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Land Use/Cover Change Analysis Using Remote Sensing Data: A Case Study, Zhengzhou Area, Henan Province, China

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Abstract

In the last two decades, arid and semi-arid regions of China suffered rapid changes in the Land Use/Cover Change (LUCC) due to increasing demand on food, resulting from growing population. In the process of this study, we established the land use/cover classification in addition to remote sensing characteristics. This was done by analysis of the dynamics of (LUCC) in Zhengzhou area for the period 1988-2006. Interpretation of a laminar extraction technique was implied in the identification of typical attributes of land use/cover types. A prominent result of the study indicates a gradual development in urbanization giving a gradual reduction in crop field area, due to the progressive economy in Zhengzhou. The results also reflect degradation of land quality inferred from the decline in yield capacity and significant degeneration. Developing land types are Barren land and urban areas (8.02%, and 246.65%). Shrinking land types are water, forest, crop, and grass areas (5.98, 11.52%, 7.09%, and 20.02% respectively). Such changes are the results of physical and anthropogenic factors. The results are expected to provide very useful information for the local government in its future planning.

***Key words**: Land use/cover change, laminar extraction technique, zhengzhou (China).*

1. Introduction

Changes in land use/cover are among the most important human alterations affecting the surface of the earth (Lambin et al., 2001). Land use represents the most substantial human alteration of the earth system in the past 300 years (Vitousek et al., 1997). Between one-third and half of the land surface has been transformed. Land Use/Cover Changes in China is powered by demand on food for its growing population (Shanzhong Qi and Fang Luo, 2006). Research on controlling factors of LUCC has recently been intense. Song Conghe et al., 2001, emphasized on monitoring and assessing large-scale ecological systems on basis of data derived from remote sensing images. LUCC is strongly linked to growth in population, market development, technical innovation and policy action. Turner et al., 1995, stated that changes in land use could have many consequences on natural resources. They listed such resources as alteration of vegetation cover, physical characteristics changes in soil, plant, and animal populations. Similar statements were quoted by Lambin et al., 1999 and Aylward, 2000. Significant land use/cover change took place in Zhengzhou area over the past two decades by natural forces and human activities. No ground truth data available for land cover change in this area. The land use/cover classification system and remote image interpretation of characteristics were established in this study. The aim of the study was to document land use/cover change since 1988 using two sets of multispectral thematic mapper TM images (1988 and 2006). In order to identify the typical attributes of land use/cover types, a laminar extraction technique was used. The land is divided into six categories: water resources, forest, grass, barren, crop, and urban areas. These landscape attributes were individually extracted using multi-layered information extraction. Applying empirical interpretation to combine the automatic computer classification and post classification has enhanced the image classification efficiency and accuracy. This procedure takes into consideration all the target features, avoiding the combinations of different attributes in a map. The outcome is a fusion of attributes into a color image for land use/cover classification. The accumulation of basic data on utility status and quantified dynamic change is now achievable.

2. Study Area

Zhengzhou is the capital city of Henan province. It's located in the lower reaches of the Yellow River Basin. The study area extends between the longitudes 112° 45′ 00″ E-114° 15′ 00″ E and the latitudes 34°10′00″ N-35°00′00″ N. It covers all of Zhengzhou municipality, including Zhengzhou city and its six constituent counties (Figure 1). The total area of Zhengzhou is 7,446.2 Km^2; the total population in Zhengzhou is 7.2 millions, of which the rural population accounted for 62.8% (BSZ, 2006). The total GDP of Zhengzhou is 21.5×10^9 US $, of which only 4.4% derives from agriculture. Therefore, the agricultural economy, despite the involvement of the majority of the population and a high fraction of the water use, accounts for a very low fraction of the total GDP in Zhengzhou.

