**Assessment and Mapping of Vulnerability to Land Degradation in Anantapuramu district of Andhra Pradesh, India Using Remote Sensing and GIS Techniques**

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**ABSTRACT:** In this paper, the spatial-temporal analysis of land degradation was conducted in Anantapuramu district of Andhra Pradesh state, India from the period of south-west monsoon season (June to September) from 2000 to 2016. The parameters used in the present study for the assessment and mapping of the vulnerability level of land degradation in the study area are NDVI, Rainfall, LST, Slope, Soil depth, Soil texture, Soil pH, and Soil drainage. The remotely sensed parameters namely NDVI, Rainfall, LST, and slope were derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices of MOD13Q1, Tropical Rainfall Measuring Mission (TRMM) 3B43 precipitation data products, MODIS surface reflectance of MOD11A2, and Shuttle Radar Topography Mission- Digital Elevation Model respectively. Finally, the 5-scale weighted overlay analysis was applied to obtain the long-term land degradation scenario of the study area. The analysis shows that about 231.13 thousand hectares (12.06 percent) of the total geographical area (TGA) of the study area comes under severely vulnerable to land degradation. Such areas are mainly distributed in some parts of the center, some parts in the north, east, south, and south-eastern parts of the district. More than half of the district about 1175.33 thousand hectares (61.31percent) fall under highly vulnerable to land degradation, these areas are distributed in western, northern, north-eastern, eastern, and center parts of the study area.

**KEY WORDS:** Land degradation, MODIS, TRMM, NDVI, LST

**INTRODUCTION**

[Land Degradation](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/land-degradation) is a serious issue that affects agricultural production (AbdelRahman et al 2019). Land degradation is the process of temporary or permanent reduction of land productivity through the deterioration of inherent physical, chemical, and biological characteristics (Han et al 2019).It has been considered a serious issue since the early 1970s as it negatively impacts the ecosystem and its productivity (Prakash et al 2016). The land degradation due to anthropogenic activities and climatic variations occurs in arid, semi-arid, and subhumid regions (Barbero-Sierra et al 2015). According to the report the Indian Council of Agricultural Research (ICAR, 2010), about 120.40 million hectares (out of 328.73 million hectares) of land in the country are affected by land degradation. The studies for the assessment and monitoring of land degradation are more crucial to preserve natural resources and improve the quality of life (Silva et al 2018). The assessment of land degradation is complex since broad temporal and spatial perspectives are essential for a detailed and accurate assessment of the extent of the process (Vicente-Serrano et al 2012). In that respect, remote sensing might be the most appropriate method because satellite images can offer detailed spatial data for a wide geographical area. Presently remote sensing and GIS techniques are the powerful tools to investigate, predict and forecast environmental changes in a reliable, repetitive, non-invasive, rapid and cost-effective way with considerable decision-making strategies (Amiri et al. 2014). The recent breakthroughs in the field of remote sensing and GIS technologies allow us to assess the spatial extent of land degradation with better accuracy in regional to local scale (Reddy 2018). The present study aimed to assess and map the land degradation vulnerability through natural factors by using remote sensing and GIS techniques.

**STUDY AREA**

Anantapuramu is one of the districts of Andhra Pradesh, locates in its southern region called Rayalaseema. The district geographically extends between the 13° 40’ and 16° 15’ North latitudes and between 70° 50’ and 78° 38’ East longitudes. The district covers an area of 1917 thousand hectors with diverse topography includes plains, hills, valley, hillocks, plateau, etc. The study area experiences a humid to sub-humid climate (Kumar et al 2020). The average annual rainfall of the district is 535 mm (Reddy et al 2020), the maximum rainfall receives during the southwest monsoon season (June-September) with mean seasonal rainfall distribution of 316 mm. The north east monsoon season becomes active from the month of October and lasts until December. The temperature in most parts reaches above 46° C during the summer season (Kumar et al. 2019) The major crops grown in the study area are millet, sugarcane, maize, groundnut, sunflower, and cotton, redgram, sorghum, finger millet, etc.

