SABKHA ECOSYSTEMS

Tasks for Vegetation Science 42

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Sabkha Ecosystems

Volume II: West and Central Asia

Edited by

M. AJMAL KHAN

Department of Botany
University of Karachi
Karachi, Pakistan

BENNO BÖER

UNESCO Regional Office in the Arab State of Gulf
Doha, Qatar

GERMAN S. KUST

Institute of Soil Science
Moscow State University and
Russian Academy of Sciences
Moscow, Russian Federation

and

HANS-JÖRG BARTH

Department of Physical Geography
University of Regensburg
Regensburg, Germany

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Cover photograph caption: The Dasht-e Kevir, or Great Salt Desert, is the largest desert in Iran. It is primarily sabkha, composed of mud and salt marshes. This image was acquired by Landsat 7 Enhanced Thematic Mapper plus (ETM+) sensor on October 24, 2000. It is a false-color composite image made using infrared, green, and red wavelengths. The image has also been sharpened using the sensor's panchromatic band. The image was kindly provided by NASA through the Visibleearth website http://visibleearth.nasa.gov/

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Contributing Authors

Abbas, Jameel A., Department of Biology, College of Science, University of Bahrain, P.O. Box 32038, Kingdom of Bahrain

Akhani, H., Department of Biology, University of Tehran, Faculty of Science, P.O. Box 14155-6455, Tehran, Iran

Al-Jaloud, ***Ali A.,*** Natural Resources and Environment Research Institute (NRERI) King Abdulaziz City for Science and Technology (KACST) P.O. Box 6086 Riyadh 11442, Kingdom of Saudi Arabia

Al-Thani, R. F., Department of Biological Sciences, Faculty of Science, University of Qatar, P.O. Box 2713, Doha, Qatar

Al-Youssef, M., Geology Department, University of Qatar, Doha, Qatar

Böer, B., UNESCO Regional Office in the Arab States of the Gulf, Doha, P.O. Box 3945, Qatar

Brown, G., Environmental Research and Wildlife Development Agency, TERC, P.O. Box 45553, Abu Dhabi, UAE

Bulatov, V. I., Institute for Water and Environmental Problems, Siberian Branch, Russian Academy of Sciences, Barnaul, Russian Federation

Chernykh, D. V., Institute for Water and Environmental Problems, Siberian Branch, Russian Academy of Sciences, Barnaul, Russian Federation

Dikareva, Tatiana V., Geographical Faculty, Moscow State University, 119992, Moscow, Leninskie gory. Russian Federation

El-Bana, Magdy I., Department of Biological & Geological Sciences, Faculty of Education at El-Arish, North Sinai, Egypt

Elizarova, T. N., Institute of Soil Science and Agrochemistry, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russian Federation

Ghazanfar, Shahina A., Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB

Gork, G., Biology Department, Science & Arts Faculty, Mugla University, Mugla,Turkey

Guvensen, A., Botany Department, Science Faculty, Ege University, Bornova-Izmir, Turkey

Hussain, G., Natural Resources and Environment Research Institute (NRERI) King Abdulaziz City for Science and Technology (KACST) P.O. Box 6086 Riyadh 11442, Kingdom of Saudi Arabia

Khan, M. A., Department of Botany, University of Karachi, Karachi-75270, Pakistan

Klenov, B. M., Institute of Soil Science and Agrochemistry, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russian Federation.

Kouzmina, Janna V., Water Problems Institute, Russian Academy of Sciences, Gubkina ul. 3, Moscow, 119991 Russian Federation

Kust, German S., Institute of Soil Science of Moscow State University and Russian Academy of Sciences, 119992, Moscow, Leninskiye gory Moscow, Russian Federation

Mahasneh, I. A., Department of Biological Sciences, Faculty of Science, University of Al al-Bayt, P.O. Box 140040, Mafraq City, Jordan

Morozov, A. N., Vodproekt, Tashkent, Uzbekistan

Novikova, Nina M., Water Problems Institute, Russian Academy of Sciences, Gubkina ul. 3, Moscow, 119991 Russia

Orlova, M. A., Institute of Soil Science, National Academy of Sciences, Almaty, Kazakhstan

Ozturk, M., Center for Environmental Studies, Ege University, Bornova, Izmir-Turkey

Plisak, R. P., Institute of Botany, National Academy of Sciences, Almaty, 480000, Kazakhstan

Qaiser, M., Department of Botany, University of Karachi, Karachi-75270, Pakistan

Rotanova, I. N., Institute for Water and Environmental Problems Siberian Branch, Russian Academy of Sciences, Barnaul, Russian Federation

Saenger, P., Centre for Coastal Management, School of Resource Science and Management, Southern Cross University, Lismore, Australia

Seifullina, S. M., Institute of Soil Science, National Academy of Sciences, Almaty, Kazakhstan.

Shirokova, Yu. I., Central Asian Institute for Irrigation Tashkent, Uzbekistan

Stow, Dorik A. V., School of Earth and Ocean Sciences, Southampton Oceanography Centre, University of Southampton, European Bay, Southampton, England, UK

West, Ian M., School of Earth and Ocean Sciences, Southampton Oceanography Centre, University of Southampton, European Bay, Southampton, England, UK

Foreword

The environmental hazards around us cannot be ignored today. They are a threat to our lives as well as to our children and our grand children and future generations of human beings.

Sabkha is an integral part of the natural heritage of West and Central Asia, in particular the Arabian Peninsula, including the State of Qatar.

In times of global freshwater scarcity, sabkha is believed to potentially contribute in coastal hyper saline zones to reduce the pressure on limited freshwater resources via the development of seawater irrigated high productivity man-made agricultural ecosystems.

In times of global warming, and a rising sealevel, sabkha can play important roles in monitoring the pace and status quo of sea level rise, providing valuable data for coastal zone planning.

Research on Sabkha Ecology commenced only a few decades ago and sabkha was considered as wasteland. Even though specialized researchers generated recommendations on sabkha management as early as the 1960s, only recently the environmental managers realized that sabkha is an ecosystem with a development, and conservation value.

