Discussion on the Landscape Pattern Change of Watershed

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Abstract: Evaluating the transition of landscape can understand that ecosystem processes are being influenced by disturbance. For this reason, it is essential that using appropriate mapping techniques and quantitative methods to assess landscape condition within different disturbance regimes. Landscape metrics were calculated for segmented areas of homogeneous land use in watershed to allow understanding and characterization of ecosystem. Chen-yu-lan watershed, located in the central of Taiwan, is a sensitivity area for disaster such as earthquakes and typhoons. In this study we focus on how the natural disaster affect landscape pattern. The study shows that landscape metrics can measure the effect of typhoon and earthquake disturbance regime. The analysis shows that evaluating landscape transition can contribute more detailed information for managing ecosystem.

Key words: landscape ecology; landscape health; watershed management; natural disturbance

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1 Introduction

Landscape Pattern is fundamental to many relationships that we seek to understand. It is important to be familiar with the metrics that are used and more importantly, to understand the factors which influence the interpretation of any landscape analysis. Disturbances create patterns in vegetation by producing a mosaic of serial stages which ecologists have previously recognized as important to landscape-level patch mosaic (Turner et al., 2001). Landscape ecology is the study of the structures, functions and changes in a heterogeneous land area composed of interacting ecosystems. A landscape consists of three main components: matrix, patches, and corridors. The matrix, which is the dominant component in the landscape, is the most extensive and connected landscape type that plays a dominant role in landscape functioning. The field of landscape ecology integrates the natural disturbance regimes and their effects on the distribution of ecological types across a landscape, the dispersals and movements of plant and animal species, and the flow of energy (Parminter and Daigle, 1997).

Landscape ecology examines the relationships between landscape patterns and ecological processes (Forman and Gordon, 1986; Turner 1989; Gustafson, 1998; Tischendorf, 2001). Landscape metrics or indices can be quantitative indices which can describe the structure and pattern of landscapes (McGarigal and Mark, 1994; O'Neil et al, 1998). In fact, landscape metrics have been widely applied to compare heterogeneity between different landscapes, and to predict response variables of ecological processes such as dispersal success, abundance, distribution, and survival probability of species or populations in heterogeneous landscapes (Tischendorf, 2001). Moreover, landscape metrics can help us to describe and investigate the changes in landscape patterns (Turner et al., 1989; Forhn et al., 1996; O'Neil et al., 1996). In the present study, we focus on the landscape metrics as a tool to detect the changes resulting from disturbances and to describe and represent the landscape changes. Documenting and calculating the rates of landscape change using satellite imagery is a useful approach for exploring the potential mechanisms affecting ecological processes and ultimately, the human impact on forest landscapes (Bresee, et al., 2004; Cohen et al., 2002; Zhang et al., 1997; Walsh et al., 1998). With data which are characteristically multi-channel, multi-temporal and multi-platform, remotely sensed imagery is considered as a useful tool for analyzing landscape pattern changes. Geographic Information System or GIS is an essential tool for analyzing spatial data. Many researches and studies show the integration of multi-temporal remotely sensed imagery and GIS facility analysis of land use and cover changes (Duncan et al., 1999; Rao and Pant, 2001; Vasconcelos et al., 2002; Hathout, 2002).

2 Methods and Materials

2.1 Study site

The Chenyulan watershed is located in the upper reaches of Choahui River in central Taiwan as shown in Figure 1. The topography of the Chenyulan Watershed is extremely steep. The average slope of the river bed is 6.75 %. The lowest point of the watershed is at the junction of the Chenyulan and Choahui Rivers which is at 310 m, while the highest point is Mt. Yushan which is 3,952 m high. Because of the variation in elevation, the climate changes from the sub-tropical type to the tundra type. Depending on the type of climate, the type of vegetation ranges from board leaf forest to

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prairie. The middle and lower reaches of the Chenyulan Watershed have several level terraces which the inhabitants cultivate. Besides anthropologic disturbances, the area of study has been exposed to extensive typhoon disturbances. Even if the typhoon does not directly hit the area, the stormy rains still result to serious disasters. By means of the anthropological and natural disturbances, the Chenyulan Watershed has created a variety of landscape mosaics.

