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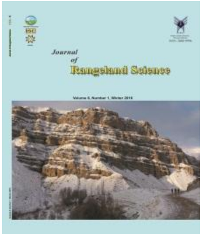

Research and Full Length Article:

Rangeland Degradation Assessment in the South Slope of the Al-Jabal Al-Akhdar, Northeast Libya Using Remote Sensing Technology

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Abstract. The degradation rate of Mediterranean steppes, especially in North Africa is 1% per year, and this considered a high rate of degradation. This study conducted in 2014 in the south slope of the Al-Jabal Al-Akhdar, northeast Libya to quantify the vegetation recovery rate and assess selected Vegetation Indices (VIs) for mapping rangelands degradation status using remote sensing technology. Through a review of VIs we found that NDVI (Normalized Difference Vegetation Index) and $MSAVI_2$ (Modified Soil Adjusted Vegetation Index) are the most useful indices for the study area to achieve the research objectives. Two Landsat (ETM+) satellite images (captured in September 2006 and 2014) used to map, monitor and assess the patterns of changes in plant cover. Three exclosures (fenced areas) with moderately to severely degraded soil and vegetation, were selected along a strong north-south rainfall gradient. Landscape Function Analysis (LFA) technique used to calculate Total Patch Area (TPA) for comparison purpose. According to the results, NDVI and $MSAVI_2$ can be employed as a consistent and comparatively simple to use a tool in management and assessment of desertification processes in the Mediterranean rangelands. It seems that $MSAVI_2$ more reliable than NDVI when the vegetation cover is very low. Overall, the plant cover did not change or increase for a large portion of regions at a time when 80% of the study area still under very severe and severe conditions of land degradation status.

Key words: Al-Jabal Al-Akhdar, Libya $MSAVI_2$, Total patch area, Vegetation indices

Introduction

The degradation rate of Mediterranean steppes especially in North Africa is 1% per year, and this considered as high rate of degradation (Le Houerou, 2000; Le Houerou, 2001). Many factors and human activities have cause rangeland degradation and led to significant changes in the landscape and original plant flora of the southern Mediterranean countries over the past 100 years (Le Houerou, 2000; Mahmoud *et al.*, 2008; Zatout, 2014).

These activities include overgrazing, deforestation, inappropriate agricultural practices, fire, urban expansion and industrial activities. All the above mentioned activities lead to destruction of the native plant flora and cause an increase in sand blowing and emission of dust. Also, incorrect policies regarding control of desertification have paradoxically increased the amount of area prone for desertification and also delayed recovery of degraded land. There are about 12672 km^2 of the Libyan rangelands considered as degrading areas, which is affecting about half millions of people (Bai *et al.*, 2008).

Signs of densification in the study area include marked reduction or complete loss of vegetation cover, Accelerated soil erosion, Increased frequency of dust storms, Edaphic drying, Reduced biodiversity, Reduced habitat diversity and Reduced primary productivity (crop yield, animal productivity).

This study aimed to quantify the vegetation recovery rate in the south slope of the Al-Jabal Al-Akhdar area, northeast Libya and assess selected vegetation indices for mapping rangelands degradation status using remote sensing technology.

Since remote sensing collects its data via space satellites that can cover a vast land area in a short span of time and can revisit an area when needed both the time and logistic issues of monitoring rangelands degradation.

Vegetation Indices

Through a review of VIs we found that NDVI and $MSAVI_2$ are the most useful indices to achieve the research objectives. (Gao, 1996; Jackson and Huete, 1991; Karmieli *et al.*, 2013; Mróz and Sobieraj, 2004; Yeganeh *et al.*, 2014).

They have been widely used in remote sensing applications of rangeland management, also it is used in available software in markets.

Normalized Difference Vegetation Index (NDVI)

The NDVI has been extensively applied in rangeland researches. NDVI minimizes the topographic and atmospheric effects (Rouse Jr *et al.*, 1974), but it is quite sensitive to soil color and brightness, higher NDVI values are led by darker soil substrates under incomplete canopies (Bannari *et al.*, 1995; Mróz and Sobieraj, 2004) (Equation 1).

$$\text{NDVI} = \frac{NIR - R}{NIR + R} \qquad \text{(Equation 1)}$$

where NIR is Near Infra-Red band, and R is the red band.

