Univ. 7:100-109 (in Korean with English abstract)

Lee, K.-J., K.-D. Kim, J.-S. Kim and I.-H. Park. 1985. Distribution of biomass and production of *Pinus rigida* and *Pinus rigida* × *taeda* plantation in Kwangju district. J. Kor. For. Soc. 69:28-35. (in Korean with English abstract)

Lee, S.-W. 1985. Biomass and net primary productivity of *Pinus densiflora* natural ecosystem in Kangwondo, Korea. J. Kor. For. Soc. 71:74-81. (in Korean with English abstract)

Lee, S.-W. and K.-H. Park. 1986. Biomass and organic energy production in pine and oak natural forest ecosystem in Korea. J. Korean Forest Energy 6:46-58. (in Korean with English summary)

Lee, S.-W. and K.-H. Park. 1991. Biomass, productivity and organic energy production in *Pinus densiflora* forest ecosystem in Koree. *In* N. Nakagoshi and F. B. Golley (eds.), Coniferous forest ecology from an international perspective. SPB Academic Publishing, The Hague. pp.31-41.

Madgwick, H.A.I. and G.L. Brumfield. 1968. The use of hemispherical photographs to assess light climate in the forest. J. Ecol. 57:537-542.

McDonnell, M.J. and S.T.A. Pickett (eds.). 1993. Human as components of ecosystems-The ecology of subtle human effects and populated areas. Springer-Verlag, New York. 364p.

Miller, R.W. and R.L. Donahue. 1990. Soils: An introduction to soils and plant growth. Prentice-Hall. 768p.

Nakagoshi, N. and Y.-D. Rim. 1994. Rural forests as a resource of fuel, feed and fertilizer at a mountain farm village in central Korea. *In* Y. Song, H. Dierschke and X. Wang (eds.), Applied Vegetation Ecology. East China Normal University Press, Shanghai. pp. 128-132.

Noss, R.D. 1993. Sustainable forestry or sustainable forests? *In* G.H. Aplet, N. Johnson, J.T. Olson and V.A. Sample (eds.), Defining sustainable forestry. Island Press, Washington D. C. pp. 17-43.

Odum, E.P. and M.G. Turner. 1991. The Georgia landscape: a changing resource. *In* I.S. Zonneveld and R.T.T. Forman (eds.). Changing Landscapes: An Ecological Perspective. Springer-Verlag, New York. pp. 137-164.

Ogawa, H., K. Yoda and T. Kira. 1968. A preliminary survey on the vegetation of Thailand. Nature and Life in SE Asia 1:21-157.

Oliver, C.D. and B.C. Larson. 1990. Forest stand dynamics. McGraw-Hill, New York. 467p.

Park, I.-H. and J.-S. Kim. 1989. Biomass regressions of *Pinus densiflora* natural forests of four local forms in Korea. J. Kor. For. Soc. 78:323-330 (in Korean with English summary)

Park, I.-H. and S.-M. Lee. 1990. biomass and net production of *Pinus densiflora* natural forests of four local forms in Korea. J. Kor. For. Soc. 79:196-204 (in Korean with English summary).

Peet, R.K. 1981. Change in biomass and production during secondary forest succession. *In* D.C. West, H.H. Shugart and D.B. Botkin (eds.), Forest Succession - Concepts and Application, Springer-Verlag, New York, pp. 324-338.

Rim, Y.-D., H.-G. Kang and N. Nakagoshi. 1991. Community ecology of *Pinus densiflora* forests in Korea. *In* N. Nakagoshi and F.B. Golley (eds.), Coniferous Forest Ecology from an International Perspective, SPB Academic Publishing, The Hague, pp. 17-30.

Shidei, T. and T. Kira. (eds.) 1977. Primary productivity of Japanese forests-Productivity of terrestrial communites. University of Tokyo, Tokyo. 289p.

Tadaki, Y. 1991. Productivity of coniferous forests in Japan. *In* N. Nakagoshi and F.B. Golley (eds.), Coniferous Forest Ecology from an International Perspective (eds.), SPB Academic Publishing, The Hague, pp. 109-119.

The Forestry Administration. 1991. Forestry Statistics. Forestry Administration. Seoul, Korea. 438p (in Korean)

The Science and Technology Agency. 1992. The Global Environment and the Utilization of Energy in Asia. The Science and Technology Agency, Tokyo, 440p. (in Japanese)

Turner, R.K. (ed.). 1993. Sustainable environmental economics and management-Principles and Practice. Belhaven Press, London. 389p.

Whittaker, R.H. and G.M. Woodwell. 1968. Dimension and production relations of trees and shrubs in the Brookhaven forest, New York. J. Ecol. 56:1-25.

Yim, Y.-J. and T. Kira. 1975. Distribution of forest vegetation and climate in the Korean Peninsula I. Distribution of some indices of thermal climate. Jap. J. Ecol. 25:77-88.

Zavitkovski, J. 1976. Ground vegetation biomass, production, and efficiency of energy utilization in some northern Wisconsin forest ecosystems. Ecology 57:694-706.

Zonneveld, I.S. 1990. Scope and concepts of landscape ecology as an emerging science. *In* I.S. Zonneveld and R.T.T. Forman (eds.), Changing Landscapes: An Ecological Perspective. Springer-Verlag, New York. pp. 3-20.

(*Received April 10, 1996*)