The use of multi-criteria evaluation and expert knowledge in developing protected area zoning plans in Jordan

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ABSTRACT

Protected areas (PAs) in Jordan are managed through scientifically based management plans (MPs). Zoning plans are created as supporting plans to MPs when different management procedures need to be applied in different parts of a PA. A GIS-based zoning plan model was developed using spatial multi-criteria evaluation technique (MCE). The model was created to provide a systematic repeatable approach to evaluate the conservation values and human threat, thus facilitating the decision making process for PA's zoning in Dibeen forest in the northwest of Jordan. Cartographic modeling was used to combine datasets with different attributes by reclassifying them according to a common comparison scale, and finally adding them according to their assigned relative weights. The resulting weighted summation rasters identified areas with high conservation values-high human threat, high conservation values- low threat, and low conservation values- high human threat. The PA was divided accordingly into three management zones: an intensive use zone where tourism and other human activities are allowed but restricted to a small area, a semi-intensive use zone where educational activities are allowed, and finally a wilderness zone that includes the most ecologically important and representative habitats of the PA where all human activities are prohibited except wildlife research and monitoring. The zoning plan model developed for Dibeen Forest Reserve can also be applied to other PAs in Jordan and within the region taking into consideration that the evaluation criteria and weights can be modified depending on the characteristics of each PA and the data available.

Key words: Protected Areas, Jordan, Forest, GIS, RSCN.

INTRODUCTION

The management of protected areas (PAs) has recently transformed to a wider and more inclusive approach. From isolated areas set aside for conservation and scientific research, PAs are now run as networks with social, economic and cultural objectives with local people more in mind (Phillips, 2003). The PAs network in Jordan was first proposed in 1979, modified and updated in 1997, 2005 and in 2008 (RSCN, 2008). The Royal Society for the Conservation of Nature RSCN is mandated by the Jordanian government to establish and manage PAs network according to scientifically based management plans (MoEnv., 2003). Management plans contain supporting documents, including zoning plans; which are created when different management actions and procedures need to be applied in different parts of a PA in order for its objectives to be met. It is a legal document that can be presented in a form of a map illustrating geographical boundaries between different zones (Phillips, 2003). Young and Young (1993) state that "Zoning defines what can and cannot occur in different areas of a park in terms of natural and cultural resources managements; human use and benefit; visitor use and experience; access; facilities and development; maintenance and operations. Through management zoning the limits of acceptable use and development in the PA are established".

For terrestrial and even marine PAs, planning has largely been based on common sense, and on simplistic approaches that have been used to provide guidance to decision makers (Villa et al., 2001). In Jordan, zoning plans were prepared by overlaying different map layers representing physical, ecological, social and other site characteristics using Geographic information systems (GIS). The layers were visually analyzed to identify the parts of the PA with high conservation value. This was applied in Wadi Rum PA (RSCN, 2003), Dana PA (RSCN, 2006), and Petra archeological park (Damhoureyeh et al., 2011). Visual analysis of different layers did not always produce satisfactory results when huge datasets with different levels of importance were involved in the analyses. It was therefore desirable to develop an objective and systematic GIS-based approach to enhance the decision making process when it comes to protected area zoning.

Geographic information systems applications have been frequently used in producing new information by combining information from different sources and by spatial analysis of existing data (Store and Kangas, 2001). Jiang and Eastman (2003) stated that 'Multi-criteria evaluation (MCE) is considered the most fundamental decision support operation in GIS'. One approach to MCE in a GIS environment is the 'additive' technique whereby the criterion scores are standardized and the total score for each alternative is calculated by multiplying each criterion score by its weight factor and then adding the results (Store and Kangas, 2001). This approach was used in GIS habitat suitability modeling (Store and Kangas, 2001), and in landscape ecological forest planning (Kangas et al. 2000), and in Marine Protected Area Zoning (Villa et al. 2001). Al-Bakri et al. (2011) used GIS database functionalities integrated with statistical analysis and 'expert' knowledge in analyzing the explaining variables that influence the spatial distribution of medicinal and herbal plants in the north western highlands of Jordan. In the same study they identified hotspots for medicinal plants with high priority for conservation by interpolating the total evaluation scores assigned for the sampled ground locations using expert chosen evaluation criteria.