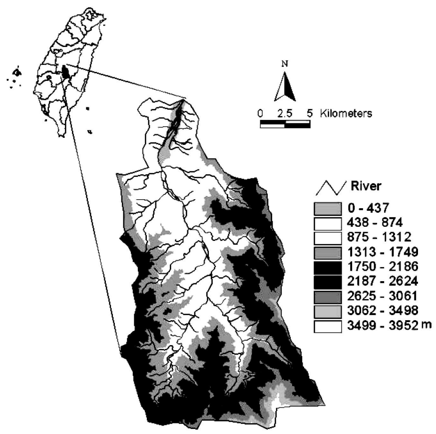

Figure 1 The site location map of Chenyulan watershed

2.2 Natural disturbance of disasters

In the present study, the three typhoons named Herb, Xangsane, and Toraji, as well as the Chi-Chi earthquake, have been selected to determine how the land cover changed. Typhoons Herb and Torji and the Chi-Chi earthquake are considered to have the most impact from among the major disaster events in the Chenyulan watershed (Lin and Jeng, 2000, Cheng et al., 2005). Typhoon Herb was a strong typhoon that had the highest sustained wind speed of up to 60 m/s and a radius of 320 kms. Herb traveled across northern Taiwan following the route shown in Figure 2. The route was particularly unfortunate because the counterclockwise air currents brought abundant humidity from the southwest, but was blocked by the Central Mountain Range of Taiwan. The obstructed humidity current was eventually transformed into heavy rainfalls on the mountainous range and the Western Plain where the population and industries of Taiwan are concentrated. The two rainfall observation stations, Ali Shan and Houn-Sir stations, measured the accumulated rainfalls as 687.5 mm and 1,986.5 mm, respectively (Table 1). With the high speed winds and heavy rainfalls, Typhoon Herb resulted to 1,315 landslides, more than 20 debris flows, 101 road closures and 49.6 kms of embankment failures in Taiwan. Moreover, there were 73 deaths, 463 wounded, 1,383 houses destroyed or damaged and one billion USD in property losses (Lin and Jeng, 2000). Typhoon Toraji hit eastern and central Taiwan (Figure 2) with heavy rainfalls (Table 1) having peak hourly intensities exceeding 70 mm/h. This rainstorm caused several major debris flows and debris floods which destroyed or severely damaged dams, roads, bridges, dikes and houses, in addition to causing 103 casualties, 111 missing (presumed dead), and 189 injured. The two Typhoons Herb and Toraji caused serious disasters in the area of study.

The Chi-Chi earthquak resulted to more than 24,000 fatalities and losses amounting to billions of dollars due to the destruction and damage of private and public buildings, roads, bridges, and hydraulic structures in central Taiwan. This Chi-Chi earthquake also triggered close to 26,000 landslides and other related disasters.

Taiwan, which is situated on the borderland between the Eurasian Plate and the Philippine Sea Plate, is one of the 6 most earthquake-prone areas in the world. When most of the people in Taiwan were sound asleep at 1:47 in the morning of September 21, 1999, the island was hit by an earthquake measuring 7.3 on the Richter Scale and whose epicenter was located at 12.5 km^2 southwest of Sun Moon Lake in Nantou County (Figure 3). The greatest destruction took place in places near the epicenter such as Nantou and Taichung where people suffered from utility failures, transportation breakdown and massive landslides. Obviously, the destructive power of the Chi-Chi Earthquake has been the most serious during the last 10 decades.

