Impact Assessment of Narmada Canal Irrigation System for Crop Cultivation using Multispectral Remote Sensing

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Abstract: The objective of this work is to study the impact assessment of the Narmada canal for crop cultivation using multispectral remote sensing. Narmada canal is a contour canal constructed in the northwestern part of India and was inaugurated in April 2008. It carries water from Sardar Sarovar Dam which passes through the state of Gujarat for about 460km and Rajasthan for about 76km. Its total running length is about 750km and has 42 branches. Hence it is the main irrigation canal in that region. The Narmada canal irrigates about 5,260,000 acres of land. The carrying capacity of this canal at the head in Navagam is 40,000 cusecs and gets reduced to 2,600 cusecs at Sanchore. The main canal is lined with concrete and has many pumping stations so that the water can reach on the elevated areas too. The objective of this project is to observe the increase in vegetation field surrounding the southern part of the Narmada canal. To calculate the impact of the canal system the data of the Landsat for the years 1985, 1995, 2005, and 2019 are used. The supervised classification of the image analysis tool is used to determine the crop area and water spread area of the Narmada canal. The data used for the years 1985, 1995 and 2005 provides Land Use and Land Cover (LULC) classification with a spatial resolution of 100m. For the year 2019, the data is derived from Landsat 8 OLI/TIRS collections land surface reflectance having a resolution of about 30m. The crop area in the year 1985 was 25414.7sq.km and is increased by 4.042% in the year 1995 and observed to be 26442.1sq.km. Similar growth is also observed in the next decade of about 3.292% in the year 2005 and observed to be 27312.5sq.km. This study aims to determine the increased crop area due to the Narmada canal and for that, the crop area of 2019 is calculated by collecting 58 spectral signatures for supervised classification over the southern part of the Narmada canal. The growth of about 52.49% is observed in the crop cultivation area. The total crop cultivation is increased by 61.04% in the last 34 years. The results may be useful to analyze the cost-benefit aspect of the irrigation system. Further study may include crop health monitoring using multispectral and hyperspectral images correlating with climate change over the Narmada canal system.

Keywords: Irrigation System; Narmada Cana; Crop Cultivation; Multispectral remote sensing; NDVI

1. Introduction

For minimizing the problems such as low productivity of crops, degradation of natural resources, drought, and poverty the central and state government carry out the irrigation development project. These projects cost millions of rupees to the government. As huge investments are made to carry out these projects it becomes so important that the project has a positive impact. Impact assessment is the process of observing or ensuring that the project is economically workable, socially impartial and able to be maintained environmentally. (Sachin Panhalkar, Rucha Joshi 2009)

Narmada canal is a contour canal constructed in the north western part of India. this canal was inaugurated on 24th April 2008. it carries water from the Sardar Sarovar dam. that's why it also called a Sardar Sarovar canal. the canal passes through the state of Gujarat for 460km & Rajasthan for about 76km. The total running length of this canal is 750km and it has 42

branches. The water-carrying capacity of the canal is about 40000 cusecs at the head in Navagam & gets reduced to 2600 cusecs at Sanchore. The Narmada canal irrigates about 5260000 acres of land. Narmada canal is lined with concrete & it has many pumping stations so that water can reach on the elevated areas too. (Water Resources Information System of India. Govt. of India. Retrieved 12 March 2015.)

Remote sensing is the process to measure the properties of an object on the surface of the earth without being any physical contact with them by aircraft or satellite. Remote sensing helps to monitor the short-term and long-term changes on the earth's surface either naturally or by human impact by providing a repetitive and consistent view. (Robert S. Schewengerdt 2007) The multispectral sensors placed on the satellite measures the reflected energy from object or area within specific sections or bands of the electromagnetic spectrum and forms an image for monitoring the variations in vegetation, Normalised Difference Vegetation Index (NDVI) plays a very important role. When sunlight strikes objects, some wavelengths of the spectrum of light are absorbed by the object while the remaining wavelengths are reflected back. The chlorophyll presents in plant leaves, strongly absorbs visible light, at the same time the cell structure of the leaves, reflects near-infrared light. (John Weier and David Herring, August 30, 2000) NDVI shows vegetation by measuring the difference between near-infrared and red light. Vegetation reflects near-infrared light and absorbs red light.

