LANDSCAPE'S CHANGE DETECTION IN THE SOUTHERN SLOPE OF THE QINLING MOUNTAINS, CHINA

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ABSTRACT:

The landscape on the southern slope of the Qinling Mountains, the home of many wildlife species including the giant pandas, golden takin and golden monkey, has been logged and influenced for a long term. This caused the obvious decreasing of the wildlife's habitat and has produced strong impacts on their survival and distribution. It is necessary for managers to have a quick and accurate method to detect the landscape changes, which can help them to be aware the changing situation. Consequently, managers could take measures to keep controlling the changes. Change detection through remote sensing has now been applied widely in terms of its quick processes and accurate results. However, it has not been well used in detecting changes of landscape in giant panda nature reserves in China up to now. This article focuses on the landscape's change detection in Changqing, Foping and Guanyinshan NRs, containing LUC change and NDVI change through spatial analyzing TM images acquired on September 15 1988 and September 8 1997. Two LUC maps from two different years have overall accuracies of 73.74% and 75.19% and kappa values of 0.6829 and 0.6968. A LUC changing map was created and show that the exact areas of "conifer", "deciduous broadleaf", and "mixed conifer-broadleaf" forests have greater changing, however, three small-area LUCs (i.e., "farmland and settlement", "water", "rock and bare-land") have larger changing rates. NDVI analysis of two years' images shows an obvious change with higher NDVI in 1988 than in 1997 in total. Most of changes are located in the regions along or near the rivers and reserves' boundaries, which reflects substantially that human being has strong impacts on the surrounding landscape.

1. INTRODUCTION

The southern slope of the Qinling Mountains is not only one of the important habitats for giant pandas in China, but also the home for many other rare and endangered species. The completion and diversity of the entire ecosystem is essential for conserving those rare and endangered species and maintaining balance of the ecosystem in the Qinling Mountains. However, the vegetations, which form the home of those rare and endangered species, on the southern slope of the Qinling Mountains has been experiencing various extends of logging and land use converting for a long term. This caused the obvious decreasing of the area of wildlife's habitat and has produced strong influences on wildlife's survival and distribution.

In order to better handle the conflicts between the conservation and develop, control the illegal forest cutting and habitat degrading activities, and follow a sustainable approach, it is necessary for managers to grasper the dynamic information of wildlife species, their habitat and human activities inside and surrounding the NRs. The remote mountain area with dense forest cover brings imaginable difficulties in collecting all kinds of information, without mentioning in-time collecting, and makes a completion of the ground survey a long period. The traditional manual recording and handling the collected information is a cost and time-consuming task and hard to in-time update information. Furthermore, without spatial information and analysis, it is not easy to make clear comparisons among nature reserves in terms of their wildlife, habitats and human impacts. Consequently, it causes managers difficulties to make decisions due to lacking of strong supporting information and evidence (Gao and Wu 2000).

Change detection through remote sensing has now been applied widely because of its quick analysis processes, accurate results and visual spatial information (Zhang 2003). LUC classification and mapping for various-period images can be used to detect the LUC type change (van Lynden and Mantel 2001), while NDVI calculation and mapping for various-period images can be applied to detect the change of vegetation quality which has been applied in vegetation coverage assessment, crop yield estimation and crop identification (Tian and Min 1998). Due to that such a research has never been done in the home of giant pandas on the southern slope of the Qinling Mountains, China, this article applied remote sensing approach to detect landscape change (i.e. LUC type change and NDVI value change) in three giant panda NRs based on two TM images acquired in 1988 and 1997. The aims are (1) to illustrate the quick and accurate remote sensing approach to the reserve managers, (2) to provide the landscape change information to the managers and other groups of people.

