Agricultural Drought Assessment of K.V. Palli Mandal Using Remote Sensing

Hemalatha T[1]

[1] Assistant Professor, Department of Civil Engineering, S.V. University College of Engineering, Tirupati- 517502, Andhra Pradesh, India. Email Id: thoti.latha@gmail.com

Abstract: Mapping of the extreme events (droughts) is one of the important strategies for consequences of increasing climatic inconsistency and climate alterations. It is one of the short-term extreme events. There is no operational practice to forecast the drought. One of the suggestions is to update mapping of drought prone areas for developmental planning. Drought indices play a significant role in drought mitigation. The main objective of the present study is to try to understand the biophysical aspects of agricultural vulnerability using the modern methods of remote sensing and GIS. Agricultural vulnerability is determined based on Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI). SPI values of rain gauge stations are interpolated to determine the spatial pattern and threshold value of drought for agricultural vulnerability. Anomaly of the NDVI and NDWI were classified to determine the agricultural drought vulnerability. These maps were integrated to classify the agricultural vulnerability of present study area namely K.V.Palli mandal of Chittoor district. The resultant map shows the spatial distribution of the areas facing agricultural drought conditions. The agricultural vulnerability map will help in the preparation of the area for mitigation measures that will in turn reduce the impacts of climatic variation on agriculture.

Keywords: Remote sensing and GIS, Standardized Precipitation Index (SPI), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI).

I. INTRODUCTION

Drought is a very less understood and complex phenomenon. It is a natural hazard as a result of an extreme event due to prolonged insufficiency in water availability. The causes for this phenomenon to occur may be sub-normal rainfall, uneven rainfall distribution, greater requirement of water than availability or the combinations of all the three. As a result, the demand on water resources increases which can lead to inconsistency in supply to users. These can create conflicts among the various competitors which is most definite throughout severe droughts. Incorrect estimation of drought might have serious consequences for ecology and economy as well. The damage caused by drought is not specific in global domain. It is slow and gradual process due to which the degree of this particular calamity varies from place to place.

1.2 Significance of Agriculture

Agriculture for decades had been associated with the production of basic food crops. agriculture and farming were synonymous so long as farming was not commercialized. Agriculture plays a crucial role in the life of economy, it is the backbone of our economic system. Agriculture not only provides food and raw materials but also employment opportunities to a very larger proportion of population. About 70 percent of our population is directly engaged in agriculture. Thus, the agriculture is a source of livelihood. Agriculture is the premier source of our nation's income. According to National Income Committee and C.S.O., in 2001-02, it contributed around 32.4 percent of national income.

1.3 Drought Definitions

The drought has no precise definition. Diversified hydro-meteorological variables, socioeconomic factors and different water demands in different regions have kept researchers away from compiling/modifying any precise definition of drought. The definition of drought which is good enough for one field does not help its implementation in another field. However, some broad definitions are sited below:

(i) The World Meteorological Organization (WMO, 1986) describes "drought means a sustained, extended deficiency in precipitation."

(ii) The UN Convention to Combat Drought and Desertification (UN Secretariat General 1994) defines "drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems."

(iii) The Food and Agriculture Organization (FAO, 1983) of the United Nations defines a drought as a hazard, "the percentage of years when crops fail from the lack of moisture."

(iv) The encyclopedia of climate and weather (Schneider, 1996) defines a drought as "an extended period – a season, a year, or several years – of deficient rainfall relative to the statistical multi- year mean for a region."

(v) Linsley et al., (1959) defined "drought as a sustained period of time without significant rainfall."

1.4 Types of Drought and Impact Of Droughts

The droughts are broadly classified in three categories. They are Meteorological drought, Hydrological drought and Agricultural drought. Any one of these categories or combinations of these could generate a fourth category of drought called as Socio economic drought.

1.4.1 Meteorological Drought

The occurrence of any category of drought is considered to be started with the deficiency in precipitation. Whenever the actual rainfall over a region is less than 75% of the long term climatological mean, the resulting drought is known as Meteorological drought. This category is estimated as a region specific matter because the occurrence of precipitation highly varies from region to region.

1.4.2 Hydrological Drought

The occurrence of Hydrological drought is noticeable from the available water in the surface water resources due to reduced precipitation events or quantity. (Hisdal and Tallaksen, 2003) showed in their study that Hydrological droughts are often lagged compared to Meteorological droughts. Hydrological drought occurs when there is marked depletion of surface water causing very low stream flow and drying of lakes, reservoirs, rivers etc.

1.4.3 Agricultural Drought

The deficiency of water from either meteorological or hydrological sources lessens the irrigation water for crop production. This water is supposed to be stored in soil as soil moisture which is ultimately affected as well. As a result, scarce soil moisture leads to Agricultural drought occurrence due to serious crop stress and affects the crop productivity.

Hence, Agricultural drought refers to a period with declining soil moisture content and consequent crop failure.

