Journal of Urban and Environmental Engineering, v.12, n.1, p.70-76

ISSN 1982-3932
doi: 10.4090/juee.2018.v12n1.070076

Journal of Urban and Environmental Engineering

www.journal-uee.org

WETLAND CHANGE ANALYSIS AND THEIR IMPACT ON DENSE VEGETATION BY SPATIAL APPROACH

Leelambar Singh* and Yashwant B. Katpatal

Department of Civil Engineering, Visvesvaraya National Institute of Technology, Nagpur, India

Received 20 September 2016; received in revised form 02 July 2018; accepted 17 July 2018

Abstract: Wetlands are the most important component of an ecosystem that provides ecological habitats and hence wetlands are supposed to be the indicators of healthy environment. It has been observed recently that the wetlands are affected by several anthropogenic impacts and climate change. Monitoring of the wetlands for their preservation has become mandatory. The present study uses MODIS satellite data of 2000 and 2014 for recording the temporal change in the status of the wetlands in Nagpur district, Maharashtra India. Least square regression correlation had been performed between wetlands area and corresponding (Normalized Difference Vegetation Index) NDVI of the selected wetlands. The study shows that the extent of the wetlands have reduced in the study area during 2000-2014. The Least square regression analysis result shows that vegetated areas within wetlands reduced during 2000 to 2014. This study highlights the present status of wetlands, which is helpful in future, conservation, assessment, and management of wetlands. The application of remote sensing and GIS techniques made analysis simpler and effective.

Keywords: Wetland; NDVI; GIS

* Correspondence to: Leelambar Singh, Cell Phone: +91 88 7126 4286.
E-mail: leeli.singh@gmail.com

INTRODUCTION

A wetland is a land feature which is covered by water. Wetlands are indicators of environmental health. These may be present in the form of Marshes and ponds, lakes, deltas at the mouth of a river or ocean and also include low-lying areas that are frequently flooded. It is an important component of the ecosystem, which maintains the hydrologic cycle, regulates climate and clarify environment pollution (Barducci et al. 2009; Beeton et al. 2002). According to 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' (Ramsar Convention, 1971). It helps in balancing the aquatic lives, improving quality of water, wildlife habitat and importantly, in maintaining the biodiversity. Wetlands also assist in reducing the flood impacts and improving the water quality.

This unique function of wetland generates importance of wetland in our lives, which provides an indirect connection between all species. The morphologic changes have occurred in wetlands all over the world due to either natural or anthropogenic processes (Du et al. 2011). Climate change is one of the reasons that cause declination in the water level due to less rainfall, which further affects the flora and fauna (McMenamin et al. 2008; Chase et al. 1999; Fragoso et al. 2011). Hydrological modification, watershed urbanization and the changes in the ecosystem use were identified as the main causes of wetland transformation (Hettiarachchi et al. 2014). Brazner et al. (1997) studied and concluded that urban growth and agriculture land expansion were the main causes for decline in the wetland conditions. Wetlands reduction is mainly due to anthropogenic activity and significantly related with loss of natural vegetation (Sánchez-Andrés et al. 2010). The water resources initiate the increasing vulnerability of aquatic plants and animals in wetlands and variation in hydrologic cycle (Sivakumar *et al*., 2016).

The purpose of this study is to monitor and report the wetland changes and hydrological changes caused as a result of human activities in the study area. To protect, conserve and manage the wetland resources, it is very important to have a record of the wetlands which require continuous monitoring. Remote sensing and Geographical Information System (GIS) are the efficient technologies available for analyzing and visualizing the earth's components. Remote sensing and GIS also plays a key role in monitoring and rehabilitation of wetlands (Gong et al. 2010; Rebolo et al. 2009; Yu et al. 1993). Hence, the aim of the study focuses on the changes of wetlands and their correlation with the vegetation content within the wetlands using the time series satellite data. The wetlands supports aquatic as well as terrestrial vegetation and change in the vegetation density has been directly correlated to the changing wetland extent in the present study.

