



Investigation of the spatiotemporal changes in the vegetation of the emirates of Fujairah using normalized difference vegetation index (NDVI) and geographical information system (GIS)

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Abstract

Fujairah is the important emirate of United Arab Emirates with native plants rich in higher nutritional values. These native plants can cope up with harsh conditions of UAE hence are an asset and hold an important interest for the authorities. Monitoring vegetation expansion for plants is essential for the agro-economical values of emirates of Fujairah, UAE. In semi-arid locations, analysis of the dynamics of the vegetation plays a vital role especially given how frequently extended droughts occur. A multi-temporal imagery dataset collected from Sentinel-2 satellite and indexed by NDVI, between January 2017 and August 2022, has been utilized in this study to investigate the dynamics of the vegetation over the Fujairah region.

Keywords: Fujairah, GIS, NDVI, native plants, Vegetation, monitoring, expansion, sentinel-2

Introduction

Groundwater is the main source of water for agriculture in the Middle Eastern countries, including the United Arab Emirates, with harsh environmental conditions including high temperatures and low precipitation. Salinity presently influences around 25% of the UAE's land. This is the issue which needs consideration as it has an impact on native plants, which are an asset to the agro-economical values of UAE (1). The climate change such as melting glaciers, increasing sea levels, intense storms, heavier floods, less snow in the north, and more drought in the south has started to have an evident impact on the overall health and economy of the world including UAE (2). Given the importance of agriculture in United Arab Emirates, it is crucial to look after the areas that are covered in vegetation and practice proper monitoring such as ensuring the favorable conditions and environment for growth, suitable water level, providing fertilizers that endorse plant production in the face of the changing climate and many other factors in the country.

Keeping in mind all these, the aim of this study is to investigate the spatiotemporal changes and analyze the vegetation expansion in the Emirate of Fujairah. For this purpose, High-end Geographical Information System (GIS) and remote sensing satellite imagery data will be inspected. The most widely used index for analyzing vegetation is the Normalized Difference Vegetation Index (NDVI), which is one of the initial remote sensing analytical tools used to reduce the complexity of multi-spectral information (3). The range of the NDVI is from +1.0 to -1.0. Areas with very low NDVI values (for example, 0.1 or less) such as bare rock, sand, or snow. Moderate NDVI values may be caused by vegetation, such as shrubs and grasslands or senescent crops (approximately 0.2 to 0.5) (4). The main goal of using NDVI is to enhance the analysis of vegetation data from remotely sensed satellite images in the Emirates of Fujairah and identify changes and improvement in the green cover over a six-year interval from 2017 to the month of August of the current year 2022.

Materials and Methods

The following procedure has been followed for data collection, time series comparison and analysis and to generate a map of the vegetation in Fujairah city based on NDVI range.

NDVI vegetation amount can be easily measured from Sentinel-2 satellite imagery dataset. Images were gathered on a range from 2017 to 2022 for each month of the year in order to gain insights into all of the dataset filtered with NDVI. A map was created to indicate the Fujairah region.

An excel database was created to collect the raw NDVI amount over the years based on GIS and calculated the minimum, maximum, and average of NDVI. A bar chart has been plotted later to monitor the difference along the years.

After data collection and processing, an analysis of the vegetation dynamics across the Fujairah region was conducted in order to identify improvements and changes in the vegetation cover over a six-year period using NDVI.

Results and Discussion

The NDVI is frequently used to evaluate the amount of vegetation expansion. Determining the growth of green vegetation and spotting changes in the vegetation are both useful. According to satellite imagery dataset, vegetation is represented by shades of green. In certain months, the green color is more intense, while in other months, it lessens and becomes lighter. It relies on the effects of climate change and other factors in each season. When NDVI colour range closer to the white (-0.1 to 0.1) represents arid regions of rocks, sand, or snow. Ranges lower than lower than 1 (values approaching -1) corresponds to the water. Similarly, the positive values represent the shrub and grassland (approximately 0.2 to 0.4) and the higher values (approaching 1) indicate temperate and tropical rainforests. The vegetation intensity can be determined by the intensity of green color (Figure 1).

