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Cause and consequence of landscape fragmentation and changing disturbance by socio-economic development in mountain landscape system of South Korea

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Abstract—Through the statistics and the analysis of landscape map, changes of lands-use regime and landscape structure during 20 years were investigated in the agriculture-forestry complexed mountain landscape system of Yangdong-Myon, Yangpyung-Gun in the central Korea. Landscape changes of this region was inter-related to the recent socio-economic development of rural life. Utilization of biomass and other traditional forest management were drastically abandoned in recent 10 years. Landscape analysis of maps showed that the area of secondary vegetation that had been sustained by human-nature disturbance was decreased by using of plantation during this time. Those decreased areas were replaced to plantation for wood production and other purpose. Past area of woody species dominated in plantation also substituted to other species. Traditional human activity on secondary vegetation was disappeared. Consequently, the advanced management regimes such as new plantation and cultivation extending areas were increased in abandoned land.

Keywords: human disturbance, Korea, mountain landscape, landscape fragmentation, urbanization.

1 Introduction

Landscape is a holistic ecosystem that complicated with human-nature factors (Naveh, 1994). In recent, anthropogenic disturbance is an important factor causing landscape heterogeneity and it appears on a world-wide level(Forman, 1995; Hong, 1995). Anthropogenic disturbances such as grazing, logging, slashing and burning, and fire changed an original structure of landscape, and it sometimes controls and maintains theirs ecological working mechanism as endo- or exogeneous factors. Spatial landscape pattern, especially in agricultural landscape, is reflecting the human and natural disturbances on the region (Hong, 1998). To understand the pattern and process of agricultural landscape as a human-influenced landscape, socio-economic background related to land-use regime is indispensable (Turner, 1988; Hong, 1995).

In history, forest-use activity is the major infra-structure of primary industry as an economy type together with rice production in Korea. Mountain landscape, therefore, had been kept the holistically integrated system combined with human and nature systems in the rural regions. Traditional landscape management on mountain landscape also had been created traditional landscape pattern as well as heterogeneous vegetation types in horizontally and vertically. Especially, human being moreover has been created the semi-natural vegetation as secondary vegetation that changed and modified from natural ones(Hong, 1994). Consequently, structure, pattern and diversity of mountain landscape system were changing more fragmented and then total ecosystems are simplified owing to disappearance of traditional landscape management by urbanization. To getting information about the past and present landscape structure and long-term vegetation dynamics through a relationship between landscape change and disturbance intensity are, therefore, necessary to establish advanced forest management strategy for sustainable and ecologically sound mountain landscape system.

Under the landscape ecological concept above-mentioned, the spatial pattern and patch characteristics of landscape mosaics through information theory by the analysis of vegetation-landscape map using several landscape indices were explored in this study. Finally, the status of

Korea mountain landscape system under the changing intensities of anthropogenic disturbance and socio-economic environment were discussed.

2 Study area

The study area locates in Yangdong-Myon at Yangpyong-Gun in Kyunggi-Do at eastern Seoul metropolitan city. The cultivation area such as paddy field and dry field was approximately 13% of the total land of Yangdong-Myon, and it shows this region can be considered as a typical mountain farm village in Korea(Nakagoshi, 1994). Yangdong-Myon is the representative forest-dominated mountain landscape at central Korea. Annual mean temperature and precipitation are 10.9℃ and 1280 mm, and potential vegetation belongs to the northern part of the deciduous broad-leaved forest zone. In view point of phytosociological hierarchy, the regions belongs to Rhododendro reticulati-Pinetum densiflorae H. Suzuki et Toyohara 1971 as an association. *Pinus densiflora* and *Quercus mongolica* communities are dominated in natural forest of the vegetation landscape.

3 Methods and analysis

3.1 Background of cultural landscape and socio-economic data

Statistics of land-use and population were refereed from the Statistical Year Book of Yangpyung-Gun by decade since 1970's (Table 1). This study compared the changes of socio-economical attributes as follows: population movement, a ratio of agricultural and forest lands, farm household, an area of cultivated land per household, production of biomass and the status of road.