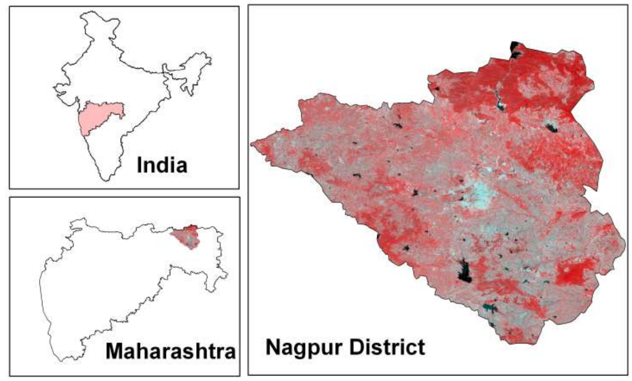

Fig. 1 Location of study area

Study area

Nagpur district of Maharashtra state (**Fig. 1**) in central India covers an area of about 9,892 km^2 which extends from 20°30′ - 21°45′ latitude to 78°15′ - 79°40′ longitude. The wetlands here mainly consist of lakes/ponds, rivers/streams, reservoirs/barrages.
The wetlands receive water either from rainfall in nearby catchment area or due to shallow groundwater inflow. The Nagpur district is dominated by man-made wetlands. Aquatic vegetation is more in pre-monsoon than in post-monsoon period. The wetlands are important features in the central Maharashtra as groundwater resources are not adequate in this region and these wetlands provide the different type of habitats and ecosystems.

Data description

High resolution satellite image (IRS P6 LISS IV) for the year 2000 and 2014 and MODIS-NDVI data (MOD13Q1) obtained from the NASA's Earth Observing System were used in the present analysis. The datasets were collected for the month of January in the year 2000 and 2014. The ground water levels were collected from the Water Resource Information System of India (WARIS) for the month of January for the years 2000 and 2014.

Methodology

Initially, the satellite data was obtained which was used for extraction of hydrological features in the GIS system (Arc Map 10.1 software) and the wetlands of Nagpur including natural (Lakes, rivers, ponds) and man-made (reservoirs, barrage) wetlands. Area of wetlands was extracted from attribute table by calculating geometry for both the years.

For calculating the variation in the NDVI responses to estimate the temporal changes around the wetlands, buffer analysis within GIS environment was carried out. For this, ten important wetlands were selected, and 500 m buffer was generated (using Arc Map 10.1). In order to understand the relationship between the areas of NDVI and wetlands, ordinary least square correlation analysis was performed which shows a linear relation between the two sets of data. The ordinary least square (OLS) regression is simplest linear modeling (**Eq. 1**) method to investigate the single response (Ryan, 1997). OLS regression is particularly powerful as it is relatively easy and also checks the model assumption such as linearity (Moutinho et al.,2011).

$$r = \frac{n\times\sum xy-(\sum x)(y)}{\sqrt{[n\sum x2-(\sum x)^2][[n\sum y2-(\sum y)^2]}} \quad (1)$$

In **Eq. 1,** x and y are dependent variables and *n* is the no of samples. Normalized Difference Vegetation Index (NDVI) was used to investigate the variation in the density of vegetation within and surrounding the wetlands. NDVI is widely used to investigate the growth and greenness of vegetation of a particular region. It is the ratio of the difference in red and near infrared bands to their sum. Mathematical calculation formula (**Eq. 2**) is

$$\text{NDVI} = \frac{NIR-RED}{NIR+RED} \quad (2)$$

where NIR is reflectance radiated in the near infrared wave band and RED is reflectance radiated in the visible red wave band of the satellite radiometer (Schowegerdt 1997; Kovacs et al., 2004). Its value ranges from +1 to -1 where positive values represent healthy vegetation cover and negative represent poor vegetation (Hsieh and Cheng, 1995; Green et al., 1998; Lin et al., 2006). NDVI based vegetation coverage classification has been done with simple linear model (**Eq. 3**) suggest by Gutman and Ignatov (1998).

$$\text{VC} = \frac{NDVI-NDVI_{NV}}{NDVI_V-ND\ \ _{NV}} \quad (3)$$

where NDVI_{NV} = NDVI value of non-vegetated component (bare soil); and NDVI_V = NDVI value of dense-vegetation component (forest). NDVI based area of selected wetlands was calculated in ArcMap 10.1 software.

RESULTS AND DISCUSSION

Wetland Change detection

In this study, changes in the extent of wetlands (change in the total area covered by wetlands) occurred during 2000 to 2014 were estimated. The quantitive data calculated to investigate the changes in wetlands of Nagpur district was generated by the satellite images (IRS P6 LISS IV) for the year 2000 and 2014. The temporal analysis of the wetlands show that most of the wetlands in the study area have reduced in their aerial extent and some of them have even dissapeared. A significant reduction in the areas of wetlands has been recorded in west of study area and a significant improvement has been found in the east region. **Table 2** shows that the area of selected wetlands have significantly reduced . The reason behind this change of area could be the expansion of agricultural area and uses of pesticides on farmlands which causes reduction in the vegetation and permit excess sediments directly into wetlands. The average changes in the area of selected wetlands in study region is 0.01017 km^2.