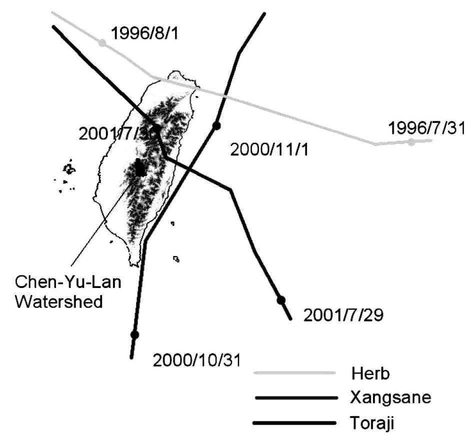

Figure 2 The route of typhoons Herb, Xangs, Toji

Table 1 Accumulated rainfalls mm

Stations	Herb	Xangsane	Toraji
Ho-Sir	687.5	202	437
Ali shan	1986.5	157	714

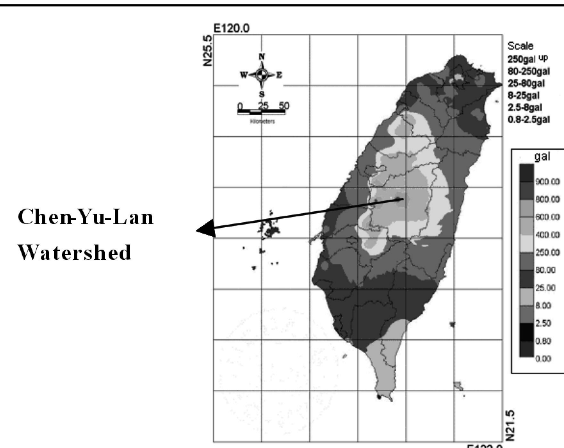

Figure 3 The disturbance of Chi-Chi earthquake

2.3 Landscape Metrics

We chose appropriate landscape pattern indices (Table 2) to represent a series of basic concepts of landscape pattern quantification (defined in McGargal and Mark, 1995). Important applications of landscape metrics similar to what Herold et al (2002) reported, include the detection of landscape pattern, biodiversity and habitat fragmentation (Gardner et al., 1993; Keitt et al., 1997), the description of changes in landscapes (Dunn et al., 1991; Frohn et al., 1996), and the investigation of scale effects in describing landscape structures (O' Neil et al. 1996; Turner et al., 1989).

Table 2 The selected landscape metrics for the study

Concept	Index	Code	Dimension
Patchness	Number of Patches	NP	#
	Mean Patch Size	MPS	ha
Edge	Total Density	TD	m
	Edge Density	ED	m/ ha
Shape	Mean Shape Index	MSI	ratio
	Area Weight Mean Shape Index	AWMSI	ratio
	Mean Patch Fractal Dimension	MPFD	ratio
	Area Weight Mean Patch Fractal Dimension	AWMPFD	ratio
Isolation	Mean Nearest-Neighbor Index	MNN	m
	Interspersion and Juxtaposition	IJI	%
Heterogeneity	Shannon's Diversity Index	SDI	ratio
	Shannon's Evenness Index	SEI	ratio

3 Results and Discussion

The metrics were calculated from the classified SPOT images covering the area of study and dated as 1996/11/08, 1999/03/06, 1999/10/31, 2000/11/27, and 2001/11/20. The results of the landscape metrics are shown in Table 3. Through the reflection of the landscape metrics, the landscape pattern changes could be obviously detected. From the trends of the patch number (NumP) and the mean patch size (MPS), we can observe that the NumP is increasing while the MPS is decreasing. Moreover, the largest value of patch number and the smallest value of mean patch size are found in the land cover of 1999/10/31 (after the Chi-Chi earthquake). This means that the disturbance of an earthquake fragmented the landscape pattern more easily than by the disturbance of a typhoon. The trends of the total edge (TE) and edge density (ED) also show that the disturbance of the earthquake has a greater ability to fragmentize the landscape pattern. One of the results of patchness and edge metrics which is worth mentioning is the landscape cover of 2001/11/20 (after Typhoon Taroji). It is the most fragmented landscape pattern from among the typhoon disturbances in the present study. To detect the patch shape change after the disturbance, the present study calculated the mean shape index (MSI), area weight mean shape index (AWMSI), mean patch fractal dimension (MPFD) and area weight mean patch fractal dimension (AWMPFD), as shown in Table 3. The MPFD and AWMPFD represent the constant for the present study. However, the trends of the MSI and the AWMSI demonstrated the influence of the disturbances. There is a notable difference between the disturbances of an earthquake and a typhoon. The force of a typhoon makes the patch shape change more easily than the force of an earthquake.

