The environmental and economic importance of *Astragalus Spinosus* in land restoration

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**ABSTRACT**

*Astragalus spinosus* is a native perennial shrubs from Leguminosae family that widely distributed in severely degraded lands at northern Kuwait. A restoration program was applied via levelling and refilling the quarries and rehabilitation of the natural vegetation and wildlife to their original outward appearance before degradation. The existence of *Astragalus* shrubs indicated that soil after depth 40 cm was very hard and compacted. Therefore, *A. spinosus* is considered as one of the efficient native plants in the rehabilitation process for highly degraded lands affected by soil compaction and sealing. The *A. spinosus* formed a maximum volume of nabkha deposits up to 1.12 m³ which makes it one of the effective plants in controlling mobile sand and dust. Every single plant has the capability to save the Kuwait economy by USD 3.6 via trapping mobile sand and saving the infrastructures from sand encroachment as a major challenge.

**ARTICLE HISTORY**

Received 8 March 2020
Revised 27 September 2020
Accepted 28 September 2020

**KEYWORDS**

*Astragalus*; land degradation; restoration; native plant; Kuwait

1. Introduction

Deserts cover around 34% of the world land area [1]. These soils are dry as they get less than 10 in. of rain a year and often are with low organic matter content [2]. Even though it is dry, desert soils support sparse vegetation, which varies with temperature and may include cacti, shrubs, grasses, and wildflowers [3,4].

Most of the Kuwait desert areas are with low variable rainfall (114 mm), nutrient-poor soil, and a little vegetation cover, but it supports shrubs that goats and sheep enjoy for a browse in addition to supporting some grasses, especially after rain animals can graze, furthermore, these desert soils are used by ranchers.

Native vegetation is the key component in the desert ecosystem and faces many threats and stresses either natural or by human activities that lead to accelerating the disappearance of vegetation and hence leads to soil degradation [5,6]. Land degradation is accompanied by weakening of soils and increasing the impact of erosion on the surface crust resulting in reducing soil fertility. The restoration of native vegetation, besides the protection and rehabilitation of remnant vegetation, can reverse these negative effects of clearing and habitat fragmentation. This deterioration of native vegetation within Kuwait causes an increase in aeolian activities [7,8]. The radionuclide’s analysis results from soil samples in Kuwait show that most of mobile sand and dust are originated from re-suspension due to lack of vegetation cover in the desert area [9].

Desert native plants are subjected to high salinity and temperature, scarcity of water in soil and nutrient deficiency [10–12]. Strategies for population survival for each species are exhibited in these severe environmental conditions [13]. 35,429,379 USD is the total cost of land degradation resulted from vegetation change every 20 years in Kuwait [14]. "The total length for off-road vehicle tracks is 14,774.7 km spread over Kuwait which is equivalent to 1.16 times more than the length of the planet earth mean diameter" [15]. Therefore, restoration projects should be implemented on a strong scientific base. The sustainable restoration of degraded lands could pave the way in India for soil carbon sequestration, agricultural extensification, agroforestry practices and biomass and bioenergy production [16,17].

The soil is the earth’s fragile skin that anchors all life on earth [18,19] as it affords mechanical port and plant nutrition to all the vegetation zones. The process of photosynthesis is responsible for the building up atmospheric oxygen plants use carbon dioxide during the process of photosynthesis, which slightly offsets the amount of greenhouse gas being released in the atmosphere [20]. Therefore, it is necessary to maintain a healthy soil to keep a healthy medium for plant growth [20]. While there are many challenges in maintaining healthy soil, there are also solutions such as preserving native plant species, soil carbon sequestration, agricultural extensification, agroforestry practices and biomass [16,17]. A native (indigenous) species are one
that occurs in a particular region, ecosystem, and habitat without direct or indirect human actions [21]. Native plant species provide the keystone elements for ecosystem restoration, with numerous benefits such as, beauty to the landscape, preserve our natural heritage, providing food and habitat for native wildlife and also serve as an important genetic resource for future food crops or other plant-derived products. Not only decrease the amount of water needed for landscape maintenance but also require very little long-term maintenance if they are properly planted and established. Moreover, produce long root systems to hold soil in place in the same way they protect water quality by controlling soil erosion and moderating floods and droughts.

