# Studies on morphometric parameter variation of Mongolian lakes

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***Abstract***

There are 4296 lakes in Mongolia with an area of more than 0.003 $km^2$ and a total surface area of 15,514.7 $km^2$.According to size of water surface area, Mongolia lakes classified in to 10 classes such as Great lakes (above 1000 $km^2$), Big lakes (500-1000 $km^2$) large lakes (100-500 $km^2$), medium lakes (20-50 and 50-100 $km^2$), small (1.0-5.0 and 5-10 $km^2$) little (1.0-5.0 $km^2$) and very little (0.1-1.0 $km^2$) etc [2]. In this study, have used the Spatial data data of the Landsat 8LIO satellite with a resolution of 30 m for period of 2017-2019and also the production data of the STRM 30-meter zone.This study was also developed using the NDWI index. The value of NDWI between 0.35 -1.00 is taken as water.Analysis on the total lake area changes were made in 1940, 2017, 2018, and 2019, respectively. 4296 lakes with a total area of more than 0.003 $km^2$ in Mongolia, the total surface area of the lake was 15514.5 $km^2$, while in 2019, 3464 lakes and the total surface area of the lake was 14312.6 $km^2$. In 2019, 832 lakes dried up and the area of dried lakes is 1201.9 $km^2$. Thus number of lakes decreased by 2.6% from the previous year and the total area increased by 0.55. However, compared to the 1: 100,000 maps or 1945 data, it decreased by 19.1% and the total area decreased by 7.7%.

***Index Terms***- DEM, NDWI, LAKE, DRIED LAKE, DGPs, QSR

## I. INTRODUCTION

Mongolia has limited water resources. There are 34.6 cubic kilometers of water in surface and underground water sources. There were 4360 lakes, covering total water surface area of 15514.7 km2, acquired from a topographic map with scale of 1:100000 and compiled based on air photos taken in the 1940$^{th}$defined by J.Tserensodnom (2000)[1].

Lakes are most valuable natural resources of Mongolia and play a significant role and impact on the development of industry, agriculture, transportation, electricity, tourism and other sectors of the country's economy.

The importance of the water balance study of lakes is to take into account the water regime of the lakes and all its ecological features and to determine the appropriate relationship between human needs and the lake's ecological balance. Also develop scientific bases on use of lake water resource for the country's economic needs and consequently to conduct better management of lake resources.

According to size of water surface area, Mongolia lakes classified in to 10 classes such as Great lakes (above 1000 km2), Big lakes (500-1000$km^2$) large lakes (100-500 $km^2$), medium lakes (20-50 and 50-100 km2), small (1.0-5.0 and 5-10 km2) little (1.0-5.0 km2) and tiny (0.1-1.0 km2) etc [2].

There are 4 Great lakes such as Uvs, Khovsogol, Khyargas and Khar-Us lakes, 2 big lakes as Buir and Khar lakes. Dorgen, Boontsagaan, Achit, Uureg, Telmen, Sangiin dalai, Airag and Orog lakes are considered to be big lakes (see Figure 1).

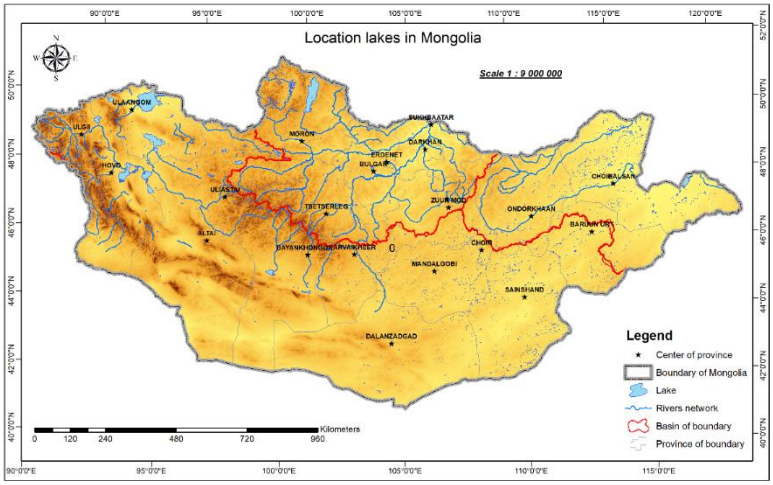


**Figure 1. The location lakes in Mongolia**

However, due to the impact of climate change and human activities, the surface area of the lake and the volume of the lakes (lake water resources) have been changing much in recent years.