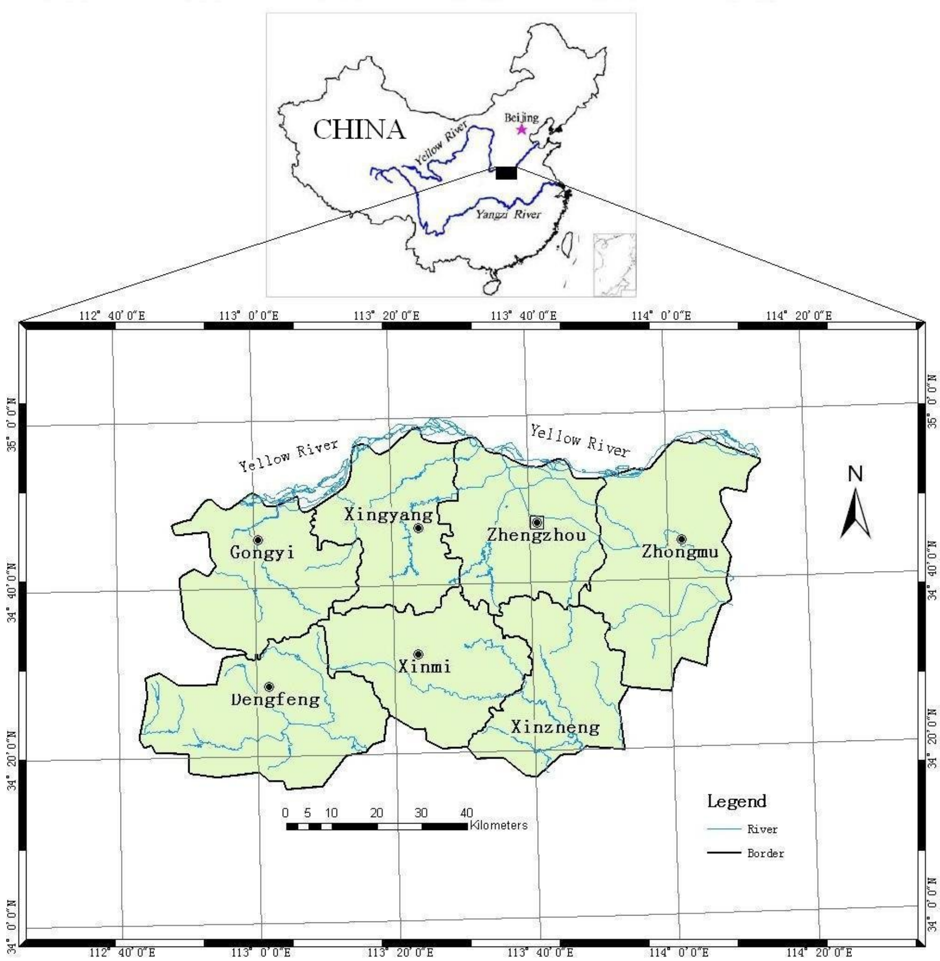

Fig.1. Location Map of Zhengzhou Area.

As a whole, the elevation of the study area decreases from southwest to northeast. The highest peak is the Shaoshi Apex of Songshan Mountain with an elevation of 1494 m. The elevation is less than 200 m in the eastern plain, with the nadir located in haogang Village in Zhongmu County. (Figure 2).

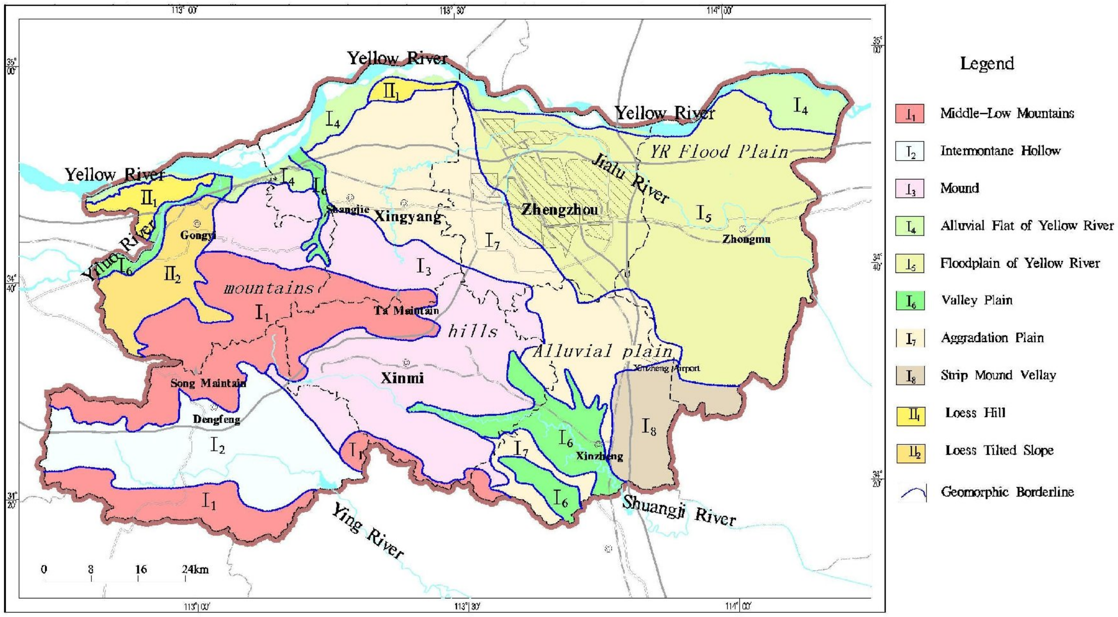

Fig.2. Geomorphologic Map of Zhengzhou.

Zhengzhou area is a continental monsoon climate. The average annual temperature is about 14.3 ºC .The mean annual precipitation of Zhengzhou is 641 mm and ranges from 751 mm in the south to 547 mm in the north, 65.0% to 67.2% of which is concentrated between June and September. The mean annual evaporation is 1016 mm.