This work aims at integrating spatial MCE and expert knowledge to develop a systematic GIS based model for terrestrial protected area multi-objective management zoning.

MATERIALS AND METHODS

Study area

The study area is Dibeen Forest Reserve (35° 48.95´ E, 32° 14.77´ N), which is located in the north western highlands of Jordan within Jerash District and covers about 850 hectares (Fig. 1). The area is located within the semiarid Mediterranean zone with precipitation ranging from 400mm – 500mm within the PA, the rainy season extends from November to April. The mean maximum temperature in the PA is around 33°C (occurring in August), and the mean minimum temperature is around 3 °C (occurring in January). The elevations range from 1060m a.s.l in the northern parts of the PA to 470 m a.s.l in the south.

The PA was established in 2004 in order to conserve the unique Aleppo pine forest, *Pinus helpensis*, that represents the south eastern limit of the species' distribution in the northern hemisphere (RSCN, 2004c). The size and shape of the PA represents a challenge for management since it consists of three small land blocks connected in the middle. The land of the PA is a treasury land, and managed by the RSCN. The PA is served by a network of paved and unpaved roads, and is surrounded by small villages. The forest suffers from illegal woodcutting, hunting and tremendous pressure resulting from the use as a recreational area.

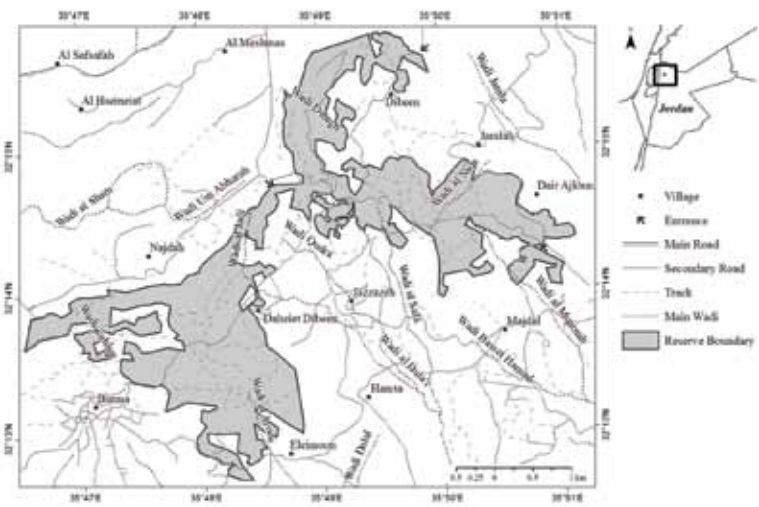

Fig. 1: General location of Dibeen Forest Reserve

According to the management plan of Dibeen Forest Reserve, its management vision was to retain a core of self-regenerating Aleppo pine habitat and become ecologically and financially sustainable, while continuing to provide an important recreational resource and valued forest habitat for local people (RSCN, 2009).

Datasets preparation and evaluation criteria

Flora and fauna baseline surveys and field data collection on land use and threats to biodiversity were carried out between 2004 and 2006 during the establishment of the PA. These surveys provided a spatial database, which represented the core for selecting evaluation criteria based on their relevance to the purpose of the zoning plan. The purpose of the zoning plan, in the context of this study, was to provide maximum protection to the parts with the highest conservation values and least disturbance due to human activities while permitting reasonable human use in limited areas. The PA evaluation criteria were in two categories: conservation values and human threats. Expert knowledge was used in defining the evaluation criteria, the type of impact and the relative weight for each criterion.