This paper includes the impact analysis of the Narmada canal system for crop area and crop quality monitoring. The paper is divided into three sections like data and methodology, Result and Discussion and conclusion. The detail discussion on the various data products and it's pre-processing for monitoring the crop area and crop quality is given in the second section of data and methodology. The technical discussion on the processes for analysing the impact is also given in the second section. The third section deals with the output of the methodology for impact on crops. The section divides into two sections as the determination of the change in the crop area before and after the construction and operation of the Narmada canal and the second part discusses the change in the quality of crop using Normalized difference vegetation index (NDVI). The conclusion includes the future scope and importance of impact assessment of the Narmada canal and provides a framework for the future impact assessment of any canal system.

2. Data & Methodology

The objective of this study is to analyse the impact of the Narmada canal by observing the increase in the area of cropland and the quality of the crops. The Narmada canal is a contour canal which passes through the state of Gujarat and Rajasthan from north latitude 21° 49′ 49″ to 21.83028° and east longitude 73° 44′ 50″ to 73.74722°. It carries water from Sardar Sarovar. The main canal has a total running length of 750 km and has 42 branches.

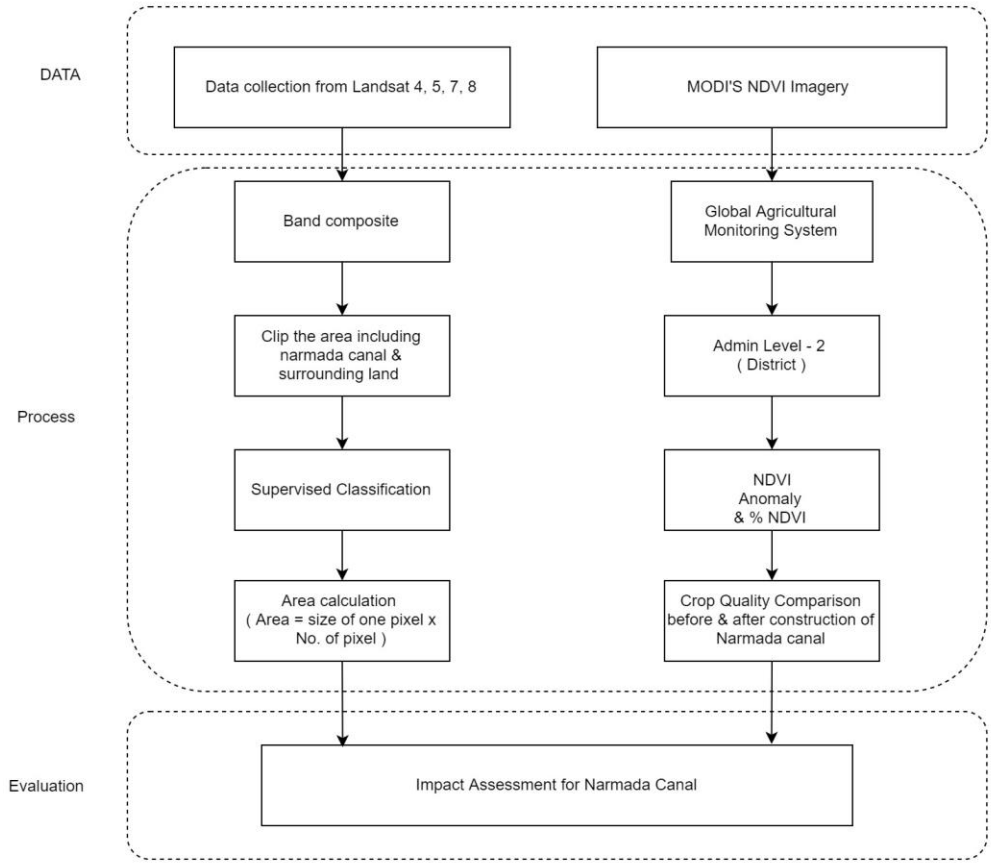


Fig: 1 Flow chart of Methodology

To calculate the area of cropland we use the data of Landsat of the year 1985, 1995, 2005 and 2019 from USGS Earth Explorer. For year 1985,1995 and 2005 we used data derived from Landsat 4 and 5 Thematic Mapper(TM),Enhanced Thematic Mapper Plus(ETM+) and Multispectral Scanner System(MSS) data, India Remote Sensing Satellite(IRS) Resourcesat Linear Imaging Self-Scanning Sensor-1 or III (LISS-I, LISS-III) data, ground truth surveys, and visual interpretation which provides Land Use Land Cover(LULC) classification having resolution 100m. For the year 2019, the data is derived from Landsat 8 OLI/TIRS collection land surface reflectance having a resolution of about 30 m. (https://earthexplorer.usgs.gov/) Vegetation Index (NDVI) data. NDVI shows vegetation by measuring the difference between near-infrared and red light. Vegetation reflects near-infrared light and absorbs red light. For acquiring NDVI data, we used the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation index. MODIS Vegetation Indices are produced on 16-day intervals at multiple spectral resolutions. A consistent spatial and temporal comparison of vegetation canopy greenness, a composite property of leaf area, chlorophyll