## II. RESEARCH METHOD

Water reflects the most in the green region of the visible spectrum and absorbs the most in the infrared region, and the NDWI index, the normalized water difference index, is more indicative of the state of the water. NDWI is calculated using a satellite channel data measured in the visible region of the spectrum, the region of the light (Green), and the region of the infrared (NIR).

$$NDWI = \frac{Green-NIR}{Green+NIR} \quad (1)$$

In addition to the various elements contained in water, chlorophyll in water has a certain effect on the spectral capacity of the water. The capacity is lower than other elements in the composition of water.

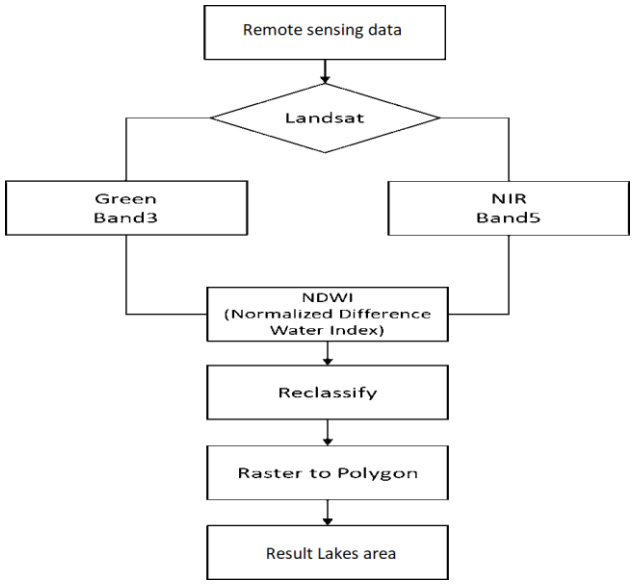

**Figure 2. Schema of method of estimation lake morphometric parameters**

The elements in the water composition perceive energy in the visible and infrared regions, while in chlorophyll the main regions are blue light and red light, and their ability to repel and scatter waves is less than that of other elements in water.

Water has different temperatures depending on its composition and therefore using a map of the infrared region of the radiation, the surface area of the water can be estimated.

**Objectives**

The main goal of the study is to estimate the water balance of Mongolian lakes in relation to their physical geography and climate change and to establish the relationship between the different components of lake water balance and lake water regime and morphometric parameters.

- Using satellite data to estimate variation of lake surface area
- Carry out field surveys in lakes to determine lake morphometry and improve ranges of lake classifications
- Establish relationships between lake morphometry and volume and water levels of selected lakes

## II. RESULTS AND DISCUSSION

**Result**

The satellite data were confirmed by field measurements on selected lakes and ungauged lakes. As an example of results of the studies, the Lake Terkhiin tsagaan with long term observation data and ungauged lake Toson are selected in this paper. The Terkhiin tsagaan lake is located in the Centre of Mongolia in the forest-steppe region (coordinates Lat $48^0$ 09’ 31” N Long $99^0$ 42’ 52” E). It’s mean surface area is 54.6 $km^2$ with mean elevation of 2058.8 m. Hydrological gauging station is operating on the Terkhiin Tsgaan lake since and 1987 years continues data have collected within Hydrometeorological service of Mongolia. The Toson lake is located It is located in the Eastern Mongolia in the dry steppe region (coordinates Lat $47^0$ 10’ 58” N, Long $109^0$ 08’ 29” E), with mean surface area of 0.101 $km^2$.

The surface area of the Terkhiin Tsagaan Lake was determined using the Landsat OLI satellite data, which has been operational for many years. The shoreline defined by NDWI using satellite data coincides with the shoreline of the lake measured by DGPs(Figure 3).

