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Principal Component Analysis for Evaluating the Seasonal Vegetation Anomalies from MODIS NDVI Time-series Datasets

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Abstract: ***In this paper, the author presents a method for analyzing vegetative seasonal (SW) anomalies using principal component analysis (PCA). The analysis was done on the Seasonal Maximum Value Composite of MODIS/VEGETATION NDVI obtained for the Northern Karnataka region over a spatiotemporal period (2000-2019). With multi-temporal data sets, the PCA was applied as a data transform to highlight areas of localized change. The objective is to monitor vegetation and evaluate land degradation in the Northern Karnataka Region. Although they offer broad spatial coverage and internal consistency of data sets, satellite remotely sensed data can be effectively used to characterize land surface conditions and land surface changes.***
Keywords: NDVI, PCA, Time-Series Analysis, MODIS, Vegetation Anomalies

I. INTRODUCTION

The global vegetation dynamic trends studies with the function of NDVI data have been perfectly-acknowledged [1][2][3]. The portion of Photosynthetically active radiation (400-700 rim) absorbed by green vegetation is mostly well correlated with NDVI [4]. Its time elementary is a moral forecaster of biomass production [5] and carbon fixation [6]. In detail, it should be able to be relentlessly exposed using the radiative transfer theory that NDVI reveals the health and movement of leaf chlorophyll pigments [7]. The NDVI is globally used as a remote sensing vegetation index due to its consistency in detecting vegetation dynamics as well as in its easiness in terms of computation and analysis. That is the foremost reason for its broader use and larger acceptance compared to other satellite-based spectral vegetation indexes. The use of the vegetation index specifies a considerable greening trend from cumulative seasonal amplitude and growing season spells in the northern high latitudes landscapes [8]. The reason for seasonal phasing is to base a classification on the appearances of the spatial NDVI profile comparatively than on the NDVI values themselves [9][10]. Such appearances consist of overall 'greenness', measured by the combined NDVI all over the year beyond a threshold value; seasonality, measured by the amplitude of the NDVI profile and speediness of brown off and also measured by the maximum negative slope in the profile.

The NDVI can be well-defined as a spectral vegetation index that shows the difference between bands of near-infrared and red reflectance divided by their sum [11]. The greater the NDVI value indicates more the concentration of green vegetation. The related studies using NDVI have discovered a close association between NDVI and seasonal rainfall in semi-arid regions [12][13].

The series of economic and social assets in rural extents have impacts on alteration in land cover patterns by climatic variability and anthropogenic actions and it eventually disturbs the urban inhabitants [14]. This study focused on the extraction of seasonal vegetation anomalies obtained from MODIS NDVI time series spanning over two decades (2000-2019) by using the principal component analysis [15] to detect and mapping of vegetation anomalies. The Normalized Difference Vegetation Index (NDVI) was used as an input parameter to run Principal Component Analysis (PCA). The PCA was used as an initial step of the data transform technique employed to enhance regional-level changes in multi-temporal data sets [15] [16]. Results from PCA were further processed using Geospatial analysis to identify and map land degradation phenomenon. The analysis was carried out by using the monthly Maximum Value Composite (MVC) of NDVI [17] acquired for the Northern Karnataka region from onboard MODIS satellite using google earth engine platforms. Northern Karnataka was adopted as an experiment location since it lies in a semi-arid region and is considered one of the most vulnerable areas to agriculture ecosystems and land degradation in South India.

For investigating and making concluding results Google Earth Engine (GEE) can be used as a cloud computing platform intended to store and process enormous data sets [18]. A surplus of data sets is stretched from coarse spatial resolution data of MODIS to finer-resolution satellite data sets such as Worldview -2 were used and it collects data at changing spatial and temporal scales.

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The collective assessment of main biodiversity variables like Fraction of Absorbed Photo-synthetically Active Radiation (FAPAR), Fraction Vegetation Cover (FVC), Leaf Area Index (LAI), and Canopy water content (CWC) utilizing MODIS chronological data [19]. One of the prime advantages of using is that it can be easily available and user-friendly, it also offers a suitable environment for collaborative data assessment and processing.

To define the spatial and time-based variability of vegetation cover PCA methods are extensively used. PCA can able to describe the peak significant modes of variability in aspects of time and space. It works on an algorithm to create a group of principal components that are orthogonal to one another and despite all variance that results in original data [20]. The first principal components that show more variance than the successive components that have less proportion of variance and related anomalies or spatial distributions are highly decentralized. Consequently, it is frequently considered only a few principal components for NDVI time series studies concerning the vegetation inter-annual deviations by use of PCA as an operational and cost-effective tool for mining-related information. [21]. PCA transformation produces different core components (PC1, PC2, PC 3, ... etc.), which are uncorrelated and arranged in terms of the amount of variation they reflect concerning the original band collection. Those bands are often easier to interpret than the data from the source. PCA is frequently used to detect changes in time series data and has become one of the most popular techniques due to its simplicity and ability to enhance even subtle modifications. PC1 describes the most variance in NDVI integrals and reflects the typical built-in NDVI pattern in space. PC1 shows the standard NDVI over the entire array. PC2 describes the overall remaining variance not described by PC1, and follows the same logic. Resultantly, the components after PC1 (particularly PC2) tend to represent specific events such as fires, drought periods, and, in specific, vegetation-related land degradation phenomena, instead of showing the general development over the period. PCA is used here as a mapping tool that shows a substantial i.e., observable degree of inter-annual variability, capable of distinguishing unidirectional variations.

