Impact of land use and land cover change on water quality: a study of Fuxian Lake

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Abstract. Water quality and basin ecological environment are seriously threatened by development around the lake. The thesis intends to assess basin land use and land cover changes impact on water quality in Fuxian Lake. To achieve this purpose, six periods Landsat images from 1990 to 2016 were used. By using remote sensing and GIS software, the five images were classified into six land use classes. The water quality information was obtained by investigation and collection. Correlation coefficient between LUCC and water quality was celebrated based on SPSS software. The results revealed that, the study area underwent an increase in construction land and farm land with the region development; but forest land and grassland are gradually reduced. In addition, potassium permanganate index is gradually increased. Furthermore, total nitrogen is significantly positively correlated with farmland and construction land, negatively correlated with forest land and grass land. In the final part of the thesis, it is believed that a series land use and land cover changes has happened due to development of Lake Basin, which poses a serious threat to water quality.

1. Introduction

Land Use and land Cover Change (here after abbreviated as LUCC) have important effects on water quality and water ecosystems within a watered [1-3]. The thesis discusses and analyzes the impact of LUCC on water quality in Lake Basin.

The present research is motivated by the facts that Lake Basin is exploited quickly on the basis of social development projects, leaded to land use and land cover have been changed greatly, and received a serious threat to water quality. Therefore, research and assess the relationship between land use change and water quality have the important research significance.

Various problems related to water quality are caused by unsuitable land use and practice in river basin, such as urbanization, industrial and agricultural activities [4]. The relationships between land use change and water quality at a watershed scale explained variations of river water quality in water resource conservation and watershed ecosystem management [5-6]. Generally, farm land use has strong influence on nutrient parameters in river water, such as nitrogen and phosphorus contents [7]. Construction land use is associated with organic pollution [6-7].

Fuxian Lake is one of the important freshwater lakes in the central Yunnan Plateau, which has played a critical role in local economic and tourism development over the past 30 years. The lake water and basin ecosystem are seriously threatened because of urbanization around the lake.
Understanding the relationships between land use change and water quality will provide useful information for water protect and land use management in Lake Basin.

Methods in the thesis include collection and investigation of water quality, experiments on land use and land cover, and the analysis for the relationship between land cover change and water quality.

The main arguments of the thesis include (1) assessing land use and land cover change in the Fuxian lake basin from 1992 to 2010; (2) analyzing the lake water quality changes; and (3) detecting the correlations between land use change and water quality.

The thesis is divided into three parts. Part 1 is about introduction in which land use and land cover change, study area status and water quality are introduced. Research methods are described in part 2, which recommended us for the correlation analysis about land use and land cover change with water quality. The last part is analysis and discussion which analyzed land use and land cover changes, water quality changes, and discussed the impact of land cover changes on water quality. The construction land and forest land have significantly influences on water quality by analysis and discussion.

2. Methodologies

2.1. A Brief Description of Correlation Analysis
Correlation analysis is used to measure the closeness of two variables, which refers to the two or more related variable elements. Correlation analysis is widely used in different research fields. Ying Hou and Qingguang Zeng in the 2000s take correlation analysis method to study the relationship between dry eye syndrome and contact lenses. Shijie Jiang has discussed the relativity of investment of elementary infrastructures and urbanization. Dr. Xu also uses this method to study the correlation between meteorological factors and the ratio of vegetation cover [6].

Correlation analysis is based on the correlation coefficient as a statistical indicator. There are three common correlation coefficients: Pearson, Spearman and Kendall. This thesis will take Pearson correlation coefficient to analysis the correlation between LUCC and lake water quality.

2.2. Main Points of Pearson correlation coefficient
Pearson correlation coefficient reflects two variables linear correlation degree, expressed as a constant, whose value depends on the samples.

\[ P_{xy} = \frac{\text{Cov}(x,y)}{\sqrt{\text{Var}(x)\times\text{Var}(y)}} \]  

In the formula, \( P_{xy} \) is overall correlation coefficient, \( \text{Cov}(x,y) \) is the covariance of random variables \( x \) and \( y \), \( \text{Var}(x) \) is the variance of \( x \), and \( \text{Var}(y) \) is the variance of \( y \). The compute correlation analysis results will have positive correlation, negative correlation and irrelevances.

Two points are worth mentioning about Pearson correlation coefficient: verifiability and reliability. By verifiability, it means that based on the existing data can repeat tests and verify the accuracy of the results. By reliability, it means that the conclusion is objective and scientific, which is based on mathematical calculations.

2.3. Acquisition of Key Elements
(1) Land Use and land Cover Changes
Using Remote Sensing and Geographic Information System technologies can obtain the study areas LUCC information. Firstly, it needs to get remote sensing image data in different periods. Secondly, by processing remote sensing images to obtain study areas land use information. Finally, it can be obtained the LUCC through land use information in different times.

(2) Water Quality
Three ways are worth mentioning about how to get water quality information: (1) Refer to the literature; (2) Download through official website; (3) Purchase from professional institute.
2.4. Application of Correlation Analysis to study Land Use and land Cover Change impact on Water Quality

The correlation analysis is justified in the study of LUCC impact on water quality in that, firstly, correlation analysis shares something in common with LUCC impact on water quality, the changes of a basin land use has a strong influence on water quality, there is a clear correlation between the two; and secondly, correlation coefficient can clearly and accurately explain the relationship between LUCC and water quality; finally, Pearson correlation coefficient could reflect two variables linear correlation degree.

