

IMPACT OF CLIMATE ON VEGETATION INDICES OVER RAINFED DISTRICTS OF UTTARAKHAND, INDIA

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ABSTRACT:

Due to a change in the landscape, the climate of Uttarakhand state is changing rapidly, impacting the weather, further affecting human beings and vegetation. Nowadays, remote sensing is a favorable tool for monitoring the vegetation condition using NDVI and EVI. Studying the relationship between vegetation and climate more extensively, it is necessary to better understand the anomaly of ecosystems with climate change. This study is carried out to evaluate the vegetation cover dynamics by establishing the association between climate parameters and vegetation indices over the rain-fed districts (Nainital, Bageshwar, Champawat, Dehradun) of Uttarakhand for the period of 20 years. In this study, Google Earth Engine (GEE) is used to extract the MODIS NDVI and EVI at 250 m spatial resolution & 16-day temporal resolution data. The climate parameters for the rain-fed district (study area) are extracted from Indian Meteorological Department (IMD) Pun website for the period from 2000 to 2020. According to the annual vegetation dynamics, the peak attained by both indices is during the monsoon season, and hence they both show identical patterns to each other. Linear Regression Analysis results show a strong impact of climate on vegetation. Both indices show a positive correlation with climate parameters where minimum temperature and rainfall are strongly correlated with EVI. Thus, the study reveals that EVI is proven to be more appropriate indices for monitoring vegetation cover as compared to NDVI for the study area.

1. INTRODUCTION

Climate is one of the significant elements which is driving the ecosystem. Frequent climate change causes high temperature, drought, rainstorms, and floods, which has some consequences on human beings and the ecosystem (Lloyd et al., 2020). In the ecosystem, vegetation helps to regulate the climate, water, and soil (Kiang et al., 1999). Therefore, monitoring of vegetation dynamics is required at spatial and temporal scales (Yi et al., 2011). Nowadays, regular monitoring can be easily done using remote sensing data, which can be used for developing new techniques. It is quite necessary to monitor the vegetation of a country like India, whose economy mainly depends on agriculture (Balaselva Kumar and Saravanan, 2009).

In the last few years, remote sensing has emerged as viable technology which collects the earth's surface data without coming in direct contact with the object (Wojtowicz et al., 2016). Remote sensing satellites collect data with the help of sensors that can be classified as active and passive sensors. Passive sensors are those which collect the object information by recording incident radiation reflected or emitted, while active sensors emit their own energy and collect the energy reflected by the object.

There are many satellites in space that provide hyper as well as multispectral data of the earth's surface on a daily basis. For monitoring the vegetation, landslides, drought condition, this daily basis data will be very useful, and for preserving biodiversity, it is required to monitor the vegetation. According to (Lykhovyd et al., 2020), with the help of remote sensing, collecting vegetation status information has become an easier

task. Vegetation Indices play a vital role in evaluating terrestrial vegetation productivity (Kim et al., 2010).

Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) are the spectral indices that provide accurate status of vegetation cover (Li et al., 2002). These indices derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data capture the surface greenness and therefore were widely used for vegetation dynamics monitoring (Lin et al. 2020). The MODIS data are derived using the Google Earth Engine platform.

Google Earth Engine (GEE) is a web-based remote sensing platform that helps in various analyses of over-collected satellite imagery. According to (Gorelick et al. 2017), Map-Reduce architecture is used in GEE for parallel processing of data. The NDVI and EVI mean value is evaluated using the Map-Reduce algorithm.

Temperature and rainfall have a strong impact on the spatial and temporal patterns of NDVI and EVI. The uncertainty in rainfall and temperature data has a significant impact on vegetation cover as they help in plant development. There have been many articles that show the connection between vegetation and climate parameters.

At present, no study is available for the study area, which shows the vegetation cover dynamics. In addition, with the growth of population, there is a rapid land-use change is occurring, which is impacting the vegetation as well as the climate.

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Therefore, this study is performed to explore the temporal variation of vegetation indices over long-term analysis and to represent the impact of climate parameters on these indices.

2. STUDY AREA AND DATA SETS

Uttarakhand state is a mountain-dominated state which lies in the foothills of the great Himalayas. Uttarakhand is famous for its natural beauty scenes, and it shares its boundaries with other Indian states. The 13 percent of the state's geographic area is under cultivation, from which around 8 percent of the area is dependent on rainfall. The average annual rainfall for the state is 1547 mm, and the state altitude varies from 200 m to 8400 m from sea level. More than 70 percent of the population is engaged in agriculture. Due to the inaccessibility of resources and topographic conditions, this sector is poorly developed. Some of the rain-fed districts of Uttarakhand are Dehradun, Champawat, Bageshwar, Nainital. The coordinates of the study area are given in table 1 and are shown in Figure 1.

