Environmental suitability evaluation for human settlements in Bosten Lake Basin

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Abstract. Environmental Suitability of Human Settlement in arid and semi-arid area is defined as an efficient eco-geographical landscape that has dense vegetation or stable water and comfortable climate condition which is applied to arid region’s human living environment. In this work, the ESHS in the Bosten Lake Basin were evaluated based on remote sensing images, socioeconomic data, grid data and annual average climate temperature data. The results revealed that the index of ESHS in the Bosten Lake Basin ranges from 12.8 to 86.73. The proportion of high suitability area, middle suitable area, low suitable area and not suitable area accounts for 9.7%, 9.6%, 41.4%, and 39.3% respectively of the total study area. Our results indicated that natural environment of Bosten Lake is rather fragile, the mountainous area in northwest and desert area in southeast is basically do not fit for human settlement. Suitable regions for human settlement were mainly distributed around Bosten Lake in the form of batches, while others are scattered.

1. Introduction

Human living environment refers geographical space that closely related to human survival activities. With the development of social productivity, the environmental quality of living space became major concern of human beings. As a basic space for human existence and activities, the human settlement environment has attracted much research interest to seek the best living environmental condition by applying different approaches to evaluate the human environmental suitability [1]. The geographical environment is the major factor that determines where human live and develop [2]. People in Northwest China are suffering from serious environmental and ecological challenges because of distinct natural environment and historical factors [3]. Bosten Lake Basin locates in the intersecting and transitional zone between Tianshan Mountains and Taklimakan Desert, which is a sensitive place of ecological and environmental change [4].

In recent years, number of ecological and environmental problems including reduction in downstream
water supplies, falling groundwater levels, land desertification and salinization, as well as vegetation loss, have been caused in Bosten Lake Basin as a result of global climatic change and uncontrolled human activity [5]. In order to understand coordinated development of the ecosystem and socio-economy in the Bosten Lake Basin, the stability and suitable scale of this area was analyzed in this study based on periods of remote sensing images and a social statistic data.

2. Materials and methods

2.1 Study Areas
Bosten Lake Basin (41°56′ N – 44°40′ N; 86°14′ E – 90°56′ E) is located on the southern slope of the Tianshan Mountains and lies in the southeastern part of Yanqi Basin (figure 1). The Yanqi Basin borders the Tianshan Mountains and the Kuruktag Mountains in the north and west, in the south linked with Taklimakan desert. Bosten Lake is one of the largest inland freshwater lakes in China with a surface lake area of 1000 km$^2$, maximum water depth of 16.2 m and an average depth of 8 m. The study area covers five counties, as well as Korla City.

2.2 Data Sources
The DEM in this study were derived from the institute of Geographical Sciences and Natural Resources, Chinese Academy of Sciences. The Monthly Normalized Difference Vegetation Index (NDVI) data derived from Moderate Resolution Imaging Spectrometer (MODIS). The grid data of average annual temperature and precipitation were generated from station-based discrete point data using an Inverse Distance Weighted (IDW) spatial interpolation method. The All datasets were re-projected to Universal Transfer Mercator Projection System (UTM) Zone 45N with World Geodetic System (WGS-1984) datum.

2.3 Study Methods
Biotic and abiotic factors such as terrain, water, climate and vegetation have different spatial combinations and the spatial combinations control or modulate the suitability of human settlement and the associated socioeconomic development [5]. In this work, the DRLS model, NDVI model, THI
model and WRI model were taken as main factor to decide human settlement environment index HEI model [6]. HEI model is shown below:

\[
HEI = \alpha \times SRDLS + \theta \times SNVDI + \beta \times STHI + \chi \times SWRI
\]

(1)

In this equation, HEI is the Human Settlements Environment Index, which value is between 0 ~ 100; where SRDLS, SNVDI, STHI, SWRI stand for a standardized relief degree (\(\alpha\)), standardized vegetation index (\(\theta\)), standardized temperature index (\(\beta\)) and standardized humidity index (\(\chi\)), \(\alpha, \theta, \beta, \chi\) represent weight of four indexes, respectively [7]. The weight of each indexes were calculated by using the equation in the below, and calculated index weights were given in Table 1.

\[
Cov_{ij} = \frac{1}{N-1} \sum_{k=1}^{N} (Z_{ik} - \mu_i) (Z_{jk} - \mu_j)
\]

(2)

Table 1. Correlation matrix.

