COMPARISON OF SOIL EROSION BETWEEN SUB-WATERSHEDS OF SHIHMEN RESERVOIR IN TAIWAN

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ABSTRACT: Shihmen reservoir in northern Taiwan is threatened by siltation resulting from soil erosion in its catchment. To quantify the relative sediment contribution from its five sub-watersheds, we used the Universal Soil Loss Equation (USLE) to estimate soil erosion in this study. Because bare land and developed land tend to produce a large amount of sediments, we mapped these lands from a past land-cover and land-use survey to calculate their hectares in each sub-watershed. Then, we calculated the values of C factors with a modified classification table and the corresponding amounts of soil erosion in each sub-watershed. Finally, we explored the relationship between soil erosion and bare land or developed land.

1. INTRODUCTION

Usually a large watershed can be divided into several smaller sub-watersheds. The amount of soil erosion in each sub-watershed varies greatly due to a number of factors. Among the factors, it is well-known that the increase in bare land and developed land will lead to the increase of soil erosion. We will explore the relationship between these land use types and the cover and management factor (C factor) in this study, and compare the results of soil erosion in the five sub-watersheds that compose of the Shihmen (or spelled as Shimen) reservoir watershed.

2. LITERATURE REVIEW

The type of land use greatly affects the amount of soil erosion. For example, Z. Chen et al. (2019) found that arable land was the main cause of soil erosion and its intensity of soil erosion was about ten times that of orchards. Similarly, G. Chen et al. (2019) discovered that lands with a vegetative cover were ten times less likely to be eroded than rain-fed croplands in the Yunnan Province of China.

3. MATERIAL AND METHOD

Shihmen Reservoir is one of the major reservoirs in northern Taiwan, so it was chosen as the research area (Figure 1). The catchment area of the reservoir is approximately 759.3 square kilometers, and the reservoir serves the functions of irrigation, industrial and domestic water supply, flood control, etc. This study divides the Shihmen Reservoir watershed into five sub-watersheds. They are the Ku-Chu, Yu-Feng, Pai-Shih, San-Kuang, and Tai-Kang sub-watersheds.

In order to calculate the amounts of soil erosion in the five sub-watersheds of the Shihmen reservoir watershed, the Universal Soil Loss Equation (USLE) was used (Wischmeier and Smith, 1978). We used ArcGIS as a tool to program USLE and calculated the R_m, K_m, L, S, C, and P factors of the model. Among them, the data of R_m and K_m came from Lu et al. (2005) and Wann and Hwang (1989), respectively. The L and S factors were computed from the Global Digital Elevation Model (GDEM) of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) released in 2011 with a ground resolution of 30 meters. The C factor was modified from the classification table originally proposed by Jhan (2014). Finally, the P factor was assumed to be one throughout the watershed.

Bare lands expose soil and cause soil erosion. Anthropogenic activities also impact negatively on land cover and soil erosion. In order to quantify these effects, we used the 2004 land use data from the Industrial Technology Research Institute to calculate the total areas of bare land and developed land in each of the five sub-watersheds of the Shihmen reservoir watershed. The results are shown in Table 1 and Table 2. In the land use classification, the bare land includes vacant land and collapsed area (as well as rock outcrop, which was not considered in this study). The area varies from 98.5 ha in the San-Kuang sub-watershed to 280.9 ha in the Tai-Kang sub-watershed (Table 1). On the other hand, the developed land includes agricultural land, forest land, land for water resource and irrigation, residential and building land, public area, recreational land, and miscellaneous (land). The Ku-Chu sub-watershed has the largest area of developed land (1250.2 ha), whereas the Pai-Shih sub-watershed has the smallest area of such land (164.4 ha) as shown in Table 2.

