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SUSTAINABLE USE OF MARGINAL LANDS TO IMPROVE FOOD SECURITY IN THE UNITED ARAB EMIRATES

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ABSTRACT

In the United Arab Emirates (UAE), about 34 percent of the area is affected with different levels of salinity, where growth of normal plants is almost impossible. The extremely low rainfall and occurrence of brackish groundwater for irrigation further complicates the crop production issues. In the hyper-arid environment of UAE, integrating trees and shrubs with other farm enterprises could be a useful strategy to increase system's productivity. Field studies conducted on UAE soils have shown that *Acacia ampliceps* can fix nitrogen under different salinity levels ranging from 10 to 30 dSm^{-1}, thus supporting the nutrient requirements for the two grasses i.e. *Sporobolus arabicus* and *Paspalum vaginatum*. These grasses produced up to 28 tons $ha^{-1}yr^{-1}$ of dry matter. When harvested at 2 m from the ground surface, these trees additionally provided ~ 10 tons $ha^{-1}yr^{-1}$ of foliage. The nitrogen fixation by the *Acacia* trees increases soil nitrogen to support forages. In the (Sabkha) coastal areas, growing halophytic plants such as *Atriplex* species can be beneficial due to low annual maintenance costs and their ability to survive high salt contents in the soil. Once the soil improves, non-halophytic trees, shrubs and grasses can also be planted. Until now 76 halophyte species have been identified for the UAE, which include 14 seawater tolerant halophytes, 29 halophytes, 31 semi-halophytes, and two parasitic plants belonging to *Chenopodaceae* and *Zygophyllaceae* family. The transformation of these saline lands into productive lands through large-scale adoption of halophytes and salt-tolerant plant species can have a significant impact on the livelihood and food security of rural pastoral communities of the dry regions.

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1 Introduction

Salinization of land and water resources is now widely known as a rising global problem to sustain agricultural production in arid and semi-arid regions of the world (Ventura & Sagi 2013; Hasanuzzaman et al., 2014). Currently, 1,030 million hectares (Mha) are affected by twin problems of salinity and sodicity, of which 412 Mha are affected by salinity and 618 Mha by sodicity (Wicke et al., 2011).These estimates do not present the area where both salinity and sodicity problems occur together. The salinity problems are the result of both natural (*primary salinity*) and human-induced (*secondary salinity)* processes. Secondary salinity affects 76 Mha, which are distributed in different continents highest being in Asia (53 Mha) (Dregne et al.,1991; Wicke et al., 2011).Out of the total 76 Mha, 43 Mha are in irrigated lands of (semi-) arid regions of the world whereas the rest 33 Mha are in non-irrigated lands. Secondary salinization has resulted due to the poor water management practices in irrigated lands and clearing of deep-rooted native vegetation in rainfed areas (Marcar et al., 1999).

The soil salinization is also wide spread in the Middle East and North Africa (MENA) region, where 11 percent of the area is affected by soil salinity (Wicke et al., 2011). Salt-affected soils vary in extent from 15 percent in Algeria to over 50 percent in Iraq. In Kuwait, more than 50 percent of the lands and about 54 percent of the cultivated area in Saudi Arabia suffers from salinity (Abdelfattah & Shahid, 2007). In Egypt, 93 percent of the cultivated lands whereas in Iran about 25 Mha are affected by salinity and water logging (Qadir et al., 2008). In the UAE, about 34 percent area is affected by salinity (EAD, 2009). The areas along the coastal sabkha (salt marshes or lagoonal deposits) are highly salinized (28 dSm^{-1}) whereas in the coastal region of the Abu Dhabi Emirate, salinity is more than 200 dSm^{-1} (Abdelfattah & Shahid, 2007). In these areas, growth of normal plants is almost impossible.

Natural desert ecosystems (such as UAE) are vulnerable to climate change and desertification. Increasing occurrences of extreme climatic events (such as droughts) and soil salinization has increased the incursion of non-native annual plants, which has resulted in reduced productivity of hyper-arid ecosystems (Toderich et al., 2013; Hussain et al., 2016).To improve livelihood of rural pastoral communities, these salt-affected areas need to be transformed into productive lands. Afforestation has the potential to re-vegetate saline lands to provide economic benefits to pastoral communities from marginal lands and lowering high water table conditions through bio-drainage (Heuperman et al., 2002; Marcar & Craw-Ford 2004; Khamzina et al., 2008). However, for long-term sustainability, afforestation needs to be preceded after complete evaluation of suitable tree species because salt-tolerant plant species respond differently to prevailing saline land and water conditions (Toderich et al., 2009).

