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Spatial patterns of landscape change in the Three Rivers Headwaters Region of China, 1987–2015

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ABSTRACT

The Three Rivers Headwaters Region is one of the most import ecological protection regions and Tibetan inhabited regions in China. Located in the Qinghai province of China, the Region is the source of the Yangtze, the Yellow and the Lantsang-Mekong Rivers. This study region was based on remote sensing imagery. An ecological landscape classification of the area is presented, as well as a suite of landscape indices for landscape pattern changes from 1987 to 2015. The influence of human activities on the landscape change of study area is discussed. The results showed landscape structure complexity, fragmentation gradually increased, while the indices of contagion and evenness were decreased. Structure characteristic of landscape change in this region are more obvious, especially, the difference in space distributions of part and the whole. There were trend of uniform distribution of different types and diversity gradually increased in the source of Yangtze River. And an opposite tendency is showing in the Yellow River and Lantsang-Mekong River. Physical-geographical conditions, climate change and government policy at study period were the main reasons of significant landscape pattern change. This study proposes management measures for sustainable development in the Three Rivers Headwaters Region.

1. Introduction

Land is the basic resources for the survival of human race. With the unreasonable exploitation and utilization of land resources, the natural land-use/cover pattern has been changed greatly, and the biodiversity of terrestrial ecosystem are changing as well. The change of land-use/cover pattern is a complicated process. Spatially the change shows the transition between different land use types and temporally. And it is subjected to land use intensity by human activity. The analysis of land-use/cover pattern is the basic study of landscape ecology [1–6]. We can analyze the spatial distribution characteristics of different land-use classes, which is the foundation of a further study on ecological function and dynamics. It has paid growing attention that the study of structural change on biological pattern interference and the relevant protection strategy, especially in the study of land-use pattern protection on a regional scale. In some areas which have significant differences on natural environmental conditions and human interferences, such as the alpine regions, the external factor especially human activities will affect the structure of regional component and spatial distribution rather than changing the structure of the whole ecosystem in a short time scale. Through the analysis of spatio-temporal differences on land-use pattern, the intrinsic interference mechanism can be revealed, and thus will provide a theoretical basis for assessing the natural and human interference factor reasonably and making effective ecology protecting and managing strategies [7–10]. There are many temples in the Three Rivers Headwaters Region. As the center of their belief, the temples are the Holy Lands of the Tibetans, and by protecting the sacrosanct temples and their surrounding eco-environments, Tibetans express worship to religion. The traditional Tibetan ecological consciousness is one of the most important cultural inheritances of the Tibetan Buddhism, and it's also a key factor for the protection of the surrounding eco-environments of temples.

The change of landscape pattern is a complicated process. Change of spatial pattern shows the transition between different land use types over time. Recent research in landscape ecology has sought to define spatial-temporal changes in landscape structure. Spatial technology tools such as geographic information systems (GIS) and remote sensing have given ecologists unprecedented capacity to quantify landscape structure, spatial heterogeneity and landscape change [11]. Landscapes differ structurally in the distribution and movement of species, energy and materials [12]. In particular, landscape management increasingly requires spatial and temporal information to make decisions regarding landscape patch size, the dispersal or aggregation of activities, edge densities and connectivity throughout the landscape [13]. The Three Rivers Headwaters Region is an important water conservation area in China. Its eco-environment plays an important role in climatic regulation, water conservation and purification, and maintenance of biological diversity.

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Scholars in our country gave a large number of researches on this area [14–25]. Using RS and GIS technologies, based on the models of landscape dynamic change, we built four term land-use spatial database. It is based on basic theory of landscape patterns, and quantitative structure and spatial pattern change. A spatio-temporal model for regional landscape changes is built in this study to analyze the landscape pattern change scale, rate, transition types and the driving force factors of the spatial distribution and changes thoroughly during the past 30 years in study area, and thus. The results of this analysis can be used to provide a strong technical background to support eco-environmental protection and implementation of sustainable development measures in the Three Rivers Headwaters Region.

2. Materials and methods

2.1. Study area

The TRHR, also known as "Sanjiangyuan", is located in southern Qinghai Province, western China (Fig. 1).The study area lies between 31°39′N and 36°16′Nand 89°24′E and 102°23′E, covering an area of approximately 3.58 × 105 km^2, with elevation ranging from 3450 m to 6621 m. The TRHR has been described as "the Water Tower of China and Asia" because several large rivers all originate in this region. The area is characterized by a cold and dry climate. Annual mean temperature ranges between −5.6°Cand 3.8 °C, and annual mean precipitation between 262.2 mm and 772.8 mm [15].

