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Vulnerability assessment of wetland landscape ecosystem services using driver-pressure-state-impact-response (DPSIR) model

B. Malekmohammadi*, F. Jahanishakib

Graduate Faculty of Environment, University of Tehran, Tehran, Iran

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A B S T R A C T

Wetlands exist in complex ecological conditions that are changeable in time and space in terms of function and structural diversity. In recent decades, wetlands have been exposed to a wide range of threats. Assessment of these threats is essential to develop an understanding of the state of a wetland ecosystem and to develop a suitable management strategy. This paper discusses wetland vulnerability in terms of analysis of human and environmental systems from application of the driver-pressure-state-impact-response (DPSIR) framework. This assessment presented a systematic methodology for assessment of wetland vulnerability in a social-ecological approach applying broad-scale ecosystem services and vulnerability functions. The method combined the hydrogeomorphic approach with estimations of vulnerability indicators and DPSIR analysis. The aim of this paper was to assess vulnerability of wetland ecosystem services and to characterize the threat indicators according to importance, severity, and probability of occurrence. Quantitative and qualitative methods were applied to characterize values for these three indicators. The Multi Criteria Decision Making (MCDM) method was used to prioritize threats and impacts of the wetland on the basis of experts' opinions. The proposed methodology was applied to the Choghakhor international wetland landscape in south-western Iran. Vulnerability assessment revealed that water requirement of the lowland and the water transfer system were the most important factors threatening the wetland. Agricultural activities, settlements and urban areas, drought, tourism, population growth, and mining activities in the upland were the next most important priorities, in that order. Hydrological balance was determined as the most vulnerable function and was considered as the most important function in the Choghakhor wetland. The DPSIR model was used to determine a management strategy to reduce vulnerability of ecosystem services in response to drivers, pressures, states and impacts indicated by modelling.

1. Introduction

Wetlands are important for human well-being. They provide an essential environmental resource through climate regulation, opportunities for fishing and provision of water resources that are essential for crop production and useful for recreation (Engelhardt and Ritchie, 2001; Adekola and Mitchell, 2011). However, the health of such valuable ecosystems worldwide is increasingly under threat from environmental pressures. Environmental pressures are primarily created by human activities: water for agriculture, discharge of industrial and domestic wastewater into wetlands and consumption of wetland vegetation for fuel and livestock feed are examples of human activities that have a detrimental impact on wetland areas. These activities affect wetland ecosystems in developing countries, particularly those in which the protection of a wetland ecosystem is often overlooked by its citizens and policy-makers (Lin et al., 2007; Kimmel et al., 2010; Adekola and Mitchell, 2011).

More recently, social and biophysical aspects have been brought together for closer examination of vulnerability in terms of 'coupled human-environment' or 'social-ecological' systems (Eakin and Luers, 2006; Folke, 2006; de Chazal et al., 2008). A coupled human-environment system, also known as a Coupled Human And Natural System (CHANS) is an integrated scientific framework for studying an interface and reciprocal interactions that link human (e.g., economic, social) to natural (e.g., hydrologic, atmospheric, biological) sub-systems of the planet (Alberti et al., 2011).

Methods to characterize vulnerability are debated in both theory and in practice (Bayliss et al., 1997; De Lange et al., 2010; Jackson et al., 2004; Metzger and Schröter, 2006; Xiao et al., 2014). Vulnerability is increasingly regarded as a condition that encompasses the characteristics of exposure, susceptibility and capacity to cope (Miller et al., 2010). Pre selection of variables is guided by the conceptual components of social and environmental vulnerability: susceptibility, capacity and exposure (Fekete et al., 2010). The first aspect is

* Corresponding author.
E-mail addresses: Malekb@ut.ac.ir (B. Malekmohammadi), f.jahani.sh@ut.ac.ir (F. Jahanishakib).