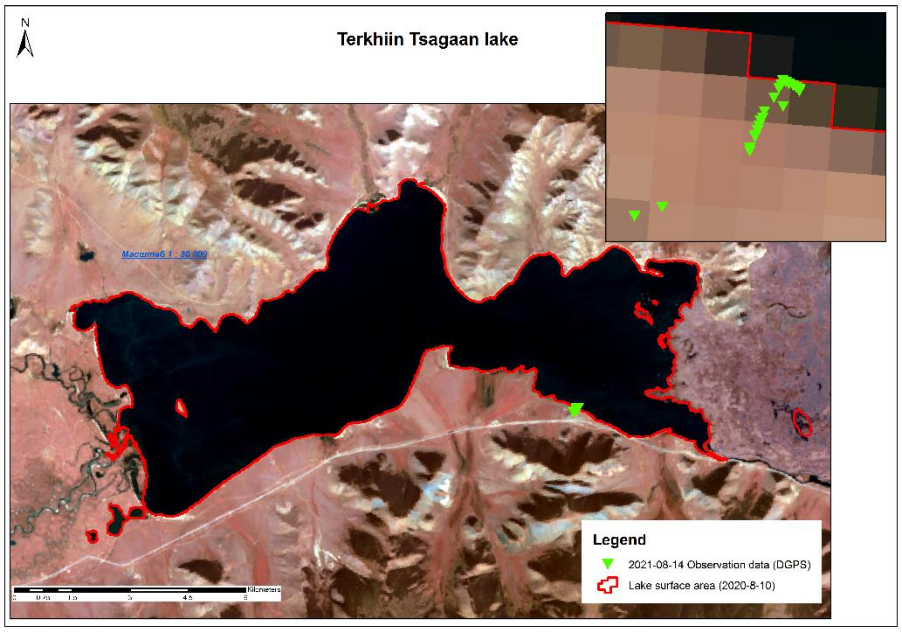


**Figure 3. Landsat LOI (NDWI)and Observation GPs data**

The following relationship has been established between lake surface area and water level of Terkhiin Tsagaan Lake expressed by the following equation.

$$F = 0.00728 \cdot H - 149.51 \qquad /2/$$

Where,

H is observed lake level, м., F is lake water area, км$^2$

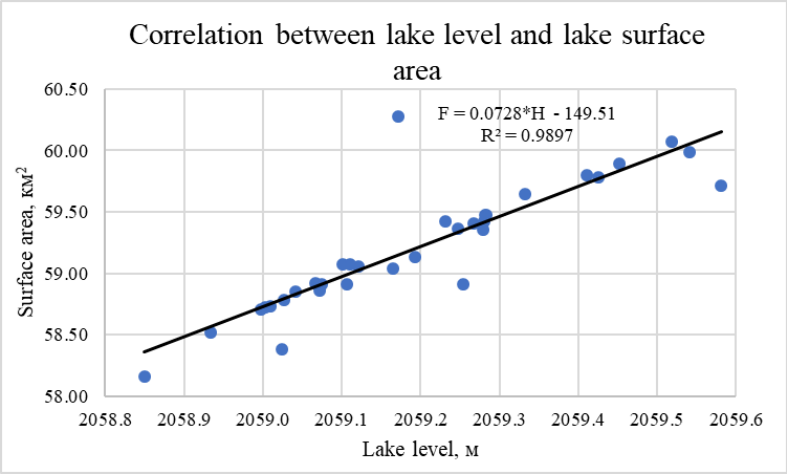


**Figure 4. lake water level vrs. it's water surface area**

The water surface area of the Terkhiin Tsagaan Lake varies from 54.6 to 62.8 km$^2$. The lake area reached a maximum of about 62.8 km$^2$ in July 1993, the minimum water surface area was approximately 54.6 km$^2$ in March 1994, which was 4.6 km$^2$ or 7.7 percent less than the lake's mean (Figure 3 and 4).

