Assessment Of Land Use Cover Change Detection Using Supervised Maximum Likelihood Decision Rule And Its Post-Classification Technique In Puer-Simao Counties, China

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Abstract: From the Post classification technique, the forest or shrub land decreased marginally to about 66% and 53% in 2002 and 2005 respectively of the total area, while the built up land increased and occupied 20 and 41 % respectively. The agricultural land slightly increased in 1999-2002. The areas covered with forest or shrub land and unused land were receding at an average rate of 06 and 05% per annum respectively, while the built up, water and agricultural land cover types were expanding at rates of 11, 08 and 05% per annum respectively over the years period. Furthermore, the from- to change matrix showed that the most significant changes in the area were in the period 1999-2005, from Forest or shrub land into built-up land (20012 ha), from Forest or shrub land into Unused land (18032ha). In the period from 1999 to 2002 the most important changes were from vegetation into built-up (17223 ha) and from Forest or shrub land into unused land (15600 ha). In the period from 2002 to 2005 the most noticeable change was from Forest or shrub land into built-up (9800 ha).
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Key words: change detection, land use cover change (LULCC), Maximum likelihood, Post-classification

1. Study Statement

Land use-land cover (LULC) classification and change detection has been one of the first and most critical applications of remote sensing to produce thematic maps (Foody 2002). LULC assessment is one of the most important parameters to meaningfully plan for land resources management. Its inventories are assuming increasing importance in various resources sectors like agricultural planning, settlements surveys, environmental studies and operational planning based on agro-climatic zones.

Classification method of three Landsat images 1999, 2002 and 2005 is carried out by using Maximum Likelihood method and. Maximum Likelihood algorithm is the most widely used of supervised classification algorithms (Wu and Shao, 2002; McIver and Friedl, 2002).

Most of studies have addressed that post-classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes (Mas et al 2004, Yuan et al. 2005). However, selecting high-quality and sufficiently numerous training sample sets for image classification is often difficult, in particular for historical image data classification. The time consuming and difficult task of producing highly accurate classifications often leads to unsatisfactory change detection results, especially when high-quality training sample data are not available. The aim of this study is to detect land use cover change in Puer-Simao mountainous counties using LandSat TM imagery according to the objectives as follows: to assess LUC change using Maximum Likelihood method as supervised classification algorithms. In the previous studies many others change detection methods were used, i.e. NDVI and topographic methods using DEM data (Diallo et al., 2009), Decision tree algorithms using data stacking method (Diallo, 2009).

The rest of the paper is organized as follow: section two presents the study material and our proposed methods; Section three presents our findings; Section four presents our discussions and finally section five conclusions.

2. Material And Methods

2.1 Study Area

The study was conducted in Puer and Simao, two counties of the southern part of Yunnan Province. The area is situated between Longitudes 100°20′ 07”-101°36′17” E and Latitudes 22°49’32”- 22°52′11” N (Figure 3-1). Puer, called Simao before January 21, 2007 is a major town with a population of 75000 persons. Simao Metropolitan County contains four urban townships, two rural townships and two ethnic rural townships. The climate is subtropical monsoon without hot summers or harsh winters. The mean annual temperature range is between 15°C and 18°C, while the mean annual rainfall of the area is around 1200 to 1400 mm. It is neither extremely hot in summer nor terribly cold in winter. The topography is extremely irregular. The major landforms are mountains, highlands, small basins and valleys. The vegetative cover is of the type of savanna or tropical arid shrubby steppe.