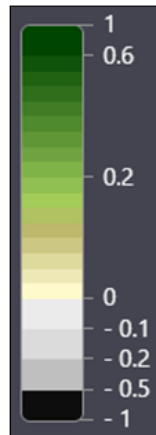


Fig 1: Normalized Difference Vegetation Index (NDVI). Color intensity and values in

As shown in (Figure 2), the declining index was apparent from 2017 to 2019 until it reached the lowest point in the NDVI range, which was equal to -0.7493 in 2020. The range widened in 2021 and 2022, which showed that the vegetation had improved.

The rate of green cover has generally increased over time and the vegetation expansion can be observed in years 2020 to 2022 relative to its maximum NDVI range. While in 2017, the maximum level was 0.287 which can be considered as the lowest maximum over the years (Figure 3).

After analysis of first year (2017) satellite images that taken from the Sentinel-2, it has been found that there is a big difference between the NDVI range for different months and this may be due to the annual blossom seasons of plants. The intensity of green cover was found to be reduced in March since most areas are covered in a color that is closer to white.

Greener areas can be observed in the month of July than the month of March across the Emirate of Fujairah, particularly in the northeast, northwest, and east that represents shrub and grassland areas. Similarly, December shows the NDVI range has extremely increased along with the intensity of green color which provide the fact that the decrease in temperature provide favorable conditions for vegetation expansion (Figure 4).

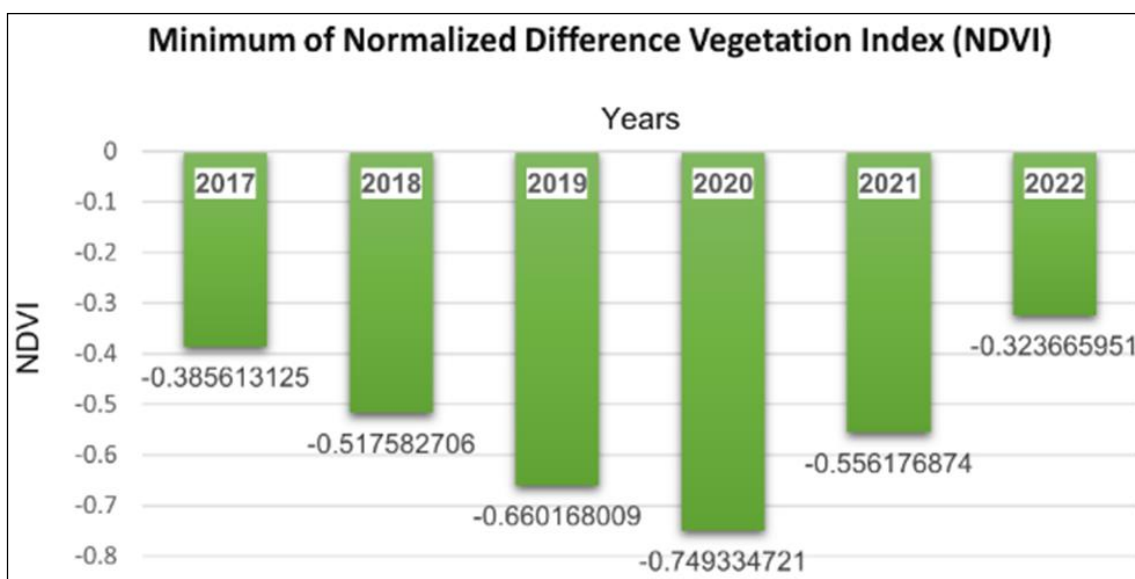


Fig 2: Minimum of Normalized Difference Vegetation Index (NDVI) over years from 2017 to 2022.

