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Application of remote sensing in analysis of impact assessment using biomass vigour changes of watersheds

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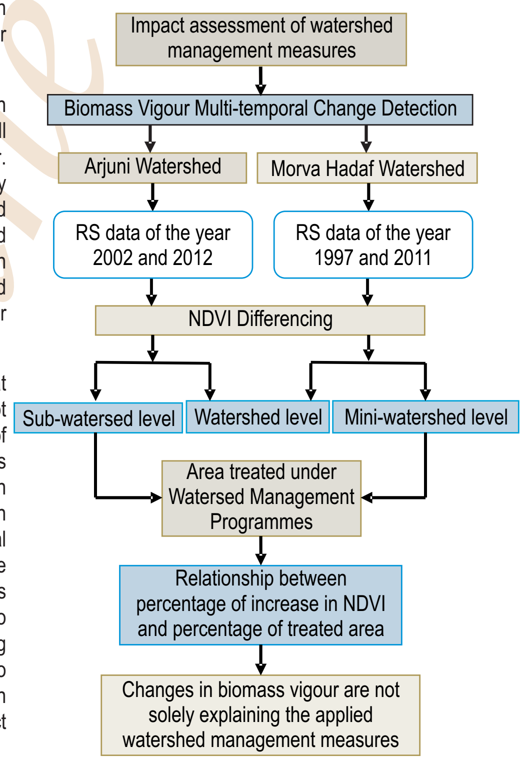
Abstract

Aim: Vegetation status analysis is the best technique to assess the impact of watershed development activities. However, this approach often ignores biomass changes which are not due to the watershed management intervention in arid/semi-arid regions. The present study focused on the biomass vigour change detection to assess the impact of watershed management measures in arid Arjuni and semi-arid Morva-Hadaf watersheds from Gujarat state, India.

Methodology: The study was carried out by multi-temporal remote sensing data for the year, 2002 & 2012 and 1997 & 2011 for the corresponding watersheds. The changes in biomass vigour were identified using the Normalized Difference Vegetation Index (NDVI) approach at watershed and sub-watershed levels for Arjuni watershed and watershed and mini-watershed levels for Morva-Hadaf watershed. The identified biomass changes were precisely tested with respect to already treated areas under watershed management programmes.

Results: The NDVI values increased in both watersheds representing an overall increase in the biomass vigour. However, the sub-watershed level study of Arjuni watershed and mini-watershed level study of Morva-Hadaf watershed showed negative relationship between the percentage increase in NDVI, and percentage of treated area under different programmes.

Interpretation: The results inferred that the increase in biomass vigour does not solely explain the implementation of watershed management measures. This clearly indicates that other than human induced factors (viz., micro-irrigation system adopted by farmers), seasonal factors (i.e., rainfall, temperature) have also influenced the NDVI values throughout the study area. Looking into the current micro-watershed clustering approach, the future work is required to distinguish between climate and human induced factors as a part of impact assessment studies.



Introduction

Approximately 170 Mha in India are classified as degraded land and roughly half of this area falls in undulating arid/semi-arid areas. These regions are facing the problems of uneven and erratic distribution of rainfall, low agricultural production and increased pressure of population. To address the problems, the watershed management approach was immersed and has been accorded high priority in India's development plans.

In recent years, remote sensing (RS) data coupled with geographic information system (GIS) help to quantify the impact of watershed management measures. A number of studies in India have demonstrated the capability of RS and GIS in impact assessment of watershed management programmes. Chakraborty *et al.* (2001) assessed the impact of National Watershed Development Programme for Rainfed Areas (NWDPRA) on the Birantiya Kalan watershed of Rajasthan based on temporal biomass vigour and land use/land cover change indicators. Dwivedi *et al.* (2003) quantified the impact of Integrated Wasteland Development Programme (IWDP) for Ghod catchment in Maharashtra using biomass and land use/land cover change indicators. Chowdary *et al.* (2001) evaluated the impact of NWDPRA, implemented in nine districts of Orissa using bio-physical, socio-economic and hydrologic change indicators. Ramachandran *et al.* (2009) evaluated the **i**mpact of Drought Prone Area Programme (DPAP) for the study area located in Ranga Reddy district, Andhra Pradesh using biomass, land use/land cover and socio-economic change indicators. These literatures made clear that the biomass vigour change, a biophysical indicator, is considered as a surrogate measure to assess the impact of watershed management measures. Whereas, looking to the inter-annual and inter-seasonal variability in arid/semi-arid regions, the phenologic/ seasonal parameters such as rainfall, temperature etc., are proved to have a dominant role in determining vegetation growth and in predicting trends in vegetation activities over the time (Propsatin *et al.*, 2007). Especially, rainfall has a strong effect on inter annual variability of vegetation in arid regions (Yang *et al.*, 1998; Richard and Poccard, 1998; Wang *et al.*, 2003).