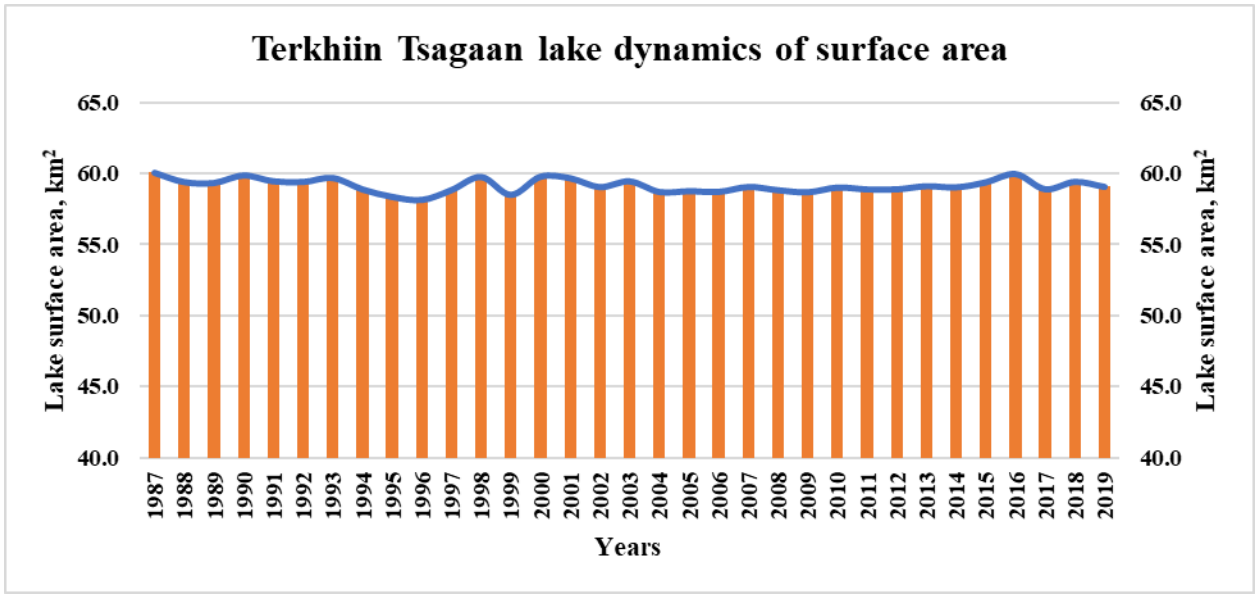


**Figure 5. Dynamics of the surface area of Terkhiin Tsagaan Lake**

Terkhiin Tsagaan lake's water surface area, water depth and level were measured and the lake's water volume was determined. As for the lake's surface area is 60.2 km$^2$ in 2019, (Figure 5).

Another important outputs of our studies are creating of bathymetric maps of the selected leaks which are very useful for different users such as environmental protection, fishery, tourism etc. It found that deepest point in the middle of the lake with the maximum depth of the lake is 22.5 m, and the average depth is 5.5 m.

