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Environmental Indicators Related to Native Plants to Assess the Quality of Life in the Degraded Desert Area

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Abstract: In Kuwait, the scarcity and irregularity of rainfall, the availability of areas of sand supply and the prevalence of strong north westerly winds significantly influence the stability of the fragile ecosystem. Naturally, grown native shrubs and trees can provide potential shelter to soil surface in desert areas. To study the environmental indicators provided by native plant and their ability to improve quality of life, the morphological properties of the vegetated nabkhas within different areas in Kuwait desert and within protected area were assessed. The vegetated dunes can trap maximum mobile sediments from 10.5 to 0.45 ton thus cost saving per plant estimated to be from 5.5 to 0.24 USD. The arrangements of the native plant from highest efficiency in absorbing carbon dioxides to the least were as follows: *Nitraria retusa*, *Haloxylon salicornicum*, *Citrullus colocynthis*, *Tamarix aucheriana*, *Lycium shawii*, *Convolvolus oxyphyllus*, *Rhanterium epapposum*, *Panicum turgidum*, *Calligonum polygonoides*, *Astragalus spinosus*, *Cyperus conglomerates.* The cost saving of CO_2 per year estimated to be from 0.95 to 1,542.1 USD. The revegetation enhanced physical and chemical quality of soil and created microenvironments for the flora and fauna. The aim of this paper is to identify the environmental indicators related to native plants for the assessment of quality of life.

Key words: Revegetation, rehabilitation, nabkhas, perennial plants, restoration.

1. Introduction

Kuwait is located in the north-eastern part of the Arabian Peninsula. It has hyper-arid desert environment. The desert ecosystem in Kuwait is almost 14,240 km^2 representing virtually 80% of the country. Desert ecosystem in Kuwait is fragile and susceptible to widespread deterioration which resulted from both anthropogenic and natural factors. Land degradation is the deterioration of vegetation cover, and the loss of fauna and flora biodiversity. The expansion of degraded lands, and the increase in the intensity of sand encroachment, increases the level of dust, causing economic and health damage and increase in the carbon dioxide concentrations. During the 1970s, In Kuwait, there is an active path of aeolian dunes and mobile sand passing from the north-west, causing severe sand encroachment problems to desert infrastructures (highways, oil facilities, power stations, and air bases). The north-westerly winds act as the main driving force for the movement of mobile sand and dust particles in Kuwait and represent almost 60% of the total wind directions [1]-[2]. About 77% of the sand drift annually occurs during the summer months of May to September [3]. Native plants, which are efficient in controlling mobile sand and dust, were present within the wadis and hydrological depressions. These plants have recently been replaced by other native plants that are less effective at controlling mobile sand and dust, according to Kuwait's vegetation map. By supporting the soil with their roots, native plants protect the soil from the erosive power of the wind [4] and were found to be effective in controlling Aeolian activities, soil sealing [5], and soil organic carbon storage. The ability of native plants to capture mobile aeolian sediments resulted in mobile sand accumulations surrounding the plant known as nabkha [6]. Aeolian accumulations

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around native plants are known as nabkha [7]-[10]]. Because it regulates the movement of aeolian particles in desert and semi-arid locations, the nabkha development around native plants and green belts is economically and environmentally vital [10, 11]. Reduced sediment transport and wind erosive forces, increased entrapment of mobile sand and dust, and lower CO_2 concentration in climate revegetation of degraded areas with naturally grown native vegetation can reduce the expense of re-vegetation operations and water limitation. According to a new perspective as a sustainable solution, an analytical assessment of the environmental indicators offered by native plants to the community was conducted. These indicators are quantitative and qualitative measures and play a critical role in preserving environmental and natural resources that has direct impact on human health and well-being.