1.4.4 Socio-Economic Drought

Socio-economic drought is associated with failure of water resources systems to meet water demands and thus associating droughts with supply of and demand for an economic good

It occurs when the demand for an economic good passes ahead of its supply due to weather related deficit in water supply. It can result from either of the three categories discussed above or their combined effects for an extended term.

II OBJECTIVES

The main objective of the present study is to make an attempt to understand the biophysical aspects of agricultural vulnerability in pallar basin

- The Standard Precipitation Index (SPI) for pallar basin is calculated for the years (2010 – 2019)
- NDVI is calculated for the pallar basin for the years 2010 – 2019 by using ARC GIS
- NDWI is calculated for the pallar basin for the years 2010 – 2019 by using ARC GIS
- Based on these indices SPI , NDVI , NDWI agricultural drought for the pallar basin was determined

III LITERATURE REVIEW

3.1 Hydrological Drought Indices

The Hydrological drought indices have been developed for the applications in the hydrological domain. They are generally the indices pointing towards low flow in streams. It is important to analyze the data from stream flow from various gauging stations to estimate he Hydrological drought indices values. This category of drought indices serves their usefulness in the irrigation water estimation (Tallaksen and Lanen, 2004).

The Palmer Hydrological drought index and Surface Water Supply Index are the best known drought indices in this category. Another popular Hydrological index Reclamation Drought Index.

The "Palmer Hydrological drought Index" (PHDI) (Palmer, 1965) is derived from PDSI. The difference between PDSI and PHDI is that the criteria for discarding or accepting of drought spells and wet spells are stringently defined in case of PHDI. The end of drought is decided by PDSI when moisture begins to rise but PHDI considers the complete disappearance of moisture deficit. As the meteorological phenomenon is faster than the hydrological phenomenon, the retarding criterion in PHDI discussed above is reasonable for a Hydrological drought index. The PHDI have also the scope to work on real time as well irrespective of the nature of PDSI, which can only work for past records.

The "Surface Water Supply Index" (SWSI) (Shafer and Dezman, 1982) is developed from the concept of water balance in a watershed. Its main motive is to quantify the processes producing discharge. It is particularly used for management purposes. The SWSI calculation also commits to the involvement of snow accumulation which is an improvement over PHDI.

Hence, it can be used in the snow covered areas also. It can also be taken to the standards of PDSI for the purpose of comparisons by certain techniques described by Garen (1992). The best suitable area of this particular Hydrological drought index to work out is the mountainous regions.

3.2 Agricultural Drought Indices

The agriculture is a very crucial sector for the well existence of the socio-economic situations. Drought is a potential threat with a destructive damage to agricultural production. The necessity of a drought index specialized for agriculture led to development of various indices with explicit characteristics for Agricultural drought assessment. They included indices based on the theories of rainfall, soil moisture, actual and potential evapotranspiration and many other factors. Some of the Agricultural drought indices are Moisture Adequacy Index, Crop Moisture Index, Crop Specific Drought Index, soil moisture and Evapotranspiration Deficit Indices.

The "Moisture Adequacy Index" (MAI) (McGuire and Palmer, 1957) is the basic Agricultural drought index to implement the concept of potential evapotranspiration. It compares a location's moisture need to the actual moisture supply. Hence, the idea behind development of MAI was, to address the understanding of moisture adequacy. The return outcome from MAI is easy to understand and utilize. MAI returns percentage value, signifying supply sufficiency to need. At 100% the supply of moisture meets the requirement.

The "Crop Moisture Index" (CMI) (Palmer, 1968) is developed from PDSI as per the specific requirement of drought assessment in agriculture. This drought index also looks at evapotranspiration and soil moisture recharge rather than only rainfall deficits, making it better than MAI. It is designed with considerations of short term crop moisture needs at weekly time scale. Wilhite and Glantz (1985) identified CMI as an indicator of availability of moisture to meet agricultural crop needs.

The "Soil moisture Deficit and Evapotranspiration Deficit Indices" (SMDI & ETDI) (Narasimhan and Srinivasan, 2005) are two recently developed Agricultural drought indices. These indices reflect short-term dry conditions, thus respond to Agricultural drought. The SMDI and ETDI have no any seasonality (i.e., the indices are able to indicate a drought irrespective of season. Both of the drought indices are spatially comparable, irrespective of climatic zones. The time scale of SMDI and ETDI is flexible at least to weekly scale. It can be extended to more by addition of weekly values on incremental basis. The SMDI is depends on weekly soil moisture whereas the ETDI uses potential and actual evapotranspiration to calculate water stress ratio as indicator.

3.3 Satellite Derived Drought Indicies

The various remotely sensed data serves as input for the various methods, which are used for the identification, monitoring and assessment of the drought. It is facilitated by several satellite based indices like (NDVI, VCI, SVI, NDWI, CWSI, TCI, VHI, TVDI) in Visible, Near Infrared and Thermal Infrared and Microwave regions, to target and analyze the concerned areas.