The conservation values were selected by conservation specialists based on their relevance to the aforementioned PA's purpose of establishment, thus the vegetation types was considered the most significant evaluation criteria. Other criteria representing the distributions of indicator plant and animal species were also selected as they indicate health of the habitat (RSCN, 2004c). Accordingly, high densities of indicator species were considered having positive impact on the conservation values. Table 1 includes the selected conservation evaluation criteria, and the data set collection source.

Table 1: Conservation evaluation criteria, data sets and data collection source

Category	Criteria/ Dataset	Dataset Source
Representation of habitats	Vegetation Types • Pine areas • Mixed Pine-Oak • Ever-green Oak • Deciduous Oak • Open Areas	RSCN (2004c) Dibeen Flora Baseline Survey

Indicator Species and species important to the forest	Plants Density Orchids and Irises	RSCN (2006a) Dibeen Flora Monitoring Survey
	Rodents Density Persian Squirrel, *Sciurus anomalus*	RSCN (2005) Dibeen Rodents and Bats Baseline survey Amr et al. (2006) Status and distribution of the Persian squirrel *Sciurus anomalus* in Dibeen nature reserve
	Birds Density • Short-toed eagle, *Circaetus gallicus* • Syrian Woodpecker, *Dendrocopus syriacus* • Blue Tit, *Cyanistes caeruleus* • Wren, *Troglodytes troglodytes*	RSCN (2004a) Dibeen Birds Baseline Survey
	Carnivores Density Stone Marten, *Martes foina*	RSCN(2004b) Dibeen Carnivore Baseline Survey
	Invertebrates Density Carabidae	RSCN(2006b) Dibeen Invertebrates Survey
	Reptiles Density • Greek Tortoise, *Testudo graeca* • Green Lizard, *Lacerta media*	RSCN(2004d) Dibeen Reptiles Baseline Survey

For the human threats evaluation, criteria representing threats or risk elements were defined by PA experts, rangers and biodiversity specialists. Anything identified by experts as having a negative influence on the health of a critical habitat or key species was considered a risk element (Schill and Raber, 2009). The relative weight of each human threat or risk element was decided based on the observed intensity of threat and its impact on biodiversity. Table 2 includes the human impact evaluation criteria and the collection source of each dataset.

Table 2: Datasets included in the human impact analysis

Dataset Category	Dataset	Dataset Source
Infra-structure	Major and secondary roads	RSCN (2004) PA's Basemap
Tourism	• Parking Areas • Picnicking Sites • Tourism and Educational trails • Tourism facilities	RSCN (2004e) Dibeen Reserve Tourism Management Plan
Threats	Woodcutting	RSCN (2006) GPS Coordinates
	Land encroachments/ private lands	RSCN (2006) GPS Coordinates
	Tree leaves Collection	RSCN (2006) GPS Coordinates
	Hunting	RSCN (2006) GPS Coordinates

The topographic basemap and main features were prepared by on screen digitizing of scanned 1:25000 topographic maps for the area produced by the Royal Jordanian Geographic Center. Field survey findings used as evaluation criteria were first collected by Global Positioning System (GPS) devices with positional accuracy of ±5 meters, and mapped in vector formats. All vector layers were converted to raster formats; distributions of plant and animal species were converted from point distributions to kernel density rasters with a spatial resolution of 5 meters using the quadratic kernel function as described by Silverman (1986). Human threat elements were also collected using GPS devices and mapped in vector formats. Threat elements were converted to Euclidean distance rasters with a spatial resolution of 5 meters where the value at each grid cell represented its proximity to the corresponding threat element. The Euclidean distance rasters were calculated within a neighborhood of 500m around each threat element as it was assumed that the impact of a threat element concentrates within this neighborhood.

