Nabkha Morphometry and Properties of Aeolian Sediments Around Native Plants in Kuwait

Ali Al-Dousari, Modi Ahmed, Noor Al-Dousari, and Safaa Al-Awadhi

Abstract

The aeolian sediments (mobile sand and dust) trapped along native plants create a geomorphological landform, known as nabkhas. About 600 core samples from aeolian accumulations settled around 15 species of main native plants in Kuwait. *Cyperus conglomeratus*, *Haloxylon salicornicum* and *Rhanterium epapposum* nabkha sediment is characterized by more alkaline (pH) values, low moisture content and electrical conductivity (EC). The later plants contain short branches spacing and are at close distances from the nearby nabkhas. The *Astragalus* sp. nabkhas mean grain sizes are considered the finest and contain considerable carbonate percentages as it grows in playa and alluvial fan deposits. *Citrulus* sp. nabkhas are characterized by the lowest pH, EC, and moisture content but the highest content of carbonate in comparison to other native plants. *Lycium* sp. has the longest distance between branches and to the equivalent nearby species. The maximum aeolian accumulation volume was noted around *Nitraria retusa*, *Lycium shawii*, *Haloxylon salicornicum* and *Calligonum polygonoides* up to 21.9, 15.5, 14.5, and 13.3 m^3, respectively, which spot them as the most effective solutions for future applications in controlling aeolian activities in the region. This study aimed to assess the sediment properties around native plants and detect the most efficient plants in controlling aeolian activities in Kuwait.

Keywords

Aeolian • Dust • Mobile sand • Nabkhas
Carbonates

A. Al-Dousari (✉) · M. Ahmed · N. Al-Dousari · S. Al-Awadhi
Environment and Life Sciences Research Center (ELSRC),
Kuwait Institute for Scientific Research (KISR), P.O. Box 24885
13109 Safat, Kuwait
e-mail: Dr.Aeolian@gmail.com

1 Introduction

Aeolian processes are activated by predominant high wind speed, scanty vegetation, long drought periods, light-textured topsoil and low topographic relief (Al-Awadhi and Al-Dousari 2013). The mobile sand and dust particles movement cause sand encroachment in human settlements and poses serious economic and environmental threats (Ahmed et al. 2015). Native plants were found to have operative control measures for mobile sand in Iraq (Fadhil 2002); Saudi Arabia (Alghamdi and Al-Kahtani 2005); Iran (Pahlavanravi et al. 2012); and South Korea (Hong and Lee 2016). The native plants were found to be effective in controlling aeolian activities, soil sealing (Al-Dousari et al. 2000), wind's erosive force and act as soil organic carbon storage (Burri 2011). Native plants are proficient in catching mobile aeolian sediments forming aeolian landform called nabkha (Al-Dousari and Pye 2005). Nabkha is an aeolian accumulation around a native plant (Cooke et al. 1993; Khalaf et al. 1995; Al-Dousari et al. 2008; Ahmed et al. 2015). The nabkha formation around native plants is economically and environmentally significant as it controls mobile sand and suspended dust particles in desert and semi-desert regions (Darwish et al. 2013; Ahmed et al. 2015) and reduce sand encroachment problem. Therefore, the aim of this study was to identify the characteristics of sediments that form around dominant plants in Kuwait and detect their efficiency in controlling aeolian activities.

2 Materials and Methods

In order to test the effectiveness of each native plant species in capturing mobile sand and dust, the morphological dimensions (length, height and width) were measured through intensive field survey in 47 site locations in Kuwait (Fig. 1a, b). These native plants are *Calligonum polygonoides, Cyperus conglomeratus, Haloxylon salicornicum,*

H. Chenchouni et al. (eds.), *Exploring the Nexus of Geoecology, Geography, Geoarcheology and Geotourism: Advances and Applications for Sustainable Development in Environmental Sciences and Agroforestry Research*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-01683-8_9

