NDVI Based Assessment of Desertification in Arid Part of Rajasthan in Reference to Regional Climate Variability

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Abstract: At the national scale, India is among the countries experiencing the heat of desertification; about 120 m ha area is degraded by various processes of degradation and in western part of Rajasthan; about 76% area has been mapped under wind erosion and deposition form of land degradation. The present study was carried out in Jaislamer district which falls within arid region of India and cover maximum area of Thar Desert in India. The district can be best described by a dominant sandy terrain and climatically a very low rainfall region of the country. Absence of any substantial vegetation cover and agricultural activities, coupled with high wind velocity make the region more vulnerable to sand movement through wind erosion and depositional processes. Satellite remote sensing provides an alternate technique for monitoring and characterizing trends of land degradation. In this paper, we used time series datasets of Normalized Difference Vegetation Index (NDVI) obtained from MODIS available from 2000 to 2009. Decline in vegetation cover is one of the indicators in the assessment of state of desertification. Therefore, NDVI derived from remote sensing satellites can also be used as indicators of desertification. Recent researches also link desertification with El Niño and La Niña events. Our observation showed, years 2002, 2004 and 2009 has very low range of NDVI values while 2001, 2003, 2006 has the combination of higher, moderate and low NDVI values.

Introduction

Over the past 40 years, there have been many definitions of desertification, few of the mostly accepted ones, are, (1) UNEP (1991): land degradation in arid, semi-arid and dry sub-humid areas resulting mainly from adverse human impact and, (2) the Earth Summit at Rio, held in 1992: land degradation in arid, semi-arid and dry sub-humid areas resulting from climatic variations and human activities". The difference between these two definitions is the recognition of climate which is a major factor to determine the spatial variability of areas vulnerable to desertification. At the national scale, India is among the countries experiencing the heat of desertification; about 120 m ha area is degraded by various processes of degradation (Anon., 2008) and in western part of Rajasthan, according to a report, 76% area of the arid Rajasthan, across all land uses, was affected by wind erosion, 2% by salinization, 3% by vegetation degradation and 0.10% by mining activities (Kar, et al, 2007a). Arid areas in India, which falls within the rainfall zones, 100 – 500 mm, under a dominant sandy terrain, experience gradual change in natural vegetation in various habitats. Thus, these regions are more vulnerable to land degradation. Adequate Information through various studies are available now to specify the major causes for land degradation in this region using both field based interpretation and remote sensing. Sikka, D.R, 1997 studied land degradation correlated with climate change. Kar, *et al.*, 2009, based on a national level mapping assessed various types of land degradation in India and presented a national level database on desertification. Kaushalya R. *et al.*, 2013, assessed vulnerability of Indian agriculture to rainfall variability using NOAA-AVHRR and MODIS (250 m) data. PiaoShilong et al. 2005 used NDVI to indicate decline in desertification in China in the past two decades. Santra and Chakrtaborty, 2011, analyzed both seasonal and annual change in vegetation and found suitability of MODIS data for quick assessment of vegetation changes in Thar Desert.

Study area and Environment

The state of Rajasthan in its western part follows a climatic gradient from 500 mm in the east bordering Aravalli hills to ~150 mm in the extreme west in Jaisalmer district. Therefore, it is expected that a very high NDVI values in the eastern fringe and a low NDVI to be associated with dry/arid western part of the region. The present study was carried out in Jaislamer (Fig. 1) which is the largest district of the state covering an area of 38,401 sq. km. Located in the extremely hot arid part of India (Latitude between 26°1′ N and 28°2′12″ N and Longitudes, 69°30′ E and 72°20′30″ E), it is classified under arid western plain as per agro-climatic zonation of the country. The district is also part of Thar Desert in India and can be best described by a dominant sandy terrain and climatically a very low rainfall region of the country. Absence of any substantial vegetation cover and agricultural activities, coupled with high wind velocity make the region more prone to wind erosion and deposition form of degradation. Gradual introduction of the Indira Gandhi canal network within this desert has led to faster changes not only in the agrarian situation but also in anthropogenic spheres. Under such climate, terrain and edaphic conditions, the region is vulnerable to land degradation of various types, the primary factor being the wind erosion and deposition. We have tried to assess the situation of land degradation using NDVI based remote sensing technique which is an alternate to understand the relationship between change in vegetation and associated land degradation.

