Land cover changes in the Ksob watershed (Western High Atlas, Morocco) using remote sensing techniques.

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Abstract— This paper deals with a large-scale case study on the Ksob watershed located in the Western High Atlas of Morocco with the aim to evaluate vegetation changes and to determine the more accurate land use land cover detection technique. Maximum likelihood classification (MLC) and NDVI differencing technique were applied to Landsat images acquired in 1988, 2010 and 2014 respectively. As a result, the overall accuracy achieved 100% using MLC while it doesn't exceed 58% using NDVI method. By applying the MLC method using GIS interface, spatial and temporal dynamics of land cover changes were quantified. The results indicate an increase of barren lands from 1988 to 2010 while vegetated land have been increased from 2010 to 2014. The decrease of barren area in the last four years highlights the importance of the climatic conditions, the implementation of the new Dam and the reforestation plan carried out.

Index Terms— Arid and semi-arid regions, GIS, Ksob watershed, land cover, Morocco, remote sensing.

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1 INTRODUCTION

THE use of remotely sensed data as input data for environmental process modeling and in mapping of natural resources played a key role in developing cost-effective methods to detect and monitor modifications at various scales [1], [2]. It has a high potential for producing indicators, which consider the basic requirements of science [3]. Notwithstanding, after three decades of remote sensing advancements, still there is a need for standardized data processing techniques that may take into account the special properties of remote sensing datasets [4].

The application of remotely sensed data allowed to study at low cost, in less time the variations in land cover with better accuracy [5] in association with GIS which provides an important platform for the analysis and the update of data [6], [7] . In this field, Normalized Difference Vegetation Index (NDVI) represents a popular technique used to indicate vegetation covering the earth's surface and crop growth status [8]. It is the example of the most common vegetation indices used to analyze in image processing the green cover of photosynthetic vegetation.

However, further analysis are required to determine the usefulness of the NDVI to estimate land cover when a high heterogeneity exists in the study area [9]. In arid and semi-arid regions which cover more than 30% of the total surface of the Earth's land, variable and low vegetation are typical features [10]. These characteristics lead to the necessity to assess the suitability of the NDVI in arid and semi-arid regions that present dry land areas characterized by high hydrological sensitivity to variations in their environment and where drought results in sets of socio-economic impacts.

In semi-arid environments, the abundance of low level of vegetation affords limited protection of the poorly developed soils, resulting in serious land degradation and severe erosional processes [11]. In addition, over the last decades, available water resources are becoming progressively scarce while water demand has significantly increased [12]. With this intense stress on the water balance, the management of local vulnerable resources has been required [13]. Reservoirs are one way to face with water scarcity by increasing storage capacity [14]. Dams of various sizes have been constructed in order to store water that flowed out to the sea and to mitigate flood hazards [13]. Unfortunately, the lifetime of small dams could vary between 5 and 20 years because of silting, and it is expected to be more than 100 years for large dams which accentuates the necessity to manage the processes of sedimentation [15], [16]. The potential for soil erosion is directly affected by land use, a slight land use change had a significant impact on erosion rates and sediment supply to rivers [17]. Therefore, adequate indicators of land cover variations need to be defined in semi-arid regions [18]. Also, understanding the influence of anthropogenic factors on landscape modifications and affording decision makers with reliable information on the environment status become crucial [3].

The Ksob watershed located in the Western High Atlas of Morocco represents a good example that illustrates the previously mentioned problems. This watershed is an ideal site for studying vegetation change in a semi-arid region because it suffers from aggressive erosion especially in frequent storm periods when the main river (Ksob River) is affected by violent floods that are short in duration [19]. To prevent the damage caused by these floods and to improve water resource management in this area, a dam (Zerrar

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Dam), absolutely threatened by the silting problem resulted from soil erosion, is recently implemented (2013). Therefore, it is important to study vegetation cover that plays a capital role by protecting the soil surface. For this purpose, NDVI and supervised classification technique (Maximum Likelihood Classification: MLC) were applied to three Landsat images.

Based on capital reforestation plans adopted by HCEFLCD and drought periods in the study area, the chosen Landsat images used correspond to November 1988, November 2010 and December 2014. Thus, this study has a dual objective: 1) to analyze land cover changes in Ksob watershed in order to evaluate vegetation changes and to determine their controlling factors for more suitable development policies, 2) to assess the usefulness of the NDVI comparing with MLC in land use land cover changes study within Ksob watershed and in the arid to semi-arid regions in general by comparing the results obtained with other studies.

