Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore.

THE USE OF A KNOWLEDGE-BASED DECISION RULE COMPUTER PROGRAM IN THE INTER-ANNUAL LAND COVER AND LAND USE CHANGE ANALYSIS OF THE UPPER MAGAT WATERSHED

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KEY WORDS: land cover and land use change, watershed, programming

ABSTRACT: Radiometric correction was difficult to perform on imageries of mountainous areas where atmospheric and climatic data were difficult to obtain, because of the absence of weather stations. It was a general knowledge that the classification of the non-radiometrically corrected imagery resulted to misclassifications, low accuracy and inconsistencies. From these problems, the objectives of this study were drawn, namely: to utilize a knowledge-based decision rule program to improve the accuracy and assist in the pre-analysis of non-radiometrically corrected land cover and land use data. The study site was the Upper Magat Watershed, Province of Nueva Vizcaya, Philippines. Eight sets of Landsat TM data taken from 1988 to 1998 were used as inputs to the project. The raw imageries were geometrically rectified, and classified image mosaics were produced. A Turbo Pascal Program was created with a set of knowledge-based decision rule criteria. The classified imageries were used as input to the program and the result was a new set of classified imageries. Cross-tabulation of the classified imageries and those refined by the computer assisted program was performed. Confusion matrices of the 1998 classified imageries were generated. Results of the cross-tabulation showed that the classified imageries refined by the computer program had no incidence of invalid change results unlike the classified imageries produced without the assistance of the knowledge-based computer program. Also, its classification accuracy was higher than that of the imageries produced without the assistance of the computer program. We therefore conclude that the use of knowledge-based decision rule computer programs to assist the standard classification procedures improved the accuracy of the land cover and land use data and the consistency of the land cover and land use change results.

INTRODUCTION

One of the major applications of remote sensing is in resource management. Resource management can be effectively implemented if the resource manager has an idea of the rate at which land cover and land use changes over time and what land uses are dominating and which ones are decreasing. Land cover and land use change analysis is done using time series analysis of imageries of an area taken at different dates. Data that are ideal for time series analysis are data taken at the same date of different years. This will somehow minimize the effect of seasonal variation on the time series analysis.

The land cover and land use change case study of the Upper Magat Watershed (LCLUC) is unique from the other land use change studies because it utilized inter-annual satellite data that are taken at different dates of the year, from 1988 to 1998. With such numerous data and with the absence of atmospheric data to perform radiometric correction, problems in the classification and change analysis arose. Problems like low classification accuracy and invalid change results are difficult to re-analyze and solve with numerous imageries. Programming using knowledge-based decision rule has done a lot of help in solving these problems. It scanned for invalid change results and vegetative growth patterns and compared the imageries automatically. It adjusted classes that were not apparent on some imagery through image comparison. It also performed value masking for null-valued pixels due to shadows and clouds.

OBJECTIVE

The objective of this study was to utilize a knowledge-based decision rule program to improve the accuracy of non-radiometrically corrected inter-annual land cover and land use data and the consistency of the inter-annual land cover and land use change results.

STUDY BACKGROUND

Study Background

This study is a sub-component of the Land Cover and Land Use Change Case Study (LCLUC) Phase II. The main objective of the LCLUC is to study land cover and land use changes using remote sensing, geographic information system and socio-economic analysis. The project has two study sites, the Upper Magat Watershed in the Province of Nueva Vizcaya and Puerto Princesa City in the Province of Palawan.

Study Site Background

The study site has an area of 229,100 ha. It is situated in the northern portion of the Philippine Archipelago covering major portions of the Province of Nueva Vizcaya. **Figure 1** shows the location map of the study site. The Province of Nueva Vizcaya is composed of fifteen municipalities namely: A. Castaneda, Ambaguio, Aritao, Bagabag, Bambang, Diadi, Dupax del Norte, Dupax del Sur, Kasibu, Kayapa, Quezon, Sta. Fe, Solano, Villa Verde and its provincial capital, Bayombong. Its population during the 1995 survey made by the regional office of the National Statistics Office was 335,221. The economy of the study site is agriculture-based. Crops like rice, corn, root crops, vegetables and fruits are the major domestic products. Farmers also engage in swine and cattle production.

Figure 1: Location Map of the study site

METHODOLOGY

Satellite Image Digital Processing

Landsat TM imageries taken from different dates were rectified, classified and mosaicked. The list of imageries used is presented in **Table 1**.

Cross-tabulation

Cross-tabulation of imageries of different dates yielded different change classes that can either be valid or invalid. The invalid change results posed a problem in change analysis. **Table 2** shows the matrix of cross-tabulation results.

To make a meaningful change analysis, the invalid change results were corrected on the classified imageries. This was the point where programming became very useful to automate the correction process.

Table 1. List of LANDSAT TM imageries used for the Upper Magat Watershed.