Table 1 Statistics of population and land-use of Yangdong-Myon

Attribute*	1970's	1980's	1990's
Population	10805	8610	5898
Population density, person/km^2	87.8	72.4	49.2
Agricultural land, %	13.3	13.9	13.7
Paddy field	7.0	7.2	7.1
Dry field	6.3	6.7	6.6
Forest land, %	78.2	79.2	79.3
Farm household	1608	–	987
Area of cultivated land			
per household, hm^2	1.02	1.08	1.07
Paddy field	0.54	0.56	0.64
Dry field	0.48	0.52	0.43
Production of biomass, *M/T*	4280	2482	130
Fire wood	240	950	0
Charcoal	2620	0	0
Leaves & branches	1420	1532	0
Status of road, km^2	1267	1689	1953

* These data were based on 〈Statistical yearbook of Yangpyong-Gun including Yangdong-Myon〉;
– ; no data in statistics

3.2 Vegetation-landscape mapping

Physiognomic actual vegetation-landscape maps of 1980's and 1990's were completed. Vegetation map of 1987-year was based on physiognomic forest stand map interpreted by monochrome aerial photography(Forest Research Institute, 1:5000 and 1:7000 scale) and it was overlapped into topographic map (1982, 1:25000 scale). Correct boundaries of vegetation patch, forest types and land-use of the period were advised from the village people and the data of local government. Current vegetation map of 1990's was completed in 1997 through direct survey on the same place. The land-use type also checked in the field survey.

3.3 Analysis of indices of landscape pattern

Patch area and perimeter were measured by area-curvimeter (X-PLAN 360 IIxi, Progis-Ushikata Inc.). Patch numbers also counted. To compare landscape structure and pattern, four indices of landscape mosaic were applied to the study(Turner, 1992).

3.3.1 Landscape patch diversity(H)

When a landscape is composed of one element, the total landscape mosaic is homogeneous. In this case, the value of H becomes 0. The larger the value of H, the more diverse the landscape.

$$H = -\sum_{k=1}^{s} Pk \cdot \ln Pk,$$

where s = number of habitat(patch) types; Pk = proportion of area in habitat(patch) k.

3.3.2 Dominance(D)

Dominance(D) is a measure of dominant element of the landscape. It calculated as the deviation from the possible maximum diversity. Large values of D indicate a landscape that dominated by one or a few land-uses, and low values indicate a landscape that has many land-uses represented in approximately equal proportions. However, this index is not useful in a completely homogeneous landscape (patch number is one) because D then equals zero.

$$D = \ln s + \sum_{k-1}^{s} Pk \cdot \ln Pk,$$

where s = number of habitat(patch) types; Pk = proportion of area in habitat (patch) k as same as diversity index.

3.3.3 Fractal dimension(FD)

Fractal dimension was obtained by regression analysis between log(P) and log(A).

$$FD = \left(\frac{1}{d}\right) * 2, d - \frac{\ln A}{\ln\left(\frac{P}{4}\right)},$$

where A = area of patch; P = perimeter of the patch at a particular length-scale.

The complexity of patch perimeter is closely related to intensity of human disturbance (Farina, 1998). If the landscape (patch) is composed of simple geometric shapes like squares and rectangles, the fractal dimension will be small, approaching 1.0. If the landscape contains many patches with complies and convoluted shapes such as natural ones, the fractal dimension will be large approaching 2.0.

3.3.4 Human disturbance index(U)

This study introduced human disturbance index to know the intensity of human disturbance on landscape. This value was calculated by comparing the relative area proportion between the naturally originated landscape element such as natural or semi-natural vegetation and the human-mediated landscape element such as plantation and cultivated landscape including inhabitant element on the area of total landscape. The higher the value, the stronger the human disturbance.

$$U = (P_k)/(P_n),$$

where P_h = area proportion of human-mediated landscape element; P_n = area proportion of naturally originated landscape element.

3.3.5 Statistical analysis of data

All obtained data was applied to statistical-graphic software SYSTAT(SYSTAT Inc., ver 5.2) and StatView (Abacus Concept Inc., ver 4.02) for Macintosh computer.

4 Results and discussion

4.1 Changes in cultural landscape

Total population and farm household were drastically decreasing since 1970's and population density of Yangdong-Myon decreased from 87.8 person/km^2 in 1970's to 49.2 person/km^2 in

1990's. This result is clearly related to the construction development of paved road (Pearson's correlation coefficient $rp = 0.969$, $p < 0.05$). It means that many people before engaged in agricultural activity had left their village by urbanization during these periods. Consequently, socio-economic development according to urbanization had been influenced on other cultural attribute (e.g. areas of paddy and dry fields and forest land) relating primary industry of the region. It also significantly related to the decrease of production of biomass such as fire wood and charcoal. The reason of decreasing of biomass, especially of fire wood and charcoal productions means disappearance of traditional landscape management with respect to forest land-use and rural energy resource(Kim, 1981). The biomass was the main energy resource in the farm village. Traditional heating system depending on the biomass, "Ondol" was most predominant energy system in the rural regions(Hong, 1998). However, this system is decreasing according to the substituting energy by fossil fuel.

