Sand drift Potential in the Saharan Atlas (South-Western of Algeria).

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Abstract The region of the Ksour Mountains in Southwestern Algeria is an arid area, affected by sand encroachment, which represents a major impediment to the local development. This study, aims to evaluate the shifted sand quantity and the efficient wind directions, over a period of 30 years (1985 to 2015) in order to quantify the phenomenon and to classify the danger.The wind data recorded from 1985 to 2015, have been analyzed to examine the sand drift potential (DP) in the region of Ksour Mountains, using the method of Fryberger(1979). The resultant DP and the directional variability of wind have also been assessed. The predicted average annual sand DP is 222VU (vector units); which classifies the region of the Ksour Mountains among the intermediate-energy wind environment (Fryberger and Dean 1979).The resultant drift potential is 76 with a migration coefficient of 0, 3 which gives a medium classification to the region and prove the Aeolian erosion complex system and its interrelation with other factors. The potential drift environment of the sand is highly variable, and 80% of the resulting annual RDP occur during the springer period, March to June. Moreover, the efficient winds generally blow from Southwest to Northeast, with an angle of 234°; with High directional Variability .

Keywords: Drift potential; effective winds; Fryberger method; Sand; Sand encroachment, wind data.

.قدرة تنقل الرمال المحتمل في أطلس الصحراء (جنوب غرب الجزائر)

ملخص

منطقة جبال القصور في جنوب غرب الجزائر هي منطقة قاحلة ، تتأثر بزحف الرمال ، مما يمثل عقبة رئيسية أمام التنمية المحليةتهدف هذه الدراسة إلى تقييم كمية الرمال المتنقلة واتجاهات الرياح الفعالة ، على مدار 30 عامًا (1985 إلى 2015) من أجل تقدير الظاهرة وتصنيف الخطر.تم تحليل بيانات الرياح المسجلة من عام 1985 إلى عام 2015 لدراسة إمكانية تنقل وهجرة الرمال (DP) في منطقة جبال قصور ، باستخدام طريقة .(1979) Fryberger كما تم حساب الناتج و المعدلات الناتجة والتغير الاتجاهي للرياح .المتوسط السنوي المتوقع لقدرة تنقل الرمال DP هو 222 VU(حدة شعاعية) ؛ الذي يصنف منطقة جبال قصور بين بيئة طاقة الرياح المتوسطة (Fryberger and Dean 1979).إمكانات الهجرة الناتجة هي 76 مع معامل هجرة 0 ، 3 الذي يعطي تصنيفًا متوسطًا للمنطقة ويثبت مجمع التآكل الإيولي النظام وعلاقته مع العوامل الأخرى. و منه قدرة التنقل المحتملة للرمال شديدة التباين ، ويحدث 80٪ من RDP السنوي الناتج خلال فترة الربيع ، من مارس إلى يونيو. علاوة على ذلك ، تهب الرياح الفعالة عمومًا من الجنوب الغربي إلى الشمال الشرقي ، بزاوية 234 درجة ؛ مع ارتفاع الاتجاه المتغير.

الكلمات المفتاحية: الانجراف المحتملة؛ رياح فعالة طريقة .الرمال. زحف الرمال ، بيانات الرياح.

1. Introduction

The Saharan Atlas , is a poorly deformed intra-continental system; extending along 1200 km in SW-NE direction, from the Eastern limit of the Moroccan High Atlas to the Western limit of the Tunisian Atlas (Benyoucef et al. 2017).The study area is located in the Ksour Mountains, occupying the Western part of the Saharan Atlas in Southwest of Algeria (Benyoucef et al. 2017). This area is one of the most sensitive regions , with high risk of sand encroachment in Algeria; characterised by continental climate with cold winter in the north, and tempered winter in the south, where the annual medium temperature reaches 24 °C with average of the maxima in July of 37 °C.and rainfall of 200 mm / year (BOUARFA 2012). The altitude ranges between 1 100 m and 2200m . The; . region is facing a serious problem of silting-up, accentuated mainly during the periods of dryness and is aggravated by the human daily activities .

The region of The Ksour Mountains introduces originality in a restrained area, a diversity of dune forms, which explains largely the geographical position of this zone; on the crossroad at the same time of air streams in the contact of two climates and topographical obstacles to the concourse . (Mansour 2007). Outcrops, essentially Jurassic, form long and narrow anticlinal structures, separated by large synclines where the sandy outcrops of lower Cretaceous constitute the major hydrogeological systems(Mansour 2007). A geological structure with fragile and erosion-sensitive surface formations, combined with climatic effects and insufficient perennial cover, resulted in a soil of poor quality for agriculture, and steppe vegetation subject to the perverse effects of climate and overgrazing; gradually decreasing towards erosion and desertification.(Bouarfa and Bellal 2018)

A continental sub arid to semi-arid climate is characterized by insufficient rainfall of less than 200 mm and strong seasonal and annual variations further marked by climate change in recent decades; in the region of the high plains the soils are shallow and less fertile with organic matter content of less than 3% (Aidoud and Touffet 1996).Fig 01

The wind remains the main element responsible for the modelling of therelief (Mainguet 2012); therefore to explain dune various forms, it is necessary to make an analysis definite in the areas of The Ksour Mountains and to put them in contact with the characteristic winds of this region. Rapid and intensive degradation of the vegetal covering makes it easy for wind to carry the sandy material .Next, this carried material is accumulated in other areas; giving rise to different sand-hill accumulations and starting processes of desertification (Ouessar et al. 2006); where the regime of the wind, including frequency, magnitude and direction is one of the mailmen

determine the form dynamics, the migration and the accumulation of the sand dunes (Cooke and Warren 1973, Lancaster 1988, Pye and Tsoar 2008). The accumulation of sands represents a real threat to the urban sites and socio-economic activities (Nouar, Toufik and Mamar 2014, Khalaf and Al-Ajmi 1993)The classification of the sand dunes depends in most cases on three mailmen: the morphology and the regime of the predominant wind the energy of the wind.and the mobility of dunes (McKee 1979, Tsoar 2001). For this purpose, anemometric recordings have been used at the National Meteorological Office of The Ksour Mountains from 1985 to 2015.

