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The importance of native plants and green belts, both environmentally and economically, in preventing the spread of mobile sand and dust hazards

Prepare

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Abstract

A substantial amount of aeolian sediment is continuously being moved due to the prevalent and strong north-westerly wind that blows in Kuwait during the summer. This movement of sediment creates significant environmental and economic risks. In Kuwait, the cost of removing encroached sand from around facilities at a rate of one cubic metre averages up to 1.32 US Dollars. The capacity of Haloxylon species to ensnare sand is significantly greater than that of Stipagrostis species by a factor of one hundred. The areas that were covered by Haloxylon in 1974 have lately lost 4385 km^2 of land to Stipagrostis for its benefits, which has resulted in the establishment of a new mobile sand corridor. The expenditures associated with sand invasion, decreased solar energy efficiency, and increased CO_2 consumption contributed to the calculation of the yearly cost estimate for the vegetation change, which comes to 35,429,379 US dollars. Rehabilitation of land that formerly supported extensive canopies of plants will almost certainly result in a drop in wind speed and air temperature, a decrease in albedo, and an increase in precipitation as well as solar energy output. It was discovered that native plants had a beneficial impact since they prevented around 115 tonnes of aeolian sediments from being deposited, which resulted in a cost savings of USD 151,800 in terms of the projected cost of removing these accumulations everywhere around human settlements. The yearly rates of mobile sand have been reduced by 94 and 95.3% thanks, in part, to the presence of native plants and green belts, which have also contributed to the decrease of dust by 64.5 and 68.4%, respectively.

Key words: Aeolian sand - Kuwait - Native plants - Environmental rehabilitation

المستخلص

تم نقل كمية كبيرة من الرواسب الرملية المتطايرة باستمرار بسبب الرياح الشمالية الغربية السائدة والقوية التي تهب في الكويت خلال فصل الصيف. تسبب هذا الحركة في الرواسب الرملية مخاطر بيئية واقتصادية هامة. في الكويت، يتراوح تكلفة إزالة الرمال المتطايرة من حول المنشآت بمعدل متر مكعب مربع متري حتى 1.32 دولار أمريكي. تتمتع أنواع النباتات من نوع Haloxylon بقدرة أكبر بشكل كبير على الاحتجاز الرمال مقارنةً بأنواع النباتات من نوع Stipagrostis بعامل مئوي. فقد فقدت المناطق التي كانت مغطاة بالسنديان في عام 1974 ما مجموعه 4385 كيلومتر مربع من الأراضي مؤخراً لصالح نباتات الـــ Stipagrostis لفوائدها، مما أدى إلى إنشاء ممر رملي جديد متحرك. ساهمت النفقات المرتبطة بغزو الرمال وانخفاض كفاءة الطاقة الشمسية وزيادة استهلاك ثاني أكسيد الكربون في حساب التقدير السنوي لتغيير النباتات، والذي يبلغ 35،429،379 دولار أمريكي. من المرجح أن يؤدي تأهيل الأراضي التي كانت تدعم سابقًا غطاء نباتي مكثف إلى انخفاض سرعة الرياح ودرجة حرارة الهواء، وانخفاض السطوع المنعكس، وزيادة الهطول المطري وكذلك إنتاج الطاقة الشمسية. تبين أن النباتات الأصلية لها تأثير إيجابي حيث منعت حوالي 115 طنًا من الرواسب الرملية المتطايرة من الترسب، مما أدى إلى توفير تكلفة بقيمة 151,800 دولار أمريكي من حيث التكلفة المتوقعة لإزالة هذه التراكمات في كل مكان حول المستوطنات البشرية. تم تخفيض معدلات الرمال المتحركة سنوياً بنسبة 94 و95.3٪ شكراً جزئياً لوجود النباتات الأصلية والحزام الأخضر، اللذين ساهما أيضًا في تقليل الغبار بنسبة 64.5 و 68.4٪ على التوالي.

