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Spatio - temporal changes in NDVI and rainfall over Western Rajasthan and Gujarat region of India

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ABSTRACT

This study examines the MODIS time series NDVI datasets to detect greenness regeneration over Western Rajasthan and the Gujarat region of India. Time series analysis was applied to 17-years (2000-2016). MODIS NDVI satellite data product. Rainfall data for the same period were also analyzed to understand its impact over vegetation. NDVI time series datasets of MODIS 16-day composite proved sufficient for deriving statistically significant trend values for identifying areas of change in vegetation cover. Areas showing positive changes in NDVI trend was clearly correlated with areas which were brought under irrigational network over these areas, indicating an increase in vegetation, due to availability of water supply. Trends in NDVI were also compared with the trends in rainfall over the selected locations from Gujarat and Western Rajasthan. NDVI was positively correlated with the rainfall in both the regions. The NDVI time series trend analysis successfully detected the changes in greenness regeneration areas in Gujarat and western Rajasthan.

Keywords: Time Series, greenness, regeneration, NDVI, MODIS

The vegetation condition and dynamics of the landmass have always been treated as a significant indicator that can be used to quantitatively detect ecosystem processes at different scales (Xu *et al.,* 2010). Many studies have tried to understand vegetation condition from satellite images, to distinguish anthropogenic land degradation or desertification by comparing the potential and actual status of vegetation (Hanafi and Jauffret, 2008; Holm *et al.,*2003).

Ecosystem in India is fragile due to its wide range of climatic conditions across its vast geographic scale and varied topography. It has been reported that around 30 per cent of the total land area of the country is undergoing degradation (SAC, 2016). Detailed reporting at a regional scale over India is required especially in areas around dry lands, but lack of up-to-date spatial data at a regional scale is a major drawback. Important indicators of land degradation and desertification for example in the form of soil maps, geological maps, or spatial data on land cover, land use, and livestock distribution were either not available or obtained at a very coarse resolution. Similarly precipitation and temperature data on local scale are not available.Avoiding all these constrains,land degradation and regeneration monitoring was done over western Rajasthan and Gujarat region of India with Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data of two decades (2000-2016) using time series trend analysis. It was hypothesized that the derived Normalised Differential Vegetation Index (NDVI) trend vectors might successfully detect changes in photosynthetically active vegetation and serve as an indicator for land degradation and regeneration processes.

MATERIALS AND METHODS

The study area is comprised of Western Rajasthan and Gujarat region of India lying between 68ºE to 76ºE and 29ºN to 20ºN. The mean annual rainfall varies between 20 cm to 100 cm over the entire region. This regions also witnessed canal and ground water management, rain water harvesting management, dry land farming, agro-forestry development and wasteland development action programs in last two decades.

Satellite data

The Moderate Resolution Imaging Spectroradiometer (MODIS) datasets are recorded by NASA's Terra platform on board two sun-synchronous satellites, near-polar orbit at 705 km altitude and cross the equator every day at 10:30 am local time. MOD13Q1 Vegetation Indices was downloaded in HDF-EOS format (Hierarchical Data Format for NASA's

Earth Observing System) for the years 2000-2016 from https://ladsweb.modaps.eosdis.nasa.gov.It contains NDVI at a spatial resolution of 250 m. The standard projection system of these images is sinusoidal grid projection. MODIS tiles measure 4800 by 4800 pixels, which correspond to about 1200 by 1200 km on the ground. Further multi-temporal Landsat/ Copernicus data sets were collected for the corresponding years (2000-2016) of some selective sites to validate and explain positive and negative trends derived from time series vectors of MODIS data.

The MODIS data stacks of 1336 datasets covering 16-days composite NDVI recordings for 17 years were searched and corrected for missing and erroneous data by reviewing the quality assurance flags provided with the data. Missing pixel data values were replaced with the corresponding 16-years mean of the specific time series vector. Negative values were replaced with a zero since they occurred only in the case of water bodies in NDVI data sets. The time series vectors were filtered using the Savitzk-Golay filter, in order to smoothen the data values (Schafer, 2011).Simple linear regression analysis was applied considering time as the independent variable and the NDVI values as dependent variable. The precision of trend estimates are strongly influenced by the variability and auto correlation of the noise present in the dataset. The regression slopes of all pixel locations were thus categorized into "positive" (>0.007), "stable" (0.004 to 0.007), and "not significant" (<0.004) categories and then mapped accordingly.

