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Mapping of Temporal Variation of Drought using Geospatial Techniques

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Abstract - *A drought is 'a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield'. Drought always starts with the lack of precipitation, but may affect soil moisture, streams, groundwater, ecosystems and human beings. This leads to the identification of different types of droughts (meteorological, agricultural, hydrological, socio-economic), which reflect the perspectives of different sectors on water shortages. Geographic Information System (GIS) and Remote Sensing play an important role for near real time monitoring of drought condition over large areas. This study shows temporal variation of drought using temporal image of MODIS NDVI based Enhanced vegetation index (EVI), Vegetation health index (VHI), standard precipitation index (SPI) and Drought severity index (DSI) using software's like Arc-GIS, Google Earth Engine coder, RStudio, SWMM*

Key Words: **Drought, Geographic Information system, EVI, VHI, SPI, DSI.**

1. INTRODUCTION

The economy of India is dependent upon agriculture sector. Thus, agriculture can be called as a backbone of India. Drought is an insidious hazard of nature which is considered by many to be the most complex but least understood of all natural hazards. Large historical datasets are required in order to study drought which involves complex inter-relationship between the climatological and meteorological data. The way to advance in any field is to gain the knowledge of the advanced technology. Remote sensing and Geographical Information System are ways to enhance in the monitoring vegetation, determination of land changes and planning work. The satellite imagery is used for yield and production forecasting, green cover inventory and assessment of drought like catastrophe. By studying the temporal and spatial variations in the vegetative structure, monitoring and analysis can be performed. Vegetation indices are widely used in this field. There are numerous indices in use to study the changing pattern of the vegetation. These indices are the indicators of health and greenness of vegetation and a measure of density. To compute the vegetation indices the band combination is used which mainly comprises of red, green and infrared spectral bands.

One of the most widely used index is Normalized Difference Vegetation Index (NDVI) to monitor vegetation stress. Normalized Difference Vegetation Index (NDVI) converts multi spectral data into single image band which displays vegetation distribution. To quantify the healthy green vegetation based on satellite images, NDVI a graphical indicator makes use of the differential reflection of green vegetation in the visible and near infrared-portions (NIR) portion of the spectrum thus providing condition of the vegetation. The value of NDVI ranges from -1 to +1, value leaning towards +1 denoting healthier vegetation. But enhanced vegetation index (EVI) offers better results and is easy to understand the vegetation change.

Further, the remotely sensed data from satellite is used to analyze the drought risk and has become widespread these days. The way to mitigate drought effectively is to monitor such risk in advance with the help of remote sensing technology. Drought indices have been developed which comprises of spatial extent of vegetation, duration, intensity of meteorological factors. Although there are many new indices that are theoretically more reliable than the NDVI (such as soil-adjusted, transformed soil adjusted, atmospherically resistant, and global environment monitoring indices), they are not yet widely used with satellite data. Among these indices, Enhanced vegetation index (EVI), Vegetation health index (VHI) with land surface temperature (LST) delivers a strong correlation thus providing information about all types of droughts beforehand.

This study aims to examine the variation of drought over the Yavatmal District (Maharashtra, India) using temporal image of MODIS NDVI based Enhanced vegetation index (EVI), Vegetation health index (VHI), standard precipitation index (SPI) and Drought severity index (DSI) using software's like Arc-GIS, Google Earth Engine coder, RStudio, SWMM. The use of Landsat dataset for examination of these indices is made and is explained in the methodology section.

2. STUDY AREA, DATA & METHODOLOGY

2.1 Study Area

Yavatmal district lies in the Southwestern part of the Wardha-Penganga-Wainganga plain. The district lies

between 19°26'and 20°42' north latitudes and 77°18'and 79°90' east longitudes. It is surrounded by Amravati and Wardha district in the north, Chandrapur district in the east, State of Telangana and Nanded district in the south and Parbhani and Akola district in the west. The district has an area of 13,52,000 hectares which is 4.41% of the total area of Maharashtra and a population of 20,77,144 which is 2.63% of the state's population

