PRESICTIONS OF FUTURE LAND USE DEPENDING ON CLIMATE CHANGE SCENARIOS AND RISK ANALYSIS FOR FURTURE ECOSYSTEM SERVICE VALUE

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KEY WORDS : ESV, , Land Use/Land Cover, Climate change, Costanza, Xie

ABSTRACT: Modeling the effects of past and current land use composition and climatic patterns on surface Run-off, sediment provides valuable information for environmental and land planning. This study predicts the future impacts of urban land use and climate changes on surface Run-off within the Hoeya River Basin, South Korea, between 2050 and 2059 Using Soil and Water Assessment Tool (SWAT). For the future LULC map, it has been drawn based on a storyline of RCP 4.5 and 8.5 scenarios with a current LULC map (2000) used as a baseline. Future climate patterns examined include the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway (RCP). Such changes will have significant implications for water availability and nutrient transport regimes in the Hoeya River Basin. Urbanization was the strongest contributor to the increase of surface runoff and water yield, replacement of desertscrub/grassland.

INTRODUCTION

South Korea (hereafter, Korea) has developed rapidly since the 1970s. However, while various development projects have been promoted, systematic and comprehensive spatial planning has been lacking and some factors crucial to balanced and sustainable development have been overlooked. The need for environmentally conscious land management has emerged as a prerequisite of future development (Lee and Kim, 2004; Lee et al., 2005). In light of these changes, scientists have been conducting intensive research on balanced development through environmentally conscious planning.

To advance this purpose, an improved understanding of land use throughout the country is necessary because land-use changes often have a significant negative impact on ecosystems and the goods and services they provide (Kreuter et al., 2001). In addition, predictions of future land-use changes and quantitative analysis of the consequent effects on environmental service values (ESVs) can aid the development of appropriate planning and policy.

The main contributions of this paper are as follows: 1. We used information obtained from land use–land cover (LULC) maps for each year of the study period to calculate ESV. In addition, we estimated LULC maps for a future period (2015–2025) based on land suitability mapping. 2. The research purposes were to compare the ESVs calculated by the Costanza and Xie methods, to analyze past and future changes, and to compare ESV characteristics in relation to the degree of urbanization.

METHODS

Study area

The study area covered all land areas of Korea including Jeju Island, except some smaller islands such as Ulleung and Dokdo. This area lies between 34°18′42″N and 37°22′43″N and 124°19′30″E and 130°52′31″E (Fig. 1). The total terrestrial area of Korea is 99,828 km2.

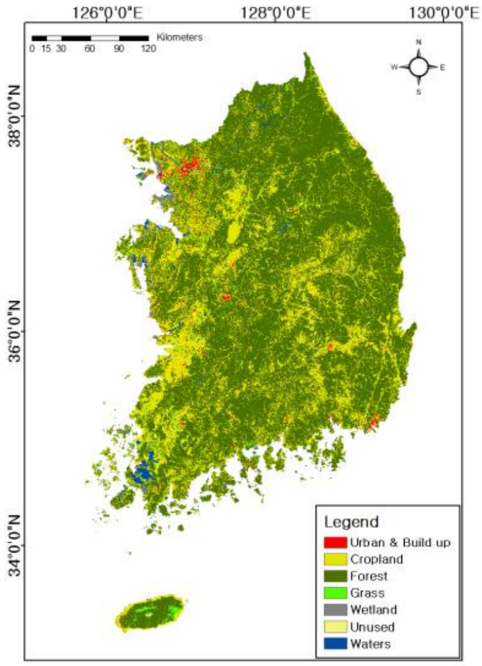


Fig. 1. Study area and LULC maps (1975~2005)

Assignment of ecosystem service value and function

To obtain the ESV for each of the seven LULC categories used to classify the Landsat and SPOT-5 datasets, each category was compared to the ESVs from Costanza et al. (1997) and Xie et al. (2003). Costanza et al. (1997) classified the biosphere into 16 ecosystem types and 17 service function types and then estimated the ESV of each function. On the basis of Costanza et al.′s (1997) coefficient, Xie et al. (2003) extracted the equivalent weight factor of ecosystem services per hectare of terrestrial ecosystems in China and modified the value coefficient for Chinese ecosystems.

