Journal of Applied Sciences Research, 5(8): 1040-1050, 2009

Relationship Between Plant Cover Type and Soil Properties on Western Coastal Region, Saudi Arabia

Hediat M.H. Salama and Najat Bokhari

King Saud University, Women Students-Medical Studies & Sciences Sections, Riyadh, KSA.

Abstract: A survey of soils and plant covers was conducted on the coastal plains of the western province of Saudi Arabia to clarify the relationships between the soil properties and the plant cover type. A belt transect of 80 m in length was established across each study area. Four mixed plant communities dominated by species such as: *Tamarix nilotica* in coastal sabkha, *Saliconrnia qassimensis* in coastal sand dunes, *Aerva lanata* in sand plains, and *Bassia muricata* in wadis areas were recognized. Soil types at the study area were determined to be sandy immature soil and peat lamina soil. Their horizon sequences were described as surface, subsurface and bottom layers, indicating layers of leaf litter, peat lamina and parent material, respectively. Coastal sabkha and coastal sand dunes were characterized by a relatively high calcium concentration in the soil horizons and tendency for podzolization in the volcanic deposit layer. The subsurface layers in coastal sabkha and coastal sand dunes were characterized by some peat lamina accumulation because of the high groundwater table, volcanic deposits in the soil profile and the strong influence of sea salt on the soil chemistry. The roots in the coastal sabkha and coastal sand dunes were distributed more shallowly than those in the sand plains and wadi areas, thus avoiding the high water table level as well as the influence of seawater in the soil. Generally, the salt marsh showed high sodium concentration and base saturation, indicating that this area was directly affected by seawater. Recently, the periphery of the plant covers on the coastal sand dunes has been declining because inundation caused by ground subsidence.

Key words: Coastal sand dune, rising sea level, sea salt, basic saturation, *Tamarix nilotica*, Saudi Arabia

INTRODUCTION

In the western coastal regions of Saudi Arabia, several investigations have been made on vegetation cover and soil properties. Vesey-Fitzgeraid[33] recognized a number of vegetation cover and ecological types including coastal desert plain, coastal foothills, littoral marshes, wadis and mountain ridges. Batanouny[5], Batanouny abd Baeshin[7], Mohamed and El-Tom[22] and Fayed and Zayed [14] described the vegetation of Makkah-Jeddah and Makkah-Taif regions. They have recognized a number of vegetation cover and ecological types, mostly in the form of zones. Batanouny and Baeshin[4,6] gave lists of 135 species belonging to 108 genera in 43 families along the Jeddah-Makkah road in the western province of Saudi Arabia. El-Shourbagy *et al.,*[13] recorded five community types in thirty stands at Jeddah-Tuwal area (western province of Saudi Arabia). Some of these plant communities reported in those studies correlated and indicated extensions of regional importance. The soil moisture-salinity interaction has been widely recognized as the most important factor in the distribution of the stress tolerant plants[28]. Also, the chemical and hydrophysical characteristics of soil affect the diversity and structure of the vegetation[10].

Vegetation of the coastal sabkha in the western province of Saudi Arabia is generally dominated by *Tamarix nilotica*, *Suaeda pruinosa*, *Zygophyllum coccineum*, and *Juncus maritimus* plant communities. While the coastal sand dunes are dominated by *Salicornia qassimensis*, *Halopeplis perfoliata*, *Aeluropus massauensis* and *Anabasis setifera* plant communities. *Aerva lanata*, *Capparis decidua*, *Salsola spinescens* and *Pergularia tomentosa* plant communities in the sand plains and Bassia muricata, Haloxylon salicornicum, Calotropis procera and Anthemis melompodina plant communities in the wadi areas. Nishijima *et al.,*[24] reported the vegetation characteristics and its relation to the groundwater table level and water chemistry on Syunkunitai sand dune. Coastal plains are affected by seawater intrusion and flooding in the soil[27], Conner *et al.,*[12] . Although a large amount of sea salt harms plants, sea salt deposition is advantageous for plants as it serves as an origin of minerals for oligotrophic soil[32]. Iyobe *et al.,*[18] reported mineral transportation by sea fog and Fujita *et al.,*[15] studied the vegetation and soil conditions.

Corresponding Author: Hediat M.H. Salama, King Saud University, Women Students-Medical Studies & Sciences Sections, Riyadh, KSA.
E- mail: hoda.salama@hotmail.com

Natural plant communities on the western coastal areas of Saudi Arabia, support many plants, birds and insects. However, the periphery of plant communities on the coastal areas has been declining recently, which is probably of seawater inundation caused by ground subsidence[24,25]. Therefore it is important to study the relationship between plant community and its surrounding environment at the coastal areas and find ways to conserve its biodiversity.

This study focused on the soil properties of the western coastal areas of Saudi Arabia along the Red Sea shore line and evaluated the relationships between the plant cover types and the soils. Also, our discussion was further extended to the effects of rising sea levels on the plant communities, because rising sea levels or seawater flooding might change the soil environments and damage the plant communities on the coastal areas.

MATERIALS AND METHODS

Study area: The study area was located on the Red Sea coastal plain, western province of Saudi Arabia (Latit. 22° to 24° N, longit. 37° to 39° E.) as shown in figure 1. Saudi Arabia is geologically divided into four distinct and extensive terrains as described by Laurent[21]. These are the Proterozoic Arabian Shield, comprising metamorphosed volcano sedimentary successions intruded by granite and gabbro; Arabian Platform dipping gently eastward. The Tertiary rocks mainly overlying the shield. The narrow Red Sea coastal plain of the Tertiary and Quaternary are composed of sedimentary rocks and coral reefs. The geologic units that outcrop in the study area from oldest to youngest are: Precambrian rocks, Tertiary sediments, Tertiary to Quaternary basalt flows and Quaternary deposits[3]. In the study area the Precambrian rocks constitute the oldest rock units and consist of a group of sedimentary and volcanic rocks that was subjected to a series of deformations[9]. The study area is mainly composed of consolidated and unconsolidated marine clastic sediments of Tertiary and Quaternary ages crop out along the Red Sea coastal plains. These sediments are mainly horizontally stratified, vari-colored, alternating with clay and gravel. The Tertiary sediments lie unconformably over the Precambrian rocks with thickness up to 60 m and overlain in many parts by Quaternary basalt flows. These basalt flows belong to Pliocene age and continued throughout the Quaternary until recent times[20].

