Desertification intensified by the impact of human mismanagement on water resources in drylands; examples from Central Iran

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1. Abstract

Desertification as the result of recent climatic changes and human impacts is a major environmental issue threatening the livelihoods of millions of people worldwide. Generally, the intensification of land use has been regarded as the main factor in human-induced desertification. This paper addresses the impacts of human mismanagement on water resources in arid lands and with examples from central Iran highlights the importance of desert ground-water resources in alluvial megafans. These are the vast fan-shaped topographic structures well developed along fault-bounded depressions. Desertification is a major problem at the distal parts of these megafans, where they grade into deserts at playa fringes and playa salt lakes toward the centre of these depressions. The ancient people well recognized the water resources in desert environments and this is why they built the cities on alluvial megafans in the desert borders in central Iran. They tried to supply the water by Qanats, an underground irrigation system invented in Iran for >2500 years ago. Recent technology advances in groundwater exploitation replaced the Qanats by deep water wells and the competition and mismanagement in water pumping and consumptions resulted in draw down of the groundwater tables, not only in megafan aquifers but also in playa lakes. This brought along serious problems, among which is the change in the trend of natural processes associated with intensified desertification in such an otherwise very sensitive environment. This study is an example stressing the needs drawing up a plan of action, something considering natural and socio-economic aspects on a local scale, for effective management of the water resources to combat desertification in arid lands

***Key words**: Desertification, water resources, drylands, alluvial megafans, central Iran*

2. Introduction

Deserts cover a considerable area in Central Iran and are closed drainage basins mostly located within the fault-bounded depressions (Berberian & King, 1981; Arzani, 2003; 2005; 2007). Playas (salt lakes) develop in the central parts of these arid to semiarid enclosed drainage basins, where the water table is close to the surface and evaporation exceeds ephemeral rivers and/or groundwater recharges. Desert sedimentary and geomorphologic systems comprise a variety of sub-environments including ephemeral fluvial rivers of the distal parts of the alluvial fans, aeolian dunes/inter-dunes, sandsheets, salt/mud flats and playa lakes. They are highly sensitive to internal and externally imposed environmental changes (e.g. Sweet, 1999; Tooth, 2000; Yechiell et al., 2002; Mountney, 2004). The sub-environments of a desert system have a close interaction and undergo sedimentary and morphological adjustments in response to environmental modification, such as change in climatic and tectonic regimes (e.g. Tooth, 2000; Műller et al., 2004; Arzani, 2005, 2007). The net result of this interaction should be considered for any proposed project to control the desert transgression.

In arid desert regions the climatic forcing functions control mainly the rate of precipitation as well as evaporation. The related externally-forced changes, such as dust-storm intensities/periodicity and the magnitude of flash floods, as well as intrinsic sedimentary behaviors, such as dune migration, mud and salt flats areas (associated with the variability of the playa lake level/underground water table) modify the geomorphology of the desert areas.

Tectonic uplift and basin tilting, because of fault activities, change the drainage net. They also controls the accommodation space for the sediment budget to be trapped and especially the place and extent of the playa lake and fringe.

This article highlights the influence of playa-lake level fluctuations on recent lacustrine/aeolian and ephemeral fluvial sediments and their importance in desertification. It represents case studies from distal part of the alluvial megafan in Central Iran (Fig. 1). The typical examples are the playas and their periphery deserts in Abarkoh and Ardestan Basins (Fig. 2; see also Arzani, 2005 for details). The recent desert transgression in Abarkoh Basin as the result of recent climatic changes and human impacts is an issue, explaining here on detail. The width of this basin is about 100 km in the studied area and is bounded by the Dehshir highlands and fault in the east and the Hambast Mountains and faults in the west

(Fig. 2A). The Abarkoh alluvial/fluvial megafan originates from the apex in a valley in Hambast Mountains in the west of the Abarkoh Basin and covers an area >940 km^2 (Arzani, 2007). It terminates in the playa-lake in the middle of this basin. The old city of Abarkoh, with ~40000 populations and ~80 km^2 in area, is located in the medial parts of this megafan (Fig. 2 A&B). In this city, >850 shallow (<100 m) to deep (up to 400 m) irrigation water wells and 103 Qanat systems (>270 km of underground tunnels) extract more water from the ground than its recharge (Fig. 2B). As the result, they dropped the groundwater table during the last 10 years (10-35 m in the city and up to 1 m in the playa fringe) and dried some of the Qanat (Kareze) systems (Arzani, 2003). The Abarkoh Basin has an arid climate with an average annual rainfall of about 90 mm. The minimum annual rainfall is 29 mm and maximum rainfall is ~132 mm with an average annual evaporation of 3632 mm during an investigated period of 15 years (Bagheri, 1995).

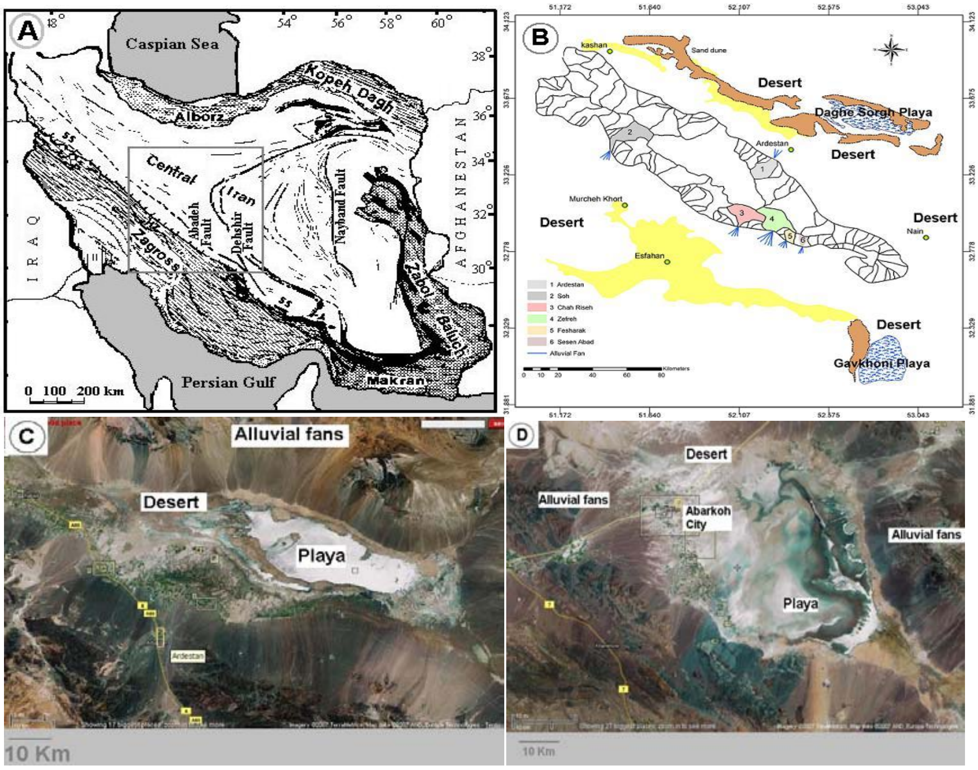

Figure 1 Deserts in central Iran. A. Tectonostructural map of Iran showing the fault-controlled depression in central Iran. B. Sketch map of alluvial fans, playas and deserts around the Kohrud Mountain Belt in central Iran. C & D. Satellite images of alluvial fans, playas and deserts of Ardestan and Abarkoh Cities in central Iran.

In the modern times, the population growth, development of industrial and agricultural production brought about the unceasing expansion of artificial oasis and abrupt increase of water demand. The artificial hydraulic irrigation engineering took the place of the natural river system, the reservoirs took the place of natural lakes, which in turn enhanced the space-time redistribution of surface water based on the natural evolution, and so did groundwater.

The ancient people well recognized the water resources in desert environments and this is why they built the cities on alluvial megafans in the desert borders in central Iran. They tried to supply the water by Qanats, an underground irrigation system invented in Iran for >2500 years ago. Recent technology advances in groundwater exploitation replaced the Qanats by deep water wells and the competition and mismanagement in water pumping and consumptions resulted in draw down of the groundwater tables, not only in megafan aquifers but also in playa lakes.

3. Methods

General geology and geomorphology of the studied area have been studied based on available geological maps (Amidi et al., 1983), Landsat (TM & ETM, Landsat 7) image data (imagery calibrated by ground survey) and field observation during several separate weeks of ground survey (1998-2004). This has been combined with the field observation in certain stations and along a west-east traverse of >45 km, from the distal parts of the fluvial system of the Abarkoh megafan toward the playa fringe.

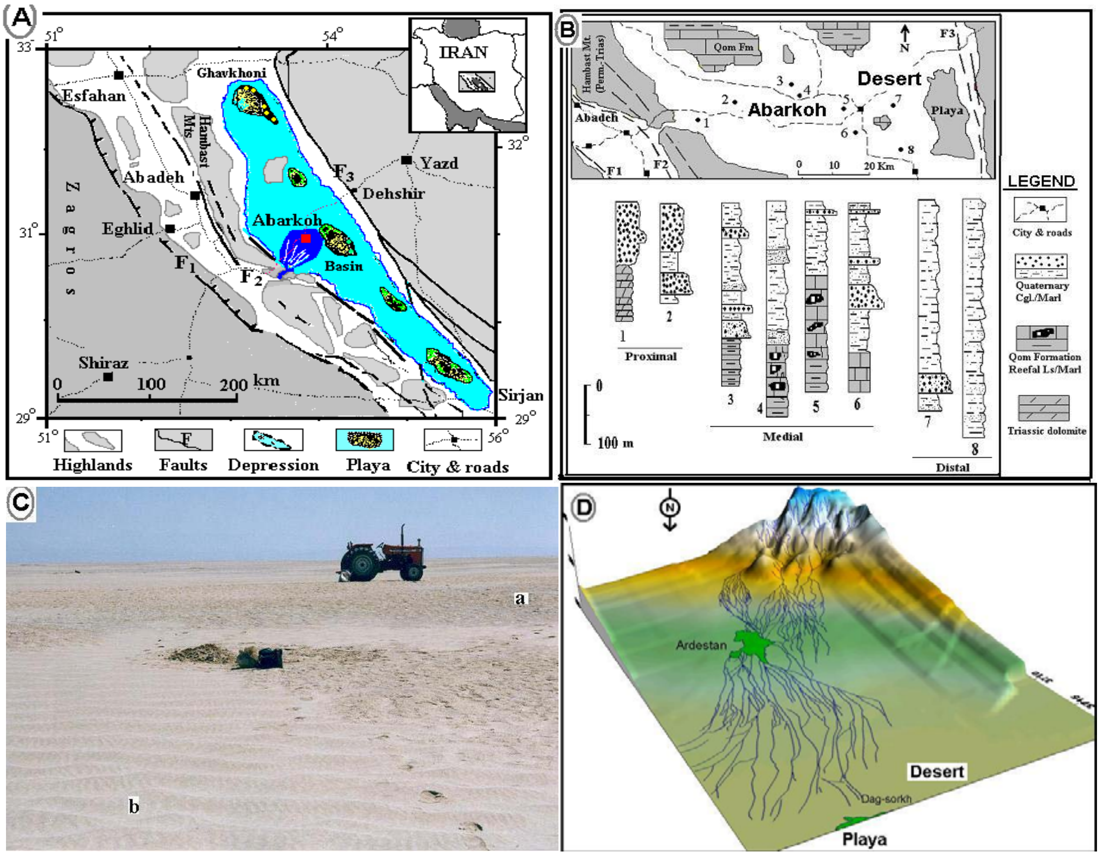

Figure 2 Sketch map of the Abarkoh Basin (A), sedimentological logs of the recently drilled irrigation water wells in this basin (B), deserts (salt flats (a) and wind-blown sand flats (b) in the distal part of the Abarkoh alluvial megafan (C) and 2D map of the Ardestan Basin (D) showing the drainage net towards the playa and its periphery desert.