**MATERIALS AND METHODS**

The parameters used in the present study are NDVI, LST, Rainfall, Slope, soil pH, soil drainage, soil depth, and soil texture. The NDVI and LST were directly developed from MODIS MOD13Q1 and MOD11A2 respectively (<https://earthexplorer.usgs.gov>). The satellite-based rainfall data sets were collected from Tropical Rainfall Measuring Mission (TRMM) which were downloaded from (<http://trmm.gsfc.nasa.gov>). The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) was acquired from the USGS website (<https://earthexplorer.usgs.gov>) and which was used for deriving slope. In addition to the satellite product ancillary data sets namely soil depth, texture depth, and pH were also used in this study, and all those data were extracted from soil survey information of Andhra Pradesh.

**Processing of MODIS vegetation data (NDVI)**

The MODIS MOD 13Q1 vegetation data sets with a spatial resolution of 250 m and a temporal resolution of 16 days were procured for a period of 17 years (2000-2016). MRT tool (<https://lpdaac.usgs.gov/lpdaac/tools>) was used to convert the projection from the sinusoidal projection system (HDF) to the UTM Zone projection system with WGS84 datum, subsequently, the NDVI raster was clipped to the study area boundary. The cloud cover and other atmospherical disturbances were removed from the projected time-series MODIS NDVI datasets, by applying the Savitzky-Golay filter (Savitzky and Golay 1964) using TIMESAT software version 3.2 (<http://web.nateko.lu.se/timesat/timesat.asp>). Following this, the major waterbodies within the study area were subtracted from the filtered NDVI datasets. Eventually, the monthly NDVI composites for growing season (June-September) and growing season long-term mean NDVI composites from the year 2000 to 2016 were generated from the processed NDVI. Finally, the long-term NDVI raster was reclassified into 5 classes, namely very high, high, moderate, low, and very low.

**Preparation of MODIS LST datasets**

In the present study MODIS monthly temperature data were used, as a foremost task the projection system of the datasets was brought to the UTM projection system using the MRT tool, and the raster was resampled from its original spatial coverage 1 km to 250m grid by using bilinear resampling technique then the raster was extracted to the study area boundary by using ‘extract by mask tool’ in ArcGIS. Monthly LST datasets were prepared and finally, they were converted from a digital number (DN) to Degree Celsius (°C) using the following equation:

(1)

where LST is land surface temperature, 0.02 is the scale factor and DN is the digital number of the pixel. Eventually, the long-term LST raster was recalcified into 4 classes, viz 30 to 33, 33 to 36, 36 to 39, and >39.

**Processing of TRMM data.**

In this study, the downloaded Satellite-based TRMM (3B43 0.250.25 degree) gridded monthly rainfall data covering the period from 2000 to 2016 were resampled to 250m grid using a bilinear resampling technique and clipped to the boundary of the study area. Later the monthly rainfall raster for the growing season was prepared, from which the seasonal rainfall raster was generated and the same layer was used to produce the long-term means rainfall raster using ‘cell statistics tool’ in Arc GIS Software. Later the long-term mean rainfall raster was reclassified as <400, 400-450, 450-500, and >500.

**Preparation of terrain data (Slope)**

In the present study, the slope raster was directly generated from the resampled SRTM DEM by using the ‘slope’ tool in ArcGIS software and it categorized into 6 classes, viz 0 to 1, 1 to 3, 3 to 8, 8 to 15, 15 to 30, and > 30.

**Preparation of legacy data**

The legacy pedological parameters, viz soil depth, soil drainage, soil texture and soil pH were extracted from soil survey information of Andhra Pradesh to use in the GIS model and quantify the land degradation process in the study area. Soil depth of the study categorized into 3 classes namely shallow, moderately shallow, and deep, Soil drainage classified into 4 classes as moderately well, well, somewhat excess, and excessive. The soil texture of the study area grouped into 3 classes as sandy, loamy, and clayey. Likewise, soil pH classified into 4 classes namely slightly acidic (5.5-6.5), neutral (6.5-7.5), slightly alkaline (7.5-8.5), moderately alkaline (8.5-9.5). Finally, all the vector layers were converted into raster using the ‘Feature to Raster tool’ in ArcGIS software.

**Modelling of vulnerability to land degradation using GIS**

All the input parameters (long-term NDVI, LST, slope, soil depth, soil drainage, soil texture, and soil pH) were integrated in the GIS environment. To develop the final integrated output the 5-scale weighted overlay method was adopted for that the input parameters were overlaid with suitable theme and class weights based on their influence on land degradation. The weight and rank assign for the inputs is given in table 1.

