Analysis of soil erosion hazard zone in Farmland

K.T. Kim[1], J.H. Kim[2], J.S. Park[3], Y.S. Choi[4]
Water Resources Research Department, Korea Institute of Consturction Technology
2311 Daehwa-dong Ilsan-gu, Goyang-si, Gyeonggu-do 411-712, Korea
ktkim1@kict.re.kr[1], jh-kim@kict.re.kr[2], parkjs@kict.re.kr[3], yschoi51@kict.re.kr[4]

Abstract: This paper is aimed at analyzing the soil erosion hazard zone in farmland. RUSLE was used for an analysis of soil erosion amount, and for the spatial data of basin, soil erosion amount was calculated by extracting the respect topography space related factors of RUSLE using DEM, Landuse, Soil map as base map. As a result of analysis on the calculated soil erosion amount according to land use type, it was analyzed that the most soil erosion occurred in orchard area, i.e., 40.08ton/ha/yr at average. It was classified into 5 classes depending on the calculated soil erosion amount, of which Class V was decided as soil erosion hazard zone, and for this area, 72.5ha or so, 2.4% of the entire farmland was assessed as erosion hazard zone.

Keywords: GIS, RUSLE, Soil erosion hazard zone.

1. Introduction

Flood and erosion are influenced from a variety of factors such as rainfall distribution, soil type, land use, etc. These factors are presented in various types by time and space, and GIS technique has been used as a method to predict the hazard of soil erosion in watershed.

GIS can evaluate the degree of hazard of erosion or the amount of erosion spatially and provide with, and a variety of researchers are proving the effectiveness of DEM in assessment of soil erosion (Burrough, 1986; Moore, et al(1993). GIS was used in calculation of the amount of soil erosion with modifying of USLE or USLE (Jetten, et al., 1988), and also Bork and Hensel (1988) used GIS USLE approach method to assess the amount of soil erosion in more wider range of watershed. Ferri and Minacapilli (1995) expanded USLE of which sediment delivery term was applied to the model for the sediments running off from watershed to be predicted. Saha (1996) has assessed the erosion hazard by giving weighted value on a certain range per factor of USLE.

Some researchers including Mitchell (1978) has been reported the soil erosion of 36.6_ 165.6ton/ha_yr at annual average in USA, and in case of Argentina, Buck (1993) announced that the soil of 6_ 12ton/ha_yr was eroded. Gupta (2001) assessed soil erosion hazard zone by classifying the amount of soil erosion into 4 classes, and Morgan (1995) has insisted that soil erosion estimate of 10ton/ha_yr was a proper level at which the agricultural experts should have interest in.

The studied for soil erosion in Korea are as follows: an analysis on environmental influence assessment for soil erosion (including Yun-Jong Kim, 1994); a study (including Chang-Ho Woo, 1998) on automatic calculation of topography factor using the multiple flow algorithm that was developed by a few researchers including Quinn (1991) as well as LS factor calculation method in USLE; and some researchers including Geun-Sang Lee (2003) have performed an analysis on optimal resolution in respect to the scaling of soil map in calculation of the amount of soil erosion.

In the studies on assessment of the degree of soil erosion hazard, Joo-Hun Kim et al. (2003) have assessed the area as erosion hazard zone using RUSLE model, where the surface gradient is higher than 20 degree and soil erosion amount occur more than 300ton/ha_yr, and also Gyeong-Hun Park(2003) has analyzed the distributional characteristics according to division classes of soil erosion by classifying it into 4 classes depending on the degree of hazard of soil erosion.

Soil erosion varies depending on the spatial and hydrological characteristics in watershed, and there is yet no correct criteria arranged for the division classes of soil erosion, so some researchers in Korea and overseas have analyzed erosion hazard zone, in fact.

This paper has purposes that the amount of soil erosion which occurs in a watershed is calculated by extracting the factors about the topography and spatial information of RUSLE using spatial data such as DEM and soil map, land use map for the farmland in the watershed of Han River watershed Gyeongan stream ; and then based on it, an assessment on hazard zone where erosion occurs is performed.

2. Research method and scope

1) Theories of analyzing the amount of soil erosion

USLE model was suggested first based on the concept of the separation and transport of particles from rainfall by Wischmeier and Smith (1965) in order to calculate the amount of soil erosion in agricultural area, of which modified equation was proposed in 1978. This formula was extended and applied to construction fields by a few researchers including Wischmeier (1971).