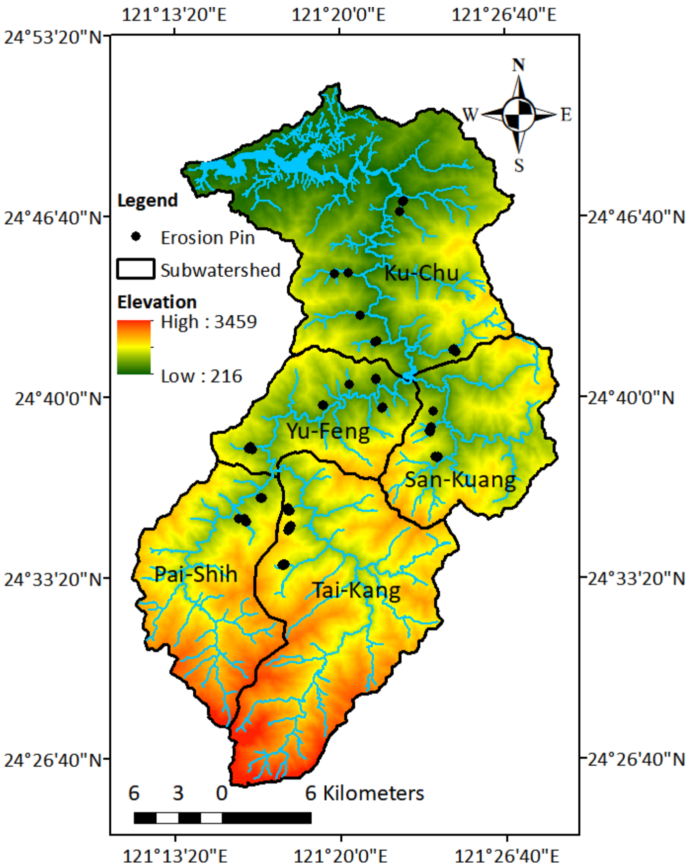


Figure 1 The Shihmen reservoir watershed and the locations of erosion pins

Table 1 The area statistics of bare lands in the Shihmen reservoir watershed

Sub-watershed	Area (ha)	TYPE	Area (ha)	Total area (ha)
Ku-Chu	25591.3	Vacant land	6.4	122.1
		Collapsed area	115.7	
Yu-Feng	8074.4	Vacant land	14.4	135.6
		Collapsed area	121.2	
Pai-Shih	11902.0	Vacant land	10.3	101.2
		Collapsed area	90.9	
San-Kuang	10711.9	Vacant land	0.4	98.5
		Collapsed area	98.1	
Tai-Kang	19653.7	Vacant land	29.0	280.9
		Collapsed area	251.9	

Table 2 The area statistics of developed lands in the Shihmen reservoir watershed

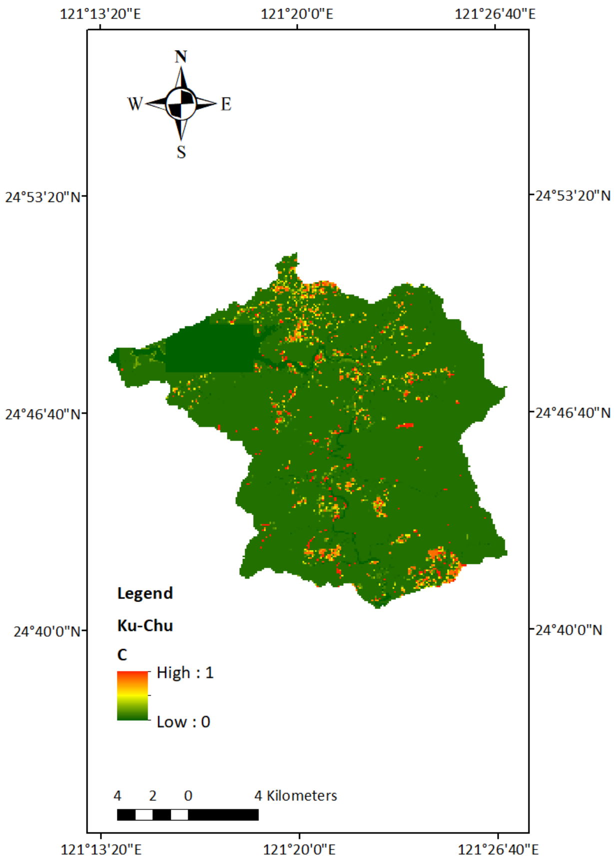
Sub-watershed	Area (ha)	Type	Area (ha)	Total Area (ha)
Ku-Chu	25591.3	Agricultural land	1006.3	1250.2
		Forest land	1.6	
		Land for water resource and irrigation	8.3	

		Residential and building land	152.6	
		Public area	19	
		Recreational land	62.4	
Yu-Feng	8074.4	Agricultural land	328.7	346.4
		Residential and building land	16.7	
		Public area	0.7	
		Recreational land	0.1	
		Miscellaneous	0.2	
San-Kuang	10711.9	Agricultural land	324.6	345.6
		Forest land	5.4	
		Residential and building land	13.6	
		Public area	1.4	
		Recreational land	0.1	
		Miscellaneous	0.6	
Pai-Shih	11902.0	Agricultural land	159.2	164.4
		Forest land	0.3	
		Residential and building land	3.6	
		Public area	1.2	
		Recreational land	0.1	
Tai-Kang	19653.7	Agricultural land	225.7	235.4
		Residential and building land	7.2	
		Public area	1.2	
		Recreational land	1.3	

