Food and Agriculture Organization
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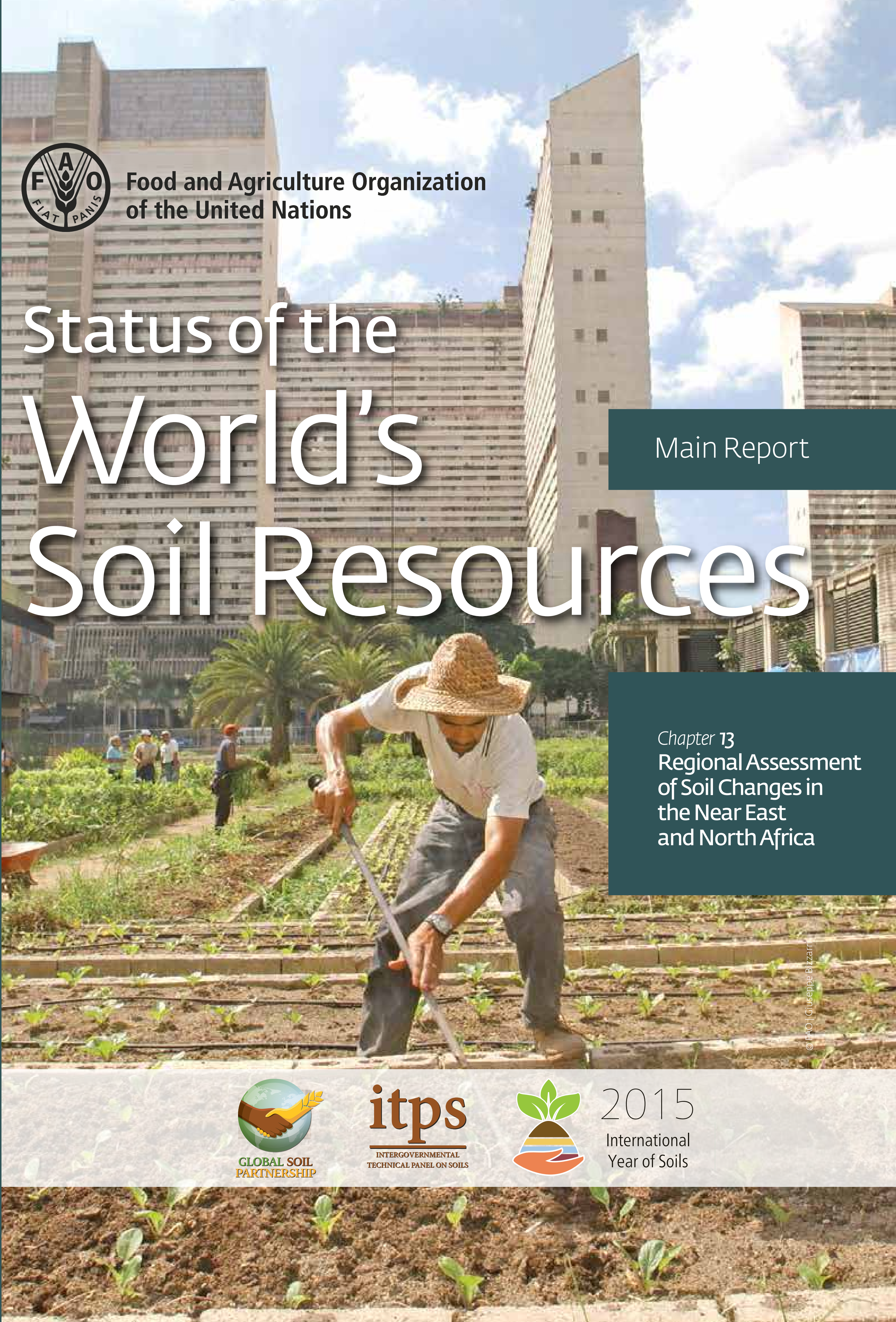
Status of the World's Soil Resources

Main Report



Chapter 13

Regional Assessment of Soil Changes in the Near East and North Africa

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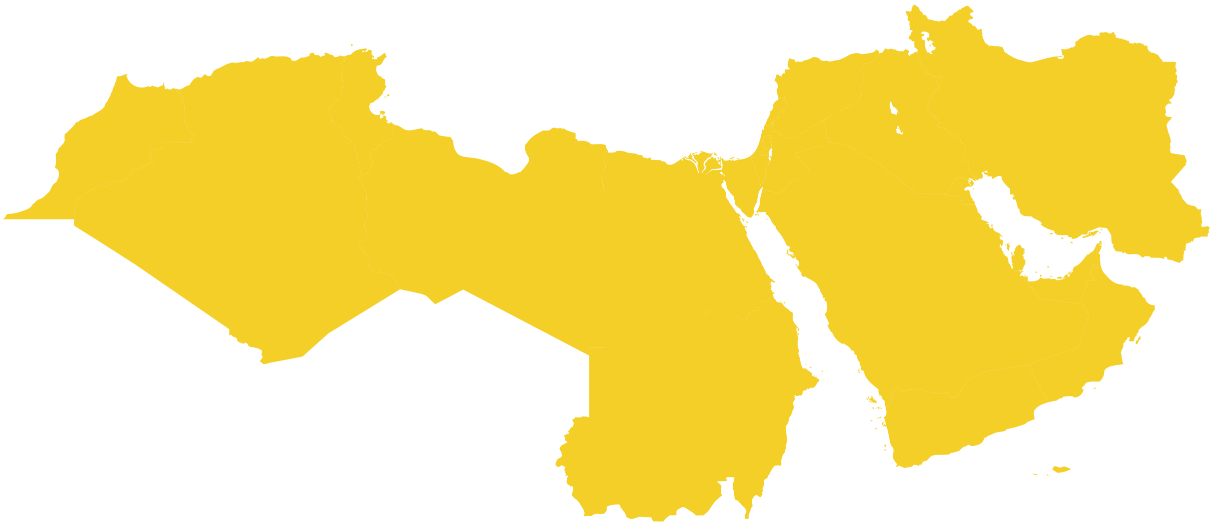
13 | Regional Assessment of Soil Changes in the Near East and North Africa



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13.1 | Introduction

The Near East and North Africa (NENA) region includes Tunisia, Algeria, Morocco, Libya, Egypt, Sudan, South Sudan, Jordan, Israel, Lebanon, Syria, Palestine, Iraq, Yemen, Saudi Arabia, Oman, Qatar, United Arab Emirates, Kuwait, Bahrain and Iran. The region has a land area of approximately 14.9 million km^2, nearly all of which is hyper-arid, arid or semi-arid. The region faces three climatic constraints: aridity, recurrent drought, and desertification, the latter also in part human induced. South Sudan is the only country in the region which falls within the dry sub-humid tropical zone. Large areas of Libya, Egypt, Bahrain, Kuwait, Qatar and the United Arab Emirates are entirely desert (FAO, 2013a).

The soils of the region are broadly as follows:

- The soils of the Maghreb region (Morocco, Tunisia, Libya and Algeria) fall into three broad divisions: (I) along the Mediterranean and Atlantic coasts productive Kastanozems (Xerolls) and Luvisols (Alfisols) occur (SEDENOT, 1999; MADRPM, 2000; Halitima, 1988); (II) Leptosols (lithic subgroups) and Cambisols (Inceptisols) are found in the Atlas Mountains away from the coast (Yigini, Panagos and Montanarella, 2013); and (III) Calcisols (Calcids), Gypsisols (Gypsids), Leptosols and Cambisols are found in the southern part (Jones *et al.*, 2013).
- Vertisols, Arenosols (Psamments), Fluvisols (Fluvents), Calcisols and Gypsisols (Aridisols) are the dominants soils in Sudan and Egypt.
- In the Mashreq region (Jordan, Syria, Lebanon, Iraq and Palestine), the soils of the valleys are Arenosols (Psamments) and Fluvisols (Fluvents). In the highlands, steppe and desert regions, the main orders are Calcisols (Calcids) and Cambisols (Aridisols), Arenosols (Psamments) and Leptosols (Lithic subgroups), and Vertisols which are calcareous in the subsoil horizons.
- In the Arabian Peninsula and the Gulf (Oman, Kingdom of Saudi Arabia, Kuwait, Bahrain, United Arab Emirates, Yemen, Iran and Qatar), there are alluvial soils rich in silt and desert soils, and sandy soils poor in organic carbon but in which evaporite Tertiary Formations played an important role in the formation of contemporary minerals (Abbaslou *et al.*, 2013).

Agriculture is an important source of income for many countries in the region. Arable land constitutes only 6.8 percent of the total land area, while about 26 percent is used for pasture and about 7 percent is under forest (Hamdallah, 1997). Based on the type of agriculture practiced, Dregne and Chou (1992) divided the productive land in the region into: irrigated land (0.7 percent, 8.5 million ha); rainfed (2.2 percent, 27.7 million ha); rangelands (40 percent, 495.6 million ha); and extremely arid land (57 percent, 705.2 million ha). Proportions vary considerably by country. Productive lands represent 30 percent of the total area in Syria and Lebanon, but only 3 percent in Egypt, Algeria and Sudan, and only 0.5 percent in Saudi Arabia, Oman and Mauritania (Mamdouh Nasr, 1999).

Natural resource degradation, especially where agriculture is practiced, is a real threat in all countries of the region and remains a major limitation to the reliable supply of food. In most countries, salinization, water and wind erosion, loss of vegetation cover, soil physical degradation (including compaction and surface crusting) are the main threats to the soil's capacity to provide ecosystem services. The expansion of agriculture into marginal lands has greatly aggravated water erosion and consequently soil degradation. In almost all countries in the region, extreme climatic conditions, overgrazing, unsuitable cropping patterns and accumulation of salts have rendered large areas of land unproductive (Abahussain *et al.*, 2002).

Mamdouh Nasr (1999) reported that rainfed cropland represents only 3 percent (about 30 million ha) of the region's total drylands, yet about 22 million ha of this total (73 percent of the cropland area) are estimated by UNDCPAC to be degraded. The extent of degradation of rainfed cropland is greatest in the countries of northern Africa: Algeria (93 percent), Morocco (69 percent), Tunisia (69 percent) and, exceptionally, Egypt (10 percent). The eastern sub-region (Iran, Iraq, Jordan, Lebanon, Sudan and Syria) is the part of the NENA region most affected by land degradation (FAO, 2004). The extent of degradation in the countries of the Middle East - Iraq (72 percent), Syria (70 percent) - is higher than that in the Gulf Countries: Oman (50 percent), Qatar (25 percent), and Bahrain (20 percent).

The Arab Centre for the Study of Arid Zones and Dry Lands (CAMRE/UNEP/ACSAD, 1996) has estimated that, overall, land degradation affects approximately 49 percent of farmland in the eastern sub-region; 29 percent in the Nile Valley of Egypt; 17 percent in North Africa; and 9 percent in the Gulf Cooperation Council Countries. More than one process of degradation can occur in a single farming system. For example, degradation is serious in one of the largest countries in the region, Sudan, a country with high agricultural potential (Ayoub, 1998). In Sudan, the 46 million ha lying in the semi-arid zone, where mixed farming of both animal husbandry and rainfed arable cropping are practiced, have experienced intensive soil degradation over the last 35 years, affecting production of field crops, gum Arabic, and livestock products.

In North Africa, causes of soil degradation are divided between overgrazing (68 percent), over-cultivation (21 percent), deforestation (10.5 percent) and overexploitation of natural vegetation for about 0.5 percent (Thomas and Middelton, 1994). In the newly created country of the region, South Sudan, there are very limited studies on land degradation. However, there are indications that land use changes have impaired the quality of the land in many places (Dima, 2006).

Land degradation in certain areas may affect adjacent areas. For example, degradation in rangelands where rainfall is low has negative effects on resources of rainfed farming areas. This is also one of the regions most vulnerable to climate change (FAO, 2011). Agriculture faces major losses due to land degradation, and yields are expected to decrease by the year 2050: rice yields by 11 percent; soybean yields by 28 percent; maize yields by 19 percent; and barley grain yields by 20 percent (FAO, 1994). Recent studies on the economic cost of land degradation in the region were reported by Hussein *et al*. (2008); they were estimated at US$9 billion yr^{-1} (2.1-7.4 percent of GDP).

This chapter will discuss the main soil threats - erosion by water and wind, salinity/sodicity, soil contamination, and organic C depletion. Major causes of soil degradation in the region are due to many factors, including: (I) excessive irrigation and poor drainage; (II) wind and water erosion; (III) waterlogging; (IV) deteriorated soil fertility; (V) over-grazing; (VI) loss of soil cover; (VII) land mis-management; (VIII) sand encroachment; and (IX) overuse of herbicides, pesticides and chemical fertilizers (FAO, 2004).

Data correlating land degradation with yields are scarce at the global level. However, recent studies (2000-2010) show that land losses due to degradation in North Africa are the highest among selected countries worldwide, and that this has resulted in a considerable food gap of 0.6×106 metric tonnes (Wiebe, 2003). There have been many efforts to tackle the issue of land degradation. Experience has shown that a key factor for success is political will. In this respect, the 21st summit of African leaders in 2013 urged member states to place land degradation at the centre of the debate on the post-2015 development agenda, and to recognize it as one of the sustainable development goals. This is particularly important for NENA because the agricultural sector in the region contributes about 10 percent of the region's GDP, but is characterized by an exceptionally fragile and vulnerable resource base.

13.2 | Major land use systems in the Near East and North Africa

Land use systems in the region have been identified and broadly delimited based on a range of characteristics (Nachtergaele and Petri, 2011). Their geographical location is indicated in Figure 13.1. They can be combined in three major systems: irrigated crop based, rainfed mixed and livestock based. These systems are briefly discussed below (Dixon and Gulliver, 2001).

Irrigated land use systems

Given the arid and semiarid nature of much of North Africa and the Near East, irrigated farming has always been of crucial importance in generating much of the region's agricultural output. The 'irrigated farming system' in NENA contains both large and small-scale irrigation schemes with high population densities and generally very small farm sizes. The prevalence of poverty within both large and small segments of the system is moderate.

Traditionally, areas within the large scale irrigation sub-system have been linked primarily to perennial surface water resources, such as the Nile (Egypt and Sudan) and Euphrates (Syria and Iraq). However, the intensification of traditional karez or qanat systems has also led to the evolution of large-scale irrigated areas where sub-surface water is abundant. More recently, the availability of deep drilling and pumping technologies has permitted the development of new areas drawing entirely on subterranean aquifers. Large-scale schemes are found across all zones of the region and include high-value cash and export cropping and intensive vegetable and fruit cropping.

Patterns of water use vary greatly but throughout the region inappropriate policies on water pricing and centralised management systems have meant that water is seldom used efficiently. Significant economic and environmental externalities have arisen through excessive utilisation of non-recharged aquifers while, in a number of cases, the excessive application of irrigation water has resulted in rising groundwater tables, soil salinization and sodification problems.

