Monitoring coastline dynamics of Alakol Lake in Kazakhstan using remote sensing data

Adilet Valeyev (1), Ainagul Abitbayeva (1), Saule Uxukbayeva (1), Marat Karatayev (2,3), Aruzhan Bektursynova (1), and Zhanerke Sharapkhanova (1)

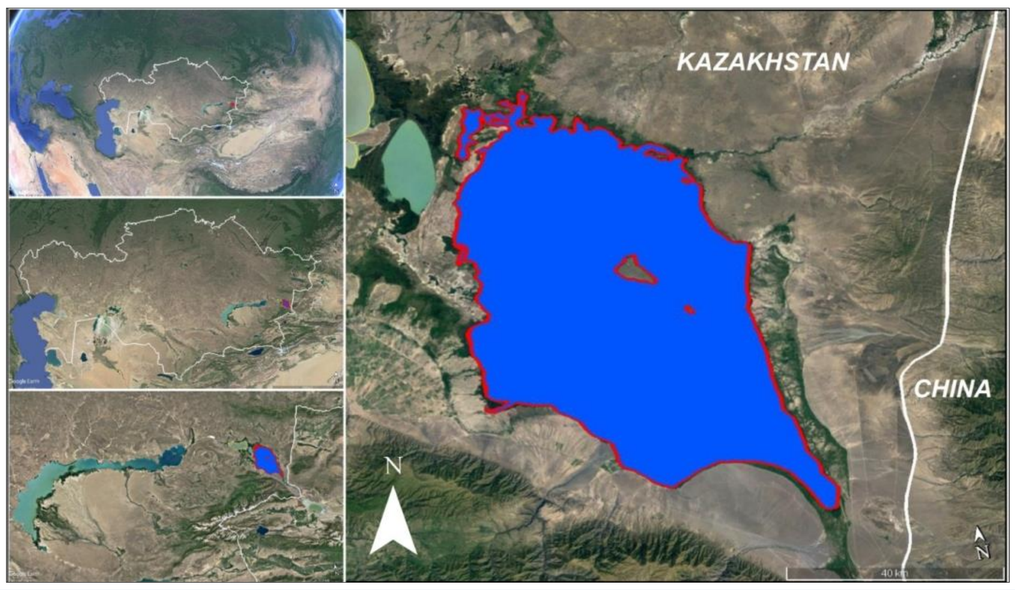
(1) Institute of Geography, Satbayev University, Almaty, Kazakhstan (adiletv@gmail.com), (2) Energy Technologies Research Institute, University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom, (3) University of Graz, Institute of Systems Sciences, Innovation and Sustainability Research, Ernst Mach Partnership Programme, Merangasse 18-1, A-8010 Graz, Austria

Abstract

- Alakol Lake is one of the largest hydrologically closed lake located in Balkash-Alakol River Basin in southeast Kazakhstan. Having a coastline approximately at 490 km Alakol Lake has faced multiple threats due to both natural and anthropogenic factors as a result of tectonic movements, geology and wind wave conditions, growing tourism activities, fishing and transport etc.
- The present study aims to investigate the coastline changes along Alakol Lake in Kazakhstan by using remote sensing data in particular scale-space images Landsat Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), Operational Land Imager and Thermal Infrared Sensor (OLI TIRS), Sentinel 2B images (S2B). Modified Normalized Difference Water Index was calculated to demonstrate the coastline changes along Alakol Lake between 1990 and 2018. Moreover, the monitoring and analysis of coastline dynamics is based on the main morphometric characteristics of Alakol including water surface area, coastline length, geomorphology of coast etc.
- Our results reveals that there is a continuous coastline shrink toward land, depending on the coast types. For example, in case of the accumulative coast (mainly northeast, north and northwest coasts) a coastline shrink toward land was from 200 to 900 m. As a result, vast areas of agricultural land were flooded and degraded wetlands. In case of the denudation coasts, a coastline shrink toward land was from 120 to 270 m between 1990 and 2018. This study demonstrates the importance of monitoring coastline dynamics, since it provides essential information for understanding the coastal response to contemporary nature and anthropogenic impacts.

