A qualitative assessment of desertification change in the Tarfaya basin (Morocco) using panchromatic data of Landsat ETM+ and oli: sand encroachment approach

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Abstract. The purpose of the present work is to assess desertification change in the Tarfaya basin (Morocco) based on quantifying sand dunes mass change at the corridor scale using two Panchromatic bands of Landsat ETM+ and OLI with 15 m of resolution covering the study area for ten years (2005-2016). In this work, the sand dunes quantification is qualitative and is based on automatic extraction and classification of sand dunes shape using co-occurence texture filters and Support Vector Machine (SVM) classifier. The statistical results show that the area covered by sand was increased during the last ten years, which reveal that desertification becomes more intense.

1 Introduction

Desertification is one of the most common and severe environmental problems in the world. Approximately 42 % of the world's land surface is threatened by this phenomenon [1]. 20 % of these areas are covered by sand materials [2], which indicate an advanced stage of this phenomenon.

Quantifying desertification change with time is necessary and essential step to assess this phenomenon in order to improve the adopted fighting strategies. Mainly, several studies have shown the importance of remotely sensed data to quantify desertification change at a large scale for long and short time period. The majority of these studies have been focused on green mass (vegetation) [3-5]. Furthermore, where the sand presents a high spectral reflectance than vegetation in the desert areas (Figure 1), other studies have been concentrated on this material to quantify and track sand dunes encroachment variability with time in order to assess and track desertification [6-8].

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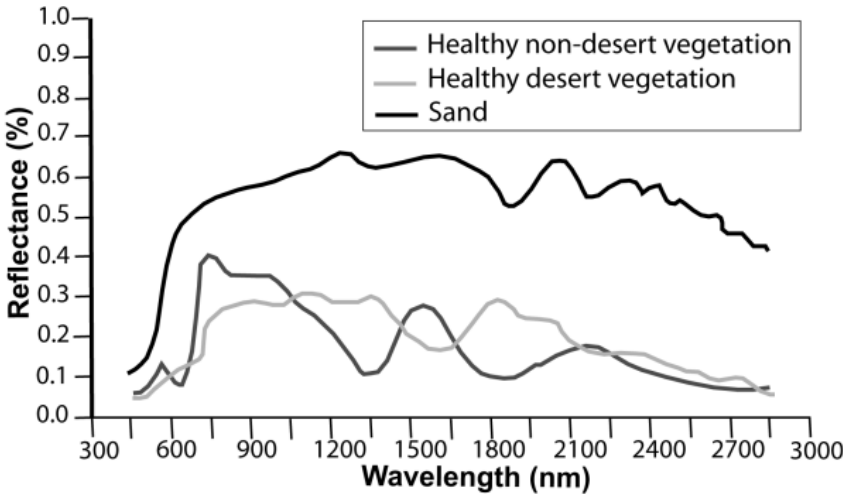

Fig. 1. Spectral response curves for healthy non-desert and desert vegetation, and sand (After [9]; in [8]).

According to [7], we can assess desertification intensity, easily from remotely sensed data, using one of the following indicators:
(i) blown sand area percentage in a region's total land area;
(ii) annual expanded area percentage of moving sand in a region's total land area;
(iii) vegetation cover percentage referring to grassland and forest land;
(iv) biomass annual reduction percentage in a region's total land area.

In this research, we used expanded sandy area indicator to quantify sand mass change in order to assess desertification change in the Tarfaya basin (Morocco). Practically, the sand mass quantification is qualitative and is based on automatic extraction and classification of sand dunes shape from two Panchromatic bands of Landsat ETM+ and OLI using co-occurence texture filters and Support Vector Machine (SVM) classifier.

2 Study area

The study area is the central dune corridor of Tarfaya basin, Morocco (Figure 2). This latter is a vast coastal platform covered by a thick Maghrebian Sandstone-Limestone flat bed (hard rock). This flagstone is overlain by movable sand dunes and broken in another place by sabkhas (Figure 2).

