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Original Article

# Assessing land use change and moving sand transport in the western Hodna basin (central Algerian steppe ecosystems)

## Batı Hodna havzasında arazi kullanım değişiminin ve kum taşınımının değerlendirilmesi (Merkez Cezayir bozkır ekosistemleri)

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### ABSTRACT

The application of land use and land cover change (LULC) techniques for identifying the state of the environment is both a suitable tool and cost-effective. The study was conducted in the western part of the Hodna Basin (province of M'sila, Algeria). In this study, we combined remotely sensed data and ground truth observations to analyze the trends of LULC and their drivers during the 30 years from 1984 to 2014. In addition, we evaluated the sand transport using wind data. We assessed LULC using the supervised image classification method. The results indicated that rangelands experienced a considerable decrease with 50,000 hectares. This shrinkage in rangelands cover is associated with an expansion in bare soil cover with an increase of 57,000 hectares. Furthermore, woody vegetation and sand experienced a decrease in their cover. However, there is an increase in agriculture area. The analysis of land cover of sand indicated a decrease in the area of this class, and the assessment of wind data revealed that within the study area there is a transition zone of moving sands. The dynamic of LULC was mostly conducted by the anthropogenic and overgrazing factors. These drivers have a considerable role in the patterning of different types of land cover in the investigated landscape. We can conclude that the LULC technique used for the assessment of the environmental state identified a regressive trend of ecosystem values and a process of land degradation which implies the need for implementation of sustainable management practices.

**Keywords:** Drivers, land use/ land cover, sand transport

### ÖZ

Arazi kullanımı ve arazi örtüsünün değişimi (LULC) teknikleri ile çevre durumunun tespit edilmesi uygun bir yöntem olmakla birlikte maliyeti de düşüktür. Bu çalışma, Hodna Havzası'nın (Mila il eyaleti, Cezayir) batı kısmında gerçekleştirilmiştir. Bu çalışmada, 1984-2014 yılları arasındaki 30 yıllık uzaktan algılama verileri ve arazi gözlemleri birleştirilerek, arazi kullanımı ve arazi örtüsünün değişimleri (LULC) analiz edilmiştir. Ayrıca, rüzgâr verileri kullanılarak kum taşınımı durumu da değerlendirilmiştir. Görüntü sınıflandırma yöntemini kullanarak LULC tekniği ile birlikte değerlendirmeler yapılmıştır. Elde edilen sonuçlara göre mera alanlarının 50000 hektar ile önemli bir düşüş yaşadığını göstermiştir. Mera alanlarındaki bu azalmanın çıplak toprak örtüsündeki 57000 hektarlık artış ile ilişkili olduğu görülmüştür. Ayrıca, odunsu bitki örtüsü ile kaplı alanlarda bir azalma ve tarım alanlarında da bir artış gerçekleşmiştir. Kum ile kaplı alanların incelenmesi ve rüzgar verilerinin değerlendirilmesi ile çalışma alanı içerisinde hareketli kumların bir geçiş bölgesi bulunduğu ortaya koyulmuştur. Arazi kullanımı ve arazi örtüsünün değişimlerinin (LULC) çoğunlukla antropojenik ve aşırı otlatma faktörlerinden kaynaklandığı görülmektedir. Bu arazi etki faktörleri, arazideki farklı tipteki arazi örtüsü modellerinde de önemli rol oynamaktadır. Çevresel durumun değerlendirilmesinde kullanılan LULC tekniğinin, ekosistem değerlerinde azalma eğilimi olduğunu ve sürdürülebilir yönetim uygulamalarına duyulan ihtiyacı ortaya koyan bir arazi bozulma sürecini tanımladığı sonucuna varılmıştır.

**Anahtar Kelimeler:** Arazi etki faktörleri, arazi kullanımı, arazi örtüsü, kum taşınımı

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### INTRODUCTION

Monitoring land use and land cover change (LULC) is an important issue for management and planning (Ateşoğlu, 2015; Fathizad et al., 2015) especially in arid and semi-arid regions characterized by harsh environmental conditions (Boydak and Çalişkan, 2015) as well as socioeconomic restrictions (Çalişkan and

Boydak, 2017). In addition, the misuse of natural resources can lead to land degradation (Gökbulak et al., 2018). LULC studies are often focused on vegetation as a comparator, this vegetation is in continuous transformation, the changes due to the human activities represent a great challenge for the researchers, the decision-makers and the planners (Manning et al., 2009). These changes are the main drivers of habitats deterioration and biodiversity loss (Abdi et al., 2018).

The steppe rangelands of Algeria are experiencing dramatic transformations under the effect of climate change and human-induced activities. These transformations are the result of complex and continuous interactions between the local population, environmental drivers and natural resources (Fathizad et al., 2015). These steppe ecosystems are located between important geomorphologic complexes; the Sahara, the Saharan Atlas, the Hodna Mountains, and the Hodna Basin. Moreover, these ecosystems reflect great ecological importance marked by endemic species (Bahlouli et al., 2012). The density of the population in steppe rangelands and high plateau expressed a remarkable evolution from 36.7 habit./km$^2$ in 1977 to 60.0 habit./km$^2$ in 1998 (Kateb, 2003). Furthermore, the survival of this population is concentrated on pastoral activities (mainly sheep farming), where the number of sheep has increased from 17.6 million heads in 2000 to 21.4 million heads in 2009. This situation has a direct effect on the LULC in steppe rangelands.

