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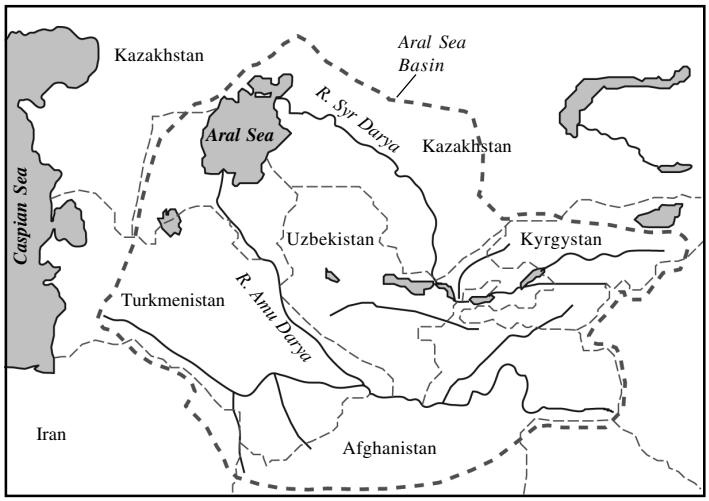
Unsustainable water management: The Aral Sea

Definitions
Desertification: degradation of land in arid, semiarid, and subhumid areas resulting from various factors, including climatic variations and human activities
Halophytes: plants and plant communities that are adapted to or can tolerate elevated levels of salinity in the root area

The Aral Sea, located on the borders of Kazakhstan and Uzbekistan in Central Asia, is a completely enclosed sea (lake) which used to be supplied by just two big rivers - the Amu Darya and the Syr Darya (Fig.1).

Fig.1 The Aral Sea

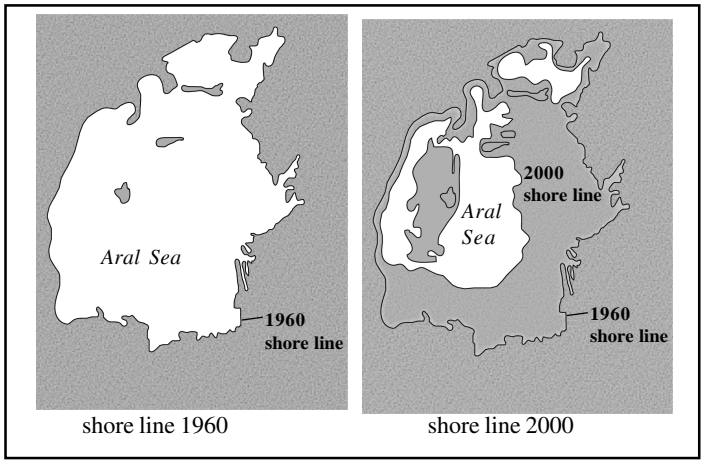


Once the fourth largest lake in the world, it used to sustain a thriving fishing industry and was the centre of cultural life for the surrounding ethnic groups. However, since the 1950s huge volumes of water have been removed from these two rivers, which also flow across Kyrgyzstan, Turkmenistan, and Tajikistan to provide irrigation water for crops such as cotton and rice.

Since the late 197Os, almost no water from the Amu Darya has reached the Aral Sea, and the Syr Darya has supplied only a minimal and ever-decreasing volume.

As a result, the Aral Sea level has dropped by about 20m and its surface area has been reduced from 70,000km^2 to 25,000 km^2 (Fig 2).