The maximum and minimum annual mean temperature are 36.0° C and 19.8° C respectively, while the annual mean precipitation is 10.8 mm. The maximum and minimum annual mean relative humidity percentages are 43.6 and 18.7 respectively. All climatic data are averages from year 2000 to 2006. The data shown that, the climate of the study area falls in a transitional zone between the Monosoon and Mediterranean climatic types, which are modified by Red Sea. Generally, the climate of the study area is warm as per most climatic classification and considered as dry climate because the precipitation is less than 250 mm[31]. Coastal sabkha and coastal sand dunes was covered mainly by coastal grasses, shrubs and deciduous broad-leaved plant covers. Mostly salt marsh plants grow along a shore line facing the Red Sea on the coastal sand dunes and on the slacks between dunes.

Study Methods: A belt transect (20 x 80 m) was set up across each study area (coastal sabkha, coastal sand dunes, sand plains and wadis) and was divided into four quadrates of (20 x 20 m). The investigation of the soils and plant cover as carried out in each quadrate. The distribution and growth status of plant cover were investigated from April 2008 to February 2009. The species and growth conditions (living or dead) were recorded from all individuals which are taller than the 1 m height in each quadrate.

The observation of soil horizons were carried out in November 2008. A pit about 50 cm deep was dug, and the soil profile was assessed. Soil samples were collected at three depths, surface (0-15 cm), subsurface (15-30 cm) and bottom (30-45 cm) for each habitat for chemical and physical analyses. The texture of the soil supporting plant covers in all habitats was determined by using sieves analyses method[29]. All samples were air-dried and passed through a 2-mm sieve. Organic carbon was determined by using Walkely and Black rapid titration method[29], while the total $CaCO_3$ was determined by titration methods as described by Jackson [19]. The soil reaction (pH was determined by a pH meter, total soluble salts (TSS) by drying methods, chlorides by titration with standard silver nitrate solution, sulfate gravimetrically as $BaSO_4$, soluble bicarbonate by acid titration[29] and soluble phosphates by spectrophotometers, Murphy and Riley[23], for soil suspensions of a 1:5 soil : water ratio. The concentrations of exchangeable cations, potassium (K^+), sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}), were determined by using atomic absorption spectrophotometer after extraction with 1N Ammonium Acetate. Heavy metals iron (Fe^{3+}) in the soil content were measured by an atomic absorption spectrophotometer after the digestion of soil samples with a mixture of HNO_3-HCl[30]. The cation exchange capacity (CEC) was determined by measuring Ammonium ion concentration with an H_2SO_4 titration (Semimicro Kjeldahl Method). Soil properties and plant cover types were analyzed by a two ways of variance analysis[11,26], which tested for the correlation coefficient and relationships between soil characteristics and plant cover types.

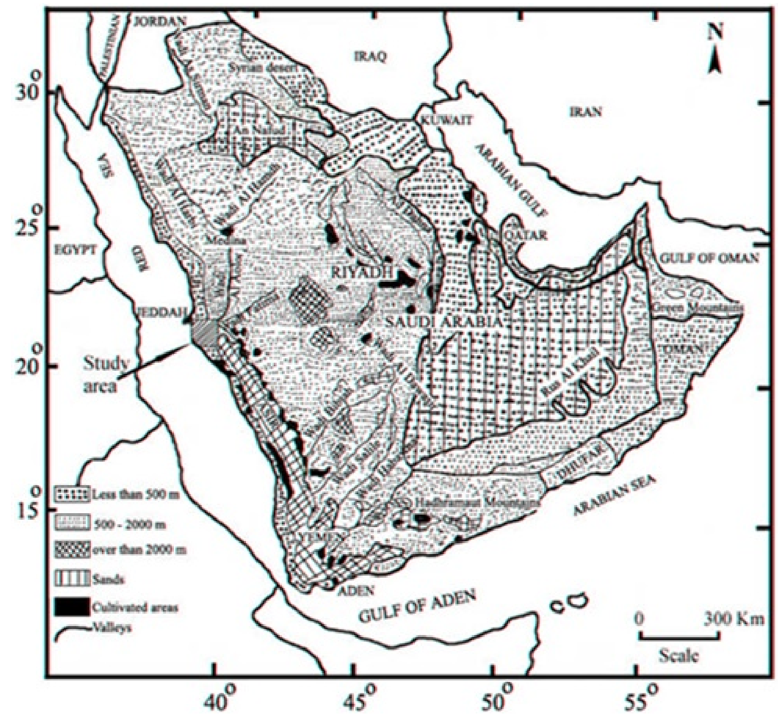

Fig. 1: Relief map of the Ambiansuln (Modified after[1]). Study area.

RESULTS AND DISCUSSION

Distribution and Growth Status of Plant Cover: The basal areas of plant cover and deciduous broad-leaved plants along the belt transect are characterized by limited living plants at the coastal sabkha and coastal sand dunes of the surveyed transect. These habitats were salt marsh with few dead standing plant cover. The plant covers grow in the sand plains and wadi areas. They have a basal area greater than 4 m2/25 m^2, which was in the sand plains (*Aerva lanata*). *Bassia muricata* dominated in the wadis areas, where the basal areas of plant cover was medium (< 2 m^2/25 m^2). Small-size of plant cover (1 m^2/25 m^2) is recorded in the coastal sand dunes (*Salicornia qassimensis*). The size and number of stems deciduous broad-lived plant cover in the coastal sabkha, were very small (< 1 m^2/25 m^2) e.g. *Tamarix nilotica*.

Soil morphological characteristics are shown in Tables 1-4. The soil types in the study area were determined to be immature sand soil and little peat soil. Their horizon sequences were described as layers of leaf litter at a depth from 0 to 15 cm (surface layer), some peat lamina were been in depth from 15 to 30 cm (subsurface layer) and parent material from a depth of 30 to 45 cm (bottom layer).

