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Monitoring Temporal Changes in Lake Nal Sarovar Water Surface Area using Satellite Imageries

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Abstract:

The Nalsarovar Lake, a Ramsar site, is a beautiful bird sanctuary on the borders of Ahmedbad and Surendranagar districts of Gujarat. It is not only full of life but also gives life and livelihood to people living around this lake. Bustling with activities and roosting of birds, this lake is also quite fragile and vulnerable to damage and degradation even with the small change in its environment. Nal Sarovar being a seasonal lake shrinks considerably during pre-monsoon period and inundates large area during monsoon season. Changes in lake area from season to season is a normal phenomena but temporal changes in lake area over the years is important to study as it might indicate adverse impact on monitoring healthy environment in a shallow lake like Nal Sarovar. In this study satellite imageries covering three decades from Landsat 5-TM (Thematic Mapper), Landsat 7-ETM+ and Landsat 8-OLI were used from years 1989 to 2016. From the imageries taken for four years (1989, 1996, 2006 and 2016) the pre and post monsoon changes in lake surface area were found out which included deep and shallow water with submerged and emergent vegetation. However, increase in lake surface area in October, 2016 (127 sq km) from December, 1989 (79 sq km) and October, 1996 (63 sq km) with almost similar rainfall range is an important event attracting attention in the study. Despite having average rainfall in these three years, the lake water surface area is seen to have increased significantly by 60.70 per cent in 2016. Many bird species have lost their habitat as the water has become too deep for them to nest and hunt. This situation can be alarming as it directly leads to a drop in the number of migratory birds.

Key Words: Nal Sarovar, Bird Sanctuary, Wetland, Remote Sensing, Lake Expansion, Endangered wetland Ecosystem.

1. Introduction

The Nal Sarovar Lake was declared a Ramsar site by The Convention on Wetlands of International Importance in 2012 on 24 September because of its importance. It is the 26th RAMSAR site of India of international importance and is a notified Bird Sanctuary with an area of 120.82 Km^2 (The Ramsar Convention on Wetlands, 2012). Hundreds of species of birds and other flora and fauna can be experienced here in a mere single visit. It is not only full of life but also gives life and livelihood to people living around this lake.

Wetlands play a very important role in life cycle of avifauna (Murthy et al, 2011), other life forms dependent on the wetlands and livelihood of people living in the surrounding area. Management of wetlands requires many parameters but hydrology is the most important one (Murthy et al, 2011). This paper highlights changes in Lake Nal Sarovar water surface area with time covering three decades from 1989 to 2016.

2. Study Area

Nal Sarovar is one of the largest shallow water lakes and a bird sanctuary in Gujarat and is situated in a flat low lying area (Management Plan for NBS, 2014). Area wise, this natural freshwater lake measures 120.82 km^2 also notified as the bird sanctuary under the Wildlife (protection) Act, 1972 (GEER Foundation, 1998) which is located between 71°92'E to 72°8' E and 22°40'N to 22°55'N in a semi-arid region of Gujarat's Surendranagar and Ahmedabad districts (Fig 1). The shape of the lake is elongated or ovo-ellipsoidal (Nirmal et al, 2006), which slopes from North-West to South direction found out by SRTM-DEM satellite imagery. The maximum depth of the lake ranges between 1.5 to 2.0 m (Tatu et. al, 2014). Table 1 shows the morphometric features of Lake Nal Sarovar. The Lake receives water from Bhogavo and Brahmini rivers apart from surface runoff during rainfall. Several small canals also flow in the catchment area. The Nal Sarovar Bird Sanctuary supports more than 260 species of birds including some threatened and

