A new method to determine eroded areas in arid environment using Landsat satellite imagery

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Abstract. Erosion (by water or wind) is an increasing problem for many local authorities and government agencies throughout the world. The identification of eroded areas in arid and humid regions can be very useful for environmental planning and can help reduce soil and sediment degradation in these regions. In this work we present a new method to determine eroded areas in arid environment. In this method were explored lithological data to determine eroded areas. These data were collected in the field using GPS (Global Positioning System) checkpoints and geological maps. For that, two lithological maps of the study areas were analysed to determine lithological data change. Those two maps were obtained from the classification algorithm by applying the maximum likelihood on two Landsat satellite images. After images classification and validation a change detection technique was adopted to determine eroded areas. This method was applied in northern part of Atlantic Sahara desert to confirm their potentiality.

1. Introduction

Erosion is any process, natural or man-made, by which material is removed from one location and deposited in another. In order for erosion to occur, an erodible material must be exposed to some form of energy or eroding force. Erosion is one of the principal mechanisms of desertification at national and regional levels. Is an increasing problem for many local authorities and government agencies throughout the world. The identification of eroded areas in national and regional levels can be very useful for environmental planning and can help reduce soil and sediment degradation in this region.
The use of remote sensing techniques has been shown to have potential for identification of eroded surfaces on regional scales [1, 2, 3, 4, 5, 6, 7]. Several methodologies applied to mapping of erosion area include spectral data [3, 5, 8], vegetation indices [2, 9, 10] and combinations of remote sensing and morphological data [11].

The Landsat Thematic Mapper (TM) and the Enhanced Thematic Mapper (ETM+) have been used to monitory changes in landforms and land degradation mechanisms [12], and forest cover change and deforestation mechanisms [13, 14]. Further, Many studies have shown the importance of Landsat imagery for lithological mapping in arid environment [15, 16]. No studies explored the litholigical data to define eroded areas.

The arid environment cover more than one fifth of the Earth's land, and they are found on every continent. These areas exist under a moisture deficit, which means they can frequently lose more

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moisture through evaporation than they receive from annual precipitation. When vegetation cover is scarce and soil and sediments are clear were explored lithological data to determine eroded areas in these zones.

2. Methodology

The methodology for this study is shown in Figure 1. In this method were explored lithological data to determine eroded areas. These data were collected in the field using GPS (Global Positioning System) checkpoints and geological maps. For that, two lithological maps of the study areas were analysed to determine lithological data change. Those two maps were obtained from the classification algorithm by applying the maximum likelihood on two Landsat satellite images. This classification was adopted for both sets of Landsat images by delimiting polygons around representative points collected in field. After images classification and validation a change detection technique was adopted to determine eroded areas.

