Integration of GIS-based RUSLE model and SPOT 5 Image to analyze the main source region of soil erosion

Geun-Sang LEE*, Jin-Hyeog PARK, Eui-Ho HWANG, Hyo-Sok CHAE

*. Hydroinformatics Research Center, KIWE, KOWACO / 462-1 Jeonmin-dong, Yusung-gu, Daejeon, Korea / E-mail : ilovegod@kowaco.or.kr)

ABSTRACT:

Soil loss is widely recognized as a threat to farm livelihoods and ecosystem integrity worldwide. Soil loss prediction models can help address long-range land management planning under natural and agricultural conditions. Even though it is hard to find a model that considers all forms of erosion, some models were developed specifically to aid conservation planners in identifying areas where introducing soil conservation measures will have the most impact on reducing soil loss. Revised Universal Soil Loss Equation (RUSLE) 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. This study calculated soil erosion using GIS-based RUSLE model in Imha basin and examined soil erosion source area using SPOT 5 high-resolution satellite image and land cover map. As a result of analysis, dry field showed high-density soil erosion area and we could easily investigate source area using satellite image. Also we could examine the suitability of soil erosion area applying field survey method in common areas (dry field & orchard area) that are difficult to confirm soil erosion source area using satellite image.

Keywords: GIS, RUSLE, SPOT 5 image, Soil Loss

1. Introduction

In Korea, extremely heavy rainfall events over the last decade have been in perceived increases and a change in rainfall has an effect on various aspects such as runoff, erosion, soil moisture distribution, irrigation, and ecological conditions. Therefore, it is difficult to design and plan of water resource. Especially, soil loss has been a threat to farm livelihoods and ecosystem integrity. Recently, Imha reservoir has been suffering from turbid water. There are two main reasons to cause turbid water. One is soil erosion by heavy rainfall events in basin, and the other is geological feature.

For nearly 40 years, the Universal Soil Loss Equation (USLE) model (Wischmeier and Smith, 1978) and its principal derivative, RUSLE model (Renard et al., 1997) have been used throughout the world to estimate average annual soil loss per unit land area resulting from rill and sheet erosion. Although RUSLE was developed to predict water erosion in temperate climates, it is easier to adapt to tropical climates than other existing models. RUSLE is an empirically based model, founded on the USLE model, but is more diverse and includes database unavailable when the

USLE was developed (Renard et al., 1997). RUSLE model can predict an average annual rate of soil loss for a site of interest for any number of scenarios involving cropping systems, management techniques, and erosion control practices. Such predictions can provide a useful basis for planning and implementing soil conservation and sediment control program, more particularly, for targeting the areas within a basin where such measures should be applied to obtain the greatest benefit. It requires too much time consuming and cost to obtain soil loss field data of basin by rainfall. So, high resolution satellite image can be used with efficient tools to estimate the results of soil loss.

The objectives are (i) to analyze RUSLE factors using distributed GIS data (e.g. soil, landcover, DEM et al.), (ii) to estimate spatial characteristics of soil loss for Imha basin, and (iii) to use SPOT 5 image to estimate the main source area of soil loss.

2. Methodology

Imha basin is located at 10 km eastern part from the city of Andong and 350 km upstream from the estuary of the Nakdong River basin, Korea and the area of Imha basin is 1361 km^2. Streams through the watershed are mainly Ban-Byeon Stream, Yong-Jeon Stream, and Dae-Gok Stream. Imha reservoir has a gross-storage capacity of 595 million cubic meters. In the spring and summer, turbid currents often occur due to a large amount of rainfall. Turbidity currents in a reservoir can carry large quantities of sediments, nutrients and various chemical substances, and therefore might become import from the environmental point of view, for the entire river-reservoir system and for the adjoining areas.