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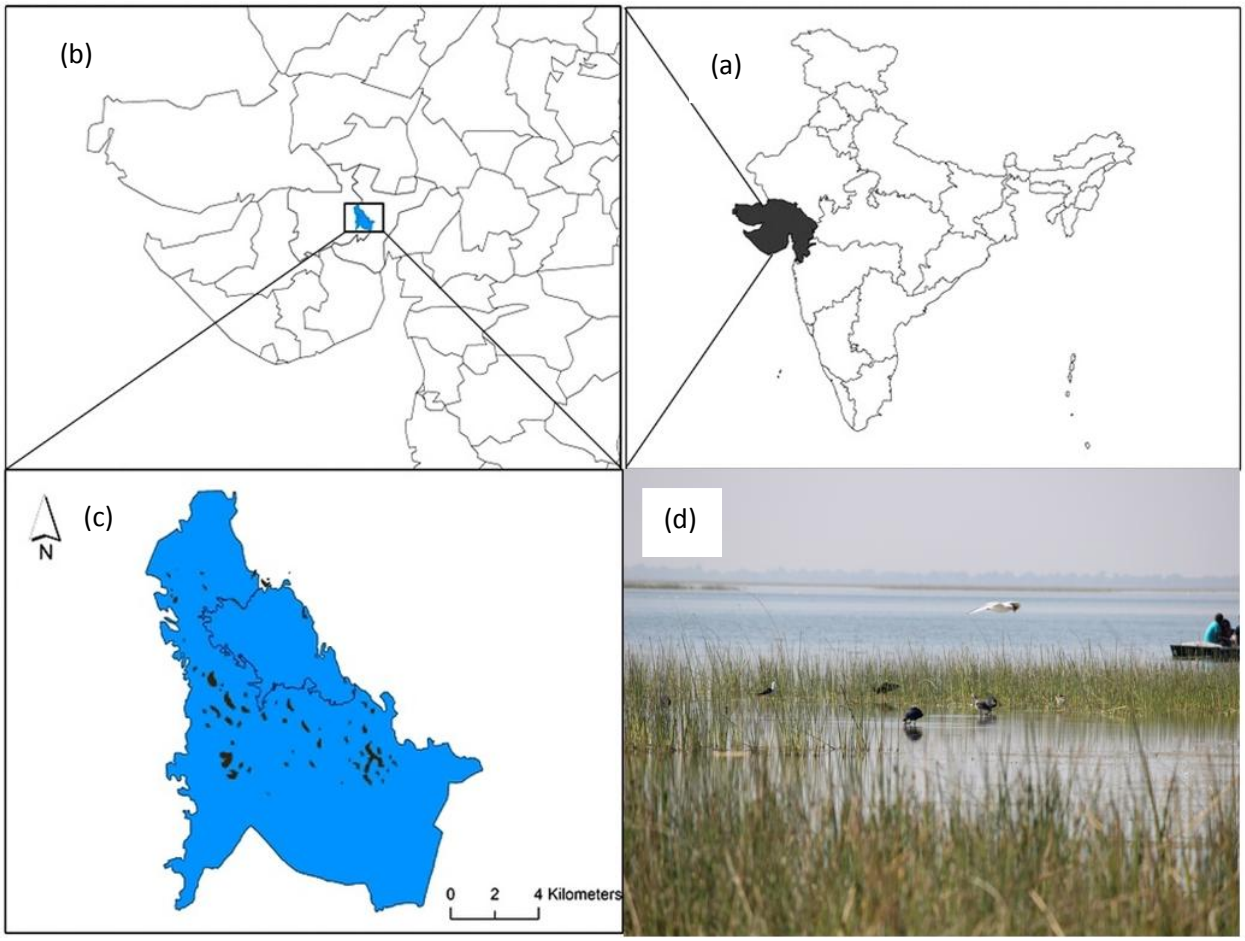

Fig. 1. Location Map of Nal Sarovar Lake, Gujarat.

endangered species, thus, clearly signifying the lake as an internationally important wetland as per criteria proposed by RAMSAR Convention (Kumar et al, 2006).

3. Materials and Methods

In this study satellite imageries covering three decades (1989-2016) from cloud free Landsat 5-TM (Thematic Mapper), Landsat 7-ETM+ and Landsat 8-OLI were used. The images were freely downloaded from Earthexplorer (USGS) web page. The satellite data set was provided in a standard GeoTIFF format with a UTM projection, using the WGS-84 datum (42N). To study the changes in lake area time steps used were 1989, 1996, 2006 and 2016. The satellite imagery for the year 1986 was substituted by year 1989 imagery due to no availability of satellite data. Images for the year 2006 were destripped to get better and clear results. Histogram equalization was applied to all the images and then images were masked out with the watershed area. To get a definite reflection of changing lake area, satellite imageries

Table 1. Morphometry of Nal Sarovar Lake, Gujarat

Latitude	22°40'N to 22°55'N
Longitude	71°92'E to 72°8' E
Biotic Province	4B Gujarat-

