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The future of the Aral Sea lies in transboundary co-operation

Diversion of water sources has caused the Aral Sea in Central Asia to decline significantly over the past five decades. It has broken into several smaller seas, leaving behind a vast desert and a multitude of environmental, economic and social problems. Recent restorative action reveals a rebound of the fishing industry in what is now the North Aral Sea, possibly indicating a turn for the better, but it has come at the expense of the South Aral Sea. Although the water levels of the Aral Sea may never return to pre-1960s levels, transboundary co-operation on the implementation and compliance of conservation policies and activities provides some hope for the survival of the Aral Sea; helping secure livelihoods of those within its reaches.


Salty shores of the Aral Sea

Why is this issue important?

Once the fourth largest lake in the world (FAO, 2012), the Aral Sea now covers approximately 10 per cent of its former surface area, holds less than 10 per cent of its former volume (EC-IFAS, 2013), and receives 10 times less water than it used to (Khaydarov and Khaydarov, 2008). The basin supports a population of more than 60 million people – a population that has increased more than 4 times since 1960 (EC-IFAS, 2013). The Aral Sea basin covers 1.5 million square kilometres (km^2) in Central Asia and is predominantly shared by six countries: Turkmenistan, Uzbekistan, Kazakhstan, Kyrgyzstan, Tajikistan and Afghanistan (Figure 1). The Aral Sea is divided by Kazakhstan and the autonomous Republic of Karakalpakstan in Uzbekistan.

Meltwater, from snow and glaciers on the southwestern Pamir Mountains in Tajikistan and the Tien Shan Mountains that border China and Kyrgyzstan, contributes water to the Amu Darya and the Syr Darya, the two main rivers that historically have fed the Aral Sea; the sea has no outflow river (Micklin, 2007). Meltwater is particularly valuable during the hot, dry summers (Rakhmatullaev et al., 2010). However, the Amu Darya and Syr Darya have been diverted to support irrigation schemes (Linn, 2008; Figure 1) and, consequently, the flow of both rivers has been altered and the sea itself has become desiccated (Figure 1). Diversion of the Amu Darya and Syr Darya rivers began as early as 1938 to provide water for irrigation (Gaybullaev et al., 2013). It also occurred naturally at times because of events such as spring floods breaching the banks of the Amu Darya, but these caused insignificant changes in water levels (Micklin, 2007). New irrigation schemes for cotton and rice farming in the arid region caused diversion to accelerate in the 1960s (FAO, 2012). While the use of groundwater for irrigation was explored, the focus remained on using surface water (Rakhmatullaev et al., 2010). Climate change could also influence water flows into, and around, the Aral Sea. Glacier shrinkage on surrounding mountains is already occurring, which could eventually lead to reduced runoff (Sorg et al., 2012), and the region could experience more floods and droughts (EC-IFAS, 2013).

The sea itself is now made up of several water bodies: the North Aral Sea (NAS), which has relatively maintained its water levels due to the construction of a dam; and two independent sections of the South Aral Sea (SAS), the deeper, more stable western portion and a shallower eastern portion, which has recently been fluctuating in size. Maintenance of water levels of the western lobe of the SAS is essential to any hope of preserving the sea as an ecological system (Breckle and Geldyeva, 2012). Additionally, some water needs to continue to remain in the eastern portion to ensure that it does not dry up completely, leaving behind a larger area of potentially dangerous dust and salt.

Figure 1. The Aral Sea Basin. Map compiled from: Gaybullaev et al., 2012; Micklin, 2007; Landsat satellite imagery from USGS/NASA; Digital Elevation Model from USGS EROS; visualisation by UNEP/GRID-Sioux Falls.

Deserted fishing boats

The significant decrease in the size and volume of the sea has contributed to the collapse of its fishing industry, compromised drinking water, soil salinisation and the proliferation of dust storms due to the formation of a man-made desert, the Aral-kum. Transboundary co-operation between upstream and downstream countries, collaborative water management and development of water resources are central to meeting the needs of water, energy, food and environmental security in the future (Granit et al., 2012). Regional projects, for example, have contributed to afforestation efforts in the Aral-kum (planting trees along the former sea-bed) and conservation of particular ecosystems. How can these efforts be sustained to increase ecosystem health and livelihoods of the surrounding populations?

