THE INTEGRATION OF SATELLITE IMAGE AND GIS DATABASE FOR MOUNTAIN AREA LAND USE MONITORING

Hsueh-Cheng Chou, Associate. Professor, Dept. of Geography, National Taiwan Normal University, Taiwan, R.O.C.
Tien-Yin Chou, Associate Professor, Dept. of Land Management, Feng Chia University, Taiwan, R.O.C.

KEY WORDS: Land_Use, Monitoring, Database, GPS

ABSTRACT

The Der-chi watershed experienced a conflict between water resource sue and farming practice. This research used remote sensing technique image to produce urgently needed land use data for land use management. The rugged terrain in this region caused great variations in spectral value of satellite images. Band ratio and two sets of training sites, one for the shadowed region and another for the unshaded regions, were used to classified the images. Satellite images and other data are put into a coherent environmental database using GIS data integration capability. A decision support system was build based on the database to help decision makers better understand the situation of environment and making better decisions.

INTRODUCTION

The 60,000 hectare Der-Chi Reservoir Watershed is the most important water resources for central Taiwan. Because its altitude, the climate of the region is similar to temperate zone. It has become the major framing areas for temperate fruits and vegetables in Taiwan since 1970s. Many sloped lands had been transformed into farm lands in the two decades. The farming practice on these sloped lands had long been suspected to induce serious soil erosion and to create eutrophication in the reservoir. The conflict been these two types of land use had created extensive debate among local interest group, academic community and policy makers.

Although many data had been collected by various agencies in the past two decades, these data have not been integrated in a coherent manner to support scientific study and policy making. In this research, GIS, GPS and Remote Sensing techniques were used to construct an environmental monitoring database and to develop an environmental decision support system. It is hoped that the database and the system will help scientists in studying this area and assist decision makers to better manage the Der-Chi area.

RESEARCH PROCEDURES

The research consisted of three phrases: Satellite Image analysis, environmental database construction and environmental decision support system development (figure 1).

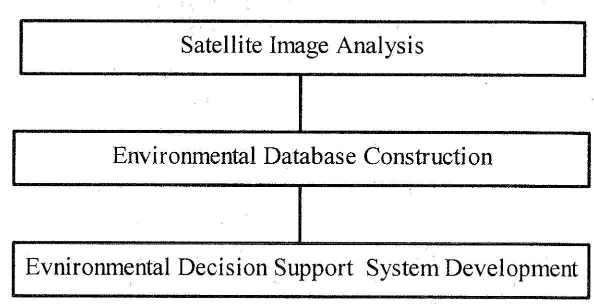

Figure 1 Research Procedures

The first phrase of this research was to determine whether satellite images were suitable for producing land use data for environmental monitoring. If satellite images had proven to be useful, a standard procedure for processing satellite image would be proposed for continuous monitoring.

In addition to the image data, other data were digitized from paper map or converted from digital sources. The quality of these data had been cross checked. Field survey was taken to further verify the data. The data was then put into an environmental database.

After the database is constructed, an environmental decision support system was built using Arcview and Avenue in MS window environment. The purpose of the system was to assist researchers and decision makers query and retrieve data from the database and to perform analysis on these data.

SATELLITE IMAGE ANALYSIS

Using satellite image to detect land use changes has the advantages of lower cost and shorter processing time over aerial photograph interpretation and field investigation.

Another advantage of using satellite image over field survey for Der-Chi area is that satellite images can be received and processed without the interference of local interest groups.

Image Source

The satellite receiving facilities in Center of Space and Remote Sensing Research at Central University receives SPOT, LANDSAT and ERS data regularly. This assured the data availability for the research and for future monitoring. SPOT images were preferred than LANDSAT images because SPOT had better spatial resolution. Two images were chosen for the study, one was taken on December 30; 1993 and the other was taken on January;7 1995.

Preprocessing

ERDAS's imagine software was used in this research to process satellite images. The images were geocoded to Transverse Mercator projection. The RMS error for the registration was 1 to 2 pixels, or 20 to 30 meters. 40m DTM was used to produce ortho Satellite images.

