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ORIGINAL ARTICLE

Monitoring Long-term Wetland Area and Vegetation Cover Change using RS and GIS

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ABSTRACT
Generally, wetland Inventory and mapping are not only requisite for analyzing practical problems, such as wetland function assessment, but are also highly necessary for resolving scientific issues, including quantifying the potential related impacts of wetlands and water resource management. To this end, we investigated the changes in area and vegetation cover of Kaftar wetland, Iran using satellite imagery and GIS over a period of 30 years (1986-2015). Results showed significantly decreasing trends in area and vegetation cover of wetland during 30-years period. Based on obtained results, mean annual rates of change in wetland area and vegetation cover were gains of -241.15 ha yr^{-1} and -88.39 hayr^{-1}during 30-years period. Figure 2 shows that the area of wetland was increased from 1986 to 1998 and mean annual rate of change in wetland area was positive in this period (105.98 hayr^{-1}) which changed to negative value after 1998 (-422.24 hayr^{-1}). The mean annual rate of vegetation cover was equal to 2.98 hayr^{-1} and -134.18 ha yr^{-1} pre- and post- 1998, respectively, resulting in a significant difference between the two periods. Finally, the result of this study can be used as an efficient tool in the planning, management, and conservation of wetlands in Iran.
Keywords: *Wetland, Remote sensing, GIS, Kaftar, Iran.*

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INTRODUCTION

Wetlands are among the most productive life support systems in the world [22]. They are critical for the maintenance of biodiversity by supporting the growth and development of wide varieties of natural vegetation and serve as breeding grounds for many wildlife and fish species [22, 26, 27,28]. Wetlands serve as "sinks," scrubbing carbon dioxide from the atmosphere, which combats global warming [23]. Communities that live around these wetlands in some parts of the world depend directly and indirectly on them for indigenous agro-pastoral activities such as farming, cattle rearing, and fishing that generate more income for the rural population. Wetlands are thus an important natural resource that can serve humans and natural ecosystems in a variety of ways. Some of these include agriculture,
fishing, hunting, grazing, collecting herbs, wood and other building materials, power generation, and for other industrial purposes. Unfortunately, such valuable resources are seldom recognized by people. The loss and destruction of wetlands are common problems that result from increased human activities [19]. Globally more than half of its wetlands have been lost in the past 100 years. The degradation and shrinkage of wetlands seriously threaten the security of the ecological environment and the conservation of biodiversity [9, 21, 5, 6, 2]. Thus, a detailed inventory and mapping of wetland systems is very useful to understand the spatial distribution of different wetlands and their linkage with other land units. Inventory and mapping are not only requisite for analyzing practical problems, such as wetland function assessment [29], but are also highly necessary for resolving scientific issues, including quantifying the

potential related impacts of wetlands and water resource management [4]. Such procedures help in the planning, management, and conservation of wetlands. Recognizing the value of wetlands, some countries and scientists have developed plans and methods for wetland mapping in important regions.

Remotely sensed images are being used to address critical wetland resource management problems, providing researchers with the ability to make rapid decisions about large spatial areas using recent data [36]. Wetland dynamics operate at multiple spatial and temporal scales, requiring researchers to be able to make multi-scale observations using satellite images [39]. Satellite images can easily detect and map both local and large area land use/land cover changes, and the impact they have on wetland processes [39, 12]. Concern about change in the size and quality of many of the world's wetland systems has been growing as more and more wetlands are being converted to agricultural or urban use and affected by natural factors like drought [15]. To date, satellite-sensor-based monitoring techniques have demonstrated a potential for determining changes in wetland cover [17, 11, 1]. Mwita *et al*. [16] used remote sensing techniques to map the small wetlands of Kenya and Tanzania. Their results showed that the use of multi-spatial resolution imagery combined with field survey and GIS produces satisfactory results for delineating and mapping small wetlands and their uses. However, most traditional wetland mapping investigations have limitations. First, using only the stock information of wetlands is inadequate for the above mentioned research. The major reason for this inadequacy is the data inconsistency between total wetland areas and actual wetland areas annually. Second, a single mapping scheme can hardly serve the complicated decision making that covers the ecological and socio-economic targets. Finally, several studies provide only relative qualitative information on wetland mapping. The qualitative information depends on the researcher's experience and descriptions, which may render the information inaccurate. Owing to these disadvantages, our understanding of wetland mapping is relatively poor. Thus, mapping wetlands must be identified and studied. Therefore, the aim of this study is report on changes in area and vegetation cover of Kaftar wetland, Iran over a period of 31- year (1986-2015).