In USDA (1996), for the calculation of the amount of soil erosion under soil conditions besides of the pilot sites such as pasture or forests, RUSLE(Revised Universal Soil Loss Equation) was announced to add many factors such as revision of weather factor, development of soil erosion factor depending on seasonal changes, and development of new calculation procedure to calcu-

late cover vegetation factor as well as the revision of the length and gradient of slope.

Although in RUSE uses the equation structure of USLE as it is, the relationship of the respective factors is updated as the types of changing soil erosion. This model is empirical equation derived from simulated rainfall and actual runoff data as well as erosion theories, which gets to be applied to wider range of areas.

USLE and RUSLE equations are as followings.

$$A = R \cdot K \cdot LS \cdot C \cdot P \qquad (1)$$

Where: A is the amount of soil erosion(ton/ha_yr) that is eroded within unit area during the corresponding period of rainfall-runoff erodibility factor(R); R is a rainfall-runoff erosivity factor;, K is a soil erodibility factor; LS is a surface characteristic factor(slope-length and steepness factor, L is the length of erosion slope, while S is the gradient of erosion slope); C is a cover management factor;, P a is support practice factor.

2) Investigation target watershed

This paper is targeting at the watershed of Gyeongan stream in Gyeonggi-do, is which has recently a social problem due to disturbing development of cities.

The watershed of Gyeongan stream is one tributary of Lake Paldang that is a main water supply for metropolitan area where rapid urbanization is progressing. Besides it was specified as a buffer zone for the national river sector as it is an important watershed for the management of water quality pollutant of a river. Gyeongan stream, which is tributary of Lake Paldang, is originated from Ho-dong in Yongin-city and it flows toward north side and then goes through Yongin-city in Gimnyang-jang-dong, and it has a basin area of 558.2㎢ and a total flow extension of 49.5㎞ . In this basin of Gyeongan stream, the soil erosion in farmland and the hazard zone where earth and sand occurs were analyzed(168.5㎢ , 30.4%).

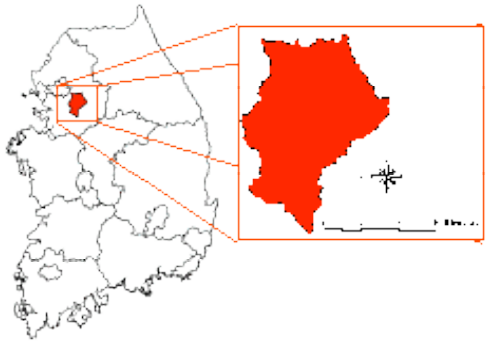

Fig. 1. Location of study area

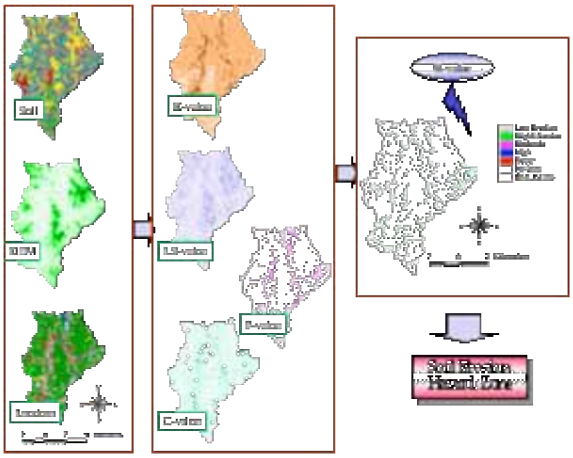

Fig. 2. Analysis procedure of soil erosion hazard zone

3) Analysis data

As the default spatial data for the watershed of Gyeongan stream, DEM that is created using 1/25,000digital map, and precision soil map (1/25,000) data of National Institute of Agricultural Science and Technology, and the land use state map of National Geographic Information Institute were used.

A spatial thematic map for the respective factors of RUSLE was created by using a basic spatial data. That is, thematic map was created as followings: LS factor that is related with the slope length and gradient of surface by using DEM; K factor for the erosion of soil by using precision soil map; and C & P that are the factors in respect to surface's vegetation cover and soil conservation by using land use state map of Ministry of Construction & Transportation(MOCT). The soil erosion of watershed is generated from a variety of factors. For specifying C and P values, especially land use state map of MOCT and land cover map of land use state map are used as basic data, while the land cover map of Ministry of Environment does not have detailed cover classification system, so land use state map is used in this paper.

