

# The Analysis of the Soil Erosion Potential by Using Seim in Taiwan

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**Abstract:** As a result of the extrusion of Eurasia plate and Philippine plate, Taiwan is provided with particular geology and topography environment. With the steep geology, fragile topography, frequent earthquakes and strong rainfall intensity, the disasters due to debris flow, hillslope landslide and rock fall are occurred frequently and endanger the human's safety and property. The landslide is possible to induce more serious soil erosion later. The research bases on the Soil Erosion Index Model (SEIM) and the factors which include rainfall, soil character, slope, cover above soil surface and land use induce landslide disasters, to assesses and predicts the potential areas of landslide is the research's objective.

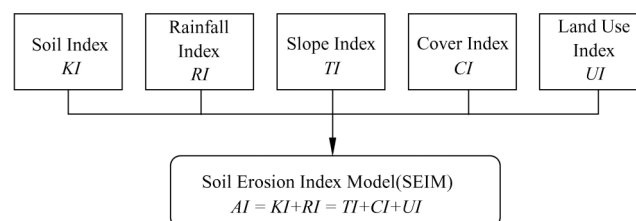
**Keyword:** soil erosion index model (SEIM), soil erosion potential

## 1 Introduction

With steep terrain and excessive rainfall, Taiwan is affected by severe soil erosion caused by summer typhoons and storms bring intensive rainfall and rapid flows. In regard to soil erosion, the geology in Taiwan is the tertiary period sedimentary rock and it's a younger and easily eroded geology. At the flat ground areas isn't sufficient for over developments circumstances, the mountainside becomes the mainly artificial development places. The torrential rain occurs in the summer and the typhoons invades Taiwan cause great damage. The research aims at the analysis of the soil erosion potential in Taiwan by using the soil erosion index model.

## 2 Introduction Of The Soil Erosion Index Model (Seim)

Erosion of land surface is a function of soil characteristics, rainfall, vegetation, slope, wind, and land use. The research followed the principles of the PSIAC model and summed the complex factors as a reference for building the soil erosion index model (SEIM). Then, those factors of SEIM were through with the field data of soil erosion in Taiwan. In this model, factors affecting soil erosion include soil properties, rainfall, terrain condition, land use and vegetation. A schematic diagram of the index model is shown in Fig. 1.



**Fig. 1** Schematic diagram of soil erosion index model

We use following methods for calculating each index value. Generally, soil erosion increases as each index value increases.

## 2.1 Soil Property Index (*KI*)

There are two ways to calculate the soil property index, *KI*. One is to substitute the local soil properties into the USLE for obtaining the  $K_m$  value which is then substituted into equation (1) to yield the *KI* value. The other method is to use the results of soil investigations conducted in Taiwan by Hsieh and Wang (1991).

$$KI = 200 \times K_m \quad (1)$$

## 2.2 Rainfall Index (*RI*)

The rainfall index value can be derived from the monthly rainfall standard deviation value  $R_s$  (unit: millimeter) and the annual precipitation  $R$  (unit: m) as shown in equation (2).

$$RI = R_s \times R / 50.0 \quad (2)$$

## 2.3 Slope Index (*TI*)

The slope index value is calculated using the average slope and equation (3) which is the related equation of the slope steepness factor.

$$TI = 10 \times S \quad (3)$$

## 2.4 Cover Index (*CI*)

The initial value of the cover factor uses the cover ratio  $C_R$  value as reference factor. Given the surface cover ratio  $C_R$ , substituting  $C_R$  into equation (4) yields the cover index *CI* value. In the present work, the  $C_R$  values with different surface and vegetation in Taiwan have been employed, the cover index value *CI* so that it can be directly adopted for estimations, as shown in Table 1:

$$CI = 20 - (20 \times C_R) \quad (4)$$

**Table 1 Cover index values with different cover types**

Type	Cover Type	<i>CI</i>	Type	Cover Type	<i>CI</i>	Type	Cover Type	<i>CI</i>
Forest	Conifer	1	Orchard	Banana	6	Agriculture	Maize	v
	Hardwood	1		Tea	6		Vegetable	13
	Bamboo	1		Orange	8		Concrete floor	1
Grass	Bahia grass	1	Agriculture	Orchard	8	Non-agriculture	Pitch floor	1
	Golf courses	1		Paddy	5		Building	1
	Weeping love grass	1		Meadow	6		Cemetery	1
	Weed	2		Pineapple	8		Denuded area	20
Orchard	Betel palm	5		Peanut	11		Water area	1

