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Research article

A multi-criteria inference approach for anti-desertification management

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ABSTRACT

We propose an approach for classifying land zones into categories indicating their resilience against desertification. Environmental management support is provided by a multi-criteria inference method that derives a set of value functions compatible with the given classification examples, and applies them to define, for the rest of the zones, their possible classes. In addition, a representative value function is inferred to explain the relative importance of the criteria to the stakeholders. We use the approach for classifying 28 administrative regions of the Khorasan Razavi province in Iran into three equilibrium classes: collapsed, transition, and sustainable zones. The model is parameterized with enhanced vegetation index measurements from 2005 to 2012, and 7 other natural and anthropogenic indicators for the status of the region in 2012. Results indicate that grazing density and land use changes are the main anthropogenic factors affecting desertification in Khorasan Razavi. The inference procedure suggests that the classification model is underdetermined in terms of attributes, but the approach itself is promising for supporting the management of anti-desertification efforts.

1. Introduction

Desertification is the impoverishment of terrestrial ecosystems under human activities – it is a deterioration process of vulnerable ecosystems that can be caused by reduced biological productivity and biomass, decreased biodiversity and increased frequency of invasive species; accelerated soil deterioration, changes in vegetation patterns, and alterations within the inhabiting human societies including effects such as an ascending trend of immigration and poverty (Dregne, 1977). The term "desertification" is generally used for referring to many different land degradation phenomena, and although there are various studies about desertification (Mainguet, 1991; Bestelmeyer, 2005, 2006; Sepehr et al., 2007; Sepehr and Zucca, 2012; Dregne, 1977; Reynolds and Smith, 2002; Downing and Lüdeke, 2002; Nearing et al., 1994; Nearing, 2003; Morgan, 1995; Rose, 1998; Thornes, 2003; Kirkby et al., 2004; Mulligan and Wainwright, 2003), most of them consider desertification to be according to the UNCCD (1994) definition: "land degradation in vulnerable environments including arid, semi-arid and dry sub-humid areas mainly resulting from excessive human activities and climatic oscillations".

Desertification can be analyzed based on the equilibrium change paradigm which focuses on oscillations in the states of an ecosystem (Scheffer et al., 2009, 2001; Scheffer, 2001; Dakos et al., 2008; Klein et al., 2003). Accordingly, desertification can be defined to mean a change of the equilibrium point of an ecosystem from a "green" state to a desert state due to certain environmental forces. The ability of an ecosystem to endure these environmental perturbations is determined by its resilience range (Gunderson, 2000). In desertification terms, a high resilience range indicates an ecosystem that is sustainable against desertification – such ecosystems are resilient and exhibit an equilibrium state. Fig. 1 illustrates the relationship between the resilience ranges and equilibrium alterations: a perturbation in the environment is increased by the desertification drivers, and this changes the equilibrium points of the system.

This paper develops a methodology for anti-desertification management and presents its application to the Iranian province of Khorasan Razavi (KR). Iran is located in a very arid area of the world and has an average yearly precipitation of a third of the world

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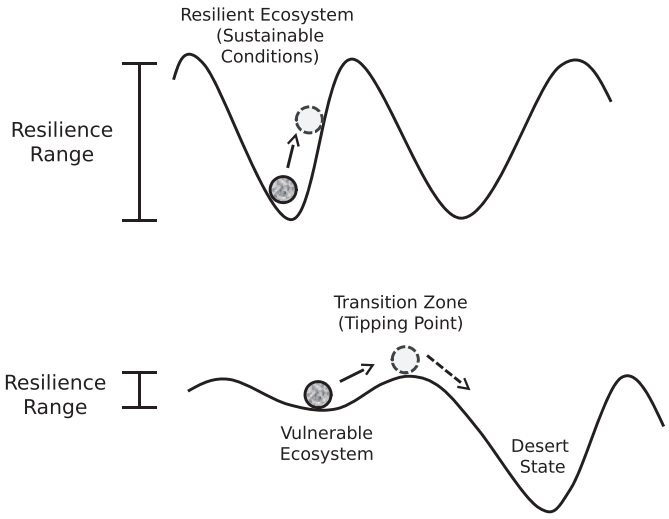

Fig. 1. The alternative stable states of an ecosystem under the influence of disturbance event. For the resilient ecosystems, a high resilience range creates sustainable conditions and high resistance ability against desertification. Conversely, in ecosystems with a low resilience range, a non-equilibrium condition occurs easily – such ecosystems are near to the thresholds points and can transform easily to desert landscapes.

average. Iran's climate ranges from arid or semi-arid (approximately 85% of the Iranian territory) to subtropical along the Caspian coast and the northern forests (see Fig. 2). KR is located in northeastern Iran and it borders North Khorasan province and Turkmenistan in the north, Semnan province in the west, Yazd and South Khorasan provinces in the south and Afghanistan and Turkmenistan in the east. More than 60% of the province includes desert and semi-desert areas. The annual precipitation ranges from 100 mm in the southern parts to 400 mm in the northern parts of the province. The average summer temperatures exceed 38 °C.