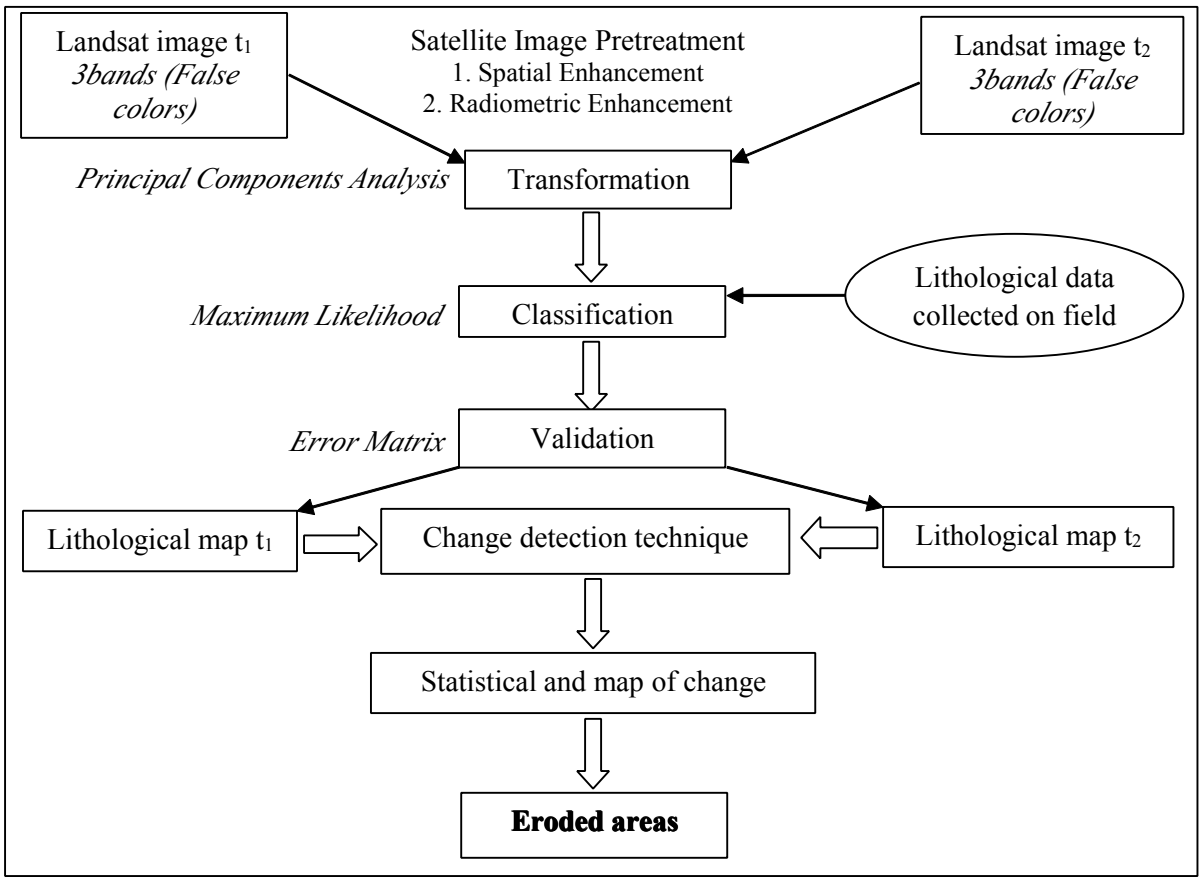

Figure 1. The methodology of this study.

3. Case of study: A northern part of Atlantic Sahara desert (SW of Morocco)

3.1. Study area

The study area is located in northern of Sahara Atlantic (SW of Morocco). It is a vast coastal platform, extending from 12°0′ 35″ to 12°23′ 55″W in longitude and 27°53′ 6″ to 28°8′ 27″N in latitude (figure 2).

Climatically, this region is a part of the Boreal domain of maritime trade winds, where precipitation is less than potential evapotranspiration. This wind is one of the most regular winds in the world [17]. Thus, the dry season extends for about 12 months. The amount of precipitation is about 33 mm per year. The yearly mean maximum air temperature is 26 °C and the yearly mean minimum air temperature is 19 °C. The extreme aridity of this area is primarily caused by large-scale atmospheric subsidence due to the Açores anticyclone.

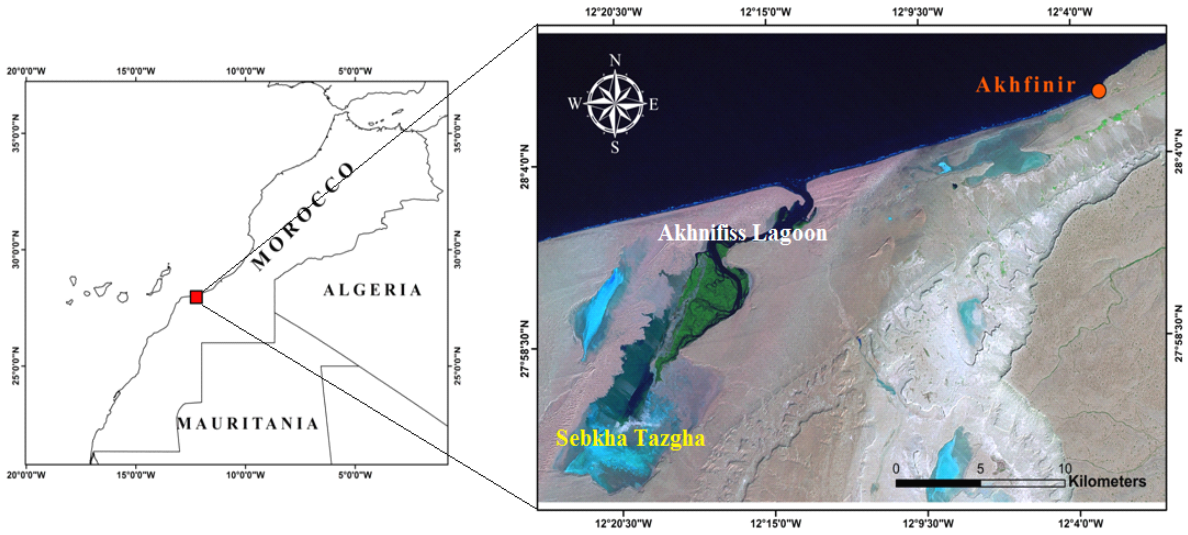

Figure 2. Location map of the study area.