and canopy structures can be obtained by this data. We derived data of year 2007 and 2013 from Global Agricultural Monitoring System. (https://glam1.gsfc.nasa.gov/v4.html) The monthly NDVI data is used to calculate the health of the crops which gives the idea about the agricultural condition in an area near the Narmada canal. The methodology is divided into two processes. The first is to calculate the crop area before and after the construction of the Narmada canal and then to determine the

quality of the crop by NDVI.For the crop area calculation, the satellite images from Landsat 4, 5, 7 and 8 are downloaded for the year 1985, 1995, 2005 and 2019. For the year 2019, the Landsat 8 level-2 data with atmospheric correction is used. The images downloaded are classified on the reflectance of the various objects or area. The processing of image involves the band composition and clipping of the area including the Narmada canal and the area surrounding it.

The band composition is done in a reprocessing tool and 7 bands are composited. Then the shape file for the Narmada canal and surrounding area is created. The clipping is done with the mask of the Narmada canal and the surrounding shape file. After the pre-processing, the supervised classification is performed. In supervised classification, the samples from the crop areas are created with the help of polygon. In supervised classification, the crop area is obtained on the basis of reflectance. The area of cropland (A_C) is calculated by multiplying the number of pixels (N_P) by the resolution (R_S).

$$A_C = N_P \times R_S \quad (1)$$

The area of cropland is calculated in the year 1985, 1995, 2005 and 2019 to understand the historical and current situation of the crop area.

After calculating the area of cropland, the quality of crops is also calculated using NDVI. The NDVI is derived from MODIS Imagery. The Global Agricultural Monitoring System provides good temporal resolution for agricultural quality based on district boundaries. For the Narmada canal impact assessment, the five districts which are Vadodara, Dahod, Narmada, Panch Mahals and Nandurbar are considered. The NDVI gives the crop quality for the years 2007 and 2013 which is before and after the construction and operation of the Narmada canal.

3. Results and Discussion

Study Area

The impact assessment of a Narmada Canal can be done based on crop area and crop quality. The area of cropland for the years 1985, 1995, 2005 and 2019 is calculated before and after the construction and operation of the canal. The crop area of the year 1985 was 25414.7sq.km. In the year 1995, it was 26442.1sq.km. And in the year 2005, it was 27312.5sq.km. After the construction of the canal, the area of cropland in the year 2019 was 41649.7sq.km.