Rainfall

Rainfall datasets from Climate Research Unit Time Series (CRU-TS) (http://www.ipcc-data.org/observ/clim/cru_climatologies.html) from 2000-2016 was used for the study. These data sets are freely available and showed a good consistency therefore was preferred for the study area.

The time series vectors of precipitation at the geographic locations of 30 weather stations in the study area were extracted from the CRU-TS database for the period of 2000-2016 and simple linear regression modeling was performed for analysis (Eckert *et al.,* 2014).Further to validate our study, selected points over satellite images were acquired at a very low resolution and visual comparison was displayed.

RESULT AND DISCUSSION

Spatial and temporal change in NDVI

Fig.1 shows the spatial distribution of average NDVI of June to September period for selected year viz. 2000, 2005, 2010 and 2015.As seen from the figure,the spatial distribution of NDVI in Western Rajasthan and Gujarat has lower values in the western part than in the eastern side. In the western part of Western Rajasthan lies the sandy Thar Desert which has typical arid climatic condition thus vegetation growth in these regions are quite tough other than Caryophyllales (Cactus) plants but recent management plans of irrigation has brought about some change in these areas. Currently agricultural crops are extensively being grown in heart of the desert. Therefore spatial change in greenness spread is clearly visible over the years. In Western Rajasthan the values of NDVI range between 0.1 to 1 and in Gujarat the values range between 0 to 1. The north western part of Gujarat near the Kutch region NDVI is equal to 0. This shows that this region is devoid of any kind of vegetation as this region exhibits extreme salty desert (Rann of Kutch). The vegetation pattern in the central Gujarat part has shown some extensive changing patterns, the greenness has increased due to the spread of the canal network in the central part which has provided Gujarat with triple crop seasons (Fig.1).

Rate of change in NDVI

The rate of change in NDVI as depicted by the slope of regression line was classified as positive (>0.007), stable (0.004 to 0.007) and non-significant (<0.004) and are presented in Fig. 2.Greenness seems to be stable in the eastern part of both the regions, while change in the extreme western part over the sandy desert and the saline desert are not much significant at this resolution of the satellite imagery. Positive change is observed in central part of both the study areas.The western Rajasthan is highly fragile and is subjected to excessive stress due to frequent droughts and low rainfall (Rao, 1996).Indira Gandhi Nahar Pariyojana (IGNP) traverses seven districts of Rajasthan viz Barmer, Bikaner, Churu, Hanumangarh, Jaisalmer, Jodhpur and Sriganganagar bringing about a remarkable changes over the time. After 2012, the effect of canal was felt in an extensive way over the western drylands with clear increase in agricultural productivity due to availability of irrigation facility.

Gujarat plains and hill region belongs to the arid and semi-arid type of climatic condition but North Gujarat is rich in alluvial aquifers naturally,therefore farming was well spread over this region since long but uncontrolled exploitation of groundwater for agricultural irrigation has resulted in many undesirable consequences, thus this region suffered from water stress (Ranade and Kumar, 2004). Post Narmada