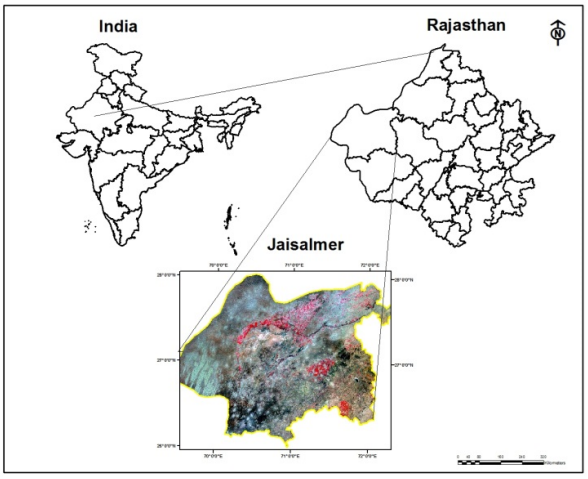

Fig.1. Location of study area

Climate variability

The eastern part of the district receives about 250 mm of annual rainfall while some of the areas in the western margin receive about 100 mm. The occurrence and distribution of the rainfall is also erratic. Of late, the region has also witnessed higher annual rainfall, for example, the rain gauze at Jaisalmer, recorded 421 mm of annual rainfall in 2006, 265 mm in 2011 and 158 mm in 2003. The maximum temperature during summer months often sores above 47^0 C, while during winter the daily minimum temperature sometimes goes down to the freezing point. Jaisalmer region experiences the highest wind speeds in the arid western Rajasthan. Peak wind speeds are observed in June which records a mean monthly wind speed of 27.2 kmph. Crop growing seasons are also about 4 – 6 weeks only. The growing season available for pastures is 8 – 10 weeks normal conditions of rainfall and the grassland are subjected to drought conditions once in four years during the growing phase, affecting the forage production. The crop production under rainfed conditions in the district is confined mainly to the south eastern part where the mean annual rainfall is around 250mm. Under all these conditions, aeolian processes become highly efficient and trigger up owing to such climatic variability, producing vast area under sand dunes and sandy hummocks. In fact such sandy plains cover more than 60 % area. While soil cover is generally thin except on sandy plains, natural vegetation consists mainly of grasses and shrubs of poor morphology which sustains only low rainfall regimes and under conserved moisture condition.

Rainfall data over the years (2000 to 2009), collected from three rain gauze stations at Jaislamer, Pokaran and Fatehgarh were plotted to understand the rainfall variability and pattern (Fig. 2). It was found that trend of rainfall was much higher in the SE part than the western part over the years.

Data used and Methodology

- NASA MODIS CMG Monthly NDVI (Global) data has been used. These data were processed by NASA Goddard from the Terra sensor projected on a 0.05 degree (5.5 km resolution) Climate Modeling Grid (CMG).

