원격탐사와 GIS를 이용한 계룡산국립공원의 토지이용변화*

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Land Use Change Detection at Kyeryongsan National Park by Using Remote Sensing and Geographical Information Systems

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국문초록

국립공원의 뛰어난 경승지와 생태적으로 보존가치가 높은 지역은 다음 세대에게 물려줄 국가의 귀중한 자원으로서 잘 보존되고 관리되어야 하나 한국의 국립공원에서는 공원의 자연환경을 해치는 개발행위가 이뤄졌거나 제안되고 있다. 이러한 개발행위를 효과적으로 평가하기 위해서는 관련 환경자원의 활용이 필요하고 특히 토지이용변화의 파악이 요구되나 한국의 국립공원은 적절한 토지이용도가 결여되어 있다. 그러므로, 본 연구의 목표는 토지이용변화도를 제작하여 향후 국립공원에서 제안되는 개발행위가 해당국립공원의 토지이용변화에 미친 영향을 파악함으로써 국립공원의 환경 및 경관 관리에 기여하는 데에 있다.

본 연구는 계룡산국립공원을 대상으로 1988년도부터 1998년까지의 토지이용변화를 파악하기 위해 원격탐사 자료를 이용하여 2개년도의 Landsat TM 영상을 기하보정하여 토지피복분류를 추출하였다. 이를 바탕으로 항공사진과 현지조사를 통해 확인하여 작성한 토지이용현황도와 토지이용변화도를 GIS에 입력하였으며 GIS의 분석기능을 이용하여 10년간의 토지이용변화에 대해 파악하였다.

토지이용변화 파악 결과, 농지와 나대지가 계룡산국립공원 전체에서 43.7ha, 102.2ha 각각 감소하였고 산림과 개발지는 121.0ha, 24.8ha. 각각 증가하였다. 산림의 증가는 1988년 영상분류당시 산림의 가장자리 유령림이 농경지로 분류되었던 것이 10년 뒤 영상에서는 산림으로 분류된 결과로 파악되며 개발지의 증가는 계룡산국립공원 동학사 제2집단시설지구의 개발로 기존 농경지가 감소, 전용되었고 나대지는 개발로 인해 감소되었다. 개발지의 증가는 취락지구와

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집단시설지구에서 두드러졌으며 이들 두 지구에서 산림, 농경지, 나대지 모두 감소하고 대신 개발지가 증가하였다.
본 연구를 수행한 결과 계룡산 국립공원의 가장 큰 토지이용변화는 건물 신축이었으며 이는 집단시설지구의 신설에 기인하고 있다. 취락지구도 개발 행위가 증가하고 있어 집단시설지구와 취락지구의 이용후 평가가 이뤄져야 한다고 생각한다. 본 연구에서 작성한 토지이용변화도는 향후 국립공원의 경관 변화를 파악하는 데에 효과적으로 이용될 수 있다고 판단된다.

Key Words : Change Detection, Land Use Change, National Park, Remote Sensing

Ⅰ. INTRODUCTION

There are many valuable places with scenic landscape and ecological preservation areas in the national park. But many site developments were done early in the history of Korea national parks. Lack of necessary resource data prevents the government from regulating proposed land activities. A actual land use mapping is required to manage the natural environment and resources effectively. Satellite remote sensing(RS) is less expensive than aerial photography or field survey for producing land use maps, and can be accessed quickly and repetitively for large areas(Jensen, 1996). RS data can be integrated with a topographic map and other thematic maps using geographical information systems(GIS) to manage the natural resources of the national park. Landsat TM data has been used widely for land cover classification. Recently the launch of IKONOS and KOMPSAT(KOrea MultiPurpose SATellite; Arirang No. 1) made it possible to use high-resolution satellite data in land use change detection.

The purpose of this study is to detect areas and types of changed land use using a matched pair of TM images from a ten year period(1988-1998) and KOMPSAT EOC data to produce a land use map using GIS to monitor landscape changes. The ultimate goal of this study is to contribute to the effective management of natural resources.

Ⅱ. MATERIALS AND METHODS

1. Study Site

Kyeryongsan National Park is located in the central part of Korea, 154km south from Seoul. The area is 61.15㎢. Of this area, 95.6%(57.88km2) is covered with forest, and 13.9%(8.5km2) of the park is designated as a Natural Preservation Zone. That area is in demand for possible development because it is only a few kilometers from Taejon Metropolitan Area. Private land occupies 43.2%(26.4km2) of the park including the Buddhist Temples(9.8%, 6 ㎢). Figure 1 shows the study site.

