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SITE SELECTION CRITERIA AND CHARACTERISTICS FOR THE INTRODUCTION OF MANGROVES IN KUWAIT

S.A. Shahid*, F.K. Taha, M. Khalil and N.R. Bhat

Aridland Agriculture Department, Food Resources Division,
Kuwait Institute for Scientific Research, P.O. Box: 24885, Safat 13109, Kuwait

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ABSTRACT

Mangroves are an important component of renewable natural resources of coastal regions. Their interactive and dynamic system involves plants, seawater, soils and marine fauna. The amenity value of mangroves offers very good potential for the enhancement of the coastal environment and enrichment of degraded coastal ecosystems. Successful plantation is only possible when the selected sites are suited for such plantation; therefore, a careful survey and evaluation of the sites are pre-requisites. Selection criteria were prepared based on the local conditions and fourteen sites were assessed. Out of fourteen sites, five were finally selected. Each site was divided into three zones, the inner, middle and the outer. The field investigation and the laboratory characterization of the soil samples showed that the inner zone (with relatively heavy texture) satisfied the selection criteria. The middle zone in some sites showed good promise; however, the outer sandy zone did not satisfy the criteria and therefore, was not recommended for mangrove plantation.

INTRODUCTION

Geographically, Kuwait occupies approximately 17,800 km^2 of the northwestern part of the Arabian Gulf, between 28°30' and 30°05'N, and 46°33' and 48°30'E. Kuwait's climate is characterized by harsh summers and mild winters. Temperature extremes are high, with means during the warmest and coolest months ranging between 46.2°C and 6.9°C (Annual Statistical Abstract, 1998). Winter brings occasional frost. Rainfall is minimal, not exceeding 115 mm per annum, but evaporation is very high, averaging 14.1 mm per day.

The relative humidity is low, and strong, dry and hot, northwesterly winds prevail during summer, particularly in June and July. Kuwait has a coastline of length 290 km, of which approximately 57% is the intertidal zone.

***Corresponding Author**

This area is included in the national greenery plan that is currently being implemented by the State of Kuwait (KISR,1997). Afforestation of intertidal zones with mangrove plants is considered a viable option to improve coastal environment and enrich marine biodiversity.

Mangroves normally grow in the intertidal zones and constitute an important renewable natural resource in the coastal regions in several tropical and subtropical countries (Saenger *et al.*, 1983; Fujiwara, 1990). For successful mangrove plantation, there are a number of important factors that must be considered while selecting the sites. A careful survey and evaluation of the sites is crucial for successful establishment of mangrove stands. Mangrove ecosystems are very varied and their structure and function depend heavily on the nature of the prevailing environment.

However, the common characteristic they all possess is the tolerance to salt and saline waters. In fact, mangroves are located in the region between the sea and dry land. Worldwide, they occupy probably between 160,000 and 170,000 km^2 (Field, 1996).

Site selection, characterization and assessment are usually the initial criteria of many projects. The results produced form the basis for future development and implementation plans such as mangrove plantation at the coastal sites in Kuwait. These undertakings are of short duration (field work), and continue throughout the duration of the project, data management and reporting. Due to the short time-frame, limited time does not allow monitoring of every aspect of the site, which seems possible or desirable. However, identification of the core issues for site assessment clarifies what important site assessment aspects should be investigated to achieve the objectives.

Formulating core issues is a way of forecasting all possible aspects including unintended and detrimental ones. If this is followed, a variety of scenarios can be developed for a direct application or as an insight to design a method tailored to a given situation. All possible scenarios were considered and the list of the most appropriate selection criteria were developed. There are a number of factors to be considered while selecting sites for mangrove plantation. The stress on mangrove growth may be caused by a number of factors, such as restricted photosynthetic production, shortage of water, light, nutrients, unfavorable site conditions such as excessive temperature, non-coverage by tidal water, high soil salinity, *etc.* (Grime, 1974). Optimum temperatures for photosynthesis in mangroves appear to be around 35°C with little or no photosynthesis at or above 40°C (Chapman, 1976; Clough *et al.*, 1982). According to Siddiqi and Khan (1996) extensive mangrove development occurs when the average air temperature of the coldest month is higher than 20°C and where the seasonal range does not exceed 10°C (Chapman, 1976). Temperature is important in regulating a large number of internal energetic processes including salt regulation and excretion and root respiration, because of its critical effect on both the photosynthetic and respiratory processes (Saenger, 1996). Almost all the mangrove species are susceptible to frosts (Markley *et al.*, 1982).