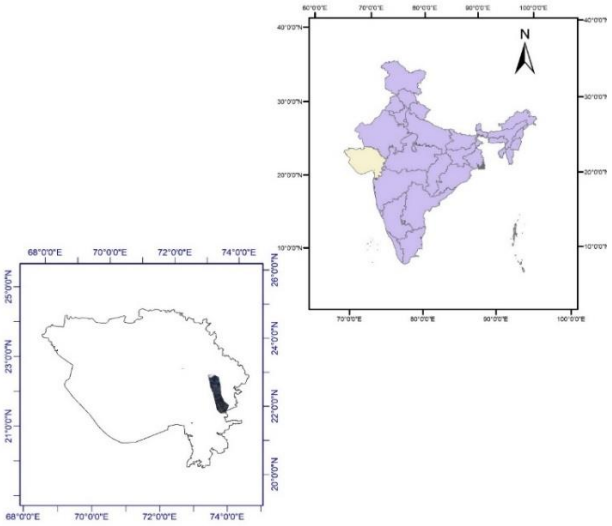
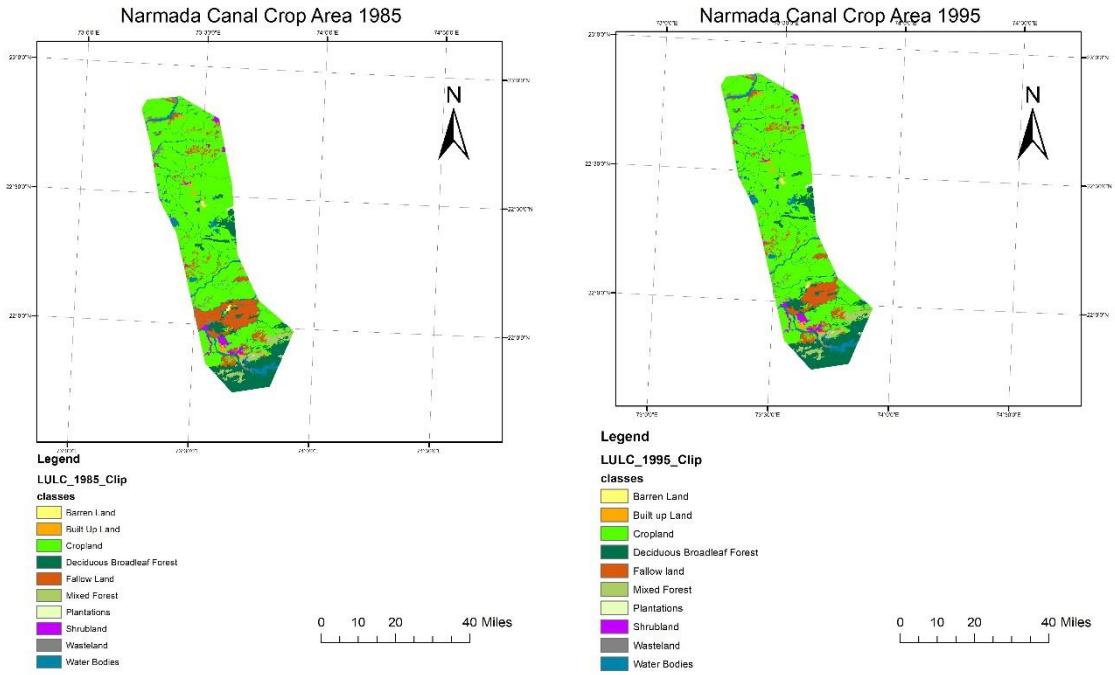