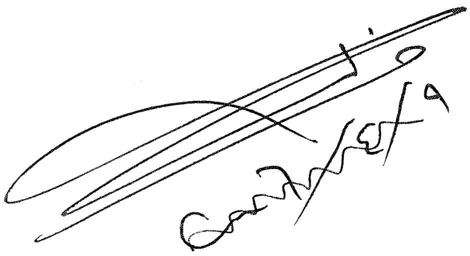
It is an essential precursor to study these ecosystems, and develop rational recommendations for development planning, research, and conservation, and in particular the sabkha related studies in view of heritage conservation, sealevel changes, and seawater irrigation for biosaline agriculture, and urbanization.

This volume covers the West & Central Asian aspects of biodiversity, botany, geology, bio-geography, vegetation, ecology, chemistry, economics, hydrology, micro-biology, and ecosystem dynamics with compliments of the distribution values, management requirements, and developments prospects of sabkha in the Arabian Peninsula and adjacent Asian countries.

The volume is a valuable guide, and it is important that these scientific findings are available for ecosystem researchers, environmental strategic planners, land developers, and decision-makers, towards sustainable development and conservation.

Finally, I warmly welcome this volume as an important step towards science-based conservation and development of sabkha environments.

Khaled Ghanem Al Ali
Secretary General
Supreme Council for the Environment & Natural Reserves
The State of Qatar



Preface

Many ecosystems in the world face severe problems due to environmental and social pressures manifested by non-sustainable economic development and increase in population. However, most ecosystems are important niches for wildlife species that are barely surviving under severe habitat degradation and under threat of extension. An example of such ecosystems is the Sabkha ecosystem, which is the Arabic term “Sabkha”/or “Sabkhat” (plural), that describes a unique coastal ecosystem covering large areas in arid or semi-arid environments in the world. The Sabkha ecosystem is a low flat saline land extending above the level of high tide, with a shallow water table that rises and forms interesting features and sedimentmorphic characteristics. Halophytic vegetation eolian deposits, tidal-flood deposits and evaporates, such as crystalline halite deposits, gypsum, anhydrite, and mineral grains of various sorts, are common characteristics of sabkha sediments.

Most sabkhas in the world are in their pristine stage due to harsh environmental conditions, high salinity of soils and low vegetation cover. Sabkha ecosystems host natural habitats important to migratory birds and coastal marine species. They are important for biodiversity conservation and have potential use in eco-tourism and environment education.

In Volume I of the *Sabkha Ecosystem*, the editors and authors presented a collection of contributions from experts of various disciplines from different countries adjacent to Arabian Peninsula. The volume enhanced the scientific understanding of the sabkha phenomenon and its potential for development. It was a first attempt from the scientific community to gather information and document the value and characteristics of the Sabkha ecosystems in different parts of the world in one document.

In this document, Sabkha Ecosystem Volume II, a broader perspective and geographical distribution of Sabkha Ecosystems in the world is presented. Volume II in the series attempts to broaden our understanding of the Sabkha environment and to appreciate the living organisms that dwell in this niche. Many authors from various disciplines and from different parts of the world contributed to the preparation of this document. The information within its chapters covers: a description of saline ecosystems, sensitivity of Sabkha habitats, wildlife, vegetation, soils and vegetation. The publication will be a basic source of information on Sabkha ecosystems that will broaden scientific knowledge and assist decision makers and environmentalists on the potential use and conservation of Sabkha ecosystems.

Dr. Samira Omer
Director
Food Resources and Maritime Division
Kuwait Institute for Saline Research
Kuwait

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Introduction

M. AJMAL KHAN, BENNO BÖER,
GERMAN KUST AND HANS-JÖRG BARTH

The information on Sabkha ecosystem was so large that all the information could not be gathered in one volume. Therefore it was decided that a detailed account of various regions will be presented in different volumes of Sabkha Ecosystem. The volume 1 entitled "Sabkha Ecosystem: Arabian Peninsula and the adjacent countries" includes ecological, geomorphic, and development studies. The Arabian Peninsula and particularly coastal areas of Arab states in the Gulf have continuously undergone massive land-use changes with projects, converting sabkha into urban lands for the establishment of harbors, settlements and other uses. Therefore this volume is a timely reminder that sabkha are important part of the ecology. The current volume (II) of Sabkha Ecosystem: Central and Western Asia brings information from those parts of central and western Asia, which was little known to English speaking scientists. It consists of twenty chapters ranging from sabkha of Sinai Peninsula up to Siberia. The volume commences with a lucid description of threatened Mediterranean Sabkha of Sinai followed by a detailed and very informative description of Flora of Iran by Hussain Akhani, whose devotion to study the halophytic flora of Iran is unique. He brings a vast perspective of the flora ranging from taxonomic, ecological and physiological point of views. Dr. Shahina Ghazanfar is widely known for her work on the flora of Arabian Peninsula. Despite the recent difficulties faced by the travelers in Iraq she has brought vivid description of sabkha of Iraq. There are two presentations on the Kazakhstan dealing with the zone of impact of Kapchagai reservoir and dust salt transference in the deserts. The description of Pakistani halophytes was strengthened with the inclusion of Prof. M. Qaiser with Ajmal Khan. Prof. Qaiser with his vast experience with the flora of Pakistan and Dr. Khan with halophytes finally brought a comprehensive picture of Pakistani halophytes. Qatar is represented by three excellent presentations including the microorganisms of Qatar by Prof. Mahasneh and co-workers, Dr. Böer and Dr. Saengar describing the biogeography of coastal vegetation and Ms. Al-Yossef and co-worker gave an excellent description of the Northern part of Dukhun sabkha. The Russian Federation was represented by five presentations. Three of them describe the Siberian region; one deals with ancient delta regions of Murghab and Tegden rivers and the last one Aral Sea area. Siberian presentations primarily focused on landscape ecology and natural cartographic analysis of natural salts by Drs. Bulatov, Rotanova and Chernykh while nature and functions of soils, rocks and water was described by Dr. Elizarova and she also shared a paper with Dr. Klenov describing the natural, geographical and halogeochemical feature of western Siberian soils. Contribution by Dr. Dikareva describes the salinization process and the formation of sabkha in delta regions. Dr. Kust and Dr. Novikova dealt with the desertification and sabkha formation in Aral Sea region. Prof. Al-Jaloud and Dr. Hussain gave a good description of halophytic communities of Saudi Arabia and Dr. Brown made an excellent contribution of the vegetation UAE. The last contribution by Morozov and Shirokova described the salinity problem in the irrigated ecosystems of Uzbekistan.