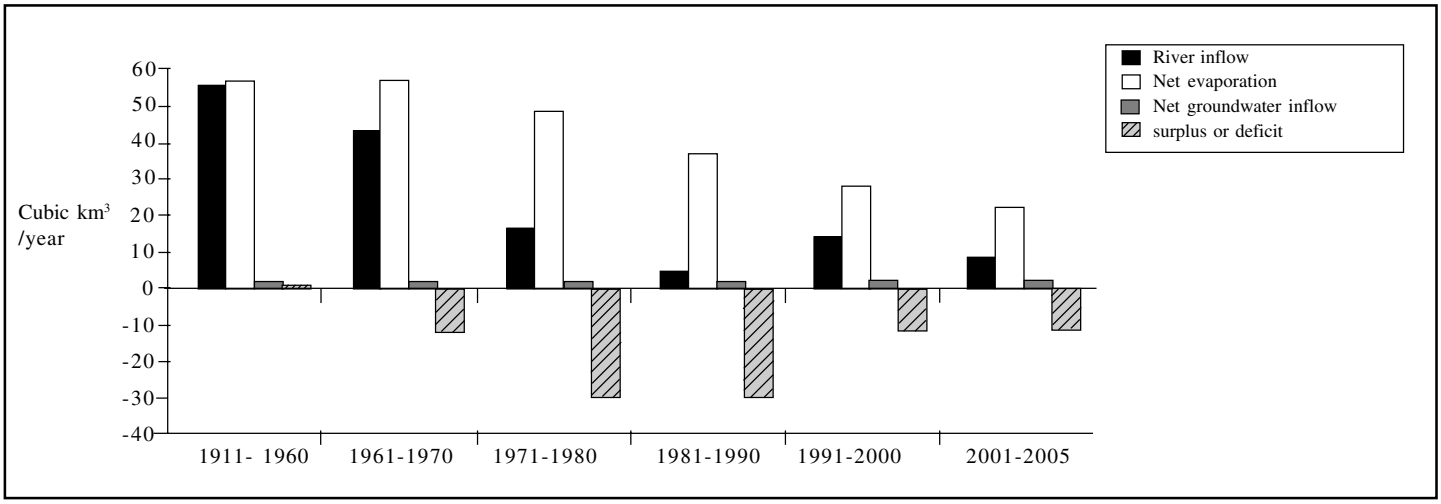
Fig 2. Declining area of the Aral Sea



The process of shrinkage is still going on. Fig 3 shows the water balance components for the Aral Sea 1911-2005

Between 1987-89 the Aral separated into two water bodies: a "Small" Aral Sea in the north supplied by the Syr Dar'ya and a "Large" Aral Sea in the south supplied by the Amu Dar'ya.

Fig 3. Water balance components for the Aral Sea 1911-2005



Between 1960 and January 2006, the level of the Small Aral fell by 13 m and the Large Aral fell by 23 m (Table 1.)

Table 1. Hydrological and salinity characteristics of the Aral Sea 1960-2006

Year	Level masl	Area Km^2	Area/ % of 1960	Volume km^3	Volume/ % of 1960	Mean salinity G/l	Mean salinity/ % of 1960
1960 (whole Aral Sea)	53.4	67,499	100	1089	100	10	100
1960 (Large Aral Sea)	53.4	61,381	100	1007	100	10	100
1960 (Small Aral Sea	53.4	6118	100	82	100	10	100
1989 (Whole Aral Sea)		39,734	39	364	33		
1989 (Large Aral Sea)	39.1	36,930	60	341	34	30	300
1989 (Small Aral Sea)	40.2	2804	46	23	28	30	300
2006 (Whole Aral Sea)		17,382	26	108	10		
2006 (Large Aral Sea)	30	14,325	23	81	8	East Sea >100 West Sea 70-80	>1000 700-800
2006 (Small Aral Sea)	40.5	3057	50	21	26	12	120

Typical Exam Question

Explain why plant growth will be reduced if saline water is used for irrigation (2)

Markscheme

Water will be osmotically drawn out of plant roots;
Plant will be unable to absorb sufficient water;
Wilting;
Loss of leaf area for photosynthesis;

A river connects the two lakes, with flow from the Small to the Large Aral which sometimes ceases completely.

Satellite images have shown that by late 2005, the Large Aral Sea became three distinct water bodies: a "deep" western lake and a "shallow" eastern lake with a narrow channel connecting them and a cut-off Gulf of Tshche-Bas.

Causes

In the late 1950s Nikita Khrushchev launched his 'Virgin Lands' scheme. The aim was to grow wheat on the arid and semi-arid steppes of western Siberia and Kazakhstan. At the same time, huge areas of land were planted with cotton monoculture. By 1990, cotton was sown on about two-thirds of the agricultural lands in Uzbekistan and on half the land area of Turkmenistan. These crops required vast irrigation schemes that were poorly designed.

Between 1965 and 2000 the irrigated area grew from 5 million to 7.9 million hectares.

Often, too much water was used and this caused the soils to become waterlogged. Excess water supply also resulted in a rising water table which brought salts up to the surface causing salinisation. 95% of irrigated land in Turkmenistan is now salinised.

The discharge of drainage water from irrigated lands also sharply increased the river water salinity level. In lower reaches of the Syr Darya salinity increased from 0.4–0.6 g l^{-1} to 1.3–2.0 g l^{-1} over the last four decades.