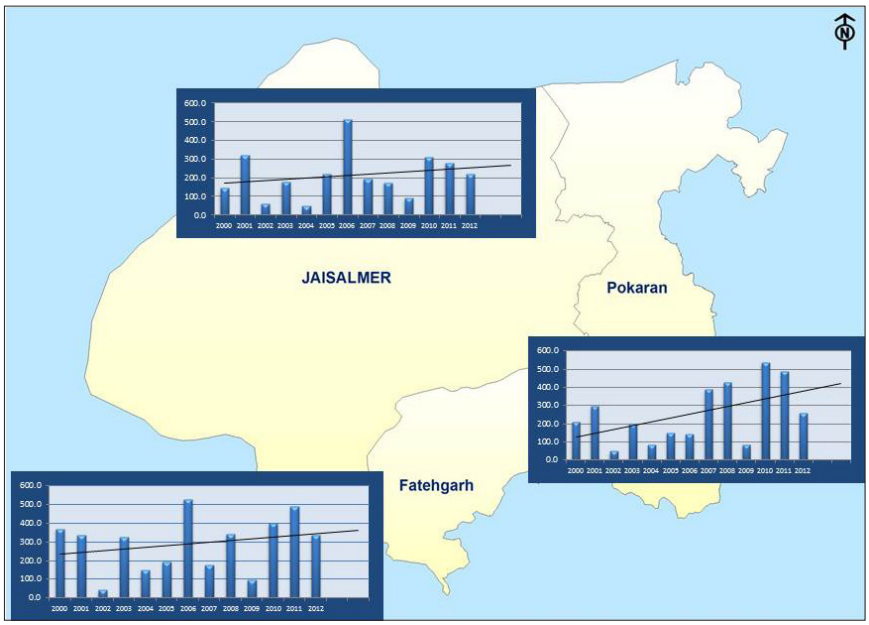

Fig. 2. Rainfall variability in Jaisalmer district from 2000 to 2009, recorded at three rain-gauze stations

- IRS - AWiFs data were used as secondary data for checking vegetated area.
- The data has been downloaded for the years 2000 - 2009. Monsoon period (July, August and September) were selected for observation

Preprocessing

- Conversion of MODIS NDVI data from 16 bit integer to 32 bit float to get the original values (+1 to -1)
- Since this data did not contain cloud covers and atmospheric disturbances, therefore, the procedures to remove such errors were not followed
- Satellite data in respect of the study area was extracted

Methods

- Generation of yearly Average scenes by raster calculator (July+August+September/3) for each year.
- Visual observation of value range from the year 2000 to 2009. Then we obtained maximum and minimum range of NDVI values (0-0.65).
- On the basis of this range, we have classified all the scenes into three categories (0.65/3) as 0-0.2 (low), 0.2-0.4 (Moderate) and 0.4-0.7 (High) using ArcGIS spatial analysis tool.
- Statistics generation and area calculation for each class
- Analysis of rainfall pattern of the study area from 2000 to 2012.

Result and Discussions

Assessment of vegetation condition

Distribution of NDVI values, extracted from MODIS terra remote sensing data indicates variation in greenness over the region from 2000 to 2009. The time series analysis of NDVI values for the respective years is presented in Fig. 3. The images present an over view of spatial changes in greenness in the region. Reclassification of this data into low, moderate and high (Fig. 4 & 5 and Table. 1) using GIS indicates condition of vegetation and their spatial extent over the years. Area under high category was only experienced during 2003 (4.8% area) and in 2001 and 2006 with <1% area under high categories. In the moderate situation, during not so good rainfall years, the areas remained at par with 10-12% while in the low categories, the percent area varied from 89 to 100 (2002), except in 2003 (36%) indicating very bad situation of vegetation.

Reclassification of NDVI values (categories)

Therefore our analysis indicates very low distribution of vegetation in Jaislamer district