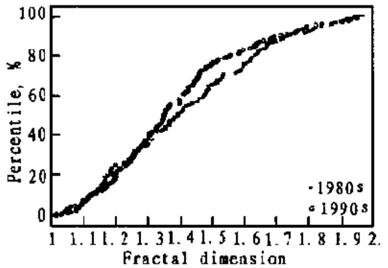

Fig.1 Percentile distribution of the fratal dimension of total landscape elements changes between 1980's and 1990's

While farm household was decreased, area of paddy field per household was increased. It shows that the relationships between the energy switching on agriculture and the arrangement of old paddy field composed of patchily divided small tasseras. Domestic animals (e.g., cow and horse) had been used for labor energy for traditional subsistence agriculture for a long time. Recent advanced agriculture depending on machinery using fossil fuel bringing additional land into cultivation. Consequently, traditional agricultural field has fragmented and therefore, their fractal geometry decreased (paddy field: 1.416 at 1980's to 1.332 at 1990's). Fractal dimension of the total landscape system was slightly increased from 1.372 to 1.406, and the increased value was frequent between 1.3 to 1.7(Fig.1).

4.2 Spatio-temporal changes in landscape structure

Table 2 shows the comparison of two landscape maps of 1980's and 1990's. Four naturally originated landscape element (deciduous forest, pine-oak mixed forest, *Pinus densiflora* forest as secondary vegetation element and stream and sand bank) and six human-modified landscape elements (four plantations including *P. densiflora* and two cultivated landscapes) were mainly counted in the map of 1980's. A white birch *Betula platyphylla* var. *japonica* as one of plantation was added to the modified landscape element at 1990's. While area of modified landscape elements as plantation and cultural land on total area were increased from 75.1% at 1980's to 80.4% at 1990's, those of national landscape were decreased from 24.9% to 19.5% at the same period. Plantation of *Larix leptolepsis* that mostly had been occupied in the mountain landscape is recently replaced by new plantation of pitch pine *P. rigida*, Korean pine *P. koraiensis* and white birch *Betula platyphylla* var. *japonica*. Plantations of *P. densiflora* and *Larix leptolepsis* were cut and replaced by fast growing alien *P. rigida* and hardwood *Betula platyphylla* var. *japonica*. Past large plantation matrix composed of *P. rigida* and *Larix leptolepsis* and natural vegetation of *P. densiflora* forest was partially fragmented and then they were mixed with new plantation like white birch.

Especially secondary vegetation of P. densiflora that had been maintained by human activity was remote from forest management and in consequent, became an isolated patch (Rim, 1998). Except for few pine forests at edaphic geoecological condition, this type of vegetation landscape is changed to deciduous oak forest via pine-oak mixed forest by natural succession. Stream and surrounding sandy bank was almost changed to cultivation field. Area of riparian landscape type was, therefore, decreased from 8 hm^2 in 1980's to less than 1 hm^2 in 1990's. Patch number of total landscape was not so much changed, but fragmentation of plantation patch was remarkable (subtotal 29.0% of the patch number of total landscape in 1980's to 48.8% in 1990's).

Table 2 Patch area and patch number of each landscape types occupied in physiographic landscape maps on 1980's and 1990's