الكلمات المفتاحية: -الرمال المتطايرة- الكويت - النباتات الأصلية- التأهيل البيئي

Introduction

The preservation of native vegetation is crucial for the sustenance of life on our planet, as it cannot be copied. Furthermore, besides from serving as a faithful depiction of a nation's cultural heritage, it also confers enduring benefits upon the society. Native vegetation has several important roles in various aspects. Firstly, it serves as an economical source of feed for cattle who are grazed upon it. Additionally, it provides a valuable gene pool that can be utilised for research and development purposes. Moreover, native vegetation serves as a crucial source of medicinal resources, meeting primary healthcare needs in different countries. Lastly, it acts as a natural supplier of organic matter, enriching the soil. Regrettably, the excessive utilisation of natural resources, including indigenous vegetation, has resulted in significant and ongoing detrimental consequences. The Earth's capacity to endure the present level of devastation is rapidly diminishing.

Omar et al. (2007) categorised the terrestrial ecosystem of Kuwait into six distinct categories. The identified categories encompass the following: coastal plain and lowland environment, desert plain and lowland ecosystem, alluvial fan ecosystem, escarpment, ridge and hilly ecosystem, wadi and depression ecosystem, and burchan sand dune ecosystem. Within each of these ecosystems, there exists a dominant species alongside a multitude of other species that are intricately linked to it. Kuwait is known to harbour a diverse range of plant species, with an estimated count of roughly 374 distinct varieties. Among the identified specimens, there exist a total of 256 annual plants and 83 herbaceous perennials. Kuwait is characterised by a limited diversity of woody vegetation, with a total of 34 species of shrubs and undershrubs documented. However, it is noteworthy that just one tree species is native to the country. The significance of the natural vegetation in Kuwait to the scientific community is in its representation of the transition from semi-desert to desert flora. Furthermore, a number of these markers serve as valuable indicators of anthropogenic alterations in vegetation patterns. Additionally, they harbour genes that are pertinent to investigations on heat tolerance, drought tolerance, and salt tolerance.

Although the historical causality between excessive grazing and the depletion of vegetation in Kuwait is well-established, it is an ongoing

concern in the present era. The regenerative capacity of vegetation in response to adverse conditions has been further compromised. Some of the challenges include the characteristics of the substrate, the level of soil compaction, the variability of rainfall patterns, and the scarcity of seeds in the soil. The process of natural regeneration of indigenous plant species in challenging climatic conditions is characterised by a notably slow pace, often taking up to 40-30 years to occur, even when moderate levels of soil moisture and microclimate are present. This phenomenon persists even in situations when the microclimate exhibits a generally consistent and unchanging pattern. Therefore, the contemporary challenges faced by Kuwait include the presence of distinct and ongoing patterns of deterioration in terrestrial ecosystems, as well as the imperative to rehabilitate areas that have experienced degradation by reintroducing indigenous plant species. To successfully overcome this challenge, it is imperative to perform extensive revegetation initiatives and diligently monitor natural processes.

The degradation of land represents a paramount environmental, social, and economic challenge currently confronting the global community. Issanova et al. (2015) assert that the phenomenon of aeolian sand movement and its subsequent soil degradation exert a detrimental influence on the livelihoods of an estimated 400 million individuals globally. Sand and dust storms are more prone to transpire at periods of high wind velocity, particularly when coupled with arid seasonal climatic conditions. The process of wind erosion selectively removes minute particles from the topsoil, as it manifests in the form of shifting sand and dust. Particles that undergo degradation due to wind action have the potential to be transported by wind and collect at distances of several meters in the downwind direction. This phenomenon might result in notable problems related to the encroachment of sand.