Fig:2 Study area map and location of Narmada Canal system



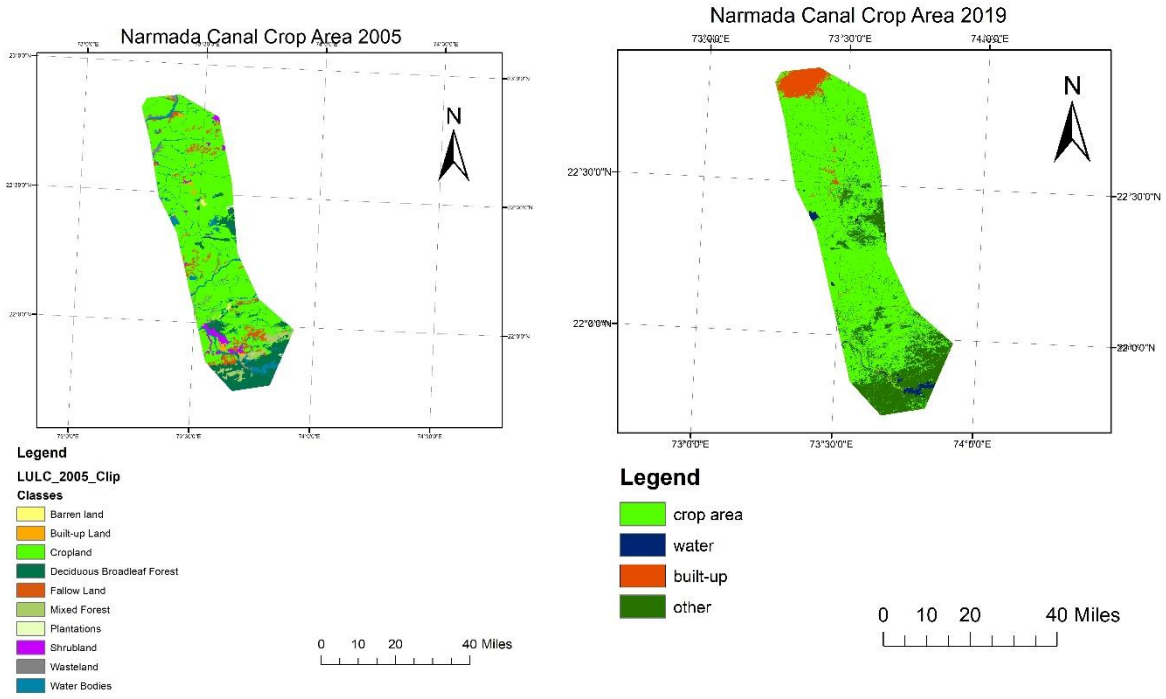


Fig 3: Classification maps based on the crop area and other classes for year 1985, 1995, 2005 and 2019

Crop Area Calculation

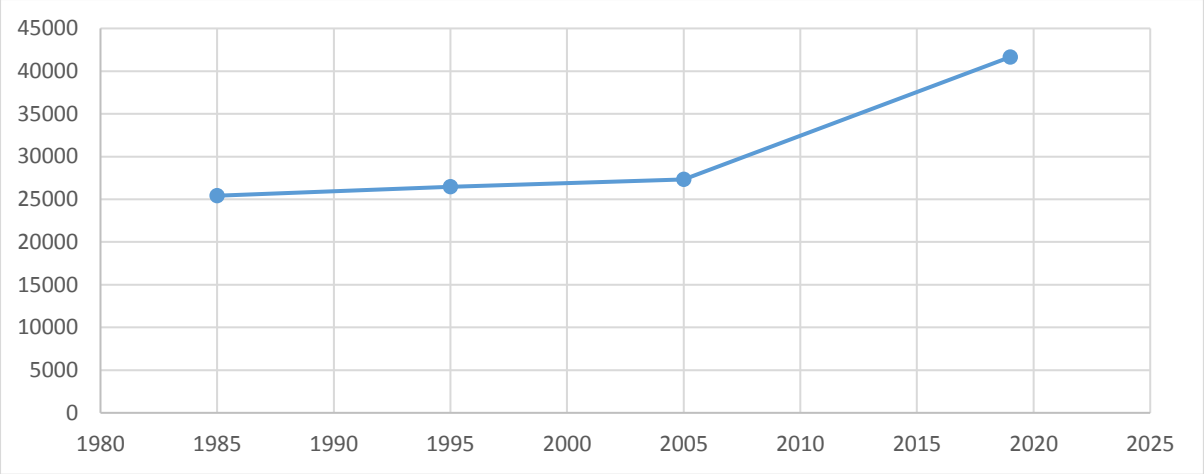


Fig 4 : Chart represents the actual change in the crop cultivation area

The above graph shows the crop area in each year. From that, we can see the increase in crop area before construction of the canal was very low but after the construction of canal the crop area increased rapidly from the year 1985 to 2019 the increase in crop area was 16235sq.km.