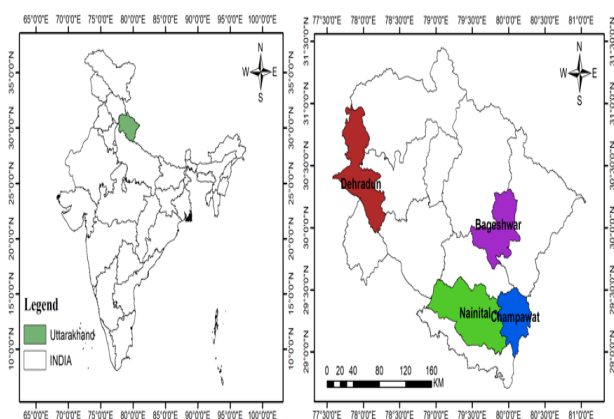


Figure 1. Study Area

District	Lat	Long	Data Period
Dehradun	30.3840 ° N	77.9739 ° E	2000-2020
Champawat	29.33 ° N	80.10 ° E	2000-2020
Bageshwar	29.9987 ° N	79.8745 ° E	2000-2020
Nainital	29.2794 ° N	79.4704 ° E	2000-2020

Table 1. Details of study area of Uttarakhand in India

In this study, MODIS time-series data is for the period of 20 years from 2000 to 2020. MODIS NDVI and EVI data is extracted with the help of the Google Earth Engine (GEE) platform, whose spatial resolution is 250 m and temporal resolution is of 16 days for the same time period. Google Earth Engine platform is a collection of a large volume of data in an efficient manner and provides the platform for analysis. The beauty of this platform is that it reduces the space complexity as there is no need to download the satellite data.

The climate parameters required in the study are collected from the Indian Meteorological Department (IMD) Pune website for the period of 20 years, from 2000 to 2020.

3. METHODOLOGY

3.1 Flowchart

The methodology adopted in the article is shown in Figure 2. The Climate parameters, i.e., rainfall and temperature, are collected on a daily basis from IMD Pune for the period of 20 years from 2000 to 2020. This daily basis data is then converted into monthly mean values for both rainfall and temperature.

At the same time, the GEE platform is used to collect the MODIS time series data for both vegetation indices, i.e., NDVI and EVI. This temporal data is very much useful for monitoring purposes. In GEE, a code editor is used for extracting the data, which works on the Map Reduce algorithm.

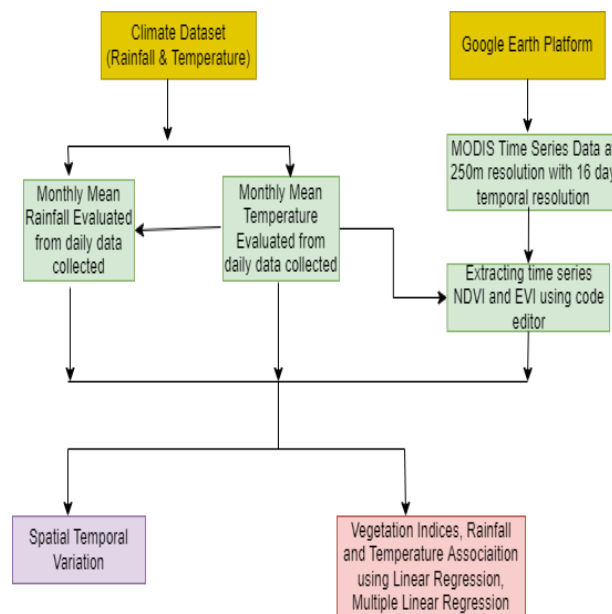


Figure 2. Methodology Adopted

After the data collection, the R platform is used to perform analysis and plot the temporal variation of climate data with vegetation indices using ggplot. The result obtained from R plots is then analysed to find out the best-suited vegetation indices from NDVI and EVI for monitoring the vegetation in the rain fed areas. Linear Regression is also used to compare the indices.

3.2 Vegetation Indices

Vegetation Indices are helpful in measuring the plant spectral characteristics based on the reflectance in visible and near-infrared wavelengths. The amount of green leaf biomass is correlated with the ratio of infra-red to the red band (Kokhan et al., 2020). NDVI and EVI are considered as most common indices used for analysing the vegetation cover.

NDVI is evaluated using the equation: (Rouse et al., 1974)

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

The ratio of these two bands is highly correlated with vegetation parameters. NDVI helps in correcting the errors due to topography and shade. A healthy forest has a strong reflection in the infra-red spectrum while absorbing in the visible red spectrum. Bare ground, soil, and rock nearly have equal reflectance in both infra-red as well as a red band, due to which NDVI value remains close to 0. For Sparse vegetation, the NDVI

value lies near 0.05, while for dense vegetation, the value remains between 0.6-0.7.

