Characteristics of woodland changes in an agricultural landscape - The case of Gwangju

Young-chang Lee[1], Woon-joo Jung[2], Keun-Ho Kim[3]*

[1]*EDI INC, CTO*
[2]*Graduate school, Yeungnam University, Gyeongsan-si, South Korea*
[3]*Department of Landscape Architecture, Yeungnam University, Gyeongsan-si, South Korea*

농촌경관지역의 산림변화 특성

이영창[1] · 정운주[2] · 김근호[3]*

[1]이디아이 환경디자인, [2]영남대학교 대학원, [3]영남대학교 조경학과

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Abstract : Recent landscape changes from human activities, such as agricultural development and urbanisation frequently result in the loss of habitats, the reduction in habitat patch size and an increasing isolation of habitat patches. However, there is little information on woodland changes in agricultural landscapes. Therefore, the aim of this research was to assess spatial characteristics and changes of woodland in an agricultural landscape and how these may have had an impact on ecological process for 33 years. One of the agricultural landscape character units was analysed based on aerial photographs from 1976, 1983, 1994, 2002 and 2009 in Gwangju city. The results indicated that landscape ecological metrics clearly showed that they could be used to monitor changes of woodland ecological conditions during the past 33 years. The results imply that particularly human activities have been leading to the decrease of the mean size of woodland patches and finally result in woodland isolation. These changes may have a negative impact on woodland bird species in the study area. This woodland information can be used to identify the potential and specific needs for setting priorities for conservation planning.

Key words **:** Agricultural landscape, Biodiversity, Landscape change, Landscape ecological metrics, Woodland

I. Introduction

Recent landscape changes from human activities, such as agricultural development and urbanisation frequently result in the loss of habitats, the reduction in habitat patch size and an increasing isolation of habitat patches (Andr n, 1994; Bender et al., 1998). Especially, changes in land use and farming infra-structure impact on the ecological value in agri-cultural landscapes (Lindhult et al., 1988). A fragmented landscape structure, which is composed of more or less isolated and smaller patches in size, impacts on a variety of ecological processes. It has been widely recognised that changes in size and isolation of habitat patches have a negative impact on species richness (Mazerolle and Villard, 1999) and the distri-bution and persistence of populations (Andrén, 1994; Bender et al., 1998; Hanski, 1999). Woodlands have been considered as one of important habitats for biodiversity conservation in South Korea (Kwon et al., 2005). Between 1995 and 2009 alone, 81,581ha of woodland have been lost in South Korea (Korea Forest Service, 2010). At the local level, Gwangju city has lost 636 ha of woodland between 1995 and 2009 (Gwangju city, 2010). However, there is little information on

***Corresponding author:** Tel: +82-53-810-2976
E-mail address: manchester99@ynu.ac.kr

woodland changes in agricultural landscapes. What are the causes of landscape change? What will be their likely impact on biodiversity? This kind of information appears to be a prerequisite for setting priorities for biodiversity conservation planning in agricultural landscapes. Thus, the aim of this research was to assess spatial characteristics and changes of woodland in an agricultural landscape and how these may have had an impact on ecological process. To achieve the research aim, this research characterises the spatial pattern of woodlands in the case study area and described how it has changed between 1976, 1983, 1994, 2002 and 2009. Implications for biodiversity conservation planning in Gwangju city would be discussed.

II. Materials and methods

1. Study area and landscape character assessment

Gwangju city covers 501 square kilometers and it has experienced strong urban growth. Between 1961 and 2009 the population increased from 318,467 to 1.44 million (Gwangju City, 2010). The building land increased from 5,079 ha to 5,536 ha between 2005 and 2009. However, agricultural lands (Dry paddy, rice paddy, orchard, pasture and forest field) decreased from 34,238 ha to 32,838 at the same period (Gwangju City, 2010). The study builds on previous research where a methodology had been developed and applied to provide comprehensive information on landscape character and its ecological conditions in Gwangju (Kim and Pauleit, 2005). Landscape character assessment, an approach originally developed in the UK (Countryside Agency and Scottish Natural Heritage, 2002; Swanwick, 2004) had been applied for the study area and fourty-six landscape character units were distinguished in previous research (Kim and Pauleit, 2005), The landscape character units were distinguished