	Rajwara (Semi-arid lands of central Gujarat)
Total Area (km²)	120.821
Slope	North-west to South
Maximum length (km)	90
Maximum breadth (km)	35
Mean Depth (m)	1.0
Average Rainfall (mm)	580
Average Temperature (°C)	15 to 35
Number of Islets	More than 300

were used for the same months each year, viz. month of May and October for pre-monsoon and post-monsoon study, respectively. To process the imageries a simple but effective method NDWI (Normalized Difference Water Index) was calculated in ERDAS IMAGINE 2010 to see changes in total lake area (Fig 3a and 3b). The change in surface water area is shown in Fig.2 with shallow and deep water areas manually digitized in ArcGIS10 on Landsat imageries. NDWI was calculated as the ratio of the measured intensities in Green (G) and Near Infrared (NIR) spectral bands (Abayazid, 2015). It is commonly computed by applying the following equation: NDWI= (Green-NIR)/ (Green+NIR).

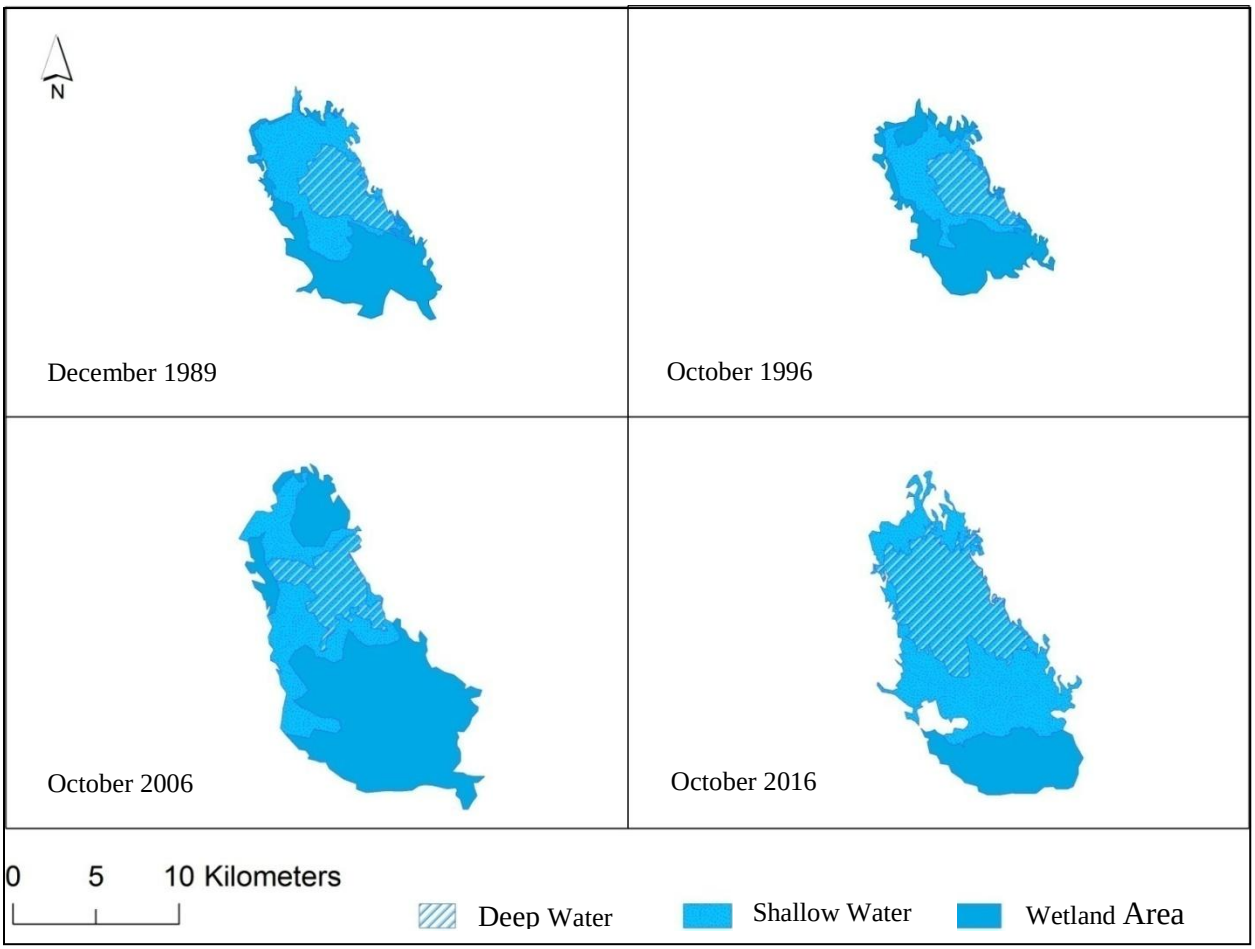

Fig.2. Temporal changes in wetland area of Lake Nal Sarovar versus year (Post- Monsoon)