NASA operated a Moderate Resolution Imaging Spectro-radiometer (MODIS) sensor on board TERRA satellites with a 2330 km long sweeping swath and 1-2day temporal resolution in 36 multi-spectral bands, easily enhancing earth observation with a higher resolution NDVI data set (http://terra.nasa.gov/). The NDVI was formerly proposed by [22] as an index used for measuring vegetation health and density. The NDVI is computed with the formula

$$NDVI = (NIR - red / NIR + red) \quad (1)$$

where, NIR and red are the reflectance in the NIR and red bands, respectively. NDVI represents plant vigor, green cover percentage, Leaf Area Index (LAI), and biomass content. The value of the NDVI differs from -1 to +1. If the NDVI value is close to +1, its dense green leaves are highly probable. So when NDVI is close to zero, green leaves don't exist and it may even be an urbanized area. Compared to other wavelengths, healthy vegetation (chlorophyll) displays more Near-Infrared (NIR) and green light. And it also retains lighter red and blue. For this reason, our eyes see plants as green in color. If you can see near-infrared, the vegetation would be high too.

Each month corrected decadal NDVI products were combined to estimate the monthly maximum NDVI (MNDVI). It was carried out with the resulting MVC technique.

$$MNDVI = max (NDVI1, NDVI2) \quad (2)$$

where MNDVI = monthly maximum NDVI

NDVI1, NDVI2 = maximum NDVI in the first and second 16-day composites of every month generated by the MVC method. This maximum monthly NDVI data set was used for the estimation of the seasonal NDVI for the study period for the southwest monsoon.

$$SWSNDVI = max (NDVI1, NDVI2, NDVI3, NDVI4) \quad (3)$$

where SWSNDVI = southwest seasonal maximum NDVI NDVI1, NDVI2, NDVI3, and NDVI4 are the four months of the southwest season (June to September). The equation for measuring NDVI is (NIR-R)/(NIR+R) where NIR and R are the representation of an electromagnetic spectrum in near-infrared and red regions. The first two spectral bands of satellite data out of five, i.e. Red (0.58 to 0.68 μm) and Near-Infrared (0.75 to 1.1 μm), were found to be generally useful for mapping clouds and land surfaces and for outlining the surface water bodies respectively when combined to detect vegetation cover on earth's surface. [23][24].

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II. LOCATION AND GEOGRAPHICAL EXTENT

The Northern Karnataka region lies between 11°30' N and 18°30' N latitude and 74° E to 78°30' E longitudes with a geographical area of thousand hectares physically it forms the southern and south-western portion of the Deccan plateau (Fig.2.1). The Western Ghats running in N-S direction bound the region on the western side. The region is situated in the Deccan Plateau and is bordered by the Arabian Sea to the west, Goa to the northwest, Maharashtra to the north, Andhra Pradesh and Telangana to the east, Tamil Nadu to the southeast, and Kerala to the southwest. The Northern Karnataka region Consists of twelve districts namely Bagalkot, Belgaum, Bellari, Bidar, Bijapur, Dharwad, Gadag, Kalburagi, Koppal, Haveri, Raichur, and Yadgir. The Northern Karnataka region has no coastal line and its altitude ranges from 300 to 600 meters above mean sea level.

