European Journal of Agricultural and Rural Education (EJARE)
Available Online at: https://www.scholarzest.com
Vol. 5 No. 10 October 2024
ISSN: 2660-5643

STUDY OF THE IMPACT OF CLIMATE ELEMENTS ON FOREST TREES IN NORTHERN IRAQ (DOHUK GOVERNORATE)

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Article history:
Received: 26th August 2024
Accepted: 5th October 2024

Abstract:
Forests of various types are spread in the northern regions of Iraq. Iraq has witnessed rapid events over the past years, which led to their deterioration, and we have lost thousands of hectares, due to the mismanagement of the natural forests and the effects of climate change, including water scarcity, drought, and the frequent occurrence of sand and dust storms. Many studies and researches in the world have proven the possibility of using geospatial techniques to estimate cases of decline and change in vegetation covers based on what is known as the Normalized Difference Vegetation Index (NDVI). This research reflects the process of collecting data using modern scientific techniques such as geographic information systems and remote sensing integrated with mathematical statistics and climate data. The study sites (Atrosh - Sarsink - Dohuk Dam) located in northern Iraq are among the agricultural and pastoral areas intertwined with forests. The study included the use of Landsat satellite images captured during different years for the study areas for the purpose of calculating (NDVI) values and adopting them as an indicator of the density of vegetation cover (forests) in the studied areas after excluding other vegetation covers through seasonality and temporal tracking of land uses, where the relationship between climate factors represented by temperatures, rainfall and the normalized vegetation difference index (NDVI) was studied by calculating linear regression relationships. The results generally proved that climate had a slight effect on the studied sites and that human activity is directly responsible for the state of the forests in terms of their decline or recovery.

Keywords: Forests of northern Iraq - Remote sensing - Vegetation difference index - Duhok Governorate.

INTRODUCTION:

The mountainous regions of Iraq are characterized by the presence of natural forests and a climate similar to the Mediterranean climate, unlike other parts of Iraq that are characterized by a semi-arid climate. These forests are considered an extension of the Mediterranean forests, as they are not considered distinct ecosystems of their kind, because they are subject to harsh topographic control with climatic and environmental variables. These forests enjoy diverse and unstable environments, such that there is a low ecological balance and are generally vulnerable to disturbances. They are considered renewable resources that can provide supply services to humans and support higher levels of biodiversity compared to other terrestrial ecosystems. They play an important role in preserving natural resources, in addition to the many environmental, social and economic benefits that forests provide (e.g., carbon stores, firewood for cooking, and soil erosion compared to unforested slopes) (Sefik 1981). Forests in Iraq are currently facing many threats such as deforestation and forest degradation. Forests in Iraq have been affected by many factors including climate change, low levels of rainfall, overgrazing of natural pastures, illegal urban expansion into developed lands (Al-Doski, Mansor, and Mohd Shafri 2013), and agricultural practices. Some of these problems may resemble forest problems in other Arab countries, but some are different from each other. Natural environmental and climatic problems, forests in Dohuk Governorate are exposed to a series of human and natural obstacles that lead to a decline in productivity and its decrease (Wahid and Manati 2024), and the most important of these obstacles are fires of all kinds, human and natural, unauthorized and unplanned cutting, unsustainable overgrazing, shifting agriculture, expansion of urban areas, environmental and climatic changes, in addition to agricultural diseases and pests, indicating that shifting agriculture and fires are among the main reasons for their current decline, and the difficulty of access currently limits their use in providing fuel and coal, which are the two basic elements of production and the demand for which is increasing in this land lacking wood. (Chapman 1950

The use of remote sensing (RS) and geographic information systems (GIS) in Iraq includes climatic and environmental applications, monitoring and mapping soil salinity and predicting its properties, monitoring and mapping land changes, close sensing to monitor soil and its fertility, and the use of spatiotemporal land cover (Hasan Eulewi and 2020), agricultural drought monitoring, and hydrological applications including spatial distribution of rainfall, runoff, drought control, geomorphometric and flood analysis, hydrological and hydraulic modeling, and optimal water resource management (Mosa 2016). Time series analysis techniques are used to identify, assess, and monitor vegetation dynamics and variability using modern remote sensing datasets. This study assesses vegetation degradation using long-term satellite-derived Normalized Vegetation Index (NVI) data (Faour, Mhawej, and Fayad 2016). The Normalized Difference Vegetation Index (NDVI) is one of the most important components of ecosystems that is a link between vegetation, water, soil, and atmosphere (Shu et., at 2009). Forest vegetation is essential for arranging the water and carbon balance, exchanging nutrients, releasing energy, and stabilizing climate factors (Roy, 2021), and working to reduce toxic carbon emissions that cause global warming (Zhe and Zhang, 2021). Therefore, the role of the multifaceted environmental and climatic factors of vegetation has a significant impact on society and human activities through ecosystem services (Prăvălie et al., 2022). Therefore, monitoring the dynamics of forest vegetation is important to interpret the impact of environmental and climatic conditions on vegetation (Liu et al., 2022a, Liu et al., 2022b, Liu et al., 2022c). The Normalized Difference Vegetation Index (NDVI) was used to create maps that show the density of vegetation cover. These maps classify vegetation cover into low and high. It estimates the greenness and health of vegetation growth, predicts agricultural productivity, and draws a map of dry desert areas. It is considered an important indicator in agricultural organizations and environmental studies, as it is a unified indicator that helps understand the relative biomass, due to its close relationship between its rates and the density of vegetation cover. To calculate this index (NDVI), there is a formula that depends on two multi-spectral bands: red light and near infrared (NIR). As a result of the differences between them, humans see leaves as green, which shows less reflection in (NIR) compared to red light. Leaves turn yellow in (NIR) and reflect less due to these plants being affected by water stress or death (Abdusamea 2018). Objective of the study: The study aims to monitor the changes that occurred in forests during two time periods in the year (1984 - 2013) AD and to show the most important environmental and climatic factors affecting the increase or decrease of their densities using sensing techniques within Duhok Governorate and in three locations (Duhok - Sarsink - Atrush) where Landsat OLI-TM was used by NASA in this study, to derive the (NDVI) index that was analyzed with climate elements.

