

Monitoring Vegetation Characteristics and Degradation Risk in Jordan Using NDVI Time Series

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ABSTRACT

Satellite derived indices e.g. NDVI have been widely used for vegetation analysis and change detection studies at different spatial scales. This study analyses the vegetation characteristics and impact of long-term variation in vegetation cover upon land degradation in Jordan. The inclination and significance of NDVI trends, which are derived from the Modified Seasonal Mann-Kendall and the Seasonal Kendall Slope, are used to determine the hotspot of vegetation degradation during the period 1989-2004. The analysis shows that the mountain regions are more vulnerable for vegetation degradation than other ecological regions due to climate variability, urban expansion, and changes in land use systems. The effect of climate variability and the impact of improper land use on the natural ecosystem in the transitional zone are becoming more vulnerable to land degradation. The vulnerability of the irrigated farms to degradation in the Jordan valley is mainly due to the fluctuations in available water for irrigation, while the pattern of ground water utilization has important effect on vegetation distribution in the desert regions. However, in the Desert regions, the NDVI trend components are not significant as the value of vegetation density is very low. It is noticeable that the land degradation triggered by rainfall variability, urban growth, expansion of irrigation, and socio-economic transformations.

Keywords: vegetation characteristics, degradation risk, time series analysis, NDVI, Jordan.

1. Introduction

Land degradation becomes a major environmental problem during the last few decades, particularly in arid and semi-arid regions of the earth (Gislisladottir and Stocking 2005). It refers to the loss of valuable land qualities through various processes such as soil erosion, depletion of nutrients and loss of vegetation cover (Dregne 1998). The natural and human factors affect the vegetation through various biophysical, chemical and biological processes, which deteriorate the soil properties and decrease plant productivity (Tagil 2007). In Mediterranean regions, land degradation is sensitive to the interaction between the natural and anthropogenic processes (Mainguet 1999; Conacher and Sala 1998). Different approaches for identifying land degradation have been implemented such as fieldwork, physical modelling and remote sensing. Different studies of remote sensing and GIS have been used for land degradation studies; such as mapping of the physiographic units (El Baroudy and Moghanm 2014), principal component analysis of Normalized Difference Vegetation Index (NDVI) time series (Lasaponara et al. 2013), fusion techniques of multi sensors images (Kumar et al. 2015), integration of multi-spectral satellite images (Lanfredi et al. 2015). In addition, other studies use the combination of remote sensing techniques (Becerril-Pina et al. 2016), landscape metrics indicators (Simoniello et al. 2015), and integration of environmentally sensitive model with vegetation cover (Imbrenda et al. 2014).

The remotely sensed research studies have developed methods for deriving individual indicators for land degradation assessment. Soil based remote sensing indices e.g. SAVI has been used in arid regions (Washington-Allen et al. 2006). Although the limitation related to NDVI time series analysis (Wessels et al. 2012), the majority of land degradation studies rely on vegetative indicators (Symeonakis and Drake 2004), and multi-temporal analysis of vegetation index data (Higginbottom and Symeonakis 2014; Wang et al. 2014). Remotely sensed derived indicators for vegetation degradation

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should be drawn according to a list of criteria, such as reliability, measurability, applicability, cost-effectiveness, and interpretability (Babaev and Kharin 1999; Rubio and Bochet 1998).

NDVI datasets are mostly used for description of vegetation conditions and productivity due to their simplicity and their relationship with rainfall (Al-Bakri and Suleiman 2004), and vegetation biophysical parameters (Bajocco et al. 2012), and plant growing cycle (White et al. 2002; Dash et al. 2007; Makhmreh 2010; Patel and Oza 2014). In addition, it is related to biophysical variables that determine vegetation evolution and net primary productivity (Bono et al. 2007; Bai et al. 2008). Therefore, the NDVI time series has been used as indicators for land degradation and environmental changes at different spatial scales (Wessels et al. 2007; Udelhoven et al. 2009; Panday and Ghimire 2012; Tian et al. 2013). In this context, it has been used for monitoring land degradation in Africa (Bellone et al. 2009; Herrmann et al. 2005; Olsson et al. 2005), in the Mediterranean region (Udelhoven et al. 2005; Evans and Geerken 2004; Hill et al. 2003), and in dryland regions (Omuto et al. 2010; Weiss et al. 2001). The objective of this research is to analyse the vegetation characteristics and identify the risk of vegetation degradation or hotspots in Jordan using NDVI time-series during the period 1989-2004.

2. Methodology

2.1 Study Area

Jordan is located in the eastern Mediterranean region between 29°11' and 33°22' N latitudes, and between 34°19' and 39°18' E longitudes with an area of more than 89 thousand km². Ecologically, Jordan consists of four ecological regions; namely, the Jordan valley, the Mountains region, the transitional region and the desert region as shown in figure (1). For analytical purposes, the mountains region is divided into three zones: northern, middle and southern regions.