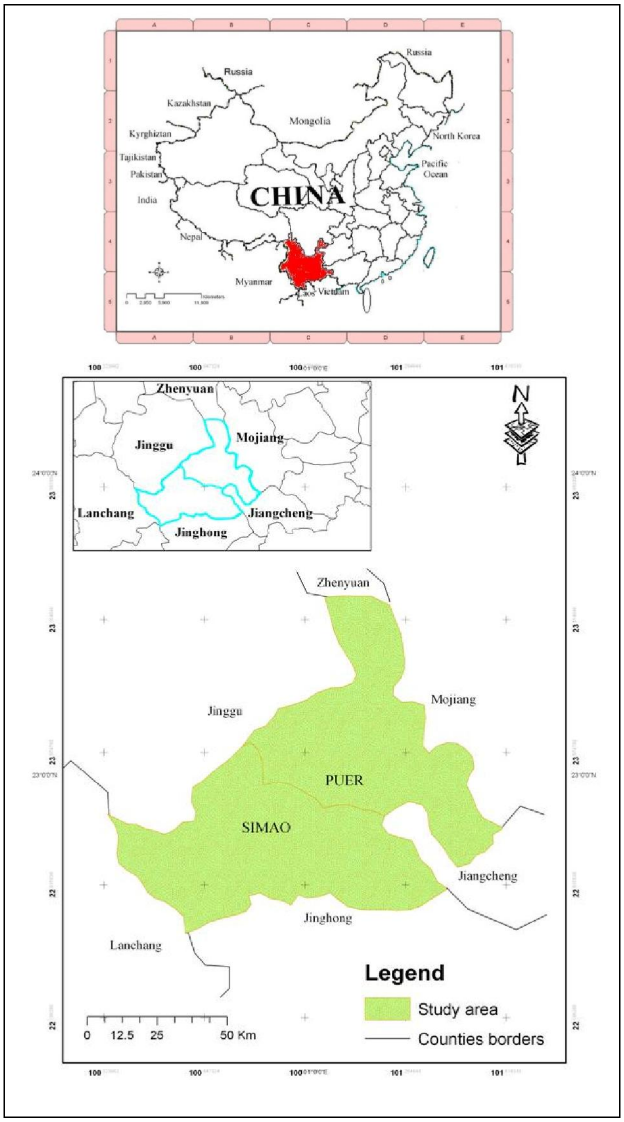

Figure 1: Location of the study area: (i) in China, (ii) in Yunnan Provice and its borders with surroundings counties

Puer Tea is grown in the mountainous forests of subtropical and tropical areas with an altitude of 1200 to 1400 meters. The shrubs include governorsplum (Flacourtia indica), boxleaf atalantia (Atalantia buxifolia) and the grasses are dominated by tangle head (Heteropogon pers). The soils are part of a series, which belongs to the group of Red Soils with erosion and water loss. According to the classification works (Vogel, Mingzhu and Huang, 1995), the soil is called Ferralic Cambisol or Haplic Phaeozem. It is called Aridic Haplustoll, according to the USDA soil taxonomy, 1992 or Haplic Dry Red Soil after Chinese Soil Classification system-Soil Taxonomic Classification Research Group, 1993. It has been called savanna red soil, red brown soil, red cinnamon soil or purple soil. Without irrigation the soils can be used for planting xerophilous plants like sisal, or produce low yields of traditional crops. With irrigation the soils can be used for rice, sugar-cane, flowering quince, water melon and peanut.

2.2 Data Acquieried And Data Sources

An area of 6900 km^2 was delineated on the Landsat scene covering the study area.

There are several Earth Resources Satellites, which share the same characteristics of capturing radiation in the visible light, and NIR spectrum at a medium spatial resolution and a return period of around 20 days. The LULC mapping and change detection for the area was based on Landsat 5TM/ 7 ETM+ of December 1999, April 2002 and January 2005 data. Obtaining images at near anniversary dates is considered important for change detection studies (Jensen, 2007). However, the summer image in 1999 was unavailable. Both time series were from Landsat TM, path 130, row 044 with. In order to prepare two or more satellite images for an accurate change detection comparison, it is imperative to geometrically rectify the imagery (Macleod and Congalton, 1998). To minimize the impact of misregistration on the change detection results, geometric registration was performed on a pixel by- pixel basis. Erroneous land cover change results may result if any misregistration greater than one pixel occurs (Lunetta et al. 1998). The images were corrected to remove atmospheric effects and then geo-rectified using 20 ground control points collected by GPS. The accuracy of image registration is usually conveyed in terms of Root-Mean-Square (RMS) error. For landsat TM imagery acceptable RMS error is approximately 0.5 pixels (Yuan and Elvidge, 1998). The registration error (RMS) obtained was 0.232 pixel for TM 2005 image and 0.225 pixel for ETM+(1999, 2002) images respectively. All the data were projected to an Universal Transverse Mercator (UTM) coordinate system, Datum WGS 1984, zone 49 North. Six bands (1 to 5 and 7) were used. Quickbird image was used as reference data.

