

Case study: Overuse of water for irrigation - an old concern revisited

Aral Sea, Kazakhstan and Uzbekistan



Relicts of the thriving fishing industry during the soviet period. Moynaq, Aral Sea.
Source: Arjan Zweegers, Flickr.com

The Aral Sea is a classic and prominent case of pollution and environment degradation resulting from massive agricultural development. An almost endless series of reports has raised public awareness through pictures of children running past ruined ships abandoned in the sand of the dry seabed, abandoned harbour facilities now located on dry wasteland and satellite images showing vast areas left dry following the rapid contraction of the Aral Sea on the borders between Kazakhstan and Uzbekistan. By 1997 the Intergovernmental Panel on Climate Change had highlighted the importance of the Aral Sea as 'a case study of the multiplicative effects of resource overuse, which can lead to local environmental and even climate change', and in an effort to identify archetypical schemes of human-environment interactions, scientists have coined the term 'Aral Sea Syndrome'¹. Today it is used as a descriptor for similar patterns of environmental degradation, socioeconomic problems and conflicts caused by dams and irrigation schemes in other parts of the world, such as the Tarim Basin of western China.

At around 67 500 km in 1960, the Aral Sea was the world's fourth-largest inland water body. It is a terminal lake, mainly fed by two rivers, the Amu Darya and the Syr Darya, which originate in the snowfields and glaciers of the Pamir and Tian Shan mountains. Located in a region with primarily arid climates, the extent of the Aral Sea depends on the equilibrium between annual fresh-water inflow and evaporation. From the mid 17th century until the 1960s, lake-level variations were likely less

than 4.5 m, and during the first six decades of the 20th century they were less than 1 m². As a brackish lake with salinity averaging near 10 g/l, the lake was home to freshwater fish species, supporting a major fishery industry.

The deltas of the Syr Darya and the Amu Darya sustained diverse flora and fauna. But they were also of considerable economic importance, supporting irrigated agriculture, animal husbandry, hunting and trapping, fishing and the harvesting of reeds, which served as both fodder for livestock and building materials³.

The lands that now constitute five of the seven basin states (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) were part of the Russian Empire and its successor, the Soviet Union, from the late 19th century until the collapse of the USSR in 1991. Irrigation was practised in the Aral Sea basin for millennia without substantially diminishing inflow to the Aral Sea. However, with the introduction

of large-scale irrigation systems in the early 1930s, traditional and sustainable water-management systems within the region were largely destroyed. Construction of the Karakum canal in the early 1950s, part of massive Soviet industrialisation in the 1940s, rerouted most of the flow of the Amu Darya westwards into the Karakum desert of Turkmenistan.

Under the 'Great Plan for the Transformation of Nature', Stalin required the reduction of the sea's surface area to close to 10% of its former size, to foster the growth of a cotton industry ('white gold')¹⁴. Between 1960 and 1980 the cotton acreage in central Asia expanded rapidly. In Uzbekistan alone, cultivated lands increased from 1.3 million to 2.1 million hectares, with increasing volumes of Amu Darya and Syr Darya river water being used for irrigation⁴. The continued expansion of irrigated agriculture through the construction of huge irrigation systems markedly reduced river discharge to the Aral Sea: in some years no water at all passed through the Amu Darya and Syr Darya deltas^{2, 3, 4}.

Since the 1960s the Aral Sea has undergone rapid desiccation and salinisation, almost entirely as a consequence of the unsustainable upstream diversion of stream flows to support expansion of irrigation. By September 2011 the lake had separated into four parts, with shrinkage in its total aggregate area (85%) and volume (92%). It suffered a maximum level drop in the most desiccated part (the Large Aral Sea) of nearly 26 m, while experiencing an increase in salinity levels in excess of 100 g/l, more than 10 times greater than in 1960³.