Research area

- Alakol Lake, located in the southeast of Eastern province of Kazakhstan (46°04’52” N, 81°45’51” E), with an area of 104×53.5 sq. km. The climate on Alakol Lake is a continental climate, with very cold snowy days in winter but very hot and dry weather in summer. Mean annual temperature and precipitation are 6.2-7.2°C and 152.9 mm. The maximum and average depth of the lake in 2018 was 54 and 22 m. The estimated living population in Alakol Lake region include settlements, irrigation systems, livestock, agriculture, tourism.



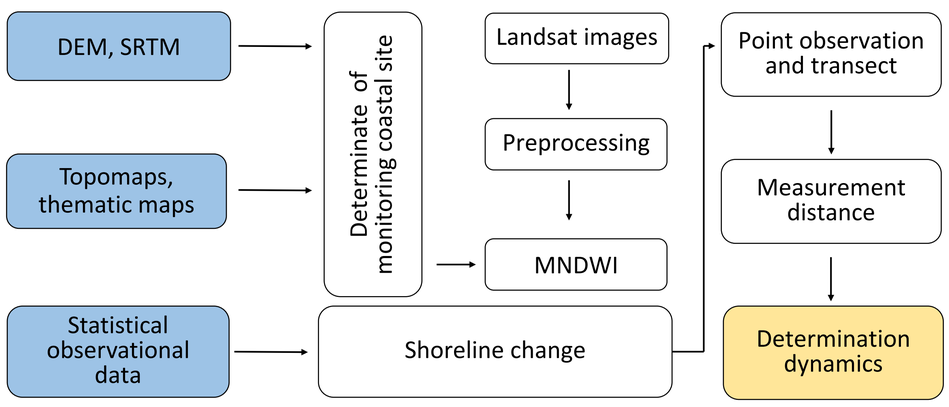
Material and method

- The 30 m spatial resolution Landsat Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), Operational Land Imager and Thermal Infrared Sensor (OLI TIRS), Sentinel 2B images (S2B) were downloaded from the USGS catalog of the US Geological Survey via https://earthexplorer.usgs.gov for the period of 1990 - 2018.