2. Data

Landsat TM images were used because of easy data acquisition and the large number of spectral bands. KOMPSAT image was used to enhance visual interpretation. Table 1 shows dates of Landsat and KOMPSAT data used.

Table 1. Satellite data used

Platform	Date	Path/Row	Sensor	Cloud ratio	Spatial resolution	Data level	Geographic coordinates.
Landsat	1988.10.2	115/36	TM	clear	30m	BK	127°00′ - 129°00′ 35°15′ - 37°00′
	1998.10.2	115/35	TM	clear	30m	BK	
Kompsat	2000. 5.8	2025	EOC	clear	6.6m	1R	127°05′ - 127°20′ 36°17′ - 36°25′

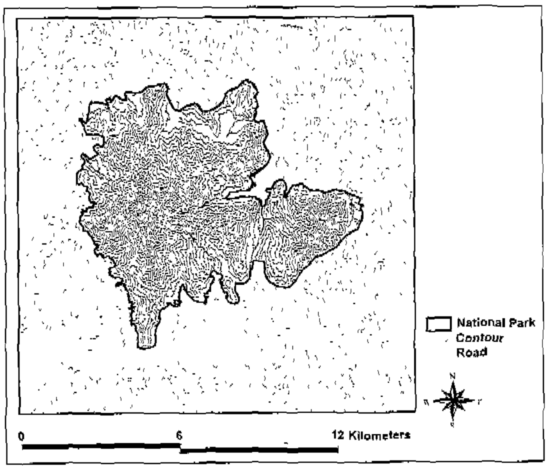


Figure 1. Study site

To correct geometric distortion, coordinates in topographic map were used. As well, a forest stand map and current vegetation map were also used for defining distinct feature spaces, and selecting training sets. Aerial photographs were used to correct land cover classification errors. Table 2 shows aerial photographs and other thematic data used.

Table 2. Air photos and other thematic data used

Thematic Map	Scale	Publisher	Year	Attribute
Topographic Map	1: 5,000	National Geography Institute	1996	Topography, Hydrology, Circulation
Digital Forest Stand Map	1:25,000	Forest Research Institute	1994	Forest stand Age Class, Diameter Class Crown density
Digital Current Vegetation Map	1:50,000	Ministry of Environment	1998	Vegetation Community
Aerial Photography	1:20,000	National Geography Institute	1998	Detailed feature

A digital elevation model(DEM) was generated from a 1:5,000 scale topographic map using ArcView. A forest stand map and current vegetation map were also integrated with ArcView GIS Ver. 3.1(ESRI Inc., 1996). ArcView was also used to analyze, edit, retrieve spatial information, and to produce output. Geomania Ver. 1.0 was used to convert data, and PCI Ver. 7.0(*PCI Software Inc., 1998*) was used for satellite image processing.

3. Data Processing

Data preprocessing consisted of terrain effect correction and geometric correction. The Lambertian assumption was used to correct for terrain slope in the area that receive direct solar illumination. Radiance is assumed to be proportional to the cosine of the incident angle. The incidence angle is the angle between the surface normal and the solar beam(Ekstrand, 1996), and the raw radiance data for pixels in each band are stretched 0 to 255(Civco, 1989). DEM was used in this procedure.

In geometric correction, ground control points(GCP's) were selected by referring to dominant features in the topographic map such as bridge, reservoir and highway intersections. After the transformation, bilinear interpolation was used in resampling.

Information classes were formed after the initial unsupervised classification and image enhancement was done. Information classes are grouped by land cover type, into which the image is to be segmented. After that, training sets were chosen by referring to topographic maps, KOMPSAT EOC image, air photos, other thematic maps, and field surveys. A maximum likelihood classifier was used for supervised land cover classification, and the resulting classes were merged according to the land use classification system. Finally, classification accuracy assessment was done by comparing on a category-by-category basis, the relationship between ground truth data and the corresponding results of an digital classification. It was represented in a confusion matrix(Lillesand and Kiefer, 1994).