2.3 Change Detection Method:
Maximum Likelihood Decision Rule And Its Post-Classification Technique

As Spectral-temporal combined analysis, expectation maximization (EM), Unsupervised change detection, Hybrid change detection, Artificial neural networks (ANN), the Post-classification comparison method is based on the classified images, in which the quality and quantity of training sample data are crucial to produce good quality classification results. In other word post-classification comparison computes the change-detection map by comparing the classification maps obtained by classifying independently two multi-temporal remote-sensing images. The time consuming and difficult task of producing highly accurate classifications often leads to unsatisfactory change detection results, especially when high-quality training sample data are not available. However Most of studies have addressed that post-classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes (Mas et al 2004, Yuan et al. 2005).

Three images (1999, 2002, 2005) were compared after classification using Supervised Maximum Likelihood method. Once the training sites were determined, Maximum Likelihood classification was utilized running ENVI4.3. From there the LULC maps were derived with the following five classes: 1. built up, 2. Forest or shrub land 3.water, 4.unused land and 5. Agricultural land (see figures 2, 3, and 4). The supervised classification technique is preferred, because the data are available and the author has a prior knowledge of the study area. The Maximum Likelihood decision rule is still one of the most widely used supervised classification algorithms (Wu and Shao, 2002; McIver and Friedl, 2002). It is considered to give very accurate results (Mengistu, 2007; Reis, 2008).

Then the post classification technique was employed to detect LUC change. The analyzing and interpretation phase included preparation of LULC maps and detection of their changes. To provide a richer information base on class membership and its dynamics, (Foody and Boyd, 1999) suggested running the post-classification comparison algorithm with fuzzy classifications instead of with conventional hard ones. The effect was especially significant when the ecosystem changes were operating at a scale finer than the spatial resolution of the sensor. The overlay consisting of LULC maps of 1999, 2002 and 2005 were made through ENVI 4.3 software. Then a transition matrix was prepared for the overlaid land use/land cover maps. That is the last step of six carried out, performing the post classification comparison.

Step 1: Classification of different images

Step 2: Conversion of classification cover types into vector file

Step 3: comparing the land cover type change one by one in different images using

ArcGIS software

Steps 4: Compute change statistics information (one by one until all land cover type is computed)