The percentage increase in crop area in the last 34 years has been 61.04% After the canal construction the increasing percentage of the crop is about 52.49%.
Table 1 : The yearly values of crop area by pixel numbers and its resolution

Year	Pixel No.	Resolution	Area in sq.km
1985	254147	100 m	25414.7
1995	264421	100 m	26442.1
2005	273125	100 m	27312.5
2019	416497	100 m	41649.7

Crop Quality

To analyse the quality of the crop we derived NDVI data from MODI'S imagery for the year 2007 and 2013 which is before and after the construction of Narmada Canal based on district boundary

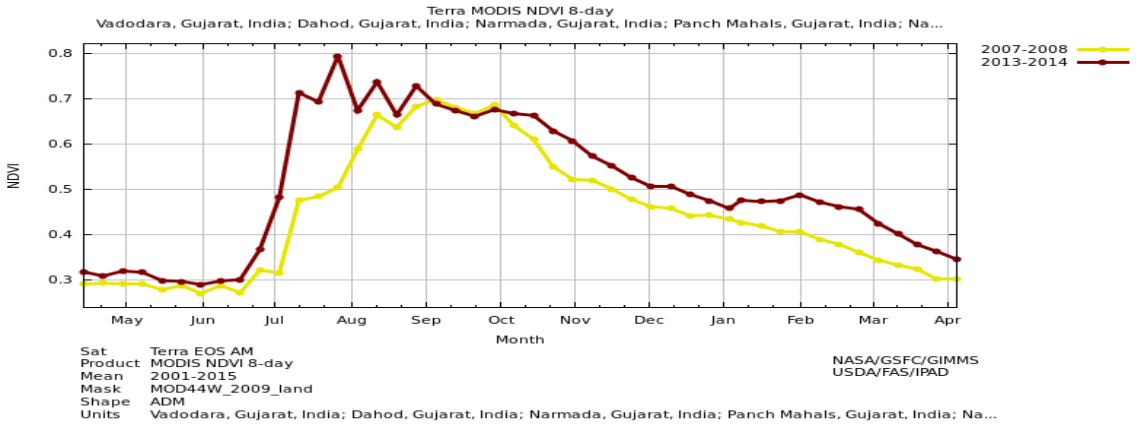


Fig 5(a) NDVI values of Narmada Canal

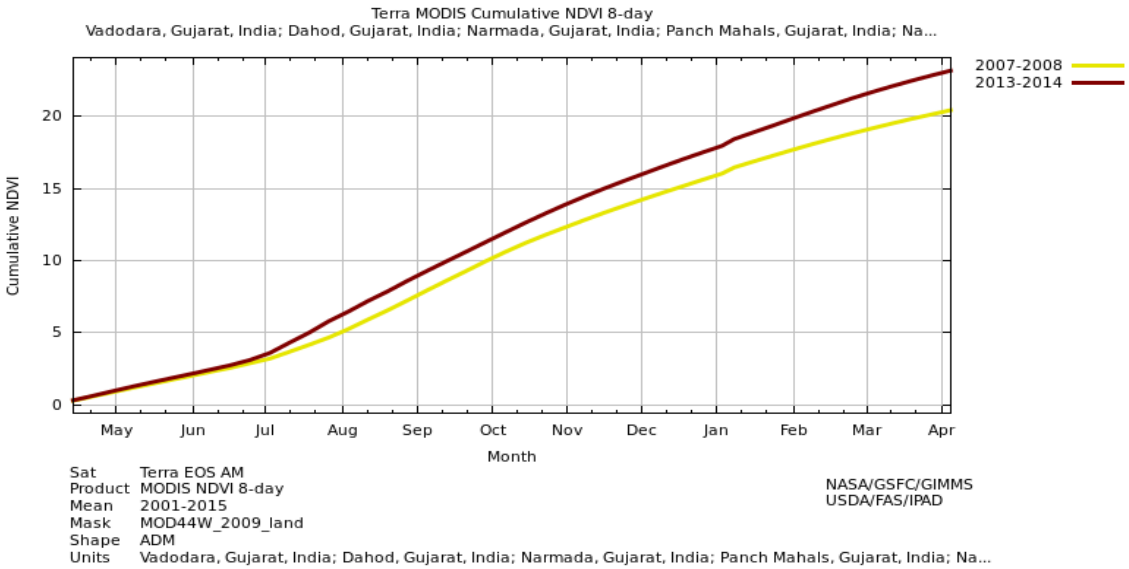


Fig 5(b): Cumulative NDVI values

The graph (a) shows NDVI values from 0 to 1 of each month for the year 2007-2008 and 2013-2014 from the area we can see that the NDVI values have increased between year 