Chapter 2
Soil Salinity: Historical Perspectives and a World Overview of the Problem

Shabbir A. Shahid, Mohammad Zaman, and Lee Heng

Abstract Soil salinity is not a recent phenomenon, it has been reported since centuries where humanity and salinity have lived one aside the other. A good example is from Mesopotamia where the early civilizations first flourished and then failed due to human-induced salinization. A publication '*Salt and silt in ancient Mesopotamian agriculture'* highlights the history of salinization in Mesopotamia where three episodes (earliest and most serious one affected Southern Iraq from 2400 BC until at least 1700 BC, a milder episode in Central Iraq occurred between 1200 and 900 BC, and the east of Baghdad, became salinized after 1200 AD) have been reported. There are reports clearly revealing that '*many societies based on irrigated agriculture have failed'*, e.g. Mesopotamia and the Viru valley of Peru. The flooding, over-irrigation, seepage, silting, and a rising water table have been reported the main causes of soil salinization. Recent statistics of global extent of soil salinization do not exist, however, various scientists reported extent differently based on different data sources, such as there have been reports like, 10% of the total arable land as being affected by salinity and sodicity, one billion hectares are covered with saline and/or sodic soils, and between 25% and 30% of irrigated lands are salt-affected and essentially commercially unproductive, global distribution of salt-affected soils are 954 million ha, FAO in 1988 presented 932 million ha salt-affected soils, of almost 1500 million ha of dryland agriculture, 32 million ha are salt-affected. Precise information on the recent estimates of global extent of salt-affected soils do not exist, many countries have assessed their soils and soil salinization at the national level, such as Kuwait, United Arab Emirates, Middle East, and Australia etc. Considering the current extent of salt-affected soils the cost of salt-induced land degradation in 2013 was $441 per hectare, a simple benefit transfer suggests the current annual economic losses could be $27 billion.

Keywords Historical perspective · Mesopotamia · Iraq · Global extent · Economic losses · Viru valley

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1 Introduction

Soil salinity is a major global issue owing to its adverse impact on agricultural productivity and sustainability. Salinity problems occur under all climatic conditions and can result from both natural and human-induced actions. Generally speaking, saline soils occur in arid and semi-arid regions where rainfall is insufficient to meet the water requirements of the crops, and leach mineral salts out of the root-zone. The association between humans and salinity has existed for centuries and historical records show that many civilizations have failed due to increases in the salinity of agricultural fields, the most known example being Mesopotamia (now Iraq). Soil salinity undermines the resource base by decreasing soil quality and can occur due to natural causes or from misuse and mismanagement to an extent which jeopardizes the integrity of soil's self-regulatory capacity.

Soil salinity is dynamic and spreading globally in over 100 countries; no continent is completely free from salinity (Fig. 2.1). Soil salinization is projected to increase in future climate change scenarios due to sea level rise and impact on coastal areas, and the rise in temperature that will inevitably lead to increase evaporation and further salinization. Salinization of soils can affect ecosystems to an extent where they no longer can provide 'environmental services' to their full potential. It is realized that recent estimates of the global extent of soil salinization do not exist. But it can be assumed that, since the earlier data gathering in the 1970s and 1980s, salinization has expanded as newly affected areas most probably exceed the areas restored through reclamation and rehabilitation. There is a long list of countries where salt-induced land degradation occurs. Some well-known regions where salinization is extensively reported include the Aral Sea Basin (Amu-Darya and Syr-Darya River Basins) in Central Asia, the Indo-Gangetic Basin in India, the

Fig. 2.1 World map representing countries with salinity problems. (https://www.researchgate.net/publication/262495450)

Indus Basin in Pakistan, the Yellow River Basin in China, the Euphrates Basin in Syria and Iraq, the Murray-Darling Basin in Australia, and the San Joaquin Valley in the United States (Qadir et al. 2014).