Salinisation and desertification

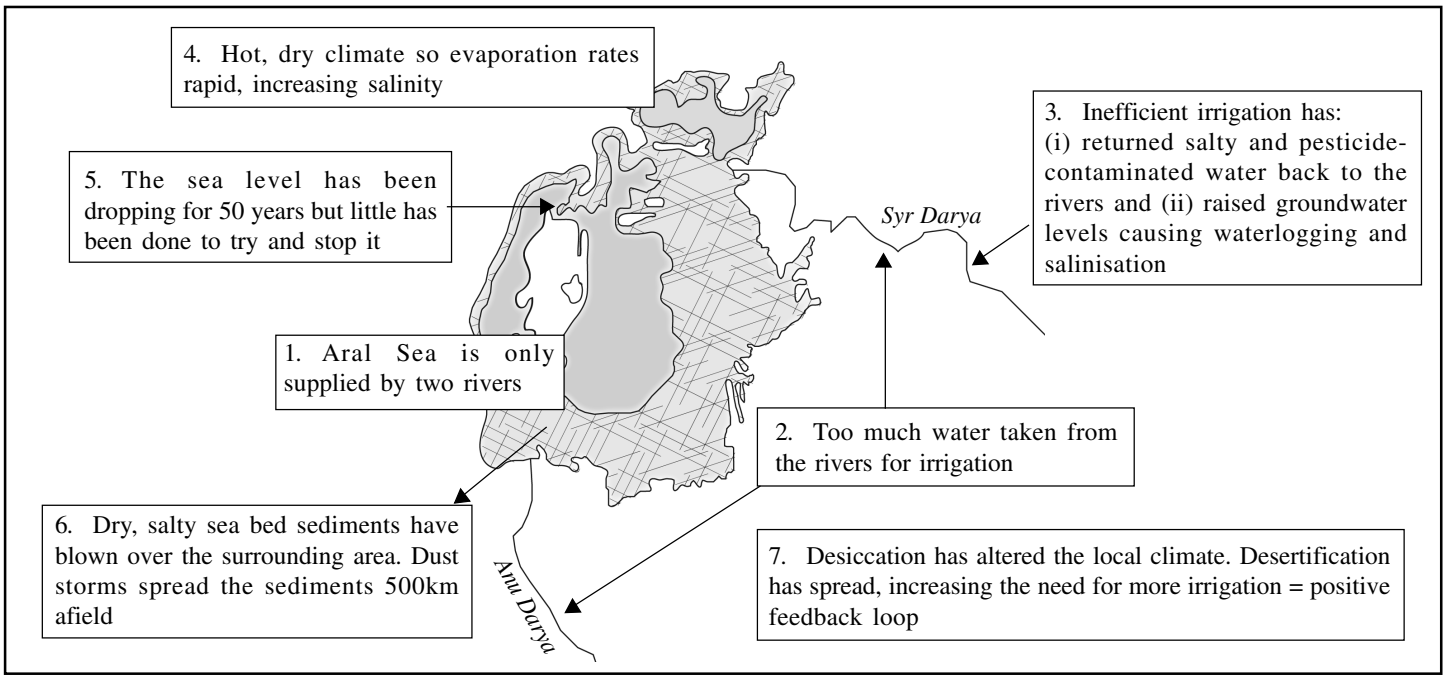
The sea bed that has been exposed as the water levels have fallen is eroding, covering huge areas around the sea with salty dust.
Halophytes and xerophytes are rapidly replacing the natural vegetation communities. In some places, salts have accumulated on the surface forming salt pans where nothing will grow.

The Sea exerted a mediating effect on the local climate, which was milder and less extreme than surrounding areas. This influence is declining and the dust storms are spreading the effects of the inefficient irrigation over a larger and larger area.

Maritime conditions have been replaced by more continental and deseritic regimes. Summers have warmed and winters cooled, spring frosts are later and autumn frosts earlier, humidity has fallen by 28%, and the growing season is shorter.

Thus the loss of the Sea has established a positive feedback loop (Fig.4) that increases desertification – It is estimated that the affected area now covers 400,000km^2.