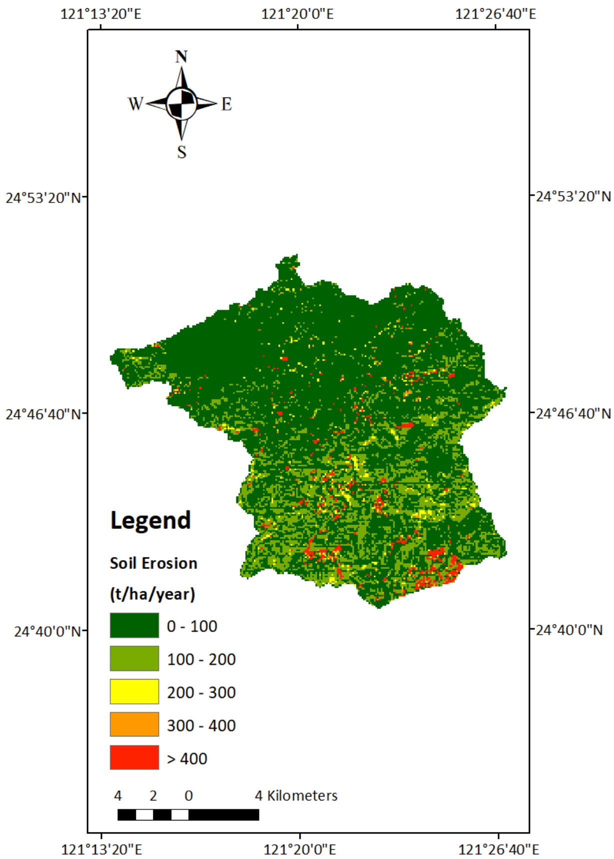
4. RESULTS

The maps of C factor distribution and their corresponding maps of soil erosion of the five sub-watersheds are shown in Figure 2. The calculation results of the five sub-watersheds are as follows: a) The Ku-Chu sub-watershed has an average C factor of 0.0206 and an average amount of soil erosion of 131.8 t/ha/year. b) The Yu-Feng sub-watershed has an average C factor of 0.0318 and an average amount of soil erosion of 281.8 t/ha/year. c) The San-Kuang sub-watershed has an average C factor of 0.0238 and an average amount of soil erosion of 207.4 t/ha/year. d) The Pai-Shih sub-watershed has an average C factor of 0.0205 and an average amount of soil erosion of 236.7 t/ha/year. e) The Tai-Kang sub-watershed has an average C factor of 0.0269 and an average amount of soil erosion of 276.3 t/ha/year. Lastly, the entire Shihmen reservoir watershed has an overall average C factor of 0.0239 and an overall average amount of soil erosion of 212.0 t/ha/year based on our analysis. It is worth noting that this is only a scenario simulation. Since the C factor classification table was changed to test different situations, the calculated amounts of soil erosion might not represent the true values under real conditions.

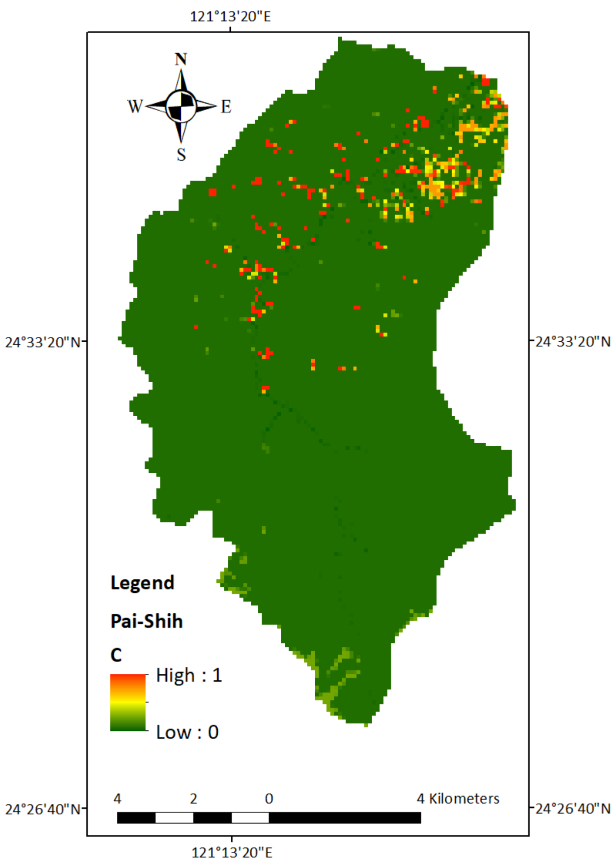
In order to examine whether the area of bare land or developed land has an impact on soil erosion or not, we computed the percentage of bare land, the percentage of developed land, and the percentage of bare land and developed land combined in each sub-watershed as shown in Table 3. Then, we plotted the average amount of soil erosion against these parameters. The results are shown in Figure 3. In addition, we plotted the average amount of soil erosion against the erosion depths as measured by 550 erosion pins installed on 55 slopes throughout the Shihmen reservoir watershed. As can be seen from Figure 3, there is only a statistically significant relationship ($R^2 > 0.36$) between the average soil erosion and the % of bare land. Other than that, the average soil erosion in a sub-watershed does not seem to depend on the % of developed land or the % of bare and developed land combined. It is also surprising to note that there is no statistical correlation between the average soil erosion and the erosion pin measurement.



