INTERNSHIP REPORT (CLIMATOLOGY DEPT)

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Acknowledgements

I am very thankful to Sir Shahbaz Mahmood (Head of climatology dept.) for his guidance. I would like to thank Madam Qudsia Zafar for involving me in very useful and focused project on droughts. I have found very informative material on droughts worldwide and I have realized the importance of predictions of such extreme events so that a catastrophes in the future can be prevented. Lastly I am thankful to Sir Shershah for his supervision on the use of ARCGIS for the indirect drought analysis using NDVI and LST data from MODIS. I am very pleased to have been given the opportunity to work in a very work-oriented and motivated environment where I have learned valuable skills and I am hopeful and excited for future work with GCISC.

Droughts in Pakistan: an overview of the current drought analysis system

Introduction:

The internship spanned over a period of 6 weeks where I have worked on droughts in Pakistan. I have reviewed many research papers and articles related directly and indirectly with the prevailing drought conditions in the country. I have explored methods used for the study of droughts and sites at which stations are located from which data is acquired. Lastly I have carried out an indirect analysis on droughts using LST (Land surface temperature) and NDVI (Normalized difference vegetation index) data from MODIS. Below are the details of my work and the useful results that I have derived.

Droughts:

Drought is a protracted period of deficient precipitation resulting in extensive damage to crops, and a consequential loss of yield. Drought is an interval of time generally of the order of months or years in duration in which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply (C.Palmer, 1965). Types of droughts include meteorological, socio-economic, agricultural and hydrological droughts.

1. Meteorological droughts: this type of drought results in reduction in precipitation due to atmospheric conditions and can last for months. The transition between atmospheric conditions can be abrupt and may occur overnight((Heim, 2002)
2. Agricultural Drought: Dryness in the surface layer (root zone) which occurs at a critical time during the crop growing season can cause agricultural droughts. ((Heim, 2002)
3. Hydrological Drought: The reduction of water levels in the surface or subsurface water reservoirs like streams and lakes due to prolonged deficits in precipitation causes hydrological droughts.((Heim, 2002)
4. Socio-economic droughts: This type of drought relates the supply and demand of any economic good with meteorological, agricultural and hydrological drought. (Heim, 2002)

Relationship between droughts:

The relationship between different types of droughts is complex e.g. stream flow is a key factor which controls irrigation in many areas and supply of water to places like hydropower stations. We can say that droughts of all types are related to each other and one can trigger another like an agricultural drought may lag a meteorological drought depending on the subsurface moisture conditions.

Droughts and Climate Change:

Changes in climate variability, including frequent and damaging extreme events such as drought, is one of many anticipated impacts of climate change. Estimating how climate variability will change in a warmer world and how that variability intersects with more slowly evolving climate change is crucial to climate risk management and adaptation efforts. El Niño plays a major role in tropical drought occurrence. For a substantial fraction of the tropics, severe droughts in the meteorological sense develop preferentially during El Niño events. The possibility of increases in the strength or frequency of El Niño events in a warmer future climate have clear negative implications for many of the already vulnerable tropical land areas. (Coelho, 2009)

Droughts in Pakistan:

Pakistan has a history of droughts, most notable was during the period 1998-2000. The Southern parts of the country below 30ºN, particularly parts of Southern Punjab, Sindh & Balochistan, are the most vulnerable regions to droughts in Pakistan. Because of the long latitudinal extent of the country from 24ºN to 37ºN, the country has a diversified climate which consist mostly of arid and semiarid regions, besides some hyper arid regions. On account of the natural deserts within 25º to 30ºN there are two rainy seasons namely winter (December to March) and summer monsoons (June to September) and two transition periods having almost insignificant rains. The rainfall pattern is highly variable and climate change might have adverse impact on the drought conditions in Pakistan.

Study areas and stations:

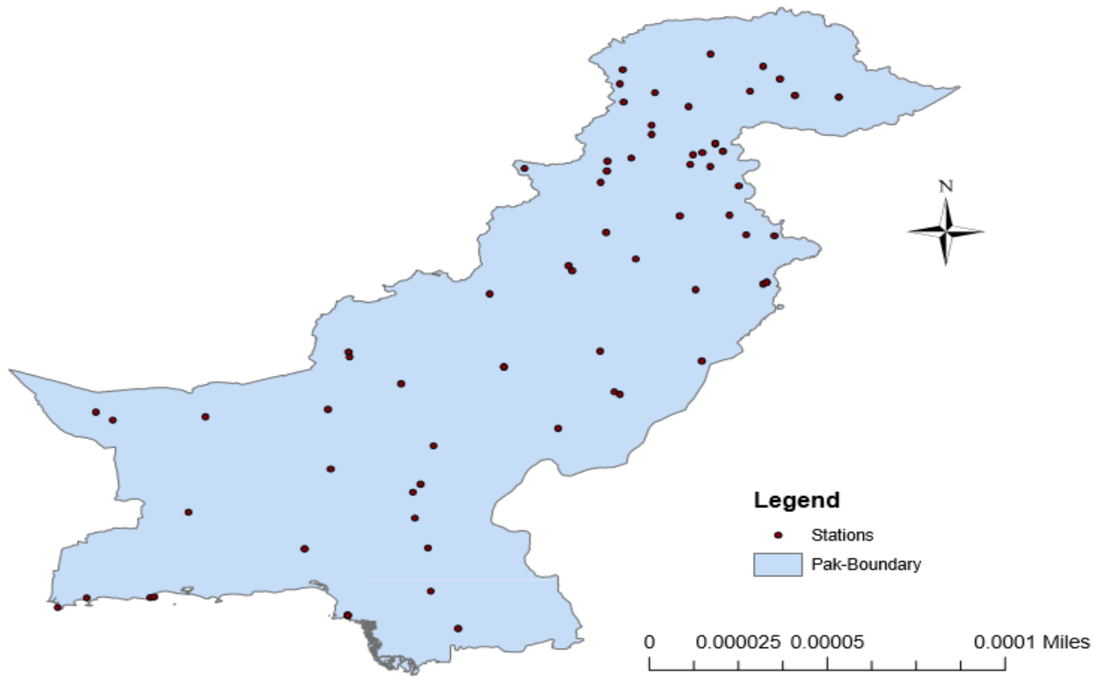
Shown below are stations and study areas on which most of the work has been done by researchers. The table below shows that the southern regions of Pakistan are the most effected regions by droughts thus these areas are studied more frequently.

Study Area	Papers
Islamabad, Rawalpindi	(Ahmad R. S., 2015)
Pakistan (All over the country)	(Ahmad B. S., 2018), (B.Ahmad, 2017) , (I.Ahmad, 2015), (S.M Malik, 2012), (M. H. Bukhari, 2011), (State Bank of Pakistan's Annual Report 2016-17), (Shardul Agrawala, 2001), (Ghulam Nabi, 2019), (Ahmed), Pakistan Meteorological Department. (2017).
Sindh and Balochistan	(W.Ming, 2013), (OCHA, 2019), (International Federation of Red Cross and Red Crescent Societies (IFRC), 2019)
Sindh	(G.Rasul, 2012)
Kohistan Region (Sindh)	(ANILA MEMON*, 2019)
Tharparker(Sindh)	(LEAD Pakistan, 2017)
Punjab	(Fatima, 2018)
518 × 598 km square area of the agricultural land positioned over the area of (28.42-32.98◦N,70.14-75.39◦E of Punjab Province	(JAHANGIR KHAN, 2018)
KPK	(Zulifqar Ali, 2017)
Balochistan	(Balochistan University of Information Technology, Engineering & Management Sciences (BUITEMS) United Nations Development Programme (UNDP), 2016), (Imran Hameed Durrani, 2018)

PMD stations across Pakistan:

For the purpose of understanding the architecture of weather stations across Pakistan specifically for drought studies we followed the steps below:

1. Accumulation of latitude and longitude of different stations from the official PMD (Pakistan Meteorology Department) website
2. Excel file making of the stations and using decimal degrees as units of lat/long.
3. Loading the file in ARCGIS and making a map.



PMD-STATIONS UTILIZED FOR DROUGHT STUDIES

The above map shows the even distribution of the stations across Pakistan with slightly more stations towards the north.

