ECOLOGICAL CAPITAL MEASUREMENT BASED ON REMOTE SENSING TECHNOLOGY AND DRIVING FORCES ANALYSIS OF ECOLOGICAL CAPITAL AROUND TAIHU LAKE

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ABSTRACT:

Taihu basin was the area where the population was dense, economy was developed and the contradiction between human and land was prominent in China. It undergone dramatic changes in land-use processes and a series of complex environmental and ecological phenomena had appeared as a result. Ecological capital could provide the basic information for people to evaluate the long-term impact of various technologies and socio-economic development approaches. In the paper, ecological capital around Taihu Lake in 1995 and 2005 were calculated by using TM images, MODIS images, DEM images, Meteorological data, Statistical data and related contributory data according to remote sensing technology. By comparing and analyzing the ecological capital quantitatively, rapid urbanization, water pollution and the degradation of ecological service functions were the main reasons for the reduction of ecological capital in areas around Taihu Lake. Specially, water pollution caused 36.76%, rapid urbanization accounted for 33.42% and the degradation of ecological service functions aroused 29.82% of the total reduction of ecological capital.

1. INTRODUCTION

Areas around Taihu Lake could be seemed as the core of Yangtze River delta and Taihu basin. The speeds of urbanization and industrialization progress were very high and the economic was increasing rapidly in these areas during the past 10 years which attracted many foreign residents to rush in (Qiu et al., 2006). As a result, the situation of land use and land cover had changed tremendously and many serious environmental risks appeared. For an instance, as the development of economic and industry and the increase of the population in the areas, more and more polluted water from industry factories and some agriculture fertilizers were discharged into Taihu Lake. The eutrophication situation of Taihu Lake had ascended one level every 10 years and it was in a deep level nowadays. The cyanobacterial bloom in Taihu Lake even caused drinking water crisis around Taihu Lake in 2007 (Qin et al., 2007). So it was important to do some researches about the changing process of ecological environment in areas around Taihu Lake.

Ecological capital could be understood as natural ecosystems and species both supporting and maintaining the survival conditions and processes for human, which can clearly describe the humanity's reliance on natural (Pan et al., 2004). So analyzing the change processes of ecological capital was an effective way to research the existing environmental problems. At present, the algorithms of calculating ecological capital was divided into two kinds and one algorithm just used per size price to estimate the statistic sum of ecological capital (Yu et al., 2006). The other one built up calculating models according to differences in ecosystems classes and quality situations (Zhou et al., 2006). Normally, using remote sensing technology to calculate the ecological capital could support the necessary information for the models and overcome the weaknesses of traditional methods. It was seemed as one popular method to estimate ecological capital in a large area.

In the paper, the ecological capital in areas around Taihu Lake in 1995 and 2005 were estimated by using quantitative measurement model according to remote sensing technology. By comparing the distributions and changes of ecological capital in two periods, the driving factors of the ecological capital change was found and it could provide countermeasures and basic theories for the sustainable management of the ecological environment and rational use of the land resources in areas around Taihu Lake.

2. STUDY AREA AND BASIC DATA

2.1 Study Area

According to the district map and different buffer zones from the edge of Taihu Lake, the cities around the Taihu Lake which refer to Wujiang, Suzhou, Wuxi, Changzhou and Yixing in Jinagsu Province, Huzhou and Changxing in Zhejiang province were selected as the study area (Fig 1). The basic terrain in this area was consisted of Campagnas, hills and mountains.

2.2 Basic Data

In the paper, satellite images and meteorological data, statistical data and related contributory data were the fundamental data. Actually, Landsat/TM images which acquired between July and August in 1995 and 2005 (only two images were big enough to cover the whole study area) were used to get land cover classification maps. MODIS NDIV images which had 11 time series annual in 1995 and 2005 and DEM images extracted from SRTM data coming from the NASA were used to calculate the net primary productivity. Meteorological data and

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Soil properties data in vector type were also needed to calculate NPP.

Fig 1 Taihu Lake study area

2.3 Data Processing

All images should be projected and resampled into Albers projection and the spatial resolution of 30 meter. All the meteorological data were observed by different meteorological stations and they should be transformed into raster data using Kringing interpolation.

