TEMPORAL-SPATIAL DYNAMIC CHARACTERISTIC OF VEGETATION IN THE AREA OF CASCADE HYDROPOWER STATION CONSTRUCTION IN THE UPPER REACH OF THE YELLOW RIVER

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ABSTRACT:

The hydropower station construction produced serious impacts on the regional eco-environment. The most obvious characteristics of the impacts caused by the cascade hydroelectric development are progressive, cumulative and regional. In this paper, the study area of Yellow river section from Longyangxia to Liujiaxia reservoir locates in the northwest Loess plateau of China. The remote sensing data of 1977, 1996 and 2006 were selected to analyze the temporal-spatial dynamic characteristic of regional vegetation coverage in last 30 years. The result indicated that : a) The vegetation coverage in study area was gradually improving, the main cause of the vegetation decrease was the hydropower plant construction, especially annual regulating reservoir, because of which many land use types were converted to water and the vegetation coverage decreased. b) With the increase of the altitude, vegetation increase rate rose firstly and then declined, while the change trend of vegetation decrease rate was opposite. c) The vegetation increase rate rose gradually as the distance to roads goes farther, while the nearer the vegetation was to the roads, the higher the vegetation decrease rate was. d) The decrease rate was relative to the population density and residents; but in some districts the decrease rate rose contrarily with distance to resident went farther. e) The vegetation change was highly related to the activities of human beings in the study area. f) This research demonstrated that there was no obvious evidence proved that there was correlativity between the cascade hydropower development and the regional vegetation coverage.

1. INTRODUCTION

China's rapid economic development has left deep marks on energy availability, and a further development hydropower energy resource will be an inevitable choice for China’s resource strategy (Zhe-Ren Dong, 2006).The Yellow River, with its own advantages, has played an important role in the country’s hydropower development. The cascade construction from Longyang gorge to Liujia gorge is the most concentrated area in the Yellow River，which is located on the northeastern Qinghai-Tibet Plateau, across Qinghai and Gansu provinces. In 2000, the total generating capacity is 20.101 billion kw·h, accounting for 24.1% of the Northwest Power Grid (Zhen-ke Zhang, 2004). But the natural ecological environment is fragile as grassland degradated and desertification intensified. As a double-edged sword, the regional hydro-power exploitation promotes the development of local economy; meanwhile, it also has an adverse influence on the eco-environment such as the regional vegetation and landscape pattern. Due to its severe impact on local natural and geographical conditions, once the vegetation is damaged, it will not be easy for restoration. Therefore, it is necessary to analyze the temporal-spatial dynamic characteristic of vegetation in the area of cascade hydropower station construction.

The most obvious characteristics of cascade hydroelectric development are progressive, cumulative and regional (Anna Brismar. 2004), which can be described by application advantages of remote sensing technology from the perspective of space-time. The Landsat series of sensors are the most popular ones in collecting regional environmental data for comparison analysis (W. Ouyang, 2007; F.H. Hao, 2007). The Multi-spectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensor series can provide continuous high spatial resolution images. Since 1972, plenty of such images captured by Landsat series of sensors have been used in the retrospective assessment of the regional environmental quality (W. Ouyang, 2007). Now, remote sensing is an effective way for regional construction disturbance observations, and satellite images have been applied widely, especially in long-term monitoring of vegetation responses to environmental change.

Spectral indices of vegetation, based on satellite observations in the near-infrared and visible (usually red) wavebands are widely employed as measures of green vegetation density. Vegetation indices have been identified by many authors with measures of the vigor and productivity of vegetation and applied at all scales of operation, ranging from continental scale vegetation dynamics, global studies of plant responses to climate change, to regional crop yield predictions and precision farming. Vegetation index was a simple and effective parameter, which was used to indicate the vegetation cover and growing condition in RS fields (N Guo, 2003; J. W. Rouse, 1974). NDVI has a good linear relationship with the condition of vegetation cover, vegetation productivity, etc., which was the important index to study the vegetation change. In this paper, we choose NDVI and f_{NDVI} as an indicator to measure the change of regional vegetation density.