2 Study area

The study area, Ksob watershed, is a mountainous catchment located in the extreme western part of the High Atlas (central Morocco). It has an area of 1520 km2 that lie between 9° and 9°46’ W longitude and 31°2’ and 31°30’ N latitude (Fig.1). The catchment elevation ranges from 50 to 1702 m above sea level (Fig.2-A) with the presence of steep slopes (Fig 2-B). The climate is arid to semi-arid characterized by an annual average temperature of 20 °C, an irregular rainfall and long periods of droughts. The monthly rainfall pattern showed a highly temporal variability with an average of approximately 300mm / year mainly received in November (Tensift Water Basin Agency data). Evenly, the spatial distribution is variable; the low values are abundant in the central part of the study site comparing with the south (high altitudes) and the north (coastal area) where the high rainfall values are concentrated (Fig.2-C). Regarding the soil cover, calcareous soils, isohumic soils, lithosols and regosols are the main soil series (Fig.2-D). All these characteristics (erodible soils, sloping terrain and high-intensity of rainfall) lead to high soil erosion and frequent floods mainly occurred in winter when Ksob River discharge can reach 20.61 g / l (Tensift Water Basin Agency data). Thus, maintaining permanent vegetation cover in this catchment is one of the most important measures to control erosion and to protect the Zerrar Dam recently implemented in order to improve water resource management and to prevent the damage caused by floods downstream of this area. Therefore, it is necessary to determine the most reliable methodology to evaluate vegetation changes and their influencing factors.

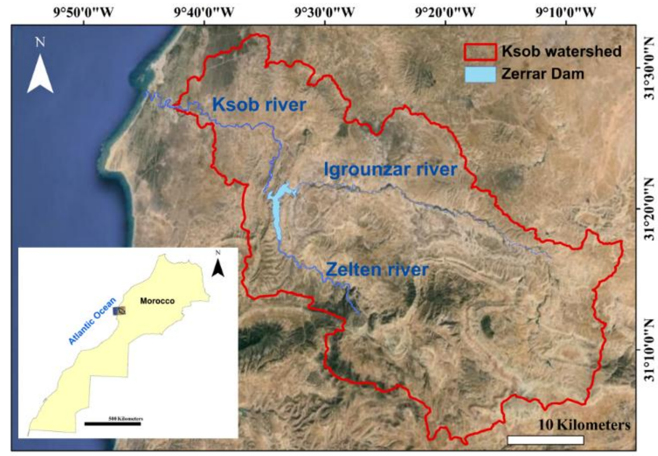

Fig.1: Ksob watershed location.

3 Methodology

The basic premise in employing remote sensing data for detection of changes consist in that land cover variations must result in the variations in radiance values and changes in radiance is a result of land cover change [20]. Changes in radiance are also affected by differences in atmospheric conditions, in sun angle and in soil moisture [21]. This inconvenient could be reduced using Landsat imagery captured in a similar time of the year and reported as reflectance values [22]. In the present work, Landsat images acquired in the same period (i.e. november 1988, november 2010 and december 2014) have been used.

3.1 Preprocessing

The Landsat 5 Thematic Mapper (TM) images acquired on november 1988 and 2010 and Landsat 8 OLI (Operational Land Imager) image acquired on december 2014 (Tab. 1 and 2) are atmospherically corrected using the dark object subtraction method after the calculation of the radiance. In this study, OLI Bands 1, 2, 9 and TM band 1 are not used. Bands 1 are generally used for atmospheric scattering, OLI band 2 is intended for retrieving atmospheric aerosol properties and band 9 is intended for cloud detection [23].