What are the findings?

The Aral Sea has gone through many changes over the past 50 years, including a significant increase in the population of the Aral Sea basin, doubled area of irrigated land and an unsustainable decline in water runoff to the sea (Table 1). As a result, shocking visible changes have occurred to the sea (Figure 2) in addition to environmental, economic and social impacts.

Indicator	1960	2007-2012
Population*	14.1 million	60.4 million
Irrigated agricultural lands	4.5 million ha	8 million ha
Total water withdrawal	60.6 km^3/yr	105 km^3/yr
Total runoff to Aral Sea	55 km^3/yr	10.6 km^3/yr

Table 1. Changes in water and land resources in the Aral Sea Basin, 1960 - 2012 (*population within Aral Sea Basin; Source: EC-IFAS, 2013).

The baseline for the Aral Sea can be considered its levels before the 1960s as it had remained relatively stable from 1901 to 1961 (Bortnik, 1996). During this time, the Aral Sea covered approximately 66,000 km^2 – 67, 500 km^2 (depending on source) in area and held about 1,060 cubic kilometres (km^3) of water (FAO, 2012; EC-IFAS, 2013; Bortnik, 1996). The Amu Darya and Syr Darya rivers contributed a combined 47 to 55 km^3/yr of water (FAO, 2012; Micklin, 2007), with some estimates as high as 60 to 70 km^3/yr (Breckle and Geldyeva, 2012) and others estimating discharge of up to 72 km^3/yr for the Amu Darya alone (Gaybullaev et al., 2013). Groundwater and precipitation contributed an additional 10.5 to 12.5 km^3/yr of water (FAO, 2012). Irrigated agricultural lands in the early twentieth century covered approximately 2 million hectares (ha) in the basin (Bortnik, 1996). The fishing industry was thriving, bringing in approximately 40,000 tonnes (t) of fish a year and was an important source of local employment (FAO, 2012).