Site assessment was initialised by integrating the internal (local knowledge) and external (views of the multidisciplinary team) factors. The multidisciplinary team (soil scientist, mangrove specialist, horticulturist and range expert) formulated the core issues expressing their ideas for site assessment. Accordingly, selection criteria was formulated for site assessment and applied to a number of sites along the coastline. Combining the indigenous knowledge and scientific assessment, the method avoids a bias in either direction and allows a problem-development-oriented assessment. Such assessment has several advantages; 1) a comprehensive method; 2) a collection of baseline information of the site; 3) the multidisciplinary team create a good capacity building effect; 4) a combination of indigenous and scientific knowledge which allows quantitative and qualitative assessment. As a part of the site selection for mangrove plantation, a careful survey of the literature was undertaken. The literature survey revealed that an intensive survey of the coastal sites has to be carried out prior to the finalization of mangrove planting sites. It is visualized that mangrove plantation cannot be made in all available sites or vacant mudflats, as the topographical and environmental conditions limit the sustainability of mangroves. As a matter of fact, the mudflats in the coast to be used for plantation should have continuous flushing by sea water, which offsets the water requirement of the plants and promotes the development of strong root systems in seedlings. The literature also revealed that temperature, wind effect, soil texture, salinity, tidal coverage and drainage have significant effects on mangrove establishment and growth. It should be noted that there is no universal procedure for site assessment; it has to be designed or tailored to suit local conditions.

DEVELOPMENT OF SELECTION CRITERIA FOR SITE ASSESSMENT

In order to complete the site selection task, all important factors were taken into consideration and a selection criterion was developed. The main components of the criteria are:

A. **Accessibility**: The site should be readily accessible for plantation and maintenance.

B. **Inaccessibility to the grazers**: The site should avoid grazing by animals.

C. **Mudflats texture**: The texture of the site should be silty/clayey muddy, rather than loose sand particularly the upper surface; sandy sites tend to be eroded and are unstable for seedling establishment. It should be kept in mind that loose mud does not provide a very stable substrate for mangroves especially when planted as propagules or seeds.

D. **Topography**: The site should be slightly sloping, which drains tidal water back to the sea rather than flat ground where the water stagnates (Qureshi, 1996). The site must not be too low, so that the coverage of tidal water persists for too long, nor too high, so that the ground is only covered by the tide a few days a month. The best site lies between the mean sea level and the mean high water level (Qureshi, 1996). Siddiqi and Khan (1996) suggested lands inundated during normal high tides but exposed during low tides to be the ideal sites.

E. **Daily tidal coverage**: The site should be covered by water during the daily high tides to get regular flushing of salts and to offset the water requirements of the plants.

F. **Non-contamination by household wastes, construction materials and rubbles:** The sea weeds and debris left behind by high tides can damage young seedlings.

G. **Non-contamination by oil spills**: The oil-contaminated sites contain heavy metals such as lead (Pb), vanadium (V) and nickel (Ni), and create hydrophobic conditions not conducive for plant growth.

H. **Non-contamination by drainage effluents**: The drainage water contains toxic chemicals from industries and residential areas. Continuous drainage to the site also causes anoxic conditions.

I. **Low salinity and non shelly**: The sites compacted with shell contents are difficult for planting the propagules or seedlings; a site having high salinity due to sea water seepage and evaporation and non coverage by high tides is not suitable for the establishment of mangroves.

Site Assessment Activities

Preliminary investigation was made along the Kuwait coastline by reviewing the aerial photographs and an Atlas of Shorelines Types and Resources (Al-Sarawi *et al.*, 1985). On visits to the sites selected from the Atlas, it was found that while the coastal sites around Al-Khairan in the southeast of Kuwait were influenced by increased construction activities (chales or houses), those near Kuwait city were affected by urban development. These sites contained sandy beaches that were devoid of silty/clayey muddy materials. The sites along the Kuwait bay (Sulaibikhat-Doha-Sabiya coastline), on the other hand, contained silty soft muddy material deposited by the Euphrates and Shatt-Al-Arab.

A transact was made from Kuwait bay starting from Shuwaikh dry port, up to the bridge (Sabiya) linking Kuwait to Bubiyan island. During the site investigation, 14 sites initially were assessed on the selection criteria and only 5 sites that satisfied most criteria and showed good potential for mangrove plantation were finally selected for detailed on-site investigation and laboratory characterization prior to the plantation of the mangroves (Figure 1).