3. Analysis on erosion hazard zone

1) Calculation of the amount of soil erosion

Rainfall-runoff erodibility factor is a factor that is established by blowing energy from raindrop per Storm event, Kinetic energy of rainfall, and Maximum 30-minute rainfall intensity. Although there are many methods to calculate rainfall-runoff erodibility factors, it is calculated using Toxopeus' expression (2) that was quoted in the study of Gye-Jong Shin (1999).

$$R = 3.85 + 0.35 \times P \qquad (2)$$

Where, R = rainfall-runoff erodibility, P = Average annual rainfall (mm/yr).

With a soil erodibility factor, a surface characteristic factor, a cover management factor, and a support practice factor, the soil erosion amount of watershed was calculated by extracting the factors in respect to each topography and vegetation from basic spatial data that was constructed using GIS, and the calculated result is as shown in Table 1.

Table 1. Soil erosion amount per land use type

LU_code / Soil rosion	adjusted paddy fields	non-adjusted paddy fields	crop field	orchard
Min(t/ha/yr)	0.001	0.004	0.005	0.4
Max(t/ha/yr)	117.56	163.28	836.01	283.03
Mean(t/ha/yr)	2.63	1.21	30.22	40.08
Total area(㎢)	36.35	3.86	40.67	0.48
Erosion area(㎢)	9.56	0.19	20.20	0.31
Erosion area(%)	26.30	5.04	49.66	64.74

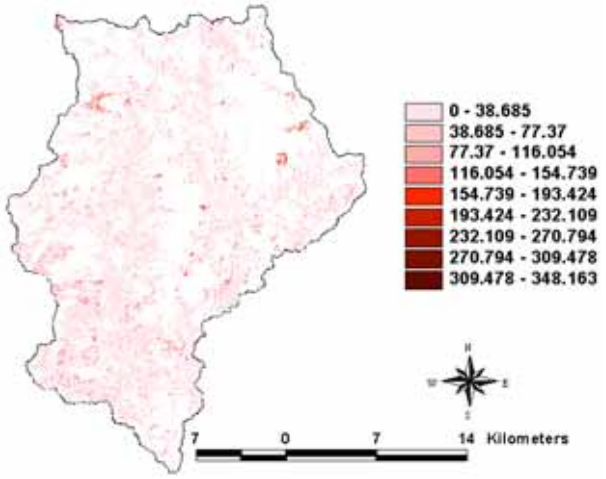

Fig. 3. Soil erosion amount distribution map

The ratio of farmland occupancy of the entire area of the watershed of Gyeongan stream is 80.9㎢, i.e., approximately 15.6% of it. It was analyzed that the area of soil erosion occurrence was 30.2㎢, i.e., 37.3% of it.

The land use of farmland is shown in the order of crop field(1210), adjusted paddy fields(1110), non-adjusted paddy fields(1120), orchard(1220), while the area where a lot of soil erosions occur is shown in the order of orchard(1220), crop field(1210), adjusted paddy fields(1110), and non-adjusted paddy fields(1120). Especially, the area where crop field is cultivated occupies about 50.3% of the entire farmland, so it is regarded as important to establish a plan to prevent from soil erosion in this area.

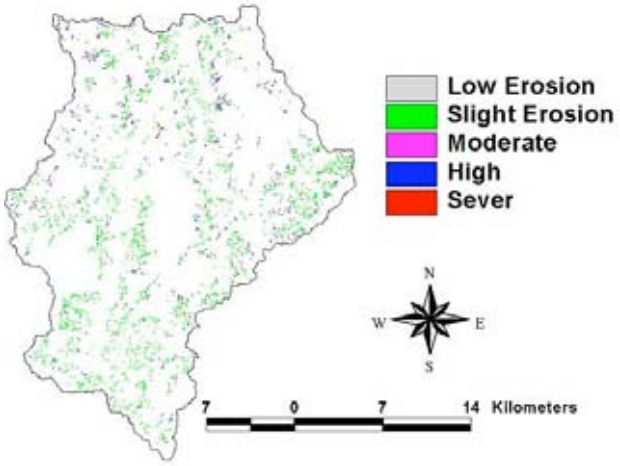

Fig. 4. Soil erosion hazard zone distribution map

2) Analysis on erosion hazard zone

The occurrence of soil erosion has close relationship with the status of land use and the status of farmland management alongside with topographical characteristics such as surface gradient.