Among these, the NDVI is one of the most popular and globally accepted remote sensing indices for Agricultural drought.

The "**Normalized Difference Vegetation Index**" (NDVI) (Tucker, 1979) is the most prominent vegetation index derived from remote sensing data to be used in identification and monitoring of vegetation. The first most application of NDVI in drought monitoring is demonstrated by Tucker and Choudhury (1987). The formulation of NDVI is:

$$NDVI = (NIR - Red) / (NIR + Red)$$

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Where, NIR is the reflectance in Near Infrared band, Red is the reflectance in Red band The NDVI Ranges between (-1 to +1) with positive values for vegetation and negative values for non-vegetative areas. The NDVI is not only used in its primary form but also used in several other forms to relate with the phenology of the vegetation cover (Chen et al., 2001; Lee et al.,2002; Stockli and Vidale, 2004; Hermance et al., 2007).
The NDVI is a foundation for derivation of various other advanced Remote sensing indices.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

The "**Normalized difference water index**" (NDWI) (Gao, 1996) is another advanced remotesensing derived index which follows a completely different theory from that of the NDVI. The bands from which it is formulated are near infrared and short-wave infrared bands.
NDWI= [(NIR – SWIR) / (NIR + SWIR)]
NIR and SWIR are the reflectance from near infrared and short-wave infrared bands. NDWI is sensitive to water content of vegetation canopy. It is often useful for interpretation of drought assessment with focus on moisture content in vegetation. According to a study done at Rajasthan by Chakraborty and Sehgal (2010), real time MODIS data implementing NDWI can be functional for Agricultural drought detection and monitoring at a regional extent and can be better than NDVI. After the introduction of NDWI, drought studies have taken a diversion regarding approaches for identification and monitoring of drought.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

IV STUDY AREA

4.1 Location and Geography

The study area falls under Palar sub-basin. The area was delineated from India water Resources Information System C18PAL41. It covers major part in Chittoor district, Andhra Pradesh.

Geographical Details of Study Area

Latitude	13 20’ to 13 50’ N
Longitude	79 5’ to 79 30’ N
Total Area	655 km^2
Monsoon period Non monsoon period	June to December June to September and October to December January to may
Climate	Semi-arid
Average monthly temperature	Maximum is 36.7 C and maximum is 24.4 C
Average relative humidity	55%

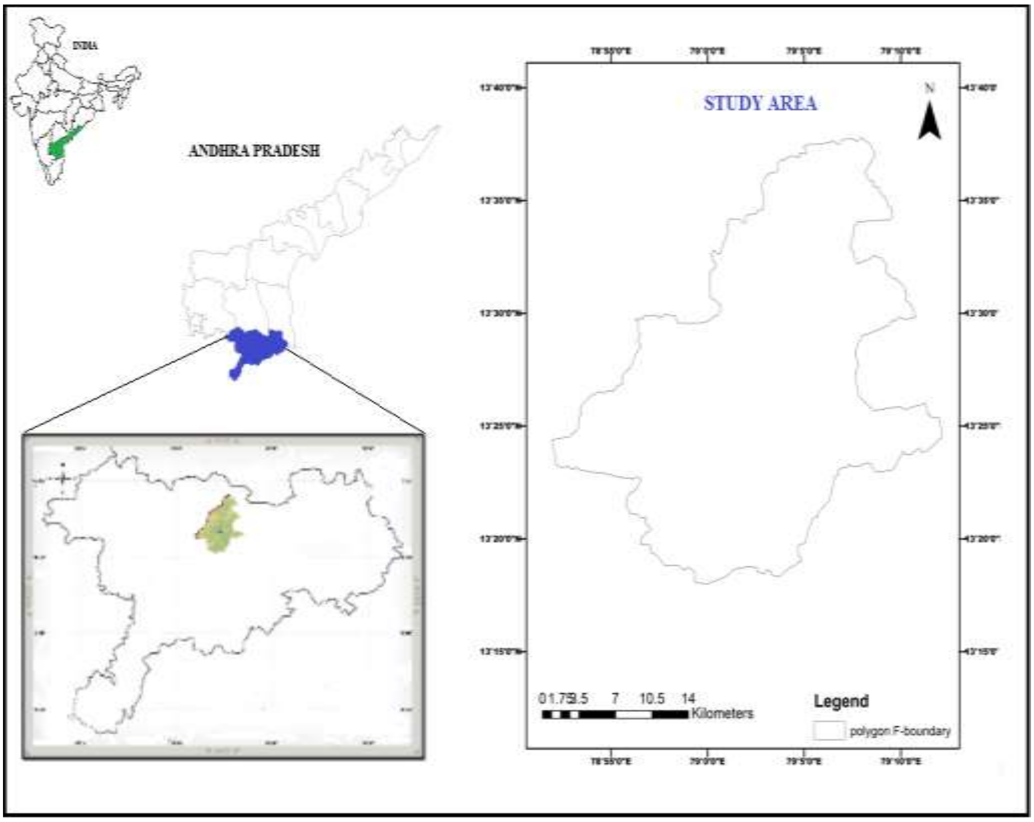

Figure 1: Study area of Pallar basin

4.2 Geology

The Chittoor District forms with part of Indian Peninsular Gneiss, which has remained stable since formation of the crust. They are exposed in the most of the district.