In this basin, the sand take origin in the beaches between Akhfinir and Tarfaya from coastal erosion [10], and is mostly transported towards the SSW in the form of barchans dunes (Figure 3), by maritime trade wind which mostly blows from NNE (Figure 3), follow three corridors of sand dunes. The eastern corridor extended from Foum Agoutir at wadi of Sakia El Hamra in south that is around 150 km in length. The shortest central corridor disappears in the Tah sabkha that is around ten kilometers in length. The western corridor is one of the longest rivers of sand in the world with 310 km in length and around 12 km in width.

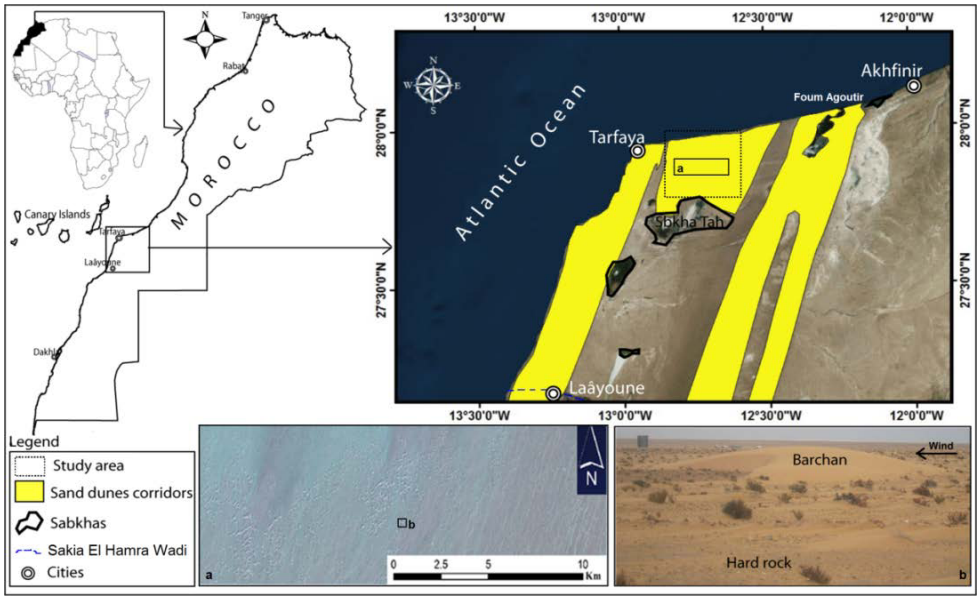

Fig. 2. Location of the study area.

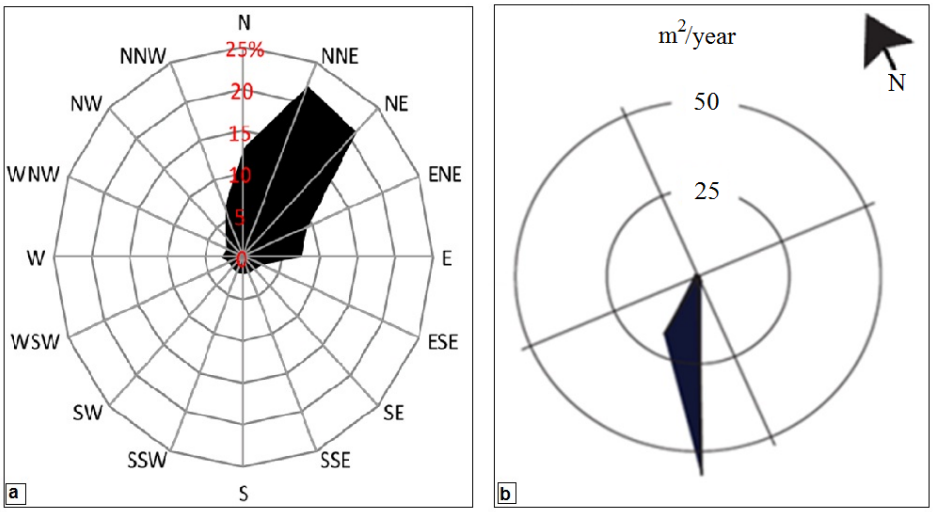

Fig. 3. Wind and sand flux roses of Tarfaya basin, a) wind rose according to [11], b) sand flux rose after [12].

