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The Relationship between Landforms and Vegetation Cover between 1984 to 2018, case study: Al-Balqa Governorate, Jordan

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Abstract

Objectives: The study aims to determine the relationship between landforms and vegetation cover in Al-Balqa Governorate during the period from 1984 to 2018.

Methods: Landforms were classified according to the Topographic Position Index (TPI) based on a Digital Elevation Model (DEM). The classification included ten different categories of landforms. The Normalized Difference Vegetation Index (NDVI) was used to classify vegetation cover.

Results: Local landforms such as moderate slopes, hills, and high mountains exhibited high NDVI values compared to other landforms. Additionally, there was a significant positive correlation between NDVI and landforms, ranging from (r=0.73) to (r=0.54). A high coefficient of determination (R^2) of 0.909 was obtained for predicting high NDVI values and classifying landforms and NDVI in 1984. In contrast, in 2018, high NDVI values were concentrated in open slopes, plains, valleys, hills, and water networks, due to urban expansion from 11.3 square kilometers (1.01%) to 104.09 square kilometers (9.29%) toward hills and high mountains.

Conclusions: The study concluded that there is a strong relationship between high NDVI values and elevated landforms, particularly mountains and steep slopes.

Keywords: Landform Classification; Topographic Position Index; NDVI; Correlation Coefficients; Geographical Weighted Regression.

العلاقة بين أشكال الأرض والغطاء النباتي بين عامي 1984 و2018، دراسة حالة: محافظة البلقاء، الأردن

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ملخّص

الأهداف: هدف الدراسة هو معرفة العلاقة بين أشكال الأرض، والغطاء النباتي في محافظة البلقاء خلال الفترة (1984-2018).

المنهجية: تم تصنيف أشكال الأرض حسب مؤشر الموقع الطبوغرافي (TPI) اعتماداً على نموذج الارتفاع الرقمي (DEM). واشتمل التصنيف على عشرة فئات مختلفة من الأشكال الأرضية. تم استخدام مؤشر الغطاء النباتي الطبيعي (NDVI) لتصنيف الغطاء النباتي.

النتائج: اتصفت أشكال الأرض المحلية بمنحدرات متوسطة، والتلال والجبال العالية بقيم عالية من (NDVI) مقارنة بأشكال الأرض الأخرى. بالإضافة إلى ذلك، فقد وجد أن هناك ارتباطًا موجبة وذو دلالة معنوية بين (NDVI) وأشكال الأرض (r=0.73) إلى (r=0.54). تم الحصول على ارتباط عالٍ للتحديد 0.909 (R2) للتنبؤ بقيمة (NDVI) العالية، وتصنيف أشكال الأرض و(NDVI) في عام 1984. في المقابل، كانت قيمة (NDVI) المرتفعة تتركز في المنحدرات المفتوحة والسهول والأودية، والتلال والشبكة المائية في عام 2018، بسبب التوسع العمراني من 11.3 كيلومتر مربع (1.01٪) إلى 104.09 كيلومتر مربع (9.29٪) كيلومتر مربع نحو التلال ، والجبال العالية.

الخلاصة: خلصُت الدراسة الى أن علاقة قوية ما بين القيم العالية لمؤشر الغطاء النباتي، مع الأشكال الأرضية ذات المناسيب المرتفعة، وتحديداً الجبال والمنحدرات الشديدة.

الكلمات الدالة: تصنيف أشكال الأرض، مؤشر الموقع الطبوغرافي، مؤشر الغطاء النباتي الطبيعي، معاملات الارتباط

1. Introduction

During the growing season. Studying the relationship between vegetation and landform classification is important because the distribution of the evergreen forest and natural vegetation in Jordan as Jordan in general has an eco-climatic transition zone between semi-humid to arid climates is known to be sensitive to environmental changes and human activities(Al- Eisawi, 1996;Al- Eisawi and Takruri, 1989).Evergreen forest in Jordan is very much related to high land and mountains Wwhere the amount of rain, especially in the north and northwest of Jordan (Abu-Irmaileh, 1989).In order to investigate the spatial distribution between the landforms and NDVI, landform classification, depending on (DEM) applying Jennens'smethod (Jenness, 2010).Landsat TM images 1984 was used toextractthe vegetated area. While Landsat ETM+ 20108 was used to monitor changes in the vegetated area during the monitoring period. For exploring the spatial distribution between landforms and NDVI, a local regression method was applied, known as Geographically Weighted Regression (GWR). (GWR) is a nonparametric technique (Fotheringham et al. 2002). (GWR) allows the relationships between dependent and explanatory variable. Many studies investigated the association between landforms and vegetation (Mokarram and Sathyamoorthy, 2015;Hoersch, et al, 2003; Zawawi, et al, 2014).However, the correlation between landforms and NDVI have been changed according to the results of 2018the as the transformation and substitution have been acquired between the vegetated area and the urban area. The condition and amount of vegetation in the study area is heavily controlled by rainfall, which ranges from approximately 100 mm in the lowland to 550 mm in the northeast and the majority of the rainfall is distributed from December to March during the winter season. Where family farms spread around urban areas inhigh ridges, hillsand mountain, and the irrigated area concentrated in low land, depending upon the water stored in dams. This situation will put pressure on water resources and. On other hand, urban expansion towards natural vegetated area in the high intensity rainfall will increase the environmental hazards, especially floods,besides the effects of the high topography of these areas, as forested area have produced floods periodically (Al-Weshah and El-Khoury, 1999; Anderson,et al, 1959 Saleh. and Al Rewashed, 2007; Warren, and Agnew, 1987).In the study area a peak of (8) events were registered in high ridges, midslope ridges, upland drainage, with the steeper topography during (2017-2018) during a high-intensity storms.

