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Habitat mapping as a tool for water birds conservation planning in an arid zone wetland: The case study Hamun wetland

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ABSTRACT

Wetlands, especially those in semi-arid areas, are highly vulnerable to human activities, droughts, and other climate variations. Regards to water resources limitations in these regions, prioritization of management strategies is essential to ecosystem conservation and restoration, particularly during the breeding season of waterbirds. The present study sought to develop a spatial conservation prioritization approach based on remote sensing and geographical information system to identify areas of a wetland which require special protective measures during waterbirds' breeding season. After the extraction of spatial information from Landsat 8 time series data, maximum entropy and weighted linear combination (WLC) methods were used to identify areas with higher conservation priority. Firstly, waterbirds' habitat suitability map during their nesting time in Hamun Wetland was constructed. Then, Habitat suitability changes until the end of the nestling period were evaluated and areas providing suitable conditions for longer periods were identified. Moreover, areas with suitable conditions in the beginning of breeding season but unsuitable conditions (caused by the drying of the wetland) in the nestling period were also determined. Considering limited water availability in the study area, carefully designed management strategies are required to conserve waterbird habitats in such parts of the wetland which are at higher risk of drying. The results of this paper highlighted areas with high conservation priority in a wetland with water limitation. This approach can be practically applied in the management of water habitats in arid and semi-arid areas facing water limitations.

1. Introduction

Over 50% of wetlands throughout the world have been destroyed during the past century and the remaining wetlands are suffering different levels of degradation caused mainly by human factors and droughts (Fraser and Keddy, 2005; Ma et al., 2010). Therefore, ecological assessment of these invaluable ecosystems is essential to protect their functions. Since wetlands provide habitats for a variety of wildlife species including waterbirds (a major component of wetland ecosystems), their loss or degradation would exert undeniable negative impacts on wetland-dependent birds, decrease their population, and threaten their health and survival (Erwin, 2002; Taft et al., 2002; Weber and Haig, 1996). Conservation of waterbird species would thus require a thorough evaluation of changes in their habitat conditions following alterations in wetland properties, especially in changing conditions. Satellite data are one of the most important tools in this evaluation (Berberoglu et al., 2004; Huang et al., 2014; Kassawmar et al., 2011; Thomas et al., 2011).

Remote sensing is a cost-effective and time-saving method based on satellite data. The diverse temporal resolution of these data makes remote-sensing a favorite tool for change detection and monitoring of field phenomena (Wilson et al., 2011; Yan et al., 2012). Landsat imagery is among the most widely used satellite data in wetland studies. In addition to their favorable repeat cycle, high spectral resolution of Landsat 8 data is useful in distinguish different phenomena. Thus, Landsat 8 Operational Land Imager (OLI) is well capable of detecting changes in different phenomena over 18-day periods (Mwaniki et al., 2015). By investigation of

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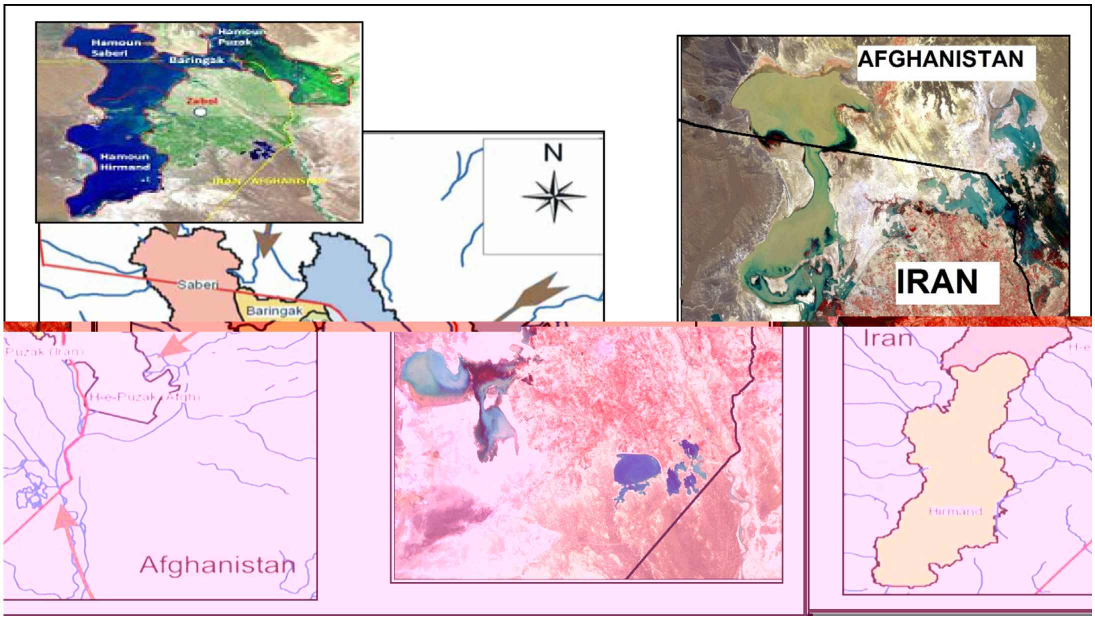

Fig. 1. The study area.