There are 35 rivers in Zhengzhou area, such as Yiluo River, Shuangji River, Jialu River, and Yellow River. Yellow River is the largest transit river (running across the northern border of the area) with mean annual runoff of 44.4×10^9 m^3 at Huayuankou hydrologic station. There are many reservoirs, of which 13 reservoirs are of medium size with storage of more than 10×10^6 m^3. Most surface water belongs to poor grade water quality (grade V or below V in Chinese terminology, of which grade I is best and grade V is only applicable to agriculture irrigation).

The surface waters have been polluted badly because of direct discharge of industrial and domestic wastewater. So, groundwater is the most important water supply source for urban and rural areas.

3. Hydro-geologic Conditions

In Zhengzhou area, the Archaeozoic to Neogene rocks are outcroped in the south and west mountain areas (approx. 50% of the study area). Quaternary unconsolidated materials cover the north and eastern plains (Figure 3).

There are mainly three kinds of groundwater, karstic water in Carbonate systems, water in fractured systems in hard and clastic rock, and primary porosity water in Quaternary unconsolidated material. Fractured rock systems generally have deep groundwater table depth and are relatively difficult to exploit. Highly porous Quaternary aquifers are widely distributed in the eastern plain (Sun et al, 2007).

The porous Quaternary aquifers are the most important in Zhengzhou. They can be divided into four more or less overlying sub-aquifers: shallow aquifer (unconfined aquifer less than 60 m deep), middle aquifer (confined aquifer 60-300 m deep), deep aquifer (confined aquifer 300-800 m deep) and super-deep aquifer (confined aquifer deeper than 800 m). The shallow aquifers have abundant groundwater because they can be easily recharged by precipitation, irrigation, rivers, and reservoirs. The confined aquifers, on the other hand, have abundant groundwater because of their huge extent and volume (Li Guirong, 2005).

The tubewells for agriculture are mostly located in the eastern plain. Because of the superposition of porous aquifers, the tubewells almost have several screens that are located in different sand or gravel layers (Sun et al, 2007).

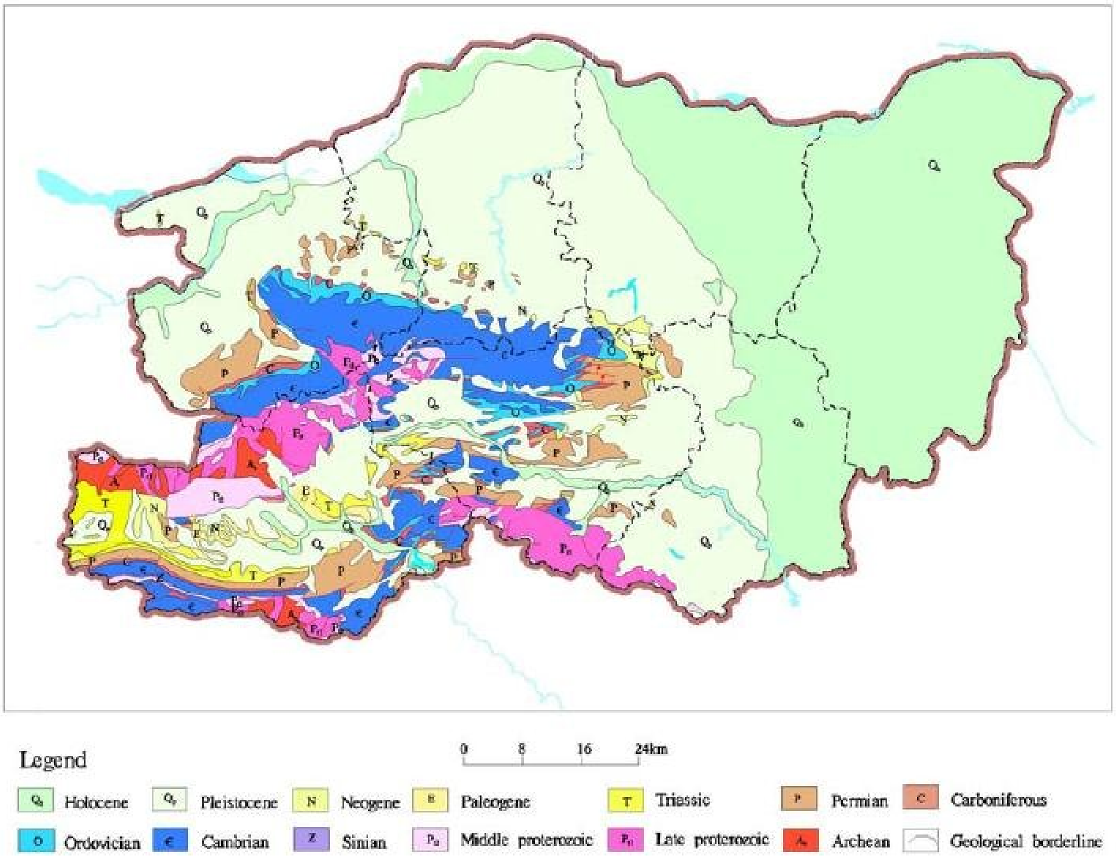

Fig.3. Geologic Map of Zhengzhou.