Over the last three decades, many plant species have shown the potential to survive in the harsh saline environment of UAE. Recently, trend of growing arable crops in association with trees (agroforestry) has become popular. Because most trees are drought tolerant, they are capable to provide fuel, fodder, fruit and other products even if the crops fail. This paper reviews the information available on species of trees, shrubs, grasses and halophytes suitable for the saline soil and water conditions of the UAE. The prospects of agroforestry to improve productivity of desert ecosystems in the UAE is also discussed.

2 Marginal environments

Marginal environments are defined as the areas where salinization of land and water resources restrict potential crop production. Marginal lands have poor permeability, high salt contents, shallow water table conditions and other associated problems which restrict agricultural production. These lands are distributed in the entire world, regardless of climatic conditions and geographical occurrence. However, the criteria of marginality may vary based on their specific use (Anderson, 2012). Most conservative estimates suggest that about 10 percent of the total arable land in the world is affected by salinity and sodicity extending into more than 100 countries and almost all continents (Wicke et al., 2011). In the Middle East, 11 percent area is affected by soil salinity and agriculture is constrained due to shortage of good quality soil and water (Hussein, 2001). Therefore, percentage of population engaged in agriculture is very low i.e. ranging from less than one percent in Qatar to 29 percent in Oman. Therefore, the contribution of agriculture in the total GDP of these countries is also less than one percent.

In the Middle East, land degradation is the result of brackish groundwater use for irrigation, insufficient leaching of salts and upward movement of saline groundwater. Rising sea levels along with the over-exploitation of fresh water resources also cause sea water intrusion in coastal zones. Increasing pressure on land resources to grow more food, rising living standards, fast depletion of fresh water resources and poor management practices have further aggravated the problem. Therefore, there is every motivation to designate more resources to reclaim degraded soils to ensure future food security for the fast-growing population of different regions especially in the Middle East.

Sustainable agricultural production from marginal lands can be attained by adopting integrated natural resource management approach. This approach includes all aspects of soil, water, plants and climate to find long-term sustainable solutions for the marginal lands and waters. The "*biosaline agriculture*" is one of the promising approaches to deal with these situations. This approach is based on adaptable technology packages composed of salt-tolerant fodders and halophytes integrated with livestock and appropriate management systems (on-farm irrigation, soil fertility, etc.). The *Biosaline* approach helps in reclaiming saline lands through the cultivation of salt-tolerant cereal and forage crops and plantation of trees. Plantation of salt-tolerant trees in combination with the salt tolerant plants is an economically viable proposition for saline areas. Salt-tolerant tress can be used as timber, firewood, fodder (e.g. *Actlcia nilotica, Acacia saligna),* soil and water erosion control, wildlife corridors and aesthetics. The trees also act as windscreens, add organic matter and nitrogen and improve soil structure by breaking hard pans. The proper selection of plant species is the key for productive agroforestry because different crops and trees show varying reactions to salinity stress.

To maximize advantages, suitable selection of shrubs and grasses considering prevailing edaphic and climatic conditions of the area is of paramount importance. This is particularly important for good to moderate environments where shrubs could be used for forage and fodder purposes. The shrubs and grasses have widely been used for amelioration and reclamation of salt-affected and waterlogged soils (Sandhu & Qureshi, 1986; Ahmad & Ismail, 1993; Barrett-Lennard & Galloway, 1996; Toderich et al., 2013). The species such as *Prosopis*, *Tamarix* and *Atriplex,* are naturally occurring plants in coastal or inland areas where soils are saline and groundwater quality is brackish. These plants are usually referred as halophytes. Marcar et al. (1999) have provided a list of salt-tolerant tree and shrub species for marginal environments as given in Table 1.

Table 1 Suitability of tree and shrub species under different soil salinity, sodicity and waterlogging conditions