Soil Adjusted Vegetation Indices (SAVI and MSAVI)

Soil Adjusted Vegetation Index (SAVI) deals with soil brightness, so it is useful in the study of areas where vegetation cover is very low and CoCa3 is quite high, which causes high soil brightness (Huete and Jackson, 1988) (Equation 2). A correction factor (L), which ranges from 0 for very high vegetation cover to 1 for very low vegetation cover, is used to reduce soil brightness effects; the most used value is 0.5, which indicates medium vegetation cover.

$$\text{SAVI} = \frac{\text{NIR}-\text{R}}{\text{NIR}+\text{R}+\text{L}} * (1 + \text{L}) \qquad \text{(Equation 2)}$$

Qi *et al.* (1994) found that L is not stable. Additionally, it differs contrarily with the measure of vegetation present. For this reason, the authors proposed the Modified Soil Adjusted Vegetation Index (MSAVI) to reduce the effects of inter patch areas on SAVI. Because of the abovementioned advantage, MSAVI is considered to be a suitable index for rangeland studies in arid areas. Moreover, it usually has a strong correlation relationship with field data related to vegetation cover (Chen, 1999; Senseman et al., 1996). It is also very useful for degradation classification in monitoring desertification (Liu et al., 2005), as well as the estimation of biomass (Phillips et al., 2009). Because of the reasons above, MSAVI may be suitable for the objectives of the current research. The calculation of MSAVI is the same as SAVI; the difference is in the calculation of the correction factor. In MSAVI, L is calculated as per (Equation 3),

$$L = 1 - (2 * S * NDVI * WDVI)$$ (Equation 3)

Where S is the slope of the soil line from a plot of red versus near infrared brightness values, WDVI is the Weighted Difference Vegetation Index (Clevers, 1988) (Equation 4).

$$WDVI = (NIR - S * R)$$ (Equation 4)

Qi *et al.* (1994) completely solved the problem of L factor by developed $MSAVI_2$ as (Equation 5),

$$MSAVI = \frac{\left[2 * NIR + 1 - \sqrt{(2 * NIR + 1)^2 - 8 * (NIR - R)}\right]}{2}$$ (Equation 5)

Methodology

The study area

The study area as shown in Fig. 1, is located on the south slope of the Al-Jabal Al-Akhdar area, northeast Libya located approximately 32° N, and 21° E, with an area of about 3000 km².The climate is Mediterranean charac-terized by winter rainfall (November to March or April). The rainfall range in the region is < 50 to 250 mm per year and temperatures reach below Zero in January and up to 35C in July and August. Fog is

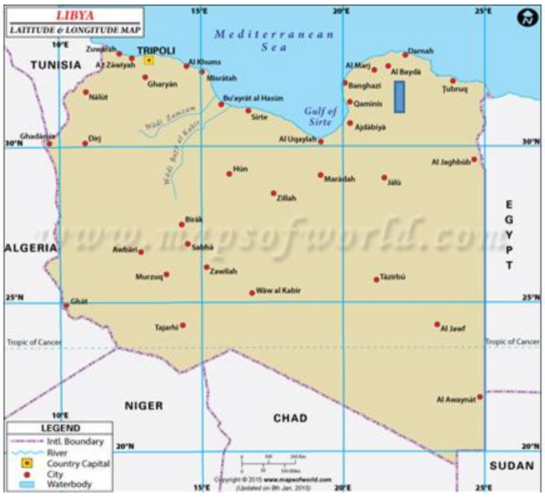

Fig. 1. The Study Area

a common in the winter months (Fig. 1).

The vegetation in the study area at lower elevations and reduced rainfall, a belt of dwarf shrub steppe consisting of *Artemisia herba-alba* and *Haloxylon scoparium* occupies the low hills, and the undulating and narrower alluvial plains. Further south, a steppe of stem and leaf succulents occupy the board flat alluvial plains and drier undulating plains. Species in this formation include,

Haloxylon scoparium, *Anabasis arti-culata*, *Suaeda pruinosa*, and *Salsola tetrandra* (Mahmoud *et al.*, 2008).

Quantify the recovery rate of vegetation

Three exclosures (fenced areas) with moderately to severely degraded soil and vegetation, were selected along a strong north-south rainfall gradient (Table 1). Landscape Function Analysis (LFA) technique used to calculate TPA index for each exclosure (Tongway and Hindley, 2004). LFA-SSA-data-entry spreadsheet (Tongway and Ludwig, 2011) was used to calculate TPA index. TPA, NDVI and MSAVI used to quantify the recovery rate of rangelands plant cover between 2006 and 2014. Since TPA, NDVI and

MSAVI reflect or related to the vegetation cover, we simply calculated the increasing or decreasing for the indices as percentages, and finally, we calculated the restoration and degradation rates per year, this calculation is helpful for judging which VIs is closer to the field data. A raised NDVI and MSAVI values for a certain pixel stands for a bigger change in the degradation status. In the surface area the pixel represents. The ground region with a decline in the vegetation cover was represented by a negative slope pixel.

