Journal of Applied Science and Engineering A,
Volume 4, Issue 1, 2023, pp.33-41.
https://doi.org/10.5564/jasea.v4i1.3221

Satellite based estimation of land cover change and soil degradation in Urgamal, Durvoljin, Erdenekhairkhan soums of Zavkhan province

Zambal Baljinnyam[1], Tuya Sanjaa [2*], Erdemjargal Purev-Erdene[3], Avirmed Buyanbaatar[4]

[1]Centre for Hydrometeorology and Environmental monitoring, Zavkhan, Mongolia
[2]Department of Physics, School of Applied Science, Mongolian University Science and Technology, Ulaanbaatar, Mongolia
[3]Institute of Geography and Geoecology, Ulaanbaatar, Mongolia
[4]School of Agroecology of the Mongolian Agricultural University, Ulaanbaatar, Mongolia

[*]Corresponding author: s_tuya@must.edu.mn

Abstract. In this research, climate change over the last 22 years (2000-2022) in Durvoljin, Ugramal and Erdenekhairkhan Sum areas of Zavkhan province was determined and desertification status was assessed using satellite data. In this research, the soil-adjusted vegetation index (SAVI) was calculated among the vegetation indices. When SAVI is calculated using data from the red and NIR channels of the MODIS satellite data, SAVI values vary between -0.4 and +0.5 as a result of image processing. The spatial heterogeneity of the land surface of the study area was mapped by SAVI values from -0.4 to +0.02 for water, +0.02 to +0.08 for gravel and rock, +0.08 to +0.11 for sand, +0.11 to +0.16 for sparse soil, +0.16 from - to +0.23 with sparse vegetation, and between +0.23 and +0.5 with good vegetation in 6 categories. As a result of the study, SAVI proved to be more suitable for determining soil types in desert and semi-desert areas.

Keywords: Soil adjacent vegetation Index (SAVI), desert, semi-desert zone, land degradation.

1 Introduction

In recent years, the number of species of vegetation cover on pastures has decreased significantly under the influence of many factors, such as the drying of the climate and the increasing use of the soil by humans and livestock. Mongolia is highly vulnerable to climate change due to its geographical location, fragile ecosystem, and economic system dependent on nature and weather [1], [2]. Along with this, crop yields are deteriorating and becoming a factor in desertification. In our country, in 2017, there

Received: 26 Oct. 2023; Revised: 07 Nov. 2022; Accepted: 26 Dec. 2022.

were 14.3% of areas with no desertification, 10.7% with mild desertification, 34.0% with moderate desertification, 24.3% with severe desertification, and 16.7% with very severe desertification. In other words, more than 75% of the total territory of our country is affected by moderate and severe desertification. Of these, 87% are due to human activity and 13% are due to nature as the main cause of desertification. Under different natural conditions, the direction, intensity and effectiveness of soil formation processes vary. Evaporation is one of the most important indicators of the state and change of grassland and vegetation cover, water balance of the land surface and climate change [3], [4]. The most important factor determining the hygienic condition of the area where the population lives is the land cover. They are the main raw materials and materials for the production of cosmetic products. According to scientific research, under normal natural conditions, it takes an average of 100-400 years to form a 1 cm thick fertile soil layer, and 3000-12000 years to form a 20-30 cm thick fertile soil layer (Protect and produce FAO, 1983). In the United Nations report "World Food Security and Nutrition Sector-2018", the number of people suffering from hunger in the world in 2017 is 821 million. In order to protect soil from degradation, restore it and prevent desertification, the National Assembly of Mongolia adopted the "Law on Protection of Soil and Prevention of Desertification" on May 17, 2012, and the Government of Mongolia adopted the "Law on Protection of Soil and Prevention of Desertification" on August 14, 2019. The "National Program for Reducing Degradation" was adopted. The methods and results of the study of soil degradation and desertification are important to make the results of these laws and the implemented program.

2 Spatial data

To create a continuous time series to process and analyze, a data column (h25v04) covering the areas of Ugramal, Durvoljin, and Erdenekhairkhan sums of Zavkhan province was downloaded from the data server website NASA, totaling 207 data between May 8 and September 13, 2000-2022. SAVI was calculated by downloading the satellite data.