Landsat 8 OLI time series data in ecosystems facing constant changes, conservational programs can be maintained.

Suitable habitat conditions in a region may be altered by the secondary effects of human activities and climate change (Lee et al., 2010). In case of wetlands, such changes can occur during short periods of time and be associated with variations in water level. In this study, application of time series data to investigate suitable habitat change was introduced as a tool for water birds habitat management, in a wetland with water limitation and high risk of degradation located in a semi-arid area. Previous studies have identified habitat assessment as an indispensable component of conservation programs (Radeloff et al., 1999; Reza et al., 2013; Yamada et al., 2003). Ma et al. (2010) highlighted the significance of waterbird habitat evaluation in wetland ecosystem management. According to Anjos et al. (2015) habitat assessment is beneficial approach in conservation planning and management. Winiarski et al. (2014) used the distribution map of seabirds for conservation prioritization. But, changes in water availability need to be incorporated into conservation planning programs in arid and semi-arid areas, where water limitation is a major challenge. In the current study, this factor was considered to determine sensitive areas for waterbirds' breeding. Although the studied wetland generally holds adequate water when water birds build their nests (the nesting time), inundation limitations trigger its drying and decrease habitat resources during the breeding season. Therefore, this study attempted to identify areas whose favorable conditions over the nesting time turn into undesirable conditions during the nestling period. This approach will determine the parts of the wetland which maintain their favorable conditions as bird habitats for longer periods. This approach will have implications in conservation prioritization programs. An index called "compared to the optimal conditions" (COC) was used in habitat suitability comparisons.

2. Materials and methods

2.1. Study area

Hamun Wetland is a wetland lying in Sistan Plain on the Iran-Afghanistan border (Fig. 1). The Sistan area is located at the tail end of a large closed inland (endorheic) basin, in one of the driest regions of the world. The average annual evaporation in the area is 3075 mm and its climate based on De Martonne classification is dry. Following severe droughts and the blockage of water flow by Afghanistan, the wetland experiences frequent inundation and drought periods even during one year.

As the only source of water in an arid region, Hamun Wetland plays a crucial role in the lives of a large number of birds. This wetland is a major stopping point for many species of migrating birds, such as flamingos, ducks, and pelicans, making their way from Russia to the shores of the Indian Ocean. In fact, roughly 150 species of migrating and non-migrating (resident) birds can be found feeding and nesting area in and around the wetlands over the course of a year (Partow, 2013). Due to its importance for

Table 1
The bird species which use Hamun wetland. (Scott, 1995; Behrouzi-rad, 2009).

Botaurus stellaris	*Limosa limosa*	*Fulica atra*	*Tachybaptus ruficollis*
Vanellus leucurus	*Botaurus stellaris*	*Egretta garzetta*	*Podiceps cristatus*
Aythya fuligula	*Phalacrocorax pygmeus*	*Anas clypeata*	*Podiceps nigricollis*
Pelecanus crispus	*Phalacrocorax carbo*	*Anas strepera*	*Cygnus cygnus*
Bucephala clangula	*Casmerodius albus*	*Anas Penelope*	*Cygnus olor*
Mergellus albellus	*Tadorna tadorna*	*Anas crecca*	*Oxyura leucocephala*
Mergus merganser	*Tadorna ferruginea*	*Anas platyrhynchos*	*Greater Flamingo*
Grus grus	*Marmaronetta angustirostris*	*Anas acuta*	*Pelecanus onocrotalus*
Rallus aquaticus	*Netta rufina*	*Ardea goliath*	*Platalea leucorodia*
Porzana pusilla	*Aythya farina*	*Ardea cinerea*	*Nycticorax nycticorax*
Porzana porzana	*Aythya nyroca*	*Ardea purpurea*	*Anser anser*

Table 2
Information about the study area.

Hamun	Hamoun-e Sabari, Hamoun-e Hirmand and Hamoun-e Puzak	
Type of Wetland	Inland, Palustrine, Semi-Permanen	Behrouzi-rad, 2009
Depth	The average depth of the Hamun even at the highest water levels does not exceed 3 m	Shamohammadi and Maleki, 2011
Number of bird species	During wet years, when the Hamoun was full, 181 bird species (migratory and resident) were recorded from this wetland	Behrouzi-rad 2009; Scott 1995
Plant species	*Phragmites australis, Typha latifolia, Potamogeton crispus, Potamogeton pectinatus, Potamogeton lucens, Potamogeton perfoliatus,Valisneria sllustris, Zannchelia palustris, Cyperus longus, Bulboschoenusmaritimus, Schoenoplectus lacustris, Schoenoplectus litoralis, Alisma plantago aquatica, Najas minor, Najas marina*	Behrouzi-rad, 2009

Table 3
Data used in this study.

