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ORIGINAL PAPER

The use of a GIS-based multi-criteria evaluation technique for the development of a zoning plan for a seasonally variable Ramsar wetland site in Syria: Sabkhat Al-Jabboul

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Abstract Zoning is an important tool used in the management of protected areas and wetlands. It has been developed to apply conservation objectives at different levels of management where conflicting uses can be taking place. GIS is increasingly used to solve land allocation problem with techniques based on zoning, varying from simple overlays to complex multi-criteria evaluation techniques (MCE). This study presents a new approach to the development of zoning plans for Ramsar sites that exhibit major seasonal variations in conservation value and human use and threats. It employs a well-defined GIS-based MCE technique which involves both expert judgment and a set of criteria based on ecological and potential threats. A GIS model using the additive approach in MCE was developed to evaluate Sabkhat Al-Jabboul the only Ramsar site in Syria. The model was applied separately for the spring and winter to accommodate seasonal changes in the intensity and spatial distribution of conservation areas and threats across the site. Separate zoning plans were developed for each of the two main seasons. The zoning plan of the spring season, which is the birds breeding season, included three management zones; the special conservation zone, the conservation buffer zone, and the wise use zone. The winter zoning plan, where the bird feeding activity was the major activity includes two zones: a special conservation zone and a wise use zone. Thus, in cases like Sabkhat Al-Jabboul, where the wetlands are subject to significant seasonal variations, in their ecology and human utilization, it is recommended that flexible seasonal zoning plans are developed to assist in the organization of permitted activities, and to reduce the potential human impacts throughout the year.

Keywords Conservation values · Human impact · Expert judgement · Weighted criteria · Wetland management

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Introduction

Zoning has become an important tool used in the management of protected areas to guide and regulate the increased impact of human activity on natural resources (McNeely 1997). It has been developed to evaluate and resolve various conservation objectives at different levels of management, where conflicts can often occur between different potential stakeholders (Walther 1986).

In spite of the many benefits zoning plans can provide, Sabatini (2003) noted the lack of such plans in most protected areas within developing countries resulting in *paper parks* that exist on maps and inform legislation. Few protected areas within the Mediterranean region currently have active zoning plans prepared to apply the conservation objectives as used for example in the Dana Biosphere Reserve and Mujib Biosphere Reserve southern Jordan.

Most published work on zoning plans have been applied to marine parks (Day 2002), and relatively few publications are available for terrestrial parks (Geneletti and Van Duren 2008), especially for wetlands (e.g., Nhuan et al. 2009). Zoning plans are particularly difficult to develop for wetlands where there are major changes in the ecology with seasons.

Geographic information systems GIS applications have been frequently used in solving land allocation problems like protected areas zoning with approaches varying in their level of complexity. Jiang and Eastman (2000) 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. 2002).

The purpose of this study was to present a new approach for establishing zoning plans for a Ramsar site that exhibits major seasonal differences in its ecology and resource utilization. The method employed uses a GIS-based multi-criteria evaluation (MCE) technique that includes input from experts on a set of criteria used including ecological value and potential threats.

