Watershed impact evaluation using remote sensing

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Watershed management is considered as a way for sustainable rural development and thus impact evaluation is a must. The common approach of post-classification comparison of pre- and post-implementation satellite imageries for watershed impact evaluation suffers from serious limitations, mainly ignoring the changes which are not due to watershed interventions. To minimize such biases, control area approach is proposed and relative change in watershed compared to control area is attributed to watershed management. The studied four clusters of watershed in Vidarbha region, Maharashtra show that the effect of the watershed could stand out irrespective of pre- and post-implementation conditions of satellite imageries.

Keywords: Advantage watershed, change detection, impact evaluation, remote sensing, watershed management.

WATERSHED is being considered as a unit for overall sustainable rural development. Convergence of resources from various ministries or agencies under the umbrella of the common guidelines of the National Rainfed Area Authority (NRAA) has laid the foundation for large-scale unified watershed programme in participatory mode. Watershed management, a dynamic concept with new challenges and complexities, renders difficulties in laying out a proper plan of development. Considering the urgency of planned natural resource management to arrest land degradation process[1], information required for efficient planning, and volume of work to be executed within a timeframe, advanced tools including remote sensing are highly desirable[2]. Increasing number of indigenous remote sensing satellites, reasonable pricing of indigenous satellite data and increasing trained manpower have further facilitated use of remote sensing for watershed management. Application of spatial data in watershed management has been evaluated[3,4] and remote sensing has been described as an effective tool for the treatment and conservation of watersheds[5]. The common guidelines have also emphasized the use of advanced tools like remote sensing, GIS and GPS[6]. The use of remote sensing has already begun in prioritizing[7], developing area-specific watershed development plan[8–10] as well as impact evaluation[11–13].

Considerable spending has been made in watershed management through various government-sponsored programmes. Though the relative performance compared to other programmes is good, replicable successes reported are scattered and over all effect is not widely visible. Under the watershed programme, several activities aimed at improving soil and water conservation, groundwater recharge, crop rotation, crop productivity, and reducing run-off and soil erosion are executed. Impact evaluation is essential to differentiate between good and bad so that good can be replicated. Nowadays, impact evaluation of selected watersheds through external agencies has become mandatory. Remote sensing has been used for impact evaluation (biophysical changes) of watershed management. Post-classification comparison of pre- and post-implementation satellite imageries is the most common remote sensing approach used for impact evaluation[4,14,15]. Change detection in land use/land cover is though a common approach in natural resource evaluation[16], especially in active flood plains[17], there are practical problems and various sources of error in this approach as it attributes all changes during the period of evaluation to the watershed activities[18–20]. Watershed programme is primarily focused in rainfed areas where the amount and distribution of rainfall play a major role in vegetation condition. Here, it is important to understand rainfall pattern and rain–vegetation dynamics in semi-arid rainfed conditions. The chance of getting similar rainfall year (in amount and distribution) in pre- and post-implementation is rare as even one rainfall event makes a difference. Therefore, the assumption of all changes are due to watershed activities in pre- and post-implementation comparison is not valid. This article deals with the practical problems in the common approach, possible solutions and case studies involving a new approach of using remote sensing in watershed impact evaluation.

Problems in the current approach

All changes are not due to watershed management: Change in natural resource (land, water and vegetation) status and management is a continuous process though

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the pace may be low without external intervention like watershed programme. Even if watershed management may not have taken place, there would have been some changes and these need to be segregated, which is not done in the current approach.

Assumption of similar conditions in pre- and post-implementation: Biophysical indicators of watershed impact evaluation in rainfed areas are highly sensitive to weather conditions, mainly rainfall. Even one rainfall event makes a difference. The approach used must be free from the bias due to different pre- and post-implementation weather conditions, especially rainfall.

