Monitoring Of Land Degradation And Desertification In The South Of Jabal Al Akhdar Mountain In North East Libya

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رصد تدهور الاراضي والتصحر في جنوب الجبل الاخضر في شمال شرق ليبيا

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الملخص :

أدى الأحترار العالمي والتدخل البشري خلال العقود القليلة الماضية إلى تغييرات وتدهور في الغطاء النباتي الطبيعي في جميع أنحاء العالم. يعتبر الجبل الأخضر ، في شمال شرق ليبيا ، أحد المناطق التي شهدت تغيرات في الغطاء الأرضي. فيما تتمتع هذه المنطقة بأهمية بيئية واقتصادية في توفير البيئة المناسبة للحياة البرية.

هناك ثلاثة أهداف رئيسية لهذا البحث:

(1) تقييم التغيرات في الغطاء النباتي الطبيعي وشبه الطبيعي في شمال شرق ليبيا باستخدام بيانات الصور الاقمار الصناعية لمدة45عاماً.

(2) تقييمأثرالأنشطة البشرية فيتغير الغطاء النباتي في منطقة الدراسة على مدى فترة 45 عاماً.

(3) تقييم العوامل الأخرى التي تؤثر على تغير الغطاء النباتي في منطقة الدراسة. و لتحقيق هذه الأهداف، استخدمت تقنيات الاستشعار عن بعد لتقييم تغير الغطاء النباتي والتغيرات في النشاط البشري من عام 1972 حتى 2017 حيث توفر صور الأقمار الصناعية بيانات لا يمكن جمعها بالطرق التقليدية وتوفر أرشيفًا تاريخيًا لما كان يبدو عليه المشهد في الماضي. استخدمت هذه الدراسة صور Landsat متعددة الأزمنة، حتى الوقت الحاضر، وتوفر السجل الزمني الأساسي لتغير الغطاء النباتي على الأرض. كما استخدم مؤشر النباتات (NDVI ,SAVI)، المستمدة من الانعكاس الطيفي للأوراق والمظلات النباتية، لتقييم التغيرات في الغطاء النباتي مع مرور الوقت. كما استخدم تصنيف الصور لتمييز طبيعة تغير غطاء الأرض، لا سيما تأثير التدخل البشري.

لقد تبين أن إحدى النتائج الرئيسية المتعلقة بالهدف هي :

(1) هي أن بعض المناطق قد شهدت تغيرًا إحصائيًا كبيرًا في مؤشرات الغطاء النباتي والذي تم تفسيره على أنه تغيير في الغطاء النباتي فيمناطق معنية. وكان الاستنتاج الرئيسي المتعلق بالهدف .

(2) هو أن الغطاء الأرضي قد تغير في بعض مناطق الدراسة بسبب تأثير الأنشطة البشرية من خلال زيادة مؤشرات النباتات واستخدام الأراضي وانخفاض مساحة الغابات

والشجيرات في المنطقة. تم استخدام مخرجات الأهداف المذكورة أعلاه لتقييم الهدف (3) للكشف عن العوامل التي تسببت في تغير الغطاء النباتي في منطقة الجبل الأخضر. ومن العوامل الرئيسية التي تسببت في تغير الغطاء النباتي كانت تأثيرات الأنشطة البشرية في المناطق المجاورة للمستوطنات البشرية، بينما في المناطق ذات الكثافة السكانية المنخفضة في جنوب منطقة الدراسةقد يكون تغير المناخ سبباً في تغيرات الغطاء النباتي. وأخيرا ، على الرغم من أن عدد صور Landsat المتاحة لتحديد التغيرات في الغطاء النباتي كان محدودًا ، كانت الطرق المستخدمة لتفسير صور مؤشرات الغطاء النباتي وتصنيف الصور لا تقدر بثمن في تحديد النتائج المهمة لأهداف الدراسة . ومن النتائج التي تم الحصول عليها من تقييم الغطاء النباتي وتغير الغطاء الأرضي وأنماط التغييرات هي خطوات رئيسية نحو سد فجوة المعلومات وإنشاء قاعدة بيانات لرصد الغطاء الأرضي في منطقة الدراسة. كما ان هذا الجهد سيساهم في تسهيل اتخاذ القرار بشأن التخفيف من تأثير تغيرات استخدام الأراضي على الغطاء الأرضي بالإضافة إلى توفير أساس للبحوث في المستقبل.

Abstract:

Over the last few decades, global warming and human activities have led to changes and deterioration in natural vegetation across the world. Land degradation in arid, semi-arid areas led to the emergence of desertification especially areas that are located along the desert margins.

The Al Jabal Al Akhdar Mountains (The green Mountain)in the north east Libya, is one of those areas that have experienced changes in vegetation cover. This region has environmental and economic importance in providing habitat for wildlife and services for local communities and cities in the Libyan Desert.

This research will investigate natural vegetation dynamics in the Al Jabal Al Akhdar region using remote sensing techniques in an attempt to monitoring the desertification over the last 42 years to determine the factors that have caused this problem. The overall aim of this paper was to evaluate the factors which have affected vegetation cover change in the Al Jabal Al Akhdar region over the last 45 years.

Key word: Desertification · Land degradation · Al Jabal Al Akhdar · Climate change · Remote sensing.

1. Introduction

Vegetation is a key component of ecosystems (Briales&Ravenel, 2013). It is involved in the regulation of various biogeochemical cycles, for example, water, carbon and nitrogen (Buriánek et al., 2013); affects soil development by increasing productivity; and provide Aes habitat for wildlife (Briales and Ravenel, 2013). Everyplant species has physiological characteristics that allow it to live in a certain range of temperatures, moisture, soil acidity, solar radiation, evaporation and nutrients (Hoffmann, 1998). Changes in these characteristics lead to changes in vegetation phenology, primary productivity, biomass and the distribution of vegetation types (Krishnaswamy et al., 2014).

Human activity, in concert with local factors such as climate change, has also caused vegetation change and increase the desertification, for example, increased population has led to significant land cover change globally since the mid-1950s (Foster, 1998). This is a result of the exploitation of areas, which,were covered by 'natural vegetation' and have been transformed by human activities, such as agriculture, urban and industrial development (Estes et al., 2012).

These changes have caused degradation in soil productivity, soil erosion, desertification and decreases in plant and animal biodiversity (Wang et al., 2004; Mansour et al., 2012).

Desertification is degradation of ecosystems due to climatic conditions and irrational human activities ,which has known in Kenya's conference in 1977 (Domay,200).