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Up to now, there is no systematic analysis research on the impact of vegetation against the cascade hydropower station construction. Hence the goal of this paper is to assess the trend and temporal-spatial distribution of vegetation base on the remote sensing imagines, and then analysis the impact of the cascade hydropower station construction on the vegetation fraction.

2. STUDY AREA

In this paper, the study area reaches to 425 km long longyang gorgre to Liujia gorge reservoir (including Longyangxia Reservoir 105 km) , the total area is about 16730.9km^2, mainly covered by grassland （59.95%）, crop land (17.73%)，unused land (8.80%)and water (4.30%). This area locates in the northwest inland plateau of China, east edge of northeastern Qinghai-Tibet Plateau, acrossing Qinghai and Gansu provinces (Figure 1).This region is typical continental climate with plateau natural condition. The coldest and warmest average monthly temperature is 0-0.5°C in January and 15-15.5°C in July. Mean annual precipitation ranges from 194 to 357 mm, most occurs between June and August. However, the mean annual pan-evaporation is between 1500 and 2131 mm, exceeding precipitation nearly up to 10 times. The study area is the upper region of Yellow River watershed, which average altitude is 2800-4800 m above sea level with a sharp eastward gradient. The Yellow River watershed is characterized by both rich natural resources and fragile eco-environments.

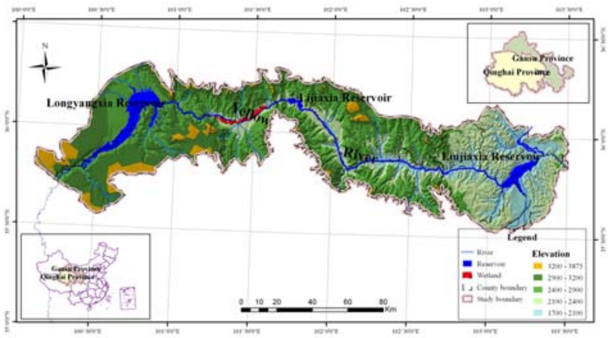

Figure 1 The location of study area

3. DATA AND METHODOLOGY

3.1 Data source

According to the construction time of each power plant, the remote sensing images in the same month of 1977, 1996 and 2006 for research area were selected to monitor the change of regional vegetation distribution in the area of cascade hydropower development for 30 years.

NDVI was extracted from the MSS, ETM+ and TM imagines, and then the vegetation fraction was estimated from NDVI through the dimidiate pixel model. Before estimating the vegetation fraction, we eliminated the errors that the NDVI from the different instruments, allowing vegetation indices from one instrument to be inter calibrated against another (Michael D. Steven, et sl, 2003).

The calculation formula of NDVI could be expressed as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \qquad (1)$$

The model for vegetation index converts to vegetation coverage:

$$f_{NDVI} = \frac{NDVI - NDVI_{\min}}{NIDVI_{\max} + NDVI_{\min}} \qquad (2)$$

Where f_{ndvi} = vegetation coverage;
$NDVI_{max}$= the maximum NDVI value;
$NDVI_{min}$= the minimum NDVI value.

DEM(1:250 000)data, roads data(1：250 000), residents data(1：100 000) and the collecting field data were used to analyze the vegetation distribution character. The ARCGIS 9.0 software were used to convert data types and did the overlay, reclassification, zonal statistic analysis.

3.2 Method

3.3.1 The classification of vegetation coverage change

According to the Criterion of Classification of Soil Erosion, vegetation coverage was divided into five kinds: high-coverage, moderate-high coverage, moderate coverage, moderate-low coverage, low coverage. The increase of the vegetation coverage could be described as the conversion of high-grade coverage to low-grade coverage, while the decrease of the vegetation coverage could be described as the conversion of low-grade coverage to high-grade coverage. In a certain regional area, the rate of the increase vegetation coverage area and the total regional area was called as the vegetation increase rate, while the opposite was the vegetation decrease rate.