A digitized map from four toposheets (F43G1, F43G2, F42L13 and F42L14) of Survey of India, Gujarat, was studied for morphometry as it shows an all time maximum extent of levels of water which is not specific for any particular season or year. Also, the same lake boundary has been considered by the forest department as an official boundary for Nal Sarovar Bird Sanctuary as shown in Fig 1.

The meteorological data used, to see if the change in lake area is related to the climatic conditions, was taken from Meteorological Centre, Ahmedabad, Gujarat, 2016. It includes total annual and monthly rainfall in millimeters (mm) and average annual and monthly temperature in Degree Celsius (°C) for the years 1989, 1996, 2006 and 2016 as shown in Fig. 3 and 4 (a and b). The maximum and minimum temperatures are generally recorded in the months of May-June and December- January, respectively. Whereas, maximum and minimum rainfall is recorded in the months of July-August and December to May, respectively (Meteorological Centre, Ahmedabad,2016).

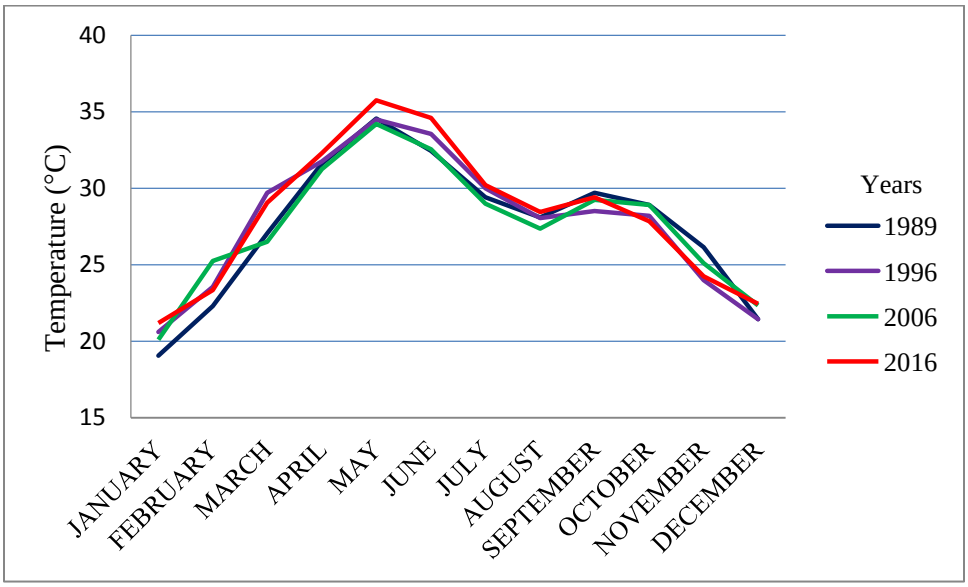

Fig. 3a: Mean Monthly Temperature from 1989 to 2016

The pre-monsoon month taken for the study is May for all the images to see the minimum extent of lake area as all the years record no rainfall till the month before monsoon. Similarly, the post monsoon month is taken as October to see the maximum extent of lake area. The other months between October and may go dry with minimal to no rainfall. However, for the year 1989, the post- monsoon month is taken as December instead of October as no satellite imagery for the same month was available.

