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Fuzzy risk assessment modelling of wild animal life in Bijar protected area

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A B S T R A C T

Bijar protected area (BPA) is suffering from land use change and livestock grazing. Since 1977, the number of main species (*Ovis orientalis gmelini*) living in BPA has reduced from 2000 to 435. In order to study the wild animal life (WAL) risk of BPA, a Fuzzy model in Geographical information system (GIS) environment and remote sensing was utilized. The seven selected input indices for the model were 'BPA conversion rate', 'Natural resource', 'Population density', 'Population growth rate', 'Social status', ' Security threat', and 'Livelihood status'. BPA conversion rate was obtained based on Landsat 8 Satellite images of 2016 and agricultural area maps of BPA villages. The weight and Fuzzy rules ranges of the sub-indices were created based on an expert opinion survey (questionnaire) developed according to the related literature. Sub-indices were union in vector format in the GIS environment to acquire the main indices and they were overly in raster format based on Fuzzy membership functions to obtain the WAL risk in three levels of high, moderate and low. Results showed that the areas with high risk were (i) agricultural lands, (ii) lands that underwent use change (rangelands to agricultural lands), (iii) areas with a large number of livestock, (iv) areas within the proximity to roads, and (v) areas far from the protected stations. From the results it can be concluded that low level of livelihood, low number of protective stations and weak protective regulations are the main reasons behind increasing WAL risk in BPA.

1. Introduction

Human activity is the main risk for wildlife and has resulted in habitat destruction in the last decades. One of the intensifying conversion efforts for protecting both biodiversity and natural areas is through establishing protected areas (PAs) (Macura et al., 2015; Pullin et al., 2013). PAs now cover 14.6% of land surface globally, and to some extent they have been able to conserve biodiversity by preventing incompatible land use (Watson et al., 2014). However, conversion success in the PAs is far from guaranteed due to their small and isolated areas (Armsworth et al., 2011), their little economic potential (Joppa and Pfaff, 2009), their poor representation of species (e.g. Iojă et al., 2010; Jackson and Gaston, 2008), and dynamic threats of their ecosystems (Araújo et al., 2011). Additionally, increasing human populations in the villages located in PAs, and settlements along the borders of PAs have increased the human-wildlife conflict (Wittemyer et al., 2008; Young et al., 2010). There are some indices that can compromise ecological integrity of PAs such as increasing visitation (Sarmento and Berger, 2017), land use changes (Martinuzzi et al., 2015; Sieber et al., 2013), population densities and livelihood status (Vedeld et al., 2012), and hunting (Pattiselanno and Lubis, 2014). Pattiselanno and Lubis (2014) showed that trade was the main reason for hunting mammals and birds in the Abun district of Tambrauw Regency at the Bird's Head Peninsula of Papua, Indonesia. They found that meal consumption of the people in their study area mostly contained wild meat (wild pig and rusa deer) rather than fish, animal products, vegetables, and noodles. Vedeld et al. (2012) explained that income inequality is one of the reasons that aggravate resource use conflict in the Mikumi National Park, Tanzania. Risk assessment of ecosystem is a useful method to show what indices could cause harm to ecosystem. Many researchers have studied application of risk assessment for the conservation of different ecosystems such as ecological risk assessment of heavy metals in soils (Tang et al., 2017), ecological risk assessment of xenobiotics (Grechi et al., 2016), identification of representative vulnerable fish species for pesticide risk assessment (Ibrahim et al., 2014), and performing quantitative microbial risk assessments (Whelan et al., 2014). Comprehensive data on ecological, social, and economical variables are needed for risk assessment analysis. Geographical information system (GIS) can be used for analysis of occurrence probability, intensity, and frequency data of risk types related to economic, social and ecological processes. Recently, remote sensing has been utilized as a reliable and inexpensive tool to observe some ecological data such as modeling wetland water quality (Amanollahi et al., 2017), land surface temperature (Fallahi et al., 2018), land use change, habitat extent, habitat

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condition, species diversity (Nagendra et al., 2013), and track anthropogenic activities and their impacts on biodiversity in Marine protected areas (Kachelriess et al., 2014). GIS and remote sensing were integrated by Dimitriou and Zacharias (2010) to identify land use change impact on the riparian area of protected wetland. Risk assessment is mostly achieved using different models. Natural phenomena modeling is challenging because ecosystem is a Fuzzy system with vague boundaries and some data are difficult to measure spatially in ecological process (Straskraba and Mauersberger, 1988). Fuzzy logic with boundary imprecision or vagueness has developed as an important method in environment risk modeling (Sarkar et al., 2016; Chen et al., 2010; Mazzorana and Fuchs, 2010). Fuzzy logic model has been applied in investigating PAs for different aims; such as, studying the vulnerability of an ecosystem to fire (Semeraro et al., 2016), measuring the insecurity index of species (Diaz-Gomez et al., 2013), and increasing the flexibility of protected areas to future climate change (Prato, 2012). Sarkar et al. (2016) developed a Fuzzy model in the GIS environment and integrated it with remote sensing for wetland risk assessment. They tried to identify the areas with varying intensity of wetland conversion risk within East Kolkata Wetland area. They used remote sensing tool to identify land use change during 2013 and 2014. The eight input indices of Fuzzy model were canal proximity, population density, livelihood status, wetlands conversion rate, road proximity, population growth rate, social status, and infrastructure status while the output was wetland conversion risk. They found that Fuzzy-based Risk Assessment Model was able to show the different levels of wetland risk zones. Regarding the mentioned problems of PAs, risk assessment of these ecosystems seems necessary to take appropriate conservation and management measures. The above mentioned studies indicated that no risk assessment has been conducted on PAs which may be because PAs are often under strict conversion regulations and there is no harmful human activity in these areas. However, in recent years there have been reports of land use change such as rangelands conversion to agricultural land, decreasing number of animal species, cross-road, and decreasing vegetation density in Bijar Protected Area (BPA) in western Iran. Accordingly, the present study was conducted with the aim of wild animal life (WAL) risk assessment of BPA in order to identify areas with various WAL risks using remote sensing and Fuzzy model.