The surface layers were formed mainly of coarse sand in all study areas and were covered by mosses and herbs as plant cover species. The subsurface layers were formed mainly of coarse to fine sands with a small lamina of peat, especially in the coastal sabkha and coastal sand dunes. The bottom layers consisted of coarse to fine sands and containing humus in coastal sabkha and coastal sand dunes. The upper part of these layers was eluviated, and accumulation was observed in the middle to lower part of subsurface layers in sand plains and wadis. No living roots were recognized in the bottom layers of the coastal sabkha and coastal sand dunes. The root distribution was restricted to surface and subsurface layers. However, roots extended to the bottom layers in the sand plains and wadis areas.

Soil Chemical Properties: The soil chemical properties are shown in Tables 5-8. The soil reaction (pH) of all layers in the study areas displayed in a relatively normal range (7.15 - 8.04); however, the pH of the soil analyses indicated that it is moderately basic. The soluble salts (TSS) were higher in the coastal sabkha (656 - 874 mg/100 gm). The TSS in the coastal sand dunes ranged from 322 to 613 mg/100 gm. In the sand plains, the total soluble salts ranged from 142 to 282 mg/100 gm, while in the wadis areas range from 92 to 285 mg/100 gm. In the study areas, the total soluble salts increased with depth. The organic carbon contents and total calcium carbonate percent ($CaCO_3$%) were low (36.46 mg/100 gm and 35.16%, respectively) at the surface layers. At the horizons become deeper, the contents of organic carbon

and total $CaCO_3$ percent increased to a level as high as, approximately 255.17 mg/100 gm (organic carbon contents) and 47.08% ($CaCO_3$%) in the bottom layers. However, the bottom layers (containing humus and sand) showed higher contents of the total carbon than the overlying layers.

The concentrations of cations in the surface layers were generally low and increased in deeper horizons. Concentrations of Ca^{2+}, Mg^{2+} and N^{a+} were higher in the coastal sabkha, coastal sand dunes and wadis areas, whereas K^+ concentrations were high in the sand plains. The concentrations of Ca^{2+} in the coastal sabkha ranging from 21.74 mg/100 gm (surface layer) to110.92 mg/100 gm (bottom layer). Magnesium had the concentrations ranged between 0.73 mg/100 gm (surface layer) in the coastal sabkha and 22.58 mg/100 gm (bottom layer) in coastal sand dunes. However, the Na^+ concentrations were the highest among the four cation concentrations at the coastal sand dunes, where the concentration ranged from 10.91 mg/100 mg (surface layer) to 42.8 mg/100 gm (bottom layer). The concentrations of K^+ ranged from 10.74 mg/100 gm (surface layer) to 21.01 mg/100 gm (bottom layer) at the sand plains area. The concentration of Fe^{3+} ranged from 0.39 to 0.68 mg/100 gm at the coastal sand dunes. The concentrations of anions in the surface layers were low and increased in deeper horizons. The concentrations of SO_4^{2-}, ranging from 470 mg/100 gm to 545 mg/100 gm at the coastal sabkha, were remarkably higher than those the other anions.

Discussion: We classified the plant communities of the surveyed transect into four plant cover types for each study area, that is, the *Tamarix nilotica, Suaeda pruinosa, Zygophyllum coccineum* and *Juncus maritimus* in the coastal sabkha; *Salicornia qassimensis, Halopeplis perfoliata, Aeluropus massauensis* and *Anabasis setifera* in the coastal sand dunes; *Aerva lanata, Capparis deciduas, Salsola spinescens and Pergularia tomentosa* in the sand plains; and *Bassia muricata, Haloxylon salicornicum, Calotropis procera* and *Anthemis melompodina* in the wadis areas.

Soil Morphological and Chemical Characteristics of the Plant Cover Types at the Coastal Sabkha: The distribution of plants in coastal sabkha is regulated by the distance from the shoreline[34]. Salt marsh areas with limited living plant covers were located between Red Sea and sand plains. Peat had accumulated thickly in the subsurface layers, reflecting high groundwater table level. The *Tamarix nilotica* - dominant area was located at the coastal sabkha mixed where *Suaeda pruinosa, Zygophyllum coccineum* and *Juncus maritimus* grow abundantly (Table 1). Although deciduous broad-leaved plant covers are present in this area, they had a basal area of only ,< 1 m^2/ 25 m^2, on average. In this area, the mean rank of saturation values of the five cations was same in all horizons, $Ca^{2+} > Na^+ > Mg^{2+} > K^+ > Fe^{3+}$ (r = 0.885, p = 0.004), where the mean rank concentration of all horizons , SO_4^{2}- > Cl- > $HCO_3^- > PO_4^{3-}$ (r = 0.874, p = 0.006) by Spearman's rank correlation coefficient. This area might be directly influenced by seawater, and TSS, Na^+, Ca^{2+} and Mg^{2+} concentrations and base saturations were higher than those of other areas (Table 5). Limiting roots were recognized in the soil profile of this area. Excessive basic cations in the soil might attribute to harm the roots of juvenile plants. The base saturation values {(cation / CEC) x 100} for five cations in each soil horizon of this area progressively increased from surface to bottom layers, and this might be attributed to the influence of the saline water from the Red Sea. Increasing of SO_4^{2-} might to the presence of thin lamina of gypsum and more evaporation processes in the study area.

Soil Morphological and Chemical Characteristics of the Plant Cover at the Coastal Sand Dunes Area: The soil condition of the *Salicornia qassimensis, Halopeplis perfoliata, Aeluropus massauensis* and *Anabasis setifera* plant cover on the coastal sand dunes was characterized as coarse to fine sands in all horizons (Table 2). The mean rank of saturation values of the five cations in this area were $Ca^{2+} > Na^+ > Mg^{2+} > K^+ > Fe^{3+}$ (r = 0.884, p = 0.003) and the four anions $SO_4^{2-} > Cl^- > HCO_3 > PO_4^{3-}$ (r = 0.873, p = 0.005) by Spearman's rank correlation coefficient (Table 6). The high Ca^{2+} concentration in all horizons might be because the plant covers preferentially limit the absorption of available Ca^{2+} from the soil [8] and the absorbed Ca^{2+} might be incorporated into plant covers biomass and only a small quantity being re-supplied to the plant cover floor through litter-fall. The deep groundwater level and temperature in this area might be interfering with litter decomposition. Meanwhile, the concentrations of Mg^{2+} in this study area might be because of the contribution from sea salt. Although the Na^+ saturation was lower than the Ca^{2+} saturation, Na^+ showed the highest saturation under *Aeluropus massauensis* plant cover in all horizons. This indicates the effect of seawater, especially in the deeper soil horizons. Despite the greater effect of seawater in the deeper soil horizons, Na^+ concentration in the bottom layer was not very high, possibly because of the low CEC values in these layers (Table 6), due to the low humus content. The base saturation in each soil horizons of the plant cover progressively increased from surface to bottom layers. This phenomenon might be attributed to the influence of the brackish water from the Red Sea, though the high concentration of SO_4^{2-} was the reason for the decay of gypsum mineral.