3.3.2 Vegetation coverage change analysis

The cause analysis of vegetation change is based on the GRID module in ARCGIS WORKSTATION. ①generating aspect by DEM data, aspect was divided into nine categories: north, northeast, east, southeast, south, southwest, west and northwest; take elevation 100m as the distance, elevation data will be divided into 11 bands ; taking into account the relation of the altitude and aspect, superimposed altitude data and slope data; ②extracting the data of settlements and roads from the digital topographic maps (scale 1:250 000), taking residents and roads as the centre and 1 km as the unit respectively , producing 19 and 14 buffer zones separately. On those bases, we obtained the number of the residents and the vegetation cover change area in different aspects, elevation and distance buffer zones, and then calculated the increase rate and the decrease rate of vegetation coverage. The correlation analysis between vegetation coverage change rate and other factors was completed in SPSS.

4. RESULTS AND DISCUSSIONS

4.1 Vegetation coverage change analysis in study area

In both two periods, from 1977 to 1996 and from 1996 to 2006, the vegetation coverage change mainly rose in study area. The proportion of increased vegetation area accounts for 27.04% and 37.77% of the total area separately, while those of decreased vegetation area are 12.74% and 7.51% respectively.

The distribution of the improved vegetation area was sporadic and patchy, mainly to a slight increase. And the distribution of the decreased vegetation area was patchy. From 1977 to 1996, the regions in which the vegetation coverage increased were surrounding the Longyangxia reservoir and Guide wetland. The regions in which the vegetation coverage decreased were mainly inside the Longyangxia reservoir.

From 1996 to 2000, the regions in which the vegetation coverage increased were sporadic, especially nearby the river. And the regions in which the vegetation coverage decreased were mainly in the Longyangxia reservoir and the Lijiaxia reservoir. All these showed that the vegetation in study area was gradually improving, and the main cause of the vegetation decrease was the hydropower development, especially annual regulating reservoir. Many land use types were converted to water and the vegetation coverage decreased.

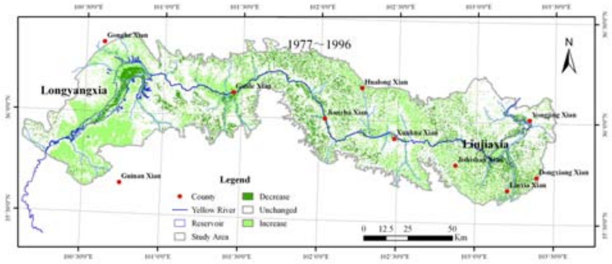

Figure 2 Vegetation coverage change in study area from 1977 to 1996

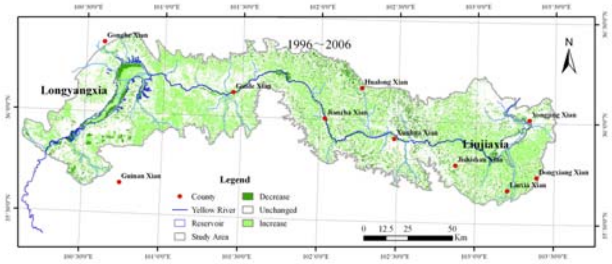

Figure 3 Vegetation coverage change in study area from 1996 to 2006

4.2 Vegetation coverage change character and its impact factors analysis

4.2.1 The relationship between vegetation coverage change and the altitude and slope

According to the relationship of aspect and environmental factors, aspect could be divided into sunny slope (the southern slope, southwest and southeast slope), shade slope (North Slope, northeast and northwest slope) and semi-sunny semi-shade slope (West Slope and east slope). From 1977 to 1996, as the altitude increased, vegetation increase rate first increased then declined. Between 1700-3300 meters above sea level, the higher the elevation was, the higher the vegetation increase rate was, and the increase rate was higher in the flat and shade slope than that in the sunny slope. While at an altitude of 3,300 meters above, it showed the opposite trend, and the increase rate in sunny slope was higher.