In this study, we are interested in the effects of winds on the sand movements and the dune modeling in the region: it is necessary to distinguish between "wind regime" and "potential sand displacement". according to 16 directions and 8 records of observations per day for 30 consecutive years, from 1985 to 2015. These data were treated for the estimation of the quantities of sand displaces and evaluates the phenomenon of sand encroachment. Precise data on the rate of transport of sand are very difficult to acquire, and numerous different expressions were diverted, according to various environmental hypotheses, to fit experimental data (Greeley and Iversen 1987).Alternative analyses based on winds in sand or a potential of transport of sand were offered and discussed by several authors in the course of the last two decades and a half for instance,(Bullard et al. 1996, Nickling and Wolfe 1994). These methods of analysis, method Press by Fryberger (1979) was most broadly accepted and adopted in the arid environments of the world. The method of Fryberger, which is a modification of the equation of Lettau (1978), is conceived to give a relating indication rather than absolute the effect of wind force on the drift of sand.

Wind force is a key variable in indications conceived to examine the potential drift of sand Such as that developed by Lancaster (1988) and Bullard and al. (1996) to consider Activities of status in dune of Kalahari. Method Fryberger is a useful tool to assess these problems and recommend measurements of control of sand.

Wind regime and grain size are the factors that determine the morphology and dynamics of sand dunes in desert areas(Cooke and Warren 1973).

This article aims at assessing the role of the regimes of the wind, in this weather station, in the determination of the potential drift of sand in the zone of The Ksour Mountains.

2. MATERIALS AND METHODS

2.1 Study area:

The study area is located between latitudes 33° 9'54.09"N to 32°42'57.58"N and longitudes 0°13'22.24"w to 0°57'20.48"w;it is a part of the Ksour Mountains chain and the western zone of the Algerian Atlas. The vigorous reliefs of the Ksour Mountains cross the plains of Oran directly by reliefs more attenuated by tops where the altitude is near 1200 m, which fall regularly towards the depression of chotts on the southern mountain side. The passage to the flat – Saharan form is violent and the difference in altitude excceds 1200 m, the zone of study is limited to the North by the line of chotts Ech-chergui and el Gharbi and to the South by the Northern piedmont of the Saharan Atlas. (Fig 01)

The watershed of the Ksour Mountains constitues of two Wadis i.e. the Tirkounte and the Breidj. Both Wadis cross the city of The Ksour Mountains, meet to form right in the center of urban cloth the valley the Ksour Mountains, then more downstream the ravine El Rghouiba, forming the party upper reaches of the Saharan pouring main pool of Namous, which unloads its waters in the big western Erg.(MELALIH 2011), It is up to the arid bioclimatic floor in cool winters; rainfall is weak and seldom exceed 200 mm / year.

Fig. 01

2.2 ind data and analysis method

2.2.1 Data collection

The station of Ain sefra, which is the only climatic station in the study area provides climatic data, including anemometric records as required by the World Meteorological

Organization standards (surface wind records are measured at 10-m height) covering the period from 1985 to 2015.
In this study, missing value analysis and homogeneity tests were conducted for all wind data. Raw state observations were tabulated on velocity value (in m/s) and direction (in degree azimuth). All surface wind records were summarized on six wind speed categories and sixteen wind direction classes, for analyzing the frequency and the directional wind distribution.
To study the wind rate we needed the control of wind speed in 16 directions during a period with 8 records per day (00, 03, 06, 09, 12, 15, 18,21H). The study of wind efficiency rate, the wind aptitude to detach and carry a sand article, with a speed higher than 4 m/s that was chosen by Y.CALLOT (1987). We needed the control of wind speed in 16 directions during a period inThe Ksour Mountains, we have distributed observations from 1985 to 2015, and the observations are gathered together in speed classes as follows: the speed class light wind, the effective wind sand, and strong wind. Y.CALLOT (1987).

2.2.2 Data analysis (Fryberger method)

By making several simplifying assumptions, using the Lettau and Lettau (1969) and made easier by S.G.Fryberger (1979) it is possible to generalize a formula that evaluates sand potential extraction as follows:
Using the Lettau and Lettau (1967) equation for sand drift:(Bouarfa and Bellal 2018)

$$q = V^{*2} (V^* - V\,t)\, C''.\, S / g \;.... (1)$$

With: q= transported sand quantity, V*: wind speed, VT: threshold velocity (sand minimal speed extraction) S: air density, g: gravity constancy: empirical constancy based on particles form, And or $C'' = C' (£ / £^*)^n$
C’: sand universal constancy (=6’7); £: diameter of transported sand particles; £*: 0. 25 mm (standard diameter) and N: empirical constancy.(Bouarfa and Bellal 2018)
Fryberger simplified this equation to:

$$Q= V^2 (V - V\,t) \;.... (2).$$

Where: Q is the appropriate amount of sand , expressed in vector units (VU);
V is the average wind velocity at 10m height for time period t, Vt the threshold velocity at 10m height, referred to V t in Equation (1); and t the time that the wind blew, expressed as a percentage in a wind summary.

The laboratory analyses of the wind movement revealed a speed of 14,4 km/h and 23,4 km/h depending on the characteristics of the considered environment (Oulehri 1992).

Bagnold (1941) determines the wind threshold speed (Vt), depanding on the size of the sand grains ;ysing classic sieving (sieve of the AFNOR type) (L. Berthois, 1959 and F. Verger, 1963). The size analysis indicated that the mean particle size (MZ=0,22 mm) ranges from 0,20 to 0,25 mm, (Fig n °02) therefore, the wind speed considered as the threshold velocity for moving sand is 22 Km/h, under dry conditions and in a sparse vegetation cover area (Fryberger and Dean, 1979)

The assessment of the sand drift potential in m3/m/year or kg/m/year has been performed by S.G.Fryberger (1979); using the equations allowing the correlation between the transport capacity or drift potential (DP) and the moved sand volume. A shift from the theoretical operation for the volume or mass estimation of a transported material through a given section and during a given period is necessary. The equivalent in m3/m/year of a (DP) in « victoriel unity) vary following the quantification equation and the user parameter values (rugosity coefficient etc…) although, this equivalent is always proportional (DP).

A sand mass occupies a volume in a dig and with a test tube, sand is over wetted with water and adding a volume(V),adding more water till it covers the sediment surface(El Ghannouchi 2007).Then, sand drift potential in volume(q) can be converted into mass(Q) in (kg/m). A straight correlation in accordance with the previous equation of Lettau (1969) converts the DP to VU to a Q estimation of sand drift potential in m3/m/year (sand volume through a section of 1m and per year.) (Callot and Oulehri 1996).

