Degree Program: Information Engineering and Computer Science, M.Sc.

GEOINFORMATICS REPORT

ON

DROUGHT ANALYSIS IN XANTEN BASED ON NDVI, TEMPERATURE AND PRECIPITATION

GROUP: R

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Abbreviations

NDVI - Normalized Difference Vegetation Index

LST - Land Surface Temperature

VSWI - Vegetation Supply Water Index

DWD – Deutscher Wetterdienst

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Abstract

Drought analysis is very helpful for the people who live in the drought-stricken region because the result of the test can be used for the studying and predicting the possible drought patterns and its intensity in the following years. The analysis has been conducted in the region of Xanten and it is a small town which is situated in the state of North-Rhein-Westphalia in Germany. The time period included in the analysis is of three years which is from the year 2015 to the year 2018. This analysis is very crucial because it can be used in the study and prediction of the drought patterns in the region of Xanten so that the people who live there can take proper measures to avoid or reduce the intensity of the after effects of the drought calculating its depth from the previous years. The difference in the intensity of the drought has been calculated among the three years and it has been found that the year 2018 was affected the most with the drought because of the least amount of precipitation received and has experienced the highest surface temperature. Therefore, the water has to be consumed judiciously. The data has been processed with the respective metrics using the QGIS software.

1. Introduction

Water is one of the basic components for life to sustain. In this era of rapid increase in the global temperature, many of the lush green and vegetative areas are turning dry and arid. This could result in temporary or permanent drought. Drought can cause a halt in the daily activities of all living beings which could create an imbalance in the healthy growth. It could adversely affect many sectors such as fisheries, agriculture and any development in the society. A detailed observation has been done in the region of Xanten which is a town located in the state of North-Rhein-Westphalia of Germany. The town has been affected by severe drought for a few years. It is important to analyze the drought-stricken region to find the cause of the drought so that it can be eliminated completely or partially. This drought analysis provides an overview on the droughts that occurred between the years 2015 and 2018, comparing the intensities of each year by taking three major factors that are the Normalized Difference Vegetation Index (NDVI), temperature and precipitation. Therefore, the result of the analysis would help to predict the possible pattern of the drought and would enable to take proper measures and precautions to lessen the after effects. The detailed study also would help to eliminate the drought completely by studying the causes but, this might take a few years to achieve the desired result.

The working hypothesis has been done on the three years of drought from 2015 to 2018 assuming that the intensity of the drought has been rising each year. The three factors which

are decided to include in the analysis are the Normalized Difference Vegetation Index (NDVI), temperature and precipitation. The drought has brought adverse impact on vegetation, temperature and precipitation of the Xanten region. The causes, intensity and pattern of the drought in each year of the three years has to be analysed and the most drought-stricken year has to be found. A research paper has assessed the drought occurrence based on the NDVI, Land Surface Temperature (LST) and rainfall pattern in Mithi which is a region situated in the Sindh province in Pakistan. Like the region of Xanten, Mithi also is affected by drought and are also assessed on the research factors like the NDVI, LST and rainfall pattern to analyse the intensity of the drought. During the research the local rainfall statistics have been acquired for the period to monitor the drought. Results obtained indicate that the Vegetation Supply Water Index (VSWI) has declined over the years. The maximum values of NDVI and LST were correlated to find out the drought event and the result ended up getting a very negative correlation in the year 2014 showing that there will not be any drought in the year 2014.

1.1 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index is an indicator of vegetation health. It is a dimensionless index. The NDVI value ranges from '-1' to '1'. The values below 0.1 are water bodies and bare ground. Higher values of NDVI denote high photosynthetic activity. Hence in order to analyse the vegetation in a particular region, NDVI plays a crucial role in it.

1.2 Land surface temperature

The temperature influences the vegetation in every possible way, high temperature conditions can be extremely harmful for the growth of the plants. Every plant has a different threshold in withstanding high temperature, if the temperature gets uncomfortably high then the plants might die. Hence temperature is an important factor that has to be considered while analysing the changes in vegetation in a particular region.