2 Soil Salinity – A Historical and Contemporary Perspective

For centuries, humanity and salinity have lived one aside the other. There is good evidence for Mesopotamia that early civilizations flourished and then failed due to human-induced salinization. Jacobson and Adams (1958), in their publication, '*Salt and silt in ancient Mesopotamian agriculture'* highlighted the history of salinization in Mesopotamia. Ancient records show three episodes of soil salinization in Iraq. The earliest and the most serious one affected Southern Iraq from 2400 BC until at least 1700 BC. A milder episode in Central Iraq occurred between1200 BC and 900 BC, and there is archeological evidence that the Nahrwan area, east of Baghdad, became salinized after 1200 AD. Flooding, over-irrigation, seepage, silting, and a rising water-table are considered to be the main reasons for these episodes of increased salinization (Gelburd 1985).

In southern Iraq in 3500 BC, both wheat and barley were equally important cultivated crops, though after 100 years wheat had slipped to one sixth, and by 2100 BC, its cultivation had become almost insignificant, dropping to only 2%. By 1700 BC, wheat cultivation was completely phased out. Historical records show that concurrent with the shift to barley cultivation, there was an appreciable and serious decline in soil fertility and gradual declines in barley yields, which for the most part can be attributed to salinization (Jacobson and Adams 1958). Thus, after almost 5000 years of successful irrigated agriculture, the Sumerian civilization failed. In the Indus plains of Pakistan and India, the practice of irrigation began about 2000 years ago during the Harapa civilization, but it is only recently that serious problems of salinity and sodicity are being encountered. In the Viru valley of Peru, irrigated agriculture began between 800 BC and 30 AD (Wiley 1953), and by 800 AD, the population was at a peak. Then from 1200 AD, the population declined appreciably and the residents of the once densely populated Viru valley bottom relocated to more narrow upper reaches of the valley. The historians partly attribute this relocation to increased salinity and a rising water- table, together with inadequate soil drainage (Armillas 1961). Tanji (1990) draws a historical perspective of irrigation-induced salinity in several regions. In a similar perspective, general remarks by Wiley (1953) clearly reveal that '*many societies based on irrigated agriculture have failed'*, e.g. Mesopotamia and the Viru valley of Peru.

3 An Overview of Salinity Problem

The earth's land surface is 13.2×10^9 ha, but only 7×10^9 ha of this is arable, of which only 1.5×10^9 ha is currently cultivated (Massoud 1981). Of the cultivated lands, about 0.34×10^9 ha (23%) are saline and 0.56×10^9 ha (37%) are sodic. Older estimates (Szabolcs 1989) described 10% of the total arable land as being affected by salinity and sodicity, with the effects extending to over 100 countries in all continents. One billion hectares of the 13.2×10^9 hectares of the land is, thus, covered with saline and/or sodic soils, and between 25% and 30% of irrigated lands are salt-affected and essentially commercially unproductive.

The countries affected by salinization are predominantly located in arid and semi-arid regions, where continued irrigation with low quality groundwater has taken place. Low rainfall has also contributed to the expansion of salt-affected soils. The largest area of the world's saline soils occurs in the arid and semi-arid regions (Massoud 1974; Ponnamperuma 1984), where evapotranspiration exceeds precipitation. The rapid conversion into barren land through salinity/sodicity has negatively affected the environment and has substantially altered natural resources in a number of countries. Worldwide, some ten million hectares of irrigated land is abandoned annually because of salinization, sodication and waterlogging (Szabolcs 1989). These degraded soils occur principally in the hot arid and semi-arid regions, although they have also been recorded in Polar Regions (Buringh 1979).

Global statistics on salt-affected soils vary according to different data sources. Saline soils occupied more than 20% of the world's irrigated area by the mid-1990s (Ghassemi et al. 1995). Since then, the extent of salinity has likely increased and, in some countries, salt-affected soils occur on more than half of the irrigated lands (Metternicht and Zinck 2003). Kovda and Szabolcs (1979) reported global distribution of salt-affected soils as 954 million ha. Data summarized from Szabolcs (1974) for Europe and Massoud (1977) for the other continents, as reported by Abrol et al. (1988) in FAO Soils Bulletin 39, presents 932.2 million ha of salt-affected soils (Table 2.1). Of almost 1500 million ha of dryland agriculture, 32 million ha are salt-affected (FAO 2000). Although recent estimates of global extent of salt-affected soils do not exist, many countries have assessed their soils and soil salinization levels at the national level, such as Kuwait (Shahid et al. 2002), United Arab Emirates