I should be noted from the above literature that the pre-post treatment periods are commonly considered for the impact assessment studies. However, this approach mainly ignores the changes which are not due to watershed intervention viz., changes due to rainfall (Kumar *et al.,* 2014). Whereas, the agricultural areas are highly sensitive to rainfall effect in rain-fed arid/semi-arid regions. Hence, it is essential to evaluate the actual impact of such programmes on the study area. The smaller duration (say for two to four years) is generally considered for the impact assessment studies, which only provide a snapshot of the ground reality (Shah, 2004). Hence, consideration of longer duration for impact assessment is preferable. The majority of the studies have been conducted on isolated micro-watersheds (area<0.01 km^2). Looking to the micro-watershed clustering approach, which replicates the benefits of the already treated micro-watersheds on a wider scale, the impact assessment studies should be conducted over a larger area.

The Normalized Difference Vegetation Index (NDVI) is seen as a response of healthy vegetation or biomass vigour (Jensen, 1996). The NDVI differencing is one of the most commonly applied pre-classification change detection techniques for detecting the biomass vigour change (Muttitanon and Tripathi, 2005; Cakir *et al.,* 2006). The change in areas can be identified through the subtraction of the NDVI image of one date from the NDVI image of another date. Various researchers have effectively assessed the biomass vigour changes using NDVI differencing approach at pre and post implementation phases of the watershed development programmes using RS and GIS tools (Alemayehu *et al.,* 2009; Bakr *et al.,* 2010; Adb El-Kawy *et al.,* 2011; Coban and Ozdamar, 2014; Atesoglu, 2015). In Indian context, various government/non-government agencies have conducted impact assessment studies either through the report of research articles. Chakraborty *et al.* (2001)**,** Chowdary *et al.* (2001), Dwivedi *et al.* (2003), Dutta *et al.* (2003) and Shanwad *et al.* (2008) have reported literatures on assessment of watershed development programmes for Indian regions.

To address the above mentioned lacunae the aim of the present study is to assess the changes in biomass vigour for the select arid Arjuni watershed and semi-arid Morva-Hadaf watershed of Gujarat, India. And also to check whether the biomass vigour changes are solely explained by watershed management measures or carrying the influence of seasonal parameters. The study can help to quantify the actual performance watershed management measures in the already treated areas of both the watersheds.

Materials and Methods

Study areas: The Arjuni Watershed is located in Mehsana, Patan and Banaskantha districts of Gujarat state. The watershed covers a total area of 979.53 km^2 and predominantly used for agriculture. Similarly, Morva-Hadaf watershed is located in Dahod and Panchmahal districts of Gujarat state. It covers an area of 1018.57 km^2. The arid and semi-arid climatic conditions are prevailing in respective study areas (Fig. 1). An erratic rainfall and water scarcity causes the frequent drought conditions in both the regions. The water requirements have been fulfilled through Hadaf Dam and Mukteshwar Dam medium irrigation projects in Morva-Hadaf and Arjuni watersheds, respectively. The watershed development programmes were also accelerated on the upstream of both the study areas. The Desert Development Programme (DDP) and Drought Prone Area Programme (DPAP) were implemented in Arjuni watershed to increase the productivity of existing agricultural area and increase the agricultural land area through land management measures. The

Table 1 : Remote sensing data and ancillary for Arjuni and Morva-Hadaf watersheds, Gujarat, India

Study Area	Data	Description	Source
Arjuni Watershed	Landsat 7 ETM	Path: 149, Row: 44, dated 21st Feb 2002	www. glcfapp.glcf.umd.edu
	IRS R2 LISS-III	Path: 93, Row: 55, dated 2nd Feb 2012	National Remote Sensing Centre/Indian Space Research Organization (NRSC/ISRO), Hyderabad, Telangana, India
Morva-Hadaf Watershed	IRS 1C LISS-III	Path: 94, Row: 56, dated 23rd Oct 1997	
	IRS R2 LISS-III	Path: 94, Row: 56, dated 22nd Oct2011	
Both Arjuni & Morva-Hadaf Watersheds	Villages treated by watershed management programmes	The names of the villages were identified having completed watershed management programmes	Gujarat State Watershed Management Agency (GSWMA), Gandhinagar, Gujarat, India

watershed crop production technologies were adopted by Vadgam and Danta talukas from Banaskantha district in the 10th Fiver Year Plan of NWDPRA (Prajapati *et al*., 2015). The watershed management practices such as crop demonstration, horticultural plot, vegetable nursery using green shade, vegetable seed store, farm implements and drip irrigation have been practiced in the study area. The Drought Prone Area Programme (DPAP) and Integrated Wasteland Development Programme (IWDP) were implemented in Morva-Hadaf watershed. The main focus of such programmes are soil and water conservation such as afforestation, farm bunding and drip irrigation, increase in crop production through the use of micro-nutrients, increase in milk production through improvement in the breeds of cattle, silvipasture and forestry on village common land/wasteland.