Temporal variation of vegetation within 500m buffer zone of wetland

To highlight the importance of wetlands on the surrounding ecosystem, variation of vegetation within 500m buffer zone of wetlands has been studied using MODIS-NDVI data. For the selected wetlands, 500m outer buffer has been generated (using arc map 10.1) and analyzed. Wetland maps and vegetation maps have been generated for the years 2000 and 2014. Ten big to medium wetlands of the study area have been selected for the analysis (**Fig. 3**).

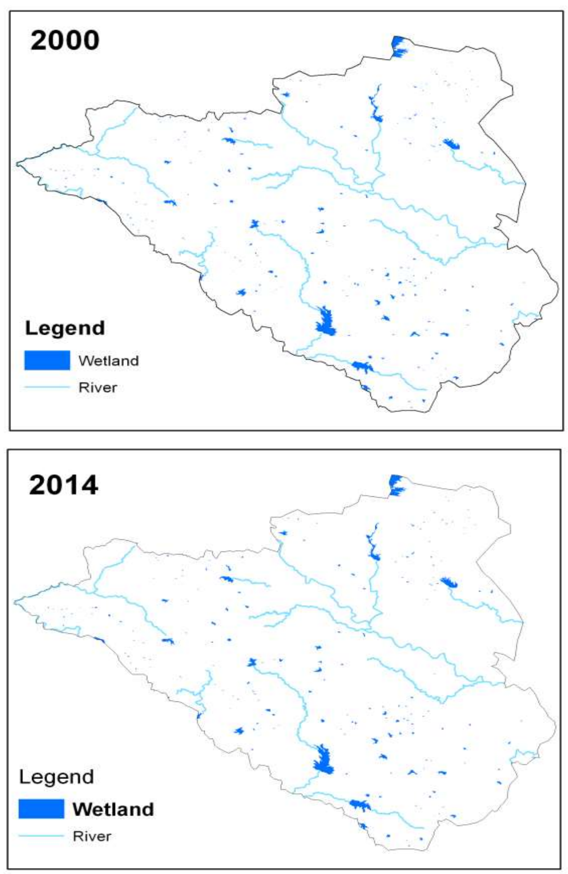

Fig.2 Map of Nagpur district showing Wetlands in 2014

Type of NDVI based vegetation image within 500 m buffer zones of selected wetlands for 2000 and 2014 are shown in **Fig. 4** and **5**. It is visible from the figure that most of the wetlands have reduced its area in 2014 as compared to that of 2000. **Fig. 4** shows the variation in average NDVI values within 500m buffer of selected wetlands. Average NDVI values of 2014 are less than that of 2000 at most of the sample points. **Fig. 5** shows the variation in the area of dense vegetation within 500m buffer zone.

Area of dense vegetation of 2014 has also been reduced as compared to that of 2000. The variation in NDVI for different selected wetland buffers for the year 2000 and 2014 as shown in **Fig. 4** and **5.** Result shows that in the year 2014, most of the NDVI area within the buffer reduced. For example, in wetland number 8, area reduced from 1.1 km^2 to 0.59 km^2 .

A Linear relation is found between NDVI and vegetation coverage (Ning et al. 2015). So, using **Eq. 3,** NDVI was converted into vegetation coverage. The vegetation coverage based vegetation classes were classified (**Table 1**) according to their NDVI ranges.

Area of selected wetlands and their vegetation coverage area within the buffer zones were analyzed with least square correlation and the result show that correlation for 2000 is weaker than that for 2014. However, both the years shows strong correlation between two parameters. Result shows that the correlation coefficient (r^2) between dense vegetation area and wetland area of 2000 and 2014 is 0.886 and 0.949 respectively, which shows impact of wetlands in 2014 is more than that in 2000 (**Fig. 6**).