Data type	Resolution	Dates of images/data used
Landsat 8 –OLI	30 m	13/05/2014
Landsat 8 –OLI	30 m	29/05/2014
Landsat 8 –OLI	30 m	14/06/2014
Landsat 8 –OLI	30 m	30/06/2014
Landsat 8 –OLI	30 m	16/07/2014
Landsat 8 –OLI	30 m	01/08/2014
Topographic map	1:50000	2004
Google Earth	varying resolution	2014
Ground observation	–	May–August 2014

water birds, Ramsar Convention introduced a large part of Hamun in Iran as a protected area. Based on this Convention, Hamun includes two sites: "Hamun-e-Puzak, south end" and "Hamun-e-Saberi & Hamun-e-Helmand" (Ramsar, 2016). In this study, both two sites were studied. Moreover, the Bird Life International has listed Hamun Wetland as an important bird area. However, alterations in the wetland's water area will cause changes in the area of suitable habitats for water-dependent bird species, i.e. suitable habitats are revived during the inundation period (early March-April) but are again lost subsequent to reduced water levels in August (Shamohammadi and Maleki, 2011). In some years, the wetland completely dries out or the existing water becomes inaccessible in the middle of the breeding season. Such a trend is particularly dangerous for altricial species, such as *Pelecanus* sp., *Phalacrocorax* sp.,

Hamun Wetland consists of three lakes, namely Hamun-e Puzak, Hamun-e Sabari, and Hamun-e Helmand. The study area was Hamun Wildlife Refuge, which covers an area of 300,000 ha in Iran.

The major species of waterbirds which use Hamun wetland are listed in Table 1. Additional informations on the Hamun wetland are presented in Table 2.

2.2. Data

2.2.1. Satelite data

Landsat 8 OLI 2014 time series images, waterbird presence data, and field studies were used in the current study. Table 3. shows data used and Images acquired date in 2014. Satellite data were downloaded from the U.S. Geological Survey (USGS) website. The study period was determined based on the breeding season and Hamun Wetland's inundation period in 2014. During this year, the inundation period of the wetland started in March and continued until August.

2.2.2. Field study

In this area, always, breeding season starts in late April that the birds start nesting and ends in August (Shamohammadi and Maleki, 2011). So, for presence data, water birds nesting and resting area were monitored in May 2014. For this purpose, a method based on Gregory et al. (2004) was used. Between 6 and 11 am, with binoculars (10 × 40) and telescopes (15 × 60) water birds were monitored in point transects, 10 min in each point (Fuller and Langslow, 1984) and their nests through 100 m line transects (Gregory et al., 2004). Stratified random sampling was used to determine the starting points and direction of transects was selected at random. These data were collected in June, July and August to check the produced maps for related months. The locations of nesting area were recorded using the Global Positioning System (GPS). At all the sampling locations, habitat factors were recorded; water depth, landscape type, vegetation height and vegetation cover percentage.

2.2.3. Expert knowledge

As Yamada et al. (2003) and Fourcade et al. (2013) discussed, Expert knowledge is an important resource that may improve the reliability of modelling. Based on Yamada et al. (2003) method, the questionnaire was used in this study to use expert knowledge data. The questionnaire has two parts. In the first task, each expert was asked to locate sites in the study area where waterbirds had been nested. These sightings were recorded into the feature attribute table of the GIS data layer as point data.

Questions of the second task were focused on deriving the key environmental variables for building the habitat model. These variables had been selected based on the literature review (Tian et al., 2008; Hua et al., 2012; Dong et al., 2014; Yuan et al., 2014) and the author past study (Shamohammadi and Maleki, 2011; Rahdari et al., 2012).

Then answers were processed based on Leblond et al. (2014) method, in this method, we incorporated variables that were selected by >50% experts.

21 people participated in this survey. The participants included park rangers, local experts and rural people how live around the Hamun. This survey was done on the meeting that has been held by SiStan Department of Environment.

2.3. Methods

Maximum entropy method was applied to prepare habitat suitability map at the nesting time (May 2014) of water birds in Hamun Wetland. The resulting map was used to determine the suitable ranges and weights of all habitat factors at the time of nesting in the study area. In order to identify the areas which maintained their suitability throughout the breeding season, the obtained ranges

Table 4
Land use classes.

Land use	Code	Description
Water	1	Water surface without vegetation
Water-veg	2	Water and vegetation in water
Veg-water1	3	Dense vegetation in shallow
Veg-water2	4	Week vegetation in shallow
Vegetation1	5	Dense vegetation on the ground
Vegetation2	6	Week vegetation on the ground
Human construction	7	Agriculture, city, village
Wet soil	8	Wet soil with weak vegetation
Other land use	9	Bare land, salt land, area without vegetation cover

were used to produce habitat suitability maps for other points of time during the breeding season. This process comprised the following steps:

2.3.1. Selection of suitability factors

First, key factors in habitat selection were identified. By analyzing relationships between waterbirds and key environmental factors of the habitat, literature review(Tian et al., 2008; Shamohammadi and Maleki, 2011; Rahdari et al., 2012; Hua et al., 2012; Dong et al., 2014; Yuan et al., 2014) and comments of local people (It was described in Section 2.2.3); access to water, food availability, and shelter conditions were selected as indices affecting waterbirds habitat suitability.

Following a review of the literature (Tian et al., 2008; Shamohammadi and Maleki, 2011; Rahdari et al., 2012; Hua et al., 2012; Dong et al., 2014; Yuan et al., 2014) and interviews with relevant experts (It was described in Section 2.2.3), we selected key factors directly affecting habitat indices that mentioned above. Land cover and distance to roads and residential areas were identified as factors influencing shelter conditions. Food availability and access to water was determined by normalized difference vegetation index (NDVI) and tasseled cap wetness-greenness difference (TCWGD).