Materials and methods

Study area

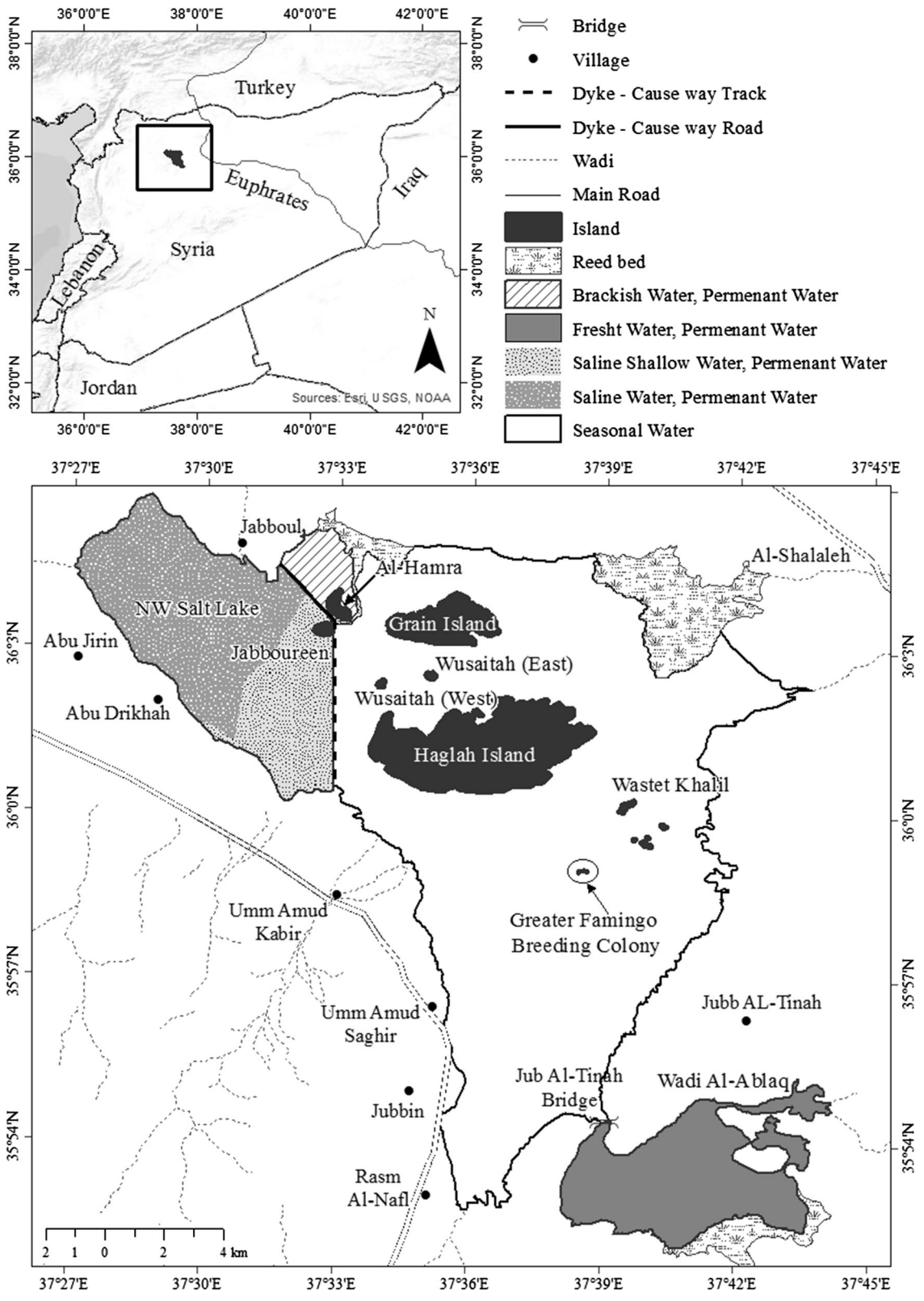
Sabkhat Al-Jabboul is one of the most important wetland areas within the Middle East region (Serra et al. 2006). It consists of a large (270 km^2) wetland area situated at the lowest point within a closed basin (5075 km^2) to the southeast of Aleppo. Due to its location and water deficit, its waters are saline in many areas (Dahman 2002). The Lake's maximum length and width are 40 and 10 km, respectively. Its elevation is 312 m (AMS), and water depth ranging from 20 to 160 cm. The Lake is surrounded by 14 villages, including Al-Jabboul, after which the lake was named.

Fig. 1 The location of Al Jabboul Lake (*inset*), and the three derived sub-lakes showing the main islands, islets, the dyke, and the culvert dam ▶

In the past, the lake was fed by water draining from the River Nahr al-Dhahab (the River of Gold), but this dried up completely in 1957 (Abdul Salam 2002). Additional water inputs came from rain and ground waters between September and mid October with water levels rising to maximum between March and April. Thereafter, water levels declined until finally drying up by mid June leaving large areas of salt deposits, which were then harvested for industrial and local use.

In mid seventies, a large-scale project was developed to draw water from Euphrates River to meet the increasing demand of water for irrigation. Three land reclamation projects were established and equipped with drainage systems that channeled excess irrigation water to the lake. As a result, large amount of extra water started to drain into the lake. An artificial dyke was built in 1996 to separate the north-western part of the lake, and to isolate the irrigation water outlets. As a result of these changes, the lake became separated into three different sub-lakes that varied in their ecological conditions and salinities (Fig. 1).

1. **The Northwestern Lake** Reached maximum surface area of 47 km^2, and is the most saline water in Jabboul. It is also the main lake for salt extraction, where salt extracting facilities, locally known as Malla'ha, exist. This lake is fed by six irrigation canals and also by ground water from the northern border of the lake.
2. **The Central Lake** This is the largest lake which receives natural runoff from the slopes of the basin and excess water from the surrounding irrigation schemes, and sewage water from nearby villages and factories. Its maximum surface area is about 194 km^2. Recently, it began to retain water until mid June or July due to the continuous and



increasing irrigation within the surrounding areas. The central Lake has nine permanent islands and a few seasonal islets that disappear when it is filled with water. After the construction of the dyke, a permanent area of water was created locally, at the northern border of the central lake.

3. **The Southeastern Lake** It is the deepest of the three lakes with a maximum surface area of about 29 km^2, and locally it is known as Al-Hamrat Lake. It is fed by natural runoff from the slopes of Jabel al Shbeith and by drainage water from irrigation schemes east of the lake, which are controlled by a culvert dam, known as Jub Al-Taineh Bridge.

Jabboul Lake is located in a semi arid climatic region, with an average maximum temperature of 45 °C and an average minimum temperature of 7.5 °C. The average rainfall is 250–300 ml/year (Abdul Salam 2002). The evaporation level is high and exceeds the rainfall level; average annual evaporation of the free water surface in the lake is 2200 ml (Dahman 2002).

In 1998, the lake became registered as a Ramsar site because it met three criteria of Ramsar convention, which were as follows:

(a) The site is a particularly good representative example of a natural or near natural wetland, characteristic of the appropriate bio-geographical region.
(b) It regularly supports 20,000 waterfowl.
(c) It regularly supports more than 1% of individuals in a population of Greater Flamingo, *Phoenicopterus roseus*.