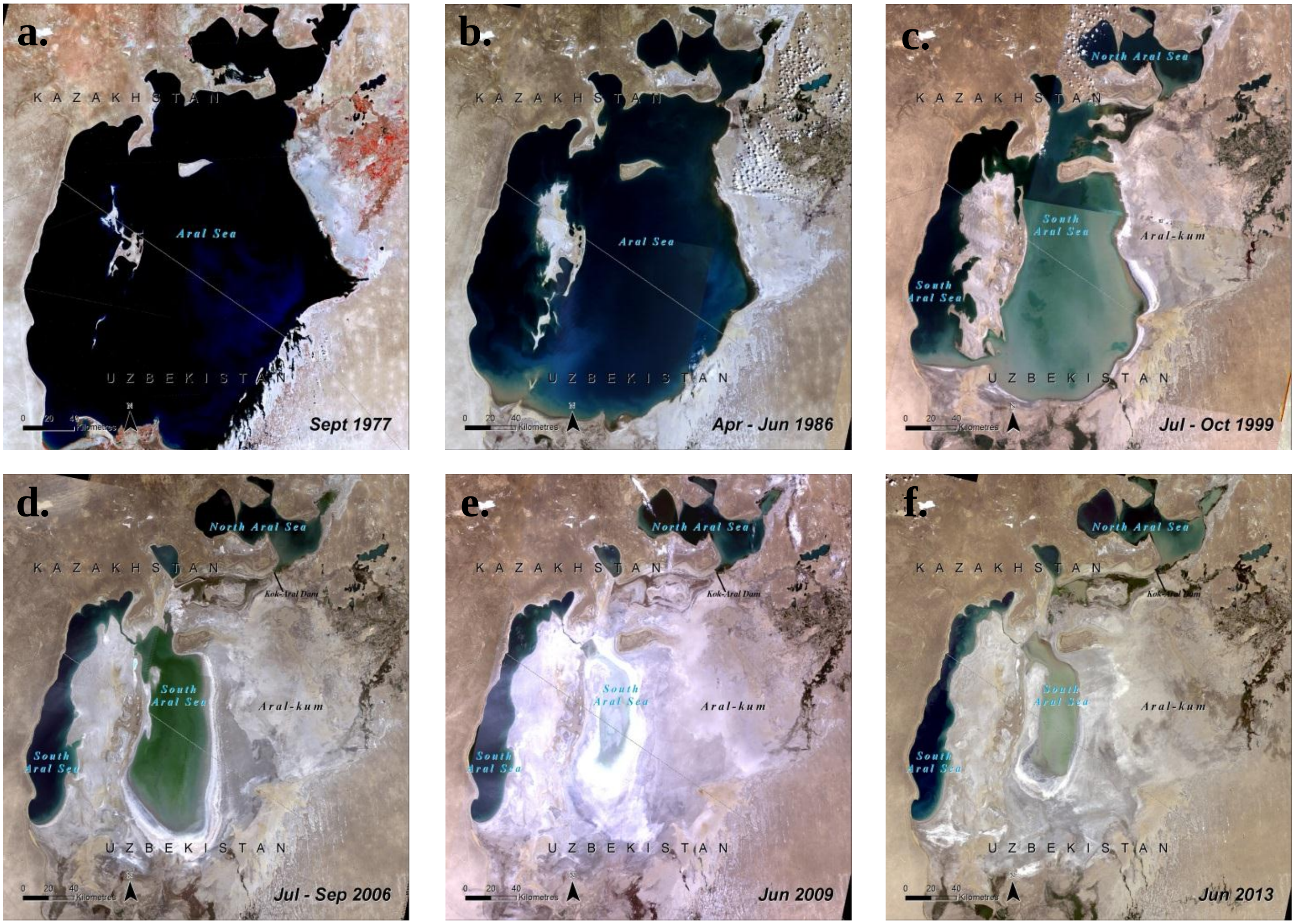


Figure 2. Landsat satellite imagery mosaics showing visible changes of the Aral Sea. Source: USGS/NASA; visualisation by UNEP/GRID-Sioux Falls**.**

During the 1960s, the Amu Darya and Syr Darya were increasingly diverted to contribute to more irrigation schemes to support cotton and rice farming, decreasing the area of the sea to slightly less than 60,000 km^2 by 1969 (FAO, 1997). Average salinity was approximately 10 grams per litre (g/L), an indicator it was becoming brackish (EC-IFAS, 2013; Gaybullaev et al., 2012). Water withdrawal in the Aral Sea basin increased from about 90 km^3 in 1970 to over 110 km^3 by the end of the decade, peaking in 1980 at 120 km^3 (FAO, 1997). This further decreased surface area and volume and prevented runoff from the rivers to reach the Aral Sea from 1974 to 1987 (Bortnik, 1996). The decrease in water caused salt concentration to rise to 30 g/L by 1989

(Gaybullaev et al., 2012) and consequently, fishing was no longer a viable economic resource (Micklin, 1988). By the end of the 1980s, the Aral Sea had split into the NAS and the SAS (Figure 2b).

With the division of the Aral Sea, the NAS reduced to half its area in 1960 by the early 1990s (from 6,000 km^2 to a range of 2,600 to 3,100 km^2) (Bortnik, 1996). To prevent the western portion of the NAS from drying up and to increase water levels, a series of dams was constructed on the southeast coast of the NAS throughout the decade. The dams were constructed to redirect flow of the Syr Darya so it would feed only the NAS (Breckle and Geldyeva, 2012), thus cutting off a water source of the SAS. The dams did not last for long, as storms repeatedly destroyed them; the breach of a dam in 1999 (Breckle and Geldyeva, 2012) led to a significant decrease in volume of the NAS with volume dropping to 12.6 km^3 from 27 km^3 in 1998 (Gaybullaev et al., 2013). As Figure 2c shows, by 1999 the island in the northern part of the SAS joined the main land mass and a significant portion of the eastern SAS retreated, leaving behind the beginnings of a salt desert, referred to as the Aral-kum (Low et al., 2013).

