COMPARISON OF VALUATION RESULT OF ECOSYSTEM SERVICES DEPENDING ON THE SPATIAL RESOLUTION OF IMAGERY

- USING KOMPSAT-3 AND LANDSAT 8 SATELLITE IMAGERY -

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ABSTRACT: Despite the continuing effort to estimate the value of function and services of ecosystem, most of the researches has used low and medium resolution satellite imagery such as MODIS or Landsat. It means that the researches to measure the ecosystem service value using VHR (Very High Resolution) satellite imagery have not been performed much, while the source of available VHR imagery is increasing. Furthermore, it is lack of study to compare and demonstrate the impact of spatial scale on ecosystem service valuation using VHR and low-medium resolution satellite imagery.

Thus, the aim of this study is to compare and evaluate the difference of ecosystem service value (ESV) using KOMPSAT-3 and Landsat 8 imagery over Sejong city, the new administrative capital of S. Korea. Total 6 scenes (3 scenes for each satellite) were used for the analysis, which have been collected during spring (March ~ April) in every year from 2014 to 2016. As a result, total value of ecosystem services has been decreased from 2014 to 2016 without difference of the resolution. It was $10.074 million and $9.895 million USD in 2014 from the result of KOMPSAT-3 and Landsat 8 respectively, however, decreased to $9.480 million and $8.078 million USD in 2016. The ecosystem service values extracted from Landsat 8 present lower value than the result from KOMPSAT-3, because ‘urban’ was overestimated in Landsat 8 data which has $0 value of ecosystem service while ‘water’ was underestimated which has highest value among the classes.

1. INTRODUCTION

The interest related to the benefits provided by ecosystems has been increased continuously since the start of the discussion about the functions, services, and economic values of ecosystems in 1970s. A full discussion about the ecosystem services has become active after publish of the book by Daily and the article by Costanza et al. in 1997, and started to receive worldwide attention through ‘Millenium Ecosystem Assessment (MA)’ performed by UN in 2000s. Furthermore, the interest related to the ecosystem services has been continued through the research of ‘The Economics of Ecosystems and Biodiversity (TEEB)’ sponsored by UNEP and G8+5 counties (Ryu and Lee, 2013).

However, most of the researches to estimate the ecosystem service values (ESV) using remote sensing methodology has used low or mid-resolution satellite imagery like MODIS or Landsat, or relatively low resolution land cover map (Konarska et al., 2002; Li et al., 2014; Grunewald et al., 2016). It could be resulted from the huge study area, however, the researches to measure the ESV using VHR (Very High Resolution) satellite imagery have not been performed much, while the source of available VHR imagery is increasing explosively. Moreover, it is lack of researches which examine and compare the difference of ESV depending on the spatial resolution of imagery, although Konarska et al., 2002 compared the results from NOAA-AVHRR and Landsat data. Nevertheless the study compared the ESV result from different resolution data, they did not use VHR images and could not find any common characteristics or

dependency according to the scale.

Thus, the aim of this study is to compare and evaluate the difference of ESV using KOMPSAT-3 and Landsat 8 imagery over Sejong city, the new administrative capital of S. Korea, which is one of the most rapidly changing city in S. Korea from 2000s.

2. STUDY AREA AND DATA

The study area is Sejong city, which is located middle of S. Korea. Sejong city has been rapidly developed since 2000s as a new administrative capital.

And KOMPSAT-3 and Landsat 8 multi-spectral (MS) images were used for this study. Total 6 scenes (3 scenes for each satellite) were used for the analysis, which have been collected during spring (March ~ April) in every year from 2014 to 2016. Following table summarizes the specification of the data.

Table 1 Specification of the data

Satellite	Acquisition Date	Resolution	Spectral Wavelength (nm)
KOMPSAT-3	03-March-2014	PAN: 0.7 m MS: 2.8 m	PAN: 450 – 900 Blue: 450 – 520 Green: 520 – 600 Red: 630 – 690 NIR: 760 – 090
	25-March-2015		
	11-April-2016		
Landsat 8	11-March-2014	PAN: 15 m MS: 30 m	PAN: 503 – 676 Blue: 452 – 512 Green: 533 – 590 Red: 636 – 673 NIR: 851 – 879
	23-March-2015		
	01-April-2016		

3. METHODOLOGY

3.1 Preprocessing of data

Ortho-rectification was performed for KOMPSAT-3 images, and 5 m DEM and 0.5 m ortho-rectified aerial photo were used for the reference data. The root-mean square errors (RMSE) of ortho-rectified images were less than 1 pixel like below.

