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RESEARCH ARTICLE

# The Impact of Precipitation Distribution on the Natural and Cultivated Vegetation Cover Changes in the Syrian Coastal Area for the Period 2000-2019

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## Abstract

*The study aims to determine the vegetation covers (natural and cultivated) affected by precipitation amounts in the Syrian coastal area from 2000 to 2019, and for this, precipitation data for 23 climatic stations were used, in addition to the spectral vegetation indices EVI and LAI from the MODIS satellite. The results showed that vegetation covers are affected by the amount of precipitation, but there is a difference in vulnerability degree in the cultivated and natural cover (forests). The cultivated vegetation covers were more affected by the decrease or increase in the precipitation amount, as the area is coastal and depends heavily on rainwater. The cultivated cover has declined significantly in the years with low precipitation, especially the years 2008, 2010, 2014 2016, while it responded well to the high precipitation values in 2003, 2012, 2015 and 2019. While the forests showed a slight impact on the decrease in the amount of precipitation due to their nature of adaptation to the conditions of the region, where most of the years maintained stable and high values for both EVI and LAI indices, except for 2014 and 2016 which were the years with the sharp decline in the amount of precipitation. When the forests were affected by the decline in precipitation in addition to the fires resulting from the crisis conditions in Syria, which increased the severity of damage in forest cover. This indicates that the forests were affected in the first place as a result of fires and in the second place as a result of precipitation, while the cultivated cover was mainly affected by the lack of precipitation.*

**Keywords:** Coastal area; EVI; Forests; LAI; Precipitation; Vegetation cover

## 1. Introduction

For five decades and more, Syria has been exposed to several droughts, and some of these waves were described as the most severe in 70 years (Hoerling et al., 2012) [1], especially the drought of 2008 and the drought of 2014 and 2017. Drought is defined as occurring when precipitation values are lower than their annual average. Therefore, drought is one of the most important challenges facing the development of agricultural production and the management of water resources in Syria, especially since 75% of the cultivated areas in Syria depend on precipitation (Statistical Group, 2017) [2].

It also negatively affects natural forest ecosystems (Sardans et al., 2008) [3], and increases the risk of forest fire and its spread (Pausas and Santiago, 2012) [4].

Therefore, it was necessary to study this phenomenon and its impact on vegetation cover growth and vitality. This study focused on the Syrian coastal area, which is diverse in its natural and cultivated vegetation. Since the area is coastal, rainfall plays a key role in the growth of vegetation. In order to be comprehensive in monitoring the area due to its wide area and the diversity of its terrain, it was appropriate to use satellite image data and link it with the rainfall data to identify the precipitation impact on these vegetation covers during twenty years.

## Study area

The study area is located in the northwestern part of Syria, within the administrative boundaries of Latakia and Tartous governorates, it is located between latitudes (34° 36´38") and (35° 57´20") N and between longitudes (35° 40´50") and (36° 18´35") E. (Figure 1), with a total area of about 4368 km$^2$.

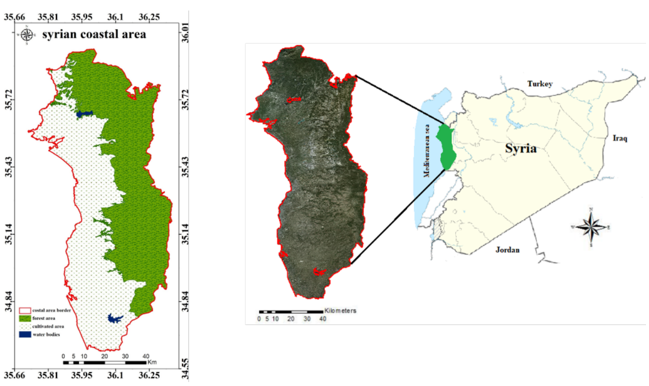


**Fig. 1. Location map of the study area**

The area of the Mediterranean region is characterized by moderate temperatures throughout the year. With differences in temperature, rainfall decreases as we rise from the sea, or move from west to east. The annual rainfall rate is 1000 mm, and in some areas 1800 mm, and the snow falls on the mountainous areas which are more than 1200 meters above sea level. The humidity is between 70-60% in winter and its between 70-85% in summer (Quezel, 1977) [5].