MATERIAL AND METHODS

Study area

According to the Ramsar Convention: "Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters." Benefits of wetlands are their natural riches, tourism and training, wetlands ecology, reduction of flood risks, effects on ground water supply, wetlands as sink (and source) of pollutions, climate change problem, and wetlands as habitat for rich biodiversity. Kaftar international wetland, having an area of approximately 9,000 hectares is the largest and unique wetland in Fars province and is located 2300 m above sea level and its geographical coordinates is 52°47′N to 37°34′E (Figure 1) [10]. This wetland is surrounded by a vast expansion of meadows which cover an area of about 4000 hectares. According Ramsar Convention documents, Kaftar international wetland with its high population of the immigrant and endemic species of the province has been ranked among top important wetlands in Iran [3]. Kaftar wetland, In accordance with the classification made by the Ramsar Convention, is one of the largest and most important wetlands of Iran And is habitat for a number of migratory birds and native province. The Catchment of wetland is affected by climate similar to climate of Shiraz. Local weather stations indicate a long-term mean annual rainfall of about 447.2 mm and a mean annual temperature of about 19.6°C. The highest amount of rainfall is recorded in January and February; July is the warmest month with a mean temperature of 37°C and January is the coldest month with a mean temperature of 17°C. Recorded absolute maximum and minimum temperatures are -5.6°C and 40°C, respectively. Relative humidity is high in these areas with an annual mean of more than 65 percent. Identified plants in the wetland area consist of marginal plants, floating leaf plants and submerged plants and among them, sedge, cattail, Butumus and Sparganinum sp can be mentioned [3].

