ESTIMATION OF TELMEN LAKE AREA CHANGES IN MONGOLIA

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ABSTRACT: Remote Sensing was used to monitor interactions and relationships between lake area change and socio-economic and climate drivers. In order to examine lake area, change Normalized Difference Water Index (NDWI) and Band 5 from Landsat data were applied for 1986-2019 years. The study area is in the Telmen lake basin of Zavkhan province in Mongolia (48"50N; 97"20E, altitude 1789 m). Climate drivers (precipitation, air temperature) vegetation condition were analysed to evaluate the impacts on Lake Telmen and its basin. Telmen lake area have caused the deterioration of with values averaging 4.7hayr $^{-1}$, which was observed from 1986 to 2019 years. This result was compared with the data from Lake data base.

INTRODUCTON

Water resources of Mongolia are dramatically sensitive to climate change; a small alternation in the precipitation might bring about sever water shortage. Water resource the water resources and their natural conditions need to be protected in the land-locked country, Mongolia has a harsh climate and is threatened by moderate desertification as approximately 23.4% is covered by the Gobi desert. The rest of the country contains semi-arid or arid areas (Batsukh, 2008). Therefore, water resource management has been one critical theme in politics and policies in Mongolia with respect to climate conditions and socio-economic impacts. Mongolia is a transformative country; after the end of the socialist regime in 1990 it has been experiencing neoliberal political economic changes. In recent years, livestock have become a major economic force. Consequently, wide-scale monitoring of livestock effect on wetland is critically needed. Due to climate change, severe drought in summer and a harsh winter conditions called “Dzud” are more frequent (Punsalmaa, Bavuu, Nyamsuren, Namjil, & Pandi, 2011). These extreme climate conditions reduce water availability in Mongolia ((WWF), 2011). Researchers have been using of remote sensing data for longer water resources assessment and coastal management (Xu , 2006). The Landsat images acquired by the TM and ETM+ sensors are largest useable database of medium resolution images for studying the dynamics of coastal areas. In addition, the Operational Land Imager (OLI) on Landsat 8 captured this image of Telmen lake. Landsat TM and ETM+ images have also been used in various studies to build digital lines of complex coastal regions such as in Louisiana (Braud & Feng, 1998); locate wetlands in flood plains (Frazier & Page, 2000); detect changes in reservoirs (Manavalan, Sathyanat, & Raiegowd, 1993); or monitor natural lakes such as the Rift Valley in Kenya (Ouma & Tateishi, 2006). Coastline is one of the most important linear features on the earth’s surface, which has a dynamic nature (Winarso, Judijanto, & Budhiman, 2001). Remote sensing plays an important role for spatial data acquisition from economical perspective (Alesheikh, Fard, & Talebzadeh, 2003). Optical images are simple to interpret and easily obtainable. Furthermore, absorption of infrared wavelength region by water and its strong reflectance by vegetation and soil make such images an ideal combination for mapping the spatial distribution of land and water. These characteristics of water, vegetation and soil make the use of the images that contain visible and infrared bands widely used for coastline mapping (Moore , 2000). Several researchers analysed the effects of regional climate and human activities on the lake changes to explore the possible driving factors. (Kashaigili, 2007), (Schuyt, 2005) and (URT, 2007) argued that wetlands have been converted to other uses such as agriculture, settlement and infrastructure. While some wet land conversions no doubt have been in the best interest of society, wetlands have too often been lost for very limited benefits and even costs to society (Munishi et al.; 2003, Turner et al.; 2003). According to (Lu, Mausel , Brondizio, & Moran, 2004) (Canty & Nielsen, 2006) well-timed and accurate change detection of features provide the base for better understanding of the relationships and interactions between human and natural phenomena to better manage and use resources. Drivers can determine both anthropogenic (e.g. demographic change) and natural forces. In general, little research exists on drivers of wetland degradation in Mongolia using Remote Sensing techniques. Telmen lake has been previously studied as past climate change indicator. Many researchers have outlined that Mongolia is important for recording and thus retrieving the Holocene global climatic sequence. Whether river and lake ice phenology (dates of ice forms, freeze-up, break-up, and maximum ice thickness) can be an indicator of past climate change in Mongolia (An, Chen, & Barton, 2008). In previous studies Telmen lake was investigated as climate change indicators with its specific location in the region. The objective of this research is to evaluate the impacts of main socio-economic activities on Lake Telmen and its basin using remote sensing techniques. Our study objective is to find change in the Telmen lake area using remote sensing methodology and to evaluate the impacts of climate change on the Lake and its basin. Remote sensing is widely used for wetlands and lake shore analysis.