Table 1. Satellite data products

№	Satellite data products	Time period
1	Soil adjusted vegetation index (SAVI)	2000 – 2022 years 5-8 month
2	Land Surface Temperature(LST)	2000 – 2022 years 5-8 month

SAVI: Soil vegetation index is more suitable for determining land surface changes and degradation in semi-desert and semi-arid steppe regions with high soil influence, which are affected by drought indices, precipitation changes, land cover changes, and soil erosion. Therefore, there are many researches to determine land degradation and drought using MODIS sensor SAVI long-term data [5], [6], [7].

LST: Land surface temperature is critical to many geoscientific issues, such as monitoring net radiation at the Earth's surface, monitoring the condition of plants and vegetation, and serving as an important physical indicator of the global and local greenhouse effect and processes at the land surface. [8], [9], [10].

3 Method

3.1 Vegetation condition assessment

For vegetation cover condition assessment, data were collected from May to August from 2000 to 2022, and soil modified vegetation index (SAVI) was calculated after initial processing in space (Table 2). The SAVI results were classified into 6 categories, and the changes in soil degradation were evaluated in relation to the meteorological data of the region.

Table 2. The formula for calculating the Soil Adjusted Vegetation Index (SAVI).

Parameter	Calculation formula
Soil adjusted vegetation index (SAVI)	$\mathrm{SAVI} = \frac{(\mathrm{NIR} - R)}{(\mathrm{NIR} + R + L)} \times (1 + L)$

NIR – near infrared spectral channel of satellite data
R – RED spectral channel of satellite data
L – Coefficient of land surface 0.5

3.2 Spatial variation of land surface temperature

The formula is shown in Table 3, taking the annual variation (Z-score) of values for which the surface temperature was +1σ higher than the long-term average.

Table3. Formula for calculating the standardized parameters

Parameter	Calculation formula
Land Surface Temperature (LST)	$Z_{score_i} = \frac{x_i - x_{average}}{\sigma}$

The changes in the vegetation of soums are expressed as follows:

1. -0.3953-0.0204: Water
2. 0.0204-0.0767: Soil and rock
3. 0.0767-0.1155: Sand
4. 0.1155-0.1613: With sparse vegetation
5. 0.1613-0.2283: Medium vegetation
6. 0.2283-0.5031: Well vegetated

The following 7 classes are distinguished by color in the Soum climate change map (land surface temperature was more than +1σ higher than the long-term average):

1. <3: Very little change
2. 4-5: with minor changes
3. 6: Less change than average
4. 7: Moderately modified
5. 8: More than average variation
6. 9: With great change
7. 10< Very variable

4 Results and discussion

Land surface temperature (LST) and spatial distribution of the region were determined and defined using the 23-year satellite data from 2000 to 2022 for the study area, which includes the deserts and deserts of Zavkhan province. From the spatial distribution of the average vegetation cover of the study area, Fig 1. shows that the soil degradation in the western part of the square is relatively poor compared to the other areas, and the vegetation cover in the vegetation area is moderate, while the area of Erdenekhairkhan is good.

