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Landscape Structure and Relationship between Water Quality and Land Use Pattern in the Watershed of the Wangsuk River in Gyunggi-do, Korea

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ABSTRACT: Land use pattern in the Wangsuk river watershed was investigated on the bases of physiognomic vegetation maps made from the aerial photograph interpretation and field check. Landscape structure was analyzed using a GIS program supported by ArcView. Landscape structure depended on the geographical position of the river, such as the upper, middle and lower river. Watersheds of the upper and middle rivers were dominated by forests composed of secondary forest and plantation. But agricultural fields dominated that of the middle and lower river. Urban area and agricultural fields increased in from the upper toward the lower river watersheds. In addition to, a transformation of agricultural pattern into an institutional agriculture was characteristic in the middle and lower river basins. Water qualities of the Wangsuk river were usually better in the order of the upper, middle, and lower river, but they were fluctuated according to the site. Such fluctuation would due to self-purification of the river and land use pattern of the watershed as the non-point source. In this viewpoint, a strategy to manage the water quality in the level of watershed is urgently required.

Key words: Aerial photograph, GIS, Land use pattern, Physiognomic vegetation map, Water quality, Watershed

INTRODUCTION

Important among environmental issues is poor water quality and water scarcity. Fresh water availability is a major factor in sustainable use of natural resources. The water scarcity is accentuated by deteriorating water quality. Environmental issues related the deteriorated water quality and water scarcity are related to watershed management. Watershed is a basic hydrologic unit, and hydrologic and ecological processes govern the quality of water resources within the watershed. It is appropriate, therefore, that issues related to sustainable management of natural resources are addressed within the context of watershed management (Lal 2000).

The pollution sources of the river are classified into two kinds of the point and the non-point sources. The point sources include urban sewage, industrial wastewater, wastewater from stock farming, and so on, which are objects for control as they are discharged from one point or narrow zone. On the other hand, the non-point sources depend on precipitation characteristics, topography, geology, and land use pattern as they are pollution sources that pollutants are discharged by running water at rain. Therefore, it is so hard to manage collectively the non-point source (Hall 1984). In these days, a standard for treatment of industrial wastewater and urban sewage is intensified. But there are no regulations or managing facilities for the non-point sources in Korea. Furthermore, the river improvement focused on flood control and water use removed the riparian vegetation, which play a role as a buffer zone for the non-point source (Stanne *et al.* 1996, Kentula 1997, Yao *et al.* 1997, Lee *et al.* 1998, Lee *et al.* 1999).

The amount of pollutants from the point source is divided into the occurred and the discharged ones, the latter is calculated by subtracting the amount reduced by the treatment facilities. But in case of the non-point source, the total occurred amount of pollutants are discharged because there are no treating facilities for them. In particular, pollutants from the non-point source in the urbanized area are more important because most of pollutants on the impermeable pavement are directly flowed into the water body through run-off without any absorption or filtering process (Ojo 1990, Chester and Gibbons 1996, Lee *et al.* 1998). In addition, agricultural field, in which the institutional farming dominates, resembles the urbanized area (Kim *et al.* 2000). But the stable ecosystem, such as a forest discharges less pollutant due to large absorbing capacity. Therefore, the importance of the land use pattern getting increased in the management plan of the water quality (Lal 2000).

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The first aim of this study is to analyze the landscape structure including land use pattern in the watershed of the Wangsuk river, which is located eastward of Seoul as a tributary to the Han river. The other is to discuss relationship between water quality and land use pattern to get the applicable information for management of water quality.

STUDY AREA AND METHODS

The Wangsuk river is located eastward nearby Seoul as a tributary to the Han river. It extends from Jinjeob-eup, Pocheon-gun to Kuri-si in Kyunggi-do on the administrative region. The upper part of the river retains the dense forest including the Kwangreung arboretum and the middle and lower river watersheds form the typical rural environment as an open field. The river plays a significant role as a source of water supply of Seoul and at the same time is under influences of Seoul because it is located close to there geographically. Expansion of the urbanized area in all lowland flat area of this watershed is due to such influences. On the other hand, the establishment of the institutional agricultural field and orchard of large acreage in the lower and middle watersheds also reflect such influences.

