

Study on the Topographic Effect on Soil Erosion Using RUSLE Model for Small Size Watershed

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Abstract: Soil erosion and subsequent sedimentation have caused serious environmental and soil degradation problems in Okinawa Prefecture, Japan. This research aims at evaluating an availability of the Revised Universal Soil loss Equation (RUSLE) for predicting the range of soil loss values for the Nago watershed in Okinawa. It shows that climatic conditions substantially influence the rainfall amount as a function of the I_{30} of the rainfall event. The rate of soil loss is higher with increasing in altitude due to greater slope steepness. By rainfall data analysis, it is concluded that the large difference in soil loss between 2000 and 2001 was due to concentrated heavy rainfall in the rainy season or the typhoon season.

Key words: RUSLE; erosion index; rainfall; soil loss; small size watershed

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1 Introduction

Soil erosion has been recognized to be a serious environmental and soil degradation problem; it can reduce soil productivity, and it can also increase sediment load in receiving water. The purpose of this research is to evaluate an availability of the Revised Universal Soil loss Equation (RUSLE) for predicting the range of soil loss values for Nago watershed in Okinawa Prefecture, Japan. Estimates of the erosion index (EI_{30}) and the erosivity factor (R) in the RUSLE were obtained from daily, monthly and annual rainfall amounts from 1997 to 2002. The soil erodibility and topographic factors in the RUSLE were evaluated using soil sampling and digital elevation data respectively. This paper describes the methods used to derive the topographic (LS), slope length (L) and slope steepness (S) factors in the RUSLE using statistical models based on measurements from high resolution of digital elevation data. Predictive variables in the statistical models included for developing the aspect and drainage maps of the study area. The measured data for sediment concentration at an observatory in the Nago was used for verification of this model. The measured and predicted average annual soil loss for the watershed is 27.7 kg/($hm^2 \cdot a$) and 28.9 kg/($hm^2 \cdot a$) from this RUSLE model. The recorded rainstorms confirm that rainfall of short duration with high intensity (I_{30}) and one of long duration with lower I_{30} cause the bulk of the soil erosion. Nakao^[1] (2000) states that two soil types are highly erosive in Japan; one is Masa-do, weathered granite; and another is Shirasu, volcanic ash soil containing large amounts of pumice andesite and sedimentary rocks. Both soil types are widespread, and

plants located on such areas have serious problems of erosion during rainy seasons.

2 Methodology

The study area, located in Nago, on the northern part of the Okinawa main-island. The summary statistics data of the study area are shown in Table 1.

Table 1 Summary statistics data of the study area

Latitude	26°56'41" N
Longitude	128°57'41" E
Elevation above M. S. L/m	203
Seasonality index	0.34
Specific gravity	2.44 g/cm ³
Maximum % of rainfall	July (23%)

For the sustainable management of a watershed, the soil loss due to erosion needs to be kept within acceptable limits by adopting appropriate land management measures. The RUSLE is the most widely used method for estimating soil loss. The equation can be written as $A = R \cdot K \cdot L \cdot S \cdot C \cdot P$.

Where, A — average annual soil loss [$kg/(hm^2 \cdot a)$] caused by sheet and rill erosion; R — rainfall erosivity factor ($MJ \cdot mm \cdot hm^2 \cdot h \cdot a$) which accounts from the energy and intensity of storm. The R -value is the sum of erosion index EI_{30} values during a one-day storm. The EI_{30} is the product of kinetic energy (KE) and the maximum 30 min rainfall intensity I_{30} ; K — soil erodibility factor ($t \cdot hm^2 \cdot h \cdot hm^2 \cdot MJ \cdot mm$) which is the measure of the susceptibility of soil to be eroded under a standard condition by using soil sampling data; L — slope-length factor (m/m); S — slope

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steepness factor; the program written by examined the elevation of the adjacent 8 grids at a fixed distances away from each central grid point. A drainage shape was assigned to the central point based on 8 points that were higher, lower or at the same elevation as the central point. *C*—cover and management factor; *P*—erosion control practice factor. The *C* and *P* factors criteria for different land use are shown in Table 2^[2,3].

Table 2 C and P factors criteria for different land use

Land use class	C-factor	P-factor
Primary forest (canopy > 40 %)	0.002	1.00
Secondary forest (canopy < 40 %)	0.006	1.00
Shrub	0.014	1.00

Higa et al^[4]. (2002) estimated the soil loss using USLE in Okinawa. He described that the *C*-factor is related to the age of the trees for the area in which predominate pine trees. He used *C*-factor value 0.05 for trees in the range three to four years age.

3 Results and Discussion

3.1 Erosion Index (EI₃₀)

The rainfall intensity is directly related to the amount of runoff produced by a specified storm. The *EI*₃₀ is a measure in which *KE* and rainfall intensity are combined for a storm to define the combined effects of rainfall and turbulence of runoff to transport soil particles from the watershed. By calculating erosivity values for individual storms over the study period, mean monthly and annual data can be obtained. The correlation between *EI*₃₀ calculated with the procedures and rainfall intensity is reasonable. It is also important to note that the rainfall variations have occurred during this study period. It is concluded from the rainfall data analysis that both the rainfall of long duration with low intensity and the rainfall of short duration with high intensity cause soil erosion.