The small scale irrigated sub-system also occurs widely across the region. Although not as important as the larger schemes in terms of numbers of people involved or in the amount of food and other crops produced, it is a significant element in the survival of many people in arid and remote mountain areas. This sub-system, examples of which are sometimes of considerable antiquity, typically develops along small perennial streams and at oases, or where flood and spate irrigation is feasible. It sometimes also draws on shallow aquifers and boreholes, although these rarely penetrate to the depths seen in the large schemes. The major crops grown within small-scale irrigation areas are mixed cereals, fodder and vegetables. These areas also provide important focal points for socio-economic activity, but intense local competition for limited water resources between small rural farmers and other users is becoming increasingly evident.

Rainfed mixed crop and livestock land use systems

The rainfed agricultural and livestock systems are the most important land use system in the region in terms of population engaged in agriculture. However, as these systems are practiced on less than 10 percent of the land area, population densities in these farming areas are moderately high. These systems covers two sometimes overlapping segments. The first segment occurs on high terraces and is dominated by rainfed cereal and legume cropping, with tree crops, fruits and olives on terraces, together with vines. In Yemen, higher reaches are reserved for qat trees and coffee, which are traditionally the most important tree crops in Yemen's mountain regions. The second segment is based primarily on the raising of livestock (mostly sheep) on communally managed lands. In some cases, both the livestock and the people who control them are transhumant, migrating seasonally between lowland steppes in the more humid winter season and upland areas in the dry season. This type of livestock keeping is still important in Iran and Morocco.

Poverty within this system is extensive, as markets are often distant, infrastructure is poorly developed and the degradation of natural resources is a serious problem. In the lowlands where rainfed production is feasible, an increasing area is now benefiting from the availability of new drilling and pumping technologies, which have made it possible to use supplementary winter irrigation on wheat and full irrigation on summer cash crops. There is some dry season grazing of sheep migrating from the steppe areas.

The more humid areas (with 600 to 1000 mm annual rainfall) that occur in the Caspian and Mediterranean coastal areas are characterised by tree crops (olives and fruit), melons and grapes. There is also some protected cropping with supplementary irrigation for potatoes, vegetables and flowers. Common crops are wheat, barley, chickpeas, lentils and fodder crops. Poverty in these more humid areas is moderate, but would be higher without extensive off-farm income from seasonal labour migration.

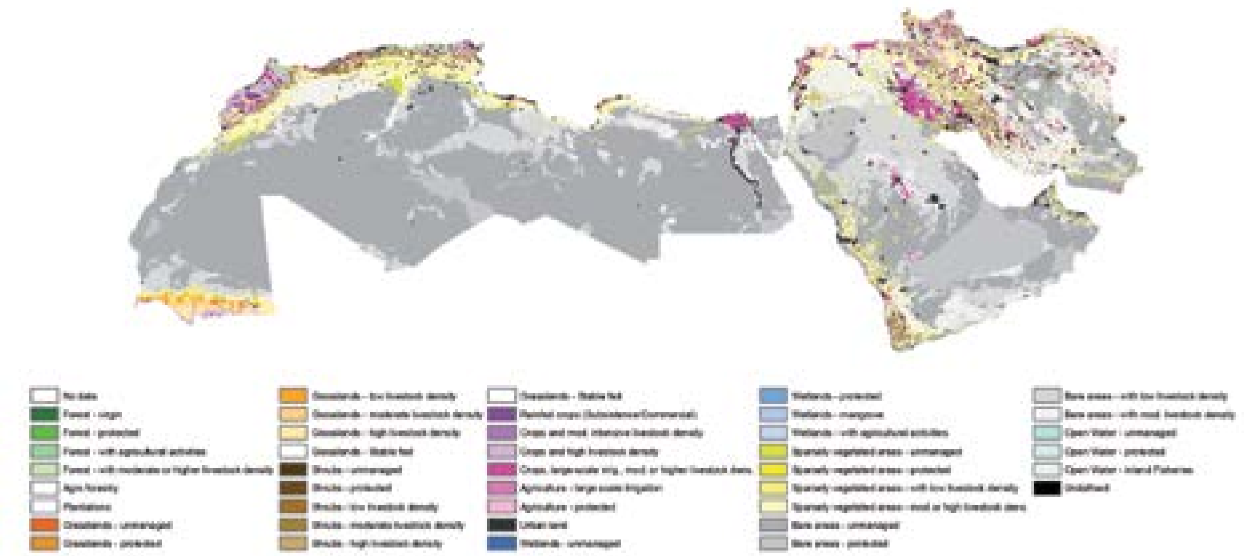

Figure 13.1 | Land use systems in the Near East and North Africa.
Source: FAO, 2010.

Livestock-based land use systems in sparsely vegetated areasù

The pastoral land use system, mainly involving sheep and goats but also with some cattle and camels, is practiced on large areas of semiarid steppe lands, and is characterised by low population densities, with more densely populated areas around irrigated settlements. There are irrigated croplands scattered throughout the system, thus boosting the agricultural population – and helping to support a cattle population. Strong linkages exist to other farming systems through the movement of stock, both through seasonal grazing of herds in more humid areas and through the sale of animals to large feedlots located around urban areas. Seasonal migration, which is particularly important as a risk minimisation measure, depends on the availability of grass, water and crop residues in neighbouring arable systems. Nowadays, pastoral herds are often partially controlled and financed by urban capital. Where water is available, small areas of crop production have been developed to supplement the diets and income of pastoral families. However, such sites are few and poverty within the system is extensive.

The sparse (arid) land use system covers more than 60 percent of the region and includes vast desert zones. People are concentrated in oases and on a number of irrigation schemes (notably in Tunisia, Algeria, Morocco and Libya). Part of the land is irrigated and utilised for the production of dates, other palms, fodder and vegetables. Pastoralists within this system also raise camels, sheep and goats. Following scattered storms and in good seasons, the system provides opportunistic grazing for the herds of pastoralists. The boundary between pastoral grazing and sparse agriculture systems is indistinct and depends on climatic conditions. Poverty within this system is generally low as population pressure is limited.

13.3.1 | Erosion

Water erosion

Water erosion is predominant in the part of the region which has sloping lands and where rainfed agriculture is practiced, although it may also occur in gently sloping areas. The degree of water erosion depends on the intensity and duration of the rainstorms, often enhanced by the terrain attributes and land use practices, particularly where these have reduced land cover. Water erosion results in the removal of fertile soil and in the reduction of irrigation efficiency and storage capacity. Considerable volumes of soil may be lost. Based on the GLASOD survey quoted by Abahussain *et al.* (2002), the total area affected by water erosion in NENA has been estimated at about 41 million ha. However, the extent varies significantly by country (Table 13.1.).

Table 13.1 | Land degradation caused by water erosion in the NENA region (1000 ha)
Source: Abahussain et al., 2002.

1 *Azimzadeh et al.*, 2008

Country	Area	Country	Area	Country	Area
Algeria	3 900	Lebanon	65	Sudan	17 300
Bahrain	0	Libya	1 300	South Sudan	n.d.
Egypt	Negligible	Morocco	3 600	Syria	1 200
Iran[1]	70 000	Oman	2 800	Tunisia	3 800
Iraq	1 150	Palestine	n.d.	United Arab Emirates	0
Jordan	330	Qatar	0	Yemen	5 600
Kuwait	0	Saudi Arabia	200		

Wind erosion

A review conducted by Abahussain *et al.* (2002) indicated that more than half of the total area in the region received annual rainfall of less than 150 mm. Consequently, large areas are without plant cover, or the cover is very sparse. This situation is aggravated further by high land-use pressure, both from human and animals, which ultimately causes severe topsoil disturbance. The resulting wind erosion is the most common environmental problem in the region and accounts for approximately 60 percent (135 million ha) of soil degradation. Countries differ in the extent they are affected, with Saudi Arabia the most affected (Table 13.2). Wind erosion has resulted in detrimental effects on land quality by removing the fertile top soils. In addition, the accumulation of eroded materials in irrigation canals, agricultural fields (sand encroachment) and water harvesting points affects the cropped areas in the region severely.

Table 13.2 | Soil degradation caused by wind erosion in the NENA region (1000 ha).
Source: Abahussain et al., (2002).

1 *Azimzadeh et al.*, 2008

Country	Area	Country	Area	Country	Area
Algeria	12 000	Lebanon		Sudan	71 000
Bahrain	n.d.	Libya	24 000	South Sudan	n.d.
Egypt	1 400	Morocco	600	Syria	3 000
Iran[1]	20 000	Oman	4 000	Tunisia	4 000
Iraq	3 000	Palestine	n.d.	United Arab Emirates	1 100
Jordan	3 000	Qatar	200	Yemen	6 000
Kuwait	300	Saudi Arabia	50 000		

An example of the problems is provided by the largest irrigated scheme in the world – the Gezira scheme in Sudan – which has been badly affected by sand encroaching from surrounding areas. One study found that over the last decade, wind erosion has decreased the soil level outside the scheme by 10 cm, whereas soil depth increased inside the scheme by 30 cm - any increase in level beyond 20 cm prevents irrigation water flow. Inside the scheme, the topsoil texture has changed from clayey to more sandy. Dune displacement in the scheme was about 3-5 m month^{-1} during the season of active sand movement (Al-Amin, 1999). This situation has forced famers to take considerable land out of production because of problems irrigating, with sand filling the irrigation canals and altering slopes (Mohammed, Stigter and Adam, 1995).

The continental sands of Kordofan and Darfur (Sudan) which support the world's major source of gum Arabic (*Acacia senegal* L.) encounter severe wind erosion due to overgrazing and mismanagement, which endangers the dominance of the species in the area. Omar *et al.* (1998) also gave the example of sand encroachment into the cultivated areas of south Kuwait that has forced famers to take 35 percent of their total cultivable land out of production. Water and wind erosion are also prevalent in the western area of Libya (Jifara Plain and Jebal Naffusah) where agricultural development is dominant, and in El-Witia area in the southwestern Jifara Plain as observed by the Remote Sensing Center in Tripoli (Ben-Mahmoud, Mansur and AL-Gomati, 2000). For example, the area of fertile cultivated soils in El-Witia classified as class 1 has decreased (1986 to 1996) from 66 000 to 44 900 ha (a 31 percent reduction), whereas the area of soils low in fertility has increased from 97 000 to 134 000 ha (a 38 percent increase). In addition, the area covered with sand dunes has increased from 32 000 to 104 000 ha (a 52 percent increase).

The Nile Valley system comprising around 2.63 million ha represents the most fertile lands in Egypt - and probably in the whole region. However, wind erosion and salinity have degraded the soil resource (El-Kholei, 2012). Sand encroachment and mobile dunes are now estimated to cover more than 16 percent of the total area of Egypt. These conditions have led to active sand encroachment on the fringes of the cultivated areas in most areas of the country. An estimated area of 0.76 million ha has been reported to be affected by sand encroachment and active dunes, causing reduction in productivity of as much as 25 percent. The annual soil loss was estimated to be about 1.0 million ha.

In Jordan, the flat topography (<8 percent) and low annual rainfall (< 200 mm) are responsible for active and strong winds carrying sediments. The severity of wind erosion in the country was reported by Khresat, Rawajfih and Mohammad, (1998) who stated that erosion by wind and water is considered the major cause of soil degradation in the north-western part of Jordan.

13.3.2 | Soil organic carbon change

There is very little information in the region relating to changes in soil organic carbon (SOC). The prevailing arid and semi-arid conditions combined with high temperatures result in very low contents of SOC in most of the region. Although in many countries of the region, the reduction in topsoil SOC cannot be overlooked, the value of remedial measures has not yet been proven. One study examined a very long-term (more than 70 years) management practice of sewage sludge application aimed at increasing C in sandy to loamy sandy soils. However, this resulted in an increase in SOC of only 1.33 percent, which indicates a very slow SOC accumulation (Abd Elnaim *et al.*, 1987).

13.3.3 | Soil contamination

Soil contamination in the region is most prevalent in countries with high population, high oil production or heavy mining. The increase of population is coupled with huge increases in both solid and liquid wastes that are dumped on land or into water resources causing degradation through pollution. The overuse of chemical fertilizers and the residues of applied pesticides are also sources of pollution of soil and water resources.

In Egypt, the construction of the High Dam reduced soil fertility as the result of sediment load reduction. This in turn forced farmers to rely heavily on inorganic fertilizers which led to high levels of nitrogen and phosphorous in run-off and drainage water, causing an off-site impact on water quality (NAP, 2002). The discharge of industrial effluents, agricultural drainage water and effluent from navigation activities into the Nile and into main canals and drains contaminates the surface water resource. Industrial effluent also directly affects the water quality of the River Nile system. This comes from sugar factories; cement and fertilizer plants; and plants producing iron and steel, coke and chemicals (EEAA, 1994). Pollutants then accumulate in waterways where, at high concentrations (Biochemical Oxygen Demand and phosphates and total dissolved salts), they cause harmful chemical and biological impacts. Other sources of soil pollution are mainly due to the impacts of heavy mining, agro-chemical residues, and the oil and other industries.

13.3.4 | Soil acidification

Acidification is not commonly a problem in the region and is restricted to coastal areas with relatively high rainfall that tends to leach bases from the soil. Land use that removes all harvested materials may also result in soil mining and acidification. The excessive use of nitrogenous fertilizers, in particular the use of acidifying fertilizers (e.g. ammonium sulphate) has in some cases caused reduction in pH. However, in Vertisols with high cation exchange capacity (over 60 cmole kg^{-1}), this reduction is found to be temporary because such soils have very good buffering capacities which can restore the initial soil pH.

13.3.5 | Soil salinization/sodification

Previous analyses (Hussein, 2001) revealed that 11.2 percent of the region's soils are affected by various levels of soil salinization. Salt-affected soils vary in extent by country from 10-15 percent in Algeria to over 50 percent in Iraq. In the United Arab Emirates 33.6 percent of the area is salinized (EAD, 2009). About 50 percent of the reclaimed lands in the Euphrates plain in Iraq and Syria are seriously affected by salinization and waterlogging, and about 54 percent of the cultivated area in Saudi Arabia suffers from moderate salinization (CAMRE/UNEP/ACSAD, 1996). In Egypt, 93 percent of the cultivated lands are affected by salinization and waterlogging. The salt-affected area in Iran has increased from 15.5 Mha in 1960 to 18 Mha in 1980, to 23 Mha in 1990, and to more than 25 Mha today (Qadir, Qureshi and Cheraghi, 2008). In the United Arab Emirates, areas along the coast sabkha (salt marshes or lagoonal deposits) are considered highly degraded due to high levels (28.8 $dS\ m^{-1}$) of salinity (Abdelfattah, 2012). In the coastal region of the Abu Dhabi Emirate, salinity is more than 200 $dS\ m^{-1}$ (Abdelfattah and Shahid, 2007).

Saline and sodic soils are influenced by climate, agricultural practices, irrigation methods and policies related to land management (FAO, 1997). Low annual precipitation and high temperatures have also contributed to problems of salinity. In many countries of the region, where irrigation completely depends on groundwater, excessive irrigation has caused the formation of a shallow water table leading to increased salinization and degradation of the soil resource base. Yield reduction due to salinization and/or waterlogging amounts to 25 percent in Egypt, and has led to a complete loss of productivity and abandoned agricultural lands in several countries. From the very scattered information on the extent and characteristics of salt-affected soils, salinity and sodicity in the region is rapidly increasing, both in irrigated and non-irrigated areas. Salinity, sodicity or the combination of both in some countries of the region are seriously affecting productive areas such as the Nile Delta of Egypt, and the Euphrates Valley in Iraq and Syria. The situation is further complicated by association with problems of waterlogging and high $CaCO_3$ (up to 90 percent in United Arab Emirates, Al Barshamgi, 1997).