1.3 Precipitation

The precipitation stimulates the vegetation to a large extent, water is one of the key factors when it comes to the growth of plants since the plants use it for the photosynthesis process. The precipitation has to be in a certain level for good vegetation, excessive rainfall could

potentially lead to soil erosion and scarcity of rainfall could lead to drought which in turn affects the vegetation.

2. Materials and methods

2.1 Area of interest

The areas of analysis are a few regions in a small town called Xanten (51°39′44″N 06°27′14″E) which is situated in the state of North Rhein-Westphalia in Germany which is 72.4 square kilometre in size and with a population around 21,690. The regions of analysis are depicted in the figure below indicated as regions coloured with yellow.

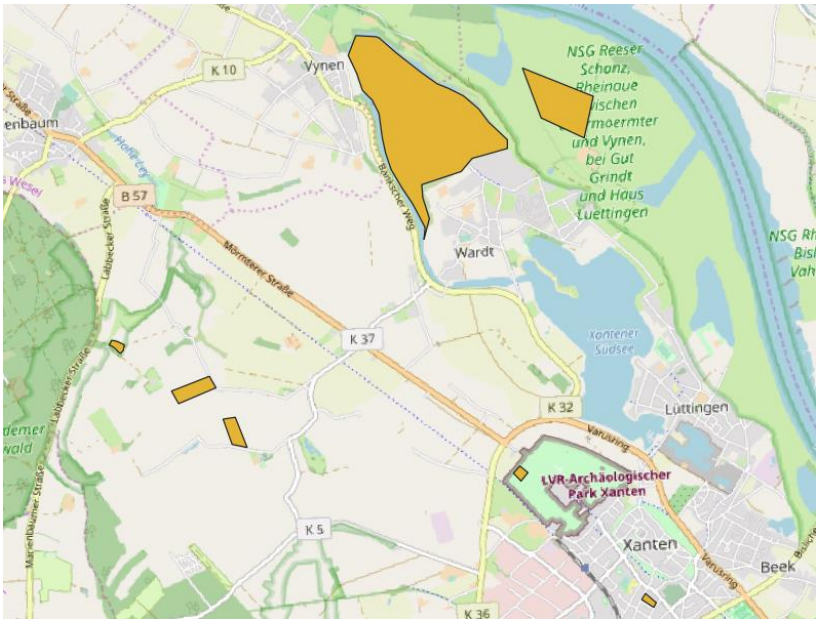

Figure 1: Regions of analysis

2.2 Data and methodology

A lot of important factors influence the vegetation in a particular area. Factors such as temperature and precipitation play the key role in that. Precipitation is considered as one of the crucial factors since it stimulates the groundwater level in that area.

Data sources:

The data about the temperature and precipitation for the analysis is obtained from DWD (Deutscher Wetterdienst) and the data about the vegetation index is obtained from Copernicus open access hub from the Sentinel-2 satellite imagery.

Data processing:

Initially the NDVI calculation for the years 2016, 2017 and 2018 is done by obtaining the sentinel-2 imagery data from Copernicus open access hub. The calculation for the three years is done using the formula given below:

$$\boldsymbol{NDVI} = (Band\ 8 - Band\ 4) / (Band\ 8 + Band\ 4) \quad (1)$$

The processing of the temperature and precipitation data is done by using the data obtained from DWD (Deutscher Wetterdienst). The data obtained from DWD has a lot of irrelevant data which is not helpful for the analysis. In order to filter the relevant data from the repository, python programming is used where it filters out the temperature and precipitation data for the years 2016, 2017 and 2018. FTP is used in python to handle the files and extract the data.

Stations under analysis and weight calculation:

In order to find the stations that have to be considered to do the further analysis, QGIS is used where the “Hub-to-point-distance” tool is used. The weights of the stations under analysis are then calculated. The formula used for the weight calculation is given below:

$$\boldsymbol{N1}: Nearest\ station$$

$$\boldsymbol{D1}: Distance\ to\ the\ nearest\ station\ in\ kilometres$$

$$Weight\ of\ \boldsymbol{N1} = 1.0$$

$$Weight\ of\ \boldsymbol{Ni} = D1/Di \quad (2)$$

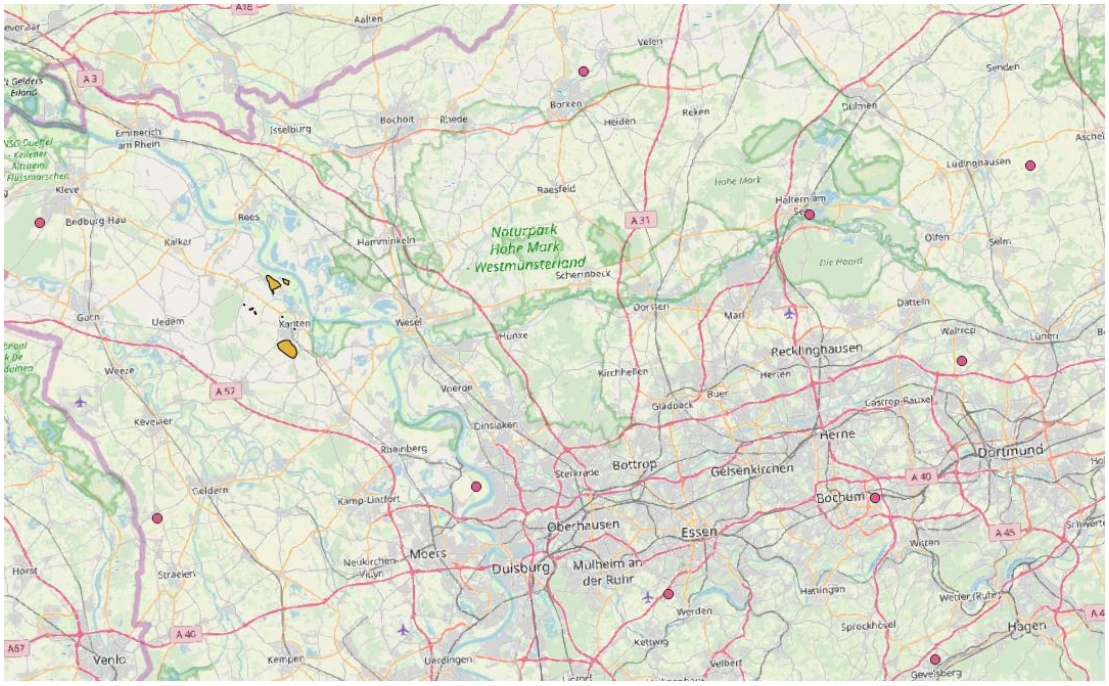

Figure 2: Weather stations

Interpolation of temperature and precipitation:

The interpolation of the temperature and precipitation is done using python with the help of the weights calculated for the nearest stations and the temperature and precipitation data obtained previously using FTP. Three values of temperature and precipitation are obtained finally where each value corresponds to the respective year. The interpolated temperature and precipitation values are further used for the analysis.

3. Results and data analysis

It is evident from the results obtained that the given regions in the Xanten area have experienced moderate to severe drought in the year 2018.It is observed that the given regions in Xanten area have received the least rainfall in the year 2018 when compared to the previous two years. The NDVI values are observed to be high in agricultural areas and forest areas when compared to the other regions in all the three years.

The tabular columns below represent the temperature, precipitation and NDVI values of the given polygons in the Xanten area over the years 2016, 2017 and 2018.

Polygon 1:

Polygon 1 - Forest (High density)			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.740
2016-2017	11.877	1.970	0.807
2017-2018	12.408	1.380	0.777

Table 1: Analysis of Polygon 1

It is observed that the Polygon 1 happens to be a high-density forest area. The NDVI values over the three years for this polygon have not displayed much variation.