The total values of terrestrial ecosystem services in the study area from 1975 to 2005 were obtained by multiplying the estimated size of each LULC category by the value coefficient of the biome used as the proxy for that category, as follows:

$$ESV = \sum_k \sum_f A_k \times VC_k, \qquad (3)$$

where k is land-use category, f is ecosystem service function type, A_k is the area (ha) of k, and VC_k is the value coefficient (USD/ha/yr) for k and f (Tianhong et al., 2010; Zhao et al., 2004). Xie′s coefficient was based on the value of the Chinese Yuan (CNY, as of 2001), whereas Costanza′s coefficient used US dollars (USD, as of 1995). For comparison purposes, the base period was set to 1995 and USD was applied for both coefficients. For the Xie coefficient, China maintained a fixed exchange rate of 8 CNY per 1 USD from 1996 to 2005, and we also adopted this rate.

Table 1 ESV Coefficient of Costanza et al. (1997) and Xie et al. (2003) (Unit : USD)

	Costanza	**Xie**
cropland	**92**	**764.29**
forest	**969**	**2416.75**
grass	**232**	**800.81**
wetland	**14785**	**6936.13**
unused	**0**	**46.43**
water body	**8498**	**5084.55**

Costanza et al., 1997 Xie et al., 2003.

As shown in Table 1, the Costanza and Xie coefficients have different values. The total sum of the Xie ecosystem service coefficient is at most 65.3% of the Costanza ecosystem service coefficient. This difference occurs for various reasons. The first involves differences in the LULC estimations. For example, whereas 0% of land was classified as unused by the Costanza method, 2.3% was unused in the Xie estimation. The difference is particularly large for wetland and water body.

Results and discussion

Analysis of changes in ecosystem service value over the past 30 years

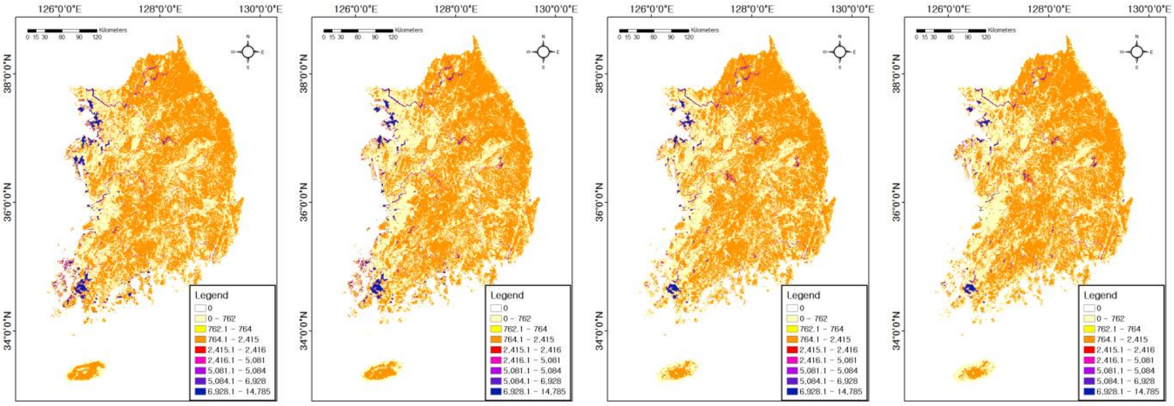
Changes in LULC : Because of uncertainties in the estimated areas of land use, the resulting changes in land use must be treated with caution. However, if the magnitude of the estimated changes is substantial, we can draw general inferences about the effect on ecosystem services of the detected changes in land-use patterns (Congalton and Green, 1999; Kreuter et al., 2001).

Table 2 Change in LULC in Korea from 1975 to 2005 (Unit : ha)

LULC	Urban & Build up	Cropland	Forest	Grass	Wetland	Unused	Water body	Total
1975	99755	2579255	6494141	128076	110645	74885	148242	9634998
	1.04%	26.77%	67.40%	1.33%	1.15%	0.78%	1.54%	100.0%
1980	142864	2601732	6361906	184044	100087	109269	135096	9634998
	1.48%	27.00%	66.03%	1.91%	1.04%	1.13%	1.40%	100.0%
1985	188438	2632982	6369484	142359	51155	91461	159119	9634998
	1.96%	27.33%	66.11%	1.48%	0.53%	0.95%	1.65%	100.0%
1990	261744	2542542	6348955	196436	37878	104697	142746	9634998
	2.72%	26.39%	65.89%	2.04%	0.39%	1.09%	1.48%	100.0%
1995	327813	2504259	6315549	211047	27569	110782	137980	9634998
	3.40%	25.99%	65.55%	2.19%	0.29%	1.15%	1.43%	100.0%
2000	404637	2509477	6209145	229951	26468	118832	136489	9634998
	4.20%	26.05%	64.44%	2.39%	0.27%	1.23%	1.42%	100.0%
2005	595107	2434604	5931932	280613	22719	146921	223104	9634998
	6.18%	25.27%	61.57%	2.91%	0.24%	1.52%	2.32%	100.0%

