*Int. Agrophysics, 2000, 14, 291-296*

# EFFECT OF WIND DIRECTION ON AEOLIAN SAND TRANSPORT IN SOUTHERN TUNISIA

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*Accepted July 22, 1999*

A b s t r a c t. Assessment of aeolian transport in three experimental stations in southern Tunisia showed a prevailing wind direction from the east, the southeast and the north over the winds coming from the south and from the west. The movement of sand (dunes) was towards the Sahara, in particular to the Oriental Erg, and the dune morphology was dynamically orientated to the west and the southwest. For the three stations it was observed that about 70% of the fine sand particles (50 - 250 μ) were transported beneath 20 cm height above the surface.

K e y w o r d s: aeolian transport, wind direction, southern Tunisia

## INTRODUCTION

In the USA, the assessment of factors determining the wind erosion processes resulted in the development of a wind erosion equation [12]. Cole *et al*. [4] adapted the equation for simulating daily soil loss by wind erosion as a submodel in EPIC [11]. In most other parts of the world field experiments on wind erosion were few and so was the establishment of a wind erosion prediction model.

Three different ways of transport in the wind erosion process can be distinguished: creep, saltation and suspension [1]. Particles transported by creep move along the surface; particles transported by saltation move at heights generally below 1 m; particles transported in suspension are carried to great heights and to long distances.

In Tunisia, although the fixation of sand dunes and the protection of infrastructure (roads, oasis, houses) against sand encroachment had started at the end of the 19$^{th}$ century [8], research on wind erosion processes was initiated by Coque [5] and further developed by Khatelli [6-9] at IRA (Institut des Régions Arides), Médenine, Tunisia.

A study was carried out at three experimental stations in southern Tunisia (Sidi Makhlouf, Menzel El Habib and Noueil) to relate sand transport to wind directions, in view of wind erosion control measures to be taken (Fig. 1).

## MATERIALS AND METHODS

Wind blown particle transport in the field was sampled with sediment catchers which consist of a vertical array of sediment traps (Photo 1). At the three experimental stations the sand was trapped in collectors placed at six different heights namely 0, 20, 40, 60, 80 and 100 cm.

Hence, creep is collected at the 0 height. Each collector consisted of a rectangular entry opening, a central part and an air outlet. The collected sand was directed to a sampler with eight divisions for the eight wind directions: north, northeast, east, southeast, south,