Data used: The description of the remote sensing data (including path description and source) and ancillary data (treated villages) used in the present study are tabulated in Table 1. An appropriate selection of RS data is crucial aspect for temporal change detection in arid/semi-arid regions. The selection of RS data for Arjuni and Morva-Hadaf watersheds follows phenological synchronization and near anniversary synchronization, respectively. The phenological synchronization is based on accumulated precipitation (AP) and Growing Degree Days (GDD) (Thakkar *et al*., 2015), while anniversary date synchronization follows the selection of RS data of same date from two different years (Lillesand *et al*., 2008; Deng *et al*., 2008). The above mentioned RS data selection helps to assess the actual change in biomass by reducing the influence of phenology/seasonality.

Remote sensing (RS) data pre-processing: The acquired RS data (Table 1) have been pre-processed using geometric corrections, radiometric corrections and sun angle corrections as described below.

Geometric corrections: This geometric transformation can be quantified by selecting pairs of suitable Ground Control Points (GCPs) on RS imagery and an appropriate geometric model. For Arjuni watershed, the Landsat-7 ETM image of 21st Feb 2002 had been geometrically corrected with reference to the already rectified IRS R2 LISS- III master image of 2nd Feb 2011. Similarly, for Morva-Hadaf watershed IRS 1C LISS-III image of 23rd Oct 1997 was geometrically corrected with reference to the already rectified IRS R2 LISS-III master image of 22nd Oct 2011. The geometric transformations were performed using the second order polynomial and the nearest neighborhood resampling algorithm. A total of 153 and 208 GCPs having corresponding RMSE values of 0.353 and 0.308 were considered for referencing the Arjuni and Morva-Hadaf watersheds, respectively.

Radiometric corrections: The radiometric corrections were applied on obtained RS data by converting Digital Number (DN) values into spectral radiance values using the external calibration coefficients provided in the satellite data header /metadata file.

Sun angle corrections: The position of the Sun relative to the Earth depends on the time of the day/year. Therefore, the Sun angle corrections were applied on at-sensor radiance imagery of RS data. The Sun elevation angles were provided in the satellite data header file.

NDVI differencing: Dramatic changes in vegetation cover can be easily identified using the spectral reflectance of remote sensing data. It represents the status of biomass vigour. NDVI images are obtained by calculating the ratio between the Red and Near Infra-Red (NIR) bands of the satellite image (Eq. 1). NDVI values are always in between –1 and +1, where higher values represent more vigourous and healthy vegetation. Very low values (0.1 and lower) correspond to barren areas of rock, river sand. Moderate values (0.2 to 0.3) indicate scrub forest, grassland, while forest/dense vegetation are represented by high NDVI values (0.6 to 0.8).

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

An NDVI difference image represents the biomass change for a particular period relative to the historical average or a previous year. NDVI difference image ($NDVI_{diff}$) between two time periods is calculated by subtracting the NDVI image of the earlier time period from the time period of interest. In the present study, for the Arjuni and Morva-Hadaf watersheds, $NDVI_{diff}$ imagery were developed using the Eq. (2) and (3), respectively. The pixels were extracted that fall in the area of mean plus double of standard deviation. The threshold value was selected based on test and trials.

