Application of Multiple Source Satellite Data to Detecting Changes of Land Cover and Ecosystem Services Value

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***Abstract*—Firstly, two sets of land cover map in China at scale of 1 to 250000 in 1980s and 2005 were produced based on Landsat TM data, CBERS data, MODIS vegetation index products as well as other auxiliary data. Secondly, changes of land cover between the two periods were detected and analyzed with Henan province of central China as a study case. And then changes of ecosystem services value in the province were further analyzed. The following conclusions were drawn: (a) during the period of twenty years from 1980s to 2005, the area of all kinds of land cover has changed. The types of land cover, area of which reduced obviously, included desert, bare soil, swamps and meadows. The area of them was reduced by 80.17%, 82.81%, 73.61% and 62.62% respectively. By contrast, area of urban settlement increased most with an increasing rate of 103.77%; (b) In the 20 years, the total value of ecosystem services in the province decreased 2.256 billion yuan. The decreasing rate was 1.24%.**

***Index Terms*—remote sensing, land cover, ecosystem services value, change detection, landsat TM, MODIS, CBERS**

I. Introduction

Land use/land cover change (LUCC) is a major part and a main cause of global environmental changes, and also the major areas of global environmental change research, it has emerged as a focus on global change studies [1], [2]. Modern remote sensing technology provides a powerful data support for land use/land cover change studies, for it can reflect the process of land cover change accurately, objectively, dynamically. Especially it can effectively monitor land cover change of areas sensitive to environmental changes in real time [3]-[6].

So far, four sets products of global land cover data at resolution of 1 km by 1 km have been developed, including the IGBP DISCover developed by US Geological Survey for the International Geosphere-Biosphere Programme (IGBP) [7], UMD developed by the University of Maryland [8], [9], GLC2000 built by Space Applications Institute (SAI) of the EU Joint Research Center (JRC) [10] and quarterly updated MODI12Q1 [11]. In China, the Chinese Academy of Sciences conducted national land resources survey and land cover mapping by remote sensing, and had established a set of national land use database at scale of 1 to 100,000 [12]-[15]. In 2007, the Institute of Remote Sensing Applications along with Institute of Geographical Sciences and Natural Resources in Chinese Academy of Sciences had completed two periods of national land cover database (2005 and 1980s) at scale of 1 to 250,000 by remote sensing. This project was funded by Data Sharing Network for Earth System Science which is a part of National Fundamental Resources Platform of Science and Technology [16].

The validation of accuracy for land cover database of China at scale of 1 to 250,000 by field survey and for the four global land cover databases mentioned in the above with the land use database of China at scale of 1 to 100,000 as reference were conducted. The results showed that the accuracy of land cover database of China at scale of 1 to 250,000 was significantly higher than that of IGBP Discover, UMD, GLC2000, and MOD12Q1 in China [17]-[19]. Therefore, in this research, Henan province in central China was taken as a case to analyze land cover changes from 1980s to 2005 and changes of ecosystem services value which were resulted from land cover changes.

II. Mapping Land Cover by Remote Sensing

A. Land Cover Classification System

In view of the actual situation of land cover in China, according to remote sensing mapping and terrestrial ecosystems perspective, a set of land cover classification system was established based on the LCCS (Land Cover Classification System) proposed by United Nations FAO along with land use classification system of resource and environment database of the Chinese Academy of Sciences (Table I).

B. Data Sources for Mapping

Land Cover Classification System includes various types of forest (evergreen, deciduous, coniferous and broad-leaved), meadow, typical grassland, desert grassland, alpine meadows, shrub grassland, etc. So it needs high time resolution remote sensing data (such as MODIS) to obtain vegetation variation and other attribute information, also requires high spatial resolution data (e.g.

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TM, CBERS) to obtain the spatial distribution of land cover types and their location information.

Therefore, Landsat TM and CBERS were used as the main remote sensing data for mapping. MODIS vegetation index products MOD13Q1 in 2005 including NDVI and EVI (250m resolution, 16 days composites), which was provided by Land Process Distributed Active Archive Center, US, was to assist in the division of vegetation types. Other auxiliary data included maps of land use, grassland, vegetation and soil map at corresponding scale as well as nationwide digital elevation model (DEM) at scale of 1 to 250,000.