## Data Used

### *Precipitation data*

Precipitation data for 23 climate stations covering the study area (Figure 2), were obtained from the Ministry of Agriculture and Agrarian Reform - Drought and Natural Disaster Mitigation Fund Directorate.

The precipitation amounts were determined for the eight-month season from September to April of the following year, as this time represents the beginning and end of the precipitation season that is important for the growth of vegetation in the study area (Le Houerou, 2004) [6].

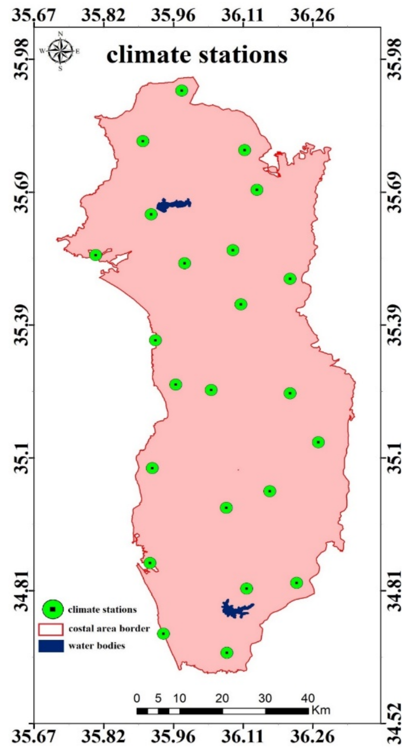


**Fig. 2. Distribution map of the study area climate stations**

All used Sensing Indices were derived from MODIS data, which downloaded from the USGS website (www.earthexplorer.com), and are:

### *Enhanced Vegetation Index (EVI)*

It was invented by Huete to simultaneously correct NDVI results for atmospheric influences and soil background signals, especially in areas of dense canopy. The value range for EVI is -1 to 1, and for healthy vegetation it varies between 0.2 and 0.8. (Huete et al., 1997) [7].

EVI = 2.5 * ((NIR – Red) / ((NIR) + (C1 * Red) – (C2 * Blue) + L))

Where:

C1 and C2: coefficient to correct for aerosol scattering present in the atmosphere.

L: to adjust for soil and canopy background.

Traditionally, C1=6, C2=7.5, and L=1

### *Leaf Area Index (LAI)*

It is a quantitative index describing the plant canopy, it is defined as the area of the leafy surface in relation to the area of the surface of the land it occupies, and the value of this guide varies according to the type of vegetation, and its value generally ranges from 0 to 12. Where the value (0) of the bare land and it exceeds (10) for very dense forests, the most vegetative values are between 0–7 (Watson, 1947)[(8)].

LAI is an important moisture laboratory for understanding the relationship between climate and vegetation, and to improve agricultural water management in a wide range of regions (Groenendijk and Coauthors, 2011; Nielsen et al., 2012)[(9,10)].

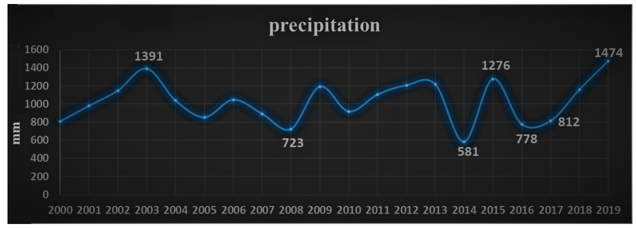


**Fig. 3. The average annual precipitation from 2000 – 2019**

## 2. Methodology

1. Using the monthly precipitation data from the climate stations, the cumulative annual precipitation for each year was calculated.
2. Satellite images processing through the steps:

   (a) The process of specifying the projection (UTM zone 37N) for all scenes was carried out according to the global projection system UTM_WGS84.
   (b) Extracting the study area based on the Ministry of Local Administration approved administrative boundaries.
   (c) Adjusting the values using the scale factor: EVI and LAI images contain raw data that must be corrected using a special correction factor, which is 0.001 for the EVI image and 0.1 for the LAI image, so that the data of each image is transformed to reflect the values of these indices. (MODIS brochure, 2004)[(11)].
   (d) Producing the distribution maps of LAI and EVI values.

      i. Results Analysis using Pearson correlation coefficient to determine the correlation between precipitation and LAI, EVI.