Land use pattern was explored based on the physiognomic map and field checks. Physiognomic map from aerial photograph interpretation (1:15,000 scale) (FRI 1996) was used to identify vegetation types and landscape boundaries. The identified landscape attributes were overlapped on the topographical maps of 1:25,000 scale. Patches smaller than 625m^2 were excluded from this study due to uncertainty of their size and shapes on 1:25,000 maps (Nakagoshi *et al.* 1992). Vegetation map was constructed with ArcView GIS (Geographic Information System), and confirmed by field check. Numbers and sizes of the patches in the vegetation maps were determined with ArcView GIS (ESRI 1996). Analysis on the landscape structure was focused to clarify the causal factors of fragmentation. Degree that each landscape element contributed to fragmentation was evaluated by ratios of the numerical percentage to that by area of each patch. In addition, we obtained the developmental indices based on the results of analysis about landscape structure: the ratios of the acreage of the landscape elements occurred from artificial interference to the natural ones. Data on water quality were obtained from Cho (1999).

RESULTS

Land use pattern

Landscape element types were identified as secondary forest, plantation, agricultural field, urbanized area and others (Fig. 1 and Table 1). Acreage of landscape elements in the upper river watershed was larger in the order of secondary forest (44.8%), plantation (31.2%), agricultural field (13.8%), urbanized area (5.5%), and others (4.7%). The order in the middle river watershed was secondary forest (32.2%), agricultural field (31.3), plantation (20.4%), urbanized area (10.7%), and others (5.4%). That in the lower river watershed was agricultural field (55.4%), urbanized area (20.1%), secondary forest (18.6%), plantation (4.0%), and others (1.9%)(Table 1).

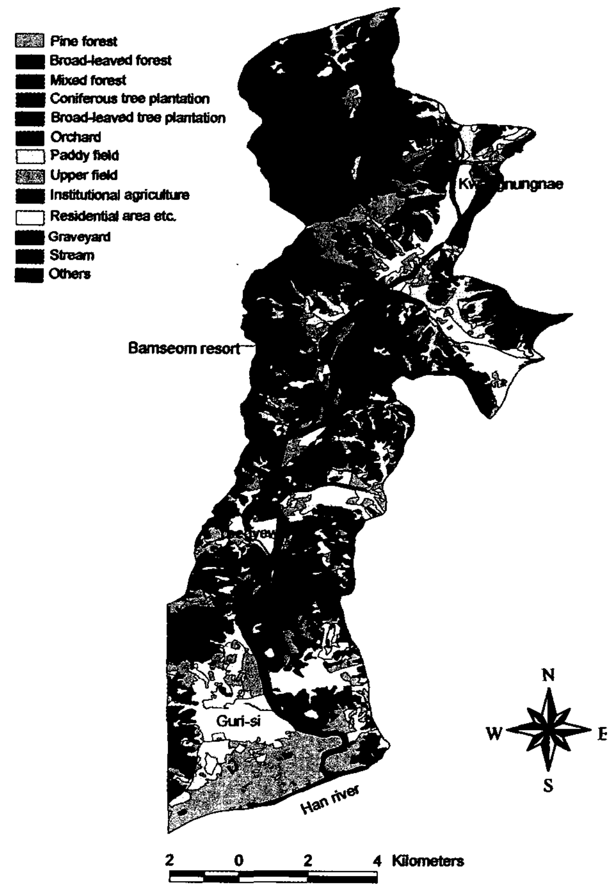

Fig. 1. A landscape ecological map of the Wangsuk river watershed.

The number of patches

The number of patches in the upper river watershed of the Wangsuk river was more in the order of plantation (47.3%), secondary forest (21.7%), agricultural field (17.1%), urbanized area (10.1%) and others (3.1%). The order in the middle river watershed was agricultural field (35.0%), secondary forest (25.5%), urbanized area (19.0%), plantation (17.5%) and others (3.2%). That in the lower river watershed was agricultural field (38.4%), urbanized area (25.4%), secondary forest (23.2%), plantation (8.3%) and others (4.7%).

Table 1. The configuration of landscape elements identified from vegetation map of the Wangsuk river

