경험적 토사유실모형에서 SDR의 적정성 검토

The Review of Optimum Level of SDR in Empirical Soil Erosion Model

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Abstract

Upland erosion pollutes surface waters and often causes serious problems when deposition occurs. This study builds a sediment rating curve using the measured sediment yield and the simulated soil erosion by a GIS-embedded empirical model. The coefficient of determination (R^2) between the simulated soil erosion and the measurement sediment yields with rainfall amount are 0.427 for Donghyang and 0.667 for Cheonchen, but the values with rainfall intensity are 0.873 and 0.927 respectively. The data are divided into two groups: one for calibration during 2002-2005 (48 months) and the other for estimation during 2006-2008 (36 months). The first data group (2002-2005) was used to derive the SDR with an aid of soil erosion calculated by the USLE and the measured sediment yield. The mean SDR with rainfall amount is 6.273 and 3.353, respectively, while 4.799 and 2.874 for rainfall intensity. But the standard deviation (STD) with rainfall intensity is 0.930 and 0.407, which is much less than that with rainfall amount (3.746 and 2.090) for both sites. The results show the derived SDR provides reasonable accuracy and rainfall intensity gives better performance in calculating soil erosion than rainfall amount.

Key words : Sediment Delivery Ratio, Sediment Yield, Empirical Soil Erosion

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요 지

상류에서 유입된 토사는 지표수를 오염시키고 때때로 퇴적이 발생시 심각한 문제들을 야기하게 된다. 본 연구에서는 GIS 기반의 경험적 토사유실모형을 통해 모의된 토사유실량과 관측된 유사량 자료를 이용하여 유사전달률 자료를 구축하였다. 모의된 토사유실량과 관측된 유사량과의 관계를 분석한 결과, 강우량에 의한 결정계수는 동향과 천천에 대해 각각 0.427과 0.667인 반면, 강우강도에 의한 결정계수는 0.873과 0.927로 높게 나타났다. 자료의 검보정을 위해 2002-2005년도(보정)와 2006-2008년도(검증) 자료로 분류한 후 USLE 모형과 관측된 유사량을 이용하여 SDR을 계산하였다. 동향과 천천유역의 강우량에 의한 SDR의 평균은 각각 6.273과 3.353인 반면 강우강도에 의한 SDR의 평균은 4.799와 2.874로 낮게 나타났으며, 표준편차는 강우량의 3.746과 2.090에 비해 강우강도가 0.930과 0.407로 낮게 나타났다. 따라서 토사유실 모델링시 강우량에 의한 방법보다는 강우강도에 의한 SDR 추정값을 사용하는 것이 더 바람직함을 보여준다.

핵심용어 : 유사전달률, 유사량, 경험적 토사유실

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1. Introduction

There are a few methods to calculate the amount of eroded soil; sediment rating curve method, measurement of sediment deposit, and other empirical methods. The sediment rating curve method is very useful to estimate total sediment yield once a relationship is constructed from the existing data which include discharge and the amount of sediment yield at a specific point. When a precipitation event occurs, water is deposited on many different surfaces and then, from these surfaces, it propagates by a number of routes into the local stream or the local water table (Maidment, 1993). The amount of soil erosion relies on the amount of water that eventually reaches the saturated overland flow, which are controlled by the abundance and type of vegetation and underlying soil. Therefore only some of the eroded soils are routed to the basin outlet, and the ratio between the basin sediment yield at the basin outlet and soil erosion over the basin is called sediment delivery ratio (SDR).

The most popular soil erosion model such as USLE (Universal soil loss Equation) or RUSLE (Revised Universal soil loss Equation) calculates the soil loss forced by a rainfall but does not account for the sediment yield. The SDR needs to be determined to effectively generate the sediment yield at the outlet. The SDR is involved in numerous uncertainties including temporal discontinuity and spatial variability (Renfro, 1975; Williams and Berndt, 1977; Walling, 1983; Wolman, 1977; Delwiche and Haith, 1983; Novotny and Chesters, 1989; Boyce, 1975; Vanoni, 1975) but usually there is no sufficient measured data available for determining the SDR.

This study presents an inverse solution to determine the SDR on a basin scale in southern Korea. To do this, the measurements of sediment yield and discharge were used to build sediment rating curves, and soil erosion was calculated with an assist from the geographic information system (GIS)-embedded soil erosion model.

2. Study region and data used for the study

The center of the Yongdam basin is 127° 33′ E, 35° 45′ N, which is about 200km south of the capital of Korea. This study selected Donghyang and Cheoncheon basin, which covers about 165㎢ and 287㎢ respectively, to calculate SDR using RUSLE model and measured suspended solid. Yongdam Dam was constructed in 2001 and Donghyang and Cheoncheon have water level station from 2002. That's why we selected Donghyang and Cheoncheon basin to the study sites. Its annual average temperature and humidity are approximately 14℃ and 74%, respectively and its annual average precipitation (=1,238mm) is slightly lower than the Korean national average (=1,283mm).

To determine the characteristics of soil erosion within the basin, the cause of sediment yields, it basically calls for the information on the Digital Elevation Model (DEM), soil, land cover, and other GIS database. First, to determine the geomorphological characteristics, the study develops a Triangle Irregular Network (TIN) using a 1:5,000-scale digital topographic map crafted by the National Geography Institute. Using the TIN, a 10m resolution DEM is crafted. The DEM distribution of Donghyang and Cheoncheon river basin covers 205～1589m.