13.3.6 | Loss of soil biodiversity

The impact of soil degradation on biodiversity has received little attention in the countries of the region and there is little information available. Nevertheless, it is estimated that the region is home to one-tenth of the recorded plant species worldwide or about 25 000 species of plants. Of these, 25 percent are endemic to the region, 10 percent are of medicinal value, and many are a source of food. This indicates the importance of the region as a store of genetic resources (Abahussain *et al.*, 2002). The lack of proper conservation practices, overgrazing of herds of ruminants, and deforestation for fuel are causing serious losses of plant cover and of valuable genetic resources, including below-ground biodiversity that is rarely quantified in this region. Proper and sustainable utilization of plant species which yield valuable products could boost incomes and help reduce poverty amongst nomads and local settled populations. However, thousands of plant species and varieties have disappeared, and a further 800 plant species are threatened with extinction (Al-Eisawi, 1998) and this loss of plant species is likely to result in changes in soil biodiversity.

Iran is renowned for having one of the richest plant reserves in the world. The country has some 12 000 species of plants, the majority of which are endemic (the Iranian National Action Programme). In the Elmalha area of Sudan, Bakheit (2011) studied the availability and distribution of famine foods and their role in times of famine. The study revealed endemic species that are considered as alternative foods in time of crisis but which are threatened by genetic erosion due to soil degradation. Soil degradation studies in South Sudan indicate the disappearance of palatable grasses such as *Panicum turgidum* and appearance of less palatable grasses such as *Aristidia funiculata*. The alien species now covers 40 percent of the pasture area, resulting in disappearance of many wild animals and decrease in biodiversity (Elfaig, Ibrahim and Jaafar, 2015). The study pointed out that drought, unsustainable use of forest and pasture, and increase in population pressure were the main causes of this environmental degradation.

In Tunisia, decades of open grazing in the Bou Hdma National Park have caused severe loss of perennials and increased density of annuals (Belgacem, Tarhouni and Louhaichi, 2013). The study reported that grazing has reduced total plant cover by 38 percent and the contribution of perennials by 72 percent, while annuals were affected 100 percent. Overgrazing of rangelands generally causes replacement of highly palatable species with less desirable plants. Along the sea coast of Egypt, overgrazing during the period from 1974 to 1979 decreased the total density vegetation by more than 15 percent, mainly due to a decrease in some perennial herbs, while at the same time the total cover increased by about 38 percent, due mainly to perennial shrubs and succulents. Also in Egypt, vegetation on Mount Elba and the surrounding valleys has been reduced, and the resulting increased runoff threatens the diversified natural plant communities in the valleys. Some of these plant species are considered to be of high value as genetic resources as they are adapted to the desert conditions. In Lebanon biodiversity is threatened by many factors, chief among them are erosion, urban development and overgrazing resulting in dominance of xerophytes at the expense of other species (Zahreddine *et al.*, 2007). Rising levels of poverty in the Ramallah area of Palestine have led to most farmers (83 percent) turning to the collection of medicinal plants for commercial use (Abu Hammad and Tumeizi, 2012).

13.3.7 Waterlogging

Waterlogging is a common constraint in irrigated areas of the region because of inadequate drainage. The problem is exacerbated by the dominant heavy textured alluvial soils and by seepage from the conveyance canals. Soil salinity, sodicity and water logging conditions have definite adverse impacts on soil productivity, estimated to be of the order of 30-35 percent of the potential productivity. In many areas of the old Nile Valley in Egypt, waterlogging has led to increased soil salinity and in certain areas to increased soil sodicity. In the Siwa oasis, for instance, the rate of water table rise during the period 1962–1977 was 1.33 cm yr^{-1}. Subsequently, the rate increased to 4.6 cm yr^{-1} and consequently subjected fertile soil to degradation (Misak, Abdel Baki and El-Hakim, 1997).

Waterlogging has also become a serious problem on many farms in the United Arab Emirates due to poor drainage caused by the presence of a strong and thick hardpan and by excessive use of irrigation water. In addition, sea water intrusion in many areas reaches the surface and causes complete vegetation failure (Abdelfattah, Shahid and Othman, 2008). In Tunisia, of the 410 000 ha of irrigated area, about 87 000 ha (22 percent) are affected in varying degrees by waterlogging. This hydromorphy affects most of the irrigated areas in the valley of Medjerda, from Ghardimaou up to Kalaat Andalous, and also affects the majority of oases. Overall, waterlogging affects 29-67 percent of irrigated areas in the north, 35 percent in the oases of Kibili and Toezure, and to a lesser extent the plains of Dorsal and irrigated areas of Gabes and Cap Bon (14-20 percent). It also affects some irrigated areas in the far north (Nefza, Sejnane and Mateur) and some irrigated areas of the centre.

13.3.8 | Nutrient balance change

The problem of nutrient-constrained agriculture is particularly acute in the region. It is associated with land use pressure and the consequent intensification of cropping systems and related soil degradation. Nutrient depletion is increasingly affecting land productivity in the region. In Sudan, continuous cultivation over nearly a century has decreased the base saturation percentage by 25 to 42 percent, indicating leaching with irrigation water of soluble anions and cations down the soil profile. Soil degradation due to nutrient depletion in Sudan is largely concentrated in the arid and semi-arid parts, particularly in southern Kordofan and Darfur, and in the dry sub-humid and moist sub-humid zones of south-western Sudan. This soil degradation is clearly related to agricultural activities and to deforestation.

13.3.9 | Compaction

Soil compaction and crusting are the most serious forms of physical degradation affecting several irrigated areas in Libya, especially in sandy soils (Ben-Mahmoud, Mansur and Al-Gomati, 2000). Most soil compaction in the region is caused by tillage practices. For example in Iran continuous tilling over more than 50 years has exposed surface soil to water run off due to an increase of up to 33 percent of soil bulk density. Surface compaction and crusting in the Arabian Peninsula, especially in the United Arab Emirates, is often due to land filling and levelling for infrastructure development. One study found that compaction increased from a bulk density of 1.15 to 1.66 g cm^{-3} (e.g. by 44 percent) and water infiltration dropped from 267 to 52 mm h^{-1} (e.g. by 81 percent). Soil compaction due to extensive tillage operations in the furrow slice (to 30 cm) is a major physical degradation in soils with high clay content where heavy mechanization is practiced. An example is documented (Biro *et al.*, 2013) in rainfed farming systems of eastern Sudan, where three decades (1979-2009) of cultivation have increased compaction in the 0-5 and 5-15 cm depth from 1.33 and 1.42 g cm^{-3} in woodland and from 1.37 and 1.56 g cm^{-3} in fallow land to 1.56 and 1.72 g cm^{-3} (e.g. 16 percent). These levels of compaction have contributed to the general decline in productive potential in Sudan. This increase in compaction is comparable to the increase in bulk density of 13 percent documented in Jordan during the half century following conversion of forest land to cultivation of wheat and barley (Khresat *et al.*, 2008).

Military activities in the Al Salmi area on the western border of Kuwait have resulted in huge disturbance and caused soil and vegetation degradation (Al-Dousari, Misak and Shahid, 2000). The soil pores in the area have sealed and the infiltration rate has declined by 19.5 to 64.4 percent. Bulk density has increased by 26-33 percent. In the Kabd area southwest of Kuwait City, pressure on land has resulted in compaction 20 percent higher in non-protected areas (bulk density of 1.8 g cm^{-3}) than in protected areas (bulk density of 1.5 g cm^{-3}; Misak *et al.*, 2002). More generally, it has been estimated that a wide range of activities in Kuwait – grazing, quarrying, camping, and agricultural and animal production – have increased compaction by 12.9 to 23.4 percent (Al-Awadhi, Al-Helal and Al-Enezi, 2005).

13.3.10 | Sealing/capping

The population of the region is approximately 6.2 percent of the world population. The region's fragile ecosystem is endangered by one of the highest rates of population increase (3 percent) in the world. This puts enormous pressure on the capacity of land resources to provide goods and services. Encroachment of human settlements on scarce good quality agricultural land or in areas of adequate rainfall for agriculture occurs in many countries of the region, jeopardizing the role of land as a source of food. For example, in Egypt the net population density in towns is more than double the recognized maximum threshold of 360 ha^{-1}. During 1987-2007, the cultivated land in the Delta and Nile Valley did increase (to about 7 260 000 ha), but at the same time human settlement and land allocated to roads and irrigation canals and drains also increased (by 33.6 percent and 40 percent, respectively). As a result, recent studies (ESCWA, 2007) have shown that urban encroachment on highly fertile agricultural land in Egypt is emerging as a significant problem. For example, in El-Mahalla El-Kobra in the Gharbiya Governorate, the rate of urbanization from 1950 to 1987 was 10 percent annually, but from 1987 to 1995 the rate shot up to 33 percent a year. In the 1950-1987 period, annual loss of agricultural land averaged 0.4 percent but it has subsequently risen considerably.

Iran has the largest urbanized area in absolute terms in the region, followed by Saudi Arabia and Iraq, while the highest Urbanization Index is recorded for Gaza Strip, Bahrain, Palestine, Israel and Lebanon (Figure 13.2).

Land sales also play an important role in the decline in the area of productive lands. In Jordan, the agricultural sector lost about 24.3 percent of its land during the period from 1997 to 2007. Rainfed cultivation, which represented 89 percent of total cultivated land in 1983, had lost 22.6 percent of its area by 1997.

The main causes of soil problems in Jordan are: (I) improper farming practices, such as failure to use contour ploughing, or over-cultivation of the land; (II) overgrazing; (III) the conversion of rangelands to croplands in marginal areas where rainfall is insufficient to support crops in the long term; and (IV) uncontrolled expansion of urban and rural settlement at the cost of cultivable land.

Urban populations are growing at 8 percent a year as opposed to just 1 percent in rural areas. In some countries of the region nearly the whole population is urban (e.g. Kuwait, 97 percent; Bahrain, 90 percent; Saudi Arabia, 83 percent; and United Arab Emirates, 84 percent). This high rate of urbanization has been accompanied by conversion of agricultural lands into urban areas. In Libya, over 25 percent of highly fertile lands have been taken over by the expansion of urban areas.

The rapid urban population growth in the region increases the pressure on the natural resources (AOAD, 2004). An example of dramatic urban expansion is found in Lebanon where a study by Darwish and Khawlie (2004) showed that during the period from 1962 to 2000, urban areas expanded by 208 percent while agricultural lands decreased by 35 percent. Much of the area converted to settlements was highly productive agricultural land on Fluvisols, Luvisols and Cambisols. Some 32 percent of class 1 (prime land) and 26 percent of class 2 land were converted into urban areas.

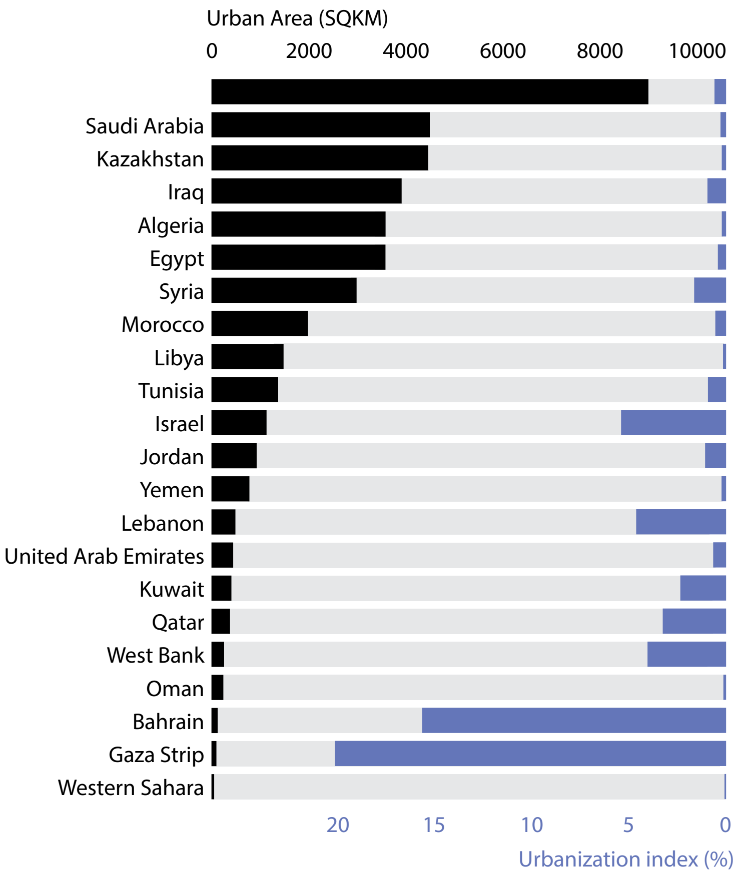

Figure 13.2 | Extent of the urban areas and Urbanization Indexes for the Near East and North African countries. Source: Schneider, Friedl and Potere, 2009.

13.4 | Major soil threats in the region

Most of the land area of the region falls in the hyper-arid, arid and semi-arid climatic zones. About 87 percent of the region is predominantly desert. Major soil threats are: erosion, salinity/sodicity, pollution, and soil C loss. Main causes of soil degradation are: mismanagement coupled with poor policies; use of inappropriate technology; increased levels of traffic movements and road construction; industrial activities and mining; urban expansion; deforestation, overgrazing and inappropriate cultivation practices; and dumping of hazardous wastes.

13.4.1 | Water and wind erosion

Wind and water erosion in the region are due to a complex interaction of factors related to the resilience of land resources, land use and management, and socio-economic conditions. In this section, a link is made to the prevailing land uses in the different countries of the region, and the consequences and responses are discussed.

Erosion caused by rainfed farming

FAO (2004) reported that the annual soil loss in Iran due to erosion is 1-2 billion tonnes yr^{-1}, and that 76 percent of the total area is under erosion threat. The area affected by wind erosion in Iran is about 12 percent of the total country surface area, six times the global rate of 1.8 percent. Other studies also report soil erosion as a serious problem in Iran, up to 20–30-times acceptable levels (Jalalian, Ghahsareh and Karimzadeh, 1996). In the north-west of Yazd in the Yazd-Ardakan plain, total soil mass transported was measured at 220.93 kg m^{-1} yr^{-1} and soil loss at 1.356 kg m^{-2} or about 13.56 tonnes ha^{-1} yr^{-1} causing topsoil C reduction at an average rate of 4 percent $month^{-1}$ (Azimzadeh *et al.*, 2008). The Iranian National Action Programme (NAP) reported in 2004 a lack of access for farmers to inputs as an additional cause of soil erosion. This is due to various driving forces like poverty, lack of security and awareness, inadequate extension, absence of technical knowledge and financing.

Elsewhere, driving forces for erosion processes were reported to be interrelated and to result in different degrees of degradation. In the El Bayadh region of Algeria, soils on limestone covers were classified as moderately vulnerable, vulnerable and highly vulnerable to degradation as a function of their vegetation cover (Belaroui, Djediai and Megdad, 2014). The study describes how the Algerian steppe has in recent years become the scene of an ecological and climatic imbalance.