Al-Awadhi et al. (2014) state that the occurrence of drought, limited vegetation cover, topsoil with a light texture, low relief of the land surface, and mostly strong winds collectively contribute to the commencement of eolian processes. Hong and Lee (2016) propose that the classification of particle transport can be based on two key factors: wind speed and particle size. They identify three main categories of particle transport, including creep, saltation, and suspension. Ahmed et al. (2015) assert that the transportation of aeolian particles is the primary factor contributing to the

phenomenon of sand encroachment in infrastructure, hence raising significant environmental and economic problems. The efficacy of employing checkerboards, wind shelter forest grids, and native plant regeneration as control measures for mitigating sand and dust movement in China has been demonstrated. The efficacy of three control techniques in mitigating the dispersion of shifting sand and dust was observed. According to Fadhil (2002), Alghamdi and Al-Kahtani (2005), Pahlavanravi et al. (2012), and Hong and Lee (2016), it was found that native plants were identified as the most efficient means of managing mobile sand in Iraq, Saudi Arabia, Iran, and South Korea, respectively. The research undertaken by Fadhil (2002) took place in Iraq. The research done by Alghamdi and Al-Kahtani (2005) took place in the Kingdom of Saudi Arabia. Recent research findings indicate that native plants have demonstrated efficacy in mitigating aeolian activities, soil sealing (Al-Dousari et al., 2000), and facilitating the storage of soil organic carbon. The stabilisation of soil by native plants through their root systems serves as a protective measure against wind erosion (Burri, 2011). The phenomenon of nabkha formation was seen as a result of the native plants' capacity to catch and retain mobile aeolian sediments (Al-Dousari and Pye, 2005). The term "nabkha" pertains to aeolian accumulations that develop in the vicinity of indigenous vegetation, as described by Khalaf et al. (1995) and Ahmed et al. (2015). Ahmed et al. (2015) argue that the formation of nabkha in the vicinity of indigenous vegetation and green belts holds substantial economic and environmental significance due to its ability to restrict the movement of aeolian particles inside arid and semi-desert regions.

Kuwait is home to a prominent trail of active aeolian dunes and mobile sand, which exhibits a consistent movement pattern from the north-west to the south-east. This phenomenon poses significant challenges in terms of sand encroachment, particularly for desert infrastructures such as highways, oil installations, power plants, and air bases. The aforementioned issues arise due to the transportation of sand particles through wind movement. Al-Halbi (2015) asserts that the prevailing wind patterns in the region are predominantly north-westerly, constituting around 60 percent of the total wind directions. The prevailing winds in Kuwait are primarily accountable for the predominant propulsive force that drives the displacement of mobile sand and dust particles. Al-Awadhi (2005) reported that a significant

proportion of the annual sand drift, specifically around 77 percent, occurs over the period spanning from May to September. The initial investigation of the morphological characteristics of aeolian sediments surrounding Nitraria retusa nabkhas in northern Kuwait was conducted by Kelio and Al-Sheikh (1986). Khalaf et al. (1995) conducted a study to examine the sedimentary properties of the nabkha formations in the northern and southern coastal regions. Ahmed et al. (2015) conducted a research investigation pertaining to the native plant species present in desert nabkhas, with a specific emphasis on the morphology and soil features of these plants.

Study objectives

The purpose of this research is to determine how effective dominant native plants and green belts are in Kuwait at preventing and mitigating the effects of aeolian activity.

Study Area

The study region, which encompasses a total land area of 17,818 km^2, is known for its climate that is characterised by being hot and arid. Kuwait exhibits a climatic profile that is defined by high temperatures, strong winds, and a predominantly arid desert landscape. The dramatic fluctuations in daily air temperature serve as a visual representation of the arid climatic conditions. The meteorological data spanning from 1958 to 2017 indicates that the average temperature during the summer months (June to October) was recorded at 37.4°C. Additionally, the mean air humidity percentage and evaporation rate were observed to be 55.3% and 6,060 mm/yr, respectively. The dominant wind direction in Kuwait comes primarily from the northwest and north, accounting for around 60% of the total wind direction distribution. Additional wind directions are associated with reduced durations, decreased frequency, and lower wind speeds. The mean wind velocity is recorded as 4.8 metres per second (Al-Dousari et al., 2021). At January has an average temperature range of only about 17 degrees Celsius, whereas at July has an average air temperature of 37 degrees Celsius. July has an average temperature range of only about 17 degrees Celsius. There is an average yearly precipitation of about 112 millimetres, although it is both sporadic and unpredictable. The precipitation totals can range anywhere from 0 to 200 millimetres. The wind that blows from the north-west is the predominant

wind direction in the area that is being studied, and it is one of the primary factors that contributes to the transit of aeolian silt as well as its deposit.