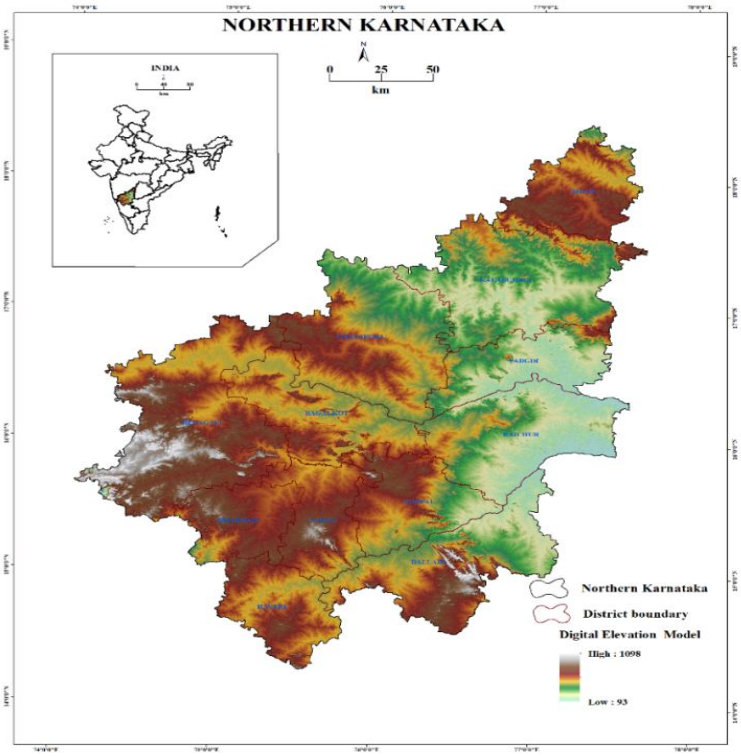


Fig 1. Study area map

The area is mainly composed of the Deccan Trap. It represents an extensive deforested plateau landscape. The climate is subtropical, with winter (January and February), summer (March through May), southwest monsoon (June through September), and post-monsoon (October through December) seasons. Maximum daily temperatures in winter reach (low 30^{o}C), whereas in the summer month temperatures rise (to about 40 °C). The highest maximum temperature in May reaches 43^{0}C in the Gulbarga and Raichur districts of NKR. The highest temperature recorded at an individual station in the region is 45.6°C at Raichur on 1928 May 23 which is 6° higher than the normal for the warmest months. December and January are the coldest months. The lowest temperature at an individual station was 2.8°C on 1918 December 16 at Bidar. The annual rainfall in the State varies roughly from 50 to 350 cm. In districts of Bijapur, Bagalkot, Raichur, Koppal, Bellary, and the southern half of Gulbarga, the rainfall is lowest varying from 500 to 600 mm [25]. Black soils are found in northern Karnataka whereas red and red loamy soils are prominent in southern Karnataka. Agriculture engages the majority of the population in Northern Karnataka and is heavily dependent on the southwest monsoon.

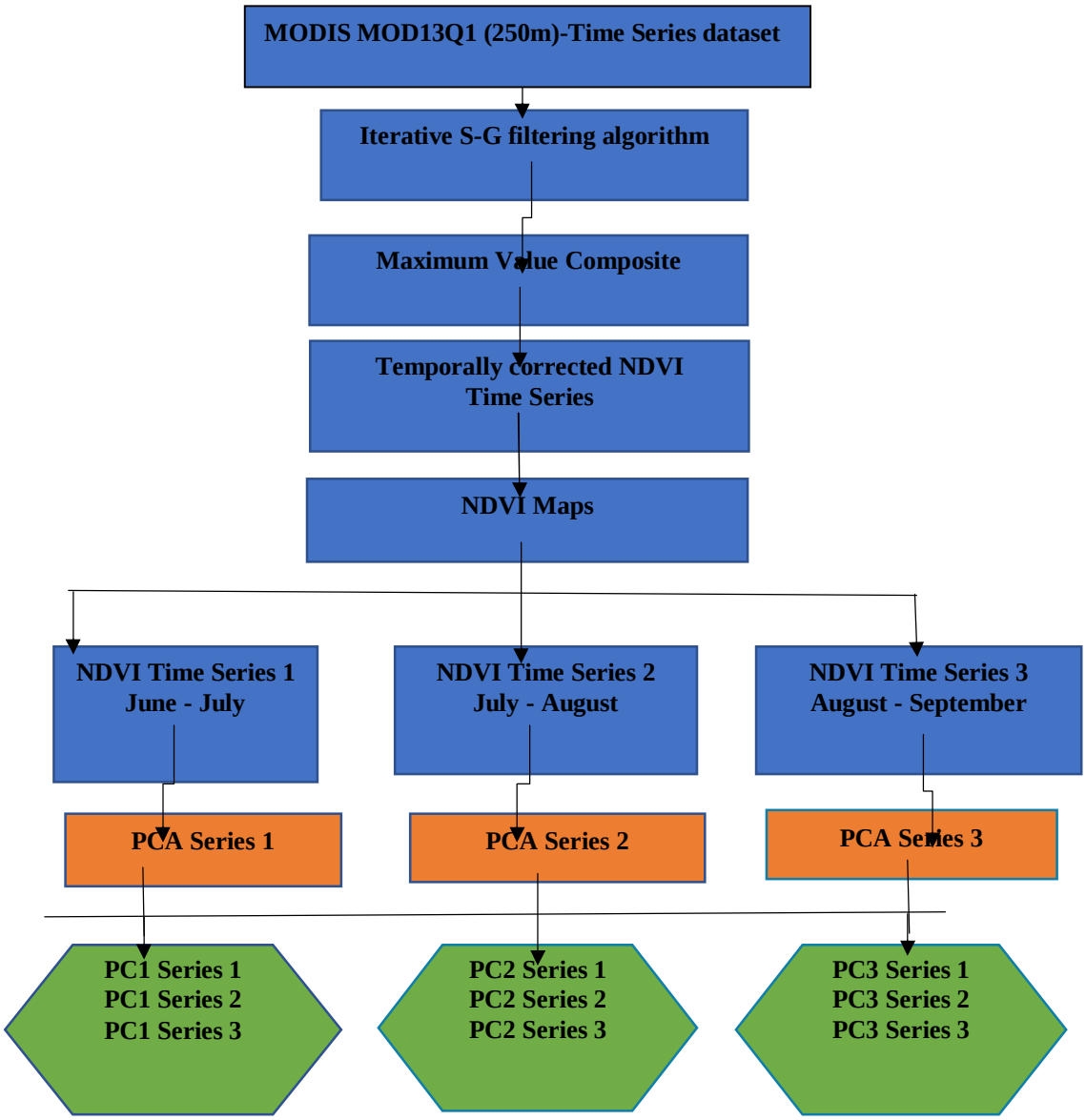
III. DATA AND SOFTWARE USED

The datasets used in the study comprised products derived from the MODIS satellite sensor. Terra MODIS surface reflectance MOD13Q1 (250m) (2000-2019) was used to compute time series NDVI. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 µm to 14.4 µm and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m, and 29 bands at 1 km). ArcGIS software version 10.3 is used to perform the NDVI and PCA processing.

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IV. METHODOLOGY



The MODIS time series (Kharif season) were integrated using its accessibility, image quality, and low percentage of cloud cover. The monthly composite images were downloaded from the google earth engine platform and then applied S-G filtering to smoothen the NDVI images using Timesat software. [26]. The enhanced NDVI profiles were generated by using a moving window algorithm in the S-G method, which removes the outliers and rectifies the errors that occur in the time series [27]. This software is intended to practice time series of vegetation indexes resulting from satellite spectral dimensions. Though, further types of data such as meteorological index, fire data, and eddy co-variance carbon flux data can able to sort out [28].

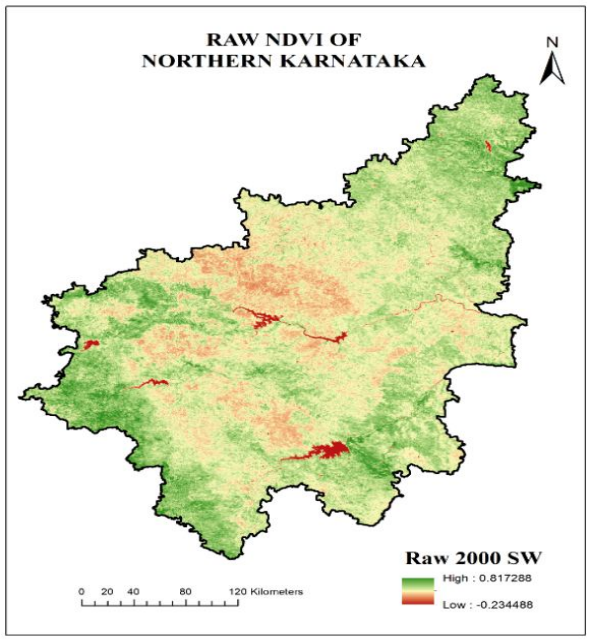
The universal formula for S-G filtering is…….$g_{i=}$

Where f_i signifies the raw NDVI values in time series, g_i indicates the filtered NDVI value and n is the width of the filter window, nL and nR relate to the left and right edge of the signal respectively. The basic idea behind the filter is to domain high moments within the data [29]. Consequently, Cn is not a constant, but a quadratic polynomial function that depends on the user's preferences and is used to fit each data value fi in the moving window.

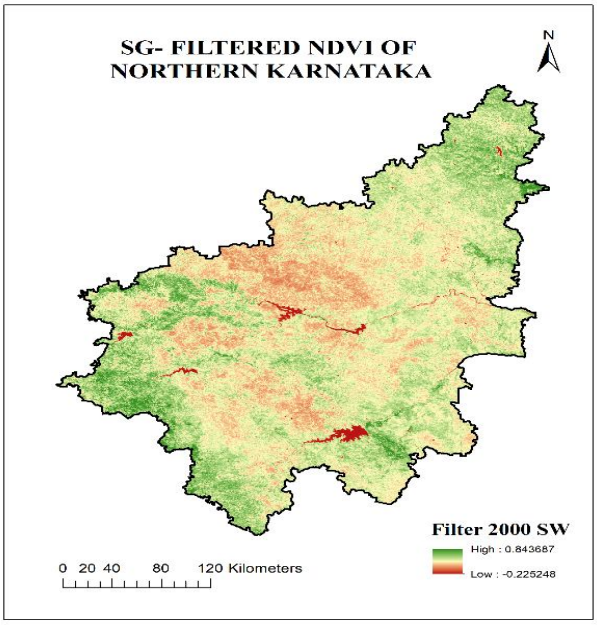
$$\mathbf{Cn(t) = c_1 + c_2t + c_3t^2}$$

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Where" t" relates to the time in days of the year in the NDVI time series. This relates to an ideal and balance value between the degree of smoothening and maintenance of the trend of the raw time series [30]. Timesat is built in ASCII file format to support several time series. The opening line of the ASCII file gives data about the number of years covered by the time series, n year, the number of data values per year, not per year, and the number of time series in the file, nts. In total there are nts lines in the time series. After producing three NDVI time series according to June-July, July-August, and August-September phases to avoid applying PCA in the temporal windows, unlike the phenological perspective. For each NDVI series, the PCA was applied and, finally, the first, the second, and the third element of each series was combined and analyzed separately.