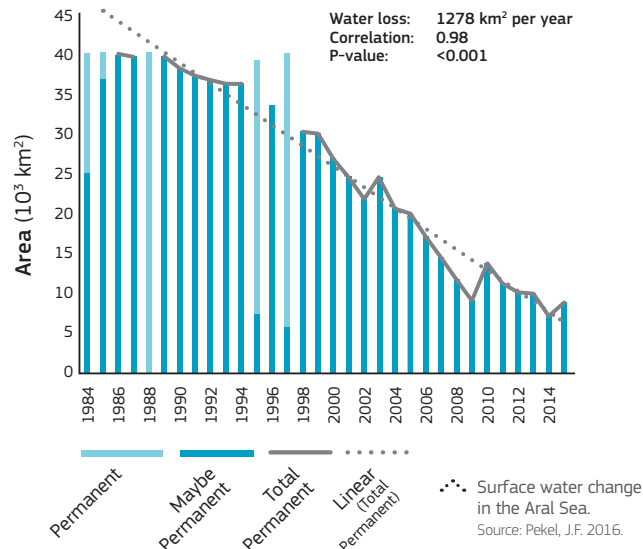
The Aral Sea Basin
All rivers basins that flow into the Aral Sea are mapped in green.
Source: Adapted from FAO.



Cotton field in the Amu Darya region.
Source: Hill, J.



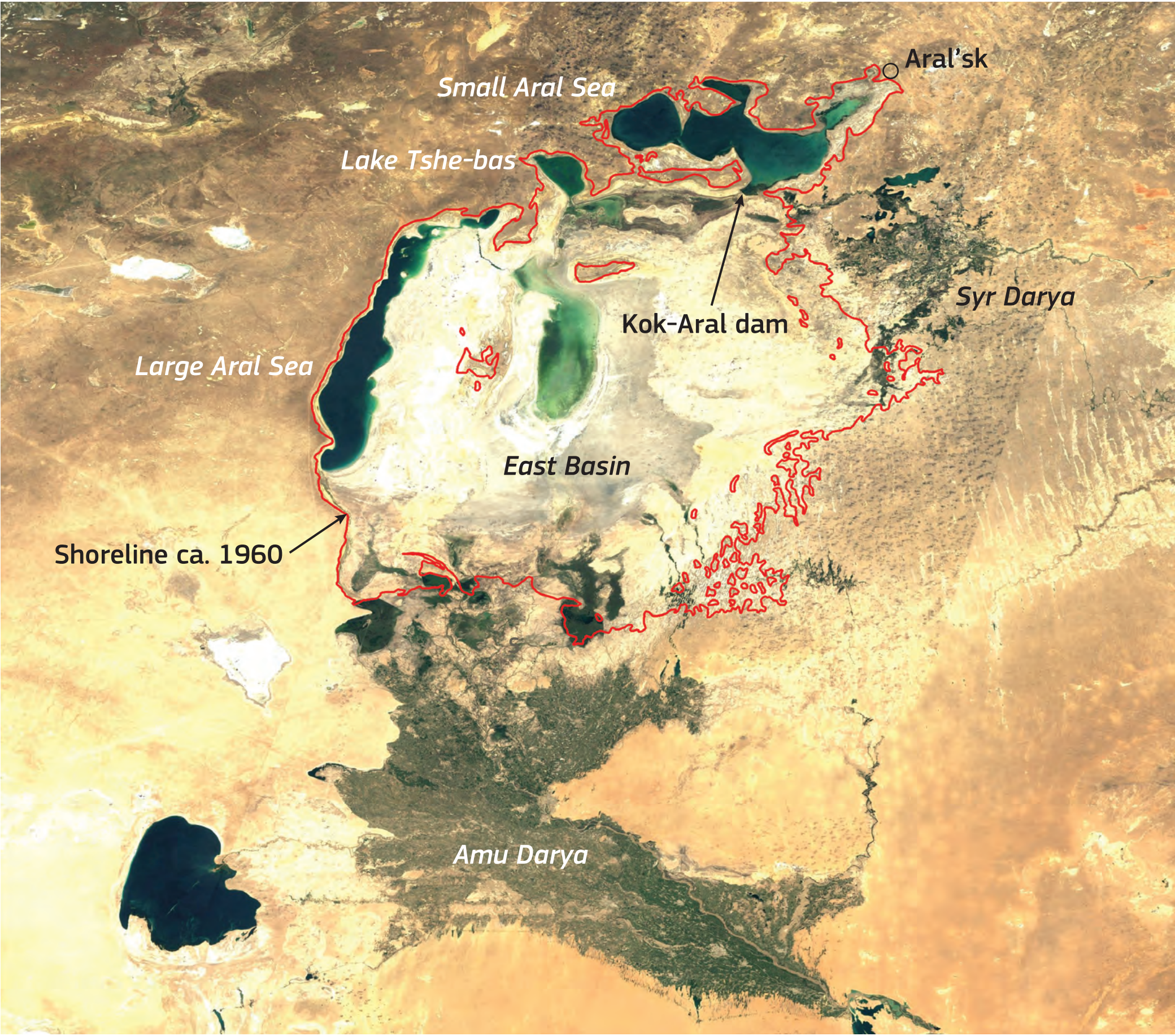
Cotton bolls.
Source: Hill, J.