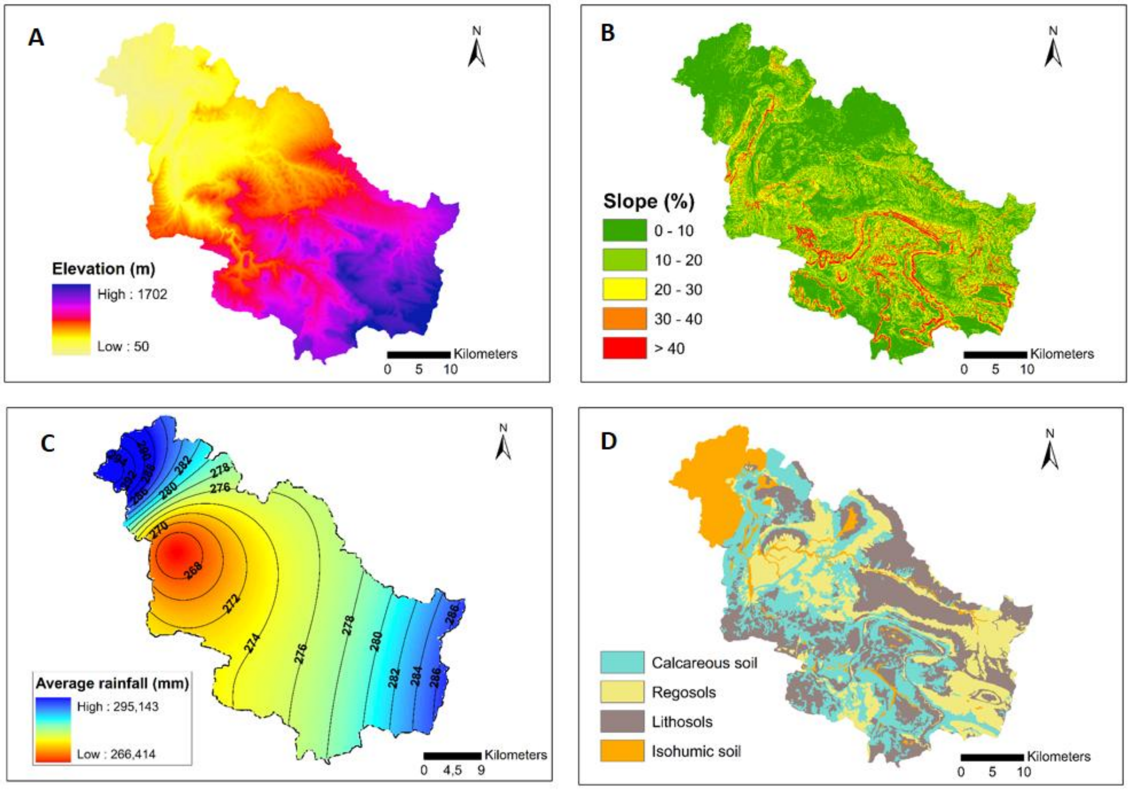

Fig.2 Elevation (A), slope (B), spatial rainfall distribution (C) and soil types (D) within Ksob watershed

TABLE 1
THE CHARACTERISTICS TM IMAGES LANDSAT 5 SATELLITE [24].

Band	Name	Wavelengths (µm)	Spatial Resolution
1	Blue	0.45-0.515	30 m
2	Green	0.525-0.605	30 m
3	Red	0.63-0.69	30 m
4	Near Infrared	0.75-0.90	30 m
5	Shortwave IR-1	1.55-1.75	30 m
6	Thermal IR	10.4-12.5	60 m / 120 m
7	Shortwave IR-2	2.09-2.35	30 m

TABLE 2
THE CHARACTERISTICS OLI IMAGES LANDSAT 8 SATELLITE [25].

Band	Name	Wavelengths (µm)	Spatial resolution
1	Blue	0.43 to 0.45	30 m
2	Blue	0.45 to 0.51	30 m
3	Green	0.53 to 0.59	30 m
4	Red	0.64 to 0.67	30 m
5	NIR	0.85 to 0.88	30 m
6	SWIR 1	1.57 to 1.65	30 m
7	SWIR 2	2.11 to 2.29	30 m
8	Panchromatic	0.50 to 0.68	15 m
9	Cirrus	1.36 to 1.38	30 m

3.2 Processing

Temporal changes were determined using both the Maximum Likelihood Classifier (MLC) and the Normalized Difference Vegetation Index (NDVI).

The MLC is one of the most popular supervised classification methods employed with remote sensing image data. This parametric classifier depends on the second-order statistics of a Gaussian probability density function model for every class [26]. This classification considers that the statistics for a particular class in each band are normally distributed and calculates the probability that a given pixel corresponds to a precise class [27].