Table 1. Summary description of study areas

Area code	Area Name	Exclosure area ha	Installation Date	Average of Rainfall mm/year
MZ	Maduar Zetun	125	2001	250
OG	Omguzlan	220	1993	150
TT	Thahar Altair	25	2002	100

VIs data sources and analysis

Previous researches indicated that Landsat Enhanced Thematic Mapper Plus (ETM+) may useful in calculation Vegetation Indices values for monitoring and mapping rangeland degradation in a large area (Fernández *et al.*, 2010; Ikeda *et al.*, 1999; Karnieli *et al.*, 2013; Najeeb, 2009). Therefore, we attempted to test this initial finding, which would cover a vast area and save time and money. Two Landsat satellite images used to monitor and assess the patterns of changes in plant cover. The satellite images captured from Landsat-7 (ETM+) in September (2006 and 2014) with eight bands ranging from first to the eightieth. There was an application of micrometer, with pixel size 30 × 30m.

Image preprocessing

ERDAS Imagine software V.9 employed to correct the satellite image's radiometric and geometric errors, and calculate VIs values. The most common radiometric errors in the images of Landsat ETM+ are striping and line dropout. The striping is caused by errors in the detector adjustment, and the result is reading very high or very low comparing to the reality. It should be noted that these errors have been minimized in the new devices of sensors. When the detector completely or temporary fail to function, Lines dropout is a result. This problem solved by replacing the effected line with the mean of the nearest two lines. We used the dark pixel subtraction method to deal with the atmospheric errors (Hall *et al.*, 2006). The UTM coordinator system used to correct the imageries geometrically. The GIS data of 28 monitoring sites (ground control points) used to correct and validate the geometric errors. This system enhanced the exact location of sites for field monitoring within the data that was remotely sensed.

Image classification

As present in Table 2, to classify degradation status, rangelands degradation severity in the study area divided into four Thresholds using The Jenks Optimization method (Jenks, 1967).

Table 2. Degradation severity classification

Degradation Severity Classes	Vegetation Cover %	Thresholds	
		NDVI	MSAVI
Very severe	< 10	0 – 0.07	-1 – -0.8
Severe	10 - 25	0.07 – 0.09	-.81 – -0.7
Moderate	25 - 40	0.09 – 0.16	-0.71 – -0.6
Slight	> 40	0.16 – 1	-0.61 – 1

Results and Discussion

Quantifying the Perennial Plant Recovery Rate

In the northern part (MZ), which receives the highest average rainfall in the study area (250 mm/year), NDVI and MSAVI indicated a 4% and 2% increase in recovery rate respectively, which is considered very low compared to the rates related to TPA index. TPA showed a high rate of recovery in MZ area (+10), this could be attributed to low vegetation cover in 2006 (7.5 ha), 6% of the exclosure area (125 ha), while the exclosure receives the highest average of rainfall in the study areas. This may be for a short term, then the rate will decrease with an increasing in vegetation cover. According to the TPA, the changing rate was twice compared to NDVI in the OG area, whilst MSAVI represented a recovery rate of 1% (Table 3). The exclosure located in the southern part of the study area (TT) had a negative rate of change per year according to MSAVI and TPA, showing the same percentage of change (-1%), while NDVI showed a higher declining rate of vegetation cover. This may be attributed to the very low vegetation cover in the TT area, as well as the high percentage of soil calcium carbonate in the study area, which affected NDVI by increasing soil brightness. In addition, the high mortality rate of planted shrub which observed in the exclosure of TT.

Table 3. Calculation of Perennial Plant Recovery Rate inside the Exclosures Depended on the Overall Means of TPA, NDVI and MSAVI

Indices	Exclosures	Area of Plant Cover (hectares) 2006	2014	Recovery Rate (% per year)
NDVI	MZ	7.50	9.75	+ 4
	OG	12.10	14.28	+ 2
	TT	0.18	0.15	- 2
MSAVI	MZ	7.50	8.70	+ 2
	OG	12.10	13.10	+ 1
	TT	0.18	0.16	- 1
TPA	MZ	7.50	13.85	+ 10
	OG	12.10	15.85	+ 4
	TT	0.18	0.16	- 1

Note: the calculation based on the vegetation cover in 2006, it is not based on the exclosure area

From the results, MSAVI seems to be more reliable than NDVI when the vegetation cover is very low because of increasing soil brightness with decreasing vegetation cover. For this reason, the Modified Soil Adjusted Vegetation Index was proposed to reduce the effects of soil brightness on NDVI values (Qi *et al.*, 1994). The results showed that NDVI is affected by average rainfall, which in turn affects vegetation cover density.

