Range Mgmt. & Agroforestry 36 (1) : 1-5, 2015
ISSN 0971-2070

Landscape ecological analysis of woodland changes in a mountain landscape in South Korea

Young-joo Kim[1] and Keun-Ho Kim[2]*
[1]Department of Agricultural Engineering, Gyeongsang National University, Republic of Korea
[2]Department of Forest Resources and Landscape Architecture, Yeungnam University, Republic of Korea
*Corresponding author e-mail: manchester99@ynu.ac.kr
Received: 26th October, 2013 Accepted: 25th March, 2015

Abstract
Recently, landscapes have undergone changes, and these changes in the size and isolation of woodland patches have negatively impacted biodiversity in mountain landscapes of rapidly developing urban regions in South Korea. However, little information is available on the extent of these changes in the mountain areas. Therefore, the aim of this study was to analyze the changes and spatial characteristics of woodlands in a mountain landscape to provide information for biodiversity conservation planning. The results indicated that this landscape underwent significant and fundamental changes between 2002 and 2012 due to activities including new road construction, and residential and commercial developments. Large woodland patches (over 5 ha in size) were particularly vulnerable to disappearance and shrinkage because of urbanization. The selected landscape ecological metrics revealed a decrease in patch size between 5 ha and 9.9 ha (n=7) and over 10 ha (n=2). The area-weighted mean patch shape index (AWMPSI) decreased from 3.86 in 2002 to 3.30 in 2012. The mean nearest-neighbor distance (MND) increased from 70.4 m in 2002 to 75.9 m in 2012. Shannon Diversity Index (SHDI) of land cover decreased from 1.31 in 2002 to 1.22 in 2012. SHDI of woodland type also decreased from 0.24 in 2002 to 0.20 in 2012. The results of landscape ecological indices suggest that the woodlands were becoming smaller, simpler, and more isolated and homogenous. These spatial changes of the woodlands probably had adverse effects on biodiversity. For more information of landscape ecological conditions, a more comprehensive analysis based on more landscape ecological metrics is needed in future study.

Keywords: Biodiversity, Landscape change, Landscape ecological metrics, Urbanization, Woodland type

Abbreviations: AWMPSI: Area-weighted mean patch shape index; **MND:** Mean nearest-neighbor distance; and **SHDI:** Shannon diversity index

Introduction
Urbanization and agricultural activities in the world have caused changes to landscape and climate. These changes have resulted in the loss of habitats, reduction in agricultural production, an increasing isolation of habitat patches and environmental degradation (Andrén, 1994; Bender *et al*., 1998; Antrop, 2004; Rathore *et al*., 2011; Baolin *et al*., 2012; Rajendra *et al*., 2014). It is widely recognized that changes in size and isolation of habitat patches negatively affect species richness (Mazerolle and Villard, 1999; Lehavävirta *et al*., 2006) and the distribution and persistence of populations (Hanski, 1999). Woodlands are considered as important habitat for biodiversity conservation in Korean cities. The average loss of woodland over the last decade has been 5,378 ha in the country (Korea Forest Service, 2011). In case of Gwangju city, 636 ha of woodland were lost between 1995 and 2009 (Gwangju City, 2010). The changes of woodlands affect the distribution and abundance of animal and plant. However, little information is available on the extent of these changes in mountain areas. This kind of information can be used to set priorities for biodiversity conservation planning and more effective strategies for landscape ecological planning in mountain regions. Therefore, the aim of this research was to analyze the change and spatial characteristics of woodlands in a mountain landscape to provide information for biodiversity conservation planning.

Materials and Methods
Study site: Forty-six landscape character units were distinguished for Gwangju City according to 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 (Kim and Pauleit, 2005). One of the mountain landscape character units was chosen in order to characterize the spatial woodland changes between 2002 and 2012 (Fig. 1).

The study site of 1,585 ha situated in the southern part is characterized by woodlands, arable lands and irregular field patterns. The agricultural fields are small to medium scale with irregular boundaries in and nearby the mountain areas.

There are few settlements in the highly mountainous areas. These areas are characterized by historic unplanned settlement layouts with a woodland background.