Table 2.1 Worldwide distribution of salt-affected areas (Million ha)

Area	Saline soils	Sodic soils	Total	Percent
Australasia	17.6	340.0	357.6	38.4
Asia	194.7	121.9	316.5	33.9
America	77.6	69.3	146.9	15.8
Africa	53.5	26.9	80.4	8.60
Europe	7.8	22.9	30.8	3.30
World	**351.2**	**581.0**	**932.2**	**100**

Source**:** Abrol et al. (1988) in FAO Soil Bulletin 39; Summary of data for Europe (Szabolcs 1974) and for other continents (Massoud 1977)

(EAD 2009, 2012), Middle East (Hussein 2001; Shahid et al. 2010), and Australia (Oldeman et al. 1991).

In a comprehensive overview of the global identification of salinity problems and the global salinity status, Shahid (2013) reported that about 200×10^6 hectares of land is affected by salinity in Southwest USA and Mexico. In Spain, Portugal, Greece, and Italy, saltwater intrusion into aquifers is appreciable; in Spain more than 20% of the land area is desert, or is seriously degraded and, thus, nonproductive.

In the Middle East, 20×10^6 hectares are affected by increased soil salinity, the reasons being poor irrigation practices, high evaporation rates, growth of ***sabkhas*** (salt scalds), and an increase in groundwater salinity. In addition, productivity of the irrigated lands of the Euphrates basin (Syria, Iraq) is seriously constrained by salinity. In Iran, 14.2% of the total land area is salt-affected (Pazira 1999). In Egypt, 1×10^6 hectares of land which could be cultivated along the Nile is salt-affected. Salt accumulation in the Jordan River basin adversely affects agricultural production in Syria and Jordan. In Africa, 80×10^6 hectares is saline, sodic, or saline-sodic, of which the Sahel, in West Africa, is the most affected.

In Asia, 20% of India's cultivable land, mainly in Rajasthan, coastal Gujarat, and the Indo-Gangetic plains, is affected by salinity or sodicity. In Pakistan, 10×10^6 hectares is affected and about 5–10 hectares per hour is lost to salinity and/or waterlogging in coastal regions and in the irrigated Indus basin. In Bangladesh, 3×10^6 hectares is unproductive due to salinity. In Thailand, 3.58×10^6 hectares is salt-affected (3.0×10^6 hectares being inland and 0.58×10^6 hectares being coastal saline soils). In China, 26×10^6 hectares of their total land area is salt-affected (Inner Mongolia, the Yellow River basin and tidal coastal regions), while in Australia the extent of saline soils is 357×10^6 hectares.

The global extent and distribution of 76.6 million hectares of human-induced salt-affected soils (Oldeman et al. 1991) and a similar distribution for irrigated lands affected by secondary salinization (Ghassemi et al. 1995) are presented in Tables 2.2 and 2.3. These soils are distributed in desert and semi-desert regions, frequently occurring in fertile alluvial plains, river valleys, coastal areas and in irrigation districts. The countries where significant salinity problems exist include, but are not limited, to Australia, China, Egypt, India, Iran, Iraq, Mexico, Pakistan, the

Table 2.2 Global extent of human-induced salinization (Oldeman et al. 1991; Mashali 1995)

	Degree of salinization and affected area (mha)					
Continent	Light	Moderate	Strong	Extreme	Total	Percent
Africa	4.7	7.7	2.4	–	14.8	19.3
Asia	26.8	8.5	17.0	0.4	52.7	68.8
South America	1.8	0.3	–	–	2.1	2.7
North & central America	0.3	1.5	0.5	–	2.3	3.0
Europe	1.0	2.3	0.5	–	3.8	5.0
Australia	–	0.5	–	0.4	0.9	1.2
World total	**34.6**	**20.8**	**20.4**	**0.8**	**76.6**	**100**

Table 2.3 Global estimates of secondary salinization in the world's irrigated lands. (Summarized from Ghassemi et al. 1995; Mashali 1995)