2. Study Area

Al-Balqa Governorate is located in the northwest of ammanand has an area of about 1120.4km². Extended between longitude of N 35º 30′–35º 50′ and latitude of E 31º 50 ′–32º 10′, Figure 1. The altitude of the study area ranges from the lowest of - 432m (low-lands)(b.m.s.l), at the Dead Sea shoreline,to the 1109 m. Slope gradient ranges from 0º -54º, about 40% from the total of the study area is nearly flat see table 4.The governorate is characterized by a diversity of climate and heterogeneous in topography. Its high areas have a cold and cold climate in the winter and moderate in summer, with average precipitation is 550 mm. The lowlands are characterized by moderate temperatures winter and high temperatures in summer and the average rainfall (150 - 200 mm).The major land use categories of the area are agriculture, rangeland, farming and forests (Saleh and Al Rewashed, 2007;and Abu-Irmaileh,1989). The governorate has the fourth largest population of the 12 governorates of Jordan, and is ranked 10th by area. It has the fourth highest population density in the kingdom after Irbid Governorate and Jarash Governorate (DOS, 2017).

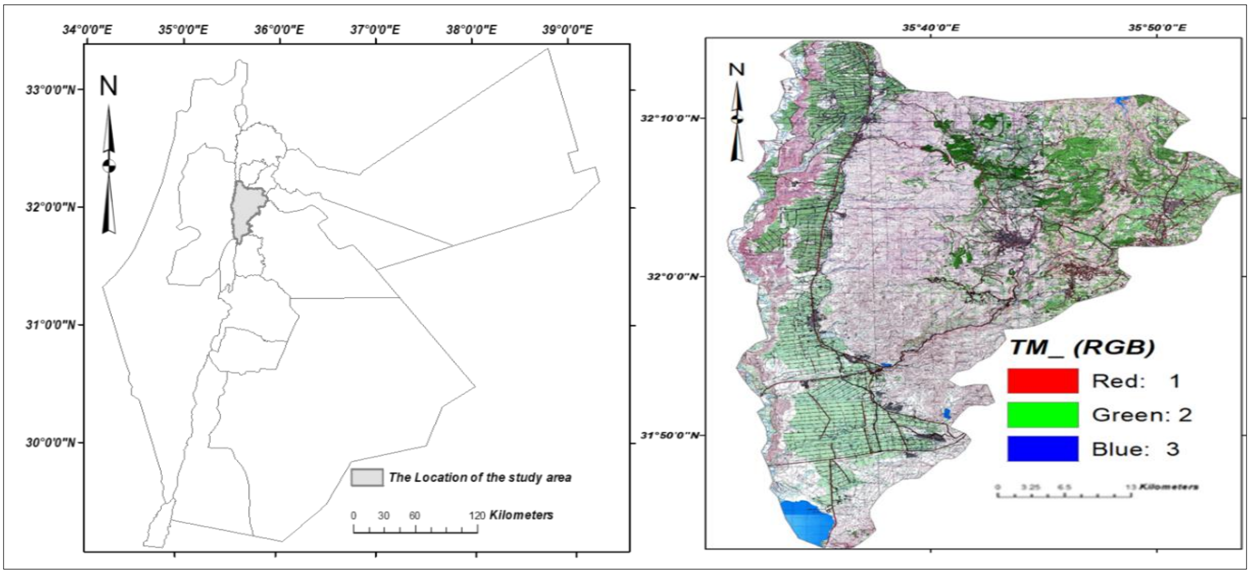

Figure (1): The location of the study area, and the topographic map -1991,(tin TM plates at scale 1:50,000 generated by the (RJGC) (Royal Jordanian Geographical Center), Mosaicked and masked the tin topographic plates at scale 1:50,000 scanned at 300 DPI (jpg) format.

3. Materials and Methods

3.1 Landform classification

In this study, (TPI) method was applied in many studied(De Reu, et al, 2013; and Seif, 2014) to perform landform classification, depending upon digital elevation model (DEM) whichwas available at the website (http://srtm.csi.cgiar.org).(TPI)tools is an extension for Arc View 3.x, v. 1.3a. Jenness Enterprises. Available at: (http://www.jennessent.com/arcview/tpi.htm).(TPI) is the difference between the elevation at a cell and the average elevation in a neighborhood surrounding that cell. Negative values indicate the cell is lower than its neighbour's, while positive values indicate that the cell is higher than its neighbours (Tagil and Jenness, 2008) are, applying (Eq.1):

$$TPI_{i = z_0} - \frac{\sum_{1-n} z_n}{n} \quad (1)$$

Where:

z_0 = elevation of the model point under evaluation Zn = elevation of grid within the local window

n = the total number of surrounding points employed in the evaluation.

The landforms in the study area was presented in figure 4.

3.2 Satellite Images

A Landsat TM image 1984and Landsat ETM+ image 2018 were used in this study. Both images chosen in the same month(April).

3.2.1 Image processing

The color composites for both images were generatedfrom Landsat TM and ETM+ (Butler, 2013) as illustrated in figure 2.