Native plants in Kuwait

Boulos and Al-Dosari (1994) documented a total of 374 species of indigenous and naturalised vascular plants, which were classified into 55 distinct families. Nevertheless, the researchers omitted the examination of cultivated plants from their investigation. Abdullah (2017) reported that a comprehensive analysis revealed the existence of a total of 402 distinct species, distributed among 256 distinct taxa. Among the aforementioned species, a total of 273 are acknowledged as really indigenous, while 25 have attained naturalisation by either deliberate cultivation or spontaneous means. Additionally, 90 species are classified as weeds, and 12 species are cultivated plants. In a recent study undertaken by Al-Dosari (2021), a comprehensive documentation was carried out on a total of 452 vascular plant species, encompassing both native and naturalised varieties. These species were classified into 61 distinct families and further categorised into 265 plant genera. In accordance with the findings of Al-Dosari (2021), the latest survey reveals that the families exhibiting the greatest species richness in Kuwait are as follows: Poaceae, with a total of 82 species; Asteraceae, with 63 species; Brassicaceae, with 42 species; Amaranthaceae, with 34 species; Fabaceae, with 32 species; Caryophyllaceae, with 25 species; and Euphorbiaceae, with 15 species. The most prevalent genera in Kuwait include Euphorbia (13 occurrences), Astragalus (9 occurrences), Plantago (9 occurrences), Silene (6 occurrences), Convolvulus (5 occurrences), Launaea (5 occurrences), Erodium (5 occurrences), Rumex (4 occurrences), Reseda (4 occurrences), Helianthemum (4 occurrences), Avena (4 occurrences), Bromus (4 occurrences), Aegilops (4 occurrences), and Cenchrus (4 occurrences). The checklist enumerates objects in a systematic manner, adhering to an alphabetical arrangement based on the nomenclature of their corresponding families. The sequence commences with ferns, followed by gymnosperms, and concludes with angiosperms, which encompass flowering plants.

Results and discussion

Economic effect of native plants and green belts in controlling mobile sand and dust hazards

In the arid region of Kuwait, a study revealed that the indigenous plant species Haloxylon salicornicum and Nitraria retusa exhibited superior efficacy in trapping mobile sand particles. Conversely, the native plant species Centropodia forsskalii and Stipagrostis plumosa demonstrated comparatively lower effectiveness in this regard. The data presented in this study was obtained by an analysis of the eight most prevalent perennial plant species found in Kuwait, focusing on their respective abilities to capture and retain mobile sand and dust particles. The Haloxylon species and Rhanterium species, which were previously the two most dominant native plants, have experienced a decline in their respective locations, resulting in the proliferation of other less proficient plants in the regulation of mobile sand and dust. The aforementioned regions were formerly inhabited by the most prevalent indigenous flora. The sand-capturing ability of Haloxylon species surpasses that of Centropodia species and Stipagrostis species by a hundred percent, while it exceeds that of Cyperus species by eighty-five percent. Based on the research conducted by Arens (1996), it has been observed that the transportation rate of particles exhibits an exponential decline as they transition from bare terrain to vegetated regions. The Huwaimiliyah-Wafra and Um Niqa-Sabiya mobile sand trajectories hold significant importance in Kuwait. Both of these trajectories are situated in the western region of the country. The Huwaimiliyah-Wafra zone has the most extensive dimensions, spanning 4,224 square kilometres and measuring 160 kilometres in length, with an average width of 20 km. The geographical expanse included by Um Niqa-Sabiya spans an area of approximately 576 square kilometres. The transportation of mobile sand along these prominent trajectories incurs a substantial cost burden for Kuwait. The western portion of Kuwait has had the most pronounced amount of degradation when compared to other areas within the country. The process of capturing mobile sand in Kuwait has led to a significant transition from high capability plants to low capability plants. This movement has also given rise to the establishment of a new wind corridor on the western side of Kuwait, including a total area of approximately 2,771 km^2. The infiltration of sand is regarded as a substantial threat to essential infrastructure due to the ability of aeolian sand and dust to readily traverse these wind pathways. The quantity of sand that was

