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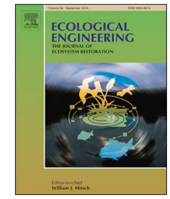

Wetland restoration prioritizing, a tool to reduce negative effects of drought; An application of multicriteria-spatial decision support system (MC-SDSS)

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A B S T R A C T

In recent years, large parts of arid and semi-arid areas in the world are dealing with water restrictions. In these areas, wetlands provide habitats for migratory birds and have a critical role in socio-ecological systems. Generally, in these areas, changing water-use patterns because of land-use change and water limitation because of climate change have led to the loss of wide areas of wetlands. Wetland restoration is suggested to restore the functions and values of wetlands that have been destroyed or affected by stresses. In this paper, a new application of wetland restoration prioritizing is introduced; restoration prioritizing to reduce the negative effects of drought. In this method, areas with the highest priority for restoration will be determined in a wetland destroyed because of water limitations. Multicriteria-spatial decision support system (MC-SDSS) was used to plan a scheme for Hamun wetlands restoration prioritizing in order to reduce the negative effects of drought and to restore the wetlands. This prioritization-determined areas that are valuable for Long-term water conservation, reduce the negative effects of dust storms and conserve water bird's habitats. This method was used in a wetland that is the only water resource in the middle of a wide arid plain. Because of water limitation, it is not possible to restore the hole wetland; therefore, different parts of this wetland were prioritized for restoration. Based on the results, it is possible to produce a model to determine which priority can be restored in each amount of water volume. In this way, it becomes clear for decision-makers to select areas for restoration in different volumes of water. The result of this study shows that since MC-SDSS decreases conflicts between alternatives in a decision-making process and uses their spatial situation, it is a preferred method to balance among conflicting goals. Furthermore, because spatial data are the most important parts of MC-SDSS, this paper shows the ability of remote sensing to be used in MC-SDSS method. It seems that in the future; remote sensing will have the most important role in MC-SDSS.

1. Introduction

Wetlands are important resources of clean water, support biological diversity, control floods and increase the quality of life for local people and wildlife (Mitsch and Gosselink, 2007). Despite these valuable functions, over 50% of wetlands have been lost because of human activities (Fraser and Keddy, 2005; Nicholls, 2004), and when wetlands are destroyed, their important functions will be destroyed (Li et al., 2005; Taft et al., 2002). This is important especially in arid areas where water restriction is a critical factor for biological life (Hassan et al., 2005); and the most important reason for destroying wetlands in these areas is water limitation (Downard et al., 2014; Minckley et al., 2013). In light of this, it is important to investigate an applicable approach to reduce the negative effects of water limitation on wetlands, and in order to get the best results, this approach must be scientific.

In recent years, wetland restoration and rehabilitation are the major options selected by international community for wetland conservation (Klemas, 2013). Most wetland restoration prioritizing projects are related to the construction of new wetlands in order to develop agriculture, increase water quality and maintain floods (Darwiche-Criado et al., 2017; Li et al., 2010; Li et al., 2005; Ouyang et al., 2011; Sun et al., 2015; Widis et al., 2015). However, this paper introduces a new application of wetland restoration prioritization; restoration prioritization to reduce the negative effects of drought. In a wetland destroyed because of water limitation, which parts have higher priorities for restoration? This is also applicable in other ecosystems that face

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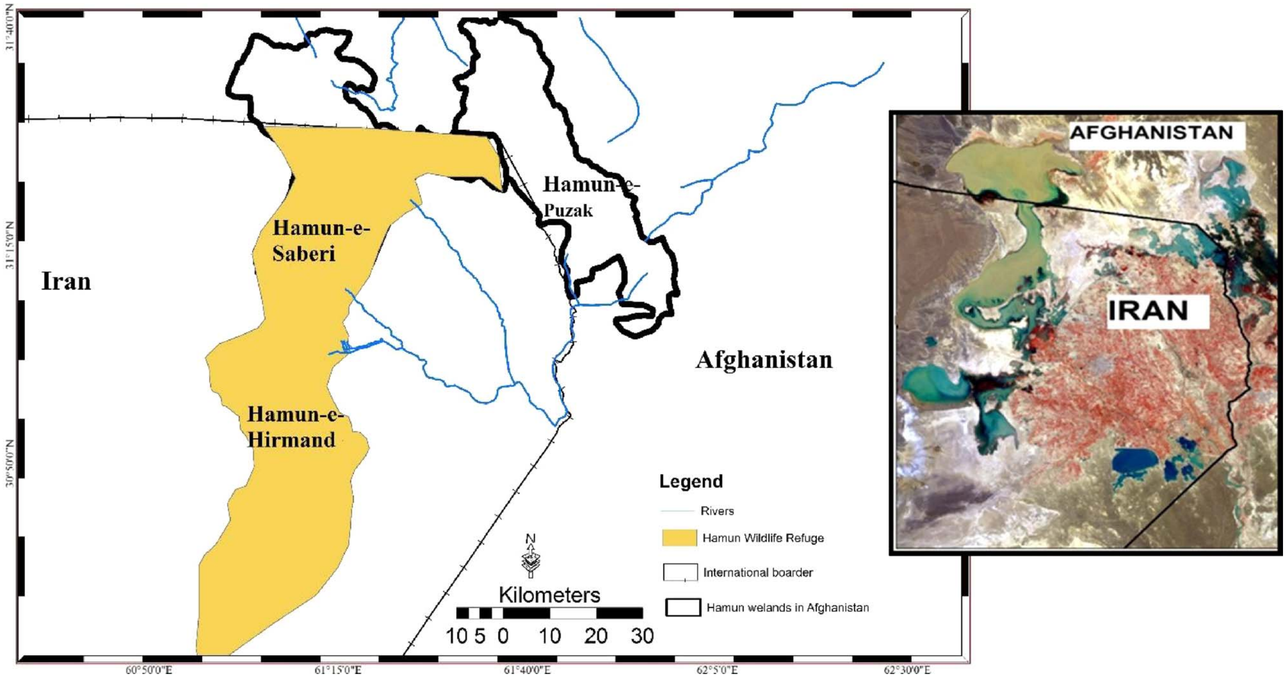