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2. STUDY AREA

The study area is located on the southern slope of the middle Qinling Mountains, Shannxi, China (Figure 1), which includes three giant panda NRs: Changqing, Foping and Guanyingshan. Its geo-location is 107° 26′ - 107° 58′ E，33° 26′ - 33° 46′ N. The total area of the study site is about 709 km^2. The elevation ranges from 800 m to 3071 m. The annual mean temperature is about 14.6℃ and annual precipitation about 813.9 mm. This region is the most northern refuge of the Giant Panda and a crossing area of the southern and northern fauna and flora. It has rich species and diverse habitats. The vegetation is well developed with a more complete vertical distribution under the sub-tropical monsoon climate. Bamboo has a wide understory distribution (CNNRA 2001, FNNRA 2001, SDIFR 2001).

Foping, Changqing and Guanyingshan NRs were established in 1978, 1994 and 2002 respectively. Therefore, Foping NR has been conserved for more than 20 years and its ecosystem and wildlife habitat are well protected and developed. Foping's ecosystem has reached a relatively stable stage. However, there are still some local people resident in the center of Foping. Changqing NR was originally belonging to the Changqing Forest Bureau (constructed in 1967) and got 9 years' protection. Changqing's strong-disturbed ecosystem and wildlife habitat has been starting secondary succession and got certain restoration. Changqing's ecosystem is still keeping changing. There are no people living inside Changqing. While Guanyingshan NR was converted from the Longcaoping Forest Bureau (constructed in 1986) and stopped forest cutting in 1998. The human activities, such as farming and commercial logging have remained the strong impacts on the ecosystem and wildlife habitat until now. Guanyingshan's ecosystem is unstable.

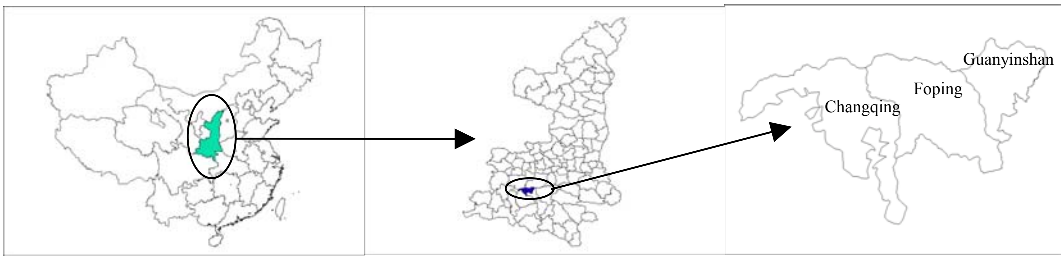

Figure 1. Location of the study area: the southern slope of the middle Qinling Mountains in Shannxi, China. Three giant panda nature reserves are included: Changqing, Foping and Guanyingshan.

3. RESEARCH METHODS

3.1 Data and preparing

This research used vector data (including boundaries of research area and nature reserves; rivers; sample points), raster data (including DEM; slope model; aspect model), and Landsat TM images acquired on September 15 1988 and September 8 1997. All map data have been geo-referenced in order to have a same coordinator system as well as spatial resolution of 30*30 m^2. Due to the incompletion of the 1997-image scene and its cloud cover, we derived the same-size area for LUC mapping and NDVI calculating for both 1988 and 1997 images without the cloud-cover area and the missed image part. Sample points were from the field survey conducted in 1999 (Liu 2001) and from the 3rd national panda and its habitat census.

3.2 Mapping LUC and assessing the mapping accuracy

In order to improve the LUC mapping accuracy for change detecting, eight data layers were used, containing TM1，TM2，TM3，TM4，TM5，TM7，DEM and aspect model (Zhao and Li 2001). DEM can help identify the LUC type with similar spectral characteristics but different elevation information, and aspect model can correct the changed spectral information caused by the mountain shadow (Mo and Zhou 2000). Eight LUC types were defined based on the previous research works, which are (1) conifer forest, (2) mixed conifer and broadleaf forest, (3) deciduous broadleaf forest, (4) bamboo, (5) shrub-grass land, (6) farmland and settlement, (7) bare-land and rock, (8) water (Liu 2001).