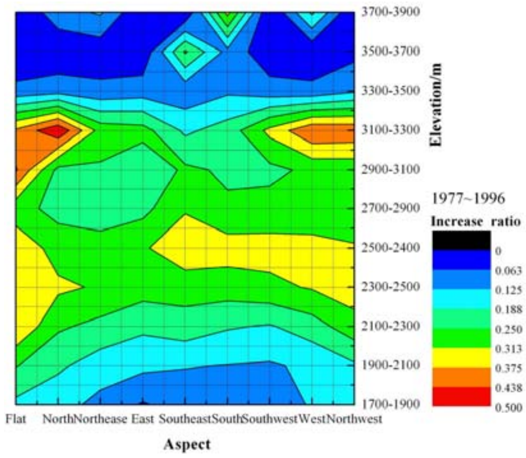

Figure 4 Vegetation increase rate in different slope aspects and elevation in study area from 1977 to 1996

The change trend of vegetation decrease rate was opposite to that of the vegetation increase rate, as the altitude increased, vegetation decrease rate first rose then declined. Between 1700-3300 meters above sea level, the higher the altitude was, the lower the vegetation decrease rate was. As a whole, all the decrease rates were between 0.138-0.275; more than 3,300 meters above sea level, vegetation decrease rate was significantly higher, especially in the shade slope.

The reason why the 3,300 meters above sea level was a turning point for the two change rates is as follows: During this period of time, the Longyangxia reservoir was set up and stored water, which is located on above 3,300 meters, resulting in the decrease of the vegetation increase rate.

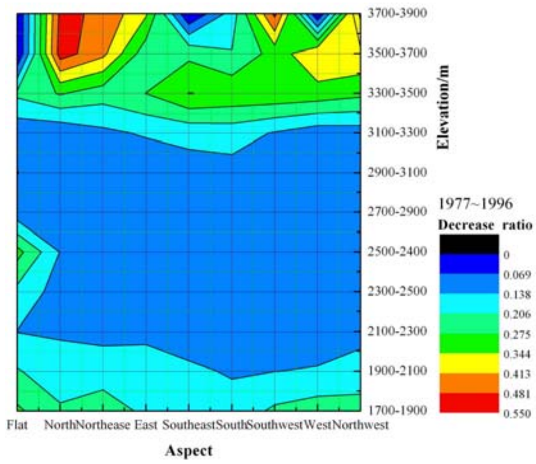

Figure 5 Vegetation decrease rate in different slope aspects and elevation in study area from 1977 to 1996

From 1996 to 2007, vegetation increase rate was in a higher level, as a whole, all values were between 0.4-0.5. Only in the sunny slope and flat at above an altitude of 3,300 meters, vegetation increase rate was lower, but all still above 0.1. Vegetation decrease rate was generally in a lower level, most values were within 0.075 and the values in sunny slope at above 3,300 meters and 2300 meters below were the lowest. The human activities on the flat were the strongest, the overall vegetation decrease rate was higher, and there was a peak value between 2500-2700 meters above the sea level. This is mainly due to the higher the elevation was, the less human interference was. Pastoralists were rarely in low-elevation areas in study area, and the soil and moisture conditions were good in sunny slope, Thus, vegetation capacity was higher, and anti-jamming capability was strong.