4. Results and Discussion

The desert system of the Abarkoh Basin covers an area of ~1750 km^2 and comprises a variety of sub-environments, including the playa-lake, salt and mud flats, aeolian dunes and inter-dunes, sand sheets, gravel pavements and the ephemeral fluvial rivers and flood plains of the distal parts of the Abarkoh megafan (Fig. 1 & 2). The playa-lake and its periphery (consisting mainly of salt-flats, mud-flat and sand dunes) cover an area of ~600 km^2 (~15 km in wide and 40 km in length) and with a general NW-SE trend of the basin are the main sedimentary environments of this desert system. The remaining areas of this desert are the deflation surfaces at the toe of the alluvial fans along the north and eastern sides of this basin. Ephemeral rivers carry the periodic flash floods and enter the playa from its sides. The major fluvial systems are those from north and west, which carry floods from north and west of Abarkoh Basin.

The representative sedimentary environments of the studied desert system and along a 45 km traverse (Fig. 2), from SE of Abarkoh City to the playa-lake margins include:

1- The flood plains of the Abarkoh megafan, where the calcareous marls and soils represent the typical surface sediments. They laterally change into gravel/sand sheets with locally exposed travertine deposits. The gravel/sand sediments form elongated ripples (up to 10 cm high and 15 m long) showing wind direction toward NE and playa center.

2- Along the studied traverse and about 15 km east of Abarkoh City, the gravel/sand sheets and travertines grade into sand dune fields. Stabilized (by small bushes or plants), isolated to joined aeolian sand dunes are oriented NW-SE and show a predominately flow from southwest. The calcareous marls and travertine deposits are exposed in very wide inter-dune areas, where the plant roots are standing up to 50 cm above the ground and the surface is also partly covered with rippled granules to sand deposits.

3- Toward the SE and 30-50 km from Abarkoh City, very wide, brown sand-salt flats with desiccated, efflorescence and partly whitish salt crusts characterize the sediments the playa lake fringe (Fig. 2C). They grade downward into inter-layered sand (rippled sand and wavy laminated sand-silt deposits) and white hard salt crusts.

The salt crusts are characterized by either elongated halite crystals ("*chevron halite crystals*") or isolated halite cubes ("*cumulate halite crystals*") associated gypsum crystals. Cumulate halite crystals are common down the trenches and below the water table (> 100 cm subsurface in summer 2004) and are mixed with the aeolian sands. The aeolian sediments are also cemented with salts and formed large irregular nodules occurring near the surface. According to the local residence of the villages of around the playa and the remnants of the salt exploration plant of a company, the lake level has been at the surface in this station in 1996. The laterally extensive sandsheets and efflorescence salt crusts have been replaced the salt crusts at the surface.

5. Conclusions

Desertification is a major problem at the distal parts of the megafans in arid lands and desert sedimentary sub-environments are very sensitive areas. Their geomorphology depends on various environmental controls, among which the human mismanagement on water resources in drylands and as the result fall in ground-water table and playa-lake level fluctuation is very important. It controls the desertification by interacting between fluvial, aeolian and playa lake environments. Fluctuation in the groundwater/playa-lake level results changes in aeolian landscape and development of a sandy saline pan. Sand dunes shift and partly stabilize toward the ephemeral streams drain into the playa fringe. It also results in a general negative sediment budget and the generation of a deflationary surface at most parts of the playa fringe. These would bring along desertification and progressive invasion of sand/salt flats toward the cultivated lands and fertile soils at the distal parts of the alluvial megafans in arid lands.

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