Table 2 RMSE of ortho-rectified images

Satellite	Acquisition Date	RMSE (pixel)	
KOMPSAT-3	03-March-2014	X: 0.198	Y: 0.593
	25-March-2015	X: 0.321	Y: 0.480
	11-April-2016	X: 0.547	Y: 0.435

As the 3 scenes of Landsat 8 images were already geometrically corrected, all 6 images were matched together with less than 2 pixels. After the preprocessing, 6 images were clipped for the overlapped area, so the final study area is approximately 14 × 14 km, total 211 km^2.

3.2 Classification and valuation of ecosystem services

There are numerous ways to measure and estimate the value of ecosystem services depending on many researchers, as well as the definition and classification scheme of ecosystem services. While there are various methodology to estimate the value of ecosystem services, mostly used methodology to measure the ESV is using classification of land

cover (Barbosa et al., 2015).

After the classification of land cover, ESV should be estimated. As it mentioned above, there are many different ways to estimate the ESV by various researchers, however, Costanza et al. (1997) classified the ecosystem of earth to 17 biomes and calculate the total value of ESV. Even if it has a limitation that the whole world is too much simplified, it has been most commonly used to estimate ESV as it provides generalized way to estimate the global ESV(Zhao et al., 2004; Park et al., 2016).

For this study, maximum likelihood method was used among supervised classification to generate land cover map. Land cover category was based on the high classification level (7 categories) according to the biomes classified by Costanza et al. (1997) and the land cover map provided by the Ministry of Environment.

Table 3 Summary of annual value of ecosystem services

Unit: USD ha^{-1} yr^{-1}

Land Cover Category	Biome	ESV coefficient
Water	Lakes/rivers	8,498
Forest	Forest	969
Grass	Grass/rangelands	232
Agriculture	Cropland	92
Bare soil	-	-
Wetland	Wetlands	14,785
Urban	Urban	0

To calculate the ESV, following equation was used, which was suggested on the article of Zhao et al., (2004).

$$ESV = \sum (A_k \times VC_k) \quad (1)$$

A_k on the above equation means the area (ha) and VC_k is the ESV coefficient ($/ha/yr) for the land cover category 'k'.

4. RESULTS

4.1 Classification results

Supervised classification was performed for the 6 images to classify the land cover to 7 categories, however, there was a problem that most of agriculture had classified to wetland because the vegetation were not grown enough on the images to identify and distinguish the different land cover. It is apprehended that the total value of ecosystem services will be overestimated, because the value of wetland has the highest ESV among the land cover within the study area. Thus, 6 land cover categories, excluding wetland, were used for the classification.

Table 4 Area of each land cover class

Unit: km^2

Land Cover	KOMPSAT-3			Landsat 8		
	2014	2015	2016	2014	2015	2016
Water	6.204	6.788	6.146	5.626	5.002	4.293
Forest	28.619	24.158	23.614	34.427	30.780	25.835
Grassland	52.800	59.925	60.768	38.565	49.893	58.945
Agriculture	87.328	72.425	60.789	96.053	69.752	60.776
Bare soil	13.198	20.233	23.324	13.924	24.235	12.744
Urban	22.711	27.332	36.218	23.207	32.140	49.209

Table 4 and 5 show the classification results. From 2014 to 2016, forest area was shrunk, while grassland and urban area were increased on both of KOMPSAT-3 and Landsat 8 land cover map. However, it was hard to find any common characteristics or trend between two datasets. It is found that the water and forest areas were somewhat under-estimated on Landsat 8 dataset, however, the level of difference was irregular year by year. On the other hand, urban area was over-estimated on Landsat 8 dataset, however, the level of difference was also fluctuated every year.