3. Analyses and Discussion

3.1. Analysis and Discussion on the Basin Land use and land Cover Changes

According to the results of second national land investigation and combined with the actual situation of study area, determining the types of land use in the Fuxian Lake Basin include: (1) grassland, (2) farmland, (3) water, (4) construction land, (5) forest land, (6) bare land.

| Land use types   | 1990      | 1995      | 2000      | 2005      | 2010      | 2016      |
|------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Grassland        | 71.341    | 53.893    | 45.484    | 92.701    | 4.771     | 28.341    |
| Farmland         | 56.599    | 74.917    | 64.394    | 75.102    | 125.931   | 96.192    |
| Water            | 216.11    | 214.969   | 214.388   | 214.715   | 213.575   | 215.991   |
| Construction land| 17.918    | 31.483    | 24.507    | 19.664    | 31.246    | 37.527    |
| Forest land      | 164.942   | 151.408   | 178.82    | 126.272   | 150.171   | 149.546   |
| Bare land        | 0.318     | 2.43      | 1.508     | 0.186     | 0.69      | 0.303     |

The remote sensing images were processed by ENVI5.3 and ArcGIS10.2, extract information of different land use types in different periods.

The data of land use and land cover changes reveal that (1) with the rapid economic development, construction land increased by 19.609 km²;(2) rich in mineral resources in the basin, forest being felled, forest land areas was reducing, and (3) grassland has great change. All these data means that business actives around the basin have intensified, water area has changed, and water quality has been threatened.

3.2. Analysis and Discussion Based on Water Quality

The main environmental parameters of water quality in lakes include chemical oxygen demand, biochemical oxygen demand, dissolved oxygen, PH value, total nitrogen and total phosphorus, etc. The potassium permanganate index usually directly reflects water pollution status, and biochemical oxygen demand can indirectly reflect the degree of contamination of water by organic matter. Nitrogen and phosphorus are the main factors leading to eutrophication of water. According the Surface Water Environmental Quality Standard and field investigation, choose potassium permanganate index, biochemical oxygen demand, annual average value of total nitrogen and total phosphorus as water quality pollution assessment indexes.

| Years | Potassium permanganate index (mg/L) | Biochemical oxygen demand (mg/L) | Total phosphorus (mg/L) | Total nitrogen (mg/L) |
|-------|------------------------------------|---------------------------------|------------------------|-----------------------|
| 1990  | 0.92                               | 0.63                            | 0.006                  | 0.12                  |
| 1995  | 1.10                               | 0.65                            | 0.009                  | 0.16                  |
| 2000  | 1.05                               | 1.17                            | 0.008                  | 0.07                  |
| 2005  | 1.11                               | 1.47                            | 0.005                  | 0.16                  |
The data of water pollution indices from 1990 to 2016 shows that total nitrogen is gradually increasing, all the other three indexes have growth and decrease. All these data means water quality has changed in the past 26 years.

3.3. Analysis and Discussion in Light with Correlation between LUCC and Water Quality

Calculate the correlation coefficient between LUCC and water quality by SPSS17.0 software. When the coefficient is positive, it indicates that the factor has a positive effect on the pollutants, which means the pollution is aggravated; when the coefficient is negative, it indicates that Land use types have a negative effect on pollutants, and reduce the pollution.

This may mean that (1) total nitrogen is significantly positively correlated with farmland and construction land, negatively correlated with forest land and grassland; (2) the correlation coefficient between total phosphorus and bare land is greater than 0.8, suggested that bare land have a significant positive effect on pollutants, other land use types is positive or negative but not significant; (3) potassium permanganate index and biochemical oxygen demand is correlated with all land use types, but not significant.

| Land use types | potassium permanganate index | biochemical oxygen demand | total phosphorus | total nitrogen |
|----------------|------------------------------|---------------------------|-----------------|---------------|
| Grassland      | -0.276                       | 0.262                     | -0.056          | -0.406        |
| Farmland       | 0.578                        | 0.087                     | -0.389          | 0.783         |
| Water          | -0.546                       | -0.508                    | 0.196           | -0.036        |
| Construction land | 0.576                | -0.295                    | 0.351           | 0.619         |
| Forest land    | -0.558                       | -0.401                    | 0.494           | -0.689        |
| Bare land      | 0.231                        | -0.321                    | 0.841           | -0.285        |

4. Conclusions

From the analysis and discussion above, three conclusions may be drawn that, firstly, there is a significant changes of land use and land cover in the Fuxian lake basin from 1990 to 2016. Secondly, the lake water quality is changing, but not significant. Finally, the increase in forest area has inhibited water pollution, construction land and farmland increase influence the water pollution index increase.

The conclusions above as drawn above may lead to the following implications that lake water quality is susceptible to the change of land use and land cover. This further implies that rational land use planning and development plans play an effective role in protecting lake water quality and watershed ecosystem.

The research of LUCC impact on water quality proves to be inadequate in that (1) research fund for LUCC impact on water quality is not enough to sustain further study; and (2) meanwhile, the water quality data is annual average, which cannot be consistent with land use data in the season. It is therefore suggested that more fund be raised to be invested into water quality collection and remote sensing data; and detailed study the impact of LUCC on water quality in different seasons or months. Based on the research, the author would like to propose that more scholars give attention to water quality and watershed ecosystem of plateau lakes in Central Yunnan.

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