Extraction of Non-Point Pollution Using Satellite Imagery Data

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Abstract: Land cover map is a typical GIS database which shows the Earth's physical surface differentiated by standardized homogeneous land cover types. Satellite images acquired by Landsat TM were primarily used to produce a land cover map of 7 land cover classes; however, it now becomes to produce a more accurate land cover classification dataset of 23 classes thanks to higher resolution satellite images, such as SPOT-5 and IKONOS. The use of the newly produced high resolution land cover map of 23 classes for such activities to estimate non-point sources of pollution like water pollution modeling and atmospheric dispersion modeling is expected to result a higher level of accuracy and validity in various environmental monitoring results. The estimation of pollution from non-point sources using GIS-based modeling with land cover dataset shows fairly accurate and consistent results.

Keywords: Land Cover Map, Non-Point Source of Pollution

1. Introduction

This study was conducted employing the land cover map of the Korean Ministry of Environment, which was produced with an extensive use of high resolution satellite images and geographical information system techniques, and spatial modeling techniques to estimate the water pollution load from non-point sources.

The water pollution loads in *Kyungan* River basin was estimated based on simultaneous analyses of a multiple number of water pollution load estimation models. The results of the water pollution load modeling using land cover map was examined through comparative studies with results of other modeling techniques.

2. Land Cover Map

The Land Cover Map is a typical GIS dataset shows Earth's physical surfaces differentiated by standardized schemes which classify the recognizable homogeneous patches.

The land cover map can be served as significant data in various fields, such as the estimation of non-point source of pollution, urban planning, atmospheric dispersion modeling and natural environmental management because it accurately reflects the present circumstance of ground surface.

1) Land Cover Classification Schemes

Land cover classification classes may have a wide variety of classes depend on the purpose of the dataset. The land cover dataset used in this study consists of 23 classes. Since the land cover dataset was produced by the Korean Ministry of Environment for environmental protection purposes, such as water pollution modeling, atmospheric dispersion modeling, and environmental impact assessment, those 23 classes well reflect the ecological characteristics of land surface. The Korean Ministry of Environment's land cover dataset was basically designed with following framework:

1. The name of each class was carefully selected with reference of the United States Geological Survey's classification scheme and European Union's CORINE project to represent Korea's peculiar landscape features in small patches caused by topography and climate;

2. The area ratio between classes and seasonal variations are considered;
3. Significant land cover classes for national-level modeling and monitoring activities are identified and selected as land cover classes in priority; and
4. Various opinions within the extent of environmental management activities were collected and referenced.

Table 1. Land Cover Classification Classes

Level 1		Level 2	
Category Name	**Code**	**Category Name**	**Code**
Urban & Built up	100	Residential areas	110
		Industrial areas	120
		Commercial areas	130
		Recreational areas	140
		Transportation areas	150
		Public areas	160
Agricultural Areas	200	Rice paddies	210
		Crop fields	220
		House crop fields	230
		Orchard	240
		Others	250
Forests	300	Deciduous forest	310
		Coniferous forest	320
		Mixed forest	330
Grassland	400	Natural grassland	410
		Golf courses	420
		Others	430
Wetlands	500	Inland wetlands	510
		Coastal wetlands	520
Barren lands	600	Mine sites	610
		Others	620
Water	700	Inland Waters	710
		Ocean	720

2) Methods

IRS-1C/D and Landsat TM/ETM+ satellite images were used as the base data to produce the land cover dataset. Topographic digital map and various environmental thematic maps, such as actual vegetation map, eco-natural map, forest map, were referenced. Satellite mage data was carefully chosen with most recently acquired scenes in appropriate off-nadir angle, amount of clouds, and image quality.

The ground control points (GCPs) for the rectification and registration of the images were collected employing a differential GPS survey method maintaining a sub-meter RMSE.

The satellite image scenes were chosen carefully in order to minimize the seasonal variations between scenes. Also, multi-temporal satellite images were referenced in order to identify such season-sensitive classes like deciduous forests.

IRS-1 C/D and Landsat TM/ETM+ satellite were fused using the radiometric image fusion method which preserves the optical information of every pixel.

In order to define the boundaries of classes and to attribute identifiable polygons, topographic digital map, thematic maps and land use map were referenced.

3) Results

The land cover map was compared with land use map to examine the validity of land cover map and propriety of classification classes.

A noticeable difference between land cover map and land use map can easily be found from the classification results of wetlands, golf courses, and built-up areas.

Figures 1 and 2 show the land cover map and land use map of a golf course. While land cover map classifies each part of a golf course, land use map only classify the golf course in a single attribute as "golf course." Also land use map does not classify the forest around the golf course because the forest is annexed to the golf course property. Land cover map directly shows the physical cover type of surface regardless of how human beings utilize the land.