As shown in table 2, forest and cropland were the dominant land-use categories in Korea, accounting for more than 80% of total land cover. Urban & built-up, grass, unused, and water body areas increased by approximately 495,352 ha, 152,537 ha, 72,036 ha, and 74,862 ha, respectively. Among these categories, urban & built-up showed the largest rate of change. The considerable decreases in forest and cropland and concomitant increases in urban & built-up and grass can be attributed to two factors: industrial and social development.

Changes in ecosystem service values : In Korea, forest was the largest land use by area and also had a large coefficient value. Accordingly, forest showed the highest ESVs among the categories in both methods. The areas of wetland and water body were not large enough to produce large ESVs, although these categories had the highest value coefficients. From 2000 to 2005, the water body category showed the largest increase and accounted for 63.45% of the ESV by the Costanza method and 63.40% of that by the Xie method. From 1980 to 1985, wetlands showed the largest reduction in area, leading to ESV decreases of -48.92% and -48.85% by the Costanza and Xie methods, respectively.



(a) 1975 **(b) 1980** **(c) 1985** **(d) 1990**

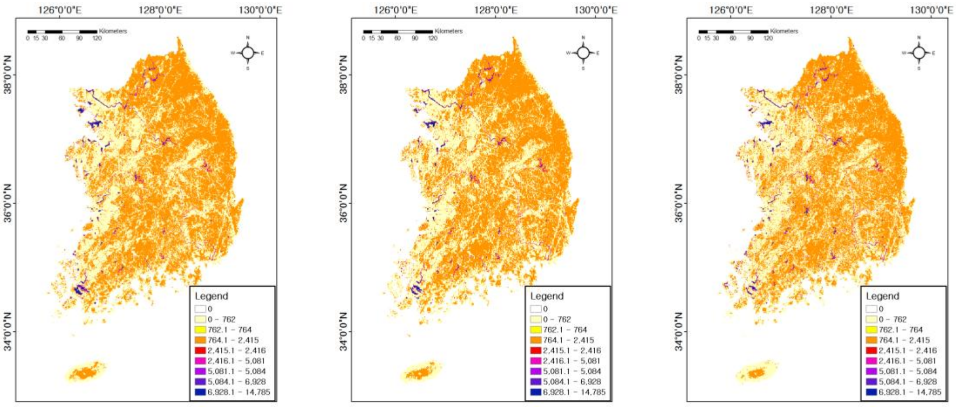
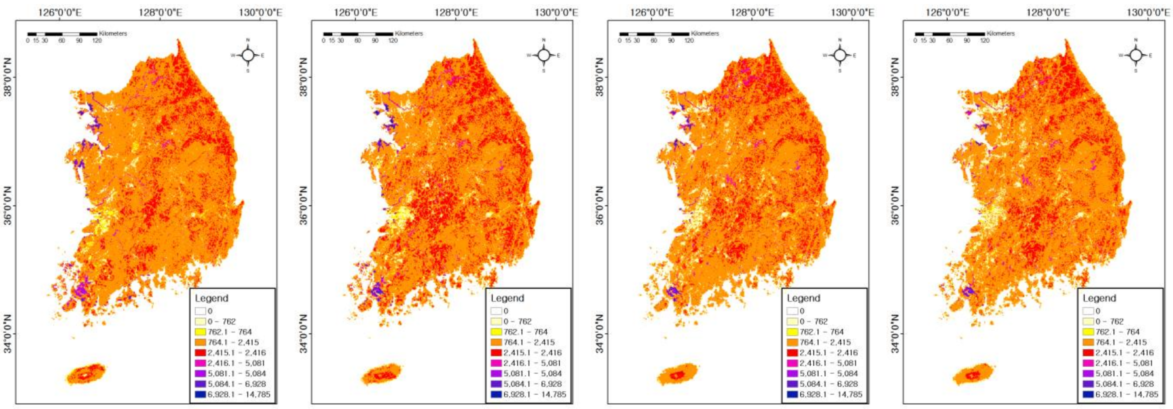


Fig. 3. Spatial distribution of ecosystem service value from 1975 to 2005 (Costanza method)