Astragalus spinosus is commonly known as “Shadad” according to the name of the place (Ahmadiyya area) in which it was grown [22]. Astragalus spinosus is a shrub species from the Leguminosae family. It has a self-supporting growth form in arid condition. Therefore, it is a drought-resistant plant and has broad leaves. Astragalus spinosus is a photoautotroph (capable to transform light into chemical energy) and fixes nitrogen [23]. In this study, we concern about one type of native plant species that are playing an important role in revegetation strategies for degraded environments. It is A. spinosus that is a terrestrial shrub which is widely distributed. The genus’ Astragalus is the largest in the Leguminosae family which is considered to be the second-largest family of flowering plants with more than 2500 species [24]. Astragalus spinosus shrub is a small perennial plant with around 60 cm height, and its width has a semicircle shape. The plant renewed its growth during the spring. It distinguishes with a white flower in January, besides its fruits, which look like chickpeas that are in April. The plant provides with strong cylindrical, long sharp thorn up to 15 cm. These thorns protect the plants from the grazing animals. However, the first stages of growth the branches are soft and the animals can graze.

Less interest has been paid for the use of such a shrub to promote sustainable agriculture; especially it is the perennial plant. It’s enormously versatile in morphology and ecology. A quantitative study of the leaf anatomy of A. spinosus is provided as the ratio of the palisade cell-surface area/the leaf or leaflet areas (Apal/A) are 226 [25]. It has a crude protein and buffer soluble nitrogen (BS-N) which was 229 and 19 g/kg DM, respectively [26]. That is why it is not only used as a source of nitrogen for other crops because their roots have bacterial nodules that have the ability to fix nitrogen but also it considers as natural fertilizer, consequently, maintains soil fertility, [27] extract total flavonoids, which found to be 86.6 g/Kg DM. It can grow everywhere including a stream of wages and top of hills. It can survive in both compacted and soft soil. This current study aims to describe A. spinosus and consider it as a sustainable plant for highly degraded desert areas.

2. Material and methods

2.1. The study area

The Liyah area is located in the northern part of Kuwait at Latitude: 29°37’16.33’’N and Longitude: 47°25’45.13’’E. Its area is around 137.2 km². The area was occupied by sand and gravel quarries and was dumped and levelled in 2003 (Figure 1). The desert habitat is slowly rejuvenating after 15 years from dumping, but some indigenous plants and trees have also been planted to provide suitable habitat for the biodiversity in this protected area. Notwithstanding as this area has undergone an intense process of environmental degradation in the early sixties of the last century due to extreme gravel extraction activities. This resulted in a radical reduction of species diversity, density, composition, and undesirable plant species composition and a sharp decline in plant biomass production. The process of rehabilitation of this rangeland to its original green shape is difficult but not impossible. Specifically begg ing with fencing the area as well as the quarries sites levelled the irregularities surface. Accordingly, the process of green island cultivation was widely used to build the plant community structure and to decrease the bare ground exposure areas. It was noticeable that the rangelands of the Liyah area have a relatively very low vegetative cover and few densities of palatable communities of Haloxylon salicornicum, Rhanterium epapposum and Lycium shawii and at the same time, there were dense stands of unpalatable shrubs Comulaca sp and few patches of Astragalus spinosus.

2.2. Field and lab measurements

A total of 10 single nabkhas that formed around the naturally existing A. spinosus plants were selected. These plants were features of their green vegetation on the soil surface for about 5–10 m. The morphometric parameters (width, the length and the height) of the nabkhas body around Astragalus sp plant were measured. Furthermore, the types of green plants that were found around A. spinosus were identified. A total of 25 soil samples were collected at three different depths of (0-20, 20-40, 40-60, 60–80 cm) around the A. spinosus plant. The samples were properly labelled and stored in plastic containers and transferred in the laboratory for analyses.

