Detection and Monitoring of High Economic Return Crop Growth Expanding for Watershed Area at Central Taiwan

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Abstract

The slopeland development which attracting the farmers to plant the Betel nut crop in order to get higher economic return has expanded widely in recent year especially at Central Taiwan area due to the mild weather and fertilized soil.

This research detected and monitored the land development changes at Shu-Li River watershed that locates at central Taiwan and consists of three reservoirs and one amendment pond. The study used Geographic Information Systems (GIS) , Remote Sensing (RS), Global Positioning System (GPS) techniques, and Universal Soil Loss Equation (USLE) to estimate the soil erosion caused by Betel nut expanding. By identifying the internal and external cost for this watershed area, the non-market numerical economic cost and benefit value for the influence by this high economic return crop can be examined. This survey can replace the traditional on-site surveying with time and labor consuming and can provide a decision reference for local government for watershed management.

Introduction

Slopeland counts for two thirds of the total land in Taiwan. Due to the rapid economic growth, the flat areas were full developed as urban land use and reduced the arable land area. There is a tendency to expand the development toward slopeland or even mountain area. From economical incentives, the result's impact has caused the suffering and degrading of the environment. Illegal or over-limited land use at sloped land area are a common phenomenon at Taiwan area and danger the sustainability of sensitive slope land.

The concentrated precipitation from May to August brought almost 80 percent of the annual rainfall amount for Taiwan island. Along with the natural geologic steep relief for most river watershed, it is significant important for soil conservation and water preservation. In recent years, Betel nut has become one of rapid expanding crop growth material at many slopeland areas. The geographically over-limited Betel nut planting created high revenue for the farmer and satisfied the consumer. The negative impact to the environment and water resources can never be ignored.

According to recent Taiwan Agricultural Yearbook, the Betel-nut planting area has reached totally 44671 hectare, which is over 1 percent of the total island area. The output income from Betel nut production in 1971 was 78,835 thousand dollars, and it reached to 10,310,025 thousand dollars in 1993. This output becomes the most important crops besides rice production in Taiwan.

With the expanding of Betel nut planting area and the annual raise of productivity, the increasing concern about the soil and water conservation impact has become one of the major environmental issue. Among these figures, the Betel nut's planting area on slopeland has exceeded 40 thousand hectares. Pin-Ton, Chia-Yi, and Nanto are three major suppliers of Betel nut production area in Taiwan, which inherited the tendency to totally replace the fruit or tea farm. This study examined the ground truth by classified Landsat TM image and surface DGPS operation at Shu-Li river watershed in Nanto county. A GIS database was composed from geographic, geologic, hydrologic, and social-economic data of this watershed area to assist the extraction of Betel nut crop growth characteristics for accurate image classification. The output result can supply the information to watershed management institute.

One of the focused issue in this study was satellite image classification. One to five thousand scaled aerial photo was used as the reference information for Landsat TM image classification accuracy examination. Ground surveying by the aided of GPS and Differential GPS (DGPS) was performed to extract the surface soil erosion simulation parameters.

Background

Shu-Li river watershed locates at the center of Taiwan, consists an area of 7400 hectare. The elevation is between 373m and 1390m. Classified Landsat TM image shows on figure 1. There are three reservoirs with power plants, and one amendment pond in this study area. Warm Climate composes the annual average temperature around 21 degree centigrade.

Bamboo, fruit trees and Betel nut are three dominated vegetation in this area. Among that cash crop growth, because of the suitable temperature and rainfall condition, as well as the ease for harvest and high economical return, Betel nut has become the majority crop in this watershed. The expanding of Betel nut growth area created several serious problems for the Shu-Li River watershed. From on-site research, Chen (1994) pointed out the Betel nut is not a good land cover vegetation for soil conservation practice.

Farming activity on slope land developments not only enhance the water evaporation, increase runoff and soil erosion, but also lower the ground water level and degrade the nature environment. At the first growing stage of Betel nut crop growth, the huge slope land development could cause significant damage for soil and water conservation and raise soil erosion rate. It's also been reported for the micro climate changes due to the over development of natural forest.

USLE & RUSLE are the most important model in soil erosion research. In USLE model application, Hu(1993) researcher estimated the hydrology and erosion impact from Betel nut farming at Lien-Hua-Chi area. In RUSLE model application,

Hung(1992) and Chui (1992), demonstrated the process to estimate soil erosion for a specific watershed. In showing the capability of combining USLE and RUSLE with GIS application, Lua(1990) and Cheng(1994), simulate soil erosion for Chi-Lung River Basin and used GIS to evaluate the impact to erosion due to large area slope land development. As proved, USLE & RUSLE model are empirical model from field experiments, which restrain the real world application. In order to accurate estimate the soil erosion from that model, it is necessary to extract sufficient parameters for model calibration and validation. Fang (1993) and Wu(1994) has examined the parameter for Taiwan area from a series of field experiments and the comparison of model prediction result. In worldwide, there are also many researches in theory or application experiments by the assist of GIS linkage with soil erosion prediction, such as "A Land information system for soil erosion control planning", to specify ownership and location of parcels rates of soil erosion, and in order to establish priorities for controlling soil erosion etc.(Ventura S.J., 1988), "Revised universal soil loss equation" to know the development of RUSLE From USLE (Renard K.G., 1991), "Using the erosion production impact calculate (EPIC) model to estimate the impact of soil erosion", to know the model and to simulation the soil