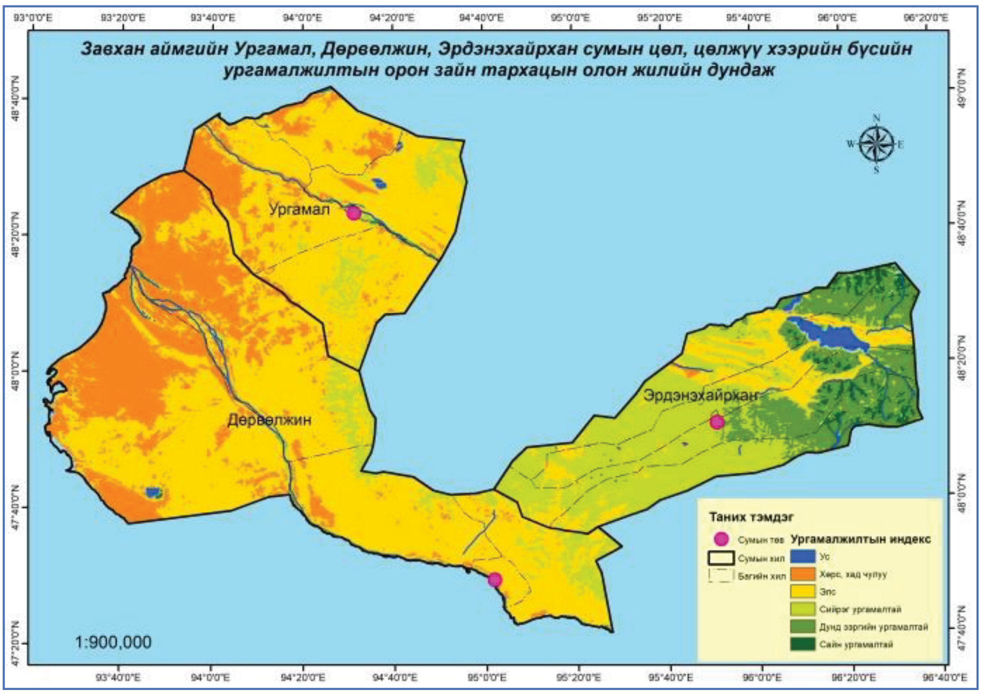


Figure 1. Spatial distribution map of perennial mean vegetation cover of the study area determined by SAVI.

Fig 2. shows the spatial distribution of multi-year mean land surface temperature of the study area. This image confirms that there is a lot of heat and drought and the condition of vegetation cover is poor for the site.

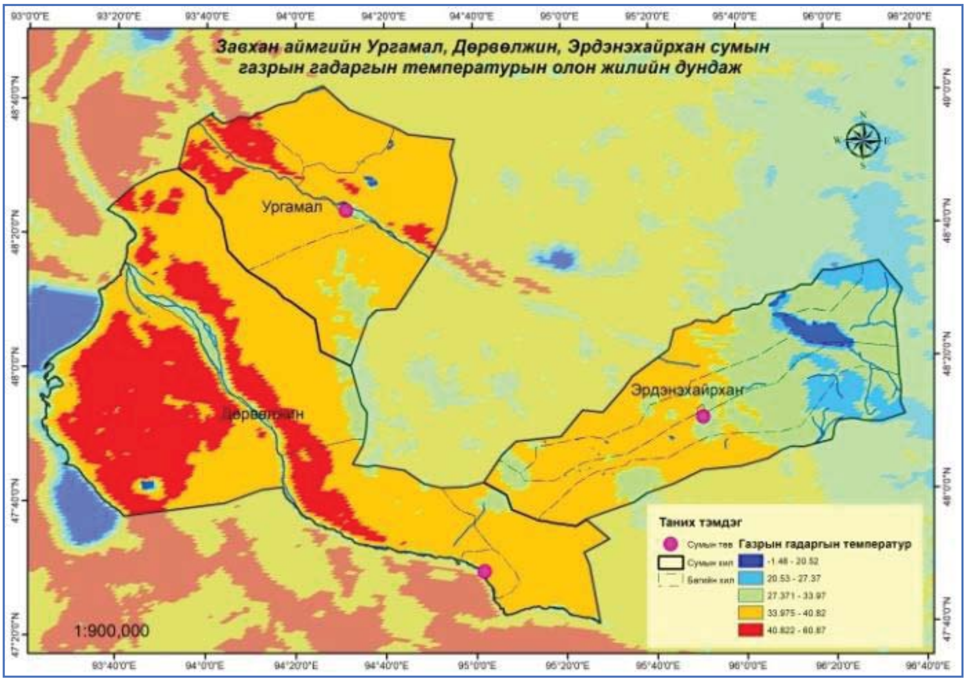


Figure 2. Spatial distribution of perennial mean land surface temperature

Comparing the vegetation cover condition and changes calculated by SAVI with the 2002 and 2003 examples with the climate data from the weather station, the vegetation cover condition in the region in 2003 was a relatively good year compared to 2002, with a good summer, high precipitation, and low heat and evaporation, as shown in Fig 3.

Differences in surface temperature of the studied counties in 2002 and 2003 compared to the long-term average were calculated using MODIS satellite data with 250 m resolution. Comparing the long-term differences in surface temperature in 2002 and 2003 in the desert and barren steppe regions, Fig 4. confirms that 2002 was a dry year with high heat and humidity throughout the study area, while 2003 was a year with good summer precipitation with favorable conditions for plant growth with low heat.