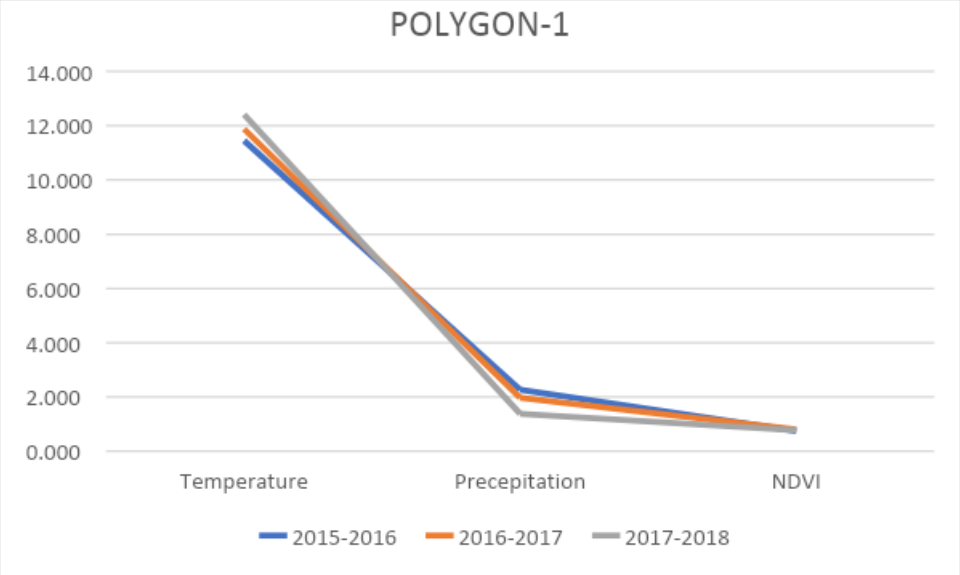

Figure 3: Analysis of Polygon 1

The above graph represents the variations of temperature, precipitation and NDVI in the Polygon 1, over the years 2016, 2017 and 2018. It is prominently seen that the NDVI values are relatively the same over the three years.

Polygon 8:

Polygon 8 – Farm land			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.812
2016-2017	11.877	1.970	0.835
2017-2018	12.408	1.380	0.828

Table 2: Analysis of Polygon 8

It is seen that the Polygon 8 happens to be a farm land. The NDVI values of this polygon over the three years have not displayed major fluctuations.

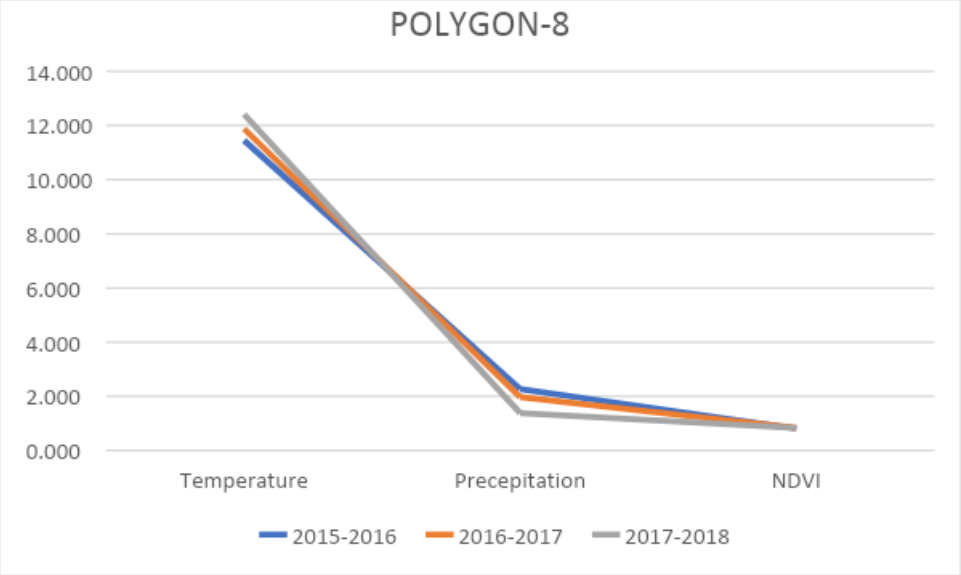

Figure 4: Analysis of Polygon 8

The above graph represents the variations in temperature, precipitation and NDVI values in the area covering Polygon 8 over the years 2016, 2017, 2018. It is obvious from the graph that the NDVI values in this region over the given three years do not have major fluctuations, whereas the temperature is observed to be the maximum in the year 2018.

Polygon 14:

Polygon 14 – Green field (Nature reserved)			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.821
2016-2017	11.877	1.970	0.850
2017-2018	12.408	1.380	0.829

Table 3: Analysis of Polygon 14

It is seen that the Polygon 14 is a nature reserve area. The area covering this polygon did not experience the intensity of the drought to that extent.

