Study of changes in land use and land cover in and around the Chah Nimeh water reservoir in Sistan and Baluchistan Province, Iran

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Abstract: Remote sensing is the technology of obtaining information and imaging from the ground using aviation equipment such as airplanes, balloons or space equipment such as satellites. Remote sensing is the science of extracting information from terrestrial objects indirectly. High remote sensing capabilities such as cost-effectiveness and availability of this data have made them an important source of information. By examining multi-time satellite images, we can understand land use changes. This study examines the trend of land use change, vegetation dynamics and water area changes in Chah Nimeh over a five-year period. For this purpose, Sentinel 2 satellite images from April 2016 to April 2020 have been used. After making the necessary corrections, using the unsupervised classification method and relying on the spectral characteristics of the phenomena in different bands, a land use map of the region was prepared. The percentage of changes in each of the uses was obtained after determining the area in GIS. The accuracy of the method was reviewed with samples taken from Google Earth images on the same date as the satellite images. According to the kappa coefficients for the years 2016 to 2020 (0.75, 0.83, 0.81, 0.79 and 0.83), the use of spectral properties of phenomena in this type of classification is highly reliable. Also, according to the results, no significant changes were observed in the area of Chah Nimeh and surrounding lands during these 5 years.

Keywords: Land use, Remote sensing, Chah Nimeh, GIS, Google Earth images, Satellite images

1. Introduction

Ground cover has been changing since ancient times and will change in the future (Ramankutty, 1998). With recent advances in remote sensing and geographic information systems (GIS) and computer science, it has become possible to assess and monitor land use change and land cover at the spatial and temporal scales (Hansen and Defries, 2004). The first land cover classification methods were applied to Landsat satellite imagery in the early 1970s. Supervised and unsupervised classification methods such as maximum likelihood and Duplicate self-organizing data (ISODAT) (Phiri et al, 2017). Monitoring of land use changes in time intervals is achieved through remote sensing techniques in a shorter period of time, at a lower cost and with greater accuracy (Kachhwaha, 1985). Mallupattu et al. Studied land use and land cover (LU / LC) changes using Geographic Information Systems (GIS) and remote sensing technology in an urban area in Tiropathy, from 1976 to 2003 (Mallupattu et al, 2013). Rwanga et al. Conducted a study with the aim of classifying land use and regional land cover in Limpopo province using remote sensing techniques and spatial information system (GIS) (Rwanga et al, 2017). Rahman et al. Analyzed land use / land cover northwest of Delhi for the period 1972–2003 using remote sensing data (Rahman et al, 2012). Butt et al. (2015) conducted a study using the maximum likelihood classification algorithm in ERDAS to determine land cover changes in the Simli watershed, Pakistan. This study was performed using multispectral satellite data obtained from Landsat 5 and SPOT 5 for 1992 and 2012. Using Markov chain and remote sensing data, Mishra et al. predicted future LULC change for 2038 and 2050. The results of this study show that rapid growth in built-up areas leads to a continuous decline in agricultural land (Mishra et al, 2016). In a study, Weigand et al. Used large-scale high-resolution Sentinel-2 images to produce land use and land cover map (Weigand et al, 2020). One of the exceptional and almost unique forms in Iran is shallow closed and open holes, which are called Chah Nimeh. This phenomenon has been reported and named only in the eastern part of Iran. These wells are the most important source of water supply in Sistan plain and large and densely populated cities such as Zahedan and Zabol (Sistan and Baluchestan Regional Water Administration Studies Office, 2004: 4). In this study, the changes in the water area of the Chah Nimeh and the land use of the surrounding lands have been investigated.

2-Materials and Methods

2-1-Study area

The study area is located between 59 degrees to 70 degrees and 30 minutes east longitude and 29 degrees to 34 degrees north latitude. Chah Nimeh is large natural holes and pits that is located 50 km away from Zabol city and 5 km away from Zahak city, next to Qala-e-Novi village. There are four Chah Nimehs 1,2,3 and 4. Excess water from the Helmand River is directed to them by a canal. The capacity of 3 (1, 2, 3) Chah Nimehs is 700 million cubic meters. The capacity of well number 4 is up to 800 million cubic meters, which has become an artificial lake. The total capacity of these Chah Nimehs is at best one-seventh of Hamoun International Wetland. Figure 1 shows the location of the study area.