4. Materials and Methods

To detect changes in land use/cover during the 18-years period (1988-2006) using remote-sensing data, a new set of land use/cover categories was developed by modifying the US Geological Survey Land Use/Cover classification system (Chen 2002) applicable to the study area, including six classes (cropland, forestland, grassland, urban and/or built-up land, water, and barren land) and taking full account of these field investigations. The chosen classes were also based on amenability to accurate identification from the available imagery and ancillary interpretation resources.

Remote Sensing based approaches have been followed in the present study. Two Landsat TM and ETM+ satellite images from the same cropping period of the years 1988 and 2006 are utilized. The image processing techniques were implemented through ERDAS IMAGINE software. Preprocessing of the remotely sensed data has been applied prior to actual analysis to improve the quality of the data. Image restoration involves the correction of distortion, degradation and noise introduced during the imaging process. Radiometric and geometric errors are the most common types of error encountered in remotely sensed imagery. The radiometric and systematic geometric errors of Landsat TM data have been removed by the commercial data provider, while the unsystematic geometric error remains in the image. The geometric errors of the Lansat TM data were corrected by using ground control points before the analysis of land cover change. The study area which was cut from the two images covers about 7319.64 Km^2. Figures (4) and (5) show the two times outcome images (1988 and 2006) resulted through a color composite technique.

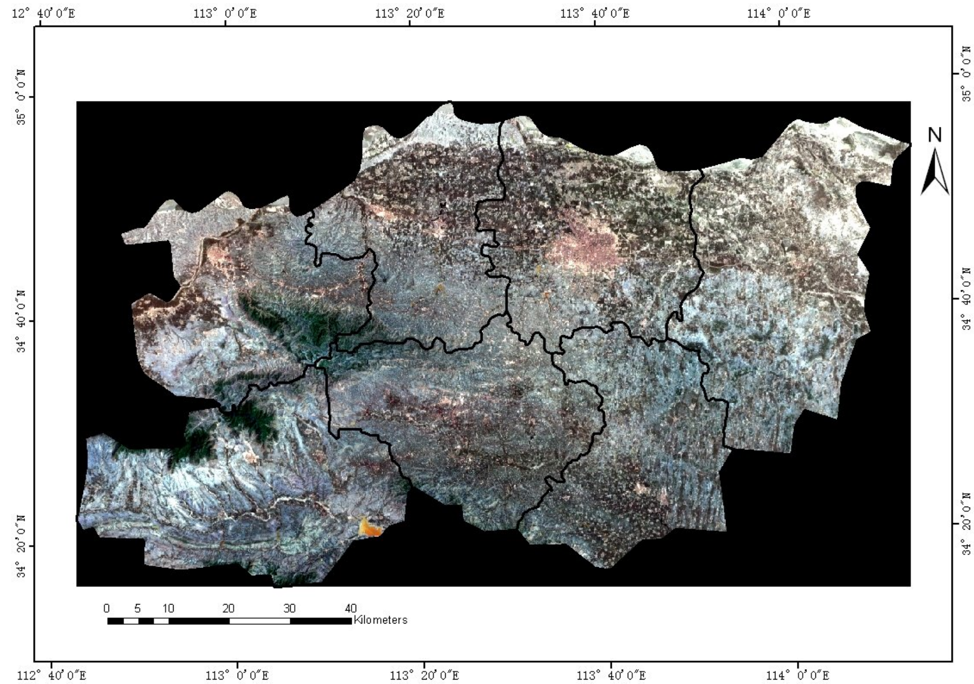

Fig.4. 1988 Color Composite Image RGB (321) of the Study Area.