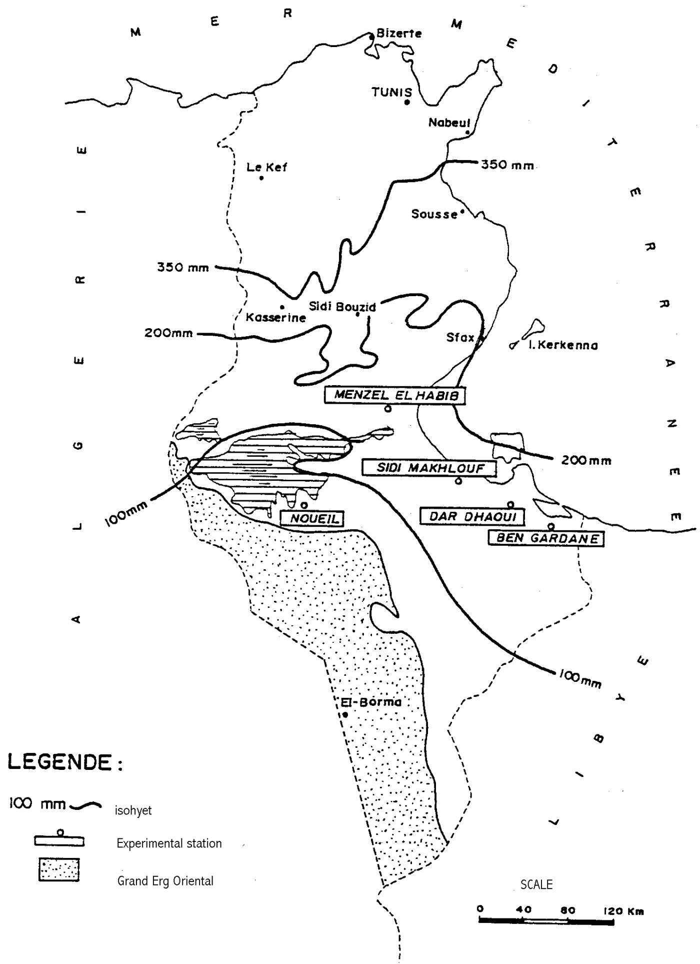


**Fig. 1.** Map of Tunisia with indication of the experimental stations.

southwest, west, northwest. The orientation of the entry opening of the collector to the wind direction was regulated by means of a vane. The collectors were operated during two years (1992 - 1993). The samples were analyzed at IRA (Institut des Régions Arides), Médenine, Tunisia.

Wind speed and wind direction were measured at the three stations with a Lambrecht type anemograph, placed at 1.5 m height. A total of 3285 measurements were made daily at 9 a.m., 1 p.m. and 5 p.m. A distinction is made between active ($u > 3$ m s$^{-1}$) and non-active winds according to the threshold windspeed initiating movement of air-dry sand.

RESULTS AND DISCUSSION

The weight distribution of the trapped samples was evaluated as a function of the height of the traps (0, 20, 40, 60, 80 and 100 cm) and of the wind direction. The mean annual distribution (%) of the trapped sand particles as a function of height and of wind direction is given in Table 1 and this for the three stations. Figure 2 shows that more than 90% of the sand was trapped in the three lowest collectors (0, 20 and 40 cm).

Table 2 also shows that about 50% or more of the trapped sand moved over the surface (0 cm). At 1 m height small amounts of sand

**Photo 1.** Sediment catcher with a vertical array of sediment traps.

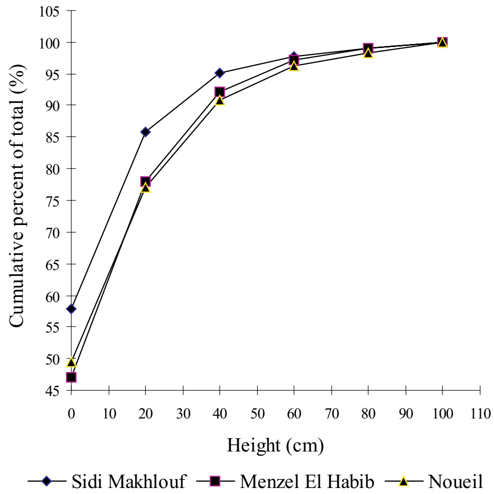


**Fig. 2.** Mass distribution with height of trapped wind-borne sediments.

**Table 1.** The mean annual distribution (%) of the trapped sand particles as a function of height and of wind direction

