

Assessment of Hydrological Impact by Tracing Long-term Land Cover Changes Using Landsat TM Imageries

Seong J. KIM

Associate Professor, Konkuk University

1 Hwayang-dong, Gwangjin-gu, Seoul 143-701, Korea

kimsj@konkuk.ac.kr

Geun A. PARK

Graduate Student, Konkuk University

1 Hwayang-dong, Gwangjin-gu, Seoul 143-701, Korea

dolpin2000@konkuk.ac.kr

Abstract: The purpose of this study is to evaluate the hydrological impact due to temporal land cover changes by gradual urbanization of a watershed. WMS HEC-1 was adopted, and DEM with 200m resolution and hydrologic soil group from 1:50,000 soil map were prepared. Land covers of 1986, 1990, 1994 and 1999 Landsat TM images were classified by maximum likelihood method. By applying the model, watershed average CN value was affected in the order of paddy, forest and urban/residential, respectively.

Keywords: land cover change, WMS HEC-1, CN.

1. Introduction

During the past two decades in South Korea, land use pattern has been gradually/rapidly changed by human activities in rural and suburban areas, respectively. It is presumed that increase of impervious areas within watershed affects the hydrograph at a stream location, which result in the reduction of time of concentration and increase of peak runoff and runoff volume.

The rapid advancement of GIS and its applicability to modelers has matured in hydrologic modeling

research. In order to trace the land use changes of a watershed during several decades, remote sensing images by Landsat earth resources observation satellite can be used.

The purpose of this study is to assess the quantitative effect of stream discharge due to land use changes, especially for paddy field. To accomplish the purpose, trace land use changes of the selected watershed by using multi-temporal Landsat images during the last two decades. Secondly, analyze the quantitative effect of stream discharge due to agricultural land use changes by applying GIS-based hydrologic model, WMS HEC-1 (1999).

2. Tracing two decades land cover using Landsat TM multi-temporal images

Anseong-cheon watershed (582.9 km²) about 70 km away from Seoul in the south direction (Fig. 1) was selected. The land use of 4 selected years (1986, 1990, 1994, 1999) with Landsat TM images was classified into 7 categories (forest, paddy field, upland crop, urban, grassland, bare field, water) by using maximum

likelihood supervised method. Table 1 shows the summarized results.

During the period of 4 sampled years, it was observed that the urban area and grassland increased 35.4 km² (6.0 %) and 6.7 km² (1.2 %), respectively. The grassland was developed mainly as golfcourses and pasture of livestock farm. According to the increase of urban and grassland areas, forest and paddy field area decreased 28.4 km² (-4.8 %) and 23.7 km² (-4.0 %) during the past 15 years, respectively.

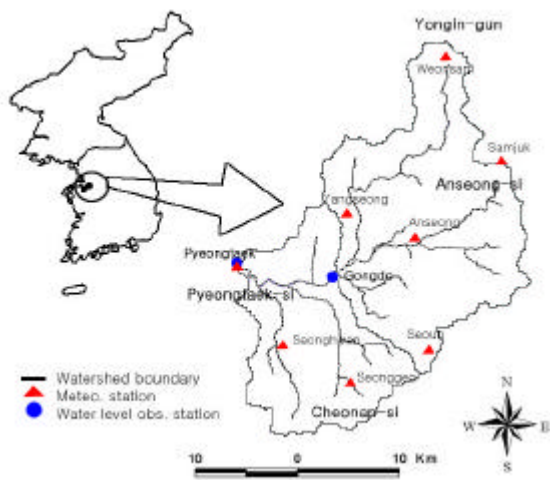


Fig. 1. Anseong-cheon study watershed.

Table 1. The classified results of land use for 4 selected years.

Items	Area (km ²)				Ratio of Area (%)			
	1986	1990	1994	1999	1986	1990	1994	1999
1.Forest	274.6	255.3	251.0	246.2	46.3	43.1	42.4	41.5
2.Paddy field	157.3	149.1	141.9	133.6	26.5	25.2	23.9	22.5
3.Upland crop	69.6	78.7	78.9	78.0	11.7	13.3	13.3	13.2
4.Urban	19.8	42.6	44.1	55.2	3.3	7.2	7.4	9.3
5.Grassland	53.5	55.5	56.2	60.2	9.0	9.4	9.5	10.2
6.Bare field	11.0	1.5	13.2	14.1	1.9	0.3	2.2	2.4
7.Water	6.8	9.9	7.3	5.3	1.1	1.7	1.2	0.9
Total	592.6	592.6	592.6	592.6	100.0	100.0	100.0	100.0

3. GIS data preparation

DEM was obtained from the NGIS (National Geographic Information Systems) quadrangle vector map of 5 m interval (1: 5,000 scale) contour lines. DEM produced by TIN was geo-referenced to TM (Transverse Mercator) coordinate system and the grid was spaced with a resolution of 30 m by 30 m grid element. The stream burning algorithm suggested by Maidment and Djokic (2000) was applied to remove sinks and generate a proper stream network in flat areas.