2.3.2. Preparing habitat factors maps

Images with minimum cloud cover were selected for the preparation of land use –land cover maps. After the application of radiometric and atmospheric corrections, the images were compared both with each other and with field observations. Field studies indicated the presence of nine land use – land cover classes in the study area (Table 4). A hybrid approach was employed to classify images. In this approach, a spectral classification based on ISODATA was first used. The spectral classes and field data were then combined and the training points for supervised classification were determined. Furthermore, PCA, TCWGD, SAVI, NDVI, NDWI, infrared ratio (IR) were compared against field data using regression model to select more accurate indices. Finally, IR, NDVI, and TCWGD were used in the preparation of land use-land cover classes. These classes were merged to produce land use-land cover map. The same procedure was followed for all studied times.

Access to water is a critical factor in waterbirds' life. According to the available literature (Rogers and Kearney 2004; Powell et al., 2010; Huang et al., 2014; Rahdari et al., 2012; Amiri et al., 2014) the NDWI, NDVI, TCWGD, IVR indices were used to determine water classes (Table 5). The TCWGD index was found to be more appropriate and was thus calculated for the studied dates.

To increase the accuracy of land use-land cover map, wrong single pixels were eliminated based on field data, FCC and High resolution images (Quickbird) obtained from Google Earth^{TM}. In order to accuracy assessment, 540 pixels were randomly selected from each map and kappa coefficient and overall accuracy were computed.

To prevent co-correlation between data, cross-correlations of variables were evaluated using Pearson's correlation analysis.

2.3.3. Producing the habitat suitability map at the nesting time (May)

MaxEnt Software (Phillips et al., 2006) was used for waterbird distribution modeling and assessment of birds' responses to the above-mentioned factors over their nesting period in Hamun Wetland (May). During model development, 70% of the recorded data were used as training points and the remaining 30% were considered as test points. The output map is a Continuous map. MaxEnt provides threshold values based on a variety of statistical measures: 10 percentile training presence logistic threshold (Young et al., 2011). In order to facilitate ecological interpretations, we used the 10 percentile training presence logistic threshold and the GIS layer that was produced from the results of the expert observations (It was described in Section 2.2.3) and the field study (see Section 2.2.2). Finally, the appropriate range and weight of each parameter was determined based on MaxEnt out puts. These results indicate the suitability ranges of the studied factors for waterbirds in this area.

2.3.4. Producing suitability maps of June–August

Maps of the mentioned parameters were created for other dates in Table 3. For this purpose Suitable ranges of all parameters were then extracted based on their suitable ranges in May. After weighting of all factors, Eq. (1) was applied to combine layers and compute habitat suitability at each particular date.

$$Mi = \sum_{j=1}^{n} Wj \times Xij \tag{1}$$

Where, M_i is the overall score of habitat suitability for ith gird cell; w_j is the weight of jth variable, and xi_j is the value of ith gird cell for jth variable.

In total, 30 nesting locations in areas with appropriate water and vegetation conditions were used to check the waterbird habitat suitability for each date after May in Table 3.

2.3.5. Higher priority of conservation

In the next stage, the prepared maps were overlaid using geographical information system (GIS) techniques to compare areas with suitable conditions at the nesting time with other dates. This comparison, spatially indicated areas with suitable conditions at the time of nesting but undesirable conditions during the nestling period. These areas were introduced as higher priority of conservation.

The COC index was used to determine the differences between conditions at each studied date and the nesting date. In order to calculate the COC index, the area of suitable habitat at each time point was compared with that at the nesting time. Eq. (2) was used to calculate this index:

$$COC = (A_i/A_{max}) * 100 \tag{2}$$

Where A_i and A_{max} are respectively the area of suitable habitat at date i and area of suitable habitat at the nesting time.

3. Results

3.1. Landuse-land cover

Fig. 2 illustrates the time series of land use and cover maps of Hamun Wetland. The areas of all land use-land cover classes during May–August are presented in Table 6 During the study period, no changes were detected in agricultural and residential

Table 5
Spectral indices that were used together with Landsat spectral bands and tasseledcap brightness (TCB), greenness (TCG) and wetness (TCW).

Spectral Index	Formula	Reference
TCWGD	TCW – TCG	Huang et al., (2014)
NDVI	(Band 4 – Band 3) /(Band 4 + Band 3	Rahdari et al., 2012
NDVI-1	(Band 4 – Band 5) /(Band 4 + Band 5)	Gao (1996)
NDVI-2	(Band 3 – Band 5) /(Band 3 + Band 5)	Rogers and Kearney (2004)
TCA	Arctan (TCG / TCB)	Powell et al. (2010)
IVR	Band 5 / Band 2	Ozesmi and Bauer (2002)
IR	(Band 5 – Band 7) /(Band 5 + Band 7)	Ruan et al., (2007)