Particle size analysis was carried out to determine the size of the different particles (particle size distribution) of soil at different depths. The soil has four constituent parts are sand (larger than 0.063 mm), silt (0.002-0.06 mm) and clay (below 0.002 mm). The analysis was carried out by passing the soil particles through a standard set of sieves, and the particles collected on each sieve was calculated by following the Folk method [28,29].

The alkalinity (pH) of the soil samples was measured using pH meter. The pH meter was calibrated using
the buffer solution. Then the meter was adjusted with known pH of buffer solutions 4.0 and 9.2. After that 20 gm of soil was weighed and transferred into 100 mL beaker, 40 mL distilled water was added and stirred well with a glass rod. This was allowed to stand for half an hour with intermittent stirring. To the soil water suspension in the beaker, the electrode was immersed, and the pH value was determined from the automatic display of the pH meter. After determining the soil pH (pHs), the soil water suspension was removed to the Buckner funnels connected to the vacuum apparatus and soil saturation extract collected in collecting vials. The electrical conductivity (EC) of the extract collected from the soil water suspension was measured using the EC meter, and the values reported as microsiemens/cm ($\mu$S cm$^{-1}$).

Organic matter was measured using oxidation method of [30]. As for every soil’s sample weighed an amount of 5 grams of the dried soil sample then it was treated with 5 ml of 0.4 N potassium dichromate solution ($K_2Cr_2O_7$) followed by addition of 10 ml of concentrated sulfuric acid. The mixture was gently swirled and left at room temperature in a fume hood for 16–18 h, and then, 100 ml of triple-distilled water was added to the mixture. The excess of dichromate was back-titrated potentiometrically with the standard 0.2 N ferrous ammonium sulfate solution. Blank titration of the acidic dichromate with ferrous ammonium sulfate solution was performed at the beginning of the batch analysis using the same procedure with no soil sample. One ml of 0.2 N ferrous ammonium sulfate is equivalent to the 0.009807 gr of $K_2Cr_2O_7$ or 0.0006 gr of carbon. Organic carbon content in the sample was calculated as:

$$\text{Organic carbon} \% = (B - S) \times 0.0006 / m \times 100$$

where B is the volume of ferrous solution used in the blank titration, S is the volume of ferrous solution used in the sample titration. M is the mass of the sample in gram used in the analysis.

3. Results and discussion

The Morphometric analysis of Astragalus sp plant parameters was identified in Table 1 for the 10 samples. First, the length of the plant lies between 50 and 76 cm. At the same time, its width found to be 49 cm for the smallest one and 120 cm for the largest value. Afterward, we measure the nabkhas that form around the A. spinosus plants as the height of the sand body with a maximum of 160 cm and a minimum value of 80 cm. At last, we identify the depth of roots at the un-compacted soil as it was hard to measure its whole length as its roots were penetrated throw the compacted hard layer of the soil. The maximum depth was 45 cm which was near to the minimum one which was found to be 35 cm.

Table 1. The Morphometric parameters of Astragalus sp. Plant.

| No | Length (cm) | Width (cm) | The height of the sand body (cm) | Depth of root in the un-compacted soil (cm) |
|----|-------------|------------|----------------------------------|------------------------------------------|
| 1  | 71          | 103        | 140                              | 41                                       |
| 2  | 72          | 76         | 160                              | 45                                       |
| 3  | 70          | 85         | 85                               | 35                                       |
| 4  | 51          | 58         | 89                               | 35                                       |
| 5  | 50          | 49         | 82                               | 40                                       |
| 6  | 77          | 55         | 90                               | 40                                       |
| 7  | 70          | 120        | 80                               | 35                                       |
| 8  | 75          | 120        | 100                              | 40                                       |
| 9  | 60          | 80         | 120                              | 40                                       |
| 10 | 76          | 56         | 91                               | 39                                       |
The particle size analyses of soil sediments at different depths were identified. The particle size distribution analysis (PSDA) is a measurement of the size distribution of individual soil/sediment particles, sand, silt and clay, which can be used to understand soil genesis and to classify soil or to define texture [31]. The results of sieve analysis are generally expressed regarding the percentage of the total weight of soil that passed through different sieves.