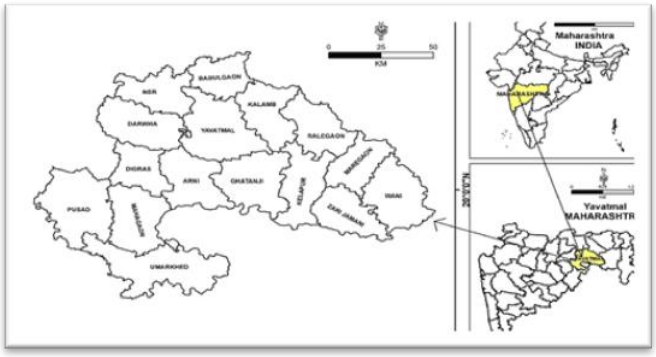

Fig -1: Study Area – Yavatmal District

2.2 Data Used

Sample Ground water data collected from Central Ground Water Board, India (cgwb.gov.in/) Ground Water Yearbook Of Maharashtra (2020- 2021), Population data collected from Yavatmal District Municipal Corporation (yavatmal.gov.in/census) , Advanced Spaceborne Thermal Emission and Reflection Radiometer (**asterDEM**) was downloaded from Nasa earth data website (asterweb.jpl.nasa.gov/gdem.asp), NDVI data (modis.gsfc.nasa.gov/) , bhuvan-app3.nrsc.gov.in, LULC, Soil Fertility, Socio-economic condition, surface runoff maps and all general data from Yavatmal District Municipal Corporation. Rainfall data over Yavatmal District is downloaded from mahavedh .

2.3 Methodology

2.3.1 Water Availability Analysis

Rainfall in Yavatmal District Ranges from 750-1150 mm and annual Average Rainfall is 886.4 mm, therefore total avg. rainfall in district = 0.8864m X 13520 X 10^6 m^2 = 11984.128 Mm^3 / year

Ground water availability in Pre monsoon (2019-20) is 1.00 to 16.60 m bgl (Fall: 0.01 to 0.93 m), Post monsoon Depth of Water Level (2019-20) is 0.90 to 15.20 m bgl (Fall: 0.009 to 0.91 m). Total draft (Irrigation + Domestic): 421.02 MCM. Projected Demand (Domestic + Industrial): 114.78 MCM. Stage of Ground Water Development: 29.85 %

Net annual ground water availability: 1410.45 MCM

According to CGWB, **78.4%** of the districts domestic and agriculture water requirement is met from groundwater sources, and the remaining **21.6%** is met by surface water sources. Total Water requirement of District is only **14.267 %** of Total rainfall available. But Most of the district water demand is fulfilled by Ground Water Sources. Which are already 5- 16.2 m bellow the Ground level and depleting day by day.

2.3.2 Calculation of monthly mean rainfall over the district

Monthly mean of 30-year rainfall from year 1990 to 2020 is calculated by google earth engine coder using CHIRPS pentad dataset to analyze the monthly behavior of rainfall in each ongoing month.

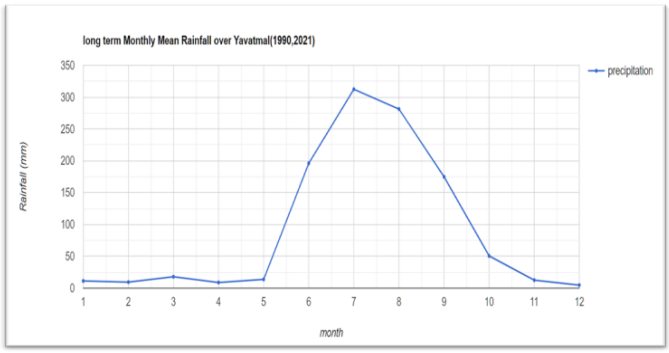

Chart -1: Monthly Mean Rainfall over Yavatmal District

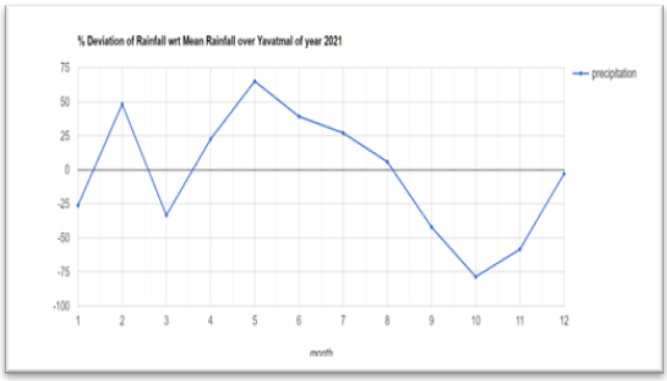

Chart -2: % deviation of Rainfall wrt Mean rainfall over Yavatmal district of year 2021

From above calculation if the percent deviation of rainfall is positive in rainy season from Jun-Sept then there is less probability of drought in following year and if it is negative there will be more probability of drought condition in following year.