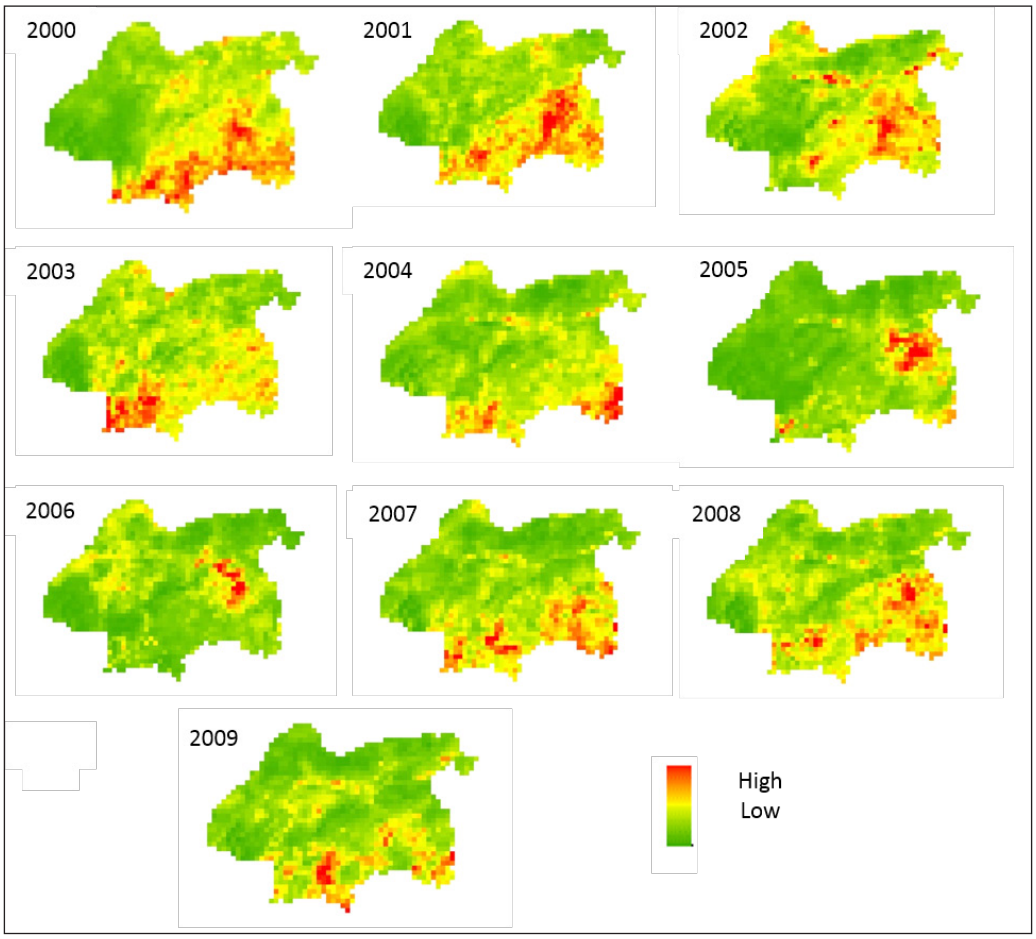

Fig: 3. NDVI derived from MODIS TERRA showing different levels of Greenness over Jaisalmer district from 2000 to 2009.

except in 2001, 2003 and 2006 when the region experienced rainfalls more than normal. A better situation was observed between 2005 and 2009, but the worst of the situations was observed during 2002 and 2004 when the region experienced acute drought condition. Most of the districts in Rajasthan were under moderate to severe drought during those years. Therefore, situations during 2000, 2007, and 2008 may be assumed as representing

Table 1. Area (sq.km) statistics of different categories of NDVI values over the years in Jaisalmer District

Categories > Years	Low (0-0.2)	Area (%)	Moderate (0.2-0.4)	Area (%)	High (0.4-0.7)	Area (%)
2000	34364.77	89.30	4116.57222	10.70	0.000	0.00
2001	23182.96	60.25	14939.9764	38.82	358.0482	0.93
2002	38481.21	100.00	0.000	0.00	0.0000	0.00
2003	15278.14	39.70	21349.6062	55.48	1853.6172	4.82
2004	38453.6	99.93	27.610274	0.07	0.000	0.00
2005	36968.37	96.07	1512.84349	3.93	0.000	0.00
2006	33293.27	86.52	4940.71273	12.84	247.21639	0.64
2007	33869.49	88.02	4611.95398	11.98	0.000	0.00
2008	34014.08	88.39	4467.40331	11.61	0.000	0.00
2009	38038.81	98.85	442.397466	1.15	0.000	0.00