More generally in the southern part of the Mediterranean region, overgrazing and cultivation of vulnerable land in arid and desert regions have induced severe wind erosion. In Morocco, erosion is a serious agro-environmental threat and was found to cause soil losses generally between 12 tonnes ha^{-1} yr^{-1} and 14 tonnes $ha^{-1} yr^{-1}$. In some areas of the Rif Mountains these values reach 30 to 70 $tonnes^{-1}$ ha^{-1} yr^{-1} (Benmansour *et al.*, 2013). Using radioisotopes (137Cs), these authors found that the tillage process on sloping lands over the last half-century had resulted in significant translocation of soils within the field. A study by Dahan *et al.* (2012) found that soil erosion in Morocco is a result of several factors. The most important factors have been: increased population pressure on limited natural resources; over exploitation of forestry assets; removal of natural vegetation from sloping lands; overgrazing; cultivation of vulnerable lands in arid and desert regions; and inappropriate land management, mainly tillage practices. They also reported that water erosion accelerated by human intervention is the main cause in Morocco of soil degradation and of the deterioration of water quality that it entails. Soil erosion in Morocco affects up to 40 percent of its territory with the total annual soil loss evaluated at 100 million tonnes, equivalent to 50 million m^3 annual reduction in dam storage capacity.

In El Bayadh region of Algeria, the Sirocco (a hot, dry wind blowing northwards from the Sahara) with a speed of 1.1 to 2.9 m s^{-1} is a dust-blowing wind which causes significant wind erosion (Belaroui, Djediai and Megdad, 2014). A recent study (Houyou *et al.*, 2014) showed that 20 million ha of steppe lands faced a high risk of wind erosion due to low rainfall and poorly rooted vegetation on sandy soils. This area is threatened by yet more intensive erosion because of newly adopted government policies favouring extensive rainfed cereal cropping. The study showed that this decision has led to very high erosion rates (74.4 Mg ha^{-1} yr^{-1}). Clearly this cropping system is unsustainable and the policy should be revised.

In Tunisia, overall soil loss due to water erosion has been estimated to be equivalent to 23 000 ha yr^{-1} in the isohyets above 200 mm. In some areas of Syria, soil loss due to water erosion has been estimated to range from 10 to 60 kg ha^{-1} (under forest), from 200 to 2 550 kg ha^{-1} (under burned forest) and as high as 960 to 3 280 kg ha^{-1} (under agricultural land). High population growth 1984-1999 (4.0 percent annually against a national average of 3.0 percent) in the village of Im Mial in the north-west of Syria led farmers to practice continuous rainfed barley production with no fallow or rotation (Nielsen and Zöbisch, 2001). This resulted in a very sparse vegetation and extensive wind erosion.

Grazing and tillage practices generally contribute to vulnerability to water erosion. In one study in NENA, the highest soil loss was recorded in over-grazed mountains, which lost up to five times more soil than slopes under managed grazing (Shinjo *et al.*, 2000). However, soil loss on tilled slopes can be one to four times that from grazed areas. Estimates of areas under serious water erosion in northern Iraq showed an increase from 12 percent in 1954 (Gibbs, 1954) to around 22 percent in 1997 (Hussein *et al.*, 1998), suggesting a rate of increase of 0.2 percent yr^{-1}. The main reason was mismanagement of cropland and rangeland during the intervening four decades. In Yemen the surface runoff to the sea measured in some major wadis is estimated at 1430 million m^{-3} yr^{-1} (Al-Hemiary, 1999).

In Jordan, water and wind erosion are both problems. Water erosion in the more vulnerable areas of the country with annual rainfall more than 400 mm and a slope greater than 25 percent – occurs on just 2.5 percent of the total area of the country. However, water erosion also occurs in the Badia region with its very low rainfall. The Badia soils are subject to water erosion because they are bare and highly exposed to what rainfall there is. The consequent formation of a slowly permeable seal and crust has enhanced runoff and water erosion (Rawajfih, Khersat and Buck, 2005). In Palestine it has been demonstrated that soil conservation pays – net profit was found to 3.5 to 6 times higher than without conservation measures. However, farmers' willingness to adopt conservation measures was influenced by other factors too, including knowledge and perception, land tenure, and the type of landscape (Abu Hammad and Børresen, 2006).

Early studies estimated the risk of water erosion in Lebanon to be 50–70 tonnes ha^{-1} yr^{-1}, but subsequently this has increased to 150 tonnes ha^{-1} yr^{-1} (Bou Kheir, Cerdan and Abdallah, 2006) and may be as high as 317 tonnes ha^{-1} yr^{-1}. Some farmers in Lebanon are nonetheless reluctant to change their cultivation practices, particularly ploughing up and down slopes of more than 20 percent. Farmers are also expanding cultivation on steep slopes, even though they may be aware that this aggravates water erosion. They justify up and down ploughing as necessary for tractor performance, and steep lands are the only available land for extending cultivation (Zurayk *et al.*, 2001). In general, human activities have been identified as causes of water erosion in Lebanon including: encroachment into agricultural land, cultivation of fragile soils, over-grazing, deforestation and overexploitation of woodland resources, uncontrolled use of fire for agricultural and forest clearing, unsustainable agricultural practices, poor irrigation practices and inefficient water use, and chaotic urban sprawl into fertile lands and forests (NAP, 2003).

In Sudan, studies showed that in areas affected by water erosion, about 74 percent of respondent households are exposed to food shortages that are sometimes severe (Akuot Gareng Apiu Anyar, 2006). The expansion of mechanized rainfed agriculture (1970–1990) at the expense of rangelands and forests led to land degradation by enhancing soil erosion. Subsequently crop yields declined sharply due to the decreased fertility. A principal driver has been the rapid growth of the population (2.6 percent per annum^{-1}) which increased demand for agricultural land. Mechanized rainfed agriculture expanded from 500 ha in the 1940s to 2.3 million ha in 2003. In the coastal part of Sudan, although total annual rainfall is low (75 mm), the sandy texture of the soils makes them very highly erodible (Elagib, 2011). With the observed increasing seasonality and intensity of rainfall, high runoff and erodibility in these areas could be expected to cause heavy soil degradation through soil loss.

Studies on factors contributing to wind erosion in Sudan showed that in rainfed agricultural zones, deep ploughing and leveling of the surface soil caused an increase in its susceptibility to wind erosion, which, in turn, has led to a severe decline in its fertility and, in some places, to the formation of sand dunes. The fragility index (degraded land in ha divided by population) is a good measure of the extent of growing pressure in fragile ecosystems. In Sudan, this value is very high in the hyper arid zone (31.1 percent), the arid zone (30.5 percent), and the semi-arid zone (22.5 percent). The value is low in the dry sub-humid zone (7.9 percent) and in the moist sub-humid zone (8 percent) (Ayoub, 1998).

Erosion caused by other land uses

In Lebanon, increasing demand for construction materials has led to extensive unregulated mining activities, including a large number of open quarries. Darwish *et al.* (2011) reported that, during the period from 1989 and 2005, quarries increased by 63 percent, covering an area of 5 267 ha. Many quarries were established on sloping lands (62.2 percent), triggering acceleration of water erosion processes. The high population density in countries like Kuwait (120 person km^{-2}) has a profound influence on soil disturbance through uncontrolled human activities. The Nabkha (stabilized aeolian landform developed as result of the deposition of wind-driven sediments around desert shrubs) along the coastal plain in Kuwait is used as a land degradation indicator (Khalaf and Al-Awadhi, 2012). The average annual sand drift rate in Kuwait is about 20 m^{3} (m width)$^{-1}$ yr^{-1} and negatively affects farms causing adverse environmental and economic impacts (Khalafa and Al-Jjimi, 1993). Al-Awadhi and Cermak (1998) calculated the average sand movement in Kuwait as 7.8×104 kg (m width)$^{-1}$ yr^{-1}. In the Jalal-Alzor (Kuwait), human activities such as the unregulated use of off-road vehicles has resulted in soil disturbance and accelerated soil erosion. There has been a consequent increase in the rate of deflated sand from 220.5 kg m^{-1} width in 1989 to 400 kg m^{-1} in 2007, a total rate of increase of 81 percent in two decades (cited by Al-Awadhi, 2013).

Grazing was found to enhance soil loss by water. In the Matash Mountains of the Alborz Mountain range in Talesh Region, Iran (slope of 16 percent and 1 286 mm of precipitation per annum), soil loss due to open grazing was more than 26 times that in rainfed agriculture (Sadeghi *et al.*, 2007). In Sudan the dominant type of housing is the traditional hut made from forest products. These buildings need to be renewed every two years on average. A study found that this practice exacerbates the process of soil erosion. Conserving and restoring the vegetation cover in these areas was achieved through adoption of mud huts. As a result, the stocking density of trees around the villages went up compared to the control (FAO, 2013b).

Deforestation is also a factor inducing soil erosion. Fuel wood or charcoal production for domestic use is one element in this deforestation. Deforestation for agriculture in semi-arid lands around settlement areas is also a cause of soil degradation, for instance in the Jifara Plain of Libya.

Dust storms

Dust storms are frequent in the region and widely reported. A dust storm carries toxic elements like Pb with concentrations as low as 20 to 288 mg kg–1 in Oman to higher levels of 742 mg kg–1 in Bahrain and 1762 mg kg–1 in Saudi Arabia (Madany, Akhter and Al-Jowder, 1994; Al-Rajhi, Seaward and Al-Aamer, 1996). The problem of sand drifting and dune migration is of special concern in some countries of the region such as Saudi Arabia, where approximately one-third of the country is covered by moving sand. Al-Harthi (2002) found that these storms have resulted in dune movement of 9.9 m yr^{-1} (for 4.9 m-high dune) up to 16.5 m yr^{-1} (for 1.9-m high dunes). This problem is exacerbated by human activities such as overgrazing or other activities that may destroy the desert pavement which protects the loose sand underneath.

In Kuwait, the sand drift potential was found to be as high as 354 vector units (Al-Awadhi, Al-Helal and Al-Enezi, 2005). Sandstorms are very frequent in summer especially when the wind speed exceeds 6 m s^{-1}. An annual amount of sand drift can measure 7.8×104 kg m^{-1} width (Al-Awadhi and Misak, 2000).

As cited by Goudie and Middleton (2001), estimates of rates of dust deposition exist for a number of sites at varying distances from the Sahara. The dust originates from southern Algeria, the Nubian Desert in southern Egypt and Northern Sudan. Volumes carried to Western Europe are less than 1 g m^{-2}. Up to 5.1 g m^{-2} may reach Spain, while over Sardinia, Corsica, Crete and the south-east Mediterranean, most values are between 10 and 40 g m^{-2}. Long-range transport of Saharan dust to the central Mediterranean is characterized by events lasting two to four days, compared to an average duration of just one day for events reaching the Eastern Mediterranean from the Arabian Desert (Dayan *et al.*, 1991).

Several studies reported the frequency of dust storms in the Arabian Peninsula and found that the average quantity of dust falling on Kuwait and Riyadh were 191 and 392 tonnes km^{-2} $year^{-1}$ (cited by Ibrahim and El-Gaely, 2012). A recent study (Jish Prakash *et al.*, 2014) on the impact of dust storms on the Arabian Peninsula and the Red Sea reported that strong winds (velocities exceeding 15 m s^{-1}) entrained large quantities of dust particles into the atmosphere with sources including the lower Tigris and Euphrates in Iraq, areas of Kuwait, Iran and the United Arab Emirates, and the basin of the Arabian desert (which includes the Rub' al Khali, An Nafud and Ad Dahna). The study also reported that the frequent dust outbreaks and dust storms each year in the NENA region have profound effects on all aspects of human activity and natural processes. The total amount of dust generated by the storms is estimated at 93.76 million tonnes, of which 80 percent is deposited within the area, around 6 percent (5.3 million tonnes) is deposited in the Arabian Sea, the Gulf received 15 percent (1.2 million tonnes), and the Red Sea roughly 6 million tonnes. In the Middle East, more than 60 dust storms occurred during the period 2003–2011 with significant impact on the countries of the region (Hamidi, Kavianpourl and Shao, 2013). Some countries are worst affected. Iraq, for example, experiences on average about 122 dust storms and 283 dusty days each year. Some experts expect this may increase to 300 dusty days and dust storms a year within the next ten years (Kobler, 2013).

Consequences of soil erosion

Erosion processes remove the fertile part of the soils and thus reduce the effective depth to be exploited by roots and the amount of water available to plants. This is considered a major constraint limiting productivity in Morocco (Dahan *et al.*, 2012). In the Maghreb region (Morocco, Algeria, Tunisia), uncontrolled runoff from terraces has reached the stage of gully formation. More generally, sheet and gully erosion has become common due to increased population, deforestation, overgrazing, and expansion of cultivation on steep land (Dregne, 2002). There are few studies on the effects of erosion on land productivity in the region. However, one research study on barley in Aridisols of Egypt (Afifi *et al.*, 1992; Wassif, Atta and Tadros, 1995) found a declining yield of 2 kg ha^{-1} Mg^{-1} of soil erosion which is equivalent to 0.21 percent Mg^{-1} soil erosion. A study in Iran found soil erodibility by water was negatively correlated with wheat yields (Vaezi, 2012). The agricultural productivity of oases in countries like Sudan and Egypt is threatened by the adverse impacts of sand encroachment and mobile dunes.

Responses to soil erosion

Ways to contain erosion are very diverse and location-specific. In the sandy depression of El-Farafra, Egypt, which suffers from wind erosion, Sallam, Elwan and Rabi, (1995) reported that mixing sandy soils with grey shale at a ratio of 15 percent (w/w) improved the quality of these soils. Organic manures, compost and synthetic soil conditioners have been used to contain wind erosion. Compost alone or compost combined with hydrogel conditioners was found to decrease erosion by 58 to 74 percent (El-Hady and Abo-Sedera, 2006). One study found that water erosion could be stemmed in Morocco by increasing levels of C in the topsoil using conservation measures (Mrabet *et al.*, 2001). Irrespective of rotation, conservation measures were found to increase topsoil C by 44 percent. The study concluded that systems with increased C are generally characterized by diminished erosion.

Government policy responses can play a vital role. For example, public policy in Egypt and Iraq has been determinant in increasing green cover in desert soils in those countries (Nielsen and Adriansen, 2005). The Iraqi case is a negative one, illustrating the effects of deliberate government policies in draining the marshlands, which resulted in significant land degradation. Recent efforts have been devoted to the re-establishment of these marshes. They are being re-flooded and vegetation is returning. The Egyptian government promoted land reclamation after the 1952 revolution aiming at increasing agricultural production. This reclamation was executed through internationally funded developmental projects and with local funding and involved distributing small areas of lands to graduates.

Efforts at containing water erosion in rainfed farming in Yemen depend on the establishment and maintenance of terraces as conservation structures, a highly labour intensive task. However, labour shortages and lack of profitability have been constraints, and the degradation of these structures has continued. In Jordan, the use of polyacrylamide (PAM) at application rates of 10 to 30 kg ha^{-1} was found to be very effective in reducing runoff and soil loss by up to 23 percent and 53.9 percent, respectively. As a result, dry matter crop yield went up by 35 to 56 percent (Abu-Zreig, Al-Sharif and Amayreh, 2007). Interestingly, this study developed an increased threshold runoff value of 0.56 mm rainfall in control sites to 1.11 mm in PAM plots (e.g. close to 100 percent). Also Abu-Zreig (2006) pointed out that PAM with more surface area (30 percent) reduced soil loss by approximately 46 percent compared to the 24 percent reduction with less surface area (20 percent).