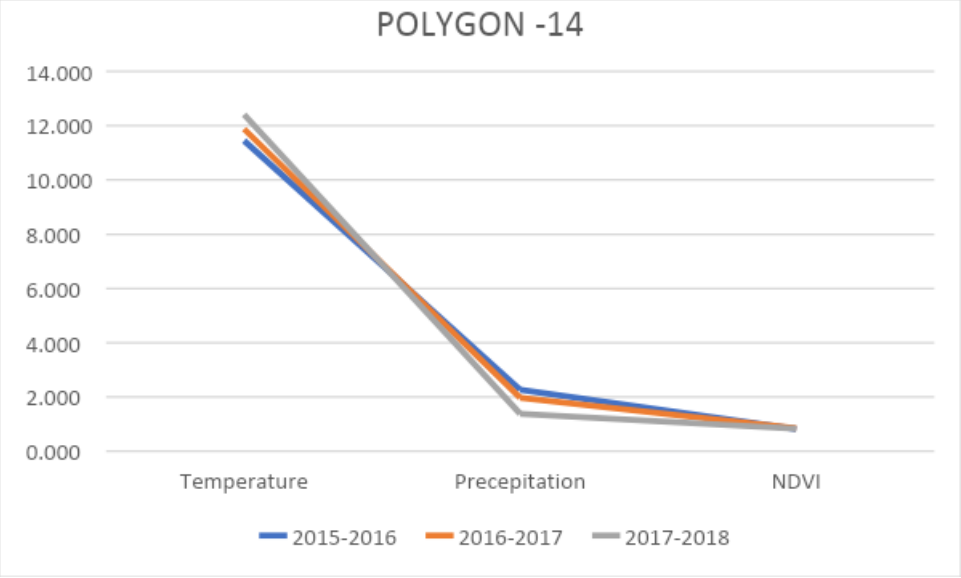

Figure 5: Analysis of Polygon 14

The above graph represents the variations in the values of temperature precipitation, and NDVI in the area covering Polygon 14 over the years 2016, 2017 and 2018. It is evident from the graph that there were not marginal deviations in the values over the given three years.

Polygon 17:

Polygon 17 – Farm land			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.733
2016-2017	11.877	1.970	0.715
2017-2018	12.408	1.380	0.827

Table 4: Analysis of Polygon 17

The region covering the Polygon 17 is observed to be a farm land. The NDVI value in the year 2018 is observed to be better than the previous two years.

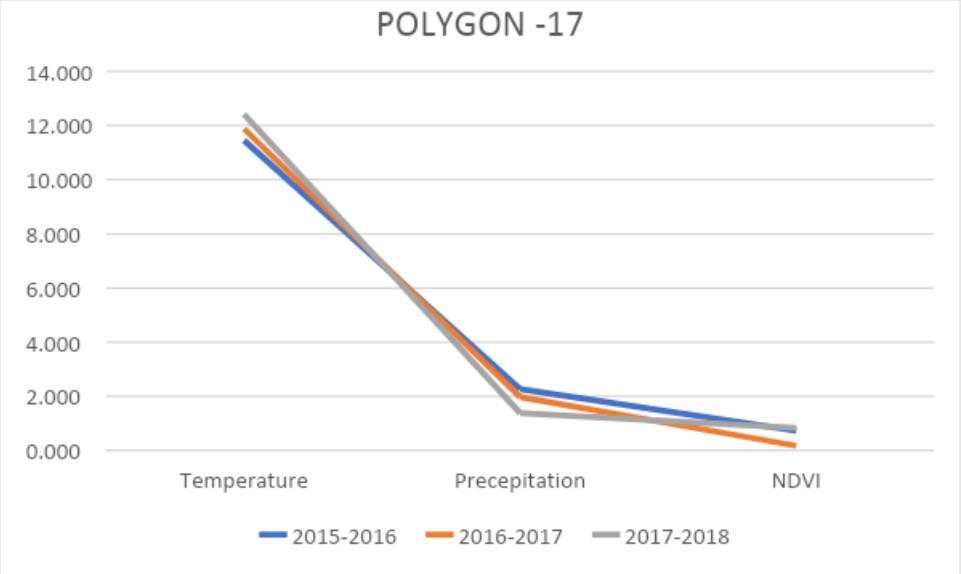

Figure 6: Analysis of Polygon 17

The above graph represents the variations in the precipitation, temperature and NDVI values in the region covering the Polygon 17 over the years 2016, 2017 and 2018. It is observed that the NDVI value of the year 2018 is higher than the previous two years.