The stratified random sampling method (Table 1) and the traditional maximum likelihood classification (Singh 1989, Chen et al. 2004) were applied for image classification and LUC mapping. The total samples used for classifying 1997-image are 1578 points and they basically cover the whole study area. Due to that the 1988-image was acquired 10 years ago, we made some adjustment during classifying 1988-image based on our knowledge on the spectrum, ground objects and experience from 1997-image classification. Therefore, some more sample points were taken into account in order to increase certainty. The final number of samples to classify 1988-image is 1848.

The error matrix and Kappa methods were used to assess the LUC mapping accuracy. The overall mapping accuracy only considers the correction of diagonal elements in the matrix, while the kappa method also takes the other elements in the matrix into account, which can compensate the disadvantage of the error matrix method (Liang et al. 2002, Ding et al. 2001). In general, the mapping results are listed very good, better, good, normal, bad, worse, very bad in turn when the kappa values fall into the ranges of 0.8-1.0, 0.6-0.8, 0.4-0.6, 0.2-0.4, 0-0.2, and <0 (Liu et al. 1998).

3.3 Detecting the LUC change and quantifying the change

The LUC change map was obtained by minus calculation of two produced LUC maps from 1988 and 1997 images. The research work detected not only whether changing happened or not but also what kind of changing happed and how much changing happened. The changing areas and the changing rates for eight LUCs were statistically analyzed (Ye et al. 2002).

	1988			1997	
LUC type	Training samples	Testing samples	LUC type	Training samples	Testing samples
CF	126	125	CF	46	51
CFDBF	241	240	CFDBF	238	244
DBF	205	206	DBF	188	193
SHGR	130	134	SHGR	46	48
BAM	23	25	BAM	40	38
FAS	48	47	FAS	51	48
WAR	82	85	WAR	61	63
RAB	64	67	RAB	110	113
Total	919	929	Total	780	798

Table 1. Number of sample points for classifying the images acquired in 1988 and 1997. CF--conifer forest; CFDBF--mixed conifer and broadleaf forest; DBF--deciduous broadleaf forest; SHGR--shrub-grass land; BAM--bamboo; FAS--farmland and settlement; RAB--rock and bare-land; WAR--water.

3.4 Measuring normalized vegetation index (NDVI)

NDVI is often measured for reflecting the energy and growing condition of vegetation (Tian and Min 1998). It can correct the atmosphere and soil influences on spectral reflection (Shi et al. 2000). The 1988-image and 1997-image were used to map spatial patterns of NDVI for the study area. The following formula was applied to calculate NDVI (Zhang et al. 2001).

$$NDVI = \frac{TM4 - TM3}{TM4 + TM3}$$

The NDVI change of two years' images was detected and quantified based on the number of pixels for a specific range of NDVI (Yang et al. 2000). The NDVI change for each LUC type in two years was also quantified, which is useful on detecting the quality change of each LUC (Zhan and Yan 2002).

4. RESULTS

4.1 LUC pattern and mapping accuracy

The LUC patterns from two different-period images are illustrated by figure 2. In general, the conifer forest and detected bamboo patches are located mostly along the northern boundaries of Foping and Changqing NRs but not in Guanyingshan NR. The mixed conifer and broadleaf forest covers the middle elevation area between conifer forest and deciduous broadleaf forest. The deciduous broadleaf forest is identified at the lower elevation area and near the human activity regions, mostly distributed at the southern boundaries of the study area. The shrub-grass land, farmland and settlement, and water body are found also in the valleys in the southern parts. The rock and bare-land area are detected mainly in Guanyingshan NR and in river valleys, few at the top mountains.