Gupta (2001) has classified the soil erosion of watershed into severe area for 200ton/ha_yr, hazard zone(high) for 101_ 200ton/ha_yr, moderate area for 51_ 100ton/ha_yr, and slight erosion area for 1_ 50ton/ha_yr.

Targeting at the soil erosion hazard zone of the farmland of Gyeongan stream watershed, the classification of soil erosion per land use type is presented as shown in the following Table 2 referring to the 4 division classes suggested by Gupta(2001) specifying slight erosion hazard zone as Class II and also severe soil erosion area as Class V, by adding the area where soil erosion is smaller than 1ton/ha_yr as Class I. In case of Class V that is regarded as hazard zone of erosion occurrence, it did not occur in adjusted paddy fields and non-adjusted paddy fields, and about 9.6% of the entire erosion occurrence areas was assessed as erosion hazard zone.

For the area where most of erosion occurs, it shows that division Class II (1_ 50ton/ha/yr) occupies the broadest area of it.

Table 2. Classification of soil erosion hazards per and use type

(Unit : ㎢ (%))

Code / Class	1110	1120	1210	1220	Sum(㎢)
Class I	0.076(0.8)	0.001(0.4)	0.084(0.4)	0.006(2.0)	0.167(0.6)
Class II	9.393(98.2)	0.182(93.7)	11.611(57.5)	0.052(16.7)	21.238(70.2)
Class III	0.087(0.9)	0.010(5.0)	5.045(25.0)	0.095(30.5)	5.237(17.3)
Class	0.005(0)	0.002(0.9)	2.735(13.5)	0.158(50.5)	2.899(9.6)

IV					
Class V	0.000(0)	0.000(0)	0.724(3.6)	0.001(0.3)	0.725(2.4)
Area(km^2)	9.561(100)	0.194(100)	20.198(100)	0.312(100)	30.265(100)

4. Conclusions

Soil erosion is influenced from a variety of factors such as rainfall distribution, soil, land use, etc. Such factors have a variety of types according to time and space. This paper is aimed at assessing the soil erosion hazard area in watershed, and for that, the factor in respect to topography and space information of RUSLE was extracted by GIS technique, and the amount of soil erosion occurring in watershed was calculated. And the hazard zone of erosion occurrence was assessed based on such amount of soil erosion.

The farmland of Gyeongan stream watershed which is, the first tributary of Han River basin, was selected as investigation target watershed.

The result of an analysis of soil erosion amount showed that soil erosion occurred in the order of crop field(1210) planting area, orchard(1220), non-adjusted paddy fields(1120), and adjusted paddy fields(1110), and also the average soil erosion in these planting areas has the most amount in crop field planting area.

As a result of analysis on soil erosion hazard zone of farmland by classifying it into 5 classes using the result of that result of analysis on the amount of soil erosion, in case of Class 5 in which the hazard of soil erosion is the highest, approximately 72.5ha that corresponds to 2.4% of the total farmland was decided as erosion hazard zone. For this erosion hazard zone, it was analyzed that dry field crop planting area was 72.4ha and orchard was 0.1ha, and Class 5 hazard zone did not appear in other farming areas. Also, it showed that Class 2 (1_ 50ton/ha/yr) area had the most ratio of the entire farmland, i.e., 70.2%, regardless of land use state.

According to the result of analysis on soil erosion hazard zone of farmland by classifying it into 5 classes, the Class V has the highest soil erosion hazard, approximately 72.5ha that corresponds to 2.4% of the total farmland was estimated as an erosion hazard zone. This erosion hazard shows 72.4ha in dry field crop planting area, 0.1ha in an orchard, but the highest hazard zone, the Class V was not shown in other farming areas. Also, it showed that Class II (1_ 50ton/ha/yr) area had the most ratio of the entire farmland, i.e., 70.2%, regardless of land use state.