| Height (cm) | Station | N | NE | NW | E | W | S | SE | SW | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | Sidi Makhlouf | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.2 |
| | Menzel El Habib | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| | Noueil | 0.1 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.5 |
| 80 | Sidi Makhlouf | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 |
| | Menzel El Habib | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 |
| | Noueil | 0.0 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.5 |
| 60 | Sidi Makhlouf | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.5 |
| | Menzel El Habib | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.9 |
| | Noueil | 0.0 | 0.7 | 0.3 | 0.4 | 0.0 | 0.0 | 0.2 | 0.0 | 1.6 |
| 40 | Sidi Makhlouf | 0.3 | 0.5 | 0.4 | 0.1 | 0.1 | 0.1 | 0.3 | 0.3 | 2.1 |
| | Menzel El Habib | 0.3 | 0.3 | 0.1 | 0.4 | 0.2 | 0.2 | 0.3 | 0.3 | 2.1 |
| | Noueil | 0.3 | 0.8 | 0.8 | 1.7 | 0.1 | 0.1 | 0.4 | 0.0 | 4.2 |
| 20 | Sidi Makhlouf | 0.8 | 1.6 | 0.8 | 0.5 | 0.2 | 0.2 | 1.1 | 0.8 | 6.0 |
| | Menzel El Habib | 0.6 | 0.9 | 0.3 | 0.7 | 0.3 | 0.5 | 0.9 | 0.7 | 4.9 |
| | Noueil | 0.5 | 1.5 | 2.2 | 2.8 | 0.4 | 0.3 | 0.8 | 0.3 | 8.8 |
| 0 | Sidi Makhlouf | 1.3 | 3.8 | 1.3 | 1.4 | 0.4 | 0.4 | 1.9 | 1.2 | 11.7 |
| | Menzel El Habib | 1.1 | 1.5 | 0.4 | 1.6 | 0.3 | 0.3 | 1.5 | 0.5 | 7.4 |
| | Noueil | 0.7 | 2.1 | 3.4 | 4.5 | 0.6 | 0.6 | 1.5 | 2.2 | 15.6 |
| Total | Sidi Makhlouf | 2.6 | 6.1 | 2.5 | 2.2 | 0.7 | 0.7 | 3.5 | 2.5 | |
| | Menzel El Habib | 2.2 | 3.0 | 0.9 | 2.9 | 0.9 | 1.1 | 2.9 | 1.7 | |
| | Noueil | 1.6 | 5.5 | 6.8 | 9.5 | 1.1 | 1.0 | 3.1 | 2.5 | |

particles are transported: 0.9% at Sidi Makhlouf, 1% at Menzel El Habib and 1.8% at Noueil.

A slight difference between the three stations could be observed with regard to the distribution of the particles as a function of height. It seemed that at Noueil and Menzel El Habib more particles were transported at greater heights than at Sidi Makhlouf. This was probably due to the fact that at Noueil the active winds ($u > 3$ m s$^{-1}$) were more frequent than at the other stations (Table 3). It may have been the turbulence which caused a cloud of particles to move higher [3]. The percentage of particles smaller or larger than 250 μ was the same for the three stations (Table 4).

Table 5 shows that on the average for the three stations about 70% of the fine sand particles (50 - 250 μ) were moving in the lower 20 cm which means that even low windbreaks (lower than 100 cm) could be very effective in controlling sand transport.

The amounts of particles trapped during the years 1992 and 1993 changed from one station to the other as a function of wind directions. Table 6 shows that most of the sand was transported with winds ($u > 3$ m s$^{-1}$) from the northeast; east and southeast.

This can also be illustrated by means of a rose showing the sand displacement as a function of wind direction (Fig. 3). At Sidi Makhlouf the most highest amounts of sand were displaced by winds blowing from northeast followed by southeast winds. East winds were more dominant at Noueil and at Menzel El Habib the east, northeast and southeast winds were equally dominant. The prevailing wind directions with dominant sand transport are east, southeast and north rather than south and west. Wind directions observed during four storms at ICRISAT Sahelian Center (Niger) in 1993 were also dominant form South-East, East and South-South-East [10]. This is an important phenomenon to be considered if wind erosion control measures are to be taken.

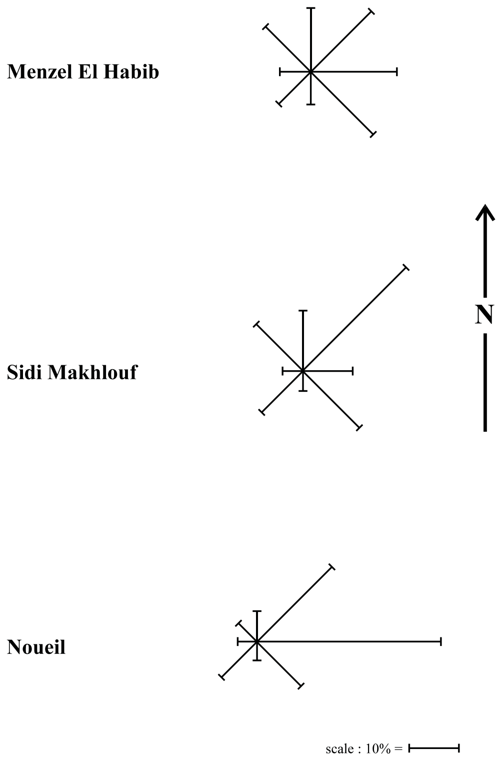


**Fig. 3.** Rose of annual sand displacement (weight %) in the three stations as a function of wind direction (period 1992-1993).