TABLE I. THE REMOTE SENSING BASED LAND COVER CLASSIFICATION SYSTEM CONSIDERING TERRESTRIAL ECOSYSTEMS

Level Ⅰ	Level Ⅱ
Forest	Evergreen coniferous forest
	Evergreen broad-leaved forest
	Deciduous coniferous forest
	Deciduous broad leaved forest
	Mixed wood
	Shrub forest
Grassland	Meadow
	Typical grassland
	Desert grassland
	Alpine Grassland
	Shrub grassland
Farmland	Paddy
	Irrigated land
	Dry land
Settlement	Urban settlements
	Rural settlements
Wetland & Water Body	Marsh
	Coastal wetland
	Inland Water
	River and lake Beach
	Snow Cover
Desert	Bare rock
	Bare land
	Sand desert

C. *Mapping Method*

The general idea of land cover classification and mapping is that on the basis of the land use database of Chinese Academy of Sciences land use database, auxiliary remote sensing information and comprehensive analysis method based human-computer interaction were used to map national land cover [16].

Firstly, land use database of China at scale of 1 to 100,000 in 2005 was used as the basic data for image analysis and interpretation. The arable land, construction land, water, desert, Gobi, glaciers, permanent snow cover in land use database could be converted into correspondent types of land cover directly according to the classification system. For the other types unable to convert directly, such as forests, grasslands, farmlands, the location and boundaries of land cover types could be captured. They constituted a fundamental framework for land cover classification. Secondly, on the basis of the location and boundaries of land cover types, automatic land cover classification by remote sensing involved only spot properties but not spot location and boundary. Such a mapping flow could ensure not only the regularity of mapping, high efficiency, but also higher cartographic accuracy. The main technical links included: (a) classification conversion from land use to land cover; (b) supplement of remote sensing classification information; (c) making base map for land cover classification; (d) zonal land cover map revision; and (e) field verification for classification accuracy.

On the basis of land cover map of China at scale of 1 to 250,000 in 2005, accurately rectified image database of Landsat TM and land use database at scale of 1 to 100,000 in 1980s were applied to get land cover classification in the late 1980s by recovery and reconstruction method. The reconstruction mainly aimed at change of land use from 1980s to 2005 [20].

D. *Mapping Accuracy*

A field survey was carried out in east Inner Mongolia along with Qinling-Dabashan Mountain area. Information from 253 sampling sites was collected to evaluate accuracy of the land cover mapping in 2005. The one or half point deduction method, which means that 1 point is deducted if the first level of category is classified incorrectly while 0.5 points deducted if the second level of category incorrectly but the first category correctly for each sampling site, was applied. The verification results showed that overall accuracy of mapping is among 75% - 84%. The accuracy of settlement, farmland is between 92% and 97%, while the accuracy of forest is relatively low, among 65% to 66% [17], [19]. Nevertheless, compared with international major land cover products (IGBP Discover, UMD, GLC2000, MOD12Q1), the land cover map of China at scale of 1 to 250,000 still has higher accuracy.

III. DETECTING CHANGES OF LAND COVER

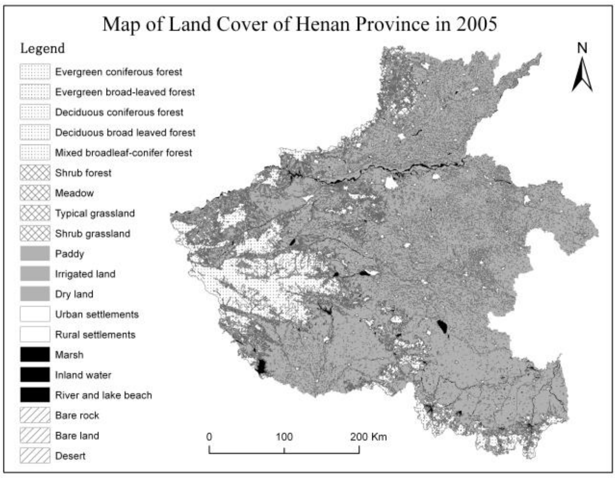

Figure 1. Land cover map of Henan province in 2005.

In this study, Henan province was taken as a case to analyze land cover changes from 1980s to 2005 as well as changes of ecosystem services value resulting from land cover changes by comparing the two-period of land cover maps. Henan is a populous and agricultural province in China. The eastern part of the province, which is flat and dominated by dry land, is mainly farming area. Mountain areas distribute mostly in west, northwest and southeast and the main types of land cover are forest, grassland and farmland (dry land). Southeast and banks of the Yellow River have a little paddy field. Distribution of land cover types in the study area is shown in Fig. 1.