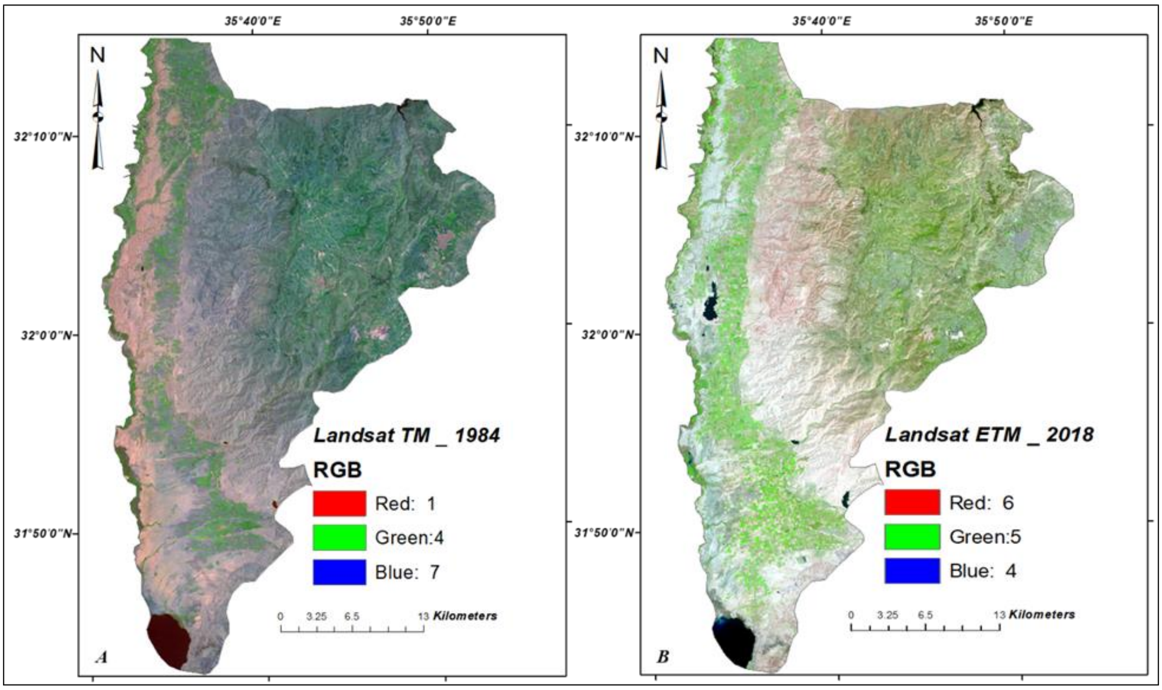

Figure (2): A: Color composite image of Landsat TM 1984 bands 1, 4, and 7. B: Color composite image of Landsat ETM+2018 exposed through the blue, green and red filters, respectively.

3.3 Vegetation cover classification using NDVI analysis

Normalized difference vegetation index to extract vegetation cover depending upon the two bands with higher spectral absorption (Red and Blue).(NDVI) an algorithm was used to monitor vegetation cover from satellite data,(April1984 and 2018).(NDVI) is computed as the ratio between two wavelengths of the electromagnetic spectrum as following, (Eq.2.):(Rouse et al., 1974):NDVI = (NIR-RED)/ (NIR+RED).NDVI values presented in tables 1 and 2..vegetated area at NDVI value ≥ 0.12=36.4% in 2018 and only 13.02 in1984 from the total area of Al-Balqa overnorate (figure3).

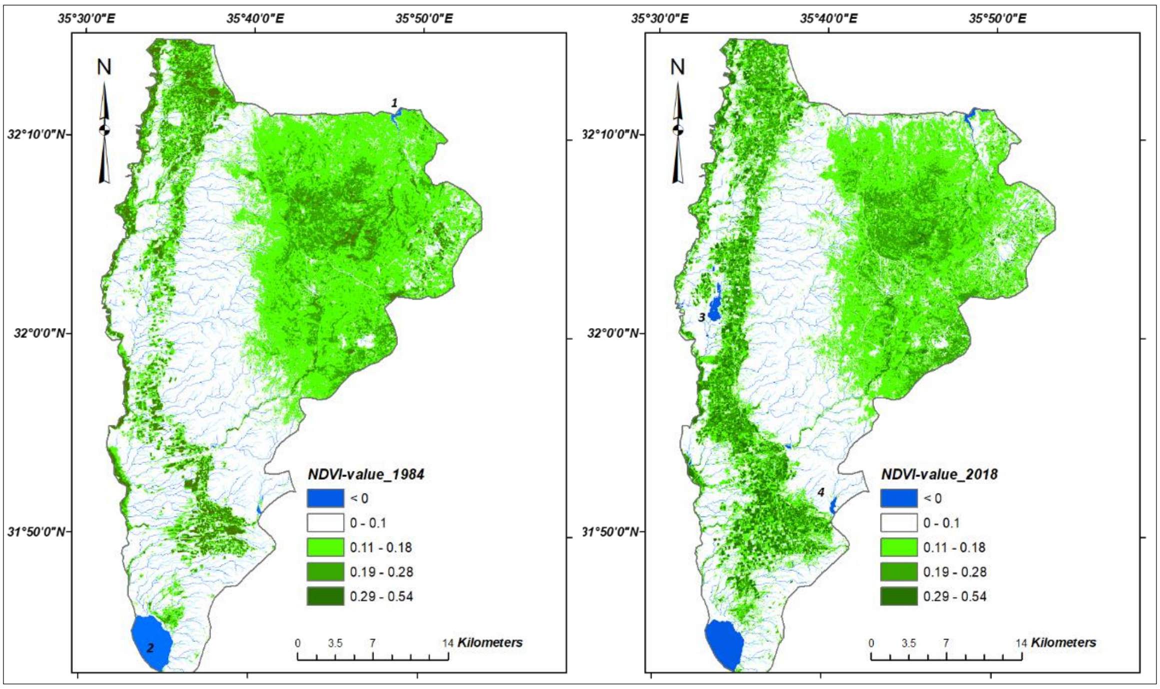

Figure (3): NDVI between 1884 to2018 and (1).King talal Dam, (2).Dead Sea (3).Shuiab (4).Al-Kafreen.

Table (1): NDVI classes and its percentages from the total study area.