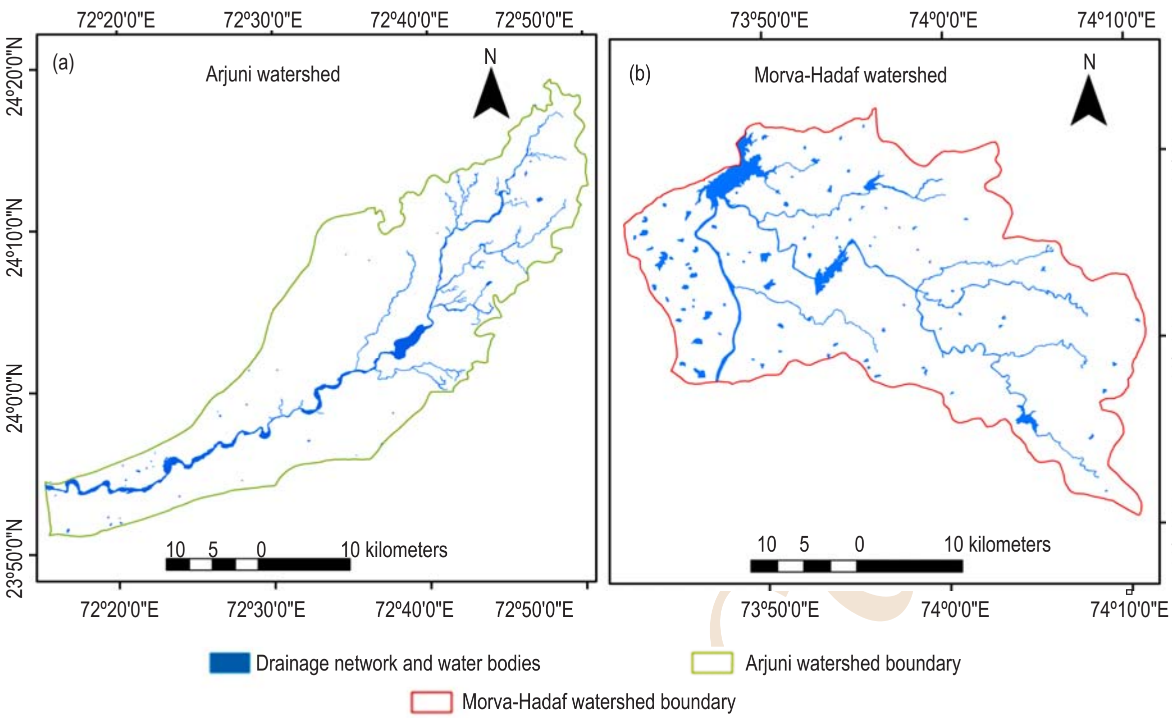


Fig. 1 : Location map of (a) Arjuni watershed and (b) Morva-Hadaf watersheds in Gujarat, India

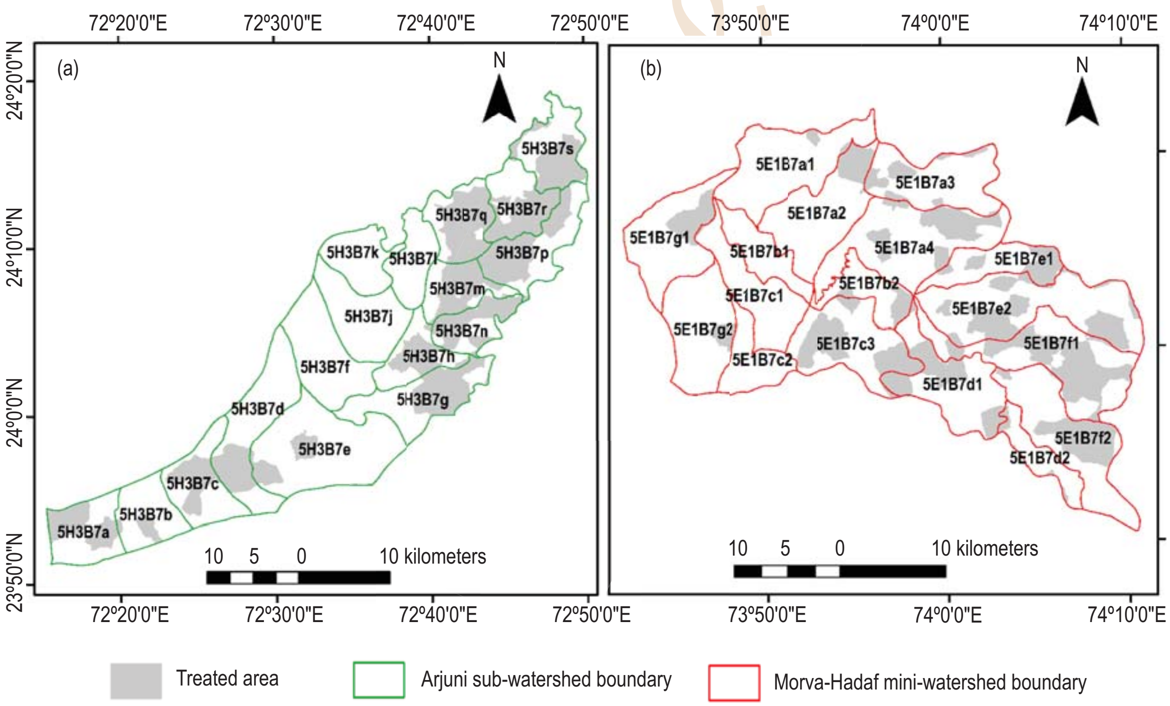


Fig. 2 : Area treated by watershed development programmes in (a) Arjuni watershed and (b) Morva-Hadaf watershed in Gujarat, India

$$NDVI_{diff} = NDVI_{2012} - NDVI_{2002} \quad (2)$$

$$NDVI_{diff} = NDVI_{2011} - NDVI_{1997} \quad (3)$$

Watershed-wise treated area development: The name of the villages treated under different watershed development programmes were identified for Arjuni and Morva-Hadaf watersheds from Gujarat State Watershed Management Agency (GSWMA). These villages are the "treated areas", where watershed management activities are already completed over the duration of 2000 to 2011 and 1997 to 2011 for respective watersheds. These villages were selected on the ESRI .shp village boundary layer [developed by Bhaskaracharya Institute of Space Applications And Geo-informatics (BISAG)] and clipped out the "treated areas" (Fig. 2).