Preparations of the datasets and the evaluation criteria

A baseline survey of birds was conducted in Sabkhat Al Jabboul in 2007 (Hamidan and El-Moghrabi 2008). This survey provided data on the spatial distribution of 'key' bird species and of those areas important for feeding and breeding, in addition to threats to biodiversity. These survey results provided the main data used in the selection and evaluation of criteria for developing the zoning plan. The model used for ranking and optimizing the various criteria (including threats) was based on Boulad (2014). The relative weightings used in the model were derived from field survey results (Hamidan and El-Moghrabi 2008) and on expert judgment. The criteria were defined and separated from the differences in the seasonal bird feeding activities and areas used for breeding across the wetland.

For the spring season, the conservation values relevant to the birds' breeding activity in the wetland based on expert judgment of conservation merit were as follows:

1. **Areas with high breeding activity for five bird species** These were considered to be "core bird breeding areas," and were given the highest relative weights. This measure was based on the highest number recorded for breeding species [five] in one location or islet. These five species were Slender-billed gull *Chroicocephalus genei*, Eurasian spoonbill *Platalea leucorodia*, Little Egret *Egretta garzetta*, Black-headed Gull *Chroicocephalus ridibundus*, and Common Tern *Sterna hirundo*.
2. **Breeding areas of terns, especially the Caspian Tern and Little Tern** These species were selected because their breeding populations in Jabboul were within the 1% threshold of their global sub-populations (Hamidan and El-Moghrabi 2008).
3. **Breeding areas of the Great-crested Grebe** This species was chosen as it is the most common breeding bird in the lake.
4. **Breeding areas of the Black-winged Stilt and Coot** Both of these species occur within the 1% threshold of their global sub-populations (Hamidan and El-Moghrabi 2008).
5. **Possible breeding areas of ducks** These were chosen due to their high breeding potential mainly the Shelduck, Ruddy Shelduck, and Mallard (Hamidan and El-Moghrabi 2008).
6. **Breeding areas of Passerines** These were chosen due to their sensitively to disturbance.

All these species were considered to be important conservation criteria and were assigned the relative weights shown in Table 1.

For the winter season, the conservation criteria were divided into two categories:

1. **Core feeding areas** These included areas that support and provide the food for more than five

Table 1 The selected conservation values/criteria for both the winter and spring with their relative weights, as determined by the experts

Conservation value	Relative weight (%)	
Breeding season (spring)		
Core breeding areas (breeding areas for five species)	30	
Terns breeding area	25	
Great-crested grebe breeding area	15	
Black-winged stilt breeding area	15	
Coot breeding areas	5	
Ducks breeding area	5	
Passerines breeding area	5	
Winter season		
Core bird feeding areas		
Flamingo feeding areas	50	
Core feeding areas for key species	50	40%
Areas with high numbers of key bird species (more than 20,000)		
Areas with high numbers of flamingo	30	
Areas with high numbers of ducks	30	
Areas with high numbers of coot	20	60%
Areas with high numbers of waders	20	

key species, and were given (40% of the total weight), in addition to Flamingos' feeding areas due to the high number of wintering birds.

2. **Areas where more than 20,000 water bird individuals were present** These areas were chosen and given 60% of total weight, as it is one of the main characteristics that contribute to the assignment of Jabboul Lake as a Ramsar site [criterion 5].

For the human impact evaluation criteria, human practices identified in Hamidan and El-Moghrabi (2008) which have a negative impact on the biodiversity of the wetland were included. Accordingly, human threats in both the winter and spring seasons were identified and their relative weights determined by the experts.

In the spring, the three "high effect" impacts were the salt collection that impacted on the breeding areas and caused many nests to be abandoned causing loss of eggs and high mortalities of chicks, in addition to the obvious physical disturbance caused by workers when collecting salt and transferring it for collection along the shoreline. A similar impact is provided by agriculture drainage, which causes a surface drainage of fertilizers from the soil into the lake. Many birds can be seen dead near the drainage points due to the high concentration of fertilizers and chemicals (Hamidan and El-Moghrabi 2008). Hunting had a high impact rank due to the negative impact of burning reeds on a large-scale resulting in large expanses of exposed marshes that could otherwise have supported large number of breeding birds if left as it was.

In winter, more factors were identified (Hamidan and El-Moghrabi 2008) including fishing and its associated noise and physical disturbances. The collection of live birds while preparing for nesting, but on a lower scale than previously recorded due to limited access to breeding islets toward the middle of the lake. However, this practice still occurred in some areas of the core breeding sites mainly for Flamingos. In addition, a significant disturbance also occurred from army training activities within the central areas close to the breeding islets. Table 2 shows the human impact evaluation criteria and their assigned relative weights for both the winter and spring seasons.

The base map of the site and main features were prepared by on screen digitizing of 1:50,000 topographic maps (n.d.). A Global positioning system GPS receiver of ±five meters positional accuracy was used (ground truthing) to collect spatial data representing conservation values and human impact during the field survey. Datasets initially mapped in vector format were converted to Euclidian distance rasters using ArcGIS Spatial Analyst extension version 10.5 developed by the Environmental Systems and Research Institute ESRI.