2.3.3 Calculation of SPI

The Standardized Precipitation Index (SPI) is an index used for measuring drought and is based only on precipitation. This index is negative for drought and positive

for wet conditions. As the dry and wet conditions become more severe the index become more positive or negative. Here SPI over Yavatmal District is calculated using RStudio Software by using the datasets of daily rainfall from year 1981- 2021provided by mahavedh.

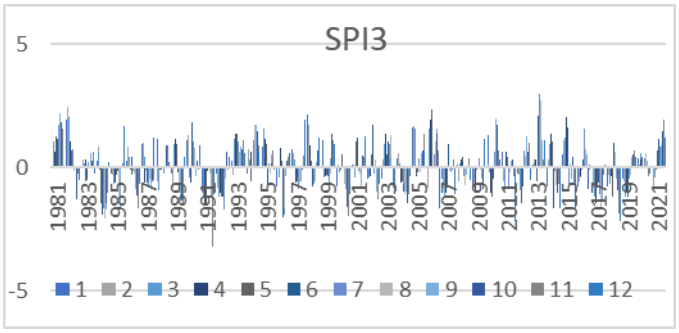

Chart -3: SPI3 over Yavatmal District

2.3.4 Calculation of EVI

Enhanced Vegetation Index (EVI) is like Normalized Difference Vegetation Index (NDVI) and can be used to quantify vegetation greenness. However, EVI corrects for some atmospheric conditions and canopy background noise. EVI has a value range of –1 to +1. Drought condition occurs when EVI is less than 0.2. Here EVI over Yavatmal District is calculated using Google Earth Engine Coder Software by using the datasets of MODIS EVI from year 2001- 2022 provided by united states geological survey.

