Analyzing Lake Surface Area Changes of Orog Nuur (Mongolia) using Sentinel 2 and ERA5 Data between 2020 and 2023

Elena Scholz, Contact: elena.scholz@stud-mail.uni-Wuerzburg.de

Institute of Geography und Geology, Physical Geography, University of Würzburg

Abstract

Lake surface areas fluctuate due to environmental changes, human activities, and meteorological variability. In this research, Sentinel-2 data was used for the detection of shoreline and lake surface area variations and the correlation of climate variables of Lake Orog Nuur (Valley of Gobi Lakes, Mongolia). The processing was conducted in the Google Earth Engine (GEE) at annual and monthly intervals using Sentinel-2 data from 2020 to 2023. To extract shoreline and lake surface area, the Automated Water Extraction Index (AWEI) and Otsu Threshold were used. These metrics were correlated with climate variables aggregated on a monthly basis from ERA5 data, including precipitation, temperature, evaporation, and available water. The results indicate high interannual and monthly variations in lake surface area, with the lake drying out twice within the summer month and refilling within two months, which cannot be directly linked to precipitation or water availability. A high correlation was found between lake surface area and precipitation/available water from October to March, and decorrelation during the summer months. The findings suggest that especially during summer, other factors such as river runoff, permafrost and snowmelt from surrounding mountains play a crucial role in lake surface area extent. Therefore, these variables should be included in further analysis in this region. [R1, R2]