encroached upon and subsequently extracted from different facilities and installations situated in Kuwait, together with the corresponding expenses, were calculated and examined (Table 1). The catastrophe had a significant impact on several facilities, including oil wells, oil gathering centres, air bases, and vital roadways. In 2013, Kuwait's principal infrastructure witnessed the extraction of a total volume of sand amounting to roughly 3,160,660.52 cubic metres. Consequently, the nation incurred expenses of approximately $4,169,766 USD. Based on updated data, it has been determined that the average cost of extracting one cubic metre of encroached sand in Kuwait is around 1.32 US Dollars. In contrast to the period spanning from 1974 to 1980, there has been a notable increase in the quantity of dust deposition in the more recent years of 2011 to 2017, exhibiting a growth rate of 2.78 times. Based on the findings of Al-Dousari et al. (2020), there was a significant increase in the quantity of dust deposition, which rose from 109.4 t.km2 between 1974 and 1980 to 392 t.km2 between 2011 and 2017.

Table 1. The annual amount and cost for removing encroached sand from main facilities and infrastructures in Kuwait during 2013.

Settlements	Total Amount of Sand Removal (m3)	Total Cost of Sand Removal (USD)	Cost for sand removal per m^3 (USD)
Oil facilities	347,310	993,862	2.862
Main Highways	2,651,431	2,141,757	0.81
Power stations	160,600	955,452	5.95
Military Bases	1,320	78,694	59.62
Average	790,165.13	1,042,441	1.32*
Total	3,160,660.52	4,169,766	

Environmental effect of native plants and green belts in controlling mobile sand and dust hazards

According to Al-Dousari et al. (2019), the authors found that Tamarix aphylla, Prosopis juliflora, and M. pterygosperma possess the ability to regulate aeolian processes. On average, the quantity of sand that accumulates in the vicinity of each trees inside green belts is approximately 10 cubic metres. However, the accumulation of sand near important native plants in Kuwait is comparatively lower, measuring around 1.92 cubic metres. Despite the considerable increase in size of the trees, research has indicated that specific indigenous plant species exhibit superior capabilities in

regulating aeolian sediments. The native plants N. retusa, L. shawii, and Haloxylon salicornium exhibited the greatest accumulation of sand, with volumes of 21.9 m^3, 15.5 m^3, and 14.5 m^3, respectively. Consequently, it is justifiable to regard these particular plant species as the most efficacious in mitigating aeolian sedimentation. Likewise, every indigenous plant possesses distinct physical attributes that are specific to its individuality. The findings of the study indicate that the implementation of green belts and the use of native plants are the most viable strategies for effectively managing aeolian accumulations. Furthermore, these solutions have the added advantage of cost reduction. Therefore, it is recommended that these applications be taken into consideration for potential future utilisation in order to mitigate the issue of sand encroachment and the dispersal of airborne dust particles.

