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SAND DRIFT POTENTIAL IN THE DESERT OF KUWAIT

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Abstract

For the period of 1998 t0 2001, wind data from eight metrological stations are analyzed to examine sand drift potential (DP) in Kuwait, using Fryberger (1979)' method. Resultant drift potential and directional variability of wind are also calculated and explained. The average annual sand drift potential is predicted to be 354 VU ' vector unit'. This puts Kuwait, in general, among the intermediate wind energy deserts, which are defined by Fryberger (1979) as those desert areas with DP between 200 to 400 VU. Potential sand drift environment is markedly variable from place to place, and 77 percent of the annual resultant drift potential occurs during the summer period; i.e., May to September. Directional variability is also relatively high in the summer period.

Introduction

Accurate sand transport rate data are very difficult to obtain, and many different formulae have been derived, based on various environmental assumptions, to fit experimental data. Alternative analyses based on sand-transporting winds or sand transport potential have been proposed and discussed by several authors in the last two and a half decades. Of these methods of analysis, the method developed by Fryberger (1978 and 1979) has been the most widely accepted and adopted in world desert environments. The Fryberger method, which is a modification of the Lettau & Lettau (1978) equation, is designed to give a relative rather than absolute description of the effect of wind energy on sand drift.

Wind energy is a key variable in indices designed to examine potential sand drift such as that developed by Lancaster (1988) and Bullard et al. (1996) to consider status activities in Kalahari dunefield. The Fryberger method is a useful tool in assessing such problems and recommending sand control measures. This paper aims to assess the role of wind regimes, at eight meteorological stations, in determining potential sand drift in the desert of Kuwait.

The Fryberger method

Fryberger simplified the Lettau & Lettau (1978) equation to

$$Q \quad V^2(V-V_t)t \qquad [1]$$

where:

- Q : appropriate amount of sand drift expressed in vector units (VU)
- V : the average wind velocity at 10 m height for the time period t
- V_t : the threshold velocity at 10 m height, referred to V^*_t in Eq. [1]
- t : time that the wind blew expressed as a percentage in a wind summary

The combination of $V^2(V-V_t)$ is termed a “weighting factor”, in which strong winds are given high weightings and weaker winds lower weightings. The value of $V^2(V-V_t)$ is divided by 100 to lower the magnitude of the weighting factors and simplify the plotting of sand roses. The weighting factors for five wind velocity categories are calculated in the manner shown in Table 1.

Table 1. Fryberger's (1979) worked example to demonstrate the calculation of weighting factors

Velocity category (knots)	Mean velocity of winds in category V	V^2	$(V-V_t)$	Weighting factor $V^2 (V-V_t)/100$
11-16	13.5	182.3	1.5	2.7
17-21	19.0	361.0	7.0	25.3
22-27	24.5	600.3	12.5	75.0
28-33	30.5	930.3	18.5	172.1
34-40	37.0	1369.0	25.0	342.3

In this study, all wind data were collected for a period of at least 2 to 5 years, and in accordance with World Meteorological Organization guidelines; i.e., at a height of 10 m. Wind speeds and directions were collected as raw data from eight stations using a data logger with a sampling interval of 5 minutes averaged for a period of 1 hr. Directional data were supplied from 16 sectors.

Fryberger method's of wind analysis was applied for each month that data were available and for each station. This involved the application of frequencies of direction and velocity-grouped data for wind exceeding the threshold velocity. A value of 11.6 knots was obtained for a parameter V_t in Eq. [1]. For this study this value was approximated to 12 knots. Using the results of the Eq. [1], Fryberger developed the following classification schemes with which to describe wind environment in terms of available wind energy (Table 2).

Table 2. The classification of wind energy environments using drift potential (Fryberger,1979)

Drift Potential	Wind Environment
< 200 vector units	Low energy environment
200 - 400 vector units	Intermediate energy environment
> 400 vector units	High energy environment

The resultant drift direction (RDD), expressed as the direction of the net trend of sand drift, and the resultant drift potential (RDP) was calculated by considering the number of vector units for each orientation class, as follows:

$$RDD = \text{Arctan}\ (C/D) \qquad [2]$$

where

$$C = (VU) \sin\theta \qquad [2a]$$

$$D = (VU) \cos\theta \qquad [2b]$$

and:

θ : is the mid-point of orientation classes

Accordingly,

$$RDP = (C^2 + D^2) \qquad [3]$$

The RDP/DP ratio gives a standardized indication of the directional variability of the wind and it varies from 0 to 1 (Table 3). Where the wind is more unidirectional, the RDP/DP ratio approaches unity.