Study Area

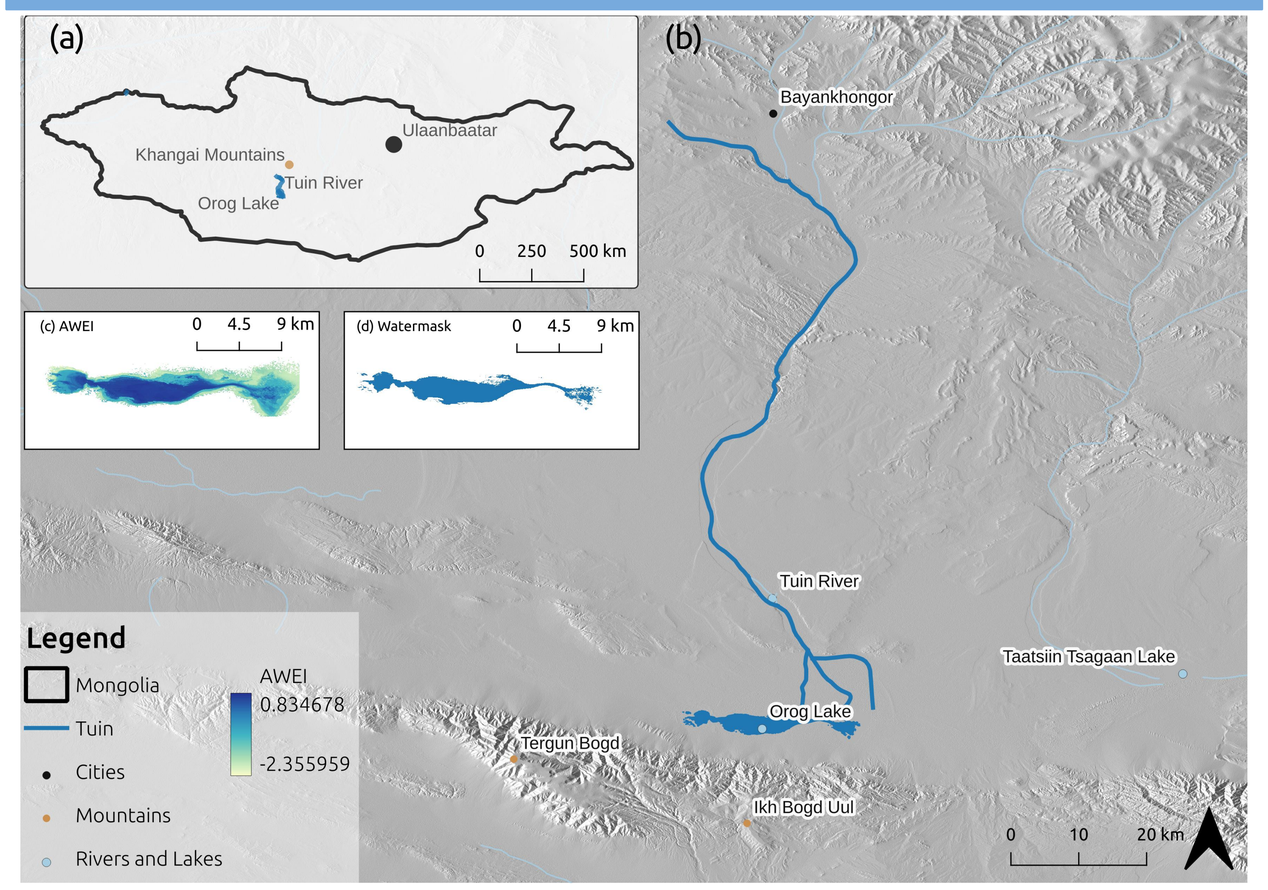

Figure 1: Study area:(a) Overview Map Mongolia, (b) Overview over Region of Interest (Valley of Gobi Lakes) with nearby mountains and cities, (c) Four-year Median AWEI image of Lake Orog with Sentinel 2 data, (d) Four-Year Median Water Mask generated with Otsu-Threshold of AWEI image (Map c).

Copernicus Sentinel-2 (processed by ESA), 2021, MSI Level-2A BOA Reflectance Product. Collection 1. European Space Agency. SRTM, NASA Shuttle Radar Topography Mission (SRTM)(2013) https://doi.org/10.5270/S2_-znk9xsj. Datasets accessed through GEE.

Proof of Concept

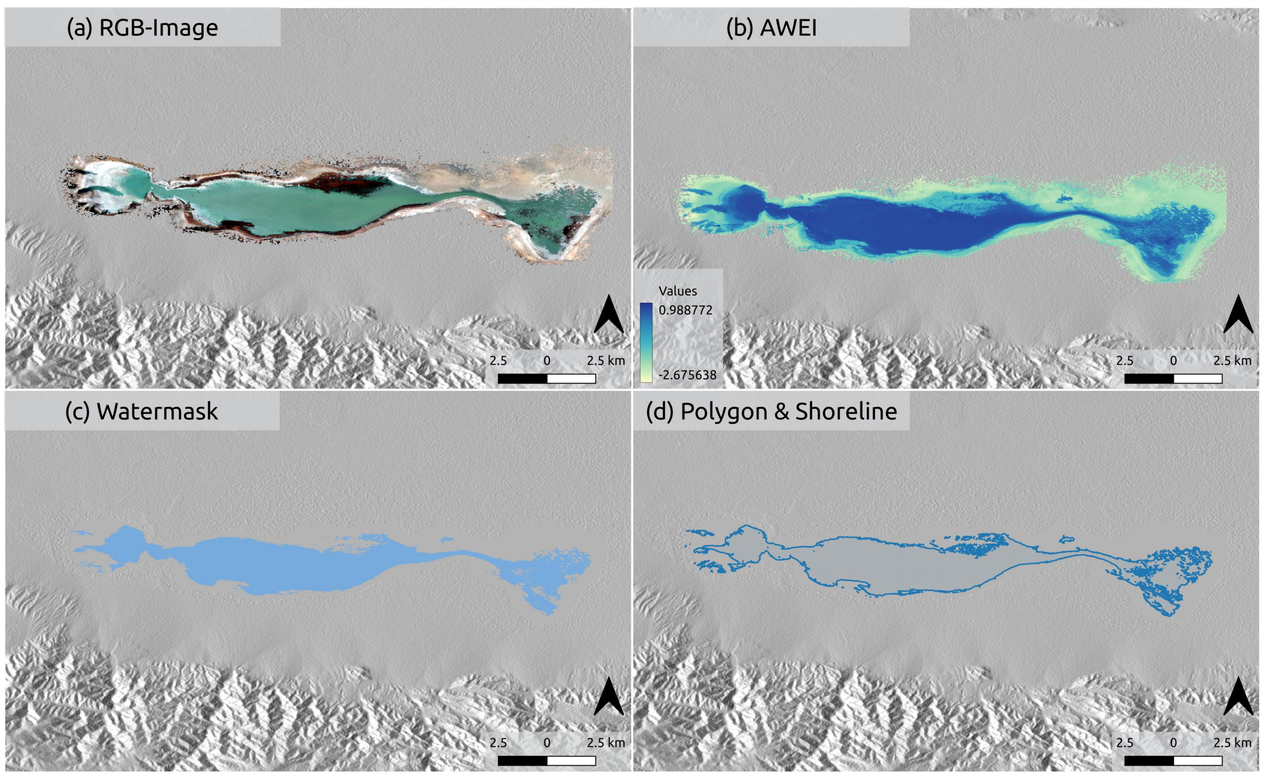

Figure 3 – Proof of Concept: Illustration of the methodological steps and results for year 2021. (a) an RGB image of Lake Orog, generated from Sentinel 2 data, (b) the Automated Water Extraction Index (AWEI) calculated from the same Sentinel 2 data, (c) the resulting water mask derived from the AWEI calculation, and (d) the vectorized water mask, displaying the shoreline and the lake area as a polygon..