3 Data and methodology

For its availability without cost and with primary process in various websites we decide to use Landsat data.

In this research, two scenes of Landsat ETM+ and OLI covering the study area for ten years (acquired in 2005 and 2016 respectively) were obtained from two different data sources at no charge, which are processed by the Level 1 Product Generation System (LPGS). These two images are geometrically and radiometrically corrected through

incorporating ground control points and Digital Elevation Model (DEM) [13]. This level of correction, called Standard Terrain Correction (Level-1T), provides a highest quality and suitable data for pixel-time series analysis [13]. For its spatial resolution (15 m), we used Panchromatic bands of these scenes to create this study. Table 1 lists the characteristics of used data sets including capture, sensor, acquisition date, data type, and data source.

Table 1. Data set characteristics.

Satellite	Sensor	Acquisition date	Data type	Data source
Landsat 7	Enhanced Thematic Mapper Plus (ETM^{+})	31.12.2005	L1T	Global Land Cover Facility (GLCF)
Landsat 8	Operational Land Imager (OLI)	27.01.2016	L1T	United States Geological Survey EarthExplorer (USGS EE)

The aim of the present work is to assess desertification change in the Tarfaya basin based on quantifying expanded sandy area from 2005 to 2016 at central corridor scale. The sand quantification is based on automatic extraction and classification of sand dunes shape. The detail of methodology applied in this study is presented in Figure 4. The all steps cited in this methodology were achieved using ENVI® software.

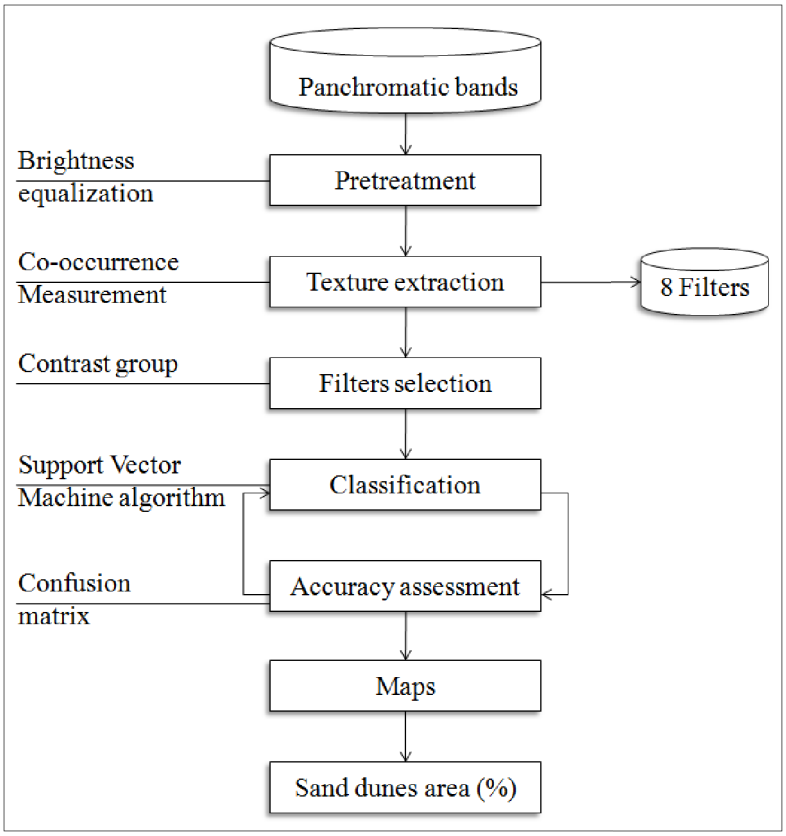

Fig. 4. Flow chart showing the steps used in this work.