Soil conservation to mitigate erosion has also been done by planting trees and grass along wadis. Construction of diversion banks and dams across watercourses has been carried out on slopes and stream beds in Libya. One study (Mohammed, Stigter and Adam, 1996) found that windbreaks reduced wind speed by about 20 percent and in turn limited sand deposition. However, sand deposition also occurred within the belt which after some time started to act as a zero permeability wind break. This study suggested that control of sands in the source area using shelterbelts may not be sufficient in the long term.

Some countries have introduced policies to reverse land degradation due to erosion. In the mechanized rainfed projects of Sudan, farmers are required to leave 10 percent of the cultivated area for forest trees. To protect soil against erosion after fire in Lebanon, a ministerial decision (181/98) imposed a five year ban on grazing on public land after fires to enhance land cover recovery.

13.4.2 | Soil salinization/sodification

Distribution of salt-affected soils in the region varies geographically with climate, agricultural activities, irrigation methods and policies related to land management. These soils are mainly confined to irrigated farming systems in the arid and semi-arid zones. The salts present are either of intrinsic origin (typical of Egypt, Sudan and Iran) or are the result of sea water intrusion in coastal regions or of irrigation with brackish or saline groundwater. In the irrigated zones of Morocco, continuous irrigation has resulted in soil salinization. Secondary salinization due to irrigation with saline water is also reported in the NENA region. In Libya, Sudan, Iran, Iraq and United Arab Emirates, large tracts of lands have been degraded due to heavy irrigation with groundwater. Salinity, sodicity or the combination of both are seriously affecting productive areas like the Nile Delta of Egypt and the Euphrates Valley in Iraq and Syria. The situation is further complicated by association with problems of waterlogging and high $CaCO_3$ (up to 90 percent in the United Arab Emirates, Al Barshamgi, 1997). In Kuwait and the United Arab Emirates, soil salinization is mainly confined to coastal areas, but also occurs on irrigated farms.

Local soil conditions can worsen the situation. For instance in the southern part of the Jordan Valley, the soil is characterized by high salt content, poor permeability and high gypsum content. The degradation is worse when low quality irrigation water, for example treated waste water, replaces fresh water. In Libya, El-Tantawi (2005) reported that the soils of the Jifara Plain are usually calcareous and often shallow, with huge areas of calcrete outcrops developed during the Pleistocene epoch. Gypsum encrustation is commonplace in the drier parts where annual precipitation is below 200 mm.

Salinity problems in the region also stem from inadequate irrigation water management (Al-Hiba, 1997). In almost all countries of the region with coastlines, heavy extraction of groundwater has led to intrusion of seawater into aquifers, thereby raising the content of salts in the water. An example is the Batinah aquifer of the Sultanate of Oman where seawater is intruding at an alarming pace (Naifer, Al-Rawahy and Zekri, 2011). The cause was the expansion of agriculture since the 1980s which accelerated the overuse of groundwater, disturbing the water balance and ultimately leading to water intrusion from the sea. In the Jifara Plain of Libya, increased human pressure on aquifers has induced seawater intrusion in the coastal zones and a combination of over-irrigation and inefficient drainage causes waterlogging and secondary salinization.

The main causes of build-up in salinity in the region are: (1) improper functioning or absence of drainage systems; (2) a rise in groundwater salinity combined with high rates of evapotranspiration; and (3) high salinity in irrigation water. Siadat, Bybordi and Malakouti (1997) recognized natural factors and humaninduced factors that cause salinity in Iran. The natural causes of soil salinity in Iran are geological conditions, climatic factors (evaporation, rainfall and wind), salt transport by water, and intrusion of saline bodies of water into the coastal aquifers. However, of greater concern and importance is humaninduced salinity. This type of salinity can stem from a number of causes, including: poor water management, over-grazing, improper land levelling, and overuse of groundwater leading to saline water intrusion.

Secondary salinization due to irrigation with saline water is also reported in the region. In the Tadla irrigated perimeter in Morocco, soil degradation through secondary soil salinity and sodicity are caused by heavy irrigation with ground- and surface water together with agricultural intensification. In Algeria, secondary salinization affects 10 to 15 percent of the total irrigated land. About 90 percent of the agricultural farms in Al Ain in the United Arab Emirates are affected by salinity (Abdelfattah, Shahid and Othman, 2009). It is clear that in some countries of the region, secondary salinization due to irrigation does not develop. One example is in the Vertisols of Sudan, despite more than 80 years of irrigation. This is mainly due to the low salt content of Nile water (EC of 120 to 220 $\mu S\ cm^{-1}$).

Consequences of salinization

Salinity in the region has badly affected cropping systems and in many cases has significantly reduced crop yields. For example, soil salinity in the Jifara plain in Libya has caused wheat yields to decrease from 5 tonnes ha^{-1} in the 1980s to just 0.5 tonnes ha^{-1} by 1987. In Iran the annual economic losses due to salinity are estimated at more than US$ 1 billion (Qadir, Qureshi and Cheraghi, 2008). The coastal area is one of the most highly populated regions of Oman, especially the Batinah area where about 52 percent of land is under cultivation and suffers from salinity. Naifer, Al-Rawahy and Zekri, (2011) showed that when salinity increases from low (less than 2.5 dS m^{-1}) to medium (7.5 dS m^{-1}) and to high (more than 7.5 dS m^{-1}) levels, losses are equivalent to US$ 1 604 ha^{-1} and US$ 2 748 ha^{-1}, respectively. Soil salinity, sodicity and waterlogging conditions have definite adverse impacts on soil productivity, in the range of 30-35 percent of potential productivity.

Responses to salinization

There are many responses in the region to contain the salinity threat such as: (1) direct leaching of salts, (2) planting salt tolerant varieties, (3) domestication of native wild halophytes for use in agro-pastoral systems, (4) phytoremediation or bioremediation, (5) chemical amelioration, and (6) the use of organic amendments. In Iraq and Egypt, surface and subsurface drainage systems have been installed to control rising water tables and arrest soil salinity. In Iran, Syria and other Gulf countries, crop-based management and fertilizers are used to combat salinization (Qadir, Qureshi and Cheraghi, 2007). In Iran, *Haloxylon aphyllum*, *Haloxylon persicum*, *Petropyrum euphratica* and *Tamarix aphylla* are potential species for saline environments (Djavanshir, Dasmalchi and Emararty, 1996). Atriplex is a fodder shrub adapted to arid lands which can bring annual income as high as US$200 ha^{-1} (Koocheki, 2000; Tork Nejad and Koocheki, 2000). Breeding salt tolerant varieties of crops (e.g. wheat, barley, alfalfa, sorghum) is also a response to saline environments, although most results so far are based on controlled environments rather than on actual yields from the field.

The use of organic amendments in Egypt showed that the mixed application of farmyard manure and gypsum (1:1) significantly reduces soil salinity and sodicity (Abd Elrahman *et al.*, 2012). Recently, phytoremediation or plant-based reclamation has been introduced in the region. In Sudan there are very good responses for control of sodicity relying on phytoremediation, superior to results from the gypsum amendment traditionally used. The production of H^+ proton in the rhizosphere during N-fixation from some legumes like hyacinth bean (*Dolichos lablab* L.) removed as much Na^+ as did gypsum application which indicates its importance in calcite dissolution of calcareous salt affected soils (Mubarak and Nortcliff, 2010).

13.4.3 | Soil organic carbon change

Information on soil carbon changes in the region is scarce. Estimates of soil C sequestration are basically confined to the work on the drylands ecosystems of West Asia-North Africa (WANA) carried out by Lal (2002). These data are nonetheless very useful and can be applied across NENA. Lal's study indicated that the total loss of soil-C from the WANA region could be about 6 to 12 Pg. Despite the low soil C levels in the region (generally less than 5 g kg^{-1}), with effective control measures of degraded soils, the region could sequester C at the rate of 0.1 to 0.2 Mg ha^{-1} yr^{-1} (for irrigated crop land) and 0.05 to 0.1 Mg ha^{-1} yr^{-1} for both rainfed and rangeland. In other words, with desertification control, reclamation of salt-affected soils, and intensification of agriculture on undegraded soils, the soils of the region have the potential to sequester 24 to 31 percent (168-380 Tg yr^{-1}) of the total global drylands soil C (710-1220 Tg yr^{-1}). The potential annual sequestration rate could reach values between 0.2 and 0.4 Pg C yr^{-1}, compared to the 1.0 C yr^{-1} in total global drylands (e.g. 20 to 40 percent).

SOC change in rainfed farming systems

The Century model was used by Poussart, Ardö and Olsson, (2004) in a study of the Arenosols of Kordofan (Sudan) to estimate soil C levels and changes with reference to values prior to known human interaction. Changes were due to pastoral activities combined with cultivation of rainfed crops like *Pennisetum typhoideum*, sesame (*Sesamum indicum*), sorghum (*Sorghum vulgare*), and groundnuts (*Arachis hypogaea*). The base scenario modelled indicates that the land management practices continued for more than a century have led to a loss of C of about 180 g m^{-2} (1.8 tonnes C ha^{-1}) which is equal to 1.6 gm^{-2} yr^{-1} or approximately equivalent to half of the historical level of C in the year 1890. Additionally, Ardö and Olsson (2003) modelled C changes in north Kordofan in the top 20 cm during the period 1800–2100, with mostly Arenosol and Vertisols soil types. They found that C estimates in cropped land have dropped from 16.64 million tonnes in the year 1800 to 9.16 million tonnes (e.g. a 45 percent reduction), whereas C in other land uses such as shrublands, savannah, grassland, or barren or sparsely vegetated land remained almost constant. Another study in north Kordofan found that rapid population growth has caused huge soil C loss (73 percent at rate of 16.9 g C m^{-2} yr^{-1}) in the top 0-20 cm from 851 g C m^{-2} in 1963 to 227 g C m^{-2} in 2000 (Ardö and Olsson, 2004).

The effects of cultivation of heavy textured soils on C change in some countries of the Mashreq region (Jordan, Syria, Lebanon, Iraq, Palestine) have been found to be broadly similar to results from the Maghreb (Morocco, Tunisia, Algeria, Libya). Masri and Ryan (2006), in a study on Syria, compared the effects of more than twenty years of wheat cultivation in rotation with lentil (*Lens culinaris*), chickpea (*Cicer arietinum*), medic (*Medicago sativa*), vetch (*Vicia sativa*) and watermelon (*Citrullus vulgaris*) with continuous wheat grown in montmorillonitic thermic Chromic Calcixert. The trial showed that, apart from the rotation of wheat with medic which has higher C (8.0 g kg^{-1}), C content in continuous wheat cultivation (6.3 g kg^{-1}) or in other rotations (6.6-7.0 g kg^{-1}) differs little from fallow (6.6 g kg^{-1}). This suggests that conventional farming systems in the Vertisols of the region may not be depleting soil C.

In the western part of Jordan, the change in C is a function not only of a land use system but also of the human impact in a specific land use. For example, cultivating tobacco and clearing residues, and growing irrigated cereals retain almost similar amounts of C (6-7 g kg^{-1}), whereas ploughing rainfed cereals and grazing with compaction consequences retain C contents of only about 1.1 g kg^{-1} (Khresat *et al.*, 1998). In the Lorestan Province of Iran, management practices on rangeland in areas with slopes of 10 to 26 percent caused pronounced reduction in C, sometimes twice levels found in dryland farming. When wheat was subsequently grown, wheat dry matter, grain yield and grain weight all reduced relative to the control dry farming (by 14, 33 and 21 percent respectively), which indicates the degrading effects of using these slopes as rangeland (Asadi *et al.*, 2012).

SOC changes in irrigated farming systems

Irrigated soils in the southern Mediterranean region can be considered as incubators providing optimal conditions (humidity and temperature) for microbial activity and thus a rapid degradation of organic carbon. A mean annual variation rate of organic matter of -0.09 percent yr^{-1} over a decade was established in the Doukkala region of Morocco (Badraoui, 1998). This decrease of organic matter is attributed to the non-incorporation of crop residues into the soils. Crop residues contribute about 30 percent of the total forage consumption in Morocco. Countries like Morocco experience rapid organic matter decomposition and turnover and hence very low levels of organic matter are converted into humus. The reasons for this rapid decomposition include: the high temperature, widespread of use of tillage, clean fallow, overgrazing, no practice of residue recycling, and climatic conditions.

Rates of C change are influenced not only by land use but also by soil type. Clay soils tend to counteract decomposition and hence reduce chances of C loss. For example, in clay soils of Morocco, Bessam and Marbet (2003) reported that in seven years of continuous tilling, soil SOC reduced in the 0-20 cm profile by 17 percent (e.g. 0.33 g kg^{-1} yr^{-1}). As cultivation of such soils advances, it was possible over time (an eleven year period was monitored) to store more C (by 3.7 percent) in the entire 0-20 cm depth but not the top 2.5 cm due to incorporation. The decrease in topsoil C noted increases vulnerability to degradation by erosion due to reduction in topsoil buffering capacity or resilience.

It is apparent that continuous cultivation does not always consume soil C. There are exceptions, however, for example the case of the irrigated Vertisols of the Gezira Scheme of Sudan which have been continuously cropped for more than 80 years. The carbon content in a furrow slice (0-10 and 10-35cm) of permanent fallow (4 and 4.61 g kg^{-1}) was lower than that in cultivated plots (6.35 and 5.44 g kg^{-1}) by about 37 and 15 percent respectively which indicates that C loss due to cultivation in such soils is not a small problem (Elias and Alaily, 2002). Physical protection of C in heavy textured soils under long-term cultivation (about 30 years) and with intensive tillage decreased C in the top 0-15 cm by 15 to 24 percent relative to wood and fallow lands (Biro *et al.*, 2013).

In desert soils carbon could likely be increased by irrigation of alfalafa rotated with wheat or wheat rotated with fallow. One study showed this to have increased C in the top 0-10, 10-20 and 20-30 cm depths by factors of 5.1-6.8, 3.0-4.6 and 6.8-11.6 respectively (Fallahzadeh and Hajabbasi, 2012a). This rotation could thus stabilize soil aggregates and consequently reduce the vulnerability of desert soils to erosion by either wind or water. However, C could also be decreased by 24 to 47 percent during bio-remediation (land farming processes) of soils contaminated with hydrocarbon of petroleum origin where microbial activities are greatly enhanced due to aeration (Besalatpour *et al.*, 2011).

SOC change and forest clearing

Tree plantations have been found to be the best system to conserve C in the region. Other land use systems practiced on light soils in the region seem to result in C loss. For example, in the sandy soils of western Sudan, taking tree C in the 0-30 cm depth as a reference, three years of sole cropping or cropping mixed with trees caused about 41 to 47 percent C reduction (El Tahir *et al.*, 2008).