Table 2 Human impact criteria and their relative weights

Human impact	Relative weight (%)
Breeding season (spring)	
Salt collection	35
Agricultural drainage	35
Hunting and live birds collection	30
Winter season	
Hunting	30
Fishing	20
Agricultural drainage	25
Chick collection	15
Army training field	10

Application of GIS analysis

The zoning model used was based on that developed by Boulad (2014), and applied here to the winter and spring seasons separately. The model employed an 'additive' method in the multi-criteria evaluation (MCE) of conservation value and human impact (Store and Kangas 2001).

Euclidean distance rasters representing proximity to conservation values were reclassified into 10 distance ranges and each distance range was given a score on a scale of 1–10 that was inversely proportional to the proximity of each raster grid cell to the corresponding conservation value. Reclassified rasters for each season were summed according to their relative weights assigned in Table 1. Similarly, distance rasters representing human impact were reclassified into 10 distance ranges, with each distance range given a score on a scale of 1–10 that is inversely proportional to the proximity of each grid cell to the corresponding human impact element. Reclassified human impact rasters for each season were summed according to their relative weights assigned in Table 2.

The weighted summation of the human impact was subtracted from conservation values for each season separately to identify locations with high conservation value-low impact, and low conservation value-high impact in both seasons. Where possible, the final boundaries of the zones were mapped using physical landmarks like islands and islets.

The GIS model results were discussed and subsequently validated by local community members familiar with the area, site experts and ecologists in a workshop held in Jabboul using the 'face-validation' method (Edward and Rykiel 1996).

Results

Three management zones were identified from the results of the spring season weighted summation rasters (Figs. 2, 3). These zones are as follows:

(a) **The special conservation zone** includes the areas with the highest conservation values and lowest impact. It is located in the middle of the central lake and includes Wastet Khalel Island and all central islands where spring breeding activities occur. The area of this zone is about 60.5 sq km, with strict conservation measures proposed. Within this zone, activities identified as having negative impact on the breeding activities like hunting and chick collection are prohibited.

(b) **The conservation buffer zone** includes the areas surrounding the special conservation zone and extends to the north to include the eastern parts of the north-western lake, and to the south to include the western parts of the south-eastern lake. The area of this zone is about 151.9 sq km with a wider range of activities allowed than for the special conservation zone. Human activities that do not have significant negative impact on bird breeding activities including bird watching are allowed in this zone.

(c) **The wise uses zone** includes the northern most parts of the central lake, most parts of the north-western lake, and the eastern parts of the south-eastern lake. This zone includes the areas found with lowest conservation values and highest impact and is mainly at the edges of the Jabboul wetland. In this zone, some activities like fishing by local people and legal salt production are allowed.

For the winter period however, two management zones (Figs. 4, 5) were identified for the Sabkhat Al-Jabboul. These zones are as follows:

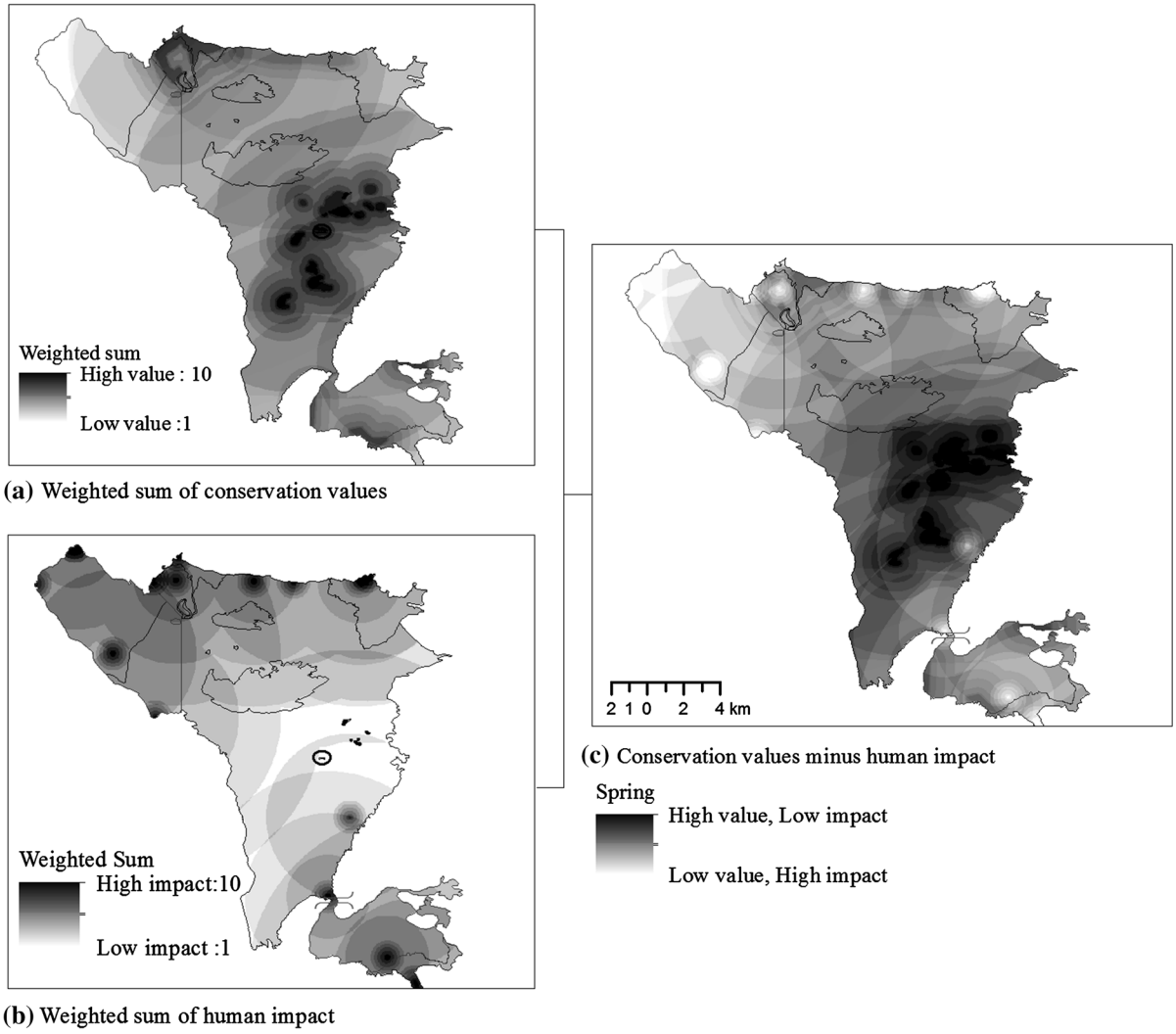


Fig. 2 Derivation of conservation areas and values for the spring period based on the weighted raster summation analysis

(a) **The Special conservation zone** includes most of the wetland including most parts of the central lake, the middle part of the north-western lake and the western parts of the south-eastern lake with a total area of about 189.1 sq km. This zone includes areas with highest conservation values and lowest impact in winter, where most activities especially hunting are prohibited.

(b) **The wise use zone** includes the northern-most parts of the central lake, most parts of the north-western lake and the eastern parts of the south-eastern lake. It includes the areas with lowest conservation values (Fig. 4a), and highest impact (Fig. 4b) with a total area of about 80.3 sq km. For this region, a wide range of local activities including agricultural water drainage, fishing, and responsible hunting can be permitted.

Discussion

In recent years, methods based on spatial multi-criteria evaluation (MCE) have been increasingly used to resolve land use conflicts in terrestrial and marine protected areas through the use of zoning (Boulad 2014; Geneletti and Van Duren 2008; Villa et al.