EVI is evaluated using the equation (Liu et al., 1995)

$$EVI = G.F * \frac{NIR - RED}{NIR + C1 * RED - C2 * BLUE + L} \quad (2)$$

Here, the blue band is used for correcting the aerosol influences in the red band (C1=6 and C2=7.5), canopy background adjustment factor (L=1), and Gain Factor (G.F = 2.5).

3.3 Linear Regression Analysis (LR) & Correlation Coefficient

Linear Regression is a statistical method for evaluating the value of a dependent variable from an independent variable. LR is used to study the trend of vegetation indices and climate parameters between 2000 to 2020. The spatial and temporal change in temperature, rainfall, NDVI, and EVI is analysed using regression. The slope is being evaluated using the following equation:

$$Slope = \frac{n \sum_{j=1}^n Y_j Z_j - \sum_{j=1}^n Y_j \sum_{j=1}^n Z_j}{n \sum_{j=1}^n Y_j^2 - (\sum_{j=1}^n Y_j)^2} \quad (3)$$

Where n is the number of years and Y_j, Z_j are the value of the independent and dependent variables. If the value of the slope is positive (increasing trend) and negative (decreasing trend).

Pearson correlation analysis is used to obtain the relationship between the vegetation indices and climate parameters. Correlation yields a quantitative way of measuring the strength of the relation between two variables, while regression mathematically describes the relationship. This method is widely used by researchers to identify the relationship between climate factors and changes in indices (Sun & Qin, 2016). The correlation coefficient can be evaluated as:

$$r_{xy} = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (4)$$

4. RESULTS

4.1 Annual Dynamic of Vegetation

Annual Vegetation dynamics cover need to be evident. The information collected from the local people of the study area is not considered a relevant source for scientific knowledge, so according to data generalization of MODIS 16-day NDVI and EVI results, the annual trend in the vegetation growth can be seen in Figures 3-6 for different locations. The monthly NDVI and EVI are obtained by making an average of all NDVI and EVI values in the same month for the duration of 2000-2020.

Figure 3. depicts the annual vegetation dynamics for the Nainital district. It is observed from the graph that vegetation peak in the district is obtained during the Kharif season or monsoon season, which ranges from 0.56-0.74 for NDVI and 0.36-0.41 for EVI indices. At the same time, the summer season is characterized by the least vegetation values as 0.50 of NDVI and 0.28 of EVI, respectively. While in the winter season, there is an increase in vegetation growth which ranges from 0.61-0.69 for NDVI and

0.29-0.35 for EVI. EVI and NDVI values gradually decrease from January to March.

Bageshwar district's annual dynamics can be visualized in Figure 4. From the graph, it can be noticed that the vegetation peak in the Bageshwar district is attained during September month of the Kharif season (NDVI:0.63 and EVI:0.34), while for the rest of the months during the same season, the values remain the same. In the winter season, a substantial increase can be noticed in vegetation growth which ranges from NDVI:0.54-0.45 and EVI:0.28-0.20. In the summer season, not much change is noticed where an average range of NDVI:0.44 and EVI:0.24.

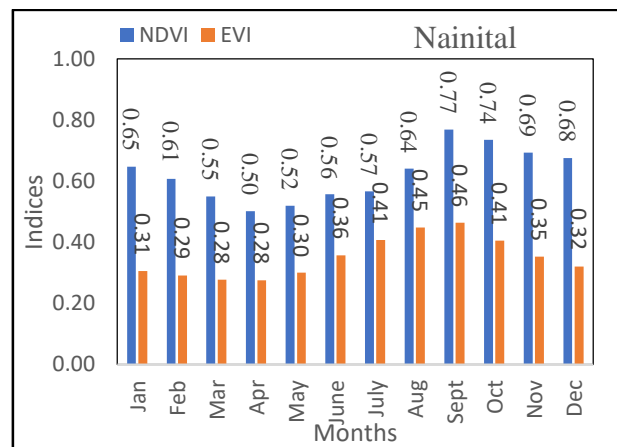


Figure 3. Nainital District Vegetation Cover (NDVI and EVI values)

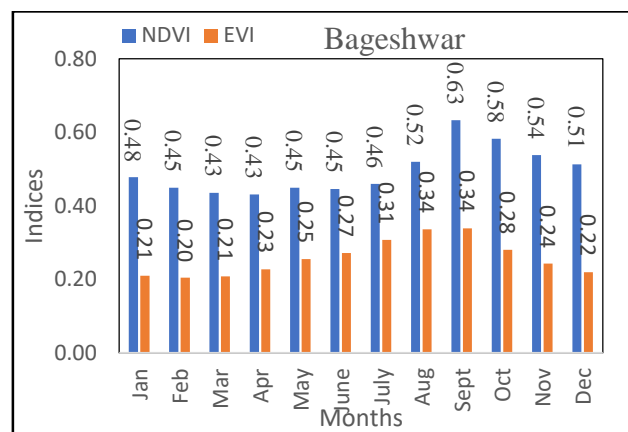


Figure 4. Bageshwar District Vegetation Cover (NDVI and EVI values)

