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Academic Papers
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Using System Dynamics to Simulate the Urban Area Development and Water Resources

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Abstract

Water resource consumption is certainly one of the most complicated and delicate issues in planning and developing an urban area. Supply and demand on a single line is very easy to handle. However, with growing population and expanding city parameters, intertwined water pipes get ever so complicated and subsequently water management becomes an enormous task. Fortunately, with the help of system dynamics analysis, this enormous task can be broken down into easy-to-manage and understand steps not only to water managers but also to the general public. Hence, in this paper, we adopt System Dynamics to build a water consumption model of Taipei region to give a clear view of water demand per capita, and to illustrate variations of the water supply versus consumption in the coming one hundred years.

Keywords: *urban area development, water resource, system dynamics*

Introduction

What is "urban"? "Almost all national governments agree that settlements of 20,000 or more people are urban, but some consider smaller settlements to be urban as well, with various cut-off points. Few, however, would consider a small urban center of 1,000 to 2,000 inhabitants to be a city" (Hinrichsen et al., 2002.) An urban settlement is normally the center of major production and consumption in a region. In addition, it is also the political, financial, and cultural center of a country, in some cases. These attractions are exactly the reasons why rural people migrate to an urban area, and result in natural population increase among urban residents [Fig.1].

As urban population inclines, the demand on water and its quality increases. We, therefore, will demonstrate in this paper how this system dynamics model simulates the relationship between Taipei city population growth and water demand for each filed.

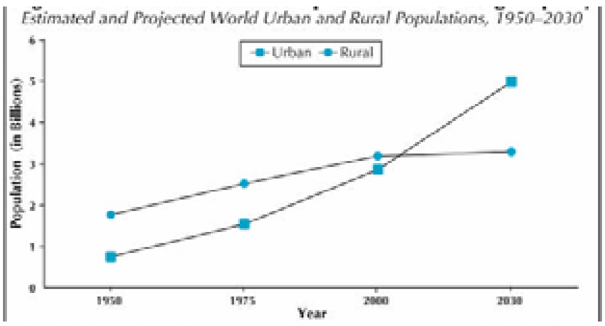

Fig.1 World's Urban Population Growing Rapidly(Reference: Hinrichsen et al., 2002)

Problem Formulation

Taipei city is located at 121°30' E and 25° 03' N, in the North of Taiwan [Fig.2]. The population of the city is 2,627,138. [2003], and it takes an area of approximately 277.7997㎞^{2}. It is the capital of Republic of China, Taiwan, also the core financial center of the island.

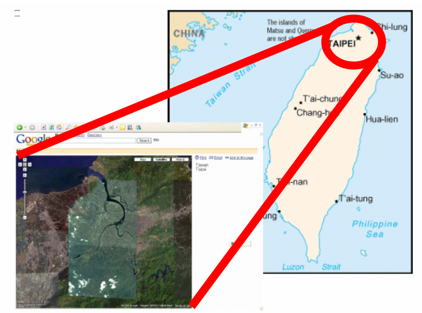

Fig2.The Study area

Source of Public Water

Taipei Water Department (TWD) has multiple sources to provide water for its public of Taipei metropolitan area (including Taipei city and nearby settlements). One is from spring water; two, from fresh water (rivers) [Fig.3].

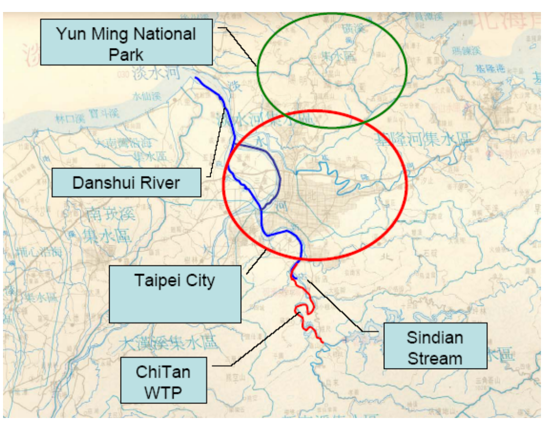

Fig.3 Geographical Location of Water Resource (Reference: Wang C.C., 2005)

Sindian Creek is one of fresh water sources for public water in Taipei region. TWD established Chitan inflow and Chintan inflow to draw water in to Chitan water treatment plant. These two inflows can supply 3,780,000 CMD, about 97% of total water supply for Taipei region [Fig.4].

Meanwhile, in the north part of Taipei city, spring water from Yang Ming Mountain National Park is the major water source. In the park, there are 6 spring wells, sufficient enough to supply 114650 CMD, about 3% of total water supply [Fig.4].

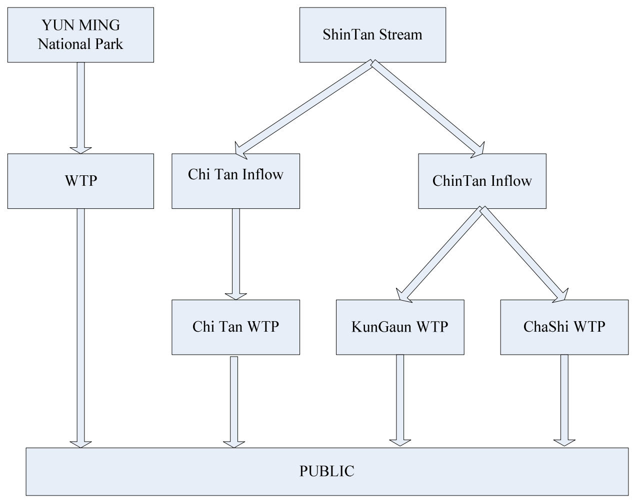

Fig.4 TWD Water supply flowchart
(Reference: Wang C.C., 2005)

Public Water Demand

Taipei City has 2,627,138 residents, plus more then 840,000 people commute to the city each day from near counties (2002 est., National Statistics). Nearby settlements have 1,245,900 residents (2002 est., National Statistics), and the people depend on TWD water supply as well. Reviewing the historical data, TWD serviced

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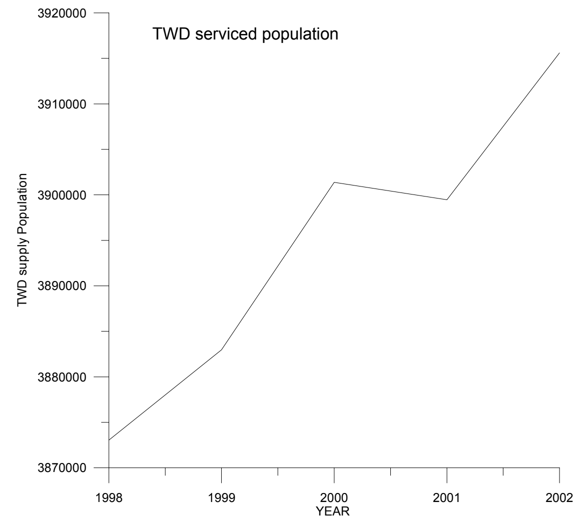

Fig.5 TWD serviced population Time series(1998~2002) (Reference: Wang C.C., 2005)

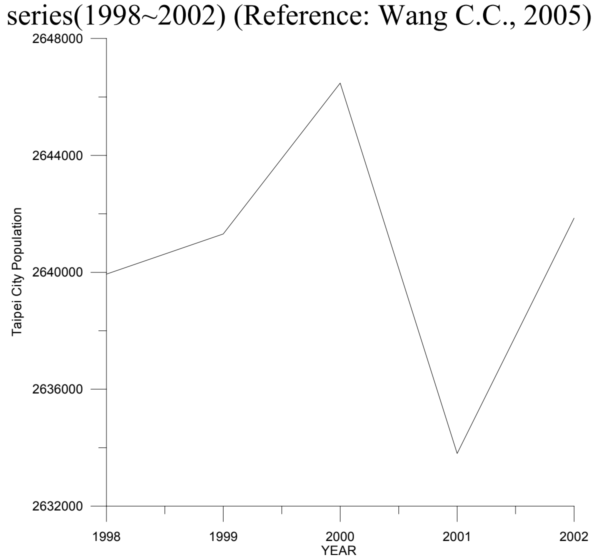

Fig.6 Taipei Population Time Series(1998~2002)(National Statistics)

population has rapidly grown from 3,873,038 in 1998 to 3,915,611 in 2002[Fig.5], even though the growth of population has slowed down in recent years [Fig.6].

However, the parameters of water demand are not only influenced by growing population, but also by every person's demand of water. To illustrate, we defined the water demand as a cyclic system as in Figure 7. The parameters in the cycle are categorized into industry subsystem, population, environment, and water consumption of Taipei city.

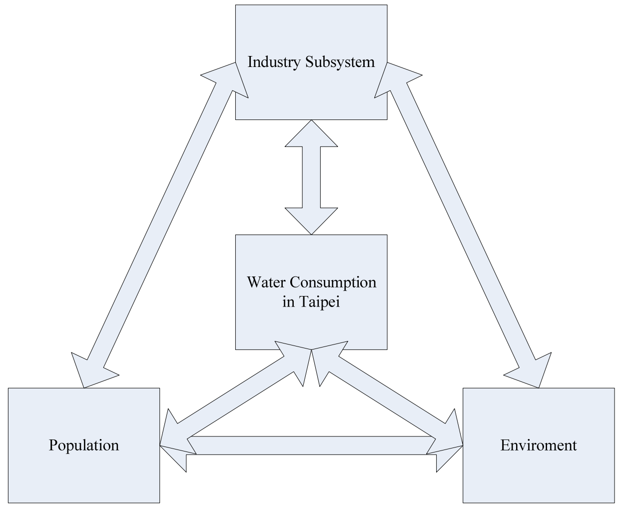

Fig 7.Sturture of Taipei Water Demand

When industry and population grow, water demand unsurprisingly goes up. Regrettably nature has its limit to provide flash water. Not only human beings, but river species need base flow discharge and water depth to survive and reproduce. TWD must figure out a way to manage and supply the ecological base flow to rivers.