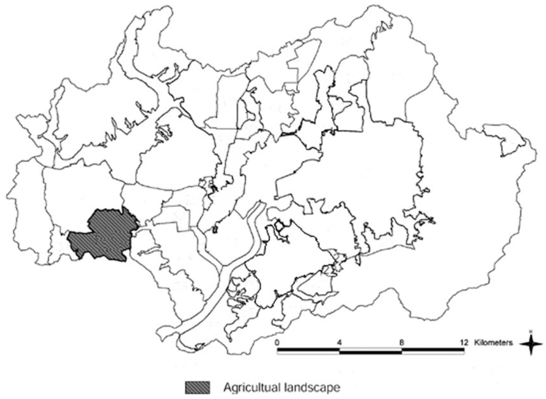

Fig. 1. The location of study area.

by their unique combination of physical and social landscape factors, such as landform, water features and vegetation areas, built-up areas and agricultural land use patterns. Agricultural landscapes are characterised by mainly agricultural land cover types and little urban land cover type. In this study, to characterise the spatial woodland changes between 1976, 1983, 1994, 2002, 2009 in the agricultural landscape, one of the agricultural landscape character units was chosen in the study area (Fig. 1).

The agricultural landscape had a size of 1,001 ha and was located in the west part of the study area. Key characteristics of this landscape were that it dominated by small to medium-scale, open, and undulating landform. Irregular mixed arable fields were surrounded by low wooded mountains. It was a quiet, harmonious and semi-natural landscape with small-scale irregular field patterns responding to the landform. It had isolated and traditional small to medium-scale settlements with little development. There were small scale terraced arable fields on lower slopes of mountains and intensive irregular rice fields along relatively flat valleys. This landscape had many narrow roads along natural landform contours across mountains and arable fields.

2. Data collection and analysis

In this study, 1: 5,000 topographic digital maps and 1: 20,000 black and white aerial photographs (from the National Geography Institute in 1976, 1983, 1994, 2002 and 2009) with 50 cm resolution were used to map woodlands for the study area. The smallest detectable unit was $1m^2$, but the classified objects had an average size of approximately $700m^2$. Woodlands were distinguished by visual inspection and then digitized on screen as polygons in Auto CAD. This data was then imported into Geographical Information System software ArcView 3.2 to analyze and display the results.

3. Quantifying the spatial characteristics and process of woodland change

Landscape ecological metrics were used to characterise the spatial pattern of woodland in the study area. Landscape ecological metrics have been widely used to characterize landscape structure (O'Neill et al., 1988; Turner, 1989; Forman, 1995; Gustafson, 1998; Cook, 2002). They are promising for landscape ecological assessments because they can be easily produced in a GIS environment from available data such as land cover. Land cover was suggested as an indicator of its ecological quality (Alberti, 2000). Therefore, it is assumed that landscape ecological metrics can be used as indicators for the comparative assessment and monitoring of the ecological condition of land-scapes. However, many of them are complex and their ecological meaning is not always clear (Wiens, 2002; Leitão et al., 2002; Li and Wu, 2004; Corry and Nassauer, 2005). While keeping the potential limitations in mind, this research used landscape ecological metrics which were suitable to analyse the spatial processes of woodland changes and biodiversity poten-tials in the previous researches (Kim and Stephan, 2005 and 2009). These were Area-weighted mean patch shape index (AWMPSI), Mean nearest-neighbour distance (MNND), Patch neighbor context (PNC) (Appendix 1). For this research, it used the previous data of landscape ecological metrics from 1976 and 2002 in the study area (Kim and Stephan, 2005 and 2009). The study also adopted concepts developed by Forman (1995) to take a closer look at the process of woodland changes. A distinction was made between dissection, fragmentation, shrinkage and attrition and expansion of woodlands in the study area. These major spatial processes in woodland transformation have significant effects on a range of ecological characteristics. Fragmen-tation refers to break up a woodland into smaller parcels. Fragmentation causes two major significant spatial processes, namely loss of the original woodland (attrition) and reduction in woodland size (shrinkage). Dissection is considered as a special case of fragmentation. The two spatial processes are differentiated in part because the separating elements typically are so different and widespread (roads, railroads and powerlines versus logged clearings, cultivated fields, housing tracts, pastures). Shrinkage is defined as the decrease in size of objects, such as woodlands. Attrition is caused by the disappearance of woodlands. Small woodlands disappear usually, though the occasional disappearance of large woodlands is apt to be especially significant ecologically because they can sustain viable populations of specialized species in interior habitats, provide core habitats and permit near-natural disturbance regimes. Expansion, on the other hand, can result from spontaneous establishment of woodlands, for instance on abandoned farmland and on brownfield sites, or from afforestation.