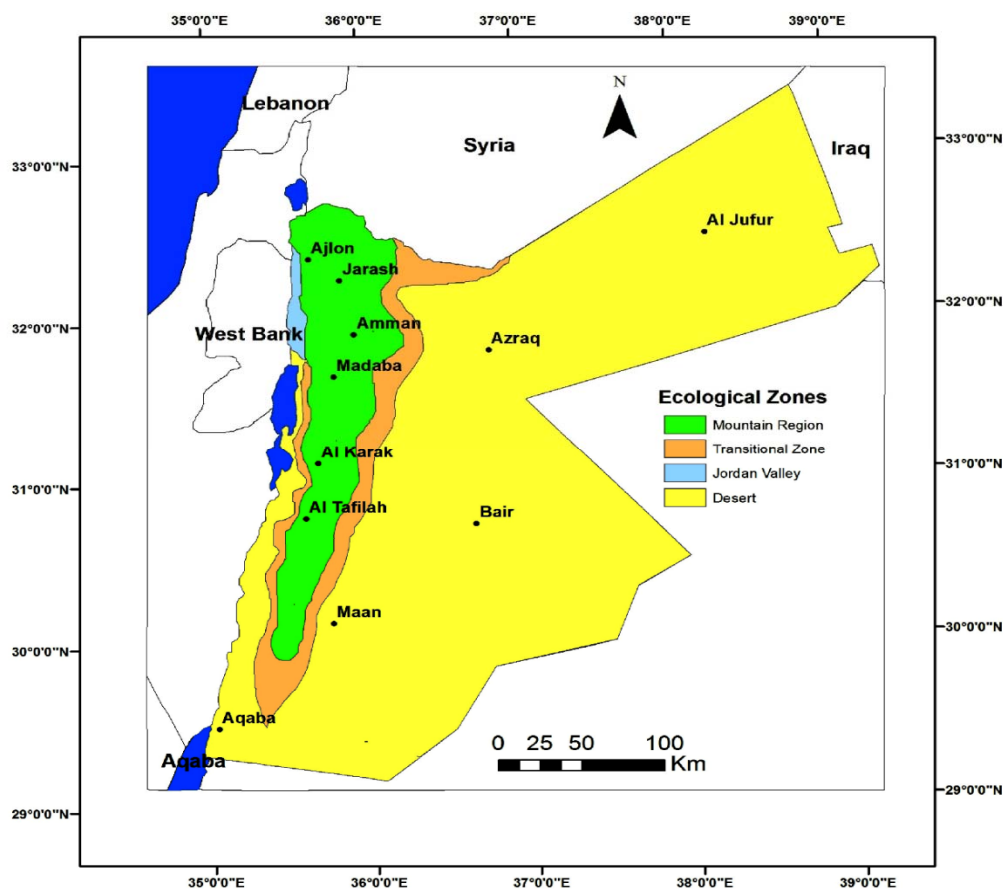


Figure 1. The main Ecological Regions of Jordan (MoA 2005).

Mediterranean climatic is prevailing in Jordan; the rainfall occurs in winter season while the summer season is dry and hot. The rainfall is characterized by a high level of annual and seasonal variability; this is in addition the decreasing rainfall pattern from north to south and from west to east. Figure (2) shows the average of long term annual rainfall and reference evapotranspiration in the main ecological regions in Jordan computed during the period from 1989 to 2004 (DOM 2005). The average annual rainfall is ranged from 550 mm/year in the northern mountains region to less than 200 mm/year in the desert region, and the annual reference evapotranspiration is ranged from 1600 in the northern mountains region to 2600 in the Jordan valley.

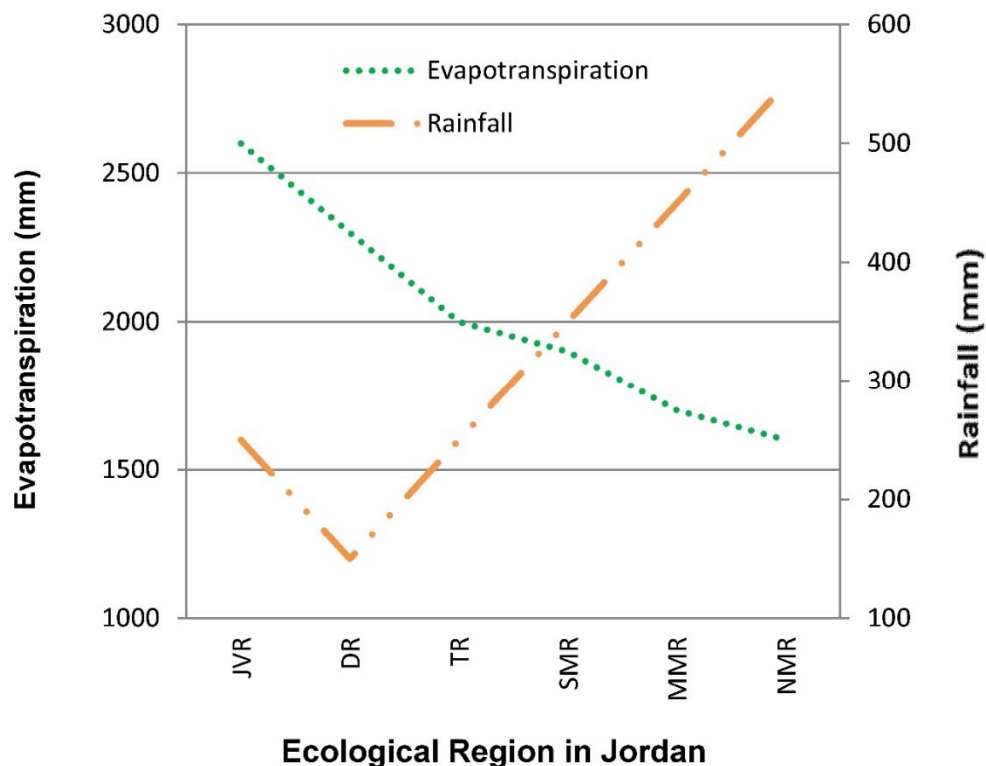


Figure 2. The average annual rainfall and evapotranspiration in the main ecological regions in Jordan computed in the period from 1989 to 2004 (DOM 2005); DR is the Desert Region; TR is the Transitional Region; JVR is the Jordan Valley Region; SMR is the Southern Mountain Region; MMR is the Middle Mountain Region; and NMR is the Northern Mountain Region.

2.2 Image Analysis

The NDVI dataset that used in this study is the “Mediterranean Extended Daily One Km AVHRR Data Set” (MEDOKADS) which provides daily, 10 days, and monthly NDVI value composites at 1 km resolution. This data set is compiled from the NOAA-11, -14- and 16 sensors and is distributed by the Institute of Meteorology, Free University of Berlin (Koslowky, 1998; Han and Kamber, 2001). These image data is selected for this study as it offers a consistent, inter-calibrated full coverage of the country that enables the analysis in a standardized way. Only some desert parts of the country, which is not covered with the images dataset and lay mainly in the Eastern and Southern parts of Jordan. The pre-processing steps, calculation of basic statistics and trend analysis derived using the TimeStats software tool, which is designed to analyse spatial-temporal data, discover trends, and stochastic components (Udelhoven 2011).

The main steps of the data analysis, which are used in this study, are data cleaning, images pre-processing and calculation of basic statistics and trend analysis. The data cleaning includes correction of outliers and missing value and filtering of noisy data. The pre-processing step includes data aggregation of monthly, seasonal, annual averages, and variances. Data

normalization includes seasonal normalization and image differencing. Calculation of basic statistics and trends analysis include the descriptive statistics, linear trend analysis and significance tests, and non-parametric trend tests such as Mann-Kendal test, seasonal Kendal test, Modified seasonal Kendall test, Kendall slope, and seasonal Kendall slope.