Classes	NDVI-1984,cell account	Percentage (%)	NDVI-2018 cell account	Percentage (%)
Water bodies: the Dead Sea, and three Dams (King Talal , Shuiab, and Al-Kafreen for collecting the rain water from the surrounding watershed catchments	16141	1.5	27792	2.2
Bare Land : Urban,Roky area	552607	43.9	686450	55.9
Agricultural Land: Crop fields, vegetables and cultivated area (Permanently irrigated farms of vegetables, in open fields or under plastic houses, and fruit trees.	598511	48.8	474814	38.9
Forest Land: Mediterranean evergreen.	67746	5.8	37949	3
Total	1227005	100	1227005	100

3.4 Geographically Weighted Regression (GWR) analysis

GWRis a local form of linear regression used to model spatially variation of the relationships.In the current study (GWR) is used to monitor the correlation between the landforms patterns and the vegetation cover. (GWR) is one of the spatial regression techniques in GIS used in geography, which is proposed by (Fotheringham, et al, 2002;and Brunsdon, et al, 1996).(GWR) widelyused to explore the spatial relations between variablesby incorporating the dependent and explanatory variables of features falling within the bandwidth of each target feature(ArcGIS 10.5.1 help).

4. Results and Discussion

4.1 Landform classification

By applying TPI, the landform classification map of the study area was generated;with ten classesas; high ridges, midslope ridges, upland drainage, upper slopes, open slopes, plains, valleys, local ridges, midslope drainage and streams.It is observed that the dominated landform is the upper slope forming the majority of landform forming 39.1% of all ten landforms classes, table2. While the smallest is the Canyons terrain.

Table (2): landforms classes according to TPI methodology.

Landform	TPI-Value	Percentage (%) from the total
Canyons, deeply incied streams; very steeply sloping.	-188 to -89	0.9
Midslope drainage, shallow valleys; steeply sloping	-89.5 to -61	2.4
Upland drainage, headwaters;Average sloping	-61.1 to - 40	4.7
U-shaped valleys	-40.3 to-22	8
Plains Open slope	-22.to -7	14.2
Upper slope	-7.9 to 6	39.1
Local ridges, hill in valleys	6.3 to 23	13.5
Midslope ridge, small hills in plans	23.1 to 42	9.2
High Ridge	42.5 to 69	6
Mountain tops	69.8 to 142	2
Total		100

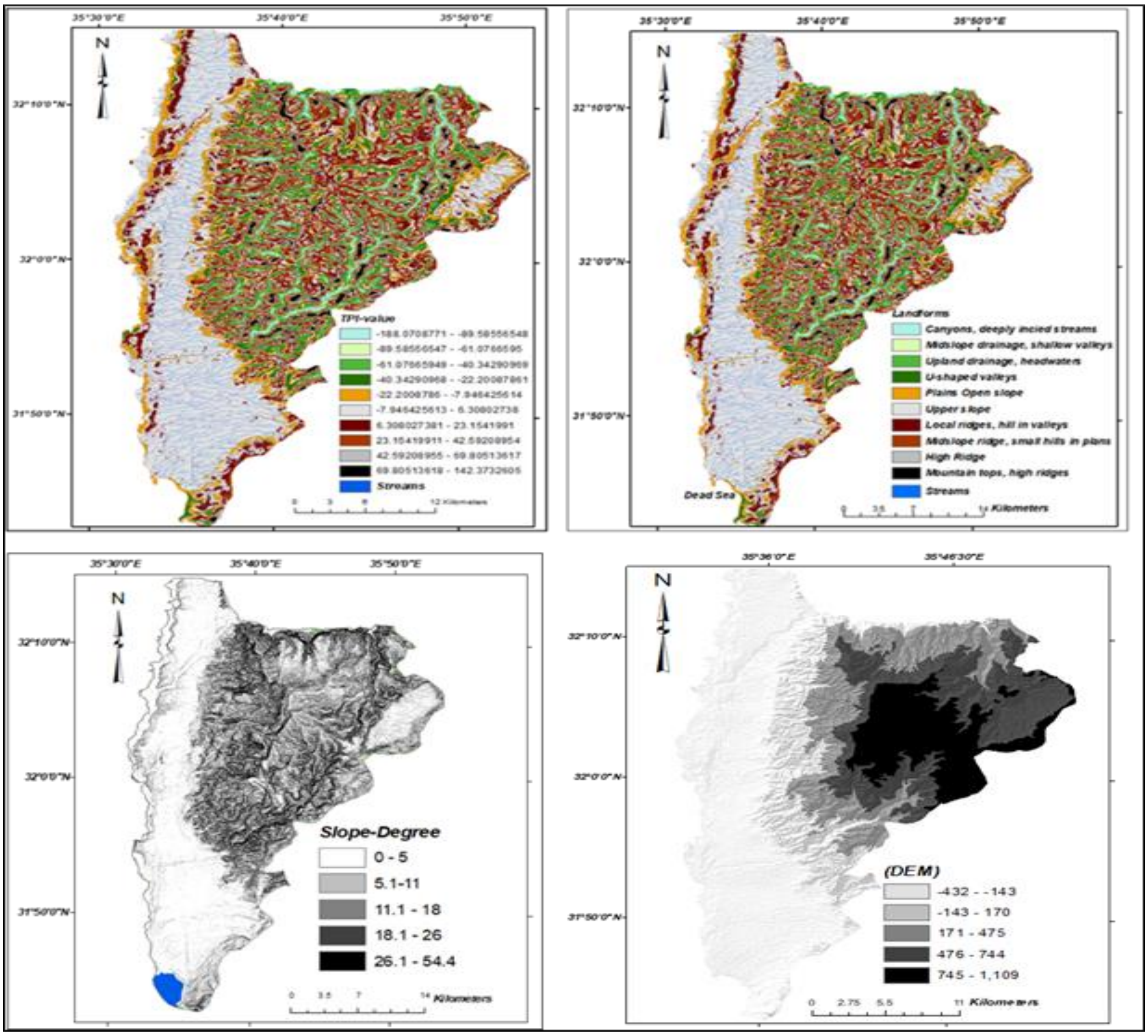

Figure (4): TPI value,landforms, slope by degree and elevation of the study area.