During the second half of the 20th century the Mediterranean region experienced changes in regional vegetation in response to climate change, drought and land use change (Ivits et al., 2014; Jiguet et al., 2011; Lasanta& Serrano, 2012). Human activity in the last few decades has affected some areas in the Mediterranean region. Increased urbanization, agriculture, industry, fires, uncontrolled grazing, salinization, pollution and deforestation in the region, have caused degradation of natural vegetation as a result of human-induced pressure on ecosystems in the region (Ispikoudis et al., 1993; Zalidis et al.,2002).

Natural vegetation in north eastern Libya belongs to the semi-arid/ arid natural vegetation of the Mediterranean (Bukhechiem, 2006). The perennial trees, (Maquis) are the main vegetation in the region, with Juniperusphoenicia one of the most important components of the vegetation. This is a perennial evergreen that comprises an estimated 80% of the total perennial tree cover in the Al Jabal Al Akhdar region (Al Mukhtar, 2005). The natural vegetation is found at the highest elevations and is concentrated in the Al Jabal Al Akhdar (Green Mountains), region which is the study area for this research. It is the richest region of biological diversity in the country (Hegazy et al., 2011). The Al Jabal Al Akhdar region is located in the south of the Mediterranean basin and is located in the Mediterranean climate zone (Figure1.1), (Figure1.2)and (Figure1.3).

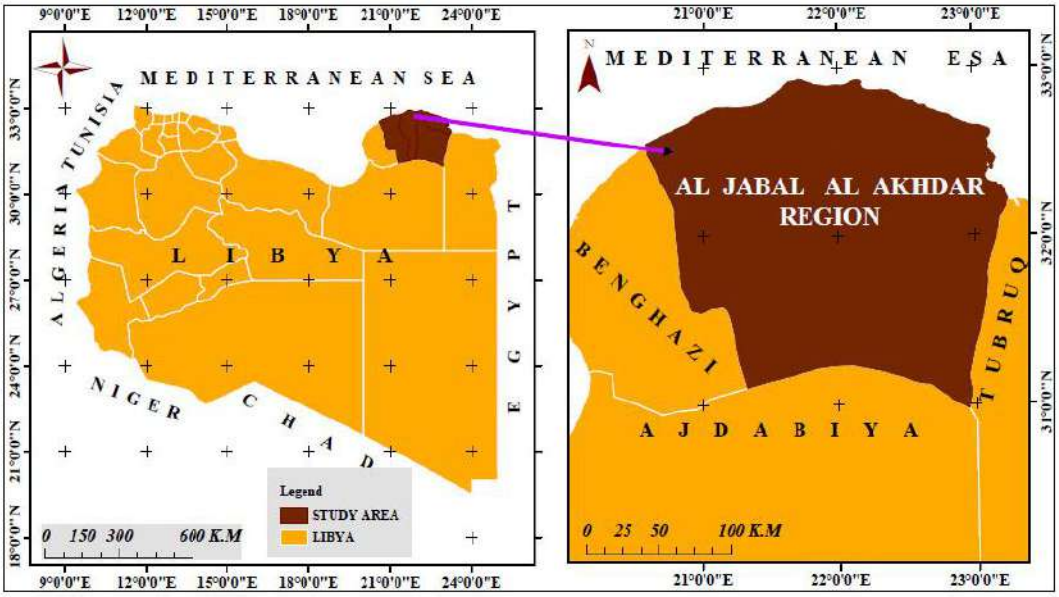

Figure 1.1: The site of Al-Jabal Al- Akhdar in the North East of Libya (Ibrahim, 2008).

Figure 1.2: The Al-Jabal Al Akhdar in the north east of Libya ((Google Earth, 2017).

Figure 1.3: The vegetation on the northern slopes of the Al Jabal Al Akhdar (Source: http://ports.com/libya/port-of-ras-el-hilal/photos).

Dense tree cover and shrubs of Mediterranean types as well as landform, calcareous soils and semi-wet climate in most of the northern slopes (Al Mukhtar, 2005; Bukhechiem, 2006; Hegazy et al., 2011) characterize this region. The trees and shrubs are considerably less dense from north to south because of lack of precipitation, drought, soil type and landform, and the influence of the desert climate.

Natural vegetation of the Al Jabal Al Akhdar has a significant impact in the region in terms of providing suitable habitat for wildlife (Hegazy et al., 2011), providing nutrients for the soil ,stabilization of the soil and preventing erosion. The north-facing slopes, where there is extensive farmland, provide vegetables and fruits for local communities in the region and the cities of the Libyan desert (Ben Khaial&Bukhechiem, 2005).

By monitoring the dynamics of semi-arid/arid natural vegetation in the south of Al Jabal Al Akhdar using remote sensing techniques, it is possible to map a large area that cannot be accessed by other means. In addition, remote sensing can provide a long temporal record of land surface observations dating back to 1972. This research will investigate natural vegetation dynamics in the Al Jabal Al Akhdar region using remote sensing techniques and examine changes in vegetation cover over the last 45 years in an attempt to determine the factors that have caused those changes.

1.1 Research aims and objectives :

The main aim of this study is to assess the natural and semi-natural vegetation dynamics of the Al Jabal Al Akhdar region, assess the areas of desertification and examine affecting of human activity on vegetation change,which was caused the desertification . Overall, this study attempts to detect of the effects human activity, in study area by examining the influence of the spatial distribution of human activities relation to vegetation cover change. This will be achieved by identifying the relationships between the areas that have experienced change in vegetation cover and the in the study area since the 1970s.This aim can be split into three specific objectives:

(i) To assess changes in natural vegetation cover in the north-east of Libya.

(ii) To assess the changes of human activities in Jabal Al Akhdar.

(iii) To assess the effect of human activities on vegetation change.

1.2 Methodology:

The first objective aims to assess vegetation cover change that requires an approach reliant on time series Landsat imagery starting from 1972. Landsat data sets are available at a relatively high spatial resolution, cover large areas, and are ideal for the aims of this research. However, one of the challenges of satellite-based land cover characterization is removing the extraneous influences of factors that

may affect the reflectance of the vegetation (Benediktsson et al., 2012). Therefore, it was necessary to first correct the images by removing

atmospheric and topographic effects in order to derive a series of cross-calibrated images of the study area. To assess the aim that there had been a change in vegetation cover during the period of study, a series of eleven images, available for the study area, was used to measure the change in green vegetation cover. This approach used time-series of NDVI, SAVI indices to detect major vegetation cover changes in the Al Jabal Al Akhdar over the period 1972-2017. Once the pattern of increase or decrease in vegetation cover had been established, the research then attempted to explain the factors causing these patterns. The second objective aims to assess the effects of human activity in the region. The research used Libyan population data and a population distribution map from the Land Scan global population database, to map the general picture of the density of human activity.

