Forecast Evaluation for Inundation Impact of Hydropower Station Supported by RS & GIS

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Abstract: This article took the Maerdang Hydropower Station on the Yellow River as an example.QuickBird image was used in this research. According to features of image, the types of land use in study area were divided into cultivated land, woodland, other woodland, grassland, resident land, road, water and bare land. The present map of land use was obtained through visual interpretation, with help of ArcGIS.Then, the forecast map of land use after the Maerdang Hydropower Station will have been built, according to design line of water level. Based on the theories and methods of landscape ecology, analyzed the impact caused by reservoir inundation, using seven landscape indexes. After the Maerdang Hydropower Station will been established, it will become a plateau canyon reservoir. Water area will increase 1784.220 hm^2, and the reservoir will inundate 938.175 hm^2 woodland, 405.850 hm^2 bare land, 368.828 hm^2 grassland, 71.22 hm^2 other woodland, and 0.15 hm^2 resident land, but cultivated lands and roads will not be inundated, which shows that the Maerdang Hydropower Station will give little impact on the local socio-economic structure, immigration task will be light, and inundation loss will be little. The matrix of landscape is grasslands before and after submersion, but landscape fragmentation and landscape heterogeneity will rise, and the spatial distribution of the landscape types will become uniform. Comprehensive analysis shows that reservoir inundation will give little influence upon ecological environment.

Keywords: QuickBird Image, GIS, Landscape Ecology, Forecast Evaluation for Inundation Impact

1 INTRODUCTION

Construction of the reservoir is an important aspect of hydropower station construction. The impact of reservoir inundation is an important comparison and choice content in the course of hydropower station design. Compensation investment for reservoir inundation is an important component of the total investment of the project [1-2].Usually, Compensation investment for reservoir inundation may be accounts for15%～30% of the total investment of this project [3]. In order to carry out a comprehensive comparison of technical, economic and socio-political factors, it is necessary to attach great importance to impact of inundation in the planning stage of the reservoir.

Traditional reservoir inundation impact evaluation totally depends on human in obtaining a variety of inundation data, which is not only time-consuming but also costly. And, it is difficult to ensure data accuracy by man-made factors. Clearly, this approach has not been suitable for decision-making of modern hydropower development. In recent years, remote sensing and GIS technologies are widely used in various fields, such as resources and environment investigation, disaster monitoring and so on. By support of RS&GIS, inundation investigation, and objective and fair evaluation of reservoir inundation impact can be quickly fulfilled, which can provide objective basis for land acquisition, compensation investment for reservoir inundation and resettlement plan, and further can provide accurate basis for project cost.

By support of RS & GIS, this paper quickly carried out forecast evaluation for inundation impact of the Maerdang Hydropower Station on the Yellow River based on the theories and methods of landscape ecology, which can provide a reference basis for the engineering decision-making.

2 THE STUDY AREA

This article took the Maerdang Hydropower Station on the Yellow River as an example. The station design normal water level is 3270m (altitude).The design dam

This research work was financial supported by “the Key Research Project of Environmental Protection Bureau of Sichuan Province (2008HBY002)”.

locates on the Yellow River, which is 5 kilometers from the Lajun Town in Maqin County, Qinghai Province.Maqin County of the Guoluo Tibetan Autonomous State locates on the left bank of the dam, and Tongde County of the Hainan Tibetan Autonomous State locates on the right bank of the dam. The NO.101 Provincial Road (from the Xining City to the Guoluo Tibetan Autonomous State) passes across the right part of the design dam. It is 363 kilometers from the Xining City.

3 DATA AND METHODOLOGY

3.1 Remote sensing data and processing

QuickBird image was used in this work, which was ordered by programming from Digital Global Company in USA. Programming period is from July 1 to September 30, 2007.The study area is east-west banded strip, and images in study area were obtained after three-stripe scanning. Ultimately provide bundled data, that is, multi-spectral (Near-infrared, Red, Green and Blue) &panchromatic data. Data standard is OrthoReady standard. Data format is Geotiff. A series of pre-treatment have been fulfilled. The overall quality of the image is better.