a)



b)

Fig 2. (a) Raw MODIS NDVI of Northern Karnataka. (b) Timesat SG-filtered MODIS NDVI of Northern Karnataka

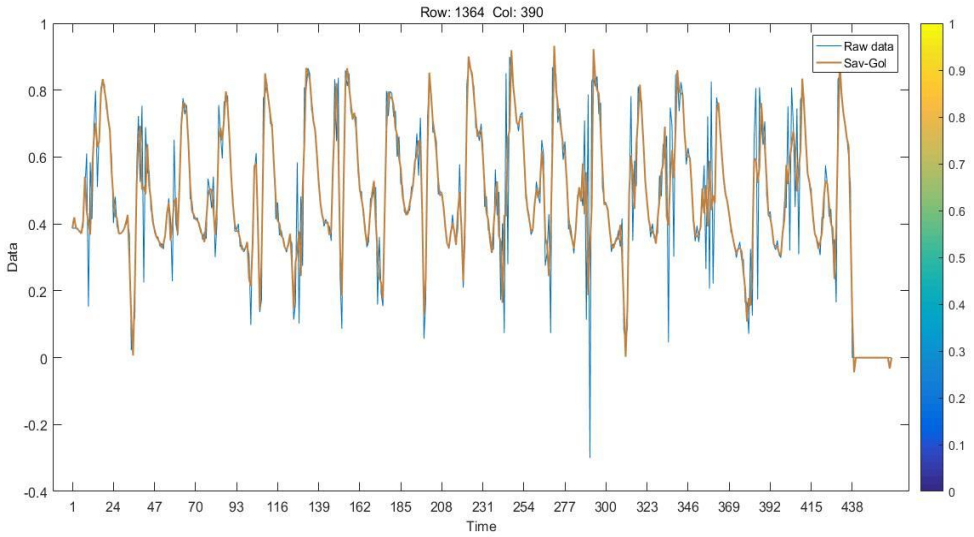


Fig 3. Fitted functions from a multi-step procedure in Timesat

V. RESULTS AND DISCUSSION

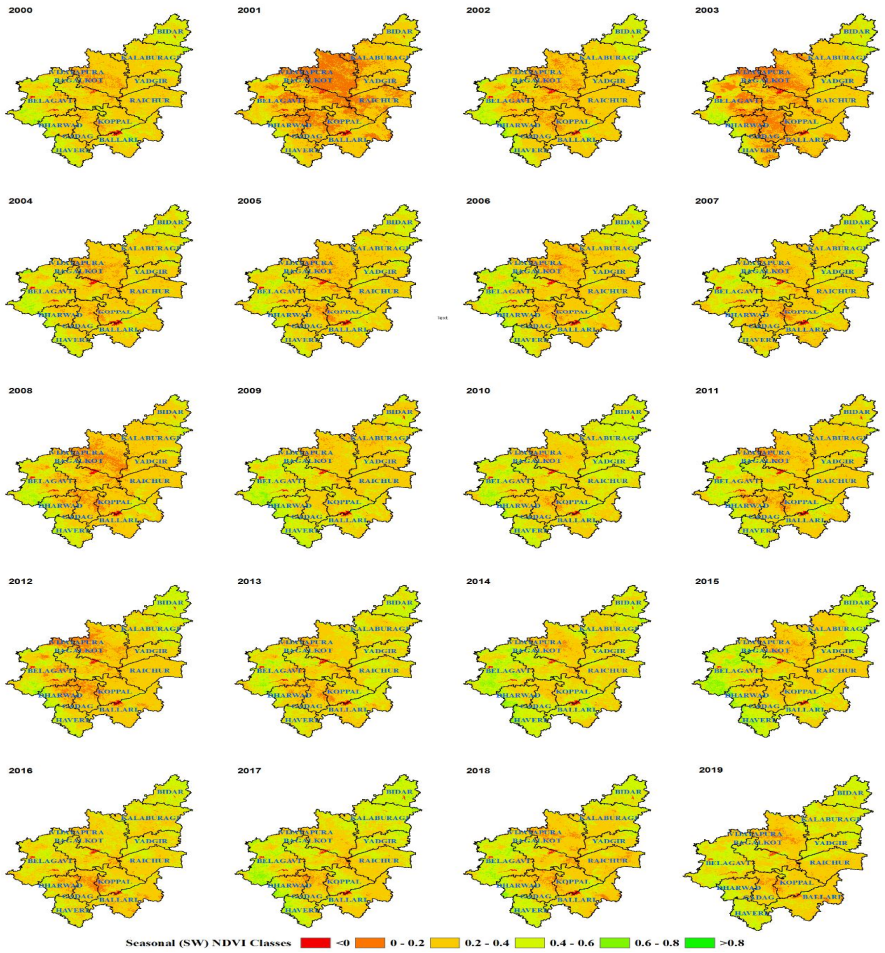


Fig 4. Seasonal NDVI of NKR

The spatiotemporal analysis of MODIS (250m) NDVI is used to monitor and study the vegetation condition prevailing over the terrain at the global level. The vegetation cover of seasonal (SW) variations can be better extracted and analyzed with the help of times series NDVI GEE datasets. And also it is used as an important indicator for detecting vegetation growth, assessing agricultural drought, and helps in determining