Drought Indices and Projection models:

Various drought indices used in the past researches are as follow which can prove helpful for future studies:

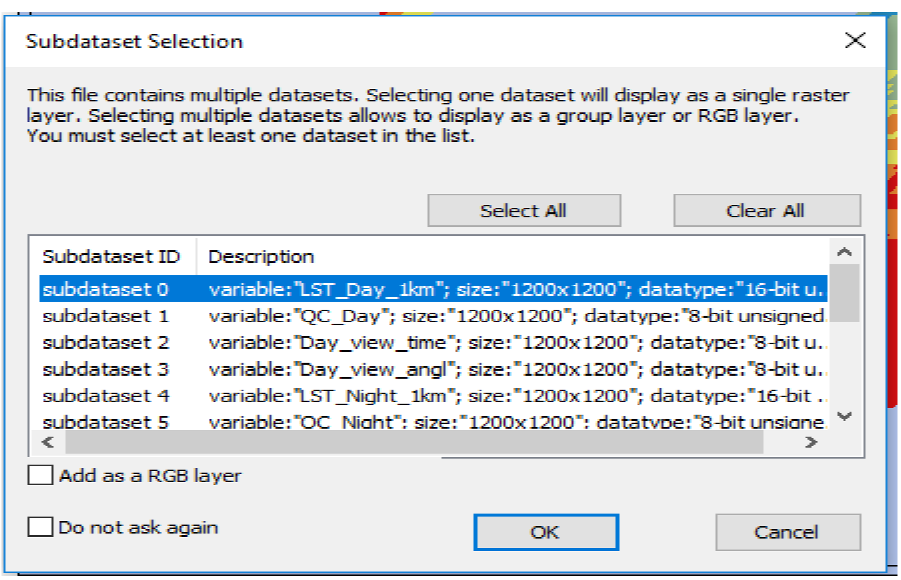
- Vulnerability evaluation index system: in which 12 indices and 3 layers according to AHP (Analytic Hierarchy Process) are calculated. (Ahmad R. S., 2015)
- Agricultural stress index, Normalized vegetation index (NDVI), Vegetation Condition Index (VCI), Vegetation Health Index (VHI), Oceanic Nino Index (ONI) and temperature condition index (TCI). (Ahmad B. S., 2018)
- Nino 3.4 Index (Ref: http://www.cpc.noaa.gov/ data/indices/).
- GCM20 and RegCM4.3 (B.Ahmad, 2017), (G.Rasul, 2012)
- Winter-spring (February-March-April) precipitation (WSP) index, Niño4 index, North Atlantic Oscillation Index (NAOI), national precipitation index, southern oscillation index (SOI) , Rainfall Index, Niño3.4 index (I.Ahmad, 2015)
- PRECIS Model (Meteorological Department, Hadley, UK) (ANILA MEMON*, 2019)
- Vegetation temperature condition index (VTCI) and geospatial near-real-time coupling (NRTC) approach (JAHANGIR KHAN, 2018)
- Regional Climate Model RegCM3
- Standardized Precipitation Index (Hua Xie, Droughts in Pakistan: a spatiotemporal variability analysis using the Standardized Precipitation Index)
- Palfai Drought Index (PaDI).

Investigating droughts in Islamabad and Rawalpindi from 2016-2019 (Growing season, Nov-April) using Land Surface Temperature (LST) and Normalized difference vegetation index (NDVI) data from MODIS (an indirect approach)

1. Introduction to project: The drought study over Islamabad and Rawalpindi was completed in 3 weeks. LST (Land surface temperature) and NDVI (normalized vegetation index) was acquired from the earth explorer official site. Data was taken of 3 years (2016-19) during the growing season from November to April. This method is not a direct instrument to measure the presence or intensity of drought but it provides and indirect clue of how temperature and vegetation changes can result in droughts. MODIS is an extensive program by which daily coverage of earth is provided by the AQUA and TERRA satellite both having a MODIS sensor onboard. We have followed the methodology used by (S.Sruthi, 2015)

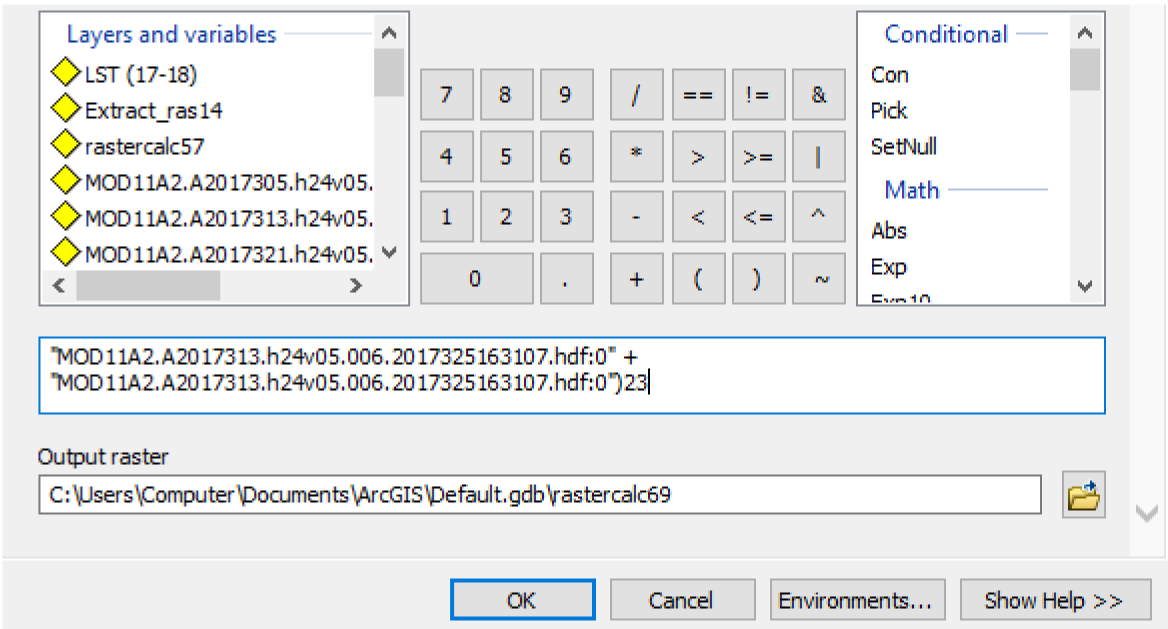
2. Software utilized: we have performed the analysis using ARCGIS and QGIS**.** In general both are easy to use and with time it's easy to get a grip on the tools provided. For classification and map making ARCGIS was used while for calculation purposes "Raster Calculator" was used from both. For graphical representation of results EXCEL was used.

3. MODIS-LST data: For LST, the "MOD11A2" datasets were used. This dataset is available with a gap of 8 days meaning we get an LST dataset after every 8th day which gives us 3 to 4 datasets for every month. Each dataset contains different layers out of which the LST for night and day are what we are interested in. The image below shows the different layers in an LST file:

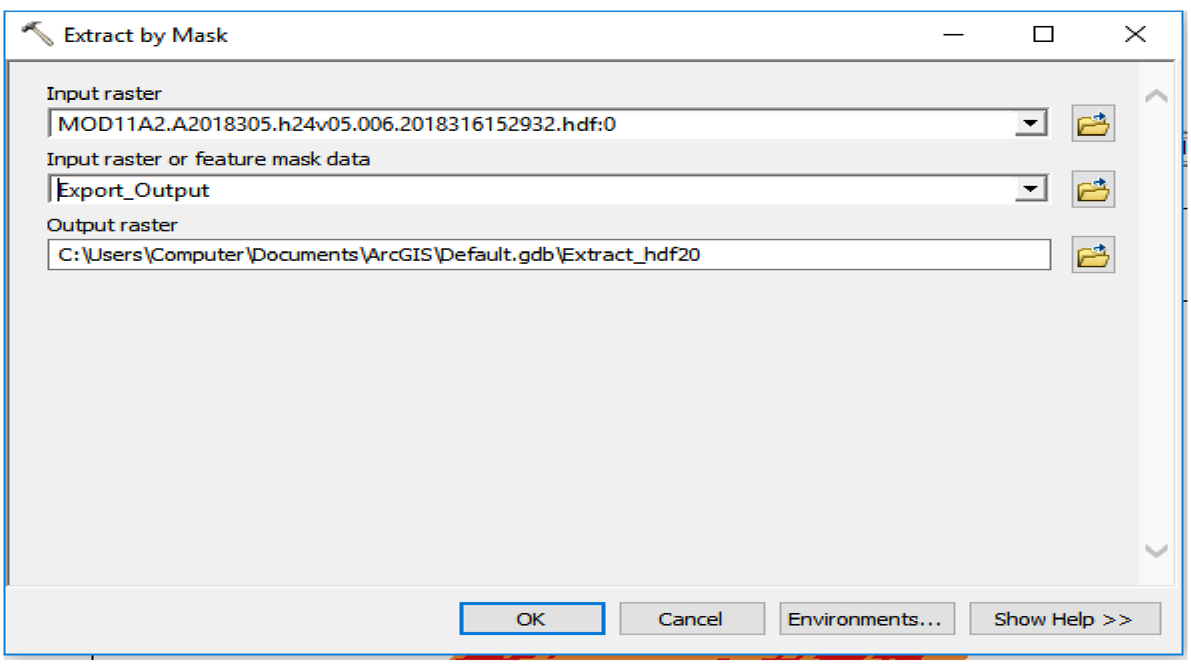


The following steps were taken for the process using the "Raster calculator" in the "Arc Toolbox" in ARCGIS.