Data in Table 2 the classification of soil texture is based on the proportion of sand 2.0-0.05 mm, silt 0.05-0.002 mm and clay (< 0.002 mm) particles. The texture of A. spinosus soil has a direct impact on the way of how this plant sustains drought through a combination of very coarse, coarse, fine sand and mud. The soil at depth 40–80 cm the percentage of very coarse and mud are high where coarse sand can resist wind and water erosion and mud are smaller particles that have a high capacity of holding water due to their large total surface area of particles.

Table 2. The particle size distribution of soil sediments at depth 0, 20, 40, 60 and 80 cm.

| Sample | Very coarse sand% | Coarse sand% | Medium sand% | Fine sand% | Very fine sand% | Mud% |
|--------|-------------------|--------------|--------------|------------|----------------|------|
| 0      | 18.5              | 19.3         | 20.8         | 21.5       | 15             | 5    |
| 20     | 7.75              | 25           | 23.5         | 25         | 17.5           | 1.25 |
| 40     | 22.25             | 18.25        | 19.75        | 19.5       | 17             | 3.25 |
| 60     | 33.25             | 14.5         | 15.75        | 16.5       | 15.75          | 4.25 |
| 80     | 27.5              | 18.25        | 19.5         | 17.5       | 14             | 3.25 |

Every plant has a suitable range of soil pH to grow. Data in Table 3 clarify that A. spinosus plant can grow in between 7.1 and 7.9 as a pH. Likewise, its electrical conductivity (EC) indicates the amount of soluble (salt) ions in the soil as well as indicative of soil salinity. The minimum value of EC in the soil water suspension around A. Spinosus plant was found to be 1736 µS cm$^{-1}$ and this value increase specifically with depth. Thus, the soil at surface EC was 1736 µS cm$^{-1}$ and at depth 80 cm was 2092 µS cm$^{-1}$. Similarly, the EC was 2058 µS cm$^{-1}$ at the surface layer then the value of EC increase to reach 2082 µS cm$^{-1}$ at a depth of 80 cm this for sample number 3.

On the other hand, the sample number 4 the value of EC hasn’t a notable change in its value as it was found to be 2854 µS cm$^{-1}$ at the surface layer and 2856 µS cm$^{-1}$ at a depth of 60 cm. C contrarily in sample number 5 as the EC value found to be 2476 µS cm$^{-1}$ at the surface layer and this value decrease to reach 1854 µS cm$^{-1}$ at 80 cm depth.

Table 3. Measurements of the chemical and physical parameters of soil at a different depth.