The selected sites were systematically traversed by the team to select a suitable mudflat within the site to consider relevant issues of importance to the selected site and to determine the objectives of the project. Different zones of a site were photographed, to assist in deciding the selection or rejection of a suitable subsite. Based on the selection criteria, relevant information was marked on the map, accompanied by extended remarks and descriptions. A comparison of 14 sites for various selection criteria is presented in Table 1.

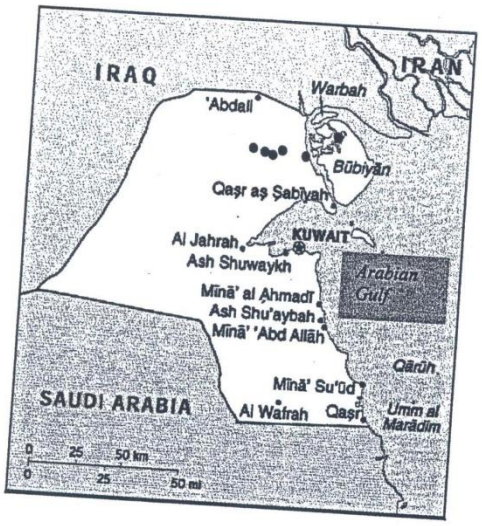

Fig. 1. Location of sites selected for detailed assessment and characterization.

Table (1). Criteria used for selection of potential sites for introduction of mangroves.

Site	A	B	C	D	E	F	G	H	I	Remarks
1	X	√	X	X	X	√	√	√	X	Rejected
2	√	√	X	X	X	√	√	√	X	Rejected
3	√	√	√	√	√	X	√	√	√	Rejected
4	√	√	√	√	√	√	√	√	√	**Selected**
5	√	√	√	√	√	X	√	X	√	Rejected
6	√	√	√	√	√	X	X	X	√	Rejected
7	√	√	√	√	√	√	√	√	√	**Selected**
8	√	√	√	√	√	X	√	X	√	Rejected
9	√	√	√	√	√	√	√	√	√	**Selected**
10	X	√	√	X	X	X	√	X	X	Rejected
11	√	√	√	√	√	√	√	√	√	**Selected**
12	X	X	√	X	X	√	√	√	X	Rejected
13	√	X	√	X	X	√	√	√	√	Rejected
14	√	√	√	√	√	√	√	√	√	**Selected**

X = unsuitable √ = suitable

Site No. 1-2 (Al-Khairan coastlines); 3-4 (KISR campus-existing mangrove sites); 5 (KISR existing mangrove site at Sulaibikhat coastline); 6-10 (Sulaibikhat coastline); 11 (Behind Doha entertainment city); 12 (Coastline near National Park); 13 (Sabiya bridge-left side); 14 (Sabiya bridge-right side).

MATERIALS AND METHODS

5 selected sites were subjected to further sampling and analyses. These sites were described as per USDA (1993) specifications, and classified according to USDA (1998 & 1999). At each site at least 3 transacts were made covering 3 distinct zones to cover each site, the inner zone (silty/clayey mudflats), the middle zone (intermediate silty/sandy area) and the outer zone (sandy area near shoreline). Multiple soil pits (referred to as pedons) were dug at each transact to just below the depth of standing water. The water table at all the sites fluctuates within 1 m from the soil surface. The samples were collected as per USDA guidelines (USDA, 1988), and a representative soil sample of approximately 2.5 kg was taken from each layer.

Soil samples were analyzed for a range of physical and chemical characteristics on < 2 mm fraction according to USDA (1995, 1996) and Page *et al.*, (1982) procedures. The laboratory measurement of pH (soil reaction), EC (electrical conductivity of saturation extract), $CaCO_3$ and Sodium Adsorption Ratio (SAR) generally help in describing the soils for their suitability, limitations and classification. Soil texture was determined by the modified hydrometer method supplemented with wet sieving (Shahid, 1992). The USDA textural class (USDA, 1993) was used to report soil texture by plotting the sand (2-0.05 mm), silt (0.05-0.002 mm) and clay (<0.002 mm) values, which defines C (clay), CL (clay loam), L (loam), S (sand), SL (sandy loam) and SCL (sandy clay loam). SiC (silty clay) and SiCL (silty clay loam). In this paper, the sum of silt and clay is taken as mud contents.