Table (3): Spatial distribution of elevation and slope of the study area.

Elevation (m)	Percentage (%)	Slope (degree)	Percentage (%)
-432-143	41.7	0-5	41.2
-144-170	13.6	5.1-11	24.1
171-475	15	11.1-18	18.8
476-744	16.7	18.1-26	12.3
745-1109	13	26.1-54	3.6
	100		100

4.2 Vegetation cover classification usingNDVI analysis

According to table 4, NDVI values for the year 1984 ranging from -0.5which represents rock, soil and bare areas,its distributed at the upper slope, open slope and midslope drainage classes, to 0.67 which represents the forest areas and irrigated areas. Flat areas and high ridges have higher NDVI values, ranging from >0.3 to 0.67. Higher NDVI values of more than 0.2 are found concentrated at valleys and streams. It was found that for the local, midslope and high ridge landforms, NDVI values are higher as compared to the other landforms figure 5.

Table (4): NDVI statistics.

Year	Min	Max	Mean	Standard Deviation (SD)
1984	-0.5	0.67	0.046	0.09
2018	-0.19	0.54	0.14	0.067

It was found that mountain tops,high ridges, upper slopes, and valleys consist of vegetation with NDVI values≥0.2 according to 1984 results. Based on this, it can be concluded that the high landhas more vegetation than the other landforms about 40% from the total vegetated area. This is as in ridges; the climate is suitable for growth of vegetation.In addition, the upper slope landformwhich is extended within the Jordan rift valley region have a suitable climate all over the year for agriculture as its dependent on irrigation from the Jordan River, and the water storage on dams.

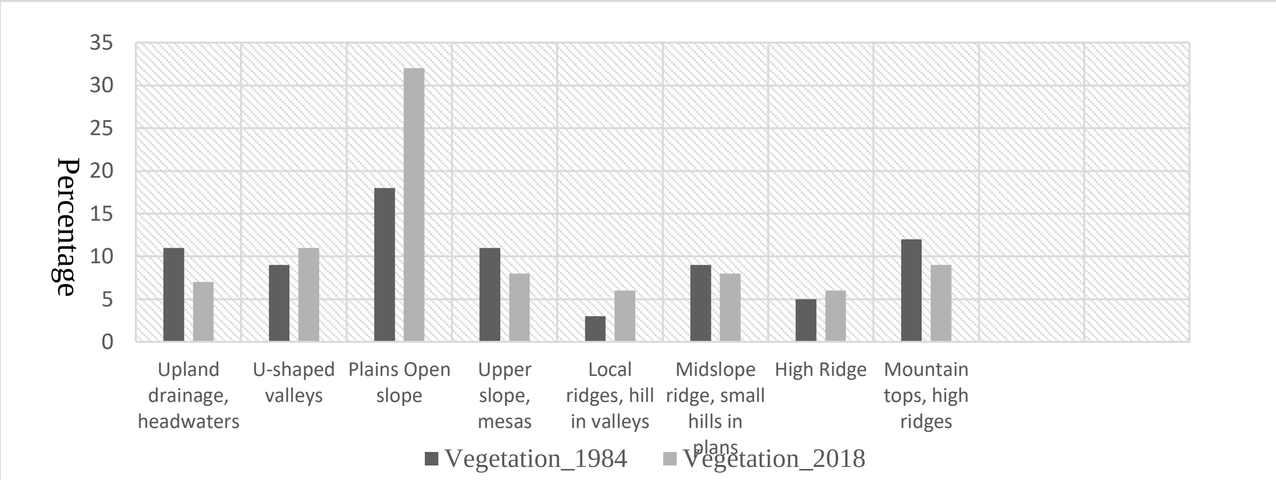

Figure (5): The relationship between landforms and NDVI during the monitor periods.

Table (5): The spatial distribution of NDVI according to the landforms.

Landforms	Percentage of vegetation-1984	Percentage of vegetation-2018
Canyons, deeply incied streams	7	4
Midslope drainage, shallow valleys	15	9
Upland drainage, headwaters	11	7
U-shaped valleys	9	11
Plains Open slope	18	32
Upper slope	11	8
Local ridges, hill in valleys	3	6
Midslope ridge, small hills in plans	9	8
High Ridge	5	6
Mountain tops	12	9

Natural forests as well as rainfed areas are distributed in mountainous regions with moderate Mediterranean climate. Therefore, the relationship is positive between the following landforms, Upper slope, ridges, and Mountain tops with vegetation area with high NDVI values in 1984. At the same time, the scarcity of vegetation and irrigated agriculture in the lowlands, which are part of the Jordan River Valley, because the conflict between Jordan and Israeli. According to the analysis of the relationship between vegetation and landforms of 2018, there have been significant changes in their relationship because of the concentration and expansion of the population at the expense of the land of rainfed agriculture, which turned into family farms.

4.3 Geographically Weighted Regression (GWR) analysis

For the meaningful interpretations and more predictable relationship between landforms NDVI at local level, the results of GWR should be spatially distributed on the map based on the significance level indicated by local P-values and Z-score, table 7.Then GWR maps of NDVI were produced, figure 6 significant location of landforms NDVI,In year 1984, with 158 locations were found significance at 95% level of confidence. However, the locations of significance 95% level in 2018 are decreased to 141 locations. It is found that, several significance locations of 95-99% confidence levelwere coincide with different landforms patterns. The calculated local linear correlation coefficients (r) between landform classes and NDVI are summarized in figure 6. It was found that there is positive and significant correlations between NDVI with high ridge andmountain tops (r = 0.640) in 1984. This indicates that landform classification and NDVI can be used to predict the spatial patterns of NDVI in such a semi-arid areas(Hoersch, et al, 2003).(As show Figure 6).