## 2.5 Land-Use Index (*UI*)

The *UI* value is calculated using the soil erosion quantity relationship of different land use as listed in Table 2 and the relationship between percentage of development and soil erosion quantity reported by Chen *et al.* (1998). The *UI* values of land-use index can be derived from equation (5) are shown in Table 3.

$$UI = U_0 / 8.5 \quad (5)$$

**Table 2 Soil erosion in different land use type**

Land-use Type	Forest	Grass	Agriculture	Denuded area	Waste land
Soil Erosion (ton/ha)	1.8	2.1	14.8	87.1	306.9
Weighting $U_0$	1.0	1.2	8.3	48.4	170.5

**Table 3 Land-use index values**

Land-use type	$UI$	Land-use type	$UI$
Forest	1	Low degree slopeland development	3
Grass	1	Medium degree slopeland development	7~9
Agriculture	2	High degree slopeland development	19~20
Denuded area	6~7	Landslide	20

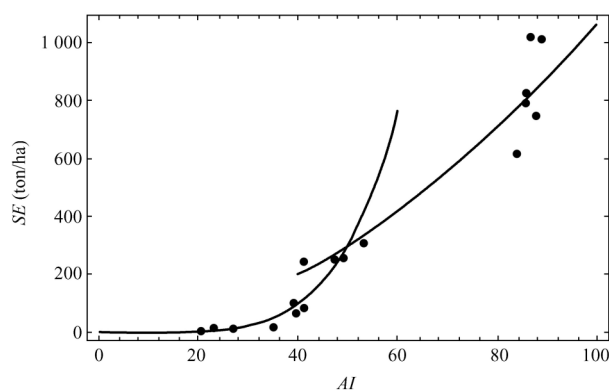
## 2.6 Soil Erosion Index (AI)

The index values of each factor can be obtained by equations (1)—(5) which can be summarized as equation (6). Applying regression analysis to the observed soil erosion field data and the total index values obtained from equation (6), we can establish the soil erosion index model (SEIM). For best simulation, the regression model is separated into two parts from  $AI=50$ . Equations (7)—(8) and Fig. 2 show the relationship between soil erosion quantity and total index values.

$$AI=RI+KI+TI+CI+UI \quad (6)$$

$$SE = 6 \times 10^{-7} AI^{5.12}, \quad R^2 = 0.88 \quad (7)$$

$$SE = 0.233 AI^{1.83}, \quad R^2 = 0.94 \quad (8)$$

**Fig.2** Relationship between soil erosion quantity and total index value and the fitting equation

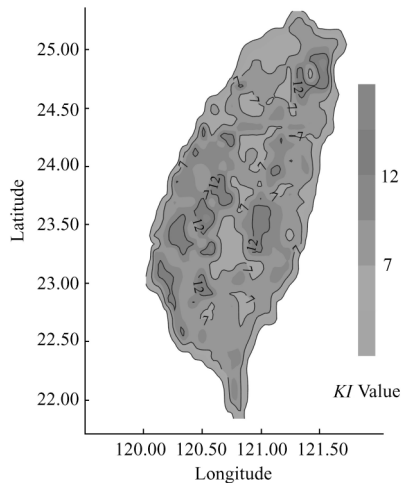
The equation (7) is for.  $AI \leq 50$ , and the equation (8) is for.  $AI > 50$ . where  $SE$  is the soil erosion quantity (ton/(ha • yr)) of the index model, and  $AI$  is the total index value. Dividing the information into two parts not only enhances the relativity of regression analysis but also avoids underestimating the values of medium soil erosion.

## 3 The Analysis Of The Soil Erosion Potential In Taiwan

### 3.1 Soil index(KI)

In regard to the geology viewpoint, most of the geology in Taiwan is easily eroded. Most of the geology in Taiwan are composed by the sedimentary rocks and the metamorphic rocks. The research

analyze the soil index value distribution in Taiwan by using SEIM in accordance with the soil distribution plot (Hsieh and Wang, 1991). The soil index value distribution plot is Fig. 3. There're four obvious regions in which the soil is easier eroded in Taiwan. Most of the easily eroded soil region are composed by sandstones, shale colluvial soil and shale alluvial soils. The detail data of soil index values in Taiwan is listed in Table 4. We can discover the *KI* values of the soil is greater than 7 occupied 75% of the all areas in Taiwan.