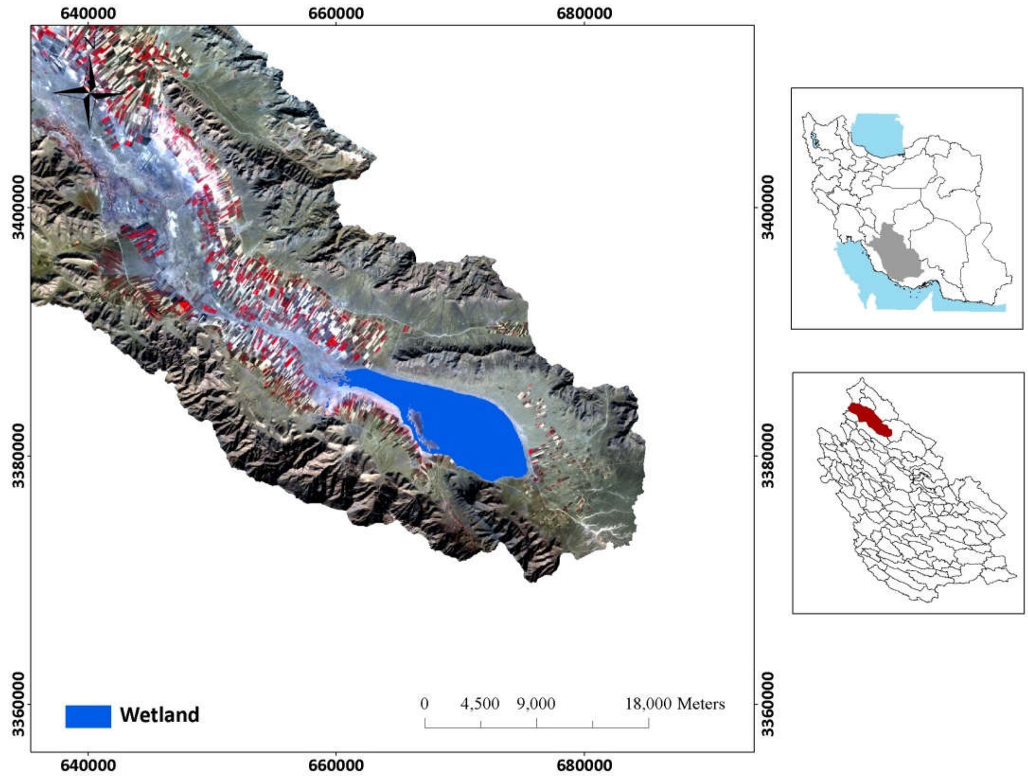

Figure 1. Geographic location of Kaftar wetland In the Fars province

Wetland change detection

Data sources

Thirty Landsat satellite images (path/row # 162/039 and 163/039) for the month of September were obtained for a 31-year period (1986 to 2016) to quantify the changes of the area and vegetation cover of Kaftar wetland. It should be noted that the limited availability of satellite images with higher resolution obliged us to choose Landsat images for assessment of wetland changes. Since cloud cover reduces the image quality and causes error in detecting the phenomena of interest in the images, we first examined a larger number of images in the archive of the Landsat satellite and used only images without cloud cover. Also, to prevent potential bias due to phenological differences arising from the change of seasons, only images from the month of September were analyzed. At this time of the year, the wetland system stands out from the surrounding upland because it alone still has dense green vegetation. Also, the wetland system is also at its weakest in the dry season and it was, therefore, anticipated that any long-term trend in wetland size and quality would be most easily detected with dry season images. For each year in the 30-year image time series, the value of area and vegetation cover of wetland was calculated.

Image analysis

Determination of exact boundaries of wetland is an important first step for assessing changes over time. To accomplish this, images were geometrically corrected for very high precision. Although Landsat C images are characterized by generally good geometric precision, we recorded a total of 100 ground control points using GPS with good distribution throughout the study area to ensure maximum possible accuracy.. For detection of the image, Landsat C images of 2016 with a root mean square error lower than one pixel (in this study, RMS = 0.143) were georeferenced with the IDRISI software. Finally, the corrected images of Landsat C were used for geometric correction of Landsat TM images taken in 1986 and 1998. None of the RMS values of the Landsat TM images in any of the corrections was higher than 0.18. All images were geo-referenced to UTMWGS-1984 Zone 40N projection and datum. Finally, Geo-referenced Landsat images were converted to top-of-atmosphere reflectance using the quick atmospheric correction model built-in ENVI 4.8 [4] before classification

Image classification

In general, maximum likelihood estimation is one of the most efficient classification methods for extracting wetlands from satellite images with medium spatial resolution [13, 16, 20]. Hence, in this study, supervised classification with a maximum likelihood algorithm was used for image classification and extraction of wetland area and vegetation. To separate wetland from surrounding areas and to draw the final borders of the study sites, Modified Normalized Difference Water Index (MNDWI) and Land Surface Water Index (LSWI) were calculated for water surface classification. With the use of the SWIR band instead of the near infrared band that is used in normalized difference water index, MNDWI can considerably improve the enhancement of open water features and quickly discriminate water from non-water features [35]. A threshold of zero was applied on MNDWI images in a decision tree schedule to distinguish water surface from non-water surface. the NDVI vegetation index was applied as one of the best and most widely used indices for quick and easy identification of green vegetation from surrounding areas [25-32]. After preparing the NDVI, MNDWI, MNDWI and using false color composites by bands of green, red and near-infrared, images were classified using supervised classification. In addition, maximum accuracy in determining the boundaries of wetland was aided by manually digitizing the border of wetland using precise visual interpretation on a scale of 1: 10,000 and with the help of a team of experts.