In addition, the time series of Landsat images of the study area was used to examine the relationship between changing land cover and land use, and the population distribution. The third objective aims to investigate the affecting of human activities on vegetation change in the study area using the outputs of the first and second objective.

With this as background, the research then examined the relationship between land cover and land use change and the

vegetation change patterns in the VI images. It then determined the contribution of human-induced vegetation change, and mapped areas of low human impact and significant vegetation cover change.

Objectives are addressed using quantitative data analysis techniques that use both descriptive and qualitative data interpretation. Detailed methodologies are presented for assessing vegetation cover change, land cover change and spatial analysis of factors affecting vegetation change in the study area.

1.2.1 Approach to assessing vegetation cover change:

High spatial resolutions (30 m) of Land sat satellite images are used to examine a long-term record for vegetation cover change in the region from 1972 to the present. Vegetation Indices (NDVI, SAVI and EVI), are used to generate linear regression and correlation coefficient images from VI images to test which pixels showed statistically significant changes in vegetation cover, and classified the images to highlight the areas that had a significant change.

1.2.2Approach to assessing the changes of human activities in Al Jabal Al Akhdar:

The research used image classification methods to identify the distribution of different land cover and land use across the area, and

compare these classified images over different periods to assess how the land cover changed. Population data was used as a proxy for human activities that cannot be observed on satellite imagery.

.2.3 Approach to assessing the affecting of human activities on 1vegetation change in the study area:

The research overlaid results of the first objective, spatial maps of vegetation cover change in the region in combination with the result from the second objective, a spatial map of human activity that identified areas of high and low activity across the study area, to examine spatial correspondence between human activity and vegetation cover change.

The research collected 14 images from different Land sat sensors to obtain a cloud-free image series and cover the whole study area over an extended period of time. There were up to 200 images from Land sat MSS, TM, ETM and OLI, for the study area but just 14 images were usable due to cloud cover, or being in a different season (Table 1.1). The research specifically used the images that were acquired in the

same season to avoid' cover changes related to seasonal differences in vegetation growth.

1.2.1 Initial image processing

In spite of the availability of Land sat images it was a significant challenge to ensure that these images were useable to show the change in vegetation cover in the study area. The images required pre-processing to produce images that were valid for study and the approach used is presented in the following sections, specifically atmospheric and topographic correction processes applied to the Land sat data

Satellite	Sensor	Bands	Spectral Range	Path - Row	Pixel	Scene	Images used
L 1-3	Multi Spectral scanner (MSS)	1,2,3,4	0.5 - 1.1 µm	183-37	79 m	185 X 185 km	1972-1978 1986
L 4-5	Thematic Mapper (TM)	1,2,3,4,5,7	0.5 - 1.1 µm	183-37	30 m		1987-2003 2006
L 7	Enhanced Thematic Mapper Plus (ETM+)	1,2,3,4,5,7 6.1, 6.2 Thermal 8 Panchromatic	0.450 - 2.35 µm 10.40 - 12.50 µm 0.52 - 0.90 µm	183-37	30 m 60 m 15 m		1999-2001
L 8	Operational Land Imager (OLI)	1,2,3,4,5,6,7, 9,10 11 8 Panchromatic	0.45- 12.51 µm 0.50 - 0.68 µm	183-37	30 m 15 m		2013-2014

Table 1.1: Landsat images used in the study

1.2.1.1 Atmospheric correction

Atmospheric correction is therefore necessary for satellite imagery data to determine 'true surface reflectance' values. For the purposes of atmospheric correction, a radiance value is converted into reflectance data in remotely sensed imagery (Tuominen&Lippinga, 2011). Several proposed methods for removing the influences of atmosphere from satellite images.

1.2.1.2 LEDAPS

LEDAPS relies on deriving "the aerosol optical thickness from each Land sat acquisition and independently correcting each acquisition assuming a fixed continental aerosol type" (Ju et al., 2012, p. 176). The LEDAPS method uses Land sat TM5, ETM+7 and OLI 8 images, metadata, and daily atmospheric data to remove the influence of the atmosphere and produce atmospherically corrected surface reflectance products (Feng et al., 2013). It also generates cloud masks for images that are covered partially by the clouds(Table 1.2).

1.2.1.3 Empirical line correction

The empirical line method uses the raw digital numbers (DN) in an image together with ground reflectance data from some source (Tuominen& Lipping, 2011; Song et al., 2001). The approach applied the method on two images from the same month for different years were used, one was an image without atmospheric correction (DN) and

other was a surface reflectance image that had the LEDAPS atmospheric correction. The research applied the method on other

images that had no atmospheric correction using the available surface reflectance images and generated new images without atmospheric effects.

 ISSN 2522-6231

Table 1.2: Methods applied to remove the influence of the atmosphere from the Land sat images selected for this study area

Sensor	Data	Surface reflectance	Empirical line corrections applied	Image pair selected	R2 Red waveband	R2 Near-infrared waveband
MSS	7/9/1972			1972 and 1987	0.67	0.66
MSS	2/9/1978			1978 and 1987	0.80	0.93
MSS	6/10/1986			1986 and 1987	0.84	0.93
TM	30/9/1987					
TM	10/9/2003					
TM	5/9/2006			2006 and 2003	0.62	0.77
TM	23/8/2010			2010 and 2014	0.71	0.74
ETM	25/10/1999			1999 and 1987	0.91	0.95
ETM	26/7/2001			2001 and 2014	0.85	0.93
OLI	8/9/2013					

OLI	**22/8/2014**					
OLI	**28/7/2015**					
OLI	**17/8/2016**					
OLI	**22/9/2017**					

1.2.1.4 Image classification

To achieve the objective of assessing the impact of human activity in the study area, the time series of Land sat imagery was next used to investigate changes in land cover and land use across the study area. As an initial step, it was necessary to correct the images by removing the topographic effects and correct the aspect and slope direction effect on image reflectance.

1.2.1.5 Topographic correction

Topographic variation has an influence on the spectral reflectance of the land surface and thus affects the value of the pixel in an image (Svoray& Carmel, 2005). The topographic effect is the difference in illumination due to the slope direction relative to the elevation and azimuth of the sun (Zhang and Li., 2011). To reduce topographic influences in the imagery, the approach used a Digital Elevation Model (DEM) for topographic correction of the 30m resolution Land sat TM

and the 79m resolution Land sat MSS and produced images with more evenly illuminated terrain without topographic effects.