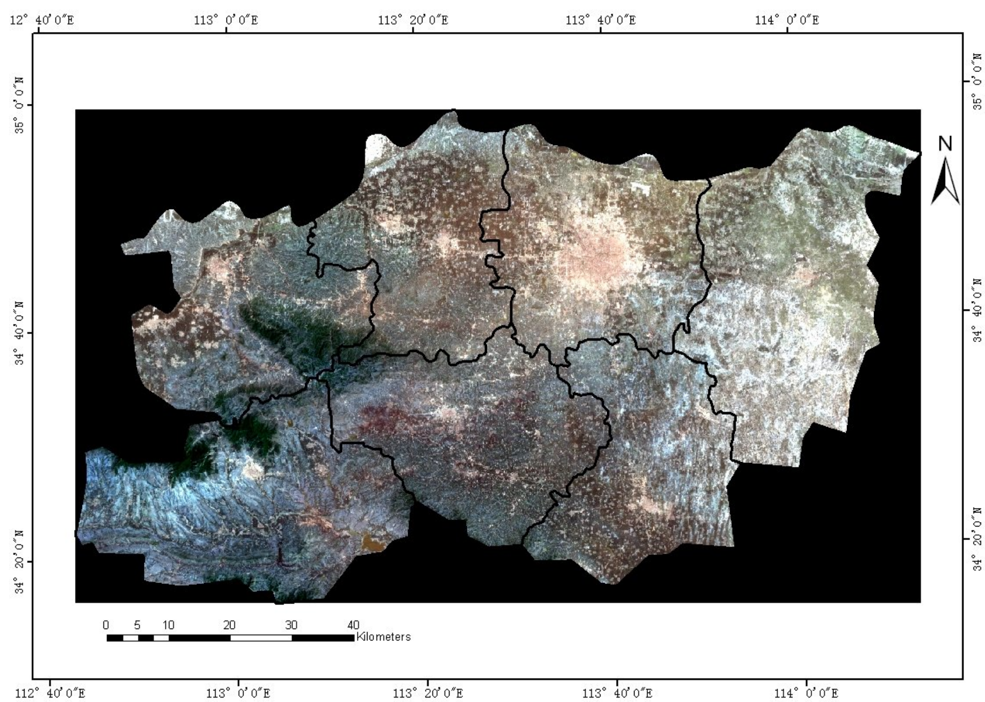

Fig.5. 2006 Color Composite Image RGB (321) of the Study Area.

Aiming at developing a new classification method by making use of the spectral information acquired by a satellite, statistical analysis of data, and the ground truth information in training data; many algorithms (image processing techniques) have been applied. These are the selection of different band combinations for visual interpretation, principal component analysis

(PCA), and IHS decorrelation stretching. These algorithms are created to display the best contrast between different land use/cover attributes. In addition to that, sixty four points were selected to be cross checked in the field to make sure that the classification results are true.

Huete et al., 1988 amended a simple model presented by NDVI (Normalized Difference Vegetation Index) which is used to describe soil-vegetation system according to the soil background's sensitivity (Soil-Adjusted Vegetation Index):

$$SAVI = \left[\frac{DN_{NIR} - DN_R}{DN_{NIR} + DN_R + L} \right] (1 + L) \qquad \ldots(1)$$

Or:

$$SAVI = \left[\frac{\rho NIR - \rho R}{\rho NIR + \rho R + L} \right] (1 + L) \qquad \ldots(2)$$

Where: L is a soil-adjusted coefficient, it is a constant determined by the actual regional conditions to reduce vegetation index reflection of the different changes in the sensitivity of the soil. (When L is zero, SAVI is equal to NDVI).

For medium vegetation cover, L generally is closer to (0.5). The Factor (1 + L) is used mainly to ensure that the final values of SAVI and NDVI are ranged from (-1 ~ +1).

Other functions were derived based on the SAVI:

$$TSAVI= [a(NIR-aR-b)]/(R+aNIR-ab) \qquad \ldots(3)$$

Where a & b are the soil background parameters.

In order to reduce the impact of SAVI in the bare soil, the Modified Soil-Adjustment Vegetation Index was developed:

$$MSAVI = (2NIR + 1) - \sqrt{(2NIR + 1)^2 - 8(NIR - R)} / 2 \qquad \ldots(4)$$

It has been proved that SAVI and TSAVI have more advantages in describing the vegetation cover and soil background. In the case of bare soil background, TSAVI has a better sense of low vegetation cover than NDVI in semi-arid areas (Wang qiao et al., 2005).

SAVI and MSAVI were tested to detect the vegetation cover in the study area. MSAVI was more effective in identifying the boundaries between the barren lands and the vegetation areas in Zhengzhou. Many functions are created to identify each attribute in the image data. Different thresholds values are tested for each attribute until the best limits were determined. Table 1 shows the functions which are used to extract the different attributes.

Table 1.
The Reference Table for Extraction the Information of Each Attribute.

Attribute	1988	2006
Water	(TM2+TM3+20 - TM4 - TM5 >0) AND (TM3<110) AND (TM5 < 70) from the raw data	(TM2+TM3+50 - TM4 - TM5 >0) AND (TM3 <90) AND (TM5<50) from the raw data
Forest	(MSAVI*1000 >230) AND (DEM >500)	(MSAVI*1000 >230) AND (DEM >500)
Crop land	(MSAVI*1000 >-300) AND (MSAVI< 230) AND (DEM < 200)	(MSAVI*1000>-300) AND (MSAVI<230) AND (DEM < 200)
Urban area	(TM2>TM5) AND (TM5>TM7) AND (100>TM7>80) AND (120>TM5>80) AND (80>TM4>60) AND (130>TM3>90) AND (110 >TM2>90) AND (TM1>110) AND (TM4-TM3<15) from raw image	(TM2>TM5) AND (TM5 >TM7) AND (100>TM7>80) AND (120>TM5>80) AND (80>TM4>60) AND (130>TM3>90) AND (110 >TM2>90) AND (TM1>110) AND (TM4-TM3<15) from raw image
Grass land	(MSAVI*1000>-600) AND (MSAVI<-300) AND (200<DEM <500)	(MSAVI*1000>-600) AND (MSAVI<-300) AND (200<DEM <500)
Barren land	(MSAVI*1000>-1000) AND (MSAVI<-600) AND (300 < DEM)	(MSAVI*1000>-1000) AND (MSAVI<-600) AND (300 < DEM)