Five major factors, rainfall pattern, soil type, topography, landcover type, and management practices, are used in RUSLE for computing the average annual erosion expected on the field slopes and are represented by the following equation (Renard et al., 1997):

$$A = R \times K \times L \times S \times C \times P \qquad (1)$$

where, A is the average soil loss due to water erosion ($ton/ha/yr$), R the rainfall erosivity factor ($MJ \cdot mm/ha/yr$), K the soil erodibility factor ($ton/ha/R$), L the slope length factor, S the slope steepness factor, C the cover management factor, and P the conservation support practice factor. L, S, C, and P are all dimensionless. In the application of RUSLE on GIS environment, soil loss is estimated within raster/grid GIS. Raster models are cell-based representations of map features, which offer analytical capabilities for continuous data and allow fast processing of map layer overlay operations. In a raster GIS, the mean annual gross soil erosion is calculated at a cell level as the product of six factors. Soil, DEM, landcover map, and rainfall data were used to estimate soil loss using GIS-based RUSLE model. RUSLE factors were calculated by empherical equation for the estimation of soil loss model. Figure 1 presents a schematic plot for general procedure used in this study.

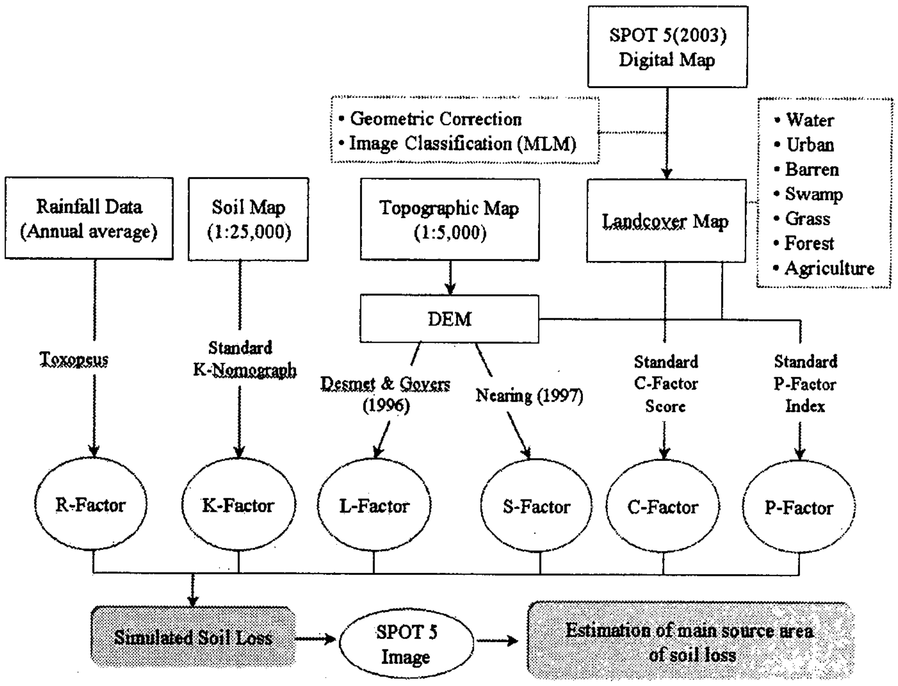

Figure 1. Schematic plot for estimating of main source area of soil loss

3. Result and Discussion

Interpolated rainfall map was acquired using the annual average precipitation (2003) of six raingauge stations in Imha basin. The grid based rainfall erosivity factor was calculated with Toxopeus formula. Soil map at a scale of 1:25,000 was applied to extract soil erodibility factor. The distribution of soil particle, organic contents and aggregate contents for soil units was analyzed, then soil erodibility classes (K factor) for identified soil units were derived from soil properties using Erickson's triangle diagram. Digital Elevation Model (DEM) methods were used to estimate topographic factors (LS). We extracted slope length (L) and steepness (S) information separately rather than use integrated terrain and drainage metrics that lump these two parameters in order to allow independent assessment of risk associated with each factor, and to determine the degree of correlation between them. A DEM was developed for this basin using 1:5,000 scale topographic maps with a resolution of 22 m. Desmet & Govers (1996) and Nearing (1997) formula was applied to calculate topographic factors using DEM. Cover management factor was predicted based on landcover map from SPOT 5 image. To determine cover management factor based on landcover types, this study used USGS standards. Support practice factor was acquired using landcover map and a gradient value from DEM. Dry land was designated as stripping method and paddy area was designated as terracing method.