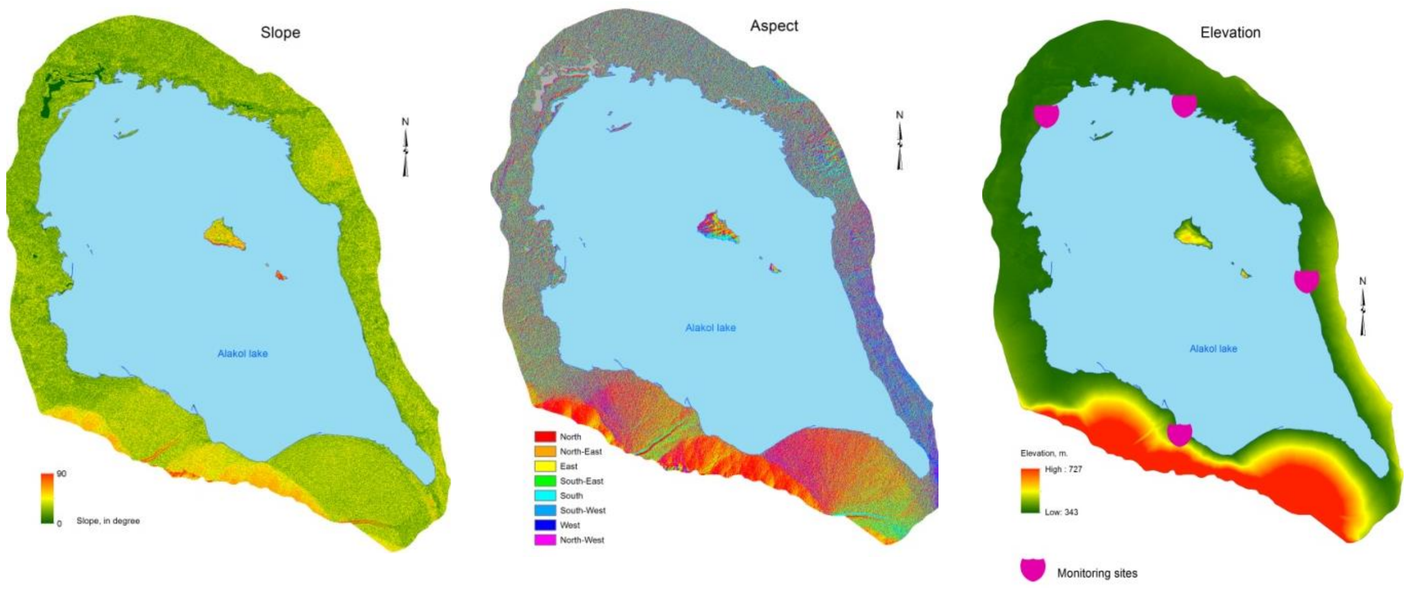
No	Satellite	Satellite images	Acquisition date	Sensor	Pixel spacing (m)
1	Landsat-5	LT05_L1TP_147028_19900606_20170130_01_T1	06/06/1990	TM	30
2	Landsat-5	LT05_L1TP_147028_19950417_20170109_01_T1	17/04/1995	TM	30
3	Landsat-7	LE07_L1TP_147028_20000727_20170210_01_T1	07/27/2000	ETM+	30
4	Landsat-7	LE07_L1TP_147028_20050623_20170115_01_T1	23/06/2005	ETM+	30
5	Landsat-7	LE07_L1TP_147028_20100808_20161213_01_T1	08/08/2010	ETM+	30
6	Landsat-8	LC08_L1TP_147028_20150830_20170405_01_T1	08/30/2015	OLI TIRS	30
7	Landsat-8	LC08_L1TP_147028_20180705_20180717_01_T1	07/05/2018	OLI TIRS	30
8	Sentinel 2B	S2B_MSIL1C_20180729T05_N0206_R105_T44TLN_2018072025	29/07/2018	S2B	30
9	Sentinel 2B	S2B_MSIL1C_20180726T059_N0206_R063_T38LNR_201804944	29/07/2018	S2B	30

- Morphometric conditions (slope, exposure, absolute heights) of the surface part of the coastal zone were analyzed via using Digital Elevation Model (DEM), Shuttle Radar Topography Mission (SRTM), medium-scale topographic map and thematic maps from National Atlas of the Republic of Kazakhstan.
- Modified Normalized Difference Water Index (MNDWI) is based on the different spectral bands - green and mid-infrared (MIR) bands. Band 2 (green) and band 5 (mid-infrared) spectral channels are used in Landsat 5 (TM) and 7 (ETM+): MDNWI = band 2 (G) – band 5 (MIR) / band 2 (G) + band 5 (MIR). Band 3 (green) and band 6 (mid-infrared) are used in Landsat 8 (OLI TIRS): MDNWI= band 3 (G) – band 6 (MIR) / band 3 (G) + band 6 (MIR).

Overall flowchart and methodology of this research



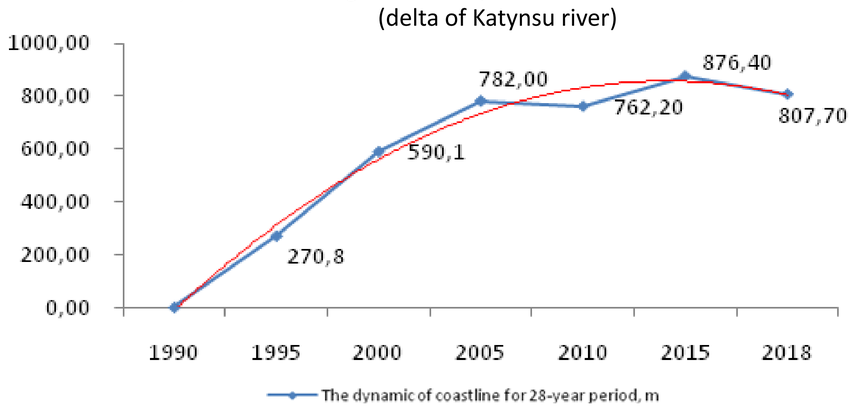
Morphometric characteristics of Alakol coastal zone