RESEARCH MATERIALS AND METHODS

General description of the study area: This study was conducted on forests and plant covers within Duhok Governorate Figure (1). For three sites (Dohuk - Sarsink - Atrush) Figure (2) in northern Iraq, and these forests are (2-45) km away from Dohuk Governorate, where the study sites were characterized by the characteristics of being mountainous areas with relatively high altitudes in which different types of forest trees grow and their climate falls within the Mediterranean Basin climate, which is characterized by climatic elements that led to the spread of many trees with special characteristics that have the ability to grow in dry and semi-dry areas (Al-Khafaji 2018), as for the coordinates of the site under study at longitude (43 ° 4 '1.18'') east and latitude (36 ° 50' 0.17'') north (43 ° 18 '1.67'') and (37 ° 1' 29.84'') respectively, and the sites (Atrosh - Sarsink - Dohuk Dam) are located Which is located within the high mountainous geographical areas represented by wide variations of depressions and elevations, in which there is a different geomorphology ranging between (0-87.9°) (Majeed 2023). These sites were chosen because they provide the characteristics of the study

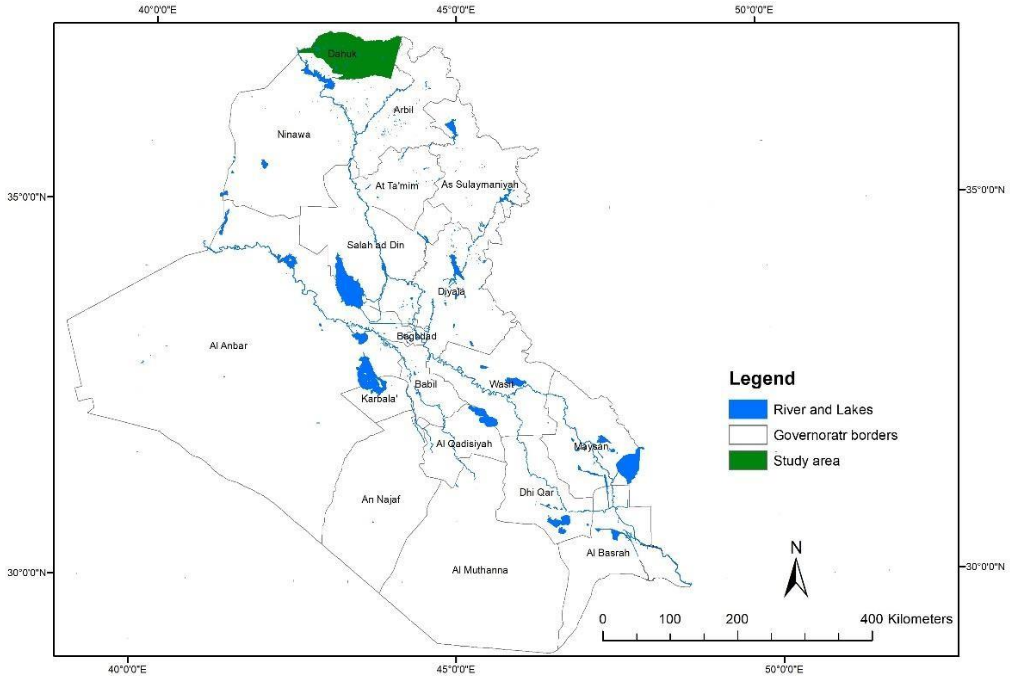


Figure (1) shows the study sites within Duhok Governorate in green.