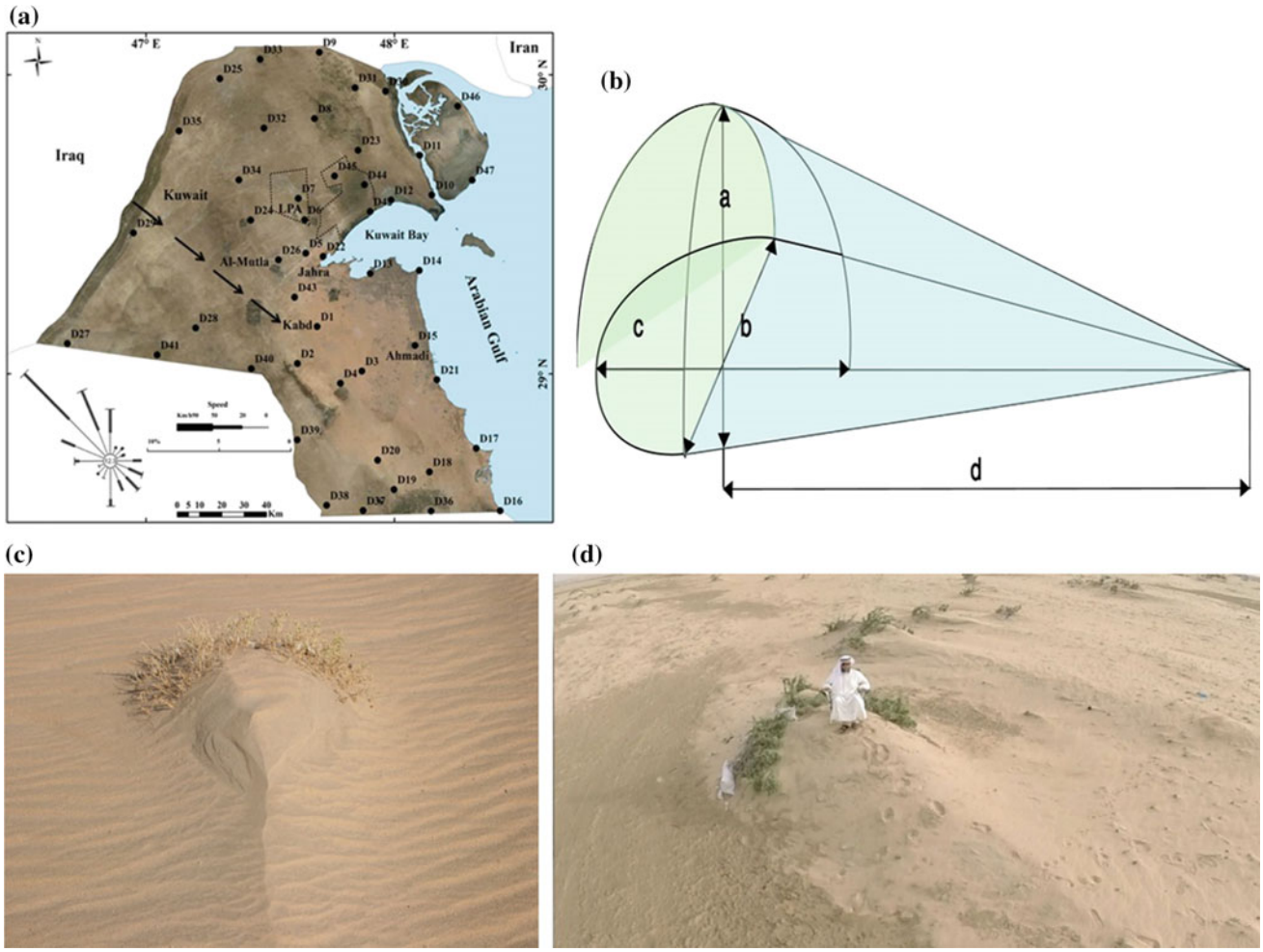

Fig. 1 Sampling location map (**a**), nabkha dimensions sketch (**b**), and field photos for nabkha of two different native plants (**c**, **d**)

Rhanteium epapposum, Astragalus spinosus, Lycium shawii, Citrullus colocynthis, Panicum turgidum, Salicornia europaea, Heliotropium bacciferum, Arnebia decumbens, Nitraria retusa, Tamarix aucheriana, Convolvulus oxyphyllus and *Halocnemum strobilaceum*. The largest nabkhas around each plant species were visually selected and measured within the 47 sites (Fig. 1c, d). In this study, the largest 20 nabkhas for each of the 15 plant species were considered for morphological dimensions and soil analysis (Alkalinity, conductivity level, moisture and particle size as well as carbonate percentages). The nabkha volume was then calculated via our formula as follows:

$$\text{The total nabkha volume} = V_E + V_P = \frac{\pi.a_1.b_1.c_1}{12} + \frac{\alpha.d^5.\tan\theta}{5}$$

where a_1 is height from ground level and equal to vertical radii, b_1 is total width, and c_1 is horizontal radius. The tailing volume is calculated by integrating the base from zero to vertical radius (a) $V_P = \int A.da_1$. The area of the surface = $b_1.d$, where b_1 = d. tan θ.