CHAPTER 1

SABKHA ECOSYSTEM AND HALOPHYTE PLANT COMMUNITIES IN SAUDI ARABIA

ALI A. AL-JALOUD AND GHULAM HUSSAIN

Natural Resources and Environment Research Institute (NRERI)
King Abdul Aziz City for Science and Technology (KACST)
P.O. Box 6086 Riyadh 11442
Kingdom of Saudi Arabia

Abstract. In Saudi Arabia, sabkhas are widespread, each covering areas from a few hectares to hundreds of square kilometers. In some cases water stands on the surface giving the impression of ponds or lakes. Usually the water table is very close to the ground surface. The salinity of the sabkha groundwater ranges between 50-585 g L^{-1} in different places. Solute chemistry indicates Na and Mg as the major cations and Cl and SO_4 as the major anions. Other ions such as Ca, K, CO_3, and HCO_3 exist in varying proportions besides B, NO_3 and F. Salt is harvested from these sabkhas for multiple uses. The texture of sabkhas soils ranges from coarse (sandy) to fine (sandy-clay-loam) at various places.

A field survey was conducted to determine the halophyte plant communities in sabkha in the Kingdom of Saudi Arabia. Plant species such as *Aeluropus lagopoides, Prosopis farcata, Bienertia cycloptera, Nitraria retusa, Salicornia europaea, Suaeda vermiculata, Tamarix amplexicaula Atriplex leucoclada, Halothamnus (sp), Plantago ovata, Atriplex glaucum, Suaeda fruticosa* and *Suaeda monoica* contain high protein contents (ranging from 4.25-19.75%) besides other mineral elements. The soil EC_e ranges between 8.25-206 dS m^{-1}. Based on the soil and plant analysis, these halophyte plants have an excellent potential for successful growth in a particular sabkha ecosystem. In conclusion, although most of the areas adjacent to sabkhas are heavily degraded, in some cases potential exists for the rehabilitation of either whole sabkhas or parts of sabkhas through halophyte plantation with the adoption of appropriate soil, water and plant management practices.

1. INTRODUCTION

Sabkha (plural: Sabkhas) is an Arabic term for a coastal and inland saline mud flat on playas built up by the deposition of silt, clay and sand in shallow, sometimes extensive, depressions. The sabkhas are commonly saturated with brine and their surfaces often encrusted with several centimeters of thick salt crusts (Chaudhary, 1992; Chaudhary & Aljuwaid, 1999; Al-Jaloud, 1983; Pike, 1970). Two major types of recent sabkha landforms have been distinguished by Kinsman and Park (1969) as coastal sabkha and inland sabkha. Coastal sabkhas are usually formed in coastal areas of arid regions where net evaporation is high and washing of soil is negligible due to limited freshwater supplies coupled with scanty rainfall and poor

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soil drainage. In Gulf Cooperative Countries (GCC), sabkhas constitute around 6% of the coastal areas (Batanouny, 1981). In Saudi Arabia, sabkhas commonly occur in the coastal areas and can also be found inland. Sabkha land is unfit for cultivation due to extremely high salt concentration. No profitable agricultural activity can be carried out in these areas. It is imperative to study these sabkhas to determine their ecological and potential economic value for the country. The main objectives of this paper are to focus on the physico-chemical properties of soils, identify plant communities and develop the relationship between these parameters for optimizing any possible use of otherwise unproductive salty lands.

1.1. Climate of Saudi Arabia

Saudi Arabia has a hot-dry climate and is classified as an arid region occupying about 5% of the world's arid zone (Bashour et al., 1983). Relative humidity is low except along the coastal zone where it sometimes reaches 100%. The average annual temperature is 33°C in summer and 14°C in winter with a wide seasonal and diurnal variation (48°C) (El-Khatib, 1980). The mean solar radiation was recorded as 550 cal cm^{-2} day^{-1} for the months of July and August; and 325 cal cm^{-2} day^{-1} for the months of December and January in the Riyadh region (Water Resources Department, Ministry of Agriculture and Water, 1988). The rate of pan-evaporation was lower along the coastal and high terrain and higher in the interior mainly due to a high presence of desert conditions. The monthly evaporation rates were 540 mm in July at Hail at 988 m elevation, 270 mm in Biljurshi at 2,400 m elevation, and 310 mm in Qatif at 5 m elevation. The rainfall variations between the years are very high and long drought periods have been recorded without any rain.

1.2. Extent and global distribution of salt affected land

Nearly 10% of the total land surface area is covered with different types of salt affected lands. Table 1 shows the distribution of salt affected lands in the world

Table 1. *Salt Affected Lands on the Continents and Sub-Continents (Kovda & Szabolcs, 1979).*

Continent	*Area (ha* x *10^3)*
North America	15,755
Mexico and Central America	1,965
South America	129,163
Africa	80,538
South Asia	87,608
North and Central Asia	211,686
South-East Asia	19,983
Australasia	357,330
Europe	50,804
Total	954,832

(Kovda & Szabolcs, 1979). The table also shows that no continent on earth is free from salt affected lands. They are distributed not only in deserts and semi-deserts, but also frequently occur in fertile alluvial plains, river valleys and coastal areas, close to densely populated areas and irrigation systems.

1.3. Characteristics of sabkha soils

Sabkha soils develop due to excessive evaporation from coastal and brine basins where net evaporation rates are very high. Gradual evaporation supersaturates the brine with respect to most insoluble salts such as carbonates of calcium and magnesium followed by highly soluble salts such as sulfate of calcium-gypsum, and or magnesium, and sodium chloride. The excess salinity decomposes organic materials, creates reduced soil conditions and produces hydrogen sulfide with a black color in the system. A comparison of salt concentration in sabkha groundwater at various locations in Saudi Arabia is presented in Table 2. It is clear that salt concentrations vary significantly in different sabkha groundwater at different places.