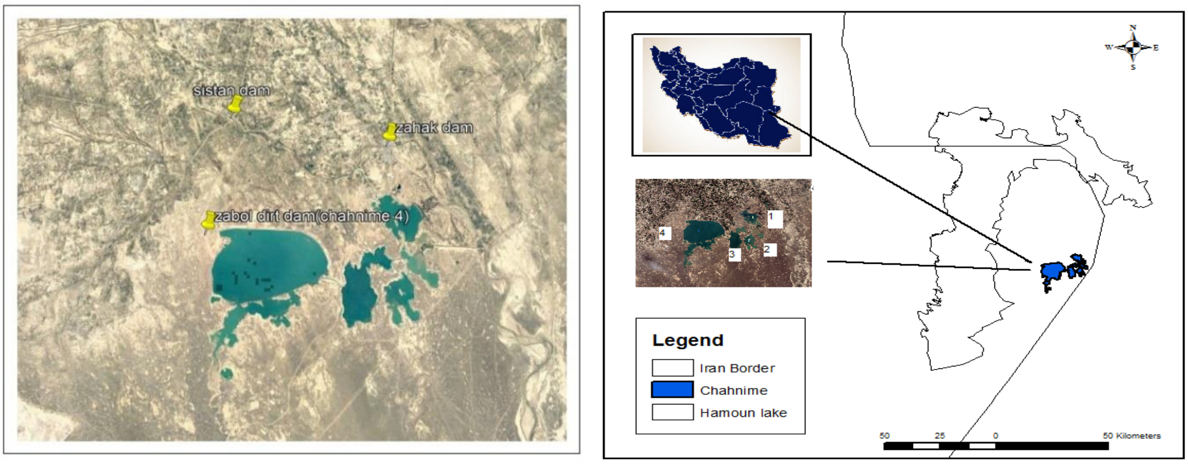


Figure 1- The location of the study area

2-2-Satellite Images

In order to study land use changes in the study area, Sentinel 2 satellite images from 2016 to 2020 were used. Due to the climate of the study area, the vegetation of this area has a short growth period due to increasing temperature and high evaporation. In this region, the growing season of plants is completed in April (Rahdari et al., 2011). With this in mind, April images were used. Table 1 and 2 show the information and date of the received images. Figure 2 shows satellite images with false colour combinations.

Table 1. Sentinel satellite specifications

Spatial resolution	Wavelength center spectral range	Spatial resolution	Wavelength center spectral range
(Meter)	(Micrometer)	(Meter)	(Micrometer)
60	Band1- aerosol 0.443	10	Band8-NIR 0.842
10	Band2- Blue 0.490	20	Band8A- vegetation 0.865
10	Band3- Green 0.560	60	Band9-Water vapour 0.945
10	Band 4- Red 0.665	60	Band10-SWIR 1.375
20	Band5- vegetation 0.705	20	Band 11-SWIR 1.610
20	Band6-vegetation 0.740	20	Band 12- SWIR 2.190
20	Band7-vegetation 0.783		