The consequences were dramatic. With the shrinkage of the fourth-largest lake in the world, a huge saline desert emerged on the former seabed, called the Aralkum⁵. From an ecological point of view it is considered the world's largest area where primary succession is taking place. The rich and diverse ecosystems of the Amu Darya and Syr Darya deltas (Uzbekistan) have suffered greatly due to reduced river flows, the virtual elimination of spring floods (owing to the construction of upstream storage reservoirs and reduced river flows) and the lowering of groundwater levels. Unique tugay vegetation complexes stretched along all the main rivers and distributary channels and covered 100 000 hectares in the Amu Darya delta in 1950. Once forming important habitats for mammals, birds and amphibians, they were reduced to only 20 000 to 30 000 hectares by 1999⁷.

The fishing industry that once employed 40 000 workers and supplied one sixth of the Soviet catch was totally eradicated, causing widespread economic distress, ultimately throwing tens of thousands of people out of work. Navigation on the Aral also ceased by the 1980s^{3, 4}. The fishing ports of Moynak (in the delta of the Amu Darya in Uzbekistan) and Aralsk (in the delta of the Syr Darya in Kazakhstan) have literally perished, the former now lying 60 km from the Aral Sea's current shores.

The Aral Sea viewed from Sentinel-2.
Source: Sentinel-2 cloudless by EOx IT Services GmbH,
WWF Global lakes and wetlands database⁶



Cotton featured in official Soviet seals of the Azerbaijan, Kyrgyz, Tajik, Turkmen and Uzbek republics.
Sources: TheSign, 1998. Wikimedia Commons.



Case study: Overuse of water for irrigation - an old concern revisited (cont'd)

Aral Sea, Kazakhstan and Uzbekistan (cont'd)

Traditional forms of irrigated agriculture in the deltas paid a high price for the expansion and intensification of agriculture in the upper reaches, as inflow into the deltas decreased owing to heavy upstream consumptive use. The water that does reach the deltas has elevated salinity from the leaching of salts deposited in fields in the middle and upper courses of the rivers. The consequences are reduced crop yields and, in conjunction with insufficient drainage of irrigated fields, secondary soil salinisation^{4, 6}. Animal husbandry, in both the deltas and the desert regions adjacent to the Aral Sea, has been damaged by a reduction in the area and declining productivity of pastures resulting from desertification, falling groundwater levels and the replacement of natural vegetation suitable for grazing with inedible species^{3, 4, 6}. The diminution of the Aral Sea water-surface area was also coupled with increasing pollution of the remaining water bodies (primarily from irrigation run-off containing salts, fertilisers, pesticides, herbicides and cotton defoliants). Highly subsidised prices within the context of a planned farm economy in the former Soviet Union prior to 1990 provided no incentive for efficient use of agro-chemicals (which were also more contaminating than those now available on the world market)⁴.