Table 1 Classification of Vegetation Based on Vegetation Coverage

Vegetation type	Vegetation Coverage
Dense vegetation	>0.7
Medium vegetation	0.5-0.7
Sparse vegetation	0.3-0.5
No vegetation	0.1-0.3
Water bodies	<0.1

Table 2 Area of selected wetland for the year of 2000 and 2014

Selected wetlands	Wetland area (km^2)	
	2000	2014
1	3.86	3.82
2	3.1	3.098
3	3.57	3.51
4	1.17	1.174
5	1.19	2.12
6	1.49	1.46
7	8.94	8.925
8	1.71	1.7
9	0.69	0.681
10	0.27	0.268

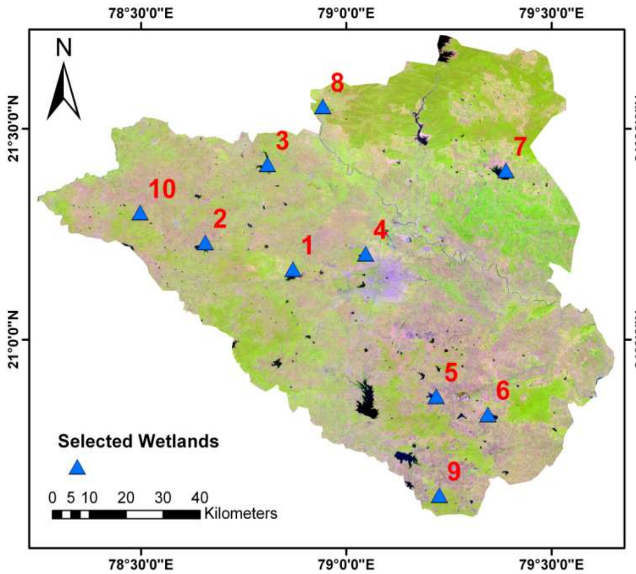

Fig. 3 Selected wetlands of the study area

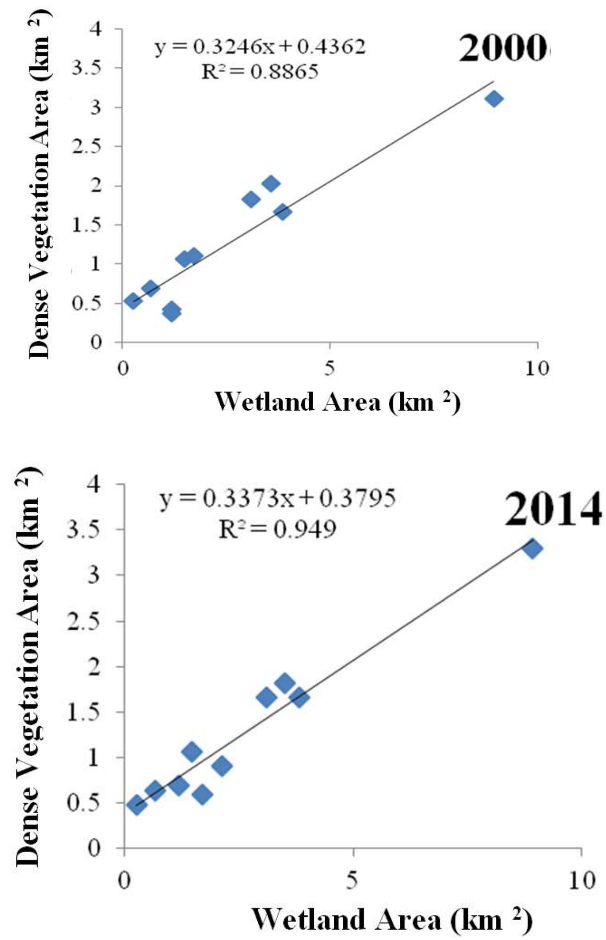

Fig.6. Relationship between dense vegetation area and wetland area of 2000 and 2014