In the 2000s, the Aral-kum continued to grow in size with the construction of a more stable and permanent dam that once again prevented Syr Darya outflows from reaching the SAS. The Kok-Aral Dam was constructed on the southeast side of the NAS, a joint project between the World Bank and the Kazakhstan government, and was completed in 2005 (World Bank, 2005)(Figure 2d). The dam caused the NAS to fill up more quickly than expected, peaking in volume in 2006 (Gaybullaev et al., 2013). This allowed for water to start slowly flowing back to the SAS (World Bank, 2006) by way of a small intermittent river that flows primarily during the spring or early summer, when runoff from the Syr Darya to the SAS is greatest (Micklin, 2007). The dam stabilised water levels of the NAS allowing for the fishing industry to begin its return (World Bank, 2013), but the minimal flow of water to the SAS was not enough. By 2006, the SAS had split into several bodies of water with two prominent lobes that were barely connected: an eastern lobe and a western lobe (Figure 2d). The total surface area of water of the SAS declined almost 50 per cent from 1999 to 2006 (Figure 3). Reduced water levels in the SAS led its salinity to increase to more than 100 g/L, approximately 10 times the salinity of the former Aral Sea in the 1960s (EC-IFAS, 2013; Gaybullaev et al., 2012).

Status today

At present, seasonal fluctuations, variations in wet and dry years and annual fluctuations in the flow of the Amu Darya (NASA, 2013) dictate water levels of the two lobes of the SAS as demonstrated by the satellite image time series in Figure 4. A general increase in surface area of the eastern lobe of the SAS can be observed from June 2009 to June 2013 as well as water retention in the Amu Darya delta (Figures 2e & 2f). Figure 4 shows how much the eastern lobe of the SAS can fluctuate, including nearly disappearing in 2012 but rebounding to more than 10,000 km^2 by 2013 (Figure 3). The surface area of the NAS remained relatively stable and some fluctuations in the Syr Darya delta are visible (Figure 3). Gaybullaev et al. (2012) estimated total volume of the Aral Sea in 2010 at 98.1 km^3 (NAS: 22.6 km^3; SAS: 75.5 km^3) and predicts that the quantity will decrease to 75.4 km^3 by 2031 based upon measurements from precipitation, evaporation and river runoff trends. River runoff has decreased to 3 to 20 km^3/yr from the pre-1960s range of 47 to 70 km^3/yr, increasing the importance of groundwater as a water resource for both the rivers and the surrounding populations (Breckle and Geldyeva, 2012).

Impacts and responses

Year	Area (km^2)
1960	67,500
1977	54,831
1986	44,790
1999	28,756
2006	16,679
2009	9,452
2013	10,464