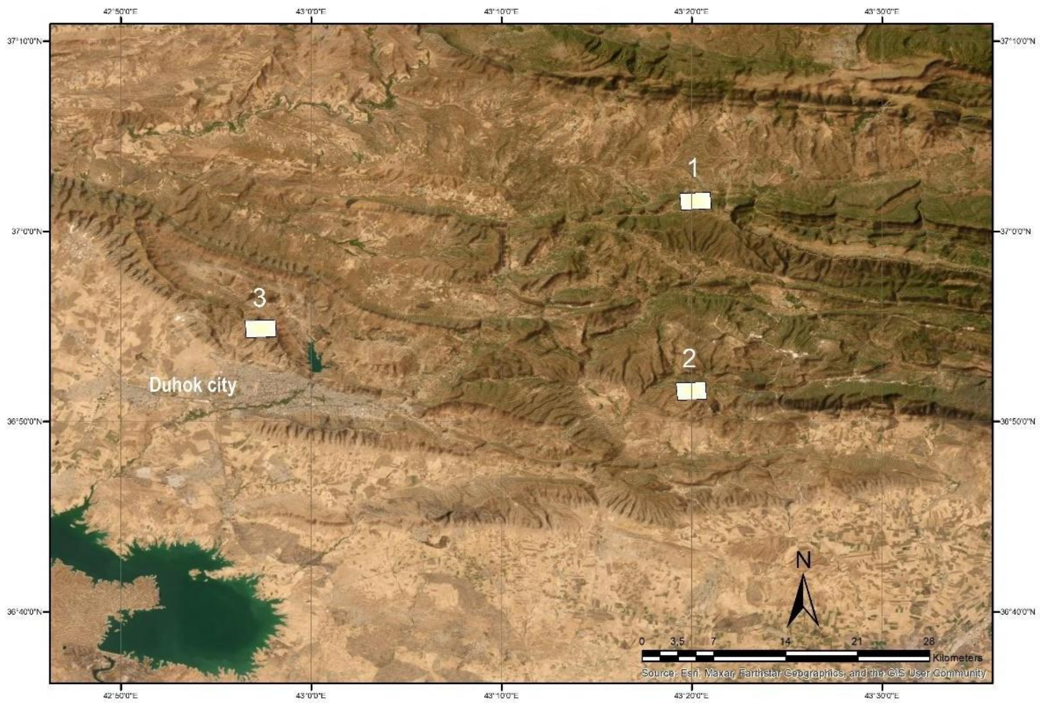


Figure (2) shows the three study sites within Duhok Governorate, namely (Duhok-Sarsank-Atrosh), with an area of 8 km2 for each site.

Table (1) Geographic coordinates of the study areas, elevations above sea level, and slope

االرتفاع عن مستوى سطح البحر	الميل	دائرة العرض	خطوط الطول	موقع العينات	ت
953 - 852	7.588976333 - 3.523453298	36 º 54' 52"	42º 57' 18"	دهوك	**1**
1167 - 1055	26.83245203 - 21.9538244	37 °1'36"	43°20' 10"	سرسنك	**2**

852 - 726	7.588976333 - 3.523453298	36º 51' 37"	43º 19' 55"	أتروش	**3**

These forests are geographically and environmentally diverse with a mountainous character, and the study samples in the research area vary in terms of the topography of the region (height and low above sea level, slope, facades), so many forest trees are distributed in it with different densities and locations.

Data used

The Landsat satellite image for the year 2013 was used, for the sensor (OLI) with a spatial resolution of 30 meters, and the Landsat image for the sensor (TM) for the year 1984, which was obtained with the same resolution of 30 meters. (Table 2) shows the characteristics of the Landsat images used. The data were obtained from the (USGS) website, and the images were selected in approximately the same season, July .

)Table 2) shows the characteristics of the visuals used in the study.

Sensor	Acquisition Date and Time	Bands	Wave length (micrometers)	Resolution (meters)
Landsat Thematic Mapper (TM)	1984	Band 1-Blue	0.45-0.52	30
		Band 2-Green	0.52-0.60	30
		Band 3-Red	0.63-0.69	30
		Band 4-Near Infrared (NIR)	0.76-0.90	30
		Band 5-Shortwave Infrared (SWIR) 1	1.55-1.75	30
		Band 6-Thermal	10.40-12.50	120* (30)
		Band 7-Shortwave Infrared (SWIR) 2	2.08-2.35	30
Landsat 8 Operational Land Imager (OLI)	2013	Band 1-Ultra Blue (coastal/aerosol)	0.435-0.451	30
		Band 2-Blue	0.452-0.512	30
		Band 3-Green	0.533-0.590	30
		Band 4-Red	0.636-0.673	30
		Band5-Near Infrared (NIR)	0.851-0.879	30
		Band 6-Shortwave Infrared (SWIR) 1	1.566-1.651	30
		Band 7-Shortwave Infrared (SWIR) 2	2.107-2.294	30
		Band8-Panchromatic	0.503-0.676	15
		Band 9-Cirrus	1.363-1.384	**30**
		Band 10-Thermal Infrared (TIRS) 1	10.60-11.19	**100* (30)**
		Band 11-Thermal Infrared (TIRS) 2	11.50-12.51	**100* (30)**

Climate Data: Climate elements (temperatures, rainfall) play an important and effective role in the growth and development of forest trees and their various productions, as the climate of the site is affected by many factors, the most important of which are topography, elevation above sea level, water bodies, and air currents, Salila and others 2020) However, the effect on tree growth is shared with the genetic composition and other site-specific conditions, and facilitating these elements in quantities that match the requirements of tree growth leads to an increase in the production of these trees and thus achieving the goals for which they were established**.**

Temperature: Temperature is one of the environmental factors that play the most important role in the geographical distribution of these types of forests and affect the physical and chemical interactions that occur inside the trees because each type of tree has a special and specific type of temperature requirements that enable the trees to grow well. Usually, by nature, trees grow at optimum temperatures ranging from (25-36) Celsius. Trees are living organisms that can sense climate elements and their changes, such as rising and falling temperatures, and thus negatively or positively affect the growth resulting from physiological processes. Rise and fall in temperatures lead to changes in physiological processes that are subsequently reflected in the growth of these forests. Therefore, temperatures were taken from the *space source of heat in months for the periods (1956-1984) AD and (1985-2013) AD http://cru.uea.ac.uk Climatic Research Unit – Groups and Centres) for the sites (Atrosh – Sarsink – Dam Dohuk) and the differences in them led to differences in the growth and development of these forests, especially during the growth period. The study areas are distinguished by representing the Mediterranean region (Al-Taai et al. 201**7).**

