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Mapping human influence intensity in the Tibetan Plateau for conservation of ecological service functions

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ABSTRACT

Human activities pose severe threats to ecosystems. As the Earth's third pole, the Tibetan Plateau (TP) provides various ecosystem services for human beings, including water resources for nearly 40% of the world's population. In this study, four categories of human pressures on the environment were analyzed firstly and then summed cumulatively to map the human influence intensity (HII) in the TP for 1990–2010 at county and 1 km scales. Subsequently, HII characteristics within valuable regions for water retention and biodiversity conservation were analyzed. The results showed that HII of the TP was low overall. The eastern and southeastern TP and the central part of the Tibet Autonomous Region saw high HII. For 1990–2010, the 1 km scale mean HII increased by 28.43%, which is much greater than the global level of 9% for 1993–2009, suggesting that the TP and the ecosystem services it provided may face with more threats. HII increase was mainly observed in the northeastern TP. Rapid increase of human activities within valuable regions for water retention and biodiversity conservation during 1990–2010 were detected, especially for the former. The obtained temporally-consistent HII datasets will be conducive to ecosystem services related decision making.

1. Introduction

For thousands of years, humans have dramatically transformed the earth systems to get benefits which were known as ecosystem services (Braat and de Groot, 2012; Vitousek et al., 1997), The transformation has resulted in the declines in wilderness areas (Watson et al., 2016), loss of biodiversity (Myers et al., 2000), and degradation of ecosystem services (de Groot et al., 2012). In the Anthropocene era, which suggests that human beings are stewards of nature (Sanderson et al., 2002), understanding human influence on ecosystem and their services are important for sustainable development (Costanza et al., 2017). Over the past decades, to advance our ability of mapping ecosystem services and narrow the gaps between scientists and policy makers, many initiatives, including CBD (https://www.cbd.int/) which was complemented with the addition of ecosystem services as an element, MAES in Europe (Maes et al., 2016), TEEB (http://www.teebweb.org/), and IPBES (https://www.ipbes.net/), were launched.

Under the influence of these initiatives and the availability of a set of integrated techniques, many studies have been conducted to quantify human influence on ecosystems and their services. Using four human pressures on the land, Sanderson et al. (2002) mapped human influence intensity (HII) on the entire land surface. Recently, these authors updated their maps for 1993 and 2009 and indicated that increases in human pressure threatened biodiversity (Venter et al., 2016). The anthropogenic biomes of the world were identified for 1700–2000 to conserve, enhance and restore ecological functions and biodiversity within anthromes (Ellis et al., 2010). However, the global scale datasets are not well suited for regional analyses. Therefore, a number of studies at medium to small scales have been conducted for conservation of biodiversity and ecological service functions, with some revisions of the method and using local data. A spatial human footprint index was formulated to evaluate human impact on habitat connectivity in the Trans-Mexican Volcanic System in Michoacán (Correa Ayram et al., 2017). Taking socio-cultural attributes into account, Rodriguez-Soto et al. (2017) identified territories of opportunity for biodiversity conservation in Mexico. Based on the study results

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of land use change and its impacts on biodiversity in Italy, Falcucci et al. (2007) suggested that the socio-political and ecological processes should be functionally integrated in a conservation strategy. Besides, the effects of cumulative human stressors on Arctic marine ecosystems were also estimated (Andersen et al., 2017).

As the third pole of the world (Yao et al., 2012), the Tibetan Plateau (TP) provides various ecosystem services for humanity, including water resources for nearly 40% of the world's population (Xu et al., 2008). In addition, it plays a significant role in climate regulation (Jin et al., 2005), and it is also a hotspot for biodiversity conservation in the world (Myers et al., 2000). Additionally, its fragile ecosystem is very vulnerable to disturbance and it is widely acknowledged that environment and ecological services in this region changed significantly in the last century due to human activities and climate change (Chen et al., 2013), including the losses of habitat and biodiversity (Myers et al., 2000), and a decrease in water supply (Pan et al., 2015). However, there are only a few preliminary works concerning HII mapping and its implications for conservation planning in the TP. To assess the HII in Tibet Autonomous Region (TAR), four pressures were employed and an analytic hierarchy process was conducted (Zhong et al., 2008). Using population density, the number of villages, and the length of roads, the HII with a resolution of 10 km for rangeland areas in the TP was evaluated (Zhao et al., 2015b). Recently, the spatial and temporal characteristics of human activities in TAR over the past half century were analyzed qualitatively, which detailed the work of more than 70 ecological specialists since 2012. It was found that the human disturbances on ecosystem in TAR were limited overall (Fan et al., 2015).