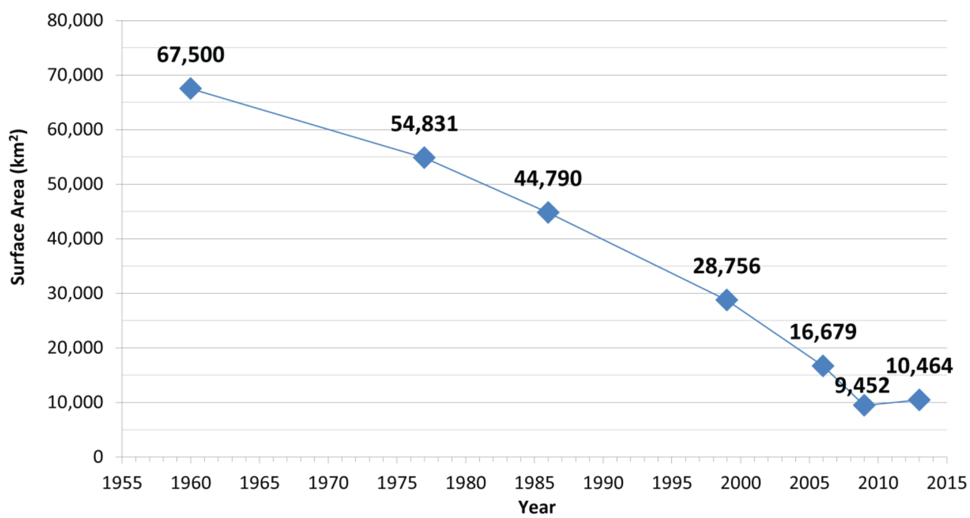
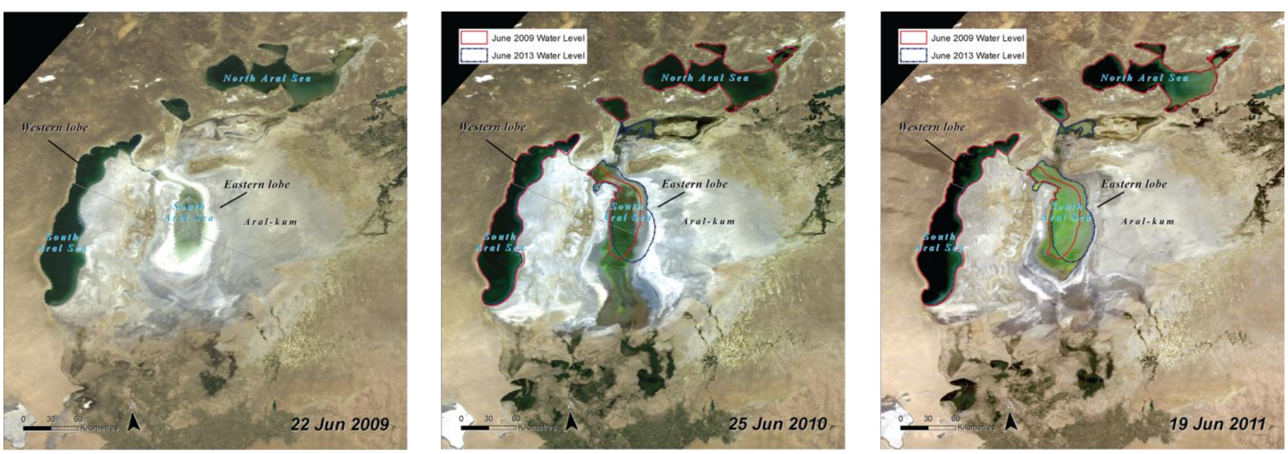


Figure 3. Changes in total surface area of the Aral Sea for select years from 1960 to 2013. Sources: 1960 water level: EC-IFAS, 2013; 1977, 1986, 1999, 2006, 2013 water levels: calculated by UNEP/GRID-Sioux Falls from digitisation of similar season Landsat satellite imagery; calculations exclude land masses; line connects the data points and should not be considered a trend line.



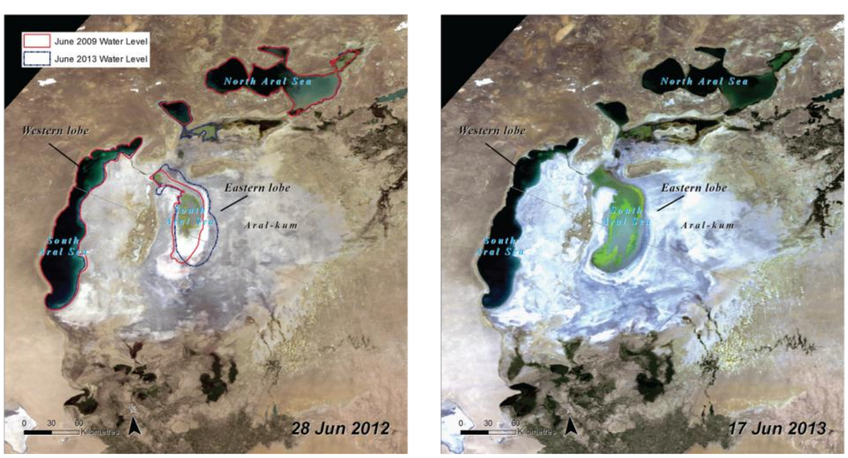


Figure 4. NASA MODIS Terra satellite imagery showing changes in the Aral Sea from 2009 to 2013. Source: NASA, visualisation by UNEP/GRID-Sioux Falls.