Russian postage stamp depicting the Aral Sea¹¹. Source: By USSR Post, Wikimedia Commons.

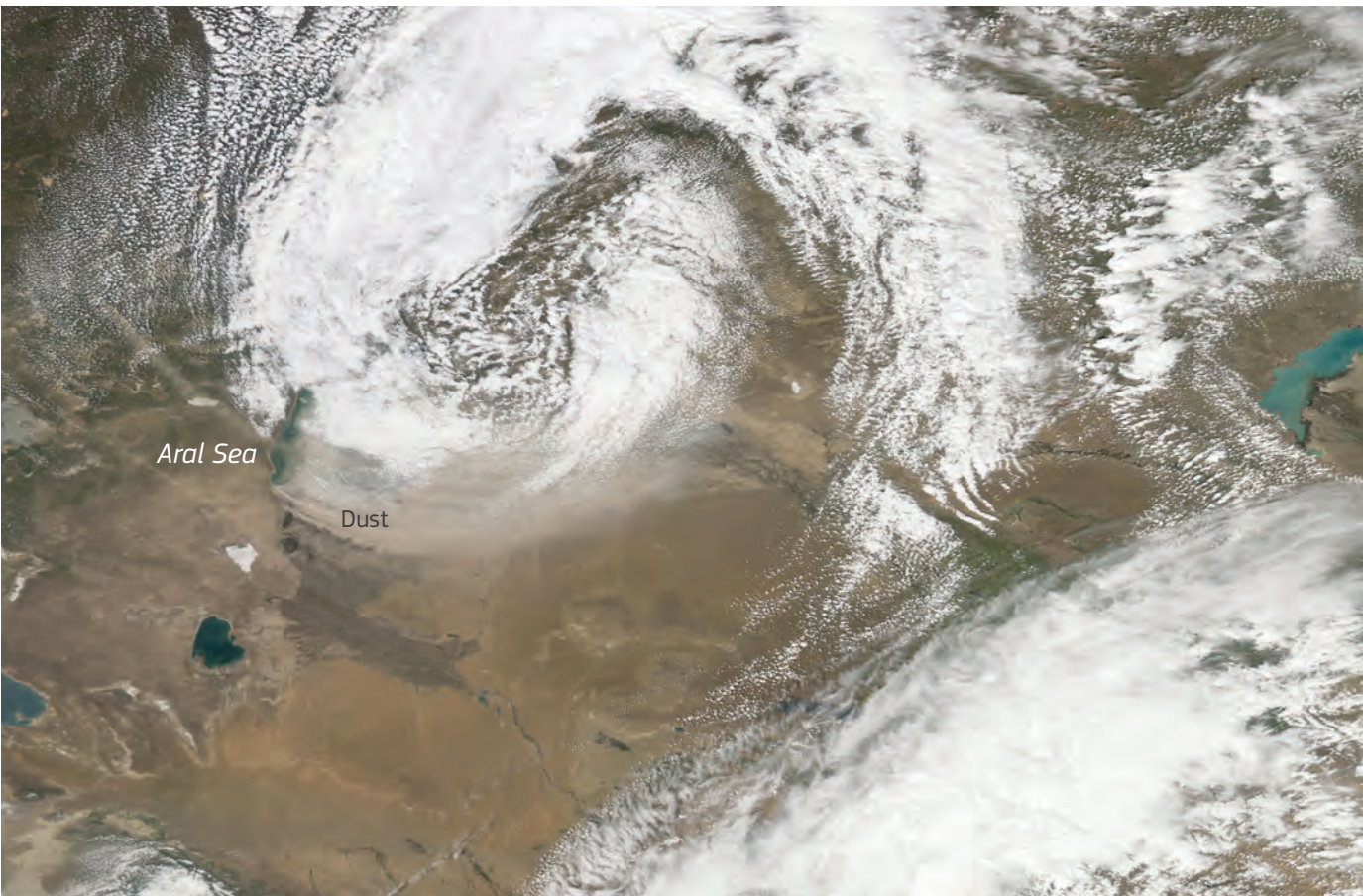
Nowadays strong winds blow toxically charged sand, salt and dust particles from the dried bottom of the Aral Sea onto the surrounding lands, which limits plant growth and reduces yields⁹. These storms are between 150 and 300km wide and salt content in the dust reaches 30-40% of the volume, and in extreme cases can be as high as 90%. Sometimes the Aralkum salts even reach intensively irrigated and cultivated lands far from the Aral Sea region¹¹.