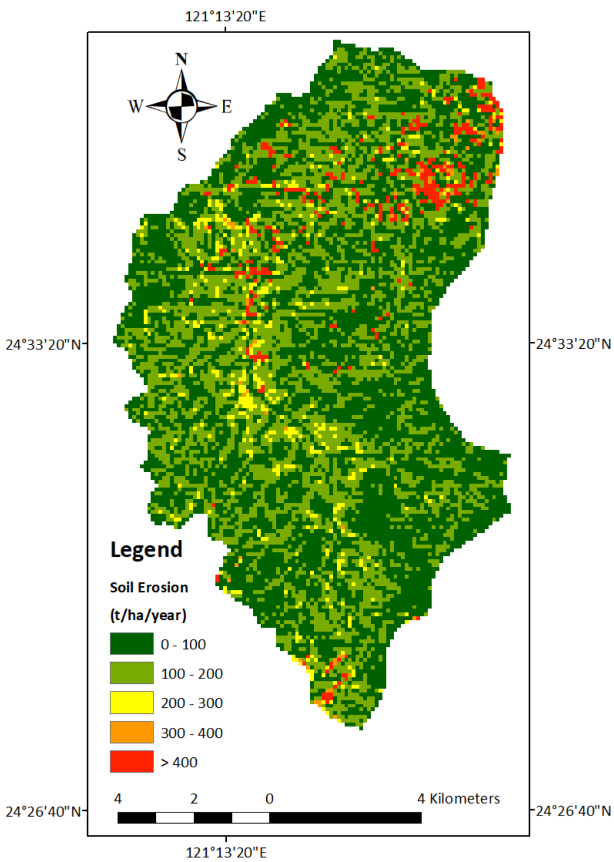
(a) Ku-Chu (C factor)



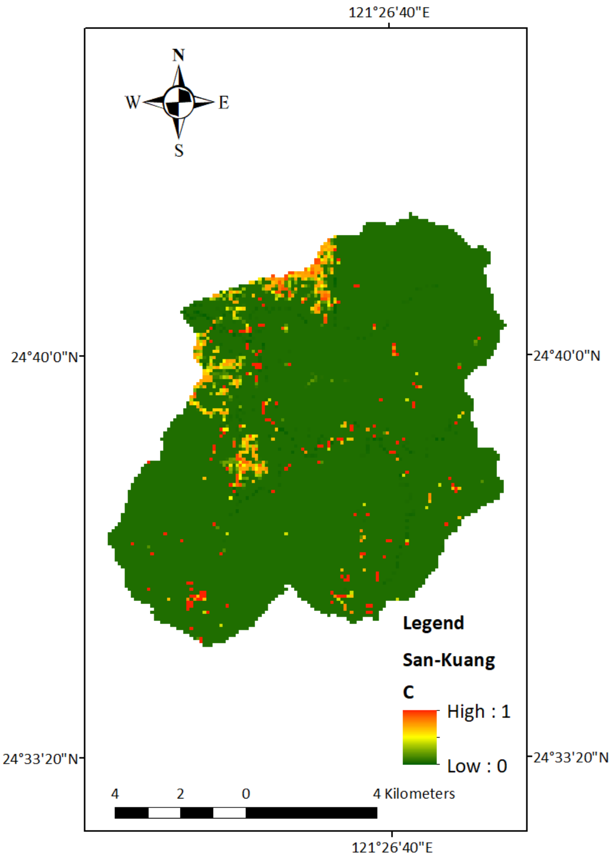
(b) Ku-Chu (soil erosion)



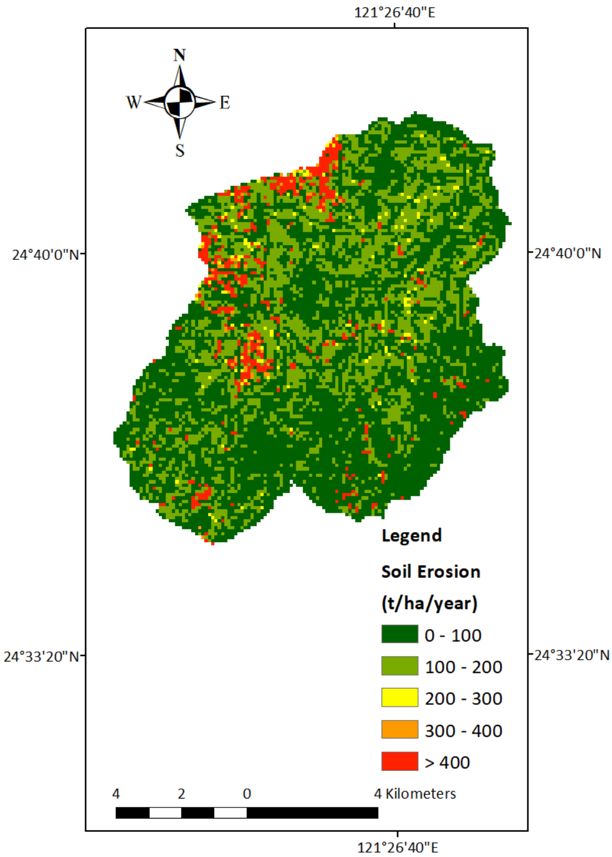
(c) Pai-Shih (C factor)