Roots were distributed on the surface and subsurface layers in the coastal sand dunes area. In this study area, a high concentration of Na^+ and the accompanying chloride have an unfavorable effect on the growth of many plants, with a basal area 1 m^2 / 25 m^2[2]. The relatively low concentration of Ca^{2+} might also have a disadvantage for the growth of plants, while the shallow-rooted of plants in the coastal sand dunes have adaptated to avoid the influence of seawater as well as high groundwater table level in deeper soils and therefore effectively utilize the poor nutrition in the surface soils of this habitat[17].

Soil Morphological and Chemical Characteristics of the Plant Cover at the Sand Plains Area: The area dominated by *Aerva lanata* was located in the sand plains area, mixed with abundantly growing *Capparis decidua, Salsola spinescens* and *Pergularia tomentosa*. Although deciduous broad B leaved plant grow in this area, they had a basal area of only 4 m^2 / 25 m^2 or more, on average. The soil horizon was composed mainly of coarse to fine sands (Table 3), and no peat lamina was detected the in this horizons. The upper part of the bottom layer was eluviated and accumulation was observed in the middle to lower part of subsurface layer. The elevation was relatively high (130 cm on average), and the groundwater table level was deep. Soil water moves downward, forming podzols in this area.

The concentration of Ca^{2+} was most abundant of the five cations, while the SO_4^{2-} was the most abundant of four anions in all horizons in all sand plains (Table 7). The Ca^{2+} rich conditions of the sand plains was also affected by the litter of broad B leaved plant covers that intruded into the coniferous plant. The mean rank of the concentration values of five cations in all horizons of sand plains habitat were $Ca^{2+} > Mg^{2+} > K^+ > Na^+ > Fe^{3+}$ (r = 0.883, p = 0.002) and anions were $SO_4^{2-} > HCO_3^- > Cl^- > PO_4^{3-}$ (r = 0.872, p = 0.004), by Spearman's rank correlation coefficient. The base saturation in each soil layer in the sand plains area increased from surface to bottom layers. This might be attributed to the influence of the brackish water from the western coastal area. Although the Na^+ saturation ranked higher in the deeper horizons, it was still lower than the Ca^{2+} saturation. The Mg^{2+} concentrations in all horizons in the sand plains area were significantly correlated with Na+ concentration (r = 0.891, p = 0.001, Spearman's rank correlation coefficient). The higher sea salt B originated Mg^{2+} concentration, a compared to the Na+ concentration in the surface layers, might be because of leaching by rainfall, which dissolves the mono-electric charged in (Na^+) more easily than the di-electric charged ion (Mg^{2+})[16].

Roots extend to the bottom layers at all sites in the *Aerva lanata*, which were deeper than those in the other plant covers in this area.

Soil Morphological and Chemical Characteristics of the Cover at the Wadis Areas: The *Bassia muricata* - dominant plant covers area - were located in the wadis areas with *Haloxylon salicornicum, Calotropis procera and Anthemis melompodina*. The mean basal area of these plant covers was less than 2 m^2 / 25 m^2 in this area.

The soil horizon sequences were changed from coarse to fine sands to fine to coarse sands in all layers (Table 4). The bottom layers (containing humus and sand) were recognized at most of the quadrates in this area. The humus of the bottom layer is probably the remains of the old vegetation that was present before the erosion from the adjoining mountains. Podzolization in the bottom layer was observed in this study area. The elevation was relatively low (52 cm on average), and the deep groundwater table level in the wadis area inhibited podzolization in this area. The deep groundwater table level also attributed to the non formation of peat lamina and humus soils in this study area.

The calcium concentration was the most abundant of the five cations in all layers. Meanwhile, the sulfate was the most common of the four anions. The Ca^{2+} - rich condition of the wadis area was also affected by the litter of broad B leaved plants that intruded into the coniferous plant. The mean rank of the concentration values of five cations and four anions in all layers of the wadis area were $Ca^{2+} > Mg^{2+} > K^+ \; Na^+ > Fe^{3+}$ (r = 0.882, p = 0.001) and $SO_4^{2-} > HCO^{3-} > Cl^- > PO_4^{3-}$ (r = 0.871, p = 0.003), respectively, by Spearman's rank correlation coefficient Table 8). The Na+ concentration in all horizons was low because of leaching by rainfall during winter. The SO_4^{2-} concentration was contributed the decay of anaerobic bacteria in the soil horizons in this study area. The base saturation in each soil horizon of the plant covers was decreased in this area (Table 8). The decreasing of base saturation in this area might be attributed to the non influence of saline water.

Roots were distributed in surface and subsurface layers at various depths (25 cm, on average) in this habitat area. The shallow B rooting habitat of the plant covers in this area might be an adaptation to avoid the low groundwater table level in deeper soils and also to effectively utilize the poor nutrition in the surface soils of this habitat.

Relationship Between Soil Properties and Plant Cover Types: The relationships between soil properties and plant cover types were analyzed using principle component analyses (PCA) displayed in Table 9 and figure 2. The chemical properties of the soil, that is, pH, organic carbon (OC), total calcium carbonate (T. $CaCO_3$), K^+, Na^+, Ca^{2+} and Mg^{2+} in the surface soil layers at all sampling sites were adopted into the analyses because most of the plant roots were located in the surface layers.