Table 1. Parameters and their weightages

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.No | Parameter | Class | Range | Rank | Weight (%) |
| 1 | **NDVI** |  |  |  | 20 |
|  |  | Very Less | <0.3 | 5 |  |
| Less | 0.3-0.4 | 4 |  |
| Moderate | 0.4-0.5 | 3 |  |
| High | 0.5-06 | 1 |  |
| Very high | >0.6 | 1 |  |
| 2 | **LST** |  |  |  | 15 |
|  |  | Very high | >39 | 5 |  |
| High | 36-39 | 4 |  |
| Normal | 33-36 | 2 |  |
| Low | 30-33 | 1 |  |
| 3 | **Rainfall** |  |  |  | 15 |
|  |  | Very low | <400 | 5 |  |
| Low | 400-450 | 4 |  |
| Average | 450-500 | 2 |  |
| 4 | **Soil Depth** |  |  |  | 10 |
|  |  | Shallow | <50 | 5 |  |
| Moderately Shallow | 50-100 | 3 |  |
| Deep | >100 | 1 |  |
| 5 | **Soil Texture** |  |  |  | 10 |
|  |  | Sandy |  | 5 |  |
| Loamy |  | 3 |  |
| Clay |  | 2 |  |
| 6 | **Soil pH** |  |  |  | 10 |
|  |  | Moderately Alkaline | 8.5-9.5 | 4 |  |
| Slightly Alkaline | 7.5-8.5 | 2 |  |
| Slightly Acidic | 5.5-6.5 | 2 |  |
| Neutral | 6.5-7.5 | 1 |  |
| 7 | **Soil Drainage** |  |  |  | 10 |
|  |  | Excessive |  | 4 |  |
| Somewhat excessive |  | 3 |  |
| Moderately Well |  | 2 |  |
| Well |  | 1 |  |
| 8 | **Slope** |  |  |  | 10 |
|  |  | Steep Slope | 25-33 | 3 |  |
| Moderately Steep | 15-30 | 2 |  |
| Moderate Sloping | 8-15 | 2 |  |
| Gently sloping | 3-8 | 1 |  |
| Very gently sloping | 1-3 | 1 |  |
| Level to nearly level | 0-1 | 1 |  |

**RESULT AND DISCUSSIONS**

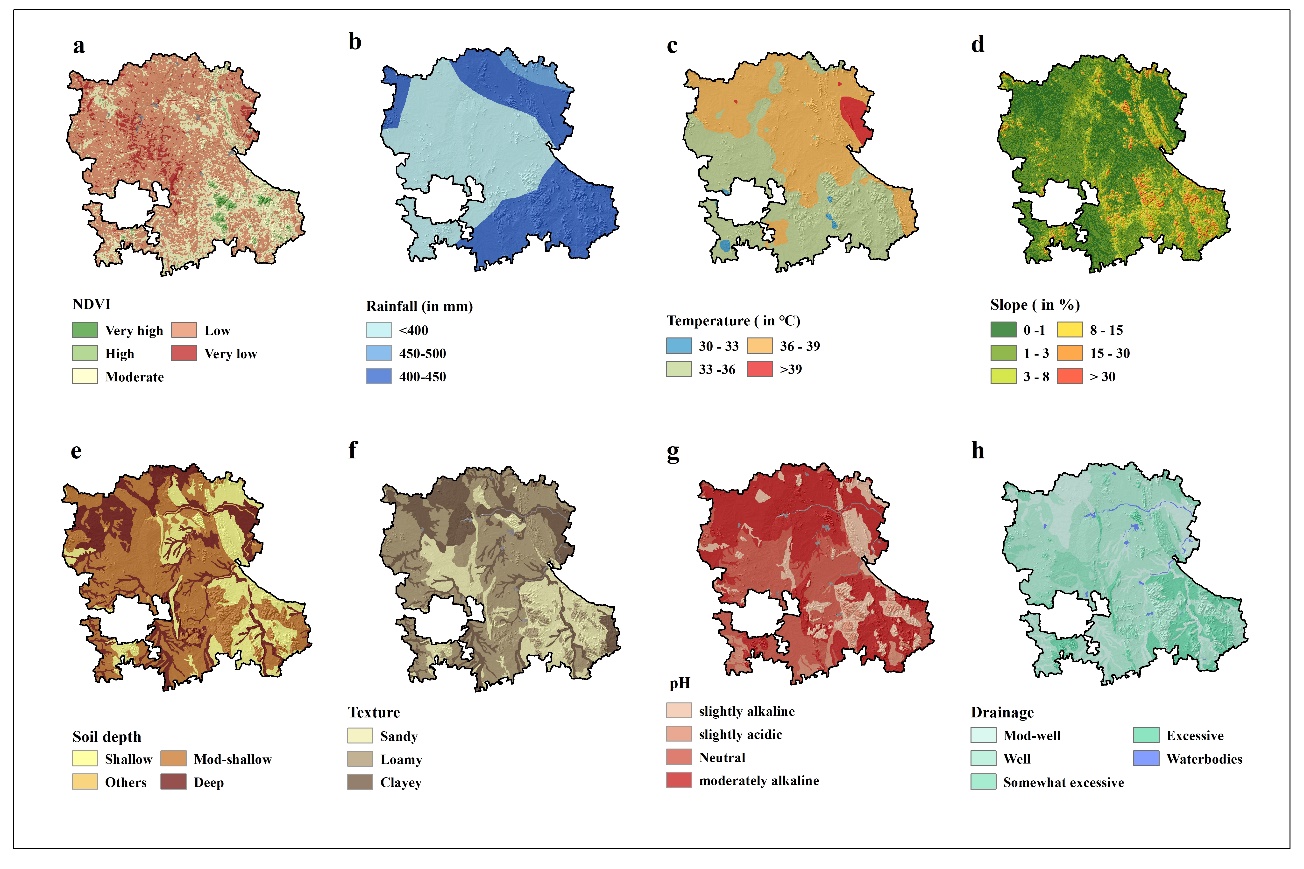
**Vulnerability level for land degradation in Anantapuramu district**