Table 2. *Comparison of Chemical Composition of Sabkha Groundwater.*

Parameters	*Range of Values*			
	Hussain & Ali (1988)[a] Western Province, Saudi Arabia	*KFUPM/RI (1993)[a] Eastern Province, Saudi Arabia*	*Seawater[a] Gulf Coast, Eastern Province, Saudi Arabia*	*Awshaziyah[b] (2001-2002) Al-Qaseem Region, Saudi Arabia*
PH	7.1-7.6	6.8-8.5	8.1	6.5-7.3
Salinity (g/l)	50-155	60.7-283.6	35	124.86-584.73
Calcium (g/l)	0.44-1.80	1.1-3.8	0.41	0.16-16.50
Magnesium (g/l)	1.83-3.31	2.9-6.4	1.28	2.48-60.07
Sodium (g/l)	20-95	20.3-81.7	10.76	15.15-100.00
Potassium (g/l)	0.5-1.90	0.7-7.8	0.4	0.80-10.40
Bicarbonate (g/l)	0.21-0.25	0.1-0.3	0.14	0.08-0.74
Chloride (g/l)	27.5-49.6	37.6-173.8	19.35	73.10-266.00
Sulfate (g/l)	3.21-4.35	2.4-10.12	2.71	2.77-51.80

(Source: [a] Sadiq, 1992; [b]Al-Harbi et al., 2002)

Besides other limitations, restricted aeration is one of the main features of sabkha soils. High sodium concentration causes dispersion of clay and blocks the soil pore space. This blockage interferes with exchange of gases between the atmosphere and sabkha soils. Hossain and Ali (1988) compared the chemical composition of the air in the Obhr sabkha in western Saudi Arabia along the Red Sea coast and in normal soil (Table 3).

Table 3. *Chemical Composition of Air in Sabkha Soils.*

Parameters	*Sabkha Soil*	*Normal Soil*	*Normal Air*
Nitrogen (%)	95	82	80
Oxygen (%)	4.7	15	20
Carbondioxide (%)	0.2	3	0.03

1.4. Chemical composition of halophytes

The chemical composition of plants depends on many plant growth factors. The most important are soil type and soil salinity, irrigation water quality and quantity, the internal atmosphere of soil (Chaudhry & Aljuwaid, 1992), the plant species and the climatic conditions of the area involved.

The mean chemical composition of some halophyte plant species in different areas is summarized in Table 4. High variability in plant elemental composition shows the influence of solute concentration around the plant root zone.

Table 4. *Ranges of Elemental Composition (%) of Halophyte Plants in Different Regions of Saudi Arabia.*

Parameters	*Al-Noaim, et al., 1991 East Province, Saudi Arabia*	*Al-Homaid, et al., 1990 Eastern Province, Saudi Arabia*	*Ali, et al., 2001 East, West and Central Region, Saudi Arabia*	*Ali, et al., 1994 East, West and Central Region, Saudi Arabia*	*Saudi Arabia*	
					E. Province	*W. Province*
N	0.58-2.02	—	0.48-1.70	0.73-3.64	0.44-3.17	0.68-2.64
P	0.04-1.18	—	0.05-0.12	0.01-0.35	0.03-0.31	0.05-0.26
K	0.46-2.00	0.20-2.74	0.09-1.55	0.30-4.50	0.40-2.88	0.05-0.26
Ca	0.5502.36	0.75-6.64	0.07-0.77	0.45-4.85	0.26-6.71	0.55-2.36
Mg	0.16-1.24	—	0.10-1.64	0.09-1.13	0.12-3.54	0.05-10.53
Na	0.10-0.98	0.07-2.75		0.04-5.05	0.02-13.25	0.68-2.64

** Al-Jaloud et al. (2002), paper submitted for publication.

The main factors for hypersaline conditions of sabkha soils are high evaporation rate, flushing of land by seawater and capillary movement of salts from a high groundwater table in coastal sabkhas. Besides these factors, inland sabkhas also receive salts by washout of outcrop from the surrounding areas during heavy rains and floods. Some important chemical characteristics of sabkha soils are given in Table 5.

Table 5. *Important Chemical Characteristics of Sabkha Soils.*

Parameters	*Ali, et al., 2001. East, West and Central Region, Saudi Arabia*	*Saudi Arabia***	
		East Province	*West Province*
PH	7.95-9.85	7.10-8.50	7.25-7.40
ECe dS m^{-1}	8.25-37.65	30.40-206.00	65-161
Ca mg L^{-1}	240-1452	79-10,010	490-1,186
Mg mg L^{-1}	103-601	23.4-4,121	290-1,532
Na mg L^{-1}	993-9269	108-58,042	13,753-35,383
Cl mg L^{-1}	1,418-14,345	556-91,661	21,959-51,894

** Al-Jaloud et al. (2002), paper submitted for publication.

To ascertain the influence of the ecosystem on the halophyte plant community, the chemical composition of some halophytes is presented in Table 6. A critical review of Table 6 reveals that some halophyte plant communities are growing successfully under a wide variety of plant growth conditions in the coastal salt marsh lands and in the inland sabkhas. Among the various species identified, *Atriplex leucoclada*, *Halothamnus sp.*, *Nitraria retusa*, *Atriplex glaucum*, *Salicornia europaea*, *Suaeda fruticosa* and *Suaeda monoica* contain high protein contents (ranging from 4.25-19.75%) besides other mineral elements.