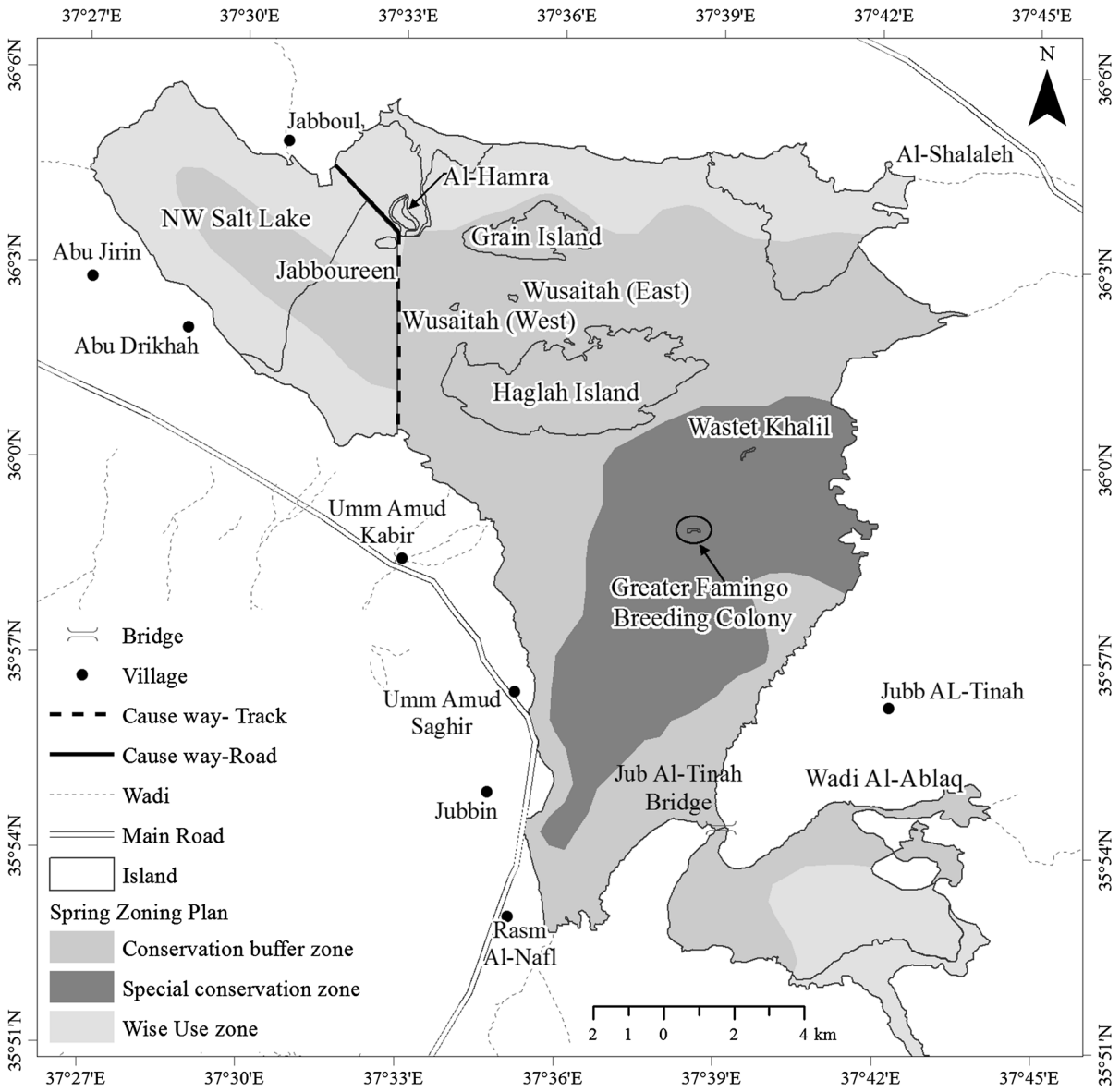


Fig. 3 Map showing the derived zoning management areas for the spring period for the Sabkhat Al-Jabboul Ramsar site

2002). In most of these publications, the land allocation problem is resolved by applying criteria used to define suitable areas linked to certain predefined management zones, like a tourism zone and or a conservation zone.

Although widely applied, this approach faces the problem of having to deal with conflicting units, which could have high suitability for more than one zone. Another issue with this approach is the recurrent opportunity of having areas that were not selected for any of the management zones, meaning that they may not have high suitability for any of the predefined management zones. These issues require further analysis to solve the allocation problem including the use of a decision tree or algorithm to optimize the choices as demonstrated by Geneletti and Van Duren (2008).

The model used here solves the land allocation problem with a conceptually different perspective as zone boundaries are decided based on the evaluation of the conservation values and human impact and not on site suitability, and by taking seasonal values in