Comment: TM2, TM3, TM4, TM5, TM7 are the spectrum of TM bands in the raw image; DEM=Digital Elevation Model

5. Classification.

A laminar extraction technique suggested by Al Bassam, 2007 was applied; the specific procedure is as follows:

1. The character of each object at each time is analyzed to identify the range values of each class. This is done for the whole bands by statistical analysis and the best band-composition for each attribute is reached;
2. Extracting the high accuracy attribute by setting up the model toward some objects with large different spectral character;
3. The concerned area on the raw image is masked;
4. Extracting other attributes by operating similar procession to step (1);

The four steps above are repeated till all the objects are extracted. Separation of land and water is attained through the process. Water is then masked from raw image and separate vegetation from non-vegetation till the entire extraction of all objects is done.

Following the extraction of each object; the model could be set up to fuse the attributes into a colored image. This is considered as the outcome of land use/cover classification. In order to ensure classification accuracy, filtering and artificial corrections of some pixels is done to overcome the limitation of TM resolution factor and topography feature. The applied filtering algorithim was (3×3), whereas artificial amendments were carried out on basis of available geological and geomorphological maps (figures 6 & 7).

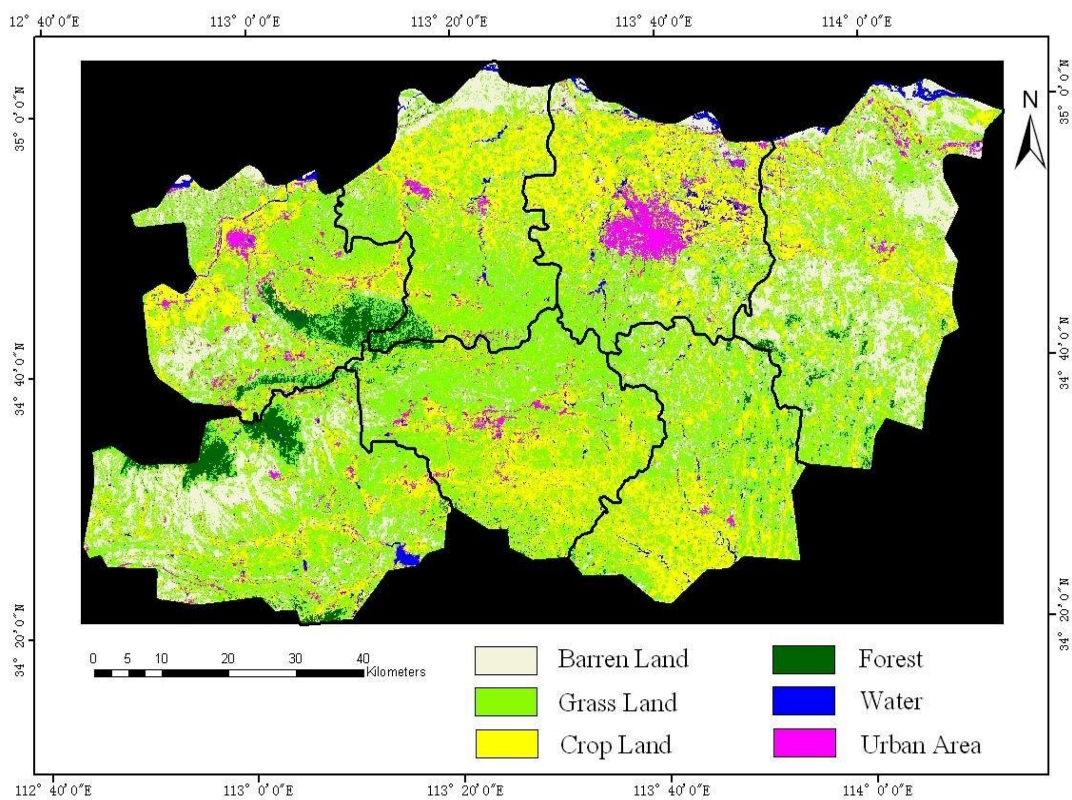

Fig.6. The 1988 land Use/Cover Classification Outcome Image of Zhengzhou Area.