2. Assessing Vegetation cover change

Vegetation cover change was observed in the Al Jabal Al Akhdar region over the 45 year study period, through a statistical analysis of available long-term Land sat imagery. The statistical analysis of regression and the correlations that were applied in this study for the VI index contributed to showing the strength of the linear relationship between the VI and time. It determined which pixels showed a statistically significant relationship, and then determined which pixels had statistically significant trend in the VI over time. The results of the analysis of VI using linear regression and correlation analysis (figure 2.1to 2.6), showed that there was a statistically significant decrease in vegetation cover in some areas over the period of study. The results of the regression analysis of the VI in the Al Jabal Al Akhdar region indicated a change in the VI in some areas over the last 42

years. The negative values of the VI slope showed a decrease in the VI trend and therefore a decrease in vegetation cover in some areas. In contrast, the areas thar have positive values saw no significant change in vegetation cover.

The correlation coefficient of the VI showed the pixels that revealed a statistically significant change at a 95% level of confidence in the study area over the 45 years. The results of the VI correlation indicated a statistically significant decrease in the VI in some areas. Although there were some differences between the NDVI, SAVI and

EVI in terms of values, all the VI shared areas which had experienced a decrease in the VI (vegetation cover) over the period of study.

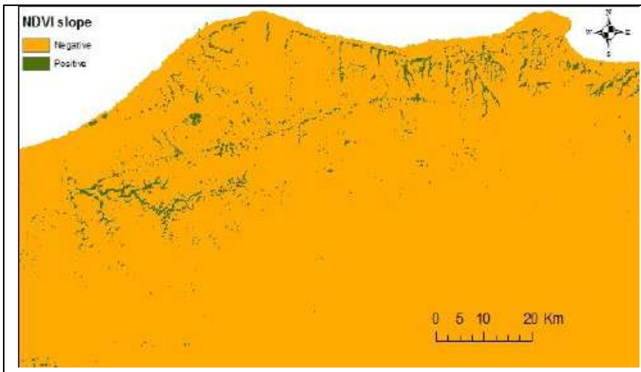

Figure2.1:The classified NDVI regression slope image.

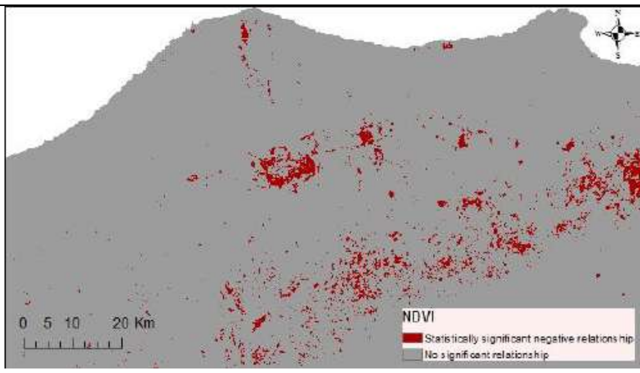

Figure2.4:The classified NDVI correlation coefficient image.

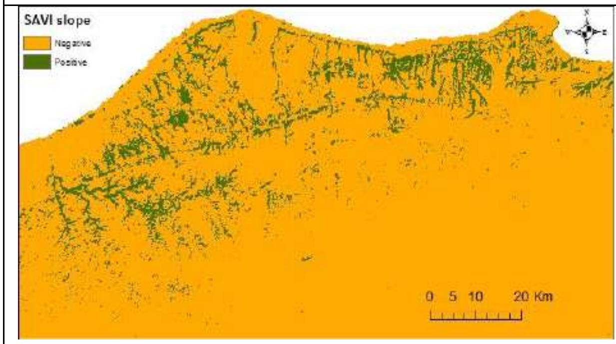

Figure 2.2:The classified SAVI regression slope image

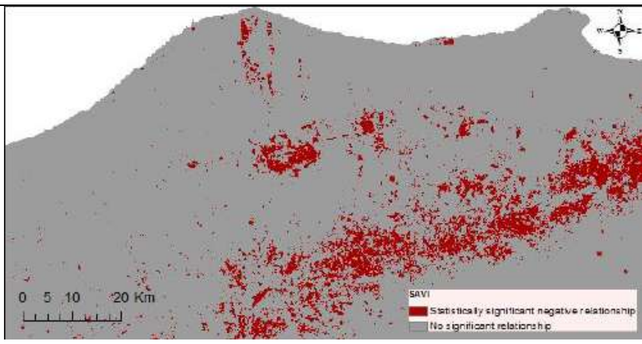

Figure 2.5:The classified NDVI correlation coefficient image.

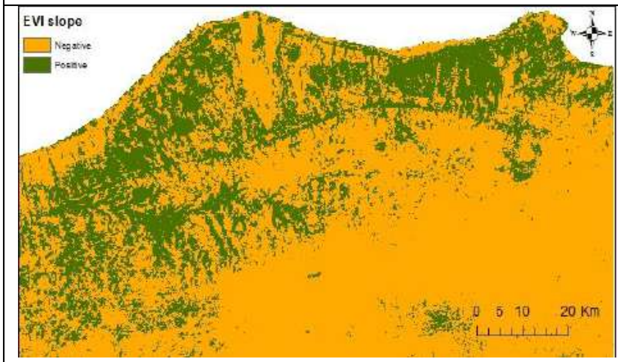

Figure 2.3: The classified EVI regression slope image

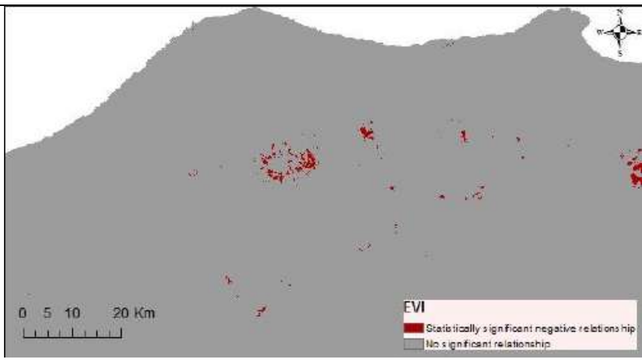

Figure2.6: The classified NDVI correlation coefficient image.