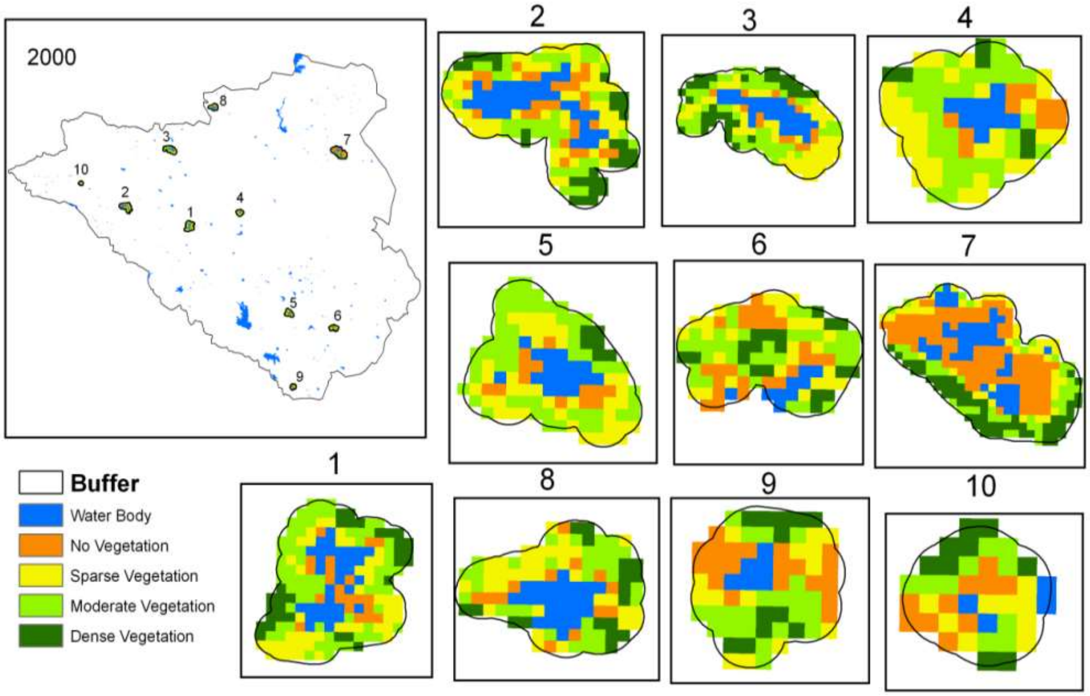

Fig. 4 variation in vegetation within 500m buffer of wetlands for the year 2000

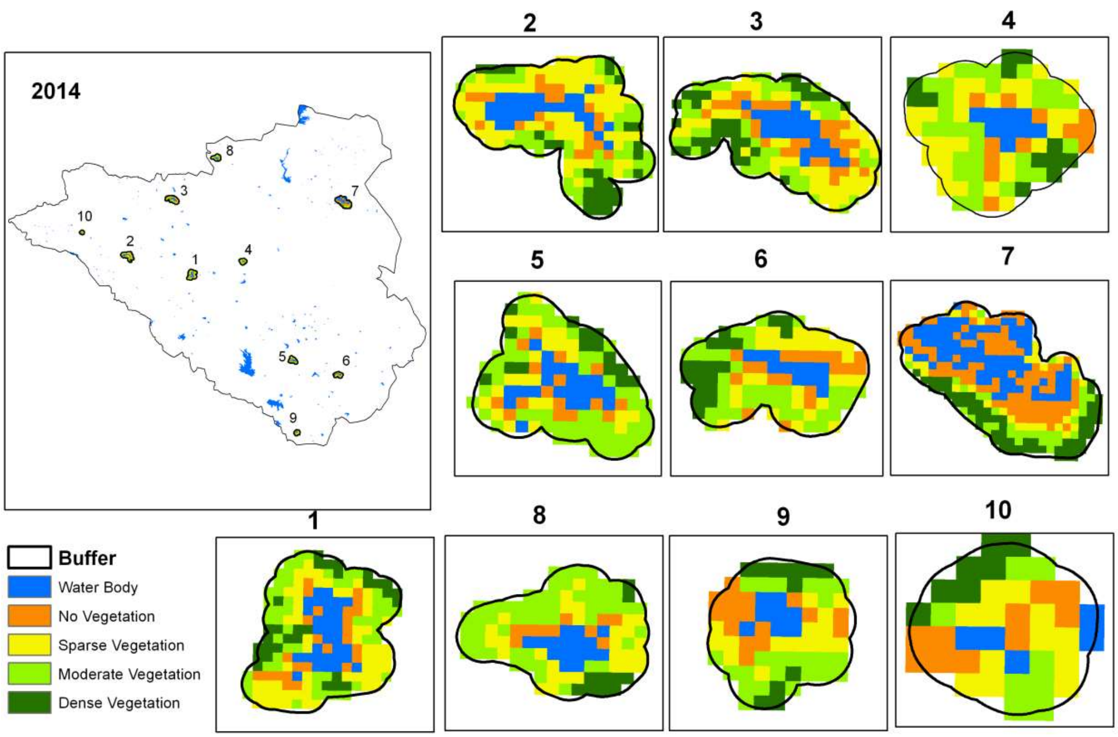

Fig. 5 variation in vegetation within 500m buffer of wetlands for the year 2014

Decrease in the dense vegetation area is noticed with the decrease in the wetland area. The greater correlation indicates the dependency of wetlands on vegetation coverage in study area. Overall relationship between wetland area and dense vegetation area has been shown in **Fig. 7**.