Rainfall: Rainfall is one of the most important main sources of water needed to provide the forests' needs for the growth and development of forest tree productivity. The amount of rainfall and its timing have a major and direct impact on the variation of physiological processes within trees. It provides moisture to the soil, which trees benefit from by absorbing water and nutrients through the roots (Challinor and Watson 2013). There are also differences in the water requirements of different species. In addition, rainfall works to maintain the environmental balance between trees and the atmosphere, and the decrease in the humidity ratio, whether in the atmosphere or in the soil, exposes trees to water shortages, which in turn affects the growth and development of trees. Temperatures were taken from the same space source of heat in months for the periods (1956-1984) and (1985- 2013(.

Software used and method of work: GIS software (Arc Map 10.8) and remote sensing techniques were used to correct and process the reflectance values of the Landsat ETM7 and Landsat 8 satellite images to enhance the image to aid visual interpretation. The calibration processing included in the relative radiometry work was included to reduce radiometric differences between images resulting from changes in surface reflectance (Yuan, 2000); (Cosnefroy et al. 1996). These adjustments are important in land cover classifications and many other applications, such as deriving the Normalized Difference Vegetation Index (NDVI) to create NDVI maps or tracking vegetation indices over time, producing a fine-scale range for a single scene and comparing scenes from multiple dates and sensors, and processing each spectrum of multiple images (Chandr et al., 2009). All images are designed to remove atmospheric effects on the reflectance values of the images, increasing the accuracy of multi-temporal image analysis. The Normalized Difference Vegetation Index (NDVI) was calculated for the region in general according to the mathematical relationship below:

NDVI = (NIR-RED) / (NIR + RED)

The equation represents the infrared wavelengths (NIR) and the red wavelength (R), especially in the early beginnings of plant growth, as it reflects a large amount of the near-infrared wavelength, and this can be seen especially in the indicators (Ideal VI). The value range for this index is in the form of scientific pixel values between -1.0 to 1.0, where the closer it is to 1, the denser the vegetation cover. Statistical analyses were then conducted for the (NDVI) values for the three sites with the values of rainfall and temperature to find a linear relationship between them

RESULTS AND DISCUSSION

Calculating the normalized difference vegetation index for the study area: (NDVI) Index Normalized Difference Vegetation

The normalized difference vegetation index for the area was calculated using satellite images for the year 1984 -2013. Figure (3) shows us the normalized difference vegetation index for the study area for the year 1984. There are three types of forest densities. Most of the forests were high in the highlands of the northern and northeastern highlands and part of the southeast. They were characterized by a dark green color and their value (NDVI) was between (0.7 -0.3), while the value of (NDVI) was (0.3-0.2) and they were represented by medium-density forests and were the most distributed and widespread in the northern and northeastern regions and some parts of the southeast. They penetrated some of the central regions of the study area and were characterized by a light green color. As for the low-density forest area, its value (NDVI) was (0.2-0) and occupied the central and western parts and parts of the southwest of the research area, and were characterized by a light pink color**.**

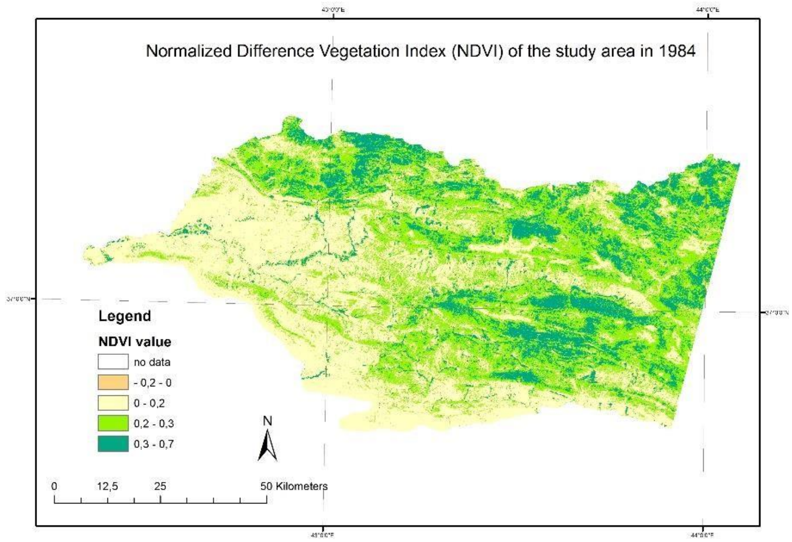


Figure (3) The normalized difference vegetation index (NDVI) for vegetation cover in July (1984) for the study area.