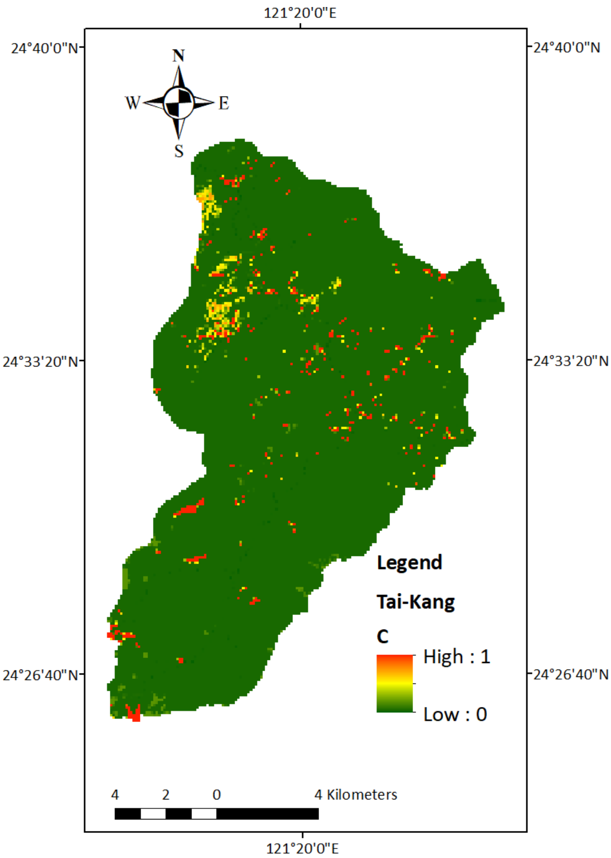
(d) Pai-Shih (soil erosion)



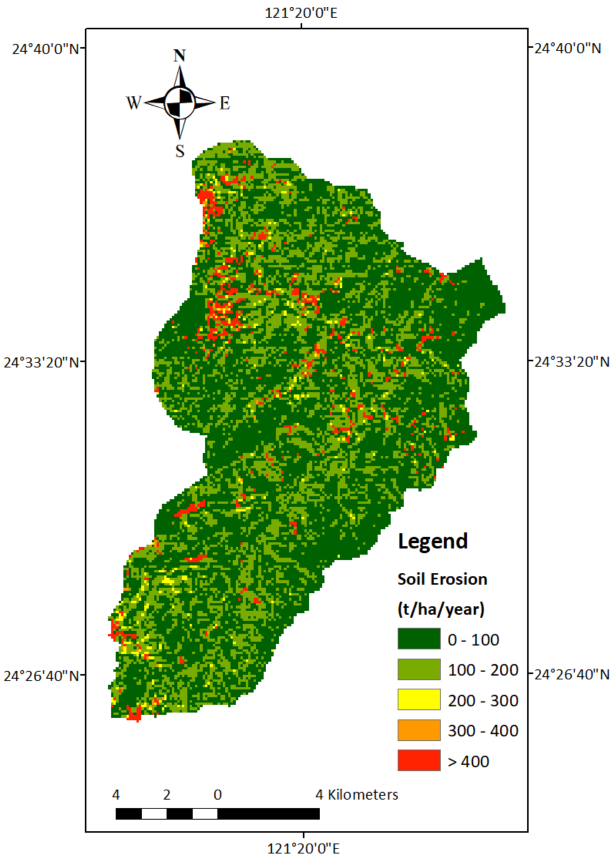
(e) San-Kuang (C factor)



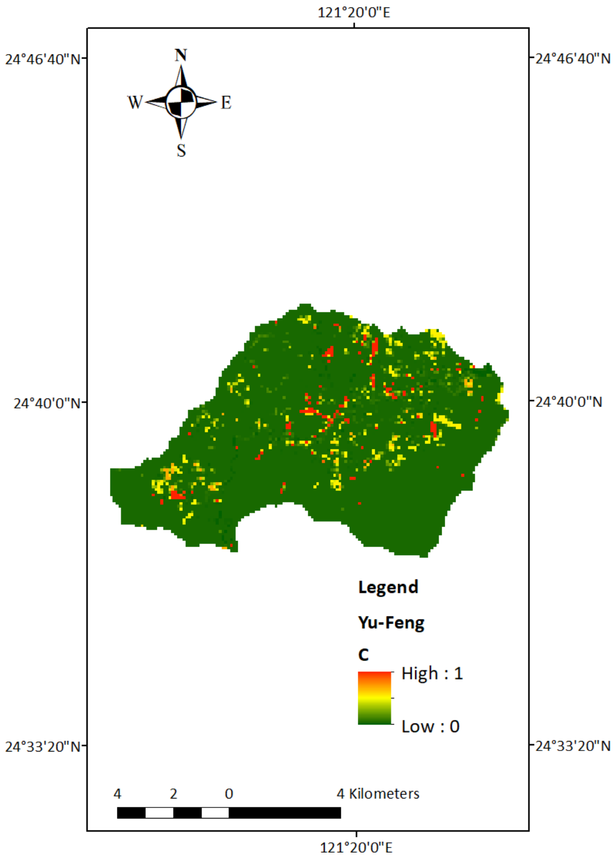
(f) San-Kuang (soil erosion)