Country	Area (mha)		
	Cropped	Irrigated	Salt-affected[a]
China	97.0	44.8	6.7 (15)
India	169.0	42.1	7.0 (17)
Commonwealth of independent states	232.5	20.5	3.7 (18)
United States of America	190.0	18.1	4.2 (23)
Pakistan	20.8	16.1	4.2 (26)
Iran	14.8	5.8	1.7 (29)
Thailand	20.0	4.0	0.4 (10)
Egypt	2.7	2.7	0.9 (33)
Australia	47.1	1.8	0.2 (11)
Argentina	35.8	1.7	0.6 (35)
South Africa	13.2	1.1	0.1 (9)
Subtotal	**842.9**	**158.7**	**29.7 (19)**
World (Total)	**1474**	**227**	**45 (20)**

[a]Salt-affected soils within the irrigated area; values in parentheses are percentage

USSR, Syria, Turkey, and the United States. In Gulf States (Bahrain, Kuwait, Saudi Arabia, Qatar, Oman, and the United Arab Emirates), saline soils mainly occur in coastal lands (due to seawater intrusion), and also on agricultural farms irrigated with saline/brackish water.

Secondary salinization (i.e., soil salinization due to human activities such as irrigated agriculture) is predominantly located in the arid and semi-arid regions including Egypt, Iran, Iraq, India, China, Chile, Argentina, Commonwealth of Independent States, Spain, Thailand, Pakistan, Syria, Turkey, Algeria, Tunisia, Sudan and the Gulf States. About 76.6 million hectares (Table 2.2) of cultivated lands are salt-affected by human-induced processes (Oldeman et al. 1991; Mashali 1995; Ghassemi et al. 1995) and approximately 30 million ha can be attributed to secondary salinization of non-irrigated lands. However, according to Ghassemi et al. (1995), globally 20% or 45 million hectares out of a total 227 million hectares of irrigated land are salt-affected (Table 2.3).

4 Distribution of Salinity in Drylands in Different Continents of the World

As reported by UNEP (1992), the distribution of salt-affected soils in drylands in different continents is presented in Table 2.4. These soils are divided into two categories: saline (412 million hectares) and sodic (618 million hectares), totaling 1030 million hectares. Australasia has the widest distribution with 357.6 million hectares, followed by Africa with 209.6 million hectares.

Table 2.4 Salt-affected soils in drylands by continents (UNEP 1992; cf FAO-ITPS-GSP 2015)

Continent	Salt-affected area (mha)		
	Saline soils	Sodic soils	Total
Africa	122.9	86.7	209.6
Australasia	17.6	340.0	357.6
Mexico/Central America	2.0	–	2.0
North America	6.2	9.6	15.8
North and Central Asia	91.5	120.2	211.7
South America	69.5	59.8	129.3
South Asia	82.3	1.8	84.1
Southeast Asia	20.0	–	20.0
Total	**412.0**	**618.1**	**1030.1**

Table 2.5 Soil salinity caused by irrigation in major irrigating countries and in the world (Postel 1989)

Country	Area damaged	
	mha	% of irrigated land
India	20.0	36.0
China	7.0	15.0
United States of America	5.2	27.0
Pakistan	3.2	20.0
Soviet Union	2.5	12.0
Total	37.9	24.0
World	**60.2**	**24.0**

5 Irrigation Practices and Soil Salinization

The practice of irrigation, if not planned and managed properly, can result in increased soil salinization. An estimate (Postel 1989) shows that about 25% of the world's irrigated lands are damaged by salinity, while Adams and Hughes (1990) have reported that up to 50% of irrigated lands are affected by salt. Szabolcs (1989) states that no continent is free from salt-affected soils and serious salt-related problems occur in at least 70 countries. Table 2.5 shows the area of irrigated land damaged by salinization for the five worst-affected countries (Postel 1989).