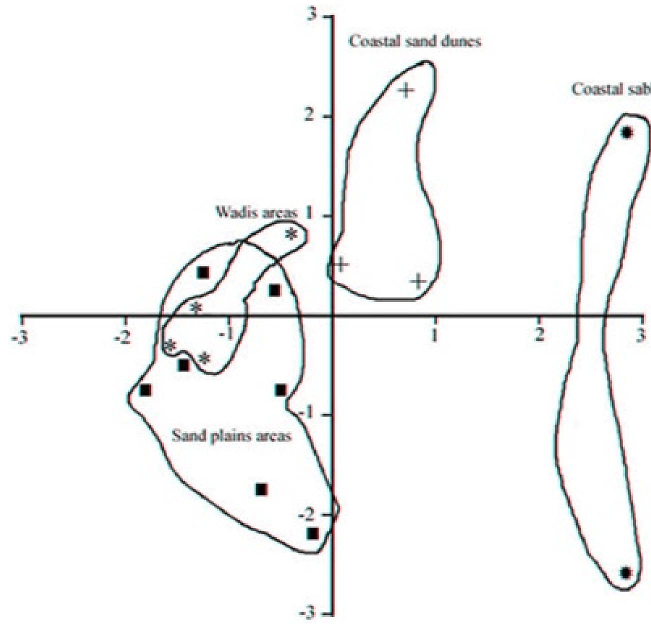

Fig. 2: Seatter diagram of 16 sites along the I[st] and 2[nd] principal component axes of the principal component analy sis (PCA) using soil chemical properties in the surface layers.
✷ Coastal sabkha + Coastal sand dunes areas
■ Sand plains areas * Wadis areas

Table 1: Mechanical analyses of soil horizons and moisture content under different plant communities at coastal sabkha.

Plant Species	Depth (Cm)	Mechanical analyses (%)			Moisture Content (%)	Moisture Content Mean (%)
		Coarse sand	Fine sand	Silt and clay		
Tamarix nilotica	0 - 15	54.4	36.93	8.67	3.77	4.42
	15 - 30	45.96	47.03	7.01	3.43	
	30 - 45	47.77	46.18	6.05	4.60	
Suaeda pruinosa	0 - 15	49.88	44.75	5.37	1.22	3.94
	15 - 30	57.62	38.07	4.31	3.33	
	30 - 45	62.76	31.81	5.43	4.29	
Zygophyllum coccineum	0 - 15	55.92	40.82	3.26	1.60	3.01
	15 - 30	58.08	38.82	3.10	2.39	
	30 - 45	62.41	32.35	5.24	1.85	
Juncus maritimus	0 - 15	46.43	45.77	7.80	1.89	2.48
	15 - 30	60.34	34.84	4.82	1.82	
	30 - 45	60.92	33.97	5.11	2.46	

Table 2: Mechanical analyses of soil horizons and moisture content under different plant communities at coastal sand dunes areas.

Plant Species	Depth (Cm)	Mechanical analyses (%)			MoistureContent (%)	Moisture Content Mean (%)
		Coarse sand	Fine sand	Silt and clay		
Salicornia qassimensis	0 - 15	44.46	48.94	6.60	2.75	2.57
	15 - 30	48.12	44.88	7.00	1.98	
	30 - 45	54.27	39.26	6.47	3.27	

Table 2: Continu

Halopeplis perfoliata	0 - 15	36.86	59.36	3.78	1.61	2.60
	15 - 30	41.07	55.44	3.49	2.02	
	30 - 45	40.91	54.67	4.42	3.00	
Aeluropus massauensis	0 - 15	44.08	53.96	1.96	2.35	3.04
	15 - 30	45.48	51.88	2.64	2.52	
	30 - 45	48.55	48.32	3.13	2.85	
Anabasis setifera	0 - 15	36.58	58.52	4.90	1.36	3.09
	15 - 30	51.13	41.48	7.39	3.15	
	30 - 45	52.11	40.94	6.95	3.58	

Table 3: Mechanical analyses of soil horizons and moisture content under different plant communities at sand plains areas.

Plant Species	Depth (Cm)	Mechanical analyses (%)			Moisture Content (%)	Moisture Content Mean (%)
		Coarse sand	Fine sand	Silt and clay		
Aerva lanata	0 - 15	41.25	55.47	3.28	1.51	2.23
	15 - 30	41.35	54.68	3.97	1.85	
	30 - 45	46.96	49.34	3.70	2.14	
Capparis decidua	0 - 15	45.22	47.63	7.15	2.94	4.29
	15 - 30	54.00	39.60	6.40	4.38	
	30 - 45	69.42	25.80	4.78	4.74	
Salsola spinescens	0 - 15	63.12	30.88	6.00	4.83	3.56
	15 - 30	54.88	42.38	2.74	5.85	
	30 - 45	67.50	29.64	2.86	6.91	
pergularia tomentosa	0 - 15	63.97	31.20	4.83	3.75	2.55
	15 - 30	59.77	35.15	5.08	3.65	
	30 - 45	38.60	55.67	5.73	3.79	

Table 4: Mechanical analyses of soil horizons and moisture content under different plant communities at the wadis areas.

Plant Species	Depth (Cm)	Mechanical analyses (%)			Moisture Content (%)	Moisture Content Mean (%)
		Coarse sand	Fine sand	Silt and clay		
Bassia muricata	0 - 15	49.48	47.17	3.35	3.41	2.79
	15 - 30	59.86	33.94	6.20	4.24	
	30 - 45	51.64	45.29	3.07	4.41	
Haloxylon salicornicum	0 - 15	72.83	24.42	2.75	3.28	3.29
	15 - 30	52.50	43.00	4.50	3.93	
	30 - 45	55.62	40.11	4.27	4.40	
calotropis procera	0 - 15	51.66	42.07	6.27	2.12	3.46
	15 - 30	55.50	39.69	4.81	2.99	
	30 - 45	58.47	36.08	5.45	3.30	
Anthemis melompodina	0 - 15	40.50	55.20	4.30	2.02	2.83
	15 - 30	46.45	48.42	5.13	2.42	
	30 - 45	48.96	45.80	5.24	3.18	

Table 5: Elements analyses and statistics of soil horizons under different plant communities at coastal sabkha.