The results from this study support findings that demonstrate a good linear relationship between rainfall and NDVI (Nicholson *et al.*, 1990). In general, our results indicate that there is an increase in perennial vegetation cover in the study area, which is probably attributed to the increase in average rainfall in the study area over the last two years.

Rangelands degradation assessment

The calculation of NDVI and $MSAVI_2$ areas showed positive changes related to vegetation recovery process in the study area between 2006 and 2014. The NDVI and $MSAVI_2$ distribution from 2006 to 2014 represented moderate and low vegetation densities positive pattern. The positive changes are noted in all classes of degradation severity. The findings showed that the very severe degradation area decreased by about 831 Km^2 and 1229 Km^2 for NDVI and $MSAVI_2$ respectively (Table 4). According to the NDVI distribution, these areas transferred to moderate severity condition while the $MSAVI_2$ distribution showed that most the study area became under sever degradation status (Fig. 2).

Table 4. NDVI and MSAVI calculation of area changing for each severity class

Rangeland Degradation Severity	NDVI			MSAVI		
	Area Km^2		Change Km^2	Area Km^2		Change Km^2
	2006	2014		2006	2014	
Very Severe	854.12	22.77	- 831.34	1229.79	0.97	- 1228.82
Severe	1042.94	785.01	- 257.92	1005.15	1827.29	+ 822.14
Moderate	366.55	1420.32	+1053.77	39.37	426.87	+ 387.51
Slight	10.66	46.14	+ 35.47	0.00	17.94	+ 17.94
Total	2274.29	2274.26		2274.32	2273.10	

The findings demonstrated that, during the period of eight years, many changes that affected the vegetation cover came from classes 1 and 2 (very severe and severe) within the NDVI as well as MSAVI maps (Figs. 2 and 3). The Severe and Very severe classes were mostly observed in the south part of the study area that receives a low average of rainfall. For this area of study, Structural characteristics were vastly variable, since NDVI ranged between 0.06 – 0.13. The high variability reduced by MSAVI which range between -0.8 – -0.6.

The high range of NDVI values is a result of different soil brightness coefficients since there are different types of soil in the study area. Our result is conformation of other similar results of previous studies which conducted that, MSAVI is suitable for the rangelands that have different soil brightness coefficients, and usually it has a strong correlation relationship with the field data related to vegetation cover (Chen, 1999; Gaitán *et al.*, 2013; Liu *et al.*, 2005; Owusu, 2013; Senseman *et al.*, 1996; Yeganeh *et al.*, 2014). However, the plant cover did not change or increase for a large portion of regions at a time when 80% of the study area still under very severe and severe conditions of degradation status.

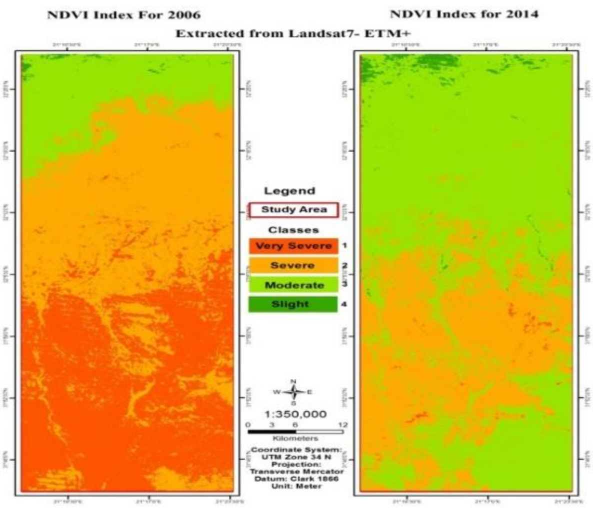

Fig. 2. NDVI Map of changing in Degradation Status (2006 – 2014)