| No | Soil depth (cm) | pH  | Ec (µS cm$^{-1}$) | Moisture% | Organic carbons% | Organic matter% |
|----|----------------|-----|------------------|-----------|-----------------|-----------------|
| 1  | 00             | 7.1 | 1736             | 2.040     | 0.000           | 0.000           |
| 20 | 7.4            | 1978| 0.000            | 0.000     | 0.000           | 0.000           |
| 40 | 7.4            | 2084| 0.000            | 2.000     | 0.400           | 0.400           |
| 60 | 7.4            | 2072| 4.170            | 2.080     | 0.400           | 0.400           |
| 80 | 7.4            | 2092| 0.000            | 0.000     | 0.000           | 0.000           |
| 2  | 00             | 7.3 | 2012             | 0.000     | 2.000           | 0.400           |
| 20 | 7.4            | 2075| 2.000            | 2.040     | 0.400           | 0.400           |
| 40 | 7.4            | 2081| 2.040            | 2.000     | 0.400           | 0.400           |
| 60 | 7.5            | 2065| 2.040            | 2.040     | 0.400           | 0.400           |
| 80 | 7.3            | 2042| 2.040            | 2.040     | 0.400           | 0.400           |
| 3  | 00             | 7.4 | 2058             | 0.000     | 0.000           | 0.000           |
| 20 | 7.3            | 1979| 2.040            | 2.040     | 0.400           | 0.400           |
| 40 | 7.5            | 2084| 2.041            | 2.040     | 0.390           | 0.770           |
| 60 | 7.4            | 2043| 2.041            | 4.041     | 0.770           | 0.770           |
| 80 | 7.5            | 2082| 2.040            | 2.020     | 0.400           | 0.400           |
| 4  | 00             | 7.7 | 2854             | 0.000     | 0.000           | 0.000           |
| 20 | 7.7            | 2870| 2.041            | 0.000     | 0.000           | 0.000           |
| 40 | 7.9            | 2058| 0.000            | 0.000     | 0.000           | 0.000           |
| 60 | 7.8            | 2856| 0.000            | 2.000     | 0.380           | 0.380           |
| 80 | 8              | 2354| 0.000            | 0.000     | 0.000           | 0.000           |
| 5  | 00             | 7.4 | 2476             | 0.000     | 0.000           | 0.000           |
| 20 | 7.5            | 2703| 0.000            | 0.000     | 0.000           | 0.000           |
| 40 | 7.3            | 1828| 0.000            | 0.000     | 0.000           | 0.000           |
| 60 | 7.4            | 1855| 0.000            | 0.000     | 0.000           | 0.000           |
| 80 | 7.5            | 1854| 0.000            | 0.000     | 0.000           | 0.000           |
On the other hand, nabkhas deposits around *A. spinosus* are characterized by low pH, low moisture content and low salt proportion, but high in carbonates compared to nabkhas around other native plants in Kuwait [32–35]. The ratio of carbonate in *A. spinosus* nabkha sediments is considered one of the highest amongst the native plants nabkhas [36–38]. It was observed that alkalinity, salinity and electrical conductivity increase till a depth of 40 cm for all the plants, as compared to surface samples. The *A. spinosus* formed a maximum volume of nabkha deposits up to 1.12 m$^3$ (Figure 2).

Every plant has a suitable range of soil pH to grow. Data in Table 3 clarify that *A. spinosus* plant can grow in alkaline soil with a pH between 7.1 and 7.9. Likewise, its electrical conductivity (EC) which indicates the amount of soluble (salt) ions in the soil as well as indicative of soil salinity. The minimum value of EC in the soil water suspension around *A. Spinosis* plant was found to be 1736 µS cm$^{-1}$ and this value increase specifically with depth. Thus, the soil at surface EC was 1736 µS cm$^{-1}$ and at depth 80 cm was 2092 µS cm$^{-1}$. Similarly, the EC was 2058 µS cm$^{-1}$ at the surface layer then the value of EC increase to reach 2082 µS cm$^{-1}$ at a depth of 80 cm this for sample number 3. On the other hand, the sample number 4 the value of EC hasn’t a notable change in its value as it was found to be 2854 µS cm$^{-1}$ at the surface layer and 2856 µS cm$^{-1}$ at a depth of 60 cm. C contrarily in sample number 5 as the EC value found to be 2476 µS cm$^{-1}$ at the surface layer and this value decrease to reach 1854 µS cm$^{-1}$ at 80 cm depth. These result clearly showed that the Astragalus sp. can resist the soil salinity up to 2100 µS cm$^{-1}$.

The soil moisture percentages were measured for all samples soil at different depths. The soil moisture percentages at the surface layer of the soil which faced the hot, dry climatic condition found to be zero% while becoming deeper, the soil moisture increase but with a very low percentage. It reached about 4.17%. An equally important parameter is the identification of organic carbon (OC) percentage. It was a measurable element of soil organic matter. It was remarkable that the percentage of organic carbon verify between 0% and 4.17% Soil organic matter (SOM) primarily consists of hydrogen, carbon, and oxygen as well as small amounts of nutrients. %OC correlates strongly to % SOM. The average % of SOM verify between 0% and 0.77% with an average of 0.4%.