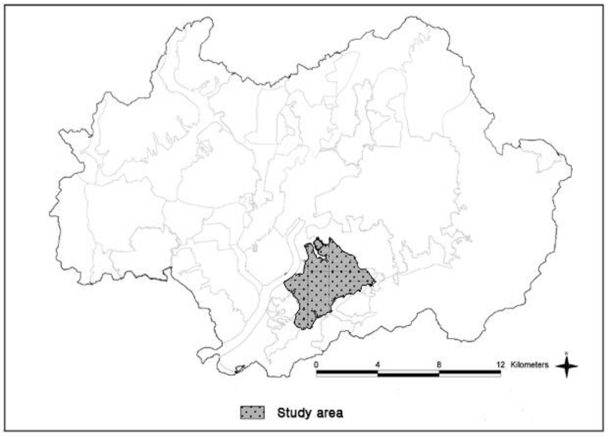

Fig 1. The selected study area

Data collection and analysis: The woodlands were mapped using 1: 5,000 topographic digital maps and 1: 20,000 black and white aerial photographs between 2002 and 2012. The woodlands were distinguished by visual inspection and then digitized on the screen as polygons in Auto CAD. The data were then imported into Geographical Information System software Arc View 3.2 to analyze and display the results. To analyze the changes of land cover, nine land cover types were distinguished and then further aggregated into three general land cover types (urban land, agricultural land and semi-natural land).Urban land is largely artificial and controlled by human activities. Urban land cover types determined for the study were residential land, commercial land and built-up area. Agricultural land is also mostly controlled by human activities for intensive agricultural productions. Agricultural land categories were defined as arable land, rice paddy field and orchard. Semi-natural land is little influenced by human activities. These land covers were reservoir, river and woodland. This research also used 1: 5,000 digital maps of woodland type provided by Korea forest service to identify biological changes in woodlands.

To quantify and characterize the spatial patterns and richness of the woodland, landscape ecological metrics were used (Wiens, 2002; Kim and Pauleit, 2007 and 2009). This research used Mean Nearest-neighbor Distance (MND), Shannon Diversity Index (SHDI) and Area Weighted Mean Shape Index (AWMSI). MND was used to analyze the degree of isolation of the woodland.

MND was defined in the study as mean of nearest neighbor distance (NND) over all patches

NND = d_{jk}

Where NND equals the nearest-neighbor distance from patch j to another patch k of the same type, based on shortest edge-to-edge distance.

SHDI for landscape heterogeneity was calculated with the land cover data and woodland types. This index provides information on the richness of habitats and its relative importance in the study area. SHDI was defined as:

$$\text{SHDI} = -\sum_{k=1}^{s} Pi In Pi$$

s = number of land cover types or woodland types; *Pi* = proportion of area in land cover or woodland type *k*. Generally, low values are connected with homogeneous landscapes where one land cover type or woodland type is highly predominant, while high values are present in heterogeneous landscapes, characterized by the presence of several land cover types and woodland types.

This research also measured AWMSI by weighting patches according to their size. Specifically, larger patches are weighted more heavily than smaller patches in calculating the average patch shape for woodland. 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 for small sample sizes. AWMSI was defined in the study as:

$$\text{AWMSI} = \frac{\sum_{i=1}^{m} SI_i x a_i}{\sum_{i=1}^{m} a_i}$$

SI_i = shape index of $patch_i$; a_i the area of the $patch_i$

Results and Discussion

Change of land cover: Agricultural lands and woodlands were the dominant land cover types in 2002, covering more than 44% and 41% of the area in this landscape, respectively, followed by urban land (12%) and water habitats (1.8%) (Table 1).However, this landscape experienced a decrease in agricultural land cover (-7.2%), woodland cover (-2.6%) and water habitats (0.6%) between 2002 and 2012, although the urban land cover increased only from 12.3% in 2002 to 22.7% in 2012.

Overall, the woodland cover gradually declined between 2002 and 2012. The result shows the conversion of woodland lost into different land cover types for 10 years. This landscape lost 40.6 ha of woodland, which was converted into school and commercial complex (24.2 ha), followed by residential site (8.9 ha) and road (7.5 ha). During this period, urban infrastructure such as roads and urban land covers greatly increased in this landscape.