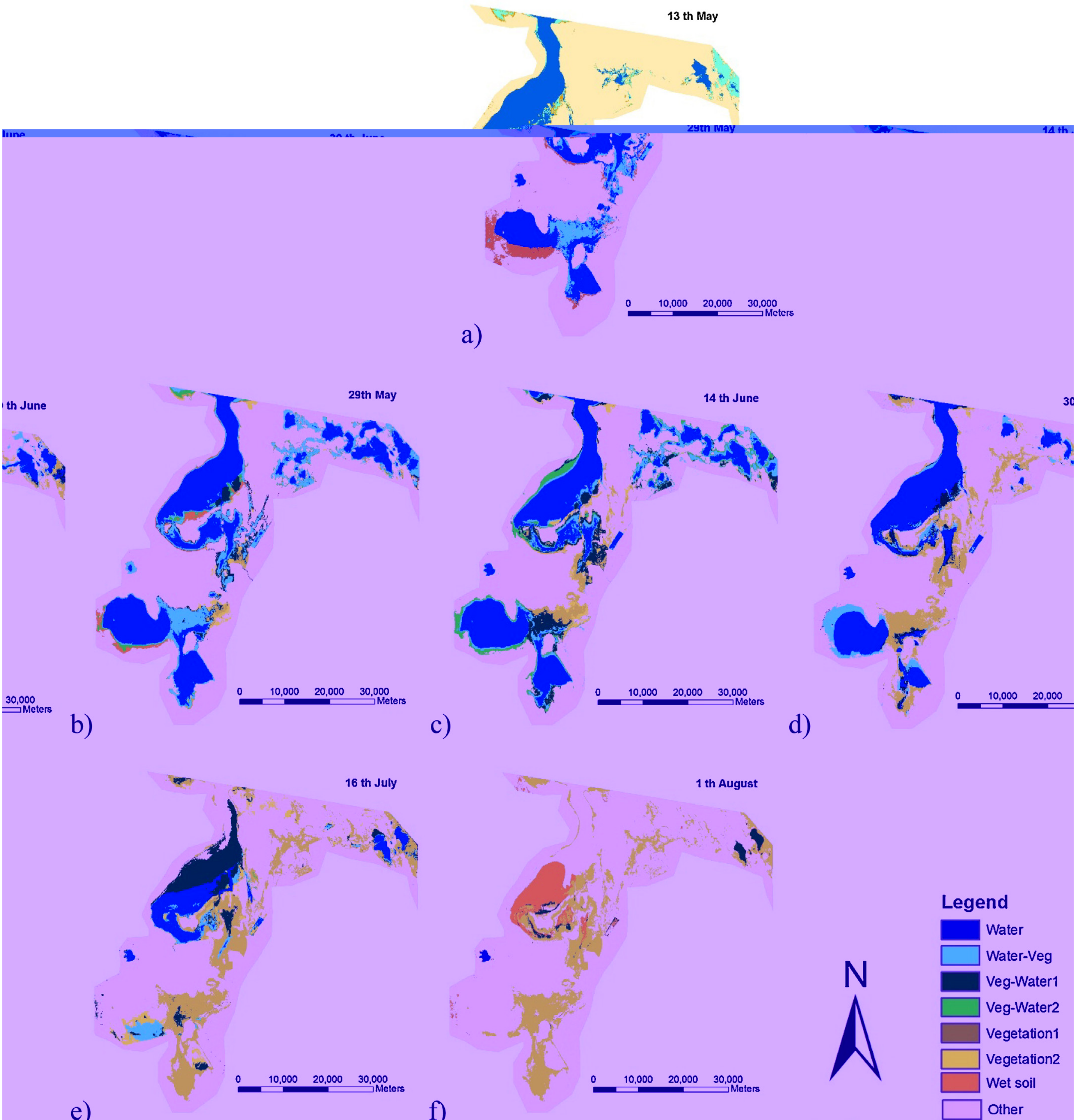

Fig. 2. Landuse-landcover May-August 2014. (a)13-May, (b)29-May, (c)14-Jun, (d)30- Jun, (e)16-Jul, (f)1-Aug.