The NDVI normally computes the normalized difference of brightness values for data of imagery as shown in equation (1) [8]. It is a ratio from −1 to +1; values <0 represent surfaces that contain no chlorophyll, while values >0 rise with increasing chlorophyll [28]. It was developed to estimate the green biomass inside study area [29].

$$NDVI = NIR - RED/NIR + RED \quad (1)$$

Where RED is visible red reflectance, and NIR is near infrared reflectance.

The NDVI change (ΔNDVI) is calculated using equation (2) by subtracting the NDVI value of the earlier year (t −1) from the value of the later year (t) [30].

$$\Delta NDV = NDVI(t) - NDVI(t-1) \quad (2)$$

4 RESULTS

Land-cover maps for each year were prepared independently. Maps obtained from the MLC are shown in Fig.4-A and the results of the NDVI differencing method are shown in Fig.4-B.

4.1 MLC results

The corrected Landsat images were classified employing spectral signatures from training sites that include all the land-cover types (Fig.3). Classes of the resulting images were recoded into five land cover classes: barren, sparse vegetation, moderately dense vegetation, dense vegetation and water. To evaluate the accuracy of the classification procedure, an accuracy assessment analysis was necessary. The validation of the classification is achieved by calculating the confusion matrix (Tab. 3, 4 and 5).The overall accuracy for the years 1988, 2010 and 2014 is 100%, 99.69% and 100% respectively, with Kappa values of 1, 0.99 and 1 respectively. These values assure the quality of the thematic maps obtained. In addition, these results were supported by field data, aerial photos and Google earth imagery.

4.2 NDVI results

The calculation of the NDVI index provides vegetation distribution for each year. Four land cover types are identified in the study site: barren land, sparse vegetation, moderately dense vegetation and dense vegetation (Fig. 4-B). In the NDVI differencing method, the identification of threshold for detection of vegetation changes is a basic issue [31]. And as it is mentioned by Cakir et al. [32], the difference image usually yields a brightness values (BV) distribution which is approximately Gaussian in nature, while pixels of no BV change are distributed around the mean and pixels of variation are found in the tails of the distribution. Accordingly in most studies, threshold values are set to equal distances from the mean BV of the difference image (e.g., ±1 standard deviation from the mean) [33]. In this study, the ΔNDVI images (Fig .5) were reclassified using a threshold value calculated as $\mu \pm n \cdot \sigma$; where μ represents the NDVI pixels digital number mean, the n factor defines the range of dispersion around the mean and σ the standard deviation. The best accuracy was acquired using a threshold of $2*\sigma$ for the period 1988-2010 and $1.5*\sigma$ concerning the period from 2010 to 2014 (Tab. 6). The overall accuracy values obtained (Tab.6) confirmed that the supervised classification was significantly better in comparison to the NDVI differencing method.

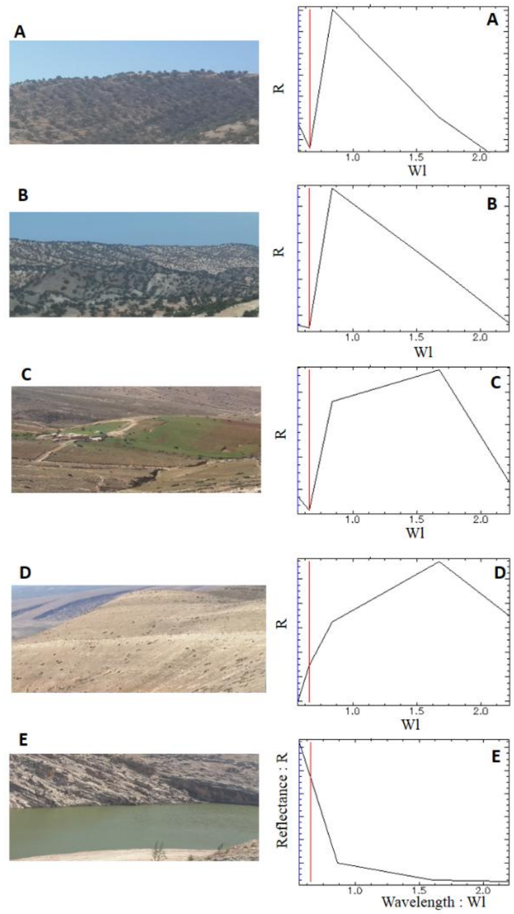

Fig.3: Spectral signatures corresponding to different land cover within study area: dense vegetation (A), moderately dense vegetation (B), Sparse vegetation (C), barren (D), water (E)