(a) 1975 **(b) 1980** **(c) 1985** **(d) 1990**

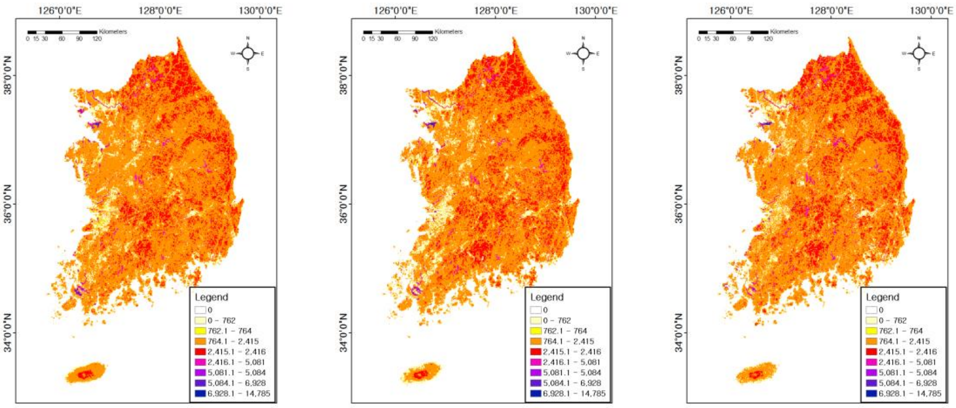


Fig. 4. Spatial distribution of ecosystem service value from 1975 to 2005 (Xie method)

Figures 3 and 4 show the spatial distributions of ESV calculated for the 30-year period from 1975 to 2005. We display the period in eight spans using the quantities method to compare the Costanza (Fig. 3) and Xie (Fig. 4) coefficients. Common characteristics shown in Figs. 3 and 4 are the differences between eastern and western Korea. The eastern region has more forest cover and thus a higher ESV value compared to western region, which is almost completely occupied by the urban and built-up and cropland categories.

Comparing Figs. 3 and 4, most of Fig. 3 is colored in yellow category with only a few areas in blue category. Figure 3 shows similar ESV values. Overall, the ESV value increased, as indicated by colors in the red end of the spectrum. By the Costanza method, the forest and cropland coefficients were 92 (yellow) and 969 (yellow). Forest and cropland cover large areas and thus most of the map is yellow, except for the wetland and water body areas, which have coefficients of 14,785 and 8,489, respectively, and are displayed in blue color. In contrast, Fig. 4 has yellow, red, and blue areas, reflecting forest, cropland, wetland, and water body coefficients of 764.29 (yellow), 2416.75 (red), 6936.16 (blue), and 5084.55 (blue).

Predicted ecosystem service value from 2015 to 2025

The variation in LULC predicted for 2015 to 2025 differs from that found for 1975 to 2005, particularly in the forest and cropland categories (Table 3). From 1975 to 2005, forest decreased rapidly, but from 2015 to 2025 the estimated rate of decrease was very slow at 0.17 to 0.13% per year. However, cropland is predicted to have a more rapid decrease of 0.05 to 0.1% per year.

This result probably reflects environmental protection zones and legal restriction zones, which were considered environmental and social factors among the dependent variables. The Environmental Evaluation Map for National Land provides environmental evaluations of the whole country and has been used by the Ministry of Environment as basic data for establishing environmental preservation policies. Our finding of an only slight reduction in forest area in the future period reflects the Ministry's forest preservation policy. Promotion of forest preservation and expansion may also explain the rapid decrease in cropland.

Figures 5 and 6 show the estimated future distributions of ESV in Korea from 2015 to 2025, calculated using the Costanza and Xie coefficients. In general, the nodata increases as forest and cropland become encompassed by urban areas. Other areas show almost no change. Common to Figs. 5 and 6 is that reductions in forest and cropland occur largely in urban areas due to the increase in the nodata, whereas other areas show little change. However, Fig. 6 using the Xie coefficient is relatively well appearing in its size compared to Fig. 5.