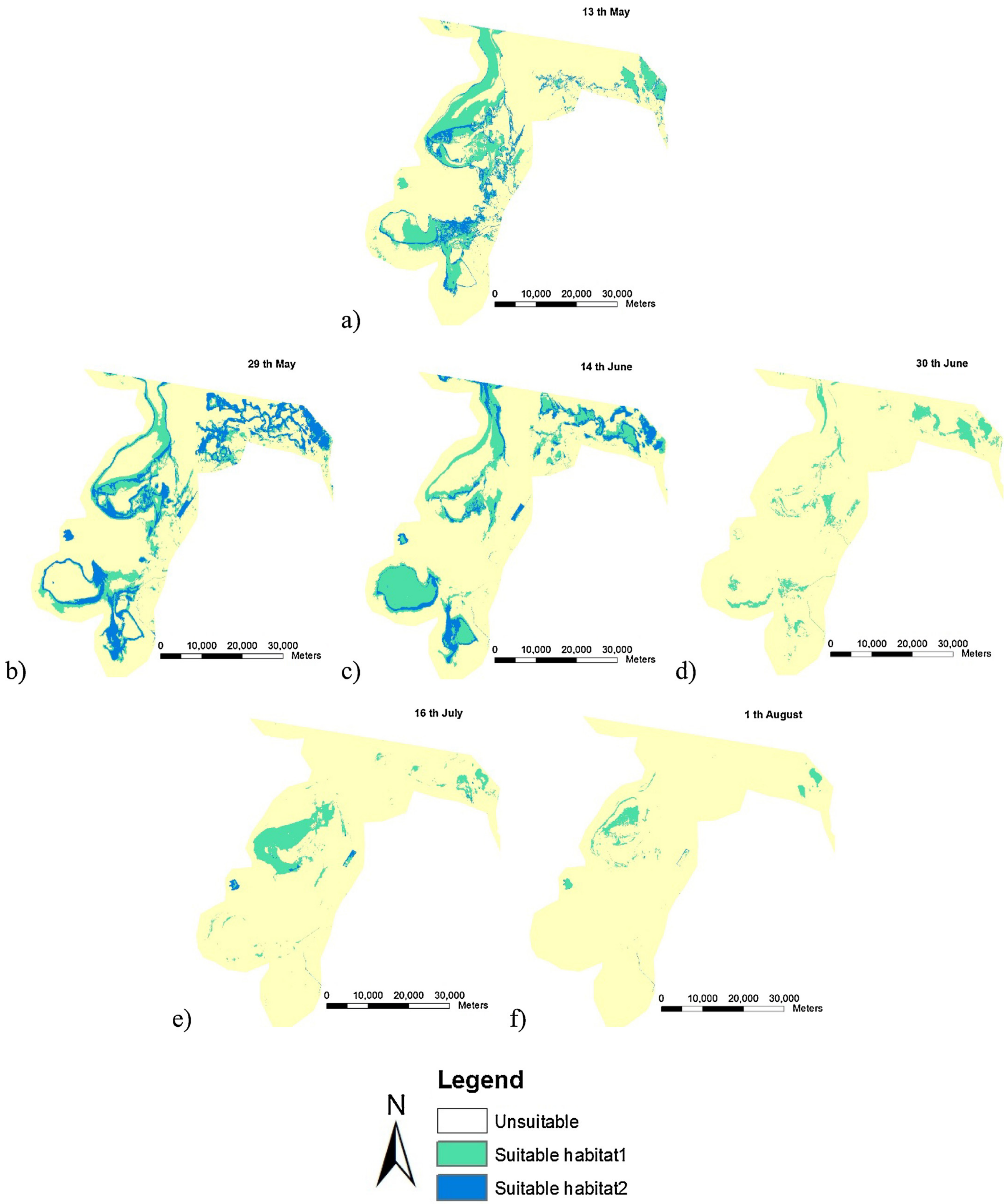

Fig. 3. Habitat suitability May-august 2014-(a)13-May, (b)29-May, (c)14-Jun, (d)30- Jun, (e)16-Jul, (f)1-Aug until.

land uses. Meanwhile, since changes in these land uses are not basically affected by the wetland's inundation, these two land uses were merged with "other uses" in all maps, i.e. the maps contain eight classes.

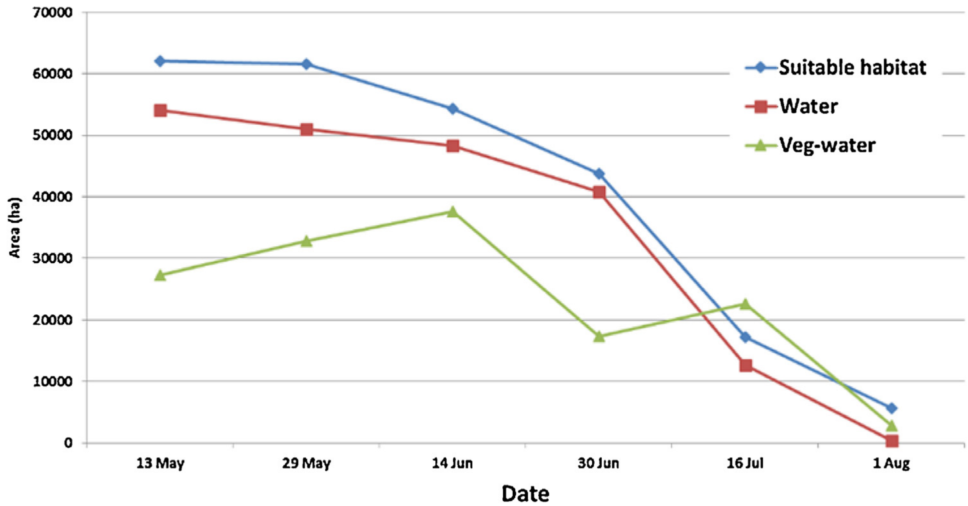

Fig. 4. Changes in habitat suitability, water area, and vegetation area during the study period in 2014.

Table 6
The Area of different land use (ha) (10Mar–1Aug 2014).

Landuse	13-May	29-May	14-Jun	30-Jun	16-Jul	1-Aug
Water	54076.8	50972	48340.8	40868.6	12713.8	411.48
Water-veg	26065.1	22343.8	14445.1	10858.4	5798.16	0
veg-water1	1182.15	5449.68	12300.7	6469.2	16702.8	2822.49
veg-water2	0	4980.78	10878.8	57.28	171.27	0
Vegetation1	696.15	1666.62	6273.27	22350.4	35662.6	37558.7
Vegetation2	204.3	2821.86	5279.04	5689.89	7234.92	0
Wet soil	7502.04	4643.19	0	0	0	11555.3
Other landuse	210275.46	207132.1	202462.3	213707.2	221726.5	247652

Table 7
Overall classification accuracy and kappa statistics.