surface moisture with varying spatial resolutions. The seasonal variations and analysis of NDVI of the Northern Karnataka region illustrate healthier vegetation cover identified in the years 2007 and 2010. In these years high vegetative cover (0.6-0.8) was noticed in the districts of Bidar, Belgavi, Kalaburagi, Raichur, and Yadgir. In the study region, NDVI displays vegetation stress during the peak of the southwest monsoon season. The year 2001 and 2003 shows poor vegetation (0-0.2) status in Vijayapura district and other central parts of Northern Karnataka. The years 2001, 2004, 2006, 2009, 2014, and 2015 were under moderate (0.2-0.4) vegetation cover.

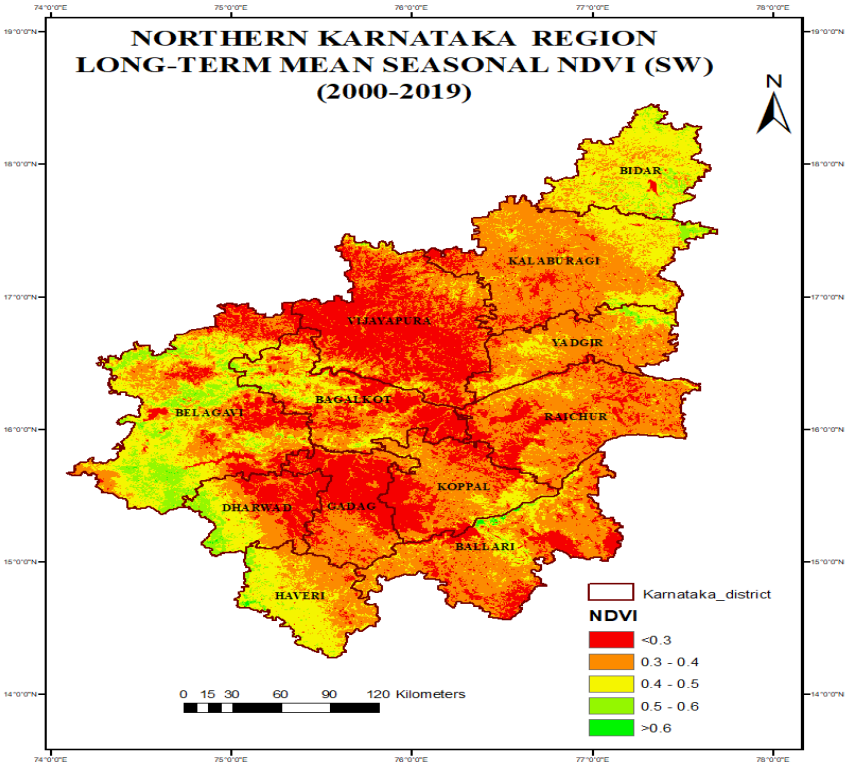
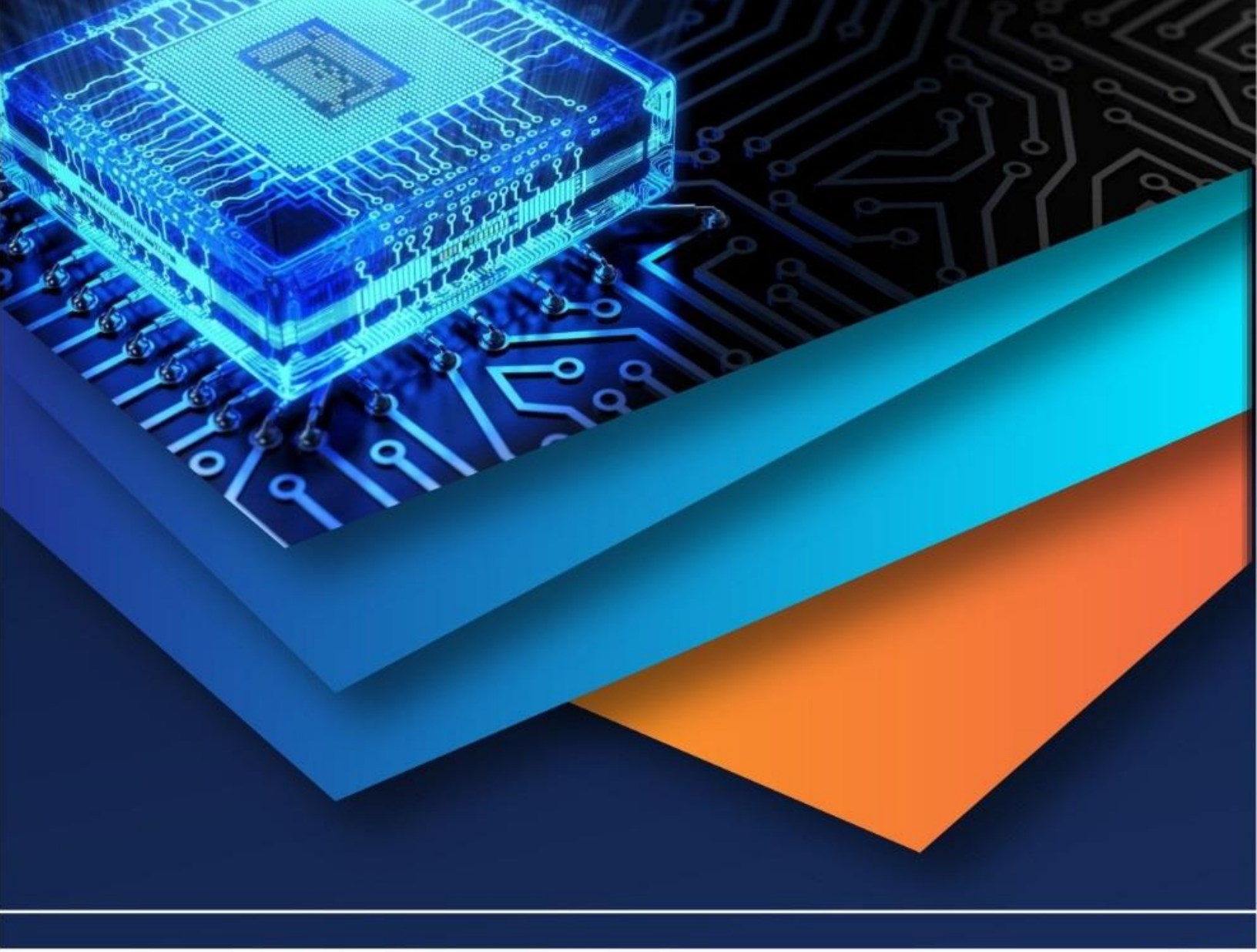


