RUSLE 모형을 이용한 임하댐 유역에서의 토양유실량 평가

Soil Erosion Modeling Using RUSLE and GIS on the Imha Watershed

김현식*, Pierre. Y. Julien**, 염경택***

Hyeon Sik Kim, Pierre. Y. Julien, Kyung Taek Yum

Abstract

The Imha watershed is vulnerable to severe erosion due to the topographical characteristics such as mountainous steep slopes. The RUSLE model was combined with GIS techniques to analyze the mean annual erosion losses and the soil losses caused by typhoon "Maemi". The model is used to evaluate the spatial distribution of soil loss rates under different land uses. The mean annual soil loss rate and soil losses caused by typhoon "Maemi"were predicted as 3,450 tons/㎢/year and 2,920 ton/㎢/"Maemi", respectively. The sediment delivery ratio was determined to be about 25% from the mean annual soil loss rate and the surveyed sediment deposits in the Imha reservoir in 1997.

Key words: Soil Loss Rate, Sediment Delivery Ratio, Trap Efficiency

1. Introduction

The Imha watershed is located in the northeastern part of the Nakdong River basin, which includes Andong city, Pohang city, Chungsong-gun, and Yongyuang-gun of the Gyeongsangbuk-do province. Major tributaries of the Imha reservoir are the Ban-Byeon Stream, Dae-Gok stream, and Young-Jeon Stream. The Imha multi-purpose dam was constructed on Ban-Byeon Stream from 1984 to1992. It is located 10km east of the city of Andong, Gyeongbuk province on the Ban-Byeon Stream, and about 350km upstream of the Nakdong River Estuary. Fig.1. presents the location map of the Imha watershed

Since Imha reservoir was impounded, it has suffered from continuous sediment-laden density currents. When the typhoon "Rusa" came to the Imha watershed in 2002, the maximum turbidity of the Imha reservoir increased to more than 800 NTU (Neuphelometry Turbidity Unit). Furthermore, when the typhoon "Maemi" struck the Imha watershed on September 12, 2003, a turbidity level of more than 1200 NTU was measured from the total 184mm precipitation of the Imha watershed.

* 정회원 · 한국수자원공사 수자원관리처 차장 · E-mail : hyeonsik@kwater.or.kr

** 비회원 · 콜로라도주립대학교 토목공학과 교수 · E-mail : pierre@engr.colostate.edu

*** 정회원 · 한국수자원공사 수자원관리처 처장 · E-mail : ykt@kwater.or.kr

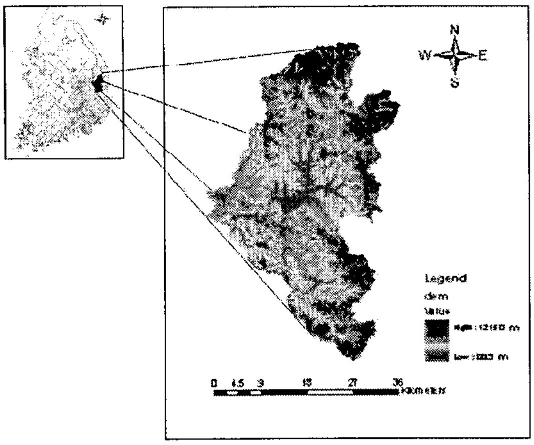

Fig 1. The map of the Imha watershed

The objectives of this study are to: (1) use the rainfall data, Digital Elevation Model (DEM), soil type map, and land cover map, and build the Soil Erosion Map (SEM) to calculate the soil loss rates on the Imha watershed. Two cases are analyzed: (1) the mean annual soil loss rate and (2) the soil loss rate caused by typhoon "Maemi". The purpose of this study is also to analyze the spatial distribution of soil erosion in the Imha watershed, and to determine the Sediment Delivery Ratio (SDR) in the Imha watershed from sediment deposits surveyed in the Imha reservoir in 1997.

2. Methods & Analysis

The Universal Soil Loss Equation (USLE) model was based on the field measurements of soil erosion rates in agricultural areas by Wischmeier and Smith (1965). RUSLE is used to estimate the gross soil erosion in the Imha watershed combined with GIS techniques. It is a widely used and accepted empirical soil erosion model developed for sheet and rill erosion based on a large set of experimental data from agricultural plots. The gross soil loss from the RUSLE model is calculated based on following equation.

$$A = R \times K \times L \times S \times C \times P \qquad \text{(Eq. 1)}$$

Where: A is a computed spatial average soil loss and temporal average soil loss per unit of area (tons/acre/year); R is a rainfall-runoff erosivity factor; K is a soil erodibility factor; L is a slope length factor; S is a slope steepness factor; C is a cover management factor; P is a support practice factor. RUSLE model has six parameters, which are rainfall-runoff erosivity factor (R), soil erodibility factor (K), slope length and steepness factors (LS), cover management factor (C), and support practice factor (P).