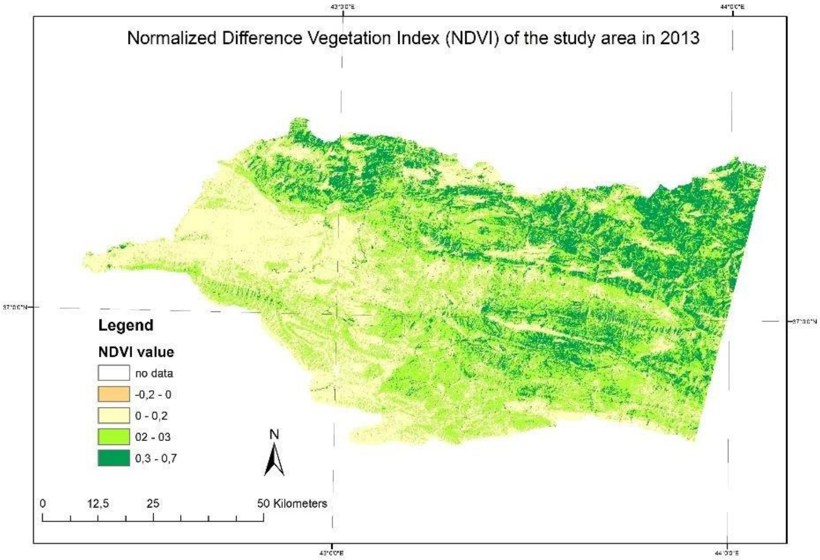


Figure (4) Normalized Difference Vegetation Index (NDVI) for the vegetation cover in July (2013) for the study area.

Figure (4) shows the natural difference vegetation index (NDVI) in (2013) AD, the distribution of forest covers varied for the three sites, as high-density forests increased in the northern and northeastern regions and were also distributed in the southeastern parts, and the dark green color appeared, as the value of (NDVI) reached (0.-7-0.3), while the light green areas, which reached (NDVI) values (0.3-0.2), which are medium-density forests, were spread among the high-density forests and were concentrated in the northern and southeastern parts. (NDVI) As for the low-density forests, they occupied the central and western regions and parts of the southwestern regions, with a value of (0.2-0), and appeared clearly in light pink. As for the selected study areas (Dohuk - Sarsink - Atrush) for the years (1984-2013) in Figure (5), they showed the great variation in (NDVI) values, which represent the density of trees.

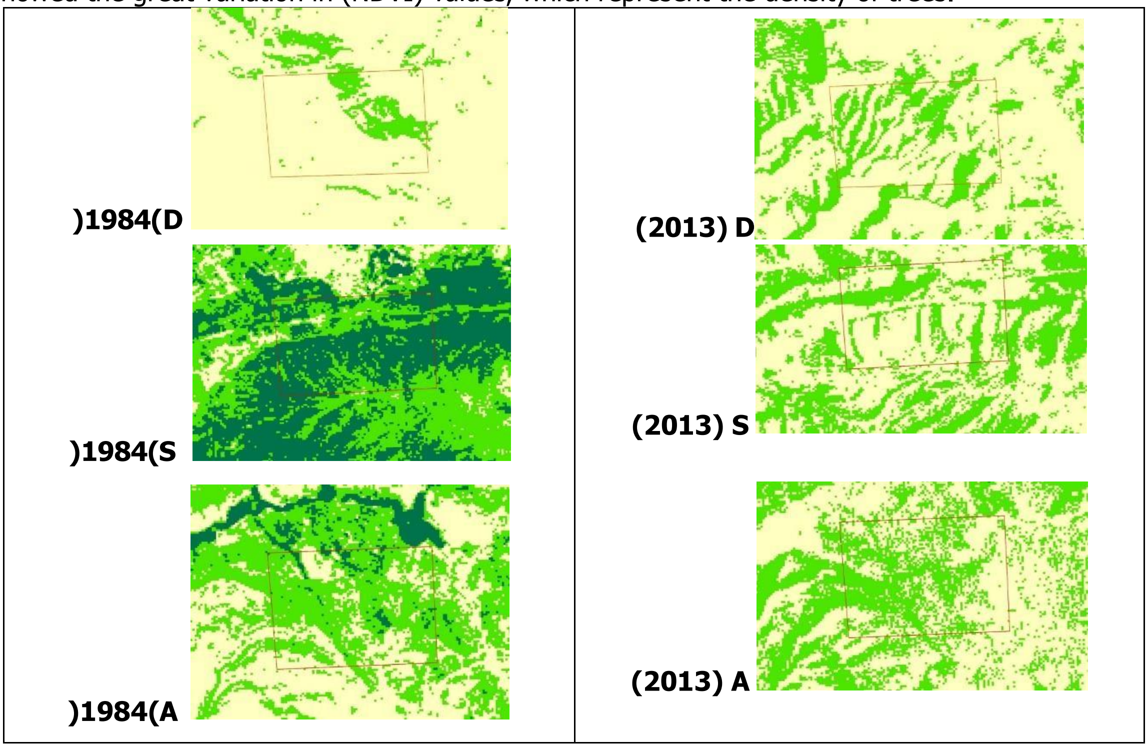
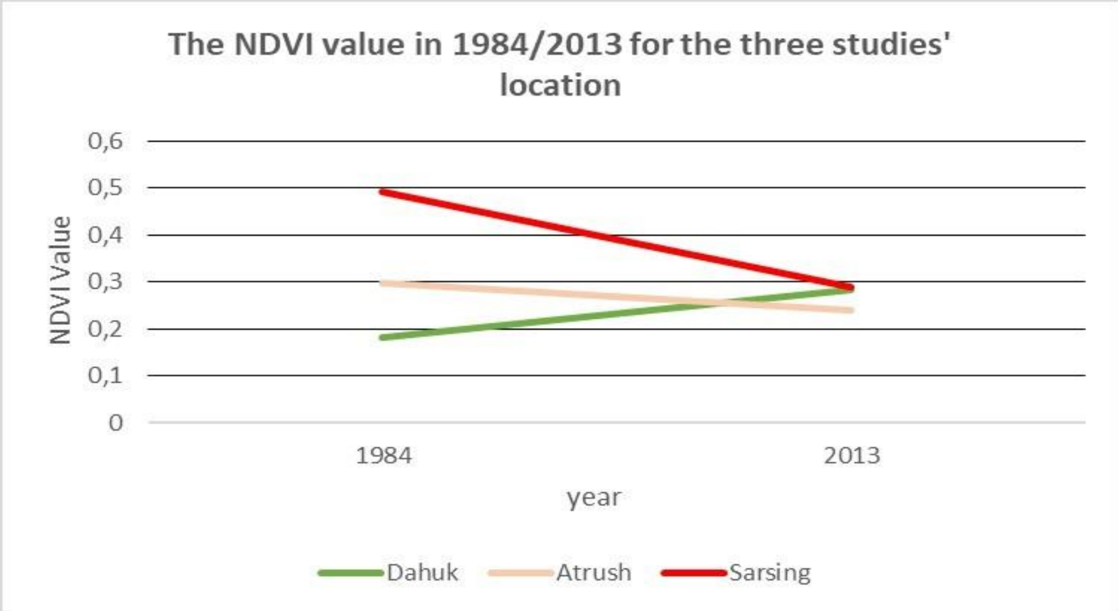