Using equation (1), soil loss for each 22×22 cell was calculated and annual average soil loss was determined with 5,782,829 $ton/ha/yr$ by considering basin area. It is difficult to survey the source area of soil loss in basin because of time and cost. So, this study used SPOT 5 image and landcover map with 5m resolution to confirm the main source region of soil loss. For example, this study would like to explain 'A' district of Figure 2. Blue color means the district shows much soil loss potentially. That area is represented as dry field in landcover map (Figure 3). We can find out 'A' district using SPOT5 image (Figure 3) more easily.

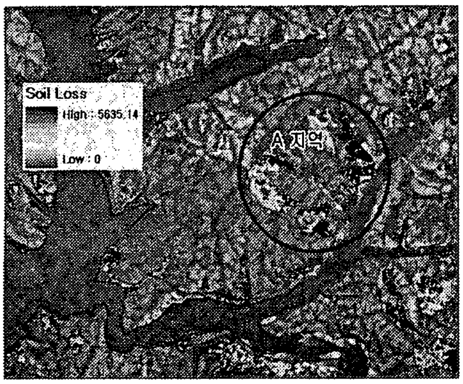

Figure 2. Distribution of soil loss

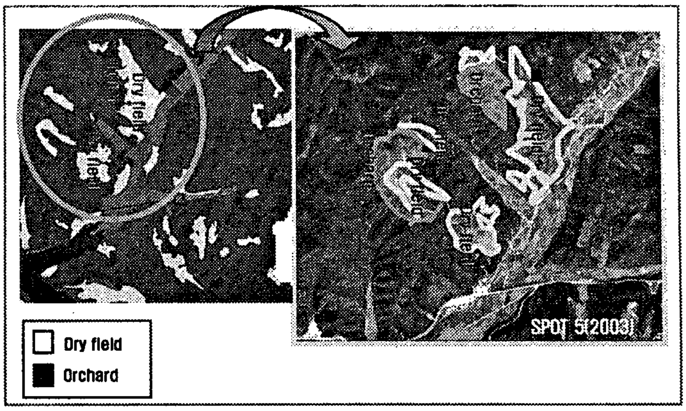

Figure 3. Landcover map and SPOT 5 image for 'A' district

4. Conclusion

This study described the application of the RUSLE model to quantify soil loss in a Imha basin, located in eastern part of Korea, using the GIS spatial analysis. The strategy adopted here is firstly to calculate six RUSLE factors using distributed GIS data (e.g. soil, landcover, and DEM) to adequately represent the surface characteristics. Secondly, it is to estimate spatial distribution of soil loss in the basin, and finally to use SPOT 5 image for main source area of soil loss. It is anticipated that the approach suggested herein will provide useful guideline for establishment of basin measurement to reduce soil loss. Especially, the spatial distribution of soil loss (5m resolution) and SPOT 5 image can provide decision making data to confirm the main source area of soil loss for the watershed management .

References

Desmet, P.J.J. and Govers, G., 1996. A GIS-procedure for the automated calculation of the USLE LS-factor on topographically complex landscape units. *Journal of Soil and Water Conservation*, 51(5), pp. 427-433.

Nearing, M.A., 1997. A single continuous function for slope steepness influence on soil loss. *Soil Science Society of America*, 61, pp. 917-919.

Renard, K. G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder, D.C., 1997. *Predicting soil erosion by water*, U.S. Department of Agriculture, Handbook No. 703.

Wischmeier, W.H., Smith, D.D., 1978. *Predicting Rainfall Erosion Losses – A Guide to Conservation Planning.* USDA-Agriculture Handbook No. 537.

Acknowledgements

We are most grateful for support from "The feasibility study of remotely sensed data for watershed management" project(2005) sponsored by Korea Aerospace Research Institute (KARI).