The region of the subject area is belonging to Peninsular Gneiss of Archean group. The Peninsular Gnessic Complex comprising migmatite gneiss, grey granodiorite, porphyritic granite and intruded by dolerite and aplite veins. The Peninsular Gneissic Complex comprises of gneiss – migmatite – granite suite of rocks. They are highly variable in mineralogical composition appearance structure and relative ages. The individual members have not been distinguished in a major part of the area. However, granite and migmatite gneiss occupy a large part of the area while bands of relatively younger coarse – grained gneissic granite occur in the north eastern part.

4.3 Climate

The Chittoor lies on 309m above sea level This city has a tropical climate. The summers are much rainier than the winters in Chittoor. This climate is considered to be Aw according to the Köppen-Geiger climate classification. The average annual temperature in Chittoor is 27.4 °C | 81.4 °F. The annual rainfall is 862 mm | 33.9 inch**.**

4.4 Population

In 2011, Chittoor had population of 4,174,064 of which male and female were 2,090,204 and 2,083,860 respectively. In 2001 census, Chittoor had a population of 3,745,875 of which males were 1,889,690 and remaining 1,856,185 were females. Chittoor District population constituted 4.94 percent of total Maharashtra population.

V METHODOLOGY

5.1 Study Area Delineation

Delineation is a part of the process known as watershed segmentation, i.e., dividing the watershed into discrete land and channel segments to analyze watershed behavior.

Delineation is used to define boundaries of the study area, and to divide the study area into sub-areas. Delineation can be adopted using two methods.

1. Automatic Delineation :

Automatic delineation is based on DEM and NED grids. Boundaries are created automatically by computer.

2.Manual Delineation :

Manual delineation is by drawing boundaries between watersheds manually. It requires underlying data for accuracy.

Delineation of area was achieved by following steps:

- Pallar basin maps were downloaded from IWRIS website.
- The downloaded map was Geo-referenced & projected using software ArcGIS.
- Study area region was marked manually and delineated from the geo-referenced map.
- A shape file of the delineated study area was created.

5.2 Standardized Precipitation Index

The entire flow diagram for this SPI calculation is demonstrated below

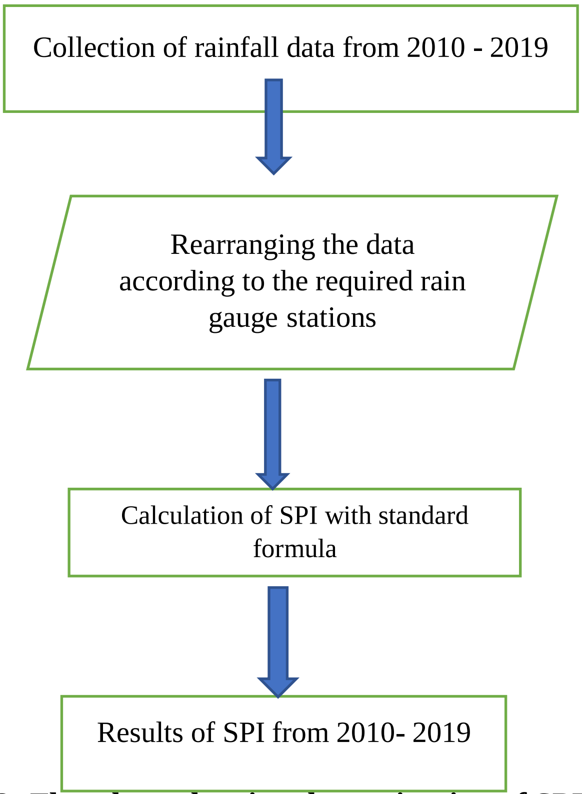

Figure 2: Flowchart showing determination of SPI Index

- Monthly rainfall data at the corresponding rain gauge stations was collected.
- Annual rainfall at each station was calculated, mean and standard deviation was calculated using spread sheets.
- SPI was calculated using the formula