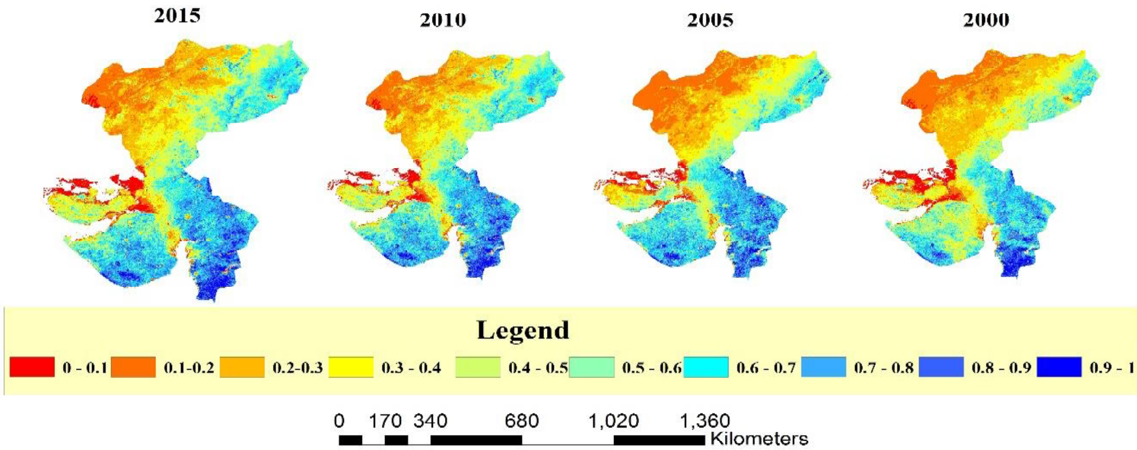

Fig 1: Temporal and spatial variation in NDVI over the study area.

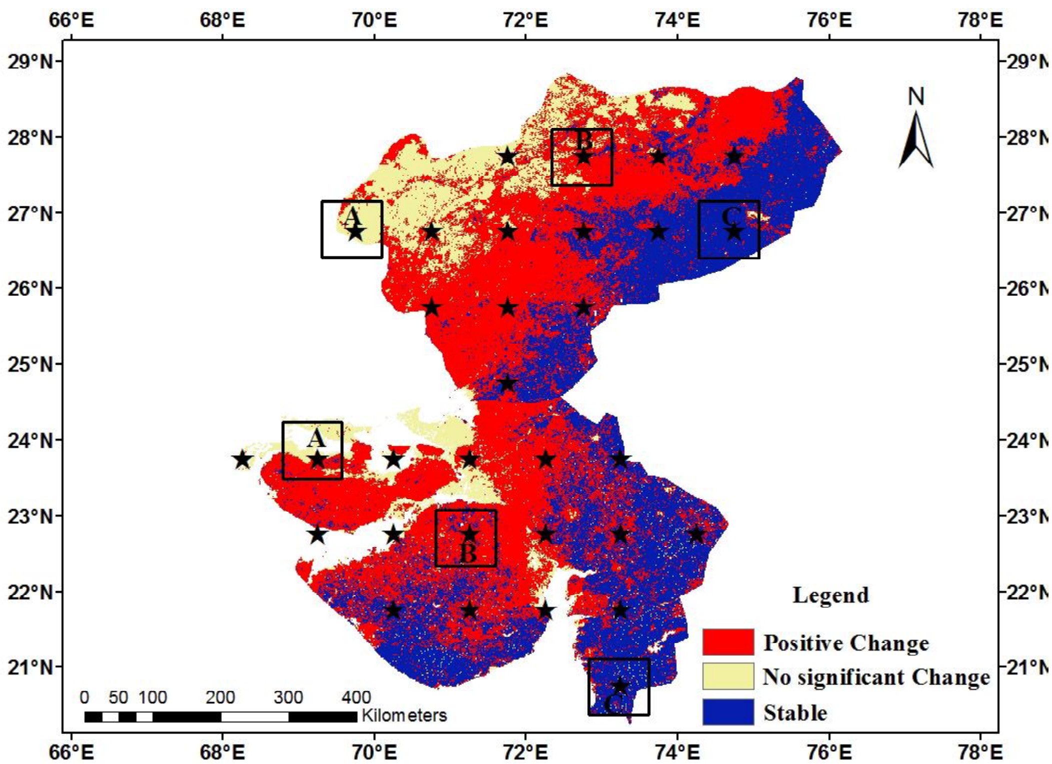

Fig 2: Linear regression slope values derived from MODIS 16-days composite NDVI observations from 2000 to 2016.

Canal construction after 2004, the supply of surface water for irrigation has resulted in changes in groundwater levels and it has also marked reduction in the salinity of groundwater over time (Kumar *et al.,* 2014).Therefore Narmada Canal was a great contribution for controlling the land degradation conditions over this region and bringing about stability.