A. Changes of Area for Land Cover

Table II showed the area of various land cover types both in the 1980s and 2005 in Henan. It was calculated from land cover map at scale of 1 to 250,000. In 20 years, various land cover types in the area had changed, the more reduction of the area occurred in desert, bare soil, swamp and meadow, reduced by 80.17%, 82.81%, 73.61% and 62.62% respectively. The most increasing of area was urban settlement at a rate of 103.77%. This change indicated that in the process of socio-economic development, especially for process of urbanization, large amounts of land were occupied by urban, and some unutilized land was also gradually developed and utilized.

TABLE II. CHANGE OF AREA OF LAND COVER TYPES BETWEEN 1980S AND 2005 IN HENAN PROVINCE

Types of land cover	Area and its change in 1980s and 2005 (km2)			
	1980s	2005	Change of area	Percentage of change
Evergreen coniferous forest	341	326	-15	-4.42%
Evergreen broad-leaved forest	4617	4690	73	1.58%
Deciduous coniferous forest	1998	2008	10	0.50%
Deciduous broad leaved forest	16647	16775	128	0.77%
Mixed broadleaf-conifer forest	530	532	2	0.34%
Shrub forest	3358	3230	-128	-3.83%
Meadow	206	77	-129	-62.62%
Typical grassland	3694	3579	-115	-3.13%
Shrub grassland	6186	5550	-636	-10.29%
Paddy	8349	8339	-10	-0.12%
Irrigated land	73252	72637	-615.63	-0.84%
Dry land	33576	33223	-353.11	-1.05%
Urban settlements	1640	3341	1701	103.77%
Rural settlements	7072	7333	261	3.70%
Marsh	52	14	-38	-73.61%
Inland water	2366	2687	321	13.57%
River and lake Beach	1631	1256	-375	-23.03%
Bare rock	4	4	0	-1.34%
Bare land	27	5	-22	-80.17%
Desert	69	12	-57	-82.81%

B. Spatial Distribution of Land Cover Changes

A map algebra operation between the two periods of land cover raster data was used to detect the locations where whether land cover types had changed or not. Fig. 2 is the result of operation. It can be easily found that land cover changes were relatively concentrated in the Yellow River bank areas. The changes also distributed sporadically across the province. The changed types of land cover mainly included: (a) much increasing of area of urban settlement, rural settlement and inland water; (b) huge decline of area of shrub grassland, irrigated land, river/lake beach and dry land. These changes were resulted from both natural and human factors.

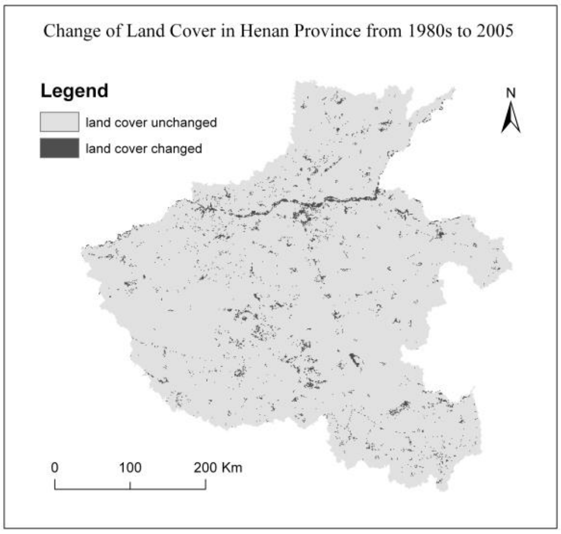

Figure 2. The distribution of land cover change in Henan province during 1980s-2005.

IV. THE CHANGES OF ECOSYSTEM SERVICES VALUE CAUSED BY LAND COVER CHANGES

A. Calculation Method

Estimation of ecosystem services value integrates different aspects of several subjects including ecology, economics, sociology and ethics, and it has become a hot topic of ecological research in the past few years [21]. Some scholars studied change of ecosystem services value based on land use/land cover change by corresponding ecological system types to land use types. Among these studies, coefficients of ecosystem services value raised by Costanza and Xie have been widely applied in China [22]. Costanza raised a global average ecosystem services value. Based on Costanza's results, Xie established a table of terrestrial ecosystem services value at unit area for China [23].