2. Materials and Methods

The study area (Kuwait) is 17,818 km^2 and protected Liyah area (LPA) is about 149.7 km^2 (1.12% of total area of the state of Kuwait). LPA is an example of degraded land in desert of Kuwait due to gravel quarrying and the condition is further exacerbated by scarcity of rainfall and intensive wind and water erosion. Environmental Public Authority (EPA) Committee issued Decision No. 973/1997 in October 1997 with a decree to organize quarrying activities and protect the natural resources of Kuwait. Another decision from the Council of Ministers was issued in August 2001 to refill quarries-sites and level the surface irregularities in order to rehabilitate the natural vegetation and wildlife to its original shape. The restoration process is tremendously leisurely in the refilled areas in Liyah. This positive process increases the usability of damaged land in Kuwait for growing more plants and generating greenery, as well as improving biodiversity in the desert. Kuwait is planning to put a National Biodiversity Strategy (NBS) to maintain land health, ecological systems and preserve biological diversity.

From June 2011 to May 2019, the land was artificially rehabilitated using a native vegetation plantation program focusing on the northern portion of Liyah, resulting in a major improvement in the soil's capacity and gradual flourishing of both flora and animals. The recovery process is extremely slow in the refilled areas in Liyah and it may take decades to recover from human disturbance [12, 13]. In LPA, some 150 thousand native plants were planted at a 3-m average spacing between them. The study focused on the most effective plants for managing aeolian mobile sediments, as well as the region's most endangered plant species, including *L. shawii*, *H. salicornicum*, and *C. polygonoides*. Summer heat, severe dust storms, and moving sand were all avoided by the seedlings. The irrigation water was brackish water from a productive well with a flow rate of 20-26 m^3/h (Total dissolved salt (TDS) = 4,900 mL/L) and no hydrogen sulphide.

A field inquiry was carried out to examine the environmental indicators offered by native plants to the community, and a fresh perspective as a sustainable solution was developed. Environmental indicators can be categorized according to their links to quality of life. Because responsible behaviour has a positive impact on environmental quality, these groups are inextricably linked. Perennial shrubs are very resistant to aridity. It can grow in hot and dry poor soil; it has efficiency in trapping dust and mobile sand, improving air quality and developing wild life.

The morphological properties of the accumulated sediments around 11 native plants (length, height, and width of the sand body) as well as morphological parameters for perennial plants (length, height, and width of the plant) were measured in order to determine the efficiency of perennial dominated native plants in controlling aeolian accumulation as a sustainable solution. These nabkhas were selected within different areas in Kuwait desert (Table 1). The volume of nabkha is associated with desert plant that obstructs the flowing wind. Dust and sand accumulates in the wake of the plant. The shape of the nabkha is elliptical near the plants with an adjacent triangular tail.

Table 1 List of dominant perennial plant species within different areas in the desert of Kuwait.

No.	Perennial plant species	Area
1	*Rhanterium epapposum*	KISR station, Al-Dhabiaya
2	*Haloxylon salicornicum*	Al-Liyah, Al-Dhabiaya
3	*Lycium shawii*	Jal-Azzur, Al-Liyah
4	*Nitraria retusa*	Al-Dhabiaya, Jal-Azur
5	*Astragalus spinosus*	Al-Liyah,Abdali
6	*Panicum turgidum*	Al-Dhabiaya
7	*Tamarix aucheriana*	Al-Doha
8	*Citrullus colocynthis*	Jal-Azzur, Al-Liyah
9	*Cyperus conglomeratus*	Kabd
10	*Calligonum polygonoides*	Al-Liyah
11	*Convolvulus oxyphyllus*	Al-Liyah

To evaluate the native plant's economic value, the mass of the sand body was calculated by multiplying the plant's density by the volume of nabkha as follows:

$$\text{The density of sand} = 2{,}500\ \text{kg/m}^3\ \text{(constant)} \quad (1)$$

$$\text{The volume of nabkha} = 2/\pi(a\cdot b\cdot c) \quad (2)$$

where, a = width of nabkha, b = length of nabkha (it occupied half of ellipse which is equal to quarter)/4 = $b1$, b-$b1$=$b2/2$, c = height of nabkha.

In 2013, the average cost of removing aeolian encroachments around desert infrastructures in Kuwait was projected to be around 1.32 USD per cubic meter [14].