The land cover plays a decisive role in causing soil erosion and then sediment occurrence according to the intensity of rainfall. Therefore, it is crucial to secure an accurate landcover map; to overcome the limit of the existing 30m-resolution LANDSAT satellite images, this study used a basic land cover map with 10m-resolution SPOT 5 images of Ministry of Environment. Cultivated areas which are most sensitive to soil loss are 22.048㎢ (13.337%)와 33.249㎢ (11.591%) for Donghyang and Cheoncheon.

3. Results and Discussion

3.1 Building sediment rating curve

Sediment discharge in a stream is commonly evaluated by integration of the product of depth-integrated concentration and unit discharge along the channel width. The daily sediment load is then calculated from the product of the average sediment concentration by the total daily volume of water. If the sediment discharge or the concentration is plotted against the runoff discharge, a power relationship can be fitted through the data:

$$Q_s = \alpha Q_w \beta \tag{1}$$

In which α and β are obtained by regression analysis. Hysteresis effects between discharge and concentration, seasonal variation, inaccuracies in flow and sediment measurements and variability in the wash load may explain the scatter of points on the sediment transport graph. Better results may sometimes be achieved when sufficient data is available and a regression analysis is made for each month (Frenette and Julien, 1987; Da Ouyang, 2001).

In this study, a sediment rating curve was built on the basis of field measurement (212 sample points for Donghyang and 234 sample points for Cheoncheon) during the period of 2002～2008. Then sediment yield data for Donghyang and Cheoncheon basins were derived from the sediment rating curves.

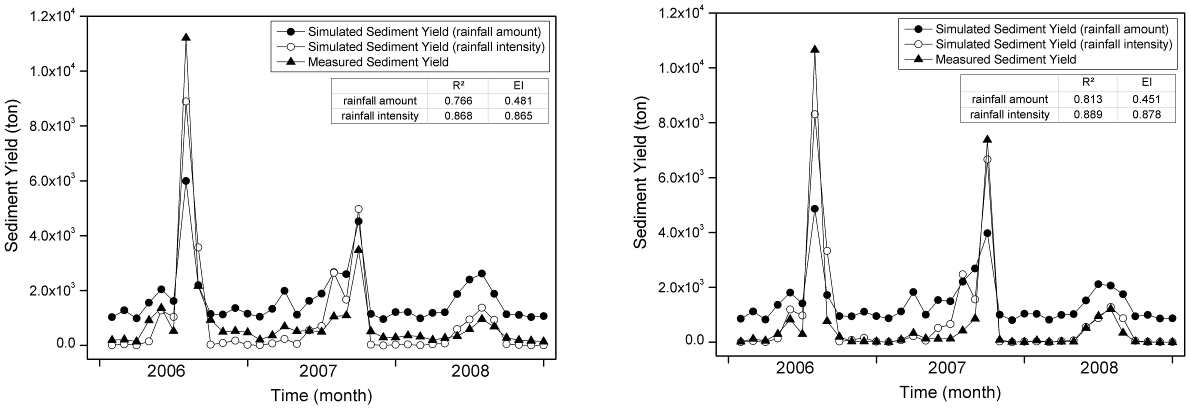
3.2 Determining sediment delivery ratio

The USLE calculated soil erosion for both Donghyang and Cheoncheon basin, and the corresponding soil erosion is shown against measured sediment yield at each site. As mentioned earlier, the effect of rainfall amount and intensity was melt into the rainfall runoff erosivity factor, and compared for estimating soil erosion. The coefficient of determination between the simulated soil erosion and the measurement sediment yields with rainfall amount are 0.427 for Donghyang and 0.667 for Cheonchen, but the values with rainfall intensity are 0.873 and 0.927 respectively.

The data are divided into two groups: one for calibration during 2002-2005 (48 months) and the other for estimation during 2006-2008 (36 months). The first data group (2002-2005) was used to derive the SDR with an aid of soil erosion calculated by the USLE and the measured sediment yield. The mean SDR with rainfall amount is 6.273 and 3.353, respectively, while 4.799 and 2.874 for both sites. But the standard deviation (STD) with rainfall intensity is 0.930 and 0.407, which is much less than that with rainfall amount (3.746 and 2.090) for both sites. Hence the coefficient of variation with rainfall intensity is less (0.19 for Donghyang and 0.14 for Cheoncheon).

Now assuming that the mean values of the SDR during the calibration periods are representative values for each site, the simulated sediment yield is validated against the measured sediment yield during the period of 2006-2008. As shown in figure 1, the R^2 and EI with rainfall intensity are higher as 0.868 and 0.865.

Based on the results, the SDR derived from the sediment rating curve provides reasonable accuracy, and the simulation of soil erosion with rainfall intensity gives better performance. Obviously, the accuracy of the results shown in this study strongly depended on the model selection for soil erosion, the quality of geospatial data, measurement accuracy, and the basin characteristics. To some degrees, error may be different for every new basin of interest, but the method used herein should work anywhere else.



(a) Donghyang (b) Cheoncheon

Fig 1. Validation of Sediment Yield according to Rainfall Amounts and Rainfall Intensity

4. Summary and Conclusions

This study determines the SDR using the sediment rating curve constructed on the basis of the measured sediment yield and the simulated soil erosion by a GIS-based empirical model. The whole data are divided into two groups and the first group is used for calibration, while the other is used for validation. To consider the rainfall effect in simulating soil erosion, two cases of equations are compared. The primary conclusions are as follows;

- The R^2 between the simulated soil erosion and the measurement sediment yields with rainfall amount are 0.427 for Donghyang and 0.667 for Cheonchen, but the values with rainfall intensity are 0.873 and 0.927 respectively.

- The R^2 andEIwithrainfallintensityarehigheras0.868and0.865invalidationprocess.
- It is generally found that the SDR derived from the sediment rating curve provides reasonable accuracy, and that the simulation of soil erosion with rainfall intensity gives better performance.

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