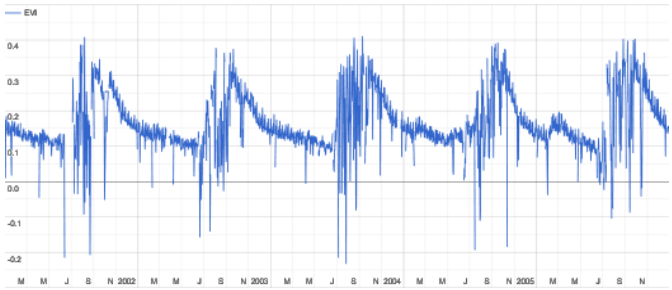

Chart -4: EVI over Yavatmal District 2001-2005

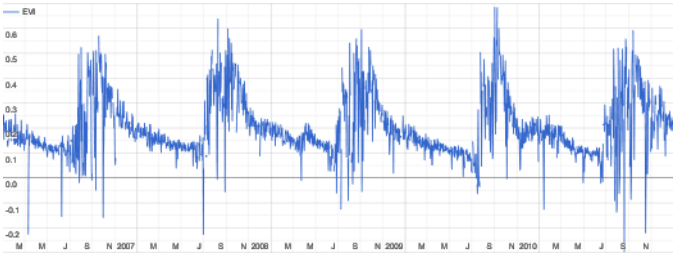

Chart -5: EVI over Yavatmal District 2006-2010

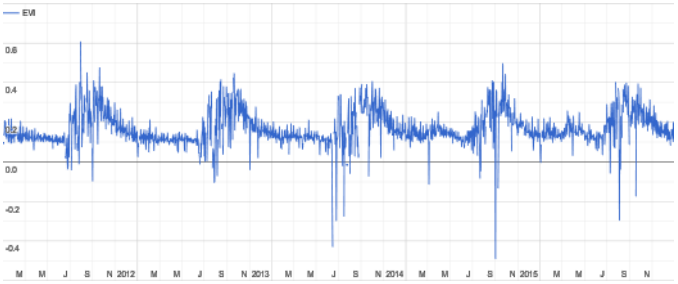

Chart -6: EVI over Yavatmal District 2011-2015

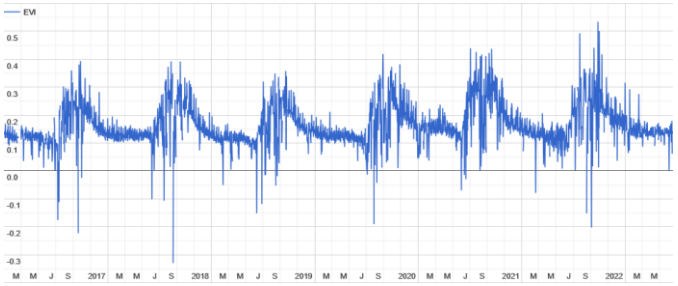

Chart -7: EVI over Yavatmal District 2016-2022

2.3.4 Calculation of VHI

The vegetation health index (VHI) is one of the most popular satellite-based indices used for drought monitoring. The VHI was developed for vegetation drought detection and is defined by two components: the Vegetation Condition Index (VCI) and the Thermal Condition Index (TCI). By using VHI we can direct predict vegetation health by doing some band color correction in ArcGIS. Here VHI over Yavatmal District is calculated using Google Earth Engine Coder Software by using the datasets of MODIS EVI from year 2001-2022 provided by united states geological survey.

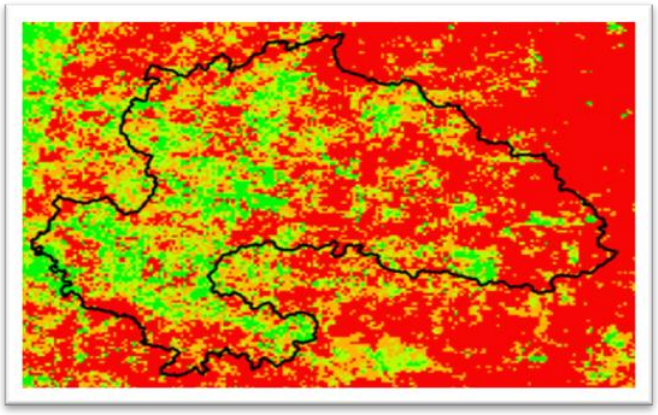

Fig -2: VHI over Yavatmal District 2003 Drought

2.3.4 Calculation of SSM

Surface Soil Moisture (SSM) is the relative water content of the top few centimeters soil (0 to 20 cm), describing how wet or dry the soil is in its topmost layer. It is

measured by SMAP satellite radar sensors and allows insights in local precipitation impacts and soil conditions. It indirectly measures the agricultural drought i.e. water available in root zone.