Table 1. Changes of land cover

Year	Urban land (%)	Agricultural land (%)	Semi-natural habitats (%)	
			Rivers and reservoirs	Woodland
2002	194.5 ha (12.3)	710.0 ha (44.8)	28.5 ha (1.8)	652.0 ha (41.1)
2012	359.3 ha (22.7)	595.4 ha (37.6)	18.9 ha (1.2)	611.4 ha (38.5)

Landscape ecological analysis of woodland changes: The woodland area decreased from 652.0 ha in 2002 to 611.4 ha in 2012 (Table 2). The mean size of the woodland patches also decreased from 7.1 ha in 2002 to 7.0 ha in 2012. The woodland patches in the mountain landscape were spatially arranged in large blocks, with patch sizes of more than 10 ha (n=31) and of between 5 ha and 9.9 ha (n=34) in 2002. There was a slight decrease in total number of woodland patches (n=5), patch size between 5 ha and 9.9 ha (n=7) and over 10 ha (n=2). There was a slight increase in the number of woodland patches sized less than 5 ha (n=4) because urban developments in woodlands caused the fragmentation, dissection and shrinkage of woodland patches. This result indicated that the value of species richness of woodlands in the mountain landscape had reduced from 2002 to 2012. Table 2 shows that MND increased from 70.4 m in 2002 to 75.9 m in 2012. This result suggested that the woodland patches in the study area became isolated because of their shrinkages and attritions due to a range of urban development activities.

The Mean Patch Shape Index (MPSI) indicated that the landscape had more complex and irregular shapes in 2002. However, there was a slight decrease in MPSI (-0.07) from 2002 to 2012. The area-weighted values were greater than the MPSI, indicating that the larger patches were more irregular in shape than the smaller ones. AWMPSI is more appropriate than the MPSI in this case where larger patches play a dominant role in the landscape function relative to the phenomenon under consideration. AWMPSI decreased from 3.86 in 2002 to 3.30 in 2012, implying that the woodland patches became simpler and more regular, with straight boundaries in the mountain landscape.

In this study, higher landscape heterogeneity diversity was assumed to mean more species and more environmental stability. The SHDI was used to represent this dimension of mountain landscape. The SHDI of land cover was greatest in 2002 (1.31), which suggested that this landscape had a wider range of habitat types in 2002. This diversity of habitat types and species diversity was hypothesized to have exerted a positive effect on the biological stability of this landscape type. The SHDI of land cover was lower in 2012 (1.22), indicating that it had been homogeneous landscape, presumably with fewer species and a less stable ecological structure.

Fig. 2 shows the dynamic changes in the woodland patches between 2002 and 2012. The woodlands suffered from shrinkage, attrition, dissection and fragmentation during 2002 and 2012. Mainly commercial complex, residential and road developments led to strong shrinkage (n=18), attrition (n=10), dissection (n=2) and fragmentation (n=1) of the woodlands between 2002 and 2012.

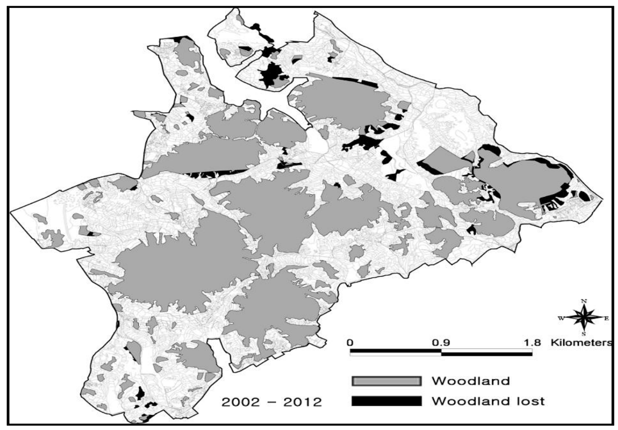

Fig 2. Dynamic changes of the woodlands

Table 2. Landscape ecological analysis of woodland changes

Year	Wood land area (ha)	Mean woodland patch size (ha)	Number of wood land patches	Patch size classes : less than 5 ha (%)
2002	652.0	7.1	91	26
2012	611.4	7.0	86	30

Year	5-9.9 ha	Over 10 ha	MPSI	AWM PSI	MND (m)	SHDI of land cover
2002	34	31	1.70	3.86	70.4	1.31
2012	27	29	1.63	3.30	75.9	1.22

Pinus densiflora and *Phyllostachys nigra* were the dominant woodland types in 2002, covering 184 ha and 121 ha of the area in this landscape, respectively, followed by grassland (109 ha) and *Pinus rigida* (105 ha) (Table 3). The area of each woodland type had a gradual decrease in grassland (-12 ha), *Pinus rigida* Mill (-11 ha) and *Phyllostachys nigra* (-9 ha) between 2002 and 2012. To identify biological changes in woodlands, this research used the SHDI of woodland type. The result indicated that it decreased from 0.24 in 2002 and 0.20 in 2012. This suggested that it was becoming homogeneous woodland which probably affected biodiversity loss in woodlands.