Landscape element types	1980's						1990's					
	A *	Mean, *SD*	%	No.	Mean, *SD*	%	*A*	Mean, *SD*	%	No.	Mean, *SD*	%
Natural landscape												
Secondary vegetation												
Deciduous forest	98	24.56(40.53)	4.2	4	1.93(1.80)	2.4	73	14.69(4.55)	3.1	5	2.64(0.69)	3.0
Pine-oak mixed forest	301	11.14(12.72)	12.9	27	1.81(1.01)	16.4	304	19.02(23.96)	13.1	16	2.32(1.62)	9.6
Pinus densiflora forest	175	13.57(8.44)	7.6	13	2.23(1.08)	0.6	77	6.44(4.61)	3.3	12	1.39(0.71)	7.2
Sub-total	574		24.7	44		19.4	454		19.5	33		19.8
Stream and sand bank	6	1.49(0.55)	0.2	4	8.70(0.21)	2.4	1	1	<0	1	1	0.6
Sub-total	6		0.2	4		2.4	1		<0	1		0.6
Modified landscape												
Plantation												
Pinus densiflora	183	18.30(11.76)	7.9	10	2.25(1.17)	6.0	118	14.83(19.95)	5.2	8	2.00(1.91)	4.8
Pinus rigida	119	29.74(30.12)	5.2	4	2.92(2.21)	2.4	394	30.27(29.89)	17.1	13	3.63(2.63)	7.8
Pinus koraiensis	376	34.19(26.77)	16.2	11	3.64(2.63)	6.7	325	20.35(15.67)	14.0	16	2.57(1.46)	9.6
Larix lepotolepsis	517	22.51(19.14)	22.3	23	2.49(1.48)	13.9	296	8.49(9.51)	12.7	35	1.81(1.17)	21.2
Betula platyphylla	–	–	–	–	–	–	161	17.71(13.27)	6.9	9	2.48(1.62)	5.4
Sub-total	1195		51.6	48		29.0	1294		55.9	81		48.8
Cultivated landscape												
Paddy field	215	9.05(8.83)	9.3	24	2.56(1.68)	14.5	170	10.75(14.46)	7.3	15	2.16(2.16)	9.1
Crop field and inhabitants	326	7.24(5.58)	14.2	45	1.74(1.08)	27.2	397	11.01(13.10)	17.2	36	2.09(1.73)	21.7
Sub-total	541		23.5	69		41.7	567		24.5	51		30.8
Total	2316		100	165		100	2316		100	166		100

4.3 Anthropogenic effects on patch fragmentation of forest landscape

The larger the value of landscape patch diversity(H), the most varied the landscape. There was no significant difference of landscape diversity between the total landscape types in 1980's and 1990's(Table 3). Presence and absence of stream and sandy bank of natural landscape type and appearance of white birch plantation were main cause of changing landscape diversity on duration. Although there were other landscape elements such as small orchard and graveyard in the area, this smaller landscape parch was counted as one element composed of cultivated landscape in the mapping. While diversity of natural landscape element except for deciduous forest was decreased, those of human-mediated landscape elements such as all plantation-except for old *Pinus* densiflora plantation was increased in the same period. It is significantly related to patch area and its number (patch area: $rp = 0.757$ at $p < 0.05$, patch number: $rp = 0.892$ at $p < 0.05$ in the analysis of 1980's map in Pearson's correlation analysis). Therefore, increasing H values of some plantations reflect the extending of fragmented landscape from 1980's to 1990's.

Larger values of dominance (D) indicate a landscape that is dominated by one or a few land-used types (landscape element), and low values indicate a landscape that has many land-uses represented in approximately equal proportions. Decreasing dominance index of landscape patch means landscape replacement by occupation with other element. For example, large matrices of *Larix leptolepsis* and *Pinus koraiensis* in before 1980's were occupied with *Betula platyphylla* var. *japonica* and *Pinus rigida* in 1990's. Dominance value of paddy field decreased from 1.108 to 0.641. However, those of dry field like crop field, orchard surrounding human settlement increased at the same duration. It means that rural economy was replaced to local government reliant-forestry and home ranged-dry field or rice field as a result of decreased population.

Human disturbance index (U) increased 2.993 in 1980's to 4.090 in 1990's. Generally considering, this result is related to both reasons of decreasing the naturally originated landscape elements such as secondary vegetation including riparian landscape and increasing area of plantations, especially of *P. rigida* and *Betula platypylla* var. *japonica*.

Table 3 Comparison of diversity(*H*), dominance(*D*) and fractal dimension(*FD*) of each landscape types in total landscape

Landscape element types	1980's			1990's		
	H	*D*	*FD*, r^2	*H*	*D*	*FD*, r^2
Natural landscape						
Secondary vegetation						
Deciduous forest	0.222	1.770	1.010(0.993)[c]	0.684	1.182	1.586(0.907)[b]
Pine-oak mixed forest	1.226	1.252	1.024(0.802)[b]	1.003	1.480	1.374(0.934)[b]
Pinus densiflora forest	1.031	1.216	1.070(0.743)[b]	0.997	0.891	1.318(0.909)[b]
Stream and sand bank	0.577	0.197	1.112(0.632)[a]	0	0.121	
Modified landscape						
Plantation						
Pinus densiflora	0.901	1.352	1.114(0.859)[b]	0.629	1.445	1.308(0.984)[c]
Pinus rigida	0.350	1.725	1.406(0.994)[c]	0.945	1.650	1.294(0.859)[b]
Pinus koraiensis	0.914	1.661	1.276(0.849)[b]	1.125	1.388	1.196(0.848)[b]
Larix leptolepsis	1.222	1.492	1.202(0.613)[a]	1.390	1.083	1.438(0.846)[b]
Betula platyphylla var. *japonica*	-*	-*	-*	0.834	1.368	1.284(0.888)[b]
Cultivated landscape						
Paddy field	1.227	1.108	1.416(0.892)[b]	1.588	0.641	1.332(0.952)[c]
Dry field and inhabitants	1.522	0.991	1.252(0.911)[b]	1.379	1.219	1.306(0.813)[b]