Polygon 23:

Polygon 23 – Green land			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.796
2016-2017	11.877	1.970	0.854
2017-2018	12.408	1.380	0.146

Table 5: Analysis of Polygon 23

It is seen that the region covering the Polygon-23 is a green land. This region has showed a marginal vegetation deterioration in the year 2018.

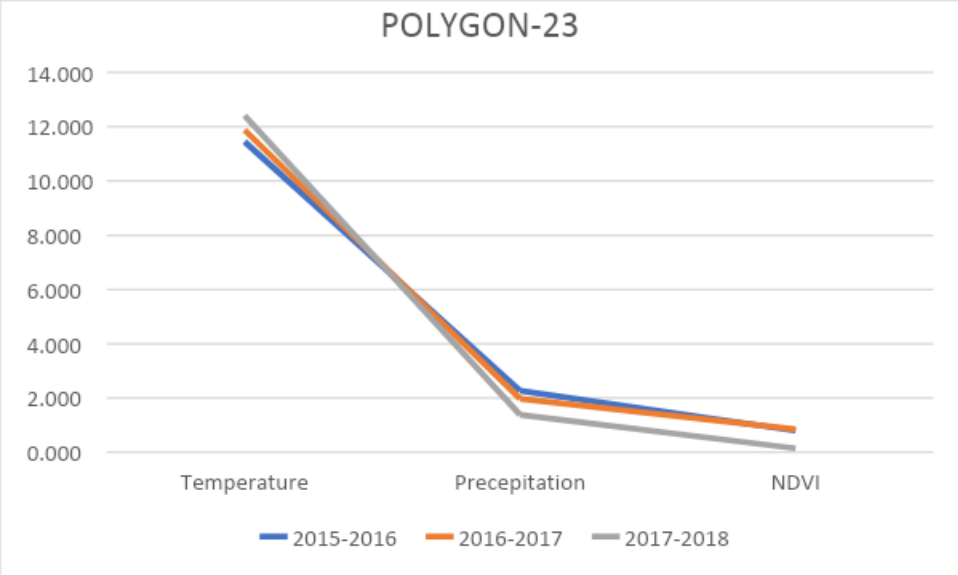

Figure 7: Analysis of Polygon 23

The above graph represents the variations in the values of temperature, precipitation and NDVI values of the region covering the Polygon 23 over the years, 2016, 2017 and 2018. There is a drastic change in value of NDVI in the year 2018, where it has reduced marginally from 2017 to 2018.

Polygon 29:

Polygon 29 – Green field (Archaeological Park)			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.829
2016-2017	11.877	1.970	0.542
2017-2018	12.408	1.380	0.799

Table 6: Analysis of Polygon 29

It is observed that the region covering the Polygon 29 is an archaeological area. It is evident from the data that the NDVI values in 2018 have increased when compared to the previous years.