The study area includes all or some of the counties from four Tibetan Autonomous Prefectures, which are Yushu Prefecture, Guoluo Prefecture, Hainan Prefecture, and Huangnan Prefecture, and one township, which is Tanggula Township of Geermu City (Fig. 1). The Tibetan ethnic group consists of about 90% of the population. The religion of most of the population is Buddhism, which was introduced to the region about 1400 years ago [26]. Over the past hundreds of years, many temples have been constructed as the religious centers for ceremonies and activities. Temples are perceived as the Holy Lands of the Tibetans, and by protecting the sacrosanct temples and their surrounding environments, Tibetans express their worship of religion.

2.2. Methodology

To examine patterns of landscape change in the TRHR, Landsat Thematic Mapper (TM), Enhanced-Thematic Mapper (ETM) and Landsat8 images in the years of 1987, 1997, 1997and 2015 were obtained from the Land Processes Distributed Active Archive Center (LPDAAC) of the U.S. Geological Survey for supervised land use classification. These four years of images were chosen for two reasons. The Landsat images, after supervised classification, were then analyzed in conjunction with a 1:250,000 scale topographic map and thematic maps of soil and vegetation of the study area, with an object-based image classification method. Compared to traditional pixel-based classification methods, the object-based classification method incorporated multi-scale image segmentation and additional attributes, such as shapes and textures, and hence was more suited to landscape scale analysis. Considering the classification schemes used previously in different areas of the TRHR [8,15, 22,25,27,28]. Two levels of classification were derived. The primary class consisted of six land use types, including farmland, forest, grassland, water, built-up land, and unused land. Each primary class was further divided into several secondary classes, resulting in a total of 25 secondary classes (Fig. 2). Classification was done in ERDAS IMAGINE 8.7.

Furthermore, ARCGIS and FRAGSTATS spatial analysis modules were used to calculate landscape pattern metrics [29]. To capture some of the synoptic feature of landscape pattern, four landscape-level metrics were calculated using the raster version of FRAGSTATS 3.3. We chose a small set of metrics that were both sensitive to changes and numerically reliable for depicting landscape patterns. As in most cases in the existing literature, the term "landscape pattern" here includes both the non-spatial composition (e.g., the number and relative abundance of patch types, patch size, and other related non-spatial measures) and spatial configuration (e.g., patch shape, juxtaposition, contrast, and boundary characteristics). Specifically, we considered 2 indices as compositional measurements: Shannon's diversity index (SHDI) and Shannon's Evenness Index (SHEI)·The remaining 2 indices we classified as configurational measurements: Inspersion and Juxtapositon Index (IJI) and

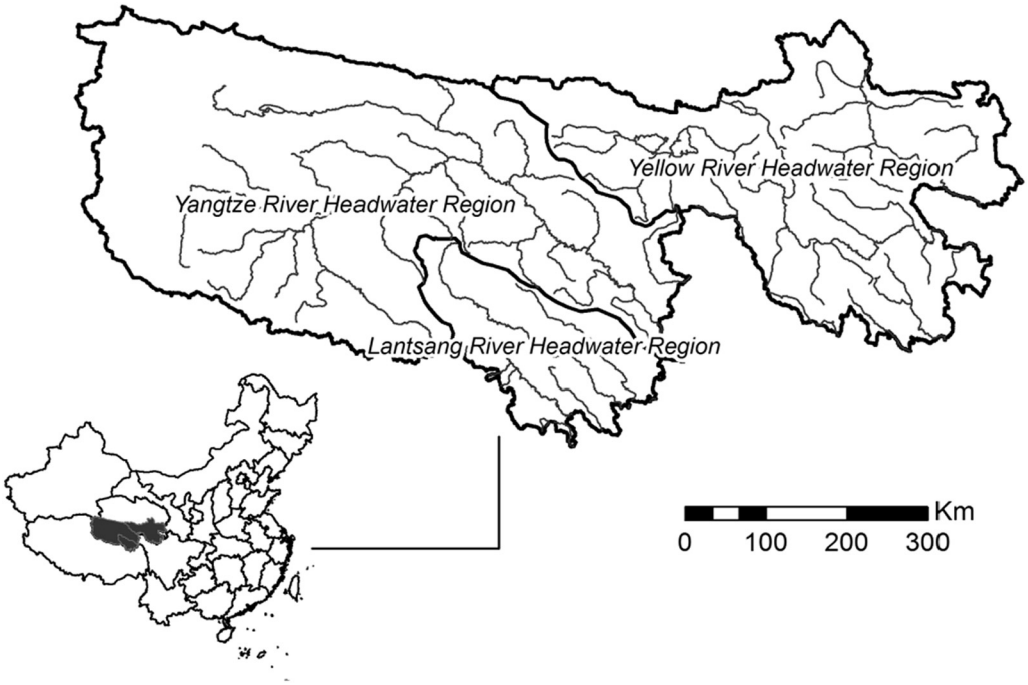

Fig. 1. Location of the study area.

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