Health experts consider airborne salt and dust, as well as the chemical pollution and excessively high salinity of drinking water, to be major causes of high levels of respiratory illnesses and cancerous diseases in the region. Substantial dioxin residues have been found in mothers' milk, and waterborne diseases such as typhus, paratyphoid and viral hepatitis have increased enormously over the past decades in the midstream and downstream areas of the Amu Darya and Syr Darya^{4, 6, 7, 8}.

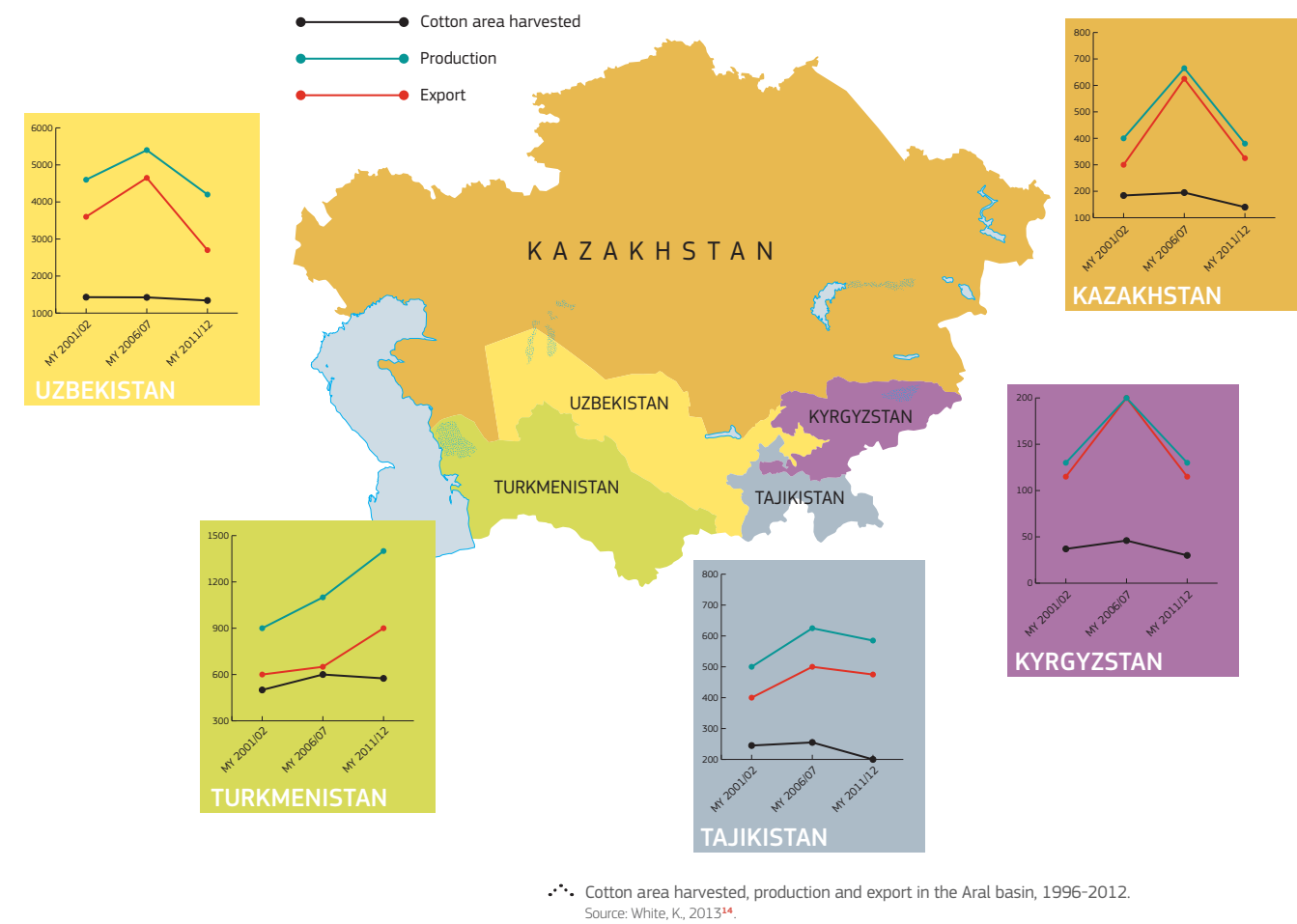
Hypersaline environments, such as the Aralkum, are also sources for a multitude of volatile halogenated organohalogenes (VOX). These compounds can affect the ozone layer of the stratosphere and play a key role in the production of aerosols¹⁰.