6 Regional Overview of Salinity Problem

More recent estimates of the regional distribution of saline soils do not exist. There is a need to update this information in order to better understand the extent of the problem and to develop soil use and management policies. Such estimates are essential given the continuing decline of soil resources for food production. An earlier search of the literature (Mashali 1995; FAO-Unesco Soil map of the world

Table 2.6 Regional distribution of salt-affected soils (mha). (cf. Mashali 1995)

Region	Solonchak – saline phase	Solonetz – sodic phase	Total
North America	6	10	16
Mexico and Central America	2	–	2
South America	69	60	129
Africa	54	27	81
South and West Asia	83	2	85
South East Asia	20	–	20
North and Central Asia	92	120	212
Australasia	17	340	357
Europe	9	21	30
Total	**352**	**580**	**932**

1974) does, however, give an estimate of the extent of the regional distribution of salt-affected soils (Table 2.6). These estimates show the total extent to be 932 million hectares of salt-affected lands, with the maximum area occurring in the region of Australasia (357 million ha).

7 Extent of Soil Salinity in the Middle East

Information regarding the extent of salinization in the Middle East is very limited. However, some general information has been obtained through the use of Remote Sensing imagery and other methods. This information was used to develop a soil salinization map of the Middle East (Hussein 2001; Shahid et al. 2010). In this map, salinization was divided into four general categories: slight, moderate, severe and very severe, as shown in Table 2.7. Earlier, an estimated area of 209,000 hectares has been reported as being salinized in Kuwait (Hamdallah 1997), which is roughly 3% of the total Kuwait land area.

Table 2.7 shows an area of 11.2% of the Middle East being affected to varying levels by soil salinization. Realizing the soil salinity, a hazard to agriculture and to the ecosystem services, Shahid et al. (1998) described soil salinization as early warning of land degradation in Kuwait. Later, Shahid et al. (2002) interpreted the soil survey data (KISR 1999) using GIS and mapped soil salinity into different salinity zones, where area occupied by each zone is as: 4.1 – 10 dS m^{-1} (0.685%), 10.1 – 25.0 dS m^{-1} (4.37%), and more than 25 dS m^{-1} (7.06%). This concludes an area of about 12.1% affected to varying degrees of salinity in the entire state of Kuwait. In the Abu Dhabi Emirate (EAD 2009), an area of 35.5% (2,034,000 ha) has been depicted to be affected to varying degrees of soil salinity. The highly saline soils on the soil salinity map are confined to the coastal land (King et al. 2013), the areas of deflation plains, and inland ***sabkha*** (salt scald) where the groundwater levels approach the surface, creating large areas of aquisalids at the great group level of US soil taxonomy (Soil Survey Staff 2014; Shahid et al. 2014).

Table 2.7 Salinization classes and affected area in the Middle East (Hussein 2001; Shahid et al. 2010)

Class	Area km^2	Area %
Slight	113,814	1.72
Moderate	109,148	1.65
Severe	380,025	5.74
Very severe	138,204	2.09
Total	**741,191**	**11.2**

8 Socioeconomic Aspects of Soil Salinization

A comprehensive review of published literature revealed very few publications dealing with socioeconomic aspects of salt-induced land degradation. On the global level, generation of such information requires appreciable resources and the commitment of properly trained staff to the project. However, Qadir et al. (2014) conclude that previous studies show a limited number of highly variable estimates of the costs of salt-induced land degradation. Even so, they have made simple extrapolations from these studies and the estimates show that the global annual cost of salt-induced land degradation in irrigated areas could be US$ 27.3 billion in lost crop production. Based on these estimates, Qadir et al. (2014) recommended investing in the remediation of salt-affected lands and noted that remediation costs must be included in a broader national strategy for food security, and defined in national action plans.

Qadir et al. (2014) identified countries where such economic cost on salt-induced soil degradation has been reported, including but not necessarily limited to Australia, India, the United States, Iraq, Pakistan, Kazakhstan, Uzbekistan, and Spain. They further indicated that the valuation of the cost of salt-induced land degradation has been mainly based on estimates of crop production losses. However, it is unclear whether their comparisons are made with crop production values taken from land not affected by salinity.

Taking the above examples into account, Qadir et al. (2014) have concluded that, considering the current extent of global irrigated area 310 million hectares (FAO-AQUASTAT 2013) and 20% of this area as salt-affected (62 million hectares), and the inflation-adjusted cost of salt-induced land degradation in 2013 as US$ 441 per hectare, a simple benefit transfer suggests the current annual economic losses could be US$ 27.3 billion.

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