Table 6. *Chemical Composition (%) of Halophytes at Different Locations.*

Plant sp.	Ca	Mg	Na	K	N	Protein	P
Zygophyllum coccineum[1]	2.19	3.58	0.53	0.37	ND	ND	0.05
Heliotropium strigosum sp.[1]	4.04	0.63	0.31	2.29	ND	ND	0.07
Atriplex leucoclada[2]	1.37	1.13	5.05	1.8	2.77	17.31	0.19
Halothamnus sp.[2]	0.99	0.47	4.54	2.90	2.38	14.88	0.19
Salsola tetrandra.[2]	1.51	0.41	2.30	0.40	1.01	6.31	0.04
Traganum nudatum[2]	1.23	0.74	3.40	1.00	1.07	6.69	0.05
Hamada elegan[3]	2.36	1.24	0.87	0.77	1.81	11.31	0.04
Prosopis farcata[3]	1.00	0.16	0.12	0.62	1.92	12.00	0.11
Panicum turgidum[3]	0.55	0.28	0.98	0.46	1.18	7.38	0.08
Plantago ovata[3]	1.96	0.31	0.30	2.00	2.02	12.63	0.12
Aeluropus lagopoides[4]	0.79	0.53	4.90	0.60	0.79	4.94	0.12
Limonium sp.[4]	1.01	0.67	4.78	1.33	0.97	6.06	0.11
Nitraria retusa[4]	3.20	1.78	3.98	0.99	1.30	8.13	0.09
Tamarix amplexicale[4]	1.39	2.04	10.53	0.99	0.68	4.25	0.08
Zygophyllum sp.[4]	3.38	0.91	5.73	0.69	0.74	4.63	0.06
Atriplex glaucum[4]	0.70	0.78	12.34	1.15	2.28	14.25	0.18
Bienertia cycloptera[4]	0.76	0.97	13.25	1.95	0.94	5.88	0.09
Halocnemum strobilaceum[4]	0.85	1.00	9.71	1.45	1.07	6.69	0.09
Salicornia europaea[4]	1.15	0.99	10.18	1.71	1.14	7.13	0.09
Suaeda fruticosa[4]	0.94	1.04	11.36	1.75	1.40	8.75	0.09
Suaeda monoica[4]	0.67	0.53	8.71	0.80	3.16	19.75	0.11

Sources: 1. Al-Homaid et al. (1990); 2. Al-Jaloud et al. (1994); 3. Al-Noaim et al. (1991); 4. Al-Jaloud et al. (2003, unpublished data); ND = Not determined.

These plants can be grown to develop rangelands in the sabkha ecosystem where soil and water salinity are the main limitations for plant growth along with adequate fresh irrigation water supplies. In order to rehabilitate the sabkha soils, promising halophyte plants are listed in Table 7 for consideration and practical use.

Table 7. *Salt Tolerance of Some Selected Species (Extracted from Firmin, 1971).*

Plant Species	*Mean Salt Tolerance ($mg\ L^{-1}$)*	*Plant Species*	*Mean Salt Tolerance ($mg\ L^{-1}$)*
Avicennia marina	40,000	*Kochia indica*	19,000
Prosopis juliflora	32,000	*Acacia pendula*	12,000
Zygophyllum	31,000	*Acacia salicina*	11,500
Tamarix maris-mortui	26,000	*Parkinsonia aculeata*	11,500
Atriplex nummularia	23,000	*Acacia arabica*	9,000
Avicennia vesicaria	22,500	*Acacia stenophylla*	8,000
Prosopis tamarugo	22,000	*Eucalyptus annulata*	6,500
Eucalyptus sargentii	11,500	*Ficus carica*	6,400
Prosopis juliflora	19,000	*Eucalyptus cornuta*	6,000
Eucalyptus calicultrix	10,000	*Eucalyptus grossa*	5,500
Eucalyptus coolabahs	9,500	*Eucalyptus robusta*	5,400
Tamarix arvensis	23,000	*Prosopis spicigera*	5,100
Tamarix deserti	22,000	*Acacia deani*	3,800
Tamarix florida	22,400	*Eucalyptus oleosa*	3,700
Acacia ligulata	19,500	*Tecoma stans*	3,700
Eucalyptus longicornis	3,200	*Populus cuphratica*	3,200
Bombax malabaricum	2,900	*Acacia tortilis*	1,900
Salix alba	1,900	*Acacua cyclopis*	1,600
Eucalyptus geradii	1,300	*Acacia radiana*	1,600

2. CONCLUSIONS

The sabkha soils and groundwater are highly saline in Saudi Arabia. A wide variety of plant communities were observed in the coastal sabkhas and inland sabkha ecosystem. The sabkha ecosystems are characterized by a very high percentage of insoluble and soluble salts, diversified types of plant communities, and varying soil conditions (i.e. soil texture and total salinity) and water quality. Some of the halophytes show that they have developed some kind of mechanism enabling them to tolerate high salinity and provide possible clues to combating salinity problems for the rehabilitation of salt affected soils in arid regions. The study also stressed the need for future investigation of the plant communities dominated by the potential halophyte plants containing high protein in the coastal and inland sabkhas. Further, the promising plant species should be used as a basis for planning future research programs making use of these halophytes. Also, these halophytes can be classified as xerohalophytes (plants in a dry saline habitat) and hygrohalo-phytes (plants in wet saline habitats). The establishment of gene banks of promising halophytes may be an appropriate preposition to combat desertification and promote greenery in the coastal and inland sabkhas.

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CHAPTER 2

AN OVERVIEW OF THE HALOPHYTES IN TURKEY

AYKUT GUVENSEN*, GUVEN GORK**
AND MUNİR OZTURK*

**Ege University, Science Faculty, Botany Department, Bornova-Izmir, Turkey*
***Mugla University, Sci. & Arts Faculty, Biology Department, Mugla, Turkey*