As a result of this study, the spatial distribution of long-term average and difference of vegetation cover and surface temperature based on satellite data in Sumy was compared with climate data and precipitation to determine which is more sensitive to land degradation and desertification.

a b

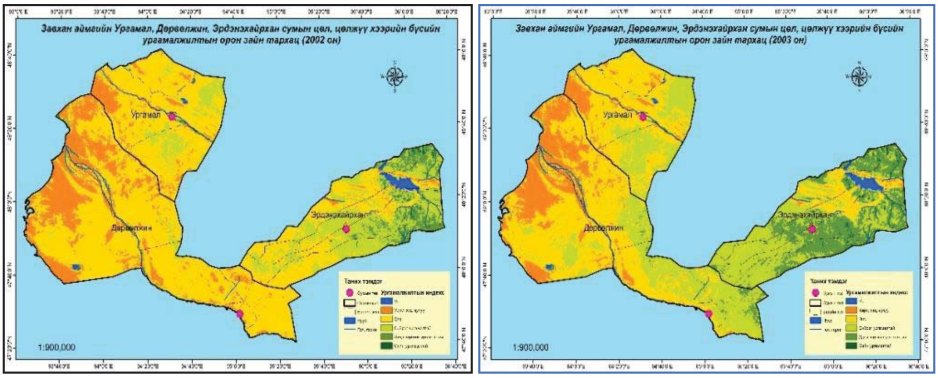


Figure 3. Spatial distribution maps of changes in vegetation status in 2002 and 2003, (a)-2002, (b)-2003.

a b

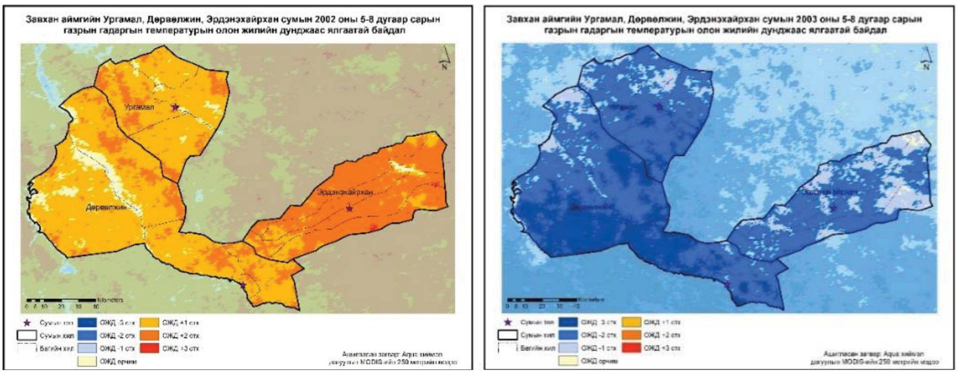
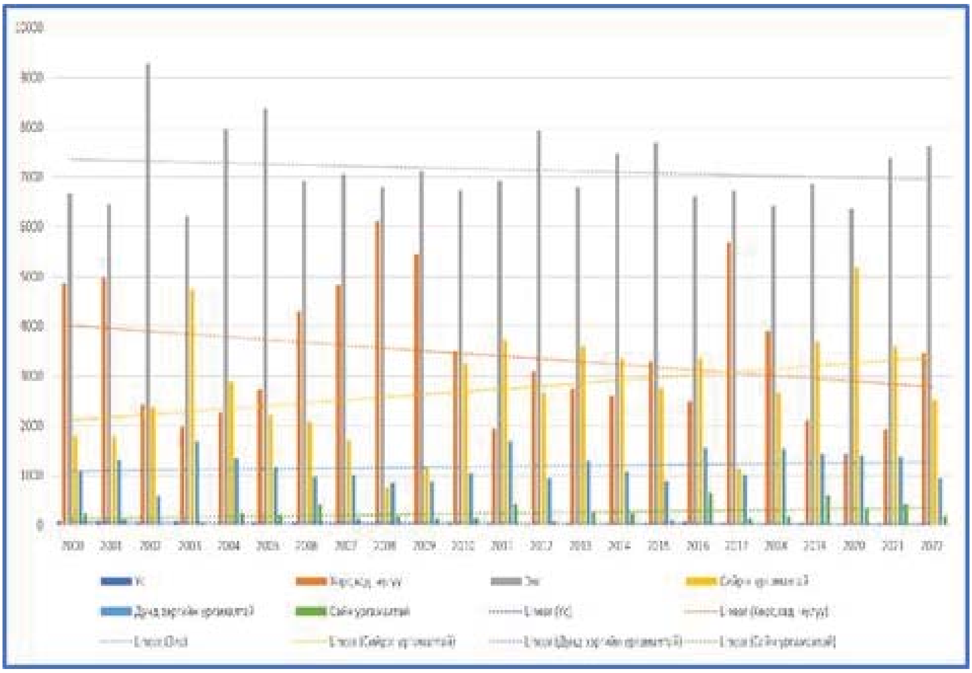
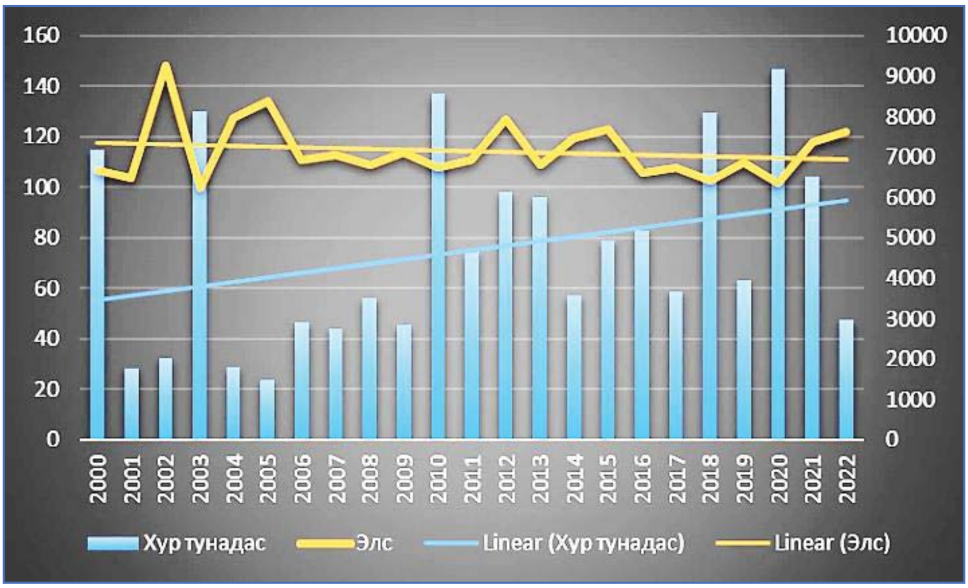