## 3. Results and Discussion

### The average annual precipitation

Calculating the average annual precipitation quantities reveals that the lowest recorded number was 581 mm in 2014, followed by 723 mm in 2008.

The highest figure was recorded in 2019, at 1474 mm, followed by 1391 mm in 2003 and 1276 mm in 2015 (Figure 3).

### Vegetation cover changes according to EVI and LAI for the time series 2000-2019

To monitor the changes occurring in the vegetation cover in terms of vitality and living mass, time series maps of EVI and LAI values for the study area were produced from the year 2000 until the year 2019 for April, which were classified within the Arc GIS software to show the distribution of values for each index. In general, these vegetation indexes are related to the vegetation cover in terms of leaf area, biomass, and percentage of land cover, which can be used as evidence of vegetative growth (Tucker, 1979; Baret and Guyot, 1991)[(12,13)].

- **Vegetation cover changes in the forest cover:**

From EVI and LAI forest indexes, it was found that they record high values in these indexes. This is due to the nature of forests, which are characterized by density and layering, which gives a high biomass and a large leaf area. Forests are also known as one of the climax stages of plant communities, this is after achieving acclimatization and appropriate adaptation to resist the surrounding conditions.

The graphs of the average values of EVI and LAI for forest cover (Figure 4) show that the values of EVI in most years maintained a constant level with the exception of 2014, where the value of plant vitality index EVI decreased to 0.32, in which vitality declined slightly due to drought and the conditions of the region during the crisis that the country went through, the forests were exposed to fires and cutting as a result of military operations. As for the LAI index, it was observed that it was affected by drought in 2008 and reached 0.99, recording low values, while forests were affected positively during the years 2010, 2013, and 2015 and 2019 recording high LAI values. The highest value recorded in 2013 and 2019, which was 1.32. This due to the good amounts of rain that the region received during these years. These values corresponded to the precipitation values in terms of low and high amounts in the same years.

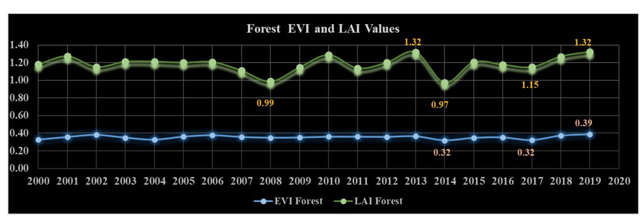


**Fig. 4. The average values of EVI and LAI forest cover in the study area for the years 2000 - 2019**

Figures 5 and 6 depict the map distribution of EVI values and LAI values, respectively, and illustrate that the majority of the locations where these index values fell were in the northwest of the forest cover. This is a result of the deterioration to which the forest cover was exposed in the north of the study area, as it was close to the armed groups that were using it in their combat operations, which exposed the forest to fires and destruction, and thus the density and vitality declined.

The other areas of the forest that were not destroyed did not show this decline during the years 2014 and 2008, despite the decrease in the index values during these years.