Figure (5) Comparison between the distribution of (NDVI) values in the study areas (Dohuk D - Sarsink S - Atrush A) for the years (1984-2013) AD

From Figure (5) it is clear that the distribution and spread of plant covers in the year (2013) in Dohuk region has increased compared to the year (1984). As for the Sarsink site, we note that the high-density forests in the year (2013) have disappeared, and as for the medium-density forests, their area has decreased and the low-density forests have increased compared to the year (1984), while we note that the medium-density forests in the Atrush site in the year (2013) have decreased in area compared to the year (1984), while the low-density forests have increased in the year (2013). The results indicate that there are changes in the values of (NDVI) for the periods (1956-1984) and (1985-2013), as the (NDVI) index has proven that there is a decline in the growth and development of plant covers for the study sites. The NDVI values are between (1+ and 1-), the more dense and green the vegetation cover is, the closer the NDVI values are to one. Conversely, the lower the density of the vegetation cover and the less the green color reflectance, the lower the NDVI values, which are close to (1-). As in the Sarsink site, we notice a noticeable decrease, with a value of (0.3-0.5), while in the Atrush site, we also notice a decrease, but a slight decrease. As for the Dohuk site, it becomes clear to us that there is an increase in the growth of vegetation cover, so we notice a noticeable and clear increase.



NDVI Figure (6) Vegetation Index Values

The relationship between (NDVI) values and climate factors, temperature and rainfall, was analyzed for the study sites (Dohuk - Sarsink - Atrush). In light of global warming, we note from Figure (7) that the trend of temperatures in the Dohuk region from (1950) to (2020) began to rise from an average of (18.0) C, where its value reached (20.0) C, and the NDVI values increased, meaning that the increase in temperature had no effect on the vegetation cover, which coincides well with the trend line of the natural vegetation index, where its value was (NDVI) (0.1) and its value increased (0.3), meaning that its value increased and the temperature increased positively, leading to a high increase in the value of (NDVI), and thus growth increased (Pan et al. 2019). But in fact, the improvement in the vegetation cover was due to the protection of forests due to their proximity to the city and the authorities' institutions that imposed strict restrictions on cutting and removing them.

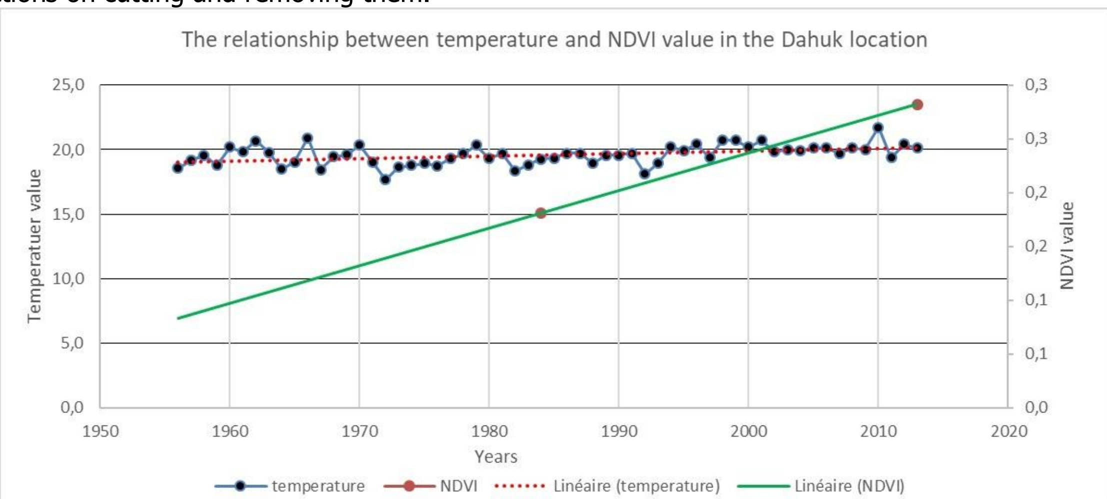
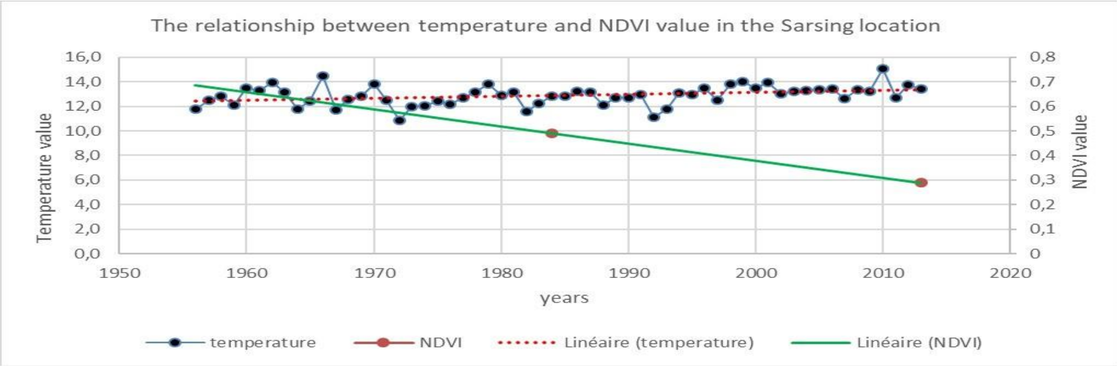