Soil saturation extract analyzed for soluble Na^+ and K^+ using Flame Emission Spectroscopy (FES), Ca^{2+} plus Mg^{2+} measured by titration with ethylene diamine tetra acetic acid (EDTA) in the presence of an ammonium chloride/ammonium hydroxide buffer solution and eriochrome black T indicator (USDA, 1954). CO_3^{2-} was undetectable. HCO_3^- was measured by titration with sulfuric acid, using a methyl orange indicator (USDA, 1954). Cl^- was estimated by titration with silver nitrate using a potassium chromate indicator. The SO_4^{2-} was calculated by difference between total measured cations and $CO_3^{2-}+HCO_3^-+Cl^-$ (Bresler *et al.*, 1982). $CaCO_3$ equivalents were determined by a standard calcimeter procedure and by the standard test for effervescence. The color of the dry and moist soil was determined using a Munsell Color Chart (Munsell, 1998). The Sodium Adsorption Ratio (SAR) calculated for the saturated soil paste extract, using the ionic concentrations expressed in me/1, for each horizon are as follows:

$SAR = Na^+/[(Ca^{2+}+Mg^{2+})/2]^{½}$ expressed in $(mmol/l)^{½}$

RESULTS AND DISCUSSION

The sites were surveyed and selected based on their evaluation on the developed selection criteria. The results of the field investigations and laboratory characterization of the representative soil samples from the three zones at each site of the five sites are presented below:

A. KISR Mangrove Project Site

This site is situated near the Biotechnology laboratories at the KISR main campus. Previously, the site was used for mangrove plantation. The site showed a good possibility for expanding the mangrove plantation. It was therefore decided to extend the site further in the northern direction to the existing plantation. The previous plantation contained gaps, which could be filled with new mangrove plants.

The site was divided into only two distinct zones; the inner mudflat and the outer sandy, as the intermediate zone did not occur. Oil contamination was observed at a depth of 30 cm in the outer zone. The representative pedon description from the inner zone is given in Pedon 1. Some selected physical and chemical characteristics are presented in Table 2.

Pedon 1

Taxonomic Name: **Typic Aquisalid**
Diagnostic horizon: **Salic**
Type of observation: soil pit — Surface condition: muddy
Slope < 1% — Slope class: nearly level
Slope morphological type: simple — Moisture status: wet
Land use: none/mudflat — Biological activity: low
Parent material: alluvium — Water table: fluctuate to sea water level

Table (2). Physical and chemical characteristics of typical soil pedons from the inner, existing mangrove site and outer zone from the KISR mangrove project site.

Horizon	Depth (cm)	pHs	ECe dS/m	SAR $(mmol/l)^{1/2}$	$CaCO_3$ % eq.	Sand	Silt	Clay	Textural Class
						——— -%———			
Inner Zone									
Akzg	0-3	8.02	74	104	31.4	26	39	35	CL
Bkzg	3-30+	7.75	32	66	24.1	41	25	34	CL
Mudflat near existing mangrove site									
Akzg	0-5	7.68	109	128	17.3	74	13	13	SL
Bkzg	5-30	7.94	55	89	17.2	71	14	15	SL
Outer Zone									
Ak	0-30	8.47	16	50	14.1	98	1	1	S
	30+	..... Oil Contaminated.....							

Morphological Description: Akzg - 0 to 5 cm; light gray (2.5Y 7/1) dry, dark gray (5Y 4/1) moist; clay to clay loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); violently effervescent; rigid dry consistence; very sticky; no gravels.

Bkzg – 5 to 30 cm +; light gray (5Y 7/1) dry, dark gray (5Y 4/1) moist; clay loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); violently effervescent; rigid dry consistence; very sticky; no gravels.

Bkzg – 5 to 30 cm +; light gray (5Y 7/1) dry, dark gray (5Y 4/1) moist; clay loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); strongly effervescent; rigid dry consistence; very sticky; no gravels.

The characteristics (mud content) of the inner zone and the mudflat at existing mangroves show better promise for plantation to the north, and for further extension. The sandy zone does not show suitable mudflat texture. In addition, it shows oil contamination below a depth of 30 cm. Therefore, the outer zone should be avoided for the plantation of mangroves.

B. Sites at Sulaibikhat Bay

Out of the 6 sites investigated at the Sulaibikhat bay, 2 were selected which fulfilled most selection criteria.