For vt = 21,6 km/h = 6m/s :Q' = 0, 0692 q

Q'' = 1670 Q'; sand quantity transported in kg/m/wan.

From this association, a temporo-spatial comparison of directions and intensities was made possible. Thus, we can calculate the sand quantity transported for every speed and direction of readings. The coefficient for any given direction is the resultant of the observation frequency (f) of each speed higher than the extraction speed and the sand drift potential, obtained by the formula (2)

100 to lower the magnitude of the weighting factors and simplify the plotting of sand roses divide Vt. The weighting factors for five wind velocity categories are calculated in the manner shown in Table 1.

Table.01

It gives an idea about the total potential of the sand drift.The drive amount according to the 16 directions. The transport capacity distinguishes the milieu in function of their different eolian energies with DP< 200 a weak eolian energy zone, 200< DP<400: medium energy zone DP >400: a strong eolian energy

The resultant drift potential (RDP) is the vector of the potential migration force of the sixteen directions; so the resultant of the transport capacity in a vectorial amount forms.(Bouarfa and Bellal 2018)

The resultant drift direction (RDD) isthe medium orientation angle, it indicates sand migration direction, and it represents the resultant vector of sand migration compass card.The consequential direction and its resultant migration potential are of great importance since it provides information about the direction that wind should take to migrate which can be compared to soil or air photography or to a satellite image. The RDP/DP ratio gives a standardized indication of the directional variability of the wind and it varies from 0 to 1. Where the wind is more unidirectional, the RDP/DP ratio approaches unity. A Simple statistical analysis was conducted to compare the mean values of DP, RDD and indices among the months. This coefficient is considered: High: when superior to 0.8 and produced in long distances of a sand transport. Medium: when it is between 0. 8 to 0.3 and always producing sand transport in long distances. Weak: when inferior to 0. 3.In this case, winds have a tendency to blow in all directions and stir sand without really moving it. These coefficients enabled us to design sand potential drive compass cards, which we analyzed and compared later.(Bouarfa and Bellal 2018)

Sand Migration rose concerns sand potential movement graphic representation and particularly coefficients mentioned above. The graphics importance of compasses of sand movement or migration and the possibility to compare between them or other regions or even neighboring regions.

According to an increasing dispersion, order(Fryberger and Dean 1979) there are five types of sand migration compasses: A uniform narrow modal with more than 90% of potential transport located in two adjacent directions inside a circular arc of 45°.

Large uniform modals with one transport direction top, but with large distribution Sharp Bi modals with two modes distribution and direction, which tops form a sharp angle (90°)Obtuse Bi modals which distribution is similar to the previous, but the two tops form an obtuse angle (BELOUFA 2003)
More than two modes complex modals, which are difficult to be established in only sixteen directions. There is generally no well-defined mode.

2.3 Method to indicate land use and land cover changes (LULC):

One LANDSAT multispectral satellite images were used (WRS_PATH =197 Starting Row = 37). They are acquired in 30 August2016. The spatial resolution of used image is 30 meters.Pre-processing of satellite sensor image is necessary in order to establish more direct linkage between the data and biophysical phenomena, removal of data acquisition errors, image noise and masking of contaminated and irrelevant spots such as clouds , which might lead to misinterpretation and detection of unreal change phenomena (Coppin et al. 2004). For false color composites (FCC), one can use each available satellite spectral band. It is common to include several spectral bands that are more targeted to a differentiation of specific surface materials; according to Eastman (2006). The first FCC has band 7 in the red color gun, band 4 in the green color gun and band 2 in the blue color gun (FCC R:7, G:4 and B:2).
Supervised Classification although many different methods have been devised to implement supervised classification, the MLC is still one of the most widely used supervised classification algorithms(Jensen 1996). In this study, a MLC algorithm was employed. It quantitatively evaluates the variance and covariance of the spectral response patterns of an unknown pixel(Lillesand, Kiefer and Chipman 2000). The latter must be done Post Classification Processing.

3. RESULTS AND DISCUSSION:

3.1 Wind distribution:

the regime of calm winds , recorded in the station of Ain sefra from 1985 to 2015.It represents relatively wind which is an average stillness sum of 50, 30%.We notice that is highly variable and exceeds 50% for only seven months: January, February,August, September, October, November and December,with a maximum of 57% and a minimum of 39.23% (Table 02) . The efficient wind is predominant in the spring ; this period is characterized by lowest calm time occurrence in the year. (Fig 02)
The analysis of directional variability of the surface wind data revealed that all-speed are ranked, within the effective winds (>21.6 km/h). The efficient wind frequencies 49.69% distributed into two speed classes, which are the speed class between 14.4 to 21.6 km/h, which is the more frequent with 77.70%,the speed class more than 21.6 km/hwith 22.29%.(Bouarfa and Bellal 2018)
Table.02

Table.03

The annual rates of wind in the station of Ain Sefra (Ksour Mountains) demonstrate: is under the influence of two opposite sectors and S with a dominance of S, SW and N (Table03 and Fig02).

The wind blows from the South sector at 11 % of time (Table 03), where the Sud-east earlies prevail at 10.7 %, the easterlies at 12.1 % and the West-south-West earlies at 24.7 % of the times (Fig 02).

Fig.02

In The observation period has been divided,onto the four seasons: Spring (March, April and May) Summer (June, July and August), Autumn .(September,October and November) and Winter (December, January and February) ; this division is associated to the winds rates. (Fig02)
The effective winds repetition is weak in the In Autumn, , with 22.7% where the winds follow many directions: South, SW, and NNW.
The winds are more frequent in the spring; during which the wind is efficient, with 30%, and follows many directions: the South, the North and the NNW.
During the Summer, we notice that efficient winds are 27.6% and are more frequent in the Southern sector, then in the SSW, the SSE and the East. In winter, the efficient winds are less frequent, with only 20.89% and follow many directions mainly the North and the NNW. (Fig02)
The connection between these annual variations, shows that efficient winds are more frequent during spring, but with different directions and sometimes they are inverted (North and South).