By overlaying the landcover classification map and thematic layers from topographic maps and other ground reference data, a land use map was generated based on the land use classification system in Table 3. In this study, the classes of level I are represented in the land use map. It was based on the land cover classification system(Korea Environment Institute, 1999) and the land use classification system(http://www.kict.re.kr), which were designed considering existing foreign systems such as USGS, Geographic Survey of Japan, Ordnance Survey(Korea Environment Institute, 1999; http://www.kict.re.kr). Also, the characteristic of the national park was also considered in this study. The affine transformation was used to convert image coordinates to corrected coordinates. The land use change detection was done by comparing the land use maps of 1988 and 1998.

Table 3. Land use classification system in study area

Level I	Level II	Note
Urban & Built-up	Urban	
	Built-up	
	Transportation	
	Recreation facilities	Golf Course
Agriculture	Paddy field	
	Dry field	
	Orchard	
Forest	Broad-leaf forest	
	Conifer forest	
	Mixed forest	
	Rock bed	
Water	River	
	Reservoir	
Bare & Open land	Under development	
	Open land	

III. RESULTS AND DISCUSSION

1. Land Cover Classification

At first, mixed forest, conifer, broad-leaf forest were not separated in images of 1988 and 1998 due to the low classification accuracy. So, forest type classes were merged and finally five classes were reclassified as forest, agriculture, water, urban and bare soil. Digital classification accuracy of both years images were assessed. Overall accuracy of the 1998 image classification was 94.6%(Table 4), and that of the 1988 image was 98.6%(Table 5). The classification accuracy assessment was obtained for the whole study site(population data) and there by, not limited to sample data. Overall accuracy was calculated from the sum of coincident values between classified data and reference data. These sum were divided by the whole area(5,888.79㏊). In this calculation, the golf course was omitted because it was not discriminated in the classification. Because most of the site is covered by mountain forest, it shows highly accurate classification.

For the reference data, aerial photography, KOMPSAT image and topographic maps were

Table 4. Confusion matrix of classification image(1988) (Units : ha)

Classified Data	Reference Data							
	Forest	Agriculture	Water	Urban and Built-up	Bare soil	Golf course	Sum	User's Accuracy[b]
Forest	5,499.09	2.52	0.72	15.03	0.18	25.56	5,543.10	99.2%
Agriculture	7.20	57.51	0.45	13.14	1.53	3.15	147.78	38.9%
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Urban	9.99	2.97	0.00	12.24	0.00	1.80	27.00	45.3%
Bare	144.18	14.31	0.00	7.92	0.09	4.41	170.91	0.1%
Sum	5,725.26	77.31	1.17	48.33	1.80	34.92	5,888.79	
Producer's Accuracy[a]	96.0%	74.4%		25.3%	5.0%			

[a], [b]: Producer's accuracy and user's accuracy mean measure of omission error and commission error respectively.

Table 5. Confusion matrix of classification image(1998) (Units : ha)

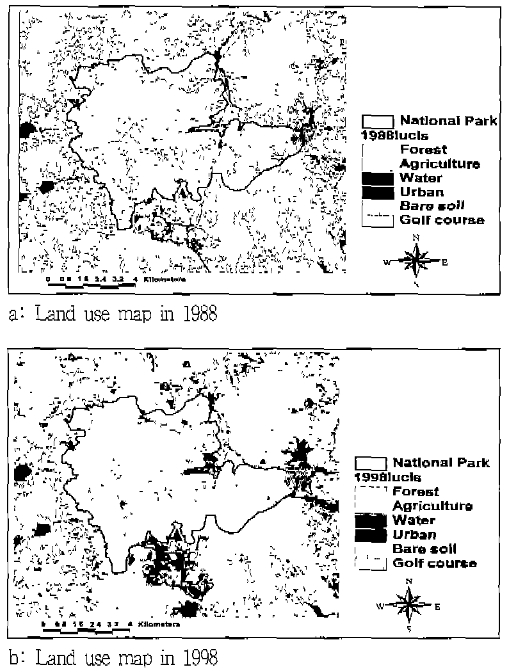
Classified Data	Reference Data							
	Forest	Agriculture	Water	Urban and Built-up	Bare soil	Golf course	Sum	User's Accuracy[b]
Forest	5,687.10	0.18	0.00	0.00	0.00	30.15	5,717.43	99.5%
Agriculture	7.47	73.44	0.00	3.42	0.00	1.44	85.77	85.6%
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Urban	30.33	3.69	1.17	44.91	1.44	3.15	84.69	53.0%
Bare	0.36	0.00	0.00	0.00	0.36	0.18	0.90	40.0%
Sum	5,725.26	90.81	1.17	48.33	1.80	34.92	5,888.79	
Producer's Accuracy[a]	99.3%	95.0%		92.9%	20.0%			