2. Method

2.1. Study area

BPA is located 15 km to the northwest from Bijar city in the northeast of Kurdistan Province (Fig. 1). It is positioned between the geographical longitude 47° 25′ 8″ to 47° 51′ 4″ east, and latitudes 35° 59′ 5, 53″ to 36° 12′ 9, 25″ north (Fig. 1). The BPA area is about 31,612 ha. Approximately half of the area has a slope of less than 12%, and the highest and lowest altitudes in the area are 2145 m and 1532 m, respectively.

Mammals, fish, reptiles, birds, and amphibians are the wildlife species of BPA. Hosseini et al. (2013) studied on diversity and frequency of wildlife in BPA. They found that the Hyena (*Hyaena hyaena*), Badger (*Meles meles*), Wild boar (*Sus scrofs*), Wild sheep (*Ovis orientalis gmelini*), Jackal (*Canis aureus*), Fox (*Vulpes volpes*), Wolf (*Canis lupus*), and Rabbit (*Lepus capensis*) were the dominant forms of wildlife in BPA. Wild sheep (*Ovis orientalis gmelini*) is the important species of BPA. Based on the rangelands canopy cover Hosseini et al. (2013) selected the three secure location including poor, good, and fair ecological conditions with 29.1%, 72% and 41.5% canopy cover respectively (Fig. 2).

Hosseini et al. (2013) emphasized that compared with fair ecological conditions, good ecological conditions have a higher successional stage but sequentially these conditions are not in climax. In Iran, mostly there is no climax for vegetation and a good ecological condition is the best condition for ranges. A poor ecological condition has a lower successional stage and is typically covered with shrubs. They described that *Ephedra major* and *Amygdalus lysioides* had the highest canopy cover in the rangelands with a poor ecological condition; *Bromus tomentellus*, and *ferola sp* had the highest canopy cover in a good rangelands condition; and *Festuca ovina*, *Bromus tomentellus*, and *Amygdalus lysioides* had the highest canopy cover in rangelands with a fair ecological condition in BPA. They found no differences of vegetation diversity, species richness and vegetation cover evenness among the three ecological conditions. They described that the wildlife richness and wildlife diversity indexes were high in the fair and poor ecological conditions. They showed that the wildlife diversity in the rangelands with good and fair ecological conditions were the lowest and highest, respectively. Lack of brushes cover used for camouflage by wildlife species was the main reason of decreasing wildlife diversity in the good area. They found that the main reason of the highest frequency of wild sheep and boar in the rangelands with fair ecological condition was the different vegetation types including grasses, shrubs and forbs. They showed that the rangelands with a poor ecological condition due to high density of shrubs, sunny and warm slopes with poor range had higher frequency of wildlife especially for wild sheep compared with that in the good area. They described that the high altitude, covered by snow in the winter, and open area of rangelands were the main reasons of low wild sheep frequency and lack of a permanent river was the main reason of low boar frequency in the rangelands with a good ecological condition. For other animal species, Firouz (2009) showed that brushes were the main habitats of Rabbits; villages and the area around them were the main habitat of Jackals where they found food such as garbage and human food waste; valleys and hole of rocks were the main habitat of Hyaena where they could hide and follow the predators to scavenge their hunting.

2.2. Selection and generation of risk assessment indicators

Risk assessment indicators were obtained based on the available literature and an expert opinion survey (questionnaire). The questionnaire was distributed in two stages among experienced experts at the Environmental Protected Agency of Kurdistan Province and professors at University of Kurdistan. The first phase involved endorsement of the indicators while in the second phase the final indicators were weighted based on their impact on WAL risk. Consequently, seven indices were selected namely, BPA conversion rate, population density, population growth rate, livelihood status, natural resource, security threats, and social status. Effect of dust storms, conversion over BPA species and biodiversity could not be estimated using the current data. Moreover, access to facilities such as schools, telephone, and drinking water in the study area were the same, and sources creating pollution such as cement plants, landfills, and fish breeding pools were far away from BPA; therefore, these factors had no effect on the WAL risk in BPA, and were not considered in the study. Table 1 shows the weight values of the selected indicators for risk assessment of WAL in BPA. As Table 1 shows the highest weight values (0.27) were obtained for BPA conservation rate and security threat indicators. The lowest weight values (0.06) were acquired for population indicators (that is, population density and population growth rate indicators). There were no significant changes for the weight values of population indicators and social status.

To develop a Fuzzy model for WAL risk assessment, all the data and layers should be raster-based. Sub-indices, including arable land, unemployment rate, livestock, literacy rate, and population density and growth rate were converted to raster-based images using Inverse Distant Weight (IDW) method. For all layers, a cell size of 30 m was selected. One of the assumptions of IDW is that each entry point should have a local impact that decreases with distance. This weighting method (Eq. (1)) is smooth, comprehensible, and relatively precise in a wide range of conditions: