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Review

Combating desertification in Iran over the last 50 years: An overview of changing approaches

Farshad Amiraslani*, Deirdre Dragovich

School of Geosciences F09, University of Sydney, Sydney, NSW 2006, Australia

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ABSTRACT

Desertification in Iran was recognized between the 1930s and 1960s. This paper traces Iran's attempts to reclaim desertified areas, evaluates the anti-desertification approaches adopted, and identifies continuing challenges. Iran has areas vulnerable to desertification due to extensive areas of drylands and increasing population pressure on land and water resources. Over-grazing of rangelands is a particular problem. Initially desertification was combated mainly at the local level and involved dune stabilization measures, especially the use of oil mulch, re-vegetation and windbreaks. Insufficient technical planning in the early years has led to changed approaches to plant densities and species diversity in plantations, and increased on-going management of existing plantations. Since the late 1980s forage and crop production has increased in areas where runoff control techniques are practiced. The social and economic aspects of anti-desertification programs have assisted in poverty reduction by providing off-season employment in rural areas. In 2004 a national plan to combat desertification was ratified and this placed an emphasis on community participation. Continuing challenges include managing existing desertified areas as well as taking into account potential future problems associated with rapidly depleting groundwater supplies and a predicted reduction in the plant growth period accompanying climate change.

1. Introduction

In the 1970s drought conditions and associated famine over large areas of the Sahelian region prompted numerous investigations of desertification in different continents, with the United Nations General Assembly in 1974 creating the United Nations Sudano-Sahelian Office and requesting the United Nations Environment Program to organize an international conference on desertification (Verstraete, 1984). Three decades later, and emphasising the continuing nature of the problem, the United Nations General Assembly named 2006 the "International Year of Deserts and Desertification" in order to raise public awareness about desertification and to help protect dryland biodiversity and traditional knowledge (Stringer, 2008). Although highlighting the importance of deserts, linking them with desertification has likely created further ambiguities in the perception of desertification (Stringer, 2008).

Desertification was initially defined as the change of productive lands into desert, caused by human activity, as suggested by Aubreville in 1949 (Herrmann and Hutchinson, 2005); later as the development of barren mobile sand dunes as described by Le Houérou in 1968 for the northern edge of the Sahara (Dregne, 1977); and also as an aggravation or extension of deserts (Hare et al., 1977). The United Nations Environment Program in 1977 defined desertification as "the diminution or destruction of biological potential of land which can lead ultimately to desert-like conditions" (Lal, 2001, p. 37). UN member countries have ratified the United Nations Convention to Combat Desertification (UNCCD) which provides international guidelines for responding to desertification. According to the definition in this Convention, desertification is "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities" (UNCCD, 1994, p. 4). In all definitions of desertification the key long-term outcomes are ecological deterioration and landscape degradation, frequently accompanied by human hardship. Deserts, although challenging environments for human occupation, do not automatically qualify as desertified areas. Only if deserts suffer from climate- and/or human-induced ecological deterioration or land degradation can they be considered as desertified regions.

In arid and semi-arid areas, "desertified" conditions may be present for lengthy periods without being permanent, as changing

* Corresponding author. Tel.: +61 2 9036 7069; fax: +61 2 9351 3644.
E-mail addresses: fami8991@uni.sydney.edu.au (F. Amiraslani), d.dragovich@usyd.edu.au (D. Dragovich).

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rainfall regimes and/or human use may allow for vegetation and landscape recovery at least temporarily. Tucker et al. (1991) reported large between-year variations in the location of the margins of the Sahara, with a maximum one-year contraction and increase (over an 11-year period) of 110 km and 99 km, respectively. The permanency or otherwise of desertified conditions in the Islamic Republic of Iran (hereafter referred to as Iran) is not being addressed in this paper. Rather, the premises relating to desertification are that biological productivity in certain areas has persistently declined over the short to medium term, and that intervention may provide a reduction in adverse impacts on ecosystems and/or human populations. Over periods of several decades, changes in rainfall regimes or human occupance may allow for self-remediation or 'greening' (Hutchinson et al., 2005) of areas previously described as desertified (Nicholson, 2005; Olsson et al., 2005) but even if this occurs, it does not alleviate problems for human use in the short term. The unpredictability of annual rainfall amounts and sequences of wet and dry years creates persistent uncertainties for human livelihoods in dryland areas.

The relationship between climate and desertification is complex and poorly understood, and some researchers (e.g. Pickup, 1998; Herrmann and Hutchinson, 2005) consider that it is impossible to separate the impacts of drought and desertification. However, the climatic environment of drylands, which is characterized by moderate to high temperatures and prolonged episodes of below-average amounts of low and variable annual rainfall, makes drylands especially vulnerable to degradation. Environmental variability combined with the complexity of landscape and vegetation responses in drylands creates unreliable conditions for human inhabitants and their resource-use activities and requirements. Under circumstances of extreme climatic events or prolonged droughts, vegetation reduction increases the erodibility of runoff-generating rains and leads to land degradation. These naturally-occurring changes become amplified when imbalances occur between the physical environment and human use, or when resource use continues with little or no adjustment in the face of adverse climatic conditions. Sivakumar (2007) believes that climate change will exacerbate desertification through changing the spatial and temporal patterns of temperature, rainfall, solar isolation and winds. However, not all currently desertified areas are likely to be affected equally. Climatic variability has a major role in desertification and the nature of this variability may also alter along with climate change (Glenn et al., 1998).

Arid and semi-arid climates cover much of Iran, making these areas vulnerable to desertification if inappropriately managed. The country has a land area of about 1.64 million km^2, made up of 30 provinces, and a variable and often extreme climate with extended periods of both sub-freezing temperatures as low as $-20\,^{\circ}C$ and high temperatures exceeding $40\,^{\circ}C$ (Koocheki et al., 2006). Maximum precipitation reaches approximately 1200 mm in the north, decreasing to a minimum of less than 100 mm in the central region (NAP, 2005). In total, deserts cover approximately 20% of Iran's area, and rangelands 55%, with the remainder being agriculture (11%), forests (8%) and industrial and residential areas (6%) (NAP, 2005). Iran's Bureau of Desert Affairs classifies the greater part of the country as being arid or hyper-arid (Fig. 1); and based on ecoclimatic subzones, Le Houérou (1992) estimated that 85% of Iran is classified under dryland categories. By 1998, land degradation and desertification was estimated to affect approximately 34 million hectares or about 20% of the country (Pakparvar, 1998).

This paper provides an outline of Iran's physical environment and land use patterns which together form the context for desertification; traces attempts made to reclaim degraded natural resources; evaluates some of the anti-desertification measures adopted; and identifies continuing challenges in combating desertification. Sources cited in this overview include Persian language publications which would otherwise be less accessible to those conducting research in English (including *Biaban*, a journal of the University of Tehran, published as the English-language *Desert* since 2007; and *Jangal-o-Marta*, the journal of the Forest, Rangeland and Watershed Management Organisation).

2. Iran – background to desertification

Iran's Bureau of Desert Affairs has identified 17 provinces as having "desertified areas" (Fig. 1); these provinces are home to nearly 70% of the total Iranian population. Since 2005 there have been debates about removing some provinces from the desertified list, even as Ilam province has been added; but for all provinces, only a portion of their total area is desertified. Desertification in Ilam province is now believed to affect 7% of its area (140,081 ha) due to over-grazing of rangelands and climatic factors (Natural Resources Administration of Ilam, 2008).

Desertified areas in Iran are often characterized by arid-land features including sand dunes whose origins vary, but Pakparvar (1998) considered that most may have resulted from degradation of topsoil in agricultural lands and rangelands. At present, the area of desert regions and sandy lands is estimated to be 34 million hectares of which 5 million hectares are active dunes; 12 million hectares are inactive sands; and the remaining areas are affected by salt accumulation, saline and alkaline soils, or are gravelly lands (Pakparvar, 1998). A special kind of desertification takes the form of encroachment by mobile sand dunes onto productive agricultural areas, communities, oases and even roads and rivers (Ahmad and Kassas, 1987). This occurs in most of the desertified provinces and affects the livelihood of mainly agriculturally-based local communities. Sand dune encroachment has adverse impacts including ruining crops and blowing away topsoils; filling water canals with sand; covering main and secondary roads with sand dunes which prevent normal traffic movement; and by sand blowing at roof and ground level of rural houses, schools and medical centres. Sand encroachment is not a new phenomenon in Iran: in 1812, an English traveller reported the rapid encroachment of desert in the extensive desolate plains of Kerman province (Seyf, 1992). Stabilization of dunes has been a major objective of anti-desertification programs over the last fifty years.

Dust storms are a recurring phenomenon in south-west Asia, including Iran (Table 1). Middleton (1986) noted that dust storms in Iran had been reported in foreign travelogues dating back to the 1890s. Dust storms impact on economies and societies by obscuring visibility, causing health problems (especially ophthalmic and respiratory diseases) and stripping agricultural soils (Reheis, 2006). Such storms are a problem especially in the eastern provinces of Iran which are most affected by water shortages and frequent droughts.

It is believed that the main causes of desertification in Iran involve climatic factors, population pressure, over-exploitation of water resources, and over-grazing (NAP, 2005). These factors often interact in contributing to desertification: for example, adverse climatic conditions may prevent the continuation of previously sustainable levels of water use, leading to over-exploitation of the resource; and secondary salinization may develop in association with irrigation (Qadir et al., 2008). The contributions of these four main potential causes of desertification in Iran are outlined below.

2.1. Climatic factors

The long-term mean annual rainfall for arid and semi-arid regions in Iran is 141.1 mm (Modarres and da Silva, 2007). Mean rainfall (data ending in 2000) at selected stations in desertified

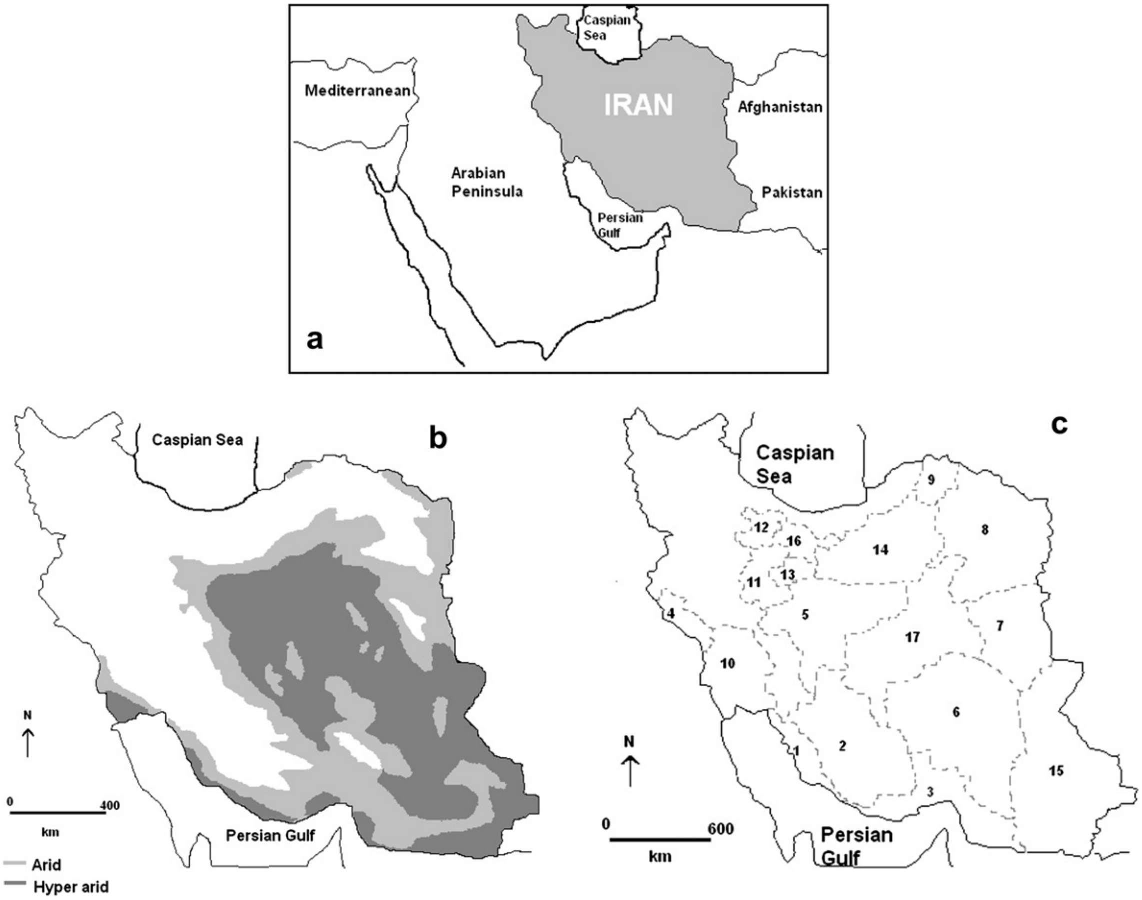

Fig. 1. (a) Regional location of Iran. (b) Hyper-arid and arid areas of Iran; (Source: modified after the Bureau of Desert Affairs). (c) Provinces containing desertified areas: 1, Bushehr; 2, Fars; 3, Hormozgan; 4, Ilam; 5, Isfahan; 6, Kerman; 7, Khorasan Jonoobi; 8, Khorasan Razavi; 9, Khorasan Shomali; 10, Khuzestan; 11, Markazi; 12, Qazvin; 13, Qom; 14, Semnan; 15, Sistan-Baloochestan; 16, Tehran; 17, Yazd (all boundaries are schematic).

provinces ranges from as low as 86 mm in Yazd province up to 271 mm in Khorasan Razavi province, with most recording dry years after 2000. It is unclear whether these post-2000 rainfalls represent a run of very dry years or the commencement of predicted rainfall decline with climate change. Using pre-2000 data, Modarres and da Silva (2007) observed significant trends in annual rainfall for northern (positive) and southern (negative) stations in dryland areas of Iran. In addition, variability in year-to-year rainfall is substantial: Bam, for example, recorded 121 mm of annual rainfall in 1991, 48 mm in 2000, and only 19 mm in 2005 (Iran Meteorology Organization, 2007, 2008). Assessing 145 precipitation gauging stations in the country including those located in arid and semi-arid areas for the period 1951–2000, Modarres and Sarhadi (2009) showed that rainfall intensity (24-h maximum rainfall) in arid regions was increasing and suggested that soil degradation and desertification is being accelerated in these areas.

Table 1
Dust storms in selected desertified cities in Iran (summarized after Middleton, 1986).

City	Frequency (Average days/yr)[a]	Features
Zabol	80.7	May–July; northerly wind (120-day winds); wind velocity up to 28 m/s; the largest frequency in the south-west Asia region
Abadan	43.1	May–July; prevailing north-westerly wind
Dezful	40.0	
Jask	27.3	February–July; prevailing north-westerly wind
Yazd	24.0	February–July; wind velocity up to 17 m/s, lasting up to 24 h; reduction of visibility up to 20 m
Bandar Abbas	23.1	February–July; prevailing north-westerly wind

[a] As a comparison, dust storm days varied between 17.5 and 46.7 for Afghanistan and between 3.6 and 36.5 for Pakistan (Middleton, 1986).

Of the total land area of Iran, about 75 million hectares are adversely affected by water erosion, compared with 20 million hectares by wind erosion and 5 million hectares by other types of chemical and physical degradation (NAP, 2005). The average national rate of water erosion is estimated to be 15–45 t/ha (Islamic Republic News Agency, 2008) and, on the basis of the Modified Southwest InterAgency Committee model, exceeds the acceptable level by 20–30 times in many watersheds (Jalalian et al., 1997).

2.2. Population pressure

In Iran's arid and semi-arid climates resource demands from an expanding population have contributed to land degradation. Major demographic changes have occurred in the country since the 1930s when total population was about 13 million, 80% of whom then lived in rural areas. By 2001, the population had reached around 65 million of whom only about 34% were in rural areas. Nevertheless this points to a doubling of the rural population over the period. Over the 40 years since 1960, population increased by 42 million (population and urbanization data from Bharier, 1972; Dehesh, 1994; Ehlers and Floor, 1993; Fanni, 2006; United Nations in the Islamic Republic of Iran, 1999; Statistical Centre of Iran, 2008; Ziari, 2006). The urban population has more than trebled over the last 50 years, leading to a sharp increase in urban water consumption. In the 17 desertified provinces between 1996 and 2006, population increased from around 38 million to 47 million. The major urban centres in 5 of these provinces had populations exceeding 1 million, comprising 77% of the total urban population in desertified provinces (Bharier, 1972; Ehlers and Floor, 1993; Statistical Centre of Iran, 2008). These demographic shifts together with economic, social and developmental changes have created a situation in which more pressure is being exerted on natural resources (soil, water and vegetation). These effects are felt in relation to livestock raising on rangelands, as well as in agricultural areas with their associated infrastructure – including irrigation canals, villages and roads – and in urban areas, where water supplies are a key issue.

2.3. Over-exploitation of water resources

Agriculture including livestock grazing has been a major cause of land degradation and desertification over recent decades. Historically, agriculture in Iran still played a pivotal role early in the 1900s, when it employed nearly 80% of the population. By the mid-1950s this proportion had decreased to around 56% and is currently only about 20%. The relative decrease in agricultural employment coincided with a substantial increase in urbanization resulting from major rural-urban migration commencing in the 1930s, and was accompanied by an increase in total population (Bharier, 1972; Floor, 1984; United Nations in the Islamic Republic of Iran, 1999; Islamic Republic News Agency, 2008; Lieberman, 1979).

Agriculture remains an important sector for meeting food requirements of the increasing population and for creating jobs. Unfortunately, the sector is associated with substantial soil erosion and adverse effects on scarce water resources. At the national level, agricultural factors contributing to desertification include variability in size and fragmentation of farmlands, lack of farm infrastructure, insufficient farmer knowledge, lack of planning mechanisms and inefficient irrigation systems (NAP, 2005). Agriculture is the biggest consumer of water in the country but a high proportion of water is lost before reaching farms: Iran has a low water use efficiency of 35–40% (Islamic Republic News Agency, 2008). Nationally, the most common irrigation method has been the gravity system in which 70% of water is lost by seepage (Karimkoshteh and Haghiri, 2004) as a result of inefficient water delivery through unlined canals that allow water to be evaporated, leading to salinization of adjacent soils. Irrigated agriculture (8.7 million ha) (Islamic Republic News Agency, 2008) uses more than 90% of the total surface and groundwater withdrawal and more than 60% of total renewable water resources (Faramarzi et al., 2009). This has prompted the Iranian government to provide funds for the installation of drip irrigation and other water-saving measures.

Since the 1960s, underground water exploitation for agricultural expansion has increased due to the availability of electric pumps. A major decline in water table levels has followed, placing the water status of plains areas in particular in a critical state (Khajeddin, 2007), as well as leading to an increase in land subsidence (Table 2). One of the desertified provinces, Qazvin, is now facing a critical deficiency of underground water, following extensive extraction (1.2 billion m^3/yr) from legal water wells (3973 deep wells, 6083 semi-deep wells) and illegal water wells (300 wells), resulting in an annual decline of 1.5 m in the level of the water table (Ardekani, 2006). It is estimated that about half of the area of plains country in Iran is threatened by land subsidence (Islamic Republic News Agency, 2008).

2.4. Over-grazing

Currently 124 million animal units graze on rangelands and forests (FRWO, 2006) and supply not only milk and meat, but also wool for the country's rug-making industry. Of the 124 million livestock, about 83 million are dependent on rangelands where approximately 916,000 pastoralism-dependent inhabitants live. This is more than five times the number of people believed by

Table 2
Underground water decline at the national level and in some desertified provinces of Iran.

Province	Area	Total/annual decline in water table (m)	Timeframe	Comments
Country	nationwide	0.41	N/A	Total extraction of 15 billion m^3; 67% of country's aquifers demonstrate negative water balance
Isfahan	Kashan plain	16 (0.6/yr)	1965–1997	increase in water salinity
Kerman	Zarand- Kerman plain	20	Since 1990	land subsidence[a] of 22–25 cm/yr
	Rafsanjan	15 [25][b]	Between 1971 and 2001	land subsidence of 50 cm/yr; excessive pumping of underground water (1798 wells, 85% for agricultural purposes); depth of wells to water table has increased from 80 to 300 m over the last 30 years
Khorasan Razavi	Mashhad and Kashmar valleys	15	Since 1980s	land subsidence of 27–30 [20][b] cm/yr
		64	Since 1960s	
Qazvin	Qazvin plain	1.5/yr	N/A	Legal water wells (3973 deep and 6083 semi-deep), illegal water wells (300 wells)
Qom	Qanavat plain	14.5 (1.16/yr)	1988–2000	1.4-fold increase in exploitation of underground water
Tehran	Varamin plain	13	Since 1990s	8000 illegal drilled wells; land subsidence of 23–36 cm/yr
Yazd	Yazd-Ardakan plain	12	Since 1970s	land subsidence of 9.4 cm/yr
	All basins	0.20–0.70 [1][b]	N/A	misuse of deep and semi-deep wells

N/A: not available.
Sources: Aflaki (2007), Ardekani (2006), Darvish (2007), Giti et al. (1999), Motagh et al. (2008), Motiee et al. (2006), Mousavi et al. (2001), National Report (2003), Rahmatian (2005) and Zehtabian et al. (2002).
[a] Land surface sinking due to natural or human-induced causes (Mousavi et al., 2001).
[b] Brackets show different figure cited for this area.

FRWO (2006) to be desirable for sustainable exploitation of the rangelands. In terms of carrying capacity, estimates of rangeland forage production vary from sustaining 50 million animal units for 100 days (Iran Daily, 2005) to 37 million animal units for 200 days (FRWO, 2006). The imbalance between livestock numbers and carrying capacity differs from one province to another with some stocking rates being very high. For Ilam, one of the desertified provinces, total forage produced in the rangelands is estimated to be 115,000 t/yr, enough to sustain 586,000 livestock units over the long term; current livestock numbers exceed this carrying capacity by more than five times (Natural Resources Administration of Ilam, 2008). At the national level, stocking rates are believed to be more than double the sustainable carrying capacity of the country's rangelands (Islamic Republic News Agency, 2008), and over-grazing of rangelands and forests is threatening to degrade natural flora and accelerate erosion (Mousavi, 2006). The problem of over-grazing is exacerbated by droughts. During the severe 1998–2001 drought, the government acted as a buffer between the rangeland inhabitants and their environment by purchasing some livestock, providing funds for buying hay, delivering water by tanker, and distributing flour rations for families who had no means of acquiring food. Even so, many farmers and livestock herders were forced to migrate to urban areas – which also suffered water shortages and rationing – or, if they stayed, to change employment (Abbaspour and Sabetraftar, 2005).

3. Combating desertification in Iran

Combating desertification in Iran is a complex combination of actions attempting to maintain non-desertified conditions in already-treated areas, advancing anti-desertification measures into untreated areas previously identified as desertified, and making long-term plans to anticipate and meet the needs of a growing population already placing pressure on fragile land and water resources (i.e. prevention of further desertification). In practice, combating desertification has been an iterative process commencing with a decision/s to implement specific measures in a particular (desertified) place, monitoring the immediate and longer term outcomes of these measures, researching new approaches, managing any challenges in already-treated areas, and making relevant changes to procedures to be used in subsequent anti-desertification activities. Identifying and prioritizing areas at risk of desertification and wind erosion forms an important and continuing challenge for those charged with anti-desertification intervention. These interventions are here classified into three main groups namely dune stabilization, the legislative framework for managing desertification, and desertification research.

3.1. Dune stabilization initiatives

Desertification was formally recognized in parts of Iran between the 1930s and 1960s (Whyte, 1977), with government measures to combat desertification commencing in the late 1950s. These early anti-desertification efforts were administered by a central office established in 1958 in Tehran with limited staff and called the "Soil and Water Conservation Committee", affiliated to the then Ministry of Agriculture (Anon, 2008a). Later the Committee was renamed the "Bureau of Combating Desertification and Sand Dune Fixation" (presently, the Bureau of Desert Affairs) which is part of the Iranian Forest, Rangeland and Watershed Management Organization (FRWO). Currently the Bureau concentrates its efforts on the 17 provinces which it has identified as including desertified areas.

Since dune stabilization began, FRWO has been responsible for these activities, which have been initiated and supervised by provincial FRWO staff in response to provincial requests. The outcome has been a series of local dune stabilization schemes without national planning or prioritizing of needs and funding. In recent years there has been an increased emphasis on monitoring and ensuring the continuation of gains made in local projects, along with a recognition that local communities can be encouraged to participate in such government-funded projects. No data exist relating to the location and outcomes of these case-by-case interventions in dune stabilization.

Combating dune-related desertification began formally with the use of techniques such as mulching and planting of vegetation (Farshad et al., 2002). The first attempt at assessing methods for stabilizing shifting sand dunes was conducted using oil mulch on 40 ha of dunes at Hamidieh, Albaravayeh and Albaji in Khuzestan Province in September 1959 (Anon, 2008a). Following the successful demonstration of reduced sediment transport and dune movement, these dune-fixing activities were accelerated and expanded in 1961 under the title of the "Hares-Abad Desertified Rangelands Improvement Plan" which involved dune stabilization in 100 hectares of desert in Khorasan Shomali (Anon, 2008a).This initiative allowed for the re-establishment of plant cover and animal life, stabilization of sand dunes, an obvious reduction in dust particles, and the possibility of sustained agricultural production after only a few years. These positive outcomes led to the adoption of similar activities by field officers in other desertified provinces (Anon, 2008a).

The sand dune stabilization programme is on-going and involves the implementation of biological and physical activities, along with monitoring of their effectiveness. These activities have concentrated on control of vegetation removal, range management, water resource development, soil protection, sand stabilization and some integrated land management (Farshad et al., 2002). The measures used included runoff control, oil mulch spraying, windbreak establishment, and biological measures including planting of seedlings and sowing of seeds (Nateghi, 2006).

3.1.1. Runoff control

Surface runoff is of considerable importance in arid environments as it promotes vegetation establishment (Thomas, 1997; Pickup, 1998). Floodwater utilization – the trapping and safe dispersal of runoff from high intensity rainfall events – is an economically feasible and environmentally sound technique with a long history in Iran. This control of surface water can be undertaken using a combination of FRWO inputs (e.g. funds, expertise) and local skills and experience, enabling desert communities to become self-sufficient in water, food, forage and fuel (Pakparvar, 1998). In the 1980s an on-going pilot project was established in 6000 ha of Gareh Bygone Plain (Fars Province), covering 2000 local inhabitants from four villages (Kowsar, 2007; Pakparvar, 1998). The area is a sandy plain with 150 mm mean annual rainfall. By constructing floodwater spreading systems, aquifers have been recharged (in a dry year, 27% of the floodwater percolates to the aquifer) and floodwaters controlled (on average 10 million m^3 of floodwater is diverted annually); 2-year average production of barley was 700 kg/ha outside the floodwater spreading system and 2150 kg/ha on terraces within it; grazing capacity increased tenfold; honey production has commenced; fresh water supplies are guaranteed; and local jobs and cooperatives have been created (Kowsar, 2007; Pakparvar, 1998; Raes et al., 2008).

3.1.2. Oil mulch spraying

Oil (petroleum) mulch – an oil-extracted material (hydrocarbon colloid) – is sprayed over sand dunes to assist with re-vegetation. The hydrocarbon colloid is a by-product of refineries and is provided by the Iranian Ministry of Oil at no cost for the purpose of sand stabilization. In Russia (1890s) and the Soviet Union (1930s) natural bitumen was spread over dunes encroaching on railways and infrastructure (Dehdashtian, 2009) and oil companies in the Middle East also spray sand dunes with crude oil to protect their facilities (Khan, 1983). Iran was the first country in the Middle East to introduce oil mulch for dune stabilization, a method that has subsequently been adopted in other areas including Abu Dhabi (Khan, 1983). The mulch, when spread, extends to a depth of about 1 mm, reaching a maximum of 5 cm after 3 years in higher rainfall areas (Dehdashtian, 2009).

Oil mulch assists both in stabilizing shifting sands and in preserving soil moisture (Kowsar et al., 1969) in preparation for establishing vegetation cover. Although oil mulch can be sprayed either before or after seedlings are planted, seedling survival is higher when mulching precedes planting (Akbarian and Mosavi, 2006). In Kerman province, germination of *Haloxylon persicum* was nearly three times greater for mulched than for untreated surfaces (Jafarian, 2006). Oil mulch is also more effective than other tested sand stabilizers in encouraging seed germination (Farahpour et al., 2005). According to recent research, no adverse effects were associated with use of oil mulch in Iran; and positive effects were noted in some cases in relation to soil organic matter, soil water holding capacity and the amount and activity of soil organisms (Pouyafar and Asgari Moghadam, 2006). In addition, it was reported that oil mulch sprayed over dunes will repel pests and mice but only for a short period (less than 1 year) after which their populations will gradually increase. Over the approximately 30 years from the mid-1960s to mid-1990s, nearly 190,000 hectares of sand dunes were stabilized using oil mulch, and this measure to combat desertification is continuing (Table 3). Using Landsat imagery and maps, it is now possible to identify mulched and unmulched areas (Alavi Panah et al., 2006).

3.1.3. Windbreak establishment

Windbreaks are used to reduce soil erosion by establishing barriers composed of biological (e.g. trees, branches) and non-biological (e.g. walls, fences) materials; these provide shelter from the wind, alter the microclimate, and alter the flow of water and nutrients (Cleugh et al., 2002). Windbreaks are designed and erected at different densities (spacing), heights and lengths based on wind direction, velocity and intensity. In Iran, various types of windbreaks are used but in very limited areas compared to oil mulch usage; the most prevalent method is to use dead and broken branches of trees or shrubs and annual grasses. In some cases, rows of trees are planted, mainly around cultivated areas. In order to support newly established plantings in desertified areas, livestock are initially excluded to prevent trampling and grazing. This exclosure period depends on the plant species, and climatic and edaphic conditions.

3.1.4. Biological measures

Conservation of water and soil resources can be assisted through manipulation of the vegetation cover. Tree and shrub plantings (referred to as 'plantations') are intended to satisfy environmental and social as well as industrial needs and, where applicable, be suitable for controlling wind and water erosion (Nasr Al-Amin et al., 2006). Such plantings directly address environmental issues which adversely impact on economic development. The greater the amount of vegetation cover, the less dynamic a sand surface is likely to be, as each individual plant acting as a roughness element (Bullard, 1997). Because most sand transport takes place near ground level (Bullard, 1997), grasses and shrubs are the most effective at reducing wind erosion. Research has demonstrated the effectiveness of various herbaceous and shrub plant species such as *Artemisia, Cephalophyllum*, *Caragana*, and *Eragrostis* in controlling wind erosion (e.g. Li et al., 2004, 2009; Anderson et al., 2004). For rill and gully erosion control in a semi-arid Mediterranean landscape in southeast Spain, the grasses *Stipa tenacissima* L. and *Lygeum spartum* L. and the shrub *Salsola genistoides* Juss. Ex Poir. were selected as suitable plant species (De Baets et al., 2009). In Iran, native plant species such as the shrubs *Haloxylon persicum, Calligonum comosum*, and *Smirnovia iranica,* and the grasses *Astragalus squarrosus* and *Panicum antidotale* (millet) are used for controlling soil erosion (Anon, 2006). The planted vegetation cover has encouraged infiltration and reduced runoff and erosion, leading to retention of surface water resources and recharging of groundwater.

Table 3
Sand dune areas stabilized by oil mulch in Iran.

Year(s)	Area (ha)
1965–1978	67,300
1979–1988	92,717
1989–1993	29,672
1994	3258
1995–1999	11,365
2000–2004	19,624
2005	2960
2006	4452
Total	231,348

Source: Peyke Sabz (2006).

Biological measures to combat desertification in Iran include techniques to expand plantations using species adapted to the harsh conditions of deserts, planting seedlings, and direct seeding of suitable plant species. Since the first steps were taken to stabilize sand dunes, various plant species have been used. Nearly all species are shrubs, apart from the perennial grass *Panicum antidotale* (millet) (FRWO, 2007). *Haloxylon* species were used from the early years of desertification control and are the most widely cultivated species in the desertified provinces (Table 4). Only in provinces bordering the coast (Bushehr and Hormozgan) and those with more adequate rainfall near the Zagros Mountains (Fars and Ilam) is *Haloxylon* not used. *Haloxylon aphyllum* and *Calligonum comosum* species, used for stabilizing sand dunes in Rezaabad, Semnan province, were shown to improve the physicochemical properties of soil including structure, organic matter, and nutrient status (N,P,K), and also to increase the density of *Stipagrostis pennata*, the native vegetation of the area (Zehtabian et al., 2006).

Other national reports have confirmed that the positive effects of biological measures used in combating desertification include an increase in the number of plant species, wildlife and soil microorganisms (Pouyafar and Asgari Moghadam, 2006; Henteh et al., 2004; Jafari et al., 2003); biodiversity is thus enhanced.

3.2. The legislative framework

A major change in approaches to combating desertification in Iran took place following the government's commitment to the UNCCD. Countries that are party to UNCCD and affected by desertification agree to prepare a National Action Programme to Combat Desertification (NAP) which will outline future short-, medium- and long-term programmes, and the country's plans for preventing desertification and mitigating the effects of droughts. As Iran is a member of UNCCD, it has prepared a NAP. The framework of the Iran NAP consists of four pivots (NAP, 2005, p. 32) namely:

- Identification and control of the factors contributing to desertification.
- Support for the sustainable use and management of natural resources through conservation and reclamation.

Table 4
Distribution of major plant species used in Iran's desertified provinces.

Plant species[a]	Desertified provinces[b]																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Atriplex canescens		•			•		•	•	•		•	•	•	•		•	
Atriplex lentiformis				•	•		•	•	•			•	•	•		•	
Calligonum comosum	•				•	•	•	•					•	•	•	•	
Calotropis procera		•	•	•						•							
Haloxylon ammodendron					•	•	•	•	•	•		•	•	•	•	•	•
Haloxylon persicum					•	•	•	•	•	•		•	•	•	•	•	
Hammada salicornicum		•			•												•
Nitraria schoberi			•		•		•	•	•		•	•		•		•	•
Panicum antidotale	•			•				•									
Prosopis juliflora	•		•	•		•				•					•		
Prosopis spicigera			•			•									•		
Seidlitzia rosmarinus					•			•					•				•
Tamarix aphylla	•		•	•			•	•	•	•		•			•		
Tamarix stricta			•		•	•			•						•	•	
Ziziphus spina-christi	•			•											•		

Source: Haghani and Hojati (2006).
[a] Alphabetical order.
[b] 1, Bushehr; 2, Fars; 3, Hormozgan; 4, Ilam; 5, Isfahan; 6, Kerman; 7, Khorasan Jonoobi; 8, Khorasan Razavi; 9, Khorasan Shomali; 10, Khuzestan; 11, Markazi; 12, Qazvin; 13, Qom; 14, Semnan; 15, Sistan-Baloochestan; 16, Tehran; 17, Yazd.

- Promotion of sustainable livelihoods in affected areas through job creation, income generation and improvement in socio-economic standards.
- Strengthening the role of rural communities in terms of decision-making, planning, designing, implementing, monitoring and evaluation.

Following the adoption of the NAP in 2004, emphasis has been placed on issues like implementing projects based on technical plans, ensuring community participation, incorporating research and traditional knowledge, and effecting sectoral and cross-sectoral cooperation (Nateghi, 2006). An important policy change is the allocation of an anti-desertification budget directly to each affected province, based on annual recommendations by the FRWO provincial administrative offices. This form of funding distribution reduces delay in supporting and implementing projects (Anon, 2008a) and also provides greater flexibility for provincial offices to respond to local needs.

Monitoring and evaluation of programs has increased in recent years and such monitoring is an essential step in any land rehabilitation programme, as well as providing some ability to identify emerging problem areas. Using Remote Sensing and Geographical Information System facilities, large-scale maps of the arid and semi-arid areas (e.g. 1:250,000 scale map of vegetation cover) in Iran have been prepared to increase the accuracy and frequency of monitoring. Analyzing climatic records, Morid et al. (2006) found that the effective drought index (EDI) was the most suitable of seven measures for identifying emerging drought. For wind erosion assessment, a national program titled "The recognition of critical foci vulnerable to wind erosion and desertification" was developed using GIS-based maps in order to provide the location of areas vulnerable to wind erosion. In total, 182 critical areas (foci) covering 6.40 million hectares, with various erosion severities, were detected (Abbasi, 2006). The findings from this research are intended as a guide for future anti-desertification activities by FRWO.

3.3. *Desertification research*

Current government involvement in developing the agricultural sector in Iran includes a research policy using public investment in agricultural research and development. This policy is implemented through establishing public research bodies and allocating annual research budgets (Hosseini et al., 2009). Over the more than 30 years of desert research activities in Iran, numerous research projects have been undertaken to improve measures for controlling desertification (Pakparvar, 1998). A number of Iranian universities provide postgraduate courses in the field of combating desertification. Several research organizations are also active, including the Research Institute of Forests and Rangelands affiliated to the Ministry of Jihad-e-Agriculture; the International Centre for Coexisting with Desert affiliated to the University of Tehran; and the Yazd International Centre for Living with the Desert affiliated to the University of Yazd. Each of these organizations has already implemented, or is in the process of implementing, research projects at various scales.

As an example, the Research Institute of Forests and Rangelands (RIFR) is one of the main research centres and it includes a desert section which is in turn composed of 5 research groups, namely those of water resources, land resources, erosion vulnerability, management of desert exploitation and vegetative capability of lands (RIFR, 2008). Some of the important work carried out by this Institute includes identification of the ecological needs of some indigenous plants in dry zones in the country; specifying the best method for *Tamarix* tree seed and seedling cultivation; selecting the most suitable height and spacing for windbreaks to be used in Khuzestan province, and comparing windbreaks established in Khuzestan and Khorasan Shomali; recognizing advantages and disadvantages of cultivating market garden products in sand dunes; introducing the most appropriate species for sand dune fixation purposes; and introducing the use of plastic mulches in forestry and farming (RIFR, 2008).

In 1996, research was undertaken in 1000 ha of *Haloxylon* plantations of Ardestan (Isfahan province) with the aim of rejuvenating existing stands through activities such as pruning and removing old plants (Haghani et al., 2007). Since then, a national Plantation Conservation Management Plan has been defined for implementation in old stands in desertified areas. The main aim is to preserve existing plantation areas through cutting out old plants, pruning, controlling plant density, and managing pest outbreaks. This plan has additional benefits in that it provides local job opportunities and surplus wood for fuel (1.2–1.5 t/ha/yr) (Haghani et al., 2007). Wood production levels in some areas exceed this, for example, in Isfahan province *Haloxylon* plantations averaged 3 t/ha (Iran Trade Point, 2006).

4. Achievements in combating desertification

In Iran, re-vegetation schemes and sand dune stabilization have both had many positive effects in local areas and desertification trends have often been reduced or prevented. These activities put Iran among the countries which have been successful in dune-fixing activities (Anon, 2008a). Of the 12 million hectares of desert in Iran, more than 1.5 million hectares went through afforestation and sowing programmes up to 1984 (Anon, 2008a) and this has since increased to 2.1 million hectares (NAP, 2005).The most important achievements in combating desertification and conserving natural resources have been summarized in Table 5. Aspects of the social and economic effects of these anti-desertification measures are outlined below.

4.1. Social aspects

Desertification adversely affects people's livelihoods and may accelerate rural-urban migration. In desertified provinces between 1996 and 2006, the urban population in Iran increased by 36% while the rural population decreased by 11% (Iran Population Census 1996–2006). For non-desertified provinces, the urban population increased by 26% and the rural population decreased by 8%. The decade from 1996 to 2006 included the worst drought (1998 to 2001) in 30 years (Morid et al., 2006). This severe drought and associated crop failures and pasture shortages contributed to a pattern of more rapid rural population decline in desertified than non-desertified provinces, and a greater rate of growth in the urban population in desertified provinces. The movement from rural areas has occurred despite a decline in rates of population growth and a reduction in the gap in fertility rates between rural and urban areas (Vahidnia, 2007), suggesting that drought has contributed to this outward movement by reducing incomes and employment opportunities.

For people remaining in rural areas, anti-desertification activities now involve increased community input. Such stakeholder collaboration is acknowledged as a feature of effective planning for natural resource management at all spatial scales (Knight et al., 2006). Recently, two communities in desertified provinces in Iran have been encouraged to participate in the design, implementation and monitoring of local projects. These are the "Sustainable Management of Land and Water Resources (SMLWR)" and "The Carbon Sequestration in the Desertified Rangelands of Hossein Abbad (CS)" projects undertaken in cooperation with international organizations in Semnan and Khorasan Jonoobi provinces respectively (Tahmasebi et al., 2004; Amiraslani, 2005; Amiraslani and Zehtabian, 2006). The SMLWR project, carried out over the six years between 1997 and 2003, was a pilot scheme established during the development phase of the National Action Programme to Combat Desertification in Iran, as part of the government's commitment to the UNCCD. The project involved coordinating managerial activities between rural communities and provincial experts in reclaiming natural resources and diversifying livelihoods (Hosseini et al., 2007). The project implemented income-generating schemes (e.g. bee-keeping), expansion of orchards (e.g. walnut and olive orchards), the recharging of aquifers, and the planting of trees (Hosseini et al., 2007; Amiraslani and Dragovich, 2010).

The main goal of the on-going CS project, commenced in 2003, was to increase CO_2 sinks in soil through re-vegetation using woody plants. Local people and project officers have been trained in the implementation of anti-desertification measures through attending courses, workshops and meetings at the national level; and several provincial experts have also been trained at an international level to learn new techniques.

At the project level, the two pilot projects of SMLWR and CS have both included serious efforts to involve local participation, including female representation, and to encourage the engagement of local communities in the planning, implementing and monitoring of anti-desertification activities (Amiraslani and Dragovich, 2010). The SMLWR project was initially planned to conclude in 2003; following assessment by a national and international group of its achievements, it was recommended that it should continue for another 6 years. Although both the SMLWR and CS projects are associated with the NAP, they are so far the only two major projects which have been deliberately established within the NAP's guidelines.

Where anti-desertification measures such as these have been successful, living standards improve and desert inhabitants are able to cope better with water shortages and drought, contributing to a reduction in out-migration and abandonment of villages (Haghani et al., 2007). The participatory carbon sequestration project in Khorasan Janoobi province, for example, is encouraging local development plans including the provision of potable water and solar-powered production of fresh water (Anon, 2008b). In the SMLWR project in Semnan province, local communities have implemented schemes to improve surface water resources and recharge aquifers through water transfer schemes, thereby reclaiming springs and water wells (Hosseini et al., 2007). Some of the general benefits of anti-desertification programs in areas affected by sand storms are a re-activation of agricultural and animal husbandry activities, an improvement in local welfare and sanitary conditions, and a decrease in disease (e.g., as described for Kerman province by Ahmadi and Jafarian-Jeloodar, 2004).

Table 5
The most important achievements of anti-desertification activities in Iran.

Activities	Area/amount	Unit
Stabilization of shifting sand dunes through afforestation	2.1	M ha
Formulation of anti-desertification plans	9	M ha
Studying of catchments throughout the country	65	M ha
Implementing watershed management projects throughout the country	14.2	M ha
Recharging water-tables	1.4	B m^3/yr
Removing livestock from areas of vulnerable rangelands	1	M animal units
Preparation of large-scale maps of the arid and semi-arid areas using RS and GIS	N/A	–
Preparation of a 1:250,000 scale map of vegetation cover using RS and GIS	1	country area

B, billion; ha, hectare, M, million; N/A, not available.
Source: mainly based on NAP (2005).

4.2. Economic aspects

Anti-desertification projects have been carried out by the government since the 1950s in all 17 desertified provinces covering areas around 97 towns and 4353 villages. These projects have protected infrastructure including roads, airports, industries, irrigation canals, farms, fisheries wharves, and houses (Abdinejad, 2007), bringing positive results to the livelihood and finances of local families. Land uses benefiting from sand dune stabilization include dry-farming, animal husbandry, fisheries, bee-keeping, and market gardening.

Anti-desertification programs such as managing plantations and plant nurseries, seed collecting, irrigating, pruning, and planting seedlings can provide local job opportunities. Implementing a "Plantation Conservation Management Plan" in an area of 800 ha can involve 250 persons for 4 months (Haghani et al., 2007). A plan carried out in Isfahan province employed an estimated 200 persons for 3 months in a 2000 ha plantation of *Haloxylon* (Iran Trade Point, 2006).

A wide-ranging study was carried out to investigate 30 years (1966–1996) of anti-desertification activities undertaken around Kerman city, Kerman province (Ahmadi and Jafarian-Jeloodar, 2004). Projects included establishing plantations (mostly *Haloxylon*) in an area of 48,300 ha, oil mulch spraying, and exclosure. The study confirmed positive effects including preservation of infrastructure of the provincial capital and surrounding villages, providing land (2850 ha) for expansion of industry (44%) and other uses (education and urban areas) (56%), increasing the area of agricultural land from 540 to 3600 ha, causing a decline in road accidents and ophthalmic diseases due to control of sand storms, providing fuel wood and creating local jobs. The study also noted the return of farmers who had left Bagherabad village in 1965; this was attributed to stabilization of sand dunes around the village.

5. Continuing challenges

The primary impediment for those combating desertification in Iran is the constraint on funding. The success of the SMLWR and CS projects was made possible through support given in the form of international funding and technical assistance. Apart from these joint projects, only national funds are available and these resources are limited. Although insufficient funding may possibly create strengths in terms of local ingenuity and self-reliance, weaknesses in implementing projects due to lack of technical and material support tend to dominate. In this situation of financial stringency, monitoring has a much lower priority than undertaking new projects to address existing problems.

The continuing challenges to combating desertification in Iran will be considered in terms of the nature and management of existing programs, and the intended shift towards a national approach to the desertification problem.

5.1. Existing programs

Despite the considerable achievements and strengths of anti-desertification activities in Iran, some problems and weaknesses remain (Table 6). Some local projects carried out in the early years (1968–1988) have since been associated with increased soil erosion and over-grazing of rangelands, often in areas subject to severe droughts and inhabited by economically disadvantaged people whose livelihoods rely entirely on livestock and agriculture. Project areas generally cover a relatively small proportion of desertified regions which have subsequently experienced considerable pressure on land and water resources, and anti-desertification measures may not have been maintained.

Lack of proper planning and ecological assessment, especially in the early years, has been a major problem in anti-desertification efforts in Iran (Anon, 2008a): almost all dune stabilization schemes lacked a sound and comprehensive ecological assessment of individual regions. This was especially the case during the early years of anti-desertification activities (1968–1988) in which projects were undertaken by government field officers on a case-by-case basis without an overall plan at the local, provincial or national level (Nateghi, 2006).

Desertification control has been funded by the central government in Iran since these activities began. In the early years, management of deserts and anti-desertification activities was concentrated solely on stabilizing sand dunes. Desertification control measures were undertaken in 8 provinces, using mainly oil mulch and planting of seedlings (Anon, 2008a). Some project successes were attributed to low population density, the allocation of appropriate budgets and effective project supervision (Anon, 2008a). After 1989 most projects had supportive plans and maps based on five-year plans, and included initiatives such as increasing the diversity of plant species, establishing runoff control projects, and ensuring project supervision (Nateghi, 2006).

A summary of the strengths – and weaknesses – of desertification control programs in Iran is provided in Table 6. A weakness which has been apparent throughout all three phases of anti-desertification activities has been the lack of sufficiently strong links between research centres and field project managers.

5.1.1. Maintaining existing plantations

The more than two million hectares of plantations, established over 50 years of anti-desertification activities, are now facing various threats including drought, grazing, pests and die-back. Iran has experienced many droughts of varying severity in different regions (Nateghi and Amiraslani, 2002), including the almost 150 cities and 7900 villages affected by drought in 2008 at the national level (Islamic Republic News Agency, 2008). In recent years, damage caused by drought has included drying-up of seasonal rivers, death of shrubs in plantations, a decline in underground water resources, degradation of farmlands, urban and rural drinking water shortages, and desiccation of internationally-recognized wetlands (National Report, 2003).

Some plantations have been destroyed by drought and others by over-grazing and grazing at inappropriate times. Light grazing can alter the species composition of the dominant plant communities

Table 6
Strengths and weaknesses of desertification control projects in Iran.

Phase	Period	Strengths	Weaknesses
1	Early years (1968–1988)	Some successful projects reported, mostly because of increased wet spells; widespread implementation of local dune stabilization using oil mulch	Lack of technical plans; government-based; lack of interaction among sectoral or cross-sectoral bodies; use of a very limited range of plant species; lack of people participation
2	Middle period (1989–2003)	Increase in diversity of plant species; attention to runoff control schemes; Increase in project evaluation; NAP consultation and preparation	Government-based; some projects implemented without technical plans; lack of people participation
3	NAP (2004 onwards)	Focus on both research and traditional knowledge; improved sectoral and cross-sectoral cooperation; all projects implemented based on technical plans; Improved people participation; increased project monitoring and evaluation; increased training of field officers; publicity about project successes	Projects are still being implemented based on limited government funds; insufficient linkage between research results and project implementation; slow emulation of successful joint national/international projects; insufficient funding available for monitoring and establishing projects

Modified after Nateghi (2006).

Table 7
Assessment of plantations in three desertified provinces.

