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 predieted average annual soil loss for the watershed is 27.7 kg/(hm^2 • a) and 28.9 kg/(hm^2 • 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/cm³
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 • a)] caused by sheet and rill erosion; R – rainfall erosivity factor (MJ • mm • hm^2 • h • 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 • hm^2 • h • hm^2 • MJ • 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/(hm^2 • a) and 28.9 kg/(hm^2 • 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

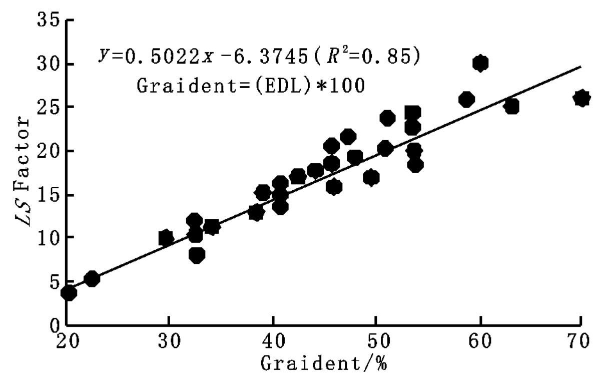

Fig 1　Relationship between gradient(%) and LS factor

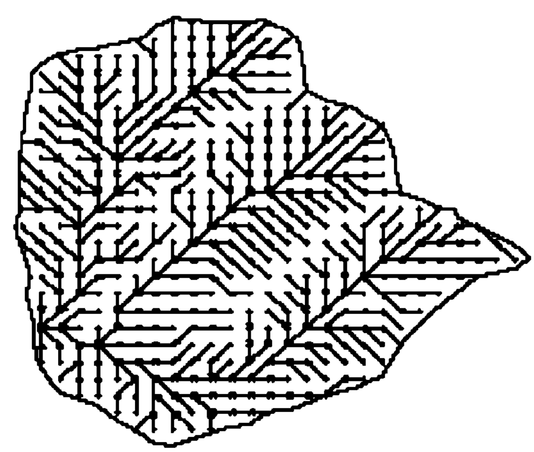

Fig 2　Drainage Map of Nago watershed

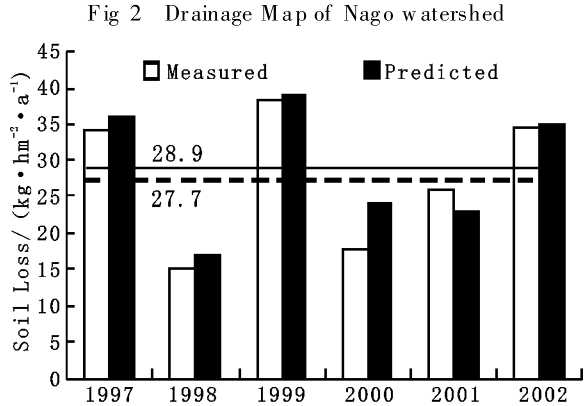

Fig 3　Measured and predicted soil loss

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(3) 适当细化经济补偿标准, 实行分区调控的政策。由于不同区域在还林还草成本及退耕地收益方面存在较大差别, 因此应该实行分区调控政策, 对不同区域实施不同的经济补偿标准。实际上, 我国在启动退耕还林还草工程的时候, 已经将长江流域及南方地区、黄河流域及北方地区进一步细化为 11 个类型区, 即: 西南高山峡谷区、云贵高原区、川渝鄂湘山地丘陵区、长江中下游低山丘陵区、长江黄河源头高寒草原草甸区、黄土丘陵沟壑区、蒙晋冀半干旱区、新疆干旱荒漠区、东北山地及沙地区、华南亚热带山地丘陵区、华东低山丘陵区。我们可以在此基础上, 充分考虑各区域在自然和社会经济条件方面的差异, 适当细化退耕还林还草的经济补偿标准。比如, 对于区域内坡耕地面积占区域土地面积的 50% 以上, 区域经济发展水平很低, 还林还草成本较高的干旱地区, 可以对退耕还林还草给予较高的补助; 对于人均耕地面积相对较大、坡耕地面积相对较小, 地方经济实力相对较强的, 可以由中央制定一定标准, 中央政府提供粮食方面的补助, 地方政府提供资金方面的补助; 对于地方经济实力很强的区域, 可以鼓励地方自主性的退耕还林还草。另外, 相关灌溉工程等需要的资金以及“老少边穷”地区相关部门的工作经费也应在预算中予以考虑。与此同时, 应根据各区域社会经济发展的水平, 适当逐年提高补助标准, 以保持人民生活水平的稳定提高。

(4) 提高补偿标准, 延长补偿期限, 建立长期有效的经济补偿机制。退耕还林还草成果能否得到长期的保护和巩固, 是生态建设成败的关键问题。根据前文的分析, 要使退耕还林还草成果得到巩固, 就必须对农民的经济利益进行相应的经济补偿。首先, 要延长补偿年限。对于造林种草的未来收益, 《国务院关于进一步做好退耕还林还草试点工作的若干意见》中规定:“谁退耕、谁还林(草)、谁经营、谁受益”。有关政策又进一步明确“生态林一般应在 80% 左右”, 而且不许自行砍伐, 所以“谁经营、谁收益”只能惠及比重较小的经济林。补偿期限结束后, 绝大多数退耕农民并不能在退耕地上形成新的收入来源, 农民生存矛盾将会凸现, 所以补偿期限必须延长, 并且要补偿到位、补偿及时, 使农民对未来收益有一个稳定的预期。其次, 要有针对性地提高补偿标准。如前文所述, 目前的补助水平对一些自然条件较好的地区不公平。退耕还林还草必须以不损害农民利益为基本前提, 因此应立足于区域差异实际, 有针对性地提高补偿标准, 尽可能使经济补偿与退耕地的实际产出相吻合。第三, 应当以法律的形式明确生态建设投资的主体, 使补偿期限的延长具有可行性。退耕还林还草是中华民族生存与发展的根本大计, 是一个永久性的事业。从这个高度看, 我们必须从长计议, 建立一种以政府投资为主体的长期有效的补偿机制, 这样才能有利于退耕还林还草成果的长期巩固。

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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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