3.2 Sand drift potential:

The characterization of wind energy and moving sand aptitude depends mainly on the drift potential amount and pattern (Fryberger and Dean 1979, Lancaster 2009). Through the quantification of sand potential movement in the study area, of the Ksour Mountains, wind readings from 1985 to 2015. We have quantified potential energies coefficients of the Ksour Mountains region, the potential movement and drift of sand quantity that wind is able to transport are done towards North-EAST (SW to NE) direction, for the period between 1985 and 2015. The results obtained are presented in Table 03 and Fig03.
Table.03

Fig.03

In The drift potentials in the Ksour Mountains, are hight and classified within the medium energy milieu according to Fryberger (1979) classification. . The sand migration coefficient is weak, and characterized by a sand mutability without noticeable movement, according to Fryberger (1979) classification; when this coefficient reaches a value less than 0,3, winds have a tendency to blow in all directions and they stir sand without really transporting sand. In fact, there are gaps in the two methods regarding the turbulence phenomena of wind that is not measured by any of the meteorological stations (Bensaid 2006).The drift potential (DP) : The transport capacity for the whole series from 1985 to 2015 ,with an extraction speed of 21.6km/h (12 knots) is 220 VU ; which allows to classifying the Ksour Mountains as medium Aeolian energy region. The equations of S.G.Fryberger (1979) correlating the transport capacity and the extracted sand volume indicated that the sand mass potentially mobilized from 1985 to 2015 is Q= 15.224 m3/m/year, which means 25.424 T/m/year .The resultant drift potential (RDP) the vector of the migration potential force of the sixteen directions is 76 VU,the whole series. The Migration Coefficient (RDP/DP) for the 30 years series is consider weak; with only 0.3 and 0.35; which means a sand mobility without real movement. Nevertheless, it ranges from 0.43 (autumn) to 0.37 (winter); the resultant direction and the average angular orientation of the series is 234°N that is a resultant direction of WSW towards ENE (Table03).The wind compass. look like a large type bimodal i.e. the opposition between the winds of the South to North and NNW, West-South-West to NNE (preponderant) (Fig 03).

Regarding the effective wind distribution, the amounts of sand drift potential showed a temporal variable pattern but with directional stability.

The monthly drift potential DP reached 138 VU in January and 450 VU in April (table 04); therefore the station of The Ksour Mountains have strong spring and summer moving-sand seasons with highest values in April, March or so 258 VU, May 355 VU and June 79VU. The net drift potential RDP ranges from 40 VU in January to 208 VU in April. The resultant drift direction RDD is often confined between 190°to 260°, which means between the South and West.(Bouarfa and Bellal 2018) (Table 04; Fig 04)

Table.04

Fig.04

The Migration Coefficient (RDP/DP) is estimated less than 0.3 in January and March (0.29-0.26), which means that the winds have a tendency to blow in all directions and stir sand without really moving the sand ,; it. does not exceed 0.8 during this period, and exceeds 0.3for the rest of the year, which is a medium energy, always producing sand transport in long distances.

The average seasonal sand DP values estimated in 16 directions for the station of Ain Sefra are presented in Figure 05. These images are drawn by a sand rose graph. The calculations of DP in different seasons revealed that the strongest winds blew in Spring and Summer (359 and 178 VU), followed by Autumn and Winter which had the lowest DP (159-161 VU). These values allowed classifying the region of the Ksour Mountains among the intermediate-energy wind milieu. Moreover, the seasonal RDP/DP value was of between 0.37 to 0.43, which indicated a medium energy and always producing sand transport in long distances.

The seasonal wind roses of the region showed that the winds were most common in the West to the Northeast, The most frequent Spring and Summer winds blew from the South and the West to the Northeast; this is possibly due to the seasonal flow patterns in a Southwest wind, coincided with the morphology of the region and the sand dunes (Fig 05).

The Seasonal transport capacity is estimated between 11- 15 m3/m/ a year and reached its maximum in Spring with 24.84 m3 / m / year. The table 05 proved that the greater frequency of effective winds confined between the direction of South and West in all seasons of the year.

Table.05

The RDP ranges from 59 VU (Winter) to 135 VU (Spring) , which means that sand transport direction is mostly from the Southwest to the Northeast (SW-NE). Furthermore, the orientation of the effective wind is between 189° to 254° , so the wind is blowing from the South and Sest and the result is between them.

4. State of sand encroachment and danger:

The land use and land cover changes (LULC) are typically mapped from digital remotely sensed data; through the process of a supervised digital image classification(Campbell and Wynne 2011, Thomas, Benning and Ching 1987). The main objective of the image classification procedure is to categorize all pixels in an image into land cover classes or themes (Chipman, Kiefer and Lillesand 2004). The maximum likelihood classifier evaluates quantitatively both the variance and covariance of the category spectral response patterns; when classifying an unknown pixel so it is considered as one of the most accurate classifiers, since it is based on statistical parameters(Shalaby and Tateishi 2007).The area was classified into five main classes: sand area (dune>2m,and sand cover) (16, 4%); the rocky outcrop (39%); the pasture (pastoral rest and fodder planting) (6, 6 %), the bare ground (very steep gradient course) (40, 7%). The land cover classes are presented in Table 06 and Fig 06.

Table.06

Fig.06

The proportion of total sand is 16 % (dune+ sand) of the total area, a significant proportion. The explanation for this phenomenon is the high proportion of effective winds and this was confirmed by previous studies. Moreover, other factors such as the nature, the morphology and the geological outcrop of the cut, etc. In addition, other humans factors such as overgrazing and burning of forests and plowing at random. .The high proportion of sand creates the phenomenon of sand encroachment, which represents a serious danger for the population, and the infrastructures.

5. CONCLUSION:

The Ksour Mountains region is suffering from is facing a serious sand encroachment problem; due to hard climatic conditions,

The analyses of the wind data, via the wind rate and the sand potential movement permitted to determine the directions of efficient winds and the annual and seasonal resultant direction of the sand potential movements., ;the the probable mobilized sand mass has also been estimated.

The dominant winds come mainly from Southern and Northern sectors and secondarily from the Eastern and Wester sectors of the sand transport rate, which is in one direction. In fact, only the winds of the Southern sector and WSW are efficient and able to generate a sand movement.

That sand transport includes two phases, in the Spring and the Summer: the DP is very high and the sand generally moves from the WSW to the NNE and from the S towards N, during this period, there is an average migration coefficient (0, 37) regularly producing a long distance sand transport The DP and the sand movement are very weak and the winds blow the least and without preponderant directions in Autumn and a Winter: .