3. ECOLOGICAL CAPITAL MEASUREMENT BASING ON REMOTE SENSING TECHNOLOGY

3.1 Measurement principles

The algorithm assumed that the total amount of ecological capital with in the region was a variable changing with time dynamically and it was the sum of the direct biological resources value of different ecosystems and their ecological service value (Chen et al., 2006). The sum of ecological capital (V) in a certain region could be seemed as in formula 1 through the algorithm (Zhou et al., 2006).

$$V = \sum_{c=1}^{n} Vc \tag{1}$$

Where c=the type of ecosystems
V_c=the ecological capital of the C ecosystem

$$V_c = \sum_{i=1}^{m} R_i \times S_j \times V_{cf} \tag{2}$$

Where i=different pixels of the C ecosystem
V_{cf}=the C ecosystem's initial values of ecological capital in unit size
S_i=the size of each pixel
R_i= the adjustment factor of V_c in different pixel

In the paper, the adjustment factor R_i was the function of the ecological parameters which reflected the quality of the ecosystem characterization. It adjusted the ecological capital change causing by the differences of the quality and characterizations in the same ecosystems. In the paper,

vegetation coverage and net primary productivity were selected to calculate the adjustment factor (Pan et al., 2004). The specific processes of ecological capital measurement by using remote sensing technology were shown in Figure 2.
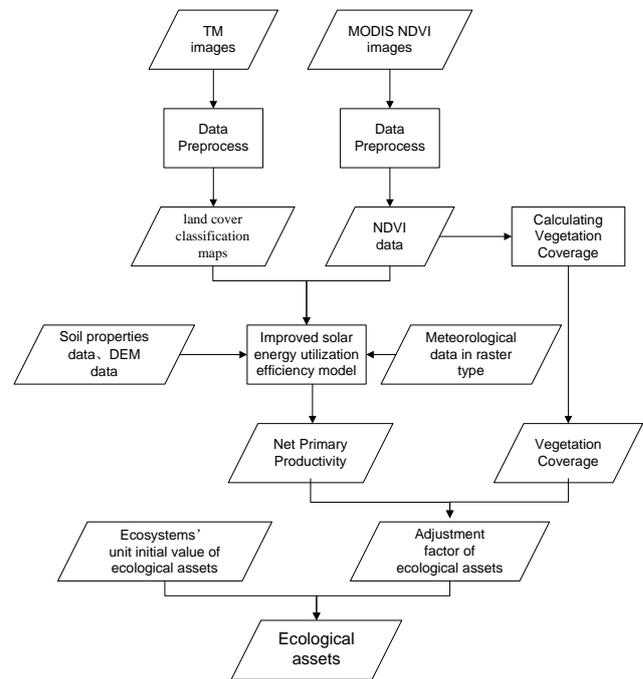

Fig. 2 The specific processes of ecological capital measurement by using remote sensing technology

3.2 Ecological capital measurement

The accuracy of land cover classification according to supervised classification in 1995 and 2005 were 83.37% and 84.24% which both met the requirements of ecological capital measurement. The land coverage around Taihu Lake could be divided into seven types and they were water, farmland, forest, grassland, traffic road, cities and towns and cyanobacteria. But cyanobacteria only existed in 2005 in Taihu Lake region.

The algorithm of calculating vegetation coverage which developed by Gutman et al (1998) was used to estimate the vegetation coverage around Taihu Lake by using MODIS NDIV data. According to improved solar energy utilization efficiency model (Sun et al., 2000), NPP (net primary productivity) could be calculated by using Meteorological data and soil properties data and related contributory data. Then adjustment factor could be extracted from vegetation coverage and NPP. Finally, using adjustment factor and different ecosystems' initial values of ecological capital in unit size and according to formula (1) and (2), the total ecological capital around Taihu Lake could be calculated.

Different ecosystems' initial values of ecological capital in unit size were extracted from the terrestrial ecosystems' initial values of ecological capital in unit size which set up by Costanza et al (1997). At the same time, the forest ecosystem in research area belongs to temperate forests and the ecological capital of traffic road and towns and cities were considered as zero. It was difficult to calculate the reduction of ecological capital caused by cyanobacteria quantitatively. In the paper, it was assumed that the decomposition of organic matters which

produced by cyanobacteria was completely when cyanobacteria die and the photosynthesis and aerobic respiration of cyanobacteria would reach a balance. Then the ecological capital of cyanobacteria also was considered as zero. Different ecosystems' initial values of ecological capital in unit size were shown in table 1.