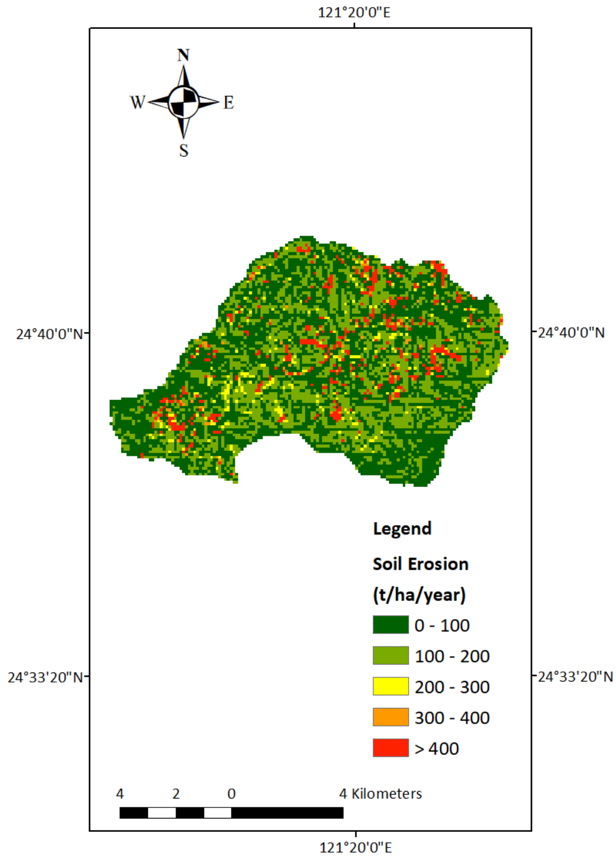
(g) Tai-Kang (C factor)



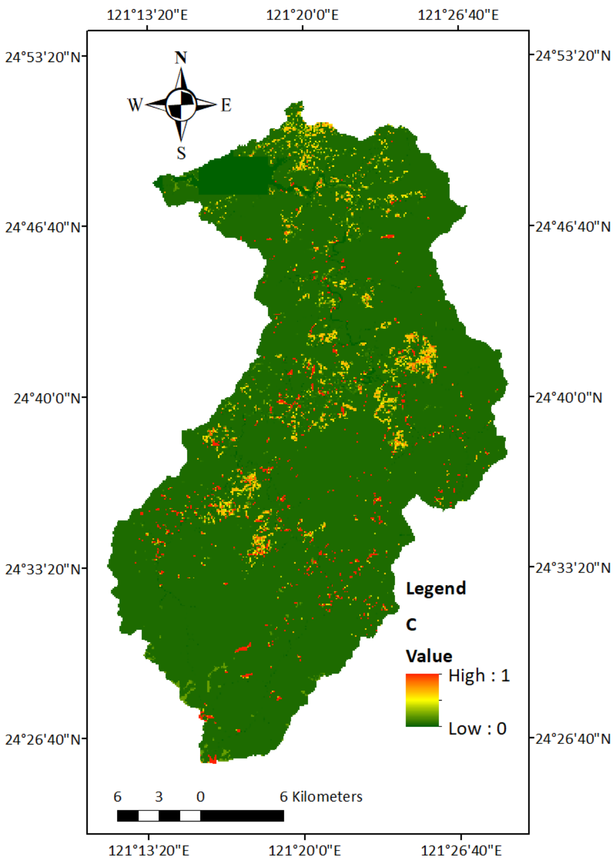
(h) Tai-Kang (soil erosion)