STUDY AREA

Lake Telmen basin is located in Khangai Province of Mongolia (48"50LN, 97"20'E, altitude 1789 m) in the North Khangai mountain region, and it is the biggest lake in this region (figure1). The lake receives fluvial input from rivers draining the Tarvagatai and Khangai Mountains mainly from Khooloin Gol and has no outflow. Lake Telmen has shore length of 93.4 km, maximum length of 26 km (E-W), mean width 12 km (N-S), and maximum width of 16 km (Jimee, 2000). Mean depth is 13 m and the maximum depth is 27 m within the central basin. Lake Telmen drains a watershed of 3940 km, has surface area of 194 km^2 including islands, and volume of 2.671 km^3.

In the Lake Telmen basin today, the mean temperature in January is -32C° (-26F) and the mean temperature in July is 12C° (54F). The mean annual precipitation is 250mm. The lake lies near the boundary between the forest-steppe and steppe ecosystems. Lake Telmen, a closed lake basin, is slightly salty (about 4g per L salinity). In July, a well-developed thermocline at 10m depth corresponds with a large increase in turbidity generated by dense patches of plankton found at this depth. As this organic matter decomposes and descends, it lowers dissolved oxygen to hypoxic levels (2.36 mg per L) in the bottom water. From 6,210 to 3,960 years ago, as determined by radiocarbon dating, Lake Telmen was between 15 and 20m shallower than it is at present. Coarser-grained sediment containing pollen from vegetation indicative of arid conditions and poor unstable soils accumulated in a small lake that covered about 40 percent of the present lake area (Peck, 2003).

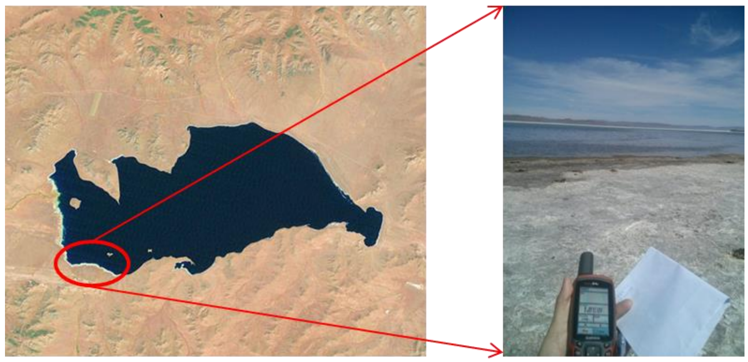


Figure 1. Field trip coastline of study area the Telmen Lake

DATA

Four types of dataset were used for this research. The time series Landsat 34 images have been downloaded from USGS archive in order to obtain a precise estimation of the lake area over years 1986-2019

NDWI and spectral band 5 LANDSAT for years 1986-2019 were used for estimation lake area change.

RED and NIR data from Landsat satellite data, over years 2000-2019 was applied for calculation MSAVI and monitoring vegetation change in the lake basin.

Ground truth measurement collected from expedition to Telmen in 2013 and 2015 (figure1). Thematic map Mongolia 1970 year was overlaid with Landsat 1986 image and used for reference map.

METHODOLOGY

Coastline can even be extracted from a single band image, since the reflectance of water is nearly equal to zero in reflective infrared bands, and reflectance of absolute majority of land covers is greater than water. Experience has shown that of the six reflective TM bands, mid-infrared band 5 is the best for extracting the land-water interface (Kelly, et al, 1998). Landsat band 5 exhibits a strong contrast between land and water features due to the high degree of absorption of mid-infrared energy. To estimate the lake area, we applied band 5 and Normalized Difference Water Index NDWI.