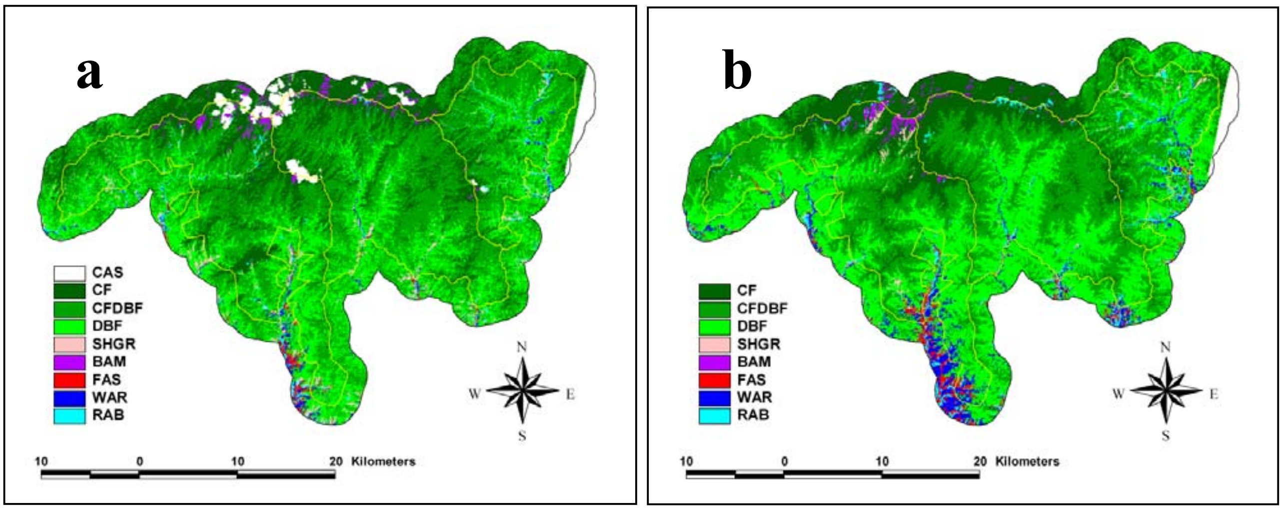

Figure 2. Map of LUC types in three nature reserves (Changqing, Foping, Guanyinshan) in the southern slope of the Qinling Mountains. The yellow line is the boundary of the nature reserves, and the black one is the boundary of the buffer zone.
a. September 15,1988; **b.** September 8,1997. CAS--clouds and shadows, CF--conifer forest; CFDBF--mixed conifer and broadleaf forest; DBF--deciduous broadleaf forest; SHGR--shrub-grass land; BAM--bamboo; FAS--farmland and settlement; RAB--rock and bare-land; WAR--water.

Visually, two LUC maps from 1988-image and 1997-image show difference. The LUC map from 1988-image has more widely distributed conifer forest, larger area of mixed conifer and broadleaf forest, less deciduous broadleaf forest and water area than the LUC map from 1997-image. Guanyingshan NR in 1997 has more areas of "shrub-grass land", "water", "rock and bare-land", as well as "farmland and settlement" than in 1988.

The accuracy assessment of two LUC mapping show that the overall accuracies are 73.74% and 75.19% for 1988 and 1997 image classifications respectively. The kappa values are 0.6829 and 0.6968 for two image classifications, which are all greater than 0.6 indicating the mapping results meet the mapping accuracy requirement.

4.2 LUC change map and quantification

The spatial pattern of LUC change was mapped as figure 3a. The LUC change for each type is quantified also as figure 3b. A great area of change occurs in Guanyingshan NR and in lower valley areas in Foping and Changqing NRs, which are mostly forest type conversion. The proportions of "rock and bare-land" as well as "farmland and settlement" are small, however, their change rates are high. The change of rock and bare-land happens in Guanyingshan NR and also at the northern boundaries of Foping and Changqing NRs. Statistical analysis shows that changing areas of "conifer forest", "mixed conifer and broadleaf forest" and "deciduous broadleaf forest" are about 31, 41 and 52 km^2; while other changing areas are less than 10 km^2. In conclusion, the LUCs with larger areas can be afford to the certain change and maintain the stable ecosystem, while the small-proportion LUCs are easily disturbed when changing happens which cause the ecosystem unstable.