3. Assessing land cover change:

The research classified eleven images of the study area and produced eleven thematic maps showing the land cover in the Al Jabal Al Akhdar extracted from Landsat MSS for 1972, 1978 and 1986, and TM for 1987, 2003, 2006 and 2010, and ETM+ for 1999 and 2001, and OLI for 2013, 2014, 2015, 2016 and 2017 (Figure 3.1). A total of 12 land cover types are displayed, namely:

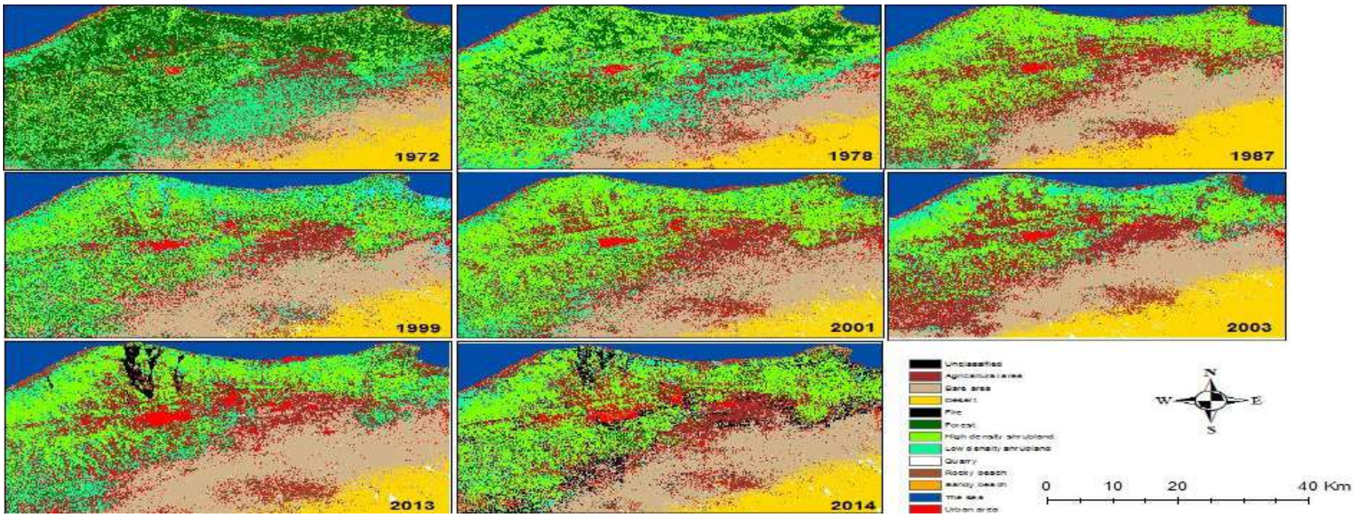

Figure 3.1: Multi-date land cover classification for the study area

Agricultural area, bare area, desert, forest, high-density shrubland, low-density shrubland, quarry,

rocky beach, sandy beach, the sea and urban area. These maps were used to assess the changes in the land cover and land use over 45 years.

The areal extents were derived from the pixel counts for class in a given land cover map, taking into account the spatial resolution of the imagery. The areal cover of each land cover class was completed and

compared between the dates (Table 3.1). For example, the areal extent of 'agriculture'

Table 3.1: The areas (km^2) of each land cover over the period of study.

Category/Years	1972 MSS	1978 MSS	1986 MSS	1987 TM	1999 ETM	2001 ETM	2003 TM
Unclassified	0.00	0.00	21.80	0.28	0.00	0.00	0.00
Agriculture	746.29	763.35	1028.38	1057.18	1230.48	1381.80	1504.0
Bare area	886.73	1025.43	1062.80	937.60	1008.46	1045.20	993.40
Desert	1045.88	847.46	852.00	946.75	927.04	921.10	921.00
Forest	661.33	643.48	357.13	256.78	225.29	252.8	208.7
High density shrubland	1338.76	1258.93	1185.66	928.65	801.69	712.3	676.7
Low density shrubland	1030.79	1070.32	1037.37	695.95	685.95	642.8	616.7
Quarry	75.06	53.63	69.85	37.89	47.59	52.9	155.9
Rocky beach	10.24	15.98	24.15	130.61	136.36	171.64	67.58
Sandy beach	27.36	5.53	8.68	4.40	3.02	923.79	775
The sea	508.56	640.67	646.52	1262.75	1090.29	4.25	4.29
Urban	96.56	102.79	133.23	168.72	271.42	319	504.4
Total area	6427.57	6427.57	6427.57	6427.56	6427.56	6427.58	6427.6

in 1987 was deemed tobe of pixels of this class*30*30/1000000 to give the area in km .Land cover in the study area has changed as indicated in the previous table. The research illustrated the long-term trends of

land cover in graphical form (Figure 3.2).The areal extent (km^2) has decreased for natural vegetation such as the forests and Shrub land.

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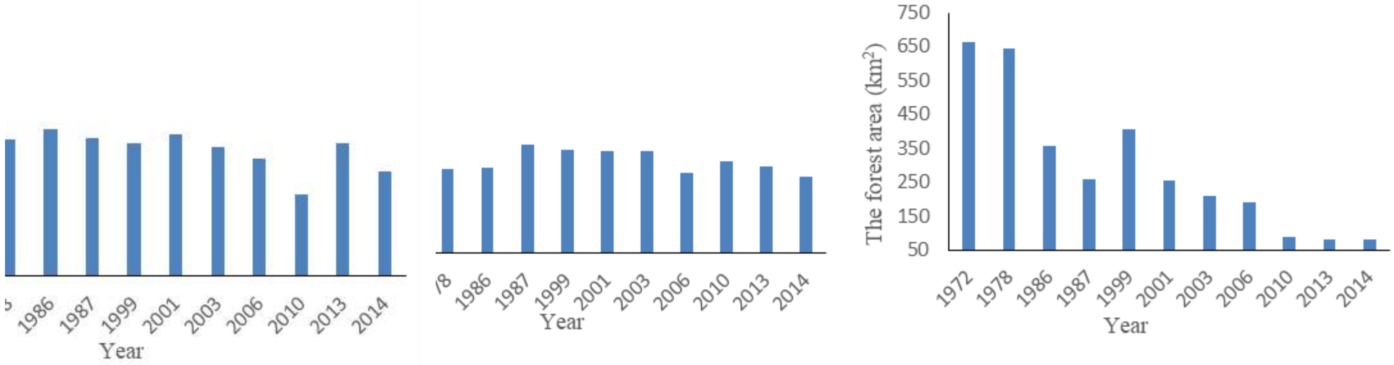
Land cover which has been exploited by humans, such as agriculture, urban and quarry, have increased over the 42 years. The influence of land use was evident in the spatial distribution of land cover change, for example forested areas declined steadily from 1972 to 2017 at a rate of -78.2%. In contrast, built up areas had notable increases at a rate of 71.7% from 1972 to 2013 with annual rates surpassing 25%, at least, for one or two dates. The magnitude and the rates of land use change in the study area exceeded 45 in percentage terms (%), and 400 in terms of spatial extent (km^2) in cultivated areas and built-up areas from 1972 to 2017.