The significance of long-term variations assessed by the Modified Seasonal Mann-Kendall test, which is suited for monotonic trend detection independent from its functional type (Piwowar and Ledrew 2002). It measures the slope coefficient in a linear trend analysis and it describes the magnitude and inclination of a trend (Box and Jenkins 1976).

The Mann-Kendall test statistic for each season is calculated as follows:

$$S_g = \sum_{j < i} \text{sgn}(x_{jg} - x_{ig}) \quad g = 1, 2, \dots, p \quad (1)$$

The seasonal Kendall test statistics is

$$S' = \sum_{g=1}^p S_g \quad (2)$$

and it is asymptotically normal with mean 0 and variance

$$\text{var}[S'] = \sum_g \sigma_g^2 + \sum_{g,h} \sigma_{gh} \quad (3)$$

The covariance are estimated using

$$\hat{\sigma}_{gh} = \frac{1}{3} [K_{gh} + 4 \sum_{i=1}^n R_{ig} R_{ih} - n(n+1)^2] \quad (4)$$

where

$$K_{gh} = \sum_{i < j} \text{sgn}[(x_{jg} - x_{ig})(x_{jh} - x_{ih})] \quad (5)$$

For each season a separate test statistic is calculated to eliminate the influence of a possible seasonal components on a trend. It is assumed that the time-series values are independent and derive from an identical basic population (Hirsch and Slack 1984). The Seasonal Kendall slope estimator represents a non-parametric test statistic measures the slope coefficient in a linear trend analysis and is applied to describe the magnitude and inclination of a trend (Box and Jenkins 1976). The slopes are estimated separately for each seasonal component. The median of the slopes is then used to describe the total trend of the series. If there is no missing data n is the number of data that values x for one season, so there will be

$$n(n-1)/2 \quad (6)$$

possible pairs of time points (x_i, x_j) in which $i < j$.

The slope for such a pair is called pairwise slope, b_{ij} , and is computed as

$$b_{ij} = (x_i - x_j) / (i - j) \quad (7)$$

The slope for each season is then the median of the $n(n-1)/2$ pairwise slopes, and the median of all the season's slopes is an estimator of the slope for a long term trend (EPA 2000).

The monthly NDVI value was calculated from the daily NDVI records for each month, the seasonal NDVI was calculated from the monthly records during the growing season, and the annually NDVI was calculated from the monthly records for the whole year. Applying time series indicators such as the Modified Seasonal Mann Kendall Test allows evaluation and the comparison of the annual variability of NDVI values. It enable to highlight the significant of trend values and detect the changes in vegetation conditions, these changes in vegetation values can be presented by either a hotspot, which represent a decrease in the long-term vegetation value and conditions or a bright spot, which represent an increase or stability of long-term vegetation values and conditions. In this case, pixels characterized by negative NDVI slopes represent hotspot areas or deterioration in vegetation conditions while the positive NDVI slopes indicate bright spot or stable vegetation conditions.

3. Results and Discussions

Analyses of the NDVI trend and magnitude for the vegetation conditions in the monitoring time between 1989 and 2004 were able to describe the vegetation conditions and to detect the major hotspots of the vegetation degradation at different ecological zones in Jordan. The main observations that can be investigated from the analysis were discussed in these two sections. The first section describes the vegetation characteristics under different ecological regions. The second section describes the hotspot area and the potential risk of vegetation degradation.

4.1 Vegetation Characteristics

Figure (3) show the NDVI values for different ecological regions in Jordan. The NDVI values, which were computed,

based on the monthly records during the monitoring time. The highest NDVI values that were computed on a pixel bases of maximum vegetation growth values during the growing season in each ecological region. The lowest NDVI values were computed on pixel bases of minimum vegetation growth value during the growing season in each ecological region.

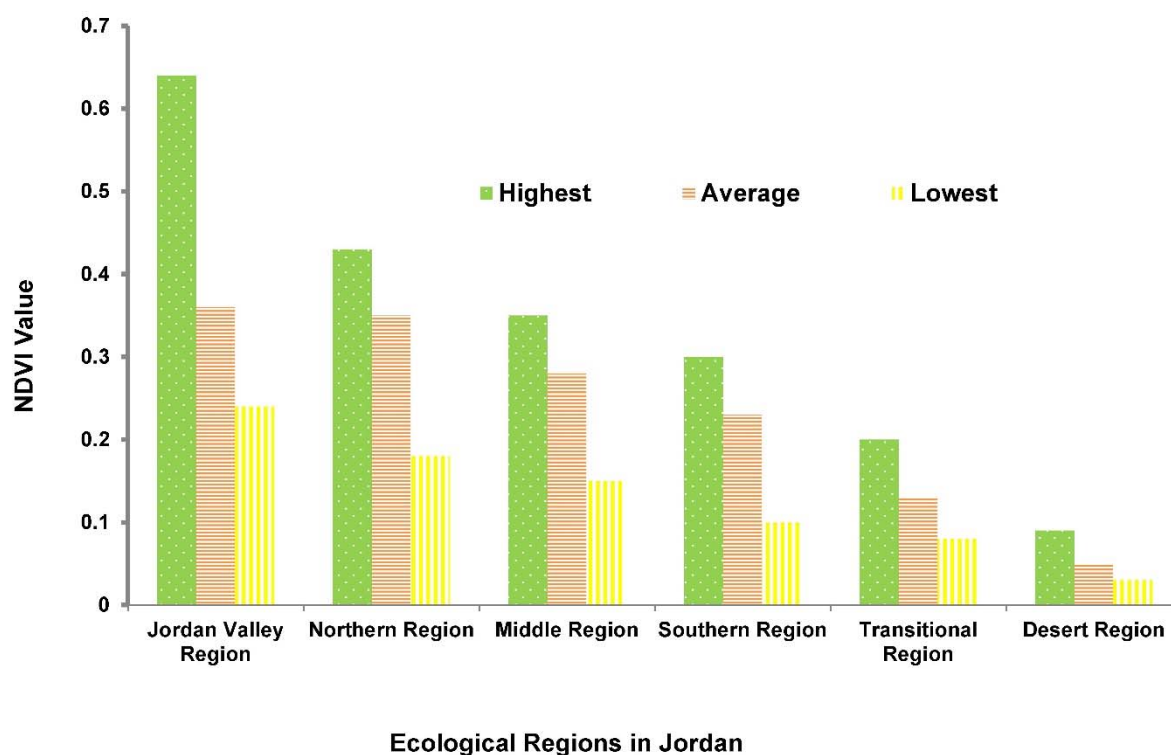


Figure 3: The highest, lowest and average NDVI values for the different ecological regions in Jordan in the time period from 1989 to 2004. DR is the Desert Region; TR is the Transitional Region; SMR is the Southern Mountain Region; MMR is the Middle Mountain Region; NMR is the Northern Mountain Region and JVR is the Jordan Valley Region.