In Jordan, land resources have been affected by rapid land use change, accelerated by socio-economic factors including high population growth, urbanization and agricultural intensification. Farmers converted a forest located in Ajloun to cultivation of wheat (*Triticum spp.*) and barley (*Hordeum spp.*). After more than 50 years of cultivation, Khresat *et al.* (2008) reported that soil C in the top 0-20 cm of mostly Inceptisols, Mollisols and Vertisols had decreased from 6.73 g kg^{-1} to 4.70 g kg^{-1} (e.g. a 30 percent reduction). In Iran, the conversion of forest or pasture to arable lands in five cultivation sites where tillage has now been practiced for 40-50 years was found to have caused 30-68 percent loss of topsoil (0-20 cm) SOC, specifically from 3.86-9.84 to 3.25-8.06 kg m^{-2} (Golchin and Asgari, 2008). Farming practices had also mixed SOC down the profile, leaving less SOC on the topsoil for surface protection against degradation by erosion and also reducing the capacity of the soil to retain nutrients.

Also in Iran, change from pasture to dryland farming on Inceptisols was found to have degraded soil and reduced SOC by about 67 percent. Recovery times can be very long indeed. For example, a study found that 30 to 60 years will be required to restore soil C to the initial content of rangeland ecosystems of Chaharmahal and Bakhtiari Province in Central Iran. After more than a century of cultivation, SOC in the top 0-15 and 15-30 cm had reduced by 25-34 percent (Chigani, Khajeddin and Karimzadeh, 2012).

The change in SOC depends on soil type. For example, continuous cultivation of Cambisols in northern Iran tends to decrease C by 29 to 74 percent as compared to grass or forest use respectively, whereas the equivalent decline for Vertisols is only 11 to 59 percent.

Another study on soil quality indicators potentially sensitive to land degradation due to land use change was carried out in a rangeland pasture in Iran's Isfahan Province that had been protected for more than two decades (Nael, Khademi and Hajabbasi, 2004). The study showed that C content in the protected range was close to double (1.7 times) that of areas of uncontrolled grazing. This study clearly indicated that in the dryland of this region, decisions that control grazing are favourable for soil C storage.

In another study, four decades after conversion from oak forest (*Quercus brantii* Lindl.) to vegetable cultivation (tomato and snap bean), soils had lost almost 53 percent of C (Fallahzadeh and Hajabbasi, 2012b). A further study found that twenty years after oak forest (*Quercus brantii*) in the Lordegan region of Iran's Zagros mountains was converted into either wheat or barley cultivation or agroforestry uses, soil C in the 0-30 cm depth decreased by 52 and 61 percent, respectively (Hajabbasi *et al.*, 1997).

13.4.4 | Soil contamination

Land degradation due to accumulation of contaminants is concentrated in either oil producing countries or those that are heavily populated. In agricultural soils, contamination is generally restricted to irrigated farming systems. In some instances, the over-use of chemicals (fertilizers, pesticides and herbicides) has sharply increased the amount of chemical nutrients in the drainage water, causing water eutrophication (NAP, 2002). Since the construction of the Aswan High Dam of Egypt in 1970, fertilizers and pesticides have been heavily used in order to substitute for the loss of fertile sediments. FAO (2012) reported that during the period from 1950 to 1990, chemical fertilizer use increased more than fourfold, from 2 143 tonnes in the 1950s up to 11 700 tonnes in 1990. These chemical fertilizers and the residues of applied pesticides have caused the contamination of soil and water resources in the Nile Delta.

In Iran, contamination of soil is increasing from a variety of sources: petroleum hydrocarbons spilled during transportation, leakage from tanks, accidental spillage, pipeline ruptures, or dumping of oil landfill. This contamination threatens soil functions. It may decrease seed germination of grasses by more than 50 percent (Besalatpour *et al.*, 2008) – although this may not necessarily affect their subsequent performance. It also reduces dry matter accumulation in sunflower and safflower by 50 and 73 percent, respectively (Besalatpour *et al.*, 2008). The two Gulf wars in 1990 and 1991 contributed to contamination of this kind through the detonation of oil wells (Al-Senafy *et al.*, 1997; Misak, Khalaf and Omar, 2009).

Case study: Kuwait experience in remediation of oil contamination

After the Iraq war, over 300 oil lakes covering an area of 46 km^2 were formed within Kuwait. The lakes were up to two meters deep, and the oil penetrated the soil to varying depths. To restore areas degraded by oil, the Kuwait Institute for Scientific Research and the Japan Petroleum Energy Centre began in 1994 to devise biological technologies for remediation and rehabilitation (Figure 13.3).

In a small scale pilot (1 920 m_2) and in field demonstrations, heavily oil contaminated soil was remediated over a 12-18 month period, using bioremediation techniques involving enhanced land farming techniques, windrow composting piles, and static bioventing piles. The programme resulted in 80-90.5 percent reduction in the total petroleum hydrocarbons and total alkanes (Al Awadhi, 1996; Balba *et al.*, 1998). This technology is considered to be economical, energy efficient, and environmentally friendly with minimal residue disposal problems. However, the volatilization of airborne volatile organic compounds in the atmosphere during the process of degradation may lead to serious human health risk (Hejazi, Hussain and Khan, 2003).

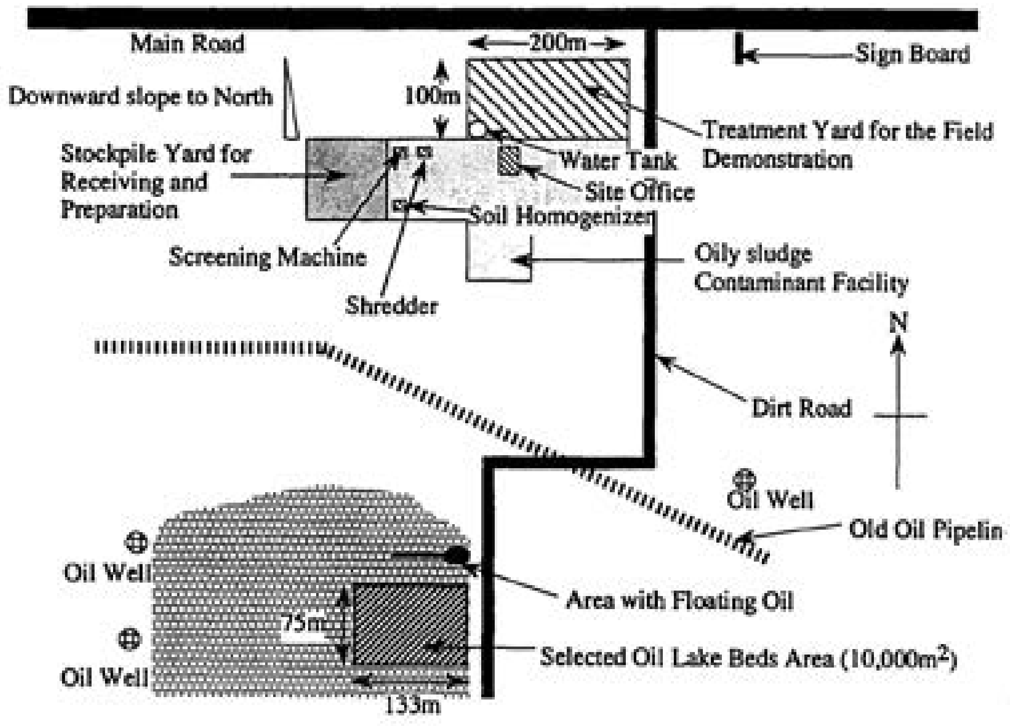

Fig. 1. Layout of the project site.

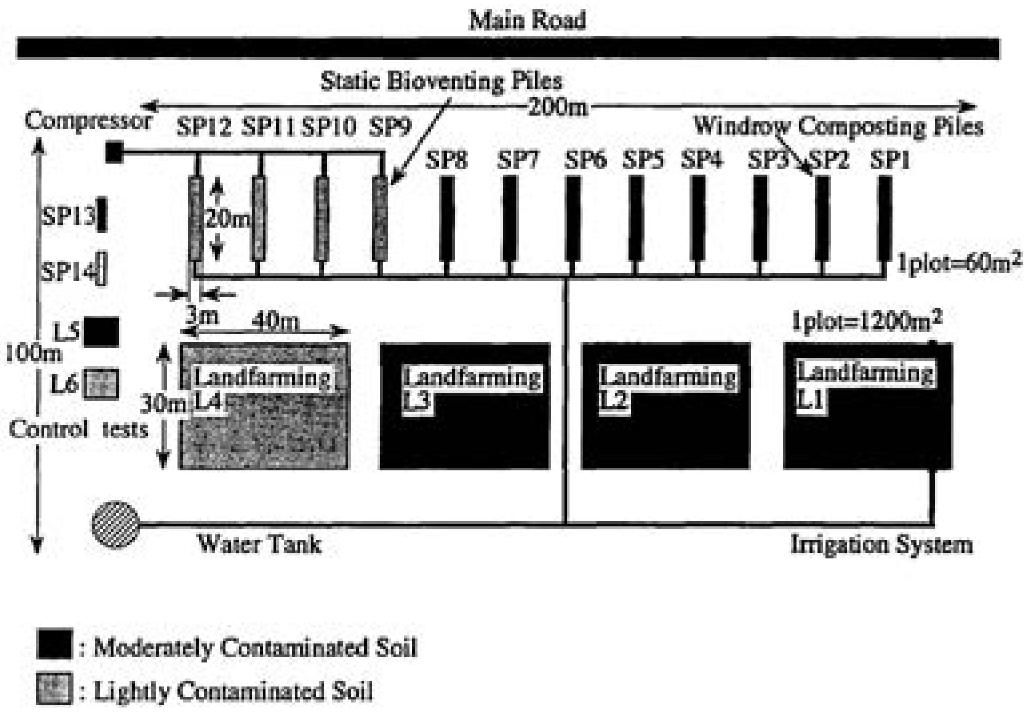

Fig. 2. Conceptual design and layout of bioremediation system.

Figure 13.3 | Layout of the project site source (a) and conceptual design and layout of bioremediation system (b). Source: Balba et al., 1998.

Contamination of soil by heavy metals is also an issue (Misak, Khalaf and Omar, 2009). In central Iran, farmers are extensively using sewage sludge as a fertilizer for vegetable production and, in the absence of regulation, heavy metals tend to accumulate in the soil (Afyuni, Rezaeinejad and Schulin, 2006). The so-called 'global dust belt' that extends from the west coast of North Africa, through the Middle East into Central Asia (see Section 7.4) transports mineral dust in the region. This dust may carry contaminants and this has been in fact the main source of soil pollution with heavy metals in the Arabian Peninsula. The dust was found to carry high levels of lead (65 mg kg^{-1} in Muscat, 742 mg kg^{-1} in Bahrain and 1762 mg kg^{-1} in Riyadh, Saudi Arabia) and nickel (43 to 3033 mg kg–1 in Muscat) (Yaghi and Abdul-Wahab, 2004).

In general, soil contamination depends on the distribution of contaminants influenced by high intensity rainfall of short duration that results in short runoff, by dust storms, and by human induced factors such as mixing residual oil with soil, transport to new areas and dumping in selected sites.

Responses to soil contamination

Regional policies for combating desertification

Most NENA countries have policies and programmes for protection of natural resources, including combating desertification. However, many of these policies and programmes (e.g. in Jordan) emphasize protective measures, and do not adequately consider rehabilitation or the dimension of the economic and social cost of land degradation (Al Karadsheh, Akroush and Mazahreh, 2012).

Iran has implemented nine strategies for sustainable development. Egypt has strategies for each agro-ecological zone. Lebanon has initiated a large-scale reforestation program and is very active in fighting the root causes behind land degradation, mainly by promoting the development of rural areas and reducing regional disparities. The national efforts to combat desertification in Oman have concentrated on development and conservation of water resources, improvement of land capability and rehabilitation of rangeland. Saudi Arabia has programmed an array of activities including capacity building, controlling urbanization, sustainable agricultural development, improvement of water sector, legislation, rehabilitation of degraded rangelands, forest development and sand dune stabilization. Sudan is integrating strategies for poverty alleviation with programmes to combat desertification and these include activities for improvement of land resources, production systems and protection of the environment. Syria has implemented many projects aimed at expansion of plant cover, controlling desert invasion, establishment of protected areas and green oases, sand dune fixation and afforestation. United Arab Emirates has ambitious programmes to improve degraded ecological systems, conserve biodiversity, mitigate climate change effects, and combat desertification.

13.5.1 | Case study: Iran

Soil nutrient changes

Change in land use and the use of fertilizers are the main factors affecting soil nutrient change in Iran (Shiranpour, Bahrami and Shabanpour, 2011). A study in Gilan Province compared the status of forest soils and the same soils turned into tea gardens over a period of 10 to 40 years and showed a significant decline in the amounts of nitrogen, potassium, phosphorus, calcium and exchangeable magnesium. Deforestation effects on soil nutrient losses have been studied in Kajoor watershed in Sari city where results indicated significant losses of organic matter and phosphorus. Land uses and different management types were compared in the Taleghan area. The study showed the negative effect of irrigation and monoculture on soil nutrients, while horticulture and pasture land uses scored better (Sohrabi and Zehtabian, 2012).

Soil pollution changes

In Iran, surveys carried out in areas where soil pollution occurs indicate that heavy elements make up the majority of soil contaminants. These pollutants originate from a range of sources, including geological and mining sources, industrial pollution, petroleum spills, sewage sludge application and excessive usage of fertilizers on agricultural soils.

Losses and sequestration of soil carbon

Loss of organic matter in soils of Iran is among the most important consequences of soil erosion. Greening barren land and improving soil management can significantly increase soil carbon sequestration. Forest ecosystems in equilibrium, with both trees and other vegetation cover, are the principal reservoir of organic carbon. Varamesh *et al*. (2010) assessed the effects of reforestation in Tehran Cheetgar Park on carbon sequestration and soil characteristics. The study indicated that soil carbon sequestration of *Acacia senega*.is equal to 78 tonnes ha^{-1}, and of Conifer Species 57 tonnes ha^{-1}. In general, the carbon sequestration process led to improvement of soil and water quality, increased fertility and an improved soil hydrology system as well as preventing erosion and reducing nutrient loss.

Salinity changes

Yazdani-Nejad and Torabi-Golsefidi (2013) examined the spatial variations and salinity zoning of agricultural soil in an area of southern Tehran. About 30.4 percent of the area, covering 20 000 ha, was found to be without any salinity problem. These lands were located mainly in areas where irrigation water from deep wells was used. A further 42.4 percent of the land had an electrical conductivity of 2 to 4 dS m^{-1}. In these sections, irrigation was with water from deep wells but wastewater was also used for irrigation due to water use restrictions. Zones with conductivity of 4 to 8 dS m^{-1} occupied 22.6 percent of the area, located in the flat plains in the southern part. These zones were frequently irrigated with waste water and water from shallow wells, and also with low quality water from the downstream sections of the Kan River. Finally, 4.5 percent of the land, located in low lying areas, had high electrical conductivity of 8 to 13 dS m^{-1}. The overall finding of the study was that it was the position of the land in the landscape, the depth to the water table and the quality of the irrigation water that determined the degree of salinization of the land. Other factors that may play a role are the length of the interval between irrigations and the texture of the soils.