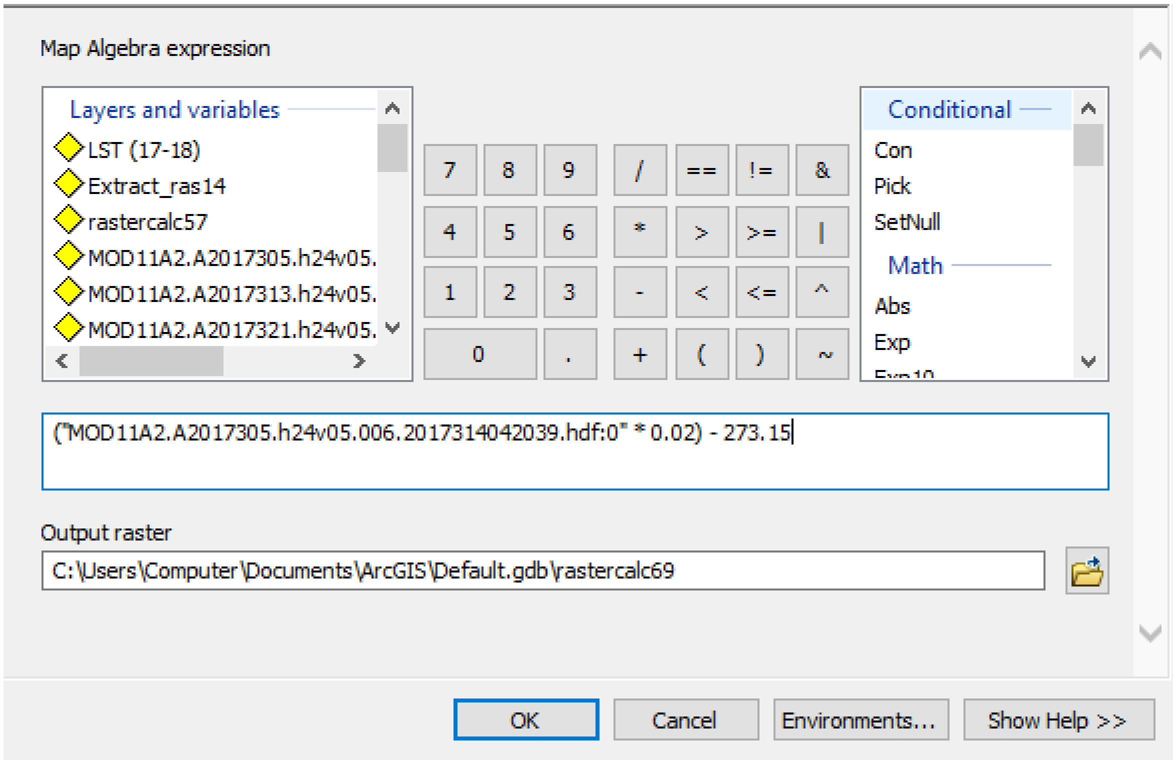
a) **Averaging all the datasets:** For this study we require one image for every growing season that is one for November 2016 to April 2017, one for November 2017 to April 2018 and one for November 2018 to April 2019. In order to obtain these images we calculated the average of all the datasets for each growing season using "Raster Calculator". For LST we have 22-23 files for each season and we get 3 resultant files for each season.



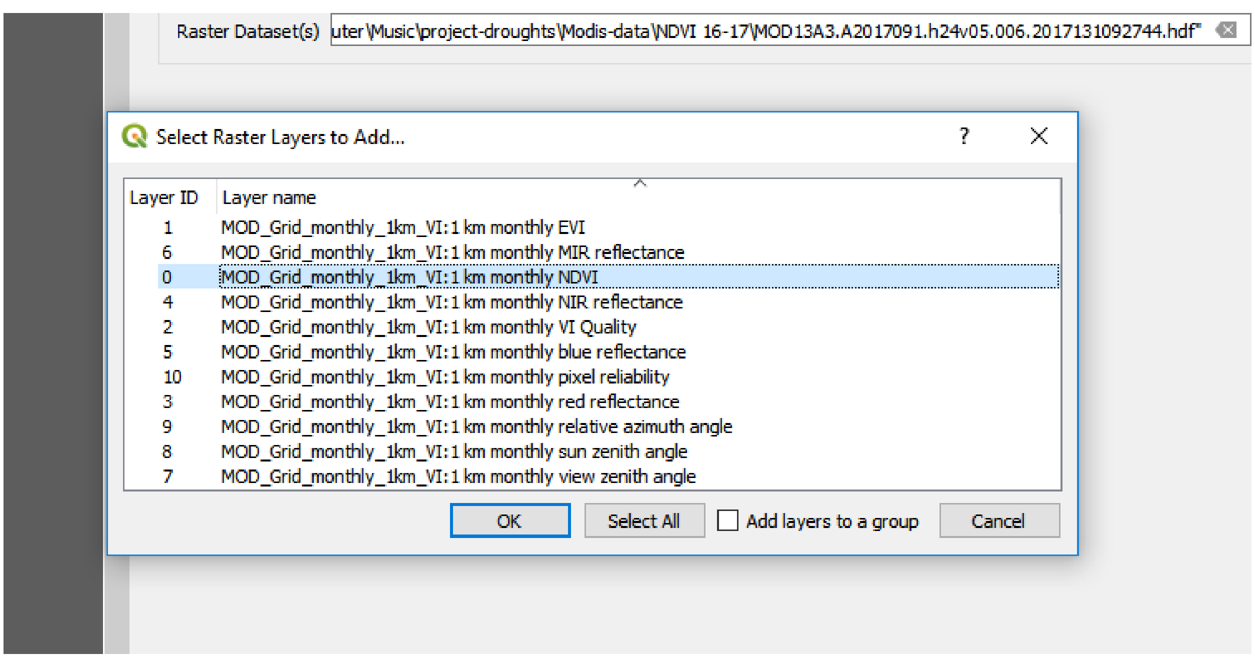
b) **Masking the resultant images:** after the above step we used the masking tool "Extract by Mask" to crop the excess raster file using a vector file of Islamabad and Rawalpindi.