Table 3 Predicted future LULC and ESV (2015–2025) (Unit : M.USD)

		Urban & Build up		Cropland		Forest		Grass		Wetland		Unused		Water body		TOTAL	
		Costanza	Xie	Costanza	Xie	Costanza	Xie	Costanza	Xie	Costanza	Xie	Costanza	Xie	Costanza	Xie	Costanza	Xie
Change of ESV	2015	-	-	216.6	1799.71	5731	14293.40	61.5	212.36	323.6	151.83	-	5.84	1895.9	1134.39	8228.7	17597.53
	2020	-	-	212.8	1768.10	5722	14270.98	60.1	207.34	323.4	151.70	-	5.53	1895.9	1134.39	8214.2	17538.00
	2025	-	-	207.8	1726.58	5717	14259.31	59.3	204.73	323.1	151.59	-	5.38	1895.9	1134.39	8203.5	17481.96

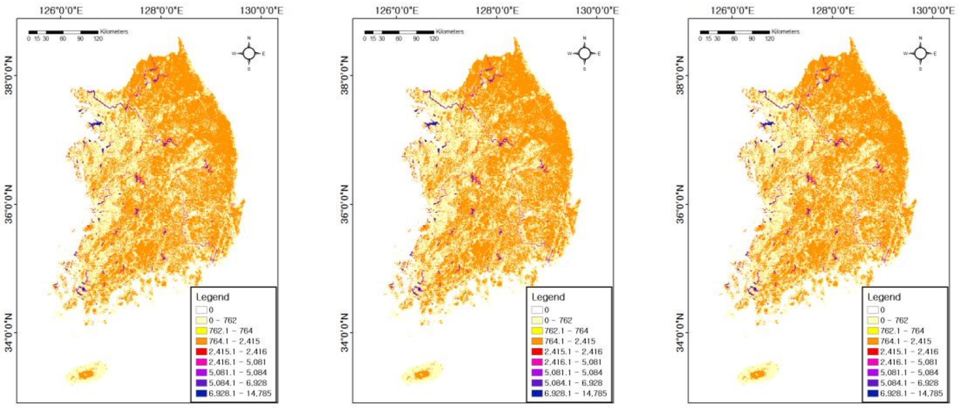


Fig. 5. Distribution of ecosystem services value in Korea (Costanza, 2015–2025)

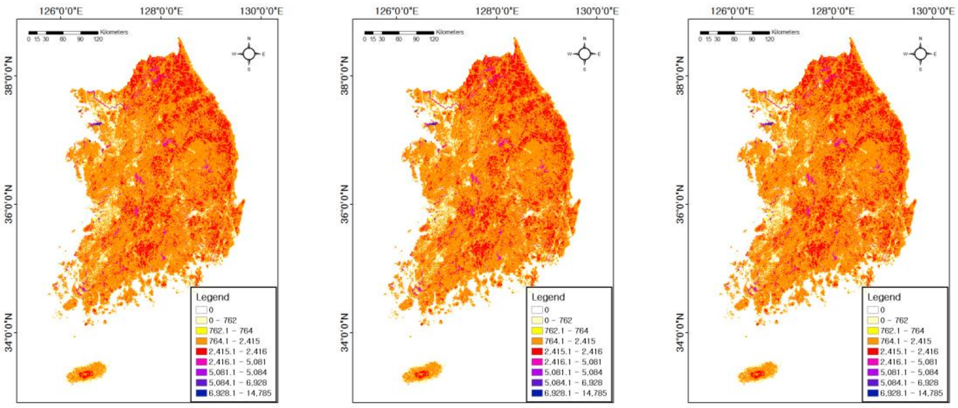


Fig. 6. Distribution of ecosystem services value in Korea (Xie, 2015–2025)

Discussion

Our study demonstrates that satellite data and GIS(geographic information system) tools are useful and inexpensive for monitoring and analyzing the changes in the value of ecosystem services (Qian et al., 2006). Moreover, the spatial scale of measurement is also an important factor that should be considered in ecosystem service valuation. When land cover is used as a proxy for ecosystem service, the spatial scale at which the land cover is measured significantly influences measurements of both the extent of the ecosystem service and its valuation (Konarska et al., 2002). In this paper, the estimation of ESV was based on Landsat TM images with 30 m resolution. Because of differences in resolution, the coefficients estimated here differ from the values reported in government data.

This study used the methods of Costanza et al. (1997) and Xie et al. (2003) to estimate ESV. The ESVs of various land-use categories were determined by multiplying the area of the land-use category by its ESV (Tianhong et al., 2010). The results obtained using the two methods differed, reflecting differences in their coefficients. Furthermore, the estimation results by these methods are coarse and contain errors and uncertainties due to the complex, dynamic, and nonlinear nature of ecosystems (Limburg et al., 2002; Turner et al., 2003), limitations of economic valuation (Costanza et al., 1997). This is because the biomasses used as proxies for the land-use categories are not perfect matches in every case (Kreuter et al., 2001). In addition, the accuracy of the average value of coefficients is uncertain because of ecosystem heterogeneity (Tianghong et al., 2010). For these reasons, we cannot directly judge the accuracy of the Costanza and Xie methods. Instead, we used GDP to suggest the accuracy of the coefficients.