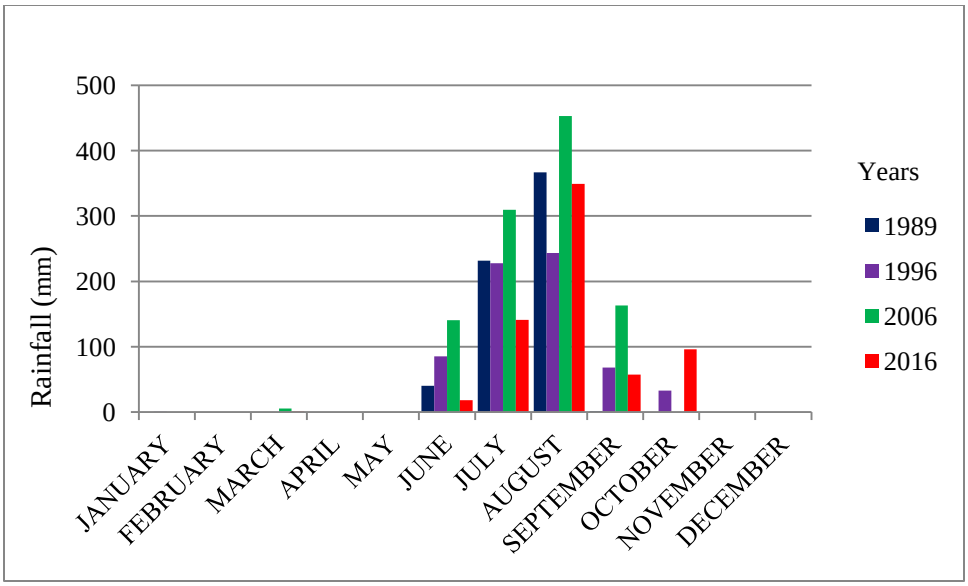

Fig. 3b: Monthly Total Rainfall from 1989 to 2016

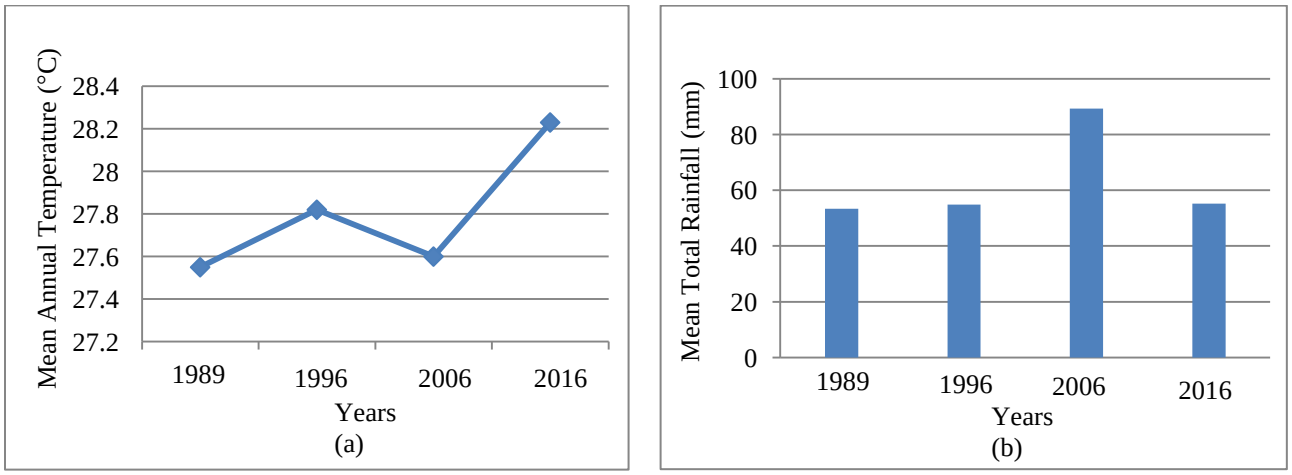

Fig.4: (a) Mean Annual Temperature (^{o}C) and (b) Mean Total Annual Rainfall (mm) between 1989 and 2016

4. Results and Discussion

From the imageries taken for four years (1989, 1996, 2006 and 2016) the pre and post monsoon change in lake surface area were found out which included deep, shallow water and moist land with emergent vegetation (Fig 2, 5a and 5b).