NDWI is defined as (McFeeters, 1996) applied for this research equation (1). Where P_{Green} and P_{NIR} are the reflectance of the green and NIR bands, respectively.

$$\mathrm{NDWI} = \frac{P_{Green-}\ P_{NIR}}{P_{Green+}\ P_{NIR}} \tag{1}$$

NDWI is designed to maximize the reflectance of a water body by using green wavelengths, minimize the low reflectance in NIR of water bodies, and take advantage of the high reflectance in NIR of vegetation and soil features (Karsli, Guneroglu, & Dihkan, 2011). As a result, the water body information will be enhanced and the background (vegetation and soil features) information will be restricted in McFeeters's NDWI images. This means that the water bodies can be identified by applying a threshold to McFeeters's NDWI images. The result output images from band 5 and NDWI we compared with ground truth measurements.

Spectral bands RED - channel (0.63-0.69 μm) and NIR - channel (0.77-0.89 μm) of Landsat satellite bands used for vegetation mapping. (Huete, 1988) suggested a new vegetation index, which was designed to minimize the effect of the soil background, which he called the soil-adjusted vegetation index (SAVI) (2) developed of an iterated version of this vegetation, which is called MSAVI (3).

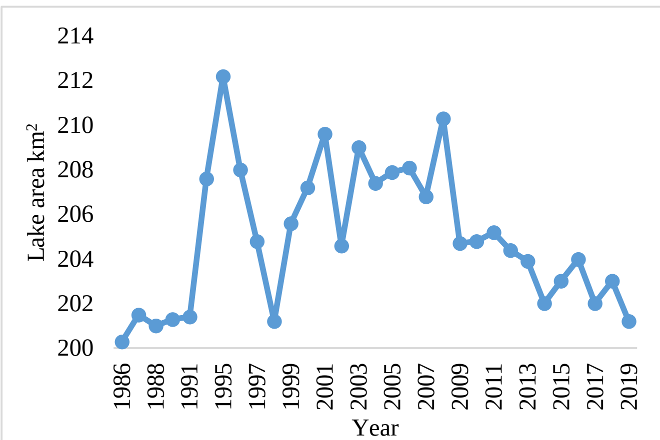
$$\mathrm{SAVI} = \frac{\mathrm{NIR-RED}}{\mathrm{NIR+RED+L}} + (1 + \mathrm{L}) \tag{2}$$

$$\mathrm{MSAVI2} = \left[2\mathrm{NIR} + 1 - (\sqrt{(2\mathrm{NIR} + 1})^2 - 8(\mathrm{NIR} - \mathrm{RED})\right]/2 \tag{3}$$

Derived MSAVI values vary from 0.1 to 0.25 for the period 2000 to 2019 which means that there is only a sparse vegetation cover in the basin. Precipitation increases while temperature decreases over the growing period. Climate drivers had no significant influence on vegetation condition in the lake basin.

ANALYSIS

The lake area changes (figure 2) were compared with results from the NDWI and band 5 figure 3. In this research we investigated how climate and socio-economic drivers influence on Lake Telmen area. Landsat 1986 and Thematic map Mongolia, 1970 have been drawn as reference map. Landsat data for 1986 was overlaid with the thematic map and there was good matching. Relationship between ground truth and NDWI and the relationship between ground truth and Landsat band 5 are good. 110 points were selected for the ground truth measurements. Telmen lake area increased from 1994 until 1998 and it decreased from 2011-2019. Figure 2 shows lake change trend over years 1986-2019. Linear regression was applied in this research in order to find relationship between lake area change and drivers. Regression analysis results are in the (table 1).