Table 2. Date of receiving satellite images

Date received	2016.4.23	2017.4.28	2018.4.28	2019.4.25	2020.4.27

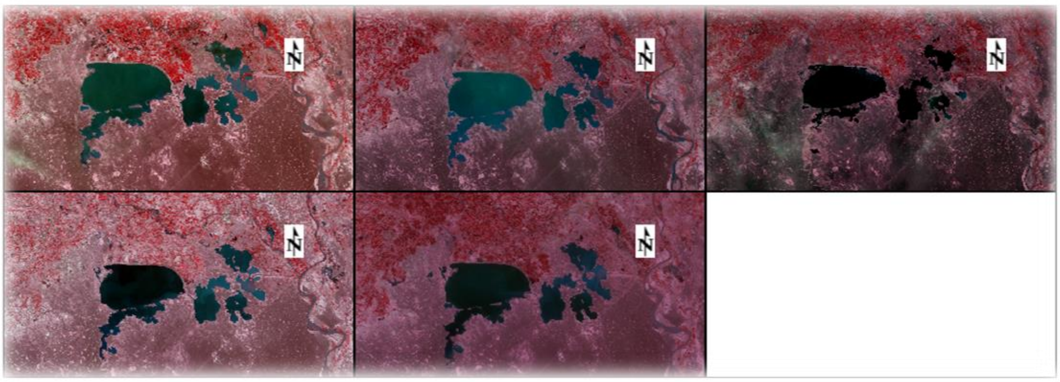


Figure 2- Satellite images with false colour combinations

2-3-Unsupervised classification

Classification techniques are used to group the pixels to show the details of the land cover. Unsupervised and supervised classifications are two of the most common types of classifications. If we do not have much knowledge about the study area, we should use unsupervised classification (Treatise on Geophysics (Second Edition), 2015; Lane et al, 2014). In unsupervised classification, clustering algorithms are used to distribute pixels in multidimensional space and create different pixel clusters. Pixels are divided into groups based on reflective properties. There are various unsupervised classification methods whose main purpose is to be able to classify different spectral information in the most optimal way possible. Spectral similarities between pixels prevent clusters from being separated correctly and easily. The analysis of the distribution of clusters around the mean is determined by the mean standard deviation of each of the recorded spectral bands. The narrower the clusters created in the feature space, the more likely they are to be separable in the feature space. The proximity analysis of clusters in the feature space is determined by measuring the distance between their centers. If the distances between the centers of the clusters are less than the desired threshold, they are combined with each other. Generally, the last cluster obtained from repeating the calculations is the best. The most commonly used cluster algorithms include K-Means, Iterative Self-Organizing Data Analysis Technique (ISODATA), and agglomerative hierarchical (Duda and Canty, 2002). After the clusters are formed in the feature space, their statistical information is extracted and then this information is used for the final classification of the original image.

2-4-SNAP software

SNAP stands for Sentinels Application Platforms, an open-source software for processing Sentinel series satellite data. This open-source software, designed by the European Space Agency, has provided the ability to perform a variety of specialized processing of Sentinel series satellites along with radar data in a practical and effective way. Snap software automatically recalls the data of the Sentinel 2 satellite, and without the need for geometric corrections, radiometric corrections and atmospheric corrections of the satellite images can be performed. The sen2cor algorithm, designed in SNAP software, makes it possible to remove atmospheric effects from the satellite's data with high accuracy (Muller-Wilm et al, 2013). After pre-processing on satellite images, each image was divided into 4 classes by K-Mean’s classification method in snap software. Figure 3 shows the classified maps.