The application of land use and land change techniques for the assessment and analysis of the change in arid and semi-arid environments has been studied previously (Badreldin and Goossens, 2014) indicated that vegetation cover decreased dramatically and more than 50% of the land was bare ground over the 11 years from 1999 to 2010. In their study, (Abdul Rahaman et al., 2017) used a Markov chain approach for the modeling of LULC and found that forest and vegetation cover decreased under the effect of population growth. Whereas, the study conducted in Yuli County (China) by (Zhou et al., 2011) revealed that natural processes were the main driver of changes, and human activities have a minor effect on the environment.

The emergence of new technologies such as remote sensing facilitates the work of managers in evaluating and proposing effective solutions for decision-makers (De Leeuw et al., 2010; Willis, 2015). This is especially so where the monitoring focuses on the landscape scales. This evaluation requires the use of human and material resources for its realization, which could be time-consuming and costly. Remote sensing technology provides useful information to evaluate the trends in environmental change and facilitates the comparison of spatiotemporal data (Zoungrana et al., 2015).

In arid and semi-arid environments, wind erosion is a determinant process in landscape modeling. Indeed, the surface wind is the climatic component most responsible for erosion, trans-

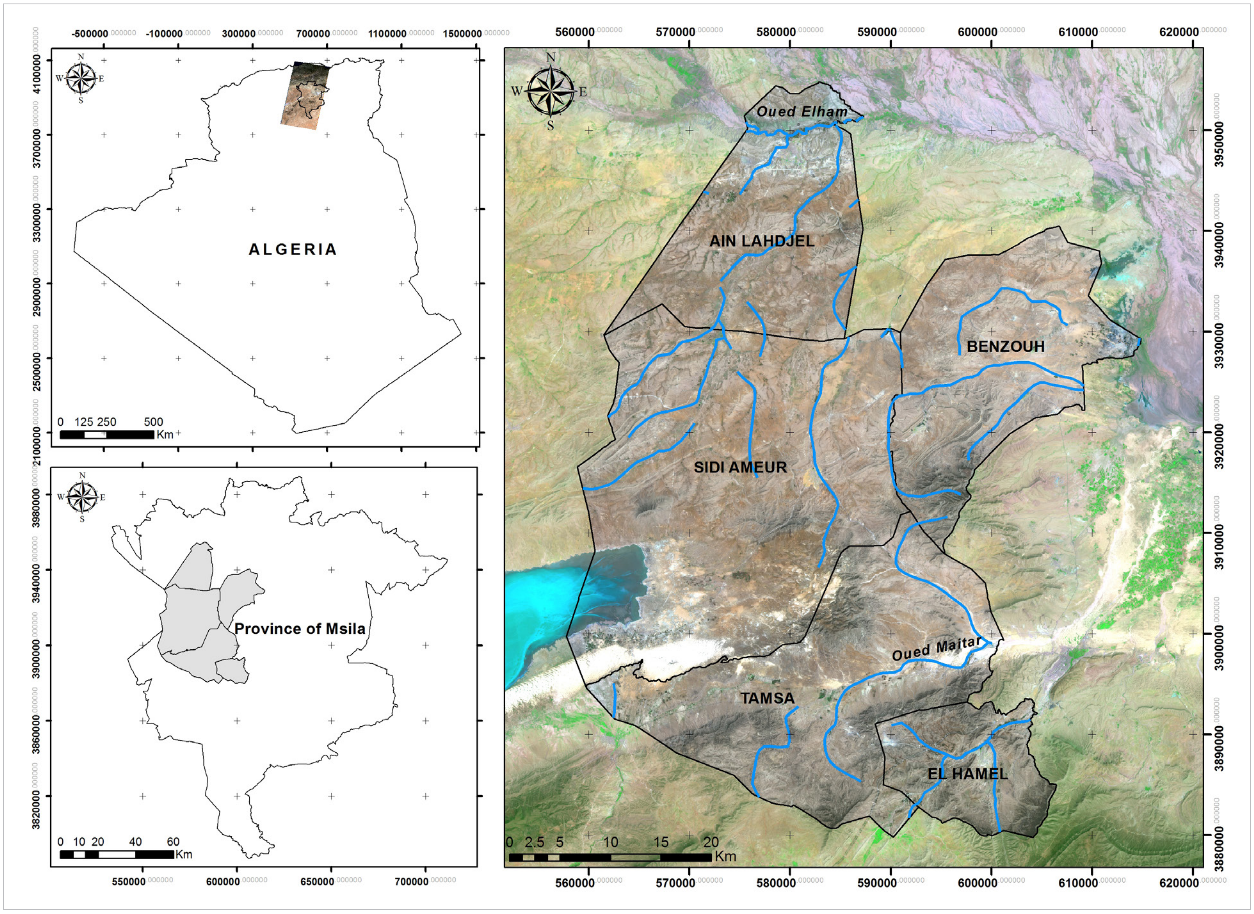


Figure 1. Study area location map (System coordinates WGS 1984 UTM Zone 31N)