Figure 5. illustrates the annual vegetation dynamics for the Champawat district, where it can be noticed that the highest vegetation peak is attained during September and October month which is a monsoon season where NDVI is 0.76-0.72 and EVI is 0.43-0.37. While during the winter and summer seasons, it is noticed that there is not much change is noticed where the NDVI ranges from 0.68-0.51, and EVI ranges from 0.32 to 0.27. Champawat district's annual dynamics are very similar to Nainital district vegetation dynamics.

Dehradun vegetation annual dynamics are illustrated in Figure 6. It is observed that maximum peak in Dehradun is attained during the September season, which is a Kharif Season when the rainfall is maximum. In this graph, vegetation value gradually decreases

during the summer season when the average NDVI is 0.49 and the average EVI is 0.28. In the winter season, the range of NDVI is 0.60-0.53, and EVI is 0.30-0.25.

4.2 Association of NDVI and EVI with climate parameters

For the growth of vegetation, climate parameters (rainfall, temperature) are considered one of the important components. So, it has become important to study the connection between vegetation indices and climate parameters.

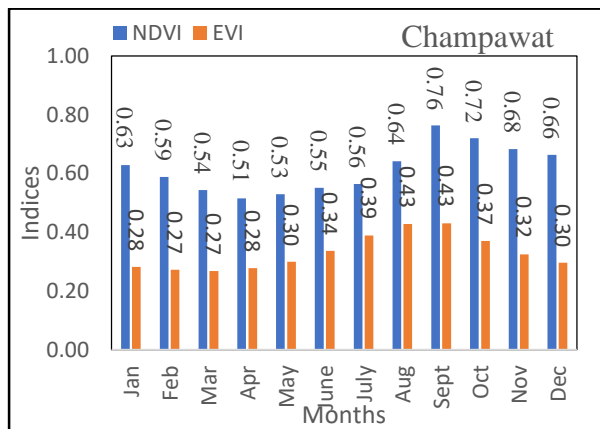


Figure 5. Champawat District Vegetation Cover (NDVI and EVI values)

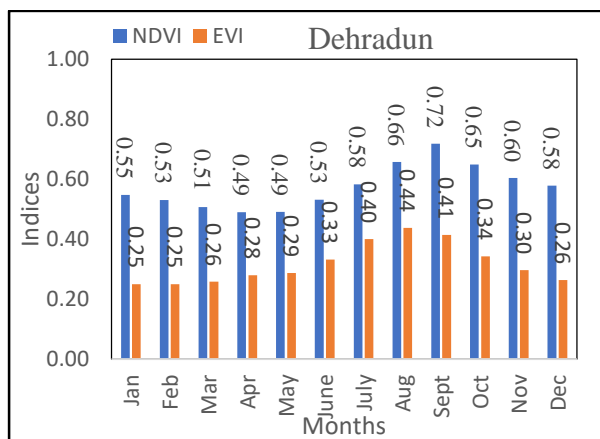


Figure 6. Dehradun District Vegetation Cover (NDVI and EVI values)

Figure 7. illustrates the temporal variation of vegetation indices with climate parameters over the Nainital district for the period of 20 years, i.e., 2000-2020. It has been observed in Figure 7(a) that maximum temperature attains its peak in the summer season when both indices show their minimum values. Figure 7(b) depicts the relationship between indices and minimum temperature. It has been observed that minimum temperature attains its peak in the monsoon season, where both indices show their higher values. Figure 7(c) shows the variation between rainfall and vegetation indices. It has been observed that the EVI value increases with the increase in rainfall while NDVI doesn't show much close relation with rainfall for the Nainital district. Rainfall shows its peak during the rainy season when both indices obtain their maximum values. In general, NDVI and EVI indices for the Nainital district increase with the increase of minimum temperature, while with rainfall EVI shows a similar pattern, but

with maximum temperature, the trend is seen to be in the opposite direction.

Figure 8. illustrates the temporal variation of NDVI and EVI with climate parameters over the Bageshwar District for the period of 20 years. It has been observed that in Figure 8(b), minimum temperature attains its peak in the rainy season, i.e., from June to October, where both indices also show their maximum values. While both indices show similar variation with maximum temperature but do not attain their maximum value when attained by maximum temperature.