Methodology

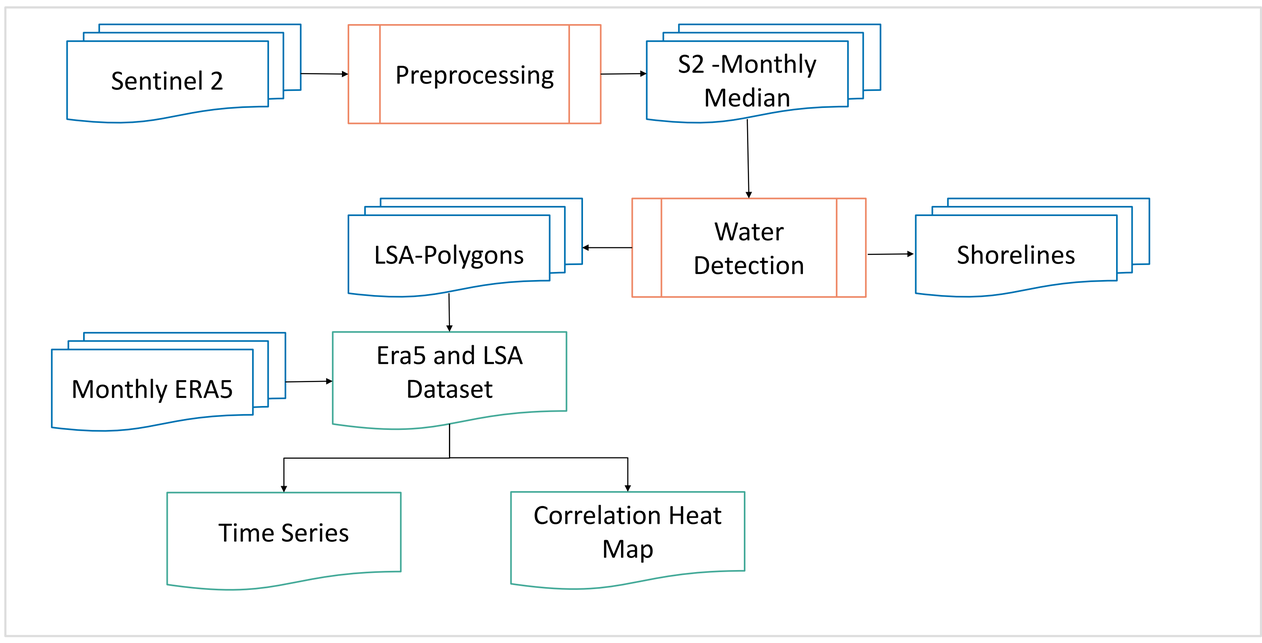

Figure 2: Methodological Workflow: Sentinel 2 data processing was done in GEE. The preprocessing includes a cloud mask (<20%), elevation mask (<1220m asl) and the calculation of monthly median images. Those are used for water detection (AWEI calculation and applying Otsu-Threshold to generate a Watermask). The results are Lake Surface Area Polygons and Shorelines.
ERA5 monthly aggregated climate datasets (precipitation sum, evaporation sum and temperature 2m) are used to quantify the results. For time series and correlation analysis R was used.

