Managing the Hazards of Aeolian, Fluvial and Coastal Erosion in Gudhi Area-Northern Kuwait Bay

Ali Al Dousari*, Modi Ahmed, Noor Al Dousari, Abeer Al Saleh1 and Teena William
Kuwait Institute for Scientific Research, Kuwait

* Corresponding author’s e-mail: adousari@kisr.edu.kw

Abstract. Kuwait Institute for Scientific Research plans to set up some research facilities within the Gudhi area, which lies north of the coastal spill of Kuwait Bay. The area is about 653,000 m², the region highly sensitive from an environmental perspective and ecological. It is a coastal strip dominated by rich fauna and flora mainly Nitraria retusa forming large nabkhas that attract many wildlife scientists. The presence of nabkhas is a good indicator of fluvial and aeolian activities in the area. The establishment of infrastructures within this area is anticipated to cause significant damage to wildlife. Additionally, any future infrastructures in the area is under the following threats: 1- Sand encroachment as it is located within an active wind corridor. 2- Fluvial action during flood seasons as it is located at downstream of Jal Al- Zur watershed. 3- The wave erosion along 1200m coastal margin. As an important role of KISR is the attention and care regarding the environmental aspects associated with project actions, therefore, it is proposed that a proper scientific research project should be implemented prior to the establishment of any infrastructure development. The main objective of this study is to assess and control hazards in the Gudhi area by implementation of native plants and mangroves landscape design. Assessment and monitoring of fauna and flora have provided initial information on existing vegetation, soil properties that are considered important to quantify ecological conditions prior to actual vegetation plantation establishment or restoration effort. Nitraria and Lycium populations were found the most proper in controlling hazards of mobile sand and flush floods for the study area.

1. Introduction

The Gudhi area is located in northern Kuwait Bay. Geomorphologically, it consists of an alluvial fan sediments and fluvial deposits accumulating from the main stream wadis that descend down from Jal Al-Zur escarpment toward Kuwait Bay. The area is located within an active mobile sand corridor. The sedimentology and morphology of the study area and surrounding areas were first studied [1] who investigated the northern coastal zone of Kuwait Bay. This was followed by many other studies [2-6], [7] which classified the aeolian depositions around Nitraria retusa and other native plants into three categories based on the number of plants within an anchored aeolian and body formed around it, namely; isolated nabkha, compound nabkha and complex nabkha. It is anticipated that any future infrastructure development in this dynamic area undoubtedly suffers from flash floods, mobile sand encroachment, severe dust deposits and coastal erosion [10-19].

Considering dominant perennial plant species are crucial in controlling the problem of mobile sand encroachment in Kuwait [18-19], The most effective native plants in Kuwait at controlling the threats of mobile sand and flush floods in the research region are Nitraria and Lycium species,
according to a comprehensive assessment of Kuwait’s major perennial plant species and their ability to collect mobile sand and dust [15-20].

The goal of this study is to evaluate and control hazards in the Gudhi area through the use of native plants and mangrove landscape design. In addition, the assessing and monitoring of fauna and flora have provided preliminary information on current vegetation, and soil qualities. that are regarded to be significant for quantifying ecological conditions prior to the real establishment of vegetation plantations or restoration efforts.

Therefore, in order to reduce the sand movement and to ensure protection of land and future infrastructure, an innovative strategy of establishing multiple layers of native vegetation plantation (nabkhas) is proposed. The approach utilizing native plantation should be implemented here in order to control anticipated hazards associated with mobile sand, flash floods and coastal erosion and to scientifically monitor the consequences of the actions.

2. Methods

For this project, the following activities will be conducted:

- A database within Crisis Decision Support (CDS) for the study area will be established including information regarding hazards, geomorphology, sedimentation, and coastal and inland native life (fauna and flora).
- Particle size parameters are determined for dust fallout. Both Moment method was employed to determine the statistical parameters of the sediments with GRADSTAT.
- In order to quantify the site’s existing flora and fauna, there will be an assessment and analysis of the study area using available aerial photos and images.
- Built on top of that inventory and assessment, detail vegetation surveys, soil and root microbial assessment, and assessment of fauna will be undertaken to establish sufficient baseline data.
- Flora and fauna maps will be prepared for the study area and surroundings (about 4.5 km² as a total area before and after establishment of control measures (Fig. 1).
- Aeolian activities will be monitored for a period of two years derived from nine separate monitoring stations.
- Drainage patterns will be delineated for the study area.
- Environmental impact assessments will be conducted before, during and after implementing the project activities at Gudhi site.
- Subsequently, a native vegetation based design will be established using about 30,000 of native plants and mangroves as the primary tools to control flash floods, aeolian activities (mobile sand and dust) and coastal erosion due to sea severe action of tidal waves.
- The plantation will be in contrast with the conventional engineered approach typically used in these conditions for the management of such hazards.
- In order to achieve relatively quick and improved vegetation establishment, two different types of container-grown nursery stock (elongated root system and regular root system) and inoculated with Arbuscular Mycorrhizal (AM), fungi will be used for the enhanced establishment of vegetation in the three prior described patterns (isolated nabkha, compound nabkha and complex nabkha) in order to control salt stress and nutrient availability as they are a major constrains to plant growth and productivity in the area (Fig. 2).
- Colonization with AM fungi with root system may enhance plant growth in various ways.
- Aeolian and fluvial samples will be analyzed focusing on the physical properties including dust fallout and mobile sand quantities, granulometric analysis and other statistical parameters.