III. Results

1. Change of woodland cover, patch size and patch numbers

Table 1 presents the numbers and mean size of woodland patches in the study area. The percentage cover of woodland was 12.1% in 1976. The agricultural

Table 1. Characteristics and changes of woodland patches between 1976 and 2009.

Year	Area (ha)	Woodland of total area (%)	Mean Patch Size (ha)	Number of Patches	The five patch size classes: Less 5ha	5-9.9ha	10-50ha	Over 50ha
1976	121.3	12.1	1.2	97	93	4	-	-
1983	118.9	11.8	1.2	99	96	3	-	-
1994	106.0	10.5	1.0	98	95	3	-	-
2002	103.1	10.3	1.0	96	93	3	-	-
2009	98.5	9.8	1.1	91	88	3	-	-

Table 2. Main spatial woodland transformation processes between 1976 and 2009.

Year	Dissection	Fragmentation	Shrinkage	Attrition	Expansion
1976-1983	-	-	11	-	-
1983-1994	-	1	35	1	-
1994-2002	-	1	12	3	-
2002-2009	1	-	8	5	-

landscape had the decrease in the overall loss of woodland area (−22.8ha) between 1976 and 2009. This landscape experienced the strongest decrease of the percentage of woodland in 2009(0.5%), followed by 1976 (0.3%), 1983(0.3%) and 2002(0.2%). The mean size of woodland patches was largest in 1976 and 1983 (1.2ha), followed by 2009 (1.1ha), 1994 (1.0ha) and 2002(1.0ha). The average size of woodland patches decreased (−0.2ha) between 1983 and 1994. The average size of woodlands increased (+0.1ha) between 2002 and 2009. This increase was not a result of woodland expansion but the main reason was that many small patches were lost while fewer large patches remained.

Table 1 also indicates that the agricultural landscape was characterized by small sized woodlands. The number (n=96) of small woodlands (less 5ha) in 1983 was higher than in 1994 (n=95), 1976 (n=93), 2002 (n=93) and 2009 (n=88). By contrast, woodland patches in this landscape were not spatially arranged in large blocks with average patch sizes of more than 10ha. There was a significant decrease in number of woodland patches of less than 5ha in size between 2002 and 2009. The reason of a significant decrease in number of woodland patches (less than 5ha in size) was that agricultural activities caused the attrition (n=5) of woodland patches in this period (Table 2). Larger areas were lost as a result of shrinkage of existing woodland patches rather than as the removal of entire patches between 1976 and 2009.

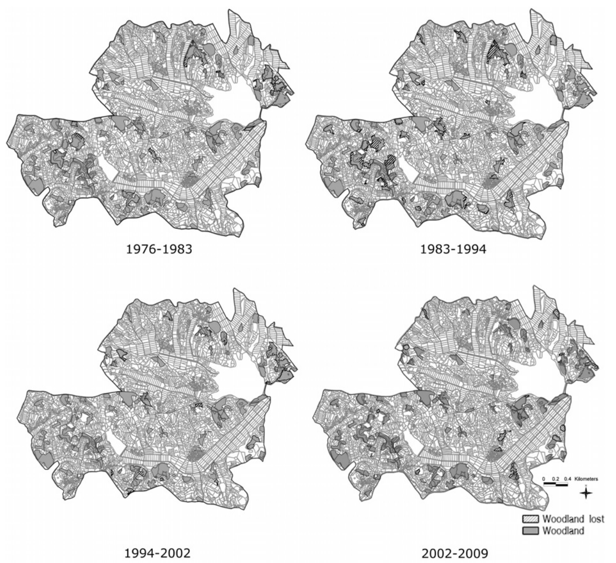

Fig. 2. Woodland transformation between 1976 and 2009.

Woodlands were in particular shrinking between 1983 and 2002 (Fig. 2). Attrition of woodland patches occurred particularly between 1994 and 2009.

Table 3. The values of landscape ecological metrics between 1976 and 2009.