Results

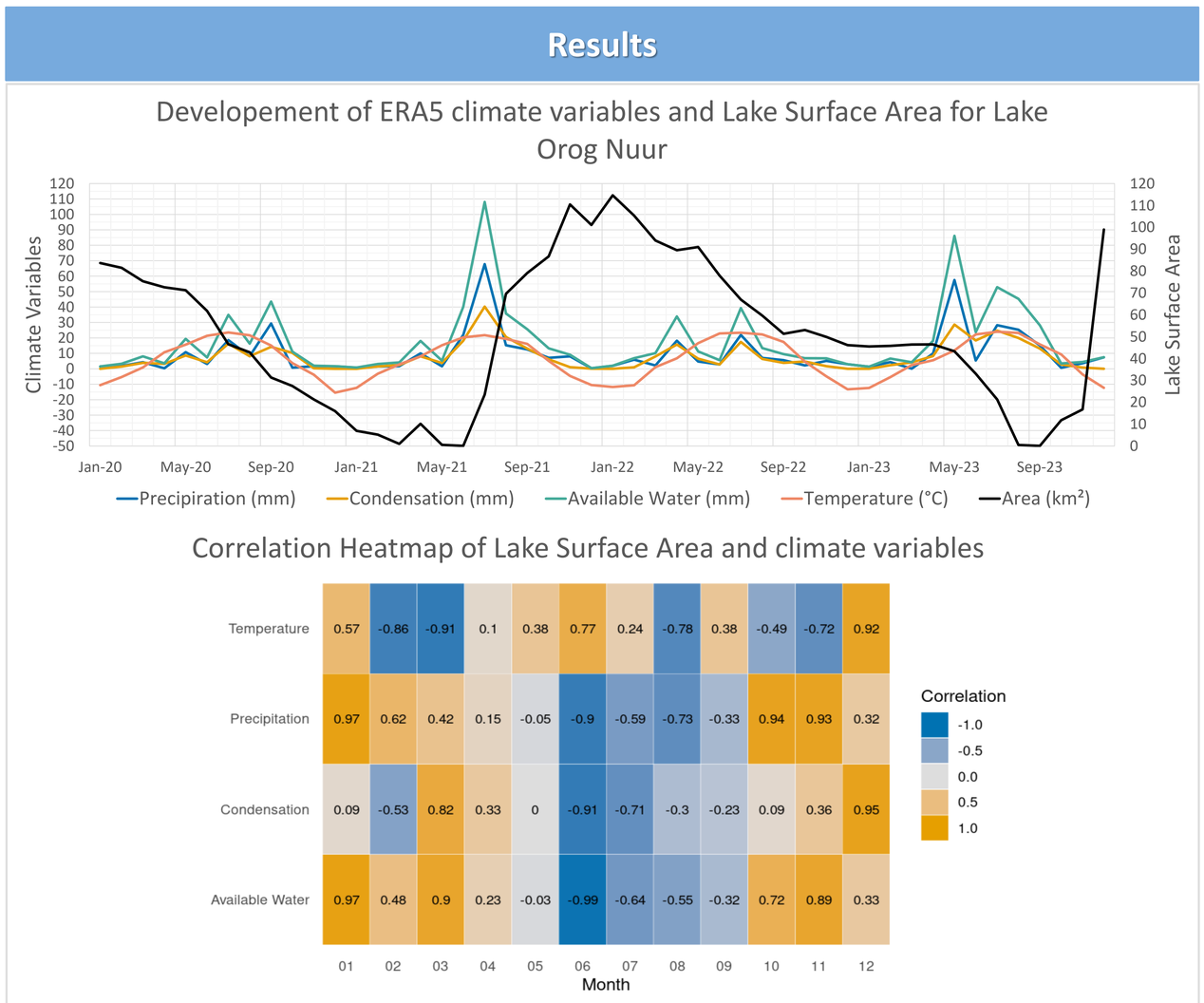

Figure 4: The results for time series Analysis including Lake Surface Area (generated from Sentinel 2 Watermask) and the climate Variables generated from ERA5.

Figure 5: Correlation Heatmap of Lake Surface Area with the ERA5 climate Variables

Highlights

I. **Lake Surface Variablity** : (I) - Variations in LSA and Shorelines can be observed between years and month,
(II) - LSA correlates with precipitation and Available Water during colder month and decorrelates during summer

II. **Climate Variables:** (I) - Climate variables alone cannot fully explain LSA variablity, (II) - Coerse Resolution of ERA5 datasets limit precise analysis, (III) - Critical facotrs like snow coverage, melted snow runoff, and river runoff are not included

III. **Lake Dynamics:** (I) - Rapid LSA increase observed within two month after dry-out events, (II) - Highlighted need for including additional environmental factors (snow cover, snowmelt, river runoff) and hydrological parameters e.g. catchment information for comprehensive analysis. (III) Summer decorrelation suggests other significant factors influencing LSA, challenging the expected relationship between precipitation and LSA.

References:
[R1]Klein, I.; Dietz, J. A.; Gessner, U.;Galayevac, A., Myrzakhmetov , A. Kuenzer, C. „ Evaluation of seasonal water body extents in Central Asia over the past 27 years derived from medium-resolution remote sensing data“ (2013)
[R2] Szumińska, D. „Changes in surface area of the Böön Tsagaan and Orog lakes (Mongolia, Valley of the Lakes, 1974–2013) compared to climate and permafrost changes“, Sedimentary Geology, Volume 340, 2016, Pages 62-73, ISSN 0037-0738, https://doi.org/10.1016/j.sedgeo.2016.03.002.