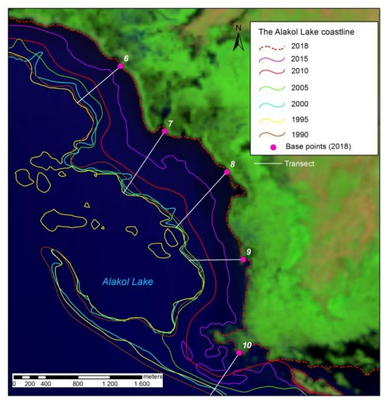


Coastline dynamics

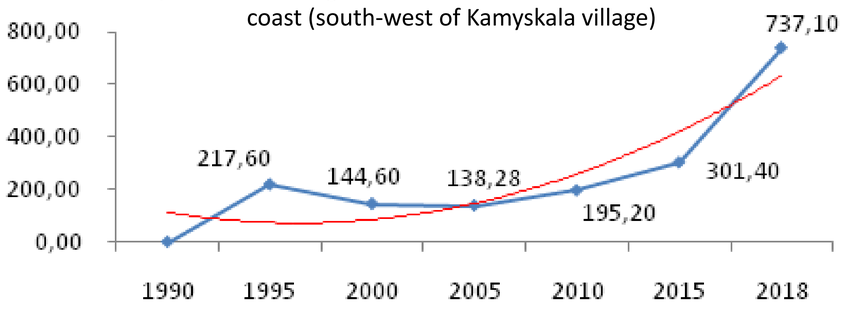
- Monitoring site (I) in delta of Katynsu river: the coastline of the lake has moved forward toward land for about 1 km in some places. These are mainly low accumulative coasts, on which extensive wetlands are located;
- Monitoring site (II) in Kamyskala village: the shift of the lake’s coastline is determined by an average of 120-180 m;
- Monitoring site (III) in Kabanbai village: over the 28-year period, the dynamics of the coastline toward land amounted to more than 200 m;
- Monitoring site (IV) in Koktuma village: the coastline has moved forward in the western direction, on average, for more than 130 m throughout the entire coast, the most drastic changes occurred during the period from 2000 to 2005.

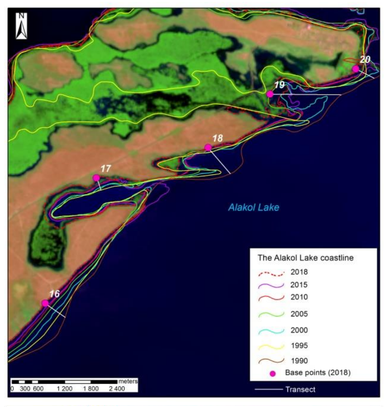
I) Coastline change in eastern, denudation-accumulative coast (delta of Katynsu river)



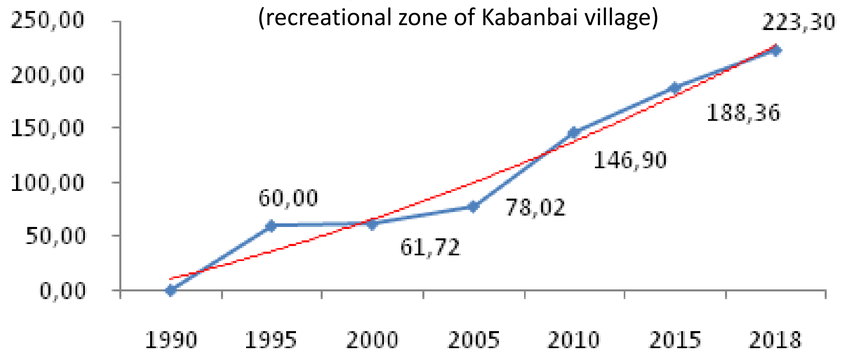


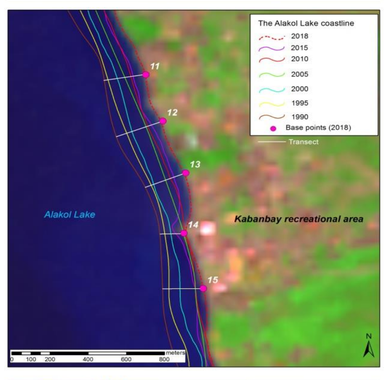
II) Coastline change in northern, denudation-accumulative coast (south-west of Kamyskala village)