Year	MPSI	AWMPSI	Mean nearest neighbour distance (m)	Neighbour context
1976	1.64	1.70	182	4.21
1983	1.63	1.68	179	4.16
1994	1.62	1.67	180	4.19
2002	1.63	1.67	185	4.05
2009	1.42	1.45	190	3.85

2. Change of woodland shape index

The mean shape index values were greater than 1, indicating that the average patch shape is noncircular. The Mean Patch Shape Index (MPSI) had more complex and irregular shapes in 1976 (Table 3). However, there was a significant decrease in MPSI (−0.21) during 2002 and 2009. This result suggested that the woodland patches became more simple and regular, and mostly had straight boundaries in the agricultural landscape during 1976 and 2009. The area−weighted values were greater than the unweighted values, indicating that the larger patches were more irregular in shape than the smaller ones. This index is more appropriate than the unweighted mean shape index in cases where larger patches play a dominant role in the landscape function relative to the phenomenon under consideration. The difference between the unweighted and weighted mean shape indices can be particularly noticeable when sample sizes are small. The Area−Weighted Mean Patch Shape Index (AWMPSI) showed that the woodland patches in 1976 (1.70) were the most irregular in shape, followed by 1983 (1.68), 1994 (1.67), 2002 (1.67) and 2009 (1.45).

3. Change of mean nearest neighbour distance

Mean Nearest−Neighbour Distance (MND) indicates the patterns of woodland patch distribution. For instance, a small mean MND implies a fairly concentrated pattern of woodland patches, whereas a large mean nearest neighbour distance indicates a more dispersed pattern of woodland patches in the study area. MND was found to be greatest in 2009, suggesting that woodland patches were the most isolated, while the MND was smallest in 1983, suggesting that patches were more closely neighboured (Table 3). The result of MND suggested that the woodland patches became isolated since 1976.

4. Change of woodland context index

Habitat patches in a landscape do not exist in isolation but are influenced by the quality of the surrounding matrix (Forman, 1995). For example, the magnitude of edge−related predation on songbird nests in forest patches may be strongly influenced by what lies across the forest boundary (Wilcove, 1985; Andrén, 1994). A high value indicates a contiguous pattern of suitable habitat patches with a high possibility for species dispersal. The value of woodland neighbour context was the greatest in 1976 (4.21), followed by 1983 (4.16), 1994 (4.19), 2002 (4.05) and 2009 (3.85) (Table 3). This result indicated that woodlands in 1976 were surrounded by a matrix of mostly near−natural habitats, and this spatial pattern therefore should enhance species dispersal. There was a steady decrease in the value since 1983. It indicated that the habitat quality of the surrounding woodland became lower.

IV. Discussion

The research indicates that woodlands have been changed in the past 33 years. The landscape ecological metrics worked well to indicate and monitor these changes. There was a common trend of woodland loss while no new woodlands were established between 1976 and 2009. Small patches (less than 5ha in size) were particularly vulnerable to and more likely to disappear due to human activities such as agriculture in the study area. The results of all processes of woodland transformation (dissection, fragmentation, shrinkage, attrition) occurred as hypothesized by Forman (1995) and proved to be useful to characterise the processes of woodland change in the study area. Moreover, it was shown how these processes could be quantified by means of landscape ecological metrics. The selected indicators allowed to assess changes in woodland quantity and quality as well as the overall effect of woodland change on landscape structure. These quantitative measures can improve understanding of the relationships between landscape pattern and process. Firstly, patch number in a landscape increases with fragmentation and decreases with the complete attrition of habitats. Secondly, average patch size decreases in the first two processes, and typically increases through habitat loss. The latter is somewhat counterintuitive but the reason is that small patches are most likely to disappear whereas a smaller number of bigger woodland patches are remaining. Thirdly, a nearest neighbor distance across the study area increases with fragmentation, shrinkage and attrition of woodland habitats.