To evaluate the impact of sand encroachment on the morphology and evolution of sand deposits, we need to link this technique with very précised topographic readings, that permit the calculation of sand volumes deposited or eroded.

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Tables

Table.01: Fryberger's (1979) worked example to demonstrate the calculation of weighting factors. (Al-Awadhi, Al-Helal and Al-Enezi 2005)

Velocity category (Km/h)	Velocity category (knots)	Mean velocity of winds in category V	V^2	(V-vt) 1.5	Weighting factor V^2 (v-vt)/100
20-30	11–16	13.5	182.3	1.5	2.7
31-39	17–21	19.0	361.0	7.0	25.3
40-50	22–27	24.5	600.3	12.5	75.0
52-61	28–33	30.5	930.3	18.5	172.1
63-74	34–40	37.0	1369.0	25.0	342.3

Table.02: Monthly frequency occurrence (in percent) of wind classes, and monthly average wind speed at the station Ain sefra airport for the period.

% 1985-2015	<14.4 km/h	14.4- 21.6 km/h	>21.6 km/h
September	53	39	8
October	57	35	8
November	56	38	6
December	57	37	6
January	54	38	8
February	54	37	8
March	48	38	14
April	39	41	19
May	42	41	18
June	47	42	12
July	50	40	10
August	55	35	9

Table.03: Directional variability of the frequency distribution (in percent) of the wind speed classes at the station Ain sefra airport for the period 1985-2015.

%	<14.4 km/h	14.4-21.6 km/h	>21.6 km/h	Total%
N	4	4	1	8
NNE	3	2	0	5
NE	3	2	0	5
ENE	4	2	0	6
E	5	3	1	9
ESE	2	1	0	3
SE	1	1	0	2
SSE	2	2	1	4
S	4	4	2	11
SSW	3	3	1	7
SW	3	2	1	6
WSW	3	2	1	7
W	5	3	1	9
WNW	3	2	0	5
NW	2	2	1	5
NNW	3	4	1	8

Table.03: Summary of the yearly drift potential DP, resultant drift potential RDP, resultant drift direction, RDD and wind variability index RDP/DP in the station Ain sefra airport for the period 1985-2015.

Threshold speed	**21.6 km/h**
RDP/DP	**0.34**
The resultant drift direction (RDD)	**234°**
Drift potential (VU)	**220**
The resultant drift potential (RDP) (VU)	**76**
Quantity sand :transport capacity :Q= 15,224 m3/m/year which is **25,424** T/m/year	

Table.04: Summary of monthly and annual drift potential, resultant drift potential, resultant drift direction and wind variability index for Ain sefra airport station (1985 – 2015)

Month	**DP**	**RDP**	**RDD**	**DP/RDP**
Sept	161	70	222°	0.43
Oct	168	52	209°	0.31
Nov	153	83	230°	0.54
Dec	126	82	264°	**0.65**
Jan	**138**	**40**	222°	0.29
Feb	214	101	235°	0.47
Mar	**258**	67	248°	**0.26**
Apr	**450**	**208**	256°	0.46
May	**355**	116	245°	0.33
June	**208**	84	194°	0.40
July	179	66	230°	0.37
Aug	181	89	188°	0.49

Table.05: Directional distribution of the seasonal drift potential. (Q: Quantity of sand transporter)

	Autumn	Winter	Spring	Summer	Annual
N	6	5	38	9	16
NNE	1	2	4	3	3
NE	2	2	3	3	2
ENE	3	3	4	7	3
E	6	9	14	13	11
ESE	6	1	4	6	4
SE	7	4	2	7	5
SSE	6	11	13	16	12
S	24	15	58	39	36
SSW	23	15	30	19	22
SW	17	5	35	16	19
WSW	23	22	53	12	28
W	13	20	34	9	19
WNW	7	14	15	4	10
NW	6	19	17	6	12
NNW	11	11	36	8	18
total DP	161	159	359	178	220
RDP	70	59	135	65	76
RDP/DP	0.43	0.37	0.38	0.37	0.35
RDD	222°	254°	249°	189°	234°

Direction	SW	WSW	WSW	S	WSW
Q m3/m/year	11.14	11.00	24.84	12.32	15.22

Table.06: different land cover classes of the study area from 2015 in the study area.

Class%	Surface (area in ha)	Percentage
Dune	37083.525	12.33
Sand	12371.158	4.11
Rocky outcrop	118222.262	38.67
Pasture	116300.634	5.36
Bare ground	16107.951	39.31