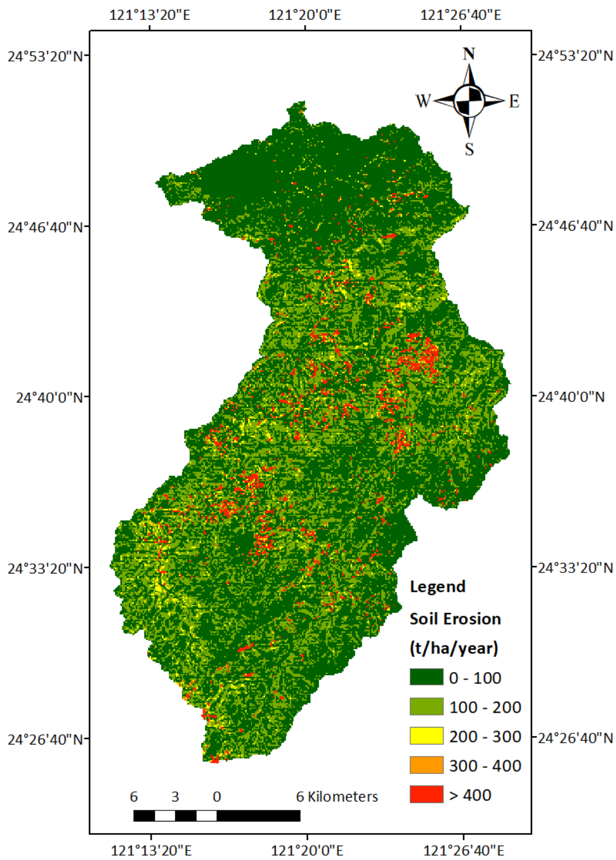
(i) Yu-Feng (C factor)



(j) Yu-Feng (soil erosion)



(k) Entire watershed (C factor)



(l) Entire watershed (soil erosion)

Figure 2 The analysis results for: (left) C factors, and (right) amounts of soil erosion

Table 3 The statistics on the percentage of area occupied by bare land and developed land

Sub-watershed	Ku-Chu	Yu-Feng	San-Kuang	Pai-Shih	Tai-Kang
Average soil erosion (t/ha/year)	131.8	281.8	207.4	236.7	276.3
% of bare land	0.48	1.68	0.92	0.85	1.43
% of developed land	4.89	4.29	3.23	1.38	1.20
% of bare and developed land	5.36	5.97	4.15	2.23	2.63
Erosion pin measurement (mm/yr)	6.0	4.7	8.9	6.4	6.8