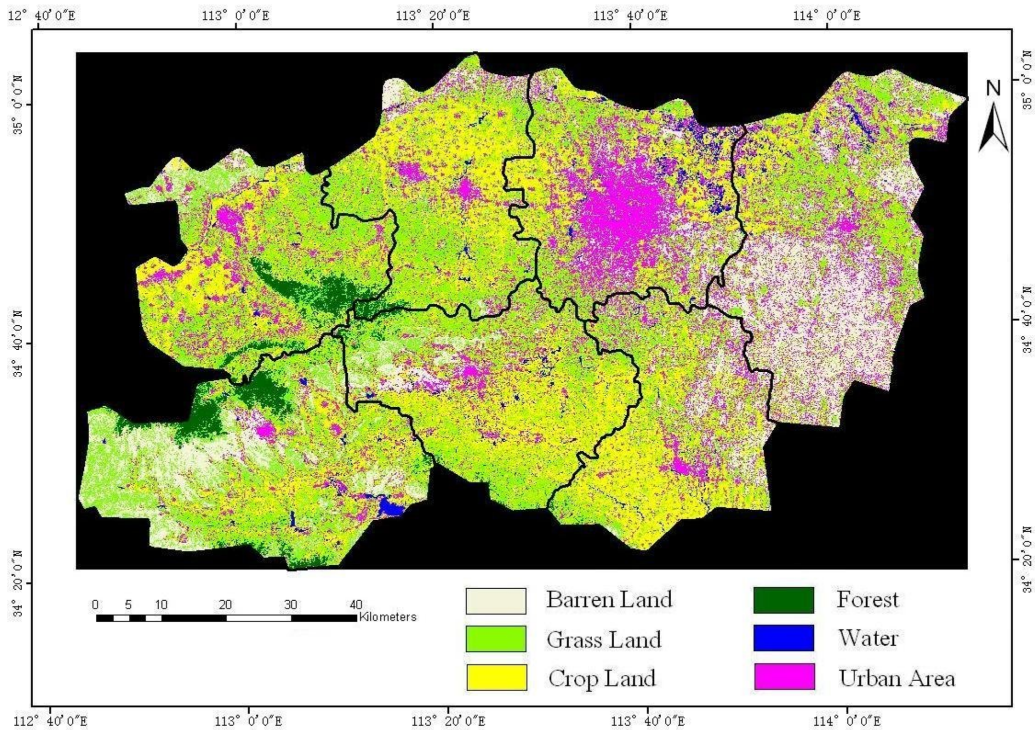

Fig.7. The 2006 Land Use/Cover Classification Outcome Image of Zhengzhou Area.

6. Results and Analysis

Figure 8 and table 2 show the statistics and the area of each attribute and the proportions over the two periods. Table 2 shows that in 7319.64 km^2 of Zhengzhou area, the greatest proportion is grass land, 47.00% in 1988 and 37.59% in 2006. The urban areas and barren land have increased individually. The areas of crop land, grass land, forest, and water have been decreased.

Unfortunately, there are few conventional data sources for the study area available at the present time. The analyses were thus primarily based on information derived from the satellite data. The reasons for land use/cover change could be analyzed as follows:

1) Rapid development in urbanization escorted the speedy growing economy in Zhengzhou city. A great change in land use/cover has occurred in 1988-2006. Uban areas and barren land increased by 246.65%, and 8.02%. On the other hand areas of grass, forest, crop land, and water shrinked by 20.02%, 11.52%, 7.09%, and 5.98% respectively through out the eighteen years (table 2). It indicates degradation of land quality. A major conclusion is the reduction in agricultural yield capacity.
2) Cultivated land area declined from 3253.85 km^2 in 1988 to 3244.2 km^2 in 2006. The ratio between the crop land areas to barren land is 1.39 in 2006 whereas it was 1.03 in 1988.
3) The residential area increased from 295.10 km^2 to 1021.59 km^2. This occurred over the exploitation of cultivated land.
4) Forest and grass land has significantly decreased whereas an enlargement in barren land took place. This imposes great disadvantages on soil conservation.
5) With the continuous increase in the population, the area of crop land has been decreased slightly but the grass land area has decreased significantly during the study period. These alterations might cause sandy desertification development in the area and the changes of regional groundwater resources.

6) Barren land in Loess tilted slope area (II2) in the western part has been significantly changed to crop land.

7) The grassland and cropland area in the eastern part of the study area has changed significantly to barren land with the continuous increase of population and livestock during the 18-years period.