TABLE 3
LAND COVER CONFUSION MATRIX OF KSOB WATERSHED (NOVEMBER 1988) BY LANDSAT IMAGERY

Class	Barren	Sparse	Moderate	Dense
Barren	100.00	0.00	0.00	0.00
Sparse	0.00	100.00	0.00	0.00
Moderate	0.00	0.00	100.00	0.00
Dense	0.00	0.00	0.00	100.00
Total	100.00	100.00	100.00	100.00

Overall Accuracy = 100.0000%
Kappa Coefficient = 1.0000

TABLE 4
LAND COVER CONFUSION MATRIX OF KSOB WATERSHED (NOVEMBER 2010) BY LANDSAT IMAGERY

Class	Barren	Sparse	Moderate	Dense
Barren	100.00	0.00	0.00	0.00
Sparse	0.00	99.75	0.00	0.00
Moderate	0.00	0.25	99.06	0.00
Dense	0.00	0.00	0.94	100.00
Total	100.00	100.00	100.00	100.00

Overall Accuracy = 99.6840%
Kappa Coefficient = 0.9942

TABLE 5
LAND COVER CONFUSION MATRIX OF KSOB WATERSHED (DECEMBER 2014) BY LANDSAT IMAGERY

Class	Barren	Sparse	Moderate	Dense	water
Barren	100.00	0.00	0.00	0.00	0.00
Sparse	0.00	100.00	0.00	0.00	0.00
Moderate	0.00	0.00	100.00	0.00	0.00
Dense	0.00	0.00	0.00	100.00	0.00
water	0.00	0.00	0.00	0.00	100.00
Total	100.00	100.00	100.00	100.00	100.00

Overall Accuracy = 100.0000%

Kappa Coefficient = 1.0000

TABLE 6
THRESHOLD VALUE ACCURACY ASSESSMENTS (OVERALL ACCURACY %)

	1σ	1,5σ	2σ
1988-2010	41	46.5	50
2010-2014	50	58	46

The comparison of the results obtained by these two different methods shows an obvious difference in the temporal variation (Fig. 6 and Tab.7)

TABLE 7
VEGETATION AND BARREN PERCENTAGES USING THE MLC AND THE NDVI

	MLC		NDVI	
	Barren (%)	Vegetation (%)	Barren (%)	Vegetation (%)
1988	25	75	31	69
2010	31	69	50	50
2014	23	77	20	80

5 DISCUSSION

5.1 NDVI usefulness

According to Anderson et al. [34], the United States Geological Survey's proposed an accuracy level of 85% as the minimum requirement for land use / cover mapping with Landsat data. This indicates that the maps obtained by applying NDVI differencing method in Ksob watershed are not sufficiently accurate for the analysis of land / canopy cover changes as the accuracy assessment doesn't exceed 58%. The same results are obtained in the desert region of the West Delta in Egypt, where NDVI results were not fitted, the produced image for the year 2008 has an accuracy assessment of 77% only [35]. Also, accuracy assessment of the use of NDVI in Khalkhal County (Iran) showed that NDVI was not suitable for canopy / land cover mapping [9]. In other side, the results obtained using NDVI in the Ban Don bay in Thailand [36], the Northern Eurasian grain belt in Russia [37], the Tamil Nadu in India [8] and in Basilicata in southern Italy [32] attest that NDVI provides a reliable identification of vegetation changes with high accuracy. As an example, in the Ban Don bay, the Kappa coefficient index calculated exceed 0.90. The following comparisons proves that in humid areas, NDVI is strongly correlated with vegetation dynamics [38] while in semi-arid and arid environments, vegetation canopies do not carry out whole coverage, making NDVI vulnerable to the spectral influence of the soil and the influence of the soil moisture [39], [40]. This can be defined by the fact that immature crops that show low density cover could be confused with poor crops [41] and as it is mentioned by Simonneaux et al., in NDVI image, young plantations are not detected and do not present high values while they consume less water than older ones [42]. Accordingly, NDVI appears to be a weak indicator of vegetation when it is low, as is the case in semi-arid and arid regions [43]. However, although its disadvantages that are discussed by several authors [44], [45], [46], [47], [48], studies examining seasonal and inter-annual behavior of different vegetation types [39], [49], [50], [51] demonstrated that the vegetation signal is discernible through inspection of NDVI time series. These authors achieved that fixed measurement areas normalize the soil background impact so that meaningful vegetation signals can be distinguished demonstrating a successful use of NDVI in arid and semi-arid environments [52]. Consequently, by combining all these results, we may deduce that NDVI can be employed in arid and semi-arid regions with limitations.