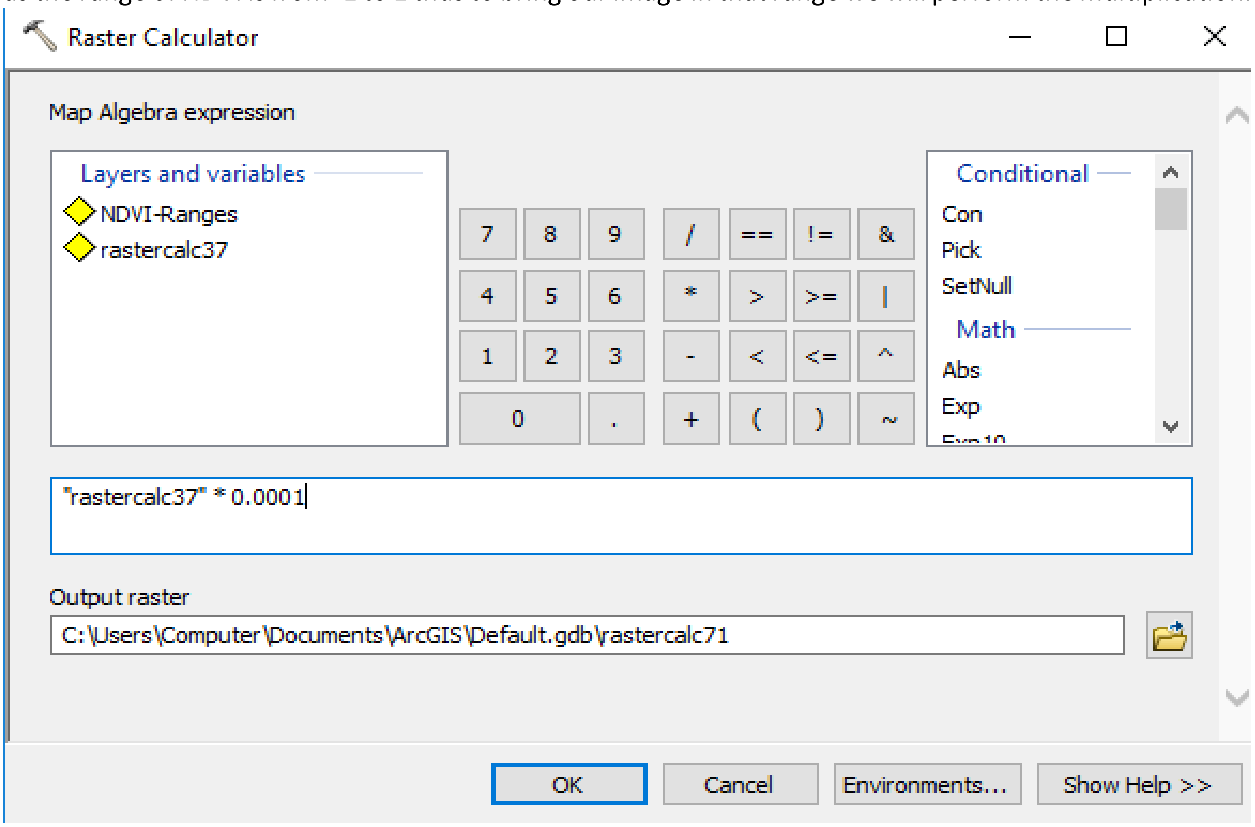
c) **Conversion to centigrade**: after the above two steps the final step requires the application of a formula on the image which converts the data from digital numbers and kelvin to centigrade which is easier to understand. The formula used is the following **(image*0.02)-273.15=image in centigrade**



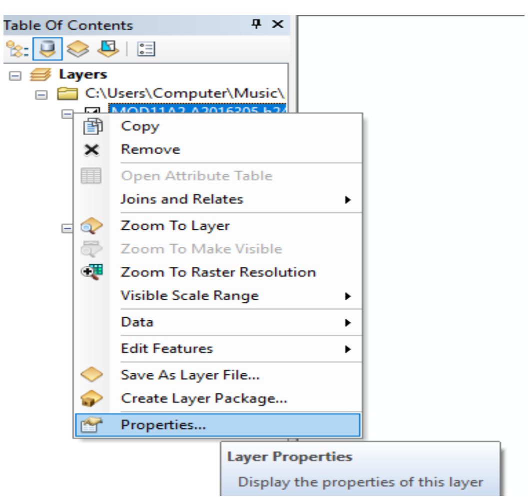
4. MODIS-NDVI data: for NDVI “MOD13A3” datasets were used. This dataset gives us one file per month having monthly average NDVI for the specified region. Each dataset has layers out of which we will use the NDVI layer. Below is the image of different layers in an NDVI dataset:

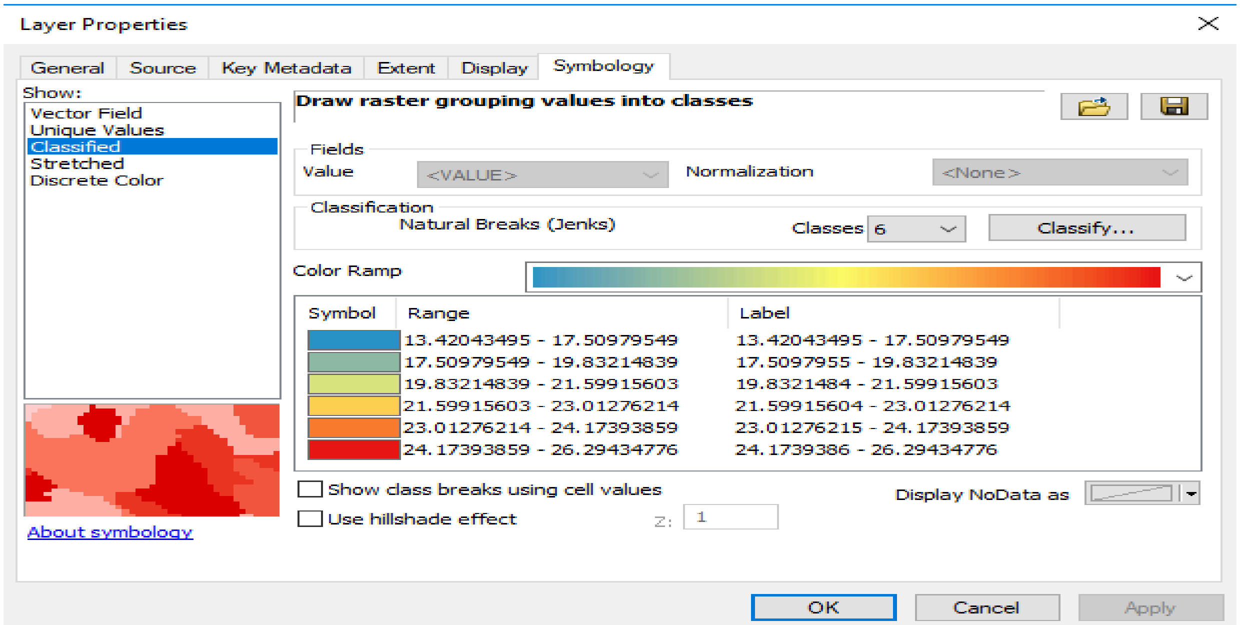


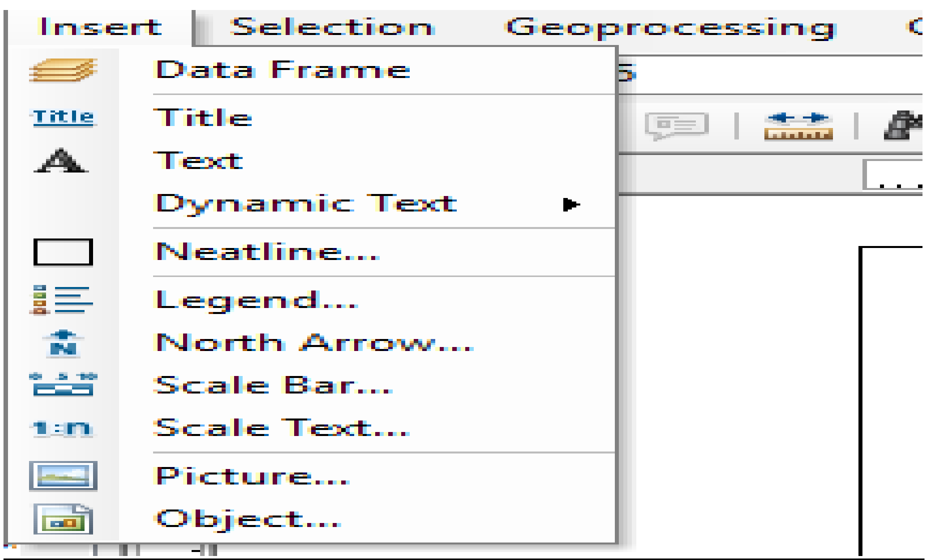
The above steps used for LST will also be used for NDVI files. We will average the files for each season to get 3 files one for 2016-17 one for 2017-18 and one for 2018-19 then we will crop the files with the shape file of Islamabad and Rawalpindi. The last step will be to multiply the final image with the value"0.0001" as the range of NDVI is from -1 to 1 thus to bring our image in that range we will perform the multiplication.