Rainfall and NDVI trends in western Rajasthan

Statistical analysis of precipitation over Western Rajasthan shows that rainfall over all the stations was an increasing pattern over the time series for the monsoon months (June, July, August and September) during the time period 2000-2015 (Fig. 3). Fig. 3(A) shows NDVI and rainfall trends at location point A (Fig. 2) of Rajasthan. In extreme western Rajasthan there is no significant change in NDVI. Although, introduction of the canal network IGNP has brought about increasing trend in NDVI but still more changes are yet to be witnessed. On the other hand station B (Fig. 2) witness's positive change even when over this region significant increase in rainfall might not have taken

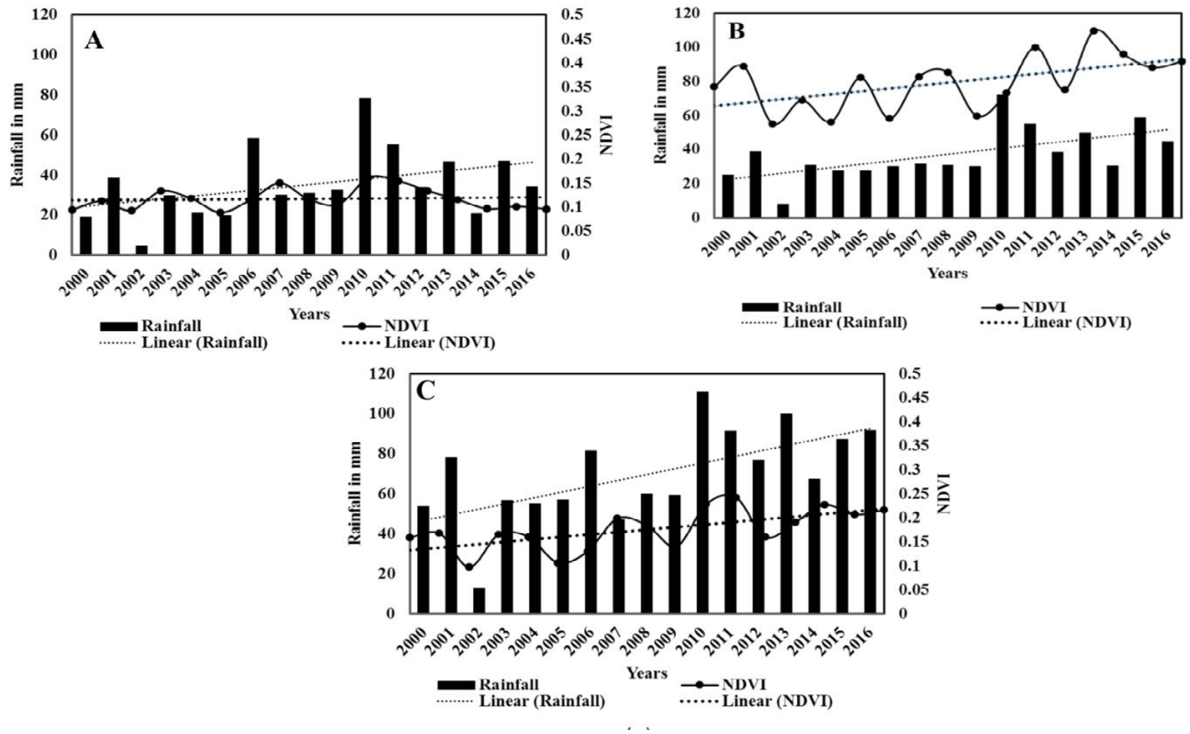

Fig 3: Rainfall and NDVI pattern over spot (A) Non-significant region, (B) Positive region and (C) Stable region over Western Rajasthan