Post-classification analysis, accuracy assessment and social survey

In the post-classification process, the filtering process was also applied to remove isolated pixels or noise from the classification outputs. The filtered classified image was then used as the final land use map for each year. For accuracy assessment of the maps derived from the classified images of 2015 and 2016, 210 sampling plots with dimensions of 30×30 meters (900 square meters) were established in the study area and the borders of wetland. Further, aerial photos, land use maps and Quickbird images of the years 1985, 1992, 1995, 2001, 2004, 2009 and 2012 were used to assess classification accuracy of other wetland maps. Following recommendations by Eslami-Andargoli *et al*. [8] and Nguyen *et al.* [18], the stratified random sampling method was used to assess the classification accuracies of the final maps, enabling the computation of user accuracy, producer accuracy and overall accuracy for mangrove maps. Changes of area and vegetation cover of wetland were then computed. Finally, the mean annual rates of change in wetland area and vegetation changes were computed for the period before and after the break-point in the time series of annual precipitation. To aid in interpreting our results of changes over time in the area and vegetation of wetland, we conducted face to face interviews with indigenous people and experts. For this purpose, 25 people aged between 50 and 60 years who had longest residence in the region (residence over 30 years) were chosen for interviews and their comments were used to place our results in context.

RESULTS AND DISCUSSION

Broadly speaking, spatial analysis is a good tool which can play an important role in planning and implementing effective conservation measures as well as reducing vulnerability of wetlands to natural and human-induced hazards by identifying and measuring changes of wetland over time [33, 34, 38, 24, 13]. In this study, changes of area and vegetation cover of wetland were investigated during 30-years period using Landsat images (1986-2015) GIS. Overall accuracy, user accuracy and producer accuracy of all classified images consistently exceeded 90% (Table 1), which indicates a high level of accuracy in the classification and mapping of wetland area and vegetation cover.

Table 1: Accuracy assessment for the classification of Landsat images

Accuracy Classified Map	User (%)	Producer (%)	Overall (%)
1986	90.3	96.6	91.7
1992	92.2	95.8	92.8
1995	92.4	94.6	92.1
2001	90.6	94.1	93.1
2004	91.5	95.3	93.4
2009	90.1	93.3	91.7
2012	91.1	94.1	92.5
2016	90.3	93.6	92.2

Figures 2, 3 and 4 show the trends of area and vegetation cover of wetland during 30-years period. The analysis of the time series of satellite images showed significantly decreasing trends in area and vegetation cover of wetland during 30-years period (Figure 2-4). Based on obtained results, mean annual rates of change in wetland area and vegetation cover were gains of -241.15 ha yr^{-1} and -88.39 $hayr^{-1}$during 30-years period. Figure 2 shows that the area of wetland was increased from 1986 to 1997 and mean annual rate of change in wetland area was positive in this period (pre-1998) (105.98 $hayr^{-1}$) which changed to negative value after post-1998 (-422.24 hayr-1). The mean annual rate of vegetation cover was equal to 2.98 hayr-1 and -134.18 ha yr-1 pre- and post- 1998, respectively, resulting in a significant difference between the two periods (Table 2). The decreasing trend of wetland area and vegetation cover changes in the period of post-1998 lead to that the values of these to variable reached to zero or very close to this at the end of 30-years period (Figure 2).

Table 2: Mean annual change in mangrove area and vegetation cover pre- and post-1998

	1986 (ha)	1998 (ha)	2015 (ha)	Mean annual rate of change pre-1998 (ha yr-1)	Mean annual rate of change post-1998 (ha yr-1)
Area	7234.54	7600.32	0	-241.15	105.98
Vegetation cover	2651.8.	2416.6	1.3	2.98	-134.25

