



Effect of climate change on the vulnerability of a socio-ecological system in an arid area



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ABSTRACT

The vulnerability of arid areas threatens ecosystems and human existence. With climate change and increasing human activities, addressing this vulnerability has become an important concern. To support this objective, we present a complex index system to analyze vulnerability at a regional scale with a 1 km × 1 km resolution. Based on the evaluation framework, which includes natural resources, the natural environment and the social economy, the results indicate that an ecosystem in a mountainous area is more vulnerable than it is in a plain. Land desertification will worsen from 2014 to 2099 under the RCP4.5 scenarios and improve slightly under the RCP8.5 and RCP2.6 scenarios, while the suitable land for agriculture increased slightly under the three scenarios. In addition, a regional sensitivity analysis of vulnerability to climate change shows that the improving region and the worsening region will occupy 1.30% and 74.51%, respectively. In view of this, the socio-ecological system will undergo a worsening trend as a whole. Finally, we simplified how to solve the problem of a socio-ecological system in the future. This research method and results would generate new insights with respect to planning for sustainable development and provide a reference for decision-making.

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1. Introduction

Global vulnerability analyses reflect generic processes of socio-ecological systems under climate change and social development (Wei et al., 2013; De Chazal et al., 2008). Since the 1960s, vulnerability has gradually become an important field following the implementation of the International Biological Program (IBP), Man and Biosphere Program (MBP), and International Geosphere-Biosphere Program (IGBP) (Viglizzo et al., 1995; Friedl et al., 2002). Vulnerability research has changed from natural ecosystems, ecological economic systems to social-economic-ecological complex ecosystems (Bardsley and Wiseman, 2012; Abson et al., 2012). Multi-dimensional fields, such as economic (Pérez Agúndez et al., 2014), social (Murphy and Scott, 2014), environmental (Petrosillo et al., 2010) and institutional (Young, 2010) ones, are covered.

Dealing with the social and ecological problem has puzzled many researchers for some time (Tyler et al., 2007). A general framework for analyzing sustainability of a social-ecological system was put forward by Ostrom in 2009, who brought significant attention to social-ecological systems (Ostrom, 2009). Dryland vulnerability at a global scale and

sub-national resolution has been classified into poverty, water stress, soil degradation, natural agro-constraints and isolation (Sietz et al., 2011). In the dryland development paradigm, the problem of livelihood and sustainable development are solved in the context of researching desertification, vulnerability, poverty and community development and from the perspective of human environment system (Reynolds et al., 2007). In this paper, the social-ecological system was considered as a complex adaptive system with unpredictability, self-organization, multiple stability, the threshold effect and dependence. These systems are an organic combination of social systems and environmental systems at a particular time and space. Social factors interact with and restrict natural factors.

Climate, landforms, water and heat in arid areas are the main factors that govern the distribution of vegetation, soil and water resources (Hupp and Osterkamp, 1985; Moore et al., 1993). Together, the ecological environment and its ecosystem functions present different diversities and vulnerability levels. In recent years, many studies have focused on the arid area's vulnerability response to global warming (Held and Soden, 2006). According to the Intergovernmental Panel on Climate Change (IPCC) report, tropics and subtropical arid region would enlarge further (Parry, 2007). Additionally, population growth, socioeconomic development and exploitation of soil and water resources have caused many hydrological and ecological environment problems (Stern et al.,

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1996; Evans and Kantrowitz, 2002). Developing adequate responses to the vulnerability of socio-ecological systems to all these changes is a critical challenge for sustainable development of arid areas.

Evaluating the vulnerability of a socio-ecological system must depend on its driving factors, so it is important to analyze the generic processes and formation mechanisms of vulnerability under climate change. In the process of evaluation, most investigations are targeted at ecosystems in the present (Kok et al., 2015). An index system for evaluation of socio-ecological systems is still not sufficient.

2. Background

2.1. Major vulnerability problems in the arid area of Northwest China

An oasis is a functional unit in arid areas with special natural conditions (Zhang, 2002). Individual oases may have different development intensities, which has led to irrational exploitation of their resources (Wang and Zhang, 2012).

First, the spatial distribution of oases is irregular (Liu et al., 2010). At the beginning of exploitation, significant attention was paid to the soil, sun hours and heat, while the water resources were ignored (Ling et al., 2013). After a long time, these activities are no longer coordinated (Shen et al., 2013). Many ecological problems such as land desertification and salinization have become very serious (Wang et al., 2013; Yimit et al., 2011).

Second, water supply and demand is imbalanced (Feng et al., 2000). Extensive management, water waste and economic expansion have led

the imbalance between supply and demand for water to become very significant (Cai, 2008). Landscape vulnerability in these oases has also deteriorated seriously (Zhu et al., 2009).