The highest mean annual NDVI values of about 0.45 were found in the northern mountains region. This region receives the highest rainfall in the country, and it covered by natural vegetation and fruit trees. The NDVI value in the middle mountain regions ranges were between 0.15 and 0.35. The southern mountains region has annual NDVI values ranges from 0.10 to 0.25. The NDVI values vary between 0.05 and 0.09 in the desert area, and from 0.18 to 0.07 in the transitional region. On the other hand, the eastern and southern desert of the country has the minimum mean NDVI with average values of less than 0.05 and have ranges of values between 0.01 and less than 0.09. The mean annual NDVI values in the Jordan valley range between 0.32-0.62, because it is dominated by two growing season of irrigated agriculture.

Figure (4) shows the characteristics of different ecological regions in terms of the altitude and rainfall values in Jordan. The influence of rainfall on land use type and vegetation density is obvious by detecting the NDVI value; there is a decrease in NDVI values along the north south and the west-east direction, which is in accordance with the decreasing pattern of rainfall and increasing pattern in reference evapotranspiration at the same directions.

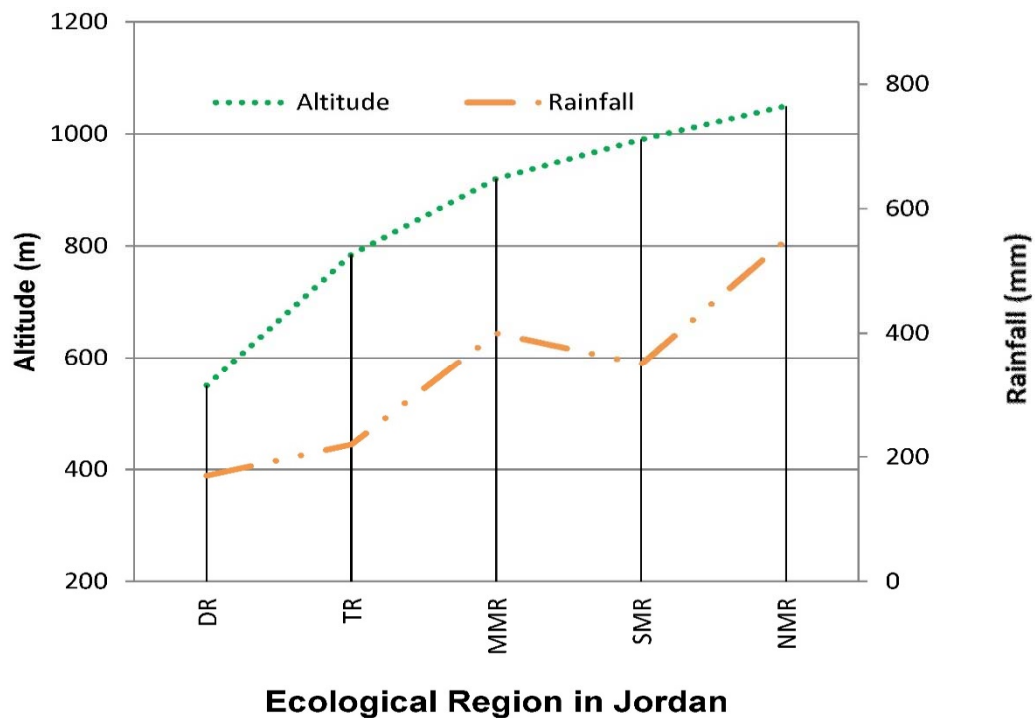


Figure 4: The characteristics of different ecological regions in terms of the altitude and rainfall values in Jordan. DR is the Desert Region; TR is the Transitional Region; SMR is the Southern Mountain Region; MMR is the Middle Mountain Region; and NMR is the Northern Mountain Region.

The northern mountains regions are characterised by rainfed agriculture, the dominant land use is the fruit trees, olives and field crops. The rainfall amounts range between 500-600 mm annually, and the altitude varies between 850-1250 m. The middle mountain region is dominant by field crops and fruit trees and some shrubs. The rainfall amounts ranges between 400-500 mm annually, and the altitude varies between 750-1100 m. The southern mountain regions are dominant by fruit tree and shrubs. The rainfall amounts range between 300-400 mm annually, and the altitude varies between 700-1300 m. The transitional region is characterised by annual grasses and barley. The rainfall amounts range between 200-300 mm annually, and the altitude varies between 600-850 m. The desert region is dominant by bare soil and bare rock and very low vegetation cover in the low depression areas. The rainfall amounts range between 100-200 mm annually, and the altitude varies between 500-750 m. The lowest dynamics of NDVI are registered in the east and South-East desert parts which have very low amounts of rainfall and high evapotranspiration. Low-density vegetation and annual grasses of short life cycle cover the largest parts of this class. Finally, the Jordan valley is dominated by irrigated farms, the mean NDVI and magnitude of annual cycle is a function of land use pattern, available water for irrigation and cannot be related to rainfall and altitude variables.

The differences in the spatial distribution of the NDVI magnitude are related to the climatic conditions, land use type, soil types and topography. The differences in rainfall and temperature conditions in the mountains regions influence the period where the maximum vegetation growth cycle can occur, and it justifies their occurrences in different months during the growing season.