Secondary soil salinisation on irrigated cotton fields. Source: Hill, J.



Dust raising from the Aral Sea. Source: MODIS Acqua acquired 7 May 2007, NASA.



Cotton area harvested, production and export in the Aral basin, 1996-2012. Source: White, K., 2013¹⁴.

reduce the consumptive use of water upstream for irrigation (which amounts to more than 90% of withdrawals from the rivers)^{3, 6, 13}. Modelling studies have shown that the impacts of water use will surpass the impact of climate change in the region¹⁵.

Improvements to irrigation infrastructure and technologies have been initiated that aim to limit leakage and evaporative losses (i.e. to increase efficiency). However, a substantial and comprehensive approach will be extremely costly and is obviously beyond the ability of basin states, even in combination with international donors. Moreover, the technical condition of the existing irrigation systems is steadily deteriorating⁶. Finally yet importantly, technical improvements must be coupled with strong institutional changes in irrigation water and drainage management that involve the more realistic participation of water users. The present high level of state subsidies results in differential support for specific crops yet discourages changes and the efficient use of water resources.

A change in agricultural practices (agroforestry) and the conversion of more of the irrigated area to less water-intensive

crops than cotton and rice (such as winter wheat, soybeans, fruits and vegetables) led to a reduction in irrigation withdrawals during the 1990s, although irrigated area increased by 10% at the same time. However, this effect will remain limited, primarily because Uzbekistan and Turkmenistan (which account for 54% and 22% of all irrigation withdrawals, respectively) seem intent on expanding irrigation. The motive is to maintain cotton as a major export crop to earn foreign currency, but also to increase food production to meet the nutrition needs of a growing population^{2, 6}. Reductions in the irrigated area are therefore unlikely in the near to mid-term future, and the fact that Tajikistan has begun to build the world's tallest hydropower dam might introduce additional complications.