Species	Salinity (EC_e = dSm^{-1})	Sodicity	Waterlogging
*Acacia ampliceps**	Severe	Severe	No
A. *auriculiformis**	Moderate		Yes
A. *cyclops*	High		
A. *machonochiena*	Severe	Severe	
A. *nilotica* Moderate	Moderate	High	
A. *salicina*	High	High	
A. *saligna* Moderate	Moderate	Moderate	
A. *stenophylla*	Severe	Severe	Yes
A. *tortilis* Moderate	Moderate		
Ailanthus excelsa	High	Moderate	
Albizia lebbeck	Moderate	Moderate	
A. *procera*		Moderate	Yes
Azadirachta indica	Moderate		
Butea monosperma	Moderate	High	
Casuarina cristata	Moderate/High	Moderate	Yes
C. *cunninghamiana*	Moderate/High		Yes
C. *equisetifolia*	Moderate	High	Yes
C. *glauca**	High	Moderate/High	Yes
C. *obesa**	High/Severe	High	
Cepparis aphylla	High		
Conocarpus lancifolius	High		
Dalbergia sissoo	Moderate	Moderate	
Eucalyptus brassiana	Moderate/High		
E. *camaldulensis**	Moderate	High	Yes
E. *citriodora*	Moderate		
E. *grandis**	Slight/Moderate		Yes
E. *coolabah*	Moderate	High	
E. *moluccana*	Moderate		
E. *occidentalis**	High		
E. *platypus*	Moderate	Moderate	Yes
E, raveretiana	High		
E, robusta	Moderate		
E, rudis	High		
E, spathulata	High	Moderate	Yes
*E. tereticornis**	Moderate	High	
Leucaena leucocephala	High	Moderate	
Melaleuca arcana	Moderate		
M. bracteata	Moderate	Moderate/High	Yes
M. halmaturorum	Severe	Moderate	Yes
M. lanceolata	High		Yes
M. leucadendra	High		Yes
M. quinquinervia	Moderate	Low	Yes
Parkinsonia aculeate	Moderate		Yes
Pinus halepensis	Moderate		
Pongamia pinnata	Moderate		
Populus euphratica	Moderate		
Prosopis chilensis		High	
P. juliflora	Severe	High	Yes
Sesbania formosa	Moderate		Yes
S. *grandiflora*	Moderate		Yes
T amarix aphy/la	Severe		Yes
T. articulata	Severe		Yes
T erminalia arjuna	High	Moderate/High	
Zizyphus jujube	High		Yes
Z. spina-vulgaris	High		Yes

Salinity is expressed as EC_e [moderate (4-8 dSm^{-1}), high (8-16 dSm^{-1}), severe (>16 dSm^{-1})]. Sodicity is expressed in terms of pH [moderate (8-9), high (9-10), severe (> I0)]. The (*) sign exhibit marked provenance to saline soils (Adopted from Marcar et al., 1999).

3 The Case of United Arab Emirates (UAE)

The United Arab Emirates (UAE) is in the south-eastern part of the Arabian Peninsula and borders Oman and Saudi Arabia. The total area of the country is 82,880 km^2 (Figure 1). Abu Dhabi is the largest of seven Emirates and accounts for 87 percent of the total land mass of the country. The main characteristics are limited arable land, harsh climate and poor renewable water resources. The UAE is dominated by low-lying, sandy desert with extensive salt flats (sabkha) present in coastal areas. The country has an arid to hyper-arid climate with high temperatures and low rainfall. The summers (May to October) months are extremely hot with daytime temperatures frequently above 40°C. Rainfall is generally restricted to winter months (November to March), when night time temperatures can drop to 4°C. Precipitation generally decreases from northeast to southwest. The eastern mountainous areas receive up to 480 mm rainfall per year compared to only 80 mm in coastal areas and far less in western and southern parts of the country. Groundwater quality is awfully poor (15-30 dSm^{-1}), which makes it unsuitable for irrigation purposes for normal crop production.

The extent of soil salinization in the UAE has changed over time. It is estimated that about 25 percent area is affected by salinity. The soil salinity ranges from 2 to 10 $dSm^{-1}$for most of the agricultural systems (Karim & Dakheel, 2006). However,