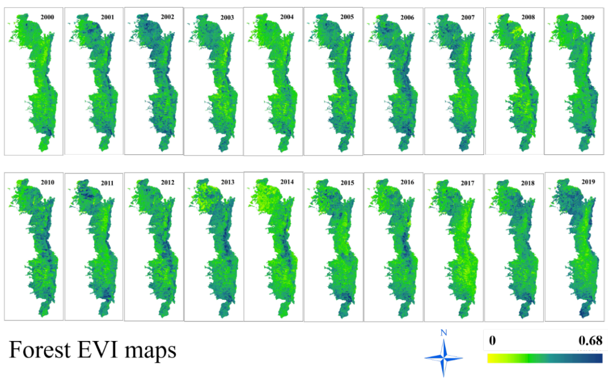


**Fig. 5. Distribution Maps of EVI values for forest cover in the study area from 2000 - 2019**

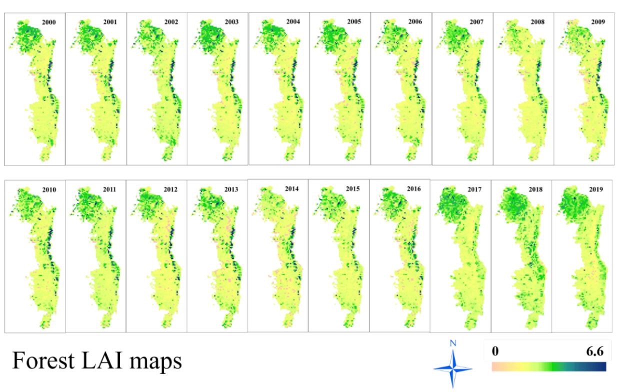


**Fig. 6. Distribution Maps of LAI values for forest cover in the study area from 2000 - 2019**

- **Vegetation cover changes in the cultivated cover:**

This form of vegetation cover in the study area is distinguished by small agricultural holdings in which fruit trees are mixed with crops in the same field. Furthermore, this cover is comparable to irrigated cover in that it receives a lot of rain due to its geographical position, which has a humid environment. This cover was very compatible with precipitation, as seen in Figure 7, which shows the average EVI and LAI values for this cover. It is noted that both indices respond and compatible in terms of high values in years with good precipitation and low values in years with bad precipitation.

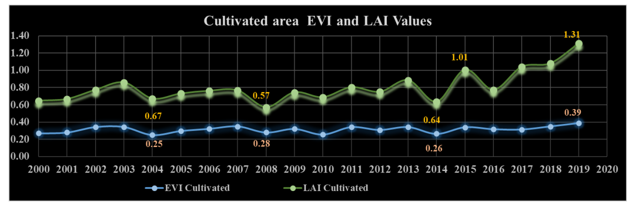


**Fig. 7. The average values of EVI and LAI cultivated cover in the study area for the years 2000 - 2019**

We note that the highest values of the studied indices were recorded in 2019, and the values were 1.31 and 0.39 for LAI and EVI, respectively. The lowest values were recorded in the years 2004, 2008 and 2014. The values of EVI were 0.25, 0.28, and 0.26, respectively, while the values of LAI were 0.67, 0.57, and 0.64, respectively.

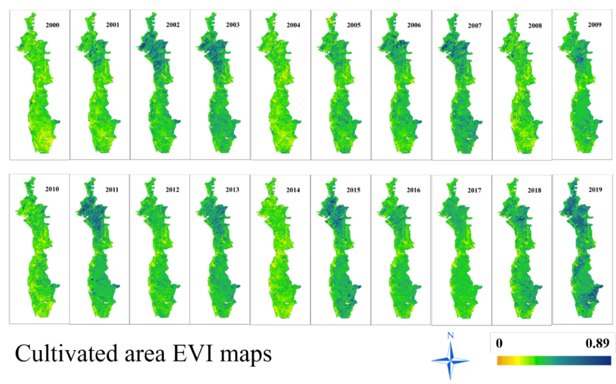


**Fig. 8. Distribution Maps of EVI values for cultivated cover in the study area from 2000 - 2019**

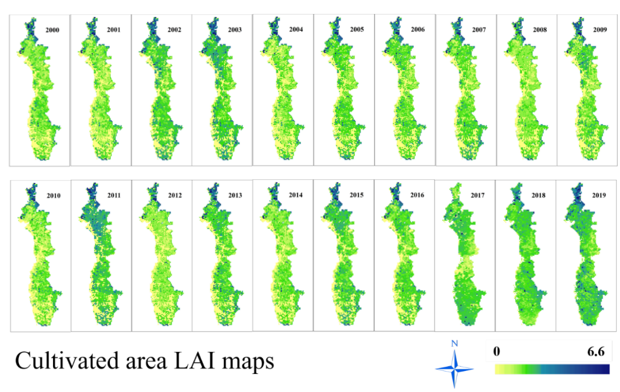


**Fig. 9. Distribution Maps of LAI values for cultivated cover in the study area from 2000 - 2019**

The distribution maps of EVI values (Figure 8) and LAI (Figure 9) show the years in which the values of these indices decreased, indicating a deterioration in the health of the cultivated cover, which are the years 2008, 2014, and 2016, where most of the studied area appears in light green, close to yellow, which indicates the lowest values of the indices, and the years in which the values were high, indicating a healthy and good condition in the cultivated cover situation, which are the years 2003 and 2015.