* Non-identified landscape types; a: $p<0.01$; b: $p<0.05$; c: $p<0.001$ at F-test of ANOVA

5 Conclusion

The change of landscape management during three decades through direct analysis and government statistics was summarized(Table 4). Before 1970's, the region was characterized with slash and burning field and sparse vegetation on naked soil, and energy depended on biomass. Therefore, human impact was severely occurred on landscape topography and natural forest. Landscape showed heterogeneous pattern caused by severe landscape management on both vegetation and other land type. Since 1960's, Koreans government decided to plant the fast growing *P. rigida* introduced from North America for the land revegetation. Nitrogen fixing plants such as locust *Robinia pseudoacacia* and alder *Alnus* spp. were also introduced for rehabilitation of soil fertility on the naked land. Current large remnant patch of *P. rigida* reflects the landscape management strategy at that time. This management strategy was continued in the period of 1970's to 1980's. Slash and burning field was completely disappeared in the region in this period. Abandoned shifting slash and burning field was occupied with plantation and crop field (including orchard). Total areas of these landscape elements increased in this period. Moreover, the areas of paddy (especially in rice-producing) field was increased during the same period. It mean that resettlement of people available for rice cultivation was accomplished. Total landscape diversity was slightly decreased owing to extension of mono-species plantation and orchard. Past complicated mosaic landscape became partly homogeneous and simplified. Sparse vegetation near village was recovered and then they had processing to natural succession. Energy use also modernized.

Since 1990's, modernization of rural regions and fast urbanization of near city have influence on the original landscape system integrated human and nature attributes. People had left their village to city. The increased abandoned field was changed to other lands use for the purpose of higher rural economy such as orchard, greenhouse and new plantation. Traditional management of agricultural landscape was almost disappeared and economic purpose on landscape also changed. However, new and advanced landscape management had influence on the landscape fragmentation of vegetation and other land. Human impact on landscape was certainly stronger and intensified in accordance which site decided by policy maker. Therefore, areas of pine forest and pine-oak mixed forest that had been exploited by people are isolated from recent landscape planning and consequently they are on natural succession to potential vegetation(e. g. deciduous oak forest).

Table 4 Spatio-temporal changes of total landscape systems in mountainous landscape in Yangdong-Myon, central Korea

	Before 1970's	1980's	1990's
Cultural landscape			
Main land-use depending people's life	Slash and burning field, paddy field	Paddy and crop fields, orchard	Crop and orchard, third industry
Condition of soil erosion and forest exploitation	Severe	Medium	Low
Plantation type and purpose	Rehabilitation Revegetation	Restoration, Timber production	Timber production, landscape beauty, ecologically soundness
Heat energy & fertilizer types	Wood, briquette Biomass, organic farming,	Briquette, petroleum, wood organic farming, chemicals	Briquette, petroleum, gas chemicals, organic farming (few)
Bio-ecological landscape			
Human disturbance on			
Vegetation	High	Decreased	Abandoned except small area
Other land type	High	High	High
Landscape pattern of			
Vegetation	Shifting-heterogeneous	Partly heterogeneous	Heterogeneous/homogeneous
Other land type	Heterogeneous	Heterogeneous (partly fragmented)	Heterogeneous(clearly fragmented)
Vegetation type	Sparse type (Early sucessional plants, esp. pine forest	Partly dense type(succession) processing, esp. pine to oak forest)	Almost dense type(succession processing, esp. pine to oak, pine to deciduous forest, oak to climax forest)

* Cultural and ecological data of 1970's were based on the social reaserch data and statistics of local goverment

Finally, it can be concluded that changing farmer's consciousness according to socio-economic modernization is the major disturbance factor on the landscape stability in a coarse-scale with a long term. However, the strongest and drastic impact on the total landscape change is the economy-oriented policy making on mountain landscape system in Korea. This holistic impact is surely caused of both land abandonment and fragmentation on original landscape.

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