Figures

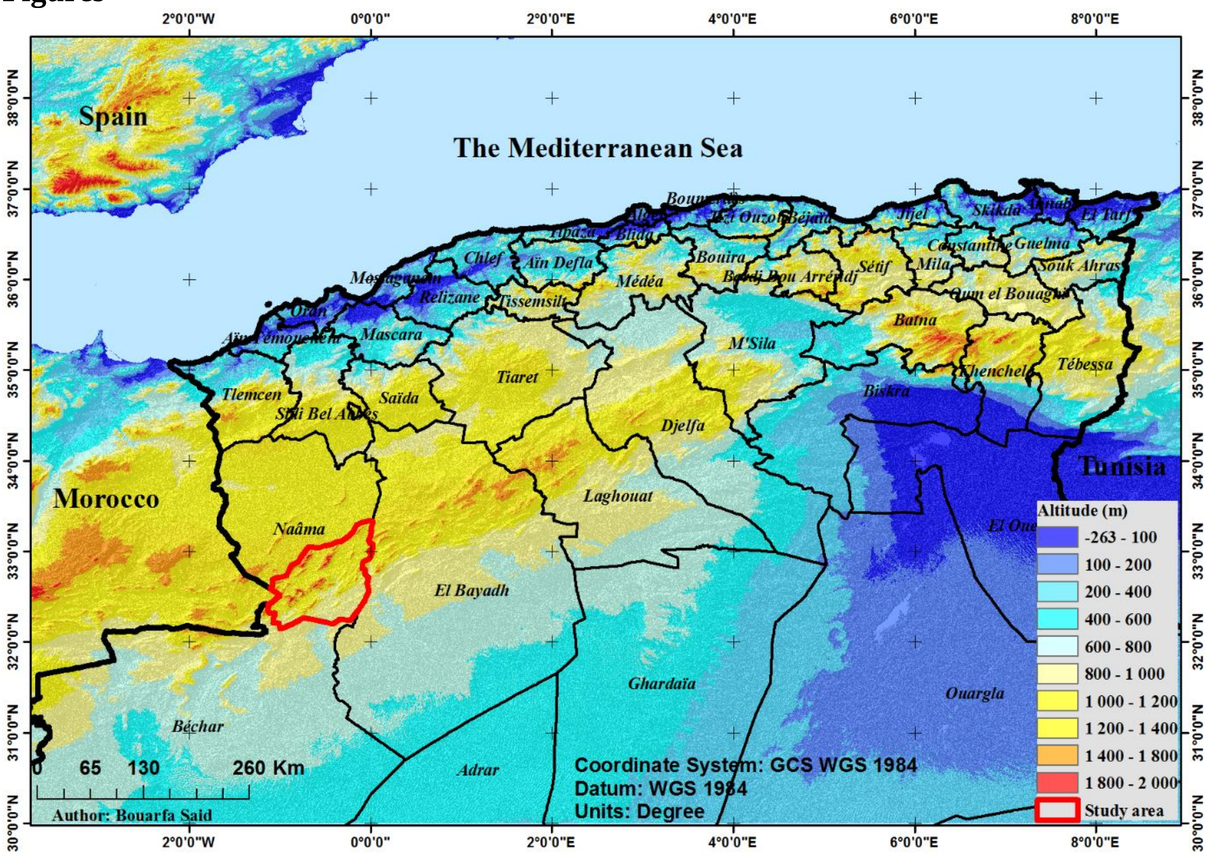


Fig. 01: Location map of the study area and reliefs: The depressions and plains have a gentle slope,
The mountains and highlands have a slope of medium to high.(The slope ratio between (0-3%) is estimated at about 12,2%;(3-6%) is 24,4%; (6-12,5%) is 34,5% ;(12,5-25%) is 21% and the >25% is estimated by 7%.

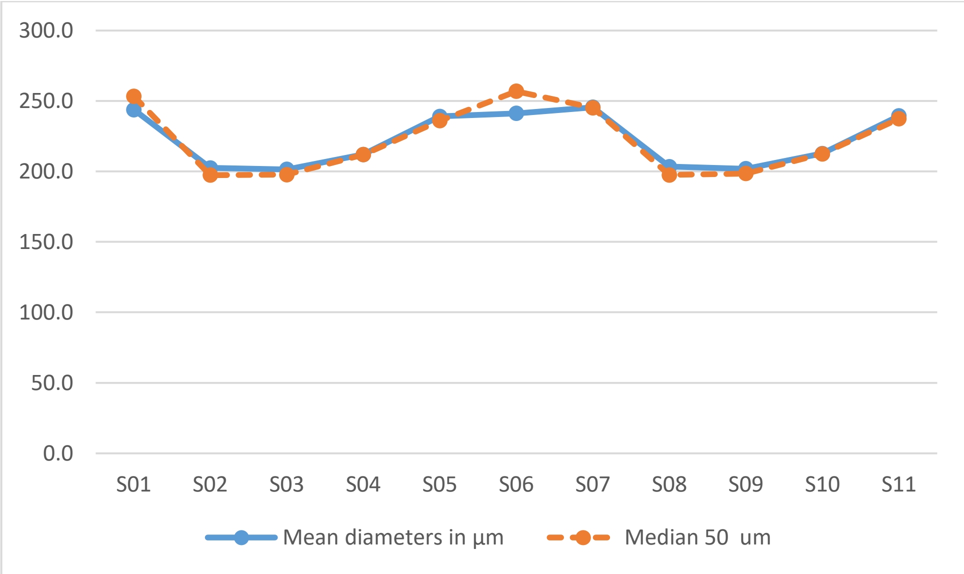


Fig.02: Mean diameters in µm and median samples (S01-S11) of sand grains in the study area.

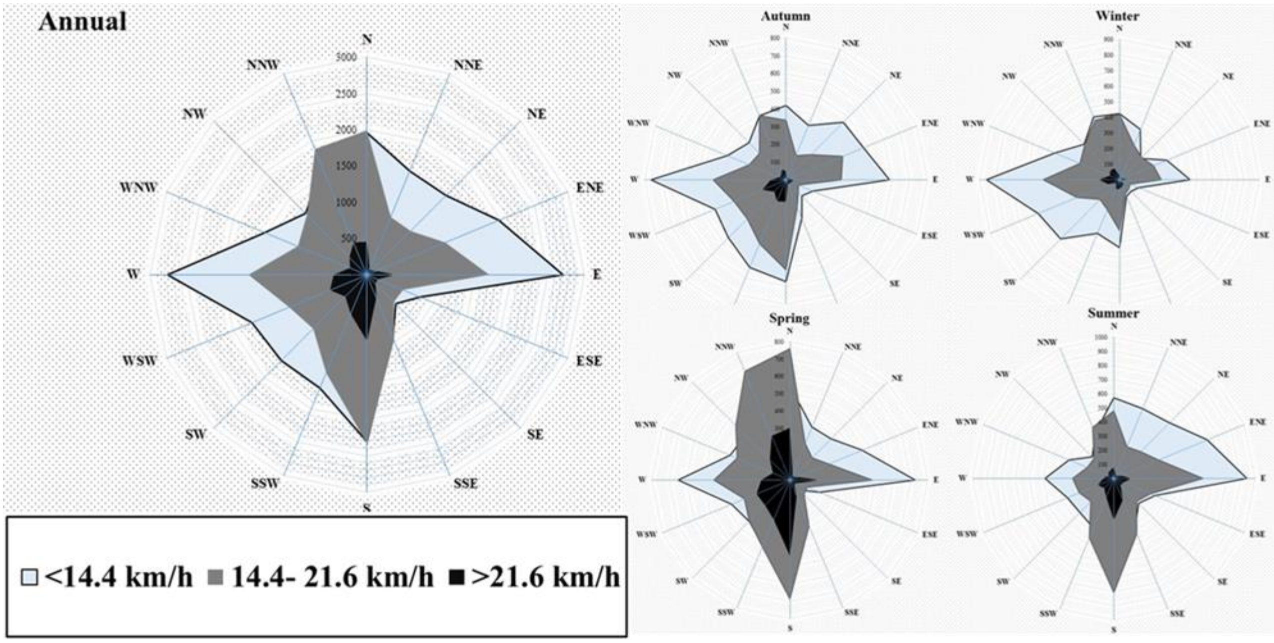
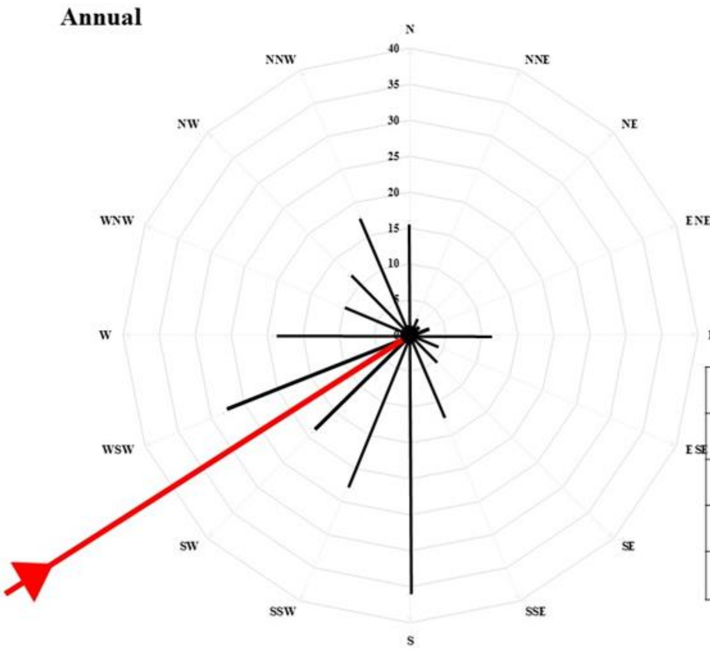