Sulaibikhat Site 1: This site is located at the northern corner of the Children Entertainment Park at the bay of Sulaibikhat. *Zygophyllum* plants growing at the site indicated its high productivity. The site was divided into 3 distinct zones; the inner mudflat (3 pedons), the intermediate are a (3 pedons) and the outer (1 pedon) area. A representative pedon from the inner zone is described in Pedon 2.

Morphological Description: Akzg – 0 to 5 cm; light gray (2.5Y 7/1) dry, gray (2.5Y 5/1) moist; clay loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); violently effervescent; rigid dry consistence; very sticky; no gravels.

Bkzg – 5 to 30 cm + ; gray (5Y 6/1) dry, gray (5Y 6/1) moist; silty clay loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); strongly effervescent; rigid dry consistence; very sticky; no gravels. Selected characteristics from representative pedons from the inner, the middle and the outer zones are presented below (Table 3).

As the characteristics of the inner and the middle zones (texture/mud contents) suggested good conditions for the plantation of mangroves, they may be exploited. However, the inner zone should be preferable, as it satisfied the selection criteria better than the other two zones. In contrast, although the outer zone contained a reasonable amount of mud below 10 cm, it is not covered by the daily high tides. Hence, this zone should be avoided for the plantation of mangroves.

Sulaibikhat Site 2: The site has similar features as the Sulaibikhat site 1. The site has a productive, least contaminated and easily accessible mudflat. At the edge, the site has a sandy area and further up contains a relatively high salt content (visible white crystals). A preliminary field observation of the site showed a strong indication for the establishment of mangroves. Therefore, the site was divided into three zones; the inner (3 pedons), the middle (2 pedons), and the outer (1 pedon) zones. *Zygophyllum* plants occurred in the middle zone. The outer zone was contaminated with oil below a depth of 20 cm. The representative pedon from the inner zone is described below.

Pedon 2

Taxonomic Name: **Typic Aquisalid**
Diagnostic horizon: **Salic**
Type of observation: soil pit
Slope: < 1%
Slope morphological type: simple
Land use: none
Parent material: alluvium
Surface condition: muddy
Slope class: nearly level
Moisture status: wet
Biological activity: high fish activity
Water table: fluctuated with sea water level

Table (3). Physical and chemical characteristics of typical soil pedons from the inner, middle and outer zones from sites at Sulaibikhat Bay.

Horizon	Depth (cm)	pHs	ECe dS/m	SAR $(mmol/l)^{1/2}$	$CaCO_3$ % eq.	Sand	Silt	Clay	Textural Class
						——— % ———			
Inner Zone									
Akzg	0-5	8.11	64	93	40.0	30	34	36	CL
Bkzg	5-30	8.13	43	111	34.2	14	47	39	SiCL
Middle Zone									
Akzg	0-5	8.40	85	120	29.8	32	33	35	CL
Bkzg	5-30	8.13	54	54	32.2	9	42	49	SiC
Outer Zone									
Akz	0-10	8.35	24	69	9.2	97	2	1	S
Bkz	10-30	7.89	25	99	29.7	32	40	28	CL

Morphological Description. Akzg–0 to 5 cm; light gray (5Y 7/1) dry, dark gray (5Y 4/1) moist; loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); violently effervescent; rigid dry consistence; very sticky; no gravels.

Bkzg – 5 to 30 cm +; light gray (5Y 7/1) dry, gray (5Y 5/1) moist; clay loam; massive structure; moderate to high excavation difficulty (wet), very high excavation difficulty (dry); strongly effervescent; rigid dry consistence; very sticky; no gravels.

Selected characteristics of the representative pedons from the inner, the middle and outer zones are given in Table 4. The outer zone was almost homogeneous in characteristics; it was exposed at 5 places. The five sites were contaminated with oil at a depth of 20 cm.

Although both the inner and the middle zones showed good promise, the former was more suitable for the establishment of the plantation of mangroves. These zones also satisfied the selection criteria better than the outer zone.

C. Site near Entertainment City – Doha

The site is located behind the entertainment city at Doha. The site was divided into 3 zones. The main features of the outer zone (2 pedons) are: the saline mudflat which was not covered by high tides daily, the reeds growing in the swamps, the halophytic plants dying due to a very high salinity, the contamination by spilled oil, and the oil contaminated rocky coastline were also observed in the outer zone.