Anantapuramu is the major district in the Rayalaseema region and it witnessed a high degree of land degradation. Inadequate rainfall and increasing levels of temperature are the main responsible factors for vegetative degradation in the district. Rainfall analysis of the 17 consecutive years shows that high variability of rainfall has been prevailing over Anantapuramu district for the last seventeen years, because of its unfavorable location, the district lies in the rain shadow region of Western ghats, and the northeast monsoon does not influence this region by cause of its location far away from the eastern coastline.

Analysis of long-term NDVI reveals that about 120.53 thousand hectares (6.29 percent) of the area are covered by very low vegetation (<0.3) at the same time about 1162.02 thousand hectares (60.62 percent) of the TGA of the district is under low vegetation coverage (0.3-0.4). About 551.30 thousand hectares (28.76 percent) of the area are covered by moderate vegetation (0.4-0.5). The spatial coverages of very high (>0.6) and high vegetation (0.5-0.6) are 9.73 (0.51 percent) and 55.64 thousand hectares (2.90 percent), respectively (Fig 1a)

About 80 percent of the areas is received rainfall in the category of <400mm, south, southeastern, few patches in the north, and northeastern parts are recorded rainfall in between 400 and 450 mm (Fig 1b). The major part of the area is recorded temperature in the ranges of 36-39oC and 32-32oC meanwhile few portions in the east received >39oC (Fig 1c). Topographically the area characterized by moderately slope to moderately steep slope (Fig 1d).

The district mainly characterized by shallow and moderate shallow soils, which affect the plant’s growth. About 444.59 thousand hectares (23.19 percent) of the study area are covered with shallow depth and nearly, 977.63 thousand hectares of the area under moderately shallow (51 percent). Deep soils share only 24 percent of the TGA (476.97 thousand hectares) (Fig 1e). The study area is mainly distributed by loamy soil whereas, the southeastern part of the study area is covered with sandy soil. Only a few patches in the study area distributed with clayey soil (Fig 1f) Approximately 921.76 thousand hectares (48.08 percent) of the area is under moderately alkaline soil, while slightly acidic and slightly alkaline soils cover an area of 113.04 (5.9 percent) and 287.34 (15 percent) thousand hectares, respectively. However, about 577.06 thousand hectares are neutral (30.10 percent) (Fig 1g). The majority of the district characterized by moderately well to well soil drainage, however, the southeastern part of the study area has excessive soil drainage (Fig 1 h)

Fig 1a-1h. Input parameters used in the study

High vegetative stress, rainfall stress, and associated drought events, increasing level of temperature, less soil depth and moisture content, and problematic soil reaction are the chief factors, which are responsible for land degradation in Anantapuramu district. There are four vulnerable classes to land degradation were identified over the district as low, moderate, high, and severe as sown Fig 2.