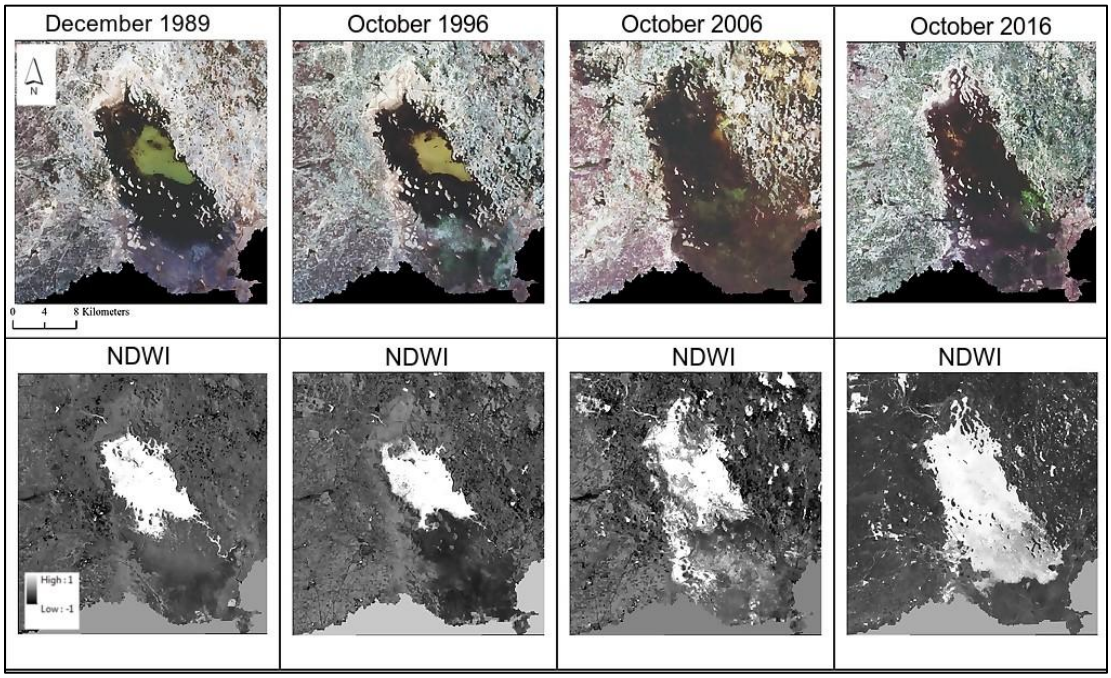

Fig 5a: Temporal Changes in spatial NDWI within Lake Nal Sarovar (Post- Monsoon)

The temporal change in water surface area was determined to be 15 sq km in May, 1989 (Pre-monsoon) and 79 sq km in December, 1989 (Post-monsoon); 8 sq km in May, 1996 and 63 sq km in October, 1996; 23 sq km in May, 2006 and 140 sq km in October, 2006; 24 sq km in May, 2016 and 127
sq km in October, 2016 as shown in Table 2. The change in percentage of the wetland area was calculated using formula:

Current Year Wetland Area- Previous Year Wetland Area/Previous Year Wetland Area.

The calculated change in wetland area in percentage is shown in table 2. The overall water surface area has increased by 60.76 per cent from December 1989 to October 2016, which is an increase of 48 km^2. The water surface area decrease to its minimum in the month of May due to lack of rainfall, high temperatures and demand of water for irrigation.