2.1 Rainfall-runoff erosivity factor (R)

Wischmeier et al.,(1958) derived the rainfall and runoff erosivity factor from research data from many sources. Wischmeier and Smith (1965) found that the best predictor of rainfall erosivity factor (R) is:

$$R = \frac{1}{n}\sum_{j=1}^{n}\left[\sum_{k=1}^{m}(E)(I_{30})_k\right] \qquad \text{(Eq. 2)}$$

Where: R is a rainfall-runoff erosivity factor—the rainfall erosion index plus a factor for any significant runoff from snowmelt ($100fttonfacre^{-1}yr^{-1}$); E is the total storm kinetic energy in hundreds of ft-tons per acre; I_{30} is the maximum 30-minute rainfall intensity;

Based on the Wischmeier method, rainfall-runoff erosivity factors for two cases, which are the average annual rainfall erosivity factor, and the rainfall erosivity factor caused by typhoon "Maemi", are estimated in the Imha watershed. Fig.2 presents the rainfall runoff erosivity factors and Isoerodent maps, which are drawn using the Ordinary Kriging interpolation method, for the 9 rainfall gauge stations in the Imha watershed, respectively.

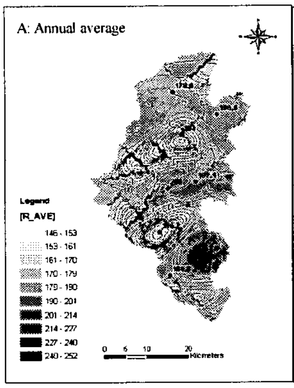

Fig 2. R factor

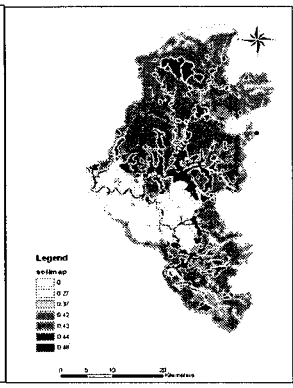

Fig 3. K factor

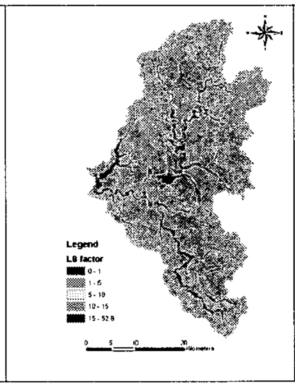

Fig 4. LS factor

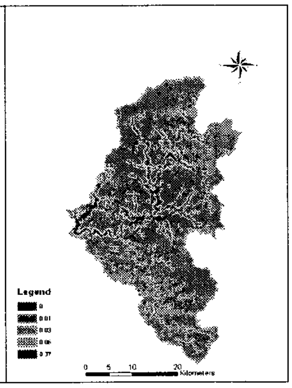

Fig 5. C factor

2.2 Soil erodibility factor (K)

Soil erodibility (K) represents the susceptibility of soil or surface material to erosion, transportability of the sediment, and the amount and rate of runoff given a particular rainfall input, as measured under a standard condition. Soils of the Imha watershed are classified divided into 35 soil types. In this study, the soil erodibility (K) of the Imha watershed can be defined using the relationship between soil texture class and organic matter content proposed by Schwab et al. (1981). Fig.3 presents the soil erodibility factor (K), which ranges from 0.16 to 0.48, based on the soil texture class.

2.3 Slope length and steepness factor (LS)

The effect of topography on soil erosion is described by the LS factor in RUSLE, which combines the effects of a slope length factor (L), and a slope steepness factor (S). The L and S factors are extracted from the Digital Elevation Model (DEM) and calculated by the equations suggested by Renard et al. (1997) in RUSLE. The slope length and slope steepness (S) can be defined from the Digital Elevation Model (DEM) (Hickey et al., 1994) and are calculated using an Arcinfo AML coded by Van Remortel et al. (2001). Fig.4, represents the slope length (L) and slope steepness (S).

2.4 Cover management factor (C)

The cover management factor (C) represents the effects of vegetation, management, and erosion control practices on soil loss. Based on the "Nakdong River Basin Survey Project, (MOCT and KOWACO, 2005)", the land cover of the Imha watershed is classified with six land cover classifications: Water, Urban, Wetland, Forest, Crop field, and Paddy field. The

National Institute of Agricultural Science and Technology (NIAST, 2003) has studied the cover management factor with crop coverage based on Lysimeter experiments from 1977 to 2001.

The cover management factor for the forested areas of the Imha watershed has been calibrated by Kim (2006) to reflect the recent changes in land use attributed to deforestation, road construction, and agricultural development. Accordingly, the appropriate C value shown in Fig.5 represents the cover management factor in the Imha watershed.