Fuller and Ottke (2002) claim that vegetation plays a crucial role in influencing the characteristics of the Earth's surface through its capacity to act as an intermediary in the interchange of energy, moisture, trace gases, and aeolian processes. Spracklen et al. (2018) assert that the land surface albedo has a significant role in influencing the climatic conditions of the land surface. Loew and Govaerts (2010) assert that the dynamics of vegetation can be characterised by the Normalised Difference Vegetation Index (NDVI), a metric that quantifies the relative abundance of vegetation in a specific region and is correlated with variations in albedo, both high and low. Spracklen et al. (2018) have established a strong and nonlinear association between the average precipitation over an extended period and the extent of vegetation cover, in relation to the average albedo. The statistical analysis revealed that this link exhibited a considerable level of significance. Fuller and Ottke (2002) believe that the impact of albedo is more significantly influenced by long-term climate trends rather than short-term variations in rainfall. The regulation of plant species and canopy structure is influenced by these climatic variations. Spracklen et al. (2018) suggest that the potential effects of future vegetation change on rainfall remain uncertain, although they could potentially be comparable in scale to the impacts resulting from climate change. The mean canopy diameter of Haloxylon species is estimated to be around 2.5 metres, but the mean canopy diameter of Centropodia forsskalii and Stipagrostis plumose is approximately 0.15 metres. The aforementioned circumstances have resulted in a rise in the

albedo, whilst the average precipitation in Kuwait has experienced a 42% decline during the recent decade (2011-2017) in comparison to the preceding decade (1991-2000). The observed phenomenon can be attributed to a significant decrease of 53% in the population of the Haloxylon species, whilst no discernible alteration has been observed in the vegetation coverage of the remaining two species. In contrast, while examining the period from 1980 to 1991 in relation to the present, there has been a rise in temperature amounting to 1.58 degrees Celsius. Based on a plant selection chart derived from temperature prediction models, it has been observed that plants possessing wider canopies have the capacity to provide a higher maximum cooling potential and exhibit lower albedo in comparison to plants with smaller canopies. This discovery was facilitated by the observation that canopies of greater size had a greater capacity to absorb solar radiation.The wind speed distribution map and wind power density (W/m^2) data obtained from 14 meteorological stations in Kuwait indicate that the northwestern regions exhibit higher values. These areas are characterised by the presence of low-capability native plants, particularly Stipagrostis species and Centropodia species. It is well-known that these plant species have limited effectiveness in capturing mobile sand particles. The aforementioned measurements were acquired at elevations of 10 metres and 30 metres above the ground surface. In the year 1974, the aforementioned areas were populated by Haloxylon salicornicum, a plant species that shown a notable ability to accumulate mobile sand, with a maximum capacity of 9.73 cubic metres. Consequently, the regions situated in the northwestern quadrant of Kuwait are deemed most suitable for the establishment of wind power facilities.

Moreover, the establishment of a third wind corridor on the western periphery of Kuwait poses specific challenges in harnessing energy through photovoltaic panels. The occurrence of thin mud and/or carbonate coatings on the surfaces of solar panels, resulting from the deposition of aeolian materials such as dust and sand, serves as a notable manifestation of these challenges. The findings of a study examining the potential feasibility of implementing solar and/or wind energy systems in Kuwait, based on a year-long collection of data from wind farms and solar units located in the western region of the country, indicated that the wind energy output surpassed the industry average. Wind energy has been associated with consistently high

capacity factors throughout the year, leading to an annual power production that is 2.3 times more than that of photovoltaic (PV) cells. This translates to the ability to power 450 homes with wind energy, compared to only 199 homes with PV cells. Throughout the year, wind energy had a strong correlation with high capacity factors. As a result of the observed change in vegetation, the affected region has become better adapted for harnessing wind-derived energy as opposed to solar energy. The decrease in efficiency of solar or photovoltaic cells in the generation of solar energy might be attributed to the accumulation of sand and dust on their surfaces. The decline in efficiency of low quality flat solar cells (TF4) amounted to a reduction of nearly 77% within an 11-month timeframe. In contrast, the efficiency of high quality cylindrical photovoltaic (PV) thin-film cells without tilting (TF3) experienced a fall of approximately 20% over the same duration. Kuwait has set forward its intention to generate an estimated 4,500 megawatts of electricity through the utilisation of solar power by the year 2030. The anticipated mean decline in efficiency resulting from the utilisation of photovoltaic (PV) panels is estimated to be around 45%. As a result, the projected energy loss, predominantly caused by alterations in vegetation, amounts to approximately 2025 megawatts. Considering the local price of 0.14 USD per kilowatt-hour in Kuwait (National Bank of Kuwait, 2020), this translates to an annual cost of 283,500 USD.