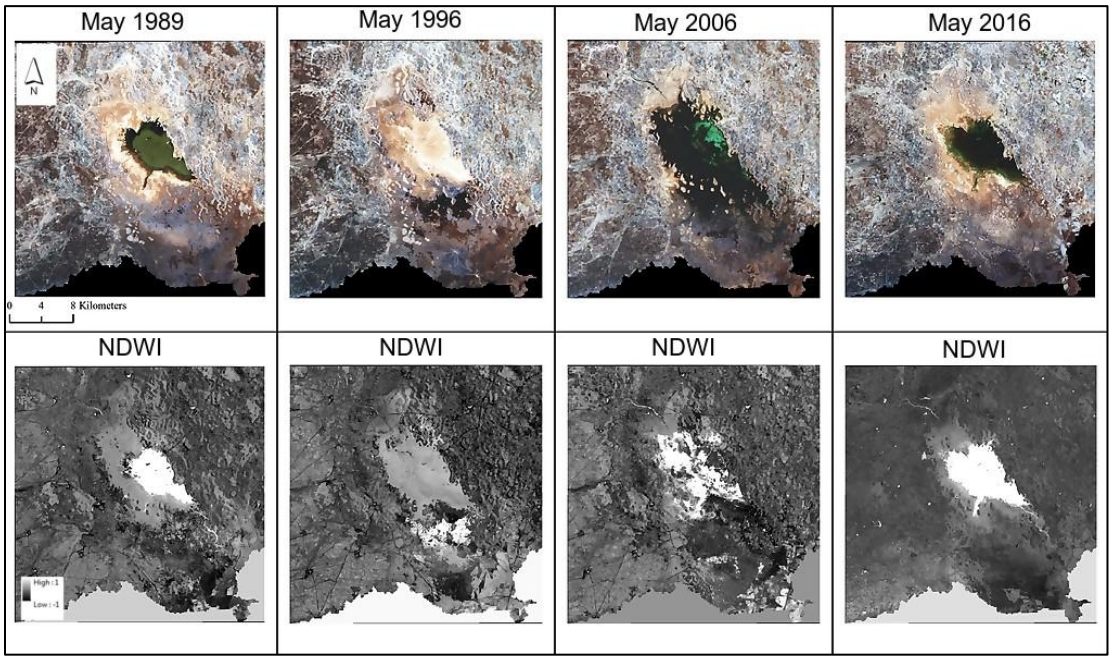

Fig 5b: Temporal Changes in spatial NDWI within Lake Nal Sarovar (Pre- Monsoon)

According to meteorology data, the total rainfall for the year 1989 was 640.3 mm, 657.6 mm in 1996, 1071.3 mm in 2006 and 662.9 mm in 2016. The total rainfall in 2006 was higher than the average rainfall resulting in an increase in the water surface area of the lake compared other years. Rainfall, temperature and water surface area for all the years are compared in table 3.

Table 2: Change in total Wetland Area from 1989 to 2016 (Post-Monsoon)

	Total Wetland Area (km^2)	↑ ↓ (km^2)	Deep Water Area (km^2)	Shallow Water Area (km^2)	Emergent Vegetation Area (km^2)	Change in Total Wetland Area in percentage (+/-)
December 1989	79	--	16	28	35	--
October 1996	63	16 ↓	13	18	32	-20.25
October 2006	140	77 ↑	19	39	82	+122.22
October 2016	127	13 ↓	43	57	27	-9.29

In terms of temperature, Fig 4a shows that the temperature has significantly increased in 2016 as compared to other years.

However, increase in lake surface area in October, 2016 (127 sq km) from December, 1989 (79 sq km) and October, 1996 (63 sq km) with almost similar rainfall range is an important event attracting attention in the study. Despite having average rainfall in these three years, the lake water is seen to have increased significantly by 60.70 per cent in 2016.

Table 3: Temporal Changes in Water Surface Area, Temperature and Rainfall of Lake Nal Sarovar

Criteria	Year 1989	Year 1996	Year 2006	Year 2016
Total Lake Surface Area (km^2)	79	63	140	127
Average Temperature (^0C)	27.55	27.82	27.6	28.23
Average Total Rainfall(mm)	53.35	54.8	89.27	55.24

The result cannot solely be related to meteorological data as there is not much of variation in rainfall but only in temperature pattern. With a sudden increase in temperature with the combination of average rainfall, the lake should be shrinking due to higher evaporation which is not happening in reality. This also shows that climate change is not the factor behind this increase in lake surface area. The important factors which could be causing this increase in water area are exterior intervention and sedimentation over a period of time. The exterior intervention can include

introduction of various canal systems through main Saurashtra Canal System which gets Naramada's water. A survey by Forest Department, Gujarat, 2016, has confirmed that water is overflowing from Narmada distributary canals to Nal Sarovar from Surendranagar has caused an increase in its water level. Though, these canals do not directly flow towards Nal Sarovar but in its catchment area. According to Forest Range Officer Prajapati, 2016, water released by Narmada to different feeder canals and Bhogavo river in catchment area find its way to Nal Sarovar through small rivulets. It can also be seen in Fig. 6 in red ellipse that the Narmada (Saurashtra Branch) canal was nonexistent in 1989 and under construction in 1996. But, in 2006 and 2016 it is seen to be fully constructed and water was released in this canal.