Woodland loss is regarded as one of the most serious threats to avian species (van Dorp and Opdam, 1987; Willson et al., 1994; Ichinose and Katoh, 1998). An avian survey in Gwangju City showed that avian species numbers and population sizes have decreased since 1990 (Lee, 2003). Landscape ecological studies showed that woodland patch size and isolation were among the most important factors influencing the viability of bird populations. For instance, studies on woodland birds showed lower frequency of occurrence of woodland birds in the smallest and most isolated woodland patches (Opdam et al., 1985; van Dorp and Opdam, 1987; Harms and Opdam, 1990; Hinsley et al., 1994). The information produced in this research can be used to identify priorities for avian conservation planning in the study area. Modernization of farming in Gwangju led to changes in the agricultural landscape. Areas of arable land and rice field were coalesced into larger complexes and woodlands were removed to make way for agricultural land use. As a result, the agricultural landscape is now characterised by small and isolated woodlands while larger woodlands are lacking. Surviving remnants of woodlands in the landscape are often the most valuable. In such a landscape, woodland fringes represent a refuge for many plants and animals. However, this landscape does provide few suitable habitats for the more sensitive avian species which live in the interior of larger woodlands. Probably the most effective way to improve the situation in the agricultural landscape would be to consolidate the existing woodlands and to establish woodland corridors in between them. There are opportunities for increasing the woodland area in this landscape because of abandonment of agricultural lands caused by changes in government policies to increase rice production and changes in rural labor structure (Kang et al., 2003). Furthermore, farm incomes are often low and there are few incentives for young people to take on farms from the previous generation. As a result, the traditional forms of management are often discarded and land is abandoned. New afforestation on abandoned agricultural lands would provide a well-connected network of woodland patches to increase and conserve biodiversity in the agricultural landscape.

V. Conclusions

The research indicated that this landscape experienced the strongest decrease of the percentage of woodland in 2009 (0.5%), followed by 1976 (0.3%), 1983 (0.3%) and 2002 (0.2%). Although the average size of woodland patches decreased (−0.2ha) between 1983 and 1994, the average size of woodlands increased (+0.1ha) between 2002 and 2009. The number (n=96) of small woodlands (less 5ha) in 1983 was higher than in 1994 (n=95), 1976 (n=93), 2002 (n=93) and 2009 (n=88). There was a significant decrease in number of woodland patches of less than 5ha in size between 2002 and 2009. The AWMPSI showed that the woodland patches in 1976 (1.70) were the most irregular in shape, followed by 1983 (1.68), 1994 (1.67), 2002 (1.67) and 2009 (1.45). The result of MND suggested that the woodland patches became isolated since 1976. The value of woodland neighbour context was the greatest in 1976 (4.21), followed by 1983 (4.16), 1994 (4.19), 2002 (4.05) and 2009 (3.85). It indicated that the habitat quality of the surrounding woodland became lower. Landscape ecological metrics clearly showed that they could be used to monitor changes of woodland ecological conditions during the past 33 years. The results also imply that particularly human activities have been leading to the decrease of the mean size of woodland patches and finally result in woodland isolation. These changes may have a negative impact on woodland bird species in the study area. This woodland information can be used to identify the potential and specific needs for setting priorities for conservation planning. Avian surveys of woodlands in the study area will be needed to validate the results of this research for conservation planning in the future. Futhermore, future researches for the prioritization of conservation will be considered not only the threat to the habitats, but also the benefit and cost of conserving a habitat.

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APPENDIX 1. Landscape ecological metrics for assessing biodiversity values.

Landscape ecological metrics	Description	Formula
Patch shape:	A simple woodland shape means that species richness is low.	
Shape Index	SI_i is the patch shape index for $patch_i$; P_i the perimeter of the patch; a_i the area of the $patch_i$ It assumes that the patch shape index = 1 when the patch is circular, and increases without limit as patch shape becomes more irregular.	$SIi=\frac{P_i}{\sqrt{ax\pi}}$
Area Weighted Shape Index	SI_i = shape index of $patch_i$; ai the area of the $patch_i$	$AWSI=\frac{\sum_{i=1}^{m} SI_i x a_i}{\sum_{i=1}^{m} a_i}$
Patch distance:	A small mean nearest neighbour distance implies a fairly concentrated pattern of patches, whereas a large mean nearest neighbour distance indicates a more dispersed pattern of patches.	
Nearest Neighbour Distance	NND equals the nearest-neighbour distance from patch j to another patch k of the same type, based on shortest edge-to-edge distance.	$NND = d_{jk}$
Patch context:	A high value index in this study means that contiguous patches have a high possibility for species dispersal and are suitable habitat for woodland species.	
Mean Neighbour Patch Value Index	NPVI equals the sum of neighbour patch value of the focal patch; NPVIi=Neighbour patch value of $patch_i$; NP = Number of patches: total number of patches in the landscape. Value (1=low, 3=high habitat value); Urban land patches(1), Agricultural land patches(2), Semi-natural land patches(3)	$MNPV_i=\frac{\sum_{i=1}^{m} NPVL_i}{NP}$