Application of GIS analysis

The zoning plan GIS model was developed based on spatial MCE using ArcGIS software (ESRI, 2008). The model was divided into three parts; evaluation of conservation values, evaluation of human threats, and combining human threats and conservation values. Cartographic modelling, a process of solving problems by spatial layer combination using map algebra operations (Bolstad, 2012), was applied in reclassifying, weighting and combining map layers representing evaluation criteria. For the conservation values part, vegetation types of high importance and high priority were given high scores as advised by experts. Each species density raster was reclassified to five density ranges; relatively high density ranges were also given high scores indicating high conservation value thus high priority. Reclassified conservation values were summed according to their relative weights. A sample of this part of analysis is displayed as maps in figure 2.

Similarly each threat distance raster was reclassified to five distance ranges, each distance range was given a score; small distance ranges were given high scores indicating high threat impact. Reclassified threat maps were also summed according to their relative weights. The weighted summation for human threat evaluation was subtracted from weighted summation for conservation values to identify the areas with high conservation value-low threat, and low conservation value –high threat.

The final geographical boundaries of the zones were mapped considering the presence of physical features like roads and wadis to make the zone boundaries easily distinguishable on the ground to make the zones easily recognized by PA staff, visitors and the local community.

Validation of GIS analysis

Face validation, a method used to validate the behavior of a model and the input and output relationships based on consulting knowledgeable people (Edward and Rykiel, 1996), was used to validate the results of the GIS analysis. The resulting maps were presented to biodiversity experts who were not part of the consultation through

biodiversity experts who were not part of the consultation through the selection and weighting of evaluation criteria to see if they found the performance of the model and resulting analysis reasonable.

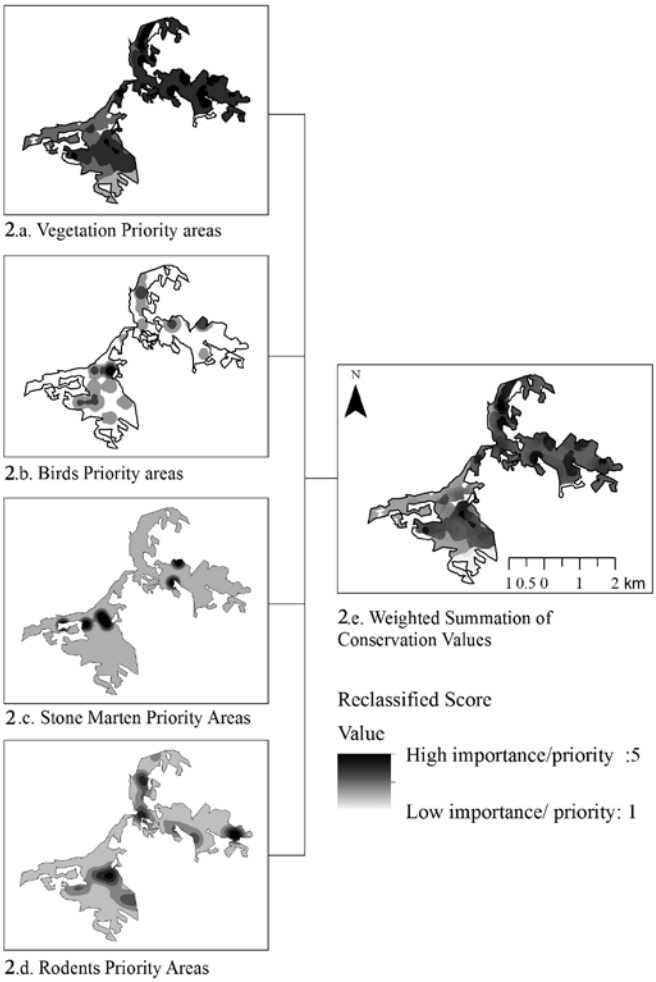

Fig. 2: A sample of the conservation evaluation analysis displayed as maps

RESULTS

The resulting weighted summation rasters (Fig. 3) were used to divide the PA to three management zones (Fig. 4) as follows:

1. Wilderness zone: This included the parts of the PA with the highest conservation values and low human threat. It is located in the pine forest areas in the middle of the northern and the south western blocks of the PA. Types of activities acceptable in the wilderness zone were restricted to ecological research and monitoring in order to preserve its critical highly important conservation values.