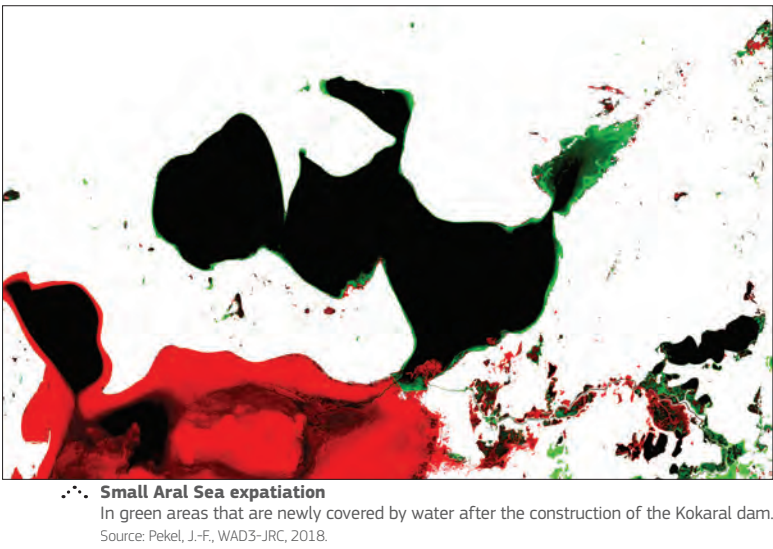
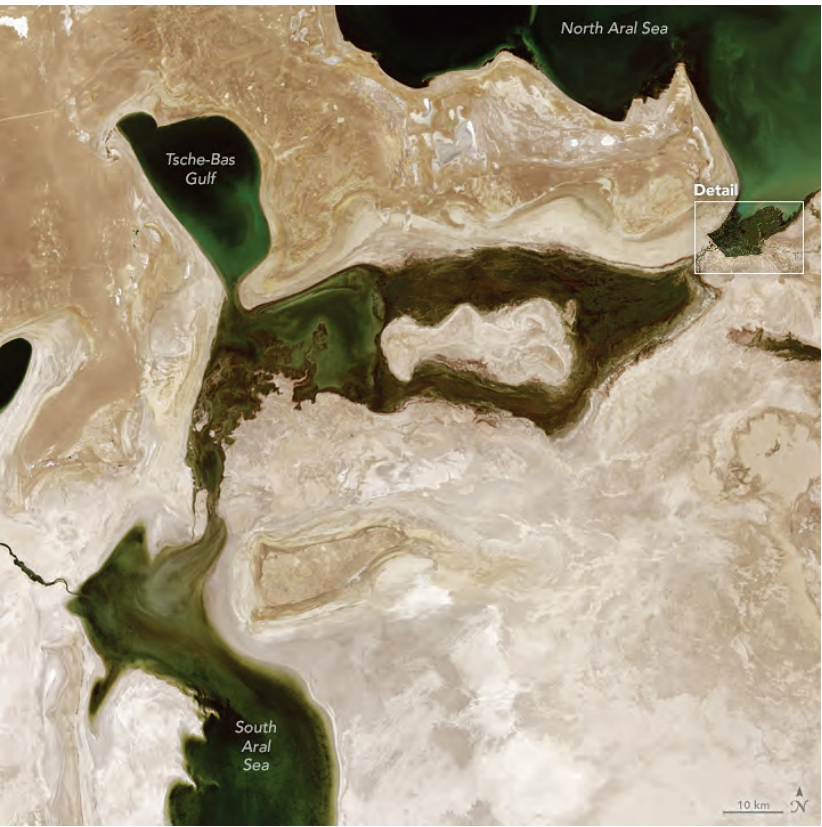
Maintaining the existing water bodies in their present condition seems possible. However, a viable option to refill the Aral Sea is not an option, given the strong dependence of 40 million people (70% of them rural) on irrigated agriculture in the basin. The Aral Sea case is thus a striking example of the systematic couplings in human-environment systems, such as reciprocal effects, feedback loops, human-aided resilience and legacy effects¹⁶.



The Kokaral dam at the North Aral Sea. Source: OSCE/Arman Smagulova, 2010.



Satellite overview of the Kokaral dam. The positive effect of the dam is resulting in the expansion of the small Aral Sea. Source: NASA⁴.



Scan here to see the Aral Sea time-series video.