[a], [b]: Producer's accuracy and user's accuracy mean measure of omission error and commission error respectively.

used. KOMPSAT EOC image was very helpful in correcting misclassified pixels by visual interpretation -e. g., golf course(EOC) vs. agricultural field(TM).

2. Actual Land Use Map

Rocks in mountain ridges were misclassified as bare soil, and some misclassification between forest and agricultural field were evident. They were corrected by referring to ground truth data. Uncertain areas for classification were verified by field check. Figure 2 shows the land use maps of the site in 1988 and 1998. It was found after field check that dry reservoirs or stream-beds which show a very high brightness values were misclassified as bare soil or urban development. So these areas were correctly identified for land use map generation.



a: Land use map in 1988

b: Land use map in 1998

Figure 2. Land use map

3. Land Use Change Detection

By correcting the misclassified pixels, land use maps of both years were generated and compared pixel by pixel. Table 6 shows the land use change in the study area between 1988 and 1998. After detecting the land use change by referring to both land use maps, agricultural area and bare soil decreased by 43.7ha and 102.2ha, respectively, while developed land and forest increased by 24.8ha and 121.0ha, respectively, from 1988 to 1998(Table 6). The reason for increase in developed area is mainly due to the development of the second Tonghaksa Service Facility Zone(SFZ). It can be also explained by the conversion of agricultural area for building construction. The increase of forest area is due to the growth of seedling forest, which was misclassified as grass area(agricultural field) in the 1988 image. However, some agricultural fields(11.6ha) and bare soil(7.7ha) were changed into developed land. Such trends are shown in Tables 7 and 8.

Tables 7 and 8 show the land use change in the Settlement Zone(SZ), and Service Facility Zone(SFZ), respectively. Forest and developed land increased by 12.6ha and 12.6ha respectively, while agricultural land and bare soil area decreased by 9.99ha and 15.21ha respectively. Table 8 shows change detection in the Service Facility Zone(SFZ). Developed land increased by 5.7ha while agricultural land and bare soils decreased by 1.53ha and 2.79ha. in the SZ and SFZ. Human effects changed agricultural land and bare soils into developed land.

Figures 3 and 4 show the land use change map in the second Tonghaksa Service Facility Zone, and Sangsin Settlement Zone, respectively. As we can see in Figure 3, agricultural area and forest are converted into urban area for the second Tonghaksa SFZ development. In the SZ,

Table 6. Land use change in Kyeryongsan National Park between 1988 and 1998 (Units : ha)

1988 / 1998	Forest	Agriculture	Water	Urban and Built-up	Bare and Open land	Golf Course	Sum
Forest	5582.07	51.48	0.45	8.46	82.80	0.00	5725.26
Agriculture	3.24	57.78	0.00	2.70	13.59	0.00	77.31
Water	0.63	0.00	0.54	0.00	0.00	0.00	1.17
Urban	16.74	11.61	0.00	12.33	7.65	0.00	48.33
Bare soil	1.62	0.18	0.00	0.00	0.00	0.00	1.80
Golf course	0.00	0.00	0.00	0.00	0.00	34.92	34.92
Sum	5604.30	121.05	0.99	23.49	104.04	34.92	5888.79
Changed area	120.96	-43.74	0.18	24.84	-102.24	0	

Table 7. Land use change in SZ between 1988 and 1998 (Units : ha)

1988 / 1998	Forest	Agriculture	Water	Urban and Built-up	Bare and Open land	Golf Course	Sum
Forest	17.01	3.33	0.00	0.00	9.72	0.00	30.06
Agriculture	0.45	7.83	0.00	0.09	0.90	0.00	9.27
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban	0.00	8.10	0.00	1.80	4.59	0.00	14.49
Bare soil	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Golf course	0.00	0.00	0.00	0.00	0.00	1.17	1.17
Sum	17.46	19.26	0.00	1.89	15.21	1.17	54.99
Change area	12.6	-10.0	0.00	12.6	-15.2	0	