Figure 9. depicts the temporal variation of NDVI and EVI with climate parameters over the Champawat district. Figure 9 (a) depicts the variation of indices with maximum temperature, and it has been observed that with the increase of maximum temperature, both indices show opposite variation. Similarly, both indices show a similar pattern with minimum temperature and rainfall. When minimum temperature and rainfall are attaining their peak, it is seen that both indices also have their maximum value. In general, NDVI and EVI for Champawat district attain their maximum value with the increase in rainfall and minimum temperature while showing minimum value with the increase of maximum temperature.

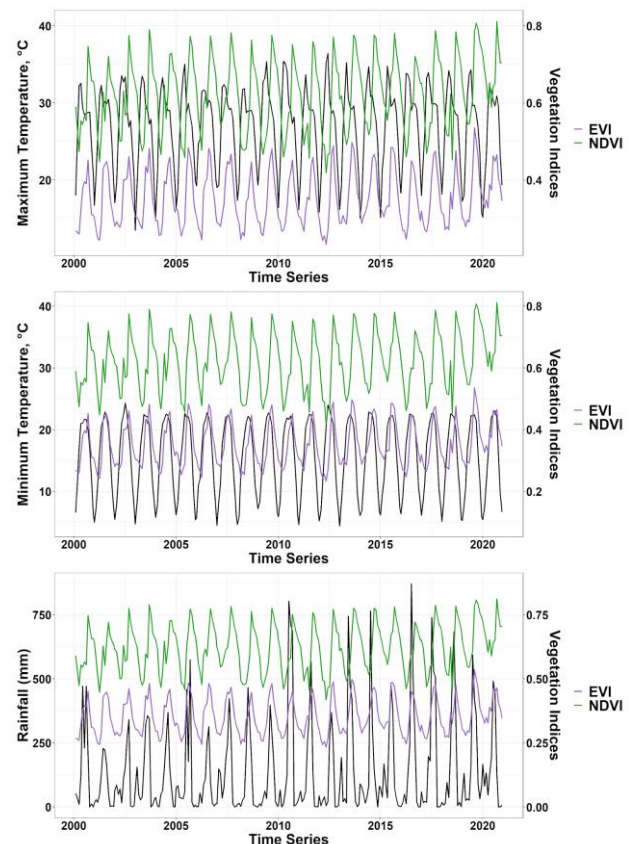


Figure 7 Temporal variation of vegetation indices and Climate Parameters in Nainital District

Figure 10 illustrates the temporal variation of vegetation indices with climate parameters for the Dehradun district. Figure 10 (b) depicts the relation between the vegetation indices and minimum temperature. It has been observed that minimum temperature attains its peak during monsoon season when both indices show their maximum value. Figure 10 (c) shows the relation between rainfall and indices. It is observed that EVI shows a similar pattern as rainfall throughout the time period while NDVI in

starting shows a similar pattern, but from 2013 onwards, it shows a different pattern as compared to rainfall. During this year, the NDVI decreases with the increase of rainfall value for the Dehradun district

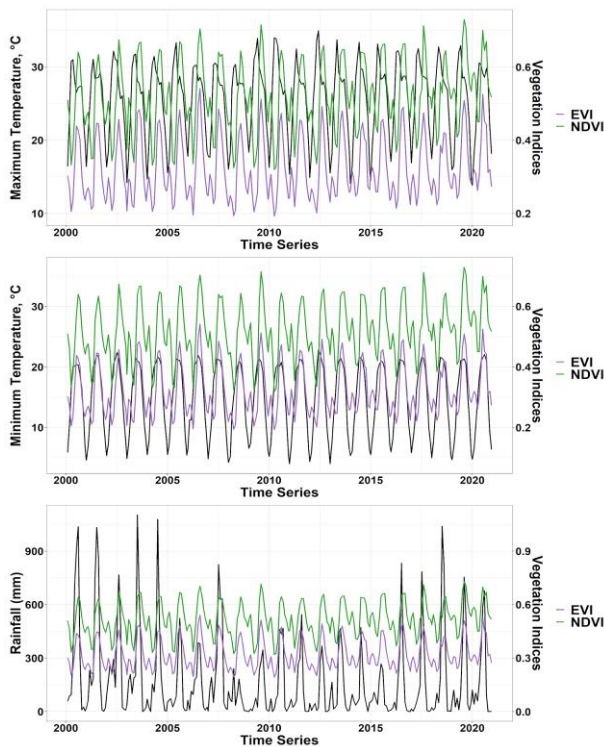


Figure 8. Temporal variation of vegetation indices and Climate Parameters in the Bageshwar District