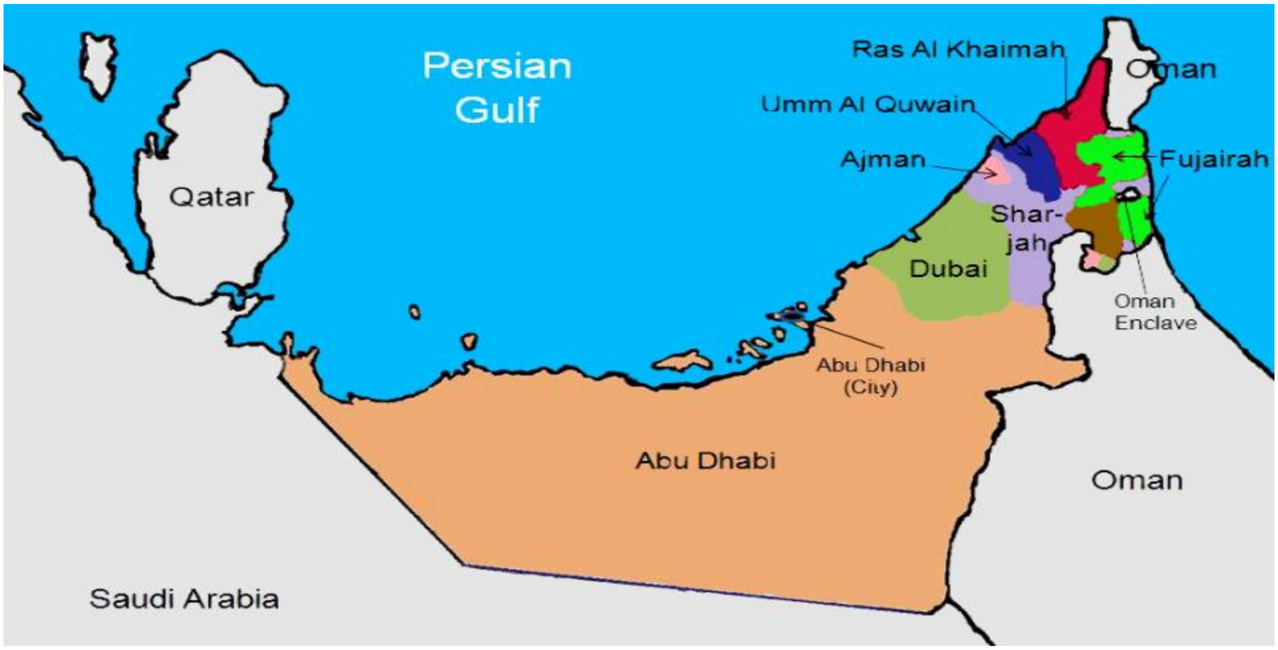

Figure1 Map of United Arab Emirates

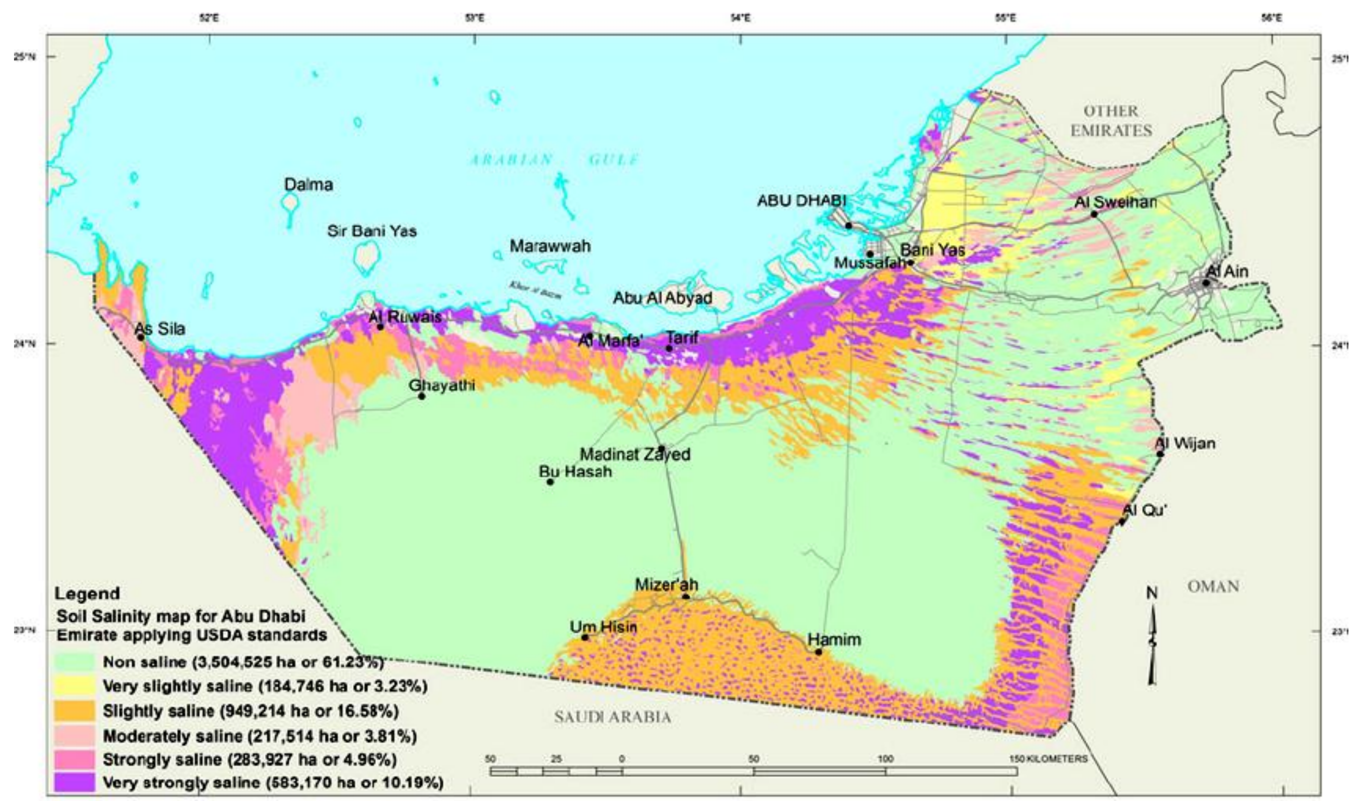

Figure2 Soil salinity map of the UAE (Source: ICBA Database)