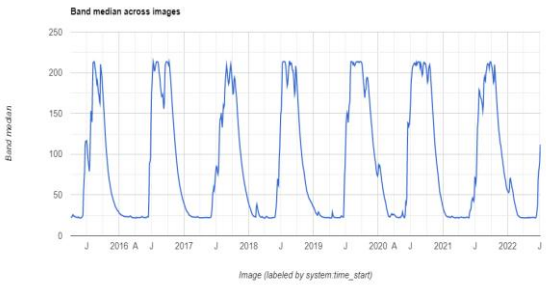

Chart -8: SSM over Yavatmal District 2015-2022

2.3.4 Calculation of DSI

year	avg rainfall	annual mean	deviation	DSI
1984	590.62	959.98	-38.476	M2
2017	653.91	959.98	-31.883	M2
1991	659.18	959.98	-31.334	M2
2004	690.82	959.98	-28.038	M2
2000	733.01	959.98	-23.643	M1
1989	748.83	959.98	-21.995	M1
1985	759.38	959.98	-20.896	M1
1996	769.92	959.98	-19.798	M1
1986	796.29	959.98	-17.051	M1
1992	806.84	959.98	-15.952	M1
2014	822.66	959.98	-14.304	M1
1987	827.93	959.98	-13.755	M1
2018	849.02	959.98	-11.559	M1
2008	864.84	959.98	-9.9106	M1
2011	864.84	959.98	-9.9106	M1
2002	875.39	959.98	-8.8116	M1
2007	891.21	959.98	-7.1637	M1
2009	891.21	959.98	-7.1637	M1
2019	912.3	959.98	-4.9668	M1
1997	954.49	959.98	-0.5719	M1
2001	959.77	959.98	-0.0219	M1
1983	975.59	959.98	1.62608	Mo
2020	975.59	959.98	1.62608	Mo
2015	986.13	959.98	2.72402	Mo
1988	996.68	959.98	3.823	Mo
1982	1001.95	959.98	4.37197	Mo
1999	1001.95	959.98	4.37197	Mo
1998	1012.5	959.98	5.47095	Mo
2016	1017.77	959.98	6.01992	Mo
1995	1023.05	959.98	6.56993	Mo
2012	1059.96	959.98	10.4148	Mo
1990	1065.23	959.98	10.9638	Mo
2003	1075.78	959.98	12.0628	Mo
2005	1117.97	959.98	16.4576	Mo
1993	1191.8	959.98	24.1484	Mo
2021	1232.56	959.98	28.3943	Mo
2006	1244.53	959.98	29.6412	Mo
2010	1276.17	959.98	32.9371	Mo
1994	1291.99	959.98	34.5851	Mo
2013	1392.19	959.98	45.0228	Mo
1981	1497.66	959.98	56.0095	Mo

Chart -9: DSI using dataset of year 1981-2021

Drought severity index (DSI) is given by Indian meteorological department (IMD) in that deviation of rainfall from its annal mean is calculated. If deviation is greater than +0% then it's no drought condition (Mo), if it is between 0 to -25% then its mild drought condition, when it is -25% to -50% then its moderate drought and for -50% to less then its severe drought condition is there. It is totally based on rainfall condition.

3. RESULTS & DISCUSSIONS

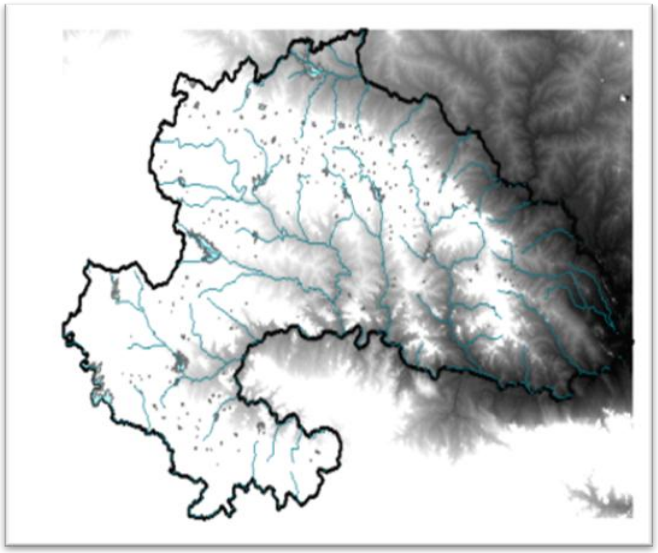

Fig -3 DEM and water bodies of Yavatmal District

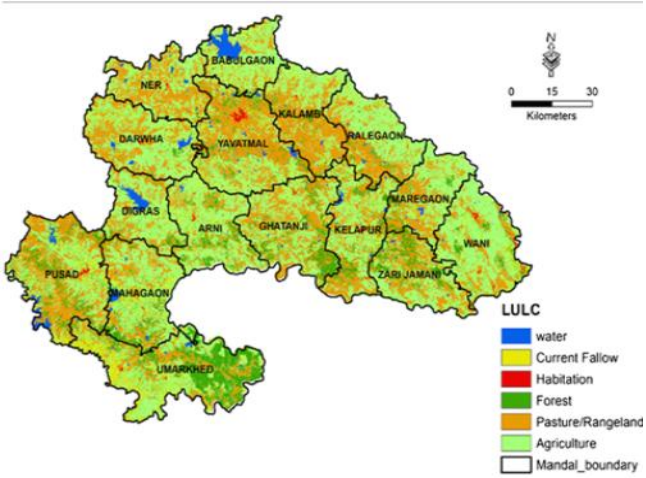

Fig -4 Land use and Land cover Map of Yavatmal District

Temporal variation of Droughts can be easily identified with the help of indices SPI, EVI, VHI, SSM and DSI calculated in methodology. Some Major Droughts are mentioned bellow with percent deviation of rainfall of previous year which causes the drought in subsequent year.