CONCLUSIONS

With regard to wind erosion in general and the dune morphology in particular, the dune dynamics were orientated to the west and southwest of Tunisia. Hence the movement of sand dunes in southern Tunisia was towards the Sahara, especially to the Oriental Erg.

Wind erosion control measures in southern Tunisia should take into consideration that the prevailing wind direction with dominant sand transport are east and southeast.

As about 70% of the fine sand particles (50 - 250 μ) were moving in the lower 20 cm, low windbreaks can be effective in controlling sand transport.

**T a b l e 2.** Mass distribution (%) of particles trapped at different heights

| Station | Collector height (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 20 | 40 | 60 | 80 | 100 |
| Sidi Makhlouf | 57.8 | 28.1 | 9.3 | 2.5 | 1.4 | 0.9 |
| | | (85.9) | (95.2) | (97.7) | (99.1) | (100) |
| Menzel El Habib | 47.0 | 31.0 | 14.1 | 5.0 | 1.9 | 1.0 |
| | | (78.0) | (92.1) | (97.1) | (99.0) | (100) |
| Noueil | 49.5 | 27.5 | 13.9 | 5.4 | 1.9 | 1.8 |
| | | (77.0) | (90.9) | (96.3) | (98.2) | (100) |

( ) cumulative values

**T a b l e 3.** Seasonal distribution of active winds (as % of total winds) at three experimental stations

| Station | Active winds (%) ($u > 3$ m s$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | winter | spring | summer | autumn | annual |
| Sidi Makhlouf | 51.0 | 53.0 | 35.0 | 37.0 | 44.0 |
| Menzel El Habib | 47.0 | 52.0 | 42.5 | 46.5 | 47.0 |
| Noueil | 40.0 | 60.0 | 54.0 | 44.0 | 49.5 |

**T a b l e 4.** Size of trapped particles

| Station | Particle size | |
|---|---|---|
| | > 250 μ | < 250 μ |
| Sidi Makhlouf | 7.2% | 92.8% |
| Menzel El Habib | 8.0% | 92.0% |
| Noueil | 5.9% | 94.1% |

**T a b l e 5.** Particle size distribution (%) of wind-borne sediments trapped at 0 and 20 cm height

| Station | Particle size | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 50 -100 μ | | 100 - 250 μ | | 50 - 250 μ | | > 250 μ | |
| | 0 cm | 20 cm | 0 cm | 20 cm | 0 cm | 20 cm | 0 cm | 20 cm |
| Sidi Makhlouf | 18 | 11.1 | 32.5 | 16.1 | 50.5 | 27.2 | 6.4 | 0.5 |
| Menzel El Habib | 14 | 12.4 | 25.5 | 17.1 | 39.5 | 29.5 | 6.9 | 0.8 |
| Noueil | 15 | 10.4 | 29.3 | 14.1 | 44.3 | 24.5 | 4.2 | 0.7 |

**T a b l e 6.** Weight distribution (%) of trapped sand (0 - 100 cm) as a function of wind direction

| Station | Wind direction | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | N | NE | NW | E | W | S | SE | SW |
| Sidi Makhlouf | 12.0 | 29.0 | 13.1 | 10.0 | 4.0 | 4.0 | 16.4 | 11.6 |
| Menzel El Habib | 12.7 | 17.0 | 12.7 | 17.1 | 6.3 | 6.5 | 17.7 | 9.0 |
| Noueil | 6.0 | 21.1 | 5.2 | 36.7 | 3.8 | 3.8 | 12.5 | 9.9 |

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