Relationship of wetland with ground water level

Ground water level contour map has been generated for the study period using ground water data for different well location in study area for the year 2000 and 2014. Ground water contour map has been super imposed over the elevation of area for better understanding (**Fig. 8**). Based on ground water contour map for the year 2000 and 2014, the ground water level was found to be high on lower slope zones. According to the results, the central-east part of study area shows high ground water level with low slope and east zone shows moderate water level with high slope. This is the area which has been found to be most affected in the present study. The result shows disappearance of wetlands in these regions. Wetland number 8 (**Fig. 8**) in north of the study area was severely affected and its area reduced in 2014.

Conclusions

The high-resolution satellite images for the year 2000 and 2014 were analyzed using remote and GIS techniques to study the variation in the extent of the wetlands. least square regression analysis result shows that area of wetlands reduced and some of the wetlands even disappeared in the study area from 2000 to 2014.the average areal change of wetland was found to be 0.01017 km^2. The reduction in the areal extent of the wetlands in the study area appears to have been caused by natural and human activities. The reduction of wetlands could disturb the balance of the hydrologic cycle, which is the main function of wetland. The wetlands change can be used to study the conversion of wetlands to other land use type and useful for improving capability of water resources in future.

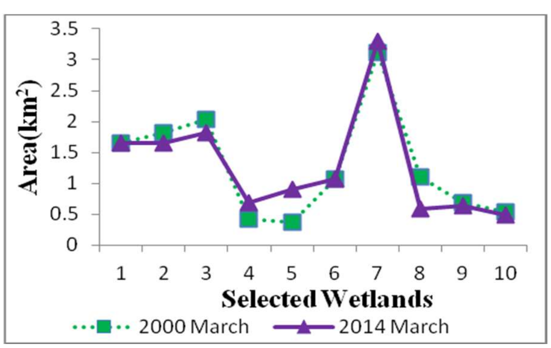

Fig. 7 Overall relationship between wetland area and dense vegetation area

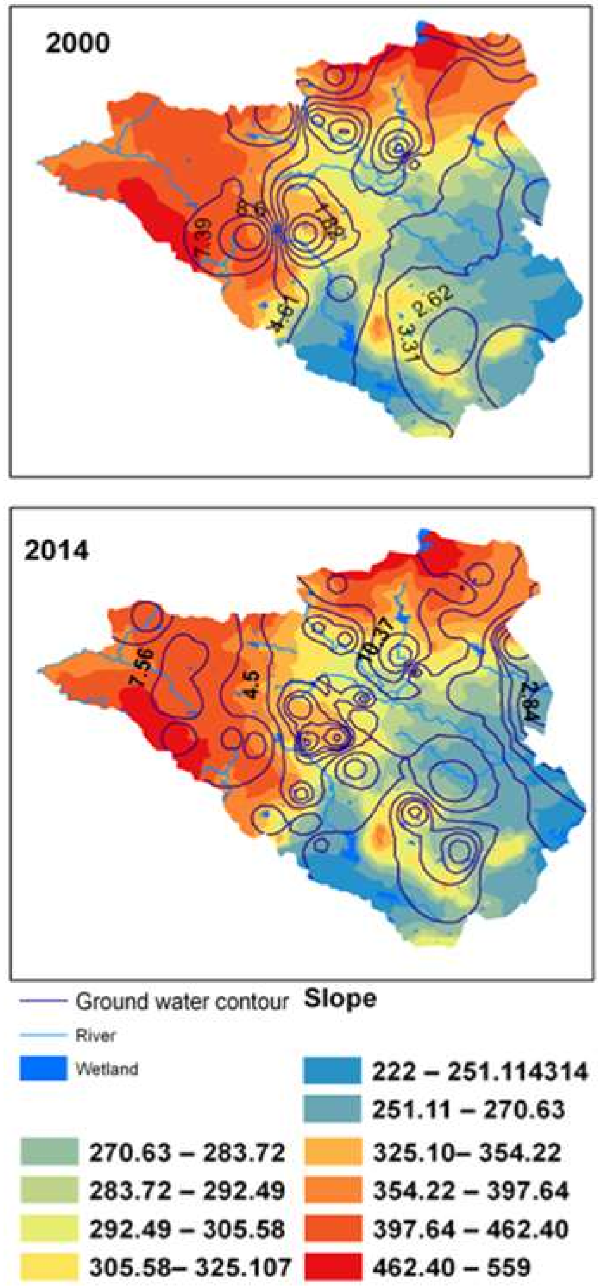

Fig. 8 Groundwater contour maps draped on DEM for the years 2000 and 2014

REFERENCES

Barducci, A.; Guzzi, D.; Marcoionni, P.; Pippi, I. Aerospace wetland monitoring by hyperspectral imaging sensors: A case study in the coastal zone of San Rossore Natural Park. J. Environ. Manag. 2009, 90, 2278–2286

Beeton AM (2002) Large freshwater lakes: present state, trends, and future. Environ Conserv 29:21–38

Brazner JC (1997) Regional, habitat, and human development influences on coastal wetland and beach fish assemblages in Green Bay, Lake Michigan. J Great Lake Res 23:36-51