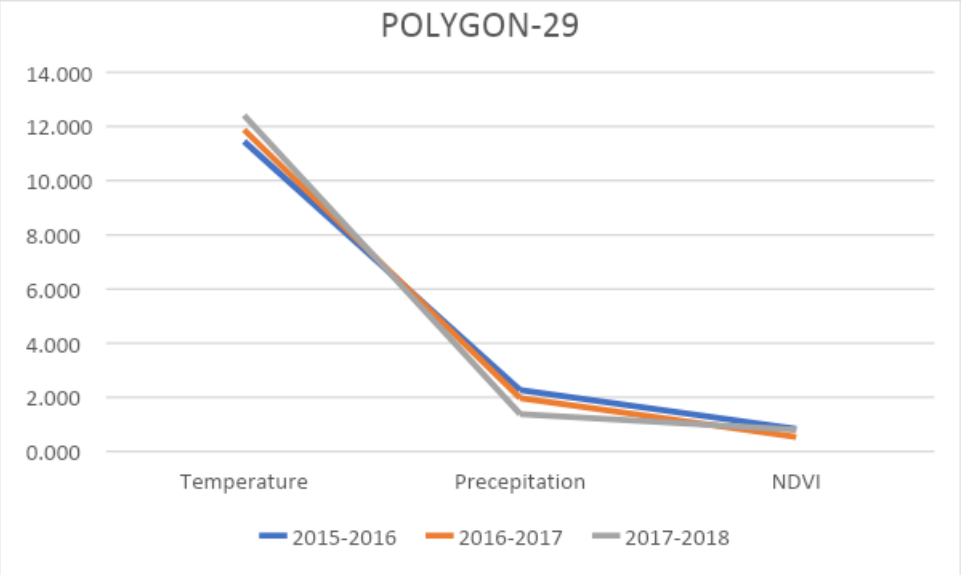

Figure 8: Analysis of Polygon 29

The above graph represents the variations in the values of temperature, precipitation NDVI in the region covering the Polygon 29. Here the values have not exhibited much fluctuation.

Polygon 36:

Polygon 36 – Residential area			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	0.446
2016-2017	11.877	1.970	0.469
2017-2018	12.408	1.380	0.442

Table 7: Analysis of Polygon 36

It is seen that the region covering the Polygon 36 is a residential area. The NDVI values of the area Polygon 36 is comparatively lesser than the values of the Polygon 1, 8, 17 and 29.

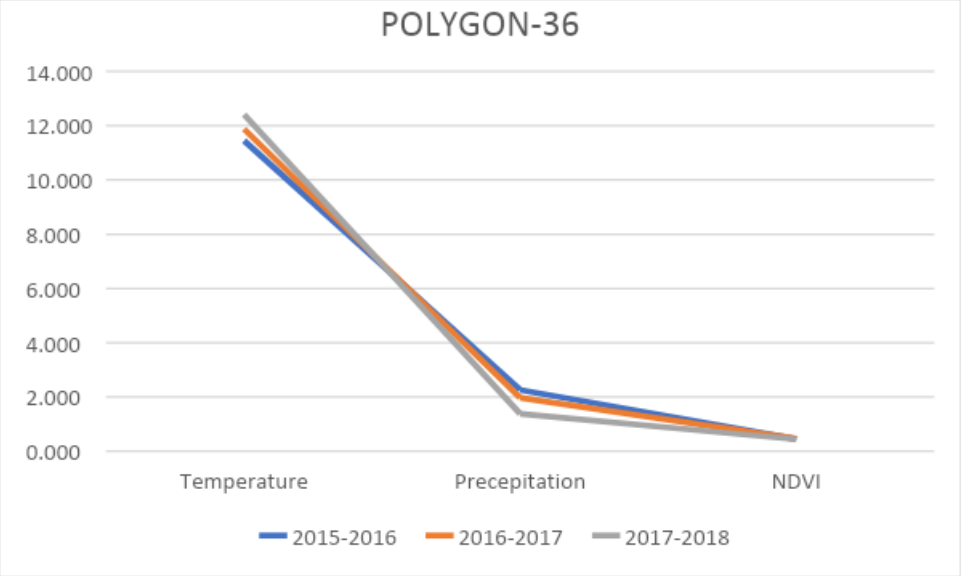

Figure 9: Analysis of Polygon 36

The above graph represents the variations in the values of NDVI, temperature, and precipitation in the region covering the Polygon 36. The NDVI value is least in the year 2018 when compared to the previous two years.

Polygon 38:

Polygon 38 – Lake			
	Temperature [°C]	**Precipitation [mm]**	**NDVI**
2015-2016	11.450	2.263	-0.110
2016-2017	11.877	1.970	-0.110
2017-2018	12.408	1.380	-0.170

Table 8: Analysis of Polygon 38

It is seen that the region covering the Polygon 38 is a lake (water body). The value of NDVI is the highest in the year 2018 when compared to the previous two years.