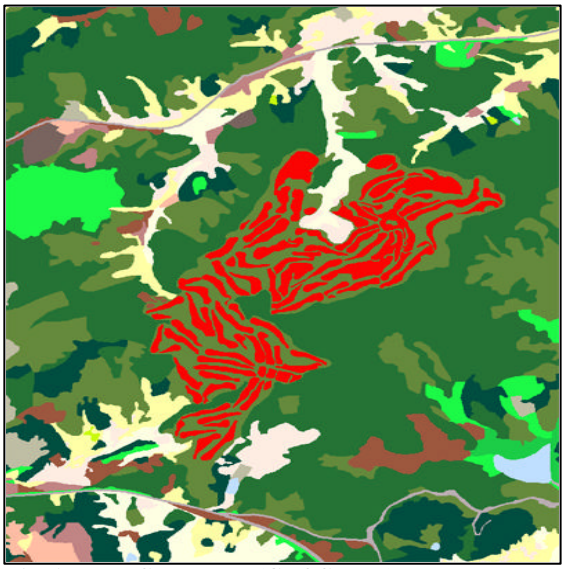

Fig. 1. Land Cover Map (Golf Course)

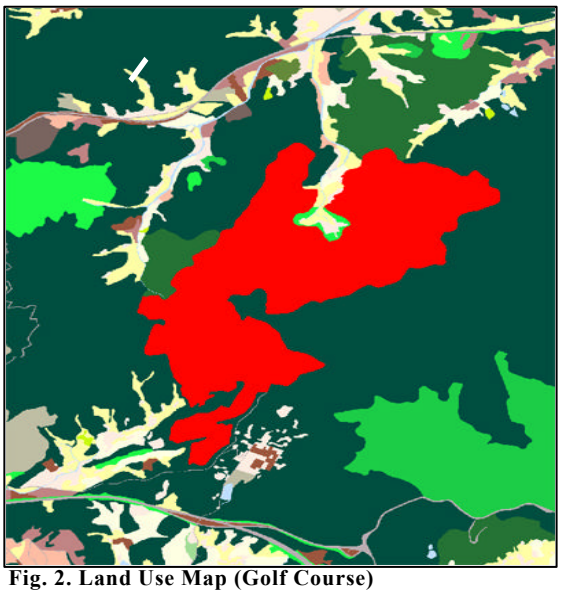

Fig. 2. Land Use Map (Golf Course)

3. Estimation of the Pollution Load from Non-Point Sources

1) Scope and Methods

The *Kyungan* River basin was chosen for the study area of this study due to the fact that many earlier studies on water pollution from non-point source have done in the area to make an effective comparison of the results from the water quality modeling employing the land cover dataset and other types of modeling methods which estimate the pollution loads from non-point sources. This comparative study will verify the modeling results using the land cover dataset.

This study employed Long Term Hydrologic Impact Assessment and Non Point Pollutant Model (LTHIA/NPS) model developed by the United States Environmental Protection Agency (U.S. E.P.A.). The LTHIA/NPS model has been developed as a long term analysis tool for water pollution from non-point sources using rainfall data to determine long-term average conditions instead of examining only the effects of extreme rainfall events. Among 23 land cover classes, only 5 classes (residential areas, commercial areas, industrial areas, agricultural areas, and forest/grassland) were used because the per-unit load information was only available for those 5 classes. The per-unit loads for 15 materials from residential areas, commercial areas, and agricultural areas, and 5 materials from forest and grassland have been considered in this study.

A 30-year rainfall data of *Kyunggi-Do* province was used for the modeling.

Table 2. Results of Pollution Load from Non-Point Sources Estimation of *Kyungan* River Basin (unit: ton)

Water Pollution Index	AnnAGNPS Model	STORM Model	Load Unit Method		Basin Flow Model by GIS Based	
			Estimate of Pollution Load In Kyungan River Basin	Using Land Cover Map & Ministry of Environment's Load Unit	Land Cover Map (Ministry of Environment '80 - '90)	Land Cover Map (Others)
BOD	946	876	1,784	2,152	985-1,724	1,290
T-N	5,983	1,639	1,624	878	879-1092	1,168
T-P	11	1,237	138	80	164-241	265

2) Results

Table 2 shows the pollution load results derived from AnnAGNPS and STORM models along with the results of LTHIA/NPS modeling using the land cover data.

The LTHIA/NPS modeling results using the land cover data and the Korean Ministry of Environment's load unit indices shows somewhat smaller estimation of T-N and T-P than the results of AnnAGNPS and STORM models. However, LTHIA/NPS model with land cover data results more consistent estimation. This might have been occur due to the fact that the load unit was applied after the 23 land cover classes were merged into 5 classes to run LTHIA/NPS model. The Ministry of Environment's land cover dataset of 1980s-1990s and other land cover map were analyzed by performing GIS based modeling techniques along with soil and rainfall data. Since the LTHIA/NPS model was developed in the United States reflecting the peculiar land cover/use types in the US, the Korean land cover characteristics and per-unit load amounts may not be suitable for such modeling.

The results of the GIS based modeling showed that the accuracy of the Korean Ministry of Environment's land cover dataset is high because it generates fairly consistent results when comparing the modeling results employing the Ministry of Environment land cover map and results used other land cover maps.

4. Conclusions

"Land use" data and "land cover" data have been defined as different concepts in the United States and Europe and a practical use of land cover map has been emphasized in environmental management practices.

The usefulness of land cover data in water pollution modeling is verified by comparing the per-unit load modeling results and the results employing the land cover data. The results of NTHIA/NPS modeling using land cover dataset showed highly accurate and consistent estimation of pollution loads from non-point sources.

To enhance the accuracy and efficiency in the estimation of water pollution loads from non-point sources, an appropriate model reflecting the peculiarity of Korean land characteristics is urgently required.

The authors of this paper suggest further studies on modification of the NTHIA/NPS model to enhance the accuracy and efficiency when applied in Korea with highly defined land cover information.

Acknowledgement

The authors of this paper are grateful for all the personnel and corporate partners who strived hard to pro-

duce the land cover dataset and map for the Korean Ministry of Environment. The authors also acknowledge the advisory committee of the project for suggesting practical and effective guidelines to produce the effective and practical land cover dataset. The authors give special thanks to professor Oh, Kyung-Doo of Korean Military Academy for conducting water quality modeling for this study.

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