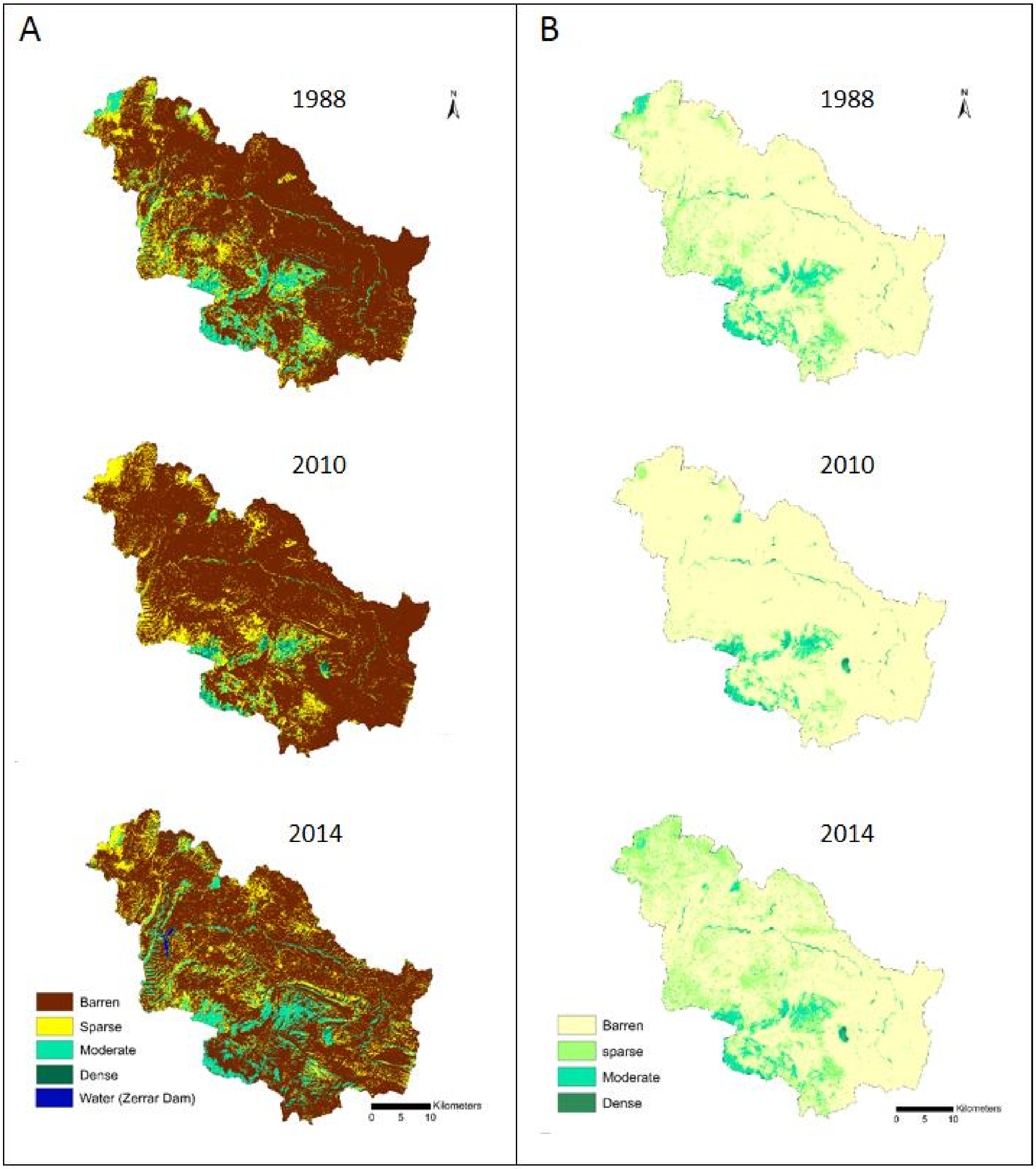

Fig. 4: Land cover maps using MLC (A) and NDVI (B) methods

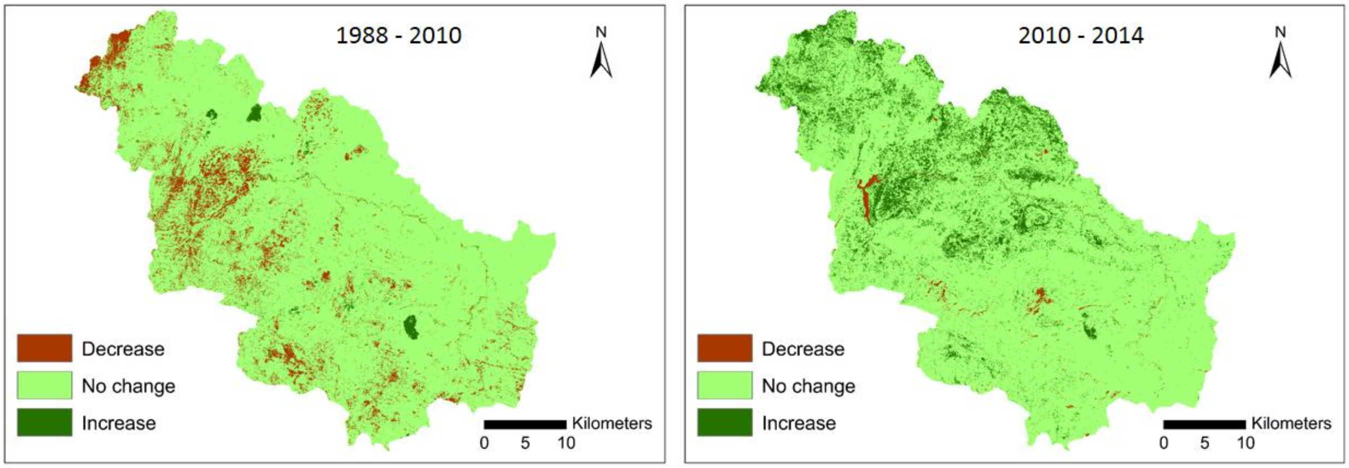

Fig.5 Vegetation changes within