Land Use Classification

This research was interested in distinguishing between natural vegetation and different types of framing and in identifying landslides.

First, unsupervised classification were used to uncover the nature categories in the images. The results indicated that the rugged terrain of the research area caused large area within shadow. The shadow regions' spectral characteristics were very different from those of the unshaded regions. Several research had proposed methods to resolve this problem (Golby 1991; Hodgson and Shelley 1993, Michael 1993). The band ratio method was chosen for this research. To further increase the accuracy of classification, two sets of training samples are chosen for the shadow regions and unshaded regions respectively for performing supervised classification.

In order to reduce the effect of shadow and distinguish different types of vegetation, a variety of vegetation Indices, such as IR-R, IR/R and (IR-R)/(IR_R) were tested. The IR-R and IR/R indices were used to classified the 1993 and 1995 image respectively. Because the correlation between the G and the R channel was very high (0.99), the R channel was not used. Vegetation index, G and IR channels were used for supervised classification.

The classification scheme must be reliable and met the requirements for policy makers. After several trail classifications, a classification scheme was derived for the research (figure 2).

The 1993 image was taken during a serious drought period. Large area of river beds and river banks was

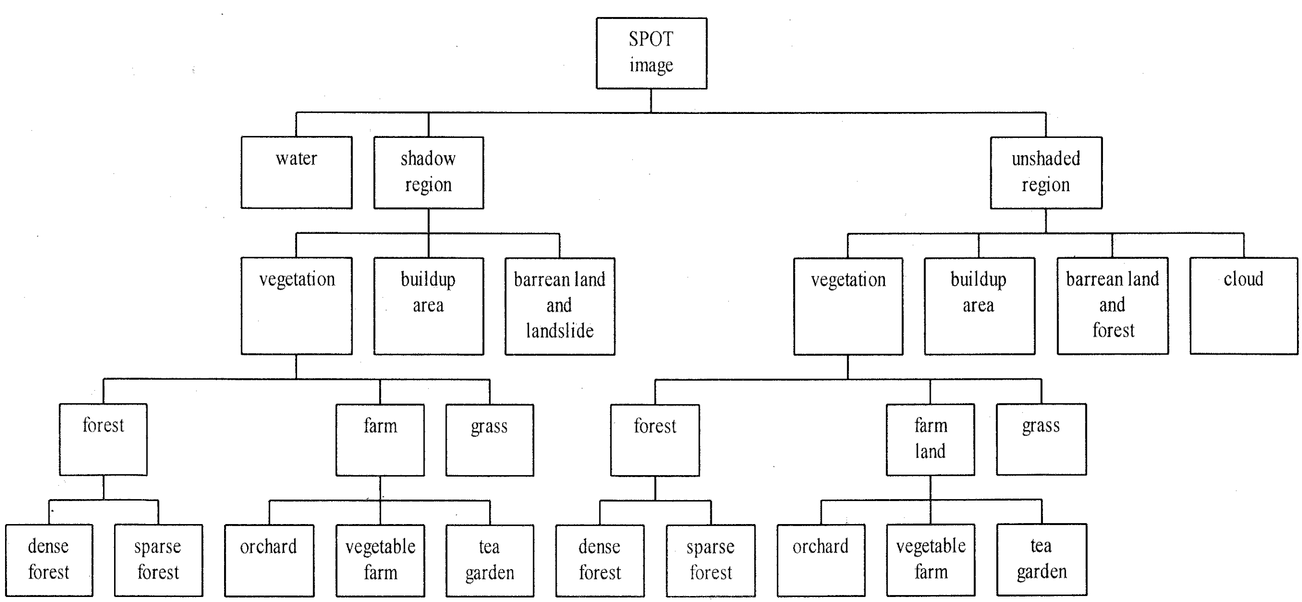

Figure 2 Classifiction Scheme

Table 1 Land Use Changes

Landuse	1993 hectare	%	1995 hectare	%	change hectare	%
dense forest	53,314.50	88.6	52,759.30	87.7	-555.2	-1.0
scattered forest	2,057.80	3.4	2,250.00	3.7	192.2	9.3
orchard	1,353.70	2.2	1,755.40	2.9	401.7	29.7
vegetable farm	222.2	0.4	542.9	0.9	320.7	144.3
tea	2	0	8.1	0	6.1	305.0
grass	582.5	1	624.7	1	42.2	7.2
buildup area	22.6	0.1	25.8	0.1	3.2	14.2
barren land and landslide	1,106.10	1.8	1,250.90	2.1	144.8	13.1
water	864.2	1.4	822.3	1.4	-41.9	-4.8
cloud	629.8	1.1	114.1	0.2	-515.7	-81.9
total	60,155.30	100	60,155.30	100		

exposed. These dry river beds were very easily confused with landslides along the river bank. A method was devised to handle this problem. The area occupied by normal river flow was digitized from 1:10000 topographic maps and used to mask the 1993 and the 1995 images.

Possible training sites for supervised classification were first identified on Arial photos and topographic maps. Field survey was taken to check the ground truths and to select final training sites. Training sites are chosen based on their representative and accessibility. Differential GPS were used to record the exact location of these training sites.

The results of supervised classifications were checked by field investigations.