Plant Species	Depth (Cm)	pH	T.$CaCO_3$ (%)	mg / 100gm		Cations (mg / 100 gm)					Anions (mg / 100gm)				CEC	BS (%)
				OC	TSS	K^+	Na^+	Ca^{2+}	Mg^{2+}	Fe^{3+}	Cl^-	SO_4^{2-}	HCO_3^-	PO_4^{3-}		
Tamarix nilotica	0 - 15	7.28	43.38	163.1	696	6.37	20.01	24.51	14.24	0.28	67	488	58	3.80	72.41	90.30
	15 - 30	7.56	44.60	165.4	717	7.75	22.84	26.98	16.74	0.57	71	496	60	3.92	61.07	122.6
	30 - 45	7.68	46.12	168.3	740	8.25	26.54	30.48	18.24	0.61	74	506	63	4.01	32.67	256.9
Suaeda pruinosa	0 - 15	7.62	42.37	46.13	706	1.13	8.98	89.78	13.95	0.38	60	470	52	2.96	114.4	99.80
	15 - 30	7.51	44.16	49.58	754	5.64	10.18	95.42	15.23	0.47	64	485	58	3.28	93.63	135.6
	30 - 45	7.41	45.70	51.64	874	7.03	17.32	106.3	20.52	0.62	85	545	77	3.80	99.92	151.3
Zygophyllum coccineum	0 - 15	7.67	42.04	37.47	656	4.26	18.42	21.74	12.25	0.27	60	478	50	3.33	96.92	58.70
	15 - 30	7.62	42.36	51.64	668	5.28	19.55	22.87	13.15	0.34	63	474	51	3.65	55.39	110.5
	30 - 45	7.39	43.00	52.66	856	6.29	19.86	105.5	19.35	0.56	82	537	72	3.85	47.26	320.7
Seidlitzia rosmarinus	0 - 15	7.56	35.16	79.18	694	1.35	2.43	81.77	0.73	0.26	63	481	54	2.39	98.06	88.30
	15 - 30	7.68	38.24	83.72	746	1.67	3.38	90.94	0.85	0.45	65	515	56	2.64	55.65	174.8
	30 - 45	7.24	40.16	89.10	798	1.83	3.76	110.9	1.03	0.59	70	535	59	2.85	42.57	277.5

Table 6: Elements analyses and statistics of soil horizons under different plant communities at coastal sand dunes areas.

Plant Species	Depth (Cm)	pH	T.$CaCO_3$ (%)	mg / 100gm		Cations (mg / 100 gm)					Anions (mg / 100gm)				CEC	BS (%)
				OC	TSS	K^+	Na^+	Ca^{2+}	Mg^{2+}	Fe^{3+}	Cl^-	SO_4^{2-}	HCO_3^-	PO_4^{3-}		
Salicornia qassinmensis	0 - 15	7.35	43.56	90.12	571	2,51	10.91	75.00	1.70	0.43	25	435	5	1.90	97.98	92.4
	15 - 30	7.58	44.78	96.28	592	4.01	13.41	82.00	3.20	0.58	28	437	8	2.3	83.38	123.8
	30 - 45	7.64	47.08	101.2	613	5.51	15.91	87.00	4.70	0.63	32	440	11	2.75	60.58	187.8
Halopeplis perfoliata	0 - 15	6.99	41.59	43.54	322	3.82	19.10	26.78	13.24	0.50	34	197	17	2.85	85.83	73.9
	15 - 30	7.75	42.52	60.75	399	4.51	37.28	48.12	15.05	0.61	40	215	26	3.43	73.39	143.8
	30 - 45	7.58	45.18	127.3	415	5.22	38.69	49.62	18.78	0.68	42	220	31	3.68	30.19	374.3
Aeluropus massauensis	0 - 15	7.19	43.55	54.68	430	6.35	39.86	31.05	19.04	0.39	38	255	33	2.85	99.28	97.4
	15 - 30	7.50	43.72	56.71	438	6.83	40.10	33.48	20.26	0.42	39	256	34	3.38	79.13	127.8
	30 - 45	7.57	44.78	70.88	469	7.27	42.80	36.19	22.58	0.62	42	268	37	3.68	28.62	382.5
Anabasis setifera	0 - 15	7.54	41.48	54.80	420	7.32	36.16	46.73	16.85	0.57	43	224	30	3.72	107.3	100.3
	15 - 30	7.61	41.53	106.3	512	7.95	38.89	48.32	20.68	0.59	46	295	35	3.85	99.38	117.2
	30 - 45	7.27	42.24	255.2	540	8.21	39.88	49.72	22.23	0.68	48	325	38	3.92	26.88	449.1

Table 7: Elements analyses and statistics of soil horizons under different plant communities at sand plains areas.

Plant Species	Depth (Cm)	pH	T.$CaCO_3$ (%)	mg / 100gm		Cations (mg / 100 gm)					Anions (mg / 100gm)				CEC	BS (%)
				OC	TSS	K^+	Na^+	Ca^{2+}	Mg^{2+}	Fe^{3+}	Cl^-	SO_4^{2-}	HCO_3^-	PO_4^{3-}		
Aerva lanata	0 - 15	7.84	34.65	75.94	142	19.91	3.13	15.87	3.20	0.15	11	70	14	1.9	78.78	56.20
	15 - 30	7.63	38.96	121.5	166	20.40	2.74	16.42	3.22	0.21	12	91	15	2.33	25.70	167.3
	30 - 45	7.67	43.09	156.9	181	21.01	3.76	18.86	4.82	0.35	14	97	17	2.38	23.60	206.8
Capparis decidua	0 - 15	7.64	38.56	75.94	144	11.82	4.07	10.97	5.98	0.24	11	79	15	2.85	98.16	33.70
	15 - 30	7.14	39.76	144.7	157	12.83	6.70	11.15	6.10	0.54	14	85	16	2.85	23.60	157.3
	30 - 45	7.89	44.61	151.2	175	14.64	6.72	12.09	8.96	0.68	16	91	19	2.85	17.85	241.4
Salsola spinescens	0 - 15	7.84	34.16	103.3	165	12.82	5.05	13.45	8.28	0.22	12	90	14	4.8	98.14	40.60
	15 - 30	7.82	37.80	170.1	177	13.63	5.90	18.61	9.31	0.32	13	94	15	5.8	25.73	185.7
	30 - 45	7.55	43.40	207.6	199	14.42	7.72	19.46	9.95	0.36	17	100	17	6.8	21.68	239.4
pergularia tomentosa	0 - 15	7.41	40.39	51.64	218	10.74	6.36	17.27	10.78	0.54	18	125	19	3.33	88.12	51.80
	15 - 30	7.18	43.76	54.68	251	12.22	8.84	19.38	13.75	0.65	23	140	26	3.85	34.12	160.7
	30 - 45	7.15	45.11	92.14	282	13.62	12.1	21.27	14.71	0.73	28	152	32	4.85	23.82	262.2

Table 8: Elements analyses and statistics of soil horizons under different plant communities at the wadis areas.