Problem Solution

Perplexed water resource management can be optimized by numerous ways to search solutions, such as the Linear Programming, Artificial Neural Networks, Genetic Algorithms, and System Dynamics. SD (shortened for System Dynamics), with no exceptions, is an iterative process, but was selected for this research because it is relatively easy to practice and simple to understand, as shown in 3.2 Case Study.

The principles and the mechanics of SD were first worked out in the 1940's and 1950's. In 1970's Meadows, D.H etc was used to predict the limits of World's growth, known as, "The Limits of Growth" (Goodman, 1974). "The Limits of Growth" was published in 1970's by Rome Club. They used five variables (population, food supply, natural resources, and industry production) to predict the resources, and industry production) to predict the development of world (Meadows D.H., 1976). The SD method consists of dynamic simulation models which explicitly consider information feedbacks that govern the interactions in a system. Since the works on SD reported by Forrester, the method has been applied to a number of water resources management (Krystyna, 2003; Chen, 2002; Guo C., 2000).

Make the System Dynamics Model

Based on the structure of Taipei water demand, we used VENSIM© to build a system dynamics model to observe the correlation of population (personal water demand) and river discharge (ecological water). Step one, we created a causal-loop diagram of Taipei Water demand as in Figure 8.

The preliminary causal-loop is the interaction of three parameters: industry, population and ecological water demand as in Figure 8. Step two, based on the causal loop, we constructed a subsystem model with three crucial variables of SD. They are, as shown in Figure 9, Level (Stock), Rate (Flow), and Auxiliary, a variable to descry or enhance Rate. These three variables connected by arrows simulate the complex system.

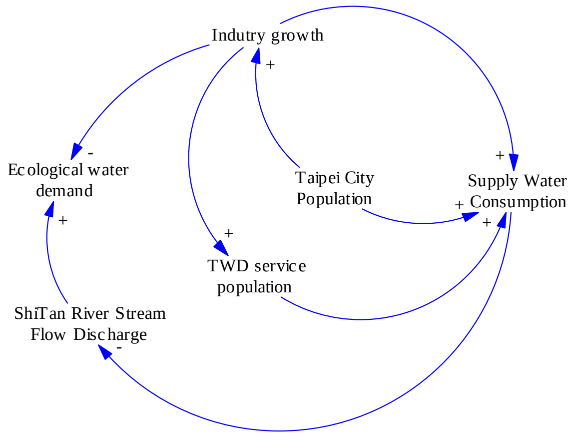

Fig.8 Causal-loop diagram of Taipei Water Demand

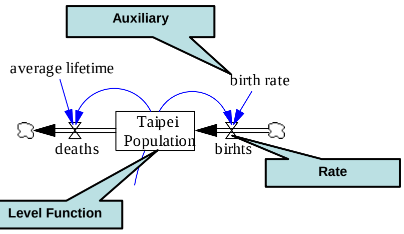

Fig 9. Taipei population function

For instance, in Figure 9, Taipei population is to be Level Function, fluctuating numbers of the population to be Rate, and birth rate and lifespan to be Auxiliary.

Now, in the following, Figure 10, we divided some variables from causal loop to assume an example model for simple tests. We adjusted different water demands and population growth rates. Then we tried out two case studies, which verified the advantages of system dynamics.

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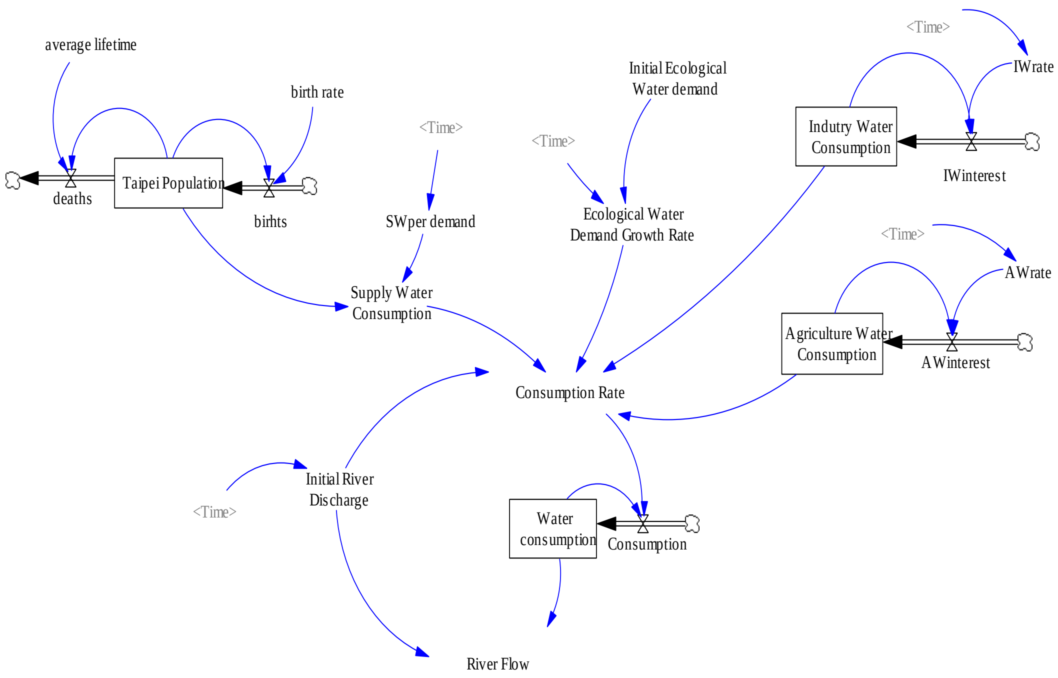

Fig. 10 System Dynamics Model

Case Study

To start, we needed to use and study the predecessor's data and outcomes to assemble our model.

Four departments of water consumption were considered, including domestic water consumption, ecological water demand volume, industry water consumption and agricultural water consumption uses.

The water consumption was controlled by the auxiliary function as shown below：

1. Domestic water demand = *f* (Taipei Region Population (historical data)、Water consumption per capita)

Two auxiliary functions are used to imitate the domestic water demand trend.

Auxiliary Function 1:

Water consumption per capita (CMD)

$$=0.35+(\exp(0.01-3*Time)) \quad \{Time,[1 \quad 10]\}$$

… Eq.(1)

Assume the people of Taipei decrease their demand of water in ten years to come.

Auxiliary Function 2:

Water consumption per capita (CMD)

$$=0.35+(\tanh(Time)-0.75)) \quad \{Time,[1 \quad 10]\}$$

… Eq.(2)

Assume the people of Taipei increase their demand of water in ten years to come (Wang C.C., 2005). See the results in Figure 11.

2. Ecological Water Demand= *f* (initial ecological water+ future demand) = Initial Ecological Water demand + exp (TANH (Time))

The initial ecological water demand is 106,842.64 CMD (Wang C.C., 2005). We assume the ecological water demand increases in the future.

For the complete descried interactive of parameters, we assume the “hyper tan” function to simulate the future demand of ecological water.

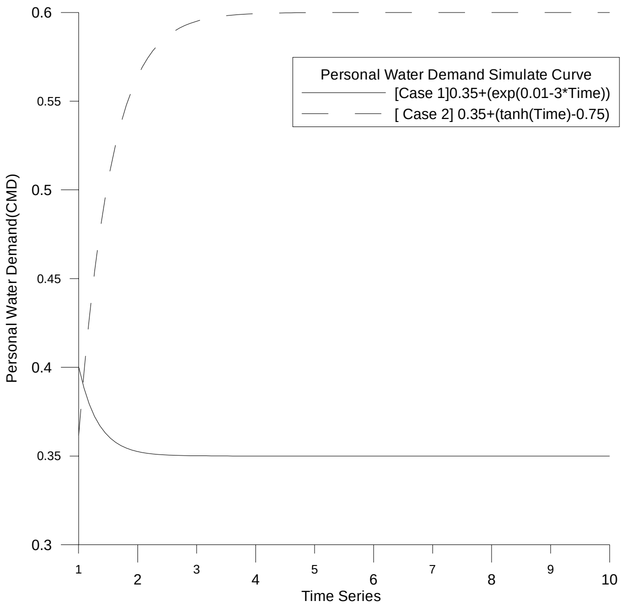

Fig. 11 Water consumption per capita

3. Industry water consumption = *f* (initial Industry water consumption+ future demand)

The auxiliary function of industry water consumption is (3-exp (TANH (Time))).

4. **Agricultural water consumption =*f* (initial Agricultural water consumption + future demand)**

The auxiliary function of agricultural water consumption is (0.25+exp (0.1-TANH (Time))).