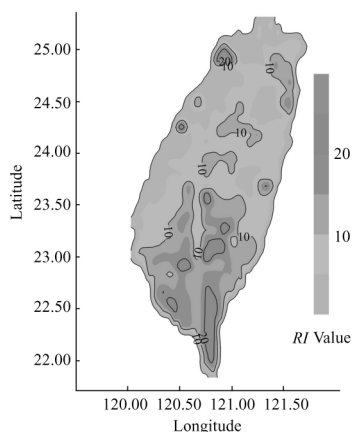
**Fig. 3** The soil index value distribution in Taiwan

**Table 4** The areas and the percentages occupied the all areas in Taiwan of three grade eroded soils

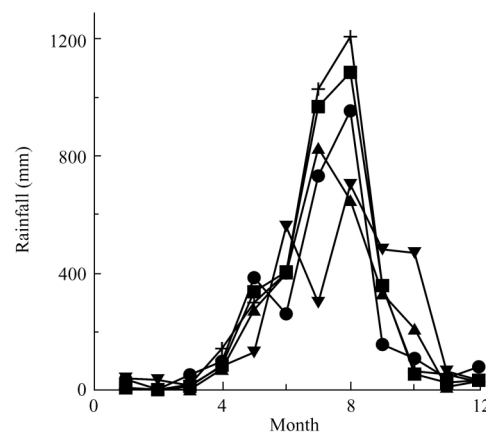
<i>KI</i> values	Eroded grade	Occupied areas (km <sup>2</sup> )	Occupied areas percentage in Taiwan (%)
$KI \leq 10$	Higher eroded	9,388.65	26.14%
$7 \leq KI < 10$	Medium eroded	17,568.96	48.93%
$KI < 7$	Lower eroded	8,955.55	24.94%

### 3.2 Rain index(*RI*)

Soil erosion by rainfall is a serious problem in Taiwan. The annual rainfall in Taiwan is about 2,500mm. There're two rainfall peaks in a year, that is, the plum rain during April to May and the typhoons often occurs during June to September. The aggregate rainfall quantity from April to September can occupied 75% of the annual rainfall quantity. The rainfall in Taiwan distributes nonuniform in space and time. The research adopt the rainfall data in 1999 and analyzes the rain index value in Taiwan. The rain index values distribution plot is the Fig. 4. The Fig. 4 only represents the rainfall characteristic and distribution in 1999.



**Fig. 4** The rain index values distribution in Taiwan



**Fig. 5** The rainfall data in the five region have higher rain index values

We can obviously gain the conclusion that there're five regions with high rain index values in the analysis of the 1999 rainfall data. We collect the rain data of the stations are located near the five regions and the data is plotted in Fig 5. We can obtain a conclusion that the rainfall quantity centralizes in the summer is the reason causes the serious soil erosion problems in Taiwan.

### 3.3 Slope Index(*TI*)

Taiwan is a steeper island. The average slope in Taiwan is  $14.67^\circ$ . The areas whose slope is lower than  $5^\circ$  occupies 25% of all areas in Taiwan. And the areas whose slope is lower than  $5^\circ$  isn't enough to economical development, the over development in the mountain is a serious problem in Taiwan. According to the data analysis, the areas whose slope is lower than  $10^\circ$  were fully developed. The areas covers by the forest occupies lower than 2% of all areas in Taiwan. The areas whose slope is from 11% to 40% occupies by the forest remainder 30.6% of all areas in Taiwan (Xiao *et al.*, 1993). The Fig. 6 is the slope index values in Taiwan.

### 3.4 Cover Index(*CI*)

In regard to the soil in the mountain, the plant cover can reduce effectively the kinetic energy formed by the rainfall and reduce the soil erosion quantity. Because a great quantity of the forest were cut down during 1960~1970 and the over development by the economical growth in 80', the annual reduced forest areas from 1920 to now is about 10 thousand ha in Taiwan. The another reason reduces the forest areas is that the high-economical value crops are cultivated on the areas whose slope is greater than  $28^\circ$ , such as vegetable, fruit trees and betel nut trees. Over development areas are about 50 thousand ha. and cause serious soil erosion problems. The research adopts the Agriculture report data ( The Council of Agriculture,1999) and the Forest statistic in Taiwan ( The Council of Agriculture, 2000). Fig. 7 is the cover index values distribution plot in Taiwan. We can obtain a conclusion that over development areas spread on the boundary between the center mountain and the southwest plain. The mainly reason there is increasing betel nuts and high-economical vegetables areas year by year.