Table 3. Changes of woodland types

Woodland types	2002 (ha)	2012 (ha)
Pinus densiflora Siebold & Zucc.	184	180 (-4)
Pinus rigida Mill.	105	94 (-11)
Pinus thunbergii Parl.	0.5	0.5(0)
Chamaecyparis obtuse (Siebold & Zucc.) Endl.	0.1	0.1 (0)
Cryptomeria japonica (L. f.) D. Don	0.6	0.6 (0)
Quercus acutissima Carruth.	2	1.5 (-0.5)
Castanea crenata Siebold & Zucc.	0.7	0.7 (0)
Populus nigra var. *italica* Koehne.	8	8 (0)
Robinia pseudoacacia L.	1.7	1.4 (0.3)
Phyllostachys nigra	121	112 (-9)
Larix leptolepis	9	8 (-1)
Quercus aliena Blume	4.2	4.0 (-0.2)
Quercus dentata	3.3	2.9 (-0.4)
Quercus serrata	3.1	2.7 (-0.4)
Grassland	109	97 (-12)
Mixed forest of soft and hardwood	100	98 (-2)
Total	652	611.4 (-40.6)
SHDI of woodland type	0.24	0.20 (-0.04)

This research analyzed the changes and spatial characteristics of woodlands in a mountain landscape to provide information for biodiversity conservation planning. The results indicated that the mountain landscape was dominated by agricultural and woodland land cover types. *Pinus densiflora* and *Phyllostachys nigra* were dominant woodland types. This landscape had been changed between 2002 and 2012 due to activities including new road construction, and residential and commercial developments. There was a common trend of woodland loss across the study area and no new woodlands were established during 2002 and 2012. Large woodland patches (over 5 ha in size) were particularly vulnerable to disappearance and shrinkage because of urbanization. Many woodlands were lost due to residential and infrastructural developments between 2002 and 2012. Selected landscape ecological indicators were used to assess changes of woodland conditions and the overall effect of woodland change on the landscape structure. Firstly, the results of landscape ecological analysis revealed a decrease in patch size between 5 ha and 9.9 ha (n=7) and over 10 ha (n=2). Secondly, AWMPSI decreased from 3.86 in 2002 to 3.30 in 2012. Thirdly, MND increased from 70.4 m in 2002 to 75.9 m in 2012. Fourthly, SHDI of land cover decreased from 1.31 in 2012 to 1.22 in 2012. Fifthly, SHDI of woodland type decreased from 0.24 in 2012 to 0.20 in 2012. Although the woodlands were dynamic for the 10 years of the study period, the ecological conditions remained relatively stable, compared to urban, urban fringe and agricultural landscape types in the study city. The results suggest that woodlands were becoming smaller and more isolated. The woodland patches also became simpler and more regular, with straight boundaries. These spatial changes of the woodlands probably had adverse effect on biodiversity.

The mountain landscape still retained relatively large woodland patches (over 10 ha in size), but the results of landscape ecological analysis clearly demonstrated that the large woodlands had become more isolated due to attrition and shrinkage. Large woodlands can provide good opportunities to enhance the dispersal of wildlife. A woodland area of over 10 ha is suggested as a proper size to support a high probability of breeding of many area-sensitive and interior woodland avian species (Hinsley *et al*. 1994; McIntyre 1995). Thus, the most effective way to improve the situation is probably to strictly protect existing large woodlands as core habitats, to keep small woodlands as stepping stones and to establish ecological green networks between them to increase sustainable ecological conditions and the values of biodiversity in the study area. However, similar to urban and urban fringe landscapes, it is difficult to create new woodlands because of high land prices. To increase woodland areas, abandoned agriculture lands caused by Korean government policy changes in rice production and rural labor structure in the last few years can be used (Kang *et al*., 2003). The introduction of new woodlands in abandoned agricultural lands nearby mountains and the conservation of wet rice and arable fields would provide a well-connected green network to increase and conserve biodiversity in this landscape. This would give greater opportunities for increasing local woodland species richness and encouraging its disperse into neighbor woodlands. Woodland boundaries play important ecological roles as transition zones between different habitats. This study demonstrated that the ecological function of woodland boundaries is reduced by urbanization. It is important to increase green habitats in transition zones between woodlands and urban areas. It would be desirable to create green spaces in public buildings and schools, and to convert linear shaped, unused lands of roadside, riversides and railway areas into green habitats.

