Application of Remotely Sensed Data and Geographic Information System in Watershed Management Planning in Imha, Korea

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ABSTRACT:

The use of remotely sensed data and geographic information system (GIS) to develop conservation-oriented watershed management strategies on Imha Dam, Korea, is presented. The change of land use for study area was analyzed using multi-temporal Landsat imagery. A soil loss model was executed within a GIS environment to evaluate watershed management strategies in terms of soil loss. In general, remotely sensed data provide efficient means of generating the input data required for the soil loss model. Also, GIS allowed for easy assessment of the relative erosion hazard over the watershed under the different land use change options. The soil loss model predicted substantial declines in soil loss under conservation-oriented land management compared to current land management for Imha Dam. The results of this study indicate that soil loss potential (5,782,829 ton/yr) on Imha Dam in 2003 is approximately 1.27 times higher than that (4,557,151 ton/yr) in 1989. This study represents the first attempt in the application of GIS technology to watershed conservation planning for Imha Dam. The procedures developed will contribute to the evolution of a decision support system to guide the land planning and dam management in Imha Dam.

Keywords: Watershed Management, Landsat, GIS, Soil Loss

1. Introduction

Recently, Imha reservoir has been suffering from the turbid water. The characteristics of land cover around river and soil erosion have been known as main reason of turbid water of Imha reservoir. Therefore, it is important to investigate time-series land cover change to analyze soil erosion in basin. To estimate soil erosion of basin more detail, GIS-based soil erosion model has been developed. Especially, RUSLE (Revised Universal Soil Loss Equation) computes the average annual erosion expected on hillslopes by multiplying several factors together: rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C), and support practice (P). The value of these factors is determined from field and laboratory experiments (Renard et al., 1997). The R-factor is measured as the product (EI) of total storm energy (E) and maximum 30-min intensity (I) for all storms over a long time. The EI parameter quantifies the effects of raindrop impact and reflects the amount and rate of runoff likely to be associated with the rain (Wischmeier and Smith, 1978). The K-factor reflects the ease with which the soil is detached by splash during rainfall and by surface flow, and therefore shows the change in the soil per unit of applied external force of energy. This factor is related to the integrated effect of rainfall, runoff, and infiltration and accounts for the influence of soil properties on soil loss during storm events on sloping areas. The LS-factor accounts for the effect of slope length and slope gradient on erosion. Soil loss increases more rapidly with slope steepness than it does with slope length (McCool et al., 1989). Value of C can vary from zero for well-protected landcovers to 1 for barren area. The P-factor is the ratio of sponding loss with up and downslope tillage. These practices proportionally affect erosion by modifying the flow pattern, gradient, or direction of surface runoff and by reducing the amount and rate of runoff (Renard and Foster, 1983). Values for P-factor range from about 0.2 for reverse-slope bench terraces, to 1.0 where there are no erosion control practices (Wischmeier and Smith, 1978).

The objectives of this study are (i) to analyze the distribution of time-series land cover types by Landsat image), ii) to calculate RUSLE factors and soil erosion amount due to time-series.

2. Change detection of land cover types

To analyze the change of land cover types, 4 time-series satellite image was used. Analyzed land cover types can be applied to calculate cover management factor (C) and support practice factor (P). Original satellite images included the wide area, much process time and capacity are required. Satellite images were exactly clipped for Imha basin and geometric correction for images was processed. Origanally, Ground control points (GCP) for geometric correction must be taken by crossing points on the road and the edge of main buildings. However, it was difficult to distinguish the road on the image because study site was around the mountain. Therefore, the geometric correction was processed by map-to-image method using 1:25,000 digital topographic maps. The number of used GCP was 25 points and RMSE for geometric correction was 0.4782 pixels. Before the landcover classification from satellite image, we analyzed USGS landcover classification system and selected the classes such as water, paddy, dry field, forest, grass, barren, and urban. Maximum likelihood method (MLM) was used to classify landcover from satellite image. Table 1 shows the results of classification using various satellite images. Take an example of the 1989 and 2003 for instances, the ratio of water was 0.22 % and 2.42 %, respectively. The increase of water shows that a wide area was submerged for containing water after the completion of dam. There was only a little change in the case of forest, grass, barren field, and urban. However, the ratio of paddy varies from 3.19 % to 11.50 % and that of upland does from 6.33 % to 16.42 %. The variation of paddy and upland shows that cultivation type is changed accodring to the year.