Table 1. The four scenes representing two dates 1984, and 2014, for LULC

| Period | Acquisition date | Image identity | Satellite | Path/row |
|---|---|---|---|---|
| 1984/Scene1 | 18/04/1984 | LT51950351984109XXX02 | Landsat 5 | 195/35 |
| 1984/Scene2 | 18/04/1984 | LT51950361984109XXX02 | Landsat 5 | 195/36 |
| 2014/Scene1 | 21/04/2014 | LC81950352014111LGN00 | Landsat 8 | 195/35 |
| 2014/Scene2 | 21/04/2014 | LC81950362014111LGN00 | Landsat 8 | 195/36 |

Table 2. Description of LULC classes

| Classes | Description |
|---|---|
| Woody vegetation | Land covered by forest, plantation, trees, small trees, bushes. |
| Sand | Area covered by sands and dunes |
| Bare soil | Area with no vegetation |
| Agriculture | Land covered by agriculture |
| Alluvium | Land covered by alluvium |
| Rangeland 1 | Land covered by dense grasslands, dominated by perennial grasses |
| Rangeland 2 | Area covered by open vegetation, generally dominated by annual plants |
| Urban | Urban and built-up |
| Chott | Area covered by a salt lake in arid and semi-arid regions. |

port of moving-sand, loess sediments, and finally the accumulation of sand dunes and bodies (Boulghobra, 2016). The sand transport aptitude is principally controlled by wind velocity and frequency where the effective wind exceeds 6 m/s and spreads the prevailing wind according to a privileged direction (Bagnold, 1941). The accumulation of moving-sand on urban areas and socioeconomic installations (roads, railroads, palm-date, land reclamation, etc.) is a serious hazard threatening the natural resources of the local population and consequently all sustainable development effort (Boulghobra, 2016). Understanding the encroaching-sand risk in a region is an essential task for predicting impacts and attenuating damages, which requires the quantification of drifting-sediment rate, transport direction from the source to deposition zones, and the characterization of the studied region in terms of wind regime and energy.

This study used the post-classification method to assess the LULC in the western part of the Hodna Basin resulting from supervised classification over 30 years. Mainly, this study has three specific objectives: (1) to quantify and analyze the LULC classes from 1984 to 2014 (2) to qualify if the current situation is stable, unstable or neutral (no change) (3) to assess the aeolian hazard by quantifying sand transport rate and direction using wind data and the universal formulae of Fryberger and Dean (1979).

## MATERIALS AND METHODS

### Study Area

The study was conducted in the central steppe rangelands of Algeria, in the western part of the Hodna Basin (Province of M'sila) (Figure 1). The average annual temperature is between 17°C and 21°C, and average annual rainfall ranges from 200 to 400 mm. The largest amount of rainfall occurs during spring and autumn which account for 31.88% and 34.22% respectively (climatic data of Boussaâda station from the Algerian National Office of Meteorology 1988-2014). Livestock grazing is the main land use system in this area. Soils are calcareous brown, and encrusted gypsum soils (Halitim, 1988). The steppe of perennial grass *Stipa tenacissima* L. represents the most important part of the landscape.

### Satellite Data

The satellite images were obtained from the United States Geological Survey (USGS), which is a web-based portal for acquiring data. The acquired multi-temporal data was needed for change detection analysis, to provide information on the quantity and possible reason for the change, especially in a semi-arid and arid environment because of the limitation of natural resources (Badreldin and Goossens, 2014). Our study is based on satellite images of two dates (1984, and 2014). A mosaic of two Landsat scenes was used to cover our study area. We acquired the scenes of the year 1984 using the Landsat 5 Thematic Mapper (TM). For the year 2014 we used the images provided by Landsat 8 Operational Land Imager OLI. The spatial resolution for all images used is 30 x 30 m. Satellite images can be downloaded free of charge from the USGS website (http://glovis.usgs.gov/) (Table 1). We ensured that the study area included in the satellite images was cloud free. Furthermore, the acquired satellite images dates corresponded to the spring season, reflecting the maximum growth of vegetation.