3. Results and Discussion

Grain Size Analysis. All dust, sand samples, and surface sediment samples (around 500 samples) were analyzed for particle size distribution using a centrifugal particle analyzer. The results were mainly obtained from intensive field study from nabkhas around two dominant plants in the study area, which are Lycium shawii and Nitraria retusa. These results were compared with sediments
around nine dominant plants in Kuwait (Table 1). The analyzer can measure the weight percentage for each size less than 0.5 micrometer. Particle size percentages and statistical parameters of sediments around *Nitraria retusa* species at the depth 70 cm (root area) are visible in Table 1.

Figure 1. Arial photo (2011) for the study area (left) and field of nabkhas in the study area (right).

Figure 2. Summary conceptual designs using native plants proposed to be implemented in Gudhi (M: meter, HA: Hectar).
Table 1. Sediments Formed around Native Plant Species in Kuwait

| Plant species                  | Mean (phi) | Sorting | Skewness | Kurtosis |
|-------------------------------|------------|---------|----------|----------|
|                               | Surface    | Root    | Surface  | Root     |
| Tamarix auberiana             | 1.41       | 1.62    | 1.49     | 1.02     | 0.40     | 0.16     | 0.90     | 1.08     |
| Citrus colocynthis            | 1.47       | 1.66    | 1.22     | 1.22     | 0.18     | 0.06     | 0.72     | 0.71     |
| Lycium shawii                 | 1.61       | 1.54    | 1.05     | 1.01     | 0.18     | 0.17     | 0.94     | 0.94     |
| Rhanterium epapposum          | 1.65       | 1.67    | 0.82     | 0.90     | 0.31     | 0.24     | 1.06     | 1.18     |
| Nitraria retusa               | 1.72       | 1.53    | 0.95     | 0.93     | 0.11     | 0.07     | 1.17     | 1.24     |
| Haloxylon salicornicum        | 1.73       | 1.75    | 0.97     | 0.94     | 0.08     | 0.10     | 1.02     | 0.93     |
| Cyperus conglomeratus         | 1.60       | 1.61    | 1.08     | 1.05     | 0.21     | 0.12     | 0.97     | 0.97     |
| Astragalus spinosus           | 1.84       | 1.70    | 1.04     | 1.06     | 0.07     | 0.03     | 1.07     | 0.85     |
| Salicornia europaea           | 1.90       | 1.44    | 2.56     | 1.16     | 0.29     | 0.12     | 2.38     | 0.82     |
| Halocnemum strobilaceum       | 2.51       | 1.68    | 1.22     | 1.02     | -0.12    | 0.26     | 1.28     | 1.21     |
| Panicum turgidum              | 2.077      | 1.809   | 1.158    | 1.38     | -0.182   | 0.279    | 1.16     | 0.811    |
| Average                       | 1.66       | 1.62    | 1.24     | 1.03     | 0.20     | 0.13     | 1.14     | 0.99     |
| Standard deviation            | 0.31       | 0.11    | 0.47     | 0.14     | 0.17     | 0.14     | 0.43     | 0.18     |
| Max                            | 2.51       | 1.75    | 2.56     | 1.22     | 0.40     | 0.26     | 2.38     | 1.24     |
| Min                            | 1.41       | 1.44    | 0.82     | 0.90     | -0.18    | 0.03     | 0.72     | 0.71     |

3.1 Fauna and Flora Assessment

Field aerial photos investigation was conducted to assess and quantify the fauna and flora of the study area (Fig. 3 a). The assessment took place before implementing the project activities. Assessment and monitoring of fauna and flora will provide baseline information on existing vegetation growing in the area and soil characteristics to quantify ecological conditions prior to an actual vegetation plantation establishment or restoration effort, the field investigation showed there are a number of animal holes like insects of ants and beetles, also noticed larger animals such as fennec foxes, lizards, and agamid lizards in the study area (Fig. 3 b and c). This task involves characterization of the existing Nitraria and Lycium populations and soil properties and surrounding micro-climate conditions. Also, around 16,500 Nitraria and Lycium plants will be planted in the area as a major step in the rehabilitation project. The rehabilitation project via native plants plantation is designed to act as arrow shape in order to divert the mobile sand aerodynamically away from the preserved area. Figure 4 shows the health of the plants in the mapped area based on an RGB sensor which pinpoints the color green as healthy, indicating an increase in chlorophyll content increasing the photosynthesis process in that zone; any other color would mean unhealthy vegetation.

Figure 3. Aerial view of the area before plantations (left), Trace of the ants (mid), and The agamid lizards (right).
4. Conclusions

Assessment and monitoring of fauna and flora have provided initial information on existing vegetation, soil properties that are considered important to quantify ecological conditions prior to actual vegetation plantation establishment or restoration effort. The main goal basically revolves around the dominant species in the area, i.e., characterization of the existing *Nitraria* and *Lycium* populations and soil properties and surrounding micro-climate conditions. Both plant species were found the most proper for the study area.