Firstly, in term of improving bands visualization the interactive stretching and histogram matching were used. The sand dunes shapes extraction is the second step; it was achieved by applying co-occurrence measurement algorithm. This algorithm provides eight filters according three groups: contrast group (contrast, homogeneity and dissimilarity), orderliness group (angular second moment and entropy) and statistics group (mean, variance and correlation). The third step involves combining contrast group filters (Figure 5). The classification is the next step; it was adopted for same data sets of combined filters by delimiting polygons around barchans (sand dunes) and space between them (hard rock) (Figure 6), and was executed using Support Vector Machine (SVM) classifier. The classification accuracy assessment is the next step; it was realized by confusion matrix by which six parameters were computed: User's Accuracy (UA), Producer's Accuracy (PA), Commission Errors (CO), Omission Errors (OE), Overall Accuracy (OA) and Kappa Coefficient (K). In order to obtain the good results the two last steps were repeated. The sand dunes area was calculated from final classified maps of 2005 and 2016. The desertification change is difference of sandy area computed from both classified maps.

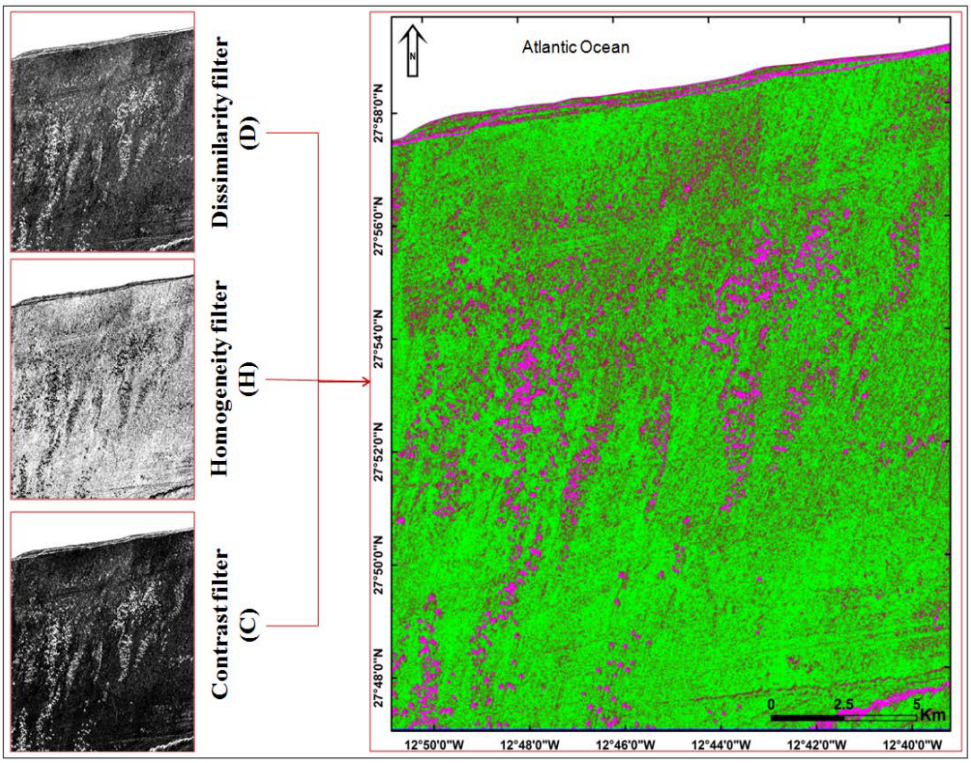

Fig. 5. Utilized filters, RGB: DHC.