Ecosystem type	Intial value in unit size
Cities and towns	0
Traffic roads	0
Cyanobacteria	0
Water	7320
Forest	260.3
Farmland	79.3
Grassland	200

Table 1. Different ecosystems' initial values of ecological capital in unit size (unit: thousand yuan/ km2)

4. THE DISTRIBUTION AND CHANGE OF ECOLOGICAL CAPITAL AROUND TAIHU LAKE

4.1 The distribution and change of ecological capital

By using ecological capital measurement model and different images and related contributory data, the distribution maps of ecological capital around Taihu Lake was got. (Fig. 3)

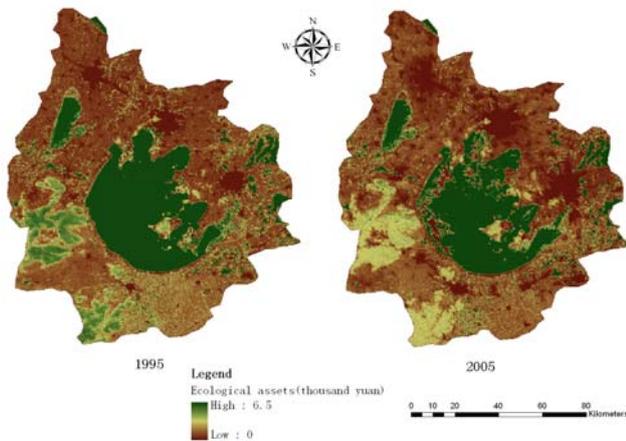The distribution maps of ecological assets around Taihu Lake in 1995 and 2005

Fig. 3 The distribution maps of ecological capital around Taihu Lake in 1995 and 2005 (The statistic unit is the pixel of TM image)

According to the distribution maps, water and forest ecosystems had higher ecological capital around Taihu Lake and they were Taihu Lake, GeHu Lake in the northwest of Taihu Lake and forests in the west and southwest of Taihu Lake specifically. The cities areas which contain SuZhou, Wuxi and Changzhou had the lowest ecological capital around Taihu Lake. At the same time, cyanobacteria blooms also caused several areas having lowest ecological capital in Taihu Lake in 2005. Through the statistics information of distribution maps of ecological maps, the detailed change information of ecological capital for different ecosystems between 1995 and 2005 was shown in table 2.

Properties Ecosystem type	Ecological capital in 1995	Ecological capital in 2005	The Margin of ecological capital between two years
Water	29.983	26.127	-3.856
Cities and towns	0	0	0
Farmland	9.31	6.90	-2.410
Forest	8.16	5.858	-2.302
Grassland	0.637	0.423	-0.214
Traffic roads	0	0	0
Cyanobacteria	0	0	0
SUM	48.09	39.308	-8.782

Table 2. The detailed changing information of ecological capital between 1995 and 2005 (unit: billion yuan)

Result shown in Tab. 1 indicated that the sum of ecological capital around Taihu Lake decreased 8.782 billion and the total declining percent reached to 18.26% in ten years. According to the land-cover change and ecological capital change around Taihu Lake, the total reduction of ecological capital were reflected by the decreased ecological capital for four ecosystems which contained water, farmland, forest and grassland. At the same time, cites and towns and traffic roads expanded rapidly and many other ecosystems were encroached, so this phenomenon was an important driving factor for the reduction of ecological capital around Taihu Lake. From the land cover classification map in 2005, cyanobacteria blooms existed in Taihu Lake which formed much lowest ecological capital area and it had a significant influence for ecological environment around Taihu Lake.

4.2 The driving factors of ecological capital change

In the above study, Rapid urbanization and cyanobacteria blooms (which caused by water pollution) were two important reasons for the reduction of ecological capital around Taihu Lake. These two factors belonged to human factors and they would play a dominant role in decreasing ecological capital. Natural factors such as the change of precipitation, temperature and so on also caused the degradation of ecosystem services for different ecosystems which will influence the ecological capital indirectly. In the following, the influences of different driving factors for the reduction of ecological capital were evaluated quantitatively.