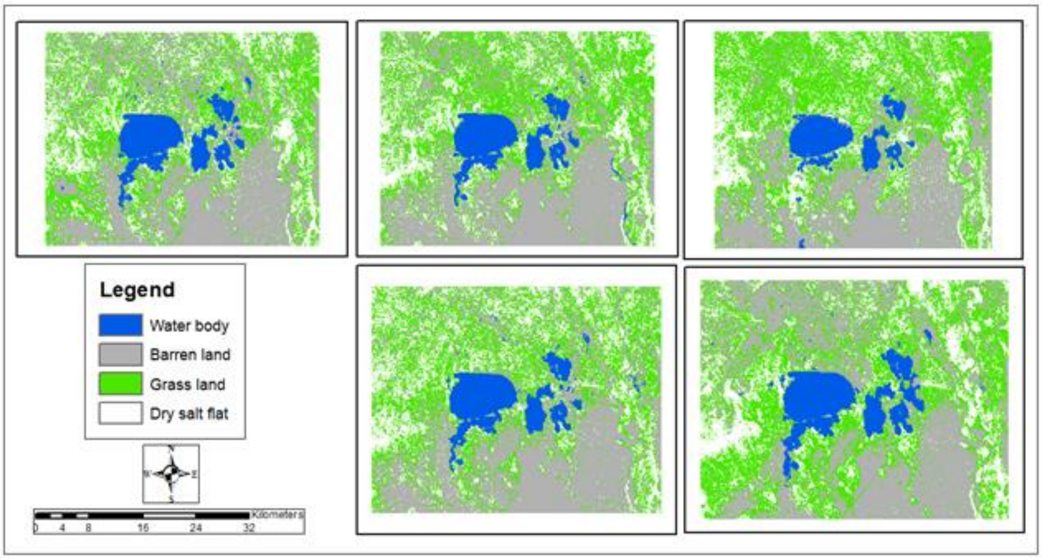


Figure 3-Unsupervised classification map

Because there is no algorithm for validating results in SNAP software, an error matrix was formed between the results and samples taken from Google Earth in ENV software. The number of samples taken is important for the validation of the classified map using remote sensing methods (Foody, 2009). Sample size (N) derived from a multinomial distribution is based on the Equation 1:

$$N= \frac{B\Pi i(1-\Pi i)}{bi^2} \quad (1)$$

Where n is the proportion of a population in the i*th* class out of *k* classes that has the proportion closest to 50%, bi is the desired precision (e.g., 5%) for this class, *B* is the upper (a/k) x l00*th* percentile of the chi square (X^2) distribution with 1 degree of freedom, and *k* is the number of classes (Congalton and Green, 2019). This study was conducted with a confidence interval of 92.5%. The value of B for X (1, 0.98125) is 5.695. As a result, the total number of required samples was 137. Figure 4 shows samples taken from Google Earth in 2016. Kappa coefficient was obtained for 2016-2020, 0.75, 0.83, 0.81, 0.79 and 0.83, as well as the overall accuracy of 0.86, 0.93, 0.89, 0.87 and 0.91 (Table 3).

Table 3-Validation results

	2016	2017	2018	2019	2020
Kappa Coefficient	0.75	0.83	0.81	0.79	0.83
Overall Accuracy	0.86	0.93	0.89	0.87	0.91