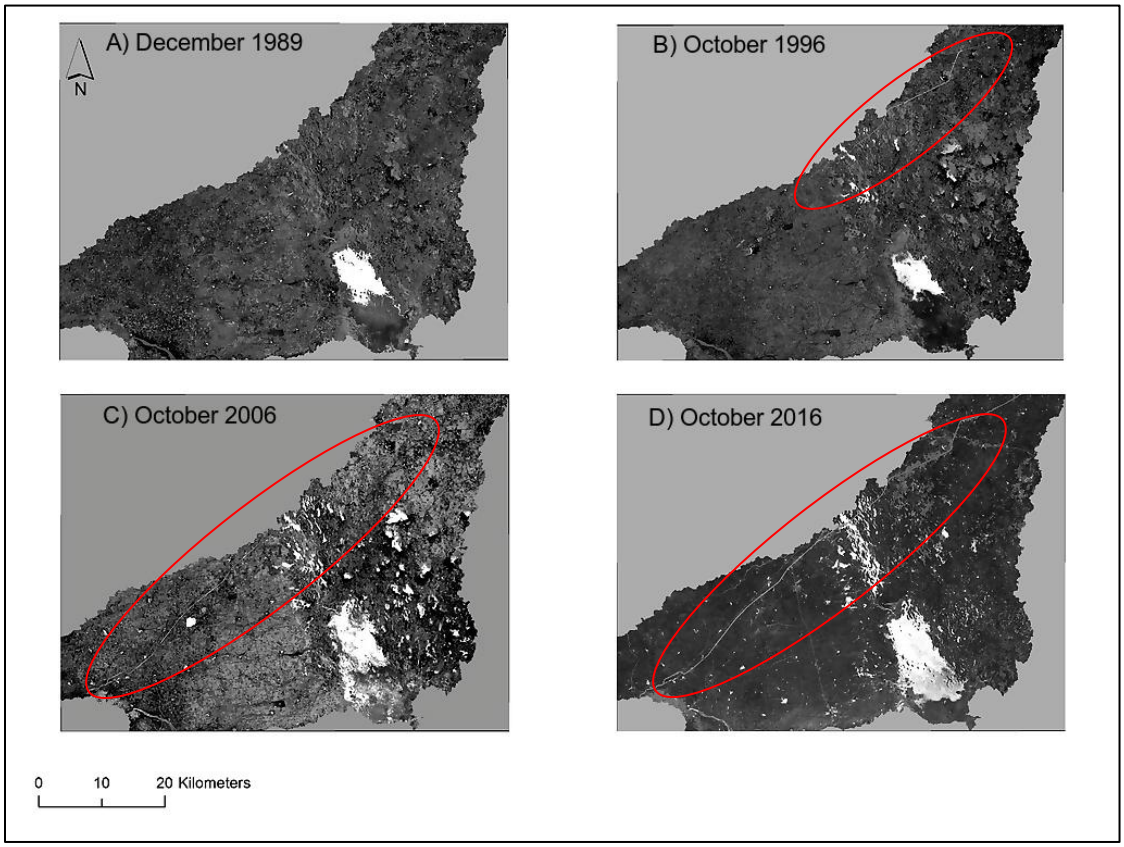

Fig 6. Progressive change in Narmada Canal (Saurashtra Branch) system in Nal Sarovar Catchment Area (1989-2016)

This canal contributes water to Nal Sarovar by releasing water for irrigation which seeps in to the lake raising its water level. On the other hand, the management plan of Nal Sarovar Bird Sanctuary, 2002- 2006, suggests that certain areas of feeder canals and small streams are affected by siltation. Desilting excavation and gully plugging were suggested as plans in this management plan. However, the most recent management plan of 2014 shows that there is no major desiltation activity happening in this area, rather it is still on the plans as mentioned by the Forest Range Officer Prajapati R. in 2016. Therefore, introduction of Narmada Canal system and siltation seem to be the plausible reasons for the rise in water level in the lake area in 2016 as compared to 1989.

5. Conclusion

In this study, the changes in Nal Sarovar Lake area were investigated using satellite images with the help of remote sensing techniques from year 1989 to 2016. Landsat images from 1989, 1996, 2006 and 2016 were analyzed with related meteorological and physical data. Over the study period an increase in the lake area was detected. With a slight change in rainfall pattern throughout years and a sudden shoot up of temperature in year 2016, when the water level should have decreased due to evaporation in high temperatures, the lake area showed and expansion in comparison to 1989 and 1996. Among the reasons for this expansion are introduction of Narmada Canal and minimal to no de-sedimentation in the catchment area. The current situation is a threat to the ecological balance of the study area. Several bird species which prefer shallow waters for breeding and hunting have left the region. It is not only a threat to bird species but other vegetation, wildlife, fish and insects as well which are adapted to shallow water environment. Therefore, it becomes important to study the area in order to save its natural ecosystem which is being altered by human interference. Also, this study has shown that satellite data can be of real help to monitor wetland ecosystems which can further suggest better ways to conserve the water resource as well as life forms connected to it.

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