Table 1. Distribution of land cover by time-series

Acquired Date		Water	Paddy	Upland	Forest	Grass	Barren	Urban
1989-10-18	km^2	2.95	156.52	113.38	1,082.39	0.00	3.29	2.81
(LANDAT TM)	(%)	(0.22)	(11.50)	(8.33)	(79.50)	(0.00)	(0.24)	(0.21)
1995-05-12	km^2	13.40	127.66	86.18	1,120.51	0.00	1.78	11.81
(LANDSAT TM)	(%)	(0.98)	(9.38)	(6.33)	(82.30)	(0.00)	(0.13)	(0.87)
2001-04-18	km^2	34.07	43.46	223.52	1,042.53	0.00	0.00	17.76
(LANDSAT ETM+)	(%)	(2.50)	(3.19)	(16.42)	(76.58)	(0.00)	(0.00)	(1.30)
2003-03-20	km^2	32.88	45.61	159.01	1,091.26	8.27	8.27	18.82
(SPOT 5)	(%)	(2.42)	(3.35)	(11.68)	(80.16)	(0.61)	(0.61)	(1.38)

3. Estimating soil erosion by time-series land cover

To calculate soil erosion by time-series images, RUSLE factors were analyzed. Typically, rainfall erosivity factor is computed as total storm energy (E) multiplied by the maximum 30-min intensity (I_{30}) (Renard et al., 1997). Unfortunately, storm intensity data was unavailable for this study site. Therefore, Toxopeus's formula was applied to calculate rainfall erosivity factor. Soil erodibility factor is computed based on soil texture, organic matter content permeability, and other factors inherent to soil. This study analyzed the grain size distribution, the amount of clay, and the condition of the drainage using 1:25,000 soil map and then soil erodibility factor was calculted by Erickson's supplemented triangle diagram. The L- and S-factor in RUSLE reflect the effect of topography on erosion. To calculate slope length factor, this study used Desmet & Govers formula, which is applied to multiplex flowing algorithm. Slope steepness factor was computed by Nearing's formula (1997). The value of C- and P-factor depends generally on the kinds of plant, the growing condition, cultivating methods, and managing factors (Dissmeyer & Foster, 1981). This study used cover management factor based on landcover types that was experimental value in Korea (Shin, 1999). P-factor was calculated using land cover type and slope.

To analyze time-series soil loss, we assumed i) there is no change of topographic variation and soil types of basin in 1989-2003, ii) error effect of land cover classification due to satellite image acquired different times is ignored. Table 2 shows the results of calculation for statistics and amounts of soil loss. Take an example of the 1989 soil loss for instance, the amount of soil loss was about 4,557,151 ton/y. Even for the completion of Imha dam in 1995, the soil loss decreased by 3,277,769 ton/y. The reason of this phenomenon was caused by the increase of the submerged area after the completion of dam. In the case of 2001 and 2003, the total soil loss was analyzed as 5,581,988 ton/y and 5,782,829 ton/y, respectively. The analyzed soil loss shows that the increase of rainfall and the change of land cover type have an influence on the the sudden increase of the soil loss.

Table 2. Statistics and amounts of soil erosion

Year	Min	Max	Mean	StD.	Soil Erosion (ton/yr)
1989	0.000	5,727.587	21.795	69.793	4,557,151
1995	0.000	5,437.359	15.678	53.231	3,277,769
2001	0.000	1,623.140	26.330	78.058	5,581,988
2003	0.000	10,903.039	41.929	121.059	5,782,829

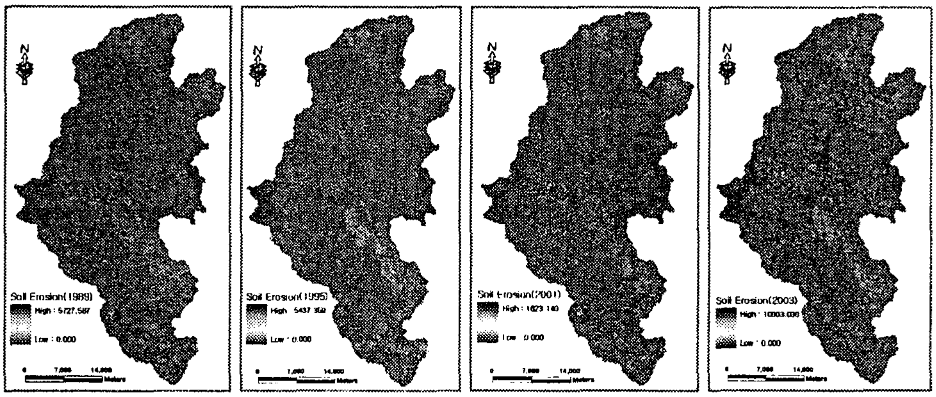

Figure 1. Distribution of soil loss by time-series

4. Conclusion

This study presented the application of remotely sensed data and GIS methodology for water management planning, especially soil erosion, in Imha basin, Korea. To do this, satellite image was used to estimate the change detection of land cover in 1989, 1995, 2001, and 2003. GIS-based RUSLE model was applied to calculate the change of soil erosion by using remotely sensed image and geospatial data such as DEM, soil, land cover, and satellite image. As a result of this study, the potential amount of soil loss was calculated as 5,782,829 ton/yr in 2003. This amounts is approximately 1.27 times higher than that (4,557,151 ton/yr) of 1989. Periodical monitoring of soil loss using remotely sensed data and GIS technique can offer very efficient information for decision maker to manage the basin or reservoir. Developed procedure in this study will also contribute to systematic watershed management.

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