The saved cost ($) of sand stabilization = volume of nabkha × cost ($) (3)

The density of desert native plants was determined to classify the function of desert plants on carbon fixation rate. The density of the dry green shoot was determined by the weight of the dry green shoot and the volume of the green shoot taken through the displaced water (final volume minus the initial volume). The density formula is as follows:

$$\rho = \frac{m}{V} \quad (4)$$

Density = mass/volume (5)

The mass of the whole plant = density × volume of canopy shrubs

The mass of plant = density × 2/3 $\pi H(A/2\times B/2)$ (6)

where, H is the height of the plant from the base to the top, A and B are diameter taken at 50% of the plant height across the plane photosynthetically.

Thomas and Hill [[15]] calculated that about 36 g of CO_2 was absorbed per 30 min by the first alfalfa crops equalled to 0.93 µmol. The average leaf weight was about 664 g and the molecular weight of CO_2 was about 44 g. The calculated CO_2 mg/h is given as:

$$\frac{36.60.10000}{80.44.664.1000} = 0.93\mu\text{mol}.\,\text{CO2 mg/h} \quad (8)$$

$$= \frac{44\ mole\ of\ \text{CO2}\times 0.93\ x\ mass\ of\ plant\ (g)X12\ h}{1000000\ \text{mg}.1000000\ \text{tons}} = \text{rate of}$$

CO_2 absorption in ton per day for plant (9)

The CO_2 market price in the United States was $3.07 per ton of CO_2 [[16]]. Saved cost ($) CO_2 = 3.07 × rate of CO_2 absorption in ton per day for the plant.

Rate of CO_2 absorption in ton per year for plant = Rate of CO_2 absorption in ton per day for the plant 365 days.

3. Result

Soil is a limited resource, and its health is essential for long-term development. Soil deterioration and, in the case of agricultural soil, progressive loss of soil richness have been the outcome of several anthropogenic actions. The diversity and activity of a soil's biota, as well as its physical and chemical qualities, determine its quality [16]].

The degraded pilot area selected was 2.500 m^2. After three years of revegetation, there are a number of soil physical and chemical soil improvements. For example, the soil moisture on the surface increased from 0.085%

to 1.62% as well as the percentage of soil moisture of retreated soil increased with depth. The control soil has a high density of bulk and low porosity compared to treated soil. The force penetration of treated soil was 190 psi where untreated soil was 273 psi. The vegetation cover acts as an insulator that keeps the soil treated cooler with depth than the control soil (Tables 1 and 2). The percentage of organic content at 60 cm depth in treated soil was 3.6 while at control soil it was 2.2 (Tables 2 and 3).

However, the image changed after the restoration operation, as the development of cultivated native plants and the density of vegetation cover increased. At the beginning of cultivation, the height of *Lycium shawii* was between 30 to 40 cm but after three years, it became a healthy plant with about 1 m of height.

The *Lycium shawii* preferred to grow in alkaline soil (pH between 7.2 to 7.9) with low Electrical Conductivity (EC). However, these plants have high capability to trap sand through forming large nabkhas [9]. The enhanced quality of soil has led to the appearance of new plant species on the treated soil such as, *Stipa Fagonia indica*, *Fagonia bruiguieri*, *Stipagrostis plumose*, *Plantago coronopus*, *plantago ciliate*, *plantago boissieri*, *Rumex vesicarius*, *Savignya praviflor*, *Launae mucronata Picris babylonica* and *Diplotaxis harra*. The vegetation cover density of vegetation cover for an area 25 m^2 to 600 plant species was 24 plants/m^2. These covers have created microenvironments for the flora and fauna, where new birds, lizard and insects (ants, bees and beetles) were noticed. It was noted that in the treated soil, there were 11 houses, 44 burrows for uromastyx and 11 burrows for lizard. These wild animals aerated soil and soil with their manure.

In Kuwait, there are 15 main native desert plants that were chosen using vegetation maps created by Halwagy and Halwagy, as well as Omar [18, 19]. They are *Cyperus conglomeratus*, *Haloxylonsalicornicum*, *Rhanterium epapposum*, *Astragalus spinosus*, *Lycium shawii*, *Citrullus colocynthis*, *Panicum turgidum*, *Calligonum polygonoides*, *Nitraria retusa*, *Tamarix aucheriana*, *Halocnemum strobilaceum*, *Salicornia europaea*, *Heliotropium bacciferum*, *Arnebia decumbens*, and *Convolvulus oxyphyllus*. To assess the efficiency of each plant species in terms of carbon fixation where shrub canopy tracks carbon accumulation, the morphological measurements (height, length, and width of the plant) were identified using intensive field survey at the five selected site locations in Kuwait. Two basic calculations are suggested for measuring the rate of CO_2 absorption: the density of the plant, and the mass of the native plant.