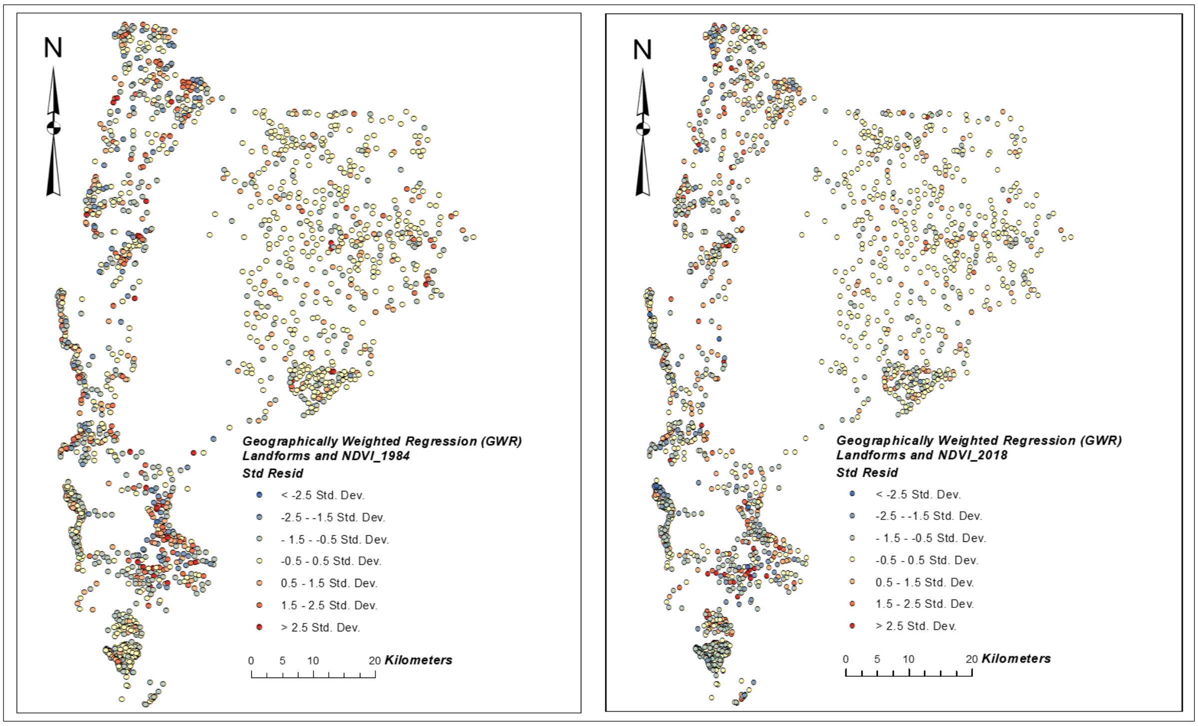

Figure (6): (GWR) feature class output with standard residuals.

Table (6): P-value and Z-score

Significance Level (P-value)	Critical Value (Z-score)
0.01	<-2.58
0.05	2.58_-1.96
0.1	1.96_-1.65
0	1.65-1.65
0.1	1.65-1.96
0.05	>2.58
0.01	>2.58

4.4 Monitoring the changes in vegetation coverusing NDVI Image differencing

For land degradation monitoring and changes in vegetation coverage, an image differencing method was adopted for pixel-bypixel comparison (Xia Cui, et al, 2013). The image differencing procedure was performed on the NDVI generated images using (Eq.3) (Rouse et al., 1974): Later Image – Former Image .Where the early image was subtracted from the later image. The results of the analysis showed the following:

1. Negative changed pixels:values equal to -1.
2. Unchanged pixels:values equal to zero.
3. The positive changed pixels:values equal to +1.

Positive changes represent anincrease in vegetation cover between the two dates. Negative changes represent a decrease in vegetationcover or an increase in lower NDVI values. The difference image indicated that significant vegetation coverchanges have occurred between 1984 and 2018.The statistical results of the difference image revealed that about 11% of the studied area had negative changes, and 10.2% had positive changes, while the other 78.7% had no changes between the two dates. Negative changes represent an increase in lower NDVI values and a decrease in vegetation cover areas. On the other hand change detection results in table 6 showed that the decline of vegetated area practically in the mountains area(local ridges, hills,high ridge, mountain) is clearly as the result of accelerated expansion of urbanization such as; northwestern, southwestern and southeastern parts; these areas have negative changes where many housing settlement have been stablished in these areas between 1984 and 2018.

Most Jordanian cities are suffering from rapid urban growth, which is due to increasedimmigration from neighboring countries as well as the urban migration of Jordaniansfrom outlying rural areas. Urban expansion concentrated mainly in the same landforms as the study area (Al- Hanbali and Kondoh, 2008). Looking at the urban expansion during the period (1984-2018), it is found that theencroachment of urban/built up areas occurred extensively over rain-fed agricultural lands which decreased by 11% andcaused land degradations and a loss of natural resources. The increase of urban/ built-up areas without comprehensive planning has a negative impact on local environment; especially, on water resources which Jordan has already a serious critical problem in this sector (Al- Hanbali and Kondoh, 2008). The change detection results of the study area show that urban/built-up areas expansion from 11.3 km² (1.01%) to 104.09 km²(9.29%)km².This represents a net increase of 103.03km², which is mainly attributed to the fast increase population due to large rural urban migration, representing loss of rain- fed agricultural lands by 11% over the period from 1984-2018, and converted to urban areas.