4.2.1 Rapid urbanization: Rapid urbanization meant the continuous expansion of cities, towns and traffic roads. According to the land cover classification map in 2005, the size of cities, towns and traffic roads reached to 3389.06 km2 which was nearly one quarter size of the whole research area. In the past ten years, the size of cities and towns increased 1426.6 km2 and the annual growth rate was high as 5.77%. But the rational annual growth rate was just between 0.5% and 0.7%. (Lu et al., 2007)

As the expansion of cities, towns and traffic roads, more and more size of many other ecosystems were encroached and the ecological capital of theses area became zero. By analyzing the increased size and which ecosystems were encroached, the reduction of ecological capital which values 2.838 billion yuan was caused by the expansion of cities and towns and it reached to 32.32% of the total reduction. In the same way, the expansion of traffic roads caused 970 million yuan reduction and it reached to 1.1% of the total reduction. So rapid urbanization caused a significant reduction of ecological capital

around Taihu Lake directly and some reasonable control and plan were needed to achieve the sustainable development of urbanization.

4.2.2   Water pollution: Taihu Lake was one of shallow lake which was in eutrophication state in China. Nowadays, it was in the state of eutrophication to re-eutrophication and cyanobacteria blooms appeared frequently as a result (Qin et al., 2007). According to land cover classification map in 2005, the size of cyanobacteria ecosystem reached to 194.36 km2 and much zero ecological capital area existed in Taihu Lake which caused a substantially reduction of ecological capital. Specifically, the reduction of ecological capital caused by cyanobacteria blooms in 2005 valued 3.228 billion yuan and it reached to 36.76% of the total reduction of ecological capital around Taihu Lake. Obviously, the water pollution had a major impact on the environment around Taihu Lake and some water quality monitor and protect measurement should be improved urgently.
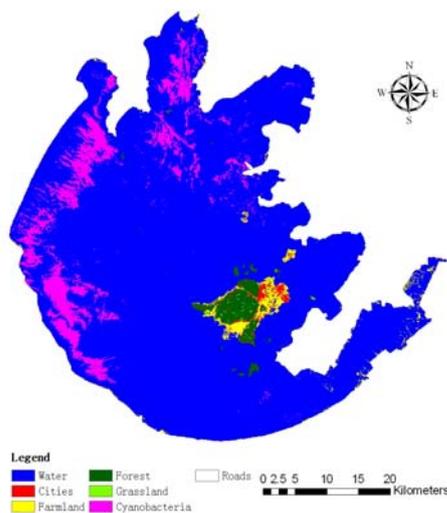

Fig. 4 Land cover classification map in Taihu Lake in 2005

4.2.3   The degradation of ecological service functions:
Ecological service functions of one ecosystem determined its total ecological capital directly. Precipitation, temperature and other weather factors influenced ecosystem service functions and it caused the different of ecological capital for one ecosystem in different time. The adjustment factor in the measurement model just reflected this kind of different. The climate around Taihu Lake did change a lot in past 10 years and it was needed to calculate the reduction of ecological capital which caused by the degradation of ecosystem service functions. Specifically, only water, forest, farmland and grassland four ecosystems needed to be analyzed. By analyzing the land cover classification maps in 1995 and 2005, unchanged areas in four ecosystems could be extracted. Then according to the distribution maps of ecological capital in 1995 and 2005, the reduction of ecological capital which caused by the degradation of ecosystem service functions could be calculated, which valued 2.619 billion yuan and it reached to 29.82% of the total reduction. It was also an important reason for the reduction of ecological capital around Taihu Lake.

5.   CONCLUSTIONS

In this study, the ecological capital around Taihu Lake in 1995 and 2005 were calculated by using remote sensing technology. The result showed that the total ecological capital in 2005 reached to 39.308 billion yuan which suffered from a significant decease comparing to 1995. The total reduction of ecological capital valued 8.782 billion yuan and it was caused by rapid urbanization, water pollution and the degradation of ecological service functions.

By analyzing the driving factors quantitatively, it was knew that: (1) Water pollution was the main reason for the decline of ecological capital and it caused the total ecological capital around Taihu Lake decreased 3.228 billion yuan which was 36.76% of the total reduction; (2) Rapid urbanization also played an important role in the decline of ecological capital and it accounted for the reduction of ecological capital which valued 2.935 billion yuan and reached to 33.42% of the total reduction; (3) The degradation of ecological service functions could not be ignored and it also caused ecological capital decreased 2.619 billion yuan which was 29.82% of the total reduction.

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