References

[1] Al-Dousari. Causes and indicators of land degradation in the north-western part of Kuwait. Arabian Gulf of Scientific Research. 23(2): 69-79. (2005)

[2] Al-Dousari, A.M.: Recent studies on dust fallout within preserved and open areas in Kuwait. In Desertification in Arid lands: causes, consequences and mitigation; Bhat, N., Al-Nasser, A., Omar, S., Eds. Kuwait Institute for Scientific Research, Kuwait, 137–147. (2009)

[3] MM Ahmed, AM Al-Dousari, S Baby Chemical and morphological characteristics of phytogenic mounds (Nabkhas) in Kuwait. - Arab Gulf Journal of Scientific Research, 2009 27(3): 114-126

[4] Al Awadhi JM, and Al-Dousari AM. 2013. Morphological characteristics and development of coastal nabkhas, north-east Kuwait. 102(3):949-958

[5] Al-Dousari Am., Bahbahani M., Al-Awadhi L and Al-Zajali, H. 2004. Analysis of dust fallout data and sediments in Kuwait. International conference on Atmospheric Pollution, Bubai, pp 21-24

[6] Al-Dousari, A.M., Aba, A., Al-Awadhi, S., Ahmed M., Al-Dousari. N. Temporal and spatial assessment of pollen, radionuclides, minerals and trace elements in posited dust within Kuwait. Arabian Journal of Geosciences, 9: 95. doi: 10.1007/s12517-015-2182-z. (2016)

[7] Al-Dousari, A.M., Al-Hazza, A.: Physical properties of aeolian sediments within major dune corridor in Kuwait. Arabian Journal of Geosciences, 6(2): 519–527, (2013)

[8] Al-Dousari, A.M., Al-Awadhi, J., Ahmed, M.: Dust fallout characteristics within global dust storms major trajectories. Arabian Journal of Geosciences, 6(10): 3877–3884, (2013)
[9] Al-Dousari, A.M., et al.: Analysis of dust fallout data and sediments in Kuwait. International conference on Atmospheric Pollution, Dubai. Pp 21-24, (2004)

[10] Al-Awadhi, J., Al-Dousari A., Khalaf, F. I.: Influence of land degradation on the local rate of dust fallout in Kuwait. Atmospheric and climate Sciences, 3:10, (2014)

[11] Al-Dousari, A.M., Al-Awadhi, J.: Dust fallout in northern Kuwait, major sources and characteristics. Kuwait Journal of Science and Engineering, 39 (2A), 171–187, (2012)

[12] Al Dousari A., et al.: Off-road vehicle tracks and grazing points in relation to soil compaction and land degradation. Earth systems and environment, 16(5): 2415-2426, (2019)

[13] Al-Hemoud A., et al.: Sand and dust storm trajectories from Iraq Mesopotamian flood plain to Kuwait. Science of the total Environment. 710:136-291, (2020)

[14] Al-Dousari, A., Al Dousari, N.: Deposited Dust. In book Atlas of fallen dust in Kuwait. 47-56, (2021), https://doi.org/10.1007/978-3-030-66977-5_2

[15] Al-Dousari, A., Ramadan, A., Al-Qattan, A., Al-Ateeqi, S., Dashti, H., Ahmed, M.: Cost and effect of native vegetation change on aeolian sand, dust, microclimate and sustainable energy in Kuwait. Journal of Taibah University for Science, 14: 628-639, (2020)

[16] Folk, R.L. and Ward, W.C. A Study in the Significance of Grain-Size Parameters. Journal of Sedimentary Petrology, 27, 3-26, (1957) https://doi.org/10.1306/74D70646-2B21-11D7-8648000102C1865D

[17] Blott, S.J. and Pye, K. Gradistat: A Grain Size Distribution and Statistics Package for the Analysis of Unconsolidated Sediments. Earth Surface Processes and Landforms, 26, 1237-1248, (2001) http://dx.doi.org/10.1002/esp.261

[18] Al-Dousari AM, Pye K (2005) Mapping and monitoring of dunes in northwestern Kuwait. Kuwait J Sci Eng 32(2):119–134

[19] Al-Dousari A., Ahmed M., Al-Dousari N., Al-Awadhi S. (2019) Nabkha Morphometry and Properties of Aeolian Sediments Around Native Plants in Kuwait. In: Chenchouni H., Errami E., Rocha F., Sabato L. (eds) Exploring the Nexus of Geocology, Geography, Geoarcheology and Geotourism: Advances and Applications for Sustainable Development in Environmental Sciences and Agroforestry Research. CAIG 2018. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development). Springer, Cham. https://doi.org/10.1007/978-3-030-01683-8_9

[20] Al-Dousari A., Ahmed M., Al-Dousari N., Al-Awadhi S. (2018) Native plants in Kuwait: Environmental and economic perspective. Journal of the Gulf and Arabian Peninsula Studies 44 (168): 277-31.