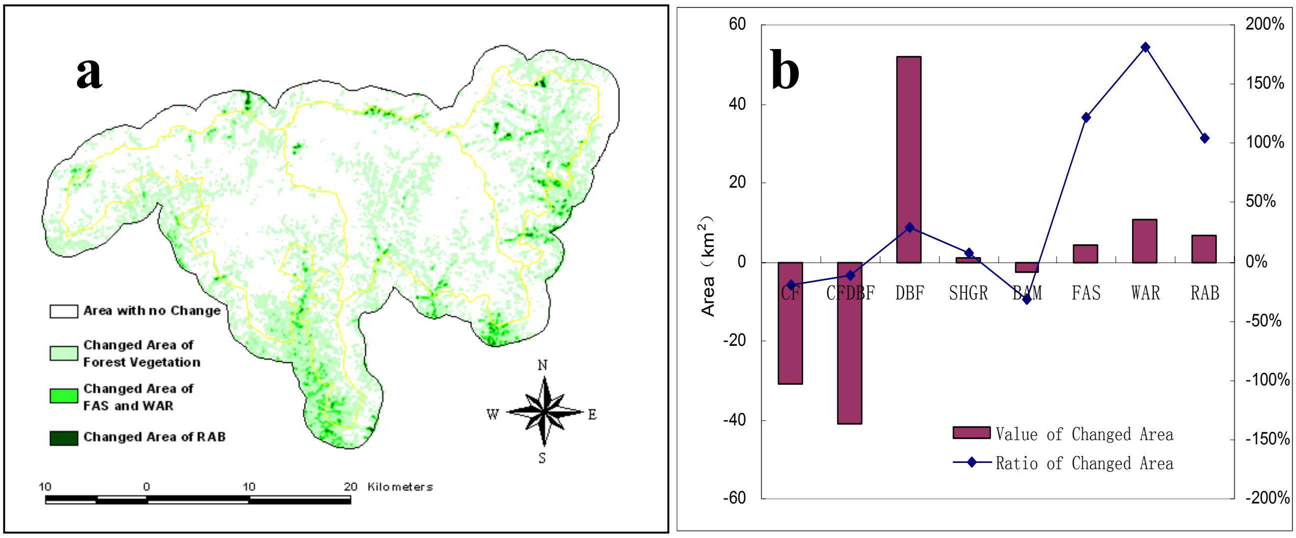

Figure 3. Change detection of LUC types in three nature reserves (Changqing, Foping, Guanyinshan) in the southern slope of the Qinling Mountains from 1988 to 1997. **a.** map of change detection. The yellow line is the boundary of the nature reserves, and the black one is the boundary of the buffer zone. **b.** figure of statistics analysis. CF--conifer forest; CFDBF--mixed conifer and broadleaf forest; DBF--deciduous broadleaf forest; SHGR--shrub-grass land; BAM--bamboo; FAS--farmland and settlement; RAB--rock and bare-land; WAR--water.