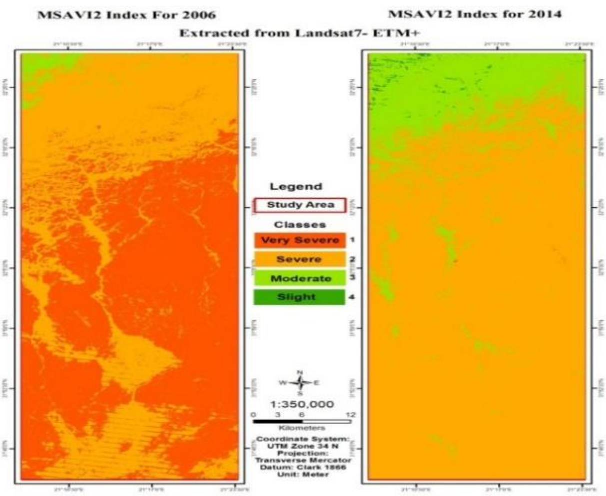

Fig. 3. MSAVI Map of changing in Degradation Status (2006 – 2014)

For several years now, accelerated erosion has been taking a great toll on Jabal Akhdar region resulting in continuous deterioration of the environment which can eventually lead to degradation. It should be noted that according to the results of this study the aridity and overgrazing are the main reasons to increase the degradation rate. Look at all their theories to explain the changes in rangeland vegetation cover the most plausible explanation is that all these changes have occurred due to human activities. The selected VIs equate to earlier field-founded studies and provide how can be employed in assessing changes in ecosystem performance over extensive special scales, it is very intricate and expensive to attain when employing only field-based assessment. Therefore, NDVI and $MSAVI_2$ can be employed as a consistent and comparatively simple to use a tool in management and assessment of degradation processes in the Mediterranean rangeland steppes. The different parameters that must be kept in mind while analyzing land degradation are the amount of rainfall, nutrient content of the soil and the grazing patterns of that area along with socio-economic studies.

Conclusion

Climatic variability can cause land degradation, so also can human activities in the form of overgrazing, deforestation, and others activities. NDVI and $MSAVI_2$ were able to determine the improvement in the vegetation cover, thus leading to the emergence of green vegetation as well as minimum soil quantities coupled with litter spectral characteristics. It tends to advance the idea that pressure reduction on rangelands may be the answer to the ending of the degradation processes. This has made it essential to adopt all-inclusive programs that will help in the preservation of natural resources for the generation that follows.

Acknowledgements

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ارزیابی تخریب مراتع در شیب جنوبی الجبال-الاخدار، شمال شرقی لیبی با استفاده از تکنولوژی سنجش از دور

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چکیده. نرخ تخریب استپ‌های مدیترانه‌ای بخصوص در شمال آفریقا یک درصد در سال است و این موضوع نشان دهنده نرخ تخریب بالا در منطقه است. این مطالعه در سال ۱۳۹۳ در شیب جنوبی منطقه الجبال-الاخدار شمال شرقی لیبی جهت تعیین نرخ احیا پوشش گیاهی انجام شد. شاخص پوشش گیاهی برای تهیه نقشه تخریب مراتع منطقه با استفاده از تکنولوژی سنجش از راه دور بکار رفت. در طی این مطالعه مشخص شد که شاخص‌های NDVI و MSAVI مناسب منطقه برای رسیدن به اهداف تحقیق می‌باشند. دو نوع تصویر ماهواره لندست +ETM (گرفته شده در بین سال‌های ۲۰۰۶ الی ۲۰۱۴) برای ارزیابی پوشش گیاهی منطقه مورد استفاده قرار گرفت. سه منطقه قرق (محافظت شده با حصار) با شدت‌های تخریب متوسط تا سنگین به لحاظ خاک و پوشش گیاهی با تغییرات شدید بارش از شمال به جنوب در نظر گرفته شد. روش آنالیز عملکرد منظرگاه برای منطقه و مقایسه تخریب‌ها بکار رفت. نتایج نشان دادند که دو شاخص مورد اشاره به عنوان ابزاری ساده و در عین حال ثابت برای فرآیند بیابانزایی مراتع مدیترانه‌ای مناسب شناخته شدند. همچنین نتایج نشان داد که در زمانی که پوشش گیاهی خیلی کم است شاخص MSAVI مناسب تر از شاخص NDVI است. در مجموع نتایج نشان داد که در قسمت زیادی از منطقه تغییری در میزان پوشش گیاهی دیده نشد و حتی وقتی ۸۰ درصد منطقه تحت وضعیت‌های تخریب شدید تا خیلی شدید قرار گرفته‌اند.

کلمات کلیدی: الجبال الاخدار، لیبی، شاخصهای گیاهی، روش TPA