Landscape element type	The upper river				The middle river				The lower river			
	Number	(%)	Area (ha)	(%)	Number	(%)	Area (ha)	(%)	Number	(%)	Area (ha)	(%)
Secondary forest												
Mixed forest	26	1.7	380.0	12.9	54	13.7	522.00	20.1	30	10.9	273.00	8.9
Broad-leaved forest	33	11.2	776.0	26.4	45	11.6	316.0	12.1	34	12.3	297.0	9.7
Pine forest	5	8.8	162.0	5.5	0	0.0	0.0	32.2	0	0.0	0.0	0.0
Subtotal	64	21.7	1320.0	44.8	99	25.5	838.0		64	23.2	570.0	18.6
Plantation												
Coniferous tree plantation	129	45.2	864.0	29.4	66	17.0	526.0	20.2	23	8.3	119.0	4.0
Broad-leaved tree plantation	6	2.1	52.0	1.8	2	0.5	5.0	0.2	0	0.0	0.0	0.0
Subtotal	135	47.3	916.0	31.2	68	17.5	532.0	20.4	23	8.3	119.0	4.0
Agricultural field												
Orchard	3	1.0	8.0	0.3	17	4.4	44.0	1.7	24	8.7	105.0	3.4
Rice field	19	6.6	206.0	7.0	42	10.8	322.0	12.4	18	6.5	242.0	7.9
Upper field	27	9.5	191.0	6.5	75	19.3	310.0	12.0	62	22.5	917.0	29.8
Institutional agriculture	0	0.0	0.0	0.0	2	0.5	134.0	5.2	2	0.7	440.0	14.3
Subtotal	49	17.1	407.0	13.8	136	35.0	812.0	31.3	106	38.4	1705.0	55.4
Urbanized area												
Residential area etc.	29	10.1	161.0	5.5	74	19.0	278.0	10.7	70	25.4	617.0	20.1
Subtotal	29	10.1	161.0	5.5	74	19.0	278.0	10.7	70	25.4	617.0	20.1
Graveyard	2	0.7	19.0	0.7	1	0.3	1.0	0.1	0	0.0	0.0	0.0
Stream	1	0.3	23.0	0.8	1	0.3	105.0	4.0	1	0.4	40.0	1.3
Others	6	2.1	93.0	3.2	10	2.6	34.0	1.3	12	4.3	18.0	0.6
Subtotal	9	3.1	135.0	4.7	12	3.2	141.0	5.4	13	4.7	59.0	1.9
Total	286	100	2941.0	100	389	100	2604.0	100	276	100	3073.0	100

Degree of fragmentation

The number of patches per unit (1,000ha) was 97.2, 149.4, and 89.8 in the upper, middle and lower river watersheds, respectively. Mean size of patch was 10.3, 6.7 and 11.1 ha in the upper, middle and lower river watersheds, respectively.

Ratios of the numerical percentage to that by area of patches were compared to clarify causal factors of fragmentation. In the upper river watershed, the ratios were higher in the order of urbanized area (1.84), plantation (1.52), agricultural field (1.24), others (0.66), and secondary forest (0.48). The order in the middle river basin was urbanized area (1.78), agricultural field (1.12), plantation (0.86), secondary forest (0.79), and others (0.59). That in the lower river watershed was others (2.47), plantation (2.08), urbanized area (1.26), secondary forest (1.25) and agricultural field (0.69).

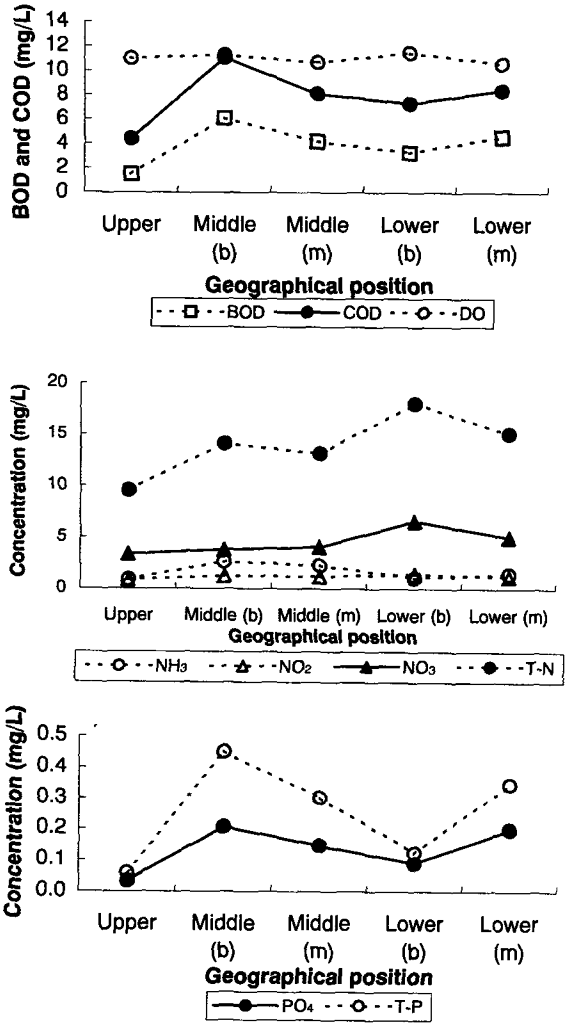

Fig. 2. Changes of aquatic environmental factors from the upper toward the lower river in the Wangsuk river (modified from Cho 1999). m: main river, b: branch of the main river.