Steps 5: Output statistics data into change matrix

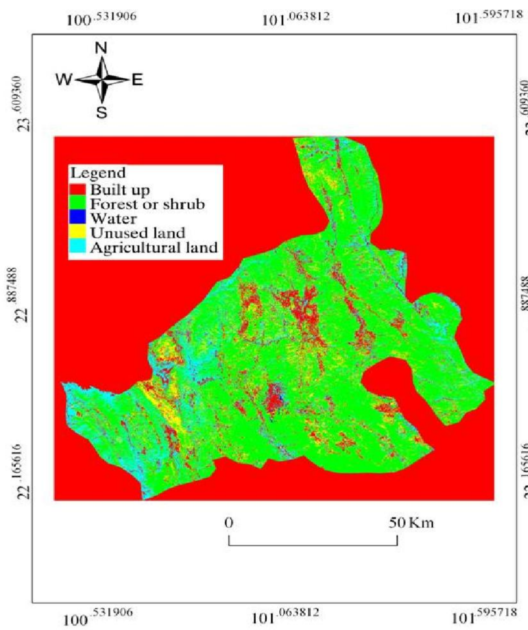

Figure 2: Land use/cover distribution Map, 1999

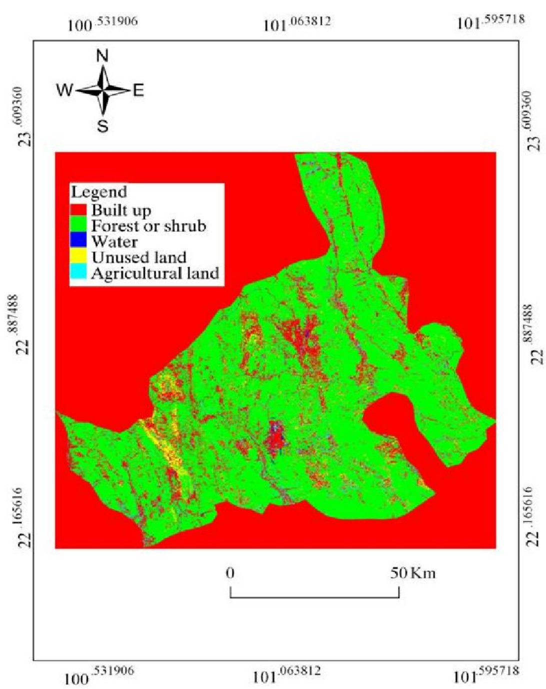

Figure 3: Land use/cover distribution Map, 2002

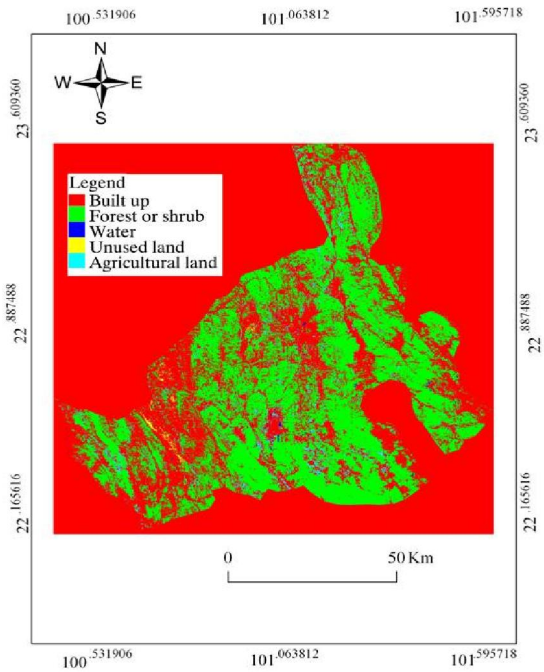

Figure 4: LULC distribution Map, 2005

3. Results

3.1 Accuracy Assessment

Accuracy assessment was performed by using confusion matrix ground truth sampling.

A Quickbird image 2008 of Simao, field data and photos were used as reference data. Our knowledge of the area also played an important role in this process. Confusion matrices were created to check accuracy of the LU/LC maps.

Table 1 shows the accuracy assessment results. All classification dates achieved significantly high user accuracy of superior or equal to 98%. That shows the high proportion of correctly classified pixels in each class to the total pixels, in other word the probability that a classified pixel actually represents that category in reality was high.

For the producer accuracy, where the lowest score was 98% represents the water cover type in 2005.

All the three classification dates achieved extremely high and identical overall accuracies of 99%, which is more than the minimum accuracy criterion of 85% overall accuracy as reported in Anderson's land use land cover classification. The Kappa coefficient was equal to 0.99 in each case. In 2005 the built up land received the lowest User accuracy score with only 98% of pixels being correctly classified, the Producer accuracy for the same date image received the lowest score of 98%.

Table 1: Summary of classification accuracy assessment

LUC types	1999		2002		2005	
	Prod.%	User%	Prod.%	User%	Prod.%	User%
Built up	100	100	100	99	100	98
Forest or shrub	99	100	99	100	100	99
Water	100	100	100	100	98	100
Unused land	100	99	99	100	99	100
Agricultural land	99	100	99	99	99	100
Overall Accuracy %	99		99		99	
Kappa Coefficient%	0.99		0.99		0.99	

3.2 Changes in land use/land cover

Post-classification produced LULC maps figures (2, 3 and 4) for 1999, 2002 and 2005 respectively. Tabulations and area calculations in table 2 provide a comprehensive data set in terms of the overall landscape and the types of changes which have occurred. The class area was measured by the pixel number multiplied by the Landsat -5-7 spatial resolution, i.e. 30m. The pixel number was given by the post-classification analysis. The change was calculated as a pixel number difference between two dates (1999-2002, 2002-2005 and 1999-2005). The change rate was computed by the pixel number divided by the study period multiplied by 100, it concerned the period the column 1999-2005 and was not computed for the two first study periods. The change matrix, that contributed to facilitate the understanding of the change, conversion and transformation processes, came from statistics output data.