Results and Discussion

The temporal behavior of biomass in Arjuni watershed has been studied by generating NDVI images from the RS data of the years 2002 and 2012. After performing differential analysis on two NDVI results, the areal distributions of NDVI changes were categorized into a decrease in NDVI, no change in NDVI and increase in NDVI (Fig. 3a). The NDVI difference image represents an increase in biomass over a substantial part of the Arjuni watershed. The calculated area under the biomass have been increased by 372.65 km^2, decreased by 3.17 km^2 and remained same by 603.71 km^2 over the period of ten years. The major part of the Arjuni watershed is covered by Danta and Vadgam talukas Banaskantha district. In order to assess the above mentioned results, the crop production is considered as one of the indicators. The results were confirmed by Pandya *et al.* (2013), where the Banaskanta district of the study area has registered the highest production of vegetable crops for the year 2010-2011. Moreover, the increased agricultural has been reported by Vadgam taluka (Kumar, 2009) and Danta taluka (Choudary and Pagaria, 2012). In the context to forest biomass, the tree cover of the Vadgam taluka was categorized as "good" (Singh, 2013). These increases in vegetation cover have confirmed that the NDVI values has been increased in Arjuni watershed over 2002-2012.

The sub-watershed scale analysis is required to understand whether the already treated area can explain the change in NDVI. The changes in NDVI are examined by considering the percentage change of all three categories viz., percent of decrease in NDVI, percent of no change in NDVI and percent of increase in NDVI (Table 2). Out of three categories, the "percent of increase in NDVI" is analyzed in the present study, because it is considered as an important biophysical indicator for impact assessment study of watershed management programmes. In the next step, the degree of relationship (correlation) between percent of treated areas of respective sub-watershed and increase in NDVI was evaluated. Normality was assessed using Kolmogorov-Smirnov (K-S) test for both percent increase in NDVI and percent of treated area. The null hypothesis

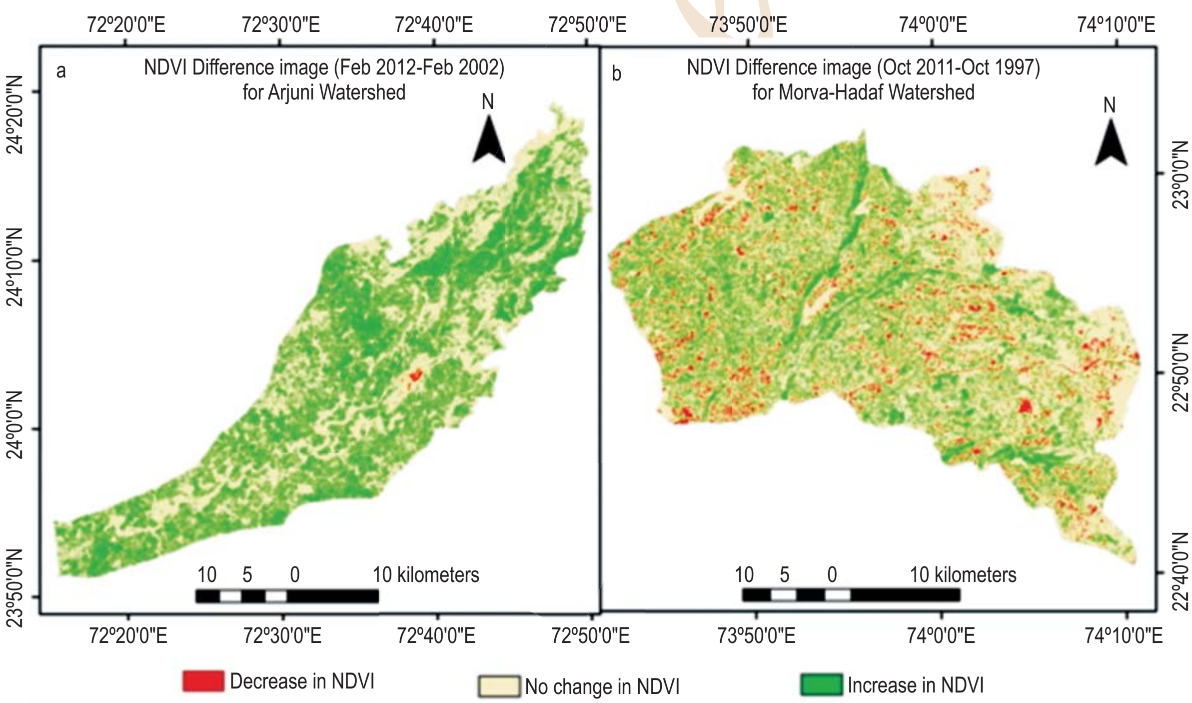


Fig. 3 : NDVI difference image of (a) Arjuni Watershed and (b) Morva-Hadaf watershed in Gujarat, India

Table 2 : Area under NDVI change category and area treated by watershed development programmes at sub-watershed level for Arjuni watershed in Gujarat, India