Table 5 Percentage of each land cover class

Unit: Percentage (%)

Land Cover	KOMPSAT-3			Landsat 8		
	2014	2015	2016	2014	2015	2016
Water	2.94	3.22	2.91	2.66	2.36	2.03
Forest	13.57	11.46	11.20	16.25	14.53	12.20
Grassland	25.04	28.40	28.82	18.21	23.56	27.83
Agriculture	41.41	34.35	28.83	45.35	32.93	28.69
Bare soil	6.26	9.60	11.06	6.57	11.44	6.02
Urban	10.77	12.96	17.18	10.96	15.17	23.23

Figure 1 and 2 present the original images and the classification results for each of dataset.

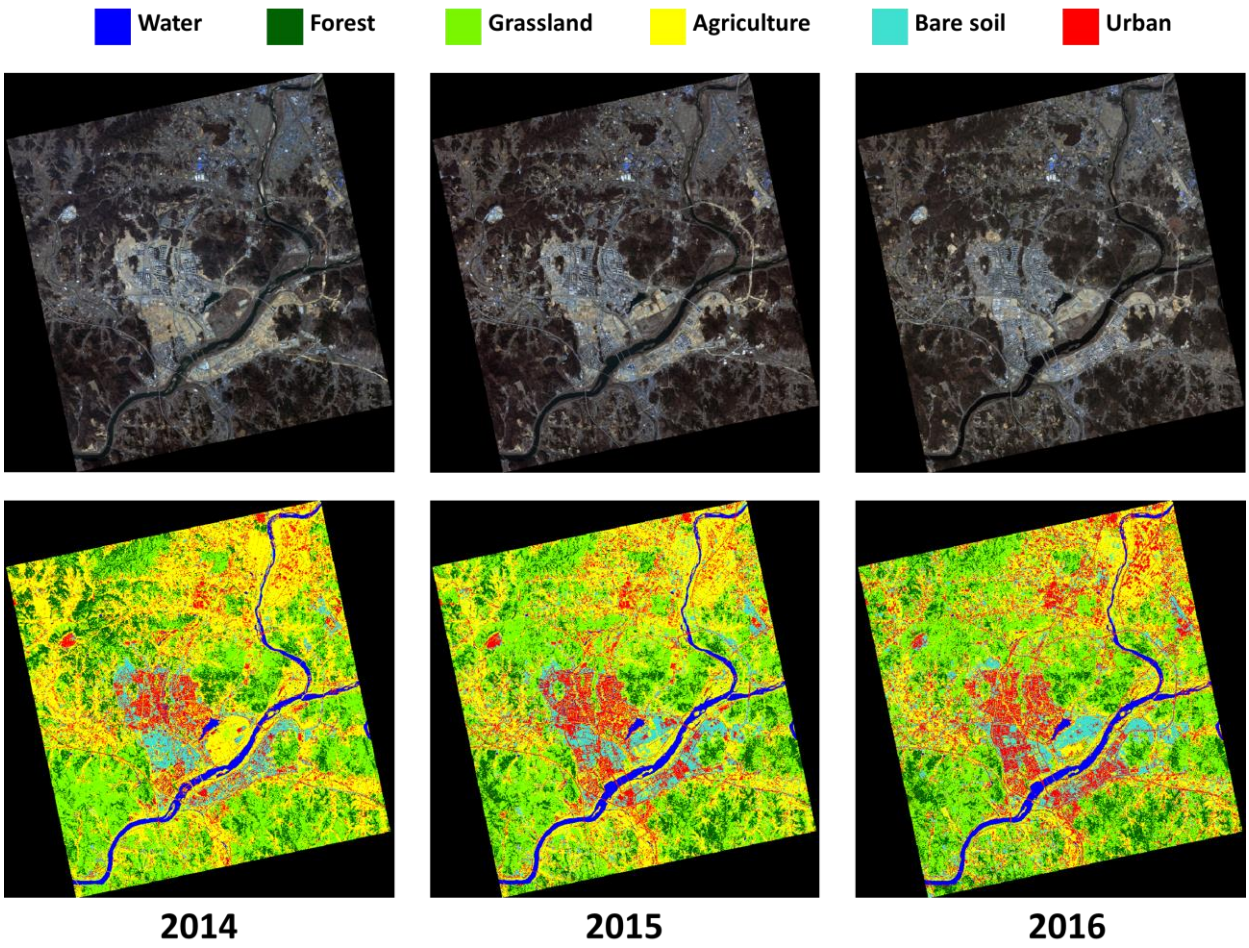

Figure 1 KOMPSAT-3 classification results

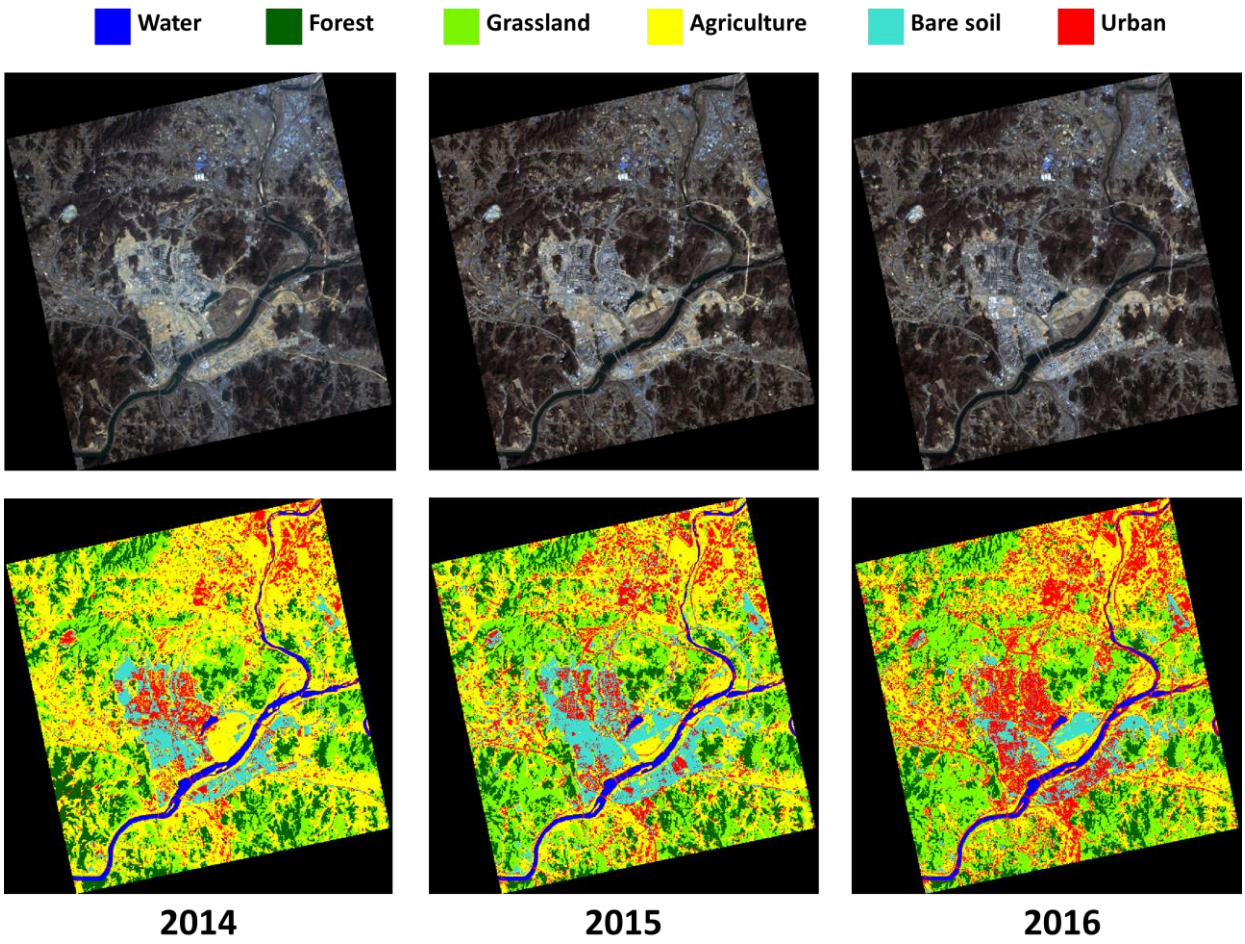

Figure 2 Landsat 8 classification results

4.2 Result of ESV estimation

Result of ESV estimation is summarized in Table 6. ESV of forest and agriculture were decreased according to a reduction of land cover areas of forest and agriculture. On the other hand, ESV of grassland was increased as the area of grassland was gradually expanded.