TM Scenes	Date Taken
K116-J48 and K116-J49	January 31, 1988
K116-J48 and K116-J49	April 10, 1990
K116-J48 and K116-J49	March 30, 1992
K116-J49	April 2, 1993
K116-J48	May 20, 1993
K116-J48 and K116-J49	August 11, 1994
K116-J49	March 25, 1996
K116-J48	July 29, 1996
K116-J48 and K116-J49	October 22, 1997
K116-J48 and K116-J49	January 10, 1998
K116-J48 and K116-J49	March 18, 1999

Table 2. Matrix of cross-tabulation results for the Upper Magat Watershed.

		TO[1]							
		Built	**Agri**	**Dipt**	**Brush**	**mossy**	**Grass**	**Bare**	**River**
FROM	**Built**	Valid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
	Agri	Valid	Valid	Invalid	Invalid	Invalid	Valid	Valid	Valid
	Dipt	Valid	Valid	Valid	Valid	Invalid	Valid	Valid	Invalid
	Brush	Valid	Valid	After 7 yrs	Valid	Invalid	Valid	Valid	Invalid
	Mossy	Valid	Valid	Invalid	Valid	Valid	Valid	Valid	Invalid
	Grass	Valid	Valid	After 10 yrs	after 3 yrs	Invalid	Valid	Valid	Valid
	Bare	Valid	Valid	Invalid	Invalid	Invalid	Valid	Valid	Valid
	River	Invalid	Invalid	Invalid	Invalid	Invalid	Valid	Valid	Valid

[1]Built stands for built-up, agri stands for non-tree agriculture, dipt stands for dipterocarp, brush stands for tree plantation/secondary forest, grass stands for grassland, bare stands for bareland and river stands for water body

Programming

The program to automate the correction process was created using a Turbo Pascal software. The matrix of cross-tabulation results became the basis for the decision-rule in the program. The program checked if the resulting change between two imageries of different dates was valid or not. If it was valid, the class value was retained. If it was not, the class value on the latter image was changed to a value hierarchically closest to the class on the first image to produce a valid change result. **Table 3** shows the change relation or matrix of change of classes given the FROM image and TO image.

In land cover and land use change, the major concern were the floras that grow and develop over time. The capability to search for vegetative growth patterns is one of the characteristics of the knowledge-based decision rule computer program. The assumptions used for vegetative growth are presented in **Table 4.**

The classified imageries were all inputted to the program. In order to simplify the change analysis, the resulting classes were merged. For example, the built-up and bareland were merged together as built-up/openland and the dipterocarp and mossy as forest. Accuracy assessments on the 1998 classified imageries were performed both on the imageries refined by the knowledge-based decision rule computer program and those produced without the assistance of the computer program. Final cross-tabulations were performed on the knowledge-based classification-assisted imageries to countercheck the results.

Table 3. Matrix showing the possible land cover change from the FROM (old) Image to a TO (new) image.

		TO[1]							
		Built	**Agri**	**Dipt**	**Brush**	**Mossy**	**Grass**	**Bare**	**River**
FROM	**Built**		**Built**	**Built**	**Built**	**Built**	**Built**	**Built**	**Bare**
	Agri			**Agri**	**Agri**	**Agri**			
	Dipt					**Dipt**			**Brush**
	Brush					**Dipt**			Grass
	Mossy			**Mossy**					**Mossy**
	Grass					**Grass**			
	Bare			**Grass**	**Grass**	**Grass**			
	River	**Grass**	**Grass**	**Grass**	**Grass**	**Grass**			

[1]Built stands for built-up, agri stands for non-tree agriculture, dipt stands for dipterocarp, brush stands for tree plantation/secondary forest, grass stands for grassland, bare stands for bareland and river stands for water body

Table 4. Matrix of assumptions used for vegetative growth searching.

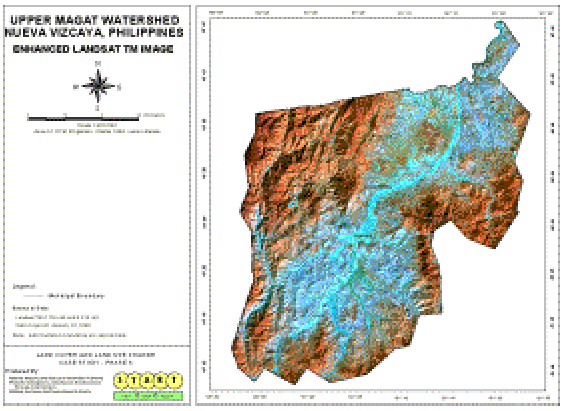
	TO[1]		
FROM		**Dipt**	**Brush**
	Brush	After 7 yrs	
	Mossy		
	Grass	After 10 yrs	After 3 yrs

[1]Dipt stands for dipterocarp, brush stands for tree plantation/secondary forest, grass stands for grassland

RESULTS AND DISCUSSION

The satellite imageries

The enhanced 1998 Landsat TM imagery of the project area is presented on **Figure 2** and the classified image on **Figure 3**.