4.2 Vegetation Degradation

The changes in the NDVI value has been evaluated using the Modified Seasonal Mann Kendall Test in the time period between 1989-2004 it allows for the evaluation of the annual variability of NDVI values, and enable highlighting the significant of trend values and detecting the changes in vegetation conditions. In this approach, pixels characterized by negative NDVI slopes represent hotspot areas or deterioration in vegetation conditions, while the positive NDVI slopes indicate bright spot or stable vegetation conditions. The spatial distribution of the NDVI slopes of trend

inclinations expressed by the Kendall-slopes and the significances level as presented in figure (5). According to the aforementioned hypothesis, red areas show a relative reduction in vegetation greenness and green areas show a relative increase in vegetation greenness during the investigated period. The decline of NDVI values is concentrated in the mountains and transitional regions along the north to south parts of the region and around the main cities and urban settlements. In addition, some parts of the irrigated areas in the Jordan Valley and desert regions are showing hotspot area as an indication for the decline in vegetation density but with smaller proportion than the mountain regions.

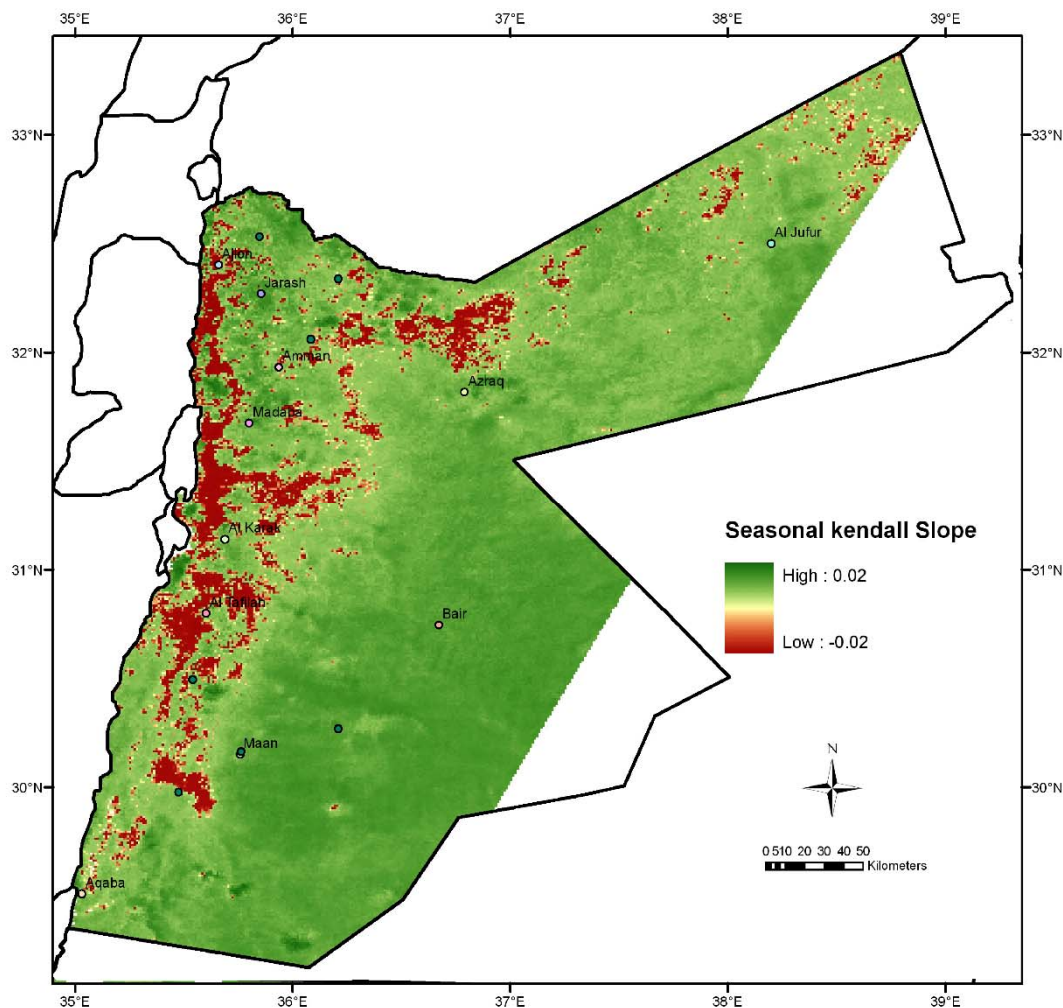


Figure 5. Spatial distribution of NDVI slopes of trend inclinations expressed by seasonal Kendall-slopes in the period between 1989 and 2004 in Jordan. The red pixels characterized by negative NDVI slopes represent hotspot areas or potential risk of vegetation degradation.

The presence of hotspot and bright spot areas can be attributed to different types of vegetation degradation processes; the first type is resulted from the nature and variability of climatic conditions particularly the rainfall pattern. The second type indicates by the urban expansion of the main cities on the cost of agricultural areas during the last decades. The third type is due to the dynamics of irrigation activities in the desert and Jordan Valley. The main factor influencing the spatial patterns of vegetation in Jordan is the rainfall gradients from north to south and from west to east directions as shown in figure (6). Patterns of vegetation and rainfall distribution display similar spatial patterns along the north-south mountain gradients but with different magnitude. The natural vegetation distribution in arid regions is related mainly to

the precipitation gradients, so that the precipitation decreases from the northern to the southern mountains region in Jordan, and thus the NDVI magnitude gradient decreases accordingly.