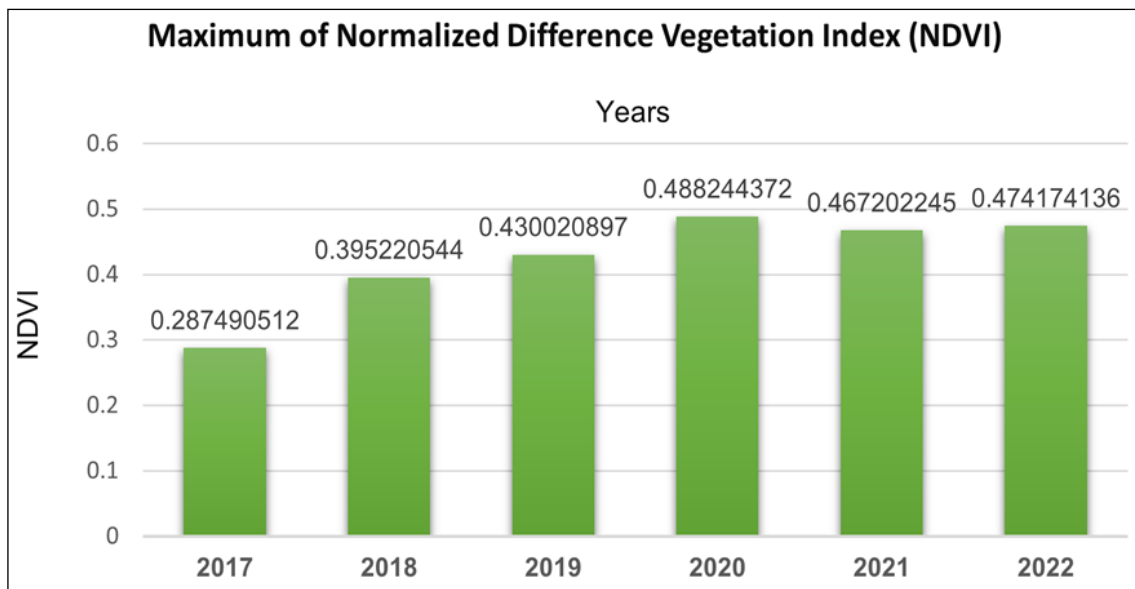


Fig 3: Maximum of Normalized Difference Vegetation Index (NDVI) over years from 2017 to 2022.

The seems to decrease from December 2017 to March 2018 according to NDVI (Figure 5). Similarly, the proportion of green cover or the amount of NDVI reduced significantly in the month of July, implying that there may be a factor behind it, such as the harvest season or temperature fluctuation. In contrast to warmer weather of July, the green cover has increased in the month of December 2018. However, the results showed the lesser greenery for December 2018 if compared to December 2017. The reason could be the low rainfall for the later year.

As indicated in the following satellite image, the vegetation significantly increased from December 2018 to March 2019. Regardless of their intensity, many previously white regions of Fujairah have now covered with green and darker shade of white to yellowish patches, which shows that the NDVI range has changed and increased. Contrary to the apparent change from December 2018 to March 2019, it is observed that the amount of greenery in July 2019 reduced dramatically as the majority of the Emirate of Fujairah was coated in white to yellowish colour. In fact, this extends from July to September in most years and in December it is noticeable that the NDVI was higher at a level than in 2017 and 2018 (Figure 6).

On March in the year of 2020, the NDVI range was greener than it had been in previous years. However, despite this great improvement in the amount of greenery, the northwest direction is dominated by places that are white or yellowish in color during March 2020. The December has also been seen as less green than the March but greener than July 2020 (Figure 7).

The year 2021 can be seen less green with least NDVI than previous years in this study. Most of the months has been seen with yellowish to white coverings (Figure 8).