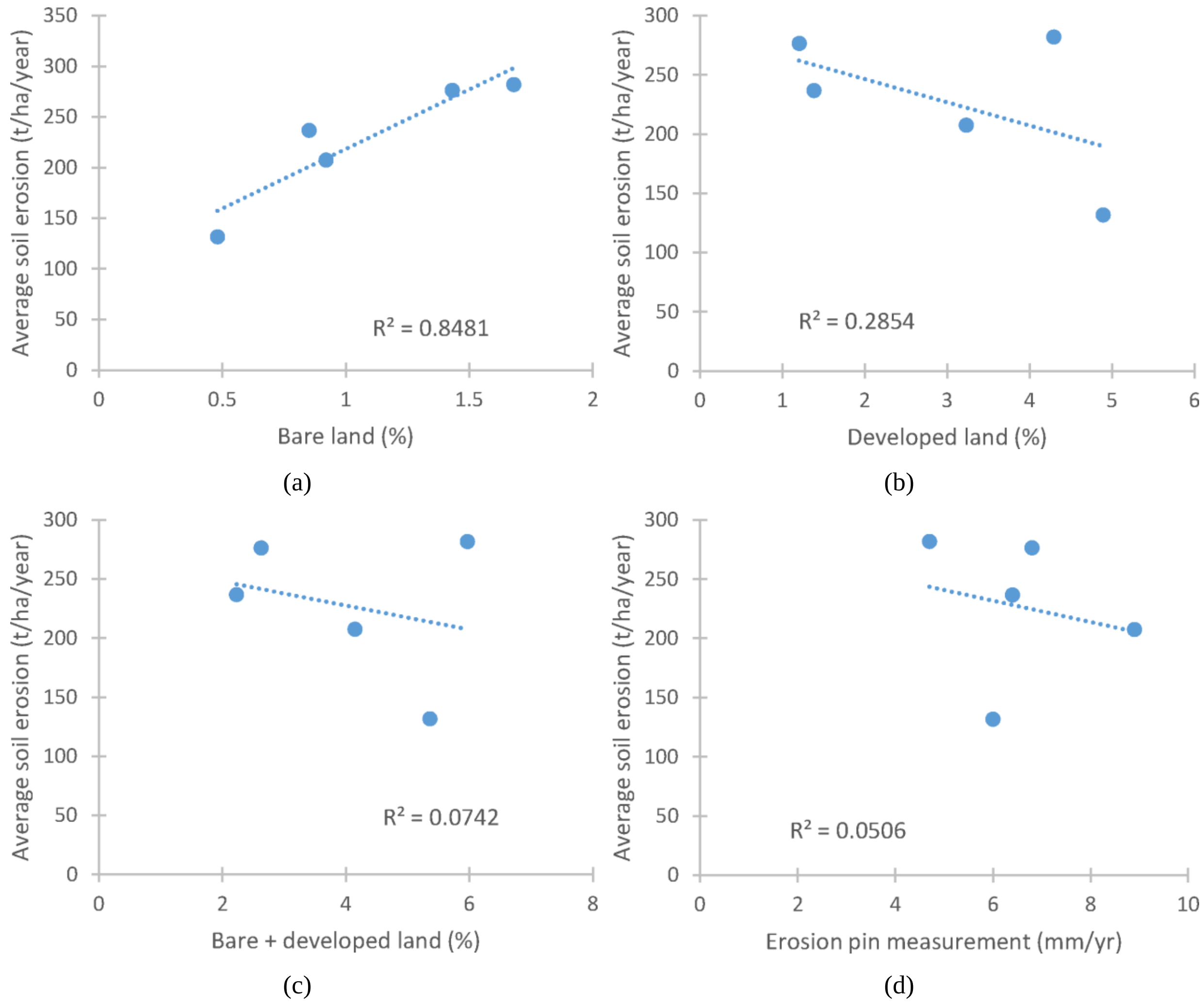
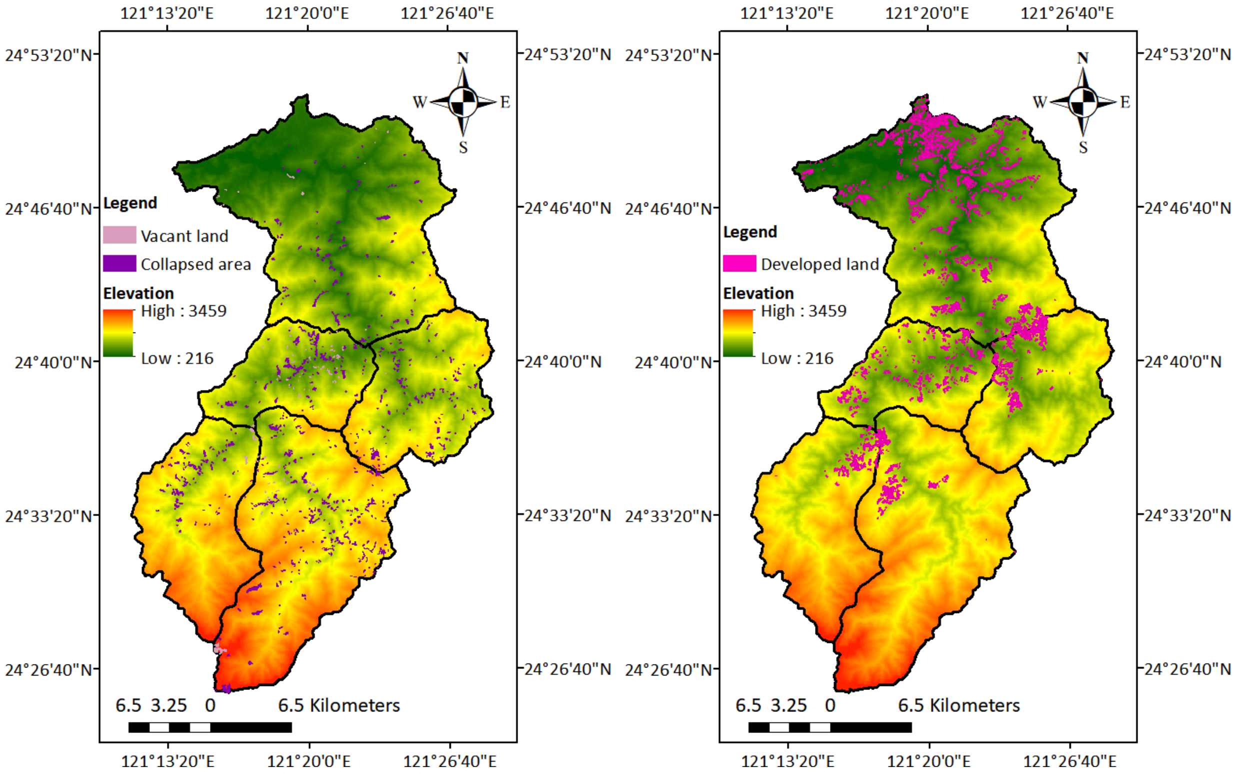


Figure 3 The relationship between the average soil erosion and: (a) the % of bare land, (b) the % of developed land, (c) the % of bare + developed land, and (d) the erosion pin measurement

5. DISCUSSION AND CONCLUSIONS

How to reduce soil erosion is a topic of concern to many researchers. In this study, it was found that the higher the proportion of bare land, the greater the average amount of soil erosion. Figure 4(a) shows the distribution of bare lands in the Shihmen reservoir watershed. It can be seen from the figure that they are not evenly distributed in the study area. Less bare lands are located near the reservoir itself. By contrast, there are more developed lands near the reservoir as shown in Figure 4(b). However, the developed lands did not lead to a drastic increase in soil erosion in the area. The fact is just the opposite. Soil erosion is the least in the Ku-Chu sub-watershed, which contains the reservoir.



(a) (b)

Figure 4 The distribution of: (a) bare lands, and (b) developed lands

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