Case 1:

Assume：

1. The River discharge during a drought. [Fig. 12].
2. The birth rate of Taipei is 0.00885 and average lifespan is 73 (National Statistics, 2003). [Fig. 13].
3. Industry and agricultural water consumption are decreasing by exponent law and function of hyper tan. [Fig. 14, Fig. 15].
4. Ecological Water demand increases. [Fig. 16]
5. Water consumption per capita declines. [Fig. 17]

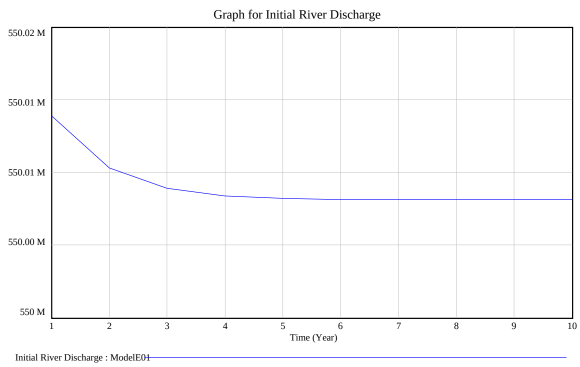

Fig .12 Initial River Discharge (Assume Drought)

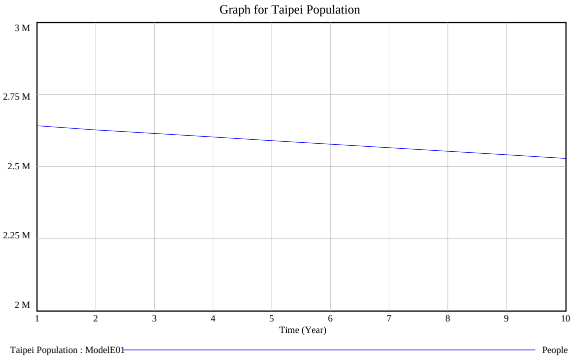

Fig.13 Taipei Population (Assume Decay)

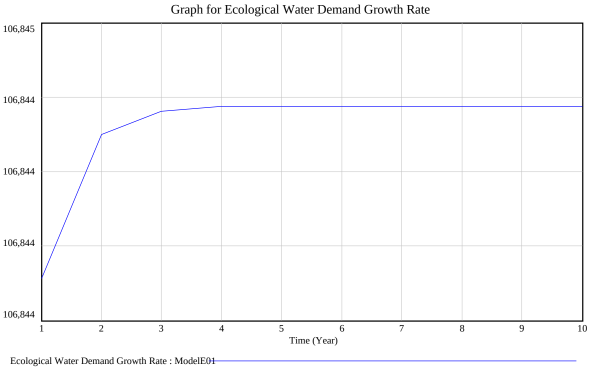

Fig. 16 Ecological Water Demand Volume

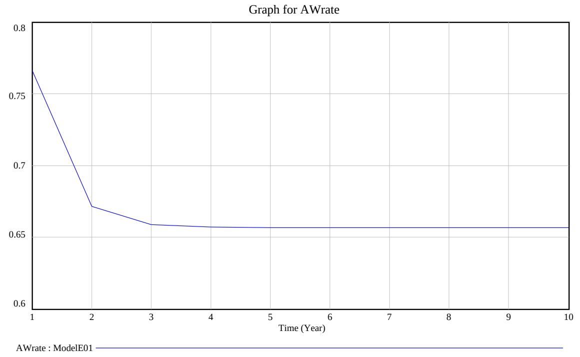

Fig. 14 Agricultural Water Consumption Demand Rate

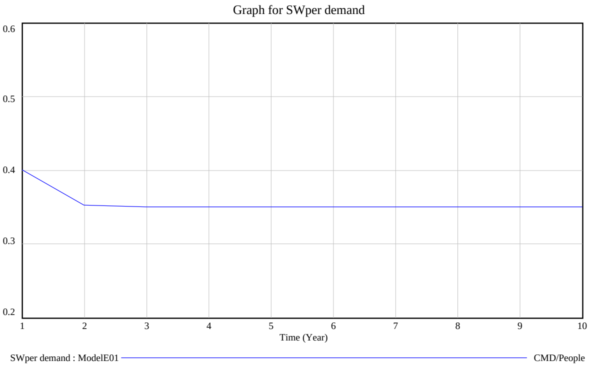

Fig. 17 Personal Water Demand

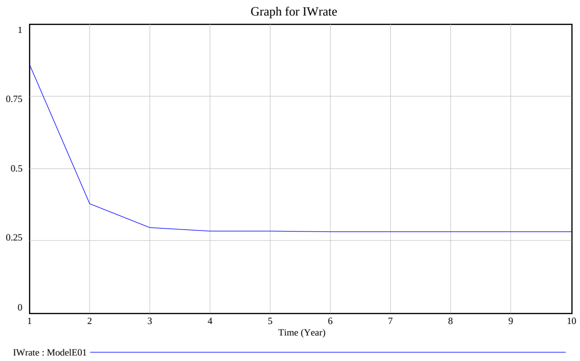

Fig.15 Industry Water Consumption Demand Rate

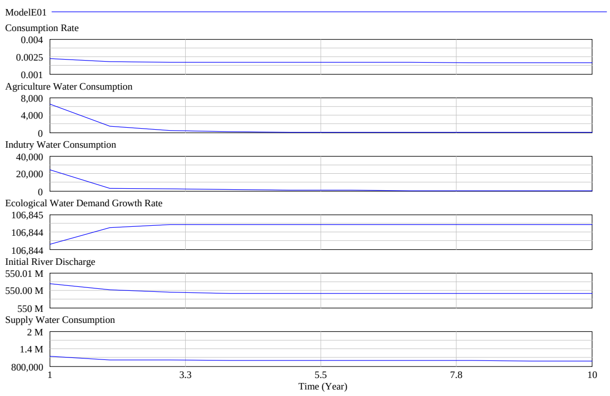

Fig. 18. A trend of Department Water Consumption in Ten Years(Case1)

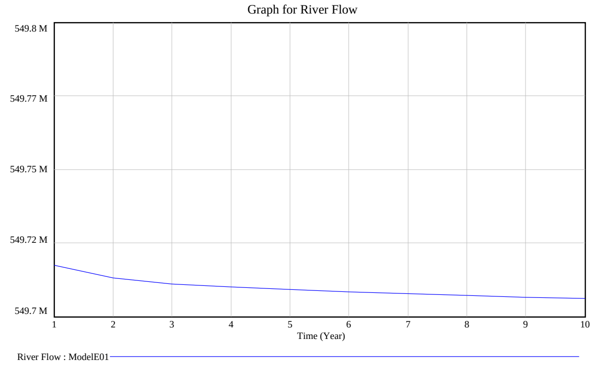

Fig. 19 River Flow Discharge in Case 1

Case 2:

Water consumption per capita is growing by Eq. (2). Other conditions stay the same as case 1.

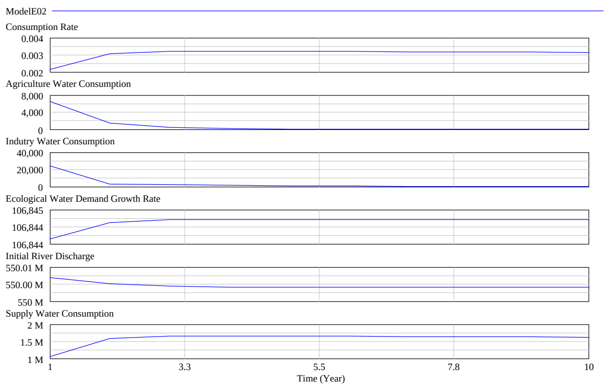

Fig. 20 A trend of Department Water Consumption in Ten Years (Case2)

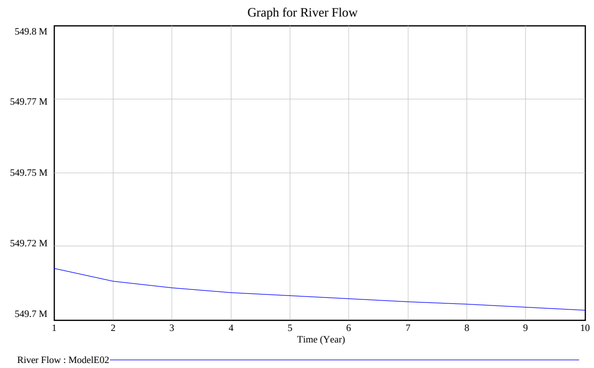

Fig. 21 River Flow Discharge in Case 2

Discussions

In comparing Case1 and Case 2, the river flow discharge dives two lines in third year [Fig.22]. After third year, the Case 2 becomes more rapidly declining. But the actual peak of water consumption dose not appear until the forth year. In other words, the river discharge reacts prior to any fluctuations of water consumption. In a sense, it can be a piece of vital information to alert water managers.

The consumption rate is first spread out to make a Cause Tree, like Figure 23, then transform to Figure 24.

As seen in the figure below, we can clearly find the consumption rate [(Agriculture Water Consumption + Industry Water Consumption + Supply Water Consumption + Ecological Water Demand Growth Rate)/Initial River Discharge] has the same trend with the water supply consumption.