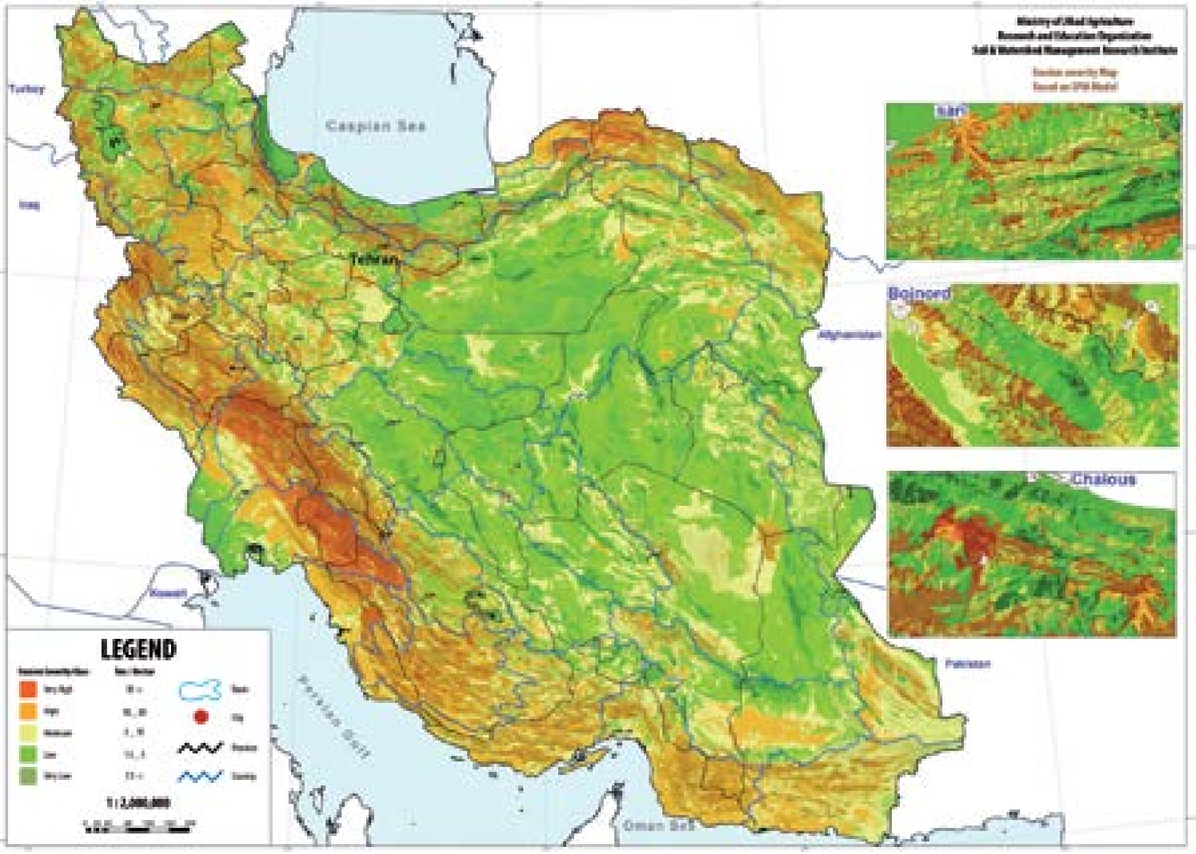

Figure 13.4 | Rate of water erosion in Iran.
Source: Soil Conservation and Watershed Management Research Institute.

Water erosion

In Iran about 40 percent of the country experiences a low erosion rate (less than 10 tonnes ha^{-1}), 25 percent of the area has a moderate rate of water erosion (10 to 20 tonnes ha^{-1}), 23 percent area of the country has a high erosion rate (20 to 50 tonnes ha^{-1}), and 12 percent has a very high erosion (more than 50 tonnes ha^{-1}). Figure 13.4 shows the erosion rates in different regions of Iran.

Results of recent research conducted in the watersheds of the country in recent years suggest an increased rate of erosion according to various models used (Hosseinkhani, 2013; Kavian *et al.*, 2014; Karam, Safarian and Hajjeh Froshnia, 2010; Zomorodian and Rahimi, 2012; Bayat *et al.*, 2011; Naderi, Karimi and Naseri, 2010; Zare Bidaki and Badri, 2014). Land-use change is one of the most important factors that exacerbate erosion in basins (Mohamadzade, Charm and Eskandari, 2014; Ajami, Khormali and Ayoubi, 2012).

Wind erosion

In Iran's deserts and arid areas, rapid changes in temperature cause pressure gradients in different parts which result in constant strong winds. Due to these strong winds and to the lack of moisture and vegetation, both small and large soil particles are transported, leading to soil erosion and deposition (Mehrshahy and Nakoonam, 2009). Sand dunes are estimated to cover 12 million ha. Half of these dunes are active or semi-active (Refahi, 2004). The density of air deposits measured over a 40 year period shows a growing trend in wind erosion in recent years. Sediment textures have also changed, with a significant increase in evaporated deposits such as salts and gypsum.

Studies show that both climatic and human factors play an important role in the development of wind erosion. The most important climatic factors are rainfall patterns, rising temperatures, intense evaporation from the playa, and reduced intake of water. High wind strengths also reduce the moisture level of the soil and enhance wind erosion rates. The human factor is related to land use and concerns the reduction of water entering the playa because of dam construction and excessive pressure on pastures and agricultural land in recent years (Hosseinzade, Khaneabad and Bargi, 2011).

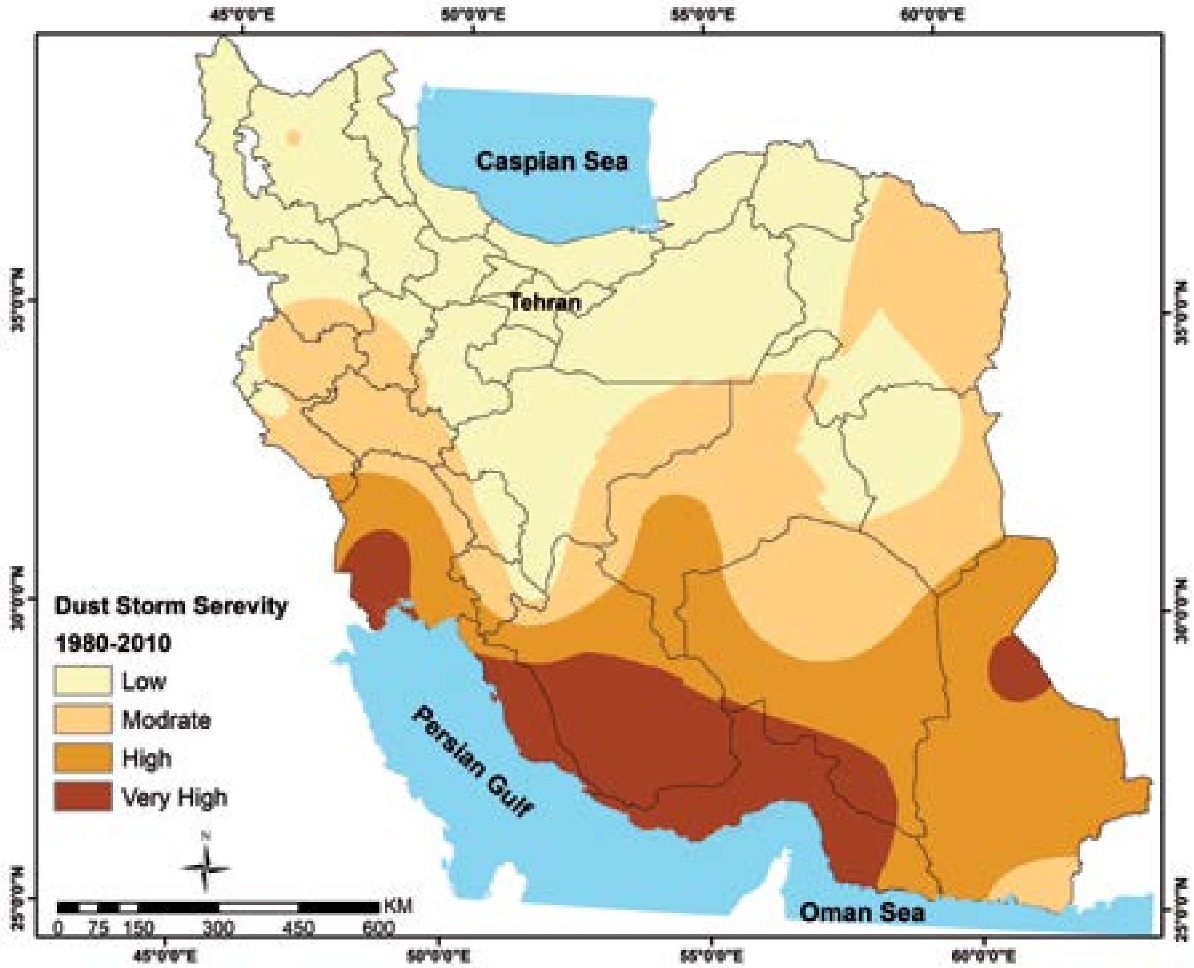

Figure 13.5 | shows days with dust storms in 2012, while Figure 13.6 shows the origin of dust storms in 2012.

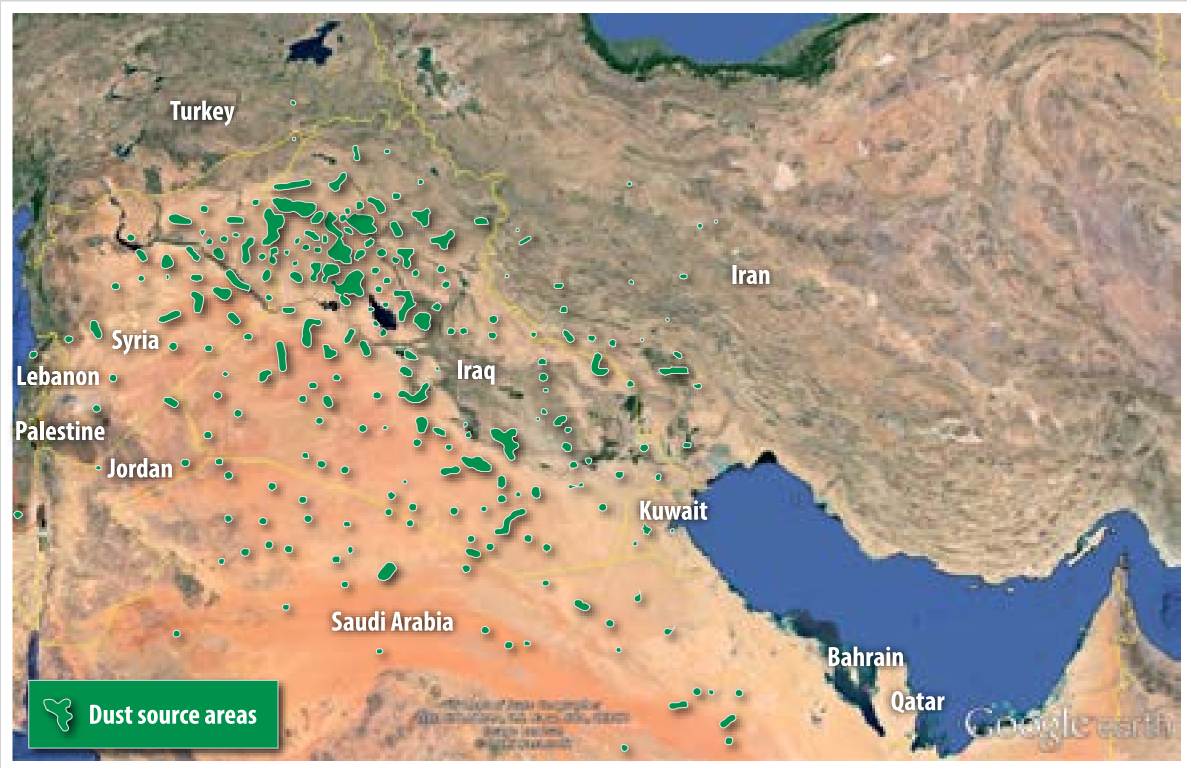

Figure 13.6 | Internal and external dust sources in recent years in Iran.
Source: University of Tehran, 2013.

The origin of dust in dust storms in Iran is both internal and external to the country. Since 2006 considerable dust has affected the west and south west of the country, originating from Iraq and Syria. Other areas such as parts of Jordan, Kuwait and northern Saudi Arabia are also involved in the creation of dust in Iran (Jalali, Bahrami and Darvishi Bolurani, 2012). Although many recent dust storms in Iran have foreign origins, this does not mean that domestic sources play no part in this phenomenon (Fattahia, Noohia and Shiravand, 2012).

13.6.2 | Case Study: Tunisia

Between 2006 and 2010 a detailed study was undertaken to assess land degradation in Tunisia. A standardized methodology was adopted to map in an interdisciplinary way all aspects of land degradation (type, extent, degree, trends and impact on ecosystem services) at a national scale. The exercise involved a large number of national institutions and stakeholders, together with international expertise (FAO, 2011a). In addition, an inventory was made of successful local practices that combatted land degradation (FAO, 2011b). This study was complemented by three investigations at local level (in Kasserine, Siliana and Médenine) that refined the identification of the socio-economic pressures and drivers behind land degradation (FAO, 2011c). The results have subsequently been expanded and refined.

Major outcomes of the investigation, relevant for the present assessment of soil change and its impact on ecosystem goods and services were:

1 - The preparation of a national land use system map

The scale of this map is 1:500 000. It is based on a rasterized database at 30 arc seconds. It was prepared using a standard methodology (Nachtergaele and Petri, 2011). The draft map was validated by regional institutions in the country and was later refined by simplifying the pastoral classes and by introducing a specific unit that concerned alfalfa areas which make up 170 000 ha of the country.

2 - Land degradation assessment mapping

The assessment used a standard methodology (Liniger *et al.*, 2011) that allowed the participatory mapping of the major types of ecosystem degradation (soil, water and biological) and sub-types (for instance, water erosion, compaction, decline in ground water quality or reduction of vegetative cover). At the same time the intensity (degree) and the trend of the ongoing ecosystem change was evaluated on the basis of arbitrary classes (typically ranging from none to severe or slow to fast). The evaluation was conducted in a participatory way involving various stakeholders in the assessment and using hard data where they were available. The direct pressures (for instance improper soil management, deforestation or natural causes) and the indirect socio economic causes (for instance lack of knowledge or investment) were also determined in the same participatory way, as was the impact on ecosystem goods and services. Examples illustrating the outcome of the assessment are given in the following maps which evaluate water erosion (Figure 13.7a) and wind erosion (Figure 13.7b). Differences in the extent of ongoing degradation processes in the country could also be mapped.