Land Use Change Analysis

The results of the classification are shown in Table 1. The vegetable farm increased from 222.2 hectare to 542.9 hectare. The orchard increased from 1353.7 hectare to 1755.4 hectare. Forest reduced 555.2 hectare. These figures indicated that farming practice was still increasing during the study period. The vegetable farm used large quantify of fertilizer and pesticide that could pull the river. The dramatic increase in vegetable farm should be closely monitored.

The increase in barren land and grass was due to two forest fires happened on December1994 and January 1995.

The analysis results have shown that satellite images could be very effective in monitoring the land use changes in Der-Chi watershed. The procedures developed in this research could be used for processing satellite images for land use monitoring.

Environmental Database Construction

The satellite images and other data were used to setup an environmental database for the Der-Chi area to support future researches and environment management tasks. Although, many data had been collected by forest services, bureau of soil conservation, Taiwan power company, bureau of aborigine management, national park services, environmental protection agency and local government These data were stored at each organization and had not been organized into a coherent database. In this research, these data were converted into a standard digital format and formed an integrated database.

The database is consists of three data sets: the physical environmental data set, the cadastral data set and image set (figure 3).

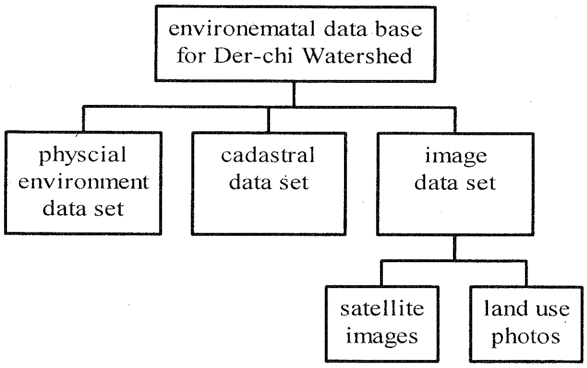

Figure 3 environmental database structure

Physical Environment Data Set

Geological, 40m EDM, forest stands and land use data were in digital format. These data were converted into Transverse Mercator projection, which was the standard projection for Taiwan. A boundary coverage of Der-Chi watershed, which was digitized from 1:10000 topographic maps, was used to clip these data to ensure they had the same spatial coverage.

Sub-watersheds for the area were delineated manually using 1:100000 topographic maps and digitized. The coverage was cross checked with the DEM data.

Several data layers were generated using ARC/INFO functions. Taiwan's soil conservation regulations use soil depth and slope as key factors in determining land use restriction for sloped land. The soil coverage was derived for soil sample points using kriging. The DEM was used to generate a TIN for the region. Slope coverage was then derived from the TIN.

A 100 meter protection zone around the reservoir was generated using buffer function.

Cadastral Data Set

Cadastral data record the ownership and the zoning restrictions for each parcel and is a vital part of the environmental database for decision support.