Ksob catchment using NDVI differencing Method

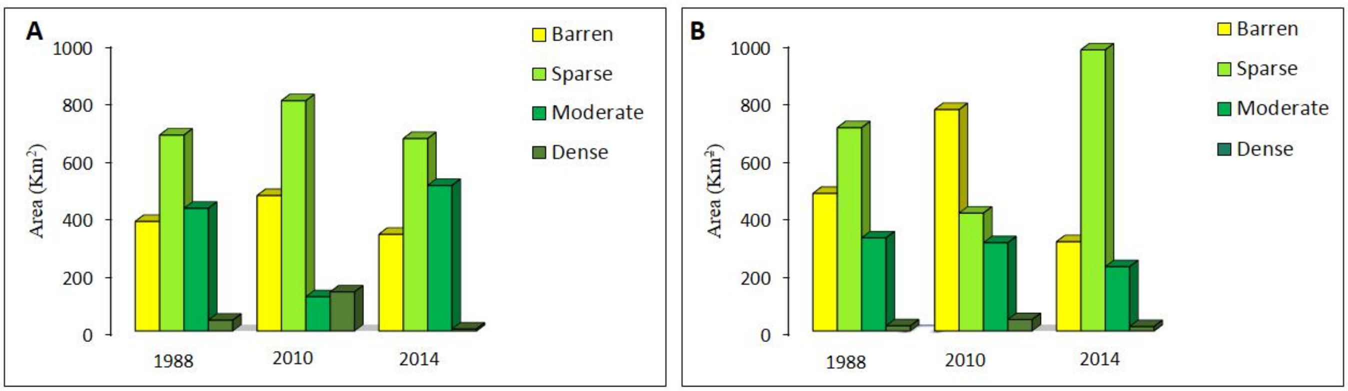

Fig.6. Area of different types of vegetation cover using the MLC (A) and the NDVI (B)