Table 8. Land use change in SFZ between 1988 and 1998 (Units : ha)

1988 / 1998	Forest	Agriculture	Water	Urban & Built-up	Bare and Open land	Sum
Forest	28.89	1.08	0	1.44	2.34	33.75
Agriculture	0	0	0	0	0	0
Water	0	0	0	0	0	0
Urban	5.85	0.45	0	4.95	0.81	12.06
Bare soil	0.36	0	0	0	0	0.36
Sum	35.1	1.53	0	6.39	3.15	46.17
Change area	-1.35	-1.53	0	5.67	-2.79	

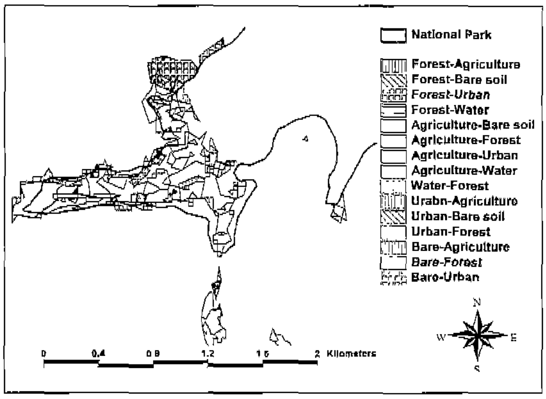


Figure 3. Land use change map in the second Tonghaksa S.F.Z.

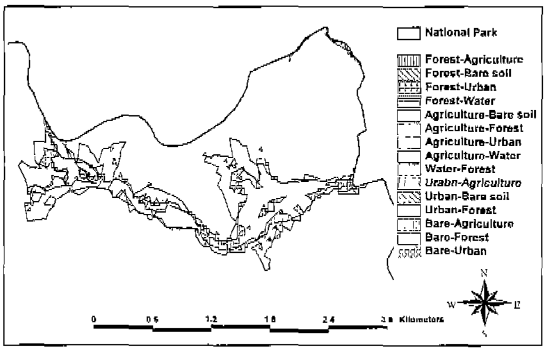


Figure 4. Land use change map in Sangsin S.Z.

agricultural area was also converted to urban area - especially residential development - as we can see in Figure 4. This confirms that there is continuous building construction in SFZ and SZ in Kyeryongsan National Park as we can see in most of Korean National Parks.

4. Discussion

After completing this study, it was found that the major land use change in Kyeryongsan National Park is due to the building construction. During the ten year period(1988-1998) new service facility zone development caused succeeding building construction. So, new SFZ development effects should be evaluated carefully for post occupancy. The change detection map generated can be used to monitor landscape changes effectively.

It should be also noted that the total area of Kyeryongsan National Park is 58.89km2 derived from RS image while the table data of the Korea National Park Authority shows 61.15km2. So, there is 2.26km2 difference in area which is not uncommon in Korean National Park data as we can see in other national parks research(Ahn, 1999). This resulted from inaccurate surveying. More accurate surveying is necessary for proper resource management.

Ⅳ. CONCLUSIONS

TM images from a ten year period(1988-1998) were processed for generating land use maps, which shows increased or decreased areas of each land use type after map overlay comparison. This change detection map is derived from land cover classification followed by ground check. The detailed land use changes are as follows:

1. In Kyeryongsan National Park, the agricultural land and bare soil decreased by 43.7ha, 102.2ha from 1988 to 1998, respectively, while developed area increased by 24.8ha.

2. The forest area increased by 121.0ha during the same period. The change is due to the misclassification of the seedling forest in 1988 as grass area(agricultural field).

3. In the Settlement Zone, agricultural area and bare soil decreased by 9.99ha, 15.21ha, respectively, while developed area increased by 12.6ha. In the Settlement Zone, agriculture area and bare soil were urbanized by 8.1ha, 4.59ha, respectively.

4. In the Service Facility Zone, forest, agricultural and bare soil area decreased by 1.35ha, 1.53ha, and 2.79ha, while developed area increased by 5.67ha. In the Service Facility Zone, forest, agriculture and bare soil area were urbanized by 5.85ha, 0.45ha, 0.81ha, respectively.

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