	13-May	29-May	14-June	30-June	16-Jul	1-Aug
Kappa	0.93	0.96	0.93	0.96	0.90	0.88
Overall accuracy	%95	%93	%95	%0.93	%0.94	%0.95

Table 8
The Area of Suitable habitat (ha) (10Mar–1Aug 2014).

	13-May	29-May	14-Jun	30-Jun	16-Jul	1-Aug
Suitable habitat	62030	61530.48	54346.23	43798.86	17186.13	5664.6

Accuracy assessment was performed for all land use land cover maps. To increase the accuracy of land use-land cover map, wrong single pixels were eliminated based on field data, FCC and High resolution images (Quickbird) obtained from Google Earth^{TM}.

Table 7 lists the classification accuracies. As seen in this table, the present study enjoyed acceptable classification accuracy (90%–93%) and yielded favorable classification results (kappa coefficient: 0.88–0.96) (Dong et al., 2014; Lua and Weng, 2009).

3.2. Habitat suitability

The habitat suitability map at the time of nesting (May 13) was created with MaxEnt Software. Based on the GIS layer that was produced from the results of the expert observations and the suitability range determined by the software, the produced continuous map was classified as suitable grade 1, suitable grade 2, and unsuitable.

Fig. 3 shows the habitat suitability from the nesting time (a) until the end of the breeding period in August (b–f). Table 8 shows the area of suitable habitat. According to this table, the suitability of the area changed during the breeding period, i.e. the area of suitable habitats decreased from 62,030 ha at the nesting time (in May) to 5664 ha in early August.

Fig. 4 depicts changes in suitable habitat area, water area and vegetation. The veg-water in the chart was obtained by aggregating classes 2–4 (where vegetation is present in water).

Fig. 5 compares the area of suitable habitats at various points of time and the nesting time (May 13). Fig. 6 illustrates the recommended protected area after the overlaying of habitat maps. The red parts require exceptional management measures since their suitable conditions during the nesting season change into unsuitable conditions over the breeding period.

4. Discussion

4.1. Remote sensing and habitat suitability

The present study used remote sensing to assess habitat changes over a short period of time. Satellite images with short repeat cycles are appropriate tools for the monitoring of rapidly changing ecosystems. Since the water area of the studied wetland changes over different months of a particular year, Landsat 8 imagery, with an 18-day repeat cycle, could well reveal habitat changes in this area. In this period, changes in water and vegetation can be monitored. Furthermore, as Huang et al. (2014) mentioned, using Landsat images an appropriate coverage with reasonable cost can be made.

Similar to previous research (Dong et al., 2013; Garcia et al., 2013; Huang et al., 2014) the current study confirmed the potential of remote sensing approaches in ecosystem analysis. However, the significance of field studies in obtaining accurate habitat assessment results should not be neglected.

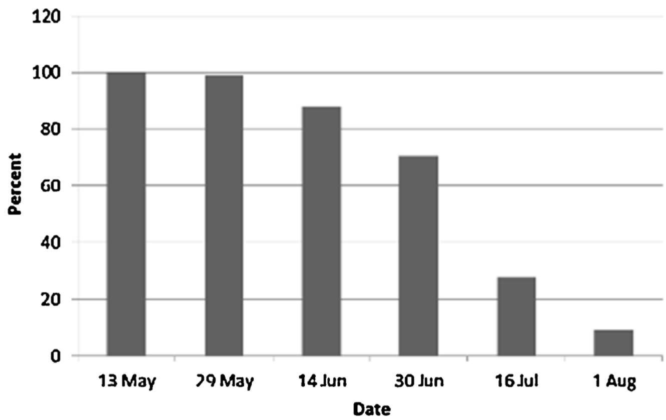

Fig. 5. Comparison of suitable habitat areas at various points of time and nesting time (May 13, 2014).

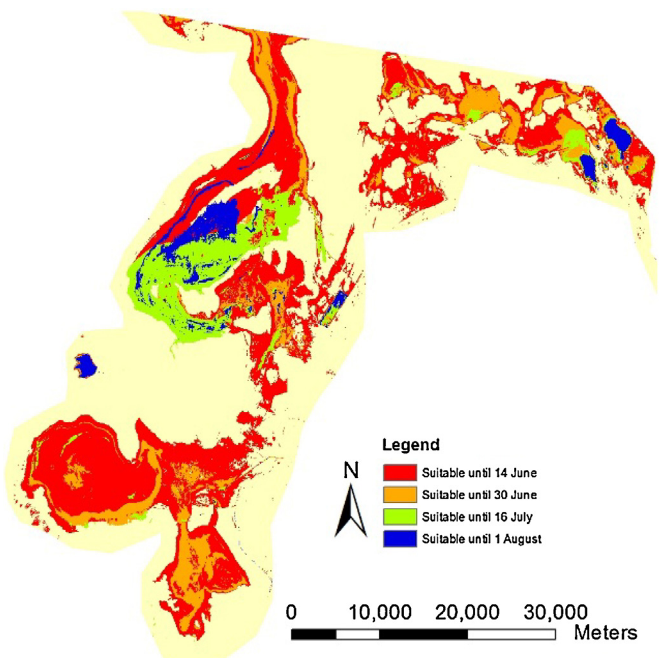

Fig. 6. The recommended protected area. The Red color parts show area that are suitable until 14th June, but turn into undesirable conditions. These area require exceptional management measures (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