in many parts, soil salinity can go up to 20 dSm^{-1}in forage (Rhodes grass) grown areas and 25 dSm^{-1}in areas where native plants (*Prosopis cineraria* and *Acacia tortilis*) are grown. The use of highly saline groundwater (20-25 dSm^{-1}) for irrigation is the major cause of this high soil salinity. The salinity on older UAE farms is also very high, ranging from 15-20 dSm^{-1}. The differences in the soil salinity and pH values in extreme *sabkhas* of the UAE are given in Table 2. The soil salinity map of UAE is shown in Figure 2.

Table 2 Measurements of salinity and pH on UAE farms and various *sabkhas*

Location	Soil salinity in farms		Soil salinity in sabkhas	
	pH	EC (dSm^{-1})	pH	EC (dSm^{-1})
Abu Dhabi	7.1 – 9.0	4.0 – 38.0	8.0	73.0
Dubai	7.1 - 9.0	1.0 - 38.0	8.6	231.0
Sharjah	9.0 - 9.8	0.2 - 10.8	9.1	67.4
Ajman	8.9 - 9.2	1.4 -3 .0	8.1	116.9
Umm al-Qaiwan	8.2 – 8.5	2.5 – 4.2	7.7	15.6
R'as al-khaimah	4.2 – 8.9	0.7 – 17.7	8.5	191.6
Al Ain	0.5 – 27.0	7.7 – 9.4	8.0	300.0
Tarif	8.0	82.0	7.2	213.0
Sabkhat Matti	7.8	98.0	6.6	219.0
Fujairah	8.0 – 9.9	0.5 – 10.5	8.4	74.0

The UAE soils are divided into three categories for plant growth (Karim & Dakheel, 2006).

3.1 Farmlands salinized due to poor irrigation practices

These lands can be reclaimed by leaching of salts using fresh water to grow conventional crops. However, in the absence of leaching facility, growing salt-affected crops may be given serious consideration.

3.2 Arid lands with brackish groundwater

Growth of sensitive crops is restricted in these areas. However, these lands have the potential to grow selected salt-tolerant crops by applying special cultural techniques and using of brackish groundwater for irrigation.

3.3 Coastal deserts

In the extensive coastal area of the UAE, most farmers are reluctant to grow crops/plants because soils are extremely sandy and only sea water is available for irrigation. In these areas, growing halophytes and highly salt-tolerant plants have the potential to generate significant income for the farmers.

Salt-tolerant plants and halophytes found on seashores and estuaries can be used to meet requirements of food, fiber, fuel and medicines. Due to these benefits, their potential use in the UAE is increasing. Many salt-tolerant genotypes of food crops have also been identified, which can be grown effectively using saline groundwater to achieve economical returns. These include carrots, onions, tomatoes, date palm, pearl millet, barley, sorghum, maize and wheat.

Salt-tolerant grasses such as *Chloris guayana* (Rhodes grass), *Panicum turgidum, Pennisetum spp., Lasiurus spp.*, along with many trees and shrubs are commonly used for grazing. Perennial salt bushes (*Attriplex spp.*) and forage herbs like *Medicago spp. and Trifolium spp.* are grown throughout the UAE due to their salt-tolerance. Salt-tolerant trees such as *Acacia spp., P. cineraria, L. leucocephala, and P. juliflora* are best suited for use as windbreaks and additional sources of fodder for livestock, which consume their pods, leaves and branches.

The salt-tolerant plants such as *Hibiscus spp., Juncus spp., Typha spp*. and *Phragmites australis* are suitable for fiber use. The latter is a marsh plant and commonly used for fencing, roofing, basket making and fuel wood. The *Sesbania bispinosa* is a well-known salt-tolerant legume and fodder crop, which is also used as a fuel and fiber. The plants such as *Tamarix, Casuarina, Acacia, Prosopis, Eucalyptus, Avicennia* and *Rhizophora* are widely used as fuelwood. Many local plants are used as medicine for treating illnesses, such as diabetes, arthritis, high blood pressure, and urinary tract disorder (Karim & Dakheel, 2006).