Abstract. Nearly 4.3 million ha of agricultural land in Turkey are degraded, out of which 1.5 million ha are arid and 2.8 million ha saline-alkaline. Plant diversity studies show that these areas include 300 halophytic taxa, belonging to 150 genera and 40 families. The dominant families are Poaceae (16.6%), Chenopodiaceae (14.0%), Asteraceae (12.0%), and Fabaceae (7.6%), while the dominant genera with highest number of taxa are *Limonium, Juncus, Salsola, Plantago, and Trifolium.* Phytogeographically, 50.67% of these taxa are imperfectly known, 9.33% are cosmopolitan, 8% Mediterranean, 7.67% Euro-Siberian, 3.33% East Mediterranean, and 2% Irano-Turanian. The life form spectrum reveals that 40% of the halophytes are therophytes, 28.33% hemicryptophytes, and 23% cryptophytes, with the majority being hygrohalophytes followed by xerophytes and psammohalophytes. The number of endemic taxa is about 39, the highest in Asteraceae (8 taxa), and Plumbaginaceae (6 taxa). The red data book of Turkish plants shows that 33 endemic and 11 non-endemic halophytes are in danger of extinction. Species like *Limonum bellidifolium* are collected in spring for indoor decorations due to their attractive floral shoots. *Halocnemum strobilaceum*, *Aeluropus littoralis* and *Arthrocnemum* sp. are grazed by cattle, and species of *Juncus* are used for basket making. A large number of people in the Aegean region have started using *Salicornia europaea* as salad. In some markets *Arthrocnemum fruticosum* is sold in place of *Salicornia europaea* for this purpose, and one has to be careful in this connection because consumption of the former in place of the latter may create health problems related to the digestive system. The littoral halophytic taxa, which occupy habitats immediately following the psammophytic plant communities, serve as a reclusive area for many animals and can serve as indicators of salinity-sodicity, whereas areas with high ground water salinity could be used for halophytic forage crop production. Some halophytic taxa can be used in erosion control alongside the coastal zones because of their deep root systems. There is great potential in the halophytic plant cover for consumption as well as amelioration of degraded lands in Turkey. Some work has already started in this direction but we have a long way to go.

1. INTRODUCTION

Turkey embodies 26.5 million ha of potential agricultural land and nearly 4.3 million ha of these soils have become unproductive; 1.5 million ha are faced with aridity and have inadequate drainage. This amounts to 20% of Turkey's irrigable land (Gungor & Erozel, 1994; Kaynak et al., 2000; Ozturk & Guvensen, 2002; Topraksu, 1980). The present situation is the outcome of longterm overirrigation. These degraded lands are mainly inhabited by littoral and inland halophytic taxa,

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some of which are obligate and others facultative and are generally regarded as a group of useless plants in Turkey in spite of the fact that elsewhere in the world they are used for food, fiber, fuel, animal feed, medicine, bread making, etheric oil and gum production (Somers, 1982). The fodder value of some halophytes has been exploited by humans for hundreds of years, but lately advances have been made through introduction, selection, proper management, and new application techniques. Some halophytes are rich in proteins as well as minerals, produce high biomass and show great adaptivity to a wide range of environmental stresses. The data base of salt tolerant plants of the world compiled by Aronson (1989) contains more than 1,560 species in 550 genera and 117 families and focuses on economic uses as well as life form, plant type, geographic distribution, maximum reported salinity tolerance and photosynthetic pathways. Dagar (1995), Ozturk & Guvensen (2002) and NRC (1990) have also worked on these lines.

Although a huge amount of literature is available on the flora of Turkey (Davis, 1965, 1988; Demiriz, 1993), very few papers have been published on the halophytes, notable among them being Beyce (1960), Birand (1960), Gehu & Uslu (1987), Guvensen (1994), Guvensen & Ozturk (2004), Guvensen et al., (1996), Ozturk et al., (1995), Yurdakulol & Ercoskun (1990), Zeybek (1969) and Zeybek et al., (1976). In this paper an attempt will be made to evaluate the halophytic plant cover of the country.

1.1. Study area

Turkey, with an area of 783,577 km^2, is situated between the 26^o-45′ east meridian and 36^o-42′ north parallels in the northern hemisphere, bridging Asia and Europe. It is geographically placed in the temperate zone embodying three climatic regions: the Mediterranean, Euro Siberian and Irano-Turanian. The Euro-Siberian region extends from Georgia to Bulgaria with a coastline of 1,500 km. There is no dry period in this area and the climatic regime resembles the Atlantic coastal regime of Europe. Annual precipitation exceeds 1,000 mm, but decreases from east (2,200-2,400 mm) to west (1,000-1,370 mm). Summers are warm and winters mild. Summer rains average 200 mm. The Mediterranean area extends from Canakkale up to the Syrian border and shows a typical Mediterranean climate in an area of 480,000 km^2, which corresponds to 20.8% of the whole Mediterranean belt (Akman & Daget, 1971). The climate is dry and hot in summer and mild in winter. Annual precipitation is around 300-1,000 mm. The Irano-Turanian region, which includes the coldest parts of Turkey, is characterized by a continental climate. The winters are very cold, and summers are hot. Precipitation as snow occurs in winter while rains are common in spring and autumn. Mean annual precipitation is 430-790 mm (Figure 1). However, southeast parts of this region experience a steppe climate with very hot summers. Aridity is also severe and evaporation reaches up to 1,000-2,000 mm (DIE, 2000). A map with representative climatic diagrams prepared according to Walter (1967) is given