2. Intensive use zone: This included the area with the highest human threat located in the middle of the eastern block of the PA.

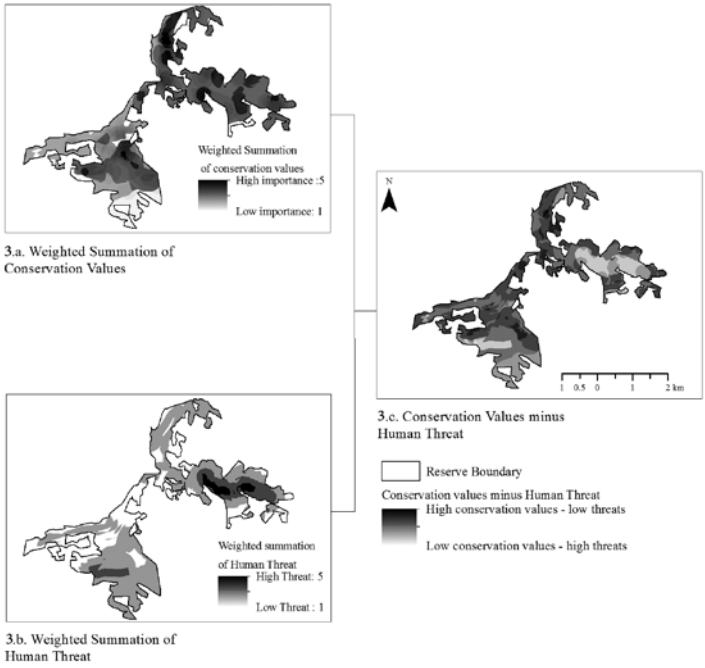

Fig. 3: The final resulting rasters of the three parts of the GIS model

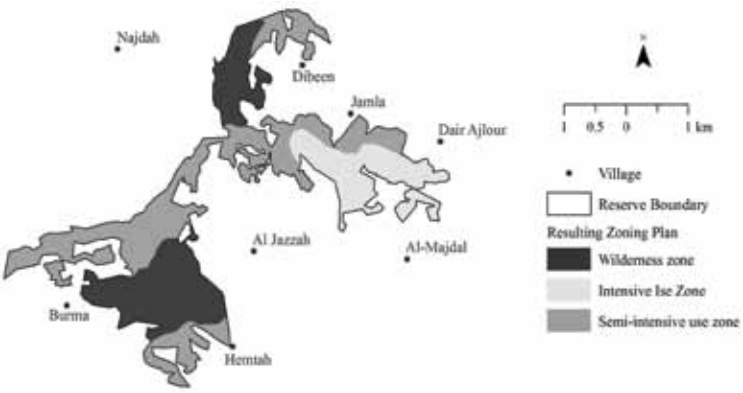

Fig. 4: The resulting zoning plan

This area included the recreation area used by local people. It already had the infrastructure and facilities constructed to serve recreational and educational activities. Types of activities allowed in this zone included recreation and picnicking, management facilities and infra-structure.

3. Semi-intensive use zone: This included the areas with medium to low conservation values and medium to low human impact. Limited human use and activities like ecological research and monitoring, bird watching. Only local people were allowed grazing access to this zone, grazing only by local people were permitted in this zone. Table 3 shows the area of each zone and the percentage it comprises of the total PA area.