Fig 2. Land degradation vulnerability level Anantapuramu district (2000-2016)

About 40.06 thousand hectares, means 2.09 percent of the TGA of the district under low vulnerable to land degradation such category of land was identified especially, in the western part of Hindupur mondal, Center part of Agali, few parts of Puttaparti, Bukkapattanam, few parts of Roddam, and few parts in Kottacheruvu. These areas are highly influenced by very high vegetation coverage as well as the area recorded low (30-330C) to moderate (33-360 C) temperature. This region is primarily occupied with two important types of soil textures, namely clayey and loamy with moderate shallow soil depth. Moreover, the region is characterized by the well and somewhat excessive soil drainage with slightly acidic soil reaction. Few pockets in the southern part, some portion of the center, and few patches in the south of the district are moderately vulnerable to land degradation. The spatial coverage of this category is 435.85 thousand hectares (22.74 percent) of the district. The maximum area of Puttaparti, the major part of the Bukkapattanam, northwestern, western, and southwestern parts of the Talupula, north and northeastern parts of the Gooty, western and northwestern parts of Yadiki, and major part of Chilamattur were observed under the same category of land degradation. This area is associated with moderate (0.4-0.5) to high (0.5-0.6) vegetation coverage, received rainfall with the range of <400 to 400-450mm, experienced by low (30-30oC and moderate (33-360C) temperature. Analysis of soil parameters shows that, majority of the area covered by loamy and clay soils with well to somewhat excessive soil drainage, and the soil affected by slight alkalinity. The terrain of the area is characterized by a moderate slope (8-15 per cent) and moderately steep slope (>30 percent).

More than half of the district under highly vulnerable to land degradation particularly western, northern, northeastern, eastern, central, and some pockets of the south. D. Hairebal, Vidapanakal, a major part of the Gundakal, Vajrakarur, Uravakonda, Rayadurgam, Gummagatta, Brahmasamudram, Settur, Kalyandurg,Tadipatri, Kanaganapalli, Rapatadu, Kambadu, Ramagiri,Bhatalapalli, Yellanur, Amarapuram, Tadipatri, Chennekothapalli, and Peddavadugura are the major mondals which are highly vulnerable to land degradation in Anantapuramu district. It distributed about 1175.33 thousand hectares (61.31 percent). This part of the district associated with less (<3) to moderate (0.4-0.5) vegetation coverage, scanty rainfall (400mm), high temperature (33-360C, >39oC), sandy and loamy soils with unfavorable soil reaction (moderately alkaline). Apart from that, the area is associated with somewhat excessive to excessive soil drainages. Severely vulnerable areas are occupied about 231.13 thousand hectares, it accounts for 12.06 percent of the TGA. Such degraded lands are distributed in some part of the center, some parts in the north, east, south, and southeastern parts of the district especially in mandals like Atmakur, Garladinne, Singanamala, Kudair, Ananatapur, Pamidi,Gundakal, Narpala, Mudigubba, Nallamada, O.D Cheruvu, Gudibanda, and Amadagur. This area usually associated with very less (<03) and less vegetation (0.3-0.4), actuate rainfall (<400 to 400-450 mm). Due to high rainfall variability, this part of the district is affected by maximum temperature (36-39oC to >39oC). Moreover, the area mainly covered by loamy soil with shallow depth, and it easily susceptibility to erosion. When considered soil reaction the area characterized by moderately alkaline soil and well to excessive soil drainage. (Table 2).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SI.No | Class | Area (000’ha) |  | Area (Per cent) |
| 1 | Low Vulnerable | 40.06 |  | 2.09 |
| 2 | Moderately Vulnerable | 435.85 |  | 22.74 |
| 3 | Highly Vulnerable | 1175.33 |  | 61.31 |
| 4 | Severely Vulnerable | 231.13 |  | 12.06 |
|  | Waterbody | 34.62 |  | 1.81 |
| Total 1917 | | |  | **100** |

Table 2. Vulnerability to land degradation in Anantapuramu district (2000-2016)