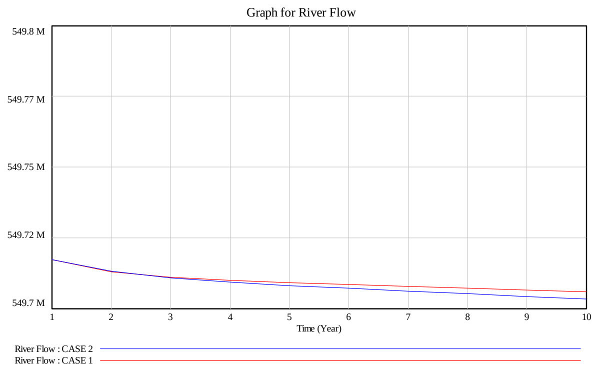

Fig.22 Comparison of Case 1 and Case 2 River Flow Discharge

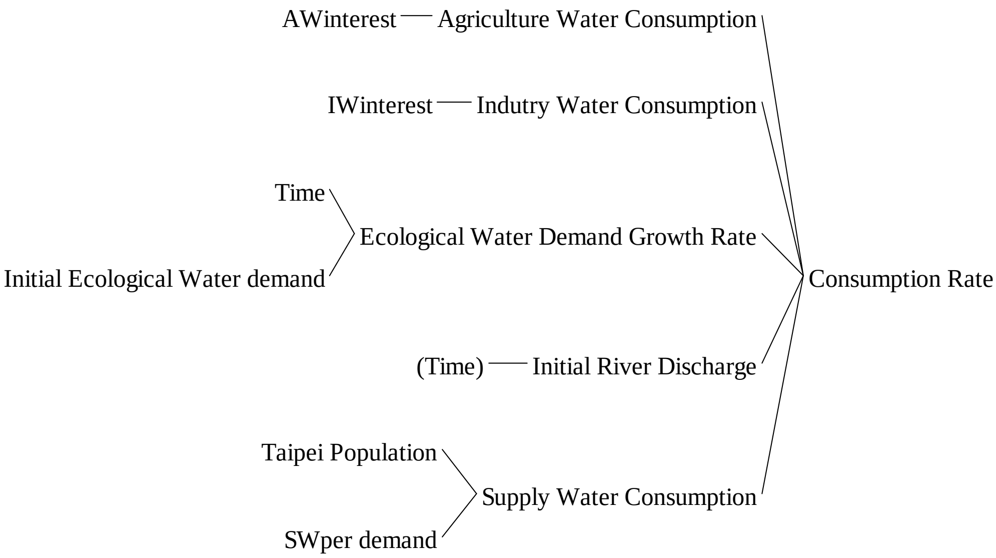

Fig. 23 Cause Tree of Consumption Rate

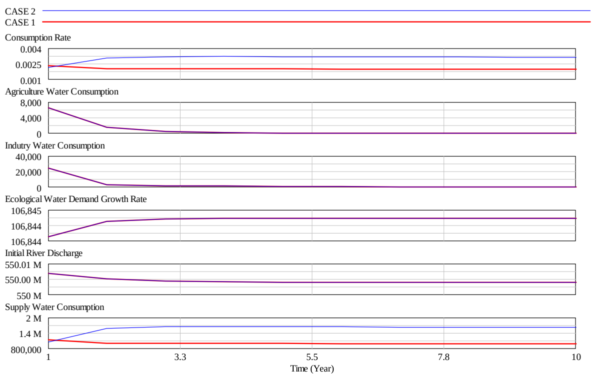

Fig. 24 Compare the trend of Department Water Consumption in Ten Years of Case1 and Case 2.

We can calculate the correlation coefficient.

$$\rho_{A,B} = \frac{\sum_{i=1}^{n}(A_i - \overline{A})(B_i - \overline{B})}{\sqrt{\sum_{i=1}^{n}(A_i - \overline{A})^2 \sum_{i=1}^{n}(B_i - \overline{B})^2}} \quad \text{.....Eq.(3)}$$

Consumption rate of case 1：CRC1

Consumption rate of case 2：CRC2

Supply water consumption of case 1：SWC1

Supply water consumption of case 2：SWC2

Agricultural water consumption：AW

Industry water consumption：IW

$$\begin{bmatrix} \rho_{CRC2,CRC2} & \rho_{CRC1,CRC2} & \rho_{SWC2,CRC2} & \rho_{SWC1,CRC2} & \rho_{AW,CRC2} & \rho_{IW,CRC2} \\ & \rho_{CRC1,CRC1} & \rho_{SWC2,CRC1} & \rho_{SWC1,CRC1} & \rho_{AW,CRC1} & \rho_{IW,CRC1} \\ & & \rho_{SWC2,SWC2} & \rho_{SWC1,SWC2} & \rho_{AW,SWC2} & \rho_{IW,SWC2} \\ & & & \rho_{SWC1,SWC1} & \rho_{AW,SWC1} & \rho_{IW,SWC1} \\ & & & & \rho_{AW,AW} & \rho_{IW,AW} \\ & & & & & \rho_{IW,IW} \end{bmatrix}$$

$$= \begin{bmatrix} 1.00 & -0.877 & 0.966 & -0.949 & -0.976 & -0.977 \\ & 1.00 & -0.89 & 0.964 & 0.924 & 0.938 \\ & & 1.00 & -0.963 & -0.983 & -0.989 \\ & & & 1.00 & 0.988 & 0.992 \\ & & & & 1.00 & 0.993 \\ & & & & & 1.00 \end{bmatrix}$$

In looking at the correlation coefficient figures from the left column, it is obvious that Case 1 and Case 2 reflect in opposite directions.

Again, we used the model to predict the water supply consumption for the coming 100 years [Fig. 26]. Assume the water consumption per capita increases to 0.65 CMD, (the very bottom bar of Fig. 26), but the population gradually decreases to 1.75M. And the result shows that the water supply consumption falls with the declining of the population.

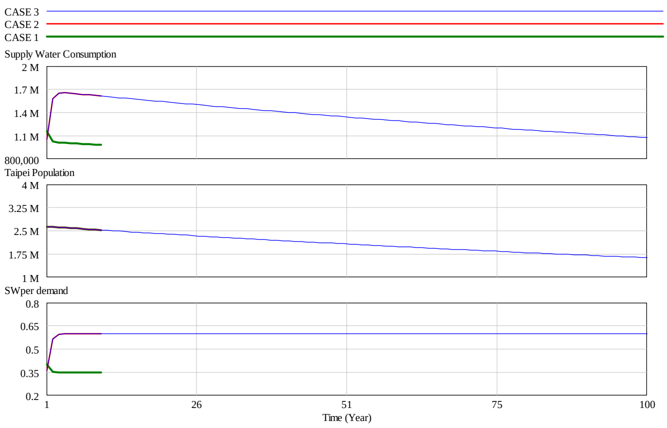

Fig. 26 Water Supply Consumption 100 Year Prediction

Conclusion

Taipei city is the most valued region in the island. Naturally, it is supported by more resources to develop more establishments. The purpose of our research was to attack possible problems, provide solutions, and discover unusual phenomena of Taipei city. By experimenting system dynamics model, we realized that it in fact can be utilized to explain and predict the correlation of urban development and water resources for the future. Meanwhile, we were also able to detect and troubleshoot different situations raised.

However System Dynamics model indicated that Taipei city was less likely to encounter any difficulties in water usage, we discovered some questionable points that need to be further studied for better analysis. To be more specific for instance, providing a reasonable auxiliary function was a challenge. Without accurate data or numbers to input, it was difficult to provide information useful to help making crucial decisions. Thus made us to think if it was possible to utilize an unconventional method to fill in the data, such as Artifical Neural Networks. Perhaps the unconventional method will in fact refine the function of System Dynamics.

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Study on the Landscape Ecological Change of Watershed with Natural Disaster

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Abstract

The landscape, which is changed as with anthropological or natural disturbance, is a heterogeneous land area composed of cluster of interacting ecosystem that is repeated in various sizes, conditions, topography, and spatial relationships. Evaluating the transition of landscape can emerge that ecosystem processes are being influenced by disturbance. For this reason, it is essential to use 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. The Chen-Yu-Lan watershed, located in central Taiwan, is a sensitivity area for natural disaster such as earthquakes and typhoons. In this study we focus on how the natural disasters affect landscape patterns. The remote sensing technology has great potential for acquiring the detailed and accurate land use information for management and planning of watershed. Hence, we choose time series SPOT images which date on 1996/11/8 (after Typhoon Herb), 1999/3/6 (before the Chi-Chiearthquake), 1999/10/31 (after Chi-Chi earthquake), 2000/11/27 (after Typhoon Xangsane), 2001/11/20 (after Typhoon Toraji), respectively. 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 ecosystems.

Keywords*: landscape ecology, landscape health, remote sensing, watershed management*

Introduction

Landscape is a heterogeneous terrain area composed of clusters of interacting ecosystems which are repeated in various sizes, conditions, topography, and spatial relationships, and is prone to change as a result of anthropological or natural disturbances. Landscape Pattern is fundamental to many relationships that we seek to understand. To be familiar with the metrics which are used is very important and more important is to understand the factors which influence the interpretation of any landscape analysis (Turner et al., 2001). 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 explained as the study of the structures, functions and changes of a heterogeneous land area composed of interacting ecosystems. There are three main components composing a landscape: 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. Patches are nonlinear surface areas which differ in terms of vegetation and landscape from their surroundings. They are units of land or habitat which are heterogeneous when compared to the whole. Corridors are areas that link patches together and serve as highways or conduits for organisms to transfer or move from patch to patch. 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; Dunn et al., 1991; 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).

The Chen-Yu-Lan Watershed, located in center Taiwan, is a sensitive area for disaster. For this reason, evaluating the transition of landscape of the Chen-Yu-Lan watershed can be helpful and useful in understanding how ecosystem processes are being influenced by disturbances. With the remotely sensed data, we can produce the appropriate map to represent the landscape composition. Landscape metrics were calculated for the segmented areas of homogeneous land use in the watershed in order to allow the understanding and characterization of the ecosystem. Therefore, the present study focuses on detecting the structures of landscape patterns that are affected by natural disasters.

Methods and Materials

Study Area

Chen-Yu-Lan Watershed, The area of study, is located in the upper reaches of Choahui River in central Taiwan as shown in Figure 1. The topography of the watershed of the study area 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 Chen-Yu-Lan 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 prairie. The middle and lower reaches of the Chen-Yu-Lan 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 Chen-Yu-Lan Watershed has created a variety of landscape mosaics.

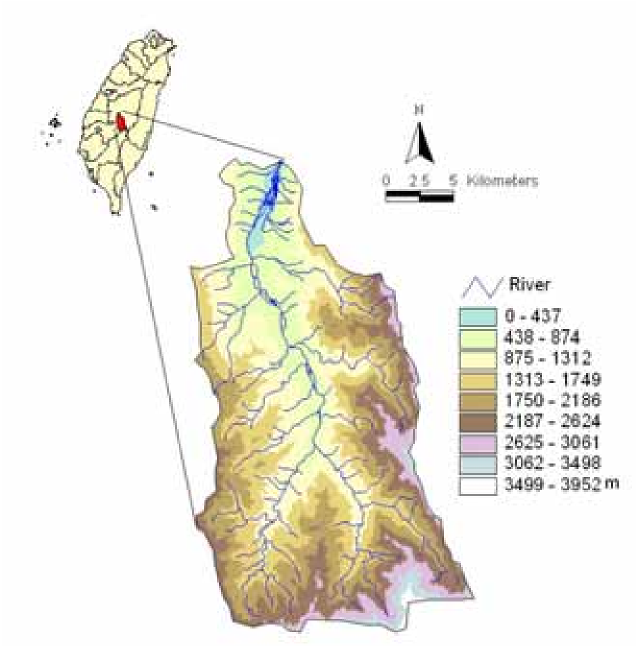


Figure 1. The site location map of Chen-Yu-Lan Watershed.