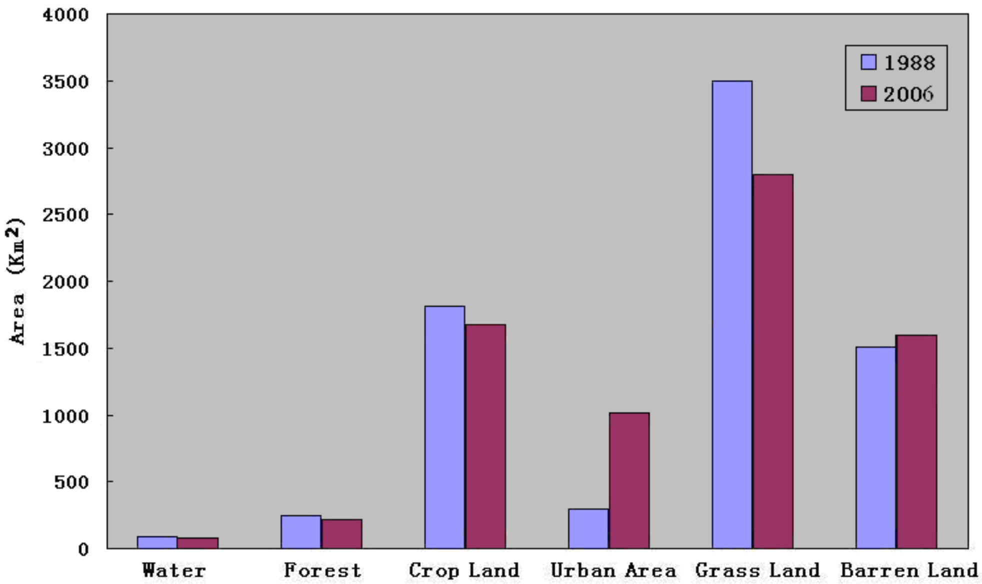

Fig.8. Dynamic Patterns of Area Change of Land Use/Cover Type in Zhengzhou Area.

Table 2.
The statistics of classification outcome over the two periods in Zhengzhou area.

Type	Area (km^2)		Proportion (%)		Change (%)
	1988	2006	1988	2006	
Water	85.51	80.18	1.17	1.10	-5.98
Forest	241.52	214.07	3.30	2.92	-11.52
Crop land	1776.04	1649.49	24.26	22.54	-7.09
Urban area	295.10	1021.59	4.03	13.97	246.65
Grass land	3437.81	2751.34	47.00	37.59	-20.02
Barren land	1477.81	1594.71	20.19	21.81	8.02

7. Conclusions and Recommendations

In the establishment of land use/cover classification, laminar extraction is the most reliable technique as it is based on the spectral characters of a typical attribute. The results show rapid enlargement in urban areas while crop fields are diminished. It reflects degradation in land quality and a decline in yield capacity could be inferred. Noticeable changes in land use/cover have taken place over the years 1988-2006 (figure 8). Urban areas and Barren land increased by 246.65% and 8.02% while the decreased land types were forest, crop land, grass land, and water (11.52%, 7.09%, 20.02%, and 5.98% respectively). These changes were the result of physical and anthropogenic factors. As a result of land use/cover changes and human activities, an environmental degradation occurred in the whole area from 1988 to 2006, such as water changes and vegetation degeneracy. In the future land use planning and management, more attention is to be paid to the effect of land development on ecological environment. Further studies concerned with the analysis of the assessment of related environmental impacts and socioeconomic consequences are suggested. Additional census data would be useful. The concerned department in the republic of China should take the following steps to overcome land degeneration, such as: Forbidding reclamation on steep slops; Redirecting land farming into land forestry in addition to planning of forestry; controlling the water loss and soil erosion; and maintaining a balance on ecology and improve the grass coverage in karst regions.

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تحليل التغير في الغطاء الارضي باستخدام بيانات التحسس النائي: حالة الدراسة منطقة جينغ جو, مقاطعة خنان, الصين

بسام فرمان البسام
كلية الهندسة/ الجامعة المستنصرية

الخلاصة:

في العقدين الاخيرين, عانت الاقاليم الجافة وشبه الجافة في الصين من التغير السريع في الغطاء الارضي نتيجة للحاجة الى الغذاء بسبب النمو السكاني. في هذه الدراسة تم تحليل ديناميكية التغير في انواع الغطاء الارضي في منطقة جونغ جو من سنة 1988 الى سنة 2006. في هذه العملية تم استخدام نظام لتصنيف الغطاء الارضي بالاعتماد على تفسير بيانات التحسس النائي. استعملت طريقة الاستخلاص الطبقي (Laminar Extraction Technique) في تحديد الصفات المميزة النموذجية لنوعية الغطاء. اظهرت النتائج انه مع التطور الاقتصادي السريع لمنطقة جونغ جو فان هناك زيادة تدريجية في المدن ونقصان في الغطاء النباتي وهذا يعكس الانحطاط في نوعية اليابسة والتدهور في الغطاء النباتي بشكل واضح. النتائج اظهرت ان انواع الغطاء الارضي التي ازدادت مساحتها هي المناطق السكانية (Urban Area) والاراضي المكشوفة (Barren Land) بنسبة 246.65%, و 8.02% في حين ان مساحات الغابات (Forest Land) , الاراضي الزراعية (Crop Land) والاراضي المغطاة بالحشائش (Grass Land) , والمياه (Water) قد انخفضت بنسبة 11.52% , 7.09% , 20.02%, و 5.98% على التوالي. النتائج يمكن ان تزود الحكومة المحلية بمعلومات مفيدة من اجل التخطيط المستقبلي وادارة نوعية الغطاء ودراسة تاثيره على البيئة.