2007 and 2013 between July and August. The graph shows the peak values in the year 2013. From the above graph in the year 2007-2008, the lowest value is 0.25 in June and the highest value is 0.7 in September. In the year 2013-2014, the lowest value is 0.29 in June and the highest value is 0.8 in between July & August. In graph (b) the cumulative NDVI value for the years 2007-2008 and 2013-2014 are shown.

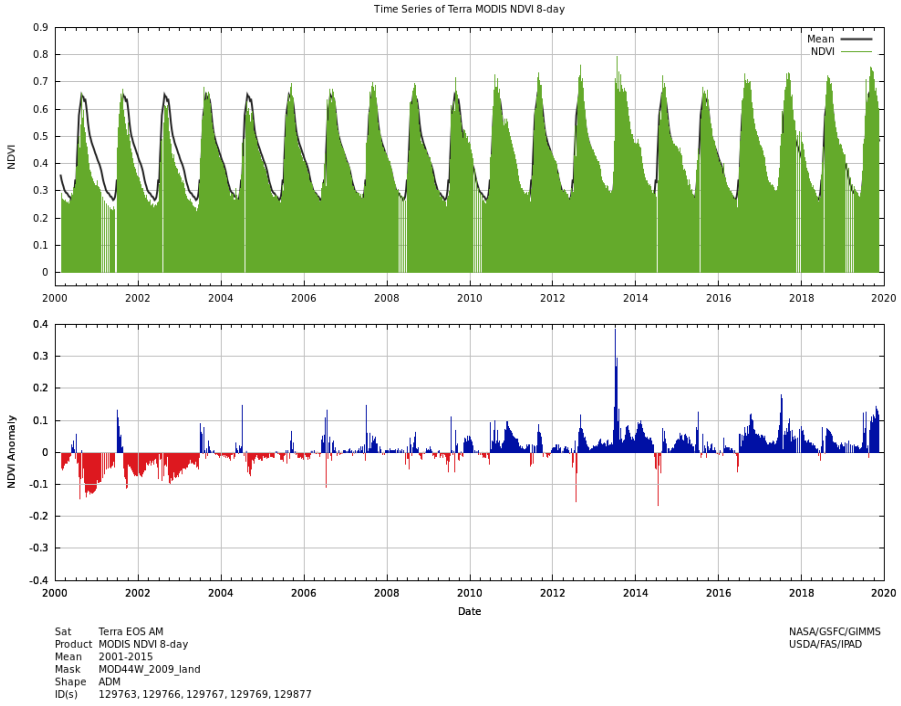


Fig 6 :Time series of Terra MODIS NDVI

The graph shows the NDVI anomaly from the year 2000 to2019 between the range -1 to +1. The negative value indicates the bad quality of crop and a positive value indicates the healthy crops. Before the construction of the canal or before 2008 the negative value can be seen which means crops were not so healthy. After 2008 the value tends to be more on the positive side which indicates the improved health of the crops