Mean nearest neighbor (MNN) is a measure of patch isolation. It is the distance between an individual patch to the nearest neighboring patch of similar type (edge-to-edge). Smaller values of class MNN indicate that the patches of similar types are closer or clustered together, while the larger values indicate otherwise. In the study, the MNN represents the land cover of 1996/11/8 (after Typhoon Herb), 1999/10/31 (after the Chi-Chi earthquake) and 2001/11/20 (after Typhoon Toraji) as being more isolated than the land cover of 1999/3/6 (before Chi-Chi earthquake) and 2000/11/27 (after Typhoon Xangsane). It means that both the erosion due to heavy rainfalls and destruction of the landscape configuration due to earthquake can split the patch into subpatches or shrink the patch size. Interspersion and juxtaposition index (IJI) measures the extent by which patch (polygon) types are interspersed (not necessarily dispersed) (McGarigal & Marks, 1994). Higher values result from those landscapes where the patch types are well interspersed (equally adjacent to each other), whereas lower values characterize those landscapes where the patch types are poorly interspersed (disproportionate distribution of patch type). The strength of interspersion index is that it is not directly affected by the number, size, contiguity or dispersion of patches. In general, the interspersion indices for the present study increased to show that the land use types become better interspersed.

Before the Chi-Chi earthquake, the SDI and SEI of 1996/11/08 were high because the heavy rainfalls of Typhoon Herb damaged the forest and created landslides and bare lands. The land recovered the forest and the meadow until the Chi-Chi earthquake. The Chi-Chi earthquake destroyed the forest and created more landslides and bare lands. As a result, the SDI and SEI of 1999/10/31 (after the Chi-Chi earthquake) were lower than that of 1996/11/08 (after typhoon Herb) and 2001/11/20 (after typhoon Toraji). However, the new forest and meadow were recovered from the bare land. It made the SDI and SEI increase the landscape pattern of 2000/11/27. Again, the heavy rainfalls from Typhoon Toraji destroyed the new cover. The disturbances of Typhoon Toraji caused the SDI to decrease.

Table 3 The results of landscape metrics

Indices	1996/11/8	1999/3/6	1999/10/31	2000/11/27	2001/11/20
NumP	20823	23328	25872	24283	24552
MPS	3.47	3.1	2.8	2.98	2.95
TE	6224350	6402462.5	6874612.5	6648537.5	6749462.5
ED	86.06	88.53	95.05	91.93	93.32
MSI	1.37	1.36	1.36	1.36	1.37
AWMSI	22.78	22.05	22.5	22.41	23.28
MPFD	1.06	1.06	1.06	1.06	1.06
AWMPFD	1.26	1.26	1.26	1.26	1.26
MNN	42.5	44.9	43.7	44.5	41.8
IJI	62.36	61.86	66.95	65.9	64.79
SDI	1.18	1.16	1.17	1.19	1.18
SEI	0.66	0.65	0.65	0.66	0.66

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感,提供公路安全性以及增加植被生物多样性等方面获得的效应。日本植被休憩功能平均为生态效益的 20 %,但由于我国的公路建设发展水平低于日本,本文取生态效益的 15 %为景观美学效益。

4 结果与建议

(1)新建公路路域生态恢复的效益主要取决于投资成本和环境收益,其中在收益中,生物工程替代效益占主要部分,其次是林草净化环境、景观美学价值和植被吸收二氧化碳的效益。

(2)提高公路生态恢复工程效益的途径有:①利用乡土植物,减少建设和养护成本;②加强投资控制和资金管理,避免公路恢复园林化的趋势;③充分利用公路建设的土地资源,尤其是表土资源,节约资源和资金;④大力提倡发展生态经济型公路生态工程,例如在公路立交区建植苗圃或适当种植经济植物,增加收益。

(3)将环境效益量化的分析研究不多,有些参数的确定还有待做更深一步的调查研究和完善。在进行效益计算时,其相当大的部分如林草杀菌、减低噪声等现在无法用货币形式进行计算,因此,本文所述的核算研究具有一定的历史局限性,还不够完整。

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4 Conclusions

In the present study, we describe a technique to quantify spatial pattern from remote sensing data in order to describe the structures and changes in the land use and land cover. Moreover, the present study shows that landscape metrics can measure the effects of typhoon and earthquake disturbance regimes, and evaluation of the landscape transition can contribute more detailed information for managing ecosystems. On the other hand, it is essential to use appropriate mapping techniques and quantitative methods to assess the landscape condition within the different disturbance regimes. The present study successfully detected the transition of the landscape as a result of natural disturbances. The results represent the ecological resilience of the Chenyulan Watershed. In order to unambiguously realize the ecological process and landscape health, we need to investigate more biotic and abiotic information and integrate these information into the landscape pattern. In this way, we can propose more efficient solutions for watershed management and ecological conservation.

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