3.2. Lithological data

The surface of the Akhfinir region is dominated by flat layering of hard rocks at the surface (Moghrebian Sandstone-Limestone Slab). This flagstone, is overlain by Pleistocene consolidated dunes, and broken, in another place, by sabkha depression where Miocene marls and silts were deposed. Ideally the surface lithology interpretation is validated in the field using GPS checkpoints and geological maps.

In this region eight facies were distinguished: sand, beach rocks, salt crust, sand-limestone slab, alluvium facies, marl and silt, limestone, and mud. Description of theses facies classes are presented in Table 1.

Table 1. Description of different facies classes of the study area.

Class	Description
Sand	is principal component of dunes
Salt crust	is sabkha components, is sand and clay cimented by the alkaline minerals
Beach rocks	is Pliocene terrigenous sandstones facies
Sand-limestone slab	is a hard rocks Moghrebian facies
Alluvium facies	is part of the recent Pleistocene sediments, are conglomeratics sand
Marl and silt	are Miocene transgressive deposit of sabkhas
Limestone	is Senonian (Later Cretaceous) transgressive deposit
mud	is a principal component, with sand, in mudflats and salt marshes

3.3. Results

The results of classification are shown in figure 3 and 4. The results obtained from the application of confusion matrix to the validation data show that all of the facies are better classified, with a high overall prediction accuracy, and low rates of both commission and omission errors.

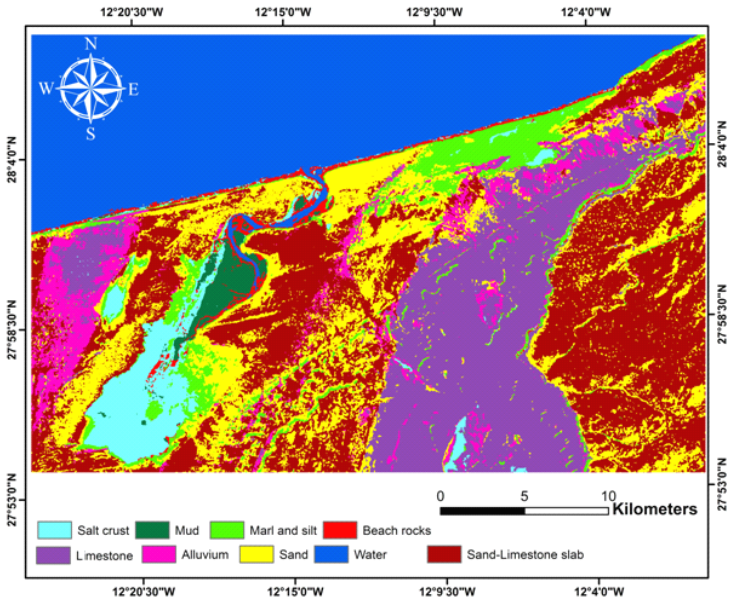

Figure 3. Lithological map of study area after classification using Landsat TM 1987.

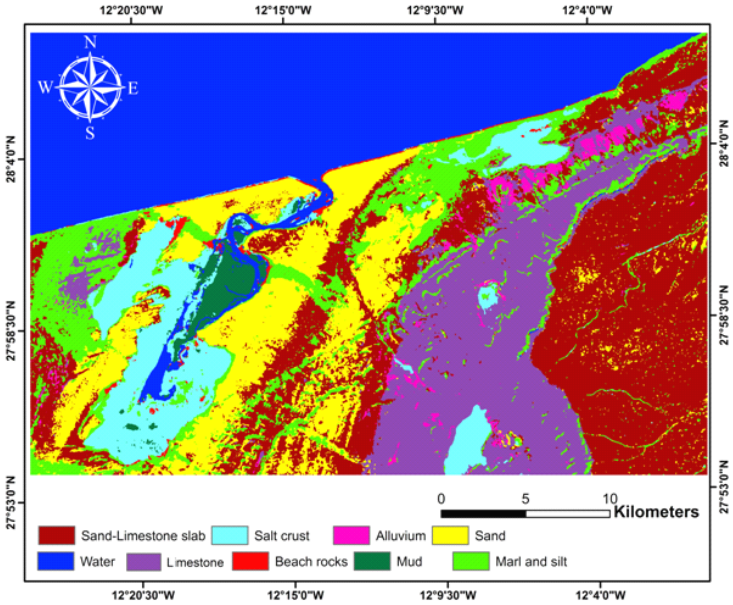

Figure 4. Lithological map of study area after classification using Landsat ETM 2011.