Pedon 3

Taxonomic name: **Typic Aquisalid**
Diagnostic horizon: **Salic**
Type of observation: soil pit
Slope: < 1%
Slope morphological type: simple
Land use: none
Parent material: alluvium
Surface condition: muddy
Slope class: nearly level
Moisture status: wet
Biological activity: high fish activity
Water table: fluctuated to sea water level

Table (4). Physical and chemical characteristics of typical soil pedons from the inner, middle and outer zones from Sulaibikhat site 2.

Horizon	Depth (cm)	pHs	ECe dS/m	SAR $(mmol/l)^{1/2}$	$CaCO_3$ % eq.	Sand	Silt	Clay	Textural Class
						——— % ———			
Inner Zone									
Akzg	0-5	8.53	73	108	ND	43	31	26	L
Bkzg	5-30	8.58	31	94	ND	16	39	45	C
Middle Zone									
Akzg	0-20	8.56	99	135	33.8	38	34	28	CL
Bkzg	20+	8.71	86	184	33.1	14	42	44	SiC
Outer Zone									
Akz	0-20	7.85	74	111	39.2	98	1.5	0.5	S
	20+	.....			Oil Contaminated	.....			

The middle zone (3 pedons) comprised of a saline/silty and sandy area (visible salt crystals), not covered uniformly by regular high tides. The inner zone (4 pedons) was covered daily by high tides. Mangrove plants were also observed at the muddy flat zone which indicated the potential of the site for a successful mangrove plantation. Among all the locations mentioned above, only the inner zone was selected for mangrove plantation. The representative pedon from the inner zone is described below.

Morphological Description. Akzg–0 to 5 cm; light gray (2.5Y 7/1) dry, gray (2.5Y 6/1) moist; loam; massive structure; low excavation difficulty (wet), very high excavation difficulty (dry); violently effervescent; rigid dry consistence; very sticky; no gravels.

Bkzg – 5 to 30 cm + ; light gray (2.5Y 7/1) dry, light olive gray (5Y 6/2) moist; clay loam; massive structure; low excavation difficulty (wet), very high excavation difficulty (dry); violent effervescent; rigid dry consistence; very sticky; no gravels.

The soil of 3 zones at the Doha site was relatively less saline (Table 5). The pHs and SAR levels in the inner zone (near sea water) were also lower than the middle zone, but had slightly higher pHs compared to the outer zone. The inner zone also shows relatively finer textured materials (higher mud) than the other 2 zones. The 15-30 cm layer of the outer zone contained maximum silt (51%), although this zone is not covered by daily high tides. It is, therefore, much easier to explain that soil characteristics of the inner zone make it highly suitable for mangrove plantation. The middle zone is partially covered by high tides.

Pedon 4

Taxonomic name: **Typic Aquisalid**
Diagnostic horizon: **Salic**
Type of observation: soil pit
Slope: < 1%
Slope morphological type: simple
Land use: none
Parent material: alluvium
Surface condition: muddy
Slope class: nearly level
Moisture status: wet
Biological activity: high crabs activity
Water table: fluctuated with sea water level

Table (5). Physical and chemical characteristics of typical soil pedons from the inner, middle and outer zones from site near entertainment city, Doha.

Horizon	Depth (cm)	pHs	ECe dS/m	SAR $(mmol/l)^{1/2}$	$CaCO_3$ % eq.	Sand	Silt	Clay	Textural Class
						——— % ———			
Inner Zone									
Akzg	0-10	8.19	124	190	35.1	44	31	25	L
Bkzg	10-30+	8.23	115	135	34.1	34	31	35	CL
Middle Zone									
Akz	0-5	8.39	152	221	40.0	49	26	25	L
Bkzg1	5-20	8.37	83	211	39.2	64	15	21	SCL
Bkzg2	20-30	8.33	113	139	39.6	62	18	20	SL-SCL
Outer Zone									
Akz	0-5	8.28	196	143	33.7	93	4	3	S
Bkz	5-15	7.67	144	120	26.9	74	24	12	SL
Bkz	15-30	7.95	145	219	27.1	43	51	6	SiL

D. Sabiya – Bubiyan Ridge Site

This site is situated on the right side of the bridge leading to Bubiyan Island at Sabiya. The site was divided into 3 distinct zones for sampling; the inner (3 pedons), the middle (2 pedons) and the outer (3 pedons) areas.