Table 2 The physical and chemical soil properties of control soil.

Soil section	Soil moisture (%)	Organic content (%)	Force penetration (psi)	Porosity (%)	Bulk density (g/cm^3)
0	0.08	1.12	273	26.9	1.97
20	0.02	1.11		29.4	1.8
40	0.15	1.48		22.6	2
60	0.085	2.29		26.3	1.9

Table 3 The physical and chemical soil properties at treated soil.

Soil section	Soil moisture (%)	Organic content (%)	Force penetration (psi)	Porosity (%)	Bulk density (g/cm^3)
0	1.82	0.57	190	98.8	0.03
20	2.23	2.32		98.6	0.04
40	0.79	2.5		99.4	0.01
60	1.161	3.6		99	0.02

Table 4 The dominant perennial plant species with their mass, volume, and density in Kuwait.

No.	Plants	Mass (g)	Mass (ton)	Volume (m^3)	Saved cost ($)
1	*Rhanterium*	871,679.0	0.872	0.349	0.460
2	*Nitraria*	10,469,853.1	10.470	4.188	5.528
3	*Astragalus*	457,226.7	0.457	0.183	0.241
4	*Panicum*	914,453.3	0.914	0.366	0.483
5	*Tamarix*	5,700,695.1	5.701	2.280	3.010
6	*Citrullus*	5,153,492.2	5.153	2.061	2.721
7	*Cyperus*	722,417.9	0.722	0.289	0.381
8	*Calligonum*	468,230.8	0.468	0.187	0.247
9	*Convolvolus*	676,090.3	0.676	0.270	0.357
10	*Haloxylon*	5,401,841.8	5.402	0.842	1.111
11	*Lycium*	2,105,014.7	2.105	2.161	2.852

Table 5 The dominant perennial plant species with measured CO_2 fixation and estimated saved costs ($).

No.	Plants	Mass (g)	Volume (mL)	Density (g/mL)	Volume (m^3)	Tons CO_2 absorbed (day)	Tons CO_2 absorbed (year)
1	*Rhanterium*	3.367	5	0.673	0.349	0.115	42.082
2	*Nitraria*	3.325	4.6	0.723	4.188	1.486	542.555
3	*Astragalus*	1.983	8.5	0.233	0.183	0.021	7.647
4	*Panicum*	1.737	4.5	0.386	0.366	0.069	25.306
5	*Tamarix*	2.058	4.5	0.457	2.280	0.512	186.909
6	*Citrullus*	3.943	6.5	0.607	2.061	0.614	224.122
7	*Cyperus*	0.72	8	0.090	0.289	0.013	4.661
8	*Calligonum*	2.373	4.7	0.505	0.187	0.046	16.948
9	*Convolvolus*	4.449	4.9	0.908	0.270	0.121	44.009
10	*Haloxylon*	2.068	3.5	0.591	0.842	0.627	228.820
11	*Lycium*	2.072	6.2	0.334	2.161	0.138	50.434

This value is then substituted using the equation $= \frac{44\ mole\ of\ co2\ .fixed\ number.mass\ g\ plant.12\ hours}{1000000mg.1000000\ tons}$ that uses a fixed number of molecular weight of CO_2 mg/h that is suggested by Thomas and Hill [15] that are visible in Table 4. Considering that about 36 g of CO_2 was absorbed per 30 min by the first alfalfa crops, (the average leaf weight about 664 g) and (molecular weight of CO_2 about 44 moles) was equalled to 0.93 µmol. CO_2 mg/h. Therefore, a new viewpoint was agreed to use statistical and analytical methods for estimating saved cost ($) of CO_2 where the CO_2 market price in the United States was $3.07 per ton of CO_2 [16], hence data were collected, and the saved estimated CO_2 is identified in Table 4 while the estimated saved cost in Table 5.