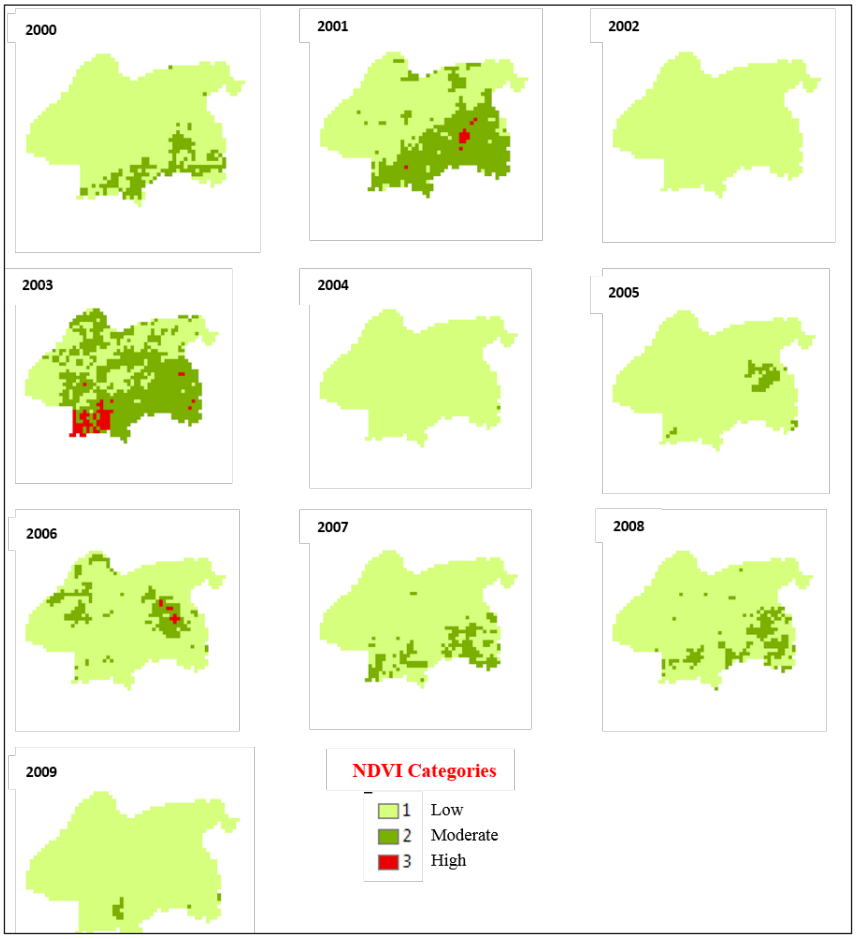

Fig.4. Reclassification of data showing sequential changes in NDVI over the years (2000-2009)

normal years and 2003 and 2006 as better rainfall years for Jaislamer as a whole.

Discussion and conclusion

Desertification which is defined as a form of land degradation in arid, semi-arid and sub-humid situation seems to be the right kind of event for this part of Rajasthan. Studies based on natural resources survey in this part by Central Arid Zone Institute, Regional Remote Sensing Centre and few other institutes of the country suggest that