3 Results and Discussion

The native plants, mainly *Nitraria*, *Lycium*, *Haloxylon,* and *Calligonum* formed the maximum volumes of nabkha deposits up to 21.9, 15.5, 14.5 and 13.3 m^3, respectively. Therefore, these plants are the most effective solutions as aeolian processes future control measures. The effectiveness of these native plants in controlling aeolian processes can be due to the morphometric parameters of these plants compared to others. This was noted by Al-Dousari et al. (2008), Ahmed et al. (2015), and El-Wahab (2018). Native plants are a workable solution to control aeolian activities in Kuwait and the surrounding areas (Al-Dousari and Al-Awadhi 2012

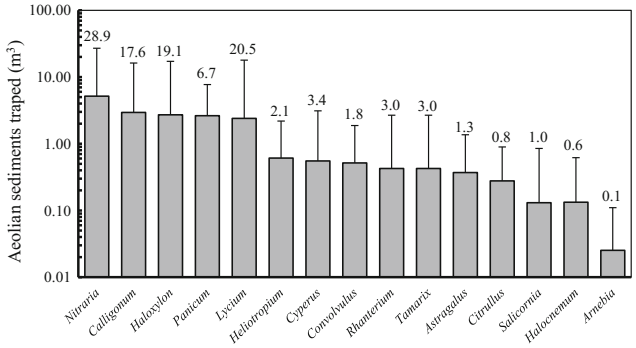

Fig. 2 The volume of aeolian accumulation around dominant native plants in Kuwait (the bars represent the maximum values)

and Al-Dousari et al. 2017). They only require 2–3 years of irrigations; then, they adapt to weather conditions (112 mm mean annual rainfall). On the other hand, aeolian sand and dust are part of the desert ecological system and they act as a healing factor for degraded lands as a constant supplier of plants seeds. Dust and mobile sand contain organic matter up to 8.96 and 4.85%, respectively from total sample weight (Al-Dousari et al. 2016). The proper use of native plants in controlling aeolian mobile sand was successful in Syria (Al-Obaid 2000), Saudi Arabia (Alghamdi and Al-Kahtani 2005), Iran (Pahlavanravi et al. 2012), Chad (Djibril 2013), Egypt (Darwish et al. 2013), Morocco (Hammouzaki 2013) and China (Hong and Lee 2016).

The *Astragalus* sp. nabkhas mean grain size are considered to be the finest and high in carbonates as it grows in playa and alluvial fan deposits. *Citrulus* sp. nabkhas are characterized by the lowest pH, EC, and moisture content but the highest content of carbonate in comparison to other native plants. *Lycium* sp. has the longest distance between branches and to the equivalent nearby species. *Cyperus conglomeratus*, *Haloxylon salicornicum* and *Rhanterium epapposum* nabkha is characterized by more alkaline (pH) values, low moisture content and electrical conductivity (EC). The latter plants develop short branches spacing and at close distances with nearby nabkhas (Fig. 2).

4 Conclusion

The average aeolian accumulation around native plants in Kuwait is equivalent to 1.92 m^3. Some native plants show the best capability in controlling aeolian sediments. The maximum volumes of aeolian accretion were noted to be around *Nitraria retusa* (21.9 m^3), *Lycium shawii* (15.5 m^3), and *Haloxylon salicornium* (14.5 m^3). It is noteworthy to consider them as the most efficient plants in controlling aeolian sediments in the region. Correspondingly, each native plant has its distinctive morphological and soil characteristics. The native plants were found to be the practical solutions in controlling aeolian accumulations and as they have a remarkable low cost. Therefore, they are recommended as potential future applications to control sand encroachment and resuspended dust particles in the region.

Acknowledgements Gratitude for supporter (KISR) Grant number: 2011/EC085C. Appreciation is extended to Abu Noor, Mamdouh and Sayed for their helping with laboratory and field measurements.