The month of January had a moderate level of greenery in the year of 2022, and most of the time this is because of the effect of the months that came before it, in this case, December 2021. The year 2022 shows constant greenery throughout the year with NDVI ranges between 0.1 to 1. When comparing the percentage of greenery in August 2022 with previous years, the NDVI range shows much higher values, which indicates temperate and tropical rainforests (Figure 9).

Conclusion

Fujairah is the important emirate of United Arab Emirates with native plants rich in higher nutritional values. These native plants can cope up with harsh environmental conditions including high temperatures, low precipitation, and high salinity. Such qualities make these plants an asset which plays a vital role in the agro-economical values of the Fujairah, UAE. In semi-arid locations, analysis of the dynamics of the vegetation is essential, especially given how frequently extended droughts occur. For this reason, high resolution imagery dataset was collected from Sentinel-2 satellite and later categorized using NDVI. Our investigation revealed the impact of climate on the vegetation. Usually, the spring months starting March to May shows highest vegetation trends in Fujairah and September to January shows comparatively less vegetation. However, the extreme summer season starting June to August showed very low levels of vegetation index. Most of the plants have the blooming period starts in spring, (March to May) which could explain the vegetation expansion in these specific months.

Conflicts of Interest

The authors declare that they have no conflict of interests.

Acknowledgments

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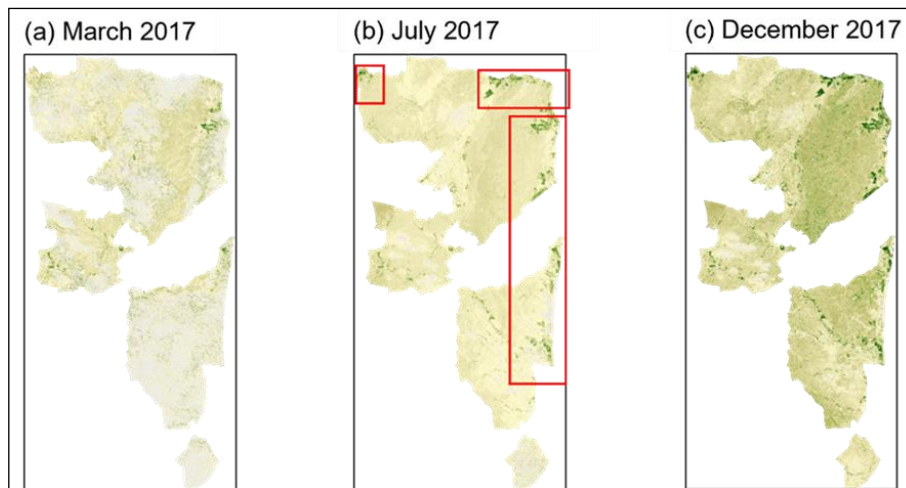


Fig 4: Satellite images of the emirate of Fujairah in three different periods of the year 2017, where (a) shows the month of March, (b) shows the month of July, and (c) shows the month of December. The areas indicated in red squares display small green spots in July which were increased by a very noticeable percentage than the month of March of the same year.