The changes in the area and volume of the Aral Sea have a serious impact on the environment, livelihoods and the economies of local populations in Central Asia. The decline of the Aral Sea's fishing industry in the 1980s cost tens of thousands of people their jobs (Micklin, 2007). Some of these jobs, and fish catch, have been reclaimed due to the stabilisation of water levels in the NAS in the past decade and the replenishment of surrounding lakes. Fishery output in the late 2000s reached an estimated range of 2,650 to 3,000 t of fish, as compared to only 52 t caught in 2004 (World Bank, 2013). The diversion itself has proved relatively successful economically, as irrigated lands, which cover only 10 per cent of all agricultural land in Uzbekistan, account for more than 95 per cent of gross agricultural products (Botman, 2009). Uzbekistan is a top global producer of cotton worldwide (USDA-Foreign Agriculture Service, 2013). However, any and all benefits have come at a cost to local populations and the environment.


A ship graveyard in Muynak, Uzbekistan

Aridification and dust storms

The Aral-kum is nearly 60,000 km^2 of sandy, salty soil, most of which is contaminated with fertilisers remnant from the agricultural lands, that is fuel for dust storms (Low et al., 2013; Breckle and Geldyeva, 2012; Spivak et al., 2012). The surface area of salty soils and bare areas surrounding the Aral Sea, the surface types that generate the greatest potential for dust storms, increased to 54 per cent in 2008 from 40 per cent in 2000 (Low et al., 2013). Its increase in size has also contributed to a more arid local climate with hotter summers and colder winters (Gaybullaev et al., 2012).

High winds that blow through the region carry an estimated 15 million to 75 million t/yr of contaminated sand and dust (Elpiner, 1999). Spivak et al. (2012) found that about 13 dust storms occurred per year between 2000 and 2009 in the Aral Sea region, carrying dust in all directions. The salt-dust clouds can be up to 400 km long and finer particles can travel up to 1,000 km away (Semenov, 2012). The densely populated areas south of the Aral Sea in the Amu Darya delta are most vulnerable to these storms because of their location downwind from the Aral-kum source area (Low et al., 2013). These dust storms have negative implications for agricultural and pastoral land. As for local populations, increased respiratory and kidney disorders have been reported and the dust affects visibility for air and vehicle traffic (UNEP et al., 2011; Micklin, 2007). Further studies regarding implications of land cover change and increased salt and dust loads are needed (Low et al., 2013) including the cumulative effects of salt and dust storms on human and ecosystem health (Semenov, 2012). Additionally, more regional weather observations and models are needed to more effectively quantify impacts (Low et al., 2013).

Widespread afforestation of the Aral-kum is needed to reduce ecological tension in the southern Aral region. Increased vegetation cover could help reduce the number dust storms (Novitskiy, 2012). In the past decade or so, several international organisations have initiated afforestation projects in the Aral Sea region (Simonett and Novikov, 2010; Vildanova, 2006; EC-IFAS, 2012), creating forest plantations on the dried seabed of the Aral-kum to help stabilise soil (Micklin, 2007; Botman, 2009). An ongoing project conducted by the International Fund for saving the Aral Sea (IFAS) plans to increase forest cover by 10 to 14 per cent (approximately 40,000 ha) across parts of Uzbekistan, Turkmenistan and Kazakhstan (EC-IFAS, 2012). Local environmental health could be increased and maintained through the continued facilitation of afforestation projects (Novitskiy, 2012). Involving local populations in afforestation could also make the projects more sustainable and less expensive to implement (Botman, 2009).