It is clearly noted from study results that the native plant can form a type of aeolian sediment accumulation that is effective in trapping sediment moving by creep and saltation close to the ground surface [39]. *A. spinosus* can form small and medium nabkha (Figure 2). The typical measurements of medium nabkha for Astragalus sp. was the height of the sand body go beyond the plant which reaches about 160, 72 cm in length and 120 cm in width. The sediment of such plant creates a microenvironment habitat for wild animals Such as lizard, mice, and insects. It was noticed widely all-over the surveyed degraded soil at the Liyah area. It strong drought-resistant plant that can survive in the harsh environmental condition through the existence of strong taproot that can penetrate vertically into soft soil until 40 cm and continue deep into rocky solid gatchi layer searching for water. It can take advantage of existing deeper soil moisture. Such shrub from Leguminosae family that acts as organic fertilizer that enhances the quality of soil has led to the appearance of native plant species around area where *A. spinosus* cultivated such as, Fagonia indica, Fagonia

![Figure 2](image-url). The cost, average volume and standard deviation for trapped mobile sand in cubic meter around dominant native plants and trees in Kuwait [40].
bruiguieri, Stipagrostis plumose, Plantago coronopus, Plantago ciliata, Plantago boissieri, Rumex vesicarius, Saviyngya praviflor, Launae mucronata Picris babylonica Diplotaxis harra Rhanterium epapposum and Haloxylon salicornicum. The total area covered by the native plant (perennial and annual plant) between 5 and 10 m. The data obtained recently from governmental agencies during this study revealed that the mean cost of one cubic meter cleaned from the civilian and military infrastructures is equivalent to 5.33 USD, where nearly 3,160,661 m$^3$ of accumulated sand around infrastructures has been removed annually in Kuwait with a total cost of USD 4,169,766 [40]. The amount of encroached sand is doubled every 20 years according to [41]. The cost that each native plant can save was obtained by multiplying the average cost of one cubic meter removal of sand (5.33 USD) with the volume of sand around the native plant. A. spinosus present one of the most effective plants in controlling mobile sand (Figure 2). Every single plant of A. spinosus will save the Kuwait economy by USD 3.6 in average, calculated via multiplying the volume of mobile sand captured by single plant with the mean cost of one cubic meter as encroached sand that was removed from infrastructure which is USD 5.33. This particular plant species compared to resident associated species have many properties the followings:

- Rehabilitation for degraded and compacted soil.
- Less palatable as a plant for the grazing animals (sheep and camels) as it contains the longest spines between all present native plants in Kuwait.
- The low moisture content with sediments around the plant indicates it is effective drought resistance plant.

4. Conclusions

Using native plants in a restoration projects often involve the identification of the locally-adapted plant, a collection of ripening seeds and cultivation of these seeds into the area to reflect the diversity. On the other hand, nabkhas deposits around A. spinosus are characterized by low PH, low moisture content and low salt proportion, but high in carbonates compared to nabkhas around other native plants in Kuwait studied by other researchers. The ratio of carbonate in A. spinosus nabkha sediments is considered one of the highest amongst the native plants nabkhas. It was observed that alkalinity, salinity and electrical conductivity increase till a depth of 40 cm for all the plants, as compared to surface samples. The A. spinosus formed a maximum volume of nabkha deposits up to 1.12 m$^3$ (Figure 2) which makes it one of the effective plants in controlling mobile sand and dust. Each single plant of will has the capability to save the Kuwait economy by USD 3.6. It is concluded that A. spinosus is as a sustainable plant for the followings reasons:

- The capacity to grow in nutrient-poor soil.
- The ability to grow on the disturbed area, undulating sandy plains, sand sheet and gravelly.
- The shape of the root system that can penetrate hard soil to reach the residual soil moisture.
- Equipped to survive in an ecosystem that contains scarce water sources, strong wind, hot temperature and lightness during the day.
- A potential control for shifting sand through the development of small and medium nabkhas that helps in extenuating the effects of climate changes.
- Provide forage for wildlife and livestock mainly for camels.
- It improves soil quality, so it can get better economic outcomes through improving land value, improved rangelands, and increased crop yield.

Future studies will be focusing on evaluating the relation between native fauna and flora within the study area. Also, to expand using A. spinosus as a native plant in future rehabilitation projects.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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