4 Prospects of agroforestry in the UAE

Over the last 15 years, International Center for Biosaline Agriculture (ICBA) has done the pioneer work in integrating trees and shrubs with other farm enterprises to increase the system's productivity in the UAE. The focus has been on the evaluation of the feasibility of *Acacia ampliceps* for Central Asia to North Africa regions because this plant has the capacity to fix atmospheric nitrogen, provides forage for animals and produce bio-energy (Toderich et al., 2013). ICBA's research has demonstrated the compatibility between *A. ampliceps* and two salt-tolerant grasses i.e. *Sporobolus arabicus* and *Paspalum vaginatum* in response to different salinity and fertilizer treatments.

Field studies conducted on UAE soils have shown that *Acacia ampliceps* can fix nitrogen under different salinity levels (10-30 dSm^{-1}), thus supporting the nutrient requirements for the two grasses i.e. *S. arabicus* and *P. vaginatum* (Toderich et al., 2013). Based on average values over the study period, the unfertilized plots showed a 7 to 13 percent reduction in biomass yields for *S. arabicus* but insignificant difference for *P. vaginatum*. These grasses produced up to 28 tons of dry matter $ha^{-1}yr^{-1}$. When harvested at 2 m from the ground surface, these trees additionally provided ~ 10 tons $ha^{-1}yr^{-1}$ of foliage. The nitrogen fixation by the *Acacia* trees increases soil nitrogen to support forages. In the (Sabkha) coastal areas, growing halophytic plants such as *Atriplex* species can be beneficial due to low annual maintenance costs and their ability to survive high salt contents in the soil. The nitrogen fixation by the *Acacia* trees helps in increasing the forage production.

The studies done by ICBA have shown that integrated trees and shrub systems such as alley-cropping, silvopasture, windbreaks, riparian buffer strips, and forest farming for non-timber forest products are advantageous for enhancing productivity of marginal lands (Toderich et al., 2009). In addition, these agroforestry systems can improve soil nutrient management thereby increasing the productivity of plants. The most commonly used alley-cropping system is where agricultural crop is grown simultaneously with a long-term tree crop. This practice enhances income diversity, control erosion, improve nutrient utilization and increase crop production. When designing an alley-cropping system, consideration must be given to the type of tree and crops that can be grown together for optimizing economic gains. There are many tree and crop combinations that can be practiced. The four basic groups of companion crops are given below:

1. **Cereal crops** - Wheat, barley, corn, soybeans, potatoes, oats, peas, and beans
2. **Forage/fodder crops** - Orchard grass, bluegrass, ryegrass, brome, clover, alfalfa. The production of forages may be enhanced in the shade of analley- cropping practice.
3. **Specialty crops** - Landscape plants like blue spruce, dogwood, redbud; Christmas trees;small fruit trees; or crops like goldenseal or ginseng.
4. **Biomass crops** - Trees including poplars, willows, silver maple, birches (herbaceouscrops like switchgrass).

For successful agroforestry systems, the tree species should have high commercial or environmental value and the capacity to create suitable micro-environments for the companion agricultural crops. Alley-cropping practices are highly diverse therefore the knowledge of the growth characteristics of trees and the companion crops is necessary to determine suitable crop combinations and to decide whether plantation is done in single or multiple rows. Since growth rates of different species may conflict, proper designing is important to avoid dominance of certain species and their negative effects on others.

5 Halophytes for agroforestry in the UAE

Halophytes can tolerate high levels of salts and/or sodium in soil or in irrigation water and are suitable to protect habitats, maintain ecological stability and developing agriculture in saline soils. They can grow in marshes, estuaries, cliffs and dunes and constitute about one percent of the world's flora (Flowers & Colmer, 2008). The facultative halophytes are also suitable for freshwater conditions, while obligate halophytes can only grow in saline lands. Halophytes are suitable for coastal and inland soils of arid and semiarid climates, where evapotranspiration is remarkably higher than the precipitation (Manousaki & Kalogerakis, 2011). They have the capacity to tolerate salinity by adjusting their internal water relations through ionic compartmentation in cell vacuoles, accumulation of compatible organic solutes, succulence, and salt secreting glands and bladders (Shabala & Mackay, 2011). Halophytes remove salts from soils through different processes such as salt excluding, excreting, or accumulating by their morphological, anatomical, and physiological adaptations in their organelle level and cellular level (Hasanuzzaman et al., 2014). Some studies have also shown the ability of halophytic plants to remove heavy metals from normal and salt-affected soils (Manousaki & Kalogerakis, 2009; Nedjimi & Daoud, 2009).

The establishment of halophytic plants such as *Atriplex* species can be beneficial in the coastal areas of the UAE where extensive salt flates (sabkha) exists (Figure 3). Once these soils are rehabilitated, growth of non-halophytic trees such as shrubs and grasses would be possible. Sabkha is a stiff environment for biological activity due to high salt content and lack of fresh water resources (Barth & Böer, 2002). However, halophytes have the potential to inhabit thin layers of aeolian sand that is deposited on the sabkha surface due to local weather conditions to support dense vegetation (Gairola et al., 2015). In these areas, major problem with halophytic vegetation is their taxonomic uncertainty and misidentification of different species (Brown, 2006). For example, some members of the *Chenopodiaceae* display significant morphological variation, and it is often difficult to separate one specie from the other.