In the periods considered, the forest or shrub land constituted the most extensive type of LULC in the study area. Accordingly, it accounted for about 75, 66 and 53% of the total area in 1999, 2002 and 2005 respectively, followed by built up and agricultural land occupying 14, 20, 41% and 05, 07, 08% of the total area respectively. LULC units under unused land and water covered 06, 11, 03% and 01, 02, 02% for above mentioned dates of the total area respectively.

In 2002 and 2005 however, the forest or shrub land decreased marginally to about 66% and 53% respectively of the total area while the built up land increased and occupied 20 and 41 %, for 2002 and 2005 respectively. The remaining area was occupied by water and unused land, which slightly increased to about 2% and 11% in 2002 respectively, whereas the unused land cover type decreased to about 03% in 2005. As the unused, the agricultural land slightly increased and decreased in 2002 and 2005 respectively. It was not possible to discriminate a famous Tea Mountain area from others growth in agricultural land cover type.

Table 2: Comparison of areas and change of the five LULC classes between 1999 and 2005

LULC Types	1999		2002		2005		Change in 1999-2002		Change in 2002-2005		Change in 1999-2005		Change Rate	
	Areaha^{-1}	%	Areaha^{-1}	%	Areaha^{-1}	%	Areaha^{-1}	%	Areaha^{-1}	%	Areaha^{-1}	%	Areaha^{-1}	%
Built-up land	97500	14	130000	20	266500	41	+32500	+25	+136500	51	+169000	+63	+28166	+11
Forestorshrub	480000	74	422400	66	307200	48	-57600	-12	-115200	-27	-172800	-36	-2880	-06
Water	6400	01	12810	02	12810	02	+6410	+50	0	00	+6410	+50	+1068	+08
Unused land	38400	06	70400	11	19200	03	+32000	+45	-51200	+72	-19200	-50	-3200	-05
Agriculturalland	32000	05	51200	08	44800	07	+19200	+38	-6400	+125	+12800	+29	+2133	+05
Total	654300	100	635610	99	637700	101								

Note: The table data are rounded

Table 3: Change matrix for the change in land cover types between 1999 and 2002 in hectares

1999-2002	1	2	3	4	5	Total
1.Built up	68250	17223	0	0	0	85473
2.Forest or shrub	4300	382000	0	1300	0	388200
3.Water	122	0	3203	0	0	3325
4.Unused land	0	15600	0	46080	0	61080
5.Agricultural land	0	0	0	0	48000	48000
Total	72672	414823	3203	47380	48000	586070

Note: Unchanged areas occupy the diagonal of the matrix, while changed areas are represented in the off diagonal elements of the matrix.

Table 4: Change matrix for the change in land cover types between 2002 and 2005 in hectares

2002-2005	1	2	3	4	5	Total
1.Built up	63700	9800	815	563	0	74878
2.Forest or shrub	150	271360	0	0	0	271510
3.Water	0	0	12000	325	0	12325
4.Unused land	120	0	0	19712	0	19832
5.Agricultural land	0	0	0	0	33000	33000
Total	63970	281160	12815	20600	33000	411545

Note: Unchanged areas occupy the diagonal of the matrix, while changed areas are represented in the off diagonal elements of the matrix.

Table 5: Change matrix for the change in land cover types between 1999 and 2005 in hectares.

1999-2005	1	2	3	4	5	Total
1.Built up	98605	20012	65	0	0	118682
2.Forest or shrub	3855	237440	356	2358	0	244009
3.Water	0	45	6200	0	0	6245
4.Unused land	544	18032	0	23232	0	41808
5.Agricultural land	0	9466	0	0	35000	44466
Total	103004	284995	6621	25590	35000	455210

Note: Unchanged areas occupy the diagonal of the matrix, while changed areas are represented in the off diagonal elements of the matrix.

The average rate of changes summarized in table 2 concern the column named change in 1999-2005. The areas covered with forest or shrub land and unused land were receding at an average rate of 06 and 05% per annum respectively, while the built up, water and agricultural land cover types were expanding at rates of 11, 08 and 05% per annum respectively over the years period.