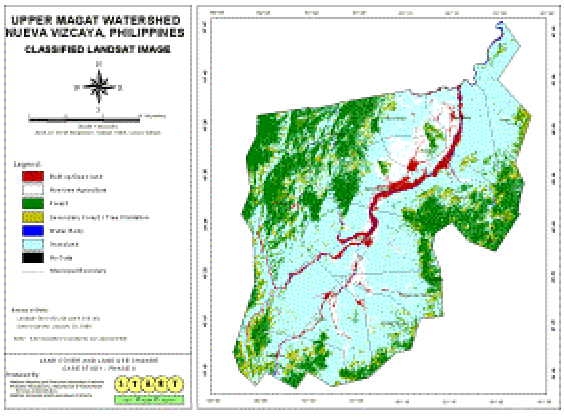


Figure 2: (left) The 1998 enhanced Landsat TM imagery of the Upper Magat Watershed.
Figure 3: (right) The 1998 classified Landsat TM imagery of the Upper Magat Watershed.

Increased Classification Accuracy

The confusion matrices of the classified imageries either verified by the knowledge-based decision rule computer program or not are shown in **Tables 5** and **6**. As indicated in these tables, it is clear that the use of knowledge-based decision rule computer programs to assist standard classification procedures improved the accuracy of the classified image of the Upper Magat Watershed.

The improved accuracy of the knowledge-based classification assisted imageries can be explained by how the knowledge-based decision-rule program behaved. The program did not just examine a particular image at a particular time but considered the past imageries to check and compare conditions. Features that are not so apparent on a particular image due to poor atmospheric conditions were identified through and extracted from the other clear imageries.

Table 5. Confusion Matrix of the 1998 classified imageries produced without the aid of a knowledge-based computer program. Based on 1998-1999 ground-verified data.

Image Data	**1999-2000 Ground Verified Data**							Total	Number of Omission	Error of Omission	Classification Accuracy
	Built-up/ Openland (1)	Non-Tree Agric. (2)	Forest (3)	Secondary Forest/ Tree Plantation (4)	Grassland (5)	Water Body (6)	Clouds/ Cloud Shadows (7)				
Built-up/Openland (1)	5							5	0	0	100
Non-Tree Agriculture (2)		7						7	0	0	100
Forest (3)			1	2	2			5	4	80	20
Secondary Forest/Tree Plantation (4)				4				4	0	0	100
Grassland (5)				5	8			13	5	38.46	61.54
Water Body (6)						1		1	1	100	0
Clouds/Cloud Shadows (7)											
Total	5	7	1	11	10	1		**74.29**			
Number of Commissions	0	0	0	7	2	0					
Error of Commission	0	0	0	63.64	20	0					

Table 6. Confusion Matrix of the 1998 knowledge-based decision rule classification-assisted Imageries. Based on ground-verified data.

Image Data	**1999-2000 Ground Verified Data**						Total	Number of Omission	Error of Omission	Classification Accuracy
	Built-up/ Openland (1)	Non-Tree Agriculture (2)	Forest (3)	Secondary Forest/Tree Plantation (4)	Grassland (5)	Water Body (6)				
Built-up/Openland (1)	5						5	0	0	100
Non-Tree Agriculture (2)		7					7	0	0	100
Forest (3)			1	1	1		3	2	66.67	33.33
Secondary Forest/Tree Plantation (4)				4			4	0	0	100
Grassland (5)				5	9		14	5	35.71	64.29
Water Body (6)						1	1	0	0	100
Total	5	7	1	10	10	1	**79.41**			
Number of Commissions	0	0	0	6	1	0				
Error of Commission	0	0	0	60	10	0				

Land Cover/Land Use Change Result Consistency

It was observed that with the use of knowledge-based decision rule computer programs to assist standard classification procedures, invalid change results such as those presented on **Table 2** were corrected. The program also placed class values on areas that were null-valued such as those with cloud shadows, clouds and terrain shadows.

Two types of invalid change results were detected on the data. The first was the highly improbable change result such as built-up to agricultural. It is highly improbable to tear down a house just to plant agricultural crops. The second was the invalid change result due to the absence of data such as forest to null value or vice versa. Such absence of data could be due to the presence of clouds on the raw image. In these two instances, the program behaved differently. If it encountered the former, it changed the class value on the second image to a value

hierarchically closest to the class value on the first image to make a valid change result. If it encountered the latter, the null value assumed the non-null value of the other image.

CONCLUSION

The results showed that the use of knowledge-based decision rule computer programs improved the classification accuracy of the imageries and corrected the invalid change results.

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ACKNOWLEDGEMENTS

The authors would like to thank the following:

Jesus Christ and God Almighty
PSCTRD-DOST
The Philippines LCLUC Team
Bobby A. Crisostomo, Flaviana D. Hilario, Alma SM. Arquero, Marvilyn Palaganas, Solita O. Castro, Victorino A. Bato, Bonifacia B. Daet, Benjamin P. Balais,
Ernestine Gayban, Sunday S. Lingad, Evangeline T. Saracanlao,
Crescencia T. Cadiente, Elena A. Reyes, Aileen H. Argente, Joselito Bernanrdo,
Francis Canonoy
Basic Remote Sensing Initiative, Department of Geography, Michigan State University, USA
SARCS-START