| Layer | Population | RDLS | NDVI | WRI | THI |
|-------|------------|------|------|-----|-----|
| Population | 1.000       | -0.45| 0.69 | 0.644 | 0.403 |
| RDLS     | 1.000       | 0.688 | 0.389 | -0.333 |
| NDVI     | 1.000       | 0.729 | -0.736 |
| WRI      | 1.000       | -0.942 |
| THI      | 1.0000      |

3. Results and discussion

3.1. Spatial Distribution of HEI in Bosten Lake Basin

Result shows the spatial distribution of HEI in Bosten Lake Basin at 1 km × 1 km grid size, ranges from 12.8 to 86.73 (figure 2a - 2b). It is noticeable that the environmental situation from the northwest to the middle part of the Bosten Lake Basin, from the mountain to plateau, from desert to the river valley, the natural environment suitability is increasing respectively.

3.2. Natural environment suitability for human settlement in Bosten Lake Basin

Through the different natural assessment model analysis and the weight assignment, to get the HEI settlement map (figure 2a - 2b) and its corresponding values. According to the HEI and its corresponding index values of RDLS, NDVI, THI, WRI distribution, we set the criterion for natural environment suitability evaluation and classify the whole territory into four types including non-suitable, low suitable, middle suitable and high suitable area. Results showed that human living environments at different scale of natural suitability were distributed different parts of study area.

(1) High suitable area, where the HEI are between 68.36 and 86.73, is mainly distributed around Bosten lakeside and in the Korla city. The high suitable area is about 7257km², which equals to the 9.7% of all research area.
(2) Middle suitable area, where the HEI is between 39 to 68.36, is mainly distributed in Konque River basin with a settlement of the main population. Because of the natural elements such as terrain, weather condition, water resource and land use are very well combined, so it is suitable for human settlement. This middle suitable area is about 7168 km$^2$ and account for 9.6% of the total area.

Table 2. Evaluation result of suitability for human settlements in the Bosten Lake Basin.

| Comforable level | Mean suitability index | Suitability characteristics | Land area (km$^2$) | Percentage (%) |
|------------------|------------------------|----------------------------|--------------------|----------------|
| High suitable area (I) | 87 | Best suitable, not restricted by natural factors, most suitable for human living | 7257 | 9.7 |
| Middle suitable area (II) | 60 | Generally suitable, slightly influenced by natural factor | 7168 | 9.6 |
| Low suitable area (III) | 30 | Marginally suitable, influenced by natural factors to some extent, not ideal for human settlement | 30960 | 41.4 |
| Non-suitable area (IV) | 5 | Extremely unsuitable, largely limited by natural factors with very limited conditions for humans to survive and conduct productions | 29483 | 39.3 |

(3) Low suitable area, where the HEI is between 20 to 38.9 and the Human Settlement environment is restricted by land use condition and water resource condition, the terrain is relatively flat. However, because of reduced vegetation cover, increased sand area, land use types and higher evaporation, which cause a negative effect on the human settlement environment. Low suitable places are mainly distributed in southeast desert places and not very suitable for human settlement. This low suitable area is about 30960 km$^2$ and account for 41.4% of the total area.

(4) Non-suitable area, mainly distributed in the Northwest Mountain. The region is located in the high hills and inter-mountain basins, which is about 29483 km$^2$ and accounts for 39.3% of the total area, where the HEI is less than 20. In this area, Human settlements environment is restricted by terrain and climate, which is not suitable for human settlement.
4. Conclusions
In this paper, using GIS software, on the basis of simulation test and empirical model, the spatial patterns of the human settlement condition of the Bosten Lake basin are investigated in 1km×1km grid dimension. The conclusions can be drawn as below.

(1) The suitability of the human settlements environment in the Bosten Lake Basin is increasing gradually from the northwest and southeast to the middle part of the Bosten Lake Basin. The high suitable region is 7257 km$^2$, and accounts for 9.7% of the total basin area. The middle suitable region is 7168 km$^2$, and accounts for 7.6% of the total basin area. The less suitable region is 30960 km$^2$, and accounts for 41.4% of the total basin area. The non-suitable region is 29483 km$^2$, and accounts for 39.3%.

(2) Using GIS software raster calculations, statistical analysis, and repeated experiments and revision tools, some important impact factors of the suitability for the human settlements environment in the Bosten lake Basin have been used to analyze their spatial pattern. These methods can accurately take into account of regional differences in the basin and provide a reasonable quantitative visualization. The ideology contributes to the suitable distribution and flows of population. Therefore, it is a key method for the basin to promote the coordinated development of population, resources and eco-topo.

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