Sub-watershed (Code-number	Total area of Sub-watershed (km^2)	Treated area (%)	Change in NDVI 2002-2012					
			Decrease in NDVI (km^2)	No change in NDVI (km^2)	Increase in NDVI (km^2)	Percent decrease in NDVI	Percent No change in NDVI	Percent increase in NDVI
5H3B7a	50.49	43.01	0.08	28.53	21.88	0.16	56.41	43.34
5H3B7b	45.22	11.50	0.21	27.14	17.87	0.46	60.02	39.52
5H3B7c	54.53	32.46	0.34	34.94	19.25	0.63	64.07	35.30
5H3B7d	83.61	21.81	0.05	53.30	30.26	0.06	63.37	36.19
5H3B7e	125.76	10.74	0.36	77.33	48.07	0.29	61.56	38.22
5H3B7f	73.59	0.00	0.14	45.47	27.98	0.19	61.86	38.02
5H3B7g	68.16	41.92	0.12	44.31	23.73	0.18	64.88	34.82
5H3B7h	40.64	42.60	1.27	26.90	12.47	3.14	66.26	30.70
5H3B7j	64.63	0.00	0.09	31.32	33.22	0.14	48.55	51.41
5H3B7k	41.64	0.00	0.04	24.95	16.65	0.09	59.74	39.99
5H3B7l	38.40	0.00	0.10	24.69	13.61	0.25	64.29	35.44
5H3B7m	40.65	59.51	0.17	25.98	14.50	0.42	63.94	35.68
5H3B7n	37.67	65.63	0.03	28.02	9.62	0.07	74.23	25.55
5H3B7p	62.36	56.81	0.04	34.54	27.78	0.06	53.57	44.56
5H3B7q	51.95	69.73	0.01	31.74	20.20	0.01	61.00	38.89
5H3B7r	47.82	58.74	0.11	26.03	21.68	0.23	54.45	45.34
5H3B7s	52.41	50.72	0.01	38.52	13.88	0.02	73.06	26.48

Table 3 : Area under NDVI change category and area treated by watershed development programmes at mini-watershed level for Morva-Hadaf watershed in Gujarat, India

Mini-watershed (Code number)	Total area of Mini-watershed (km^2)	Treated area (%)	Change in NDVI Oct 1997- Oct 2011					
			Decrease in NDVI (km^2)	No change in NDVI (km^2)	Increase in NDVI (km^2)	Percent decrease in NDVI	Percent no change in NDVI	Percent increase in NDVI
5E1B7a1	76.44	2.83	7.82	52.42	16.20	10.24	68.59	21.19
5E1B7a2	68.74	13.81	6.65	47.57	14.52	9.68	69.19	21.13
5E1B7a3	59.97	17.26	11.40	36.99	11.58	19.04	61.66	19.32
5E1B7a4	90.92	25.37	8.48	63.38	19.06	9.33	69.71	20.96
5E1B7b1	29.20	0.00	2.94	19.93	6.33	10.06	68.26	21.68
5E1B7b2	28.88	22.35	2.92	19.77	6.19	10.13	68.47	21.43
5E1B7c1	49.17	0.90	5.19	33.24	10.74	10.56	67.60	21.84
5E1B7c2	30.45	0.47	3.44	20.19	6.82	11.30	66.33	22.39
5E1B7c3	67.76	40.47	6.80	46.96	14.00	10.03	69.32	20.66
5E1B7d1	63.87	34.51	6.24	44.36	13.27	9.76	69.47	20.78
5E1B7d2	23.42	10.12	2.26	16.27	4.89	9.66	69.48	20.88
5E1B7e1	36.35	35.06	3.46	25.51	7.38	9.51	70.17	20.31
5E1B7e2	102.69	31.66	9.26	72.49	20.93	9.02	70.59	20.38
5E1B7f1	88.05	46.74	8.27	61.69	18.09	9.39	70.06	20.54
5E1B7f2	76.01	30.62	7.41	52.59	16.01	9.75	69.18	21.06
5E1B7g1	63.08	17.68	6.78	42.14	14.16	10.75	66.82	22.45
5E1B7g2	63.65	7.03	6.62	43.44	13.53	10.39	68.35	21.25

of normal distribution was accepted for both the studied variables. The K-S test resulted the D = 0.158 and p-value = 0.20 for percent of the increase in NDVI, and D = 0.163 and p-value = 0.20 for percent of treated area. The p-values for both the cases are greater than 0.05, indicating the normal distribution. Since the Pearson's correlation is conditioned to normal distributions, the Pearson's Correlation Coefficient is selected to measure the degree of association between both the variables. It has resulted in the negative correlation (r = -0.29) between percent of increase in NDVI and percent of the treated area (Fig. 4a).