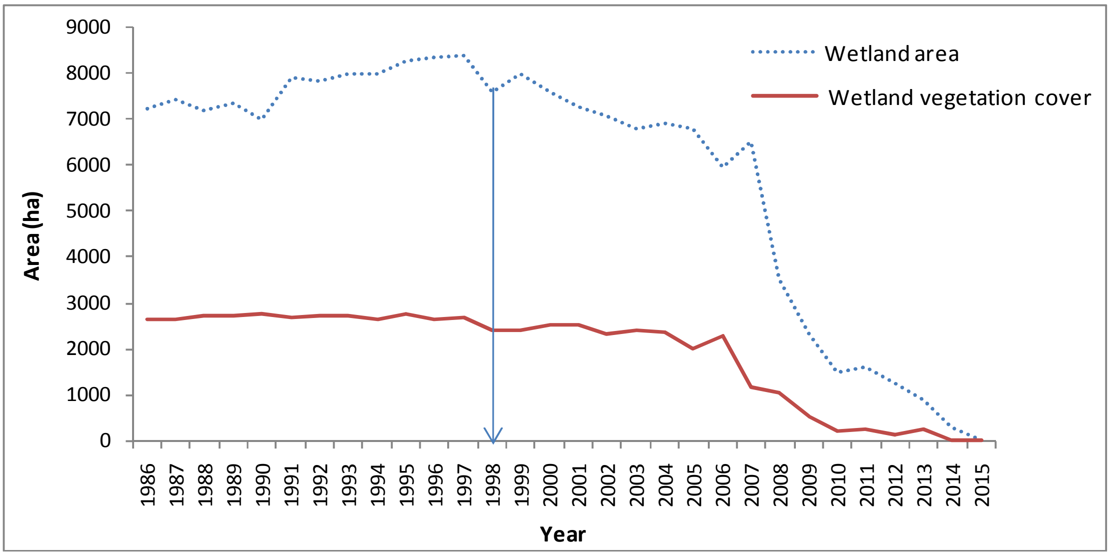

Figure 2: Wetland area and vegetation cover change during 30-years period (1986-2015)

The results showed that the area and vegetation cover of wetland significantly decreased in recent years. Located in the desert belt of the world (25 to 40 degrees north latitude), Iran exhibits a substantial climatic variability with mean annual rainfall amounts of about one third of the global mean [30, 21]. As a consequence, rainfall deficiency and drought occurrence in Iran have a high frequency and severity [14]. In addition, severe and very severe droughts in recent years have caused a significant reduction in the volume of fresh water resources in the Middle East, and especially in Iran [10]. However, not all regions of Iran are not subject to equal drought occurrence, so that severe to extremely droughts occur more frequently in the central and southern part of the country [9]. Occurrence of sever and very severe droughts in Iran can be one the main reasons for a significant reduction in the extent of Kaftar wetland in recent years. Owing to the semi-arid climate, where potential evaporation greatly exceeds precipitation, the water balance of wetlands is highly sensitive to the effects of climate change and to changes of land use on the surrounding uplands. Small changes in hydrological conditions, particularly those affecting runoff, can have major impacts on water levels in the wetlands [34, 5]. However, quantifying the effects of drought on wetland is beyond the scope of this study.