Fig 5. Long-term mean seasonal NDVI of NKR

To monitor and analyze the spatial extent and severity of vegetation stress and agricultural vulnerability, the long-term NDVI has been computed in the study. For instance, long-term NDVI reveals that very less (>0.3) vegetation covers an area of 2207.60 thousand hectares (25.12 percent) and has found in most regions of Vijayapura district, and other central parts of districts like Bagalkot, Dharwad, Belgavi and Gadag, Western parts of Koppal and Raichur districts. And also less vegetation cover (0.3-0.4) is being observed in an area of 3698.79 thousand hectares (42.09 percent) of the TGA of Karnataka region. The same class of coverage has been identified in most parts of Kalaburagi, and Ballari Raichur, and also it spread over the southern parts of Dharwad, Gadag, and the north-western parts of Haveri. Moderate vegetation cover (0.4-0.5) has been identified in the entire region of Bidar districts and north-eastern parts of Kalaburagi, and a few parts north of Yadgir and Raichur. This classification can also see in northern parts of Bagalkot, central parts of Ballari, north-eastern regions of Koppal, and northwest and southwest of Haveri and Dharwad. The spatial coverage of the moderate vegetation class of Northern Karnataka is 2008.07 thousand hectares (22.85 percent) of TGA. The high vegetation cover (0.5-0.6) is mainly found in the north and southwest of Bidar district, northeast of Yadgir, northwest and southwest regions of Dharwad, northwest and western regions of Haveri and accounts for 603.42 thousand hectares (6.87percent) of the TGA. Very high vegetation cover (<0.6) is observed in a few parts of western Haveri and northwest of Ballari districts and also covers about 270.55 thousand hectares (3.08 percent) of the study area.