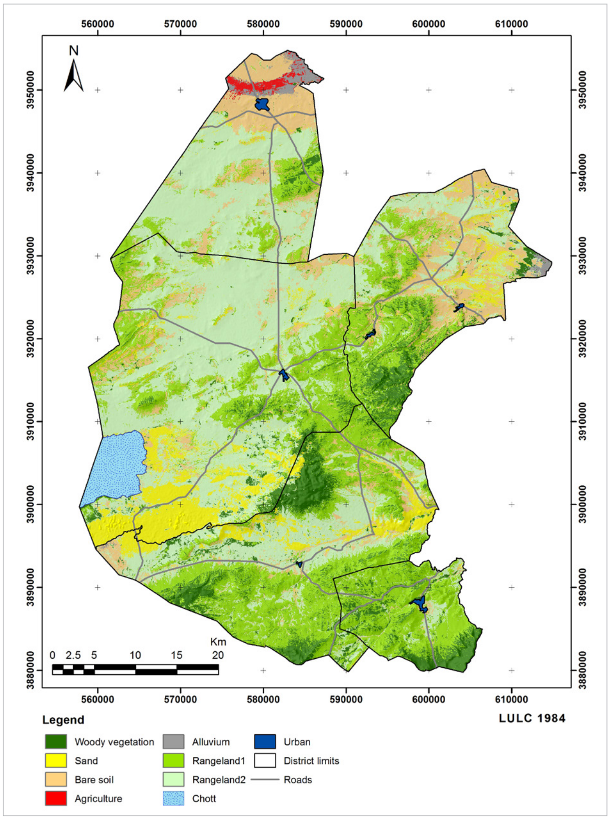


Figure 2. Land use and land covermap of 1984

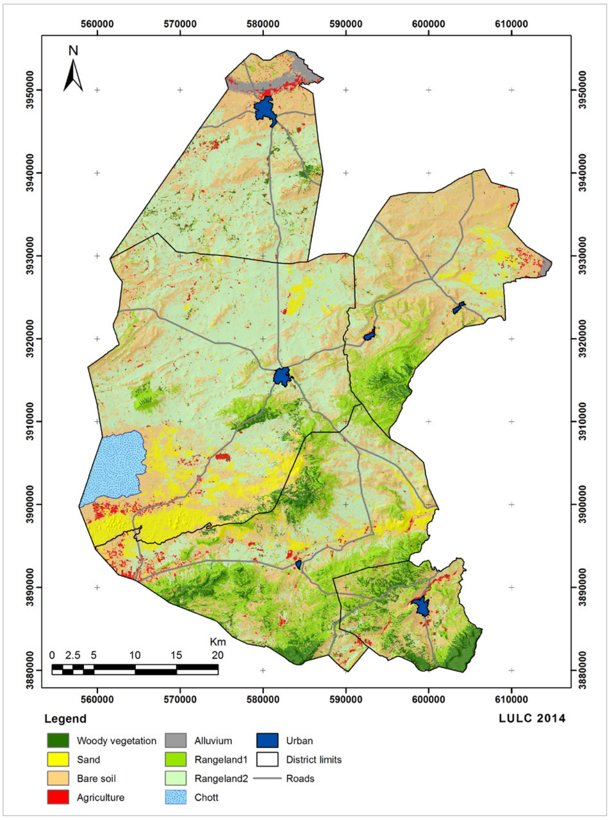


Figure 3. Land use and land covermap of 2014

**Ground Truth**
The study area was surveyed in a previous project of the National Fund of Research during 2010-2013 (Mostephaoui et al., 2013) and during this study in 2014. The necessary information and data were collected to identify different land cover areas (area of interest), and according to these data, we conducted the image classification and accuracy assessment processes.

**Image Preprocessing**
The images acquired by the satellites are influenced by several agents, which affect image quality and accuracy. Therefore, it will be necessary to perform several correction operations, including geometric corrections based on ground control points. The radiometric correction was performed using the dark object subtraction model (Pons et al., 2014; Zhang et al., 2018). Finally, the images were georeferenced to the Universal Transverse Mercator (UTM) projection WGS 1984 Zone 31N.

**Supervised Classification**
Before classifying the images, we proceeded to the extraction of the part of images that covered our study area. This was possible using a shape file covering five districts of the province of M'sila, namely Aïn El Hadjel, Benzouh, Sidi Ameur, Tamsa, and El Hamel corresponding to our zone of study. This operation was carried out using the ENVI 4.4 software (Exelis Visual Information Solutions, Boulder, Colorado, USA). The maximum likelihood algorithm was used for the implementation of the supervised classification. We classified the satellite images into seven classes of land use; Woody vegetation, Sand, Bare soil, Agriculture, Alluvium, Rangeland1 (not degraded) and Rangeland2 (degraded). In addition, two other classes: Urban and Chott, the latter two classes were determined using a mask for each class and were not included in the classification (Table 2). The problems of misclassified areas and overlapping classes were overcome before the classification (Amarnath et al., 2017).

**Post-Classification Comparison**
The effective use of remotely sensed data is determined by the accuracy assessment (Lyons et al., 2018). The accuracy assessment is an important factor for successful change detection research (Badreldin and Goossens, 2014). Moreover, this can be helpful for the analyst to identify changes of interesting land use (class) (Tewkesbury et al., 2015). The error matrix is considered the most recognized method for assessing the accuracy of the classification (Badreldin and Goossens, 2014; Lyons et al., 2018). The accuracy assessment is achieved by the measurement of overall accuracy (Mubako et al., 2018) and the Kappa coefficient which is an important parameter in this process (Metelka et al., 2018).

**Wind Data and Sand Transport**
Hourly wind data from the nearest meteorological station of Boussaâda (Lat. 35.3; Long. +4.2; Alt. +459 m) are available for