**CONCLUSIONS**

In the present study, mainly used satellite and ancillary datasets to analyses the vulnerability to land degradation over the 17 years by investigating the impact of climate, vegetation, terrain, and soil on vulnerability to land degradation. The study demonstrated the importance of remote sensing and GIS techniques in the assessment and mapping of land degradation vulnerability. The analysis shows that in Anantapuramu district, subjected to considerable land degradation, and the degree of land degradation vulnerability level of the district was categorized into four, namely low, moderate, high, and severe. About 231.13 thousand hectares (12.06 percent) of the TGA occupied under severely vulnerable while Highly degraded areas spread about 1175.33 thousand hectares (61.31 percent). Whereas only 2.09 percent of the TGA under low vulnerable to land degradation.

**REFERENCES**

AbdelRahman, M.A.E., Natarajan, A., Hegde, R., & Prakash, S.S., 2019. Assessment of land degradation using comprehensive geostatistical approach and remote sensing data in GIS-model builder. The Egyptian Journal of Remote Sensing and Space Sciences, 22, pp.323–334.

Amiri, F., Rahdari, V., Najafabadi, S.M., Pradhan, B., & Tabatabaei, T., 2014. Multitemporal landsat images based on eco-environmental change analysis in and around Chah Nimeh reservoir, Balochestan (Iran). Environmental. Earth Science, 72 (3), pp. 801–809.

Barbero-Sierra, C., Marques, M. J., Ruiz-Pérez, M., Escadafal, R., & Exbrayat, W., 2015: How is desertification research addressed in Spain? Land versus soil approaches. Land Degradation and Development, 26, pp. 423–432.

Da Silva, R. M., Santos, C. A. G., Araujo Maranhao, K. U., Medeiros Silva, A., & Porto de Lima, V. R., 2018. Geospatial assessment of eco-environmental changes in desertification area of the Brazilian semi-arid region. Earth Sciences Research Journal, 22(3), pp 175-186.

Han, W., Liu, G., Su, X., Wu, X., & Chen, L., 2019. Assessment of potential land degradation and recommendations for management in the south subtropical region, Southwest China. Land Degradation and Development, 30, pp. 979–990.

ICAR (Indian Council of Agricultural Research): State of Indian Agriculture, 2012–2013, A report of Department of Agriculture and Cooperation, New Delhi, 9, 2010.

Kumar, P.B., Babu, R.K, Rajasekhar, M., Ramachandra, M.,2019. Assessment of land degradation and desertifcation due to migration of sand and sand dunes in Beluguppa Mandal of Anantapur district (AP, India), using remote sensing and GIS techniques. Journal of Indian Geophysical Union ,23(2), pp.173–180.

 Kumar, P.B., Babu, R.K., Rajasekhar, M., & Ramachandra, M., (2020). Identification of land degradation hotspots in semiarid region of Anantapur district, Southern India, using geospatial modeling approaches. Modeling Earth Systems and Environment, **6**, pp.1841–1852.

Prakash, S., Sharma,M.C., Kumar, R., Dinwa, P.S., sastry, K.L.N., & Rajwat, A.S.,2016.Mapping and assessing land degradation vulnerability in Kangra district using physical and socio-economic indicators.Spatial Information Research.24, pp. 733-744.

Reddy, G.P.O., 2018. Spatial data management, analysis, and modelling in GIS: Principles and Applications. Springer, edited by Reddy, G.P.O., Singh S.K., Geospatial technologies in land resources mapping, monitoring and management. Geotechnologies and the environment Cham Switzerland, 21, pp.127-142.

Reddy, G.P.O., Kumar, N., Sahu, N., Srivastava, R., et al., 2020. Assessment of spatio-temporal vegetation dynamics in tropical arid ecosystem of India using MODIS time-series vegetation indices. Arabian Journal of Geosciences,13, pp704.

Savitzky, A., & Golay, M.J.E., 1964. Smoothing and differentiation of data by Simplified Least-Squares Procedures. Analy. Chem. 36, pp.1627-1639.

Vicente-Serrano, S.M., Zouber, A., Lasanta, T., Pueyo, Y., 2012. Dryness is accelerating degradation of vulnerable shrublands in semiarid Mediterranean environments. Ecological Monograps, 82, pp. 407–428.