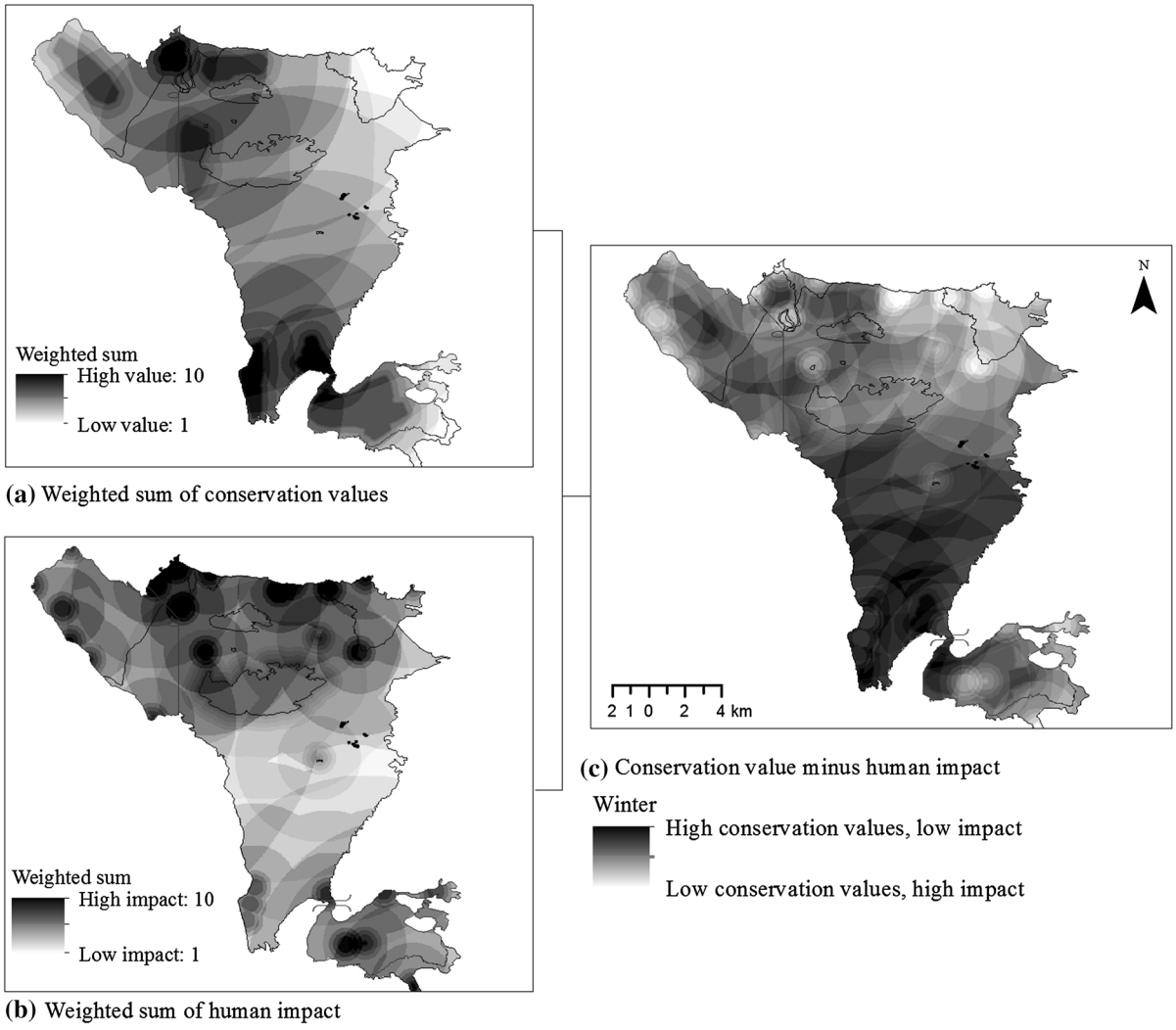


Fig. 4 Derivation of conservation areas and values for the winter period based on the weighted raster summation analysis

account. This approach identifies areas with high conservation values-low impact which are allocated for the 'conservation zone,' while areas with high impact-low conservation values are assigned to the 'wise use' zone. The decision whether a buffer zone between the conservation zone and the wise use zone can be decided afterwards based on the site variability as presented in the current case of Jabboul Ramsar site.

In Nhuan et al. (2009), seasonal variations were taken into consideration in a wetland vulnerability analysis that was carried out in the Xuan Thuy Rasmar site in Vietnem. This study recognized the different high, medium, and low bird density seasons in the site vulnerability analysis and produced three vulnerability maps for the three different seasons. Nevertheless, the authors decided to combine the three vulnerability maps in one vulnerability map for the whole year. The final vulnerability map was also kept as a continuous raster evaluation without reclassification into defined zones causing some confusion and subjectivity in the interpretation of the boundaries of high, medium, and low vulnerability zones.

The new guidelines for management planning of Ramsar sites and other wetlands adopted by resolution VIII.14 of the Ramsar Convention (Ramsar 2002) stressed on the importance of having a zoning scheme that ensures the conservation of the core of