### 3.5 Land Use Index(*UI*)

The population in the city keeps on increasing in the last few years, and the range of the development in the mountain around the city keeps on expanding. The over development without soil and water conservation in the sensitive mountainside will cause a great soil erosion quantity and a serious damage. The research adopts the Forest statistic in Taiwan ( The Council of Agriculture, 2000). The Fig. 8 is the land use index values distribution plot in Taiwan. The regions whose land use index values is greater than 15 is the three big city regions, Taipei, Kaohsiung and Taichung. These region which is the serious over development region need more local soil and water conservation.

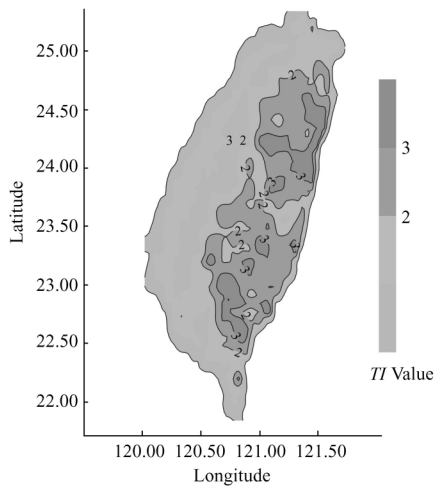
### 3.6 Discussion

The research analyzes the soil erosion potential according to the 5 indexes in SEIM in Taiwan. We can understand the difficult grades of the soil eroded under the original natural conditions and the influence took by the over artificial development. The research classifies the 5 indexes in SEIM to two types, and one is the natural factor which includes the soil index, rainfall index and the slope index; and the other one is artificial factor which includes the cover index and the land use index. Fig. 9 is the natural index values (the accumulation of the soil index value, the rainfall value and the slope index value) distribution plot in Taiwan. Fig. 10 is the artificial index values (the accumulation of the cover index value and the land use index value) distribution plot in Taiwan. Fig. 11 is the soil erosion index value distribution plot in Taiwan.

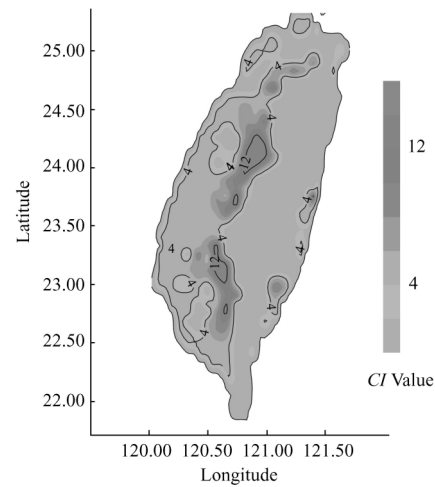
The south region in Taiwan is the worse natural condition in regard to soil erosion. The main reasons

are the rainfall and the soil property. The geology there is the higher eroded sandstone and shale alluvial soils, and the rainfall there is great and centralized in the summer. Except the south region in Taiwan, the natural index values in the other regions in Taiwan are smaller than 20. we can obtain another conclusion on the Fig. 10 that the artificial index values in the three big city (Taipei, Kaohsiung and Taichung) is all more than 20. Soil and water conservation will need to protect the local soil resource on the over development regions. Except the three big city regions, the artificial index in the other region in Taiwan are smaller than 15.

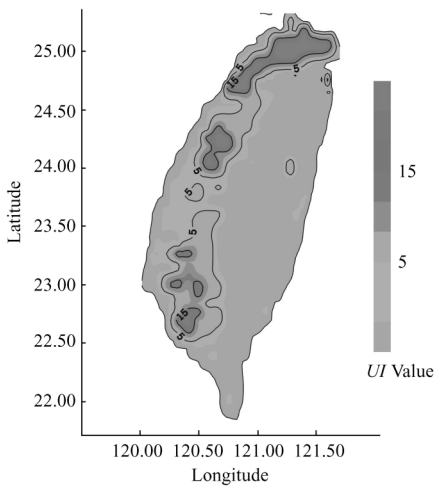
Fig. 11 is the soil erosion index values distribution plot in Taiwan. We classifies three serious grades of the soil erosion potential by the *AI* values are 45 and 25. Table 5 is the classification data. The most serious soil erosion areas are more than triple the areas of the Taipei city (we use two hundred and seventy-two km<sup>2</sup> as the Taipei city areas). The most serious soil erosion potential region is the liugui village in Kaohsiung county and the soil erosion index value there reaches 62. The annual soil erosion quantity is equal to be 444.05 ton/(ha • yr) there.