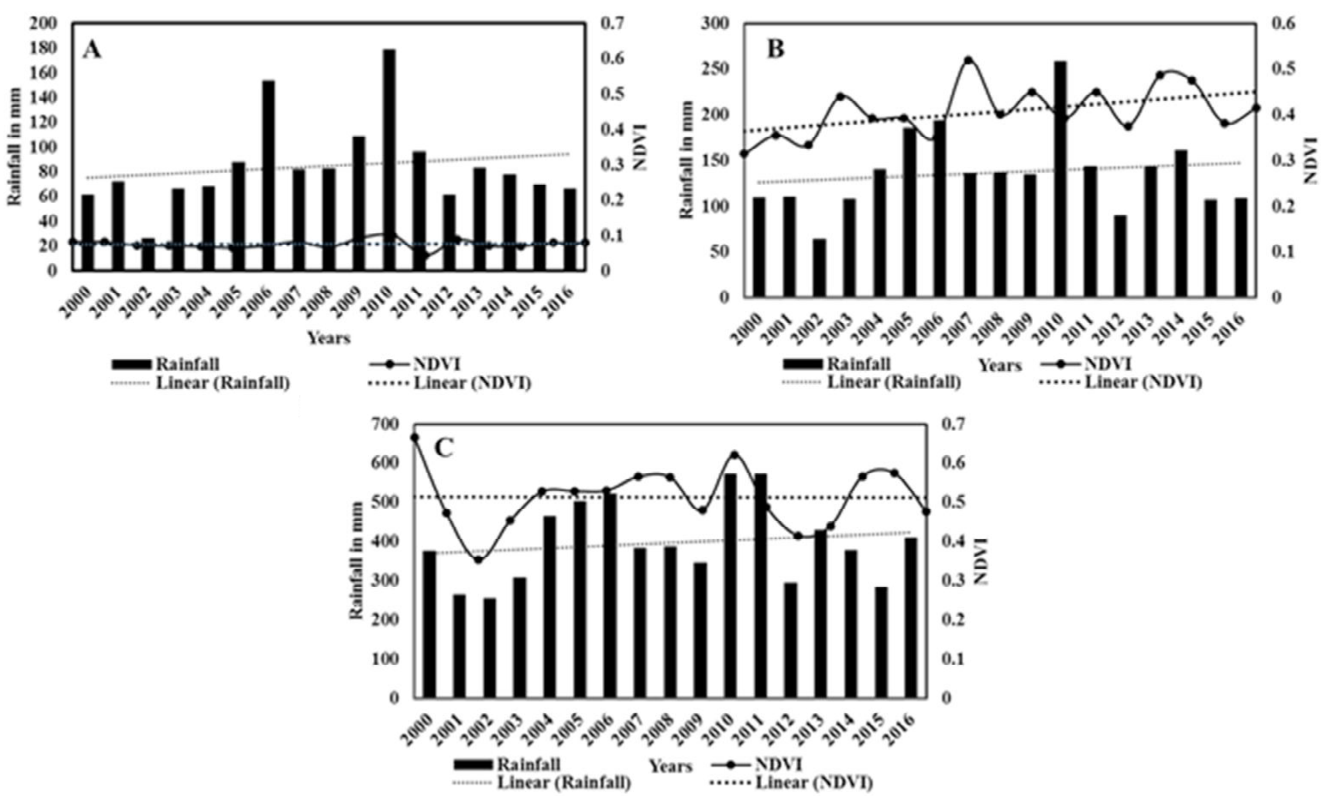

Fig 4: Rainfall and NDVI pattern over (A) Non-significant region, (B) Positive region and (C) Stable region over Gujarat

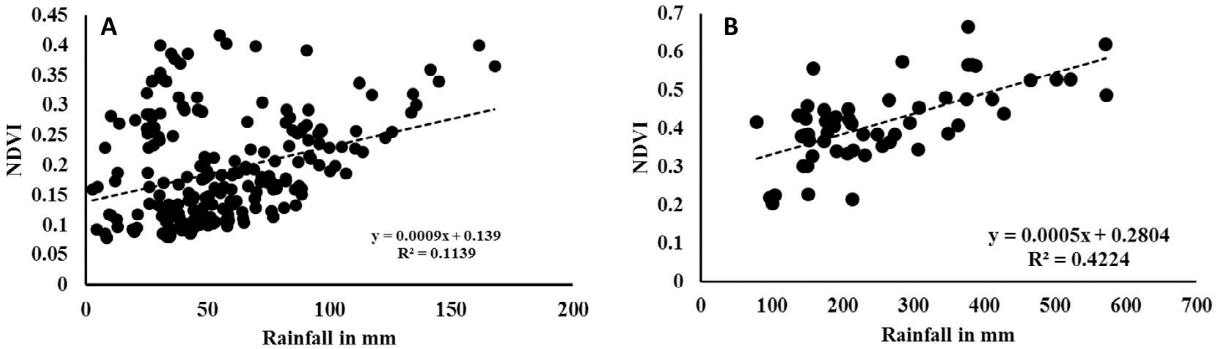

Fig 5: Relation between NDVI and rainfall over (A) western Rajasthan and (B) Gujarat region