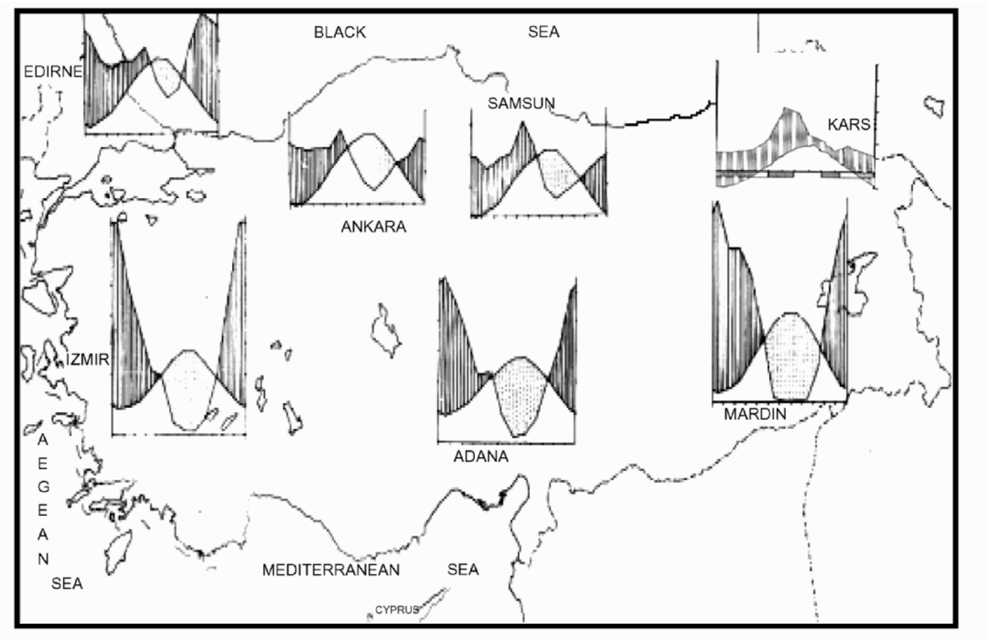

Figure 1. *Map showing climatic diagrams of representative areas in Turkey.*

below. These were compiled from the data covering the last 40 years obtained from the national meteorological survey, Ankara.

1.2. Salinity and alkalinity problems

Although the first classification of Turkish soils was given by Caglar (1949) on the basis of dominant ions, more detailed studies were conducted by Oakes (1954). He classified soils as saline hydromorphic alluvial (650,200 ha), solonchacks (69,700 ha), young alluvial (820,400 ha), hydromorphic alluvial (681,280 ha), and beaches, sand dunes, and marsh complexes (89,800 ha). The saline areas in Turkey are smaller in size than in neighboring countries like Iran (27,085,000 ha) and Iraq (6,726,000 ha), but larger than in Syria (532,000 ha) and Bulgaria (25,000 ha). Some investigations on the salinity-alkalinity problems were carried out earlier in Turkey (Okur, 1989; Ozturk et al., 1995, 1998; Saatci & Tuncay, 1971). The factors responsible for the salinity-alkalinity problems can be summarized as: accumulation of salts in plains due to heavy rains, a long standing high water table, the impact of sea water on the coastal alluvial plains, and geological features of Turkey, in particular the existence of saline areas as internal seas or sodic lakes, and over irrigation practices. The size of individual saline areas is generally less than 500 ha in Thrace, Southeast Anatolia, and the East Black Sea regions, but more than 100 thousand ha in Konya, Nigde (Central Anatolia) and Adana (South Anatolia) (Figure 2; Tables 1, 2). In these last regions, arid and semiarid climatic conditions play a great role in the formation of saline-alkaline soils, because precipitation and leaching are very low. Arid and

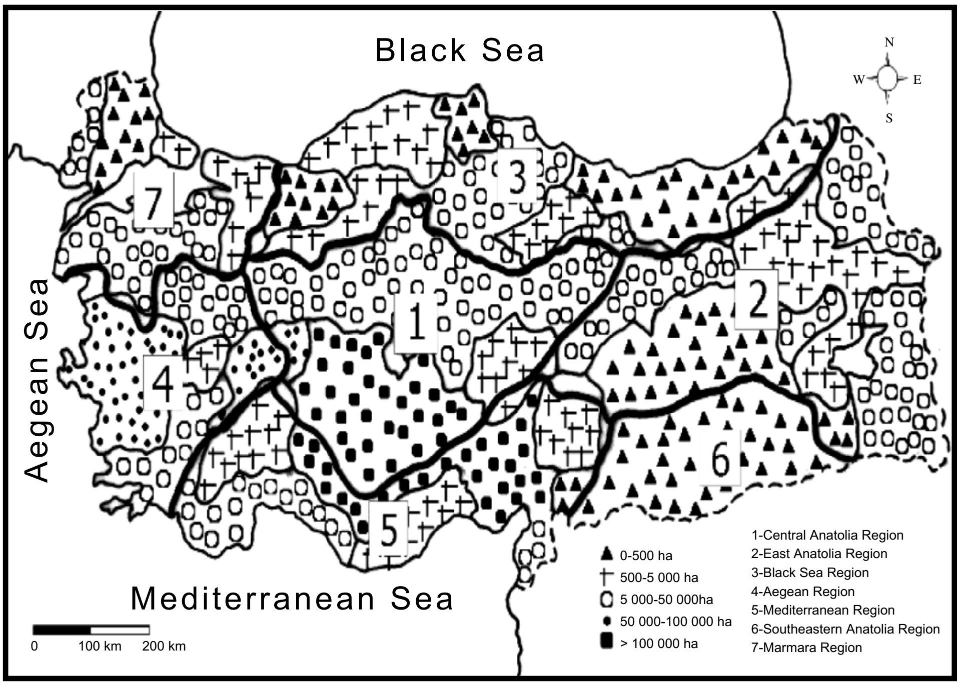

Figure 2. *Map showing the distribution of saline-alkaline soils in different geographical regions of Turkey (Modified from Ayyildiz, 1983).*

alluvial soils affected by salinity are most present in the Konya basin, followed by the Kizilirmak and Great Menderes basins (Figures 3, 4). In the Konya, Firat, Kizilirmak, Van Lake and Sakarya basins hydromorphic alluvial soils affected by slinity cover large areas (Figure 5).

Soil characteristics of representative samples (0-30 cm) from the Meric, Gediz, Antalya, Kizilirmak, Konya and Seyhan basins reveal that pH varies between 7.5-7.9, and that EC, Na^+, K^+, Ca^{++}, Mg^+, Cl, SO_4 and ESP values range between 9.65-60.7 (mmhos/cm), 2.4-20.50 (meq/100gr), 0.01-0.86 (meq/100gr), 1.5-31.97 (meq/100gr), 10.82-84.75 (meq/100gr), 0.58-29.41 (meq/100gr), 1.68-21.55 (meq/100gr), and 10.82-84.75 respectively (Dizdar, 1978).

1.3. Halophyte diversity

True halophytes are plants that are able to live under elevated salinities (greater than 0.5% NaCl), but also vary in their salt content from slight to brackish to medium to severe to above seawater salinity. In general 2,500-3,000 species of halophytes are found in the world (Khan & Duke, 2001). Nearly 700 species are distributed in the Mediterranean climatic zone (Choukr-Allah, 1991).