Table (7): Changes in vegetation cover during the study period

Classes	Percentage Change (%)
-1	11
0	78.7
1	10.2

Planned and unplanned housing is increasing while green areas are decreasing,for that urbanization, planning in the major cities in Jordan must be taken into accountto protect the fertile lands in the mountains areas (Al-Bilbisi Tateishi,2003; Saleh, and Al Rawashdeh,2007).Plant biodiversity in Jordan is exposed to several threats leading to sharp decline in most of the Jordanian flora and the extinction of several species(Al- Eisawi, 1996). Many species have become at risk. This situation has resulted from various natural and man-made activities, as well as from general lack of knowledge and awareness (Oran, 2016; & Oran and Abu Zahra, 2014).

4.5 Discussion

A GIS has been used to integrate the relationship between landforms and NDVI areas and the spatial distribution for the two time series and generate a thematic map to examine dynamics of these features during the period (1984-2018), it was clear that the expansion of NDVI areas towards of Jordan valley (low land). As results of the urban expansion in the mountain area. While urban/built up areas occurred extensively over agricultural lands which decreased by 11% and caused land degradations and a loss of natural resources. The increase of urban/ built-up areas without comprehensive planning has a negative impact on local environment; especially, on water resources which Jordan has already a serious environmental problem in this sector. 34-year change detection analysis showed changes with respect to irrigated agriculture there was transformation from one type of land-use to another and particularly from cropland to built-up area, with the area of built-up land increasing from 11.3 km² (1.01%) to 104.09 km²(9.29%)km² during the period .Rain-fed agricultural area decreased, while a significant increase in irrigated area using the water stored in dams.

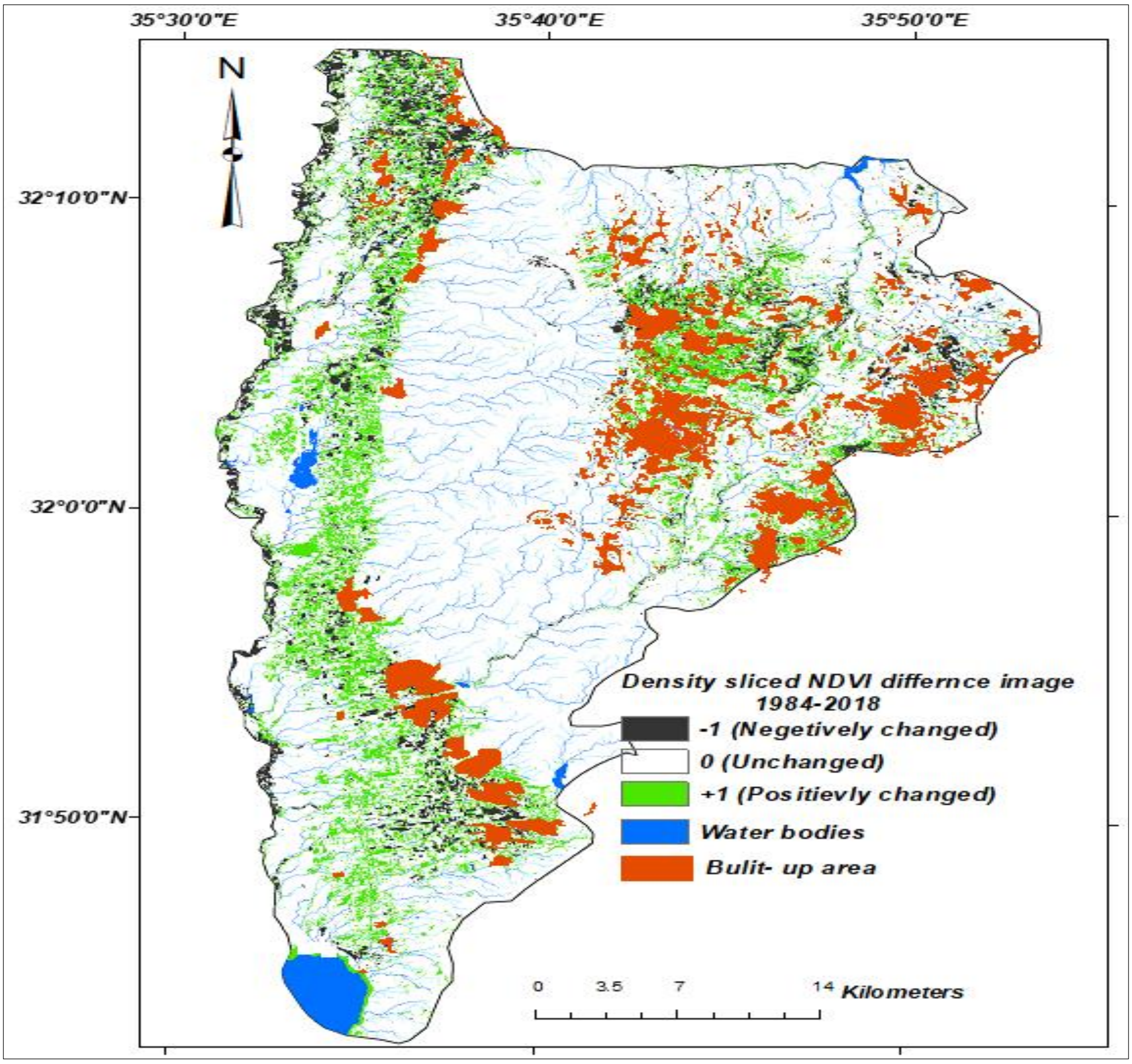

Figure (7): The spatial changes of the NDVI between 1984 to 2018.

4.6 Conclusion

Information about land forms patterns, area and spatial distribution of NDVI is necessary; partially in semi-aridarea, Landform classifications using TPI show that the landform classification map of the study area was ten classes. Fromthe analysis, NDVI with high value1984has very much related mainly in mountains, high ridges, and midslope ridges, with positive and significant correlations between NDVI and these landforms (r = 0.62).While the open slopes and plains led to the non-exploitation because the political conflict between Jordan and Israel.While NDVI with high value2018 concentrated in open slopes and plains; relates to urban expansion in the mountainous region.Urban expansion was analyzed in this studyareas covered 11.3 km² (1.01%) to 104.09km²(9.29%)km² during the monitor period, and agriculturallands were converted to urban areas. Thus, it willimprove their predictions toward the amount of urbanizationchanges and the location of future built-up areas, and enhancethe existing urban strategies for better sustainable landmanagement.