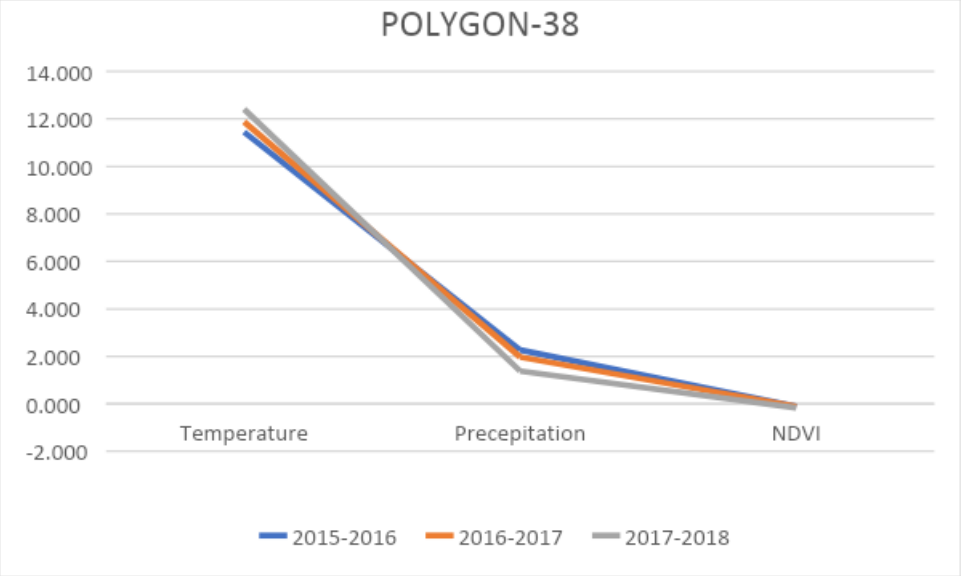

Figure 10: Analysis of Polygon 38

The above graphs represent the variations in the values of temperature, precipitation and NDVI for the region covering the Polygon 38 over the years 2016, 2017 and 2018. It is evident from the data that there is no effect of the drought on vegetation in this polygon.

4. Discussion

The inferences which were interpreted from the obtained data for each polygon is given below:

Polygon 1:

The Polygon 1 is a forest area, in general the vegetation in the forest area has extremely different properties when compared to other regions .The trees present in the forest areas have deeper and stronger roots. Hence, they naturally have a higher threshold in withstanding the adverse effects of the drought. Similarly, in this case the region did not face much intensity of the drought.

Polygon 14:

The Polygon 14 is a nature preserving area(green field). The sole purpose of the nature preserving areas is to preserve the ambience of that area. Hence in this case the vegetation is maintained to a good extent though the NDVI value has reduced when compared to the previous year.

Polygons 8, 17 and 23:

The Polygons 8, 17 and 23 are farm lands, it is known that the farm lands are usually irrigated well and the nature of the soil is well preserved in order to grow healthy crops. Hence in these regions the effect of the drought is not seen much.

Polygon 29:

The Polygon 29 is an archaeological park. In general, the ambience of an archaeological area is well maintained. The vegetation in such areas are usually given enough importance. Hence, in this case it is observed that the NDVI value in the year 2018 is comparatively higher than the previous years.

Polygon 36:

The Polygon 36 is a residential area. It is usually observed that the vegetation in the residential area is not anyone's responsibility and it does not receive enough care. Hence, it is seen in this case that the NDVI value has marginally dropped in the year 2018 when compared to the previous years.

Polygon 38:

The polygon 38 is a lake area. The vegetation in the lake area usually depends upon the water body. Hence in this case it is seen that the NDVI in this area has decreased in the year 2018 since it experienced the highest temperature and least rainfall when compared to the previous years.

5. Conclusion

After the detailed study of drought scenarios of the three years it has been found that the year 2018 was the most drought-stricken year of all the three years. The result obtained matches exactly with the hypothesis that 2018 was affected the most. In order to extend the analysis, a few more potentially influencing factors such as nature of the surface, climate and fertility of the soil could be taken into consideration.

6. Bibliography

“A research paper has assessed the drought occurrence based on the NDVI, Land Surface Temperature (LST) and rainfall pattern in Mithi which is a region situated in the Sindh province in Pakistan. (Muhammad Arslan, Rao Zahid Khalil, Badar Ghauri, 2016).”

7. Appendix

https://github.com/kiruthika987/interpolation