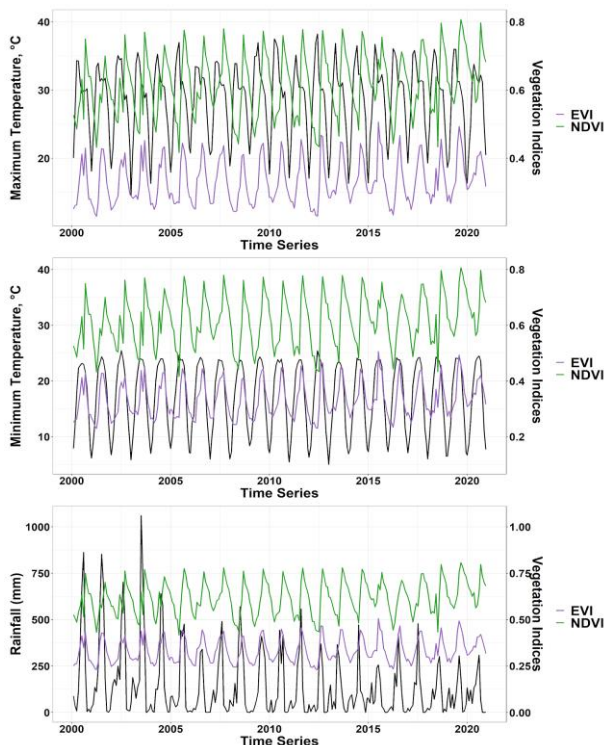


Figure 9. Temporal variation of vegetation indices and Climate Parameters in the Champawat District

4.3 Linear Regression Analysis

The temporal change in NDVI, EVI, and climate parameters are evaluated, which is shown in table 2.

According to table 2, NDVI and EVI both show an increasing trend during the study period. Champawat shows a high rate of change in NDVI, EVI, and maximum temperature while showing a decrease in rainfall and minimum temperature. It is observed that there was a continuous decrease in minimum temperature for all stations during the study period. While for maximum temperature, only Dehradun depicts decreasing change, while for all other stations, a significant increase is noticed.

	Dehradun	Nainital	Bageshwar	Champawat
NDVI	0.0022	0.0021	0.002086	0.002648
EVI	0.001095	0.001131	0.001152	0.001259
Rainfall	1.299132	3.5637	-5.68526	-6.95155
Min Temp	-0.01978	-0.01362	-0.02998	-0.0242
Max Temp	-0.001	0.008173	0.006807	0.005705

Table 2. Rate of Change in parameters during 2000-2020

Figures 11-14 illustrate the Scatter plot between vegetation indices and climate parameters (rainfall, min temp & max temp) for different locations considered in the study. The scatter plot (figure 11(a), figure 12(a), figure 13(a), and figure 14(a)) shows the correlation between NDVI and EVI vs. maximum temperature. From the determination coefficient (R^2) (Nainital: EVI-0.07, NDVI-0.08; Bageshwar: EVI-0.27, NDVI-0.001; Champawat: EVI-0.1, NDVI-0.001; Dehradun: EVI-0.1, NDVI-0.05), it can be noticed there is almost no (very weak) correlation between the indices and maximum temperature for all districts. Similarly, figure 11(b) to figure 14(b) depicts the correlation between NDVI and EVI vs. minimum temperature having a determination coefficient (R^2) as (Nainital: EVI-0.28, NDVI-0.02; Bageshwar: EVI-0.52, NDVI-0.01; Champawat: EVI-0.36, NDVI-0.01; Dehradun: EVI-0.51, NDVI-0.01). It can be perceived that for all locations, EVI shows a high correlation with minimum temperature as compared to NDVI. EVI ranges from 0.28 to 0.52, while the average NDVI value is 0.02, which shows almost no correlation with minimum temperature. EVI shows a good correlation in Bageshwar and Dehradun, with an average value of 0.52. Figure 11(c) to Figure 14(c) display the correlation between NDVI and EVI vs. rainfall having a determination coefficient (R^2) as (Nainital: EVI-0.31, NDVI-0.01; Bageshwar: EVI-0.26, NDVI-0.01; Champawat: EVI-0.26, NDVI-0.01; Dehradun: EVI-0.48, NDVI-0.09).

It has been noticed from the scatter plot that EVI shows a better correlation with rainfall as compared to NDVI, and for the Dehradun district, it has a good correlation, while for other districts, it shows a weak but positive correlation.

5. DISCUSSION

In precision agriculture, NDVI is considered an important index for vegetation characterization (Olive, 2010). Due to distortion caused by soil reflection and cloudiness, NDVI doesn't function well for determining vegetation dynamics and vegetation cover (Lykhovyd, 2021) because NDVI does not consider soil reflection and atmospheric hindrance.