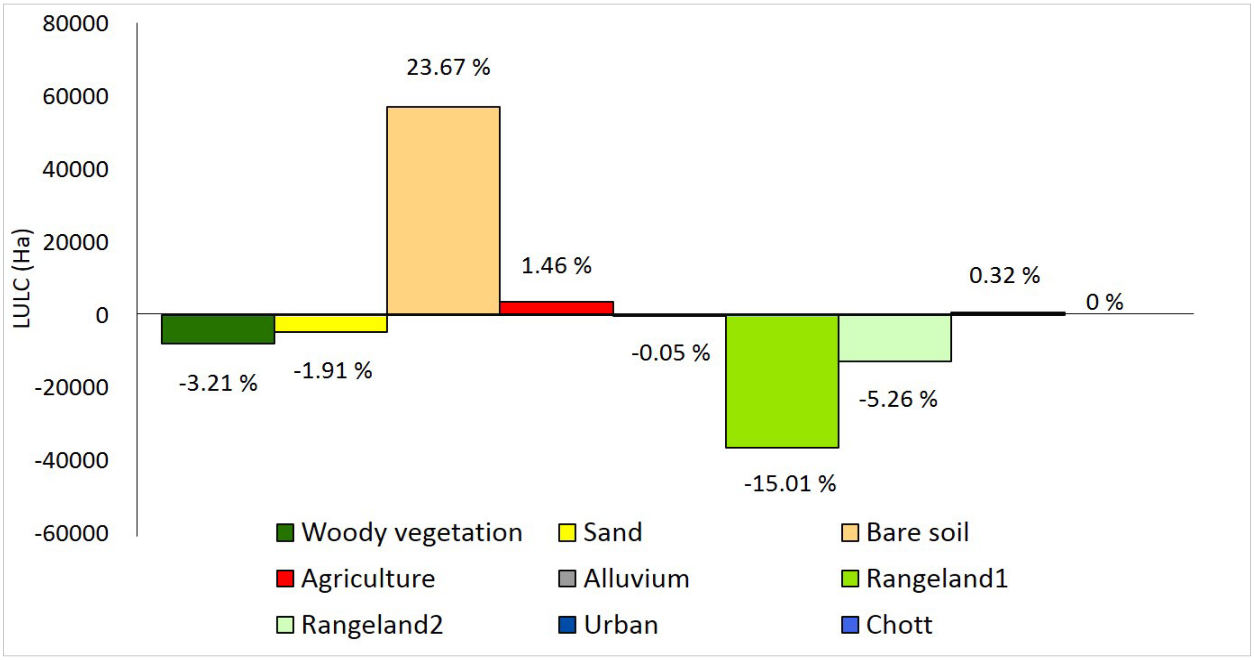


Figure 4. Land use and land coverchange from 1984 to 2014

Table 3. Classification of wind energy and wind regime according to Fryberger and Dean (1979)

| Drift Potential (VU) | Energy of wind environment | Ratio RDP/DP | Wind variability | Wind regime |
|---|---|---|---|---|
| ≤ 200 | Low | ≤ 0.3 | High | Complex |
| 200 – 400 | Medium | 0.3 – 0.7 | Medium | Bimodal |
| ≥ 400 | High | ≥ 0.7 | Low | Unimodal |

a ten-year period of continuous recording (2006–2015) with a temporal resolution of 8 records per day (45.154 values in total); wind data values are expressed as speed (m/s) and direction (degree clockwise).

Based on speed/direction wind data, the weighting model of Fryberger and Dean (1979) is widely used for assessing the rate and direction of sand transport. The formula expressing the Drift Potential (DP) is presented as follows:

$DP=V^2 (V-Vt)t$ (1)

DP : Rate of sand drift on vector unit (1 VU=0.07 $m^3/m$)
V : Average wind velocity
Vt : Threshold wind velocity (6 m/s)
t : Effective wind occurrence (%)
$V^2(V-Vt)$ : Weighting factor that depends on wind strength

In addition to the sand drift potential, three parameters could be derived from the equation of Fryberger and Dean (1979):

The Resultant Drift Potential RDP which corresponds to the magnitude of sand transport, the Resultant Drift Direction RDD which represents the direction of sand movement, these two parameters could be calculated as suggested by Al-Awadhi et al. (2005) :

$$RDP = \sqrt{C^2 - D^2} \quad (2)$$

Where:

$$C=\sum(VU)\ \sin(\partial) \quad (3)$$

$$D=\sum(VU)\ \cos(\partial) \quad (4)$$

VU is the corresponding DP for each direction (among 16 directions) in vector unit, and  is the midpoint of the wind classes.

$$RDD=atan(C / D) \quad (5)$$

The ratio RDP/DP (ranging from 0 to 1) which expresses the variability of wind direction, where lower values (close to 0) indicate strong directional variability and higher values indicate lower variability (values close to 1). Depending on the DP value, wind environment can be classified in terms of energy (transport sand transport aptitude), while the wind regime of the region is identified in function of the ratio RDP/DP (Table 3).

In this study, the sand transport parameters are calculated and interpreted by applying the equation of Fryberger and Dean (1979) on wind data from the station in Boussaâda for the temporally significant period 2006–2015.

## RESULTS AND DISCUSSION

### LULC During 30 Years

The 1984 LULC map indicates the pastoral character of the study area. The steppe rangelands constitute the most important part of the study area - 68%. On one hand, the north and north-west part are characterized by degraded rangelands (Rangeland 2) representing 96,878.16 hectares, which is equivalent to 40% (Table 4). On the other hand, the southern part is characterized by rangelands in good condition (Rangeland 1) covering 68,736.06 hectares (28%). In the extreme south-east part we find Fernan mountain (1600 a.s.l) covered by forest vegetation (Woody vegetation), with a combination of Aleppo pine and holm oak. In addition, the Halfa grass *Stipa tenassicima* L. the woody vegetation represents 9% of the total LULC map for 1984. The valley of Oued Maitar is a corridor for sandy wind movements. The western part is characterized by the presence of dunes in the south of Chott Chergui. The Agriculture occupies an area of 1,004 hectares and is concentrated in the northern part of the study area near Oued El Ham where water is more abundant (Figure 2). The accuracy assessment indicated that the overall accuracy for the image classification of the year 1984 is evaluated as 97.21%. The Kappa coefficient value of this year is 0.96 (Appendix 1).