Third, the desert landscape is being destroyed (Qian et al., 2004). With the increase of oases over the last 40 years, the boundaries between oases and the desert has expanded, which qualitatively changed the structure and function of the desert landscape (Zhang et al., 2003). Today, this situation continues.

The aim of this paper is to analyze the vulnerability of socio-ecological systems based on natural resources, the natural environment and economic activities and to evaluate the effect of climate change on a region's vulnerability.

2.2. The study area

The arid area of Northwestern China was selected as a case study and is considered to be representative of a typical arid area. It is located to the west at 106°E and the north at 35°N (Ersi et al., 1999). It is situated in the hinterland of the Eurasian continent and covers a surface area of approximately 1,972,765 km² (Fig. 1). The landforms are characterized by a series of undulating mountains ranges sitting parallel to low, broad valleys. This area is dominated by a continental dry climate. The average annual precipitation is no more than 160 mm, and the average annual evaporation is more than 2000 mm in the plain. It is one of the most drought-prone areas of the world and one of the major grain-producing areas of China (Yin et al., 2006). Moreover, the socio-ecological system is very fragile (Deng et al., 2006).

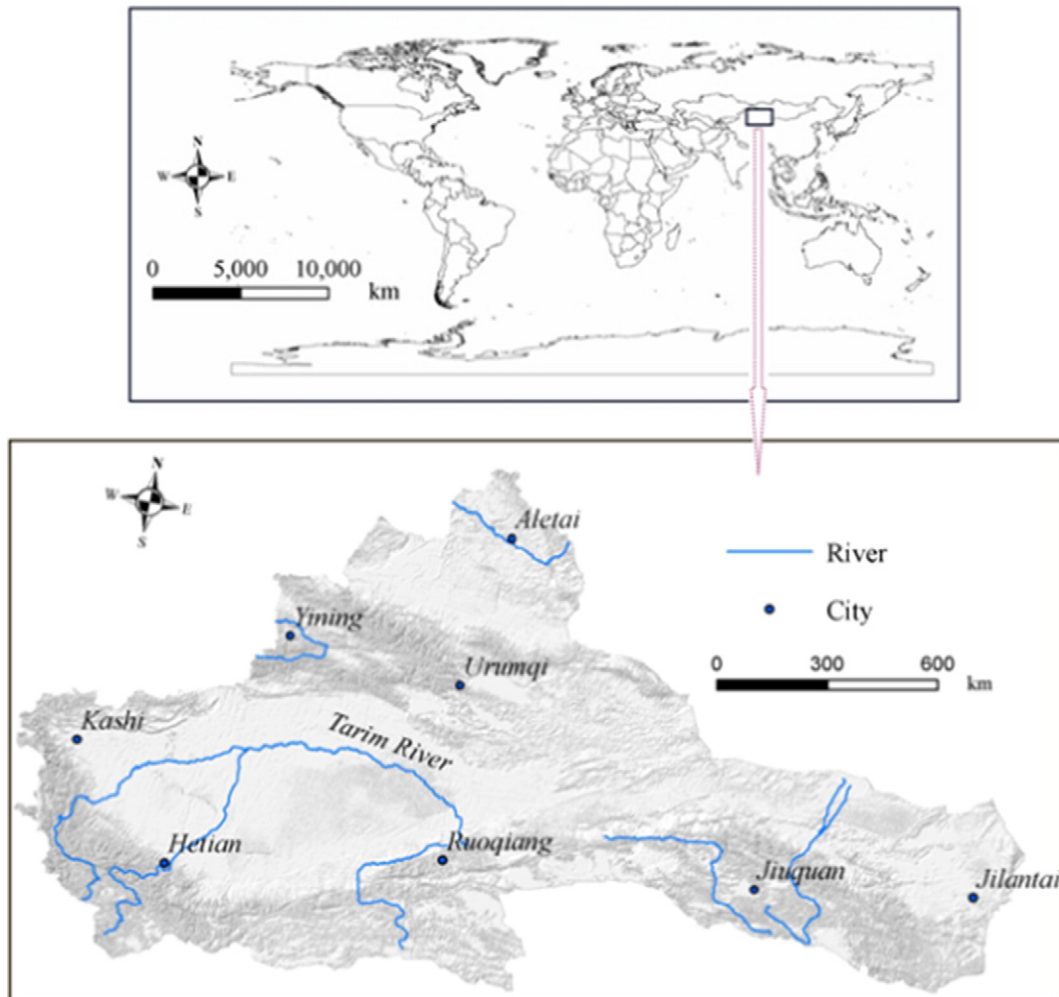


Fig. 1. Location of the arid area of Northwestern China.

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