Table 6 Annual value of ecosystem services

Unit: USD ha^{-1} yr^{-1}

Land Cover	KOMPSAT-3			Landsat 8		
	2014	2015	2016	2014	2015	2016
Water	5,272,289	5,768,080	5,222,667	4,780,890	4,250,870	3,648,191
Forest	2,773,190	2,340,890	2,288,242	3,335,957	2,982,582	2,503,450
Grassland	1,224,965	1,390,269	1,409,816	894,708	1,157,525	1,367,515
Agriculture	803,414	666,307	559,263	883,691	641,717	559,140
Bare soil	-	-	-	-	-	-
Urban	0	0	0	0	0	0
Total ESV	**10,073,859**	**10,165,547**	**9,479,988**	**9,895,246**	**9,032,693**	**8,078,297**

As bare soil and urban areas do not contain any ESV, total value of annual ecosystem services was decreased on both dataset. ESV of 2015 derived from KOMPSAT-3 image was somewhat increased, however, it is caused by the extended volume of water during 2015. Total value of annual ecosystem services derived from KOMPSAT-3 images

was dropped to $9.480 million in 2016, which was $10.074 million in 2014. Similar to those results, total ESV from Landsat 8 images was also dropped from $9.895 million to $8.078 million per year, in 2014 and 2016 respectively.

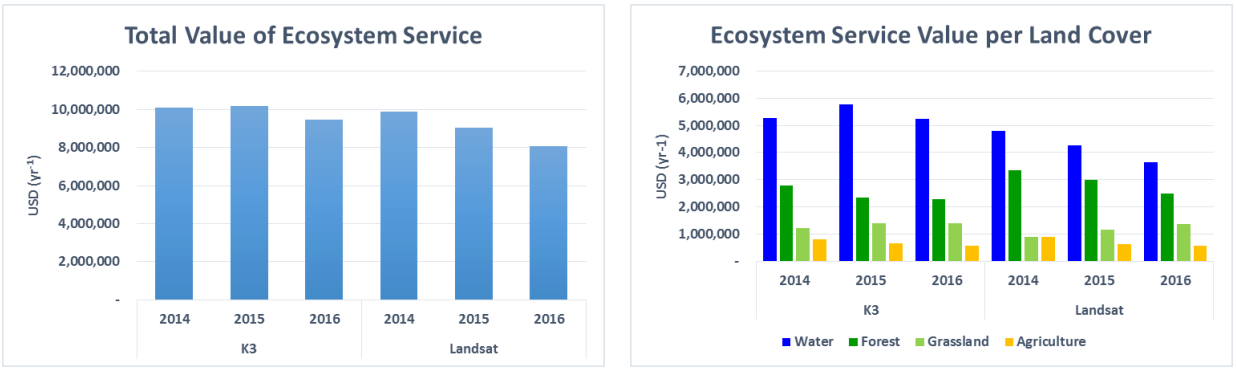

Figure 3 Changes of ESV from 2014 to 2016

Commonly, the total values of annual ecosystem services were under-estimated in the dataset of Landsat 8, though the difference of each land cover area between two datasets illustrates fluctuating values.

5. CONCLUSION

In this study, KOMPSAT-3 and Landsat 8 imagery were used to estimate and compare the ESV over Sejong city, S. Korea. Supervised classification analysis was performed to classify the land cover of each dataset, and ESV was calculated using ESV coefficient.

As a result, annual ESV of Sejong city was decreased continuously in both datasets. Originally, is was $10.074 million and $9.895 million in 2014, which was extracted from KOMPSAT-3 and Landsat 8 images respectively, but declined to $9.480 million and $8.078 million in 2016.

It is found that the water and forest areas were somewhat under-estimated on Landsat 8 dataset, while urban area was over-estimated, however, the level of differences were fluctuated every year. Although any common characteristic or correlation between KOMPSAT-3 and Landsat 8 classification results was not easily recognizable, the total values of annual ecosystem services were under-estimated in the dataset of Landsat 8.

It is expected to use those results to make plan for sustainable development in the future. For further research, more spatiotemporally accumulated data seem to be needed to identify and define the scale dependency of the ESV results between very high resolution and middle resolution data.

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