5.2 MLC usefulness

In this case study, the MLC is a reliable methodology to analyze the vegetation cover variation that was validated based on accessible thematic datasets, field work and aerial photos. A similar result was found by Shalaby et al. [53] in the Northwestern coast of Egypt and El kawy et al. [54] in desert region of the western Nile delta. Therefore this widespread method seems to be more suitable to study vegetation cover in dry areas. This result match with the statement mentioned by Erdas [55], the MLC performs better than the other different known parametric classifies. It takes into account the variance-covariance in the class distributions and for normally distributed data [56]. Then, the analysis of land cover changes in the Ksob catchment was based on the maps obtained by applying MLC.

5.3 Land cover changes within Ksob watershed

Spatial and temporal variations of the vegetation cover density within the study site during 26 years are shown in Fig.4-A and Fig.6-A.

- Temporal variations

At the beginning of the study period (1988), sparse vegetation was the dominant land cover, covering 44.63 % of the area, followed by moderately dense vegetation (27.95%), Barren (24.95%) and dense vegetation (2.47%). In 2010, sparse vegetation areas increased to 52.46%. It covered 797,392 Km2 of the study site. The areas occupied by moderate and dense vegetation that present forests declined by 13.71% when barren lands increased to 30.84% representing 468,768 km2. From 2010 to 2014, moderately dense vegetation increased by 25.36% while barren lands declined by 8.82% about 134,064 km2. Furthermore, the classification of the satellite image of 2014 has shown the extension of the New Dam (Zerrar Dam) which occupied 8.36 Km2. In general, from 1988 to 2010 the total area of vegetation cover have been reduced significantly (Table 7); about 12000 ha of vegetated land have been lost. This is probably related to successive years of drought (from 1999 until 2008) and population activities mainly overgrazing and deforestation. The National Forest Inventory (1996) reported a strong tendency to the reduction of forests by several factors: conversion of forest land to agricultural uses, overuse of wood resources, overgrazing and urban extensions [57]. From 2010 to 2014, barren lands have been declined and the percentage of moderately dense vegetation have been increased. This variation can be explained by the availability of water due to the increasing tendency of the precipitations and the implementation of the new dam. In addition, the convention signed the 26 April 2010 between the High Commissariat for Water, Forest and Fight against Desertification (HCEFLCD) and the FAO through a second phase of the supporting the implementation of national forest program [58] allowed to the implementation of young plantations.

- Spatial variation

Concerning the spatial distribution, thematic maps resulted (Fig.3-A) show that the Eastern part of the Ksob watershed is mainly occupied by barren lands, excepting the Igrounzar river boundaries, the south west is mostly covered with moderate to dense vegetation while sparse vegetation is scattered in all the study site. This spatial variation can't be linked only to rainfall distribution (Fig.4-A) but also to several factors that define land characteristics including soil types, relief, and hydrological conditions (Fig.2). The northern part is characterized by an oceanic climate, low topography and the abundance of isohumic soils which promote agricultural growth. In the Eastern zone, the dominance of regosoils and the lithosoils in addition to the high altitudes are the main causes of the scarcity of vegetation. On the contrary, in the south west, the soils (isohumic and calcareous) are more developed and favorable for vegetative growth. In addition, the high slopes in this area have positive influence. They reduce the overuse of woody plants making logging much more difficult.

6 Conclusion

In this article, two different techniques (MLC and NDVI differencing method) have been applied to detect vegetation changes occurred during 26 years in one of the planning units for water resource management in Morocco "the Ksob watershed". The results obtained illustrate that the MLC represents the more reliable technique in detection vegetation changes within the study area. The comparison of these results with other studies in other semi-arid regions helped us to conclude that MLC gives a great description of the vegetation cover in dry lands while NDVI has several limitations in such areas.

The application of the MLC was a useful tool for the determination of the rate and trend of land cover transformation within Ksob catchment. The maps obtained were helpful to illustrate the impact of the drought and climatic variations on vegetation cover density and to understand the factors controlling the spatial and temporal variations that are water availability, distribution of soil types, relief, hydrological conditions and human activities.

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