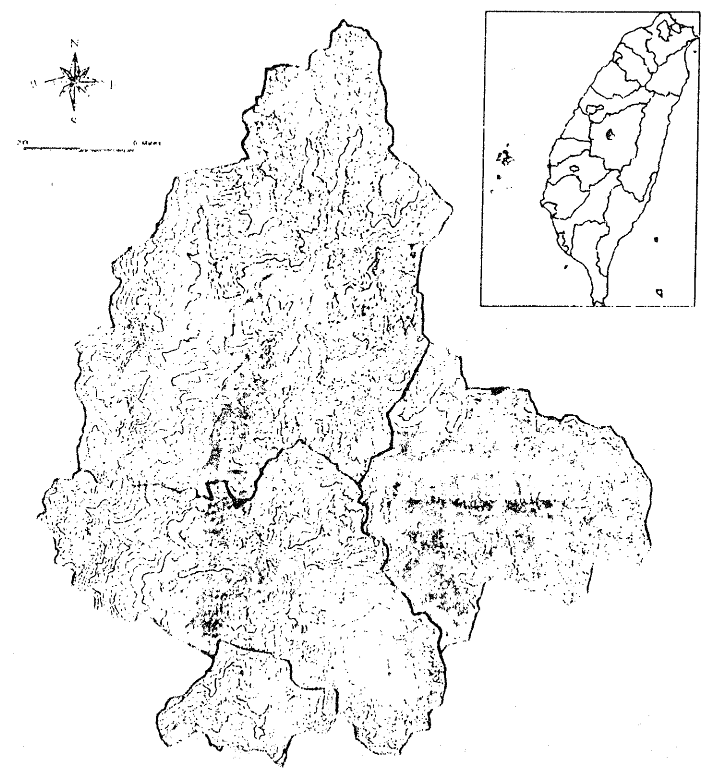

Figure 1. Landsat TM image for study area

climate plant
process in agriculture production and to estimate the impact of soil erosion on resource productivity (Putman J., 1988).

Many researches concluded the modified slope factor has the characteristics of complexity and most hydrologists suggested to put the value of one as slope factor when using RUSLE model. This paper also assign the value of one to the slope factor of RUSLE model.

USLE（Universal Soil Loss Equation）

USLE model has been developed through 40 year's experiments in USA. Parameters in this model were extracted from standard field scale. The standard site is 22.13 meter long with average 9% in slope, and plowing toward up and down direction, composed by uniform soil profile. The equation can be shown as:

$$A = RKLSCP$$

where：

A = computed average soil loss per unit of area, expressed in units selected for K and for period selected for R. In practice these are usually so selected that they compute A in tons per acre per year.

R = rainfall and runoff index- the number of rainfall erosion index units plus s factor for runoff snowmelt or applicde, where such runoff is significant, for suiting the condition in Taiwan, Domestic scholars Huang in 1979 studied R factor for Taiwan area according to geographic characteristics for local condition. He established average R factor contour map for whole Taiwan island using nonlinear regression equation and the relationship between average rainfall and R factor. The reference figure shows as figure 2.

K = soil erodibility factor—the soil loss rate per erosion index unit for a specified soil as measure on a unit plot, the reference value shows as Figure 3.

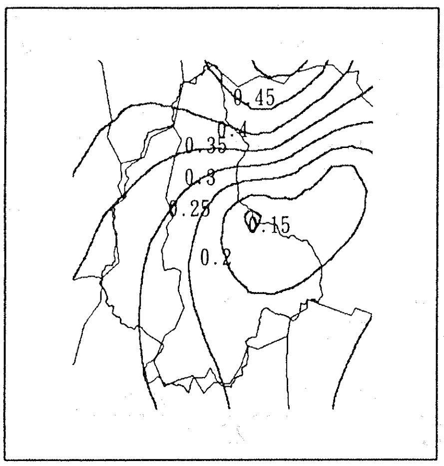

Figure 2 The K value reference figure

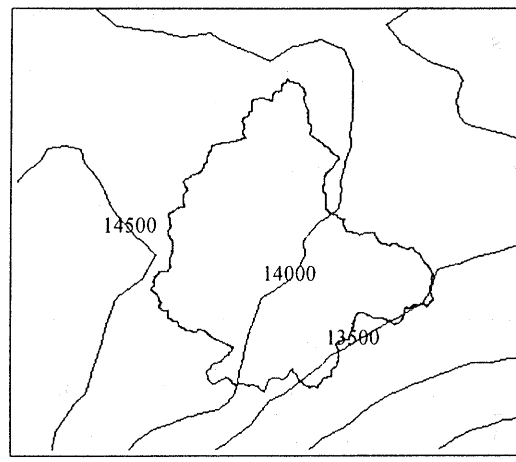

Figure 3 The R value reference figure

L = slop length factor—the ratio of soil loss from the field slope length under the unit plot conditions as above.