3.2 Topographic Factor

Slope is one of the most fundamental measures of landscape characteristics. Slope refers to the steepness of the land as measures in percent or degrees (Fig. 1). Through using a computer, slope can be calculated for each grid point from digital elevation data for a large area in the time it takes to measure slope for a small watershed. This procedure yielded average slope gradients (%) and length of each facet in the watershed, which were then girded and the *LS* factors computed. By examined the elevation of 8 grids at a fixed distances away from the central grid. The drainage way was assigned to the central grid based on the neighboring 8 grids. The drainage map of the Nago watershed is shown in Fig. 2.

3.3 Soil Erosion

The rainfall factor has an important effect on the overall rate of soil loss. The actual rainfall amount used for estimating *R*-factor in this study and other storms were omitted as insignificant amount because these storms cannot create runoff. Fig. 3 shows that the average measured and predicted soil loss for the study area were found to be 27.7 kg/(hm² · a) and 28.9 kg/(hm² · a) respectively. The rainfall amount

in 1999 was 1 729 mm, however the soil loss was more than that in 1997 due to concentrated heavy storms. In 2000, the predicted soil loss was more than the measured value due to the high *EI*₃₀ and *I*₃₀ in this year. Soil loss in 2001 was opposite of the one in 2000. In this case, the trend of the predicted value is less than the measured one due to low *EI*₃₀ and *I*₃₀ in this year. Rainfall amount and maximum intensity had a major effect on soil loss. The output is dependent on the sweeping power due to water movement over the slope and hence linked to the rainfall amount and rainfall intensity. The soil loss under different slopes was computed as a reference standard, when compared with other practices and soil types. By using RUSLE, the factors *R* and *LS* have great variation in soil loss according to the slope of watershed. The maximum rainfall intensity determines the amount of soil splash, rainfall amount controls the removal of loose soil

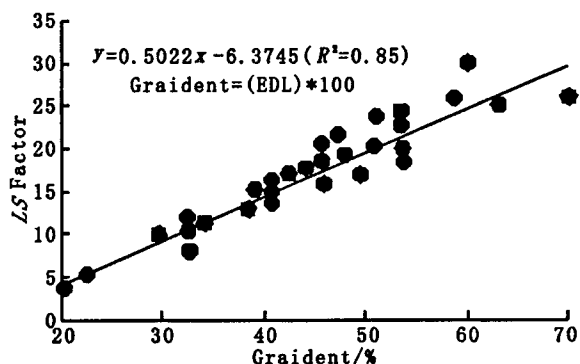


Fig 1 Relationship between gradient(%) and LS factor

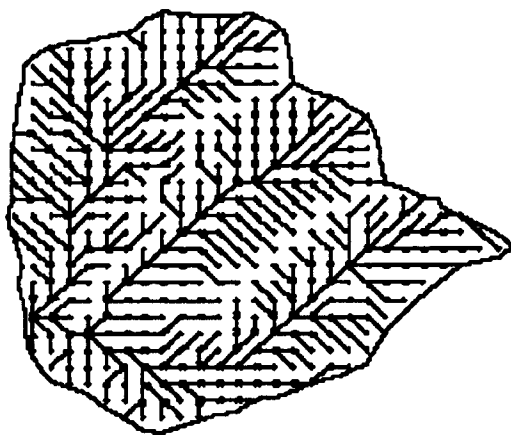


Fig 2 Drainage Map of Nago watershed

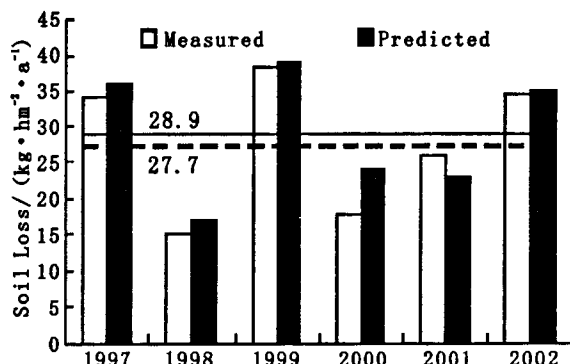


Fig 3 Measured and predicted soil loss

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particles by generated splash. From the large difference in soil loss between 2000 and 2001 was due to concentrated heavy rainfall in the rainy season (June to July) or the typhoon season (Sept. to Oct.).

4 Conclusion

The study is carried out in the Nago to test the applicability of specific kinetic energy calculation for R factor used

in the RUSLE. It shows that climatic conditions substantially influence the rainfall amount as a function of the I_{30} of the rainfall event. The rate of soil loss is higher with increasing in altitude due to greater slope steepness. By rainfall data analysis, we concluded the difference in 2000 that some short duration rainstorms with high rainfall intensity have low amount of measured soil loss and opposite of the same action in 2001.

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