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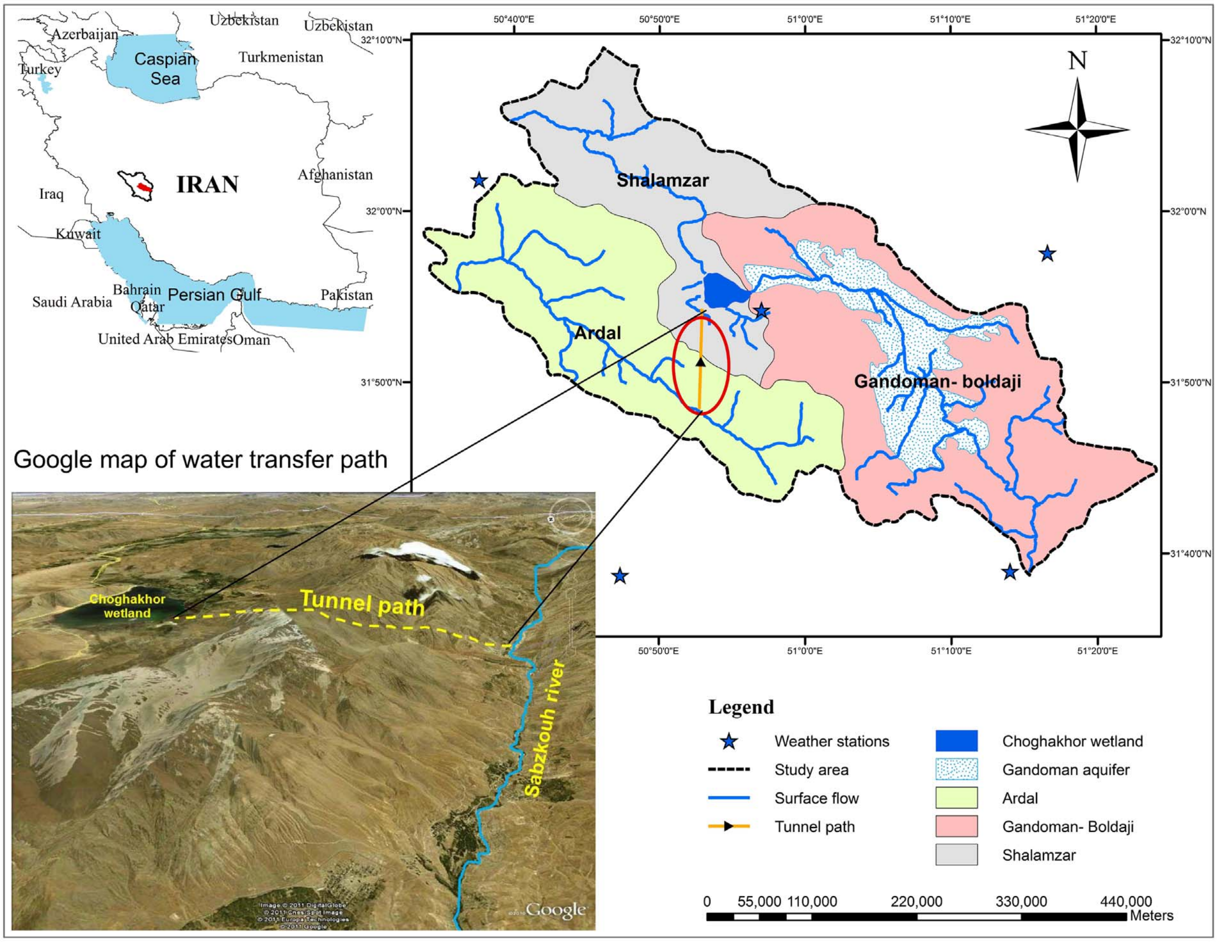

Fig. 1. Location of Choghakhor wetland and related landscape in Iran.

susceptibility to exposure and this can be described by various ecological traits. The second aspect is sensitivity to the stress factor which is the sensitivity of the structural components (species), but it also needs to be described for functions within an ecosystem and trophic relations. The third aspect relates to recovery potential of the system which is determined by population recovery, community resilience, existence of positive feedback loops within an ecosystem and potential for adaptation (De Lange et al., 2010). In another method that has been used to assess vulnerability, stakeholder values of ecosystem services and matrices were used to link social and ecological information to changes in the ecosystem services and information on ecosystem properties that provide such services (de Chazal et al., 2008).

Newton and Weichselgartner (2014) Reports on vulnerability related to four main coastal hotspots to demonstrate the complexity of coastal vulnerability. They used the Driver, Pressure, State, Impact, Response (DPSIR) framework to analyse causes and consequences of coastal vulnerability in those four sites. Responses focused on particular societal, technological and engineering solutions. These included raising awareness, advancing forecasting, enhancing preparedness and improving governance.

DPSIR is a tool for detailed analysis that integrates economic, social and natural systems into a systemic approach (Bidone and Lacerda, 2004). The driver, state, response (DSR) method was developed by the United Nations to assess and monitor sustainability. The DPSIR method presents mechanisms for analysing and depicting environmental problems in an integrative way. The basic idea of DPSIR method is that social, demographic, and economic development; consumption or production patterns in a society and the corresponding changes in motivation and lifestyle as known 'drivers' produce certain pressures (Müller and Burkhard, 2012).

Pressures are consequences of human activities that have the potential for adverse effects (impacts) such as release of chemicals, physical, and biological agents, climate change, extraction and use of resources, patterns of land use, and creation of invasion corridors (Omann et al., 2009). The state of the environment is the quantity of biological, physical and chemical features of an ecosystem, and/or of environmental functions, vulnerable to (a) pressure(s) in a certain area. Impacts include socio-economic impacts of environmental degradation. A response is a policy action, initiated by institutions or groups such as politicians, managers and consensus groups to alleviate environmental pressures and to enhance the quality of the environment (EEA, 2000; Omann et al., 2009). Land management has been identified as the main driving force for change of land use and respective indicators should represent this interrelationship (Müller and Burkhard, 2007; Zacharias et al., 2008; Atkins et al., 2011; Syrbe and Walz, 2012; Van Oudenhoven et al., 2012).

In this study, the DPSIR model was used to analyse relationships and interactions between humans and the environment in a wetland environment in order to understand the ecological status of the wetland. The method included integrated landscape management by providing an appropriate management strategy. For this purpose, the Choghakhor wetland in south-western Iran was selected as a case study. Ecosystem services and assessment of vulnerability functions of this wetland have been made on a broad scale using a social-ecological approach. Also, a trend of land cover change from 2003 to 2013 was interpreted through Landsat satellite images. Vulnerability scores were assigned to threats according to importance, probability of occurrence, and severity of impact on the ecosystem services and functions. Eventually, according