place but NDVI shows a sharp increase (Fig. 3 B). Increase in NDVI may be a resultant of the canal network. As canal water sustains for entire year and helps in triple cropping pattern over the year. Fig. 3 (C) shows much more stable situation where rainfall and NDVI both are increasing in a steady way because this region has no interference of any artificial network and this region has comparatively better climatic as well as soil condition than the western part.Any changes in monsoon rainfall have strong impact on agriculture effecting the greenness regeneration or degradation of any area (Attri *et al.,* 2018).

Rainfall and NDVI trends in Gujarat region

Similar situation is witnessed over the Gujarat in all the three categories of classification in case of monsoon rainfall (Fig. 4).Distinct rise in rainfall amount is observed for various meteorological stations but apparently this region is different from the Western Rajasthan in terms of rainfall quantity as this region receives rainfall around 500mm in the eastern parts and the western parts receives around 180mm in the monsoon season proving it shares a semi-arid climatic condition. In both the cases we see that the rainfall trends increase from west to east and this pattern is quite similar to the vegetation pattern over this region.Temporal and spatial variability of rainfall analysis suggested occurrence of flood and drought side by side in case of Gujarat (Pandey *et al.,* 1999).

Although these precipitation trends observed between 2000 and 2015 for both regions may be temporary phenomena, because they might partially explain the large clusters of NDVI trend areas detected or named. Some locations showed no clear trends but seasonal variation in precipitation is high in some areas, indicating that there are both extremely dry and extremely wet years.Reliable precipitation record for a long period is needed to draw any conclusions regarding existing rainfall trends. Facts and figures clearly show that there is a clear increase in trend of NDVI in all three regions but quantity of rainfall remains varied in three distinct places. Positive changes therefore clearly observed from the graphical analysis which shows that both climatic parameters and irrigational facilities have marked remarkable changes over these areas.

Relationship between NDVI and rainfall

Fig. 5 shows the NDVI in relation to rainfall in Gujarat as well as in western Rajasthan. In both the regions correlation between NDVI and rainfall is positive indicating that, increase in rainfall increases NDVI over the regions. Although it shows positive correlation the relationship is not strong enough since R^2 is around 0.11 in case of Western Rajasthan clearly proving the contribution of canal network over the region as evident form high NDVI at low rainfall (Fig. 5 A). Fig. 5 (B) also exhibits positive correlation with R^2 0.42 over the Gujarat region which is also moderate relationship, thus the impact of canal in this region is also visible.

Validation using spatial-temporal high resolution satellite datasets

By analyzing rainfall data, the larger clusters of NDVI trend areas are explained but multi-temporal high-resolution datasets acquired during 2000-2016 around the meteorological stations will help to define the categories in a more refined way as the high resolution images gives better overview of the region. However, visiting each category of changes and presentingin documentation is quite difficult thus for validation purpose positive change category has been chosen as our interest revolved around the regeneration of the vegetation cover since negative changes were almost negligible.

Distinct difference in vegetation growth has been spotted around the canal regions of Western Rajasthan and Gujarat. Irrigation facilities over typical arid and semi-arid regions have turned as a boon over the region. Fig.6a shows a part along the IGNP canal in Western Dry lands which has