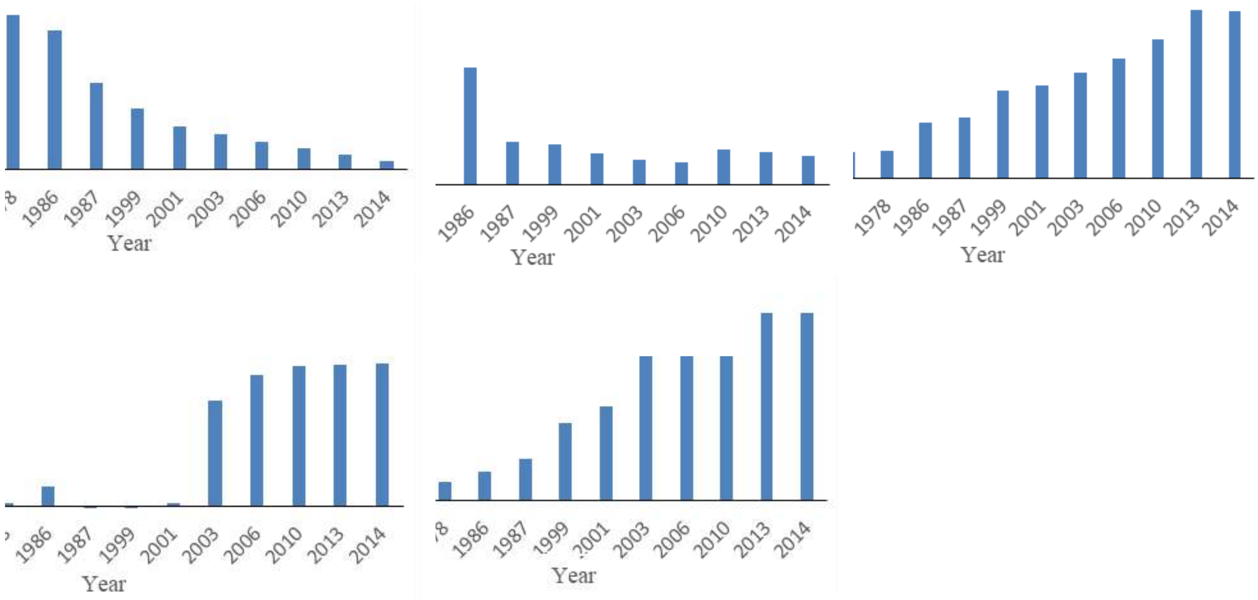


Figure 3.2: Long-term land cover change in the study area

4.Spatial analysis of affecting human activities on vegetation change in the study area:

To investigate the factors affecting vegetation change in the study area, the research used the outputs of previous objectives to identify the relationships between vegetation change and land cover changes, and then the influences of human activity on vegetation cover change. The proposal related to the third objective is that areas which exhibit statistically significant vegetation cover change over the last 45 years, are the same areas that have dense populations and a variety of human activities, while other areas with significant vegetation change and sparse populations may be responding primarily to climate change.

The research evaluates the relationship between the areas experiencing vegetation cover change and the main factors that may be

causing this change. Population data are used to assess possible relationships between vegetation cover change and the likely distribution of human activity.

4.1 Assessing the relationship between vegetation cover change and population:

Population has an influence on vegetation cover by exploitation of land leading to land cover change. The research examines the spatial correlation between areas that exhibited vegetation cover change and the distribution of population. The population data were classified as 1 km resolution population counts for 2013(Figure 4.1). The three VI correlation images were used in a binary classification with 0 representing no significant VI change and, 1 representing statically significant change

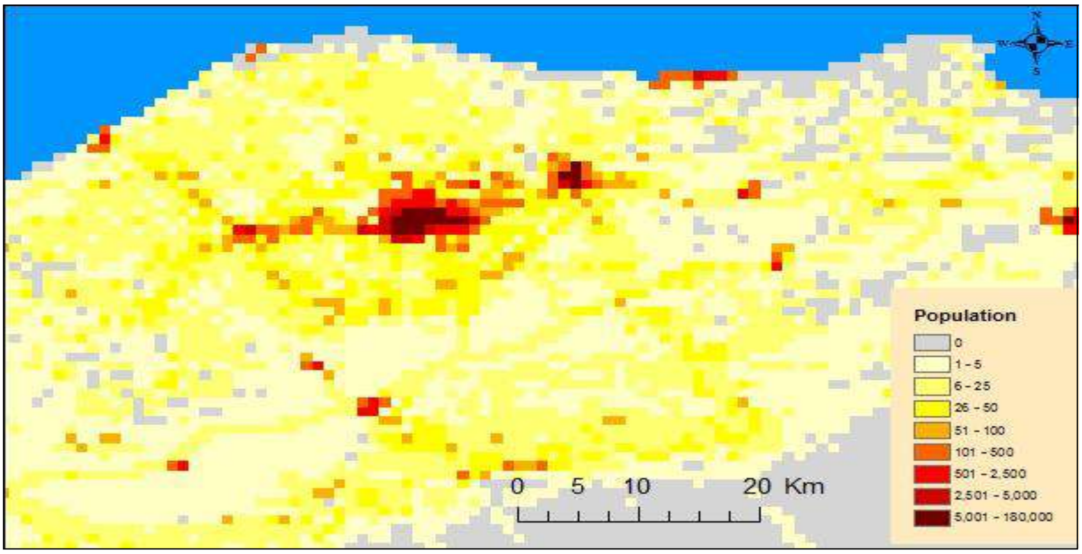


Figure 4.1: The distribution of Libyan population data in the Al Jabal Al Akhdar region in 2012

(p< 0.05).

These data were overlaid on the population data and the two layers multiplied together. The outputs were new data layers showing the population of 1 x 1km pixels where there was a significant change in the VI detected at finer resolution using the Landsat data. The results are shown in(figure 4.2) with the VI change periods coloured by population.