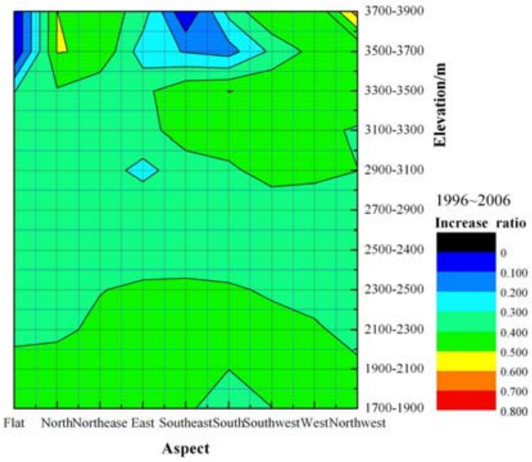

Figure 6 Vegetation increase rate in different slope aspects and elevation in study area from 1996 to 2006

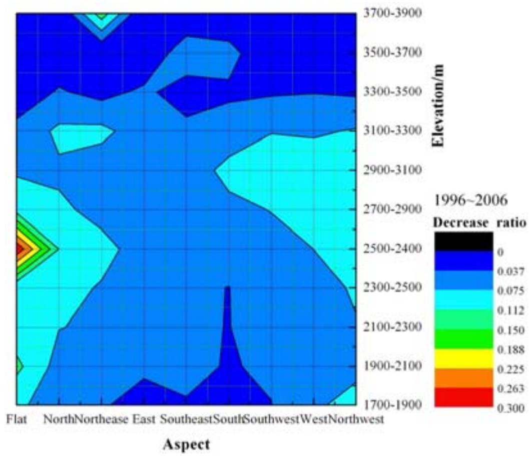

Figure 7 Vegetation increase rate in different slope aspects and elevation in study area from 1996 to 2006

4.2.2 The relationship between vegetation coverage change and the roads

During 1977~1996, on the 19 buffer zones with a space between of 1km, the vegetation increase rate tended to rise first and then fall as the distance to road went farther. From 0 to 4km, it increased in a linear way, while at farther than 4km, it went down, especially when the distance was more than 8km. It is because during this period of time, the Longyangxia reservoir was set up, which is located on out of 8km to the roads, resulting in the decrease of the vegetation increase rate. As a whole, the vegetation decrease rate tended to drop as the distance to road increased, which decreased linearly with the correlation coefficient up to -0.928 (for a level of significance 0.05) during 0~4km, but change trend was irregular out of 4km, showing that there was no obvious relationship.

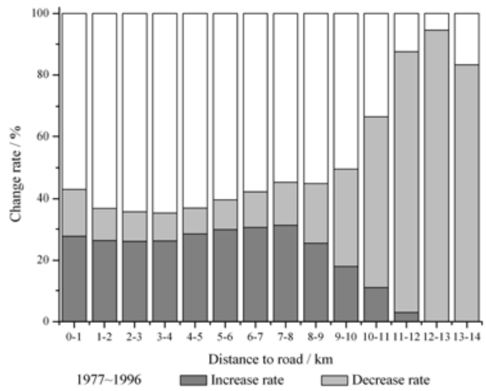

Figure 8 Relationship of vegetation change rate and distance to road in study area from 1977 to 1996

During 1996~2006, the vegetation increase rate, as a rule, rose gradually as the distance to road went farther, while the vegetation decrease rate tended to fall. From 0 to 4km, it decreased in a linear way with the correlation coefficient up to -0.912 (for a level of significance 0.05). Analysis on the density of residential spots showed that in a distance of 0~4km to road, there was 93.2% of the total residential spots, which confirmed, to some extent, the effect of human activities (mainly grazing) on vegetation.