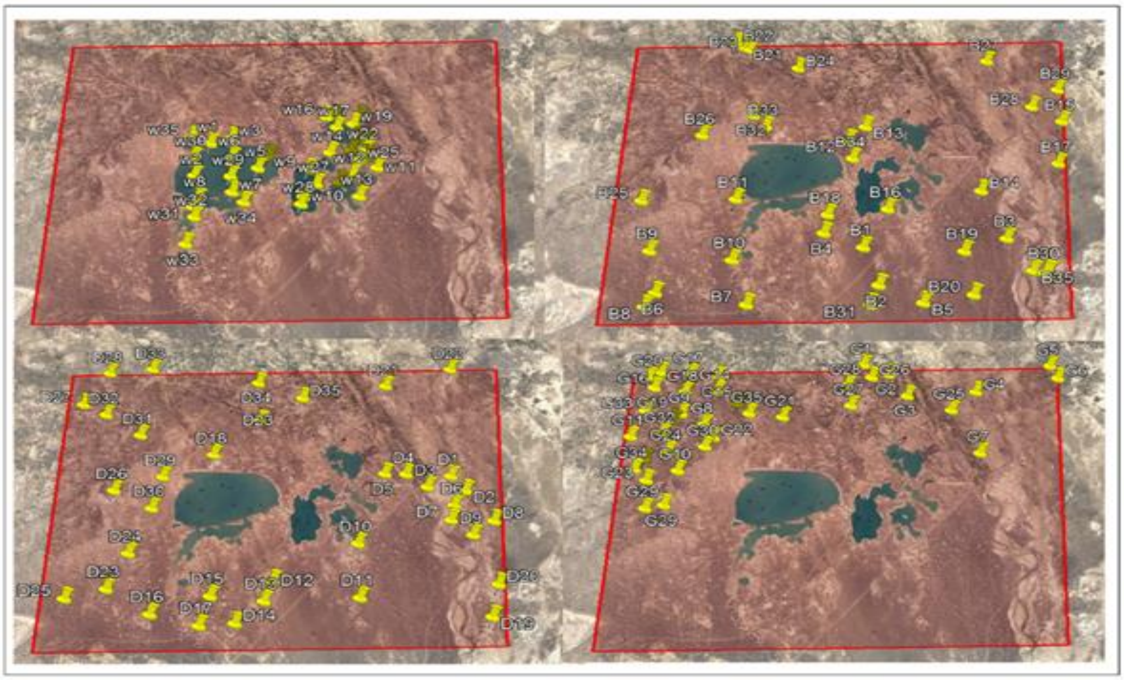
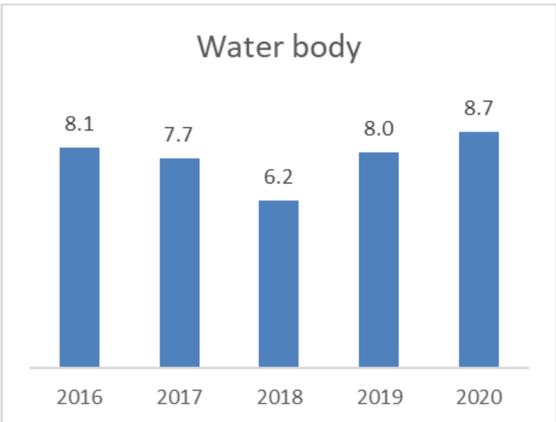
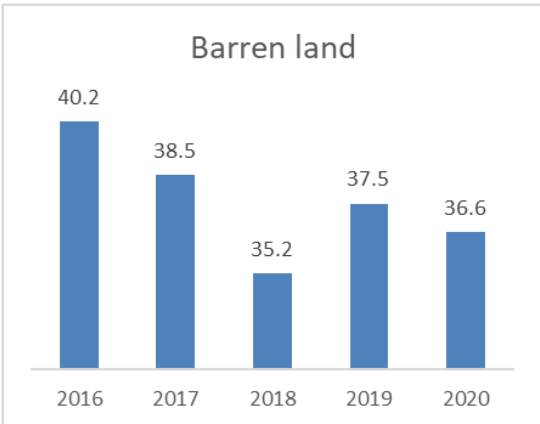


Figure 4- Examples taken from Google Earth in 2016

3-Results and Discussion

As the results of the classification in Figure 3 show, there are four general categories of water, barren land, grass land, and salinity in each period. In order to determine the percentage of land use changes in the study period, the area of each class for 5 consecutive years was extracted with the help of GIS software. Figure 4 shows the percentage change of each class.





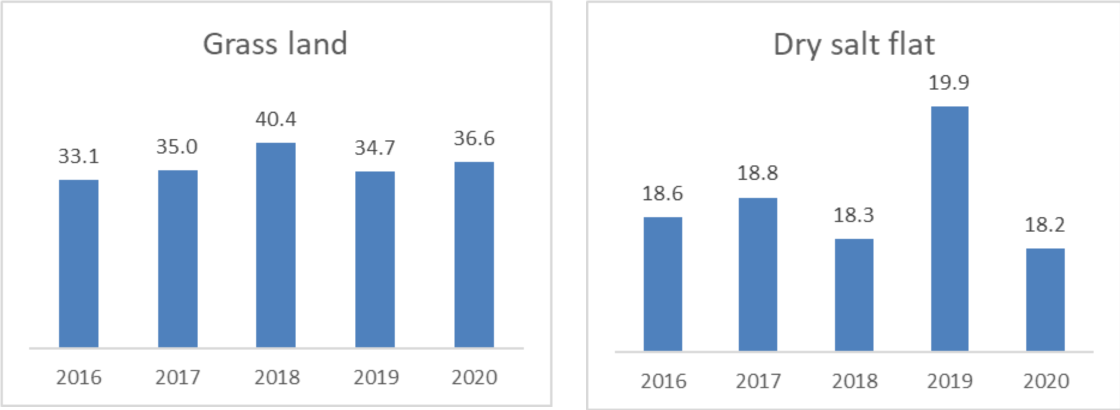


Figure 5- Results of land use changes in the study area

The classification results show that the water area had an almost constant value, except for a two percent decrease in 2018. Barren land area has been declining until 2018, after which it has increased by 3%. Most of the grass land class was observed in 2018 with a value of 40.4%. The saline area was almost constant from 2016 to 2018, and 2019 had the largest area with 19.9%. Table 4 shows the area of each class from 2016 to 2020.