Human water consumption

Increased agriculture has been accompanied by an increase in use of fertilizers and pesticides, which has compromised the quality of ground and surface water, contaminated seabed sediment and led to rising groundwater levels (UNEP et al., 2011; Granit et al., 2012). Granit et al. (2012) report that groundwater levels have risen as much as 2.5 metres in some areas, including in parts of Turkmenistan, which can lead to further soil salinisation. Water quality, especially for drinking, has also decreased because of increased salinity, bacterial contamination and the introduction of pesticides and heavy metals (UNEP et al., 2011; Khaydarov and Khaydarov, 2008). Low-energy and low-cost desalinisation techniques to increase quality of drinking water have yet to be developed or widely adopted in Uzbekistan (Khaydarov and Khaydarov, 2008).

Biodiversity

Diversion of the Amu Darya and Syr Darya has not only resulted in lower water levels of the Aral Sea, but also in the disappearance of smaller lakes and deltas that these rivers once supported and of riparian habitats such as tugai forests and reed beds (UNEP et al., 2011). The Amu Darya delta supported about 2,600 lakes in the 1960s, but the number had fallen to 400 by 1985 (Kreuzberg-Mukhina, 2006). Tugai forests and reed beds once covered more than 500,000 ha and now only about 10 per cent remains, having been replaced with irrigated cropland or having disappeared because of lack of water regeneration (UNEP et al., 2011). To restore the ecological situation of the surrounding deltas, numerous man-made lakes or reservoirs have been constructed. As a result, wetland cover has increased and some migratory waterbirds have taken refuge (Kreuzberg-Mukhina, 2006). Diversity remains low, but some species of waterbirds have expanded their breeding ranges along valleys of the Amu Darya and Syr Darya (Kreuzberg-Mukhina, 2006). Additionally, a conservation project was completed in 2011 to establish Uzbekistan’s first biosphere reserve – 68,718 ha of protected area in Karakalpakstan – aimed at the conservation and sustainable use of biodiversity resources, including the tugai forests (UNDP, 2012).

What are the implications for policy?

Transboundary co-operation is needed to address the future use of water resources between upstream (Tajikistan and Kyrgyzstan) and downstream countries (Kazakhstan, Turkmenistan and Uzbekistan) in the Aral Sea basin (Eshchanov et al., 2011), but conflicts of interest can inhibit co-operation (EC-IFAS, 2013). Attempts for transboundary co-operation for water and land management within the basin dates back to the early 1970s when the Aral Sea first showed signs of decline (FAO, 2012). Integrated Water Resources Management (IWRM) has been implemented in Central Asia, but may not yet transcend the differences among the nations it involves (Sojamo, 2008) and the principles are not fully applied (EC-IFAS, 2013). A deeper integration of the critical issues at hand into institutional frameworks is needed to encourage co-operation (Granit et al., 2012). A lack of regional coordination to implement restoration effectively and awareness projects has been cited as the reason some attempts at cooperation have proved unsuccessful (Sojamo, 2008; UNDP, 2006).

Several committees, organisations and institutions have been created and third-party donors have been engaged to cope with the consequences of the loss of the Aral Sea. Most recently, the 2013 High-Level International Conference on Water Cooperation held in Tajikistan addressed implementation of policies and highlighted the outcome of a multi-agency project that included a tangible set of analytical policy tools related to the water, agriculture and energy sectors adopted by all participating member countries (FAO, 2013).

Historically, countries across the globe have leaned toward co-operation in response to transboundary water competition (UNDP, 2006; Mirumachi and Allan, 2007). Competition for water in the Aral Sea basin has led to the desiccation of the Aral Sea and a multitude of negative consequences for people, economies and the environment. The ecosystems and livelihoods supported by the Aral Sea may never be what they were five decades ago, but they have a chance for revitalization (Walters, 2010) with proper attention to water resource management, ecosystem health, human and energy needs and political will (EC-IFAS, 2013; Granit et al., 2012).

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