Table 3. Directional variability of winds (Fryberger, 1979)

RDP/DP	Relative Value of Ratio	Directional Variability of Winds	Probable Direction Category
<0.3	Low	High variability	complex/obtuse bimodal
0.3 -<0.8	Intermediate	intermediate variability	obtuse bimodal/acute bimodal
>0.8	High	Low variability	wide/narrow unimodal

Results and discussion

Average monthly sand drift potential (DP) estimated from eight stations, in sixteen directions, are presented in Figure 1 as sand rose plots. The average monthly DP is estimated at range of 10 VU in November to 65 VU in June. Sixty four percent of the average annual DP occurs during summer period; i.e., May to September. The results indicated that some areas in Kuwait are classified among the high wind energy deserts, which are defined by Fryberger (1979) as those desert areas with DP equal to or greater than 400 VU. Figure 1 shows that the KISR and Rawdatain stations, located within coastal zone and minor aeolian sand pathway, respectively, constitute a low energy group. Subiya, Wafra and Kuwait Airport stations are grouped as intermediate energy.

The average monthly amount of resultant sand drift potential (RDP) in areas studied is estimated to be 19.5 VU with a range of 4.2 VU in November to 53 VU in June. Cumulative resultant drift potential during the period January-April is less than 16% of the annual RDP. Seventy seven percent of the annual RDP occurs during May to September.

Resultant drift direction (RDD) for the period from May to November is southeast (140^o to 146^o from N-direction), while it varies slightly during other months with a range of 137^o (in December) to 170^o (in March).

The unidirectional index (RDP/DP) for each month was calculated. It was found that July had the highest index with an average value of 0.83. This means that variations in the sand drift direction are very limited. Low directional variability characterizes the month of March with an index value of 0.28. The remaining months are characterized by intermediate directional variability with index values between 0.4 and 0.79. Annual RDP/DP values indicate that intermediate directional variability characterizes Kuwait potential sand transport environment.

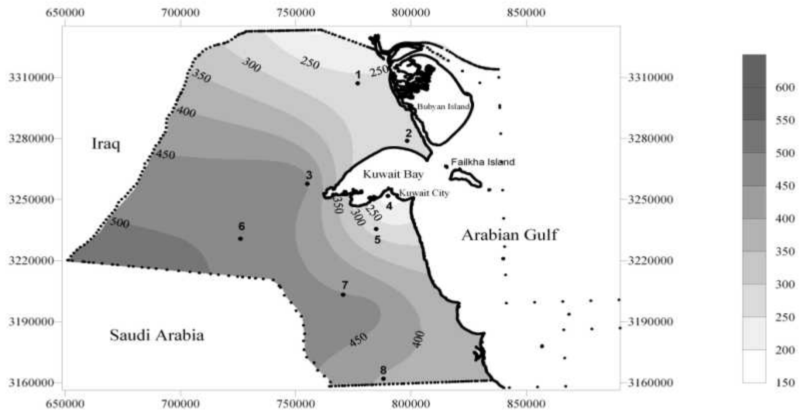

Figure 1. Annual spatial variation of sand drift potential (in VU) in Kuwait. The numbers indicate the station names as follow: (1) Rawdatain, (2) Subiya, (3) Mutla, (4) KISR, (5) Kuwait International Airport, (6) Umm-Amara, (7) Tweel and (8) Wafra.

Conclusions

The desert in Kuwait constitutes mainly a high (DP > 400 VU) to intermediate (DP between 200 to 400 VU) – energy group. Sand drift potential and its resultant are markedly varied from a study area to another. Consequently, the problem of sand drift should be considered seriously during the planning and design of major desert development projects. The maximum annual sand drift potential is estimated to be 480 VU. The average resultant drift potential is found to be 227 VU with limited variation in its direction; i.e., mainly blowing from the NW in summer and the SE in winter.

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