Fig.03: Wind rose diagram showing the directional and frequency variability of the all wind speed categories, from the station Ain sefra airport. Similar to the whole period: Annual and seasonal by observations of 1985-2015.



Sand Rose indices	
DP	220
RDP	76
RDD	234°
RDP/DP	0,35

Fig.04: Average annual sand roses of drift potential in the study area during the period 1985-2015.

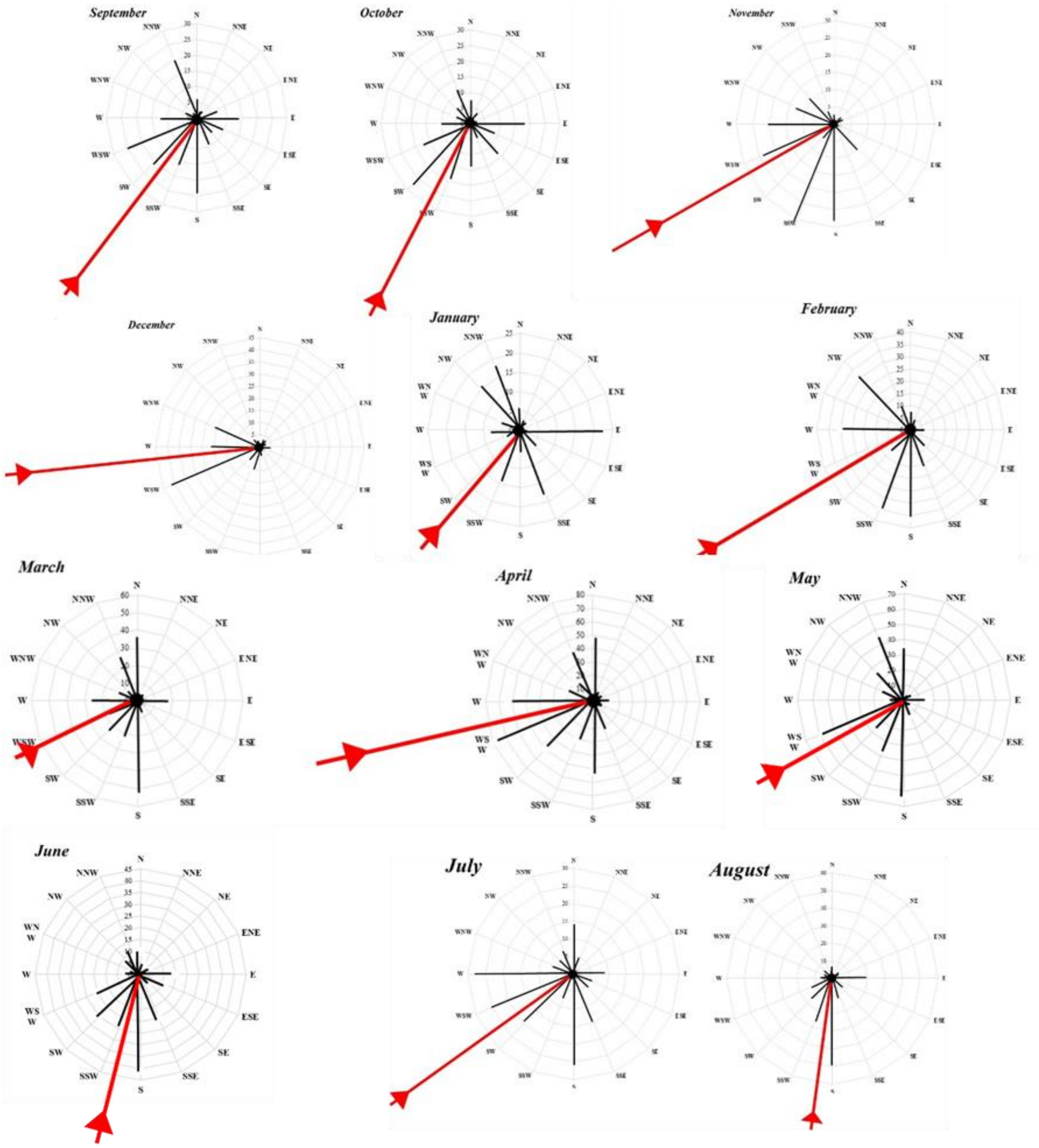


Fig.05: Average monthly sand drift potential rose in the study area 1985-2015.