Lack of pre-watershed implementation ground data: As the impact evaluation agencies come into the picture mostly after completion of the watershed project, pre-implementation ground data provided by project implementing agencies are often not sufficient for supervized classification and proper interpretation. It is difficult to retrieve the pre-implementation ground data at the time of impact evaluation.

Satellite images on anniversary dates are rarely available: Ideally, the post-implementation image selected for comparison should be on the anniversary date of the pre-implementation image which is rarely available. Mostly, end of *kharif* season or beginning of *rabi* season satellite data are used for comparison. In both the cases, even a week duration makes a difference in greenness of the vegetation because at the end (senescence) as well as in the beginning of the crop season, greenness of vegetation changes fast with time.

Boundary issue: Watershed delineation and codification have not yet been done to the micro watershed scale of 500–5000 ha, which is by norm a unit (watershed or cluster of watersheds) for watershed management. Project implementing agencies often fail to properly delineate the watershed because of either unavailability of good quality elevation data or trained manpower.

Time of impact evaluation: Impact of many interventions like plantations (horticulture, agri-horticulture and forestry) takes time to get reflected. In most of the watersheds, drainage line treatments are implemented at the end phase of the project. If these activities are taken in the last 1–2 years of the project, impact evaluation should be preferably done after 3–4 years of completion of the project. Impact evaluation just after completion of the project may underestimate its success.

Possible solution

The approach for segregating impact of watershed interventions from the changes due to non-watershed activities can be borrowed from the traditional method of impact evaluation in which 'with and without' concept is considered along with 'pre and post' concept. A similar approach, wherein imageries from watershed area along with those outside the watershed are analysed and compared to assess the changes attributed to watershed interventions, can possibly address some of the issues unattended in the conventional approach. In the case studies discussed below, this new approach has been followed and the practical problems mentioned above have been partly addressed.

Approach

Watershed impact evaluation is a task that involves techniques of social science, survey and use of advance tools. Four clusters of watershed, viz. Asoli, Buldhana, Dharamour and Wardha in Vidarbha region, Maharashtra were subjected to impact evaluation. These clusters were treated with soil and moisture conservation measures during 2007–2010.

A multi-disciplinary team of scientists and technical officers visited the area for 15 days and collected socio-economic data by survey and interview and primary ground biophysical data using GPS. Attempt was made to collect pre-implementation data through structured proforma and memory-based interviews. Vidarbha region, a drought-prone semi-arid area, was once in the news due to drought and farmer suicides. Watershed projects were taken up extensively in the region.

Points considered in remote sensing-based approach

Watershed management induced major biophysical changes mapped/monitored through remote sensing are increased vegetated area, increase in cropped area, change in cropping pattern, increase in vegetation greenness and increase in water availability expressed as water spread area. Changes in cropping pattern which is a gradual process are difficult to detect, especially if changes are confined to existing crop calendar and pre-implementation ground data are insufficient. For agricultural dominant watershed, classification of pre-implementation images in the absence of proper training site (limited pre-implementation ground data) is a challenge that often leads to more errors than actual changes. Total cropped area remains the feasible indicator. Unavailability of *kharif* season (main crop season in rainfed areas) optical remote sensing data is the reason that in most of the cases only *rabi* season pre- and post-implementation imageries are used for impact evaluation. However use of *rabi* season imageries has its own advantages. Relevance of impact evaluation through change detection for cases other than *kharif* season needs to be discussed here. During *kharif* season most of the cultivable areas are covered by vegetation (crop or natural vegetation); therefore the change in terms of cropped area is less detectable through remote sensing. During *rabi* season, the change in cropped/vegetated area is more likely to be associated with water/moisture availability and thus more meaningful for impact evaluation. Water-harvesting structures, if developed during implementation period can be detected on satellite imagery in the beginning of *rabi* season unless all harvested water is used during *kharif* season itself. Increase in groundwater availability is also expressed either in terms of increased cropped area or increased greenness during *rabi*/summer season. Other conservation measures like trenching, bunding, terracing, levelling, drainage line treatments, etc. are spectrally inseparable on the economically feasible satellite data (IRS LISS III/IV), but can be assessed in terms of increased green area as well as greenness which are common to all of these treatments. Vegetated area with varying degrees of greenness and water spread area in cases other than *kharif* season were considered as robust indices of watershed impact studies. These indices are suitable for preliminary impact evaluation and are actually a compromise for limited data. Well-structured ground data collection in watershed planning phase (pre-implementation) is highly desired for more meaningful impact study with supervised classification at levels II and III. One GPS point in every 10 ha area of watershed along with associated information, photographs, time and direction of photography for all crop seasons (*kharif*, *rabi* and summer) in pre- and post-watershed implementation would be sufficient for better impact evaluation. As availability of GPS is no longer an issue, the structured ground data collection must be a rule for all watershed management projects.