SPI = Xi – X / σ

Where X : The mean annual rainfall

Xi : The Annual rainfall at any year

σ : Standard deviation

5.3 Normalised Difference Water Index

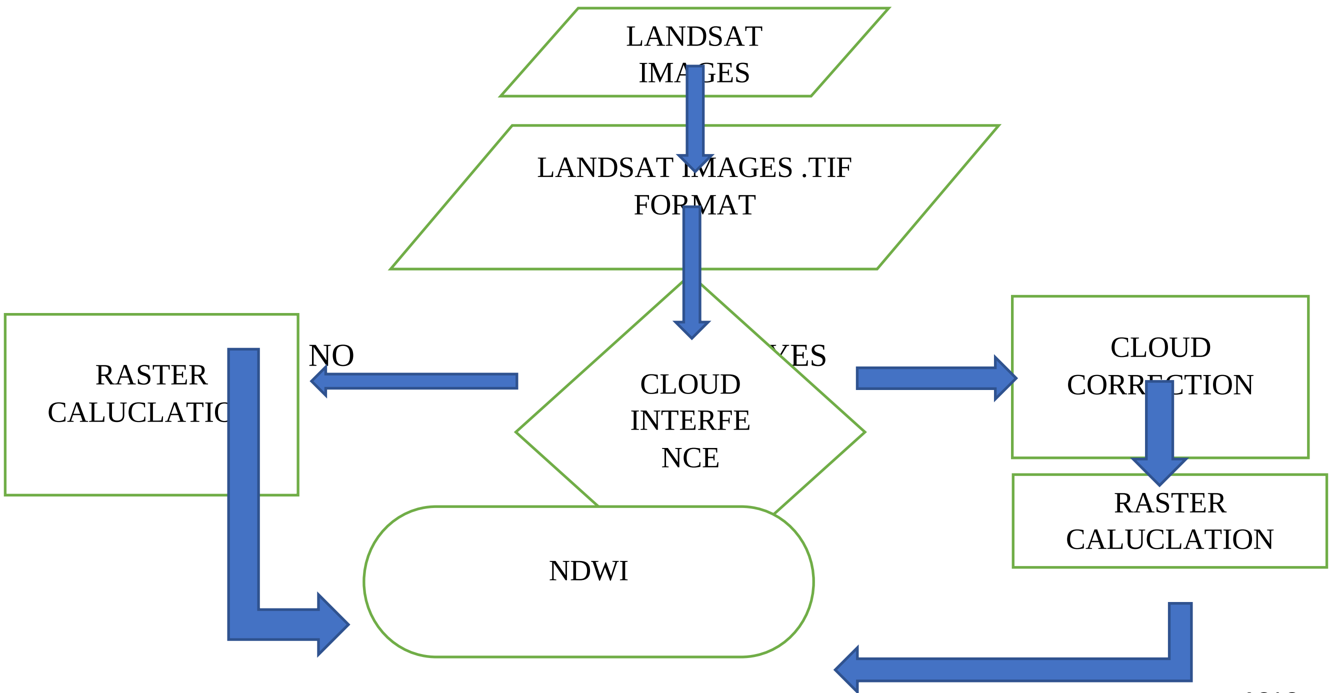

Figure 3 Flow chart for NDWI

NDWI calculation:

- MODIS images consisting from were downloaded.
- Corrections for cloud interference was applied to each band 4 (NIR, reflectance) band 5 (SWIR reflectance).

Cloud correction=

(band specific reflectance_multi values* DN values) + (band reflectance_add values)

- NDWI was calculated using the raster calculator function under spatial analysis tool.

NDWI= (band 4-band 5)/(band 4+band 5)