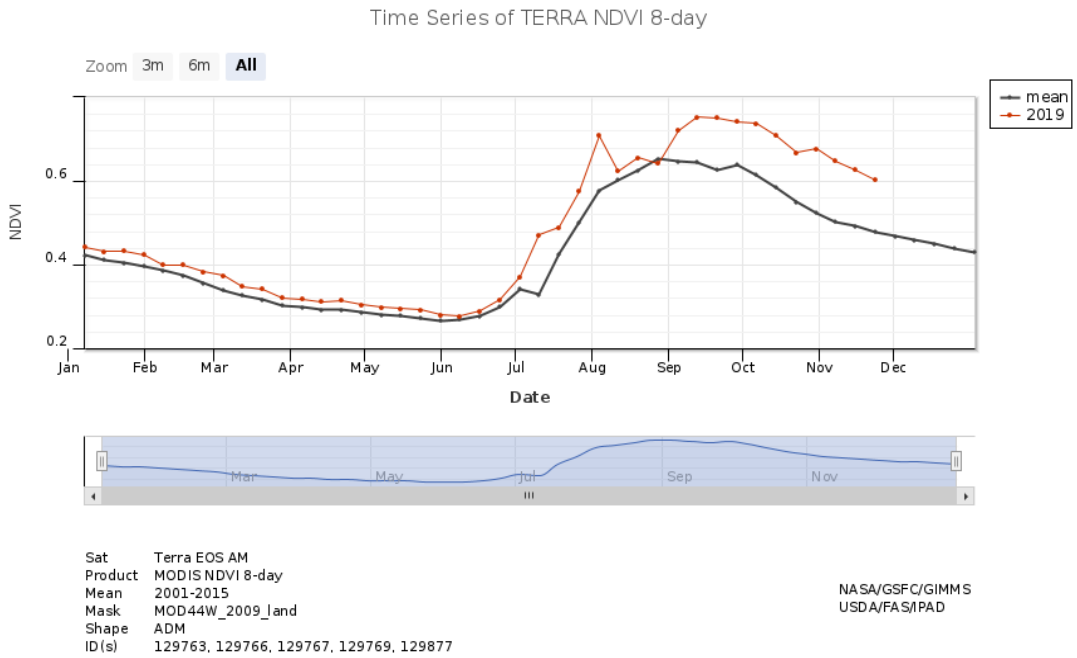


Fig 7: The graph shows the NDVI values of 2019 and Mean values of NDVI

The above graph shows the difference between the values of NDVI in 2019 and the average or mean value of years between 2000 to 2018. The graph clearly shows the quality of crops are increased in the year 2019 as compared to mean values of NDVI.

5. Conclusion

The impact analysis of the Narmada river is carried out by the multispectral image analysis by supervised classification for calculating the change in the area of crop cultivation. The crop area in the year 1985 was 25414.7sq.km and is increased by 4.042% in the year 1995 and observed to be 26442.1sq.km. Similar growth is also observed in the next decade of about 3.292% in the year 2005 and observed to be 27312.5sq.km. This study aims to determine the increased crop area due to the Narmada canal and for that, the crop area of 2019 is calculated by collecting 58 spectral signatures for supervised classification over the southern part of the Narmada canal. The growth of about 52.49% is observed in the crop cultivation area. The total crop cultivation is increased by 61.04% in the last 34 years. The results may be useful to analyze the cost-benefit aspect of the irrigation system. Further study may include crop health monitoring using multispectral and hyperspectral images correlating with climate change over the Narmada canal system. The crop quality is judged by the amount of chlorophyll content by Terra MODIS product of Normalized difference vegetation index (NDVI). The clear demarcation in the NDVI graph shows the improved quality of the crop after the construction and operation of the Narmada Canal.

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