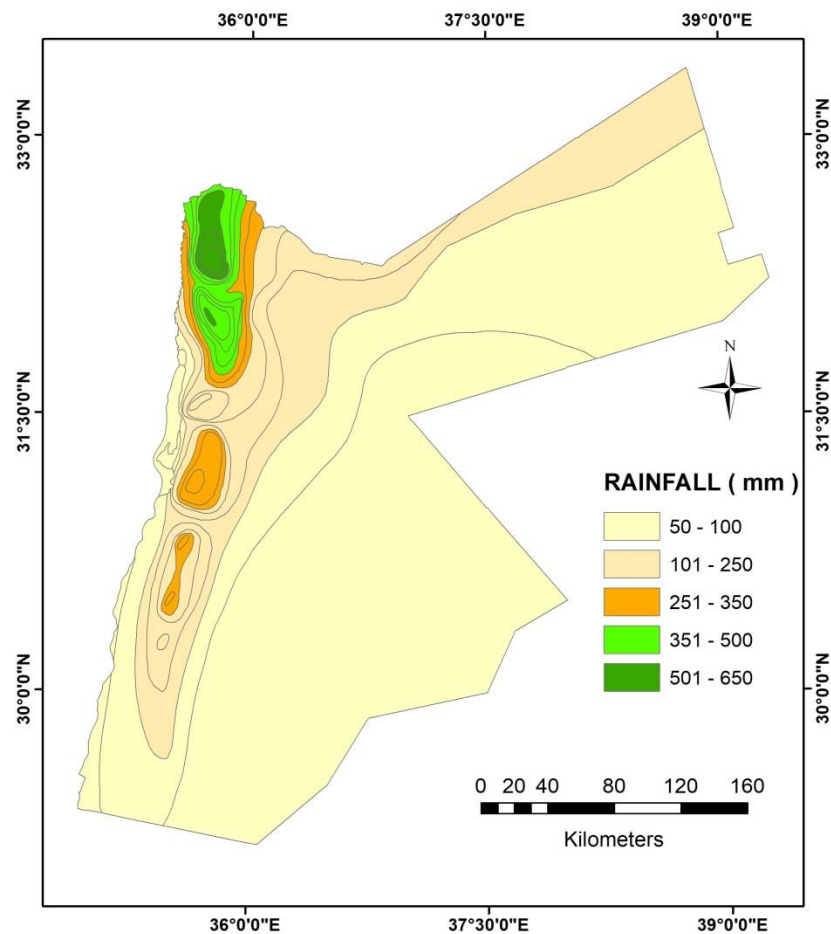


Figure 6. Pattern of rainfall gradients calculated using long term average precipitations in Jordan (DOM, 2005).

Figure (7) show the annual rainfall and the magnitude of vegetation density expressed by NDVI values. The negative trend of the NDVI along the north-south direction of the mountains region can be attributed to the rainfall variability during the monitoring period. The analysis of monthly rainfall data for selected stations in mountains regions shows a pattern of variability in the rainfall and vegetation density during the period from 1989 to 2004. In addition, there is a lag time between the rainfall events and NDVI value as obviously noticed by visual investigation of rainfall-NDVI relation during the monitoring time, and this lag is obvious in the northern mountain region. This variability in rainfall affects the vegetation cover, which has been verified by the NDVI results analysis. This lead to an increase in the risk of vegetation degradation as indicated by the presence of clear hotspot areas in the middle mountains regions.

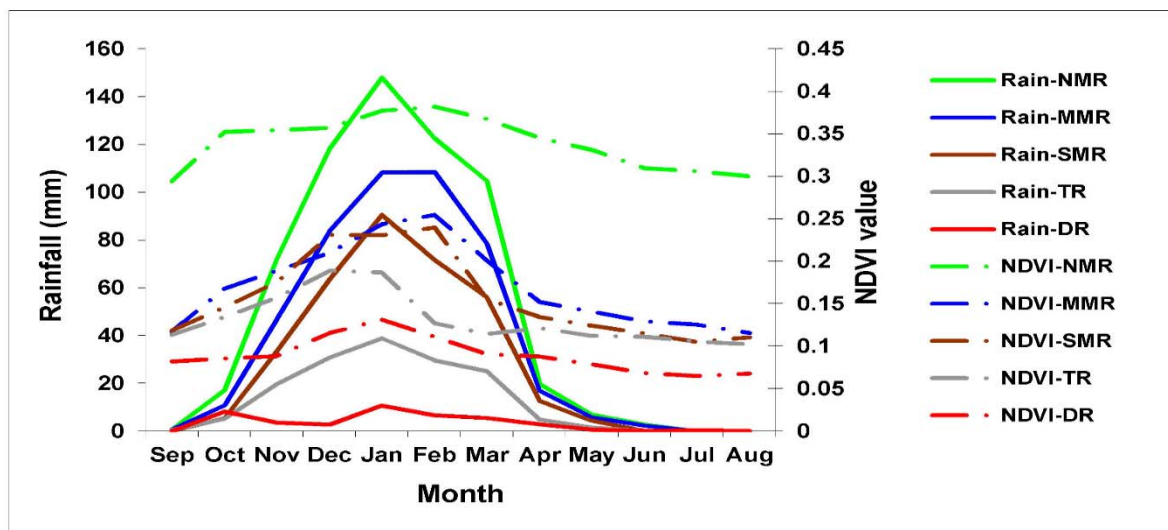


Figure 7. The NDVI and rainfall characteristics under different ecological regions in Jordan, DR are the Desert Region; TR is the Transitional Region; SMR is the Southern Mountain Region; MMR is the Middle Mountain Region; and NMR is the Northern Mountain Region.

The second type of vegetation degradation resulted from human induced factors, which are represented by high population growth and expansion of built-up area. The population numbers in Jordan has increased more than forth fold during the last five decades from mid-eighties to 2004. However, most of the population is concentrated in the main cities in the mountain regions particularly Irbid, Ajloun, Amman, Madaba and Karak since more than 75% of Jordan's total population resides in these cities, and these regions are characterized by negative NDVI Kendall slopes as shown in figure (5). These demographic changes have transformed the main cities of Jordan particularly Amman city from a small town in the early 1950s to a mega city that has become connected in all direction to the other cities in the west south and east parts. Figure (8) shows the development of total built-up area in Amman from 1989 to 2004. These developments brought significant changes in the social and economic structure activities in the mountain region, in terms of its population density, land use pattern, and socio-economic characteristics. High population growth and the acceleration of urbanization processes are the main factors influencing land use change in mountain regions, and thus lead to loss of agricultural land and increasing the risk of vegetation degradation around the main cities in Jordan.

