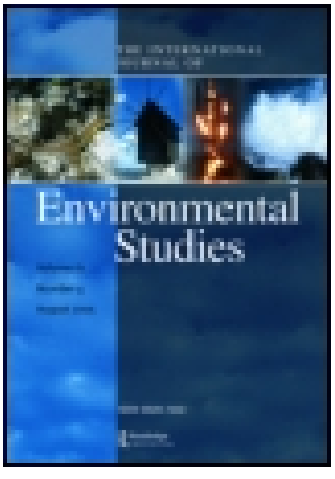

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Fatemeh Zafarnejad [a]

[a] Apt. 5, 27 Golestan 7th, Pasdaran Ave., Tehran 1668618114, Iran

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The contribution of dams to Iran's desertification

FATEMEH ZAFARNEJAD*

Apt. 5, 27 Golestan 7th, Pasdaran Ave.Tehran 1668618114, Iran

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There has been dam building in Iran since Achaemenian times (2500 years ago) as a means to control water streams. While dam building was stopped for a time, other indigenous approaches to water management, such as qanats (known for more than 3,000 years), surface ponds and underground small ponds for rain harvesting have been continuously used by farmers to date. The new era of dam building was begun in Iran in the mid 50s by international companies and has since remained the major approach to water supply. Yet dam building has affected the quantity and quality of water in watersheds, rivers and other water bodies, leading to noticeable destruction of natural habitats and species. Dam building has inundated forests in reservoirs, helped in timber smuggling upstream, and decreased forests downstream, thus accelerating desertification. The actual benefits of dams do not offset even a part of the costs incurred for construction, and their operation and maintenance.

Keywords: Indigenous knowledge; Dam building; Water constructional supply management; Demand management; Decision-making; Environmental impacts; Deforestation; Desertification; Dam alternatives

1. Indigenous knowledge and the Iranian Constitutional Law

Iranians have held strong beliefs about water since ancient times. The goddess Anahita was considered to be responsible for conserving and saving rivers, lakes and other water bodies. There is a lyric to her in *Avesta*, the holy book of Zoroaster. Later in Islam, water was considered wealth and was the dowry of the Prophet's daughter. Since early Iranian civilisation more than 3000 years ago, farmers of the region have used and conserved water resources by creating canals, qanats, dams and rain harvesting in ponds.

Qanats, which were invented in this region, have successfully contributed to water supply for irrigated farming and domestic consumption [1]. Many are still in use despite the destruction of the old system and its replacement with deep wells which encourage over-pumping of water or construction of dams which have inundated the qanats' mother wells. Semsar Yazdi (2004) [2] notes that there are 31,000 qanats all over Iran, providing more than nine billion cubic metres of water per year at 15% of the annual discharge of the country's aquifers. Qanats do not need electrical energy or fossil fuel, and have no harmful environmental impacts. The qanat system consists of a series of wells dug in the earth in order to conduct

*Email: znejad@hotmail.com

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water from aquifers toward dry lands, using underground water up to the sustainable yield of the aquifer.

An indigenous method of rain harvesting in surface ponds, called *Ab-bandan*, is common in the southern plains of the Caspian Sea, north of the Alborz Mountains. Rainfall is gathered in winter for use in paddy farming. Achaksar and Babolsar, two of many *Ab-bandans* of the region, are located downstream on the Babolrud River covering areas of about 50 ha and 90 ha, respectively. They provide water for paddy farms and orchards [3]. Another indigenous rain harvesting exists in Bushehr south of Iran, near the Persian Gulf, in the 10th-century port city of Siraf [4]. This method gathers the rare rainfall (about 200 mm annually) in relatively small ponds dug in stony mountains to cultivate orchards in underground chambers.

There have been dams in Iran to control streams of water for more than 2500 years. The Bahamn dam in Fars province (south of Shiraz) was built on the Mond River during the Achaemenian period (500 BC). The dam is 100 m in length and 20 m in height. The Shadorvan dam, 250 m long, was built during the Sassanid period (280 AD) near Shushtar on the Karun River. Isad-Khast, the oldest Arc Dam in the world, located 41 km south of Isfahan, was built with 65 m length and 6 m width also during the Sassanid Period. Band-e-Amir dam, which is 75 m long and 9 m high, was built during the Buyid (Al-e-Buye) period in 960 AD on the Kor River. The Saveh dam, which is 45 m long and 18 m high, was built in 1284. The Kebar Arc dam located 25 Km south of Ghom is of 55 m length and 26 m height. Fereidoon Dam located 85 km south of Mashhad, was built during the Safavid period (finished in 1667). It is 85 m long and 36 m high [1]. Finally, the Kurit dam in Tabas with 60 m height probably was the highest dam in the world for 550 years until the early 20th century [5]. Filled with sedimentation Kurit and all other dams proved to be an inefficient approach to solve water problems. Iranian farmers and civil engineers left the dam building approach behind.

Rudaki, the ninth-century poet writes ‘Who learns not from passing days, can learn not from any teacher’ [6]. Dam building was re-commenced in Iran after the collapse of the national government in August 1953, with the influx of international companies. Iran began to develop its infrastructure on Western models. Despite significant policy changes with respect to development and fervour for indigenous technology and culture, after the Iranian revolution in 1979, dam building continued to remain the main system of water management.

The New Constitution Law approved in 1979 after the formation of the Islamic Republic, includes three important Acts which should have been instrumental in stopping any further dam building.

The Act 44 of the Constitution insists on participation of private and cooperative sectors in all economic efforts. But, governmental dam building companies ignore this Act. Private sector participation in decision-making could have resulted in fewer mistakes.

Act 48 of the Constitution enforces economic equity in natural resource exploitation. This Act prohibits discrimination between rural and urban societies, in the allocation of natural resources. This implies that distribution of the benefits of dams should consider all upstream and downstream indigenous people and communities. The law has not been taken into consideration in dam building. Urban areas have been benefited with water to the detriment of indigenous people living near reservoirs, tribes and nomadic communities dependent on rangelands, farmers living in the plains or flood plains downstream.

Act 50 of the Law enforces conservation of the environment and prohibits any activity which may have harmful impact on the environment. The impacts of dam building on watersheds, water bodies, and forests call for serious revision of the current water management practices in the country.

2. Water supply constructional management and decision-making

It appears that Iran is not alone in its faith in water supply constructional management and the public supply approach. As Postel (2001) notes, experience elsewhere has also shown that water policies relying on the public supply approach, leave little motivation to conserve water or use efficient methods of irrigation [7]. Water public supply constructional management started in the United States in the early 20th century, and then expanded as a development approach all around the world. Patrick McCully [8] has analysed the reasons motivating water authorities, technocrats, consultants, and contractors to defend and continue dam building and identifies public financing and concentrated decision-making as the main reasons that have led to uncontrolled dam building all around the world.

Dam building has also created an illusion of plentiful water in the cities. Tehran uses more than 1.7 BCM (billion cubic metres) of water annually from Karaj, Jajrud, Lar and Shahrud and some other rivers, diverted by four very large dams. These dams are the Karaj (435 MCM), Lar (418 MCM), Latian (290 MCM), and Taleghan (460 MCM); and also smaller dams such as Mamlu (195 MCM) [9]. Dam building has changed the traditional water use of these rivers and has ignored the water rights of farmers. Tehran had about 500 qanats, with the capacity to take care of the fresh water needs of the city. At least 40% of Tehran's water supply is through underground water sources [10]; and recent daily reports on water production and consumption, by the Tehran Province Television Channel have even quoted figures as high as 47%. The efficiency of the city's water supply has been estimated to be 38% [11]. Downstream water tables in these rivers have fallen significantly and the aquifer of south Tehran has become overloaded and polluted. The low price of water has accelerated over consumption, at a rate beyond the sustainable yield of such a region. In a news report in *Iran-Daily* the head of the Tehran Water and Sewage Company, stated that per capita water consumption is 390 cu. m./p.a.; whereas its availability is 100 cu. m/capita/p.a. [12]. A graph published by the Tehran Province Water and Waste Water Company (TPWWCo) [13] showing Tehran city's water consumption is presented as figure 1.

Engineers never ask farmers what they would do if their traditional water rights were diverted. Dam building data are treated as confidential by technocrats and most often agricultural water has been allocated for the domestic use of urban dwellers in an obscure process of decision-making.

Dr Kader Asmal notes in his preface to the report of the World Commission on Dams (2000) [14] that 'countries built dams without comprehensive analysis of performance and without acceptable outcomes'. His observations hold true for Iran, as the author has discovered in her working experience in the area for more than 15 years.

The author conducted an independent adaptive research assessment of Tajan dam (in the north part of the country in the Alborz mountains) in 2005. Documents for this large dam show about 100,000 ha of paddy fields as benefits. But all these lands already had paddy (rice) as the predominant crop, before and without the dam. The indigenous rain harvesting systems *ab-bandan* successfully supplied water for almost all uses in the area including paddy cultivation [15].

Studies of the Alborz dam go back to 1972. In 1989, feasibility studies for building the Pashakola dam and three rivers, Talar, Babol, and Haraz, were conducted by Mahab Ghodss Company [16].

Due to the importance of paddy farms and 13 villages in Lafur Dehestan, which would be inundated by the dam reservoir, changes were recommended to the project. The Mazandaran

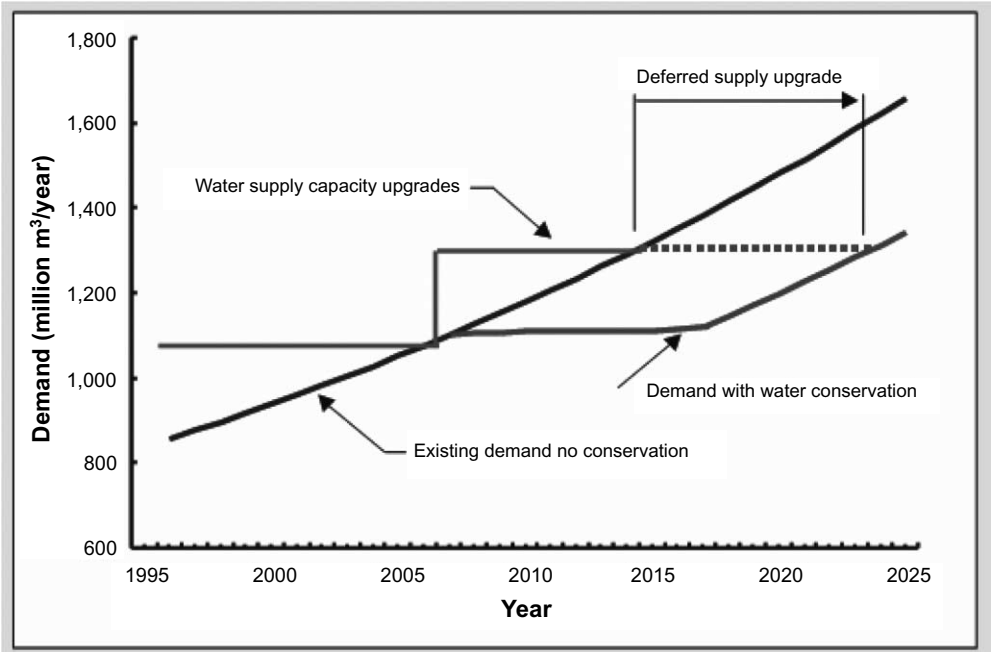

Figure 1. Water demand for Tehran.

province water authority appointed a new consultant, with a new name 'Alborz' for the same Pashakola dam, and subsequently approved the revised studies in 1995. Diversion systems were built in the same year and the dam body started in 2002. Construction of a 78-m high, 838-m long dam was finished in July 2008 and the flooding of the lands and villages in its reservoir has begun. The impacts of the dam on the Babolsar estuary, people and economy will be visible in a couple of years. This beautiful estuary is currently the city's high spot for tourism, which contributes significantly to the city economy and is the main source of livelihood for the local community [17].

The author travelled to the Alborz dam region in August 2008, before the reservoir inundated 13 villages in Lafur Dehestan. Preliminary investigations showed that indigenous rain-harvesting systems (Achaksar and Babolsar *ab-bandans*) supplied the water needed for paddy fields and orchards without needing a dam. The dam had not added to the benefits of the farmers living downstream, despite enormous costs to the National Treasury, and on the contrary had negative impacts on the indigenous communities who were moved from the reservoir.

Overestimation of never justified benefits always goes with underestimated costs. Estimated costs in feasibility studies, on an average, always increase by up to 400% and more, by constant prices, during the performance stage [18,19]. Compared to the financial resources allocated to dam building, the real identified benefits are insignificant.

The new consultant had announced the income of the existing paddy farms and orchards as the benefits of the Alborz dam. In the documents related to the dam, the rate of return of the project was recorded as 17.7% [20], which was unrealistic. The project must have had considerable negative net present value and definitely an under 1 benefit/cost ratio. The project consultant and the water authority had enormously exaggerated the benefits of the dam.

The decision-making procedure was repeated for Bar-Neishabur dam. The construction of the dam was justified by changing the name of the dam and hiring a new consultant [21]. Another dam, Nahrein-Tabas was built on the mother well of an old active qanat.

Both dams destroyed indigenous communities and their socio-economic traditions, as well as the traditional water management systems to irrigate the same or even fewer lands than the qanats did.

The National Treasury of Iran finances all dams through the National Budget, from inception including feasibility study, design, construction, etc. to operation and maintenance. This is one of the reasons for lack of concern about the costs and return on investments. Saeed Kadiver, a commissioner of WCD, in his 47-page preface, translated in Farsi as "Dams and Development", a WCD report [22], attributes the problem to a centralised and top-down dam building approach. Data on dams are not available to the public. Beneficiary companies and contractors make decisions related to dams without being held accountable.

Changing the process of dam feasibility analysis is vital. The test should be whether there is efficiency in allocating resources and cost-effectiveness for the proposed projects.

3. Dam project studies and phasing

Current dam project feasibility studies are poor or incomplete for decision-making. For example, one of the most important priorities for sustainable management of watersheds is a comprehensive and integrated watershed study. Today almost all watersheds in Iran are dammed without such investigations. Another important priority is the formulation of goals according to water resources and needs in watershed systems. The third priority is finding alternatives, for sustainable supplies that correspond to the justified demands.

The Nahrein-Tabas dam, mentioned above, was built on the main well of an ancient qanat. It destroyed an active, sustainable supply system, for the goal of irrigating the same or even less area of farm lands downstream prior to the building of the dam. The current shortfall in irrigation is due to the high rate of evaporation in the Tabas reservoir. That problem was eliminated in the old active Nahrein qanat system, designed for such arid climates as an underground reservoir to prevent evaporation. The Mashkid dam in Baluchestan, and the Surk dam in Isfahan face a similar situation. These examples indicate poor project assessments which show a complete disregard for local conditions.

While many dams have been justified for agricultural irrigation, there is no related documentation to show the dam's irrigation network or even a map of the related dry or non-irrigated lands. Most of the agricultural dams have no documentation for their related irrigation networks.

To cite an example, Sivand dam has been justified as an agriculture dam, despite the absence of studies or documentation related to agricultural lands or the needed volume of water. The dam inundated a valuable watershed Tange Bolaghi with more than 2500 years of civilisation and cultural heritage sites, endangering Pasargadae, the tomb of the Achaemenian King, Cyrus.

In a single watershed, more than one dam may be built without accurate or basic studies for coordination and comprehensive integrated planning of different water resources and required consumption. This has endangered water bodies such as the Urmia Lake, which is also a Ramsar Site. Nearly 40 dams divert the 14 rivers discharging into this lake.

Overestimation of hydrological potential runoff of rivers has led to empty dams such as Saveh, Pishin, or semi charged dams such as Gavoshan. Poor geological studies have led to

significant leakage such as in the Lar dam North of Tehran, Abshine in Hamedan province, and Karkhe earth dam with 8.6 CM/s leakage. Repair costs are prohibitive [23].

Overall, in dam feasibility studies, there is an absence of socio-economic studies, investigation of indigenous knowledge and participation of local people.

Clearly, dam feasibility studies have not been thorough. Lack of accountability has resulted in a gross repetition of costly mistakes. Technical mistakes abound, showing a general lack of understanding of local climatic, hydrological and geological features. Integrated watershed studies are absent. Socio-economic studies have ignored the local and indigenous communities. Existing indigenous knowledge has not been investigated for its effectiveness. Lack of transparency in disclosing information regarding the anticipated benefits of the dam and the beneficiaries, has excluded the opportunity for wider discussions for achieving more efficient solutions.

Although it is contrary to general perception, the fact is that there have been few benefits, if any, from dam building. On the contrary, the losses have been enormous. The next section attempts to establish the facts that lead to this conclusion.

4. The impacts of dams on land degradation

Dam building activities in Iran, whether before or after the Islamic Revolution, have violated articles 3, 5, 10, 17, and 19 of the UN Convention on Combating Desertification (UNCCD) [24]. Participatory decision-making and indigenous community involvement have been completely ignored. Dam building has accelerated deforestation, and in the last five decades has been responsible for wide based destruction in almost all watersheds, forests, rivers, wetlands, lakes, floodplains and plains of Iran [25]. Fresh water evaporation from the surface of dams ranges from 5 MCM in the Alborz dam, in the wet and humid climate of the north part of the country, to 320 MCM in the Karkhe dam in southwest Iran. At a conservative estimate, in total, the reservoirs of the 500 existing dams evaporate at least 5 BCM of Iran's precious fresh water resources [26]. Dam building could be said to be one of the main national level activities which has accelerated desertification in Iran.

It has been established that the impact of dams on their watershed environment ranges from the source of the river toward the sink [8]. Dams in Iran have imposed negative impacts on their watershed environment, causing widespread destruction in 1) upper parts of rivers from source to reservoir, 2) dam site and reservoir, 3) downstream up to the estuary, 4) and the sink, which could be water-bodies, floodplains or wherever the river ends. Dam building impacts may be also be classified according to the different components of the affected environments: 1) physical environment: land, water, air, 2) biological environment: fauna and flora, 3) socio-economic environment: human societies including upstream tribes, reservoir villages, downstream societies like riparian villages and tribes, floodplain societies, estuarial societies, and societies dependent on water bodies.

There are currently about 500 operating dams in Iran, 100 under construction, and 400 being designed or undergoing feasibility study. As already stated, many have been built without comprehensive integrated studies of the watershed, in which they are located, and this has led to not only serious damages to physical, biological, and socio-economical environments of watershed, but also resulted in empty dams. It is estimated that only about 40% of the reservoir capacities of Iran's dams are being used because of overestimation of hydrological discharge of the river. This shows that such mistakes are not rare or accidental. Larger dams mean larger profits for the companies that are involved, but the losses in

terms of damages to the socio-economic and natural environment and national costs are immeasurable.

To cite examples, the Pishin dam in southeast Iran, Saveh dam in central and Gavoshn in west Iran are almost always near-empty even after 10–25 years of operation. The situation may be attributed to overestimation, on the higher side, of rivers' discharges to justify the need for a bigger dam body.

The following section details the impacts that dams built in Iran in the last five decades have had on the physical, biological and socio-economic environment in their watershed regions. These negative impacts have not been offset by demonstrable benefits.

4.1. Deforestation

Dam building has changed the land use patterns in watersheds and helped desertification through deforestation. Forests are among the most important ecosystems ruined by constructional water management. More than 20 dams have been built in the northern provinces of Iran, in the Hyrcanian forests. The more important among them are the Sefid-rud dam (built about 40 years ago) with a reservoir capacity of about 2200 MCM, the Tajan dam with 180 MCM capacity, Alborz with 160 MCM reservoir, Syabishe with 180 MCM, Shafa-rud with 170 MCM, Golestan dam with 140 MCM and Shahr Bijar dam with 165 MCM capacity. An estimate prepared by the author [27] showed that each dam has likely ruined tens of thousands of hectares of forests in the watershed areas of the rivers on which they were constructed and has played a major role in deforestation in the area. Other constructional water management structures such as the Chalus- Sardabrud Ground Canal, have also played an important role in the deforestation of the Hyrcanian forests.

Deforestation has lead to unprecedented floods in the region. Heavy rainfall in July 2001 damaged the Dasht earth dam in northern Khorassan, leading to flooding the Dasht village with fatalities and serious damage to farmlands. The Water Resources Basic Studies office of North Khorassan Water Authority report in their study [28] as follows:

> The 150mm heavy rainfall of 30 July 2001 could have (had) fewer damages by itself, but the Dasht earth dam doubled the hydrograph of the flood (900M/s) and its failure caused much larger humanitarian and financial damages; since a decade of deforestation, degradation of rangeland and vegetation, and changed land-use in watersheds, have increased the volume of runoffs.

Valuable forests in the west of the country in the Zagross region and tropical forests (Hara) in the south and east parts of country have been destroyed by dam building. The Karkheh dam has inundated 160 km^2 of forests and rangelands in its huge reservoir.

4.2. Desertification of riverbeds and estuaries

Dam building shrinks water bodies downstream. It is a redoubtable fact that decreasing water downstream threatens related habitats and seriously endangers species and the food chain in wetlands or lakes. The thin drains of polluted wastewaters downstream of dam sites, once riverbeds, leave no doubt about the destruction of riverine and riparian habitats and species and show all the symptoms of a ruined ecosystem. This has been the destiny of Karaj, Sefidrud, Jiroft, and Tajan – and almost all rivers in Iran.

Estuaries have borne significant damage due to dam building. The Sefidrud riverbed and its estuary in Caspian Sea dried after the building of the 2200 MCM dam. This led to the disappearance of migrant fish such as salmon and trout; reptiles, amphibians, invertebrates of riverine, riparian and estuarial ecosystems, which once thrived in the Sefidrud. The Tajan dam led to the drying of the river in Sari. Almost all estuaries in the Caspian Sea have been affected, the Babolrud estuary being the latest in the series to be impacted by the Alborz dam. As mentioned elsewhere in this paper, Babolsar city's economy is closely tied to this estuary, not only for fishing but also for tourism. But none of the dam's feasibility studies refer to these potential but obvious negative impacts.

4.3. Damaged-threatened sinks: wetlands, lakes, etc.

The Jiroft dam in Kerman province, not only damaged downstream lands by discharging more water into traditional farms, leading to water logging, but also seriously affected the Meh-Ruieh forest and Jazmurian wetland with their rare ecosystems and rich biodiversity.

The Zayandeh Rud dam built in 1969 by the Isfahan Province water authority, is diverting 1200 MCM of water with severe damages to the Gav-Khuni wetland.

Dam building has damaged the Chagha-Khor wetland in Isfahan Province, while need or benefit from the dam has not been identified. Interestingly, a few years after its completion, a second project was proposed for increasing the height of Chagha-khor dam. This project had no identified benefit either. Although this wetland is estimated to be worth $3200/ha [29], it does not seem to concern the water authority and dam building companies. This negligence is compounded by the fact that most dams have no documentation for the alleged necessity of water supply.

For example, the Hana dam has no identified benefits in its documents; nor has the Ghare Aghaj-Samirom dam, which is under construction, or the Behesht Abad dam which is under study. Despite inadequate reasons for its construction, the Behesht Abad dam with a capacity of 1100 MCM is ready for construction with the full support of the Isfahan Province Water and Waste Water Company.

Dam building on upstream rivers and tributaries has seriously damaged natural water bodies in Fars province. According to the Habitats Office of the National Department of Environment, 90% of Maharlu Lake, 95% of Bakhtegan Lake and 80% of Parishan Lake have dried, their lakebed turned into desert. All three are Ramsar Sites.

The 25,000 ha Maharlu Lake depends on two rivers, Soltanabad and Khoshkshiraz. The lake is the natural habitat of flamingos, whose population has been recorded to have dropped from 100–150,000 to only 5000 [30].

The National Park of Bakhtegan with an area about 117,047 ha and 250 mm average annual rainfall is located in Fars Province, 50–60 km from Shiraz toward Zagross Mountains. The park is formed by Bakhtegan Lake and part of mountain lands to its north. The lake water is sweet in estuaries and semi-saline to saline in internal areas. The Bakhtegan Lake with maximum 2 m depth forms a unique lake with the Tashk Lake and wetland during wet years. The Kor River discharges into the Kamjan wetland and the Tashk River continues from Kamjan to the Tashk Lake. They together form one water body of about 136,500 ha area. Only in some dry years are these two water bodies separated by a thin band of land. The International World Wild Life Fund has listed the lake as an important habitat of domestic, local, or migrant birds. Dam building upstream of Tashk river, has threatened this important biome [31]. The Kamjan wetland was an area about 10,000 ha with sweet water. Today its area is only 5250 ha with saline water. The Bolaghi River is one of the feeding streams of the

Bakhtegan water body. It is less well known that the controversial Sivand dam, which is expected to destroy one of Iran's important cultural heritage sites, the Pasargadae, will also contribute to the destruction of the Bakhtegan water body [32].

During the last decade, the narrow dividing land between the Bakhtegan and Tashk lakes has been consistently increasing mainly as a result of water diversion and dam building by the Fars Water Authority. The two adjacent water bodies are expected to dry if the trend continues.

In August 2007, the Fars Province's Bureau of Environment Conservation reported that the only way to save flamingos in the Bakhtegan National Park from dying is by releasing water upstream of the dams. They asked the Ministry of Energy to release water from the dams for the sake of saving the Bakhtegan lake and its flamingos. The Tehran metropolitan newspaper *Hamshahri* [33] reported that an unprecedented effort was mobilised for saving the Bakhtegan flamingos in January 2008. Local environmental NGOs cooperated with the local environmental organisation employees and the community of the Bastrum village in the area to conduct a night march to gather thousands of young flamingos stranded in the saline desert created by the dried Bakhtegan lake and to transport them to less damaged safer parts.

Urmia Lake, another Ramsar Site, is the second largest saline lake in the world, and one of the six major water basins of the country. The Urmia basin area is about 52,000 km^2 and 14 major rivers discharge their runoff into this lake, estimated at about 5.5 BCM yearly. The lake area is about 4810 km^2 with about 102 islands. In the last decade 150,000 hectares of the lake-bed has dried to become a saline desert. According to Shahrokh Hakim-khani a member of the scientific board in the Faculty of Natural Resources of Urmia University, about 40 dams built on the rivers discharging into this lake have been responsible for the drying of the lake. Hakim-khani also disclosed that although the dams are built for agricultural proposes their maximum efficiency of irrigation is only 34%; and raised doubts as to the need for the dams, in view of the fact that there was no existing or forecast shortfall of water availability in the area [34]. Just the three dams of Zarrine-rud, Simine-rud, and Baranduz, prevent a total 1.1 BCM runoff discharge to the lake; each dam preventing respectively 605 MCM, 269 MCM and 264 MCM.

According to the head of the Research Center for Artemia and Aquatic Animals of Urmia University, 'Urmia Lake is the world's second largest habitat of artemia, and the *artemia urmianan* are unique to this lake. Within the decade artemia production in the lake has decreased to a hundredth of the original, indicating the critical condition of the lake' [33]. The *artemia urmianan* form a crucial part of the food chain in Urmia National Park. Flamingos, pelicans and other birds depend on the Artemia in the first stages of the food chain.

The head of the Natural Environment section of the Department of Environment of West Azarbaijan province reported that the population of birds in the Urmia National Park has decreased significantly [34]. The average depth of the Urmia Lake has decreased from 12 m to 6 m.

In a newspaper report [35], Esmail Kahrom, environmentalist and a professor at Tehran University writes, 'If I had not seen the dried Hamun Lake (a wetland in the Sistan Baluchistan province), Gav-Khuni Lake (in Isfahan province), and the Bakhtegan lakes (in Fars province), it would have been impossible for me to believe that Urmia could be drying.'

Figure 2 shows two Landsat satellite pictures of the Hamoun lake taken in 1976 and in 2001 [36], prepared by H. Partow as part of a UNEP project to prepare an 'Atlas of Global Change'; which amply demonstrates the drying of the Hamoun wetland within a short period of time.

Kahrom reports that salinity levels in the lake have increased from 120–130 mg/l to 310 mg/l. The *Artemia Urmianan*, which are resistant to salinity levels of 120–130 mg/l are dying

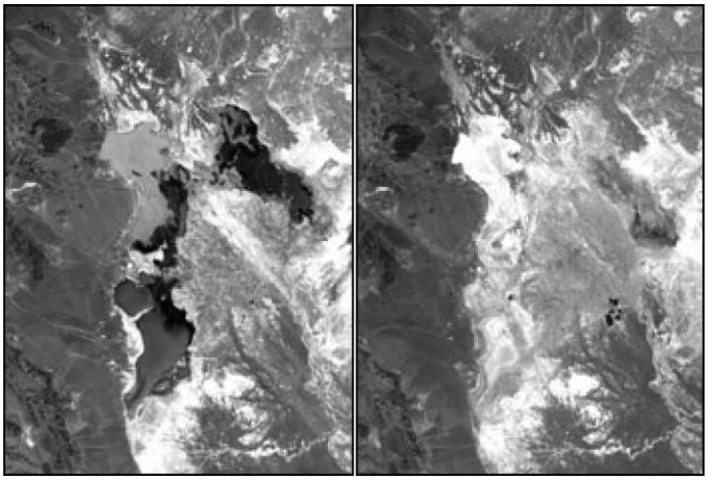

Figure 2. Drying up of the Hamoun Wetlands.
Left: In 1976, the Hamoun wetlands were still thriving. Dense reed beds appear as dark red, while tamarisk thicket fringing the margins of the upper lakes shows up as pink. Bright red patches represent irrigated agriculture, mainly wheat and barley. The lakes flood to an average depth of half a metre denoted by lighter shades of blue, while dark blue to black indicates deeper waters not exceeding four metres. Landsat MSS false colour composite (bands 4, 2, and 1).
Right: By 2001, the Hamoun wetlands had vanished after Central and South Asia were hit by the largest persistent drought anywhere in the world. The only sign of water in this scorched landscape of extensive salt flats (white) is the Chah Nimeh reservoir in the centre right of the image, which is now only used for drinking water. Degraded reed stands in muddy soil are visible as dark red in the southern end of Hamoun-i Puzak. Landsat 7 ETM+ false colour composite (bands 4, 3, and 2). (Image courtesy of H. Partow, UNEP).

due to the rising salinity of the lake and can be seen as millions of black dots on the lake surface. He also reports seeing a white headed gull with salt crystals covering its head and eyes. Up to 60,000 flamingos and pelicans have been reported on the lake's Doguzlar Island, which are threatened by the new levels of salinity.

4.4. Water quality deterioration

Deterioration of water quality is obvious both in upstream reservoir and downstream in riverbed or wetland and lake, wherever dams have been built.

Decomposition of inundated organic maters and vegetation can deplete the oxygen level of the reservoir. This may lead to a fast aging of the reservoir lake in tropical climates where reservoirs confront accelerated eutrophication. Nutrient enriched Minab dam in the south province of Hormozgan next to the Persian Gulf, with a 236 MCM reservoir capacity, was built to supply drinking water to Bandar Abbas. Deterioration of water quality soon started and within a couple of years, the eutrophication of water produced a foul smell which spread many kilometres in the area, and the water could no longer be used for potable purposes. Such water is not always suitable for agriculture. Alternative dams under construction, aiming to provide drinking water to Bandar Abbas, such as Shamil and Nian are destined to the same fate [37].

In the downstream, water quality degradation is also obvious when many dams take water from the same river system. A few years ago tests conducted in the Karun River at the end of the stream near the Persian Gulf in Abadan showed electrical conductivity levels on par with the saline oceans. The Karun, in this city, was always a traditional source of drinking water.

High temperatures in semi-arid areas like Khuzestan, lead to high evaporation of water, especially in reservoirs with large surface areas. The Karkhe dam, with a reservoir area of 160 km^2 evaporates 320 MCM of sweet water yearly. This means not only loss of such a high level of valuable water, but also deterioration in water quality.

Water loss and degradation do not appear to be of concern to public dam building companies or governmental water authorities, since no efforts have been made to date to overcome the problem.

4.5. Social impacts

In dam reservoirs, submerged villages, farms, and rangelands cause significant damage to indigenous people and marginalised ethnic minorities. These societies lose their livelihood and homeland. They are forced to leave the region. As a result, their particular indigenous knowledge and culture disappears fast.

The experience of the people of Lafure Dehestan with the building of the Alborz dam reservoir is typical. They lost everything they had, home, paddy farms, horticulture, rangelands and forests. In return they were paid compensation money insufficient even for buying a house. Productive farmers became unemployed and were compelled to migrate to nearby cities.

National guidelines issued in 1996 recommend compensation in the form of houses and farms for displaced communities. But this has never happened. Despite more than 500 built dams in the country, there is no research to follow up the situation of the displaced communities [25].

In the flood plains, farmers who use aquifer water for growing crops have also lost their water resources because of the water diversion upstream. Many qanats and wells have reduced discharge after dam building. No compensation has been paid for the loss of water resource and crops in flood plains.

Estuary related societies lose their fishery, tourist complexes, and recreational facilities. The Sefidrud dam has damaged the estuary and fishermen's livelihood, south of the Caspian Sea. There were no concerns about Tajan estuary's related populations and societies during dam building. The Alborz dam, as mentioned elsewhere in this paper, is expected to have a catastrophic impact on the Babolrud estuary with associated socio-economic impacts in Babolsar city. In an independent primary survey in this beautiful Caspian estuary, which is one of the few remaining, the author found that the local community in Babolsar did not believe that the estuary could vanish within a short period of time, such as one to two years [17]. But this has been experienced before in the Tajan estuary.

Sink wetlands and lake-related societies also confront adverse impacts of dam building. They lose their means of subsistence, such as fisheries and income from tourism. There is no compensation for these unfavourable effects of dam building. It is expected that Urmia Lake will soon face this crisis, being a primary tourist attraction. The increased salinity and reduction of lake area, with consequential loss of biomes is bound to affect the quality of the tourist experience, with loss of tourist markets. But it is unlikely that any of the feasibility studies of 40 built dams have any analysis on this important socio-economic or physical environmental impact.

4.6. Economic impacts

Dams and diversion projects are among the most expensive in Iran, costing up to a couple of billion dollars, each imposing a significant impact on the national economy. It has been

observed that, as a norm, estimated costs of dam building increases up to four times during the construction and due to constant prices [18,19]. The average period of performance is about nine years, underscoring the fact that the performance of irrigation networks is not even studied as part of the project. To date, 1 million ha of promised irrigation networks have not even started. Return of investment on dams is not a concern of decision-makers, who are normally public water authorities. The real benefit/cost ratio for many of built dams is zero, which means using large amounts of public funds for destroying the natural environment and disrupting well established and fairly successful socio-economic structures and systems.

4.7. Cultural and scenic heritage

Dam sites and reservoirs have inundated many valuable cultural heritage sites, particularly in this ancient nation, which has many archaeological sites from the Persian-Mesopotamian civilisation, especially in watershed regions and along rivers.

The Karun-3 dam and its 60-km long reservoir inundated many cultural heritage sites of ancient Izeh such as the Khar-Syadoon. There has been much publicised information on the impacts of the Sivand and Molla Sadra dams on the cultural heritage sites in the Bolaghi Pass [38].

The upper traces of watersheds are always among the most beautiful scenic areas of a region. A mountain ecosystem and the source or upstream of a river in a watershed is always unique and beautiful. More or less all dams have adverse impacts on these scenic heritages. The Tange-Bolaghi watershed is one of the rarest natural museums in Iran, but submerged recently by Sivand dam near Pasargadae [39].

5. Sustainable alternatives for water resource management

Current approaches to water resource management clearly need to change in favour of more sustainable and economical alternatives, with fewer negative impacts on the environment. While costly de-damming projects are unavoidable for the next generation in order to reverse the damage caused to the environment, containment of further damage is possible only if further construction of dams is stopped. Some of the sustainable approaches are outlined below.

5.1. Restoration and regeneration of traditional systems

Of the more obvious and accessible alternatives, revival of traditional systems of water management such as the qanats and *ab-bandans* is one that demands immediate attention, for their proven viability and widespread distribution in Iran.

Qanats are among the most efficient methods of water resources infrastructure in arid regions, since they exploit underground water within sustainable yield, without any adverse impacts on the environment.

South of the Caspian, farmers use winter and spring rains for cultivating paddy by collecting water in a*b-bandans*. These traditional ponds of Gilan, Mazandaran, and Golestan provinces are efficient small reservoirs surrounded by short dikes which gather rainfall for use in traditional irrigation networks. These rain-harvesting systems are operated and maintained by farmers' traditional cooperatives. They impose no costs on the public budget.

Review of existing, threatened and disused qanats and other traditional systems for the possibility of restoration and regeneration, and revival of the art, incorporating new technologies if necessary, needs urgent attention.

Since these systems are operational through community participation, their sustainability is ensured in the community's cooperation for mutual benefit.

5.2. Containing wastage of water, increasing efficiency of use and recycling waste water

Agriculture constitutes 85% of the total potable water consumption. Improved methods of irrigation can decrease agricultural consumption. Irrigation efficiency is about 35%. Any change in this figure could lead to huge amounts of water saving.

Urban networks face a huge loss of water as well. Total efficiency of water use in the country is less than 40% [10,11]. Per Capita water consumption in urban Iran is high at about 390 m^3 annually [12]. Increasing efficiency up to 80%, can save more than 40 BCM of water, which is the total capacity of all the dams built or being planned for construction.

Recycling wastewater for use in agriculture, forestry, industry, urban green spaces has not been given serious consideration. As long as dam building and supply management governs the water sector, water recovery is meaningless.

Because of low water prices, industries do not feel the need for recycling their used water. There are few motivations, regulations or penalties for industries to recycle and treat used water.

5.3. Alternatives to generation of hydroelectricity

Electricity from water turbines, mainly on dam sites, constitutes 7.55% of the total national production. During years with low rainfall, production of electricity is affected.

Instead of hydroelectricity, solar energy appears to be a more plausible alternative for Iran. Some work has been done in this area. Shiraz Solar Parabolic Plant is a thermal solar plant pilot project directed by the engineering faculty of Shiraz University. This plant comprises 48 solar parabolic collectors. Taleghn1 MGW plant is another thermal solar plant. A photovoltaic solar system of 2 KW capacity has been installed in Mehrshahr for agriculture, and road lights.

Conclusions

More than 35 years ago, M. Taghi Farvar and John P. Milton warned about anticipating ecological costs and environmental consequences when decisions had to be made on dam building, nomadic resettlement, and road construction [40].

Selecting careless technologies, ignoring past national experiences such as sedimentation in dams and neglecting the real means of development have led to uncontrolled dam building instead of sustainable water management.

The 500 dams built in Iran, have seriously affected watersheds and water bodies. These mostly useless constructions have caused deforestation, affected the productivity of the ecosystems and resulted in significant destruction of the physical, biological environment. Dam building in Iran could be considered a prominent national activity that has contributed to the process of desertification and thwarted development efforts. Lastly, though the most important perhaps in terms of direct costs to human lives, dams have disrupted indigenous

communities both upstream and downstream, with complete disregard for their indigenous knowledge and traditions and Iran's rich cultural traditions and heritage of many civilisations.

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