4.2. Habitat suitability model

Selecting a combination of factors which can best describe habitat conditions is one of the most important components of habitat suitability evaluations (Tian et al., 2008). The NDVI, for instance, is a key index in determining vegetation growth status and coverage. It is also a relative measure of forage for waterbirds. Moreover, land cover can be considered as a relative index in evaluating shelter safety and suitability for rest (Brotons et al., 2004; Dong et al., 2013).

After selection of factors, it is essential to calculate Pearson's correlation coefficients to prevent redundancy in analyses (Broome, 2001).

Suitable habitats at the nesting time of −water birds were identified in MaxEnt Software. MaxEnt is widely used in habitat assessments (Hermosilla et al., 2011; Ready et al., 2010; Rupprecht et al., 2011) since it can determine habitat suitability with limited presence data and without the need for absence data (Phillips and Dudik, 2008; Weber, 2011). The area under the curve (AUC) in the present study (0.91) indicated the applicability of the developed model (Elith et al., 2011). MaxEnt generally produces a continuous raster map in which habitat suitability is quantified as values between zero and one. The classification thresholds will be determined based on the existing data, the modeling objective, the studied species and statistical indices presents by Max Ent such as 10 percentile training presence logistic threshold (Martin-Garcia et al., 2014).

4.3. Land use-land cover map

Land use and cover maps provide an insight into the current conditions of areas under study and are thus particularly important in environmental studies. Nine land use classes were initially defined in the current study. Agricultural and residential land uses were merged because their changes did not depend on the inundation of the wetland (of course they had no particular changes during the course of the study).

Considering the diversity of land cover in the study area, a hybrid model was applied to benefit from the potentials of different remote sensing methods and indices (Misra and Balaji, 2015).

According to Table 7 the created land use-land cover maps enjoyed acceptable accuracy. In other words, the proposed hybrid model was an appropriate approach for the preparation of land use-land cover in an area experiencing a diversity of phenomena.

4.4. The application of the method to ecological conservation

How can managers determine the areas with higher conservational priority using an ecological approach? The method was used in this paper can answer this question and prioritize areas for conservation. In this approach, comparison of habitat suitability at the nesting time with other dates in breeding season of waterbirds was used as an index for conservational goals. By this comparison, areas at higher risk of degradation and in greater need of management practices can be determined. These areas were, in fact, parts of the wetland whose suitable conditions at the nesting time turned into unsuitable conditions over the nestling period (due to the drying of the wetland). Following the identification of such areas, an appropriate ecological model of management practices can be formed to prioritize areas with higher habitat significance and greater risk of degradation.

The current research used the COC index to quantitatively compare wetland conditions over 18-day periods with optimal conditions of the wetland during the course of the study. This can serve as a scientific approach to determine the percentage of an area which requires management measures to reach its optimal conditions.

4.5. Habitat conservation and restoration

Available evidence suggests habitat loss and reduction to play a major role in the reduction of biodiversity and extinction of various species (Dong et al., 2013; Riley and William, 2005; Roddriguez and Delibes, 2003). Therefore, conservation of biodiversity will require the development of efficient management practices to protect species' habitat. Especially in areas that conditions change in short period, these changes cause some parts of habitat which have suitable conditions at the nesting time lose their suitability over the nestling period. Such conditions are dangerous to all nestlings, particularly those of altricial birds. Evaluation of the relations between changes in habitat suitability and variations in water area and vegetation over waterbirds' breeding season in Hamun Wetland determined areas which provided suitable conditions for the longest periods. Moreover, areas with suitable conditions during the nesting season but unsuitable conditions and inadequate water over the nestling period were also introduced as conservation area (Fig. 6). The obtained results can also be used to prioritize areas requiring water management and habitat conservation.

Several approaches have been proposed for conservation prioritization. However, as Kentula (2000) and Ma et al. (2010) discussed, wetland management is dependent on the type, function, and degradation degree of the wetland. Level of changes in the ecosystem is also another determinant of management practices. Although the technique presented in the current study was designed for a specific area, it can be well adopted to use in areas with high levels of change. On the other hand, while most of the existing wetland management approaches are academic (Ma et al., 2010) our method incorporated both theoretical and practical aspects of wetland management. Furthermore, the richness and abundance of waterbirds, commonly used in the wetland management (Konisky et al., 2006; Ma et al., 2010; Neckles et al., 2002; Wolters et al., 2005) seem to be appropriate indices when ecosystems with stable conditions are involved, i.e. changes in environmental conditions should also be included in management planning for constantly changing ecosystems. Also, Winiarski et al. (2014) argued that in order to eliminate errors, a combination of data, depending on the situation of the study area, needs to be used in priority setting for waterbird conservation.

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