The 2014 LULC map shows that 48% of the total area was occupied by rangelands. In this map, there was an increase in the cover of Urban class, especially in the north. The city of Ain Lahjel represents the largest agglomeration in the study area. While the LULC of Agriculture remains in a constant state indicating the development of rainfed agriculture in the direction of Oued Maitar, in the northern part it benefits from the contributions of Oued L'Hem (Figure 3). The degraded rangelands represented 34% of the total area, and the rangelands in good condition represented 13%. In this year, the bare soil class increased remarkably, representing 36 % (Table 4). The accuracy assessment results of the year 2014 reported that the overall accuracy was 97.02% and the Kappa coefficient was 0.96 (Appendix 2).

### Drivers of LULC Change

The Land Use Stability / Instability Analysis is very important for policymakers who may have better planning for future land use (Fathizad et al., 2015).The results show that the period from 1984 to 2014 (Figure 4) was marked by a decrease in the area of degraded rangelands and rangelands in good condition. The non-degraded rangelands (Rangeland 1) lost half of their area during this period. Consistently, the area of bare soil increased significantly from 30,634.38 ha in 1984 to 87,846.21 ha in 2014,

Figure 5. The cultivation of steppe rangelands initially covered by *Stipa tenacissima* L. and *Artemisia herba-alba* Asso

Table 4. Areas of different classes for 1984 and 2014

| Years | 1984 | | 2014 | | Change |
|---|---|---|---|---|---|
| Classes | Hectares | Percentage % | Hectares | Percentage % | Percentage % |
| Woody vegetation | 21 746.25 | 8.99 | 13 962.24 | 5.78 | -3.21 |
| Sand | 20 276.01 | 8.39 | 15 663.60 | 6.48 | -1.91 |
| Bare soil | 30 634.38 | 12.67 | 87 846.21 | 36.34 | 23.67 |
| Agriculture | 1 004.22 | 0.42 | 4 540.41 | 1.88 | 1.46 |
| Alluvium | 2 001.60 | 0.83 | 1 897.53 | 0.78 | -0.05 |
| Rangeland1 | 68 736.06 | 28.43 | 32 443.02 | 13.42 | -15.01 |
| Rangeland2 | 96 878.16 | 40.07 | 84 156.03 | 34.81 | -5.26 |
| Urban | 29.46 | 0.01 | 797.1 | 0.33 | 0.32 |
| Chott | 456.6 | 0.19 | 456.6 | 0.19 | 0 |