A change detection statistics and the difference map operations were carried out for the classification results of 1987 and 2011 images in order to produce the statistical data about the spatial distribution of different lithological classes (table 2) and a eroded areas map (figure 5). Examination of statistical change (table 2) is beneficial to ascertain the reasons behind the observed changes.

Table 2. Change in lithological classes between 1987 and 2011 (unit: Km^2). Classes signification 1: Water, 2: Limestone, 3: Salt crust, 4: Alluvium, 5: Mud, 6: Sand, 7: Marl and silt, 8: Beach rocks, 9: Sand-Limestone slab.

		1987									
		1	2	3	4	5	6	7	8	9	Sum
2011	1	279.11	0.92	0	4.72	0	1.18	0.41	9.03	0	295.37
	2	0	138.01	0.3	5.13	0	5.16	0.73	0.03	0.41	149.77
	3	0.03	4.39	29.07	3.09	0.56	8.19	18.77	1.24	8.74	74.08
	4	0	5.62	0	7.22	0	0.73	0.03	0	0.26	13.86
	5	0	0	1.72	0	10.5	0.02	0.22	0.79	0.03	13.28
	6	0.01	0.43	5.36	0.62	1.22	65.6	2.42	0.22	59.77	135.65
	7	0.02	13.74	2.8	22.76	0.06	15.68	29.19	0.35	18.37	102.97
	8	0.07	0.01	0.82	0.01	0.1	1.22	2.42	1.25	0.77	6.67
	9	0	6.15	0.21	16.69	0	26.81	1.25	0.01	174.24	225.36
	Sum	279.24	169.27	40.28	60.24	12.44	124.59	55.44	12.92	262.59	
Change		16.13	-19.5	33.8	-46.38	0.84	11.01	47.53	-6.25	-37.23	

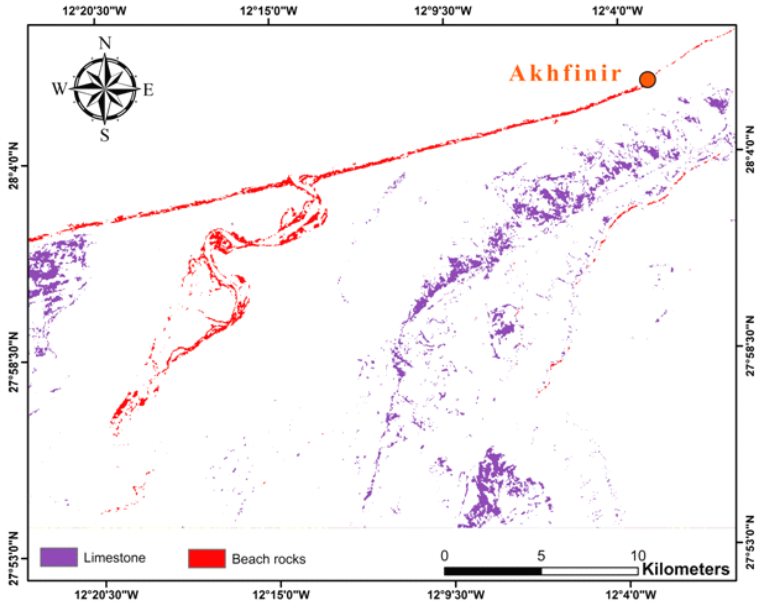

Figure 5. Eroded areas in region of study.

4. Conclusion

The objective of this study was to determine eroded areas in arid environment using new method based on lithological changing data. In this study a change detection technique was applied on two classified lithological map to provide eroded areas map. Further, the statistical change results were beneficial to ascertain the reasons behind the observed changes.

The results of application of this method in northern part of Atlantic Sahara desert confirm their potentiality. The obtained erosion map could be used as a decision tool for sediment erosion management.

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