KR is a critical zone regarding land degradation and erosion. Urban developments in the recent years have brought overexploitation of natural resources, and many of the region's past pastures and scrublands have been transformed into environmentally degraded areas or settlements. These changes have caused vegetation degradation and the appearance of unvegetated areas with low resilience towards desertification. Based on the UNCCD Agenda (UNCCD, 1994), Iran has prepared a National Action Program (NAP) to combat desertification. The NAP framework involves four components: (i) determining parameters affecting desertification, (ii) soil and water conservation, (iii) rehabilitation and promotion of sustainable livelihoods in the affected areas, and (iv) participating rural communities in decision making and anti-desertification measures. As wide range of Khorasan Razavi areas are covered by Erg lands (sand dune landforms), sand dune stabilization is the main anti-desertification measure in the province. Sand dune stabilization projects have been successful in some parts of Iran (Amiraslani and Dragovich, 2010, 2011), but in the collapsed ecosystems of KR with harsh desert conditions, vegetation and sand dune stabilization is challenging. Some areas of KR have seen past dune stabilization projects with unsatisfactory results. The overall shares of anti-desertification plans implemented in KR from 2005 to 2012 are presented in Table 1.

To combat desertification and to manage national anti-desertification programs, it is deemed necessary to distinguish vulnerable and fragile ecosystems within the regional level. The ecosystems' soil properties, vegetation densities and ecogeomorphic factors determine their resilience ranges. The main hypothesis of this research is that we are able to distinguish ecosystem susceptibility to desertification based on their resilience ranges and biomass alterations. We present a methodology for identifying

Table 1
The most important anti-desertification measures in the Khorasan Razavi Province from 2005 to 2012.

Anti-desertification measure	Share of all measures
Education of rural communities	21%
Stabilizing sand dunes	32%
Culturing of Halophyte species	26%
Improving agricultural irrigation	9%
Implementing watershed management	12%

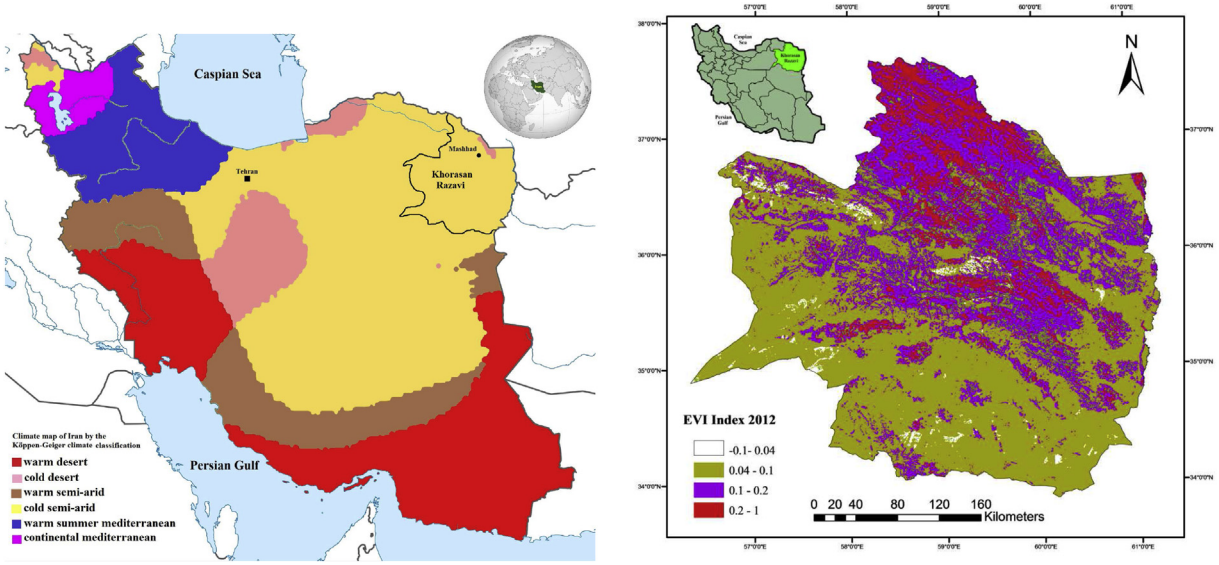

Fig. 2. The research has been done for Khorasan Razavi province located in northeastern Iran. The ecosystems of this region are susceptible to desertification processes. The right-hand image visualizes the region's EVI, an index of vegetation cover extracted by MODIS imagery data, for June 2012. According to this image only less than 15% of the study area contains higher vegetation cover density than 40%, which indicates presence of highly fragile ecosystems.