Many species of halophytic plants such as *Suaeda maritime, Sesuvium portulacastrum, Arthrocnemum indicum, Suaeda fruticosa*, *Tamarix aphylla*, *Atriplex nummularia, A. halimus* have been used to clean contaminated soils as they can absorb more salts in their tissues thereby reducing salts from the saline land (Ravindran et al. 2007; Nasir 2009). These species are also useful for reclaiming salt-affected soils. Halophytes can maintain productivity of agricultural lands up to a salinity level of 70 dSm^{-1}, if accumulation of salts in the root zone is maintained through effective leaching (Glenn et al.,2013).The species like *Cynodon dactylon*, *Ruppia maritima* and *Inula crithmoides* can produce biomass through *biosaline* agriculture (Öztürk et al., 2014). The *Salicornia europea,* a high-quality edible-oil yielding plant with high economic value, can also be used to reclaim salinized soils (Muscolo et al., 2014).

Böer (2002) have recognized 76 commonly existing halophyte species for the UAE. These include 14 seawater halophytes, 29 halophytes, 31 semi-halophytes, and two parasitic plants belonging to *Chenopodaceae* and *Zygophyllaceae* family. Since halophytic plants behave differently in regulating salt content in their tissues, it is important to explore the morpho-anatomical adaptations and physiological significance of different halophyte species. The Environmental Agency of Abu Dhabi has found that many of the halophytes can grow in hyper-saline Sabkha (salt marshes), where salinity reaches several folds greater than the sea

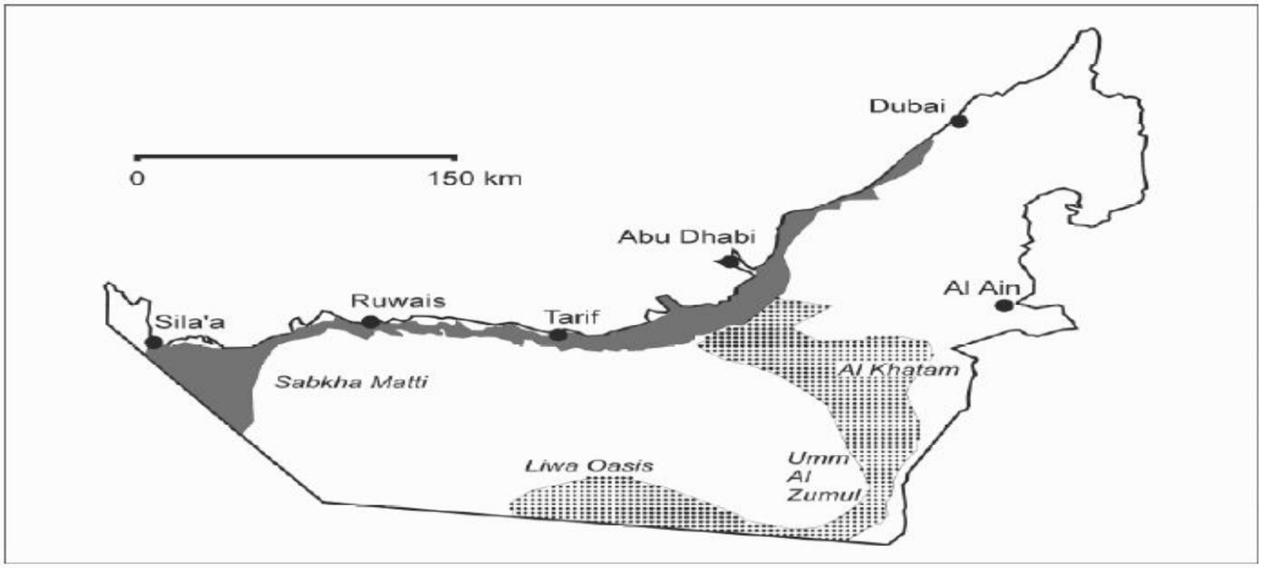

Figure3 Map of UAE showing the extent of coastal Sabkha (grey shaded area), and Sabkha Matti, as well as areas with inland Sabkhat (dotted area)

water salinity (EAD, 2012). However, they propose that more research is needed to understand structure and function of salt glands, nature of secreted material, mechanism(s) of ion secretion and the way halophytes handle the salts. This information is needed to select best halophytic species for bio-reclamation of salt-affected soils in arid and semi-arid regions of the Arabian Peninsula (Shabala, 2013). The halophytes commonly used in the coastal areas of Abu Dhabi are given Table 3.