Table 3: Area of each zone and the percentage it comprises from the reserve area

Zone Name	Area in sq km	Percentage of PA
Wilderness Zone	2.8	33%
Semi-intensive use zone	4.1	48.2%
Intensive use zone	1.6	18.8%

DISCUSSION

Spatial multi-criteria evaluation was used in other regions in habitat suitability modeling (Store and Kangas, 2001) and marine protected area zoning (Villa et al., 2001). The approach presented by (Villa et al., 2001) was based on the defining suitability factors that decide the suitability of an area to certain types of activities. The approach presented in this paper is more concerned with the identification and evaluation of conservation values, and human threat intensity within the site rather than its suitability to certain activities. The current paper deals with the zoning plan from a different perspective corresponding to the need to understand and evaluate the current status of the PA, and then planning the zones accordingly.

Other more simplistic approaches followed in Jordan in developing the zoning plans for Rum PA (RSCN, 2003), Dana PA (RSCN,2006), Petra archeological park (Damhoureyeh et al., 2011) did not involve advanced spatial analysis, and could be considered based on visual interpretation of available layers without demonstrating how datasets could be weighed, prioritized and combined to reach a decision on the zone boundaries.

Although the GIS model did not directly produce the final boundaries of the zones, the model enhanced the decision making process. Zone boundaries had to be slightly extended to physical boundaries like roads, tourism structures or other landmarks on the ground in order to be easily recognized by PA rangers, visitors and community members. The conservation value hotspots did not comprise large continuous zones rather than spots or patches with high conservation values. Small patches of high conservation values were merged into one zone as it was not practical to have isolated patches as different zones. The intensive use zone and the wilderness use zones were easily distinguishable and could be located on the weighted summation rasters of the conservation values and human threat respectively. The subtraction raster combined these two datasets and gave a clear idea on the relationship between them in each grid cell.

Dibeen PA was also found to be a hotspot in another study conducted on medicinal and herbal plants in the north western highlands

of Jordan with a different GIS based approach (Al-Bakri et al., 2011). Although that study used similar evaluation criteria to identify medicinal plants hotspots and conservation priorities, their approach was based on interpolating the total evaluation scores assigned at certain surveyed ground locations assuming that the total evaluation score is spatially auto-correlated. The approach presented in this study evaluates each layer separately within the analysis extent based on the value of each grid cell then sums the scores from all evaluation criteria. A future project could apply both approaches using the same set of evaluation criteria and compare the results.

The parts of the PA having high conservation values were mainly areas with pine forest vegetation as it was given the highest weight among other evaluation criteria. The locations where indicator plant and animal species were recorded within the pine forest had relatively higher conservation values than other pine areas because of the overlap of high densities of different indicator plant and animal species. These parts had low human impact thus qualified to be included in the wilderness zone. This result was consistent with the management vision and conservation priority of the PA. The eastern block of the PA where intensive tourism activities occur had the highest human threat as the tourism was given the highest relative weight among all other human threat criteria in addition to its overlap with other threat criteria like the presence of roads and other facilities. The management decision was to define this area as an intensive use zone where tourism activities can be sustainable and well organized as it already had the necessary infra-structure and it had already been used by visitors for picnicking for decades.

CONCLUSION

A major challenge for any organization managing a PA involves developing the management approach itself. The approach presented in this paper demonstrates how GIS can be used to provide guidance and support strategic decisions in managing protected areas. The GIS-based zoning plan model evaluated and quantified characteristics of the PA like conservation values and human threat in order to reach a decision on how the PA should be managed. The model development process enabled a wide range of stakeholders from man-

agers to executive staff and local community members concerned to have a comprehensive assessment and understanding of the PA, and developing a more reasonable zoning plan.

The zoning plan model developed for Dibeen Forest Reserve can also be applied to other PAs in Jordan and the region taking into consideration that evaluation criteria and weights can be modified depending on the characteristics of each PA and the data available. It is therefore hoped that this approach, will be adopted more widely by the RSCN in utilizing a spatial multi-criteria evaluation procedure in developing ecological and human impact hotspot maps in order to provide guidance for the PA zoning.

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