Plant Species	Depth (Cm)	pH	T.$CaCO_3$ (%)	mg / 100gm		Cations (mg / 100 gm)					Anions (mg / 100gm)				CEC	BS (%)
				OC	TSS	K^+	Na^+	Ca^{2+}	Mg^{2+}	Fe^{3+}	Cl^-	SO_4^{2-}	HCO_3^-	PO_4^{3-}		
Bassia muricata	0 - 15	7.83	37.53	75.71	165	11.06	2.91	19.44	2.70	0.22	9	106	9	2.85	108.7	33.4
	15 - 30	7.55	38.87	106.3	182	6.56	1.93	23.6	4.31	0.43	7	118	15	3.80	106.3	43.7
	30 - 45	7.56	40.83	146.8	185	4.27	9.74	8.44	4.87	0.44	9	127	15	3.80	101.9	27.3
Haloxylon salicornicum	0 - 15	7.82	39.12	42.27	126	12.34	2.09	8.19	6.87	0.11	5	76	8	3.80	105.4	28.1
	15 - 30	7.30	44.07	58.95	130	1.53	10.3	7.91	3.19	0.40	11	78	14	2.28	104.7	22.3
	30 - 45	7.28	46.53	114.4	136	0.88	11.3	12.48	3.56	0.57	13	81	8	2.85	103.9	27.7

Table 8: Continue

calotropis procera	0 - 15	8.04	31.24	49.62	92	2.65	2.02	8.69	1.76	0.15	5	57	7	4.75	65.78	23.2
	15 - 30	7.75	38.22	70.88	95	3.54	0.37	9.62	2.06	0.26	6	61	8	2.38	63.54	24.9
	30 - 45	7.92	38.87	71.89	129	4.85	2.87	19.63	3.10	0.12	12	73	9	2.85	101.4	30.1
Anthemis melompodina	0 - 15	7.61	35.98	36.46	82	1.52	0.74	7.29	1.20	0.15	5	57	6	2.85	45.82	23.8
	15 - 30	7.81	44.27	59.74	95	2.18	0.89	9.10	1.64	0.23	6	63	7	2.85	53.12	26.4
	30 - 45	7.60	44.60	84.04	110	2.65	0.79	11.36	2.49	0.17	8	71	9	2.70	51.45	33.9

Table 9: Results of principal component analysis (PCA) using soil chemical properties in surface horizons.

Variable	Eigen Vector	
	1st principal component	2nd principal component
pH	0.0603	0.6038
OC	- 0.4807	0.3520
T. CaCO3	0.2773	0.5803
K+	0.0411	0.4907
Na+	0.5764	- 0.0984
Ca2+	0.3396	- 0.1689
Mg2+	0.5266	0.1479
Eigen Value	2.7458	1.5716
Contribution (%)	39.25	22.46
Cumulative contribution (%)	39.25	61.56

The first principle component had a contribution of 39.25%. Plant cover types (*Tamarix nilotica and Salicornia qassimensis* plant communities) in the coastal sabkha and coastal sand dunes were distinguished along the 1st axis. Na^+ and Mg^{2+}, the major elements in the sea salt, showed high positive Eigen Vectors on the first principle component. Organic carbon had a high negative Eigen Vector; the low carbon content of the salt marsh area was because of an interfusion of sands into the peat lamina by tides. Thus, the first principle component indicates the effect of sea salt and/or the sea (tidal transportation). The first principle component score significantly correlated with the basal area of the plant covers, including deciduous broad B leaved species at each study area ($r = 0.757$, $p = 0.005$, Spearman's rank correlation coefficient), which indicates the strong negative influence of the sea or sea salt on the growth of plant covers.

The second principle component showed a contribution of 22.46%. Total $CaCO_3$, pH and K had high positive Eigen Vectors. *Aerva lanata* - dominant sites and *Bassia muricata* - dominant sites were arranged along the 2nd axis. However, the sand plains and wadis habitats overlapped, making the interpretation of the 2nd axis unclear. Sand plains habitat is the transition zone, showed high scores in the second principle component. This might be attributed to their location that is, facing the coastal sand dunes that receives nutrient rich water from the coastal areas.

Conclusion: Surface soil characteristics were recognized in the *Tamarix nilotica* and *Salicornia qassimensis* plant communities in the coastal sabkha and coastal sand dunes, that is, peat lamina accumulation because of high groundwater table and the strong influence of sea salt on the soil chemistry. The influence of sea salt on the soil properties was stronger in the *Tamarix nilotica* habitat than in the *Salicornia qassimensis* habitat. Roots of plant covers in the coastal sabkha were distributed more shallowly than those in the coastal sand dunes, thus avoiding the high groundwater table level as well as the influence of seawater in the soil. Rising sea level, because of global warming, would accelerate the submergence of coastal sand dunes; this seawater inundation might be fatal to the plant cover. A natural plant cover communities growing on a coastal sand dunes are rare. Natural plant communities on the coastal area support high biodiversity. Furthermore, the coastal sand dunes are valuable for the observation of the influences of the global climate change on coastal plant communities because they are easily affected by sea level fluctuations.