This result provides an ideal panel data set of the relationship between population and vegetation cover. The histograms show the population of the 1 x 1 km areas where one or more statistically significant change in the VI was recorded and the counts of population in the new outputs represent the influences of population on vegetation cover through its activities in these areas .The main conclusion showed that most of the areas with a statistically significant decrease in VI are low population areas.

4.2Assessing the relationship between the VI change and land cover change in the study area:

Land cover has changed in the study area due to the expansion of human activity during the last 45 years. Land use such as agriculture, quarrying and urbanization has significantly increased, while the forests and high and low density shrub lands have declined as a result of increased human activity which has led to the development of farmland and industrial areas. The research produced 12 binary images, one for each land cover class (figure 4.3), for each year. Each image represents one type of land cover in which every 30 m pixel has number 1 and all other classes have number 0. Each new layer was

overlaid on SAVI, which showed the largest area of significant vegetation change compared to the NDVI due to the removal of the soil's influence and the longer period of study. The two layers were multiplied together

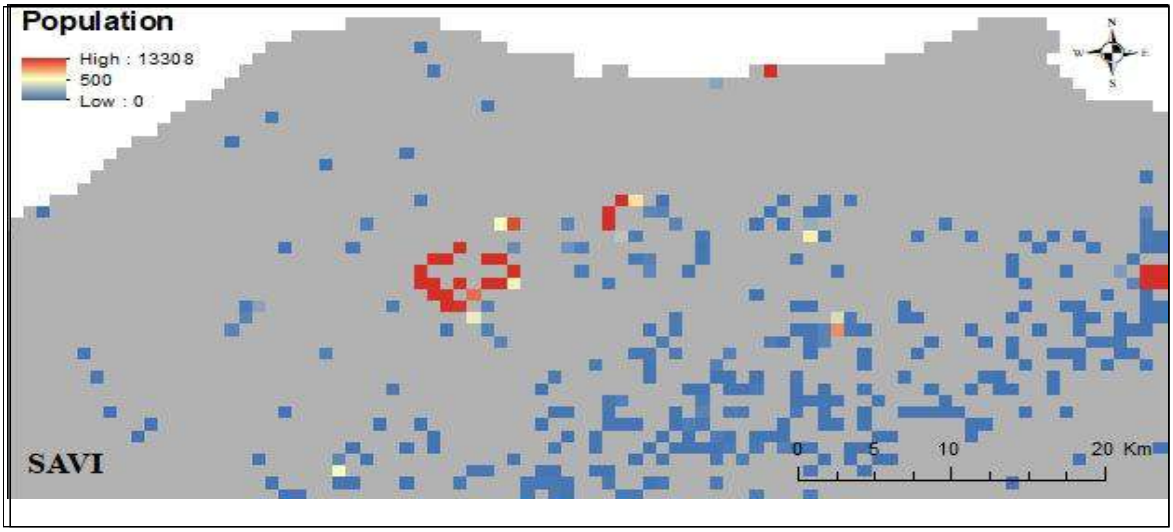


Figure 4.2: The relationship between the population and VI change.

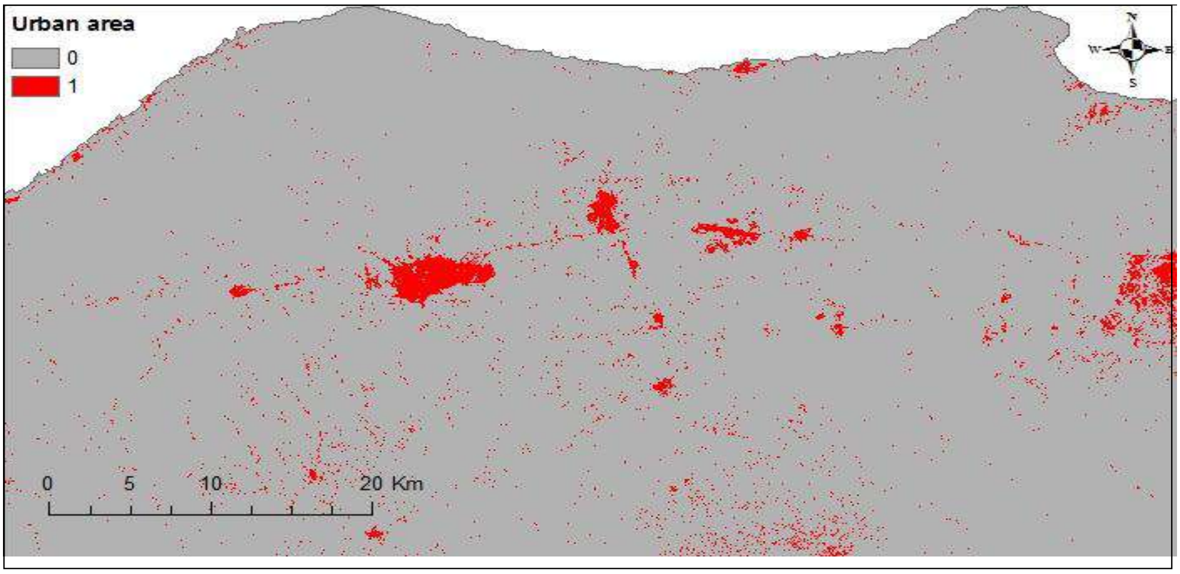


Figure 4.3: The urban area classified image of 2003

And Produced new data layers showing land cover in pixels where there was a significant change in the SAVI. The results are show in(Figure 4.4)with the SAVI change coloured by the urban area. The results show pixels classified as Urban in 2003, which also show a long term significant decrease in SAVI. The areas within the urban boundary have seen a reduction in vegetation cover due to urban development. Also, new data layers show a decrease in vegetation cover in some areas as a result of agricultural expansion over the period of study.