Field measurements and data analysis were carried out to assess the effectiveness of native desert plants in CO_2 fixing. As shown in Table 5 and Fig. 1, *Nitraria* sp. has a high efficiency of CO_2 absorption and a high CO_2 saved cost when compared to other native plants. The native plants were arranged in the following order, from most efficient carbon dioxide absorber to least efficient carbon dioxide absorber as follows: *Nitraria retusa*, *Haloxylon salicornicum*, *Citrullus colocynthis*, *Tamarix aucheriana*, *Lycium shawii*, *Convolvulus oxyphyllus*, *Rhanterium epapposum*, *Panicum turgidum*, *Calligonum polygonoides*, *Astragalus spinosus*, *Cyperus conglomerates.* The annual cost of conserving CO_2 is predicted to range from 14.310 to 1,665.645 USD.

In Kuwait, the prevailing and strong North-westerly wind especially during the summer season is consistently causing a significant movement of aeolian sediment that poses serious environmental and economic risks.

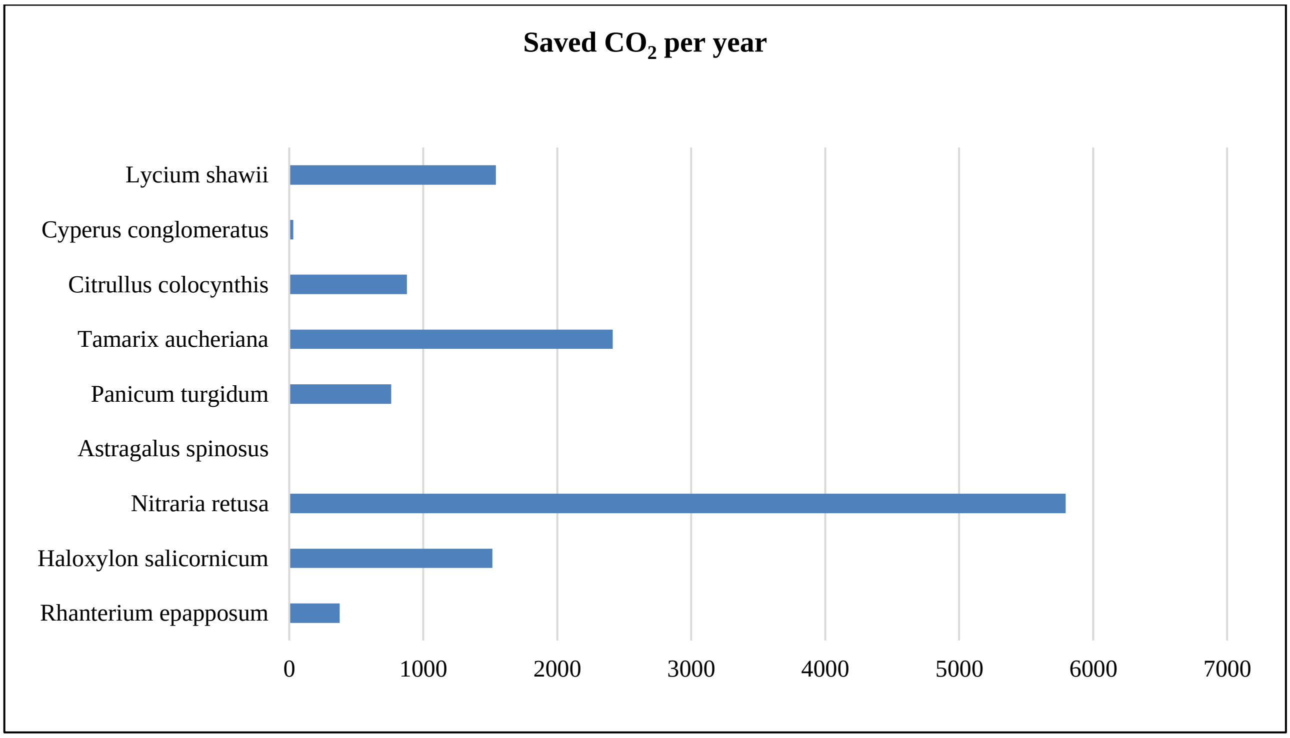

Fig. 1 Native plant with measured CO_2 fixation and estimated yearly saved costs ($).