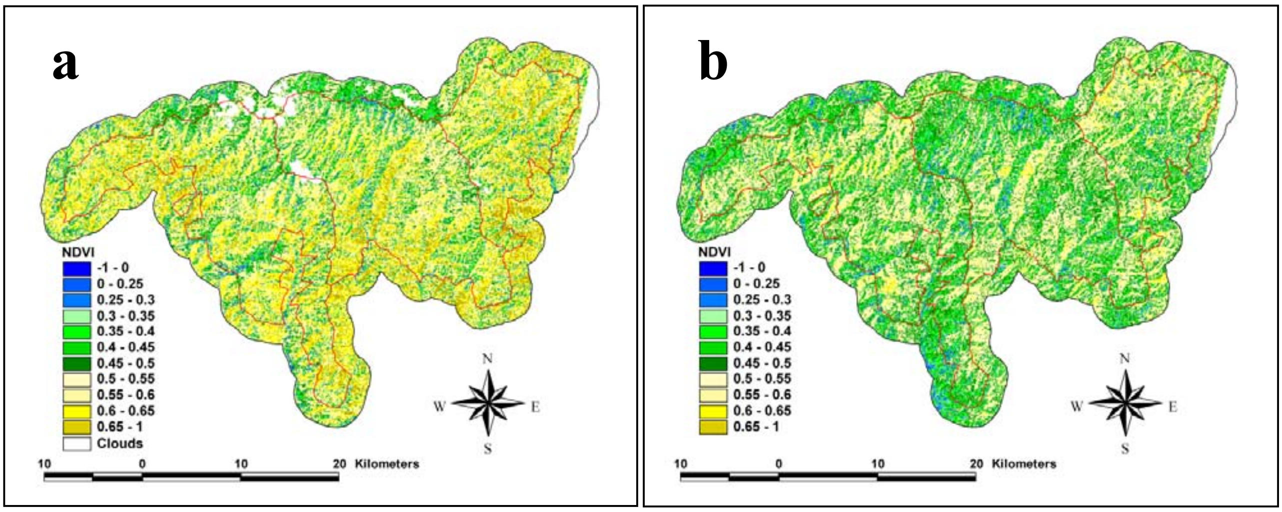

Figure 4. Map of NDVI in three nature reserves (Changqing, Foping, Guanyinshan) in the southern slope regions of the Qinling Mountains. The red line is the boundary of the nature reserves, and the black one is the boundary of the buffer zone. **a.** September 15,1988; **b.** September 8,1997

4.3 NDVI patterns and quantification

The calculated NDVI patterns of 1988-image and 1997-image are shown in figure 4. The total pixels to the certain NDVI were curved in figure 5. Obviously, the NDVI of 1988-image is higher than the NDVI of 1997-image from both figures 4 and 5, particularly at the lower elevation area or along the rivers. From figure 5, it can be seen that most of the NDVI are located between 0.45~0.55 for 1988-curve and 0.55~0.65 for 1997-curve, and the 1988-curve in pink color seems to be shifted by 1 to the left to the 1997-curve in blue color.

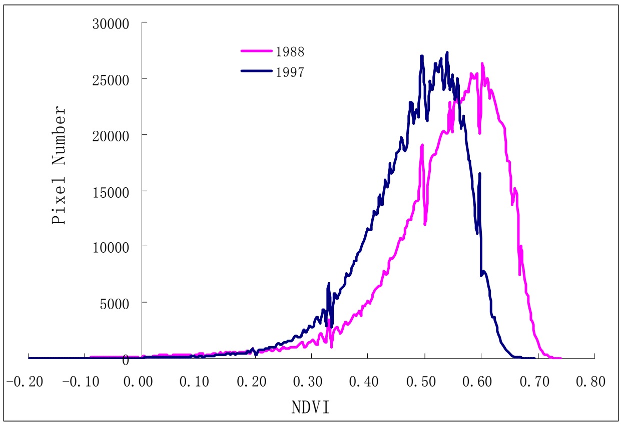

Figure 5. NDVI curves for images acquired in 1988 and 1997 in three nature reserves (Changqing, Foping, Guanyinshan) in the southern slope regions of the Qinling Mountains.

For detailed analysis of NDVI change, figure 6 was created to display the NDVI ranges and the pixels to relevant NDVI value for each LUC type mapped previously. Figures 6c and 6d are the enlarged parts of the small-proportion LUCs with few pixels. Comparing Figures 6a and 6b, "conifer forest" has almost no change, while "deciduous broadleaf forest" and "mixed conifer and broadleaf forest" have great changes: shifted NDVI values and changed shapes of NDVI-pixel curves. From 1988 to 1997, pixels of "mixed conifer and broadleaf forest" are greatly reduced and pixels of "deciduous broadleaf forest" increase. Comparing Figures 6c and 6d, the differences are more obvious for four LUC curves between 1988-NDVI and 1997-NDVI. The numbers of pixel of "water", "rock and bare-land", and "farmland and settlement" increase, while the pixels of "bamboo" and "shrub-grass land" decrease. The NDVI values of bamboo and shrub-grass land are higher, then farmland and settlement, rock and bare-land, and water in turn.