The spatial resolution of panchromatic data of QuickBird image is 0.61m, and that of multi-spectral data is 2.44m. ENVI(The Environment for Visualizing Images is internationally well-known image processing system.ENVI version 4.4 affords a new image processing tool- SPEAR, which could wizard-style finish image fusion. The tool of SPEAR provide four fusion algorithms for the panchromatic and mufti-spectral images, that is, PCA(principal component analysis) transformation, Gram-Schmid transformation, Brovey transformation and HSV transformation. According to comparative analysis, the best effect is Gram-Schmid transformation, combined with fusion images through PCA transformation, Gram-Schmid transformation, Brovey transformation and HSV transformation. So, data fusion between panchromatic and multi-spectral data in three different strips was fulfilled by method of Gram-Schmid transformation. The fusion images maintain not only spatial resolution advantages of panchromatic data but also spectral information of multi-spectral data, which greatly enhance image effects. After fusion, geometric correction of images in three different strips was fulfilled in software of ERDAS IMAGINE according to topographic map & digital elevation model (DEM) with scale of 1:10000.Then, image in three different strips was spliced into the whole work image of the study area with help of ERDAS IMAGINE.

3.2 Classification and mapping of land use landscape

Landscape classification in this work was fulfilled in accordance with the land use [4]. According to features of image, the types of land use in study area were divided into cultivated land, woodland, other woodland, grassland, resident land, road, water and bare land. Based on treated image of QuickBird, the present map of land use was obtained through visual interpretation on computer, with help of ArcGIS.

According to *Code on compiling pre-feasibility study report of hydropower project* (DL/T 5206-2005, in Chinese), the scope of reservoir inundation was ascertained in accordance with the station design normal water level. The station design normal water level is 3270m (altitude), so the scope was 3271m (altitude).Then, with help of Update Module of ArcGIS, forecast map of land use was fulfilled, according to the scope of reservoir inundation. Making use of GIS mapping function, landscape maps of land use before and after inundation were produced. Figure 1.is the map before inundation, and Figure 2.is the map after inundation.

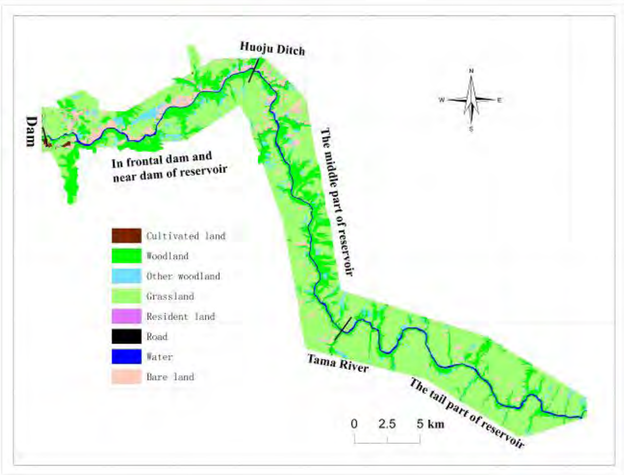

Figure 1.The present map of land use before inundation

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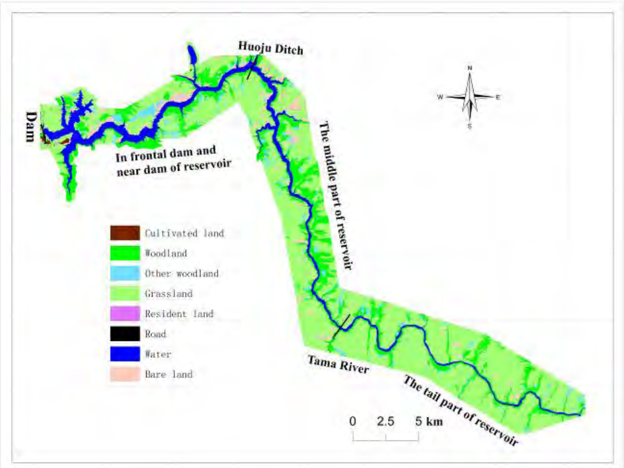

Figure 2.The forecast map of land use after inundation

3.3 Selection and calculation of land scape pattern index

Landscape pattern information reflects the composition of structure and spatial distribution characteristics of landscape. Landscape pattern changes are evaluated through landscape pattern index in different periods. Impact of reservoir inundation on landscape pattern still embodies in the landscape pattern index changes. Consequently, impact of reservoir inundation can be quantitatively evaluated adopting landscape pattern index.