Fig 4 Positvie feedback increases diversification



Typical Exam Question

(a) Explain how shrinkage of the Aral Sea could have caused the local climate to change (4)

(b) How can inefficient irrigation lead to saline soils? (2)

Markscheme

(a) water absorbs large amounts of solar radiation / heat;
cools slowly;
reduces seasonal variation in temperature;
smaller Sea area reduces this effect;
smaller volume of water stores less heat;
for release in winter;
smaller area of lake so less evaporation;
drier summers / lower humidity / less rainfall;
albedo increased

(b) If too much water is used the water table may rise/ soil becomes saturated;
When water evaporates, salts are left behind;
Irrigation water may be saline;

Impact on wildlife

The substantial Aral fishing industries ended in the early 1980s, as indigenous fish became extinct because of increasing salinity and loss of shallow spawning and feeding areas.

However, fish still survive in the deltaic lakes and Amu Dar'ya and Syr Dar'ya rivers and the introduced kambala or Black Sea flounder providing a sizable catch in the Small Aral.

Much of the rich biodiversity of the extensive Amu Dar'ya delta in Uzbekistan Syr Dar'ya delta in Kazakhstan has been lost. Prior to 1960, more than 70 species of mammals and 319 species of birds lived in the river deltas. Today, only 32 species of mammal and 160 bird species remain.

Human health threats

The areas where cotton has been grown were originally cleared using defoliants. These, along with pesticides, fertilisers and salts have been washed back into the two rivers and into the groundwater. Such pollutants have been blamed for the increasing incidence of cancer, liver and kidney disease and increasing child mortality rates-up in Uzbekistan from an average of 45/1000 live births in 1965 to 72/1000 in 1986.

Wind-borne dust will also contain these pollutants and may be responsible for the increasing incidence of eye and respiratory complaints.

In the early 1950s, the Soviet military selected Vozrozhdeniya (Resurrection) Island as a secret biological weapons testing ground. At the time, this was a tiny, isolated island in the middle of the Aral Sea.

Over the next 40 years they tested various genetically modified and weaponized pathogens, including anthrax, plague, typhus, and smallpox. Since the 1960s, as the sea shrank and shallowed, Vozrozhdeniya grew in size, and in 2001 it united with the mainland to the south as a huge peninsula extending into the Aral Sea.

The fear is that some weaponized organisms survived and could escape to the mainland via infected rodents or that terrorists might gain access to them. In 2001 the US sent a team of experts to the former island to help the Government of Uzbekista ensure the destruction of any surviving weaponized pathogens.

Typical Exam Question

Outline **two** ways in which local people may have been affected by the changes to the Aral Sea (2)

Markscheme

Loss of jobs through extinction of fishery;
Out-migration because no form of income;
Declining health due to declining food/pollutants in water/dust;

Current situation

Excessive water use for irrigation continues and, worse, some of the countries plan to irrigate more land in the future

Four of the five regional governments agreed in 2002 to shift the focus of relief work from the condition of the sea itself to the socioeconomic problems stemming from it. They agreed, that is, to make do with environmental conditions as they stand, and to work only to provide a livelihood for those living there.

The World Bank has funded the construction of a 13km dyke to block the flow from the Small to Large Aral Seas.

This has improved the situation on the Kazakh side significantly - sea level is rising, salinity is falling and fish production is increasing - but has done nothing for the southern, Uzbek side.

Typical exam Question

How may large-scale irrigation may alter the dynamic equilibrium of the water cycle? (2)

Markscheme

There will be a change in a named process e.g. evaporation / runoff /transpiration/ percolation/ infiltration/;
And there will be a linked change in e.g. soil moisture/ water table/ river regime/ atmospheric water vapour/ biota/ other reservoir;

Managing international rivers

The 1972 Stockholm Declaration on the Human Environment sets out that states can use their resources e.g. rivers however they please, but only in accordance with international law. Specifically, their actions must not damage the environments of other states or of areas outside their boundaries.

The Helsinki Rules (1966) state that nations must not pollute waterways in such a way as to substantially damage a nation sharing its drainage basin.

The 1997 UN Convention on the Law of the Non-navigational Uses of International Watercourses sets out extensive rules for the use of transboundary water resources. However, only one of the five former Soviet Central Asian republics (Uzbekistan) has signed the convention.

The three states that continue to draw huge volumes of water for irrigation - Kazakhstan, Turkmenistan and Uzbekistan - are the three that have suffered the most salinisation and desertification. States upstream of these three use the river water mainly for hydroelectricity. Thus, the solution seems to be in their own hands. However, none of the three states has plans to try to reduce their irrigation demand and two of them have even suggested that they may increase the area!