S = slope steepness factor—the ratio of soil less from the field slope gradient under unite-plot conditions.

Slope length and steepness is recorded by soil map unit area on aerial photographs, and can be interpreted from soil maps for farm planning purposes to help control erosion. Steeper slopes have greater soil erosion potential because runoff is more rapid, and longer slopes have more water-gathering capacity to move larger volumes of sediment. Slopes can be made shorter and less steep with terraces.

This study produced slope and aspect information from ten meter contour line and on Figure 5. through digitizing transfer into Vector file and using the GIS to generate the slop and aspect date.

Table 1. The C & P reference value

	C Value	P Value
Forest	0.01	0.01
Betel nut	0.025	0.14
Urban	0.01	1
Bare 、 Collapsed	1	1
Water	0	0

C = cover and management factor—the ratio of soil loss from an area with specified cover and management to that from a unit plot in tilled continuous fallow. This study extracted land cover factor as shown from Table 1., which consider classified landcover type and other references.

P = supporting practice factor, the ratio of soil lost with a support practice, like contouring, stripcropping, or terracing to that with straight row farming up and down the slop. This study established P value from many previous reports and references as shown on table 1.

Economic

Although there were many discussions about the affect on soil erosion caused by Betel nut farming activity. None of those papers evaluated the external cost and the degrading of social welfare which not been covered by most of the farmers. Still, there are lots of models relating to the evaluation of external cost for non market value from Environmental Economics and Environmental Impact Assessment theory. This study used produces materials and real market price for labor cost to count the change of goods price. Real market value from environmental protect facilities were evaluated to count the prevention, updating, and shadow cost for soil and water conservation facilities. The idea for counting the economic externality is strategically try to internalize the cost been paid by social welfare and eliminate the free rider for soil erosion. The result from these non market price evaluation methods are described as following:

Table 2 The internal and external cost of the Betel nut (dollars / hectare)

items	internal cost	external cost		
	benefit	prevention	Recovering	Shadow engineer
Average	221800	490.8	671.9	2279.5

During the analytical of Shui-Li River watershed, the benefit goes to the farmer's part will be covered by the social "worse off" payment where the prevention, recovering, and shadow engineer costs. Still, in the study, some of the important externalities has not been input as the calculation for externalities, such as the micro climate changes due to the over development of natural forest land, the impact on water quality and quantity, the change of the diversity of animal. The summing up for all these cost should go much higher than the estimation from table 2

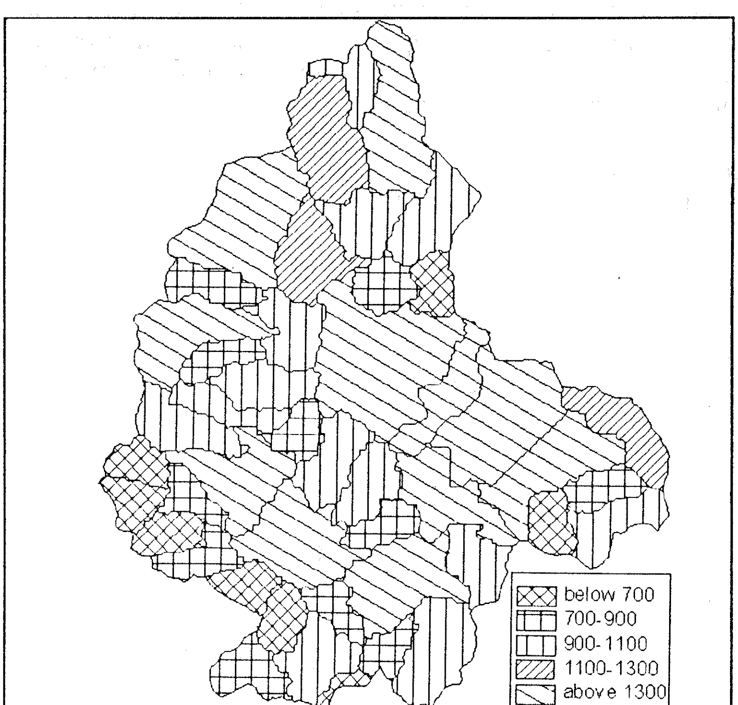

Figure 4. The Slope Length figure

Discussion and Conclusion

In the past, the studies of watershed land use/cover monitoring were based on analog data. Coarse accuracy, low compatibility and high time and money consuming, and the lack of updating capacity were the major obstacle of those data been used for environmental monitoring system. Although the field surveying technique can cope with the low accuracy issue, but it can not be used for large area investigation due to the time and money consuming.

This study applied the means of Geographic Information System (GIS) and Remote Sensing techniques for this study area. Land utilization patterns can be easily classified from satellite image. Ground information were as well other watershed information can also easily be converted into digitized data for overlay analysis and hydrologic analysis. The impacts of Betel nut crop on social-economic at this study area were examined. One of the major contribution of this paper is the evaluation of externality cost where most of the previous discussion has been ignored. This paper found the externality cost for soil erosion prevention can not be paid back from the local farmer's benefit. The watershed manager should also put this result as the consideration for better environment management.

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