In this paper, landscape pattern index was calculated according to algorithms of Fragstats 3.3.Combined with previous research results [5-7] and the purpose of this study, seven indexes were selected from Fragstats software as evaluation indicators [8].

（1）Number of Patches-NP

$$NP = n_i \tag{1}$$

n_i =number of patches in the landscape of patch type (class) i.

Units: None. *Range:* NP ≥ 1, without limit.

NP = 1, when the landscape contains only 1 patch of the corresponding patch type; that is, when the class consists of a single patch.

（2）Class Area-CA

$$CA = (\frac{1}{10000}) \times \sum_{j=1}^{n} a_{ij} \tag{2}$$

a_{ij} =area (m^2) of patch ij.

Units: Hectares. *Range:* CA > 0, without limit.

CA approaches 0 as the patch type become increasing rare in the landscape.

（3）Patch Density-PD

$$PD = \frac{n_i}{A_i} \times (10000) \times (100) \tag{3}$$

n_i =number of patches in the landscape of patch type (class) i.

A =total landscape area (m^2).

Units: Number per 100 hectares *Range:* PD > 0, constrained by cell size.

PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area. However, the maximum density of patches of a single class is attained when every other cell is of that focal class.

（4）Largest Patch Index-LPI

$$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A} \times 100 \tag{4}$$

a_{ij} =area (m^2) of patch ij;A =total landscape area (m^2).

Units: Percent. *Range:* 0 < LPI ≤ 100.

LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.

（5）Percentage of Landscape-PLAND

$$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A} \times 100 \tag{5}$$

P_i =proportion of the landscape occupied by patch type (class) i.

a_{ij} =area (m^2) of patch ij;A =total landscape area (m^2).

Units: Percent. *Range:* 0 < PLAND ≤ 100.

PLAND approaches 0 when the corresponding patch type (class) becomes increasingly rare in the landscape. PLAND = 100 when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.

（6）Shannon's Diversity Index-SHDI

$$SHDI = -\sum_{i=1}^{n}(P_i \times \ln P_i) \quad (6)$$

P_i =proportion of the landscape occupied by patch type (class) i.

Units: None. *Range:* SHDI ≥ 0, without limit.

SHDI = 0 when the landscape contains only 1 patch (i.e., no diversity). SHDI increases as the number of different patch types (i.e., patch richness, PR) increases and/or the proportional distribution of area among patch types becomes more equitable.

（7）Shannon's Evenness Index -SHEI

$$SHEI = \frac{-\sum_{i=1}^{n}(P_i \ln P_i)}{\ln n} \quad (7)$$

P_i =proportion of the landscape occupied by patch type (class) i.

m =number of patch types (classes) present in the landscape, excluding the landscape border if present.

Units: None. *Range:* 0 ≤ SHEI ≤ 1.

SHEI = 0 when the landscape contains only 1 patch (i.e., no diversity) and approaches 0 as the distribution of area among the different patch types becomes increasingly uneven (i.e., dominated by 1 type). SHEI = 1 when distribution of area among patch types is perfectly even (i.e., proportional abundances are the same).

In software of Fragstats 3.3, above seven indexes of landscape maps of land use before and after inundation (Figure 1. and Figure 2.) were calculated. The results occur in Table 1.

4 Results and conclusions

Analyze landscape pattern change before and after inundation according to Table 1.

(1)Analysis of CA (Class Area) & PLAND (Percentage of Landscape) changes

The basic elements of landscape structure include patch, corridor and matrix, and their space-time configuration constitutes landscape pattern. Matrix is the background of landscape, and it is an important element of landscape. To a large extent, matrix determines the nature of the landscape, and plays a leading role in landscape dynamics. The following are differentiating criteria of matrix: large area, higher degree of connectivity and dynamic control functions. According to statistics in Table 1, the area percentage of grassland is 64.317% before inundation, and which is matrix of landscape. Though way of land-use changes after inundation, the area percentage of grassland still is 62.776%, and so grassland still is matrix of landscape.