5.4 Normalised Difference Vegetation Index

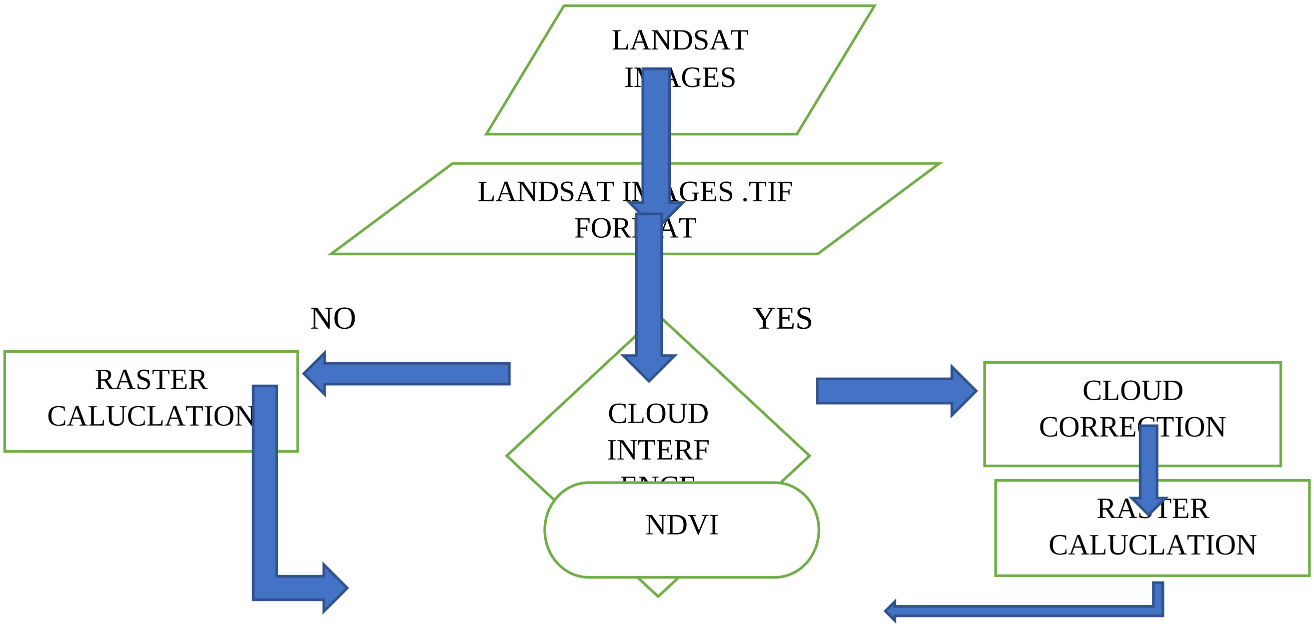

Figure 4: Flow chart for NDVI calculation

NDVI calculation:

- MODIS images consisting from were downloaded.
- Corrections for cloud interference was applied to each band 1 (RED reflectance) band 4 (NIR reflectance).

Cloud correction=

(band specific reflectance_multi values* DN values) + (band reflectance -add values)

- NDVI was calculated using the raster calculator function under spatial analysis tool.

NDVI= (band 4-band 1)/(band 4+band 1)

VI RESULTS AND DISCUSSIONS

6.1 Meteorological Drought in K.V. Palli Region

The following observations were notified in various meteorological stations spread in K.V.Palli. There are four meteorological observation stations spread in

K .V. Palli. Those are namely T.Sundupalli , Kambamvaripalli , Pileru, Kalakada. The average rainfall for 13 years of observations (2006-2019) is shown in the table , according to which the meteorological drought years have been categorised.

Table 1: SPI Index of K.V. Palli and Their Classification

Year	Annual Rainfall Data	SPI	Nature of Drought
2006-2007	2702.6	-0.779	Near Normal
2007-2008	4830	1.537	Very Wet*
2008-2009	2674.8	-0.809	Near Normal
2009-2010	2182.4	-1.345	Moderately Dry
2010-2011	4204.2	0.856	Near Normal
2011-2012	2860	-0.608	Near Normal
2012-2013	3417	0.001	Near Normal
2013-2014	3039.4	-0.412	Near Normal
2014-2015	2359.2	-1.152	Moderately Dry
2015-2016	3944.8	0.573	Near Normal
2016-2017	5371.15	2.126	Extremely Wet
2017-2018	3202	-0.235	Near Normal
2018-2019	3648.5	0.251	Near Normal
Average Rainfall Data	3418.12		
Standard Deviation	918.63		

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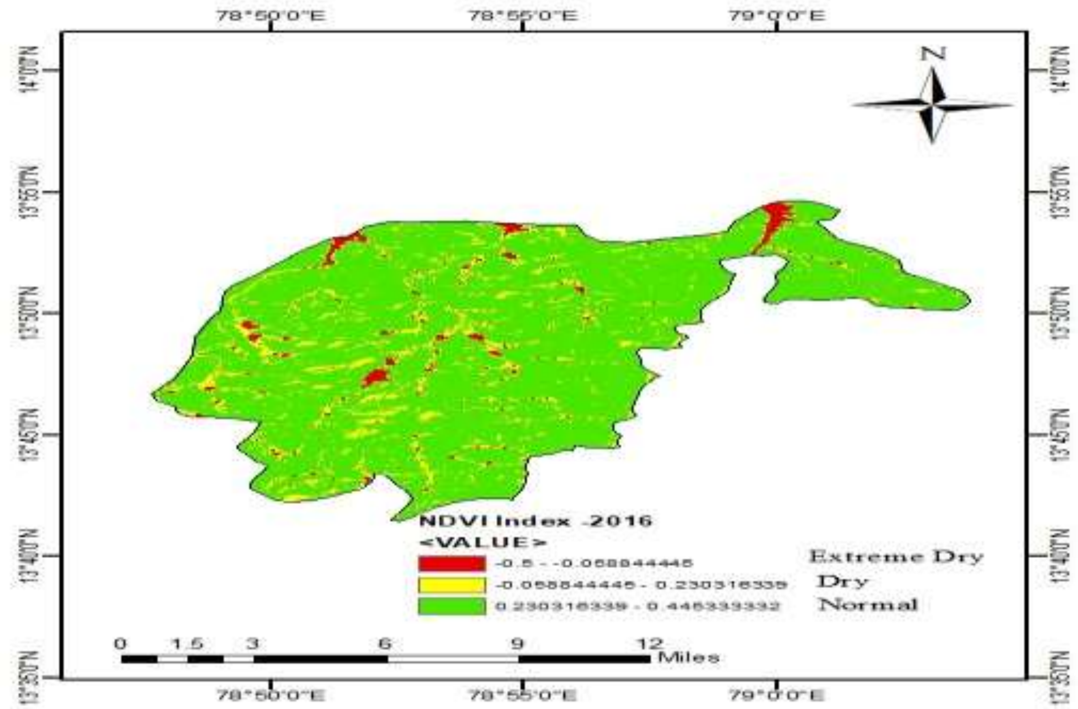