Fig. 1. The study area.

limitations. Moreover, in this study, restoration is prioritized in order to reach 3 sub-objectives: Long-term water conservation, reduction of negative effects of dust storms, and conservation of water birds' habitats.

Wetland restoration prioritization was investigated in the Hamun Wetlands, which is a valuable ecosystem because it is the only water resource in a wide arid area, it is located on the global migration route of birds and it is a valuable stop site for migrating birds (Maleki et al., 2016; Partow, 2003). The wetlands are an important source of fish and fresh water for local people, and their dense marshes and clear lakes are suitable habitats for large groups of species. Despite valuable functions in this area, Hamun is endangered because of water restriction. Irrigation expansion, coupled with droughts, has left the Hamun dried out (Maleki, 2016). The wildlife and the human communities that used to surround the Hamun have all decreased, and nearly 100 villages have been damaged by windblown dust (Partow, 2003). Agriculture is not possible and livestock and wild animals sensitive to water restriction cannot survive. All these are the results of water limitation in an arid area. These problems can also take place in other regions of the world dealing with water limitation.

Wetland restoration-prioritization has been developed using different methods. The differences between these methods are based on the objective of prioritization and the study area (McAllister et al., 2013; Schleupner and Schneider, 2013; Zhang and Song, 2014). One of these methods is a scoring system, which uses socio-economical ecological, hydrological and geographical parameters and makes scores for each parameter to restore wetland, and − is widely used in the prioritization projects (McAllister et al., 2013; Palmeri and Trepel, 2002; White and Fennessy, 2005). Another widely-used method is the Geographic Information System GIS-based method (Baban and Wan-Yusof, 2003; Holzmueller et al., 2011; Jasrotia et al., 2009; Kauffman-Axelrod and Steinberg, 2010; Palmeri and Trepel, 2002), which is a valuable tool for wetland restoration site selection using a set of spatial data. Different geographic scales are easily applied, and input data flexibility and spatial data make GIS-based wetland prioritization model an applicable method used in different wetland restoration plans (Drummond and French, 2008; Palmeri and Trepel, 2002; Widis et al., 2015). In recent years, a decision support system (DSS) that is based on GIS technology has been used in wetland restoration prioritizing. This method includes multicriteria-spatial decision support systems (MC-SDSS) that refer to those DSS systems that use geographic or spatial data (Malczewski, 1999). MC-SDSS (Malczewski, 1999) use Geographic Information System and Multi Criteria-Decision Method (MCDM) to combine spatial data and decision-maker's comments and uncertainties to provide spatial data for decision-making about the decision alternatives and their spatial attributes (Ferretti and Pomarico, 2013). MC-SDSS is different from conventional MCDM techniques because this method uses geographical data about decision alternatives (Jankowski et al., 2001). In MCDM method, the important criteria that are effective in decision making are combined based on their weight. These weights show the importance of each criterion in decision-making. In MC-SDSS method, in addition to the decision-makers' idea and a set of criteria, the spatial locations of alternatives are used. This means both decision making preferences and geographical attributes of alternatives are used to judge them; - it also includes the social participation and experts knowledge (Ascough et al., 2008). These benefits make MC-SDSS a useful method in wetland restoration prioritizing because wetland restoration is a complex project that needs all this information. In this way, accurate spatial data play an important role in MC-SDSS. In recent years, remote sensing has been applied as an important source to produce spatial data (Guo et al., 2017; Klemas, 2013; Widis et al., 2015). Its ability to produce data for a wide and remote area with enough accuracy acquires data in different spatial and temporal resolution and flexibility in method is the reason for the wide application of remote sensing. It seems that, in the future, these benefits of remote sensing will change it to a vital tool in MC-DSS.

In this study, MC-SDSS was used to plan a scheme for Hamun wetlands restoration-prioritization in order to reduce the negative effects of drought and to restore Hamun. These prioritization-determined areas - are valuable for Long-term water conservation, for reduction of negative effects of dust storms and for conservation of water bird's habitats.

The structure of this paper includes 5 sections. The next section (Section 2) is material and method. The study site and the database are presented in 2.1 and 2.2. The database is including satellite images and experimental measurements. Methods to produce the priority maps are described in Section 2.3. Results of wetland restoration prioritizing and its description are presented in Section 3. Finally, discussion is