The amount of soil erosion calculated in this paper was not compared with the data measured for the actual amount of soil erosion, so it is difficult to mention the correctness of analysis result. However, it seems to be utilized as preliminary data to install soil runoff suppression facility or that sort of things for the management of water resource in watershed by analyzing the erosion hazard zone in accordance with physical validity of soil erosion.

Meanwhile, in case of Korea, it is yet insufficient to study on the soil erosion inflowing into river, which is generated from watershed, and also additional studies should be followed in respect to the influence of the generated earth and sand on river, etc.

Acknowledgement

This study was performed receiving research expenses supports from Korea Research Council of Public Science & Technology's general research project (Project Name : Study on public utilizing of satellite data - Study on production and utilization of river information using satellite images) and from Sustainable Water Resources Research Center (Project No.: 1-2-2), 21C Frontier R&D Program.

References

[1] Burrough, P.A. 1986. Principles of geographical information systems for land resources assessment. *Monographs on Soil and Resources Survey* No 12. Oxford, UK, Clarendon. 193pp.

[2] Jetten, V., Henkens, E. J., De Jong, S. M. 1988. *The Universal Soil Loss Equation.* Version 1.0, release 1.0, distributed. Department of Physical Geography, Utrecht University, The Netherlands

[3] Bork, H. R. and Hensel, H. 1988. *Computer aided Construction of Soil Erosion and Deposition Maps.* Geologisches Jahrbuch, H.104, S.357-371.

[4] Ferri, V. and Minacapilli, M. 1995. Sediment delivery processes at the watershed scale, *Hydrol. Sci. J.*, 40:703-717.

[5] Saha, S. K. 1996. Integrated use of Remote Sensing and GIS for Soil Erosion Hazard Modeling-A Case Study. http://www.gisdevelopment.net/aars/acrs/1996/ss/ss1005.html

[6] Moore, I.D., Turner, A.K., Wilson, J.P., Jenson, S.K. and Band, L.E. 1993. GIS and land-surface-subsurface process modelling, in Goodchild, M.F., Parks, B.O. and Steyaert, L.T. (eds), *Environmental modelling with GIS*. pp. 213-230.

[7] USDA. 1996. Predicting soil erosion by water : A Guide to conservation planning with the RUSLE, *Agriculture Handbook* No. 703. 384pp

[8] Gupta, H. S. 2001. Terrain Evaluation for Eco-Restoration using Remote Sensing and GIS. http://agile.lsegi.unl.pt/conference/Brno2001/RemoteSensing.pdf. pp424-434.

[9] Joo-Hun. Kim, Kyung-Tak. Kim and Gyu-Bang. Yeon. 2003. Analysis of Soil Erosion Hazard zone using GIS. *Journal of Korea Association of Geographic Information Studies*. Vol. 6, No. 2. pp.22-32

Author Information

Dr. Kyung-Tak Kim
Senior Researcher

Korea Institute of Construction Technology
Water Resources Research Department
P.O. Box : 411-712
2311 Daehwa-dong, Ilsan-gu, Koyang-si, Kyeonggi-do
Republic of Korea
Phone : +82-31-910-0267
Fax : +82-31-910-0251
E-mail : ktkim1@kict.re.kr

Dr. Joo-Hun, Kim
Senior Researcher
Korea Institute of Construction Technology
Water Resources Research Department
P.O. Box : 411-712
2311 Daehwa-dong, Ilsan-gu, Koyang-si, Kyeonggi-do
Republic of Korea
Phone : +82-31-910-0619
Fax : +82-31-910-0251
E-mail : jh-kim@kict.re.kr

Jung-Sool Park
Researcher
Korea Institute of Construction Technology
Water Resources Research Department.
P.O. Box : 411-712
2311 Daehwa-dong, Ilsan-gu, Koyang-si, Kyeonggi-do
Republic of Korea
Phone : +82-31-910-0548
Fax : +82-31-910-0251
E-mail : parkjs@kict.re.kr

Yun-Seok Choi
Researcher
Korea Institute of Construction Technology
Water Resources Research Department.
P.O. Box : 411-712
2311 Daehwa-dong, Ilsan-gu, Koyang-si, Kyeonggi-do
Republic of Korea
Phone : +82-31-910-0548
Fax : +82-31-910-0251
E-mail : yschoi51@kict.re.kr