Economic growth often appears to be in conflict with ecological protection. From 1975 to 2005, GDP (reflecting the rate of inflation) increased by 418.4%, with an average growth rate of 13.9% per year, while the ESV

decreased by 12.5% with an average rate of decline of 0.4% per year by the Costanza method and by 8.2% with an average rate of decline of 0.3% per year by the Xie method (Tianghong et al., 2010).
The Costanza total ESV for Korea was about 565.7% of GDP in 1975, which had decreased to 118.2% in 2005. The Xie total ESV for Korea was about 991.4% of GDP in 1975, which had declined to 217.6% in 2005. In Costanza et al.'s (1997) study, the global ESV was about 1.8 times the global GNP. In comparison, by the Xie method, the ESV of China was 1.73 times the Chinese GDP in 1994 (Chen et al., 2000; Tianhong et al., 2010). Relative to these results, the ESV level in Korea is extremely high. The Korean ESV was 1.3 times the national GDP by the Costanza method and 2.7 times the GDP by the Xie method in 1995. Because Costanza et al. (1997) conducted their research in 1997 and Chen et al. (2000) examined data for 1994, we also used data for 1995.
Over time, the ESV of Korea has become progressively lower. To examine the future situation, we also predicted the future ESV for Korea as well as the future GDP (based on that for 2000–2010). To forecast the future GDP, we assumed that the GDP and GDP deflator would increase linearly (GDP increase = 529.85/yr, GDP deflator increase = 2.26/yr). To calculate ESV/GDP, we used a future LULC map and the respective Costanza (as of 1997) and Xie (based on 2003 data) methods, considering the GDP deflator.

Table 4 Future GDP and ESV (2015~2025)

	E S V(M.USD)		G D P(M.USD)			ESV / GDP	
	Costanza	Xie	GDP	Deflator (1997=100)	Deflator (2003=100)	Costanza	Xie
2015	8228.7	17597.53	13130.07	8911.23	10374.91	92.3%	169.6%
2020	8214.2	17538	15779.32	9801.41	11411.30	83.8%	153.7%
2025	8203.5	17481.96	18428.57	10552.46	12285.71	77.7%	142.3%

As shown in Table 4, the ESV/GDP was 92.3%, 83.8%, and 77.7% for 2015, 2020, and 2025, respectively, by the Costanza method and 169.6%, 153.7%, and 142.3% for the same years by the Xie method. In general, the results of the Costanza method are closer to previous findings using GDP than those of the Xie method.
During the period 1975–2005, industrialization and development increased rapidly in Korea. As a result of these changes, the weight of ESV relative to GDP became progressively smaller. A compromise between economic development and ecological protection must be addressed (Tianhong et al., 2010). Previous studies have noted that high ESV categories such as wetlands and water bodies should be protected (Tianhong et al., 2010; Zhao et al., 2004; Li et al., 2010). Nevertheless, in Korea, wetlands and water bodies represent less than 30% of the total ESV in future.(23% by the Costanza method and 6% by the Xie method; Table 3). Consequently, the forest category must also be protected because it covers the largest area and also has a high ESV.

Conclusion

We analyzed changes in ESV in Korea from 1975 to 2005 and as predicted for 2015 to 2015 based on LULC. On the basis of our results and discussions, we conclude the following. From 1975 to 2005, the most evident change in LULC was the approximately six-fold increase in urban & built-up area. This change impacted changes in other categories. Cropland, forest, and wetland categories decreased and grass, unused, and water body categories increased. The difference in ESVs estimated by the Costanza and Xie methods differed by category. The values by category were smaller by the Xie method than by the Costanza method. However, in Korea, a larger ESV was estimated by the Xie method than by the Costanza because of the high value given to forests in the Xie method.
From 1975 to 2005, total ESV declined. The rates of change in cropland and forest categories were very slight. However, the rates of change in grassland, wetland, unused, and water body exceeded 50%. Even if the same data are used to calculate the rate of change in ESV, the Costanza and Xie method results differ because of differences in the grass, wetland, and unused areas.

ACKNOWLEDGEMENT

"This work was researched by the supporting project to educate GIS experts"