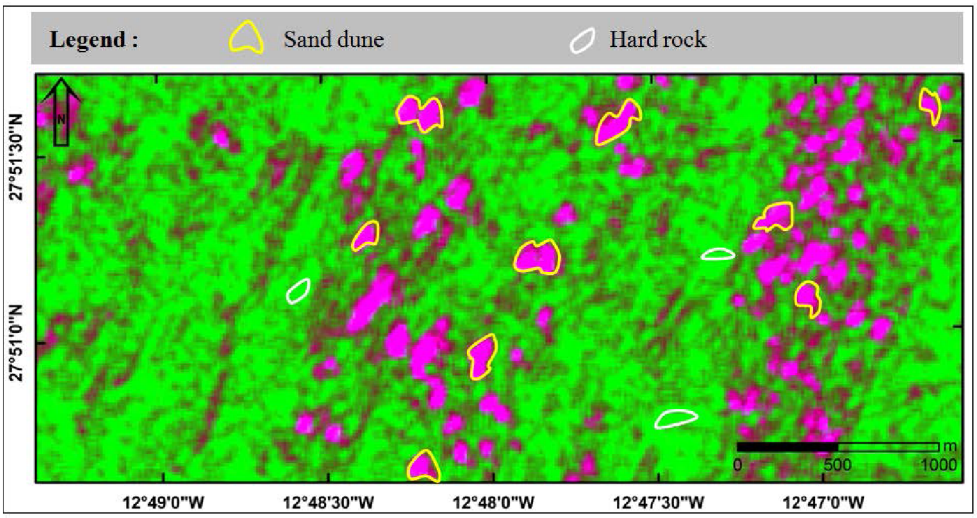

Fig. 6. Example of test areas used for classification.

4 Results and discussion

The classification maps from Panchromatic bands of Landsat ETM^{+} and OLI are shown in Figure 7. The accuracy statistics of these classifications are shown in Table 2.

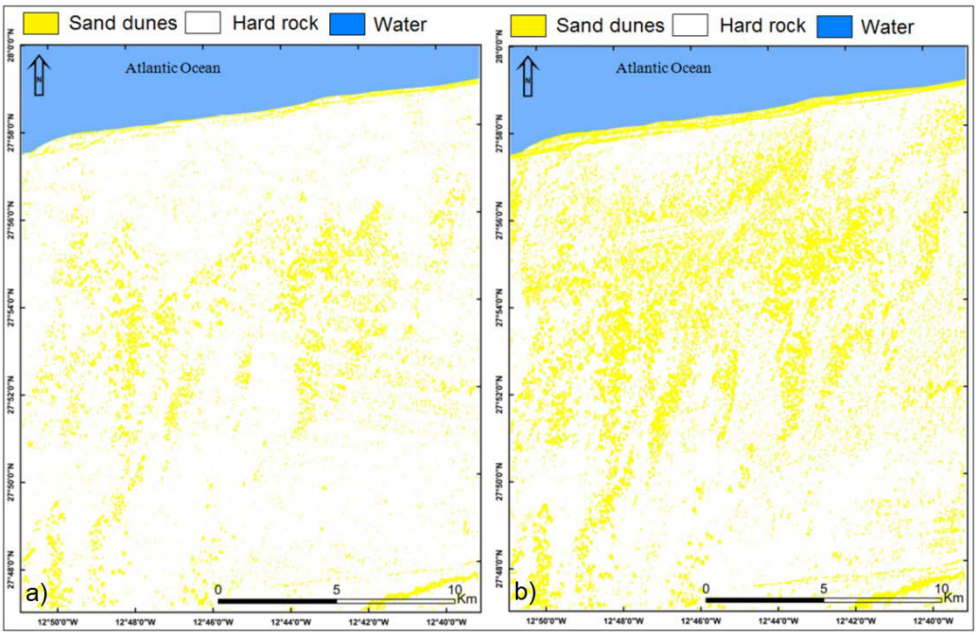

Fig. 7. Final version of classified maps for the years: a) 2005 and b) 2016.