Table 4- The area obtained of each of the classes (km^2)

	2016	2017	2018	2019	2020
Water body	120.04	113.98	91.02	117.18	128.32
Barren land	592.77	566.66	518.17	552.65	538.46
Grass land	487.41	516.10	594.69	511.25	538.82
Dry salt flat	273.45	276.92	269.79	292.58	268.07

Chah Nimeh is of the sights of Sistan and Baluchestan and is a special place. This region has prevented the threat of drought in Sistan and Baluchestan. In fact, these wells are a symbol of endurance and resilience against the wrath of nature. Drought has been threatening the land of Sistan and Baluchestan for many years. For this purpose, several very large artificial lakes have been created in this area to direct the excess water of the Helmand River to them. The Helmand River is the only vital artery of Sistan that originates from the Baba Yaghma Mountains in Afghanistan, and after a distance of about 1050 km enters Lake Hamoun. Helmand is divided into two branches on the border between Iran and Afghanistan. The main branch, called the Common River, forms part of the common border between the two countries, then enters Afghanistan. The other branch is in Iran, which is divided into two branches. One goes to Chah Nimeh and the other goes to Kohk and Zahak areas on which two diversion dams have been built in these two areas. Also, Sistan Dam has been constructed on a branch that is supplied through a Chah Nimeh. These Chah Nimehs, while storing water to irrigate more areas of Sistan, prevent the damage caused by the flooding of the Helmand River. In addition to irrigation, these reservoirs can also be used for fish farming. Currently, the number of Chah Nimeh is limited to four large basins. The water of these wells plays a vital role in the lives of the people of Sistan region. An important part of the drinking water and agriculture of the locals is supplied from these artificial lakes. It should be borne in mind that dams in different stages of construction, operation and end of their useful life will have a profound and tremendous impact on the environment. Due to the construction of various dams around the wells, it is necessary to study their environmental effects in this area.

4- Conclusion

Remote sensing technology provides significant information to determine the temporal and spatial variations of many natural phenomena. Remote sensing has played an important role in the field of earth science research and environmental monitoring due to its wide coverage, high separation capacity and low cost of obtaining data from the earth as an efficient tool. One of the most important applications of remote sensing is the ability to detect changes. Timely and accurate diagnosis of these changes in local and global scale, for optimal management of resource utilization, is important. Land use has a direct impact on environmental elements like soil, water and the atmosphere. Studying land use changes plays an essential role in regional development and planning and making principled decisions. Land use change maps that are the result of the change detection process can be prepared based on remote sensing multi-time images. Therefore, satellite data are of great importance in the preparation of land use maps due to the provision of timely and digital information, variety of forms and the possibility of processing. For this reason, in recent years, satellite imagery has been widely used for classification. Also, reviewing these changes through satellite imagery can help environmental planners and natural resource managers make more informed decisions. In this study, changes in land use and land cover in and around the Chah Nimeh water reservoir in Sistan and Baluchistan province were examined. This study examines the trend of land use change, vegetation dynamics and water area changes in Chah Nimeh over a five-year period. For this purpose, Sentinel 2 satellite images from April 2016 to April 2020 have been used. After making the necessary corrections, using the unsupervised classification method and relying on the spectral characteristics of the phenomena in different bands, a land use map of the region was prepared. The percentage of changes in each of the uses was obtained after determining the area in GIS. The accuracy of the method was reviewed with samples taken from Google Earth images on the same date as the satellite images. According to the kappa coefficients for the years 2016 to 2020 (0.75, 0.83, 0.81, 0.79 and 0.83), the use of spectral properties of phenomena in this type of classification is highly reliable. Also, according to the results, no significant changes were observed in the area of Chah Nimeh and surrounding lands during these 5 years.

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