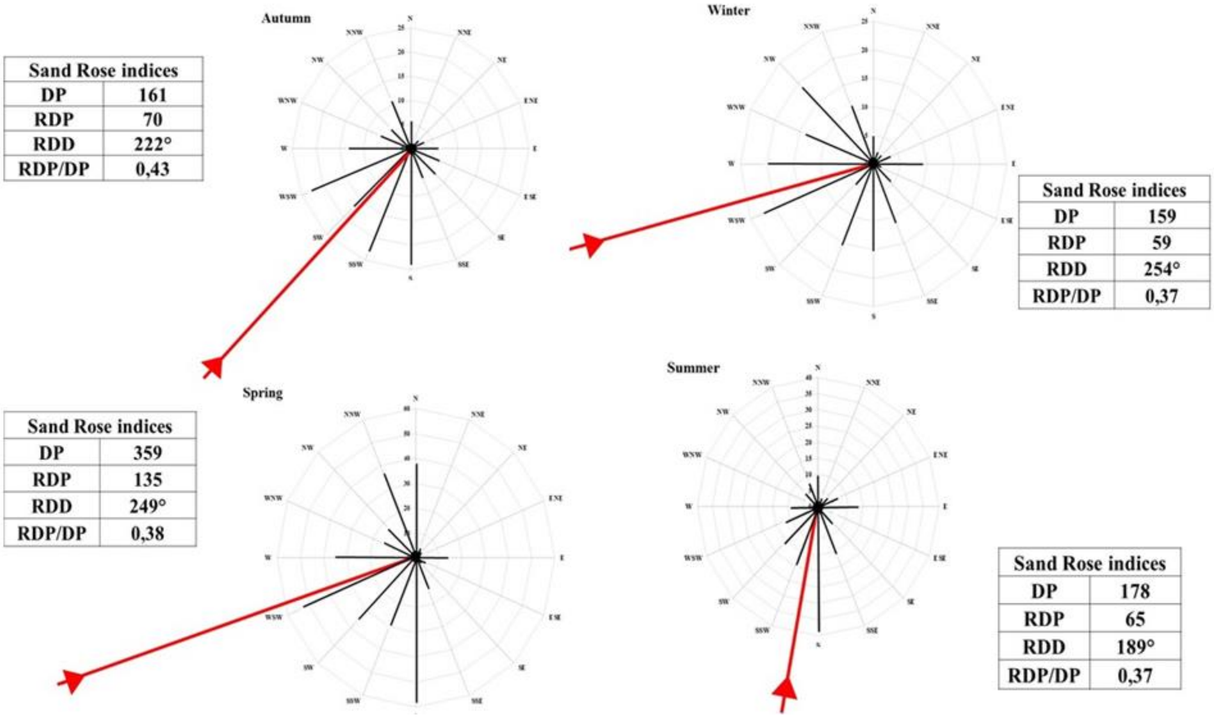


Fig.06: Average seasonal sand roses of drift potential in the study area during the period 1985-2015.

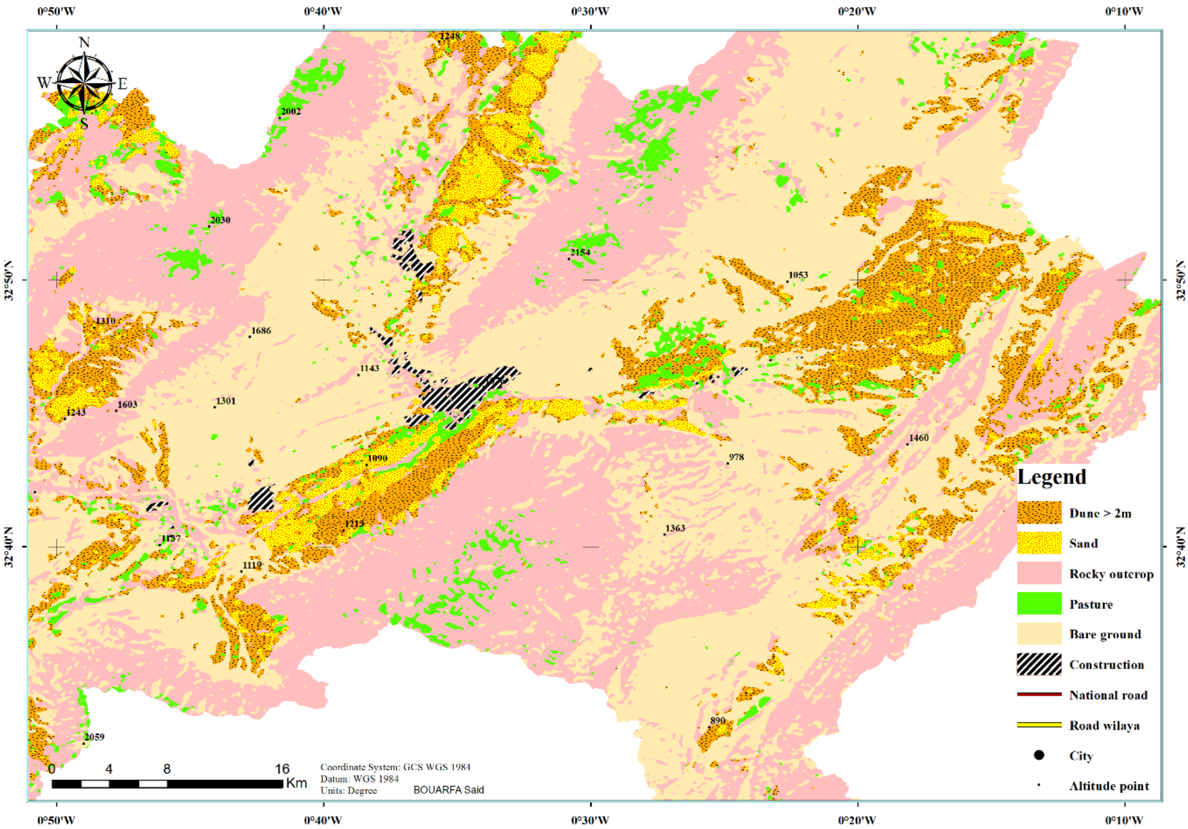


Fig.07: different land cover classes of the study area from 2015 in the study area: Percentage of sand area (dune + sand) is equal 16, 4%; the Rocky outcrop is 39%; the Pasture (pastoral rest and fodder planting) is 6, 6 %, the Bare ground (very steep gradient course) is estimated 40, 7%).

Fig .08: Some of the dangers of sand encroachment on the study area “Ain sefra”: threatens people, homes, roads (photo 01: 32° 45.343'N; 0° 36.401'w.photo 02: 32° 58.551'N; 0° 30.805'w. photo 03: 32° 45.643'N; 0° 32.763'w)