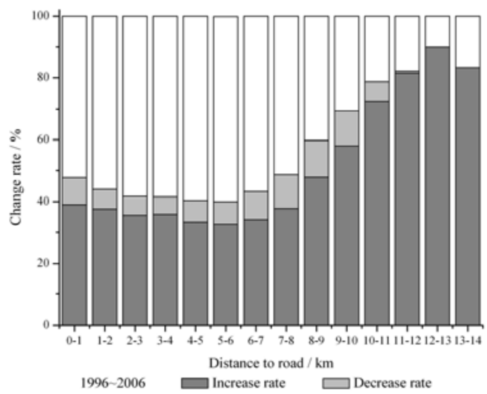

Figure 9 Relationship of vegetation change rate and distance to road in study area from 1996 to 2006

4.2.3 The relationship between vegetation coverage change and the residents

On the 14 buffer zones with a space between of 1km, the vegetation coverage change and the change rate had a clear relationship with the distance to residents. During 1977~1996, the vegetation increase rate was inclined to rise first and then fall as the distance to road goes farther. It is because during this period of time, the Longyangxia reservoir was set up and stored water, and then the vegetation coverage decreased inside the reservoir. Furthermore, the reservoir is located in a distance of 8~19km to residents, resulting in the decrease of the vegetation increase rate. However, during 0~4km, the decrease rate of grasslands delined linearly, while it changed irregularly out of 5km, which showed that there was no obvious relationship, and human activities had made slight effect on it.

The closer the vegetation to the residents was, the more it degraded. Speaking of the two periods of 1977~1996 and 1996~2006, the vegetation decrease rate tended to go down as the distance to resident increased. Nevertheless, during the previous period, the change was relatively big, especially from 0 to 4km, the vegetation degradation rate decreased linearly with the correlation coefficient up to -0.828 (for a level of significance 0.05).

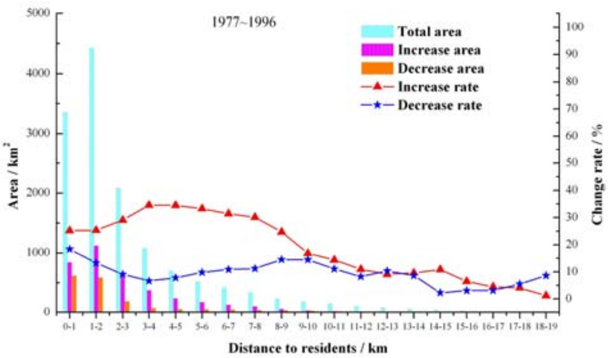

Figure 10 Relationship of vegetation change and distance to resident in study area from 1977 to 1996

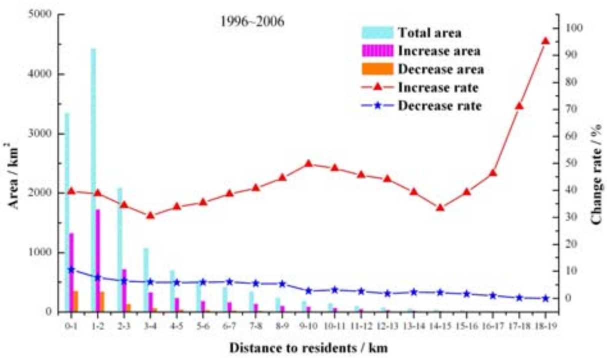

Figure 11 Relationship of vegetation change and distance to resident in study area from 1996 to 2006

5. CONCLUSIONS

Results showed that a) The vegetation coverage in study area was gradually improving, the main cause of the vegetation decrease was the hydropower plant construction, especially annual regulating reservoir. Many land use types are converted to water, and the vegetation coverage decreased. b) As the altitude increased, vegetation increase rate first increased then declined, while the change trend of vegetation decrease rate was opposite. c) The vegetation increase rate rose gradually as the distance to roads went farther, while the nearer the vegetation was to the roads, the higher the vegetation decrease rate was. d) The decrease rate was relative to the population density and residents; but in some districts the decrease rate rose contrarily with distance to resident went farther. e) The vegetation change was highly related to the activities of human beings in the study area. f) This research also demonstrated that there was no obviously evidence proved that there was correlativity between the cascade hydropower development and the regional vegetation coverage.

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