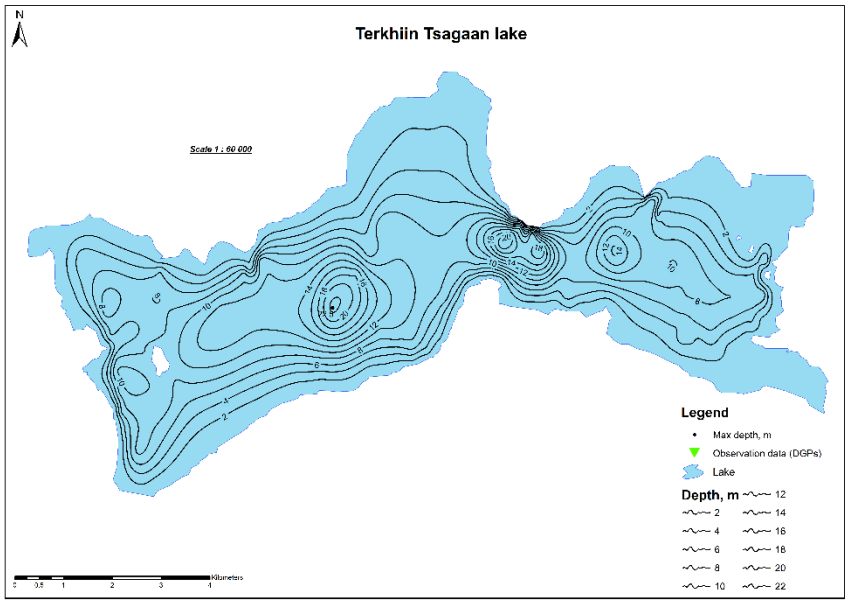


**Figure 6. Measurement observation depth data in the Terkhiin Tsagaan lake**

The Toson lake which is selected as case of ungauged lake and have conducted field measurements for depth and surface area and shoreline length. Results of field measurements compared with satellite data.

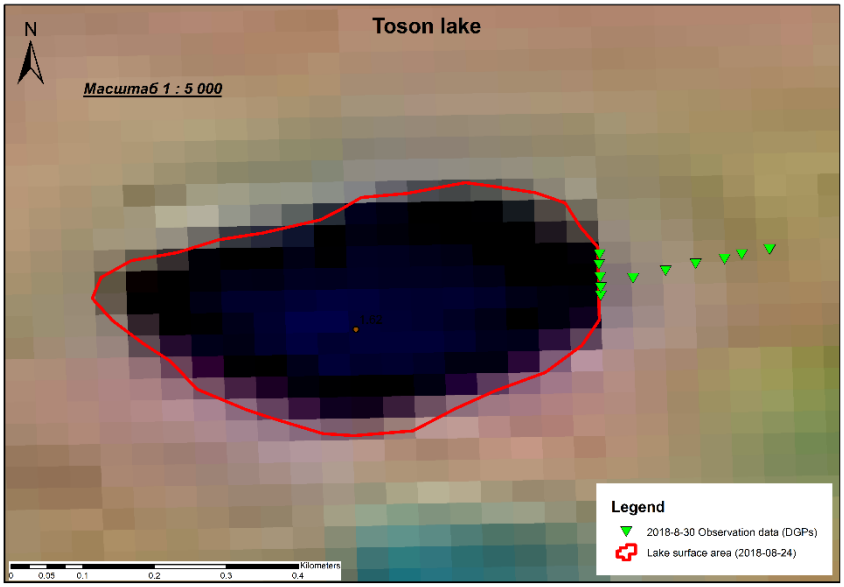


**Figure 7. Landsat LOI (NDWI)and Observation GPs data**

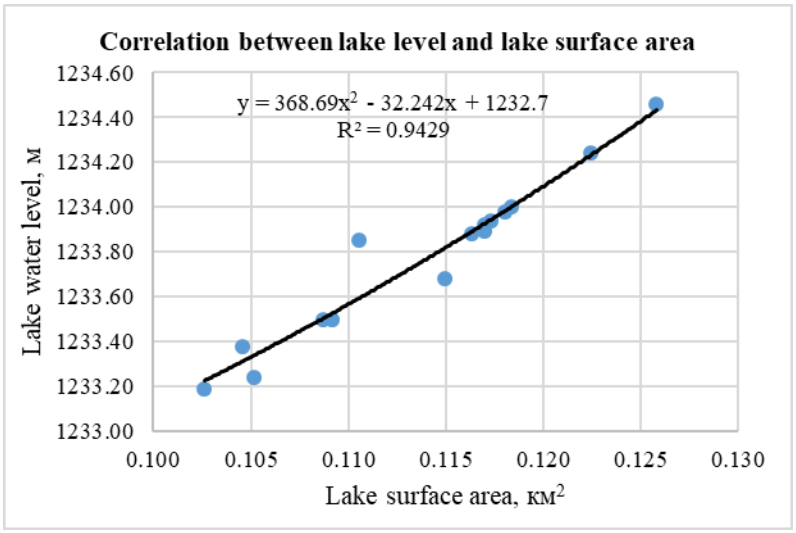


**Figure 8. Toson lake correlation between lake level and lake surface area**

The relationship between Toson Lake's water level and area is expressed by the following equation:

$$H_{\text{Toson}} = 368.69 \cdot F^2 - 32.242 \cdot F + 1232.7 \qquad /3/$$

Where:

H-Observed lake level, м.
F-Surface lake area, км$^2$

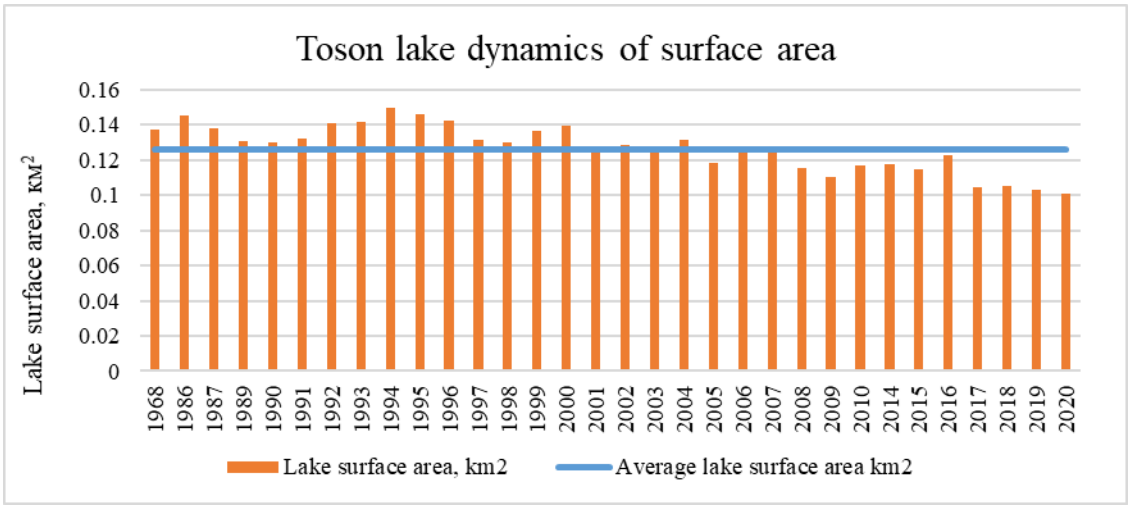


**Figure 9. Dynamics of the surface area of Toson lake**

The surface area of Toson Lake varies from 0.101 to 0.149 km$^2$, reaching a maximum of approximately 0.149 km$^2$ in 1994 and a significant decrease to 0.101 km$^2$ in 2020 (Figure 9).

There were 4296 lakes, covering total water surface area of 15514.7 km$^2$, acquired from a topographic map scaled as 1:100 000, compiled, based on air photos taken in the 1940th.

**Table 1. Changes in the number and area of lakes**

| Size of lake | Size of lake area | topographic map scaled as 1:100,000 | Landsat ETM (2017) | Landsat OLI (2018) | Landsat OLI (2019) |
|---|---|---|---|---|---|

| | | Number of lakes | Sum of lake area, sq. km | Number of lakes | Sum of lake area, sq. km | Number of lakes | Sum of lake area, sq. km | Number of lakes | Sum of lake area, sq. km |
|---|---|---|---|---|---|---|---|---|---|
| Large | >1000 | 4 | 8824.8 | 4 | 8736.4 | 4 | 8792.3 | 4 | 8851.6 |
| Big | ≥500.0-<1000.0 | 2 | 1245.3 | 2 | 1205.0 | 2 | 1255.5 | 2 | 1203.6 |
| Moderately big | ≥100.0-<500.0 | 8 | 1903.8 | 8 | 1732.0 | 7 | 1613.6 | 7 | 1624.8 |
| Medium | ≥50.0-<100.0 | 11 | 784.5 | 11 | 706.0 | 12 | 811.0 | 11 | 729.4 |
| moderately medium | ≥20.0-<50.0 | 8 | 228 | 8 | 222.1 | 9 | 269.7 | 12 | 362.1 |
| small | ≥10.0-<20.0 | 26 | 368.4 | 19 | 272.4 | 18 | 250.3 | 15 | 211.1 |
| Moderately small | ≥5.0-<10.0 | 60 | 418.2 | 41 | 276.7 | 40 | 284.5 | 38 | 263.2 |
| Very small | ≥1.0-<5.0 | 376 | 788.9 | 225 | 458.4 | 230 | 470.7 | 239 | 485.4 |
| Extremely small | ≥0.1<1.0 | 3159 | 897.4 | 1889 | 492.6 | 1759 | 464.0 | 1929 | 505.5 |
| Natural lagoon | <0.1 | 642 | 55.2 | 1301 | 78.1 | 1522 | 94.4 | 1207 | 75.8 |
| Total | | 4296 | 15514.5 | 3508 | 14179.9 | 3603 | 14305.98 | 3464 | 14312.6 |