Figure 5 NDVI Index of the year 2016

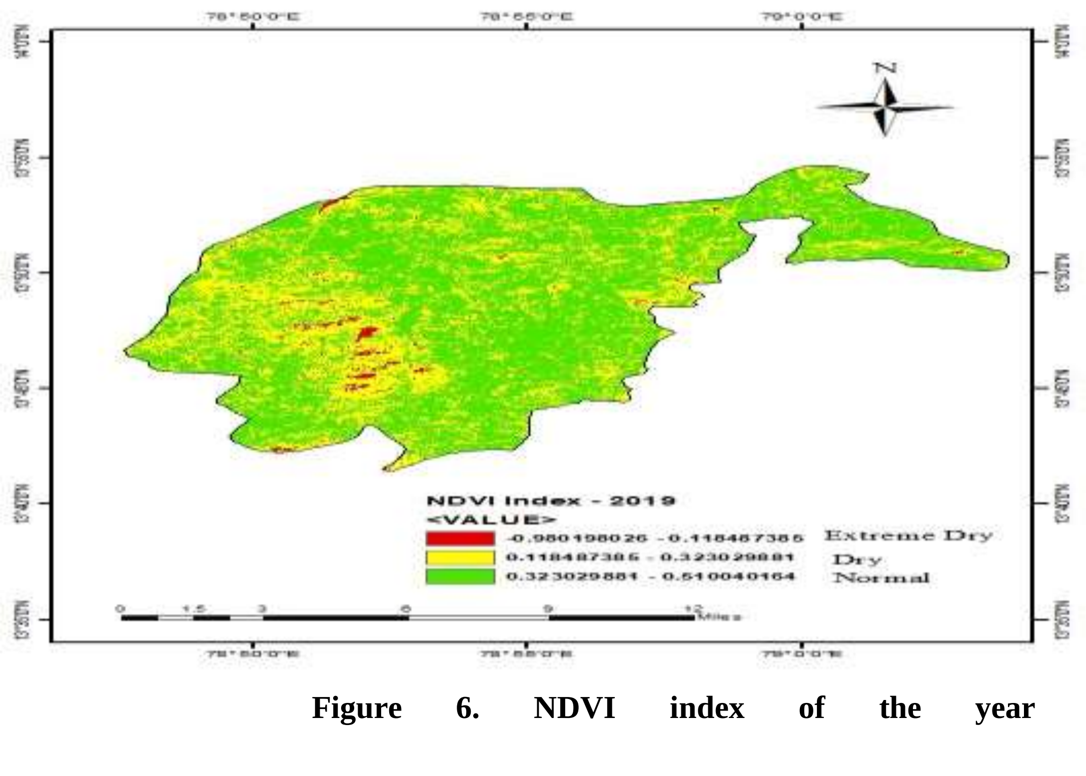

Figure 6. NDVI index of the year 2019

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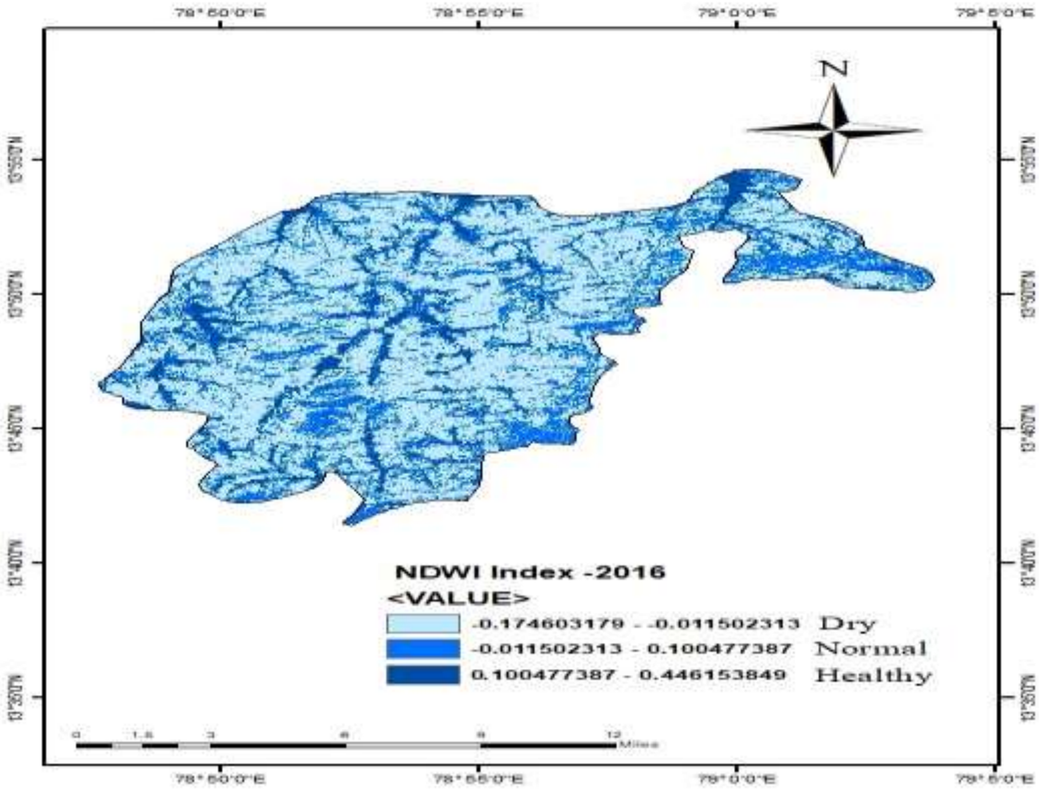