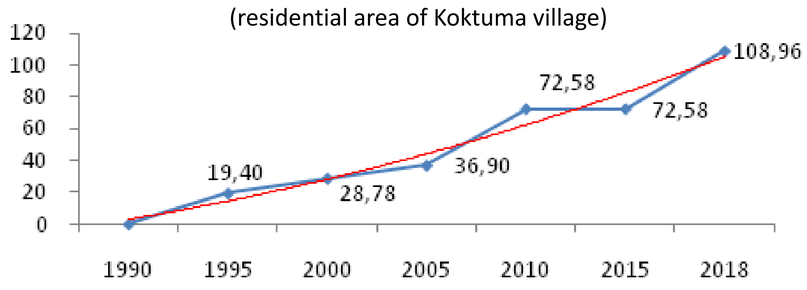


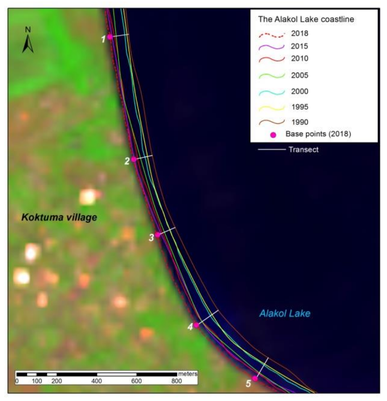
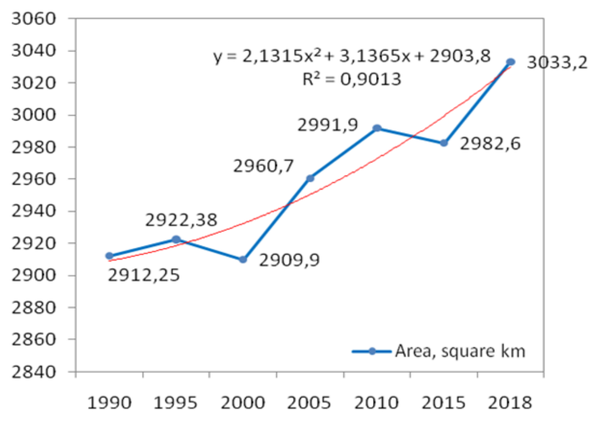
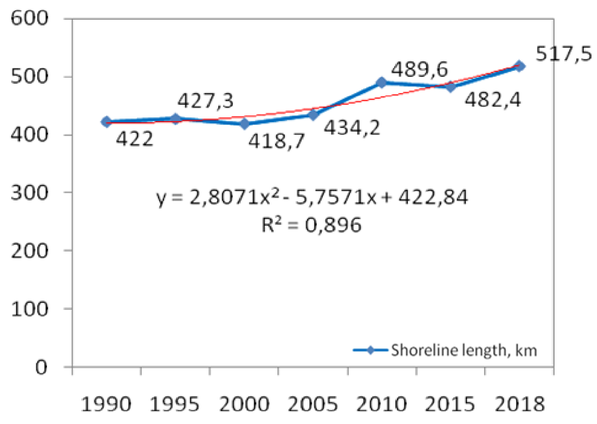
III) Coastline change in north-eastern, accumulative coast (recreational zone of Kabanbai village)





IV) Coastline change in south-western, denudation coast (residential area of Koktuma village)





- The water surface areas of Alakol Lake increased from 2912.3 to 3033.2 between 1990 and 2018; the length of the coastline increased from 422.1 km in 1990 to 427.3 in 1995; from 434.2 in 2005 to 489.6 in 2010; from 482.4 in 2015 to 517.2 km in 2018.