The soil map of 1: 50,000 was rasterized to a 30 m grid size from the vector files supplied by the RDC (Rural Development Corporation) to prepare hydrologic soil group map for WMS input data.

The point vector coverage with 8 meteorological stations around the study watershed was prepared by editing the points with internal IDs and the geographic (latitude/longitude) coordinate information. Then Thiessen polygons were generated from the point vector file using the common function of GIS software, and it was geo-referenced to TM (Transverse Mercator) coordinate system.

4. WMS HEC-1 calibration

WMS is a computer program that utilizes digital terrain data to delineate watershed and sub-basin boundaries and computes geometric parameters used in hydrologic modeling. WMS includes the HEC-1 flood hydrograph programs used by many hydrologic engineers to model the rainfall-runoff process.

The model was calibrated by comparing observed with simulated discharge results for 5 summer storm events from 1998 to 2001. The watershed (WS) was constituted by two subwatersheds based on the water level observation stations (Pyeongtaek and Gongdo) as shown in Fig. 1. One subwatershed (WS1) is the

upstream area of Gongdo station and the other one (WS2) is the area between Gongdo and Pyeongtaek stations. The average lag time for WS1 and WS2 was 8.3 hours and 4.4 hours, and the average Muskingum storage constant (K) and weighing coefficient (x) were 1.3 and 0.4, respectively. The Nash-Sutcliffe model efficiency (Nash and Sutcliffe, 1970) ranged from 0.630 to 0.965.

5. Assessment of the quantitative effect of stream discharge due to land use changes

To identify the impact of streamflow by temporal area change of a target land use, a) determine a base year and select a target land use item to analyze, b) calculate representative CN value of areas except the target land use area of the year and use the CN value to other years, c) build an equation for calculating watershed average CN value by using CN of target land use and representative CN of 'b', d) calculate watershed average CN value of other year by applying the changed area of target land use, e) evaluate streamflow of each year by applying SCS-CN method.

Table 2 shows the result of streamflow impact by the area change of paddy, forest, and urban areas, respectively. By applying the method, the watershed average CN decreased 1.0 for 23.7 km² decrease of paddy areas. On the other hand, the watershed average CN increased 1.1 and 1.0 for 28.4 km² decrease of forest areas and 35.4 km² increase of urban areas. The changing rate of watershed average CN per unit area (1 km²) change is 0.042 for paddy, 0.039 for forest, and 0.028 for urban area. The watershed average CN value and was affected in the order of paddy, forest and urban areas, and it affected proportionally to the peak runoff. The changing rate of peak runoff per unit area (1 km²) change was 0.72 m³/sec for paddy, 0.68 m³/sec for forest, and 0.49 m³/sec for urban area.

Table 2. Hydrologic impact of streamflow due to area change of one land use item.

Year	Paddy			Forest			Urban		
	Area	Basin	Peak	Area	Basin	Peak	Area	Basin	Peak
	(km ²)	CN	runoff	(km ²)	CN	runoff	(km ²)	CN	runoff
			(m ³ /s)			(m ³ /s)			(m ³ /s)
1986	157.3	60.7	360.8	274.6	60.0	349.8	19.8	60.6	360.1
1990	149.1	60.3	354.5	255.3	60.8	363.3	42.6	61.2	371.5
1994	141.9	60.0	349.6	251.0	60.9	365.9	44.1	61.3	372.2
1999	133.6	59.7	343.8	246.2	61.1	369.0	55.2	61.6	377.6

6. Conclusions

A GIS and RS-based hydrologic modeling approach was tried to assess the quantitative effect of stream discharge due to agricultural land use changes. To identify the impact of streamflow by temporal area change of a target land use, a simple evaluation method that the CN values of areas except the target land use are unified as one representative CN value was suggested. By applying the method, the changing rate of watershed average CN per unit area (1 km²) change is 0.042 for paddy, 0.039 for forest, and 0.028 for urban area, respectively.

References

- [1] Maidment, D. and D. Djokic, 2000. *Hydrologic and Hydraulic Modeling Support with Geographic Information Systems*, ESRI, CA.
- [2] Nash, J. E. and J. V. Sutcliffe, 1970. River flow forecasting through conceptual models, Part I - A discussion of principles, *Journal of Hydrology*, 10: 283-290.
- [3] Brigham Young University Environmental Modeling Research Laboratory, 1999. *Watershed Modeling System*.