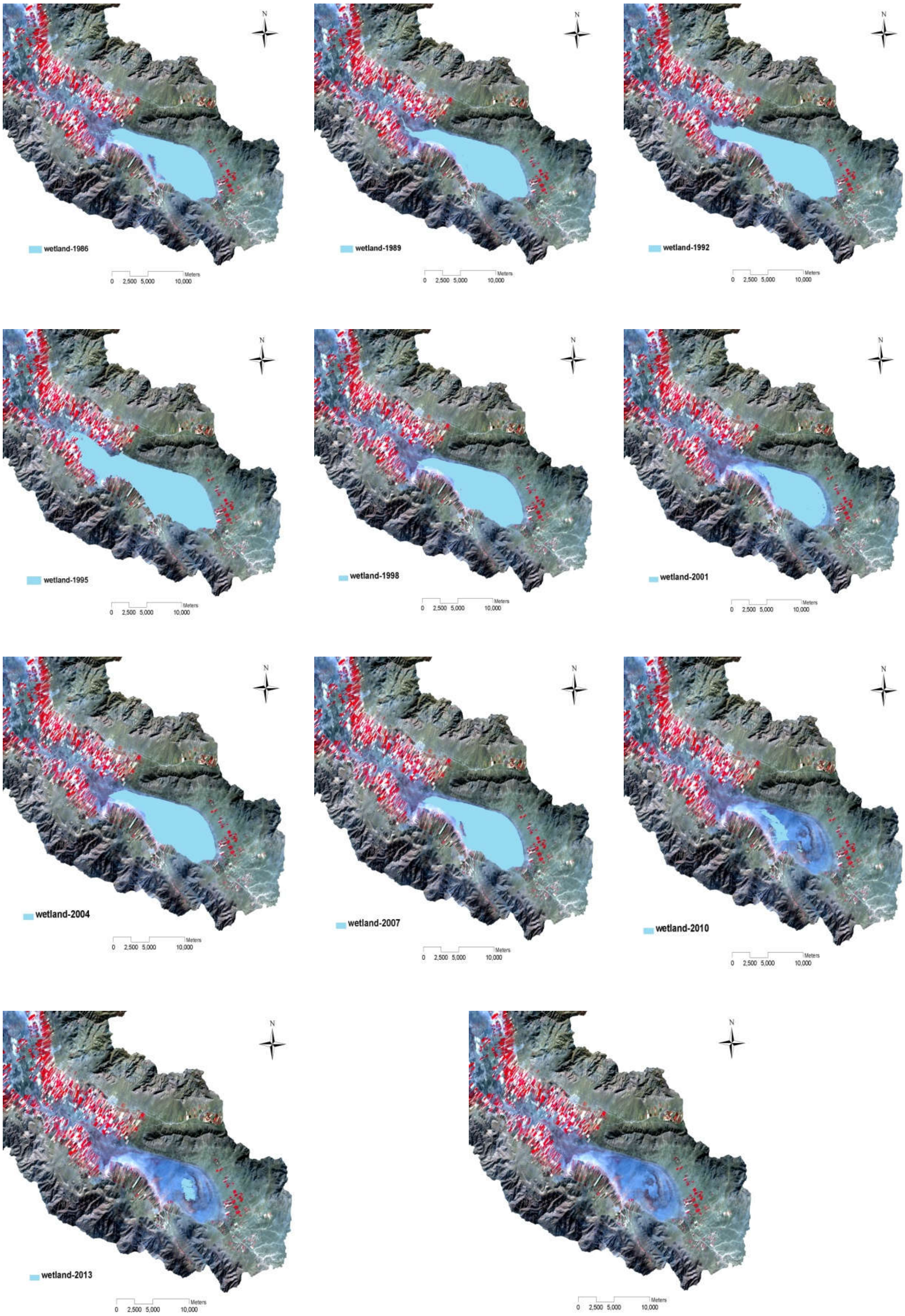

Figure 3: Wetland area changes in 3-years interval during 30-years period (1986-2016)