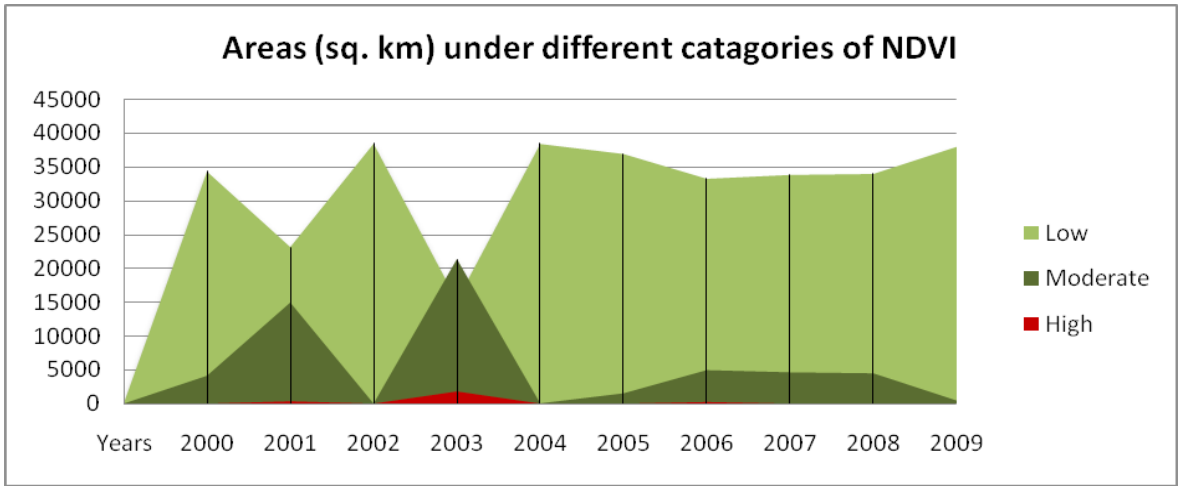

Fig.5. Distribution of classified categories of NDVI over the years in Jaisalmer District

this region because of climatic limitations has a dominant arid ecosystem. Wind erosion is the dominant process of land degradation and is regarded as the major factor responsible for the presence of a vast sandy terrain with various types of sand dunes. As per CAZRI, the region has substantial area (~54 %) under various types of sand dunes, dominant amongst are longitudinal, parabolic and mega-barchanoids. The morphology of such dunes indicates stability as well as some of the recent formations. In the same time, about 40% area around Jaislamer city is sculpted into a rocky terrain and some of these surfaces present imprints of fluvial signature.

From the results obtained from NDVI re-classification, it was found that the years, 2002, 2004 and 2009, had low distribution of vegetation indicating drought like situations, and in fact, these were under severe drought during those years. As per the concept of EL Nino years which represents a global weather phenomena for dry conditions for region like India, the conditions matched our results. Similarly, the classification also indicated better occurrences of vegetation (all the categories, high, moderate and low) during 2006, which was also a LA Nina year (wetter periods). Analysis of rainfall variability indicated that rainfall was better in the South Eastern part than the rest, particularly over the western part.

As per wind erosion index (Kar, 1993 and Ann. 2000), Jaislamer district is classified under extremely high value of index (480 and above). Our results (based on NDVI trend and rainfall variability) indicate that in most of the years, the conditions are favourable for higher wind erosion / depositional activities. In the absence of trees the dominant sandy terrain in the west and north-west gets a look of sparse grasslands and are represented by low value of NDVI for all the years. The major grasslands have dominance of *Lasiurus sindicus* type in more than 80% area (Ann. 1992). In the south east, similar habitats support *Calligonum Polygonides, Calotrois procera, Aerva pseudotomentosa* as shrubs and some of the areas are now irrigated with better groundwater. It has been seen that in spite of high vulnerability, the stable dunes can support adequate grass and shrub cover under un-disturbed condition which reduces the aeolian hazards, but situations of sand accentuations occur only in areas receiving the advantages of canal water and are being utilized for agriculture. The sandy undulating plains or hummocky lands area are at higher risk of Aeolian hazard where grasses and shrub density is low. In the NW part these lands support excellent cover of *L. Sindicus* grass but due to droughts, majority of them are dead or dried up. However, grasslands in this part of arid lands have been found to regenerate with slight improvement in moisture condition as has been seen in NDVI of 2003 and 2006 under better rainfall conditions. Since distribution of NDVI category low is observed in more than 80% area, the state of vegetation in the district can be termed as poor while it is also seen that with slight better rainfall situation, the greenness has improved as depicted in moderate category (38 – 55 % area). Thus, NDVI based technique has been found suitable to get a quick look at the spatio-temporal variability in the vegetation and so as to correlate their status in response to rainfall occurrences and land degradation.

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