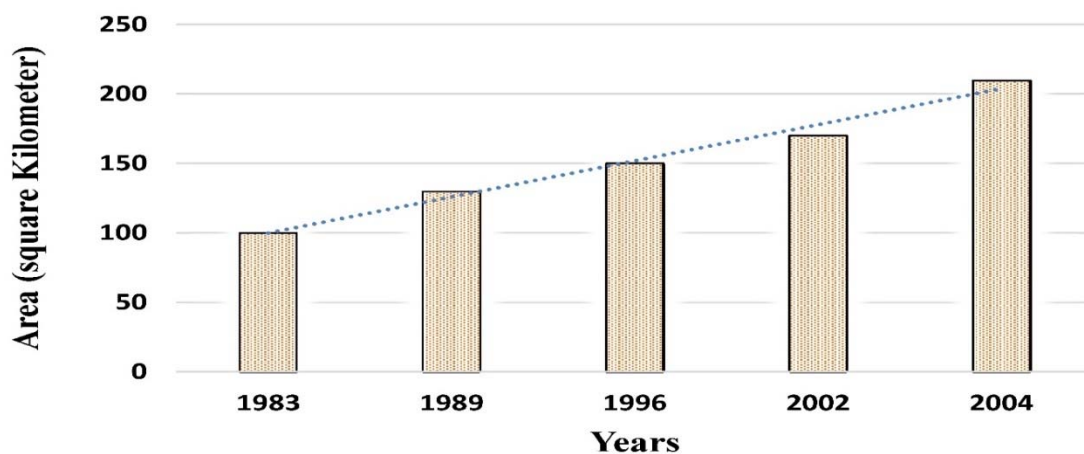


Figure 8: Development of the build-up area in Amman from 1989 to 2004 (DOS, 2005).

The third type of vegetation dynamics is due to the irrigated agriculture, which is located mainly in the Jordan Valley and some parts of the desert region that are famous with irrigated vegetables and horticulture farms. Figure (9) shows the changes in the total planted area and land use types in the Jordan valley in the period from 1989 to 2005.

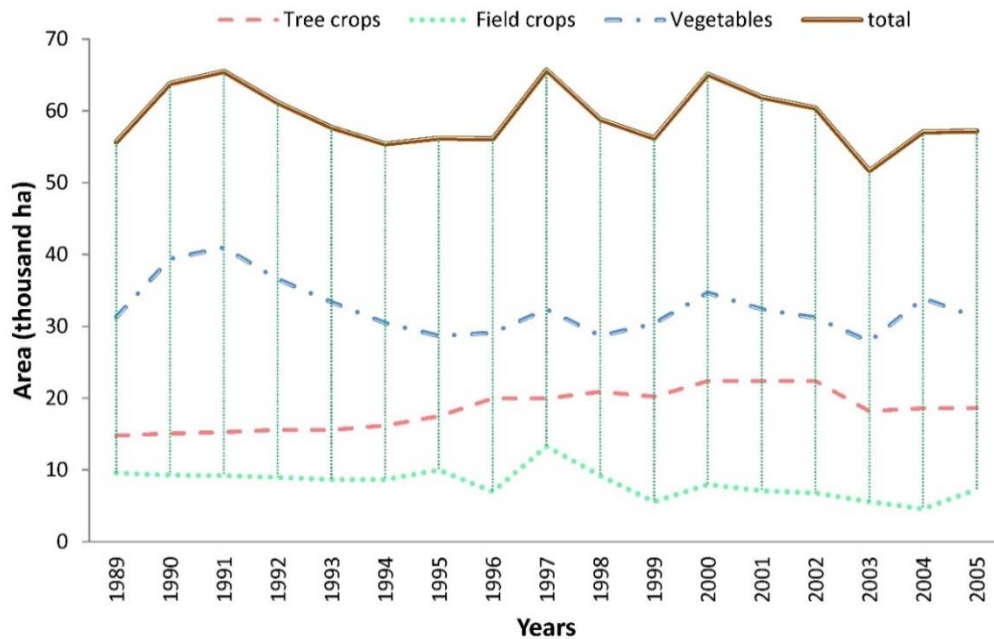


Figure 9: Changes in the total planted area and the main land use types in the Jordan valley between 1989 and 2005 (JVA 2006).

The influence of rainfall variability is also obvious on the amounts of stored water in the dams from the mountain regions. These amounts tend to vary because of the decreases and variability in the annual rainfall, therefore, the available water for irrigation in the Jordan valley, which depends partially on the harvesting of surface water from the upper-catchments, has fluctuated from one year to another. It is worth to mention that there are two growing season in the Jordan Valley as mentioned before, and this affects the total area of plantations besides the changes in the spatial distribution of the irrigated farms from one season to another depending on the available water for irrigation and pattern of land use. Accordingly, this affects the total areas of irrigated farms and distribution of irrigated farms and hence the fluctuating pattern of NDVI, which lead to increase the risk of vegetation degradation. As an indication of the effect of irrigation schemes on land degradation, figure (10) shows an example of the fluctuations of ground water abstractions for irrigation in some parts of North-Eastern desert region during the monitoring time. This period shows clear developments in the irrigation sector in the desert region that have taken place in order to maintain the crop production and expansion of irrigation especially in the desert region of Jordan. The irrigated areas are characterized by a seasonally variations pattern of irrigated land use types, and this dynamic pattern of irrigation was obvious when investigating the seasonal and annual change in the location of vegetable farms. The development of seasonal land use dynamics in irrigated desert areas was confirmed by a distinct spatial of shifting in the vegetation greenness and farms pattern distribution during the monitoring period.