In this study, with support of GIS software, Land cover grid data at a resolution of 1km by 1km, which was converted from vector data at scale of 1 to 250,000, were first used to calculate ecosystem services value in study area in 1980s and 2005 respectively according to Xie's coefficients table of ecosystem services value. Then the difference of ecosystem services value between the two periods was detected by comparing ecosystem services value in the two periods. Coefficients of services value for various ecosystems are listed in Table III. Ecosystem services value in study area was calculated as:

$$E=\sum_{i=1}^{n}(P_i \times S_i) \quad (1)$$

In the formula: E is total ecosystem services value in the study area; S_i is the area of land cover type *i*; P_i is ecosystem services value coefficient for unit area of land cover type *i*.

TABLE III. THE TYPES AND SERVICES VALUE COEFFICIENTS OF ECOSYSTEMS CORRESPONDING TO LAND COVER TYPES (10^4 YUAN/KM^2)

Land cover types	Ecosystem types	Coefficients
Farmland	Farmland	61.14
Forest	Forest	193.34
Grassland	Grassland	64.05
Wetland Water	Wetland Water	1285.77
Settlement	Desert	3.71
Unutilized land	Desert	3.71

B. Calculation Results

Based on (1) and coefficients in Table III, the ecosystem services value per square kilometers could be easily calculated with land cover raster data as parameters. Fig. 3 is distribution of ecosystem services value of Henan province in 2005 at resolution of 1km by 1km. According to the raster data sets of ecosystem services value in 1980s and 2005, the relevant statistical index of ecosystem services value the two periods could be counted out. The results are shown in Table IV.

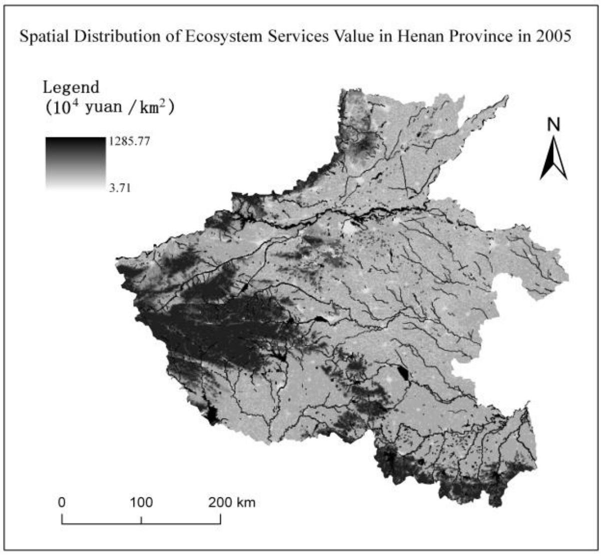

Figure 3. The spatial distribution of ecosystem services value of Henan province in 2005

TABLE IV. CHANGES OF ECOSYSTEM SERVICES VALUE IN HENAN PROVINCE BETWEEN 1980S AND 2005

Time		1980s	2005
Total area (km^2)		165545	165545
Statistical indicators of ecosystem services value(104yuan/km^2,except Sum)	Min	3.71	3.71
	Max	1285.77	1285.77
	Range	1282.06	1282.06
	Mean	109.95	108.59
	Std	137.77	132.14
	Sum(10^4 yuan)	18202400	17976800

It can be seen from Table IV that in the 20 years from 1980s to 2005, the total ecosystem services value of Henan province decreased 2.256 billion yuan with a decreasing rate of 1.24%. And standard deviation of ecosystem services value on different grid cell decreased from 1.3777 to 1.3214 million yuan). This change indicated that ecosystem services value among different region had a tendency to close. Therefore, in order to achieve coordinated and sustainable development among social, economic, ecological and environment, protection of ecological system must be laid stress on when land resource is developed and utilized.

V. CONCLUSIONS

In this paper, technological flow and method for mapping land cover of China at scale of 1 to 250,000 based on multi-source remote sensing data were firstly introduced. Secondly, Henan province in central China was taken as a case to detect land cover changes from 1980s to 2005. Thirdly, According to the corresponding relationship between land cover types and types of ecological system, ecosystem services value in the study area in the two periods was calculated. The following conclusions we were drawn:

(a) During the period of 20 years from 1980s to 2005, the area of various land cover types in the study area had changed with the development of society and economy. The area of desert, bare soil, swamps and meadows reduced by 80.17 %, 82.81%, 73.61% and 62.62% respectively while the area of urban settlement increased with a rate of 103.77%.

(b) In the 20 years, the total ecosystem services value in the province decreased 2.256 billion yuan with a rate of 1.24% for large amount of farmland were replaced by urban settlements and parts of the wetland water were exploited.

(c) It is demonstrated from this study that remote sensing technology is an effective means to detect changes of land cover and ecosystem services value.

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