Natural disturbance

So far in this 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 biggest impact from among the major disaster events in the Chen-Yu-Lan Watershed (Lin and Jeng, 2000, Chu, et al., 2004; 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 km. 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 1986.5 mm and 687.5 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 earthquake, a 7.3-magnitude earthquake, with epicenter located around the Chi-Chi Town in Nan Tou County, occurred in the early dawn on September 21, 1999. It resulted in more than 24,000 fatalities and losses amounting to billions of dollars due to the destruction and damage

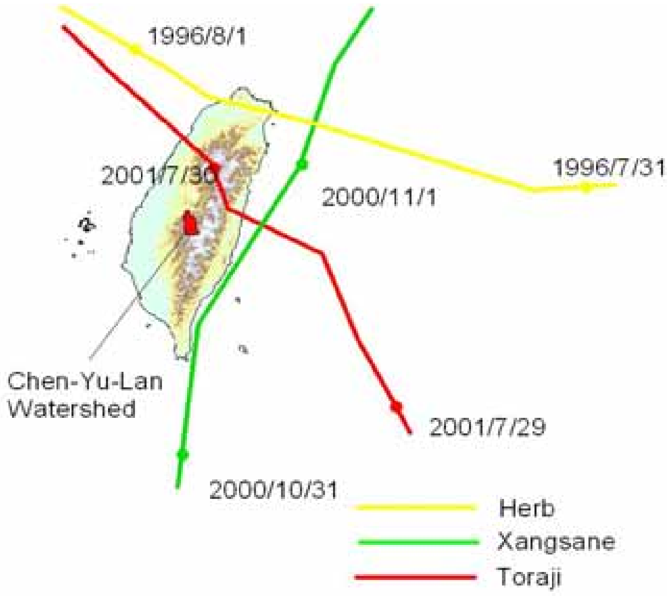


Figure 2. The routes of typhoons Herb, Xangs, Toji.

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 is one of the 6 most earthquake-prone areas in the world, because it is situated on the borderland between the Eurasian Plate and the Philippine Sea Plate. When most of the people in Taiwan had already fallen in sleep at 1:47 in the dawn on September 21st, 1999, the island was hit by an earthquake measuring 7.3 on the Richter Scale, and the epicenter was located at 12.5 kilometers southwest of Sun Moon Lake in Nantou County (Figure 3). According to experts, the maximum vibration acceleration reached up to 989 gal. The quake resulted in more than 2,400 deaths and over 8,700 injured. About 50,000 homes collapsed. 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.

Table 1 Accumulated rainfalls (unit: mm)

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

Source: Central Weather Bureau, www.cwb.gov.tw

Remotely Sensed data source and Image Classification

Five cloud-free SPOT images of the study area were acquired, and they were dated as 1996/11/08, 1999/03/06, 1999/10/31, 2000/11/27, and 2001/11/20 from the Center for Space and Remote Sensing Research (CSRSR), National Central University. Figure 4 shows that the relationships between the SPOT images and the disturbances. All images have been geometrically corrected by the CSRSR. The image classification and accuracy procedures used in the present study were performed with the ERDAS Imagine 8.5 (Leica, 2001). The present paper applies the supervised classification (maximum likelihood method) to classify the conditions in land use/land cover, and then to integrate the spectral characters and GIS data obtained by knowledge-based systems in order to increase classification accuracy and categories. Assisted by field inspections, the accuracy of the classified results was evaluated against the 1999 aerial photographs. A total of 727randomly selected pixels were used for the evaluation of the classified results. The accuracy assessment shows that the overall accuracy of the classified images is at least 90% while the Kappa reached 0.8.

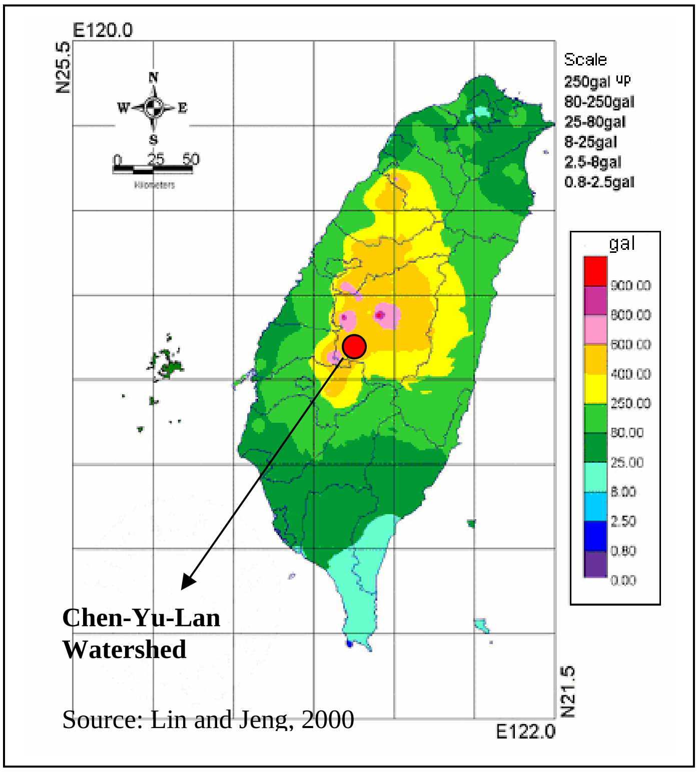


Figure 3. The disturbance of Chi-Chi earthquake.

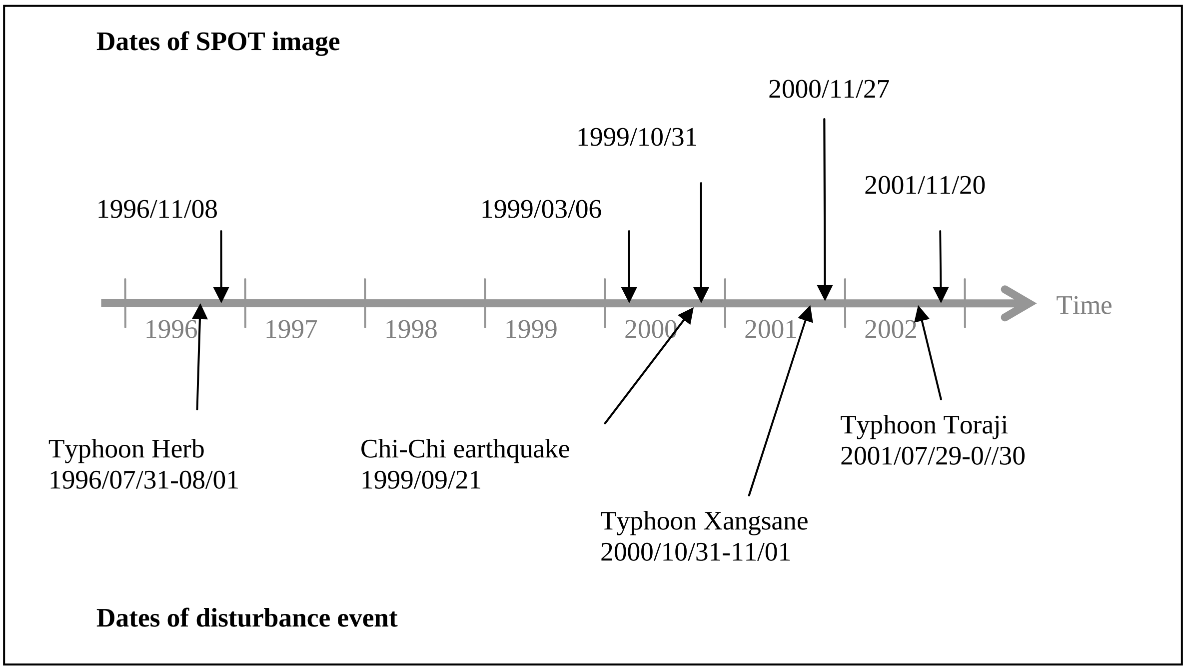


Figure 4. The relationship between the SPOT images and the disturbances.

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

Landscape Metrics

Appropriate landscape pattern indices were chosen, shown as 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). For each metric, the mathematical formula is described in narrative terms to facilitate interpretation of the formula.

