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Impacts of climate change and evapotranspiration on shrinkage of Aral Sea

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The massive desiccation of the Aral Sea (figure 1), the fourth largest lake in the world, has led to severe ecological problems in the Aral Sea basin (ASB). The ongoing shrinkage of the Aral Sea should be halted urgently (figure 2). Finding the causes of its crisis can offer hope of partially rehabilitating its water body and restoring the ecosystems, which could be crucial to the health and socioeconomic welfare of millions of people. The expansion of cropland (especially irrigation land) has been considered the prime factor for a long time. However, we think that the situation might have changed since the turn of the 21st century, as changing climate and degraded cropland have been observed in the ASB recently. These complicate the attribution of the Aral Sea shrinkage, and few studies have quantified the driving factors of that shrinkage comprehensively.

Extensive datasets based on Earth observation and climate reanalysis were constructed in the present study and used to the quantitative comparative climate-land-water-ecological dynamics across the ASB and its subregions from 1980 to 2019 (figure 3).

The study performed a long-term land cover/use (LCLU) change assessment for ASB to show that the cropland stopped expanding in 2000, of which the cropland in the ASB plain area decreased significantly (-140 km^2/year) from 2001 to 2019. By contrast, this study finds the hydrological cycle in the ASB has intensified, with a 10.13% increase in annual total actual evapotranspiration (AET) for the whole ASB during 1980-2019.

The main conclusions are:

- Changing climate and increasing annual total actual evapotranspiration AET have accelerated the desiccation of the Aral Sea, and the expansion of cropland is no longer the main factor of that shrinkage.
- After more water was conserved in the ASB plain area, evapotranspiration plays a more vital role in the Aral Sea shrinkage.
- Reducing AET and unproductive water losses are key initiatives in future projects to save the Aral Sea.

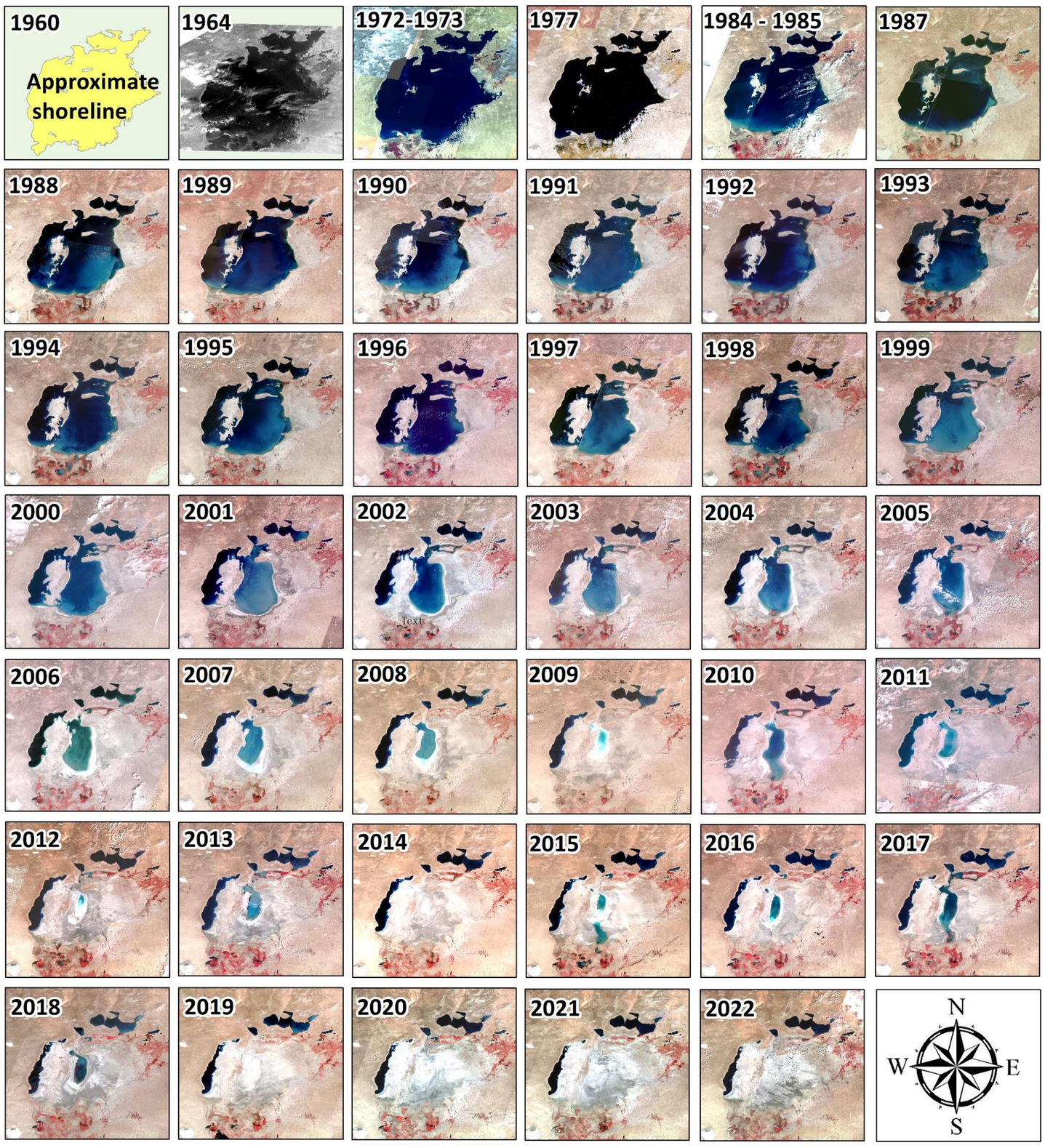


Figure 1. Maps of sharp shrinking of the Aral Sea from 1960 to 2022 based on the Argo and Landsat satellite images. To reduce the impact of seasonal changes as much as possible, most of the Landsat images used in this study were selected mainly from June to August, associated with cloud shadow and image quality.

Figure 2. Photos taken during the field survey in 2019. The dry lakebed of the Aral Sea has gradually become a huge source region for dust storms containing various pollutants. Hence, severe ecological disaster has occurred across the ASB, such as the rapid desertification and soil salinization. Due to long-term exposure to a polluted environment, millions of people are being threatened by a wide range of health issues.

Figure 3. Overall map of the study area. a) Location of ASB in Central Asia. b) Three parts of the study area, which were organized based on DEM data. c) Ten subregions of the ASB, covering upstream, middle stream, and lower stream.

Why has the Aral Sea shrunk ?

Changing climate

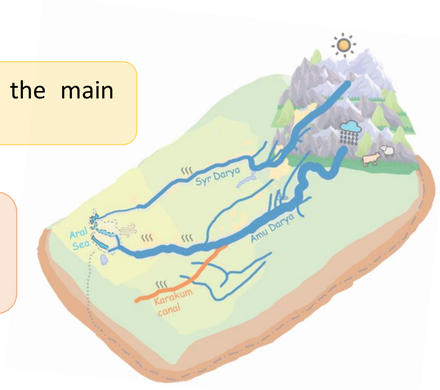
increasing AET

accelerated

Shrinkage of Aral Sea

The expansion of cropland is no longer the main factor of the Aral Sea shrinkage.

After more water was conserved in the ASB plain area, **evapotranspiration plays a more vital role** in that shrinkage.



Reducing AET and unproductive water losses

rehabilitate

Partially of the water body

key initiatives in future projects to save the Aral Sea.

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