Table 2. Accuracy statistics for the final version classified maps. UA: User's Accuracy, PA: Producer's Accuracy, CO: Commission Errors, OE: Omission Errors, OA: Overall Accuracy, and K: Kappa Coefficient.

		Sand(%)	Hard rock(%)	UA(%)	PA(%)	CE(%)	OE(%)	OA(%)	K
Map 2005	Sand(%)	97.20	0.25	99.49	97.20	0.51	2.80	98.8	0.97
	Hard rock(%)	2.80	99.75	98.62	99.75	1.38	0.25		
Map 2016	Sand(%)	99.96	1.59	98.11	99.96	1.89	0.04	99.1	0.98
	Hard rock(%)	0.04	98.41	99.96	98.41	0.04	1.59		

To ensure that the classification results are dependable and acceptable for evaluating change their overall accuracies must be higher than 85% [14]. In this work, the overall accuracy exceeds 98% for both classification maps, which meet the limit for classification results acceptance. This accuracy explained by clarity of lithological data in the study area (desert zone). However, even if the classifications indicate a very high Kappa coefficient for the both maps (equal 0.97 and 0.98 for the years 2005 and 2016 respectively), the commission and omission errors point out low rates of misclassification (Table 2). This later may be explained by the sand incorporation in the small fissures observed on the hard rock surface.

A closer observation on the classified maps reveals an increase of surface covered by sand dunes and a decrease of surface occupied by hard rock. The detail of sand dunes and hard rock surfaces change for the years 2005 and 2016 is shown in Figure 8.

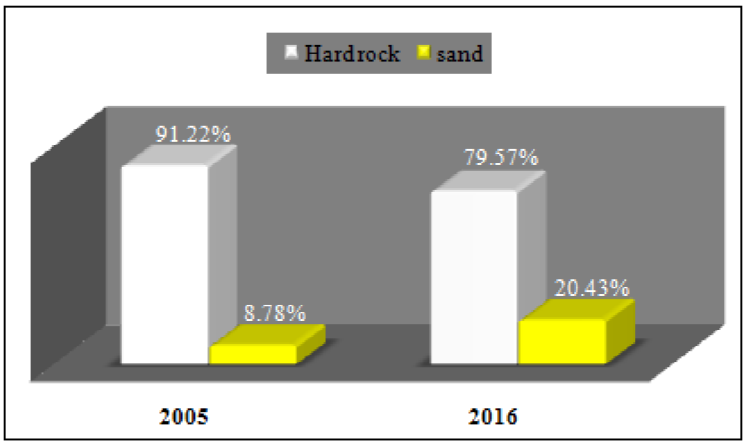

Fig. 8. Percentages of surface covered by sand dunes and hard rock for the years 2005 and 2016.

The sand dunes were covered 8.78% and 20.43% of the total zone respectively in 2005 and 2016, which indicate that the surface occupied by these dunes was increased by 11.65% during the last ten years. The sand dunes increasing indicate that desertification becomes more intense in the study area.

The hard rock was decreased by same value of sand dunes increasing, which was occupied 91.22% in 2005 and 79.57% in 2016. The hard rock change is in relation with sand dunes contribution.

According to [10], the sand dunes increasing is partially due by marine contributions, which is indicated by an active coastal erosion and by a decrease of suspended sediments in the sea surface, and mainly attributable to the continental contributions which is manifested

by erosion of composed sand dunes and by barchans migration towards the interior of the continent.

5 Conclusions

The aim of this study is to assess desertification change during the last ten years in the Tarfaya basin (Morocco) through assessment of sand dunes expansion using Panchromatic bands of Landsat ETM^+ and OLI collected in 2005 and 2016, respectively. In this work, the classification technique was used after sand dunes automatic extraction using co-occurence texture filters.

The results show that the area covered by sand dunes has increased between 2005 and 2016 by 11.65%, which indicate that desertification becomes more intense in the last ten years. Those findings emphasize the need for improving the old techniques or proposing a new strategy to fight against this problem.

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