Further, the from- to change matrix as seen in tables 3, 4, 5, show that the most significant changes in the area were in the period 1999-2005, from Forest or shrub land into built-up land (20012 ha), from Forest or shrub land into Unused land (18032ha). In the period from 1999 to 2002 the most important changes were from vegetation into built-up (17223 ha) and from Forest or shrub land into unused land (15600 ha). In the period from 2002 to 2005 the most noticeable change was from Forest or shrub land into built-up (9800 ha).

4. Discussions

The accuracies of classification were turned out to be better than expected. The excellent overall accuracies of all classification process can be explained by the fact that the total number of correctly classified pixels was high. The LULC types were correctly chosen, the precision of the classification might be another if we tried to classify separately classes, i.e. forest and shrub land, or cropland and fallow (Diallo et al.2009).The high quality of user and producer accuracy could be explained by the fact that the probability that a classified pixel actually represents that category in reality in very high.

The satellite-based analysis reveals some interesting trends as regards the land cover development in the period 1999 to 2005. From our results figures 2, 3 and 4 it is clear that the study area had been subjected to intensive use influence and degraded with +63% and -36% of change under built-up and vegetation respectively. It is worth mentioning that most of the deforestation took place south and south-east of the study area in 2002 and 2005. The increase in built-up land and the decrease in vegetation cover was found as deforestation at the profits of built-up elsewhere (Mengistu and Salami, 2007, Reis, 2008). In line with this, the LULC data of the up mentioned years indicated a change. The retreating of areas covered with vegetation and unused land and expanding of built up land is common in the region. This indicates the encroachment of buildings towards vegetative areas and unused land; this was established by the field investigation on June 2009. The phenomenon is found to be a forest clearing and caused by anthropogenic disturbance (Roy, Chowdhury and Schneider, 2004). In other words the additional people have placed considerable pressure on the land for new housing. As saying up the changes might due to the government policies that aim to balance the need to encourage rural development, the removal of compulsory grain crop quotas, promoting livestock with ecological stability. That is found to be similar to the situation in a neighboring area Xishuangbanna Prefecture (Xu et al., 1999). The driving force for building area (urban) expansion of Puer as Chinese city might be the phenomenon of development zones that are created to host innovative activities and foreign investment. Hence, the expansion of built -up was responsible for the disappearance of the vegetation cover type in the study period, even if the 1999 and 2002 images were taken in winter period. The relationships between the vegetation and built-up areas was found to be consistent with the range reported elsewhere (Fearnside, 2001, Lambin et al. 2003, Velazquez and al., 2003). Land use/land cover changes reflect the dynamics observed in the socio-economic condition of a given area. Similarly, changes in the socio-economic situations cause land use/land cover changes through their influence on land management techniques used and other various aspects of the farming systems, institutional settings, environmental policy and others. Reported percentage changes in world gross domestic product ranged from -0.17 to 0.09 percent. For a “moderate impacts” scenario, world gross domestic product would increase by 0.01 percent. In brief LULC change detection analysis derived from landsat imagery has provided an accurate account of the situation of the study area during the period 1999-2005. Land use activities were towards more urbanization, agricultural production and deforestation. The areas covered with vegetation and unused land were receding at an average rate of 06 and 05% per annum respectively, while the built up, water and agricultural land cover types were, respectively expanding at rates of 11, 08 and 05% per annum over the years period. It was not possible to discriminate a famous Tea Mountain area from others growth in agricultural land cover type.

5. Conclusions

From the Post classification method, the forest or shrub land decreased marginally to about 66% and 53% in 2002 and 2005 respectively of the total area, while the built up land increased and occupied 20 and 41 % respectively. The unused land cover type decreased to about 03% in 2005. As the unused, the agricultural land slightly increased in 1999-2002. Decision Tree showed the similar trends, whereas from 1999 the Forest or shrub land (49%) decreased continuously to about, 35 and 30% of the total vegetation area in 2002 and 2005 respectively. The Built-up land increased progressively to about 20, 23% in 2002 and 2005 respectively, while the agricultural land cover type increased to 19 and 25% in 2002 and 2005 respectively.

The conclusion of this study is a retreating of areas covered with vegetation and unused land and expanding of built up land and agricultural land areas. That explains the encroachment of buildings and agricultural activities towards vegetative areas and unused land.

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