REFERENCES

[1] Tucker, C. J., Townshend, J. R. G. and Goff, T. E., African land-cover classification using satellite data, Science2, 27, 369-375, 1985.
[2] Tucker, C. J., Fung, I. Y., Keeling, C. D., and Gammon, R. H., Relationship between atmospheric CO2 variations and a satellite-derived vegetation index, Nature, 319, 195-199, 1986.
[3] Tucker, C. J., Dregne, H. E., and Newcomb, W. W., Expansion and contraction of the Saharan desert from 1980 to 1990, Science, 253, 299-301, 1991.
[4] Asrar, G., Fuchs, M., Kanemasu, E. T, and J. L. Hatfield., Estimating absorbed photosynthetic radiation and leaf area index from spectral reflectance in wheat, Agron. j., 76, 300-306, 1984.
[5] Tucker, C. J., A critical review of remote sensing and other methods for non-destructive estimation of standing crop biomass, Grass Forage Sci., 35, 177-182, 1980.
[6] Fung, I. Y., C. J. Tucker, and K. C. Prentice., Application of advanced very high-resolution radiometer vegetation index to study atmosphere- biosphere change of CO2, J. Geophys R.es.,9 2, 2999-3015, 1987.
[7] Myneni, R. B., Hall, F.G., Piers, J. Sellers., and Marshak, A. L., (1995). The Interpretation of Spectral Vegetation Indexes. IEEE, Geoscience and Remote Sensing,33, 2,1995.
[8] Myneni, R. B., Tucker, C. J., Asrar. G., Keeling, C. D., Interannual variations in satellite-sensed vegetation index data from 1981 to 1991. Journal of Geophysical Research, 103, NO. D6, 1998.
[9] Lloyd, D., A phenological classification of terrestrial vegetation cover using shortwave vegetation index imagery. International Journal of Remote Sensing, 11, 2269-2279, 1990.
[10] SAMSON, S. A., Two indices to characterize temporal patterns in the spectral response of vegetation. Photogrammetric Engineering and Remote Sensing, 59, 511-517, 1993.
[11] Curran, P. J., and M. D. Steven., Multispectral Remote Sensing for the Estimation of Green Leaf Area Index. Philosophical Transactions of the Royal Society of London, Mathematical and Physical Sciences 309: 257–270, 1983.
[12] Tucker, C. J., and Nicholson, S. E., Variations in the size of the Sahara Desert from 1980–1997. Ambio 28: 587–59, 1999.
[13] Anyamba, A., and Eastman, J. R. Interannual Variability of NDVI over Africa and Its Relation to El Nino/Southern Oscillation. International Journal of Remote Sensing 17: 2533–2548, 1996.
[14] Richards, J.A., Remote sensing Digital Image Analysis. Springer–Verlag, Kensington, pp. 127–138, 1986.
[15] Lasaponara, R., On the use of principal component analysis (PCA) for evaluating Interannual vegetation anomalies from SPOT/VEGETATION NDVI temporal series. Ecol. Model. 194, 429–434, 2006.
[16] Howarth, P., Piwowar, J., Millward, A., Time-Series Analysis of Medium-Resolution, Multisensor Satellite Data for Identifying Landscape Change. Photogrammetric Engineering and Remote Sensing 72(6), 653–663, 2006.
[17] Kundu, A., Dwivedi, S. & Dutta, D., Monitoring the vegetation health over India during contrasting monsoon years using satellite remote sensing indices. Arabian Journal of Geosciences, 9:144-159, 2018.
[18] Kumar, L., & Mutanga, O., Google Earth Engine Applications Since Inception: Usage, Trends, and Potential. Remote Sens., 10, 1509, 2018.
[19] Campos-Taberner, M., Moreno-Martinez, A., García-Haro, F.J., Camps-Valls, G., Robinson, N.P., Kattge, J., Running, S.W. Global Estimation of Biophysical Variables from Google Earth Engine Platform. Remote Sens., 10, 1167, 2018.
[20] Li, Z., & Kafatos, M., "Interannual Variability of Vegetation in the United States and Its Relation to El Niño/Southern Oscillation." Remote Sensing of Environment 71: 239–247, 2000.
[21] Antonio Lanorte, Teresa Manzi, Gabriele Nole, and Rosa Lasaponara., On the Use of Principal Component Analysis (PCA) for evaluating the Seasonal Vegetation anomalies from LANDSAT-TM NDVI Temporal series in the Basilicata Region (Italy), ICCSA, 204-216, 2015.
[22] Tucker, C.J., Red and Photographic Infrared Linear Combinations for Monitoring Vegetation. Remote Sensing of Environment, 8, 127-150, 1979.
[23] Tucker C J., Pinzon J E & Brown M E., Global Inventory Modelling and Mapping Studies, Global Land Cover Facility, University of Maryland, College Park, Maryland, 1982-2006, 2004.
[24] Tucker C J., Pinzon J E., Brown M E., Slayback D., Pak E W., Mahoney R., Vermote E and Saleous N El., An extended AVHRR 8-km NDVI Dataset Compatible with MODIS and SPOT vegetation NDVI Data. International Journal of Remote Sensing 26(20): 4485-4498, 2005.
[25] Reddy. N.B.K. and Murthy. G.S., (1967). Karnataka state gezeteer1982
[26] Savitzky, A. and Golay, M., Smoothing and differentiation of data by simplified least squares procedures. Analytical chemistry, 36(8), pp.1627—1639, 1964.
[27] Chena Jin, Per. Jonssonc, Masayuki Tamurab, Zhihui Gua, Bunkei Matsushitab, Lars Eklundhd. A simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky–Golay filter. Elsevier, Remote Sensing of Environment 91 .332 – 344, 2004.
[28] Verbesselt Jan, Per Jonsson, Stefaan Lhermitte, Jan van Aardt, and Pol Coppin., Evaluating Satellite and Climate Data-Derived Indices as Fire Risk Indicators in Savanna Ecosystems, IEEE, Geoscience and Remote Sensing, 44, 6, 2006.
[29] Press, H., Flannery, B., Teukolsky, A., Vetterling, W., Numerical Recipes in C, Cambridge University Press, New York, 1992.
[30] Eklundh and Johsson., Timesat 3.1 software manual, Lund University, Sweden, 2012.



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