Province	Species composition	Plant density (plants per ha)	Plant age (yr)	Comments
Kerman	*Haloxylon*	200–500 and occasionally 1000	25–30	Mono-culturing; wilting appearance
Isfahan	*Haloxylon*	200–250 and occasionally 2000	N/A	Mono-culturing
Khuzestan	*Tamarix*	100	25–30	Mostly mono-culturing; *Tamarix* stands affected by pests
	Prosopis	50		

N/A, not available; Source: Haghani et al. (2007).

while heavy grazing can induce vegetation change, reduce productivity and increase the risk of soil erosion (Thomson and Simpson, 2007). In addition, plantations established in desertified provinces are affected by human interventions such as fuel wood harvesting, littering, development activities (including road construction and oil exploitation), fire, soil harvesting or illegal occupation of plantations by adjoining farms (Haghani et al., 2007). For example, in Kerman province 1000 ha of established *Haloxylon* plantations were gradually destroyed by the expansion of pistachio orchards and urbanization (Ahmadi and Jafarian-Jeloodar, 2004). Pests also threaten plantations in some regions, including a recent plague of locusts in 4000 ha of *Haloxylon* plantations at Sabzevar, Khorasan Razavi province, which has been attributed to dry conditions (Kayhan, 2008). Plagues of other insects and mice have also adversely affected *Haloxylon* plantations by consuming the above-ground biomass.

Lack of prior environmental assessment has sometimes led to plantation failures: for example, in Chah-e-Afzal of Yazd province, re-vegetation attempts were not successful because of the salinity factor and the severe cold weather of the region (Anon, 2008a). Additional challenges include inappropriate plant densities and species diversity in existing plantations. For many years, the plant density issue was neglected and only a limited range of plant species like *Haloxylon* were planted. High density plantings have caused yellowing and wilting of *Haloxylon* species in provinces like Khorasan Jonoobi, Yazd, Kerman and Semnan and, due to the high water demands of dense stands, resulted in a reduction in surface and groundwater resources in many areas (Anon, 2008a).

Species composition and diversity are fundamental characteristics of ecosystems and vegetation diversity should be considered in the course of vegetation restoration (Yang et al., 2006). Mono-culturing or utilization of a limited number of plant species increases species-specific pests and diseases, and amplifies inter-species competition for water, light and soil nutrients among existing plant associations (Haghani and Hojati, 2006). This has raised the vulnerability of re-vegetated areas to pests and diseases, and caused vast areas of vegetation to be destroyed. An assessment of species composition of plantations established in three provinces showed that mono-culturing was a common feature (Table 7) (Haghani et al., 2007). Haghani and Hojati (2006) studied the trend of plant species diversification since the beginning of anti-desertification projects in Iran and listed 37 plant species used in these projects. They concluded that the introduction of additional species has increased diversity by up to 48% in recent years.

Gains made by establishing plantations can only be consolidated with continued monitoring, maintenance and renewal/regeneration, processes which are now gaining greater recognition as components of successful anti-desertification projects.

5.1.2. Coordinating research and project activities

The link between results obtained in research centres and the transmission of this knowledge to those managing anti-desertification projects is unfortunately weak, lowering the potential benefits of the research centres. At present, project managers and research institutes engaged in anti-desertification activities are working parallel to each other without having any joint project or plan, despite both being located within the Ministry of Jihad-e-Agriculture. Seyed-Akhlaghi et al. (2008) noted the dominance of sectoral vision, lack of a single managerial body to integrate research findings with field operations, and an over-estimation of managerial capacity to surmount problems involved with anti-desertification projects. Overall, the agricultural sector absorbs nearly a quarter of total public research funds in the country (23% in 2004) (Hosseini et al., 2009). There is thus no funding shortage for agricultural research: rather, the research suffers from a lack of coordination between research results and their application in the field.

The coordination of managerial and research efforts could be improved by prioritizing research activities through implementing joint projects, holding workshops, increasing the number of local extension service centres, and allocating joint funds between the managerial and research sectors. Internationally, a lack of interaction between research institutes and the local people, policy-makers and politicians has been recognized as a problem in implementing advances in desertification responses (Seely et al., 2008). Measures such as “translation, information dissemination, communication, discussion platforms and boundary organizations to facilitate the application of such advances” have been recommended (Seely et al., 2008, p. 241).

5.1.3. Implementing a national approach to desertification management

Much of the recent change in desertification management in Iran coincided with the development and implementation of the National Action Programme to Combat Desertification (NAP). FRWO as the National Coordinating Body embarked on the formulation of the NAP in the late 1990s after consultations, workshops and meetings with national, provincial and local authorities, stakeholders, beneficiaries and NGOs. Cross-sectoral participation included personnel from the Ministries of Jihad-e-Agriculture; Energy; Oil; Foreign Affairs; Interior; Science, Research and Technology; Health; the Management and Planning Organization; Meteorological Organization; Geological Survey; and Department of Environment (NAP, 2005).

Over the past decade, multi-stakeholder participation involving various national, provincial and local stakeholders has been conceptualized and incorporated into anti-desertification activities. From 2004 onwards, project implementation has included technical plans and an increasing focus on research, in addition to greater community participation and improved sectoral and cross-sectoral cooperation (Amiraslani and Dragovich, 2010; Nateghi, 2006). For all future anti-desertification work, provinces are required to implement projects based on technical maps and data, and to provide detailed project specifications (Nateghi, 2006). This is intended to enhance the success of project implementation and eliminate potential overlapping activities.

6. Conclusion

Iran is exposed to various environmental and social factors which accelerate desertification and land degradation, and a range of measures has been undertaken over the past fifty years to reclaim affected areas.

The Iranian experience in combating desertification has involved changing approaches whose degree of success may have useful implications for anti-desertification activities in other countries. In particular, shifting from a case-by-case project approach to province-wide and national planning has been beneficial, as has the involvement of a range of government and non-government stakeholders along with local people. The combination of national and provincial level stakeholders allows for the provision of expertise, funding and personnel to be engaged at the local level. Ensuring that all local people are both given the opportunity, and are encouraged, to participate in projects has been a major positive component of Iranian anti-desertification measures.

In the mid-twentieth century efforts to curb sand dune encroachment onto infrastructure in Iran were begun on a case-by-case basis in localised areas using oil mulch and planting suitable plant species. These early anti-desertification activities were based solely on the views of field officers, without considering local knowledge and capacities, social conditions, environmental realities and economic outlook, and without any detailed technical plans. Lack of local participation in early desertification projects in Iran has been blamed for failure to achieve project outcomes and sustainability (Nateghi, 2006). These early case-by-case attempts responded to provincial demands, leading to considerable expenditure without specific benchmarks or goals. This process has gradually changed to the implementation at the provincial level of plan-based projects, but stronger links still need to be developed between researchers and managers of field projects.

In recent years the scale of planning and implementation has expanded to the national level. Disadvantaged areas have been allocated funds, human resources and sufficient time for measures to be implemented. Once anti-desertification measures have been undertaken, interventions have to be maintained, especially in relation to floodwater systems, plantations and dune stabilization, in order to remain effective. Additional desertified areas already require measures to combat desertification, and population pressure on existing land and water resources is continuing to increase, leading to the potential development of new desertified areas. The predicted reduction of rainfall in parts of the drylands of Iran will impose further pressures on sustainable use of rangeland resources. Challenges facing those involved in the management, mitigation and control of desertification in Iran will remain considerable, and require planned and flexible responses incorporating changing approaches to maintain existing momentum in anti-desertification policies and research.

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