Figure (7) The relationship between (NDVI) and the average annual temperature in the Dohuk region

Figure (8) shows the annual trend of the natural vegetation index and annual climate factors in the Sarsink area, where it is clear to us that the trend of the maximum natural vegetation index decreased significantly, reaching a value of (0.3), while the average annual temperature showed a very slow positive change, reaching a value of (12.0) C, meaning that the effect of temperature was relative. However, the average annual temperature increased significantly at a rate of (14.0) C in the early eighties, and the value of the natural vegetation index decreased to reach (0.3), meaning that in these areas there is no clear link between the average annual temperature and the (NDVI) index, meaning that this site is greatly affected by human factors and is not subject to environmental laws.

Therefore, the vegetation covers were affected by destructive human activity, which led to their decline despite the slight change with temperature



.Figure (8) The relationship between NDVI and the average annual temperature in the Sarsink area

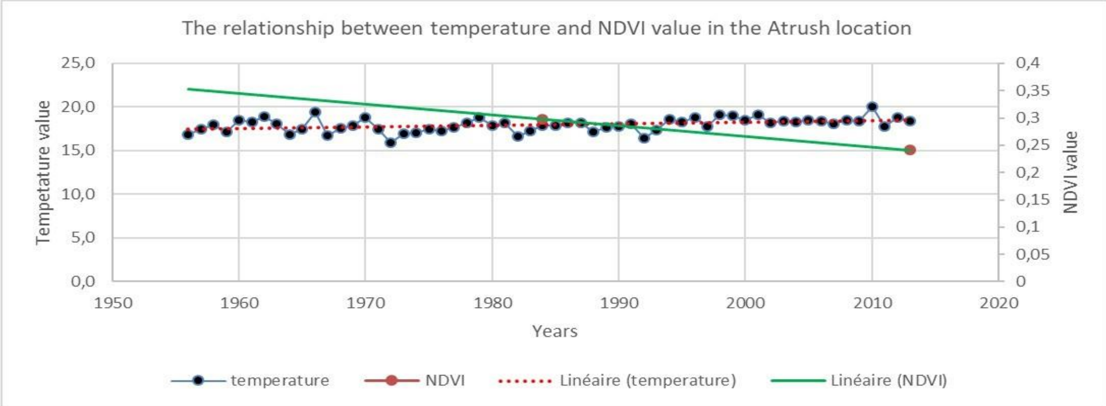


Figure (9) The relationship between (NDVI) and the average annual temperature in the Atrush region

It is clear to us from Figure (9) that there is a decrease in the values of the natural vegetation index, as we notice that the values decreased from (0.35) to (0.25), and this indicates a decrease in growth as a result of the increase in temperatures, as it was (17.0) to reach a value of (19.0).