However, in recent years, the area of the lake and the number of lakes have changed. According to the lake classification, number of different lakes within classification range have changed much. For example, survey, studies and analysis conducted in 2021 show that in Mongolia counts 4 Large lakes as Uvs Lake, Khuvsgul Lake, Khyargas Lake, Khar-Us Lake and Big 2 (Buir Lake, Khar Lake), Medium 7 Lakes (Durgun Lake, Buuntsagaan Lake, Achit Lake, Uureg Lake, Telmen Lake, Sangiin Dalai Lake, Airag Lake), Medium 11 (Orog Lake, Khar Lake, Big Lake, Khukh Lake, Yah Lake, Khorgan Lake, Dayan Lake, Khar-Us Lake, Oigon Lake, Bayan Lake, Terkhiin Tsagaan Lake, Khoton Lake ), 12 medium lakes (Dood Tsagaan Lake, Tal Lake, Bayan Lake, Jugnai Lake, Ogii Lake, Kholboo Lake, Bust Lake, Tunamal Lake), 15 small lake, 38 medium small lake, 239 very small lake, 1929 Extremely small lake, 1207 natural lagoons (Table 1).

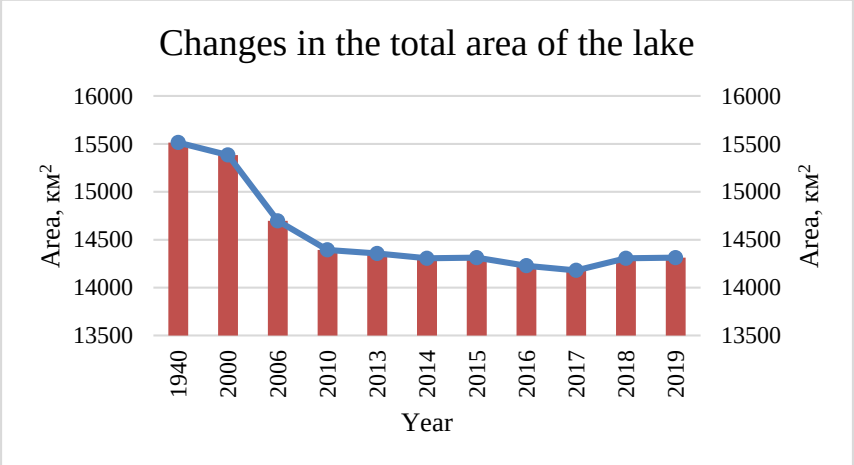


**Figure 10. Changes in the total area of the lake**

The lakes are classified by 10 areas, of which 4 lakes with an area of more than 1000 km$^2$ have an area of 8824.4 km$^2$ or 57% of the total surface area of the lake, and 2 lakes with an area of between 500-1000 km2 have a surface area of 1245.3 km$^2$ or total 8% of the lake's surface area, and between 100-500 km$^2$, 8 lakes account for 1903.8 km$^2$ or 12% of the total lake surface area. It shows that 14 lakes account for 77% of the total surface area of lakes in Mongolia and the remaining 23% are 4228 lakes (Figures 10 and 11).