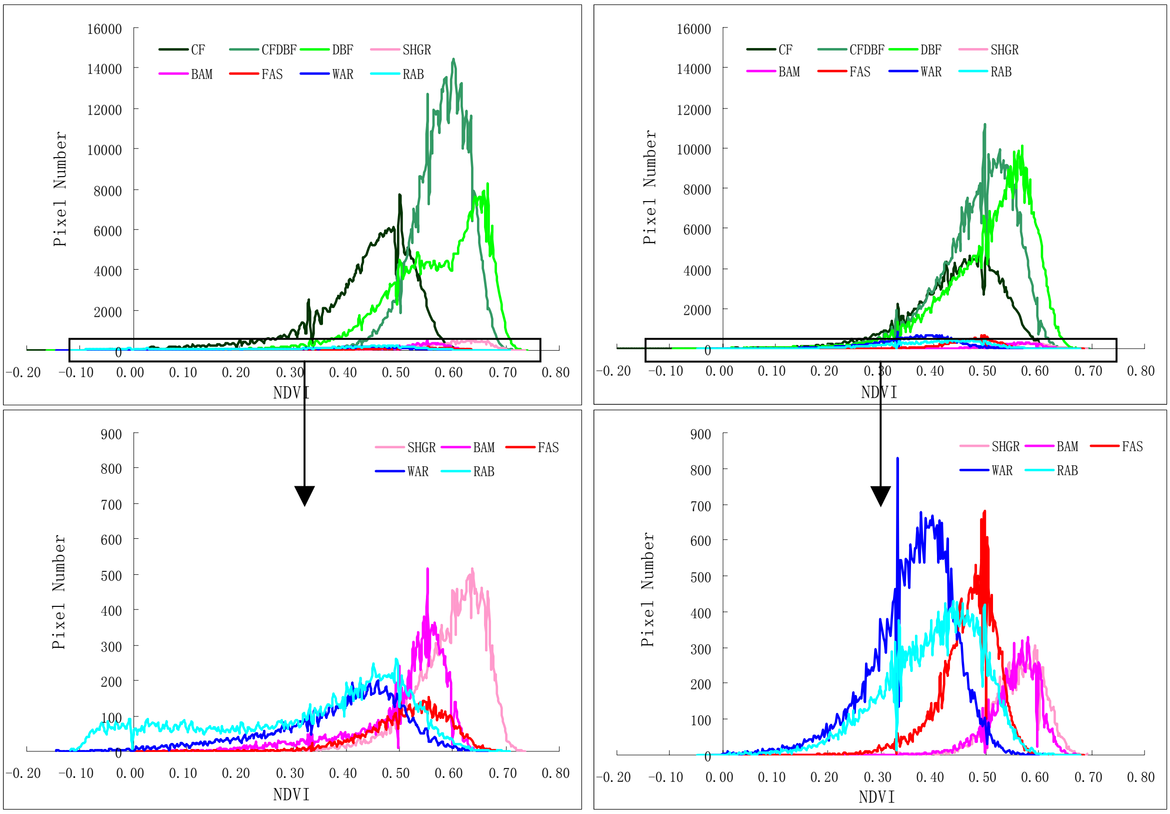

Figure 6. NDVI curves for various LUC types in three nature reserves (Changqing, Foping, Guanyinshan) in the southern slope of the Qinling Mountains. **a & c.** September 15,1988; **b & d.** September 8,1997. CF--conifer forest; CFDBF--mixed conifer and broadleaf forest; DBF--deciduous broadleaf forest; SHGR--shrub-grass land; BAM--bamboo; FAS--farmland and settlement; RAB--rock and bare-land; WAR--water.