The amount of carbon dioxide (CO_2) utilised by plants, whether they experienced a net gain or loss, was estimated and subsequently translated into kilowatt-hours (kWh) using a conversion factor of 0.28307 kilogrammes of CO2 per kWh. In conclusion, the prevailing local pricing of 0.14 USD per kilowatt-hour (National Bank of Kuwait, 2020) will be utilised. The total annual expenditure resulting from the use of carbon dioxide amounts to $4,199,002 USD.

The anticipated financial impact of vegetation change in Kuwait is projected to exceed 35.4 million US dollars due to the ecological benefits provided by native plant species, including their ability to regulate mobile activities and sequester carbon dioxide. This phenomenon can be attributed to the inherent capacity of indigenous plant species to regulate mobile activities. The principal cost component of this estimate is attributed to the removal of encroached sand and dust, amounting to 30,946,877 USD. This activity is

necessitated in order to mitigate the impact on primary infrastructure and human populations.

Conclusions

Kuwait is recognised as one of the global locations with high expenses associated with the removal of encroached sand. The average cost incurred for the extraction of one cubic metre of encroached sand in Kuwait is estimated to be $1.32 USD. Research findings indicate that Kuwait experiences a greater impact from aeolian activities compared to other nations. This is mostly attributed to the expected transition in dominant plant species, specifically from Haloxylon salicornicum to Stipagrostis species and Centropodia species. The anticipated influence on aeolian activity in the future is expected to be particularly important due to the severe deterioration of the western region of Kuwait. The financial implications of the change in vegetation in Kuwait can be attributed to three main factors. Firstly, the cost associated with sand invasion amounts to 30,946,877 USD. Secondly, carbon dioxide emissions have resulted in a cost of 4,199,002 USD. Lastly, the loss of energy efficiency in solar panels has incurred a cost of 283,500 USD. Collectively, these factors add to an annual total cost of 35,429,379 USD. Hence, the existence of vegetation cover stands as the foremost crucial element in mitigating wind-induced erosion of the surface soil. The primary discovery of this study is to the influential role of vegetation type and spatial arrangement on wind-driven mass movement. This phenomenon can be attributed to the impact exerted by alterations in vegetation on the turbulence of wind patterns and the overall magnitude of mass displacement within a given area. Consequently, the examination of the impact of a modification in vegetation on a broader scope may serve as a prospective expansion of this study. Recent study has provided insights into the potential impacts of modifications to vegetation cover, highlighting their substantial implications for both the economy and human well-being. Therefore, it is highly recommended that additional attention be devoted to examining the impact of alterations in spatial and temporal dimensions on vegetation. The assessment of the impacts of vegetation changes on local and regional economies, as well as rainfall, temperature, and aeolian wind patterns, should be an integral component of the regulations governing sustainable development. It is imperative to acknowledge that Haloxylon salicornicum

possesses considerable potential for substantial economic relevance in the context of biosaline agricultural exploitation in forthcoming times. The Haloxylon species has remarkable efficiency in trapping sand due to its ability to thrive in diverse desert environments such as wadi terraces, sandy and gravel plains, and sand dunes. Based on the results obtained from this study, it is recommended that exerting management measures over the regions previously inhabited by Haloxylon species represents the most effective approach for conserving the ecosystem in its original undisturbed condition. The preservation of places previously occupied by Haloxylon species is expected to result in several environmental changes, including a decrease in wind erosion, a decrease in surface reflectivity, a decrease in atmospheric temperature, an increase in rainfall, and an increase in solar energy generation.

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