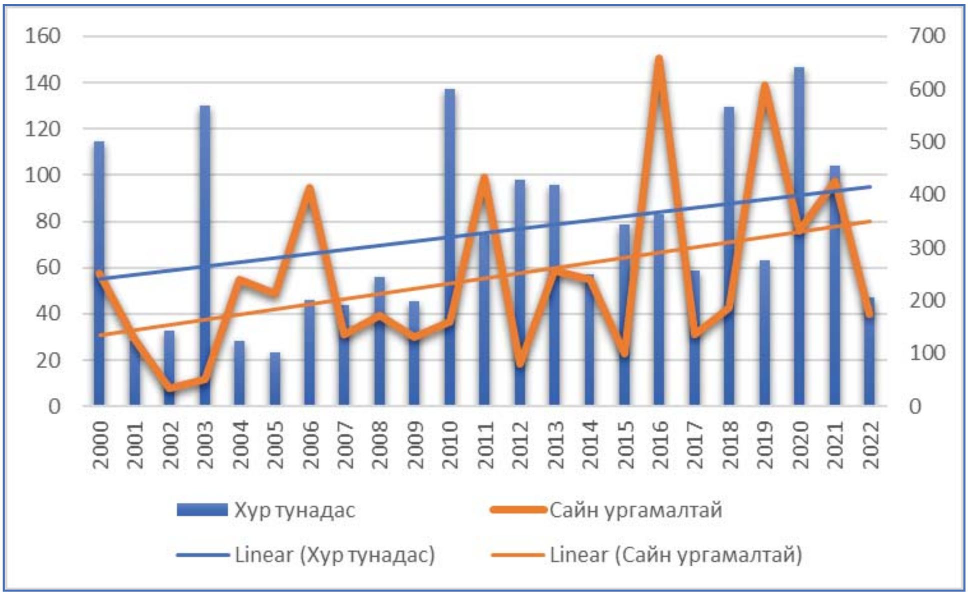
Figure 4. Spatial distribution of land surface temperature deviation from long-term average, (a)-2002, (b)-2003.