REFERENCES

Anderson, H., & Hobba, R. (1959). Forests and floods in the northwestern United States. *Int. Assoc. Sci. Hydrol. Publ.*, 48, 30-39.

Al-Bilbisi, H., & Tateishi, R. (2003). Using satellite remote sensing data to detect land use/cover change and to monitor land degradation in central Jordan. *Journal of Japan Society of Photogrammetry and Remote Sensing*, 42(6), 4–18.

Butler, K. (2013). Band Combinations for Landsat 8. Retrieved from https://www.esri.com/arcgis-blog/products/product/imagery/band-combinations-for-landsat-8/?rmedium=redirect&rsource=/esri/arcgis/2013/07/24/band-combinations-for-landsat-8

Chavez, P., & MacKinnin, D. (1994). Automatic detection of vegetation changes in the southwestern United State using remotely sensed images. *Photogrammetric Engineering & Remote Sensing*, 60(5), 571–583.

De Reu, J., Bourgeois, J., Bats, M., Zwertvaegher, A., Vanessa Gelorini, V., De Smedt, P., Wei Chu Marc Antrop, De Maeyer, P., Finke, P., Van Meirvenne, M., Verniers, J., & Crombé, P. (2013). Application of the topographic position index to heterogeneous landscapes. *Geomorphology*, 186, 39–49.

DOS (2010). *Jordan in figures*, Department of statistics, Amman.

AL-Eisawi, D.M. (1989). A checklist of wild edible plants in Jordan. Arab Gulf J. Res. Agric. *Biol. Sci*, 7(1), 79–102.

AL-Eisawi, D.M. (1996). *Vegetation of Jordan*. UNESCO-CAIRO OFFICE: Regional office for science and technology for the Arab States.

Fotheringham, A., Brunsdon, C., & Charlton, M. (2002). *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*. Wiley, Chichester.

Grey, W., Luckman, A., & Holland, D. (2003). mapping urban change in the UK using satellite radar interferometry. *Remote sensing of Environment*, 87, 16–22.

Hoersch B., Braun G., & Schmidt U. (2003). elation between landform and vegetation in alpine regions of Wallis, Switzerland. A multiscale remote sensing and GIS approach. *Computers Environment and Urban Systems*, 26(2), 113–139. doi: 10.1016/S0198-9715(01)00039-4

Abu-Irmaileh, B.E. (1989). *Poisonous plants in the Jordanian environment- Rangelands. Unpublished Master's thesis*, University of Jordan, Jordan.

Jenness, J. (2006). Topographic Position Index (tpi_jen.avx) extension for ArcView 3.x", v. 1.3a. Retrieved from http://www.jennessent.com/arcview/tpi.htm

Mokarram, M., & Sathyamoorthy, D. (2016). Relationship between landform classification and vegetation (case study: southwest of Fars province, Iran). *Open Geosci*, 8, 302–309.

Rouse, J. W., Hass, R. H., Schell, J. A., & Deering, D. W. (1974). Monitoring vegetation system in the Great Plains with ERTS. *Submitted to 3ed ERTS Symposium- NASA*, Washington D.C., USA, 309-317.

Royal Jordanian Geographical Center (RJGC).

Saleh, B., & Al Rewashed, S. (2007). Study of Urban Expansion in Jordanian Cities Using GIS and Remoth Sensing. *International Journal of Applied Science and Engineering*, 5(1), 41–52.

Oran, S. A. (2016). Plant diversity of Al-Balqa Governorate, Jordan. *International Journal of Biodiversity and Conservation*, 8(5), 93-104.

Seif, A. (2014). Using Topography Position Index for Landform Classification (Case study: Grain Mountain). *Bulletin of Environment, Pharmacology and Life Sciences*, 3(11), 33–39.

Singh, A. (1989). Digital change detection techniques using remotely sensed data. *Int. J. Remote Sensing*, 10, 989–1003.

Tagil, S., & Jenness, J. (2008). GIS-based automated landform classification and topographic, land cover and geologic attributes of landforms around the Yazoern polje, Turkey. *Journal of Applied Sciences*, 8(6), 910–921.

Townshend, J., & Justice, C. (1986). Analysis of the dynamics of African vegetation using the normalized difference vegetation index. *Int. J. Remote Sens*, 7, 1435–1445. DOI:10.1080/01431168608948946.

UNEP. (1994). United Nations Convention to Combat Desertification, Interim Secretariat for the Convention to Combat. Retrieved from http://www.unep.ch/inch.html

Warren, A., & Agnew, C. (1987). An Assessment of Desertification and Land Degradation in arid and Semi-arid Areas,. *International Institute for Environmental and development*, available on: https://www.iied.org/sites/default/files/pdfs/migrate/7315IIED.pdf.

Al-Weshah, R., & El-Khoury, F. (1999). Flood Analysis and Mitigation for Petra Area in Jordan. *Journal of Water Resources Planning and Management*, 125(3), 170–177.

Xia, C., Gibbes, G., Southworth, J., & Waylen, P. (2013). using Remote Sensing to Quantify Vegetation Change and Ecological Resilience in a Semi-Arid System. *Land*, 2(2), 108–130.

Zawawi, A., Shiba, M., & Jemali, N. (2014). Landform Classification for Site Evaluation and Forest Planning: Integration between Scientific Approach and Traditional Concept, Jordan. *Sains Malaysiana*, 43(3), 349–358.