2.5 Support practice factor (P)

The support practice factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, runoff velocity, and hydraulic forces exerted by runoff on soil. Most of the Imha watershed is forested and only 15 percent is used for agriculture with paddy and crop fields. The support practice factor is calculated according to the cultivation method and slope (Shin, 1999).

2.6 The mean annual soil loss rate

In order to predict the annual average soil loss rate in the Imha watershed, the six parameters of the RUSLE model are multiplied. Fig.7 represents the mean annual soil loss rate map in the Imha watershed. The annual average soil loss rate is predicted to be 3,450 tons/km^2/year. Table 1. shows the annual average soil loss rate based on the land cover type. The total annual average soil loss rate of the Imha watershed is about 2.7million tons /year. Of this soil loss rate, forested area covers primarily 93% of total annual average soil loss rate and crop field area is the second order.

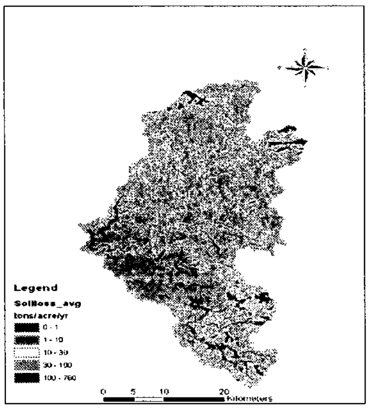

Fig 7. Mean annual soil loss

Table 1. The annual average soil loss rate

Land cover type	Area (km2)	Portion of area (%)	Soil loss rate (tons/km^2/year)	Portion (%)
Water	15.0	1.1	0.0	0.00
Urban	9.9	0.7	0.003	0.00
Wetland	4.2	0.3	0.0	0.00
Forest	1122.4	82.5	2248.6	93.49
Paddy field	61.9	4.5	19.8	0.05
Crop Land	147.6	10.8	1181.2	6.46
Total	1361.0	100.0	3449.6	100.0

2.7 Sediment Delivery Ratio

The Sediment Delivery Ratio (SDR) denotes the ratio of the sediment yield Y at a given stream cross section to the gross erosion A_T from the watershed upstream from the measuring point (Julien, 1998). Sediment delivery ratio can be calculated as follows:

$$S_{DR} = \frac{Y}{A_T} \qquad \text{(Eq. 4)}$$

Where: Y is a sediment yield; A_T is gross erosion per unit area

KOWACO carried out the sediment deposits survey at the Imha reservoir in 1997. Based on the "Sediment Deposits Survey Report of the Imha reservoir (KOWACO, 1997)", the observed sediment deposition is about 890 tons/km^2/year at the Imha reservoir. The annual average soil erosion predicted by the RUSLE model is 3,450 tons/km^2/year. Fig.11 presents the results of SDR in the Imha watershed.

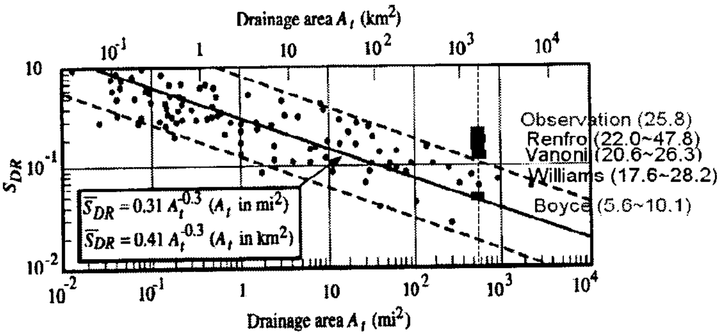

Fig. 11. The results of SDR in the Imha watershed

2.8 Soil loss rate caused by Typhoon "Maemi"

Typhoon "Maemi" struck the South Korea Peninsula on the evening of September 12, 2003, dumping 432mm of rain and triggering massive floods and landslides. Due to the typhoon "Maemi", the average soil loss rate of the Imha watershed is estimated about at 1330 ton/km^2/Maemi and is around 39 percent of the annual average soil loss rate.

3. Conclusions

The RUSLE model was combined with GIS to analyze the mean annual soil loss rates and soil losses caused by typhoon "Maemi". The spatial distribution of soil loss rates under different land cover is also determined. Specific conclusions are summarized as following:

1) The annual average soil loss rate was analyzed to be 3,450tons/km^2/year and gross annual average soil erosion was about 2.7million tons/year in the Imha watershed. The average soil loss rate caused by the typhoon "Maemi" was analyzed to be about 1,330 ton/km^2/"Maemi".
2) The SDR of the Imha watershed was estimated to be 25.8%. This SDR is fairy high compared to the Boyce, Vanoni, Williams, and Roehl models. Several reasons for high SDR were found such as high, steep slopes, no floodplain, and many crop field areas near the reservoir and streams.

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