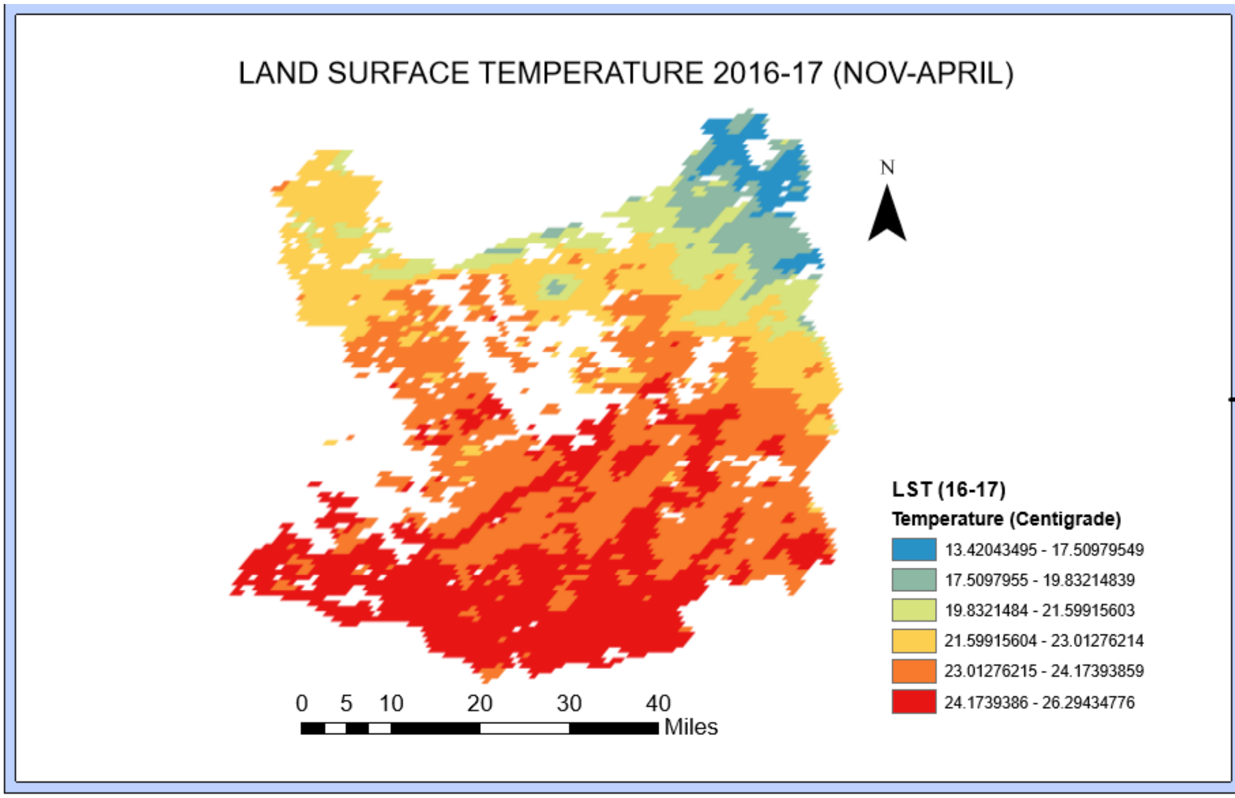
5. Map-making: After getting a final image for LST and NDVI we performed classification using a simple "classify" tool in the "Symbology" option in the "layer properties" of the final images. We made 6 classes and added a color ramp. For NDVI we will add a green color ramp and for LST we added a color ramp which transitions from blue to red. Afterwards we added a north arrow, scale bar and legend.