References

Ahmed, M., Al-Dousari, N., Al-Dousari, A.: The role of dominant perennial native plant species in controlling the mobile sand encroachment and fallen dust problem in Kuwait. Arab. J. Geosci. **9** (2), 134 (2015). https://doi.org/10.1007/s12517-015-2216-6

Al-Awadhi, J.M., Al-Dousari, A.M.: Morphological characteristics and development of coastal nabkhas, North-East Kuwait. Int J Earth Sci. (Geol Rusdsch) **102**, 949–958 (2013). https://doi.org/10.1007/s00531-012-0833-9

Al-Dousari, A., Doronzo, D., Ahmed, M.: Types, indications and impact evaluation of sand and dust storms trajectories in the Arabian Gulf. Sustainability **9**(9), 1526 (2017). https://doi.org/10.3390/su9091526

Al-Dousari, A., Misak, R., Shahid, S.: Soil compaction and sealing in Al Salmi area. J Land Degradation Dev **11**, 401–418 (2000). https://doi.org/10.1002/1099-145X(200009/10)11:5%3c401:AID-LDR396%3e3.0.CO;2-4

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. Arab. J. Geosci. **9**, 95 (2016). https://doi.org/10.1007/s12517-015-2182-z

Al-Dousari, A.M., Ahmed, M., Al-Senafy, M., Al-Mutairi, M.: Characteristics of nabkhas in relation to the dominant perennial plant species in Kuwait. Kuwait J. Sci. Eng. **35**(1), 129–150 (2008)

Al-Dousari, A.M., Al-Awadhi, J.: Dust fallout in northern Kuwait, major sources and characteristics. Kuwait J. Sci. Eng. **39**(2A), 171–187 (2012)

Al-Dousari, A.M., Pye, K.: Mapping and monitoring of dunes in northwestern Kuwait. Kuwait J. Sci. Eng. **32**(2), 119–134 (2005)

Alghamdi, A.A., Al-Kahtani, N.S.: Sand control measures and sand drift fences. J. Perform. Constructed Facil. **19**(4), 295–299 (2005). https://doi.org/10.1061/(ASCE)0887-3828

Al-Obaid N.: Economic and environmental assessment for direct and indirect factors causing desertification (base study in Bushra-Syria). The Arab Center for the Studies of Arid zones, Syria (2000)

Burri, K.: Plant and mycorrhizal Fungi in wind erosion control. Ph.D. Dissertation, Swiss Federal Institute of Technology in Zurich (ETH Zurich) (2011)

Cooke, R.U., Warren, A., Goudie, A.S.: *Desert Geomorphology,* pp. 357. Taylor & Francis, London (1993). ISBN 1-85728-017-2

Darwish, K., Safaa, M., Momou, A., Saleh, S.A.: Egypt: Land degradation issues with special reference to the impact of climate change. In: Heshmati, A.G., Squires, R.V. (eds.) Combating desertification in Asia, Africa and the Middle East: Proven practices, pp. 113–136. Springer, Netherlands, Dordrech (2013)

Djibril, H.: Desert environments of republic od chad. In: Heshmati, A. G., Squires, R.V. (eds.) Combating desertification in Asia, Africa and the Middle East: Proven practices, pp. 169–189. Springer, Netherlands, Dordrech (2013)

El-Wahab, R.A., Al-Rashed, A.R., Al-Dousari, A.: Influences of physiographic factors, vegetation patterns and human impacts on aeolian landforms in arid environment. Arid Ecosyst. **8**(2), 97–110 (2018)

Fadhil, A.M.: Sand dunes fixation in Baiji, Iraq. J. China Univ Geosciences **13**(1), 67–72 (2002)

Hammouzaki, Y.: Desertification and its control in Morocco. In: Heshmati, A.G., Squires, R.V. (eds.) Combating Desertification in Asia, Africa and the Middle East: Proven practices, pp. 91–110. Springer, Netherlands, Dordrech (2013)

Hong, S.H., Lee, E.Y.: Restoration of eroded coastal sand dunes using plant and soil-conditioner mixture. Int. Biorem. Biorem. **113**, 161–168 (2016). https://doi.org/10.1016/j.ibiod.2016.04.021

Khalaf, F.I., Misak, R., Al-Dousari, A.M.: Sedimentological and morphological characteristics of some nabkha deposits in the northern coastal plain of Kuwait Arabia. J. Arid Env. **29**(3), 267–292 (1995). https://doi.org/10.1016/S0140-1963(05)80107-7

Pahlavanravi, A., Miri, A., Ekhtesasi, M.R.: The impact of different kinds of dust storms in hot and dry climate, a case study in Sistan region. Desert **17**(1), 15–25 (2012). http://jdesert.ut.ac.ir