Graph 1. The statistics of 23-year changes in 6 categories of land cover from 2000 to 2022 in Ugramal, Durvoljin, and Erdenekhairkhan subdistricts of Zavkhan province are shown.



Graph 2. Statistics of 23-year changes in total annual precipitation and sand distribution in Ugramal, Durvoljin and Erdenekhairkhan subdistricts of Zavkhan province from 2000 to 2022 are shown.



Graph 3. Correlation between annual total precipitation and vegetation cover in Vegetation, Durvoljin and Erdenekhairkhan subdistricts of Zavkhan province from 2000 to 2022. Increase in precipitation is associated with improvement in crop yield.

5 Conclusion

1. From the 22-year spatial distribution of SAVI produced from MODIS satellite data from 2000-2022, it appears that changes in vegetation cover generally increased, although they depended on the climate of the year.

2. As the amount of precipitation increases, it can be observed that the predominant area of sand and bare soil decreases, as well as the land area with sparse vegetation.

3. Based on the satellite data of Sumy, which was studied in the desert and steppe region, the spatial distribution of deviations from the long-term average of surface temperature has increased in recent years, which is taken as an indication of the impact of global warming on the area.

4. Although the temperature of the earth's surface has tended to increase in recent years, it is clear from the above graphs that the amount of precipitation has a stronger influence on the condition and changes in vegetation cover.

References

1. National climate change program. Ulaanbaatar, Appendix to Resolution, 2 (2011), Ulaanbaatar, Mongolia.
2. Asian Development Bank, Grassland Sustainability in Mongolia: Herder Livelihoods and Climate Change, 2014.
3. S. Tuya, K. Kajiwara and Y. Honda, Estimation of Evapotranspiration in Mongolian Grassland using Landsat-ETM and NOAA-AVHRR, Proceedings of The Second International Workshop on Terrestrial Change in Mongolia, December 2-3, (2003) JAMSTEC Yokohama Institute for Earth Science, Yokohama, Japan, pp.19-22
4. S.Tuya, Satellite based evapotranspiration estimation in the steppe area of Mongolia, PhD thesis, 2016, Ulaanbaatar, Mongolia.
5. A.R Huete, A soil-adjusted vegetation index (SAVI), International journal of Remote Sensing of Environment, 25-3 (1988), pp. 295-309. https://doi.org/10.1016/0034-4257(88)90106-X
6. Genesis T. Yengoh , David Dent , Lennart Olsson , Anna E. Tengberg , Compton J. Tucker III, Use of the Normalized Difference Vegetation Index (NDVI) to Assess Land Degradation at Multiple Scales, Springer, Briefs in Environmental Science, 2016.
7. Compton J. Tucker, Jorge E. Pinzon, Molly E. Brown, Daniel A. Slayback, Edwin W. Pak, Robert Mahoney, An extended AVHRR 8-km NDVI dataset compatible with MODIS and SPOT vegetation NDVI data, International Journal of Remote Sensing, 26-20 (2005), pp. 4485-4498. https://doi.org/10.1080/01431160500168686
8. Jun Yang, Jiayi Ren, Dongqi Sun, Xiangming Xiao, Jianhong (Cecilia) Xia, Cui Jin, Xueming Li, Understanding land surface temperature impact factors based on local climate zones, Journal of Sustainable Cities and Society, 69 (2021), https://doi.org/10.1016/j.scs.2021.102818
9. R. Oyun, S. Altanhuyag, S. Tuya, Monitoring of surface temperature daily dynamics using NOAA-AVHRR data, Proceedings of 13rd Asian Conference on Remote Sensing October 7-11, 1992, Ulaanbaatar, Mongolia.
10. S.Tuya, Net radiation estimation under arid and semi-arid areas in Bayan-Undur soum, Uvurkhangai aimag of Mongolia, with Landsat TM data, Proceedings of the International Conference on climate change on arid and semi-arid regions April 20, (2013), pp. 174-180