These include the species with high salt tolerance belonging mainly to the Chenopodiaceae, Potamogetonaceae, Hydrocharitaceae, Plumbaginaceae,

Table 1. *Area of degraded and saline soils in different geographical divisions of Turkey.*

Geographical Divisions	*Area (ha)*	*Saline Soils*		*Total degraded soils*	
		(ha)	*(% of total area)*	*(ha)*	*(% of total area)*
Marmara	6,700,000	65,698	0.98	351,678	5.24
Central Anatolia	15,100,000	681,147	4.51	1.614,181	10.68
Aegean	7,900,000	351,353	4.44	907,033	11.48
Southeast Anatolia	7,500,000	236	0.003	6,336	0.08
East Anatolia	16,300,000	168,270	1.03	449,884	2.76
Black sea	14,100,000	41,074	0.29	352,500	2.5
Mediterranean	12,000,000	209,510	1.74	635,197	5.29
Total	79,600,000	1,517,288	1.90	4,316,809	5.42

Table 2. *Area covered by saline-alkaline soils in different states of seven geographical divisions.*

Geographical Divisions							
Marmara	*Central Anatolia*	*Aegean*	*Southeast Anatolia*	*East Anatolia*	*Black Sea*	*Mediter-ranean*	*Saline and sodic soils covered areas (ha)*
Tekirdag Kirklareli			Adiyaman, Urfa Gaziantep, Siirt Diyarbakir, Mardin	Malatya, Elazig, Tunceli, Bingol	Ordu, Sinop Giresun, Bolu Trabzon, Artvin Gumushane, Rize		>500
Kocaeli Istanbul Bilecik Sakarya		Usak		Erzurum, Bitlis, Agri	Tokat Zonguldak Kastamonu	K. Maras, Isparta Burdur	500-5,000
Canakkale Balikesir Bursa Edirne	Eskisehir Ankara Kırsehir Nevsehir Sivas Corum Cankiri	Mugla Denizli Kutahya		Erzincan, Kars Mus,Van, Hakkari	Samsun Amasya	Hatay Antalya	5,000-50,000
	Kayseri	Izmir Aydin Manisa Afyon				Mersin	50,000-100,000
	Konya Nigde					Adana	100,000>

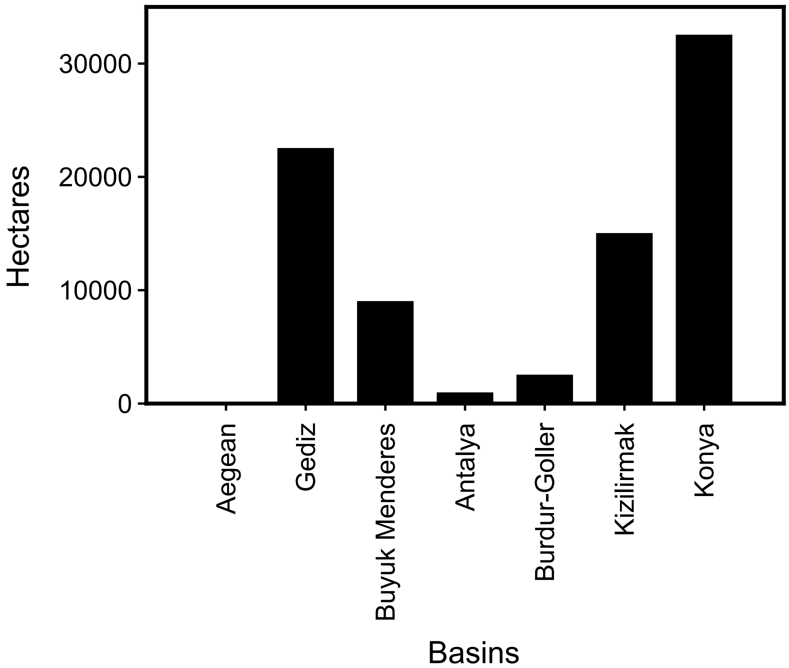

Figure 3. *Distribution of saline soils in different basins (modified from Dizdar, 1978).*

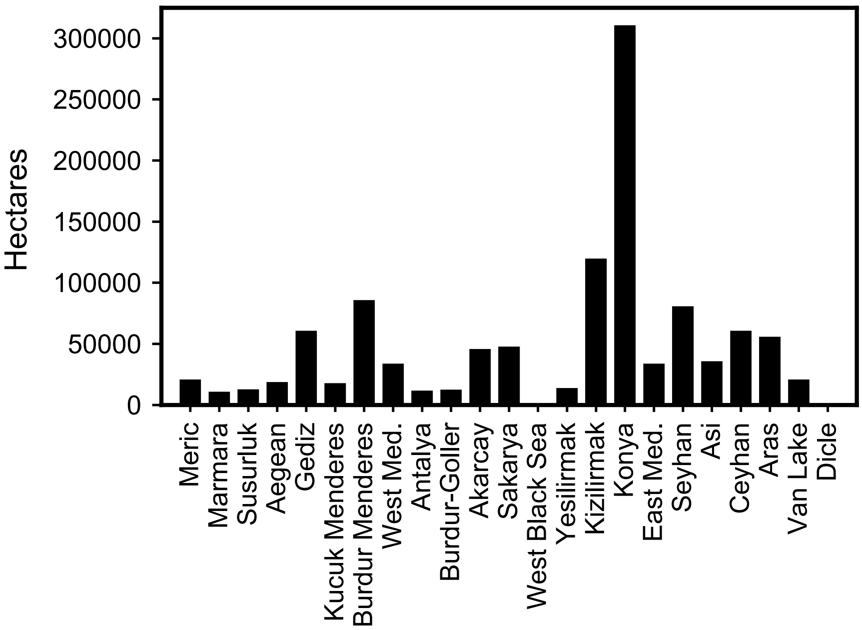

Figure 4. *Alluvial soils affected by salinity (total soluble salts 0.15-0.35%; ESP around 15%) in different basins (modified from Dizdar, 1978).*