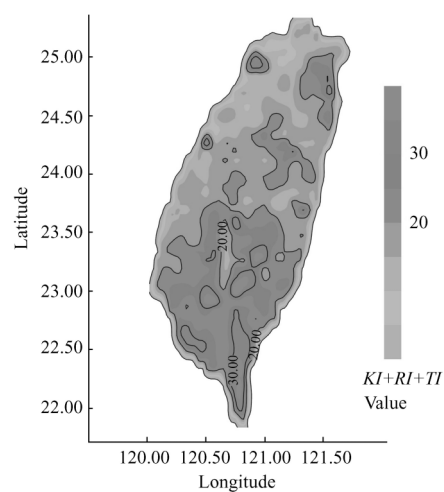
**Fig. 6** The slope index values distribution in Taiwan



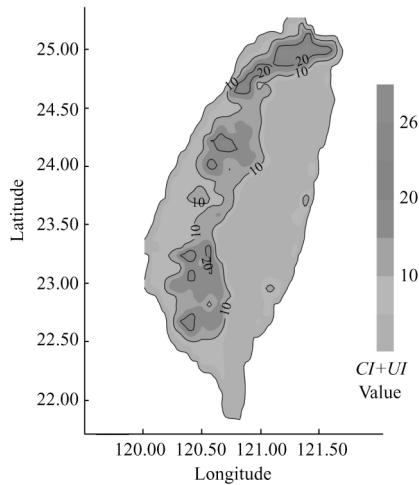
**Fig. 7** The cover index values distribution in Taiwan



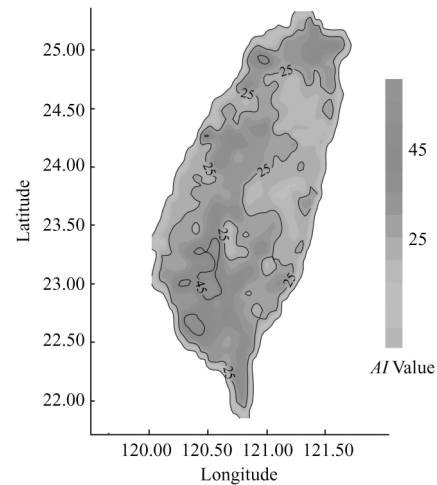
**Fig. 8** The land use index values distribution in Taiwan



**Fig. 9** The natural index values distribution plot in Taiwan



**Fig. 10** The artificial index values distribution plot in Taiwan



**Fig. 11** The soil erosion index values distribution plot in Taiwan

**Table 5** The classified grades and the occupied areas of the soil erosion potential data

The classified grades of the soil erosion potential data	The classified boundary	Occupied areas (km <sup>2</sup> )	Occupied percentage of the all areas in Taiwan (%)
Serious soil erosion region	$45 \leq AI$	826.32	2.3
Medium soil erosion region	$25 \leq AI < 45$	19,725.20	54.8
Light soil erosion region	$25 < AI$	15,437.52	42.9

#### 4 Conclusion

The study uses SEIM to analyze the soil erosion potential in Taiwan. In regard to soil erosion, the natural condition in Taiwan is worse. The soil whose index values is greater than 7 occupies about 75% of all areas in Taiwan. The rainfall in Taiwan distributes very nonuniform in space and time, and the monthly rainfall is often greater than 300mm during May to September. The average slope in Taiwan is  $14.67^\circ$  and the areas whose slope is greater than  $5^\circ$  occupies about 75% of all areas in Taiwan. In regard to the artificial development condition in Taiwan, the forest areas is decreasing year by year. The land use index value which is greater than 15 centralizes in Taipei, Kaohsiung and Taichung. The sensitive mountainsides around the three big cities is over development and need more soil and water conservation. The analyze make a comprehensive survey of the soil erosion potential in Taiwan.

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