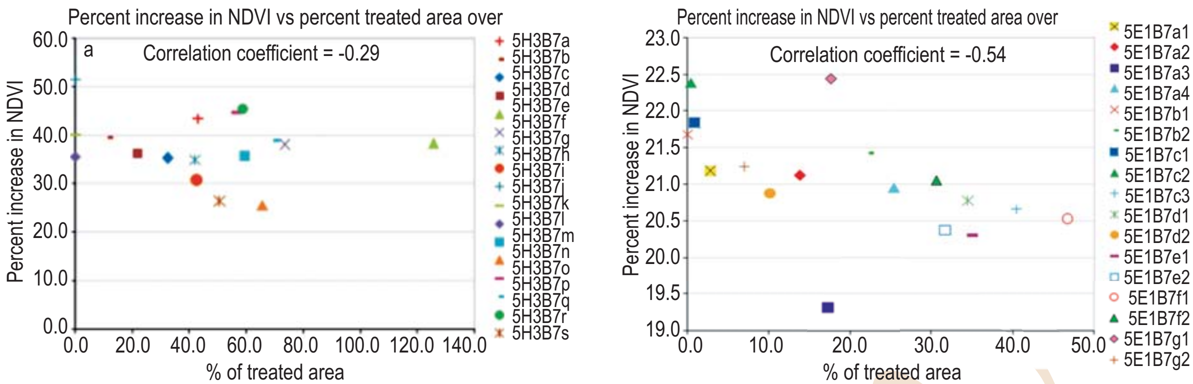


Fig. 4 : Relationship between percent increase in NDVI and percent treated area for (a) Arjuni watershed and (b) Morva-Hadaf watershed in Gujarat, India

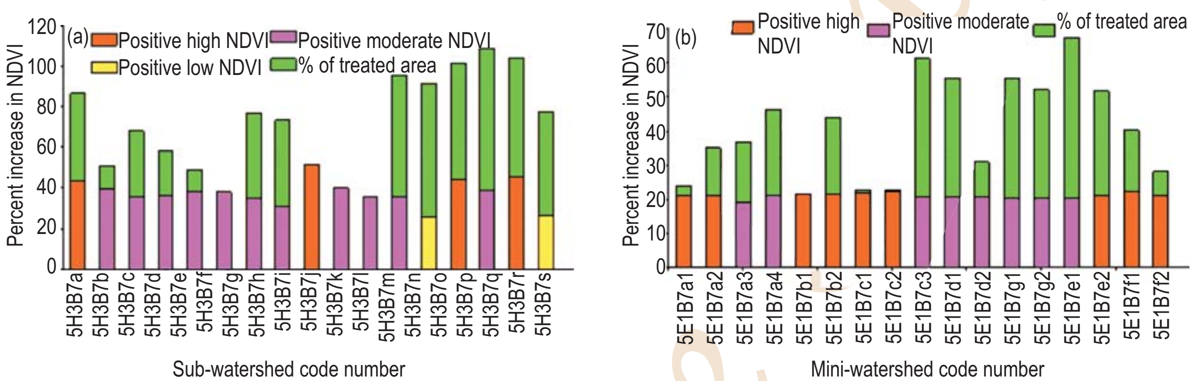


Fig. 5 : Percent increase in NDVI under positive moderate, positive high and positive poor classes for (a) Arjuni watershed and (b) Morva-Hadaf watershed in Gujarat, India

For the more detailed analysis, the percent of increase in NDVI was classified into three classes as: (1) positive high- if percent of the increase in NDVI is between 40 to 50%; (2) positive moderate- if percent of the increase in NDVI is between 30 to 40%, and (3) positive poor- if percent of the increase in NDVI value is between 0 to 30% (Fig. 5a). Out of the seventeen sub-watersheds, eleven sub-watersheds belong to the class of "positive moderate"; four classes belong to the class of "positive high", and two classes belong to the class of "positive poor". Within the "positive moderate" class, the Sub-watershed No. 5H3B7q has the highest treated area of 69.73%. The corresponding 38.89% of the geographical area of this sub-watershed showed increased NDVI value. Within the "positive high" class, the Sub-watershed No. 5H3B7r has the highest treated area of 58.74%, and its corresponding 45.34% of the geographical area showed increased the NDVI value. Similarly, within the "positive poor" class, the Sub-watershed No. 5H3B7n has a higher treated area of 65.63% as compared to 5H3B7s. The corresponding 25.55% of the geographical of this sub-watershed increased the NDVI value. However, three sub-watersheds (5H3B7f, 5H3B7k, 5H3B7l) from "positive moderate" class and one sub-watershed (5H3B7j) from "positive high" class increased the NDVI values in spite of no implementation of watershed management measures. These increased NDVI does not only comply with the watershed management activities. These results reinforced the earlier findings that NDVI trends are explained by both seasonal parameters (i.e., rainfall) and human induced land use/land cover changes (Shisanya *et al.*, 2011). In the present study, the NDVI changes can influenced by human induced parameters (viz., micro-irrigation system adopted throughout the study area) and seasonal parameters (viz., rainfall, temperature) on the selected RS imagery over the years 2002 and 2012. The notable change in the area under different crops of Kharif, Rabi and Summer seasons have shown an increase for the year 2013-2014 in Banaskantha, Patan and Mehsana districts due to micro-irrigation system (Viswanathan *et al*., 2016).