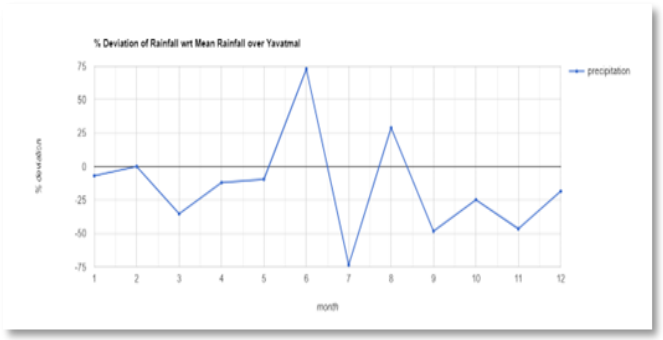

Chart –10 % deviation of rainfall of year 2002

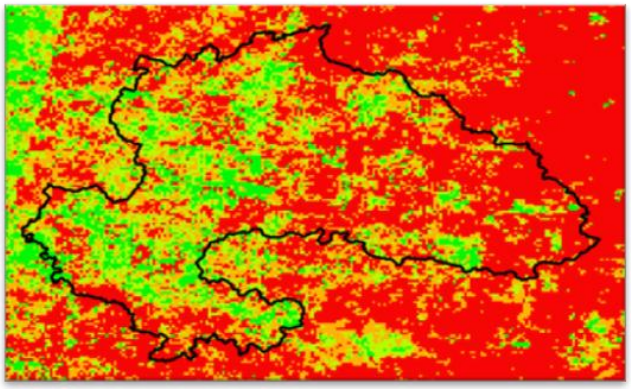

Fig -5 VHI of year 05.2003

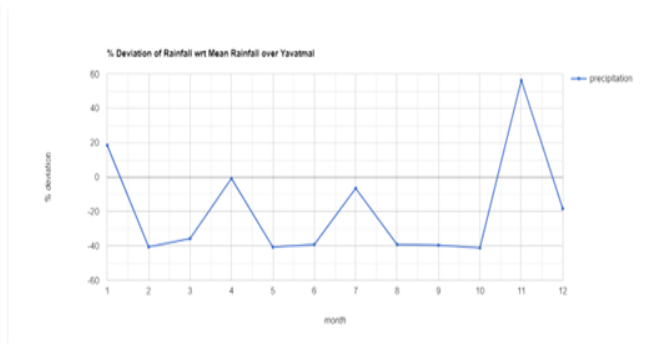

Chart –11 % deviation of rainfall of year 2004

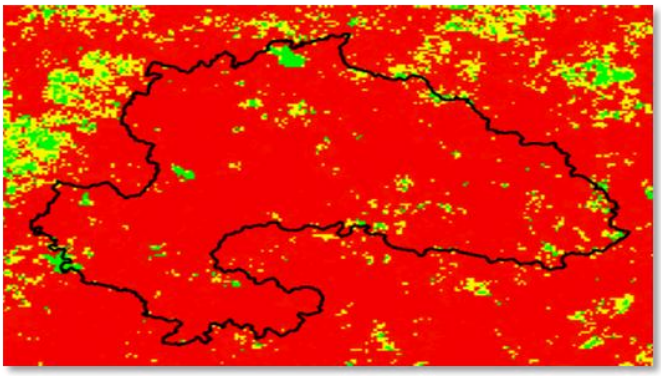

Fig -6 VHI of year 05.2005

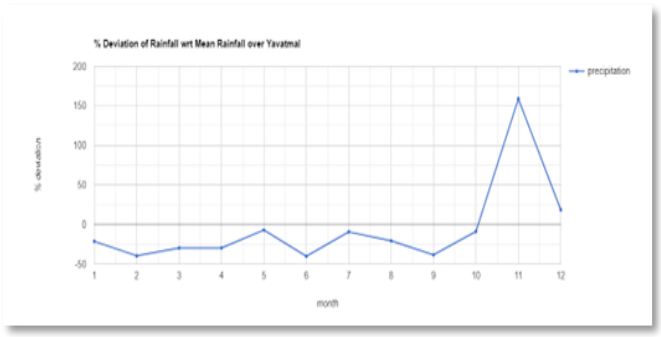

Chart –12 % deviation of rainfall of year 2009

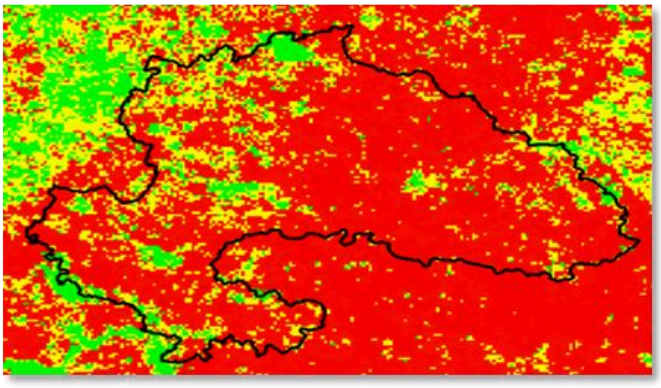

Fig -6 VHI of year 05.2010

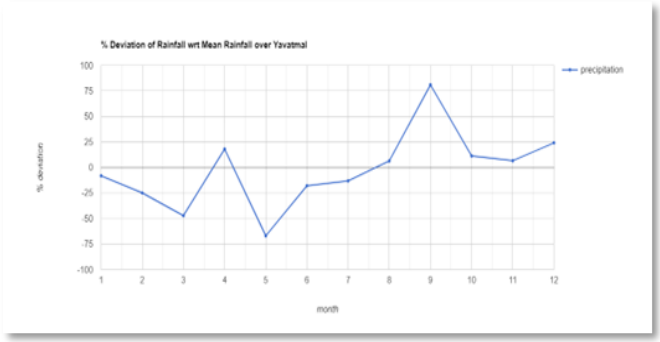

Chart –13 % deviation of rainfall of year 2018

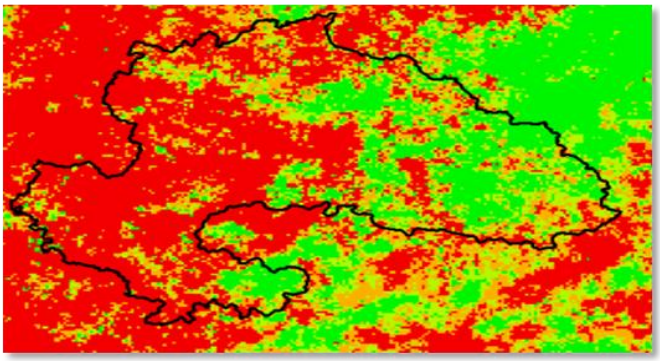

Fig -6 VHI of year 05.2019

Here in VHI it is clearly proved that vegetation health i.e. from red to green, drought probability condition varies as severe to no drought. The impact of negative deviation of rainfall of previous year directly affects the vegetation health in next year.

4 CONCLUSIONS

It was seen from result that maximum value of EVI for Yavatmal District is 0.83 and minimum value is -0.47. As per water availability analysis Yavatmal District receives 959.98 mm of average rainfall each year but from the digital elevation model DEM topography of the district is such that all the rainwater flows into the river and drains out of study area. According to CGWB, 78.4% of the districts domestic and agriculture water requirement is met from groundwater sources, and the remaining 21.6% is met by surface water sources. Total Water requirement of District is only 14.267 % of Total rainfall available. But Most of the district water demand is fulfilled by Ground Water Sources. Which are already 5- 16.2 m bellow the Ground level and depleting day by day and district face frequent drought condition in almost 5 times a decade.

Drought Indices like SPI and DSI are totally based on single type of dataset i.e. rainfall dataset are not effective in predicting rainfall. As per rainfall analysis of Yavatmal District which receives 959.98 mm of average rainfall each year, indices like SPI and DSI do not show the probability of drought but due to topographic and climatic condition District faces frequent drought.

Hence drought indices like Enhanced Vegetation Index (EVI), vegetation health index (VHI) which is defined by two components: the Vegetation Condition Index (VCI) and the Thermal Condition Index (TCI) considers both vegetation condition and temperature conditions should use along with the SPI and DSI which will increase the probability of exact and effective drought prediction.

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