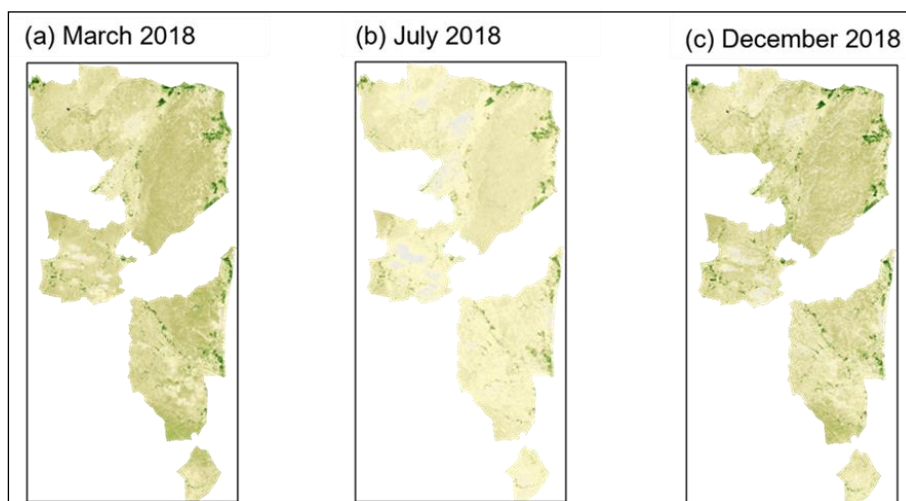


Fig 5: satellite images of the emirate of Fujairah in three different periods of the year 2018 where (a) shows the month of March, (b) shows the month of July, and (c) shows the month of December.

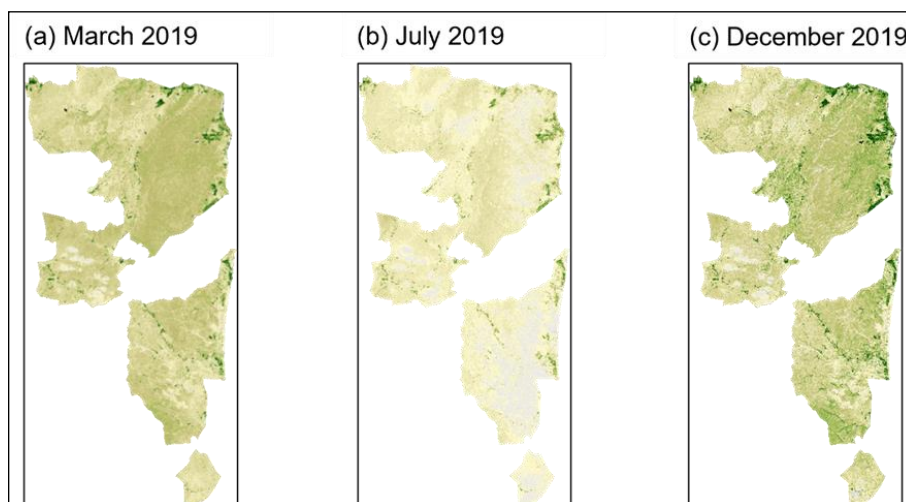


Fig 6: satellite images of the emirate of Fujairah in three different periods of the year 2019 where (a) shows the month of March, (b) shows the month of July, and (c) shows the month of December.

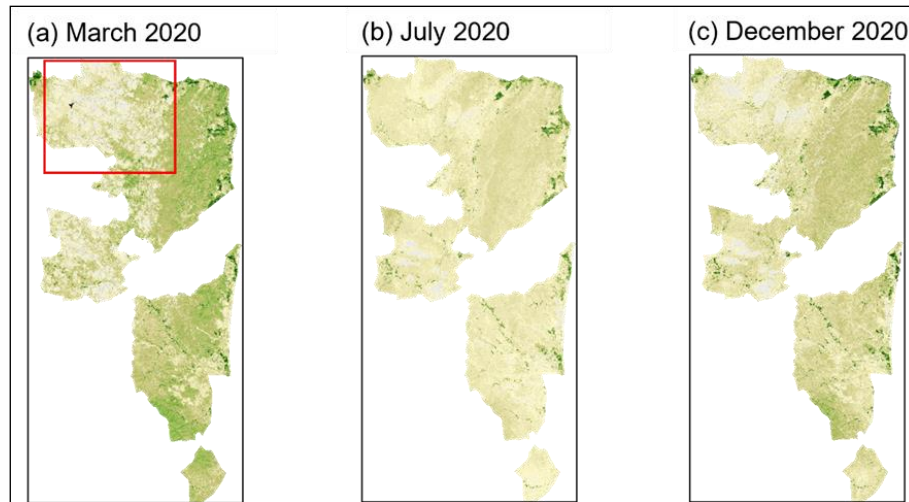


Fig 7: satellite images of the emirate of Fujairah in three different periods of the year 2020 where (a) shows the month of March, (b) shows the month of July, and (c) shows the month of December. The area indicated in red square displays small white color spot in March despite the vast green cover in that month.