Zygophyllum plants were observed in the inner and the middle zones. There was high crab activity in the inner zone, which raises the mudflat to about 6 cm and makes it highly productive. As this zone fits very well to the selection criteria, it is proposed for the plantation of mangroves. The representative pedon is described below.

Morphological Description. Akzg–0 to 10 cm; light gray (5Y 7/1) dry, olive gray (5Y 5/2) moist; sandy loam; massive structure; low excavation difficulty (wet), very high excavation difficulty (dry); violently effervescent; rigid dry consistence; very sticky; no gravels.

Bkzg – 10 to 30 cm +; light gray (5Y 7/1) dry, olive gray (5Y 5/2) moist; sandy loam; massive structure; low excavation difficulty (wet), very high excavation difficulty (dry); violent effervescent; rigid dry consistence; very sticky; no gravels.

Selected characteristics of representative pedons from the inner, the middle and the outer zones are given in Table 6.

Comparison of the soil characteristics of the 3 zones clearly show that in the inner zone (near sea water), lower ECe and pH values are noticeable compared to the other zones. However, it showed a slightly higher SAR than the outer zone, whereas the middle zone attains the highest SAR values than the other 2 zones.

Pedon 5

Taxonomic Name: **Typic Aquisalid**
Diagnostic horizon: **Salic**
Type of observation: soil pit
Slope: < 1%
Slope morphological type: simple
Land use: none
Parent material: alluvium
Surface condition: muddy
Slope class: nearly level
Moisture status: wet
Vegetation: none
Water table: fluctuate with sea water level

Table (6). Physical and chemical characteristics of typical soil pedons from the inner, middle and outer zones from the Sabiya-Bubiyan ridge site.

Horizon	Depth (cm)	pHs	ECe dS/m	SAR $(mmol/l)^{1/2}$	$CaCO_3$ % eq.	Sand	Silt	Clay	Textural Class
						——— % ———			
Inner Zone									
Akz	0-10	8.01	51	186	15.3	72	16	12	SL
Bkzg	10-30+	8.08	28	170	19.8	69	18	13	SL
Middle Zone									
Akz	0-10	8.31	92	589	12.7	95	4	1	S
Bkzg	10-30+	8.15	93	361	16.7	78	13	9	SL
Outer Zone									
Akz	0-5	8.25	172	114	16.8	90	6	4	S
Bkz	5-20	8.48	92	129	9.4	96	2	2	S
Bkzg	20+	7.89	82	183	18.9	77	13	10	SL

Limited data is available on the tolerance of mangrove species to high and low salinities (Hutchings and Saenger, 1987). However, the response of mangrove trees to high salinity is more variable in the field than in culture experiments. Mangroves have been found at soil salinities considerably higher than those suggested by laboratory experimentation. The inner zone also attained finer textured soil materials (high mud contents) than the other two zones. Therefore, it is much easier to explain that the soil characteristics of the inner zones of five sites are the most suitable to the developed selection criteria for mangrove plantation at the Subiya site. The water table in the inner zone fluctuated shallower than the outer zones as a factor of daily tidal coverage. The influences of water table are less important in determining plant distribution and performance of mangroves than factors such as the frequency of inundation and exposure, the mechanical action of tidal water and soil salinity (Clarke and Hannon, 1969).

CONCLUSIONS AND RECOMMENDATIONS

Mangroves cannot be planted at all coastal sites. The site should have characteristics favorable for such a plantation. Present investigation on the coastal sites of Kuwait showed that to the southeast at Al-Khairan the coast is influenced by the construction of Shellay houses, and the coasts are generally sandy in nature. In Kuwait city, the coasts have urban development and became public places. A field survey showed that some sites between Sulaibikhat bay and Sabiya, where sufficient muddy flats occur are most suitable for establishing mangrove plantations in Kuwait. During the field investigation, the multidisciplinary team initially selected 14 sites. These were assessed on the selection criteria and 5 sites were finally selected for mangrove plantation.

From the field and laboratory investigations, it can be concluded that the outer zone is not covered by daily high tides and is mainly loose sand contains rubbles, shells, and in some places is contaminated by oil. Occasionally visible salt crystals are observed. The middle zone is partially covered by high tides and has less mud (silt/clay) contents. The inner zones have better topography, higher mud contents and covered daily by high tides compared to the other zones. Therefore, the inner zone in all 5 sites and the middle zone in only 2 sites (Sulaibikhat & Sabiya) have been recommended for the establishment of mangrove plantations. The inner zone should be the first choice.

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