Based on above analysis, there have been no studies in which the HII of the entire TP was mapped, not to mention its implications for conservation of ecosystem services and biodiversity, which severely constrained the making of ecological conservation planning in the third pole. Therefore, the objectives of this study were to map the HII for the TP by tailoring the methodology of Sanderson et al. (2002) and taking the conservation of ecological service functions and biodiversity into account. The period investigated was set as 1990–2010 as well as the spatial assessments were conducted at county and 1 km scales. Four categories of human pressures were considered and assigned influence scores based on local studies and empirical analysis, and were then summed to obtain HII maps. HII and its changes in valuable regions for water retention and biodiversity conservation were analyzed further to determine the human pressures faced by these regions. Finally, a range of additional uses of the HII datasets for conservation of ecosystem services and biodiversity were formulated.

2. Materials and methodology

2.1. Study area

The TP covers an area over 2.5 million km^2, stretching from the Pamir and Hindu Kush in the west to the Hengduan Mountains in the east, and from the Kunlun and Qilian mountains in the north to the Himalayas in the south (Fig. 1). With mean elevation of over 4000 m, the TP is the largest and highest mountain region on earth. It is often referred to as "the Roof of the World" and "the Third Pole" (Yao et al., 2012). As the "Asian water tower" and hotpot of biodiversity conservation of the world, it has received considerable public attention (Yao et al., 2012).

2.2. Overview of the method

Sanderson et al. (2002) have noted that the methodology they developed are general and can be applied locally with more accurate and detailed datasets. In this study, taking the regional, biophysical and cultural characteristics of the TP into account, we tailored this method and selected land use/cover, population density, road distribution, and grazing density (Hu et al., 2015; Lu et al., 2017) to map HII of the TP for 1990–2010 (Fig. 2, step 1). Taking the data availability and credibility into consideration, we assessed HII at county and 1 km scales. The county-scale assessment results will provide a scientific basis for administrative-level conservation planning, while the 1 km scale assessment will

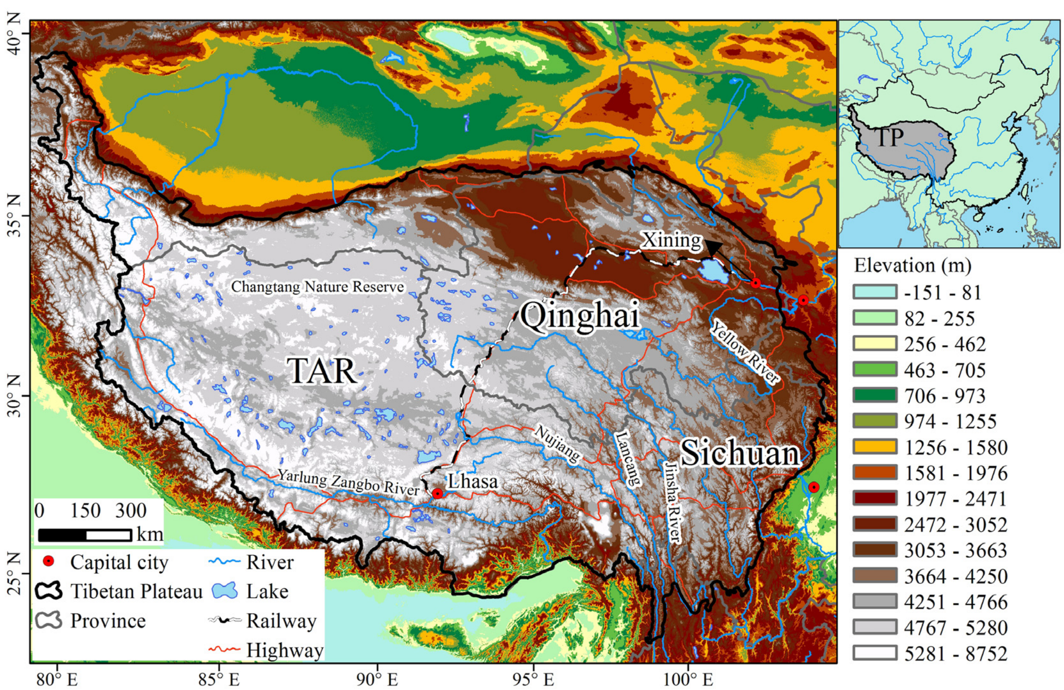

Fig. 1. Location of the study area. The boundary of the Tibetan Plateau (TP) is cited from Global Change Research Data Publishing & Repository (Zhang et al., 2014). TAR: Tibet Autonomous Region.

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