Native plants play a major role in controlling mobile sand and dust hazards. The mass of sediments deposited around 11 species of desert native plant was measured equivalent to a ton from the highest efficiency in trapping aeolian sediments: *Nitraria retusa*, *Tamarix aucheriana*, *Haloxylon salicornicum*, *Citrullus colocynthis*, *Lycium shawii*, *Panicum turgidum*, *Rhanterium epapposum*, *Cyperus conglomeratus*, *Convolvolus oxyphyllus*, *Calligonum polygonoides*, *Astragalus spinosus*, and such vegetated dunes can trap maximum mobile sediments from 10.5 to 0.45 ton thus cost-saving per plant is estimated to be from 5.5 to 0.24 USD (Table 6), which makes them the most resourceful keys for present and future applications in controlling aeolian processes as well as providing a significant contribution to the environment. The volume of sediment trapped by different plants in Liyah area and their economic values (Table 7).

Table 6 The volume of trapped sediment around dominant perennial plant species with estimated saved costs in Kuwait.

No.	Plants	Saved CO_2 per day ($)	Saved CO_2 per year ($)
1	Rhanterium	0.354	129.193
2	Nitraria	4.563	1665.645
3	Astragalus	0.064	23.477
4	Panicum	0.213	77.689
5	Tamarix	1.572	573.811
6	Citrullus	1.885	688.055
7	cyperus	0.039	14.310
8	calligonum	0.143	52.032
9	Convolvolus	0.370	135.107
10	Haloxylon	1.925	702.478
11	Lycium	0.424	154.832

Table 7 The volume of sediment trapped by vegetated nabkha planted in Liyah and their economic values.

No.	Name of native plant	No. of plants	Volume of sediment (m^3)	Saved costs (KD)
1	*Haloxylon salicornicum*	2,550	248,110.42	40,229.24
2	*Lycium shawii*	2,270	236,660.9	40,229.24
3	*Ochradenus baccatus Delile*	2,075	10,572.24	38,373.5126
4	*Rhanterium epapposum*	2,175	4,903.465	7,950.477746
5	*Panicum turgidum*	100	509.5055	426.3812776
6	*Cenchrus ciliaris* L.	2,250	11,463.87	18,587.52511
7	*Atriplex leucoclada*	1,380	7,031.176	11,400.34873
8	*Calligonum polygonoides*	6,900	61,704.86	100,048.2626
9	*Acacia tortilis*	6,022	62,785.06	101,799.6886
10	*Salvadora persica*	520	1,172.323	1,900.803875
11	*Ziziphus spina-christi* (L.) Wild	200	450.8433	731.0784134

Table 8 Environmental indicators after rehabilitation of degraded lands relevant to quality of life.

Category	Indicators
Soil	Improvement of physical and chemical parameters
Plant	Growing of planted plant, diversity
Animal	Return of wild animal, appearance animal food chains
Aeolian process	Controlling aeolian process related to vegetated nabkha and saved cost
Carbon dioxide concentrations	Improved air quality and saved cost

4. Conclusion

The rehabilitation and restoration of the desert environment is essential for the preservation of biodiversity and the enhancement of soil production. The quality of life is affected by such rehabilitation. Soil, plant, animal, aeolian process, and CO_2 concentration are all examples of environmental indicators (Table 8).

The essential aspect in shielding the soil surface from erosive wind is vegetation cover. The current research has shed light on how the native plant can have a significant impact on the economy, people, and way of life. Native plants are more efficient in absorbing carbon dioxide and controlling aeolian sediments than non-native plants. Carbon dioxide was found to be readily absorbed by *Nitraria retusa*, *Haloxylon salicornicum*, *Citrullus colocynthis*, *Tamarix aucheriana*, *Lycium shawii*. The most capable natural plants in regulating aeolian sediments include *Nitraria retusa*, *Tamarix aucheriana*, *Haloxylon salicornicum*, *Citrullus colocynthis*, *Lycium shawii*. As a result, it is advised that such plants be given special attention due to their economic significance. Similarly, each native plant has its own set of morphological characteristics that have the potential to reduce expenses. As a result, native plants are a valuable and cost-effective way to improve air quality.

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