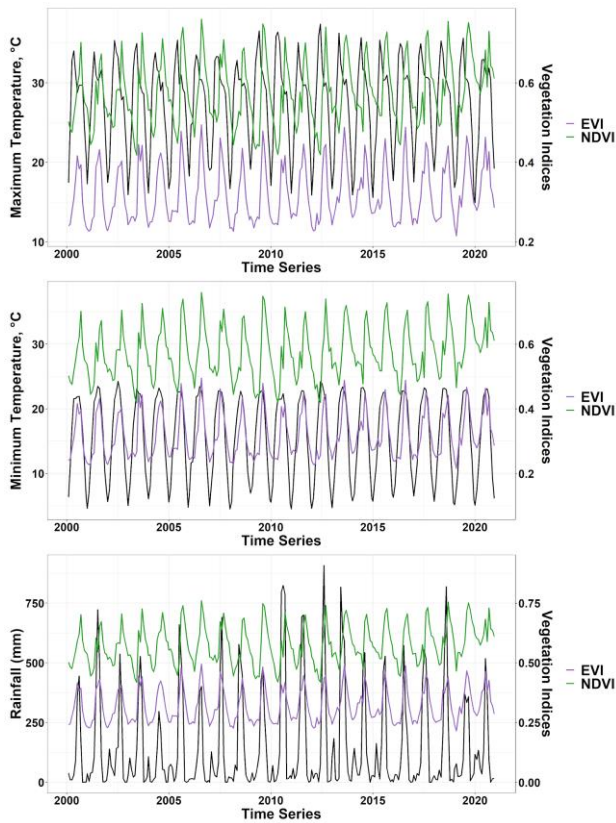


Figure 10. Temporal variation of vegetation indices and Climate Parameters in Dehradun District

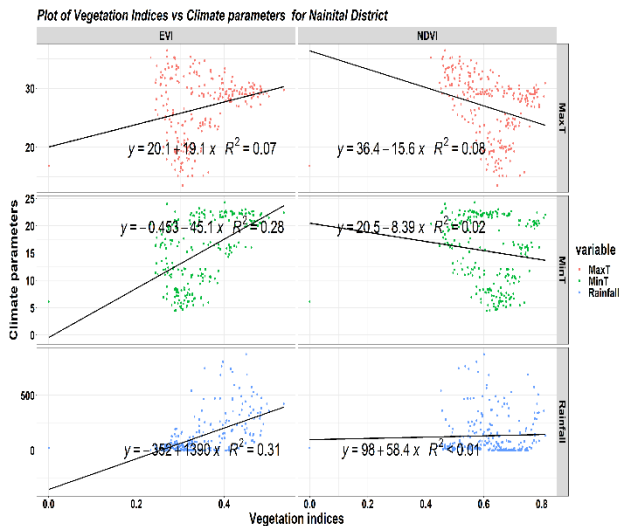


Figure 11. Scatter Plot between Vegetation Indices and Climate Parameters for Nainital District

Moreover, NDVI is mainly dependent on chlorophyll content while less practical on an area of canopy cover (Lillesaeter, 1982). At this point in time, EVI plays an important role, and it seems to be more authentic as hindrance caused due to soil reflection and atmosphere is taken care of while evaluating EVI index, but EVI gets distorted due to topography (Matsushita et al. 2007).

From the annual trend of vegetation indices results, it is depicted that for all the locations, i.e., Nainital, Bageshwar, Champawat, and Dehradun, NDVI and EVI both indices reflect a similar

pattern during all seasons, but NDVI values are high as compared to EVI

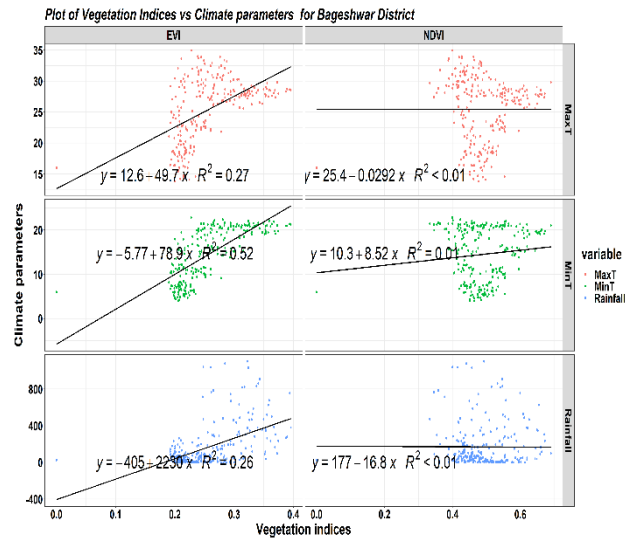


Figure 12. Scatter Plot between Vegetation Indices and Climate Parameters for Bageshwar District