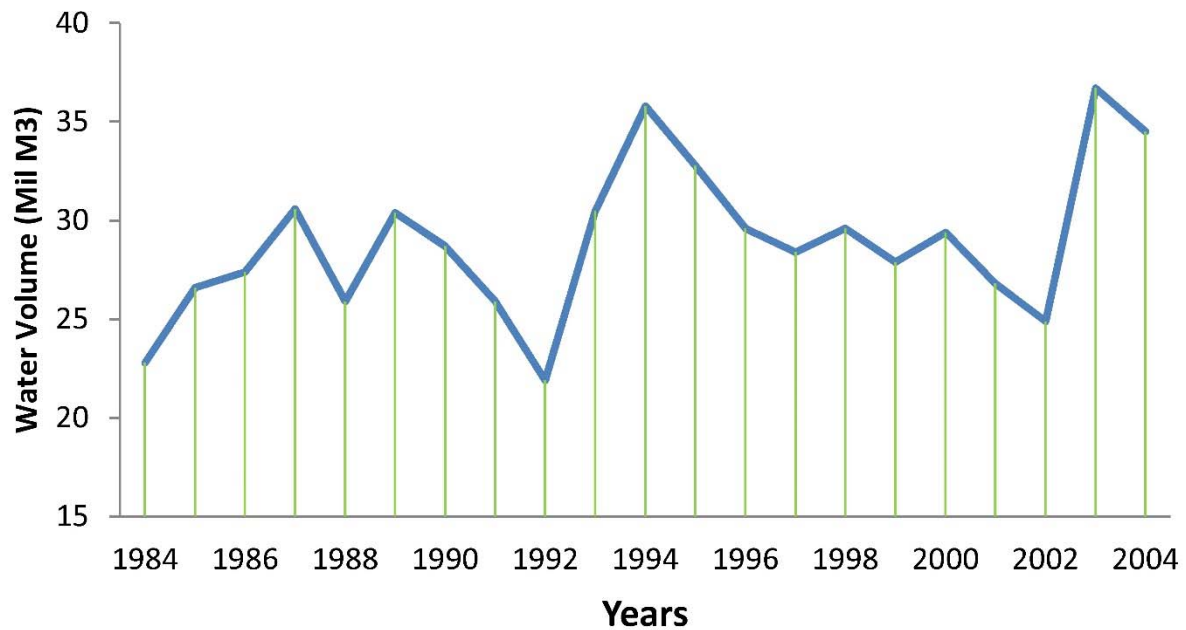


Figure 10: The volume of ground water abstraction in some parts of the North-Eastern desert region during the period from 1984 to 2004 (MIW 2005).

4. Conclusion

Land degradation is an important issue to both ecological and social aspects. Earth observation data offers a quantitative assessment of land degradation on a large scale. In this study, a time series analysis of AVHRR NDVI dataset used to detect the risk of vegetation degradation in different ecological regions in Jordan. The inclination and significance of NDVI trends used as indicators of vegetation degradation derived from the Modified Seasonal Mann-Kendall test and the Seasonal Kendall Slope to determine the trends of vegetation degradation during the period from 1989 to 2004. This enables to highlight the potential hotspots of vegetation deteriorations and risk for land degradation, which could be a consequence of complex interactions processes between stressed vegetation, climate variability and human interference. The NDVI trend analysis show different hotspot areas in the mountain regions and along the major irrigation areas in the Jordan valley and desert regions. The detected hotspot areas that indicate a risk for vegetation and land degradation are located at different climatic and ecological regions, which exist under drylands ecosystem, this needs more attention in order to sustain productivity in cultivated areas and maintain the ecological stability of the ecosystem. The importance of the land management role increases under regions of high and medium degrees of risk and therefore, implementation of proper environmental policies to promote sustainable land use management is highly required. The potential reasons that led to vulnerability of vegetation degradation in Jordan are variability of rainfall amounts, explosive expansion of urban agglomerates and changes in the pattern of irrigated land use system. Therefore, the vulnerable areas for vegetation degradation locate in the middle and southern mountain regions, and around the main cities. In addition, many smaller regions of hotspot area exist in the northern and middle parts of the Jordan Valley.

The main land use types in this region are the irrigated farms and this can be an indication of variations in the available amount of irrigation and fluctuations in the planted area. In desert region and some parts of the transitional region, no significant negative NDVI trends identified during the last two decades except for some spots in the eastern parts of Jordan where intensive irrigated farms exist; on the contrary, vegetation conditions in these parts considered relatively stable in the monitoring period. At the end, the presence of the hotspots areas over the most important regions of agricultural production in Jordan, represent a high potential risk of vegetation degradation and therefore additional attention should be given for improving the management practices and minimizing the risk of vegetation and land degradation in the mentioned regions. This study shows that the temporal trends profile derived from NDVI data were

effective for identifying the potential risk for vegetation degradation compared with traditional approaches. The benefit of this approach is to produce maps showing the degradation risk that it be updated regularly, enabling to monitor the evolution of hotspots areas. The results show the need for using remotely sensed data for long-term vegetation assessment and the future development of this work is to analyse a finer spatial resolution images like LANDSAT or SENTIENAL in the hotspot areas and relate the NDVI results with the actual productivity levels from the field. Also, application of this approach in the context of a continuous monitoring strategy for the other periods could be a useful tool for assessing the evolution of land degradation risk in order to achieve sustainable agriculture in Dryland ecosystem.

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مراقبة خصائص الغطاء النباتي ومخاطر تدهوره في الاردن باستخدام سلسلة زمنية لمؤشر الخضرة النباتي

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ملخص

يستخدم مؤشر الخضرة النباتي المشتق من المرئيات الفضائية بشكل واسع في تحليل خصائص النباتات وكشف التغير بالغطاء النباتي على مقاييس مختلفة. تهدف هذه الدراسة إلى تحليل التغيرات في خصائص الغطاء النباتي على المدى البعيد وتأثيرها على تدهور الأراضي الزراعية و الطبيعية في الاردن. اعتمدت المنهجية على استخدام التغير في درجة ميلان مؤشر الخضرة النباتي المشتق من السلسلة الزمنية للمرئيات الفضائية لتحديد المناطق ذات المخاطر العالية لتراجع الغطاء النباتي خلال الفترة الزمنية بين (1989 - 2004). بينت نتائج التحليل بان المناطق الجبلية ذات حساسية عالية للتدهور اكثر من المناطق الايكولوجية الاخرى، وذلك بسبب التذبذب المناخي، و التوسع العمراني و التغير في نمط استعمالات الاراضي. بينما كان تأثير التباين المطري وسوء الاستعمال واضحاً على تراجع الغطاء النباتي في المناطق الايكولوجية الانتقالية، اما حساسية المناطق المروية للتدهور في غور الاردن فتراجع بشكل رئيسي الى تذبذب كميات المياه المتاحة للري من سنة لآخرى. بينما يشكل نمط استخدام المياه الجوفية للري في المناطق الصحراوية تأثير كبير على نمط زراعة الاراضي المروية، بالرغم من ان التغير في نمط الخضرة النباتي في المناطق النباتية الطبيعية ليس مهماً اصلاً لان قيم المؤشر النباتي منخفض جداً في هذه المناطق. في الختام يمكن الاستنتاج بان نمط تدهور الاراضي في الاردن يتأثر بشكل واضح بالتذبذب المناخي، و التمدد العمراني، و التوسع في الزراعات المروية والتغيرات الاقتصادية و الاجتماعية.

الكلمات الدالة: خصائص الغطاء النباتي، مخاطر التدهور، تحليل السلاسل الزمنية، مؤشر الخضرة النباتي، الاردن.

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