Chase TN, Pielke RA, Kittel TG, Nemani RR, Running SW (1999) Simulated impacts of historical land cover changes on global climate in northern winter. Clim Dyn 16:93–105

Du Y, Xue H, Wu S, Ling F, Xiao F, Wei X (2011) Lake area changes in the middle Yangtze region of China over the 20th century. J Environ Manage 92:1248–1255

Fragoso Cr, Marques DM, Ferrira TF, janse JH, Nes EV (2011) Potential effect of climate change and eutrophication on a large subtropical shallow lake. Environ Model Softw 26:1337-1348

Gong P, Niu Z, Cheng X, Zhao K, Zhou D, Guo J, Liang L, Wang X, Li D, Huang H, Wang Y, Wang K, Li W, Wang X, Ying Q, Yang Z, Ye Y, Li Z, Zhuang D (2010) China's wetland change (1990–2000) determined by remote sensing. Earth Sci 53:1036–1042

Gutman, G., and Ignatov, A.(1998). The derivation of the green vegetation fraction from NOVAA/AVHRR data for use in numerical weather prediction model. Int. J. Remote Sens., 19(8), 1533–15

Hettiarachchi, M., Morrison, T.H., Wickramsinghe, D.,Mapa, R., Alwis, A.D.,MaAlpine, C.A. (2014) The eco-social transformation of urban wetlands: A case study of Colombo, Sri Lanka. Landscape and Urban Planning 132:55-678

McMenamin SK, Hadly EA, Wright CK (2008) Climate change and wetland desiccation cause amphibian decline in Yellowstone National Park. Proc Natl Acad Sci USA 105(44):16988-16993

Moutinho, L. and Hutcheson, G.D. (2011) The SAGE Dictionary of Quantitative Management Research, SAGE Publications, Thousand Oaks, 224-228

Ning, T., Liu, W., Lin, W., and Song, X. (2015). "NDVI variation and its responses to climate change on the northern Loess Plateau of China from 1998 to 2012." Adv. Meteorol., 2015, 1–10

Rebelo L, Finlayson CM, Nagabhatla N (2009) Remote sensing and GIS for wetland inventory, mapping and change analysis. J Environ Manage 90(7):2144–2153

Ryan, T.P. (1997) Modern Regression Methods. Chichester: John Wiley and Sons.

Sánchez-Andrés, R., Viedma, M.O., Sánchez-Carrillo, S. (2010) The Effect of Anthropogenic Stressors on Wetland Loss and Habitat Quality Deterioration in the Upper Guadiana Rive Basin: A Long-Term Assessment (1970-2000). Ecology of Threatened Semi-Arid Wetlands pp 85-107

Sivkumar, S. and Gosh, S. (2016) Wetland spatial dynamics and mitigation study: an integrated remote sensing and GIS approach. Nat Hazard (2016) 80:975-995.

THE RAMSAR CONVENTION AND ITS MISSION (1971) http://www.ramsar.org/about/the-ramsar-convention-and-its-mission

Yu LZ, Xu Y, Cai SM, Zhang XY (1993) A GIS-based study on recent environmental change in Honghu Lake. J Lake Sci 5(4):350–357