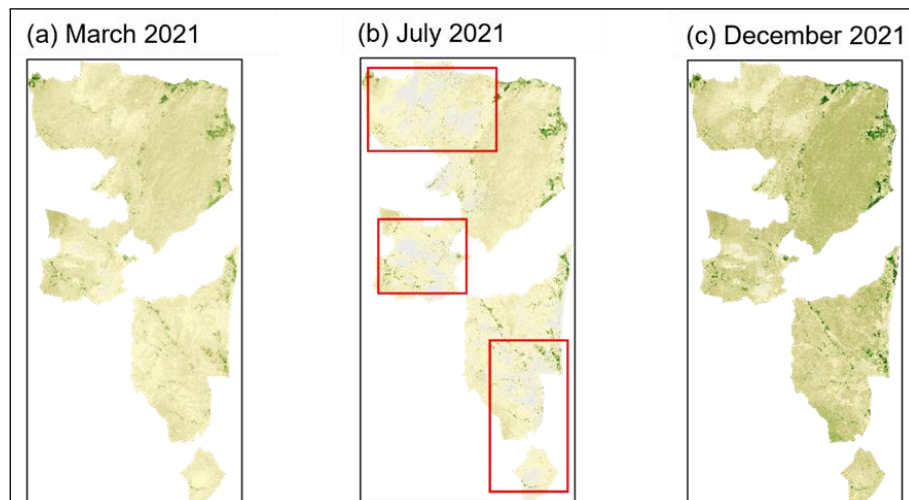


Fig 8: Satellite images of the emirate of Fujairah in three different periods of the year 2021. where (a) shows the month of March, (b) shows the month of July, and (c) shows the month of December. The areas indicated in red squares display small green spots in December and generally in this year NDVI levels were reduced by a large and very noticeable percentage from the satellite images.

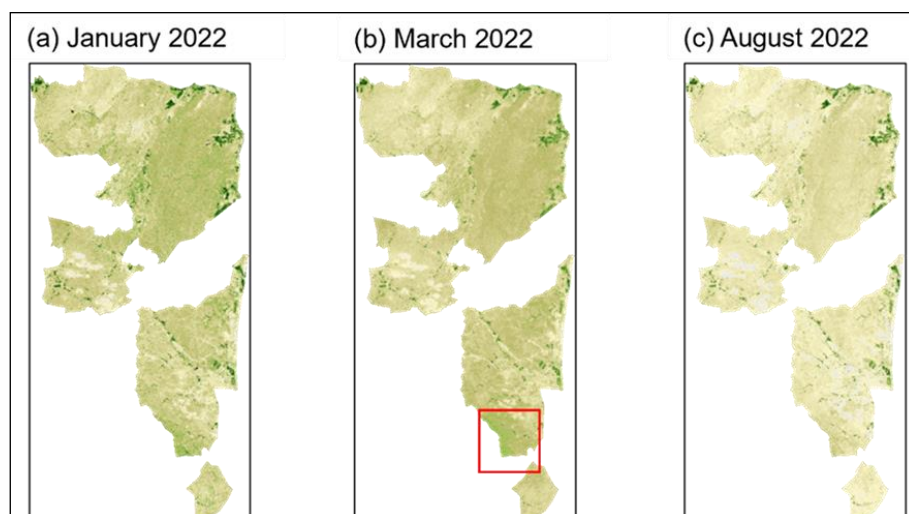


Fig 9: satellite images of the emirate of Fujairah in three different periods of the year 2022 where "p" shows the month of March, "q" shows the month of July, and "r" shows the month of December. The areas indicated in red squares display small green spot in March with constant intensity since the month of January.

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