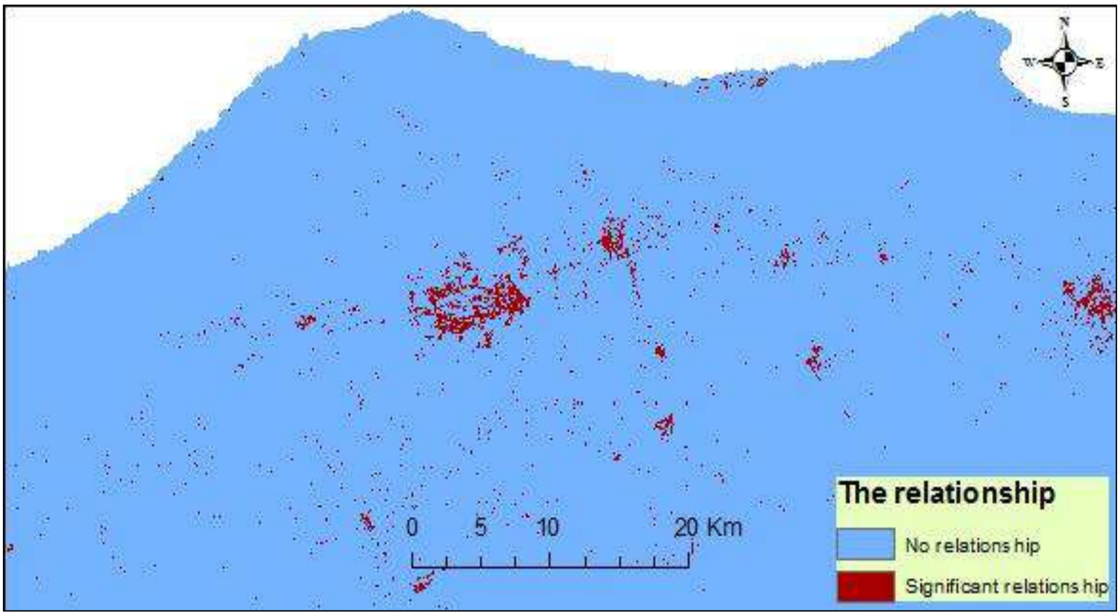


Figure 4.4: The relationship between SAVI and urban area in 2003.

The approach assessed all the land cover classes over the period of study with SAVI to assess the land cover in those pixels where there was a significant change in the VI.Overall, the graphs show that the land cover of pixels showing statistically significant VI change are mostly from the low density shrubland and agriculture classes, although they also occur for other land cover classes. The

inference here is that VIchangein the agricultural areas are most likely caused by changes in land cover and land use. However, in the areas of low density shrubland, where there is likely to be less human influence, the VI change may be more directly related to climate change.

5. Conclusion

This research demonstrated the relationship between vegetation cover change, land cover change, the population data in the region to determine whether these factors may be affecting vegetation cover change. Based on the results obtained in vegetation cover change and land cover change in relation to the study area using a remote sensing technique, the research in this chapter synthesized all these results to assess the relationships, and the following conclusions were drawn:

(i) Increase the desertification in the south of Al Jabal Al Akhdar region over the period of 45 years.

(ii)The research evaluated the relationship between vegetation cover change and the population data of the study area to identify the effect of population distribution on vegetation change. The result indicated a large number of areas that experienced change in vegetation cover where population density ranged between medium and high-density.

(iii) The influence was clear in the areas around the cities where population density was highest and vegetation cover decreased over the period of study.

(vi) There was a relationship between the distribution of population and land cover change, where the concentration of population in the

urban areas was higher than the population in shrubland, forests, desert and bare areas.

Overall, there are a variety of factors affecting vegetation cover change, however, the effect of human activity on vegetation was clear and rapid through changing land use in the region over the 45 years. However, the research suggests that the areas that experienced changes in vegetation cover in shrubland areas with low population density, especially in the areas in the south of the Al Jabal Al Akhdar, responded to increasing temperatures that there are areas with low human activity which have experienced significant changes in vegetation cover over the period therefore, the probability is that climate change may be responsible for this change. This result needs more investigation for these specific areas by field work and more research needs to be conducted to determine which factors are causing vegetation cover change.

5. 1The results

(i) The results of the analysis of VI using linear regression and correlation analysis showed that there was a statistically significant decrease in vegetation cover in some areas in the region over the period of 45 years.

(ii) The magnitude and the rates of land use changed in the study area from 1972 to 2017, which was expected since most of the changes were caused by human action. The area covered by forests in 1972 was about 128.9 km^2 and declined in 2014 to 35 km^2. In contrast, there was an increase in the area of agriculture from 50 km^2 in 1972 to 201 km^2

in 2014 due to an increase in population and increased requirements for food.

(iii) Thereis affecting vegetation cover change. However, the effect of human activity on vegetation was clear and rapid through changing land use in the region over the 45 years. The important conclusion was that there are areas with low human activity, which have experienced significant changes in vegetation cover, especially in the south of the study area and increase the desertification, Therefore, climate change may have been responsible for this change, or it may be due to overgrazing, decreasing groundwater and the making of charcoal using the wood of trees. This result needs more investigation for these specific areas by fieldwork and more research needs to be conducted to determine which factors are causing vegetation cover change.

6.Discussion

The key points from the research are discussed in the next three sections:

6.1 Vegetation cover change

Vegetation cover change was observed in Al Jabal Al Akhdar region over the 42 year study period, through a statistical analysis of available Landsat imagery. The main limitation in the analysis of the spatial and temporal records here was the lack of Landsat imagery available to cover all of the study area. There was up to 200 images for the study area but just 14 images were usable due to cloud cover, or being in a different season. In spite of this limitation, the results provided maps

for vegetation cover change in the study area, and confirmed the local-scale results of Al Mukhtar (2005) and Ibrahim (2014), for vegetation cover change in the region. In the future, images from different sensors may become available to use for long-term observation of vegetation change and the time-series can then be extended, promoting more confidence in future, assessments of the nature and patterns of vegetation cover change.

6.2 Land cover change

The effect of human activity on vegetation cover was clearly observed in the study area through changes in land cover. There were classification errors in all outputs for the study area and there is a need to improve some accuracy within individual classes in the classification process. This was a key limitation in this objective. The results confirmed the change in land cover with overall classification accuracy of about 72%. The remaining work for this objective was based on identifying the negative effect of human activity on land cover change, in an attempt to provide the evidence for environmentalists and decision-makers who are concerned with the effects of human intervention on vegetation cover.

6.3 Exploring the causes of vegetation change

Population expansion and human activities were the main factors causing change in vegetation cover in the study area, through concentration of the population in the areas that experienced a change in vegetation cover. In terms of the effect of climate change, the

research assumed that in the areas that had changes in vegetation cover combined with low human population and human activity, climate change might have been responsible for this change. There were three limitations in this objective: First, non-availability of population data for previous years to determine the relationship between the time series of population and vegetation cover change. Second, limited background research on the factors affecting vegetation change in the study area, which may help to explain the factors causing vegetation cover change.

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