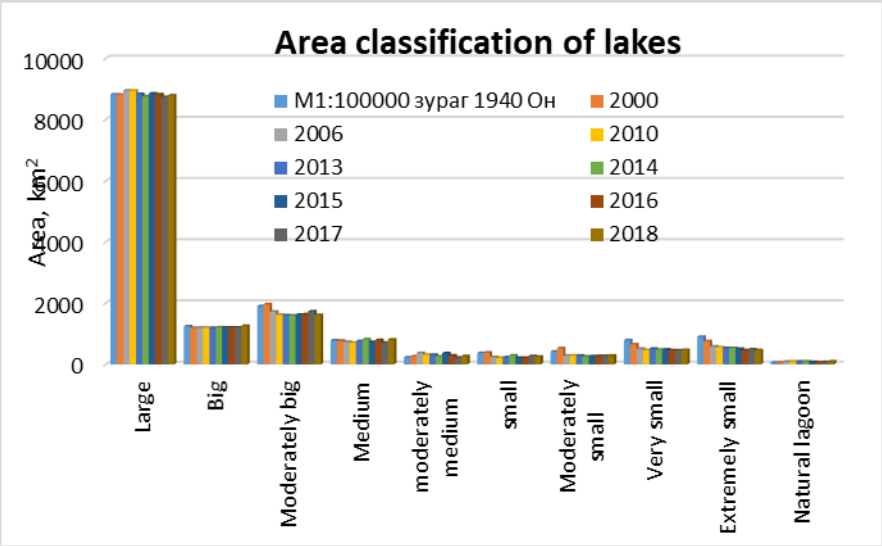


**Figure 11. Area classification of lakes**

In recent years, according to landscape satellite data, 788 lakes dried up in 2017 which is 18.3% of the total lakes, and in 2018, 693 lakes dried up which is also 26.7%, respectively. In terms of natural zones of these dried lakes, the lakes in the steppe desert dried up by 51.3% or the largest, in the dry steppe zone by 22.3%, and in the meadow steppe zone by 10.1% (Figure 12).

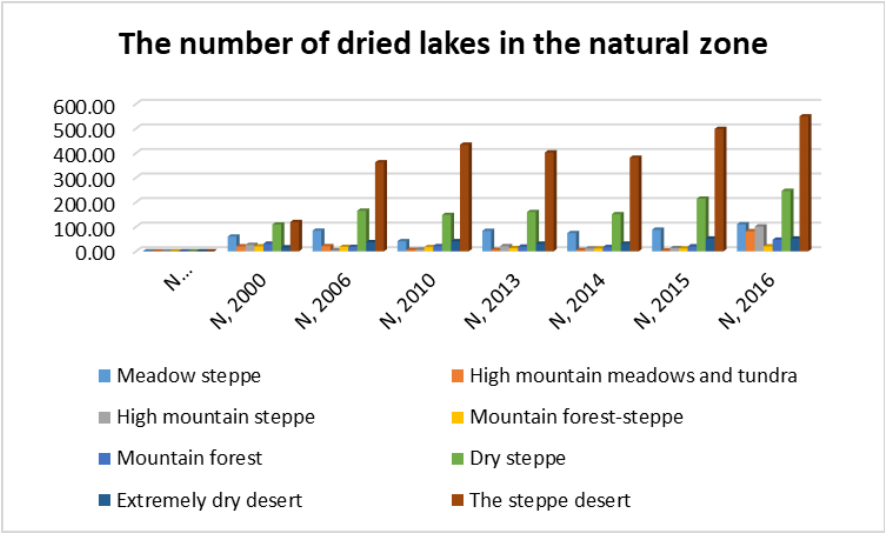


**Figure 12. The number of dried lakes in the natural zone**

## III. CONCLUSIONS

- Due to climate warming significant changes have occurred in lake water resource of Mongolia, especially for small and little lakes, in recent years. Total number of lakes have been reduced by 19.1 percent since 1945 and number of little lakes reduced by 2.6% only within one year.
- In terms of natural zones, most changes have observed in the dry steppe and desert regions where percentage of dried lakes reached 22.3-51.3%.

- Relationships established between volume or water level and morphometric parameters certainly will support different issues of the lake water managements such as protection, recovery and rational use etc.
- Further studies in near future plan to include Survey and measurements of morphometric parameters in large and big lakes and improvement of accuracy estimation of different components of lake water balance

## ACKNOWLEDGMENT

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