The water area will increase from 668.515 hm^2 to 2452.735 hm^2, and it will increase by nearly 3 times. The proportion of landscape will increase from 2.792% before inundation to 10.243% after inundation. The area and landscape proportion of woodland, other woodland, grassland, resident land, and bare land all will reduce. The reduced area respectively is 938.175 hm^2, 71.22 hm^2, 368.828 hm^2, 0.15 hm^2 and 405.850 hm^2, and the reduced landscape proportion respectively is 3.918%, 0.297%, 1.541%, 0.001% and 1.695%.The area and landscape proportion of cultivated land and road will not change.

Above analysis shows that construction of the Maerdang Hydropower Station on the Yellow River has great impact on woodland, bare land and grassland. These results basically are consistent with their spatial distribution characteristics. They will firstly be inundated after reservoir would store water, because they mainly distributed in the slope belt on both sides of the Yellow River. Storing water will have no impact on cultivated land and road, because they is away from reservoir area. Above analysis shows that the Maerdang Hydropower Station will give little impact on the local socio-economic structure, and immigration task will be light and submersion loss will be little.

(2)Analysis of NP (Number of Patches) & PD (Patch Density) changes

Total number of patches will increase. The number is 1224 before inundation and will be 1373 after inundation. Patches will be more diffused and broken. There will be greater difference among all kinds of patches.

The number and density of patches will change except for cultivated land and road.

The patch number of water will decline from 62 to 42, and the patch density will decline from 0.259 to 0.175, which indicates that connectivity of water will enhance and landscape heterogeneity will decline after reservoir would store water. The patch number and density of resident land will also decline, but the range will be little.

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The patch number of woodland, other woodland, grassland and bare land respectively will increase from 150,271,129 and 149 to 258,277,152 and184. The patch density of woodland, other woodland, grassland and bare land respectively will increase from 0.626, 1.132, 0.539 and 0.622 to 1.077, 1.157, 0.635 and 0.768.These results will indicate that patches will be more diffused and broken, and landscape heterogeneity will go up.

Above analysis still shows that construction of the Maerdang Hydropower Station on the Yellow River has great impact on woodland, bare land and grassland.

(3)Analysis of LPI (Largest Patch Index) changes

LPI of grassland is a maximum before inundation. LPI of water will be a maximum after inundation, and that of grassland will occupy the second place. Though LPI of water will be higher than that of grassland after inundation, the area of water is far less than that of grassland. Therefore, the matrix status of grassland will do not change.

(4)Analysis of SHDI (Shannon's Diversity Index) & SHEI (Shannon's Evenness Index) changes

The number of patches is 1224 before inundation and will be 1373 after inundation. Many big patches will be divided into small patches for reservoir inundation. SHDI (Shannon's Diversity Index) and SHEI (Shannon's Evenness Index) will respectively increase from 1.059 and 0.509 before inundation to 1.137 and 0.547 after inundation, which indicates that landscape heterogeneity of will go up and landscape types in spatial distribution will become more and more uniform. In general, reservoir inundation will not cause great change of environment. Grassland will still plays leading role in ecological environment, and it still is matrix of this area. Woodland as the second largest type will not change.

Above comprehensive analysis shows that reservoir inundation will give little influence upon ecological environment.

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[8] FRAGSTATS USER GUIDELINES Version 3.

Table 1. Contrast of landscape pattern index before and after inundation within study area

Types of patch	NP		CA(hm^2)		PD		LPI		PLAND	
	Before	After	Before	After	Before	After	Before	After	Before	After
Cultivated land	10	10	41.798	41.798	0.042	0.042	0.069	0.069	0.175	0.175
Woodland	150	258	5130.585	4192.410	0.626	1.077	3.765	1.981	21.425	17.507
Other woodland	271	277	1151.858	1080.638	1.132	1.157	0.425	0.425	4.810	4.513
Grassland	129	152	15401.533	15032.705	0.539	0.635	6.706	6.670	64.317	62.776
Resident land	419	416	39.163	39.013	1.750	1.737	0.004	0.004	0.164	0.163
Road	34	34	10.950	10.950	0.142	0.142	0.017	0.017	0.046	0.046
Water	62	42	668.515	2452.735	0.259	0.175	2.781	10.239	2.792	10.243
Bare land	149	184	1502.038	1096.188	0.622	0.768	0.828	0.614	6.273	4.578
Total	1224	1373	23946.438	23946.438	-	-	-	-	100.00	100.00
Before	SHDI=1.059;SHEI =0.509									
After	SHDI=1.137; SHEI=0.547									