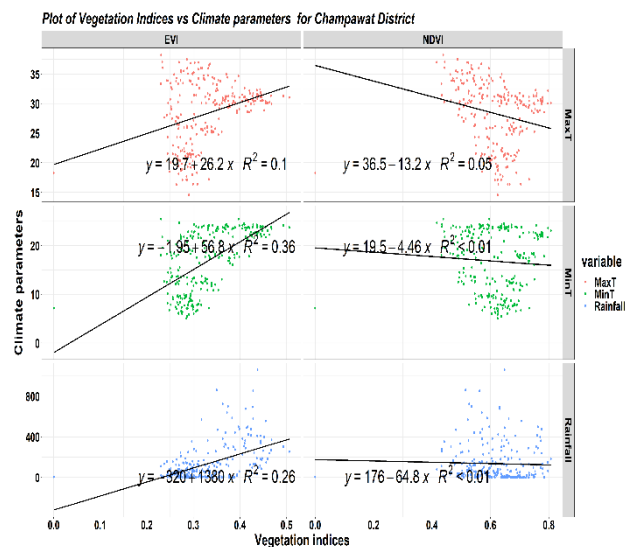


Figure 13. Scatter Plot between Vegetation Indices and Climate Parameters for Champawat District

Values for all stations. The NDVI value range from 0.76 to 0.52 and EVI range from 0.43 to 0.25. This higher value of NDVI can be due to the hindrance caused by soil and atmosphere. It is also noticed, EVI values gradually decrease as compared to NDVI values after the harvesting period, and this can be due to the soil reflection as EVI counters soil and aerosol reflection while evaluating its index. According to (Lykhovyd, 2021), both indices depict a similar pattern on an annual scale.

Temporal variation of NDVI and EVI is analysed with different climate parameters (max temp, min temp, and rainfall). It is noticed that with maximum temperature, both vegetation indices show less association for all districts, as maximum temperature attains its peak during the April season, while during that season, both indices reflect less value during the year. Moreover, during the monsoon and winter seasons, both indices attain their maximum value for all districts. According to (Hao et al. 2012)

NDVI and EVI have a better association with minimum temperature and rainfall as compared to rainfall.

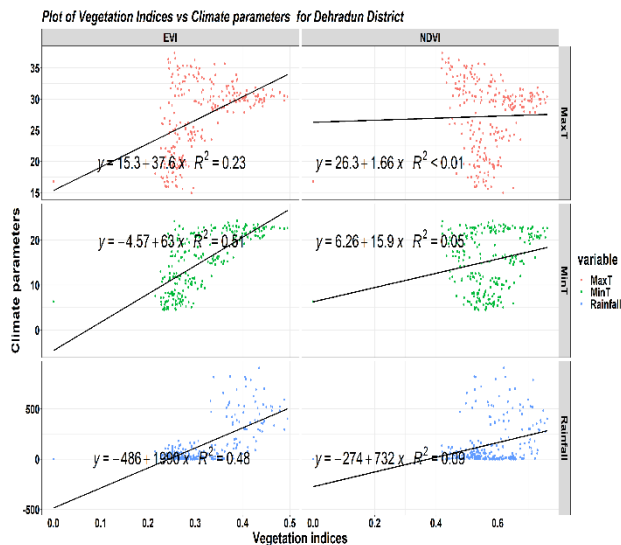


Figure 14. Scatter Plot between Vegetation Indices and Climate Parameters for Dehradun District

For evaluating the relationship between climate parameters and vegetation indices, Linear Regression analysis is performed. The result of statistical analysis revealed that the EVI index shows a better correlation with climate parameters as compared to the NDVI index. From the result, it can be concluded that EVI is more accurate for monitoring the vegetation cover as compared to the NDVI index for all districts. (Olmos et al., 2020) have found EVI to be more effective for monitoring vegetation cover, which supports this study. (Bagheri et.al 2021; Lykhovyd, 2021) article also revealed that EVI is more correlated with temperature and rainfall as compared to NDVI.

6. CONCLUSION

Statistical analysis is performed to examine the best-suited indices from NDVI and EVI for predicting the vegetation cover. Based on the study results, it can be concluded that:

- NDVI and EVI both indices show an identical pattern when plotted on a monthly basis for all stations considered in the study area.
- Both indices attain a peak during the monsoon season, i.e., during the June- October month, while the minimum values are observed during the summer season for all districts.
- Temporal patterns of NDVI and EVI with climate parameters are analysed and found to have a close association with min temperature and rainfall as compared to maximum temp.
- According to LR, EVI is highly correlated with minimum temperature and rainfall as compared to NDVI for all the districts.
- Finally, the study discloses the EVI indices to be more effective and appropriate indices for predicting and monitoring the vegetation cover based on climatic factors.

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