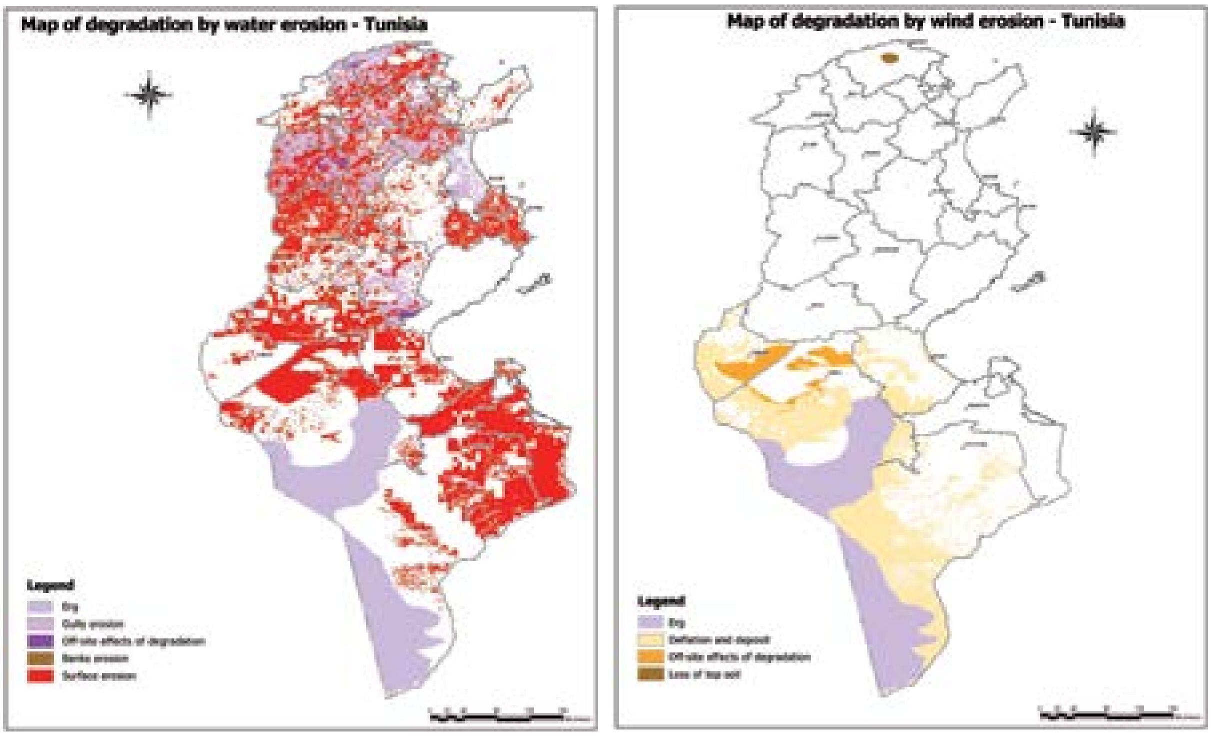

Figure 13.7 | Assessment of Water (a) and Wind Erosion (b) in Tunisia

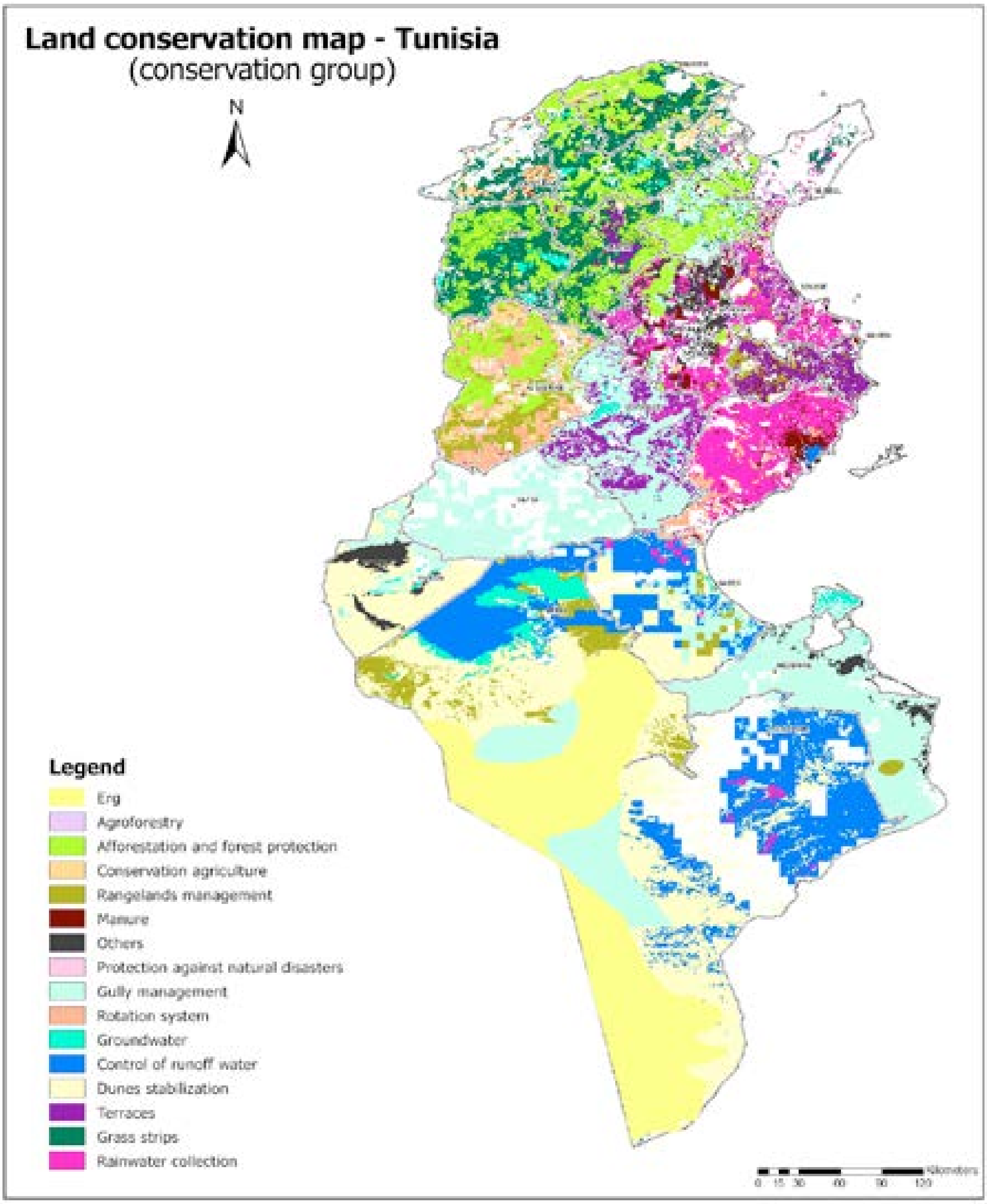

Figure 13.8 | Soil Conservation in Tunisia

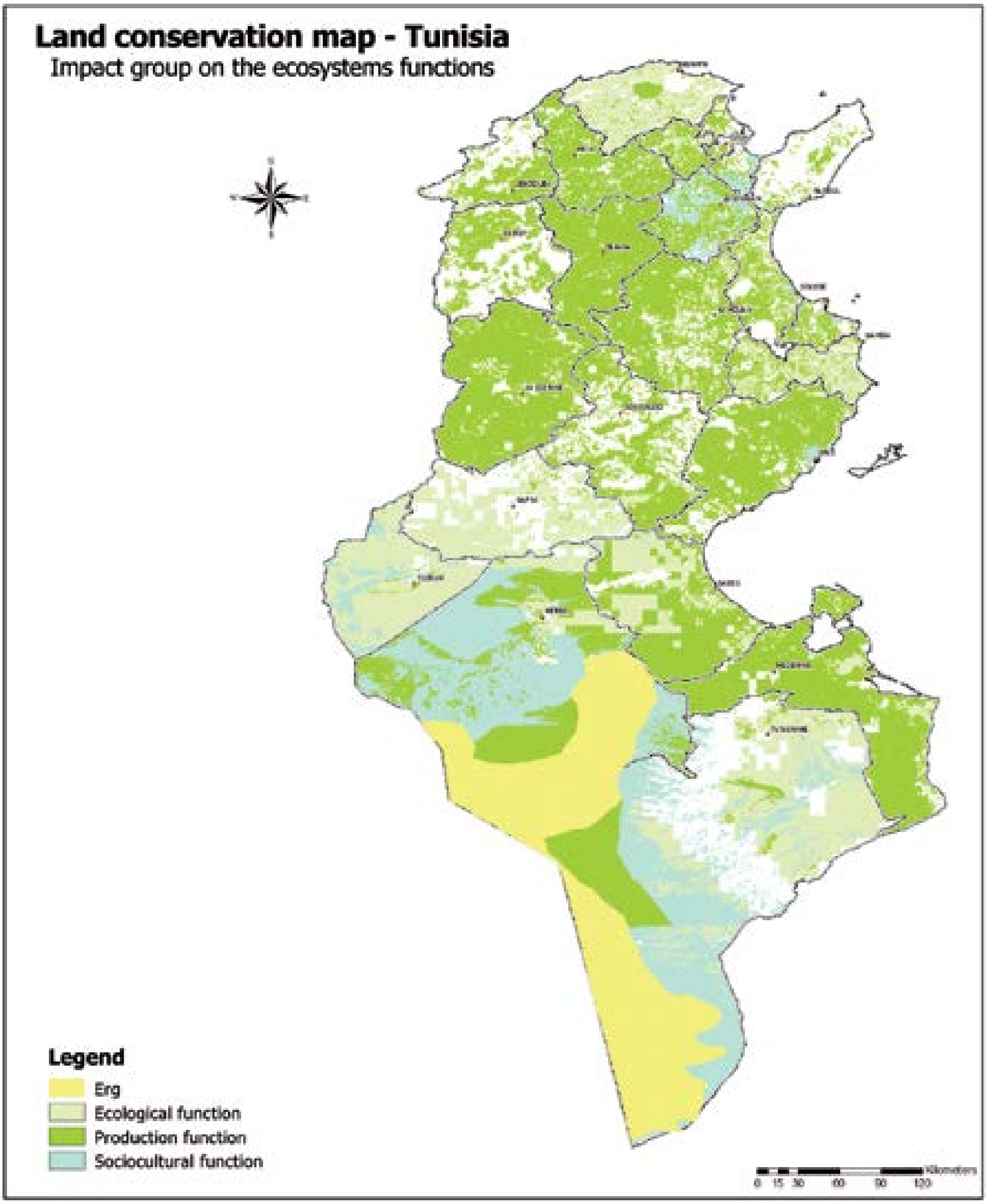

Figure 13.9 | Type of ecosystem service most affected.

3 - Sustainable land management mapping.

In each unit of the national map, the prevailing land management practices were inventoried using a standard methodology (Liniger *et al.*, 2011). This allowed the characterization of practices in terms of type of intervention (agronomic, vegetative etc) and in terms of objectives (prevention, mitigation or rehabilitation). At the same time, the extent, trend and efficiency of the conservation practices were assessed. Examples of outputs are given for the main conservation types used in the country (Figure 13.8.) and for the impact of soil degradation on ecosystem goods and services (Figure 13.9.).

13.6 | Conclusions

Although there is a wealth of local and national studies on soil change in the region, a systematic and standardized approach is lacking. Results on the extent and intensity of soil change processes still refer to the GLASOD study carried out in the late 1980s.

The degradation of natural resources in arable lands is considered as one of the main threats to agricultural production in all countries of the region. Ecosystem service quality and capacity is greatly reduced by degradation caused by salinity, erosion, contamination and poor management that leads to a loss of soil organic matter. Water erosion is predominant in that part of the region which has sloping lands. Where rainfed agriculture is practiced, water erosion may even occur in gently sloping areas. Wind erosion is also a causative factor of topsoil removal. Population increase has resulted in soil disturbance due to uncontrolled human activities such as mining and open quarries that have triggered and accelerated erosion processes. Degradation due to salinity and sodicity varies geographically with climate, agricultural activities, irrigation methods and land management policies and is mainly restricted to irrigated farming systems. Causative factors are of intrinsic origin, seawater intrusion or irrigation from groundwater with elevated salt content. Degradation due to contamination is mainly found in countries with high population, high oil production or heavy mining. In irrigated farming systems with overuse of chemicals, the load of toxic elements in groundwater is increased. Salinity has greatly reduced crop yields and increased economic annual losses across the region to nearly US\$1 billion, equivalent to as much as US\$1 604 ha^{-1} to US\$2 748 ha^{-1}. In some countries the reduction in soil productivity was estimated to be in the range of 30-35 percent of the potential productivity.

Responses to degradation caused by erosion include improving soil resilience by increasing C inputs. This can be achieved using organic manures, compost and synthetic soil conditioners and soil conservation measures on sloping lands. Policies and regulation and socio-economic factors at individual country level were found to help reverse land degradation due to erosion. Ways of reclaiming salt-affected soils include: salt leaching and drainage interventions, crop-based management, chemical and organic amendments, fertilizers, salt tolerant plants, crop management and phytoremediation. Measures to contain degradation caused by oil contamination include farming techniques that partly eliminate hydrocarbons through decomposition, and bio-remediation using some grass species. With effective desertification control, the potential annual C sequestration rate could reach values between 0.2 to 0.4 Pg C yr^{-1}, compared to the 1.0 Pg C yr^{-1} in drylands worldwide. Ranking of soil threats is given in Table 13.3.

Stable =

Variable ↗↙

Improving ↗

Deteriorating ↙

Evidence and consensus is **low**

Evidence and consensus are **limited**

Adequate high-quality evidence and **high level** of consensus

Table 13.3 | Summary of soil threats: Status, trends and uncertainties in the Near East and North Africa

Threat to soil function	Summary	Condition and Trend					Confidence	
		Very poor	Poor	Fair	Good	Very good	In condition	In trend
Soil erosion	Wind erosion and dust storms are a problem throughout the region. Sand stabilization in source areas is difficult and expensive to undertake. Water erosion can be controlled with adaptive management.	↙					Adequate	Adequate
Salinization and sodification	Salinization is a widespread problem in the region due to the high temperatures, inappropriate irrigation practices and sea water intrusion in coastal areas. There is adequate research and technical knowledge in the region to counteract the problem. Socio-economic conditions hamper widespread implementation in some countries.		↙				Adequate	Adequate
Organic carbon change	High temperatures throughout most of the region result in a very high turnover of soil organic Carbon. SOC change is sensitive to soil management changes.		↙				Limited	Limited
Contamination	Contamination is locally a significant problem in the region particularly in urbanized areas that produce waste dumped on the land and in oil producing areas.	↙					Adequate	Adequate
Sealing	Substantial expansion of housing, quarrying and infrastructures is a concern. There are no reliable data on sealing and land take.	↙					Adequate	Adequate
Compaction	Compaction is a problem where heavy clay soils are intensively tilled (e.g. rainfed and irrigated Vertisols) and to a lesser extent is caused by off-road vehicles.		↙				Limited	Limited

Loss of soil biodiversity	The extent of loss of soil biodiversity due to human impact is largely unknown in the NENA region. More studies need to be undertaken to understand the scope of the problem.		↙					
Soil acidification	Given the dry conditions throughout most of the region, acidification is restricted to some coastal areas with higher rainfall.					=		
Nutrient imbalance	Nutrient imbalances occur in areas with continuous cultivation where nutrients are lost in harvested crops and no engagement in fallowing, manuring or mineral fertilizer application.				=			
Waterlogging	Waterlogging is a very localized problem in the region limited to flash floods, heavily irrigated areas and excessive rise in subsoil water level.				=			

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