The cadastral information of Der-Chi watershed consisted of 189 cadastral maps and related records. These maps were based on a local coordinate system. No exact mathematical relationship existed between the coordinate system and Transverse Mercator coordinate system, which was used for other data.

Several steps had been taken to integrate these maps with other data. First, a set of points was identified on the cadastral maps as candidate control points. The positions of these candidate points were located in field and differential GPS was used to obtain the coordinates of these points. Finally, these control points were used to transform the cadastral maps. The accuracy of the transformed cadastral maps was checked by overlapping the roads and rivers on cadastral maps and those on the physical environmental data set. The results indicated that the transformed cadastral data was suitable for environmental monitoring purpose.

Image Data Set

Image data set includes two types of data. The first type is satellite images, including raw images and classified land use maps. The second type is photos taken in the field to record land use. The photos were scanned and stored in jepg format.

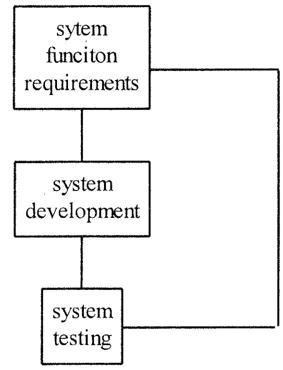

Figure 4 Monitoring System Development Procedures

Environmental Decision support System Development

The purpose of the environmental monitor system was to build a decision support system which enables researchers and land managers to query and retrieve information from environmental database and to perform analysis required by management tasks. The procedures used to develop the system is shown in Figure 4.

First, a series of interview with agencies involved in the land management of the Der-chi area was taken to understand each agency's responsibility and requirements.

The results of interview were used to formulate the initial system function requirements. The system was developed according to these requirements. The system was delivered to the agencies and tested. Feedback from users was use to modified the system

The system is developed using Arcview/Avenue in MS Window environment. All functions are menu or icon driven. The system is still under development. At the present, the system includes the following modules.

Data Access and Data Management

Users could retrieve data by various location schemes, such as political boundaries, sub watershed units, parcels, or by subjects, such as geology, land use, slope and soil.

The system uses optical disks to store large quantity of image data. The information on these optical disks is an integrated part of the database system and can be accessed easily from query menu. New images can be added to the image database quickly.

Map Production

The system provides predefined layouts for map and/or attribute data output. Users can quickly generate maps and reports to be used in the field or as presentation materials.

Summary Statistics Calculation

The system can generate summary statistics which would help land managers better comprehend the situation of the Der-Chi area. Better management decisions can thus be made.

Land Management Functions

Several functions directly related to land management tasks have been implemented.

For example, by combining land use data and zoning restriction data, land manager can quickly identify which parcels do not follow the zoning restrictions. These areas could then be targeted for law enforcement.

Another example is that land within the reservoir's protection zone should be purchased and land managers must estimate how many funds are required. Overlaying reservoir protection zone with cadastral data could easily find out how many private properties are within the protection zone and the funds required to purchase they could be estimated.

Conclusion

This study has shown GIS GPS and Remote Sensing technologies are power tools in assisting management Der-Chi watershed. Remote Sensing images can be used to generate land use data in a cost-effective way. A procedure for generating land use data from SPOT images for monitoring land use changes in Der-Chi watershed is developed.

The GPS technology can provide accurate location in field investigations. To know the accurate position of object is important for integrating spatial data. Differential GPS is necessary to achieve the accuracy required by land management tasks.

The GIS technology is used to integrate data from different agencies into an environmental database. A decision support system is developed based on the database.

Reference

Golby, J.D., 1991. Topographic Normalization in Rugged Terrain. Photogrammetric Engineering and Remote Sensing. 57(5), pp. 403-410.

Foody, G. M. et. al., 1992. Derivation and Applications of Probabilistic Measures of Class Membership from the Maximum-Likelihood Classification. Phtogrammetric Engineering & Remote Sensing. 58(9).

Hodgson, M. E., and Shelley, B. M., 1993. Removing the Topographic Effect in Remotely Sensed Imagery. ERDAS Monitor, fall 1993.