Figure 7 NDWI index of the year 2016

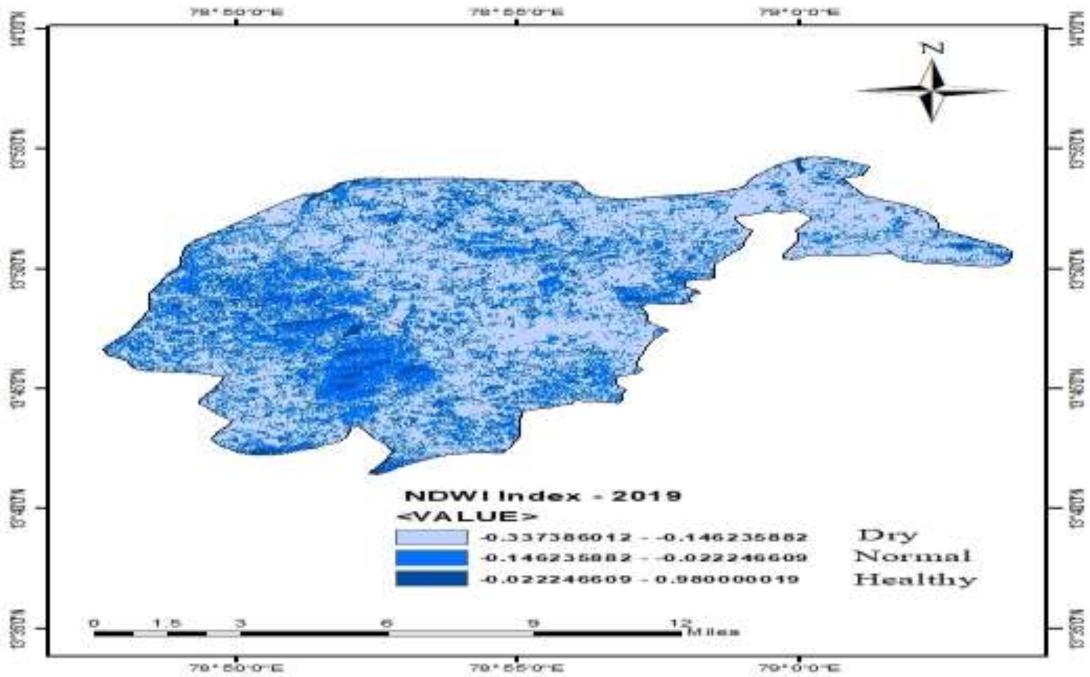

Figure 8 NDWI index of the year 2019

VII CONCLUSIONS AND FUTURE SCOPE

Drought assessment is very important in terms of planning and operation of water systems. At present there are several drought indices, modern tools such as remote sensing are available to assess and monitor the drought. In this investigation a detailed study of drought assessment has been carried out by using Standard Precipitation Index (SPI). A summary of the results of these studies are presented below.

Drought has been occurring in K.V. Palli mandal of Chittoor district for the past one century .It is essential to come out with the most appropriate techniques to assess the drought in a better way and to map mild , moderate , and severe droughts. From the present study , the following conclusions are drawn :

- Quantification of the drought for the period 2006 - 2019 reveals that the study area is affected by moderately dry for every 4 years.
- The frequency analysis carried out based on SPI reveals that K.V.Palli mandal of Chittoor district is mild drought prone area.
- Satellite data drought analysis is the most effective technique for spatial analysis and real time drought assessment. NDVI represented the drought conditions accurately.
- Normalized Difference Vegetation Index (NDVI) in 2016 shows that the percentage of dry area is less when compared to NDVI in 2019.
- Normalized Difference Water Index (NDWI) in 2016 shows that the percentage of dry area is less when compared to NDWI in 2019
- The year 2016 shows the normal wet year as per SPI, NDVI and NDWI index. Whereas the year 2019 shows dry year as per SPI, NDVI and NDWI index.

However integrated approach using SPI, NDVI and NDWI is suggested for Assessment of drought conditions taking place in K.V. Palli mandal of Chittoor district.

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