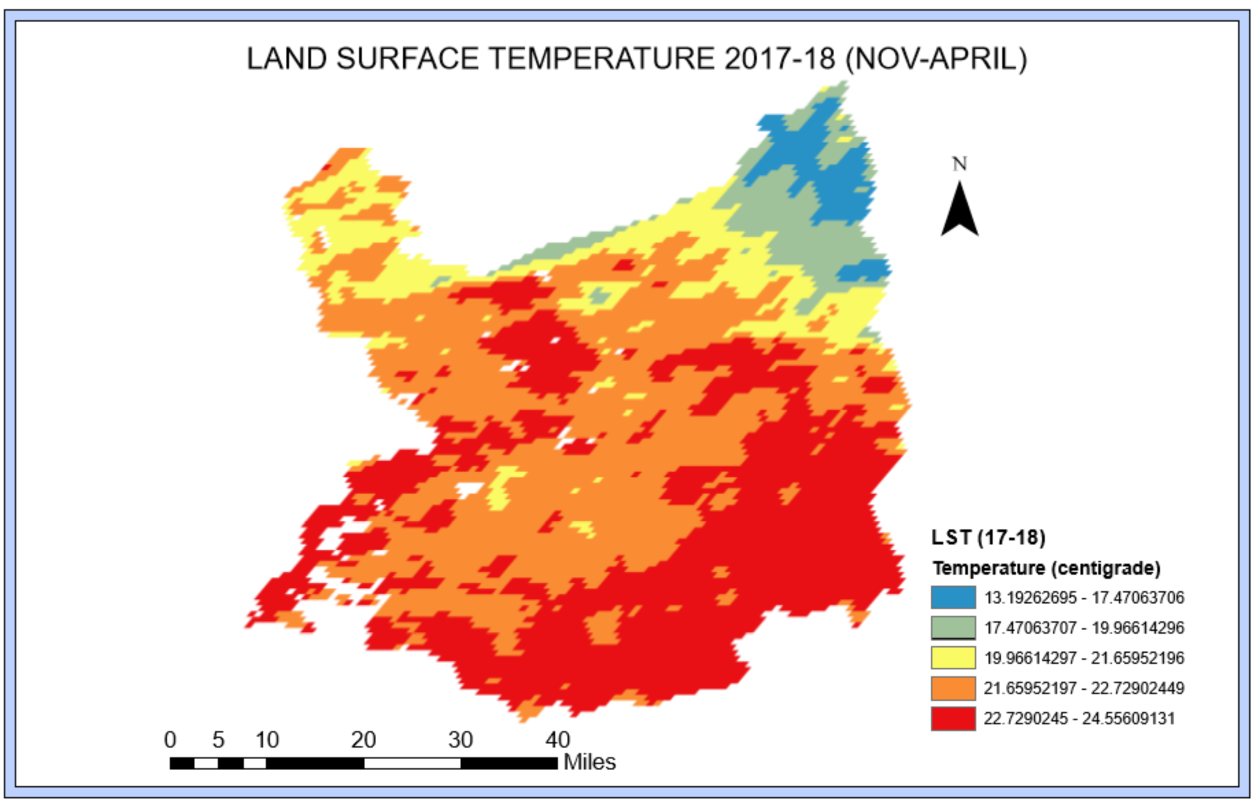


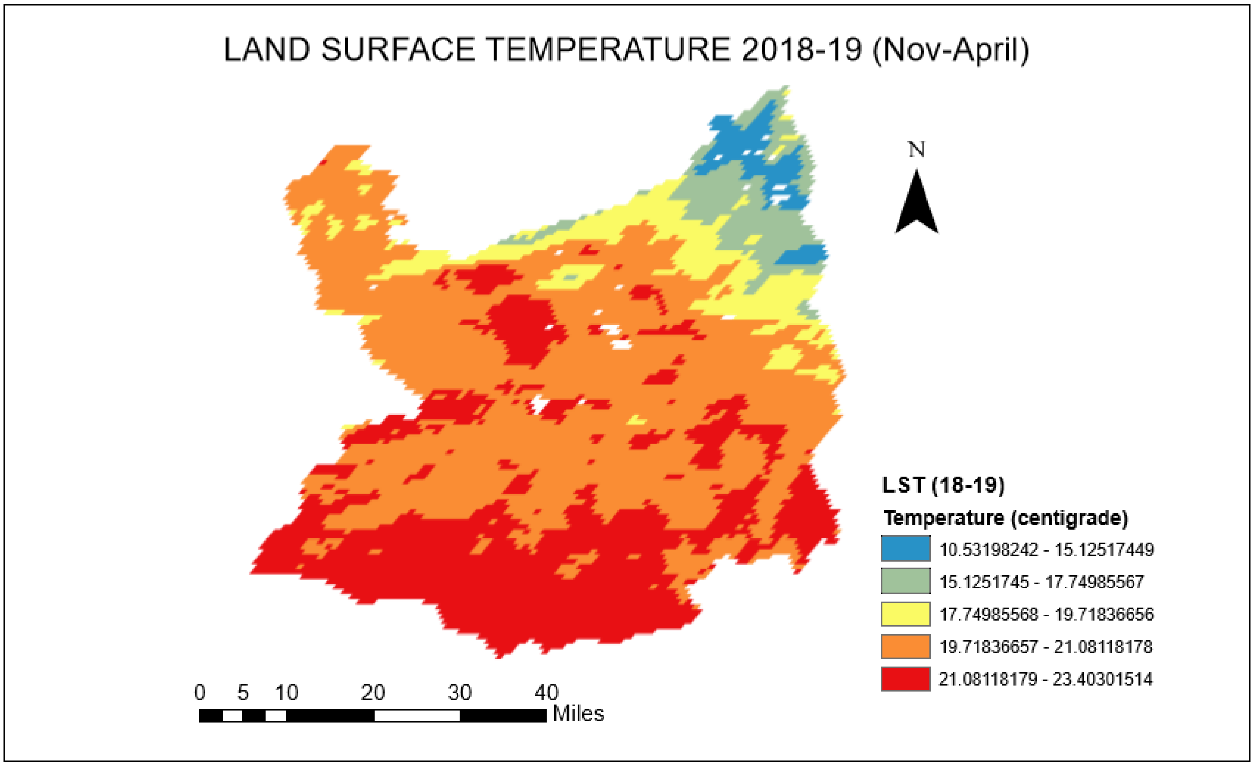


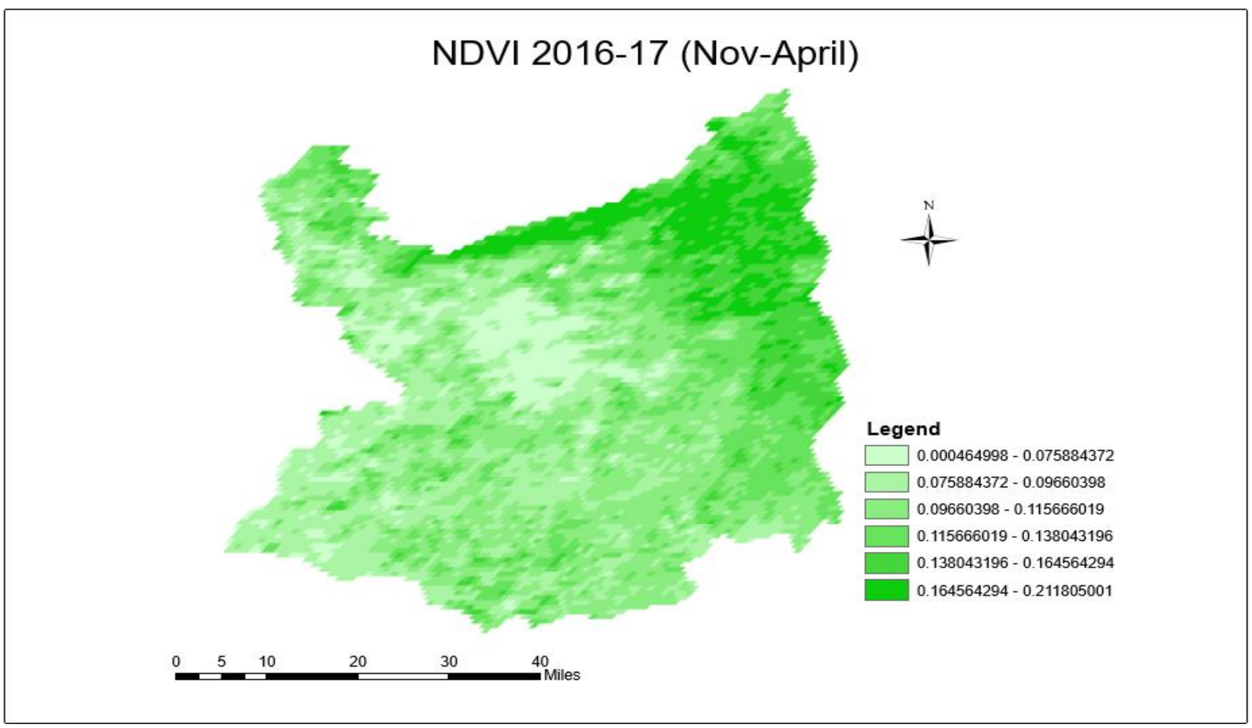


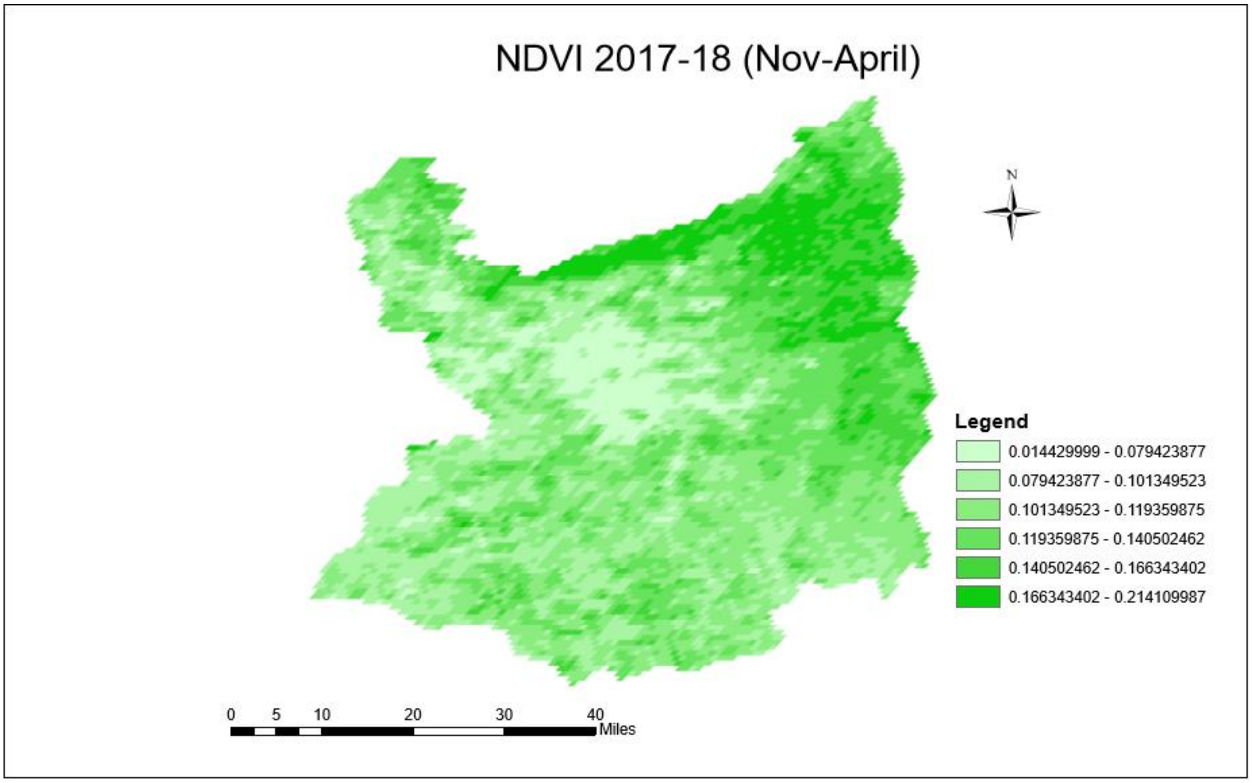
6. Graph Making in Excel: we calculated the average LST and NDVI for each season and then we added the values in excel to make a graph. This proved helpful to show a trend of average LST and NDVI over the past years. Afterwards we calculated the correlation value between LST and NDVI from 2016 to 2019 using the "CORREL" function in Excel.
7. LST, NDVI Maps and Graphs:

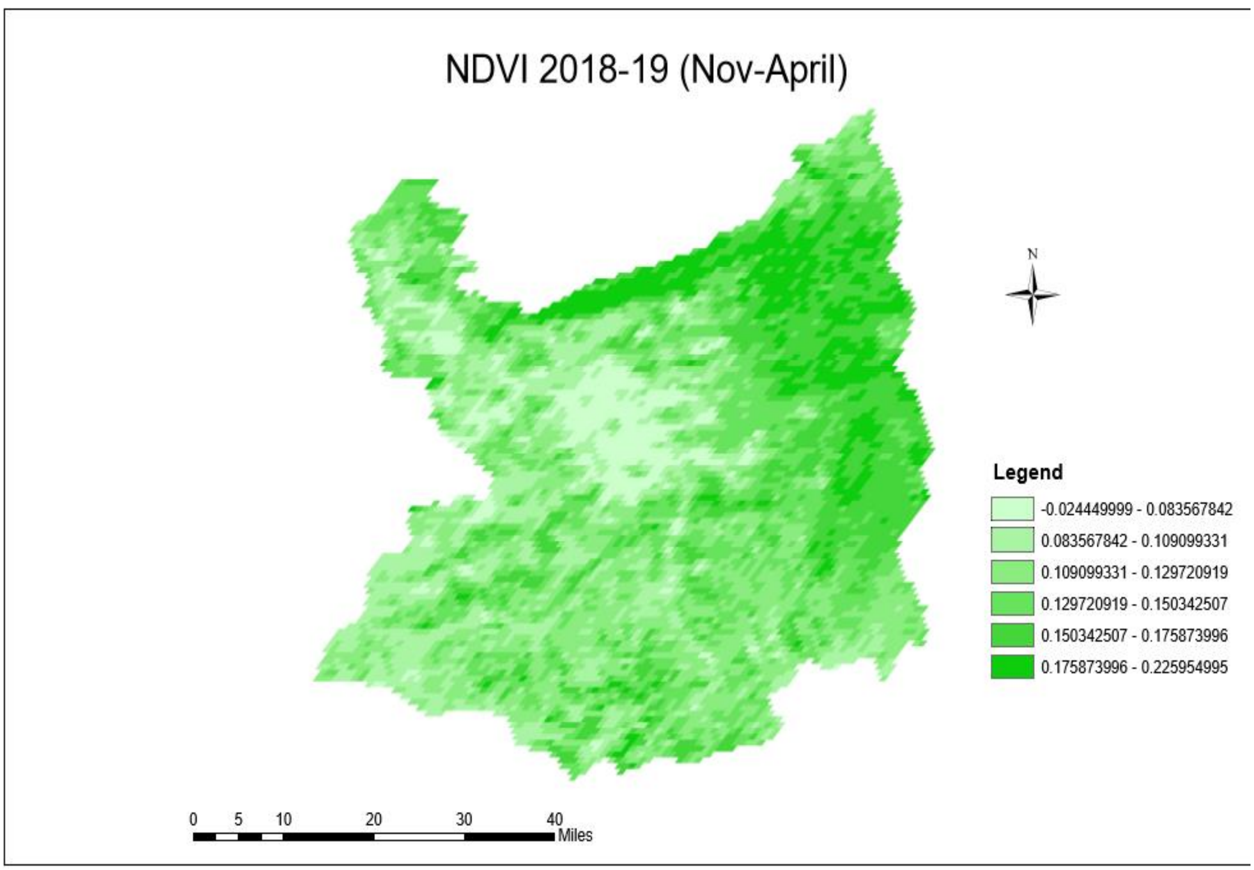

LAND SURFACE TEMPERATURE 2016-17 (NOV-APRIL)
N
LST (16-17)
Temperature (Centigrade)
13.42043495 - 17.50979549
17.5097955 - 19.83214839
19.8321484 - 21.59915603
21.59915604 - 23.01276214
23.01276215 - 24.17393859
24.1739386 - 26.29434776
0 5 10 20 30 40
Miles

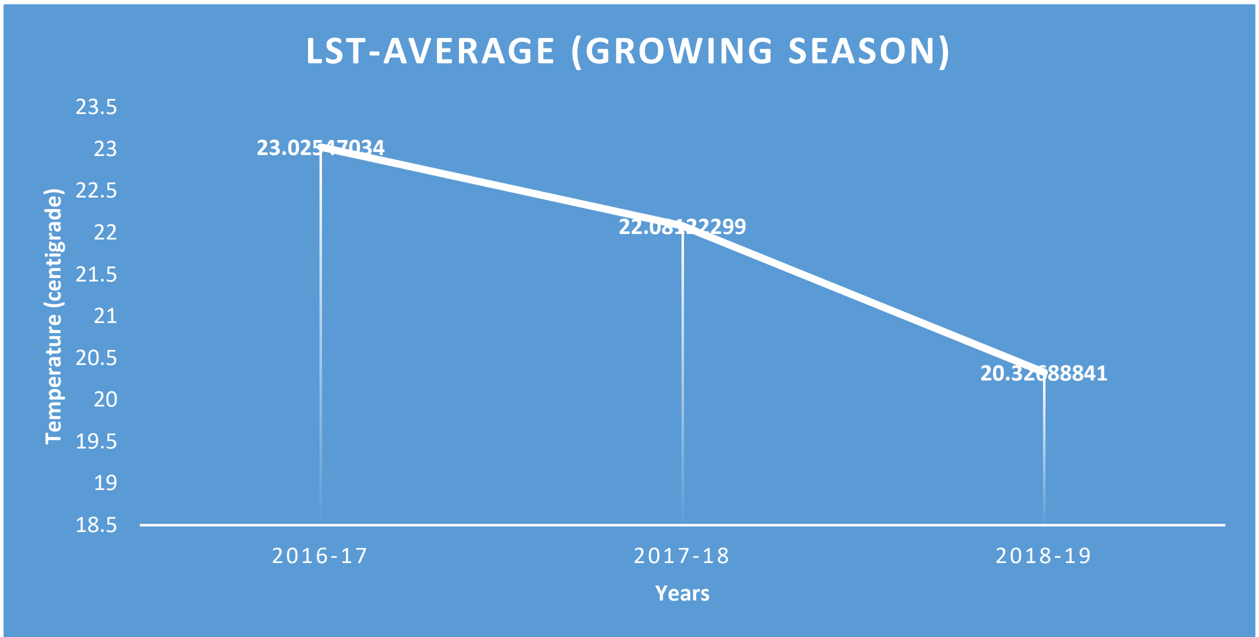

LAND SURFACE TEMPERATURE 2017-18 (NOV-APRIL)
N
LST (17-18)
Temperature (centigrade)
13.19262695 - 17.47063706
17.47063707 - 19.96614296
19.96614297 - 21.65952196
21.65952197 - 22.72902449
22.7290245 - 24.55609131
0 5 10 20 30 40
Miles

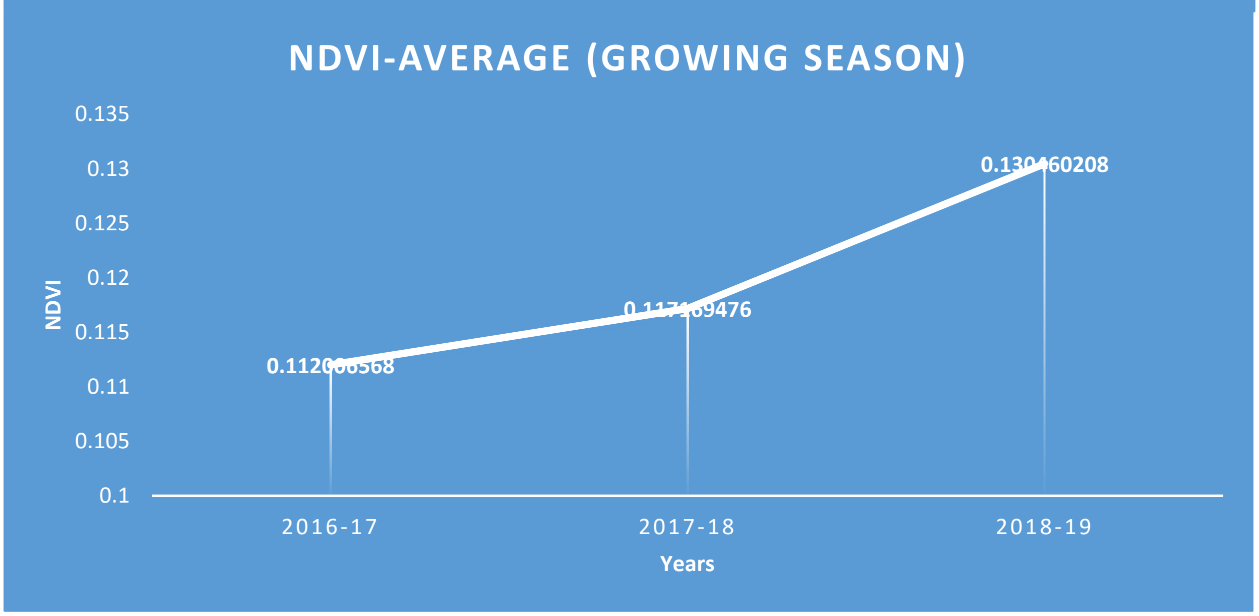

LAND SURFACE TEMPERATURE 2018-19 (Nov-April)
N
LST (18-19)
Temperature (centigrade)
10.53198242 - 15.12517449
15.1251745 - 17.74985567
17.74985568 - 19.71836656
19.71836657 - 21.08118178
21.08118179 - 23.40301514
0 5 10 20 30 40
Miles