5. DISCUSSION

Results of LUC mapping and LUC change detection show that the forest has a larger changing area, and "deciduous broadleaf forest" has increased and "mixed conifer and broadleaf forest" decreased. The changes mostly happen near or along the river valleys and at the southern boundaries where local people are living. Human activities, such as forest cutting, crop farming, mushroom producing (Liu 2002), have created long-term impacts on the surrounding forest environment. The consequence of forest cutting is the simplification of forest structure and reduction of species diversity. The preferred plantation in the valleys and at the lower elevation region is the deciduous broadleaf species including the economic tree crop species. Due to that the forest covers most of the study area, although it has a larger changing area, but the changing rate is still smaller comparing with the small-proportion LUCs, such as “farmland and settlement”, “water”, “rock and bare-land”. LUC “water” has the largest changing rate because the rainfall in September 1997 was much higher than the one in September 1988. More surface flow filled into the rivers which made “water” easy detected. The changing rates of “rock and bare-land” and “farmland and settlement” are listed the second. Their changing areas are more concentrated in Guanyingshan NR because it continues commercial forest cutting from 1986 to 1998. Some patches of “rock and bare-land” are caused by forest clear-cutting. There are about 60 and 244 local people living inside Foping and Guanyingshan NRs respectively which causes the increasing of “farmland and settlement”.

NDVI spatial calculation is also proven as a good approach to detect LUC quality change. The NDVI pattern of 1997-image was found great different from the one of 1988-image, which indicates the environment in the study area has changed not only on the LUC types in some areas but also on the quality of the same LUC. The mushroom production happened during 1995-1999 might be the cause of NDVI reduction of deciduous broadleaf forest at the lower elevation areas. Another possible reason for NDVI reduction could be the difference of weather condition between September 1988 and 1997. But we believe it is human activities are playing a major role on the change of panda landscape. The important point obtained here is that the curve of NDVI value and pixel number for different LUCs can be used to explain which LUC has changed and how much LUC quality has changed.

Two methods, i.e. maximum likelihood classification (MLC) and NDVI calculation, were applied to map the LUC change on type as well as on quality. Each has its advantages and disadvantages. MLC used more layers’ data to identify various LUC types which can be used to detect the change of LUC types. However, for some LUCs, although they have no change on their types but they do have change on quality, which MLC cannot detect this quality change. Another disadvantage of MLC is that the classification of the past image lakes of ground truthing data which makes the image treatment more time and energy consuming (Liu et al. 1999, Wu and Wang 2003, Liu and Zhang 2004, Fuller et al., 2003). While NDVI calculation based on the spectral bands and is a fast and easy-handle approach, it can be used to detect the quality change. This can compensate MLC and explain more information. NDVI also has its disadvantage, namely that the plant growing condition can greatly influence NDVI values, consequently the background information could be magnified (Tian and Min 1998, Gao et al. 1998). Two methods, if combined for change detection, can play a very good role on deriving information of detected changes.

6. CONCLUSION

Two methods successfully detected the landscape changes in the southern slope of the Qinling Mountains. During the period of 9 years from 1988 to 1997, the landscape (including LUC types and also quality through NDVI values) does have a great deal of changing. Most of changes were detected from the areas along the river valleys and the southern boundaries of the reserves where the local people are living or where are easy accessed by local people. It indicates the human activities are the main driving force of landscape change in the study area. In conclusion, forest types have a larger changing area, while “water”, “farmland and settlement” and “rock and bare-land” all have very high changing rates. In Foping and Changqing NRs, the major changes are the conversion among forest types and the forest quality reflected by the reduced NDVI. In Guanyinshan, the conversion from forest types to “farmland and settlement”, “rock and bare-land” needs to pay attention. In Changqing and Guanyinshan NRs, the second succession is the natural force to change the landscape to the better condition. It is expected that the forest environment will be protected effectively and success naturally after the law of “natural forest protection program” and the functional shift from forest production to nature conservation.

Remote sensing approach can be used as an effective tool for detecting the landscape change and for long-term monitoring. Multi-method is recommended to detect change in order to improve accuracy of change detection and to explain more change information because of their capability compensation (Li 2003). The outputs of change detection will help the managers to make the right decision, policy, planning and take actions.

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