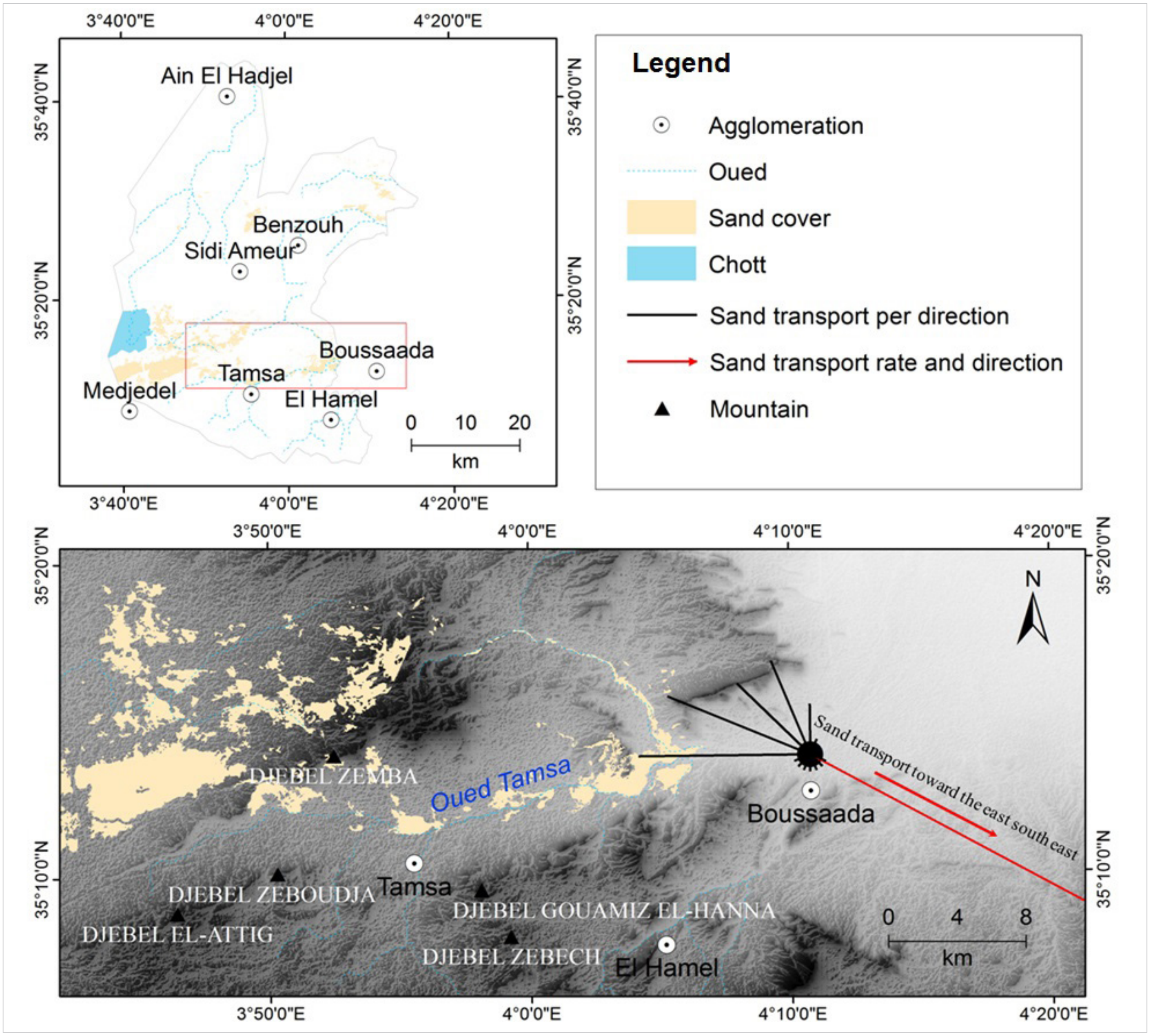


Figure 6. Sand cover distribution and transport direction in the region of Boussâda. Note that sand transport mainly comes from the western sectors and is generally oriented east southeast

Table 5. Seasonal and directional pattern of sand transport and its parameters in the region of Boussaâda for the period 2006–2015

| Sand transport parameters | Directions | Autumn | Winter | Spring | Summer | Decade (2006-2015) |
|---|---|---|---|---|---|---|
| DP (UV) | N | 10 | 15 | 24 | 9 | 58 |
| | NNE | 3 | 5 | 5 | 4 | 17 |
| | NE | 0 | 0 | 1 | 1 | 3 |
| | ENE | 0 | 0 | 1 | 0 | 2 |
| | E | 2 | 1 | 3 | 2 | 8 |
| | ESE | 2 | 2 | 4 | 3 | 11 |
| | SE | 1 | 0 | 6 | 6 | 12 |
| | SSE | 1 | 0 | 9 | 4 | 15 |
| | S | 2 | 2 | 4 | 8 | 16 |
| | SSW | 2 | 3 | 5 | 3 | 13 |
| | SW | 1 | 1 | 4 | 5 | 11 |
| | WSW | 3 | 10 | 10 | 6 | 30 |
| | W | 31 | 80 | 74 | 11 | 195 |
| | WNW | 31 | 76 | 73 | 4 | 185 |
| | NW | 14 | 52 | 47 | 4 | 117 |
| | NNW | 16 | 50 | 59 | 6 | 130 |
| | All directions | 120 | 298 | 330 | 76 | 824 |
| RDP (UV) | - | 85 | 245 | 224 | 17 | 571 |
| RDD (degree) | - | 300 | 300 | 301 | 258 | 290 |
| RDP/DP | - | 0.71 | 0.82 | 0.68 | 0.22 | 0.61 |

N: the north; NE: the northeast; NNE: the north-northeast; E: the east; ENE: the east-northeast; ESE: the east-southeast; S: the south; SE: the southeast; SSE: the south-southeast SW: the southwest; SSW: the south-southwest; WSW: the west-southwest; W: the west; WNW: the west-northwest; NW: the northwest; NNW: the north-northwest; DP: the Drift Potential; RDP: the Resultant Drift Potential; RDD: the Resultant Drift Direction

this is consistent with the findings of (Mohamadi et al., 2016) where the bare lands increased. Moreover, vegetation cover had a determinant effect on desertification (Heidarizadi et al., 2017), the low vegetation cover can directly lead to land degradation. This degradation can be explained by the combination of human and animal activities as well as the climatic factor by the irregularity of the precipitations and the arid climate that marks the study area.

Indeed, the study area is a region with a pastoral vocation; the pastoral activity exerts continuous pressure on the resources of the study area. In arid and semi-arid areas of North Africa, overgrazing is generally considered the main driver of degradation of natural ecosystems (Merdas et al., 2017; Slimani et al., 2010). The pressure of grazers is not limited to the steppe rangelands, but forest grazing is very common in this area, and this is confirmed by the presence of grazing tracks in the forests and even the existence of settlements.

In arid regions, the vegetation cover is less dense, the bare or partially exposed soil becomes vulnerable to the erosive action of water, which can remove or reduce the thickness of the topsoil and consequently the decrease in soil capacity. Mostephaoui et al. (2013), indicated that the soil loss in El Hamel district is estimated at 7 t/ha/yr. This value is considered as a low potential erosion risk (Benchettouh et al., 2017). However, there is also a loss of vegetation cover with the soil, especially where the vegetal cover consists of woody vegetation.

The rapid increase of the population caused a conquest of new lands by clearings in the short and medium term. The latter became an easy task, firstly because of mechanization (tractor plowing) which destroys the perennial vegetation and allows the appropriation of large areas. Secondly because of the total openness and facilitation of vehicle movement within the forest (Kerrache, 2011).

The cultivation of the steppe (Hourizi R., Hirche A., 2017; Yerou, 2013) by uncontrolled extension of the cereal crop, outside the traditional areas reserved for this purpose, was developed without taking into account the microclimate, the soil or the existing vegetation (Figure 5). The only criteria preventing this extension were the topography and the presence of stones on the surface (Mahyou et al., 2016).