Table 3 Plant species along the Abu Dhabi coastline and the ecosystems in which they occurs

Species	Ecosystem	Species	Ecosystem
Suaeda v. Arthrocnemum	SS	*Phoenix dactylifera*	SS
Prosopis cineraria	SS	*Pluchea dioscoryides*	BW
macrostachyum	SM	*Sesuvium verrucosum*	BW
Salsola drummondii	SS	*Aeluropus lagopoides*	BW
Halopeplis perfoliata	SS	*Arundo donax*	BW
Avicennia marina M,	SM	*cf. Cymbopogon sp.*	SS
Halocnemum Strobilaceum	*SM*	*Dipterygium glaucum*	SS
strobilaceum	SM	*Helianthemum lippii*	H
Zygophyllum qatarense	SS	*Lotus garcinii*	H
Anabasis setifera	SS	*cf. O. compressa*	*BW*
Biennertia cycloptera	SS	*Taverniera spartaea*	H
Salsola imbricata	SS	*Calligonum comosum*	H
Zygophyllum mandavillei	SS	*Euphorbia serpens*	BW
Cyperus arenarius	SS	*Heliotripium dyginum*	SS
Heliotropium bacciferum	SS	*Lasiurus scindicus*	H
Cornulaca monacantha	SS	*Leptadenia pyrotechnica*	SS
Limonium axllare	SS	*Limeum arabicum*	SS
Prosopis juliflora	SS	*Pennisetum divisum*	SS
Tamarix sp.	BW	*Phyla nodiffora*	BW
Cyperus conglomeratus	SS	*Sesuvium portulacastrum*	BW
Salsola c. Cornulaca	H	*Sporobolus iocladus*	SS
Salvadora persica	BW	*Haloxylon salicornicum*	H
cf. leucocantha	SS	*Seidlitzia rosmarinus*	SS
Halopyrum mucronatum	SS	*Shpaerocoma aucheri*	SS
Panicum turgidum	SS	*Ipomea pes-caprae*	BW
Phragmites australis	BW	*Suaeda aegyptiaca*	SS
Atriplex leucoclada	SS	*Zygophyllum simplex*	SS
Stipagrostis sp.	H	*Chloris sp.*	BW
Sporobolus spicatus	BW	*Farsetia cf. aegyptiaca*	H
Dactyloctenium scindicum	SS		

Here H = (Rocky) Headlands; SS = Sand Sheets; M = Mangrove; SM = SaltMarsh; BW = Brackish Water (*Source: Böers & Saenger, 2006)*

For the Abu Dhabi Gulf coast; 59 plant species (without irrigation) have been identified. These include one species for mangroves, three salt marsh species and 55 species for areas other than mangroves or salt marsh. The sand sheet vegetation is referred to vegetation of sandy beaches or "*storm berms*" whereas others are marked as vegetation of brackish ground, or rocky headlands. The coastal vegetation usually forms a narrow band separated from true terrestrial vegetation by a wider band of coastal sabkhas.

Conclusions and recommendations

The world's most productive lands have already been utilized and the need to use marginal lands of lower quality is increasing to ensure food security and environmental sustainability. Over the last three decades, considerable work has been done in identifying crops, trees, shrubs and grasses that can potentially grow under marginal environments of the UAE. The salt-tolerant species of trees, shrubs and grasses have the potential of lowering the groundwater levels through either control of accessions or pumping groundwater. The extracted groundwater can be used to irrigate salt-tolerant trees, shrubs and grasses as they can tolerate Ecup to 10 dSm^{-1} without compromising on transpiration rates. In the UAE, tree production systems can be of great value because of the presence of sandy soils and saline groundwater. However, the success of the sea water plantations will depend on the effectiveness of selected plant species grown for the management of salt concentrations in the root-zone and the concentration of sodium carbonate in the irrigation water. Since leaching fractions for the sandy soils are high, areas with deeper water tables will be most suited for these plantations. Integration of fodder halophytes into the agro-silvi-pastoral system can offer cost-effective rehabilitation of degraded rangelands and farm lands.

Promoting sustainable use of marginal land and water resources for food-feed crops and forage legumes will improve food security, reduce poverty, resilience against climate change, and enhance ecosystem health in crop-livestock systems. The adoption of native and introduced halophytes and salt-tolerant plant resources can have a significant impact on salinity control and remediation, which can lead to the economic development of salt-affected dry regions. The agroforestry concept can help in solving on-farm drainage problems and create favorable environmental conditions for the desert and semi-desert areas of the region.

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