Finally, the interrelations between woodland change and biodiversity must be considered for the successful implementation of biodiversity issues into conservation planning. This woodland information can be used to identify the potential and specific needs for conservation planning. Furthermore, this research only used MND, SHDI and

AWMPSI for landscape ecological analysis. For more information of landscape ecological conditions, a more comprehensive analysis based on more landscape ecological metrics is needed in future study.

Acknowledgement

This research was supported by the Yeungnam University research grants in 2011.

References

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat. *Oikos* 71**:** 355-366.

Antrop, M. 2004. Landscape change and the urbanisation process in Europe. *Landscape and Urban Planning* 67**:** 9-26.

Baolin, M., P. Zhenhua and G. Jian. 2012. Driving system of ecological construction. *Range Management and Agroforestry* 33: 8-12.

Bender, D. J., T. A. Contreras and L. Fahrig. 1998. Habitat loss and population decline: a meta-analysis of the patch size effect. *Ecology* 79: 517-533.

Gwangju City. 2010. *Gwangju Statistical Year book*. Gwangju City., Gwangju.

Hanski, I. 1999. *Meta population Ecology*. Oxford University Press, Oxford.

Hinsley, S. A., P. E. Bellarmy, I. Newton and T. H. Sparks. 1994. *Factors Influencing the Presence of Individual Breeding Bird Species in Woodland Fragments-Research Report 99*. English Nature. Peterborough.

Kang, B., S. Shim and K. Ma. 2003. Floristic composition of plant community in set-asides with regard to serial stages. *Korean Journal of Environmental Agriculture* 22: 53-59.

Kim, K. H. and S. Pauleit. 2005. Landscape metrics to assess the ecological conditions of city regions: application to Kwangju city, South Korea. *International Journal of Sustainable Development* and *World Ecology* 12: 227-244.

Kim, K. H. and S. Pauleit. 2007. Landscape character, biodiversity and land use planning. The case of Kwangju City Region, South Korea. *Land Use Policy* 24: 264-274.

Kim, K. H. and S. Pauleit. 2009. Woodland changes and their impacts on the Landscape structure in South Korea, Kwangju city region. *Landscape Research* 34: 257-277.

Korea Forest Service. 2011.*Statistical Year book of Forestry. Vol. 41*. Korea Forest Service., Korea.

Lehavävirta, S., D. Kotze, J. Niemelä, M. Mäntysaari and B. OōHara. 2006. Effects of fragmentation and trampling on carabid beetle assemblages in urban woodlands in Helsinki, Finland. *Urban Ecosystem* 9: 13-26.

Mazerolle, M. J. and M. A. Villard. 1999. Patch characteristics and landscape context as predictors of species presence and abundance: a review. *Ecoscience* 6: 117-124.

McIntyre, N. E.1995. Effects of forest patch size. *Landscape Ecology* 10: 85-99.

Rajendra, P., A. K. Pandey, N. Ram, S. K Dhyani, N. K. Saroj and V. D. Tripathi. 2014. Risk and vulnerability due to climate change and adaptation initiatives for agricultural resilience in Panna district of Madhya Pradesh, central India. *Range Management and Agroforestry* 35:157-162.

Rathore, V. S., J. P. Singh and M. M. Roy. 2011. Shrubs of hot arid Rajasthan: economic and ecological imperatives. *Range Management and Agroforestry* 32: 71-78.

Wiens, J. A. 2002. Central concepts and issues of landscape ecology. In: K. J. Gutzwiller (ed). *Applying Landscape Ecology in Biological Conservation,* Springer. New York. pp. 3-21.