We can notice from the maps that the entire area is affected by a decline in plant vitality values or a decline in leaf area, which indicates that the entire cultivated cover is affected by surrounding factors, including a decline in rainfall amounts, in contrast to what we observed in the forest cover.

- **Precipitation influence on vegetation cover:**

To determine how strong the relationship between vegetation vitality and precipitation, the correlation between EVI, LAI values and precipitation values were studied.

The study of the correlation between precipitation and vegetative indices showed a significant correlation between all vegetative indices and precipitation at the level of significance 0.01. But the correlation was strong for the planted cover where R exceeded 0.6, which indicates the great role that rain plays in the growth of this cover. But the correlation was not strong enough for forests, as the R value for EVI was 0.573 and for LAI was 0.588 (Figure 10). This indicates that precipitation has little effect on the vitality of the forest and that there are other factors that are more effective.

**Correlations**

| | | EVI Forest | LAI Forest | EVI Cultivated | LAI Cultivated | precipitation |
|---|---|---|---|---|---|---|
| EVI Forest | Pearson Correlation | 1 | .610** | .635** | 0.388 | .573** |
| | Sig. (2-tailed) | | 0.004 | 0.003 | 0.091 | 0.008 |
| | N | 20 | 20 | 20 | 20 | 20 |
| LAI Forest | Pearson Correlation | .610** | 1 | 0.209 | 0.158 | .588** |
| | Sig. (2-tailed) | 0.004 | | 0.377 | 0.505 | 0.006 |
| | N | 20 | 20 | 20 | 20 | 20 |
| EVI Cultivated | Pearson Correlation | .635** | 0.209 | 1 | .771** | .680** |
| | Sig. (2-tailed) | 0.003 | 0.377 | | 0 | 0.001 |
| | N | 20 | 20 | 20 | 20 | 20 |
| LAI Cultivated | Pearson Correlation | 0.388 | 0.158 | .771** | 1 | .623** |
| | Sig. (2-tailed) | 0.091 | 0.505 | 0 | | 0.003 |
| | N | 20 | 20 | 20 | 20 | 20 |
| precipitation | Pearson Correlation | .573** | .588** | .680** | .623** | 1 |
| | Sig. (2-tailed) | 0.008 | 0.006 | 0.001 | 0.003 | |
| | N | 20 | 20 | 20 | 20 | 20 |

** Correlation is significant at the 0.01 level.

**Fig. 10. Table showing Correlation values between studied indices**

## 4. Conclusion

The used vegetative spectral indices indicated some changes in the vitality of natural and cultivated vegetation cover, indicating a high vitality and healthy condition of the vegetation cover in the years 2019, 2015, and 2013, which were also accompanied by high amounts of precipitation.

There were also indications of a decline in the health and vitality of the vegetation cover in the years 2008 and 2014, which also witnessed low amounts of precipitation.

The correlation study between the indices showed a high correlation of the cultivated cover with the amounts of precipitation, the effect of its decline or increase affecting all agricultural lands.

As for the forest cover, we noted that in the years in which there was a decline in the vitality and health of the forest, some areas were the most affected, and by returning to the records of fires and forest data in the Ministry of Agriculture, it was found that these areas in the northwest of the study area witnessed acts of sabotage and burning, especially in the years 2014 and 2016.

This indicates that the situation of the forests in the Syrian coast is affected by several different factors, including precipitation, fires and human interventions, and if they occur together, this affect appears clearly, but the decline in precipitation did not severely affect the forest that has adapted to the site conditions.

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