In case of Morva-Hadaf Watershed, the areas under decrease in NDVI, no change in NDVI and increase in NDVI are clearly shown in the NDVI difference image (Fig. 3b). The decrease in NDVI values is in scattered form in both the agricultural land and forest land. Overall, the NDVI values have been increased over the entire study area. At the watershed scale, the calculated area under the biomass has been increased by 213.69 km^2, decreased by 105.94 km^2 and remained same by

698.94 km^2 over the period of fifteen years. In order to understand whether the already treated area under watershed management programmes (from 1997 to 2011) can explain the change in NDVI at the mini-watershed level, the NDVI changes at mini-watershed level is summarized in Table 3. The Morva-Hadaf watershed consists of Panchmahal and Dahod districts in the central Gujarat region. The forest cover present into the study area is mainly deciduous dense forest and open forest/scrub forest. In the last decade, under the Joint Forest Management (JFM) projects, the regeneration of the forest area was carried out in Dahod and Panchmahal districts. The aforementioned results were confirmed by the state environment report of the year 2012 [developed by ENVIS Centre: Status of Environment & Related Issues, Gujarat (http://gujenvis.nic.in/PDF/soe-land.pdf)], in which the Dahod district has the highest forest cover (704 km^2) in the year 2011. The large-scale extension of cultivated land was carried out to utilize marginal and sub-marginal lands in the study area. The Gujarat Rural Institute for Socio Economic Reconstruction Vadodara (GRISERV) for the Wadi Project reported that the talukas of the Morva-Hadaf watersheds (viz., Dhaod, Garbada, Dhanpur and Limkheda) have shown a considerable increase in crop production for the year 2011-2012. These increases in vegetation cover have confirmed that the NDVI values have been increased in Morva-Hadaf watershed over 1997-2011.

In the next step, the correlation between percent of treated area within a mini-watershed and corresponding increase in NDVI were analyzed. Normality was assessed using the K-S test for both percent of increase in NDVI and percent of treated area. The K-S test resulted the D = 0.115 and p-value = 0.20 for percent of increase in NDVI, and D = 0.117 and p-value = 0.20 for the percent of treated area. The p-value for both the cases is greater than 0.05, which represents the normal distribution. Based on the Pearson's method, the negative correlation (r = -0.54) was found between percent of increase in NDVI and percent of the treated area (Fig. 4b). It seems that the increase in NDVI values in Arjuni and Morva-Hadaf watersheds are not only driven by watershed management /human induced measures, but also influenced by other climatic and human induced factors.

For the more detailed analysis, the percent of increase in NDVI values was classified into two classes as (1) positive high: if percent of the increase in NDVI is above 21%, (2) positive moderate: if percent of the increase in NDVI is below 21% (Fig. 5b). The classification is restricted to only two classes as the range of increase in NDVI is relatively small. Out of seventeen mini-watersheds, eight mini-watersheds belong to the class of "positive moderate" and nine mini-watersheds follow the class of "positive high". Within the "positive moderate" class, the mini-watershed No. 5E1B7f1 has the highest treated area of 46.74%. The corresponding 20.54% of the geographical area of this mini-watershed showed increased NDVI value. Similarly, within the "positive high" class, the mini-watershed No. 5E1B7f2 has the highest treated area of 30.62%. The corresponding 21.06% of the geographical area of this mini-watershed showed increased NDVI value. However, three mini-watersheds (5E1B7b1, 5E1B7c1 and 5E1B7c2) from "positive high" class increased the NDVI values, in spite of no or relatively less area treated by watershed management measures. It clearly indicated the influence of other climatic and human induced parameters over the year 1997-2011. In non-forest areas of Morva-Hadaf watershed, the "tree farming" is being practiced and it constitutes major income in the total income of the farmers of this region. It can be considered as one of the major human induced parameters. The numbers of trees are also improved (Singh, 2013).

In the present research, the case studies for Arjuni and Morva-Hadaf watersheds are selected to assess the impact of watershed management measures through biomass vigour change detection using NDVI differencing approach and compared with already treated areas. The comparison between the percentage of NDVI change and percentage of treated area obtained the negative relationship for both the watersheds. Considering the arid/semi-arid climatic conditions and heterogeneity in landscape pattern, this result suggests that the temporal change in biomass vigour cannot be solely due to applied watershed management measures. It is influenced by the climatic parameters (viz., rainfall, temperature) and other human induced parameters. In arid and semi-arid regions the correlation between NDVI and rainfall/accumulated rainfall has been proved strongest (Tucker *et al.*, 1991a; Schmidt and Karnieli, 2000; Martiny *et al.*, 2006). Hence, it is required to develop a methodology that will distinguish between climate induced and human induced measures. In this direction, some researchers have demonstrated a technique to discriminate between climate and human induced land degradation using NDVI and rainfall data in arid/semi-arid regions (Evans and Geerken, 2004; Wessels *et al*., 2007). In the current watershed clustering approach, we are recommending to conduct impact assessment of already treated area on a larger scale and over the longer duration of time by keeping a distinction between the effects of climate and watershed management measures. This can help to assess the actual impact of watershed management measures on biomass vigour by nullifying the influence of seasonal factors.

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