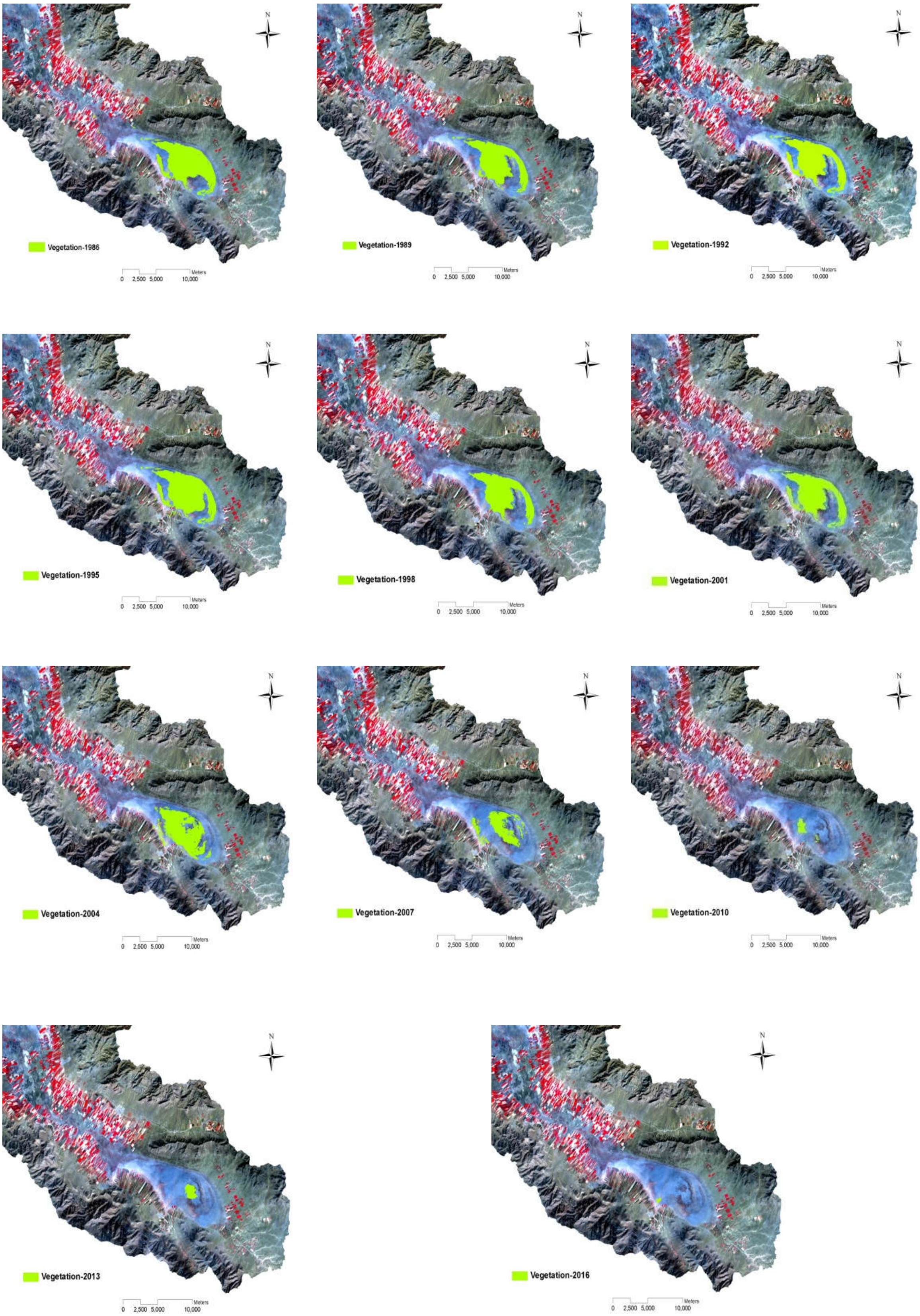

Figure 4: Wetland vegetation change in 3-years interval during 30-years period (1986-2016)

The changes of land use patterns certainly provide many social and economic benefits. However, they also come at a cost to the natural environment. One of the major direct environmental impacts of development is the degradation of water resources and water quality [31]. Land use in the catchment of wetland is a critical aspect of the water balance of the wetlands. Snow accumulation and snowmelt runoff is highly sensitive to the vegetative cover on the land and to the degree to which soil structure is disturbed by tillage. Undoubtedly, landuse/landcover changes in the catchment of Kaftar wetland during 30-years period had a great impact on wetland. Further studies can show the relationship between wetland changes and adjacent landuse/landcover changes.

In this study, the surface area and vegetation cover changes of Kaftar wetland, Iran in the period 1986–2015 were investigated. Results showed that significant change was occurred in area and vegetation cover of wetland during studied period. The year 1998 was the change-point in the 30-year time series of area and vegetation cover of wetland (1986 to 2016), when a sudden and significant reduction in the annual rate of changes were observed that have lasted until the present time. The determination of the year 1998 as the change- point in the trend of wetland area and vegetation cover is consistent with reports that documented extensive, severe, and continuous drought occurrences in all of Iran since 1998, which was attributed to the effectiveness and continuity of the strongest La Nina of the last half century [2, 33]. Based on forecasts that predict reduced rainfall amounts at low latitudes and subtropical areas due to climate change [26], we recommended the use of satellite imagery and atmospheric general circulation models to detect changes in wetland in a timely manner. Finally, we conclude that restoration wetland should become a priority in management plans to prevent the further loss of this important ecosystem and maintain the ecological functions provided by wetland.

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