Water quality

DO did not indicate remarkable change but BOD and COD increased from the upper river toward the lower one. Nitrogen showed different aspects depending on the forms; total (T-N) and nitrate (NO_3) increased but nitrite (NO_2) and ammonia (NH_3) tended to decrease with the process of water flow. Phosphorus concentration increased with water flow.

On the other hand, BOD, COD, ammonia, nitrite, and total phosphorus were higher in the tributary of the middle river compared with those in the other sites but those of the lower river did not show such trends. This result implies that the branch stream is an important pollution source in this river. Water qualities of the Wangsuk river showed variation depending on the site from the upper to lower river watersheds (Fig. 2). Such variations are due to the repeated appearances of the pollution source and the self-purifying action of the river.

DISCUSSION

Difference in landscape structure among areas

Forests composed of secondary forest and plantation dominated the upper and the middle river watersheds, while agricultural fields dominated the lower one. This difference of land use depends on the topography of each area considered the fact that agricultural fields need flat and wide-open area.

On the other hand, agricultural fields in the middle and the lower river watersheds showed a big difference from that in the typical rural areas (Lee 1998, Kim 2000). In view of the percentage of the agricultural fields, this area indicates a form of rural area. But composition of the agricultural fields was very different as most of them transformed to fields for the institutional agriculture. Such transformation is very significant in terms of environmental conservation as the agricultural fields including rice paddy possess diverse ecological functions, such as flood control, conservation of diverse biota, purification of pollutants, and so on (Kim *et al.* 2000).

Urbanized area increased from the upper toward the lower river watersheds and thereby showed an urban sprawl, such change was also progressed by occupying agricultural field. Taking into consideration that this transformation occurred in relation to a change of the governmental policy, discreetness of decision makers in the process of deciding a policy is urgently required.

Degree and cause of fragmentation

As the results of analyses on the number and size of landscape patches, fragmentation was more severe in the order of the middle, upper, and lower river watersheds. This result reflects the diverse land use and reflects the recent rapid urbanization in the middle river watershed. The upper river basin showed similar tendency but was different in an aspect that forest use through plantation contributed significantly to fragmentation. Low fragmentation in the lower river watershed is related to the developmental restriction in relation to the Green-belt and earlier urbanization compared with the other areas.

Causal factors of fragmentation can be explained by ratio of the numerical percentage to that by area of patch classified by landscape element. In the upper river watershed, landscape elements that numerical percentage is larger than that by area were urbanized area, plantation and agricultural field. Those landscape elements in the middle river watershed were urbanized area and agricultural field, and all elements except agricultural field fell under such a criterion in the lower one. This result showed that artificial interference, such as urbanization and agricultural activities usually caused landscape fragmentation. Fragmentation in the lower river watershed showed a different aspect. Agricultural field functions as a matrix and diverse factors contributed to fragmentation, the factors were artificial ones as well. But secondary forest appeared as a factor inducing fragmentation in this area. Such situation may due to succession of secondary forest escaped from the excessive forest use as a result of socio-economic change caused by rapid economic growth since 1980's (refer to Kamada and Nakagoshi 1996). In fact, succession of the secondary forest escaped from human use was progressed more rapidly in the urbanized area like the lower river watershed than that in the rural area (Kim 2000). Such background due to that urbanized area experienced fuel revolution earlier than the rural area did (refer to Kamada and Nakagoshi 1996). In this aspect, the number and size of patches reflects both natural and artificial processes in the human-influenced landscape (Forman and Gordron 1986, Turner 1989, Forman 1995, Raedeke and Raedeke 1995).

Relationship between water quality and land use pattern

Water quality was usually better in the order of the upper, middle, and lower river (Fig. 2). But the aspect showed fluctuation depending on the site when it is subdivided (Park, J. H. unpublished data). Such fluctuation would due to self-purification of the river and continued discharge of pollutants in each small watershed. Examples of self-purification can be also conformed in the change of nitrogen forms with water flow from tributary of the middle river toward the lower river (Fig. 2). For example, ammonia and nitrite concentration decreased from tributary of the middle river watershed toward the lower river one, while nitrate and T-N increased. These changes are due to nitrification of the organic pollutants over time after inflow. This nitrification is regarded as a self-purification as a biological process occurring in the river. In the present study, we focused on the relationship between water quality and land-use pattern. We regarded the developmental indices obtained from the ratio of urbanized area and/or agricultural field to the total area as a tool representing land-use pattern of an area (refer to Table 1). Despite such self-purification, water quality became worse from the upper toward the lower river. Water quality in each geographical position was proportionate to those developmental indices. Taking into consideration on the fact that the river showed a purifying capacity (Park, J. H. unpublished data) as was mentioned above, this correlation reflects that water quality of a river is closely related to land-use pattern of the watershed. In this respect, a strategy to manage the water quality in the level of watershed is urgently required (Lal 2000).