Addressing practical problems

For addressing problems mentioned earlier, control area approach was explored. Here control area refers to the area outside the watershed, similar in all features to the watershed in pre-watershed implementation condition, but without planned external intervention (government-supported programme) being taken during the period under consideration. This approach nullifies the limitations mentioned above to a great extent, but the probability of such paired watersheds is remote and therefore a compromise is made. Three options in this regard are (i) an area bigger than the watershed around the watershed, (ii) multiple polygons (two or more) of similar size around the watershed and (iii) a similar watershed near the watershed. Assumption of no treatments in control area is common to all three options. No additional cost is required in these approaches as usually satellite images cover much bigger area compared to micro watersheds/clusters (<5000 ha) taken for management. Possibility of getting similar size watershed nearby is remote. Multiple polygon approach is statistically sound but needs structured ground data. With limited ground data, option (i) was used in this study.

Satellite data and processing

Indian remote sensing (IRS P-6) LISS III data were used (Table 1). One satellite datum of each watershed was geometrically corrected with reference to SOI toposheet, limited ground control points and Google Earth images[21]. All images and toposheets were converted to Geographic WGS 1984 system. Rest of the images of each watershed were geometrically rectified with reference to the already rectified images (image to image) with RMSE < 0.00015 (in degrees). Top-of-atmospheric correction was applied to all imageries. Normalized difference vegetation index (NDVI) images were developed from reflectance data of all imageries. NDVI was sufficient for vegetation class identification and categorization of low, medium and dark green vegetation, but not sufficient for segregation of water body. Density slicing of NDVI images was performed and classes were later merged to get three categories of vegetation. Decision of merging classes was based on visual comparison with the false colour composite (FCC). Decision of NDVI range for each vegetation class of an image was common for the watershed and the control area around the watershed. For water spread area, classifying NDVI image was not sufficient and even after classifying into more than 40 classes, there was commission error. For segregating water spread area, normalized difference water index (NDWI) image was developed and density slicing was performed; the water class stood out, but still some of the unidentified areas (probably shaded area or cloud shadow, though cloud or sensor drops were not visible) on three images were classified as water. To segregate these areas, the spectral signature (in four bands) was compared with water and band-4 (SWIR) was successfully used for the computation of an NDWI in place of band-3 (NIR). Hereafter we will refer to this index as modified NDWI (NDWI(m)) in this article. For IRP-6 LISS III image,

$$\text{NDVI} = (B3 - B2)/(B3 + B2),$$

$$\text{NDWI} = (B1 - B3)/(B3 + B1),$$

$$\text{NDWI(m)} = (B1 - B4)/(B1 + B4).$$

The index was computed with the help of model maker of ERDAS IMAGINE 9.3. Vegetation layer was stacked with water spread layer for display purpose and statistics were combined. To evaluate reported boundary, SRTM data

Table 1. Satellite imageries used for watershed impact analysis of four clusters of watershed