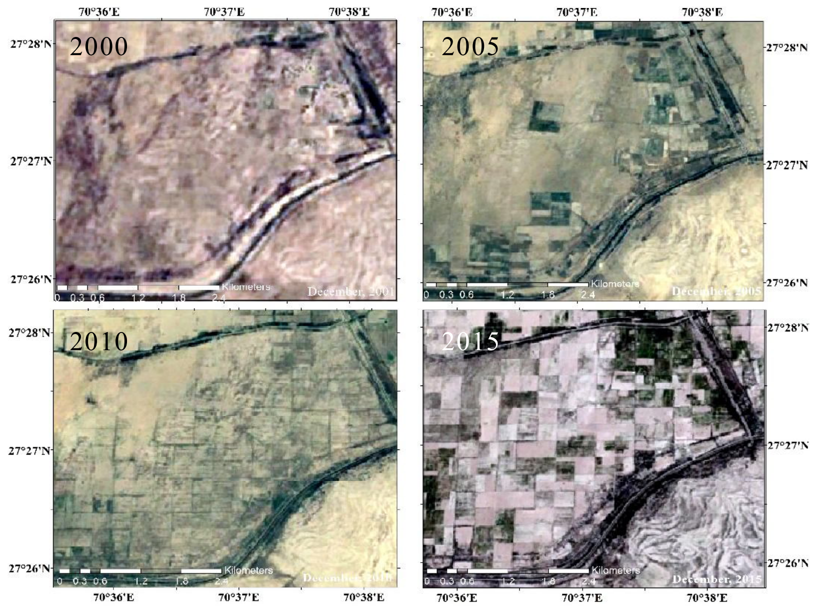

Fig.6a: Spatial change along the IGNP canal in Western Rajasthan

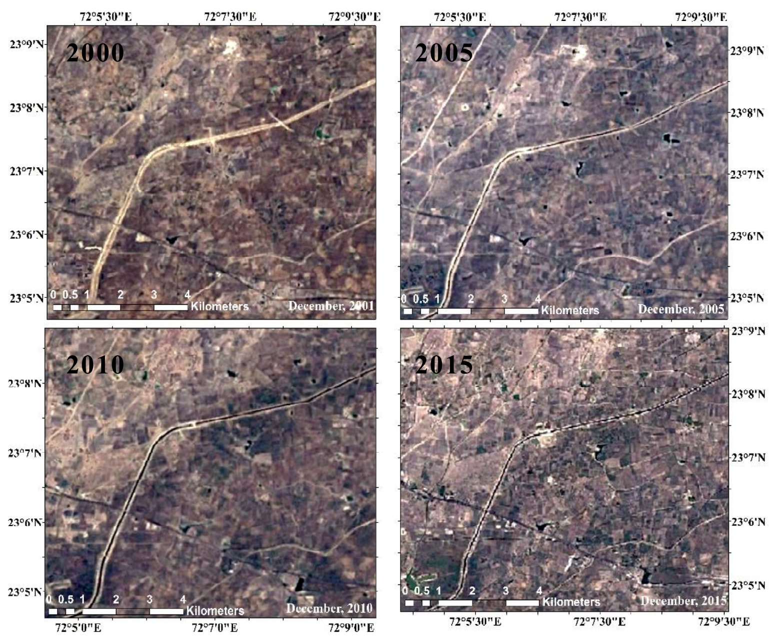

Fig.6b: Spatial change along the Narmada canal in Gujarat

undergone complete change over the years. Earlier this region was under sandy barren land but with human endeavor over the time, greenness has spread with the expansion of agricultural fields which is distinctively visible. Similar change is witnessed in Fig.6b along the Narmada canal which has rejuvenated the Gujarat region again by recharging the ground water and providing irrigation facility for the entire region giving rise to agriculture productivity. The canals not only have developed the areas along it but, also it has brought a sustainable development over the entire region. Positive externalities automatically outshined with the rejuvenation of the regions. Three cropping seasons were witnessed, with the shifts in cropping patterns towards water-intensive, high-value crops and improved higher yields leading to remarkable economic growth standards.

CONCLUSION

This study explored 15 years of MODIS 16-days composite NDVI time series to detect vegetation cover change focusing on land degradation and regeneration areas of Western Rajasthan and Gujarat of India. It can be concluded from this study that the areas showing positive trends in NDVI are most widespread towards the Central part of Western Rajasthan and Gujarat of India. Negative trends are less frequent overall; they are interspersed between areas showing positive trends and stable places therefore they are of no significance.The western part of the study area is more or less stable and hardly shows any change throughout the time frame.15-year seasonal precipitation data coincide well with the detected spatial spread of NDVI change areas. This indicates that changes in precipitation might have an influence on large NDVI trend areas. Validation of more localized NDVI trends with the help of multi-temporal high-resolution satellite data was successful. Changes due to irrigation facilities were clearly seen over the time series.

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