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LITERATURE CITED

Chester, L. A. Jr and C. J. Gibbons. 1996. Impervious surface coverage; The emergence of a key environmental indicator. J. Am. Planning Association 62: 244.

Cho, Y. M. 1999. A study on water quality management of the Chansil water resources. Seoul Development Institute, Seoul. 169p.

Environmental System Research Institute (ESRI). 1996. ArcView GIS. Environmental System Research Institute, Inc. New York. 350p.

Forestry Research Institute. (FRI) 1997. Physiognomic maps of Deokso, Yangji, and Songwoo. Forestry Research Institute, Seoul.

Forman, R.T.T. 1995. Land Mosaic: The ecology of landscapes and regions. Cambridge University Press, New York. 632p.

Forman, R.T.T. and M. Godron. 1986. Landscape Ecology. John Wiley, New York. 620p.

Hall, M. J. 1984. Urban hydrology. USA. Elsevier Applied Science Publisher: 28.

Kamada, M. and N. Nakagoshi. 1996. Landscape structure and the disturbance regime at three rural regions in Hiroshima Prefecture, Japan. Landscape Ecology 11: 15-25.

Kentula, M. E. 1997. A step toward a landscape approach in riparian restoration. Restoration Ecology 5: 2-3.

*Kim, D. S, Um, K. C., Yun, S. H., Yun, S. K. and Hwang, S. W. 2000. Why we have to keep the rice field? -Rice farming and the public function of the rice field-. Tdanim Publishing Co., Seoul. 171p.

Kim, J. E. 2000. Changes of landscape structure *in* rural areas with different land use regime. M.S. Thesis. Seoul Women's

Univ., Seoul. 49p. (In Korean with English Abstract.)

Lal, R. 2000. Rationale for watershed as a basis for sustainable management of soil and water resources. *In* R. Lal (eds.), Integrated water shed management in the global ecosystem. CRC Press, Boca Raton. pp. 3-16.

*Lee, C. S. 1998. Nature of Chungju and Jecheon. Ministry of Environment. (In Korean.)

Lee, C. S., S. K. Hong, H. J. Cho and J. M. Oh. 1999. Techniques for restoration of the natural environment. Donghwagisul Publishing Co. Seoul. 236p.

Lee, J. H., H. Y. Lee, J. K. Lee, D. K. Lee and H. H. Kim. 1998. A study on the conservation, rehabilitation and creation of naturalness of rivers (I) -The correlation of the degree of pollution on a river and the land use in rural area-. J. Korean Env. And Reveg. Tech. 1: 84-94. (In Korean with English abstract)

Nakagoshi, N., M. Kamada and S.K. Hong. 1992. Map of actual vegetation map in Miwa-cho, Hiroshima Prefecture. Bull. Biol. Soc. Hiroshima Univ. 58: 3-6 + Map.

Ojo, O. 1990. Recent trends in precipitation and the water balance of tropical cities: the example of Lagos, Nigeria in hydrological process and water management in urban areas. In H. Massing and J. Packman (eds.), U.K. IAHS. Pp. 33-41.

Raedeke, M.A.M. and K.J. Raedeke. 1995. Wildlife habitat design in urban forest landscapes. *In* G.A. Bradley (ed.), Urban Forest Landscapes, integrating multidisciplinary perspectives. pp. 139-149. University of Washington Press, Seattle.

Stanne, S. P., R. G. Panetta and B. E. Forist. 1996. The Hudson: an illustrated guide to the living river. Rutgers University Press, New Brunswick, New Jersey. 209p.

Turner, M.G. 1989. Landscape ecology: The effect of pattern on process. Ann. Rev. Ecol. Syst. 20: 241-251.

Yao, Y. J. C. Nelson and K. S. Lubinski. 1997. Bottomland hardwood forests along the upper Mississippi river. Natural Areas Journal 17: 164-173.

* Title is a tentative translation for the original title written in Korean by the authors.

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