(1) $$MSI = \frac{\sum_{j=1}^{n}\left(\frac{0.25 p_{ij}}{\sqrt{a_{ij}}}\right)}{n_i}$$

(2) $$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}\left(\frac{1}{10000}\right)$$

(3) $$ED = \frac{\sum_{k=1}^{m'} e_{ik}}{A}(10000)$$

(4) $$MPS = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}\left(\frac{1}{10000}\right)$$

(5) $$SEI = \frac{-\sum_{i=1}^{m}(P_i \ln P_i)}{\ln m}$$

(6) $$MPFD = \frac{\sum_{j=1}^{n}\left(\frac{2\ln(0.25)p_{ij}}{\ln a_{ij}})\right)}{n_j}$$

(7) $$AWMPFD = \sum_{j=1}^{n}\left[\left(\frac{2\ln p_{ij}}{\ln a_{ij}}\right)\left(\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}\right)\right]$$

(8) $$SDI = -\sum_{i=1}^{m}(P_i \ln P_i)$$

(9) $$IJI = \frac{-\sum_{k=1}^{m'}\left[\left(\frac{e_{ik}}{\sum_{k=1}^{m'} e_{ik}}\right)\ln\left(\frac{e_{ik}}{\sum_{k=1}^{m'} e_{ik}}\right)\right]}{\ln(m'-1)}(100)$$

(10) $$\text{MNN}= PRD = \frac{m}{A}10^6 \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} h_{ij}}{N'}$$

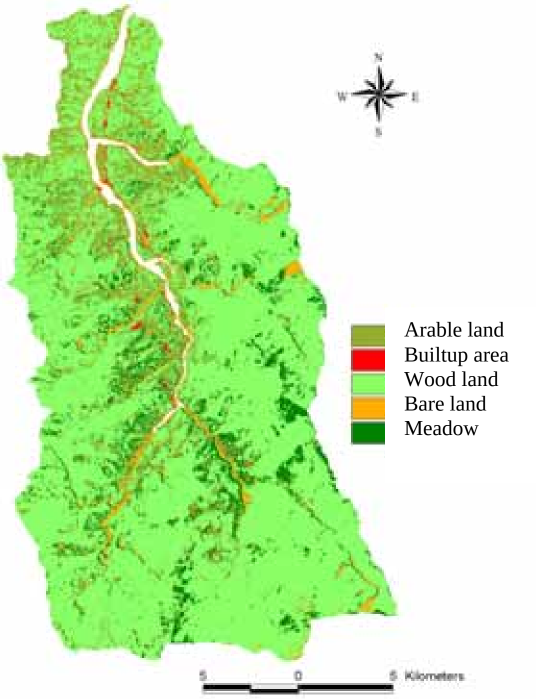
Where are (a)A, Total landscape area (m^2).(b) aij , area (m^2) of patch ij.(c)pij, perimeter (m) of patch ij.(d)E, total length (m) of edge in landscape; includes entire landscape boundary and background edge segments regardless of whether they represent true edge.(e) eik , total length (m) of edge in landscape between patch types (classes) i and k; includes landscape boundary segments representing

true edge only involving patch type i.(f)N, total number of patches in the landscape, excluding any background patches.(g)N , total number of patches in the landscape that have nearest neighbors.(h)nij, number of disjunct core areas in patch ij based on specified buffer width (m).(i) hij, distance (m) from patch ij to nearest neighboring patch of the same type (class), based on edge-to-edge distance.

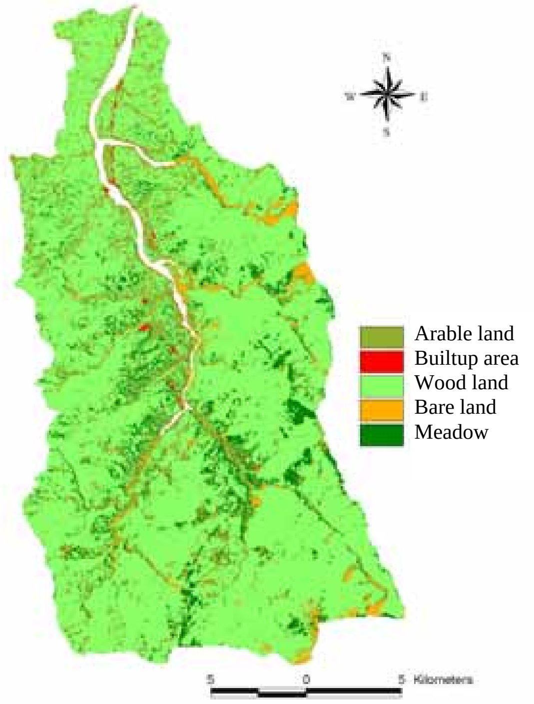
Results and Discussion

The land cover compositions

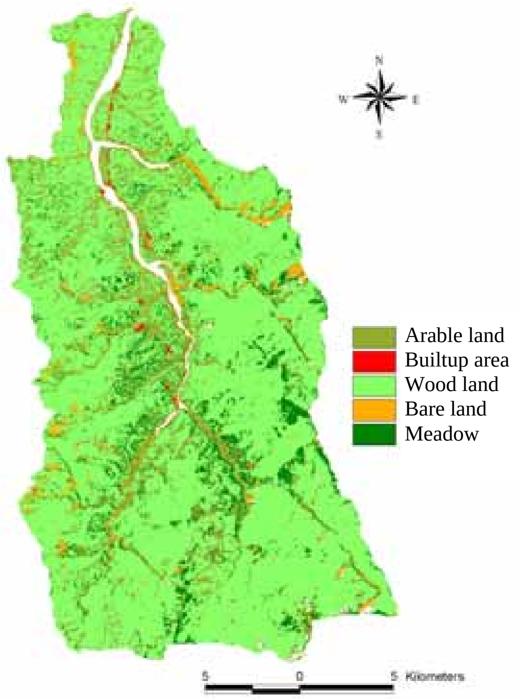
The separation of the different land uses and land cover classification is the first objective on the basis of special structure. There are five categories of land covers. Figure 5 shows an example of the area of study for the five categories: arable land, built-up area, wood land, bare land, and meadow. The details of each category per classified image are accounted for in Table 3.



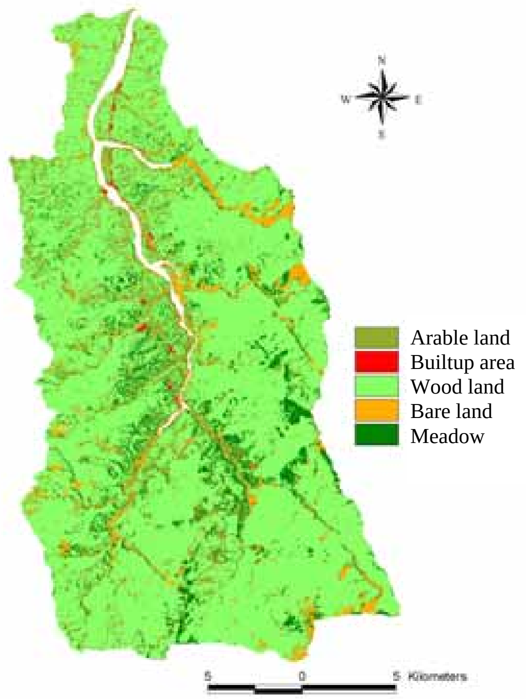
(a) 1996/11/08



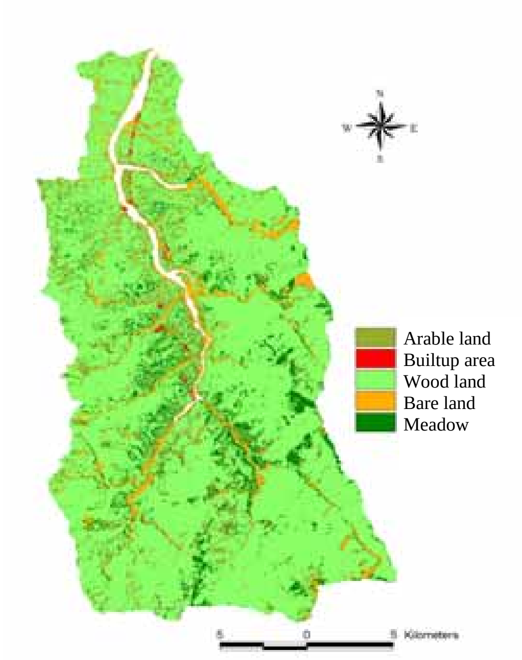
(b) 1999/03/06



(c) 1999/10/31



(d) 2000/11/27



(f) 2001/11/20

Figure 5. (a)~(f) The classified SPOT images taken on the five different dates.

Table 3. Classified SPOT images taken on the five different dates.

Category	1996/11/08			1999/03/06			1999/10/31		
	Pixels	Area	%	Pixels	Area	%	Pixels	Area	%
Wood land	2093479	327.106	74.2%	2125282	332.075	75.4%	2099225	328.004	74.4%
Meadow	249196	38.937	8.8%	239053	37.352	8.5%	251407	39.282	8.9%
Arable land	380114	59.393	13.5%	356098	55.640	12.6%	345529	53.989	12.3%
Built-up area	17491	2.733	0.6%	17491	2.733	0.6%	17491	2.733	0.6%
Bare land	76508	11.954	2.7%	81976	12.809	2.9%	87415	13.659	3.1%
Unclassified	3112	0.486	0.1%	0	0.000	0.0%	18833	2.943	0.7%
Sum	2819900	440.61	100%	2819900	440.61	100%	2819900	440.61	100.0%

Category	2000/11/27			2001/11/20		
	Pixels	Area	%	Pixels	Area	%
Wood land	2106609	329.158	74.7%	2119256	331.134	75.2%
Meadow	241368	37.714	8.6%	238940	37.334	8.5%
Arable land	321869	50.292	11.4%	300683	46.982	10.7%
Built-up area	17491	2.733	0.6%	17491	2.733	0.6%
Bare land	129537	20.240	4.6%	142230	22.223	5.0%
Unclassified	3026	0.473	0.1%	1300	0.203	0.0%
Sum	2819900	440.61	100%	2819900	440.61	100%

Landscape metrics and landscape pattern change

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 4 and Figure 6. 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) (Figure 6(a)), 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)

(Figure 6(b)) 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.

Detecting the patch shape change after the disturbance, the present study calculated the mean patch fractal dimension (MPFD), mean shape index (MSI) , area weight mean patch fractal dimension (AWMPFD), and area weight mean shape index (AWMSI), as shown in Figure 6(c), 6(d) and Table 4.

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.