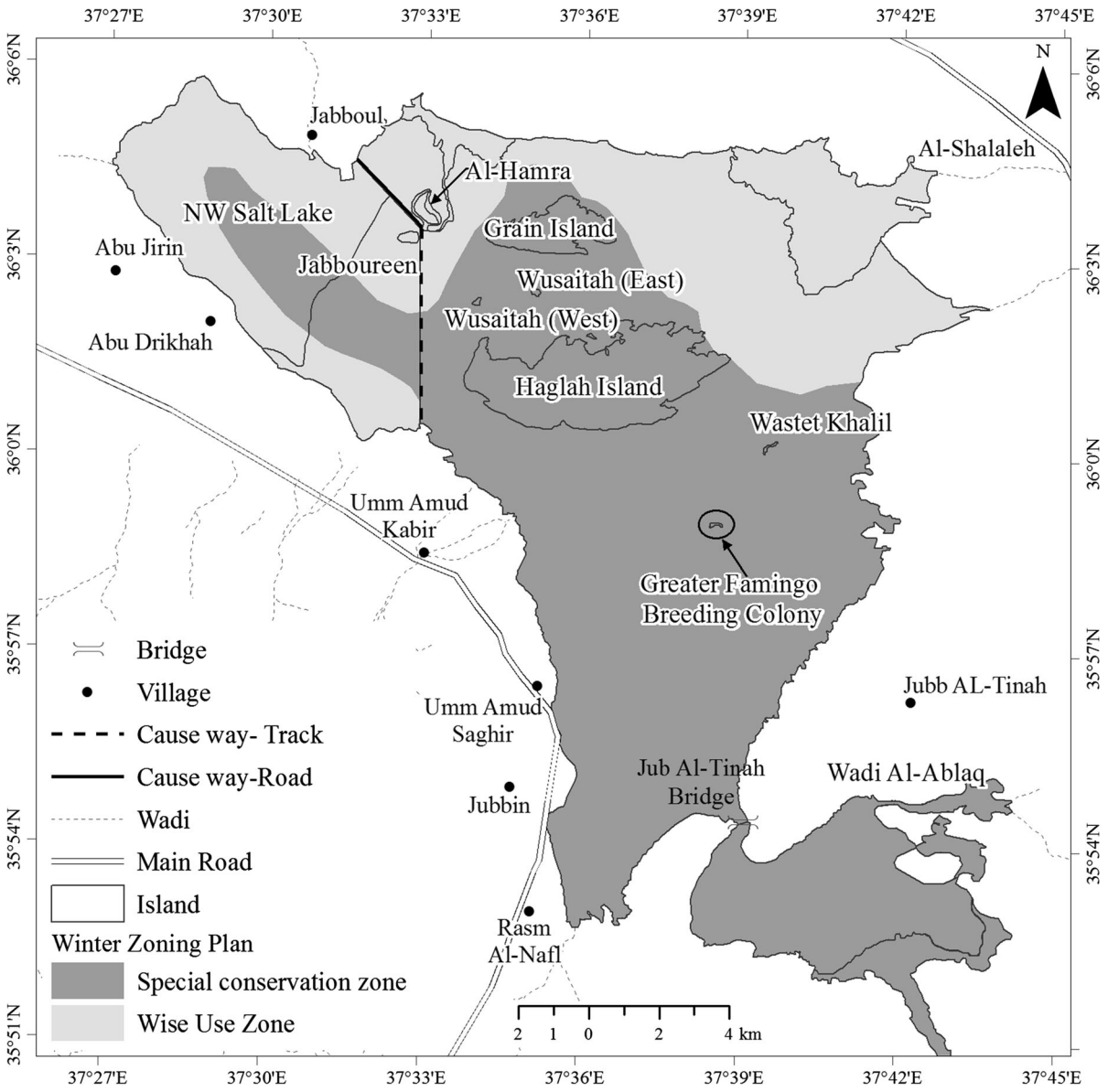


Fig. 5 Map showing the derived zoning management areas for the winter period for the Sabkhat Al-Jabboul Ramsar site

the Ramsar designated site, but recognized at the same time, additional potential uses offered by a wetland site to surrounding communities. The guidelines however are flexible with respect to the zoning methods applied, their names, and number of zones that can be used. Multi-criteria evaluation as applied to many other protected areas could also be used for Ramsar sites.

Spatial multi-criteria evaluation was applied to prepare the zoning plan of the Azraq Ramsar Site in Jordan based on the evaluation of ecological values and human impact (RSCN 2013). The Azraq wetland had no significant seasonal variations since 1994, thus one zoning plan applied all year round was developed for the site. Some wetlands could encounter significant seasonal variations related to biological processes like breeding, feeding or bird migration, which could make the proposal of a fixed zoning plan applied all year round impractical and ineffective to achieve the full conservation and use objectives.

In the case of Al Jabboul, the conservation values and their spatial distribution varied significantly between spring and winter. In spring, the weighted summation of the conservation values was high in the middle of the central lake because it included the islands where breeding occurred (Fig. 2a). The same areas had low conservation values in winter as they were more related to the feeding and roosting sites of the winter migratory birds, which were highest in the north-western edge and the southernmost part of the central lake (Fig. 4a). As for the weighted summation of the human threat, an overlap of the type and spatial distribution of human threat 'hotspots' was found between spring and winter (Figs. 2b, 4b). This was because these threats were mostly present throughout the year.

The final zones were mapped based on the conservation values minus human threat maps for each season because the areas with high scores, which represented the combined high conservation values and low threats, were easily identified (Fig. 2c); accordingly these areas were included in the "special conservation zone." Similarly, the areas with low scores representing the combined low conservation values and high threat were used to identify the "uses zone." The spring zoning plan included three zones with three levels of permitted/prohibited uses while the winter zoning plan included only two zones. In addition to the special conservation zone and the uses zones, an additional conservation buffer zone was added to the spring zoning plan as a transitional permitted use zone to ensure enough conservation measures are applied around the breeding hotspots. In the case of Al Jabboul, the combined maps of conservation values and human threat were used in mapping the final boundaries of the zones as a consensual option since the area is located in proximity of several villages which depend on and use the wetland resources. In other cases, seasonal zoning could be based solely on conservation value, with human impact maps being used to identify areas of potential conflicts where dialogue with wetland users is needed.

In fixed zoning plans, planning is based on suitability or vulnerability, which could be more efficient to protect zones of high potential conservation value in areas with minor seasonal changes. In flexible zoning, planning is based on seasonal values of disturbed areas. In the case of Al Jabboul, the situation was different due to the size of seasonal changes. The highly impacted areas in one season (e.g., hunting areas in winter) showed high conservation values in spring and summer (e.g., breeding islands of the Greater Flamingo). These breeding areas were not impacted by the winter hunting in spring mainly because it becomes surrounded with a wide area of mud after the water is evaporated, which prevents land access, and provides isolated breeding grounds for key species especially Flamingos.

The advantage of seasonal zoning plans compared with fixed "year around" is that major changes are monitored in depth as values to be conserved by season. Specific actions, and focused objectives toward this temporal, with high values can be applied. While in the fixed zoning plans, a more generic approach is applied on all values all the time, which cannot consider the seasonal variation, and could not harmonize the wise use of wetland resources and the conservation of wetland values in the same zone.

In addition, the seasonal zoning plan gives more flexibility toward the wise use of wetlands' resources by allowing the use in high values conservation zones, but in different seasons as in the case of Jabboul Wetland. Finally, such approach is more accepted by wetland users and stakeholders. Unfortunately, the full implementation of the revised management plan has yet to be resumed due to current political instability with the region.

Conclusion

Fixed zoning plans, where plans are applied all year round without considering seasonal variations related to the biological processes, are suitable to most terrestrial protected areas and many wetlands. In cases where the wetlands are dynamic and encounter significant seasonal variations in the spatial distribution of ecological values or uses, it is recommended to apply flexible seasonal zoning plans to direct and organize the types of permitted activities. This work represents the first documented study, which has applied a spatial multi-criteria method of evaluation in the production of clearly defined yet flexible zones, for a seasonally variable inland Ramsar Site.

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