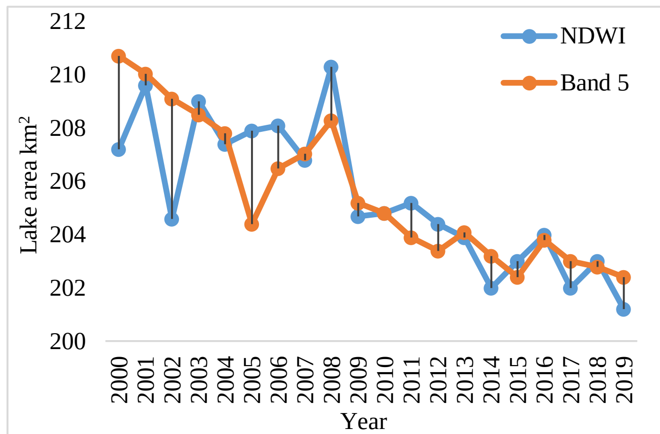


Figure 2. Lake area change from Landsat using of the Telmen lake 1986-201

Figure 3. Lake area change from NDWI and Band 5 of the Telmen lake 2000-2019

RESULTS

In this paper we have explored the changes on Telmen lake from Landsat Band 5 and NDWI. The socio-economic data of basin seven soums surrounding Telmen lake area was investigated. Socio-economic data livestock and climate data (precipitation, and temperature and vegetation change) were collected from ground stations and vegetation taken from MSAVI. The lake area increased from 1994 until 1998, while decreasing from 2011 until 2019 (figure 2). From the table 1 it can be seen that livestock number (R=0.57; P=0.0006), precipitation (R=0.51; P=0.002) and household population (R=0.46; P=0.043) has significant relationship with the lake area change.

The MSAVI values vary from 0.13 to 0.26. By means of MSAVI variation alone we cannot assess the land degradation process in the lake basin. The result indicates that the vegetation is not a main driving factor for Lake basin. Lake change has been weakened profoundly as a result of increase in land demand for forage as a consequence of rapidly growing livestock and climate change. For the making forage herders use small rivers around the lake which fill the lake. Many rivers are used for irrigation for forage and crops. Findings of this study revealed that precipitation and temperature was related significantly (R= 0.51; p=0.002) the lake area. This can be attributed to the increase in livestock (R=0.57; p=0.0006). Furthermore, there is increased livestock and demand for vegetation. This implies increasing stress on the lake water resources to assure people's basic needs. Livestock is the major economic and social activity for the majority of the communities and relates negatively with the lake area. Despite its great potential in supporting local people's livelihood, Telmen lake was found to be decreasing at a rate of 4.7ha during years from 1986 due to various socio-economic activities.

According there has been experiencing remarkable lake shrinkage during the recent decades because of intensive human activities and climate changes in Mongolian plateau. They found that lake shrinkage across the plateau, and find a greater decreasing rate between the late 1980s and 2010 in Mongolia. This is due mainly to an unsustainable mining boom and agricultural irrigation in the former. Disastrous damages to the natural systems are threatening the livelihood of local people, and urgent action is needed to prevent further deterioration. In this research we did not monitor mining activities and damages in the lake basin.

Table 1: Relationship between lake area changes and drivers

	Telmen lake	
Variable	r	P
MSAVI	0.42	0.08
Precipitation (mm)	0.51	0.002
Temperature (C°)	0.46	0.043
Livestock (thousand)	0.57	0.0006

Crop and forage area (ha)	0.15	0.31

RECOMMENDATIONS

Human based drivers can be altered by policy and societal influences or societal responses. Natural based drivers (e.g., climate variability) cannot be controlled by people directly, but must be considered for future land management and are more or less policy related. Data collected for only few years used for ground truth measurements. Although data from segments of the coastline show good result. Combination NDWI and Band 5 is good source for area estimation for Telmen lake basin. This research recommends that, natural resources management for the Telmen lake area should be integrated in the education and the awareness raising campaign on wise use of Telmen Lake resources. Good land use practices should be promoted for reducing the impacts. It is important to monitor water usage for livestock around Lake basin. It can be done detailed research on lake water usage for life stock in the region. In the future, should be developed mixed research method with the interpretative approach by conducting interviews, focus group discussions on livestock management and water quality and quantity data analysis in the study area. Furthermore, these findings may assist to appropriately formulate the competing socioeconomic demands for sustainable water in future policy implementation of Mongolian water resource management.

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