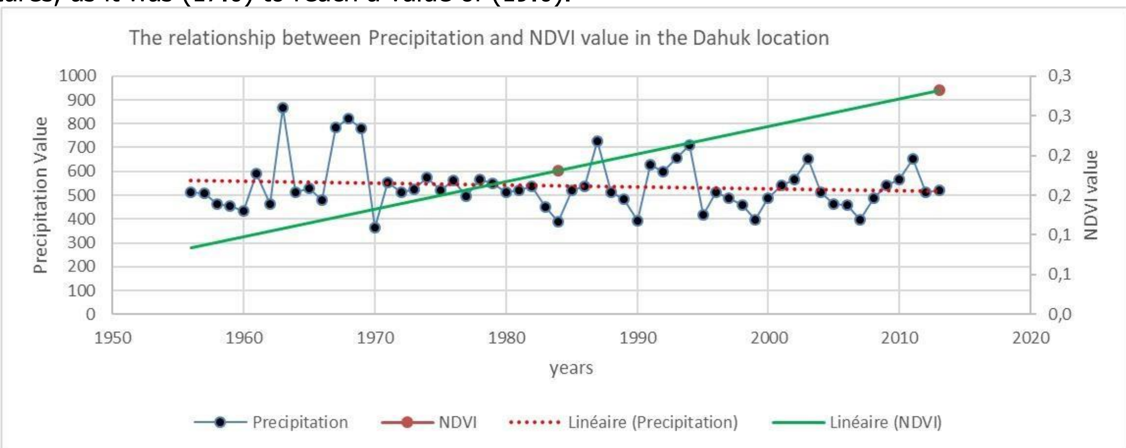


Figure (10) The relationship between (NDVI) and rainfall in the Dohuk region

From Figure (10) it is clear to us that the rainfall from the year (1956-2013) has decreased, as we notice that the rainfall regression line had a value of (560) mm and decreased to (500) mm. Through the intersection of the two plots, the rainfall regression line and (NDVI), it becomes clear that the decrease in rainfall versus the increase in vegetation cover indicates that the increase in vegetation growth has nothing to do with climate, as the relationship is inverse, and this indicates that there is another factor, which we mentioned previously about forest protection laws (Ali et., al 2019.)

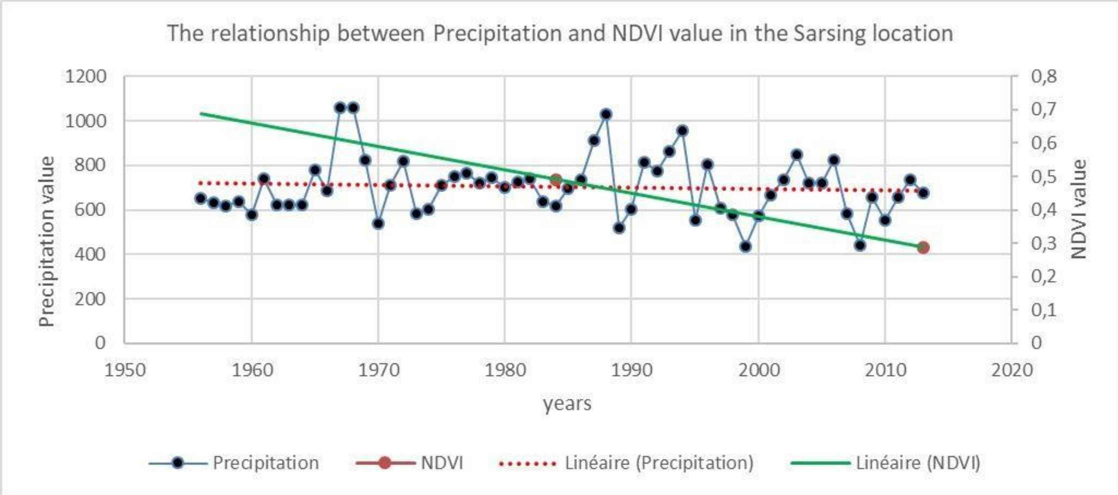


Figure (11) The relationship between (NDVI) and rainfall in the Sarsink area

From Figure (11) we notice that the values of (VDVI) decreased between the years (1984 - 2013) AD, a noticeable decrease, which was matched by a very slight and imperceptible decrease in the percentage of rainfall. This indicates that the decrease in the growth of the vegetation cover has nothing to do with the rainfall, i.e. there is another factor, which is the human factor, that caused this decrease in growth in this region, which may be (fires - logging - overgrazing), as mentioned by (Tuoku et., al 2002).

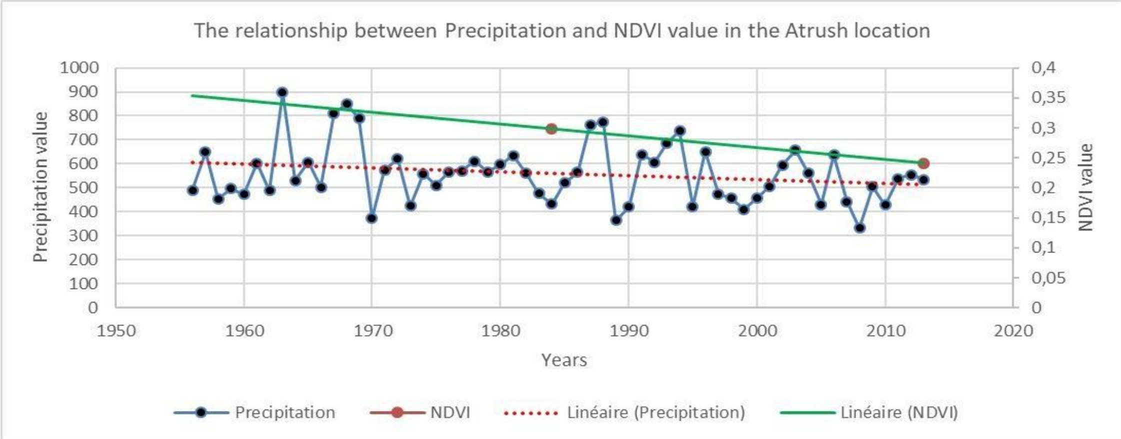


Figure (12) The relationship between (NDVI) and rainfall in the Atrush area

From Figure (12), we notice a decrease in the rainfall rate by about (100) mm and the values of (NDVI). The decrease in both rainfall and the natural difference index was balanced and noticeable compared to the Sarsink site. Therefore, rainfall has a role in influencing the growth of the vegetation cover in addition to human activity in this region (Yuan et al. 2015).

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