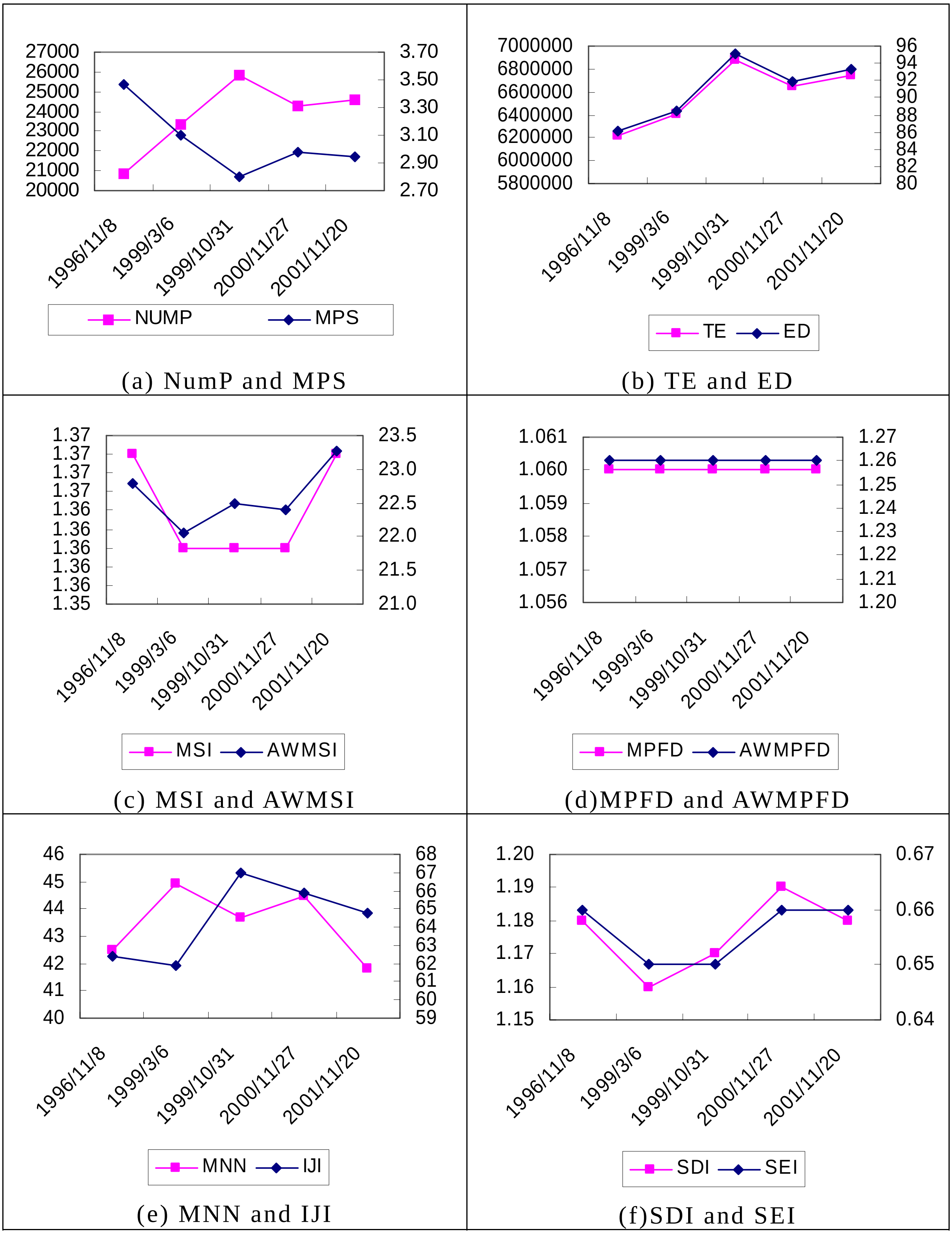
Mean nearest neighbor (MNN) is a measure of patch isolation. It is the distance between an individual patch to the nearest neighboring patch of similar type (edge-to-edge). Smaller values of class MNN indicate that the patches of similar types are closer or clustered together, while the larger values 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) as shown in Figure 6(e). It means that both the erosion due to heavy rainfalls and destruction of the landscape configuration due to earthquake can split the patch into sub-patches 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. In the present study, the IJI have the same trends as the MNN. As a consequence, the results show that some new patches have been created in the area of study. The patches were shrunk and fragmented due to the disturbances, and extended by means of self-restoration.

Table 4 The results of landscape metrics.

Indices \ Date	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

In the heterogeneous landscape, we calculated the Shannon’s diversity index (SDI) and Shannon’s evenness index (SEI). Both landscape metrics showed similar trends. However, the Chi-Chi earthquake disturbance was the turning point of the trends in the heterogeneous landscape as depicted in Figure 6(f). 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.



(a) NumP and MPS

(b) TE and ED

(c) MSI and AWMSI

(d)MPFD and AWMPFD

(e) MNN and IJI

(f)SDI and SEI

Figure 6. The trends of landscape metrics.

Conclusions and future work

In the present study, a technique was characterized to quantify spatial pattern from remote sensing data, for describe the changes of the land use and land cover, and their structures. Besides, this 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.

This study detected the transition of the landscape as a result of natural disturbances successfully. Results of the studies represented the ecological resilience of the Chen-Yu-Lan Watershed. For realizing the ecological process and landscape health unambiguously, investigation is needed to obtain more biotic and abiotic information and integrate this information into the landscape pattern. In this way, more efficient solutions can be proposed for watershed management and ecological conservation.

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Application of Ecotechnoloy to Houfanzikeng Creek Improvement

Wen-Sheng Liang, Ph. D., P.E.

I. Introduction

Houfanzikeng Creek is located at Shuangxi, Taipei County with a drainage area of 376.12ha and total length of 1.25km, as shown in Figure 1. The annual precipitation in the basin is more than 3,000mm, and therefore heavy rainfalls usually bring large amount of runoff and sediment from the watershed during typhoon events, and causes severe damages to adjacent areas. The Soil Conservation Bureau decided to improve a reach of the Houfanzikeng Creek using ecotechnological methods in 2003, and became a demonstration project of Ecotechology Exposition of 2003.

Fig. 1 Houfanzikeng Creek

II. Houfanzikeng Creek Prior to Improvement

As shown in Figure 2, Houfanzikeng Creek is a small mountain creek having 2~3m of bottom width and approximately 6m of top width. The bed material is mainly boulder of approximately 20~30cm in diameter. Both banks are natural without protection, the proposed 250m improvement reach are protected by rock protection works.

Fig. 2 Houfanzikeng Creek Prior to

III. Improvement Works

1. Length of improvement: 250m
2. Cross section
   (1) Widen bottom width from 2~3m to 4m.
   (2) Widen top width from 6m to 9m.
3. Bank Protections
   (1) The left bank along the reach upstream of Shenlong Bridge, the existing rock bank protection work was preserved due to limited land available, however wood piles were used for toe protection.
   (2) The existing rock protection work along the right bank upstream of Shenlong Bridge was removed and replaced by stepped bank protection work using wood piles and native vegetations.
   (3) Both banks along the reach downstream of Shenglong Bridge, the existing rock protection works were removed and replaced by sloped bank protection using wood piles and native vegetations.
4. Bed stabilizations: eleven (11) arched grade control structures were constructed using boulders found in creek bed to reduce flow velocity and create habitats.

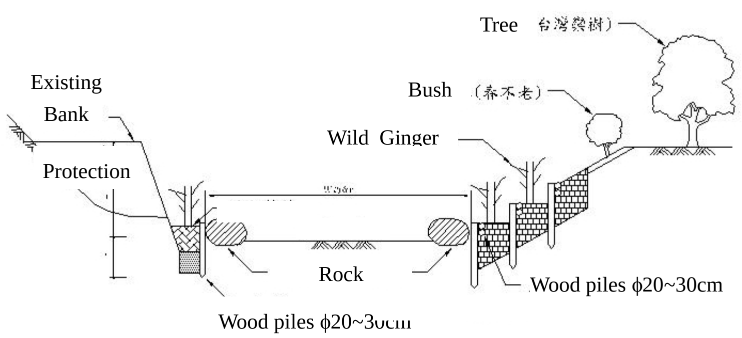


Fig. 3 Improved Section U/S of Shenlong Bridge

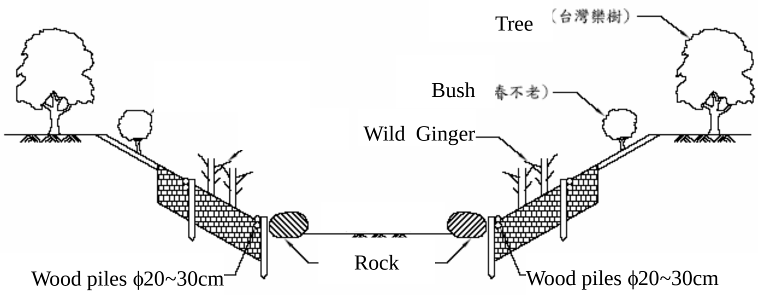


Fig. 4 Improved Section D/S of Shenlong Bridge

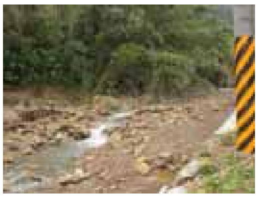
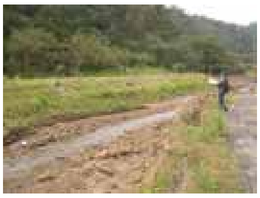
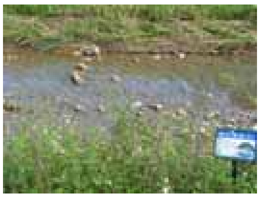
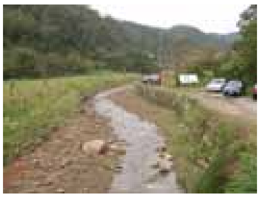
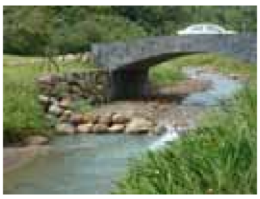
Fig. 5 Typical Grade control Structure

IV. Post Construction Observation

1. Flood Events Experienced in Year 2004

Date	Max. Rainfall Intensity (mm/hr)	Return Period (year)	Peak Discharge (cms)	Average Velocity (m/s)
8/25/04	65	2	24.71	3.08
9/11/04	56.5	2	26.04	3.15
10/25/04	109.5	25	55.08	4.20

2. Houfanzikeng Creek After Flood Events

6/29/04	8/25/04	9/17/04	11/02/04
			
			
			
			
			
			
			

3. Discussion

After flood events in year 2004, the improved reach of Houfanzikeng Creek has suffered some damages, however the improvements have met most of ecotechnology requirements.