In terms of international laws governing freshwaters then, no one nation has been substantially victimized by another. The disaster was the result of Soviet agricultural policy and is being perpetuated by the domestic policies of the successor states.

However, the five states are parties to the United Nations Convention to Combat Desertification. Large tracts of arable land (and sea bed) have been turned into desert and the Convention could be used to try to force the states to take more active measures to prevent further desertification.

Critics of the Convention point out that it is a weak instrument because it:

- consists largely of recommendations rather than binding commitments for signatory governments
- takes a bottom-up approach, encouraging the involvement of local populations, local government, NGOs, etc., as the primary agents in preventing desertification, when what is needed is an international effort

Organizations which have been set up e.g. the International Council for the Aral Sea (ICAS), the International Fund for the Aral Sea (IFAS), and the International Commission on Water Management Cooperation (ICWC) have achieved little on the ground.

Equally, critics claim that the international community is also to blame. The World Bank, the United Nations Development Program (UNDP) and the United States International Development Agency (USAID) have all funded projects in various states but critics argue that many of these have been at cross-purpose.

Who owns the water?

The Syr Darya flows from Kyrgyzstan through Uzbekistan and Kazakhstan. Kyrgyzstan maintains the Toktogul Reservoir on the Syr Darya and uses it to generate electricity over winter. Thus, Kyrgyzstan prefers that water be released during the winter heating season to generate power; the downriver states prefer that it be released during the summer for irrigation. This problem, plus the problem that the dam and reservoir need maintenance has led Kyrgyzstan to charge Uzbekistan and Kazakhstan for the river water that flows from the reservoir.

In 2001 Kyrgyzstan introduced the Law on Interstate Water Use, which declared that water on Kyrgyzstan's territory was the property of the state, and was a commodity with an international market price. It has threatened to shut off the water supply if it is not paid.

There are two problems with this:

1. The sale of water in international watercourses appears to be illegal under the Convention on the Protection and Use of Transboundary Watercourses and International Lakes

2. Shutting off another country's water supply is clearly illegal

There are signs that water conflict may lead to military conflict. Turkmenistan has undertaken a further large withdrawal of water from the Amu Darya to feed a large artificial lake in the nation's central desert, increasing overall demand for river water. There have been reports of isolated military clashes between Uzbekistan and Turkmenistan in the area where the Amu Darya demarcates their border.

Water is a limited resource. The break-up of the Soviet bloc into states has not helped the situation. Each state, as it defends its own water-access interests, limits access for the others.

Solutions?

There are three broad strategies that could be attempted, each with its own advantages and problems (Table 2)

Strategy	Advantages	Problems
Stopping cotton production and letting the waters of the Amu Darya and the Syr Darya flow again into the Aral Sea	Seen by some as the "natural" solution Hugely reduced demand for water, pesticides and fertilsers	Huge economic loss- the region produces 10% of world cotton Resistance from farmers
Replace cotton monoculture with diverse crops and practice rotation	Monocultures heavily reliant upon fertilisers and pesticides	
Pumping water from the Black Sea (at ASL 0 m) and/or the Caspian Sea (at ASL -26.5 m) to the Aral Sea	Could be achieved using solar pumps	40 billion m3 would be required annually to maintain a constant level Topographically, Black Sea water couldn't be channeled directly to the Aral Sea, without passing through Georgia and Iran among others, possibly creating more trans-boundary problems. Using only Caspian Sea waters would lead to a significant lowering of the Caspian Sea level Salt composition of the Aral and Caspian are very different
Diversion of Siberian rivers into the Aral Sea	Would maintain the existing economic structure Would require only a relatively small fraction of the annual runoff of big rivers such as the Ob Technology already proven in other parts of the world Could partly use existing canals	Hugely expensive engineering task Pollution problems in Siberian rivers would have to be tackled May adversely affect HEP and irrigation in Siberia

Rehabilitation techniques

A variety of approaches are new being tested to try to restore soil fertility:

- Use of GM salt-tolerant (halophytic) plants
- Introduction of 35-day-old early maturing rice varieties that can tolerate high soil and irrigation water salinity
- Use of certain tree species as biological pumps to lower groundwater levels in waterlogged areas
- Mulching of salty furrows to reduce evaporation and salinity build-up in the root zone
- Establishment of multipurpose tree and shrub species for biomass production as a source of renewable energy

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