REFERENCES

1. Abd El-Raham, A.A., 1986. The desert of the Arabian Peninsula, hot desert and arid shrubland. Ecosystem of the World, 12(B): 29 B 55.
2. Allen, J.A., J.L. Chambers, and S.R. Pezeshki, 1997. Effect of salinity on baldcypress seedling: physiological responses and their relation to salinity tolerance. Wetland, 17: 310 - 320.
3. Al B Sayari, S.S. and J.G. Zolt, 1978. Quaternary period in Saudi Arabia. I: sedimentological, hydrological, hydrochemical, geomorphological and climatological investigation in central and western Saudi Arabia. Spingler Verlag, New York, USA.
4. Batanouny, K.H. and N.A. baeshin, 1978. Studies on the flora of Arabia. I: The Jeddah B Makkah road, Saudi Arabia, Taeckholmia, 9: 67 - 81.
5. Batanouny, K.H., 1979. Vegetation along the Jeddah B Makkah road: pattern, process as affected by Human impact. J. Arid Environ., 2(1): 21 - 30.
6. Batanouny, K.H. and N.A. baeshin, 1982. Studies on the flora of Arabia. II: The Medina B Bader road, Saudi Arabia. Bull. Fac. Sci. King Abdulaziz Univ., 6: 7 B 29.
7. Batanouny, K.H. and N.A. baeshin, 1983. Plant communities along the Medina B Bader road across the Hijiaz Mountains, Saudi Arabia. Vegetation, 53: 33 - 43.
8. Blandon, D.M.Z., F. Satoh, K. Matsuda, K. Sasa, and T. Igarashi, 1994. The mineral condition of soil and tree species in serpentine and non-serpentine areas of northern Hokkaido. Research Bulletin of the Hokkaido University Forests, 51: 1 - 13.
9. Brown, G.F., 1960. Geomorphology of western and central Saudi Arabia 21st International Geological Congress. Copenhagen Rep., 21: 150 - 159.
10. Bulter, J., H. Goetz, and J. Richardson, 1986. Vegetation and soil-landscape relationship in North Dakota badlands. Am. Midland Nat., 116: 372 - 385.
11. Cole, D.A., S.E. Maxwell, R. Arvey, and E. Salas, 1995. Multivariate group comparisons of variable systems: ANOVA and Structural Equation Modeling. Psychological Bulletin, 114: 174 - 184.
12. Conner, W.H., K.W. McLeod, and J.K. McCarron, 1997. Flooding and salinity effects on growth and survival of four common forested wetland species. Wetland Ecology and Management, 5: 99 - 109.
13. El B Shourbagy, M.N., N.A. Baeshin, and El B K.F. Sahhar, 1986. Studies on the ecology of the western provinces of Saudi Arabia. I B Vegetation and soil of the Jeddah-Tuwal area. Feddes Repertorium, 97: 705 - 712.
14. Fayed, A., K. Zayed, 1989. Vegetation along Makkah-Taif road, Saudi Arabia. Arab Gulf J. Sci. Res., 7: 97 - 117.
15. Fujta, H., M. Nakata, and S. Kojima, 2002. Vegetation and soil condition of sakhline spruce (Picea glehnii) forested mire in Cape Ochiishi, eastern Hokkaido, Japan. In: wetlands of Hokkaido (Tsujii, T. &. Tachibana, H., Ed), pp: 107 - 119. Maeda Japoen Foundation.
16. Goto, I., 2001. Exchange and fixation of cations and anions. In: Introduction to soil science (Inubushi, K. and Anzai, T., Eds), pp: 21 - 30. Asakura press, Tokyo, Japan.
17. Harada, H., 1976. Suitable sites for silviculture. Hoppo Ringyo, 28: 85 - 88.
18. Iyobe, T., A. haraguchi, H. Nishijima, H. Tomizawa, and F. Nishio, 2003. Effect of fog on sea salt deposition on peat soil in boreal picea glehnii forests in Ochiishi, eastern Hokkaido, Japan. Ecological Research, 18: 587 - 597.
19. Jackson, M.L., 1962. Soil chemical analysis. Constable and Co. Ltd. London, pp: 67.
20. Karpoff, R., 1957. Soil B geology of Arabian region. Bull. Soc. Geol. France., 6: 653 - 697.
21. Laurent, D., 1993. Kingdom of Saudi Arabia Atlas of Industrial minerals. Saudi Arabia, Ministry of Petroleum and Mineral Resources, Directorate General of mineral Resources, Jeddah, Saudi Arabia. pp. 7 -10 22.
22. Mohamed, A. And M. El - Tom, 1985. Ecological relationships of some vegetation units in the Jeddah-Makkah region, Saudi Arabia. Arab Gulf J. Sci. Res., 3: 607 - 622.
23. Murphy, J. and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural water. Anal. Chem. Acta, 27: 31 - 36.
24. Nishijima, H., T. Iyobe, F. Nishio, H. Tomizawa, M. Nakata, and A. Haraguchi, 2003. Site selectivity of Picea glehnii forest on Syunkunitai sand spit, northeastern Japan. Wetlands, 23: 406 - 415.
25. Nishijima, H. and M. Nakata, 2004. Relationship between plant cover type and soil properties on Syunkunitai coastal sand dune in eastern Hokkaido. Ecological Research, 19: 581 - 591.
26. Statsoft, Inc., 2000. Statistical for windows (Computer Program Manual) Ver. 5.5, Tulsa, UK.
27. Pezeshki, S.R., R.D. Delaune, and W.H. Patrick, Jr. 1990. Flooding and seawater intrusion: potential effects on survival and productivity of wetland forests along the U. S. Gulf coast. Forest Ecology and Management, 33/34: 287 - 301.
28. Pinder, L. and M. Rosso, 1998. Classification and ordination of plant formation in the pantanal of Brazil. Plant Ecol., 136: 151 - 165.
29. Piper, C.S., 1955. Soil and plant analysis. A laboratory Manual of Methods for Examination of soil and Determination of Inorganic Substituents of plant. New York Int. Pub. Inc., USA.

30. Soon, Y.K. and S. Abboud, 1993. Iron and manganese. In: Soil sampling and methods of Analysis, carter, Lewis, M. R. (Ed.), Boca Raton, Fl., pp: 111 - 120.
31. Trewartha, G.T. and L.K. Horn, 1980. An introduction to climate. McGraw-Hill, New York, USA, pp: 89.
32. Van der valk, A.G., 1974. Mineral cycling in coastal fore dune plant communities in Cape hatteras national seashore. Ecology, 55: 1349 - 1358.
33. Vesey - Fitzgerald, D. F., 1957. The vegetation of the Red Sea coast north of Jeddah. Saudi Arabia. J. Ecol., 45: 547 - 562.
34. Yoshioka, K., 1951. An ecological study on coastal pine forest. J. of the Japanese Foresty Society, 33: 359 - 362.