NDVI 2016-17 (Nov-April)
N
Legend
0.000464998 - 0.075884372
0.075884372 - 0.09660398
0.09660398 - 0.115666019
0.115666019 - 0.138043196
0.138043196 - 0.164564294
0.164564294 - 0.211805001
0 5 10 20 30 40
Miles


NDVI 2017-18 (Nov-April)
N
Legend
0.014429999 - 0.079423877
0.079423877 - 0.101349523
0.101349523 - 0.119359875
0.119359875 - 0.140502462
0.140502462 - 0.166343402
0.166343402 - 0.214109987
0 5 10 20 30 40
Miles


NDVI 2018-19 (Nov-April)
N
Legend
-0.024449999 - 0.083567842
0.083567842 - 0.109099331
0.109099331 - 0.129720919
0.129720919 - 0.150342507
0.150342507 - 0.175873996
0.175873996 - 0.225954995
0 5 10 20 30 40
Miles





8. Discussion and conclusion:

The above maps indicate that Land surface temperature and normalized vegetation index haven't changed considerably over the period of the past 4 years. The LST map of 2017-18 does indicate higher temperatures in the south-eastern regions. The correlations between LST and NDVI graphically indicate that the two are inversely related. The above graphs represent the behavior of LST and NDVI from 2016 to 2019 and it can be seen that NDVI has increased while LST has decreased. The correlation between the two comes out to be -0.997 for the past 4 years. From 2014 till now Pakistan has been experiencing droughts specifically in the southern regions. 190 children died and 22,000 were hospitalized in 2016 in Tharparker for that reason data from 2016-2019 were chosen but looking at the above maps of LST and

NDVI we do not get a clear idea of the drought conditions. NDVI and LST are related to soil moisture, agriculture and the atmosphere thus if coupled with data of precipitation and soil moisture we can understand droughts in a more precise manner which can prove beneficial to policy makers and the government in preventing droughts in the future.

Bibliography

Climate Change: Past and Future Trends. (n.d.). Retrieved from http://www.mocc.gov.pk/moclc/userfiles1/file/ECCO/Chapter-06.pdf

Ahmad, B. S. (2018). Analyzing Agricultural Stress Index over Pakistan with Phase Change of Oceanic Nino Index in 2015–16 El Niño Episode. *Pakistan Journal of Meterology, 14*(28).

Ahmad, R. S. (2015). Water Resource Vulnerability Assessment in Rawalpindi and Islamabad, Pakistan using Analytic hierarchy process.

Ahmed, I. (n.d.). *GLOBAL CLIMATIC CHANGE AND PAKISTAN'S WATER-RESOURCES.* Retrieved from http://www.sciencevision.org.pk/BackIssues/Vol7/Vol7No3-4/Vol7No3&4_9_Global_Climate_Change_Imtiaz%20Ahmed.pdf

ANILA MEMON*, K. A. (2019). Projected Rainfall Variability Based on PRECIS Regional Model. *Mehran University Research Journal of Engineering & Technology, 38*, 513-524.

B.Ahmad, A. (2017). Evaluation of Past and Projected Climate Change in Pakistan Region Based on GCM20 and RegCM4.3 Outputs. *Pakistan Journal of Meteorology, 13*(26).

Balochistan University of Information Technology, Engineering & Management Sciences (BUITEMS) United Nations Development Programme (UNDP). (2016). *Drought Risk Assessment in the Province of Balochistan, Pakistan.*

C.Palmer, W. (1965). Meteorological Drought.

Coelho, C. A. (2009). El Niño–Induced Tropical Droughts in Climate Change Projections. *Journal of Climate*, 20.

Fatima, S. (2018). Forecasting Rainfall in Potohar Region of Pakistan in the Perspective of Drought.

G.Rasul, A. M. (2012). Vulnerability of the Indus Delta to Climate Change in Pakistan. *Pakistan Journal of Meteorology, 8*(16).

Ghulam Nabi, M. A. (2019). *The crisis of water shortage and pollution in Pakistan: risk to public health, biodiversity, and ecosystem.*

Heim, R. (2002). A Review of Twentieth–Century Drought Indices Used in the United States. *Bulletin of the American Meteorological Society*.

Hua Xie, C. R. (2013). Droughts in Pakistan: a spatiotemporal variability analysis using the Standardized Precipitation Index. Retrieved from https://doi.org/10.1080/02508060.2013.827889

Hua Xie, C. R. (n.d.). Droughts in Pakistan: a spatiotemporal variability analysis using the Standardized Precipitation Index. Retrieved from https://doi.org/10.1080/02508060.2013.827889

I.Ahmad, R. Z. (2015). Winter-Spring Precipitation Variability in Pakistan. *American Journal of Climate Change*.

Imran Hameed Durrani, S. A. (2018). Historical and Future Climatological Drought Projections Over Quetta Valley, Balochistan, Pakistan.

International Federation of Red Cross and Red Crescent Societies (IFRC). (2019). *Emergency Plan of Action (EPoA) Pakistan: Drought .*

JAHANGIR KHAN, P. W. (2018). Mapping MODIS LST NDVI Imagery for Drought Monitoring in Punjab Pakistan.

LEAD Pakistan. (2017). *Loss & Damage from Drought in Pakistan: Notes from Tharparkar.* Retrieved from http://www.lead.org.pk/lead/Publications/Loss%20&%20Damage%20from%20Drought%20in%20Pakistan%20-%20Notes%20from%20Tharparkar.pdf

M. H. Bukhari, E. A. (2011). *Emerging Climate Changes and Water Resource Situation in Pakistan.* Retrieved from http://pu.edu.pk/images/journal/studies/PDF-FILES/Artical-8_V_12_No_2_Dec11.pdf

OCHA. (2018). *Asia and the Pacific: Weekly Regional Humanitarian Snapshot (25 September - 1 October 2018)*. Retrieved from Reliefweb: https://reliefweb.int/report/indonesia/asia-and-pacific-weekly-regional-humanitarian-snapshot-25-september-1-october-2018

OCHA. (2019). Pakistan: Humanitarian Dashboard - Drought 2019.

S.M Malik, H. N. (2012). Mapping Vulnerability to climate change and its repercussions on human health in Pakistan. Retrieved from http://www.globalizationandhealth.com/content/8/1/31

S.Sruthi, M. M. (2015). Agricultural Drought Analysis Using the NDVI and Land Surface Temperature Data; a Case Study of Raichur District. *4*, 1258-1264.

Shardul Agrawala, M. B. (2001). *The Drought and Humanitarian Crisis in Central and Southwest Asia: A Climate Perspective.*

Shumaila Sadiq, A. S. (n.d.). Drought Monitoring across Agro-Climatic Zones: .

State Bank of Pakistan’s Annual Report 2016-17. (n.d.). *Water Sustainability in Pakistan – Key Issues and.* Retrieved from http://www.sbp.org.pk/reports/annual/arFY17/Chapter-07.pdf

W.Ming, A. B. (2013). Impact of El-Nino on Summer Monsoon in Southern Parts of Pakistan. *Pakistan Journal of Meteorology, 10*(19).

Zulifqar Ali, I. H. (2017). Forecasting Drought Using Multilayer Perceptron Artificial Neural Network Model. 9.