Precipitation can have a positive effect on the quality of steppe rangelands. On the other hand, a decrease in the amount of rainfall can have a negative effect on the health of the vegetation. In arid conditions with low rainfall, rangelands in good condition can be converted into degraded rangelands. According to the National Meteorological Office, there was no rainfall recorded in April for 2014. An earlier study conducted by Merdas et al. (2017) reported a high stocking rate in the same study area. Overgrazing and population growth combined with harsh environmental conditions (shortage of rainfall) are the drivers of LULC technology in the study area. These results indicate a situation of instability due to the degradation of natural environments.

### Sand Transport

As shown in Table 5, seasonal rates of sand transport (drift potential) range from 76 VU during summer to 330 VU during spring. The net values of sand transport (RDP) oscillate between 17 VU (1.2 $m^3$/m) during the summer season and 245 VU (17 $m^3$/m) during winter. The sand transport direction (RDD) is almost uniform during autumn, winter, and spring (300 degrees). This means that sand is effectively moving according to the wind blowing from the west-northwest (WNW) toward the east southeast (ESE), except for during the summer where the RDD is about 258 degrees and consequently sand movement is directed to the east northeast (ENE). The ratio RDP/DP ranges from 0.22 in summer and 0.82 in winter, this means that sand is moving from different directions (high directional variability) during summer, compared to the other seasons which manifest sand movement according to one privileged direction (low directional variability).

For the period considered (2006–2015), the drift potential DP, resultant drift potential RDP, the resultant drift direction RDD and the ratio RDP/DP are respectively about 824 VU, 40 $m^3$/m, 290 degrees and 0.61. This indicates that the region of Boussâda is a high-energy wind environment, where important volumes of sand grains are almost uniformly transported toward the east southeast according to a Unimodal wind regime (Figure 6).

## CONCLUSION

The analysis of the changes showed that the most important regressive evolution is that of the rangelands. This class represents an indicator of the good functioning of the ecosystem in the past. The loss of 50,000 ha to bare soil indicates a stage of advanced degradation of the ecosystem. It shows that the state of stability is very much related to the class of undegraded rangelands. This finding of land-use transition can be considered an effective way for future scenarios. This reflects the importance of the conservation and rational management of steppe ecosystems. The region of western Hodna is a high energy wind environment, where significant sand fluxes from western source zones are permanently transported toward the east-southeast sectors and, this could endanger socio-economic installations downwind. Sand risk mitigation and management strategies are highly recommended.

**Ethics Committee Approval:** This study does not contain any studies performed on human or animal participants by any of the authors. Therefore, ethics committee approval was not necessary.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – S.M., N.B.; Design –S.M., N.B.; Supervision –S.M., T.M., M.B.; Materials –S.M., N.B., H.F.; Data Collection and/or Processing –S.M., N.B., H.F.; Analysis and/or Interpretation –S.M., N.B., T.M., M.B., H.F.; Literature Search - S.M., N.B., T.M., M.B., H.F.; Writing Manuscript –S.M., N.B.; Critical Review –S.M., N.B., T.M., M.B.

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Appendix 1: Confusion Matrix 1984
Overall Accuracy = (13345/13728) 97.2101%
Kappa Coefficient = 0.9648
Ground Truth (Pixels)

| Class | Woody vegetation | Sand | Bare soil | Agriculture | Alluvium | Rangeland1 | Rangeland2 | Total |
|---|---|---|---|---|---|---|---|---|
| Unclassified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Woody vegetation | 1992 | 0 | 0 | 0 | 0 | 101 | 5 | 2098 |
| Sand | 0 | 2453 | 7 | 0 | 0 | 0 | 74 | 2534 |
| Bare soil | 0 | 43 | 877 | 0 | 0 | 10 | 11 | 941 |
| Agriculture | 0 | 0 | 0 | 336 | 0 | 0 | 0 | 336 |
| Alluvium | 0 | 0 | 0 | 3 | 611 | 0 | 0 | 614 |
| Rangeland 1 | 118 | 0 | 0 | 0 | 0 | 2807 | 0 | 2925 |
| Rangeland 2 | 0 | 3 | 1 | 0 | 0 | 7 | 4269 | 4280 |
| Total | 2110 | 2499 | 885 | 339 | 611 | 2925 | 4359 | 13728 |

Appendix 2: Confusion Matrix 2014
Overall Accuracy = (11204/11548) 97.0211%
Kappa Coefficient = 0.9635
Ground Truth (Pixels)

| Class | Woody vegetation | Sand | Bare soil | Agriculture | Alluvium | Rangeland1 | Rangeland2 | Total |
|---|---|---|---|---|---|---|---|---|
| Unclassified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Woody vegetation | 890 | 0 | 2 | 1 | 0 | 32 | 0 | 925 |
| Sand | 0 | 2906 | 24 | 0 | 0 | 0 | 19 | 2949 |
| Bare soil | 8 | 21 | 2056 | 0 | 9 | 15 | 19 | 2128 |
| Agriculture | 2 | 0 | 16 | 372 | 2 | 2 | 0 | 394 |
| Alluvium | 1 | 0 | 4 | 1 | 1532 | 0 | 0 | 1538 |
| Rangeland 1 | 128 | 0 | 28 | 1 | 0 | 854 | 0 | 1011 |
| Rangeland 2 | 0 | 1 | 8 | 0 | 0 | 0 | 2594 | 2603 |
| Total | 1029 | 2928 | 2138 | 375 | 1543 | 903 | 2632 | 11548 |