(1) The bank protection measures using wood piles and native vegetation have stabilized channel banks except two locations along outer banks of curved channel (U/S of grade control structure No.1 and the reach between grade control structures No.9 and No.10). It indicated that wood piles with vegetation might not able to resist flow impact along outer bank of curved channel along Houfanzikeng Creek.

(2) The native vegetations along bank toe were bended to form a protection layer to reduce bank erosion potential.

(3) Most of the grade control structures were damaged or buried after the flood event on 10/25/04 because of rocks were not properly placed and the fluvial processes of the channel bed were not considered in the design stage. The improved channel has been gradually changed back to its original shape. It is believed that grade control structures are not needed in Houfanzikeng Creek expect for creating habitat.

♦ Bended Vegetation

♦ Channel prior to Improvement

♦ Improved Channel after flood events in year 2004

(4) Based on ecological survey results, the construction of improvement works have only minor impacts to the ecological environments. The survey results have also indicated that ecological system has recovered gradually.

V. Restoration Works

1. Rocks of suitable size was recommended to place at two damaged outer banks for bank protection.

♦ Restored U/S Outer Bank

♦ Restored D/S Outer Bank

2. Wood piles and vegetation that were washed out during flood events were restored using same materials.
3. Four (4) grade control structures have been restored for educational purposes.

♦ Restored No.2 Grade control structure

♦ Restored No.8 Grade control structure

Workshop of Best Management Practice

The Editorial Department

Date and Time: 8:30am-12:00pm, 11/07/2005 (Monday)

Location: Conference Hall, 5F of Civil Engineering building, National Taipei University of Technology

Speakers:

1. Dr. Mow-Soung Chen
   PG County Department of Environmental Resources
   Prince Georges's County Department of Environmental Resources, Maryland, USA.

2. Prof. Shaw L. Yu
   Dep. of Civil Engineering, The University of Virginia, USA.

Sponsors: Water Environment Research Center, NTUT, Taiwan.

Agenda

Time	Topic	Speakers & Chairman
08:30~09:00	Check in	
09:00~10:20	BMP Decision Support System BMPDSS phase I	Dr. Mow-Soung Chen
10:20~10:40	coffee break	Dr. Mow-Soung Chen
10:40~12:00	BMP Decision Support System BMPDSS phase II	Dr. Mow-Soung Chen
12:00~13:00	lunchtime	
13:00~14:30	Application of BMPs Tool Box	Prof. Shaw L. Yu
14:30~14:50	teatime	
14:50~15:30	Discussion	Prof. Jen Yang Lin WERC, NTUT

The workshop of "Best Management Practice" was sponsored by Water Environment Research Center, NTUT. We invited Dr. Mow-Soung Chen who came from the institution where the BMP modules were developed. The researches of BMP have been developed much more and become more important in the water resources management field. Dep. of Civil Engineering of The UVa has emphasized the researches and applications of BMPs for years, so we were lucky to have Pro. Shaw L. Yu giving us the speech about "Application of BMPs Tool Box". Most participants were very enthusiastic in response to the workshop. The participants were from many universities like NTU, NCHU, NTOU, etc., and also from many government institutions and private companies.


Dr. Mow-Soung Chen from Maryland, USA.


Prof. Shaw L. Yu from the UVa, USA.


Situation of enthusiastic participation


The discussion was still hot even after end of the workshop

2005 Conference of Water, Environment and Community

The Editorial Department

Date and Time: 8:30am-5:00pm, 10/22/2005 (Saturday)

Location: The Third Conference Hall, B1 of Comprehensive building, National Taipei University of Technology

Sponsors: Water Environment Research Center, NTUT, Taiwan.

Water Resources Agency, Ministry of Economic Affairs.

This year is the fifth year of the "Conference of Water, Environment and Community" with a traditional feature that the public were taken as the principle topics in this conference. Following the tradition, we had 3 main issues including "Water Sources Environment Conservation and Construction", "Cooperation with NGO and the Public", and "The Public's Participation to the Water Resource Environment Conservation", and there were 9 topics of speeches presented and discussed. In the first issue, we had some academic topics about "Water and Green, Theory and Practice of Ecological Landscape", "Sustainable Environment: Urban Drainage Work", and "Landscape and Vegetation Conservation in Wetland". In the second issue we had some more active presentation by NGOs, including elementary students and teachers, etc. And in the third issue we shared some success results of the past cases in Da-tuen creek, Ba-li park and Shanmeidana valley. The contents of this conference were diverse and interesting. There were more than 140 people participating in this conference, and they showed enthusiastic and positive response to this successful conference.

Time	Issue		Chairman
08:30-09:00	Check in		
09:00-09:10	VIP Speech	Water Resources Agency, Ministry of Economic Affairs	Chih--Hong Huang Chairman, Dep. of Architecture, NTUT
09:10-09:40	Special Issue	《The NGO Participation with General Development in the Network Generation 一for Water Resources in Taiwan》 Jen-Shiou Lin	
09:40-10:00	Coffee Time		
10:00-12:00	Water Resource Environment Conservation and Development Wei-Ta Fang, Kuang-Yen Cheng, Shin-Hwei Lin		Cheng-Daw Hsieh Division Director, Conservation Division, WRA
12:00-13:00	Lunch Time		
13:00-15:00	Cooperation with NGO and the Public Yung-Kuen Wu, Association of Keelung City Neighborhood Concern, Wu Gu Junior High School		Kuang-Hui Peng Professor and Dean, Colledge of Design, NTUT
15:00-15:10	Tea Time		
15:10-16:30	Water Resource Environment and the Public Participation Mao-Shin Lin, Yung-Jaan Lee		Jiann-Hsing Wu Secretary, Taipei County Government
16:30-17:00	Discussion		Jen-Yang Lin Director, WERC, NTUT.

The conference hall at the Comprehensive building

Tieh-min Lee, Deputy Chief Engineer of WRA, are giving a VIP's speech.

The chairman,.Jen-yang Lin, the professor of Civil Engineering Dep. of NTUT.

The participation and discussion condition during the conference

Manuscripts Submission Guidelines

Journal Content

The Journal of Ecotechnology will publish (1) academic papers in watershed management or ecological engineering, (2) description of local or international meetings or activities, (3) case studies, (4) technical reports, and (5) review articles. Fields of interest include, but not limited to, hydrology, water and soil conservation, ecology, vegetation engineering, environmental engineering, and civil and hydraulic engineering.

1. **Language**: All manuscripts must be submitted in English. The manuscript title, authors, affiliation, and abstract should also include a Chinese translation.
2. **Format**: Manuscripts shall be typed in Times New Roman, 12-point font. Please submit both a Document (.DOC) file and a Portable Document Format (.PDF) file for editing purposes.
3. **Figures**: Please do NOT reduce the resolution of illustrations. If illustrations were not included in the text files, please send them separately with at least 300 dpi resolution.

Manuscripts Submission

1. Please submit your manuscripts by E-mail if the file size is less than 10 MB.
   E-mail to: jauntysl@gmail.com
2. Please submit your manuscript stored in CD-ROM disks by mail if the file size is larger than 10 MB.
   Mail to: Miss Jaunty Liu
   Water Environment Research Center,
   National Taipei University of Technology
   No. 1, Sec. 3, Chung-hsiao E. Rd. Taipei, Taiwan, R.O.C. 10608

Note

The editors of the J. of Ecotechnology have the rights to edit manuscripts submitted for publishing. If authors do not wish their manuscripts to be edited, please specify. Manuscripts will not be returned whether the articles are published or not, unless requested by the authors at the time of submission.

稿約

稿件內容

廣邀各界撰寫有關水庫集水區、生態工法之學術論文，以及國內外地方或國際性、學術或工程界活動報導、案例介紹均可，領域包含水保、水文、生態、植生、環工、土木、水利等相關領域，凡符合此主題之學術論文、技術報告、理念介紹、文獻回顧等論述，皆歡迎來稿。

來稿須知

1. 本期刊投稿撰寫一律以全英文稿為限，惟論文題目與作者名、機關名、摘要均請同時並列中英文。
2. 稿件一律橫寫，以 MS WORD 格式之電腦文書軟體編輯，全文統一字體大小 12，字型 Times New Roman，各標題並請盡量勿套用特殊格式，以利編輯小組調整。
3. 投稿請一併附上 Document (.DOC) 檔案以及 Portable Document Format (.PDF) 檔案，以利本期刊編輯小組編輯。
4. 圖表若非附於文章內，請另附清晰之圖片檔案(300 dpi 以上)，連同光碟寄至本期刊編輯小組。

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1. 小於 10MB 之檔案，可以 E-mail 寄至 jauntysl@gmail.com
2. 將光碟檔案寄至 10608 台北市忠孝東路三段一號
   台北科技大學土木館三樓 水環境研究中心 劉儀如小姐 收

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