Watershed	Path/row	Pre-implementation	Post-implementation
Asoli	99/58	20 October 2007	28 October 2010
	99/58	24 January 2008	1 February 2011
Dharampur	98/58	20 October 2006	29 September 2010
	98/58	24 January 2007	27 January 2011
Dudhlam	98/58	24 January 2007	27 January 2011
Wardha	99/57	25 October 2006	15 December 2010
	99/57	5 January 2007	1 February 2011

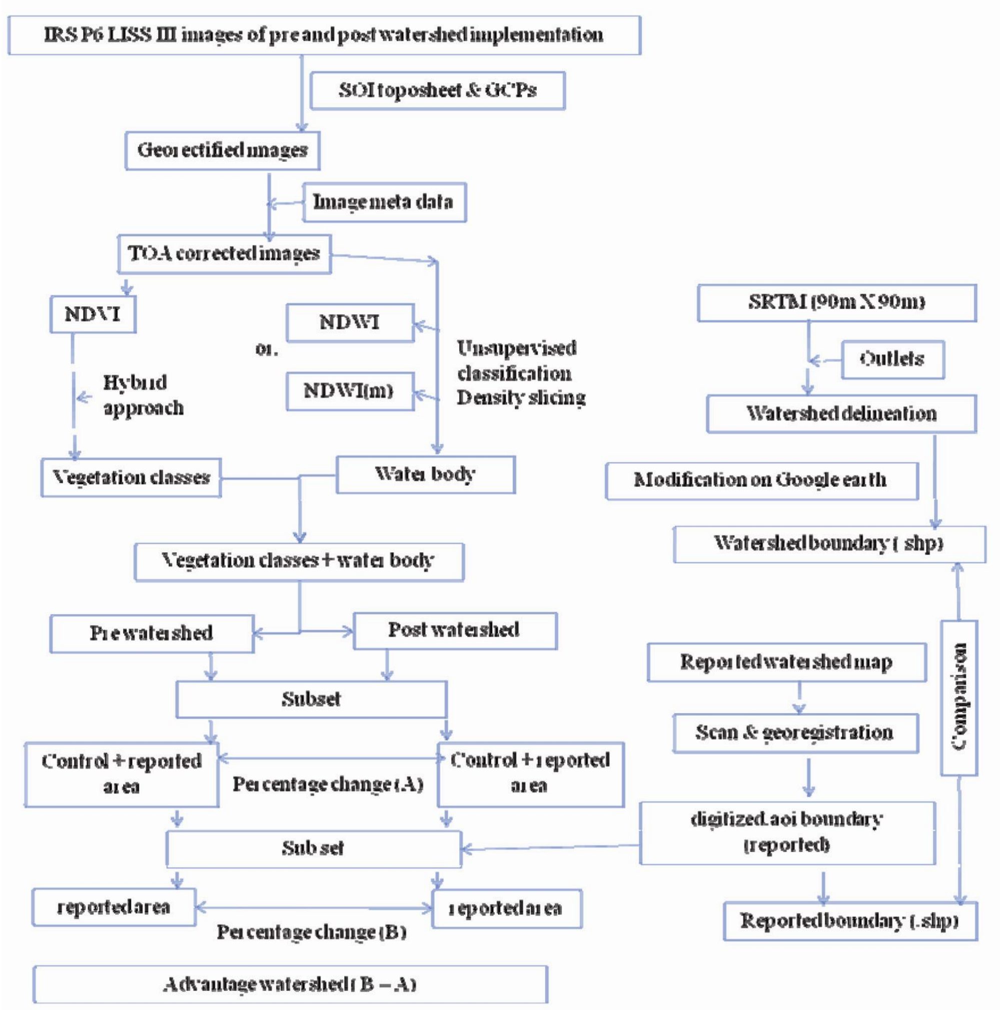

Figure 1. Flow chart for watershed impact evaluation through remote sensing using control area concept.

of 1° × 1° tiles were downloaded, projection-matched with the satellite imageries and watersheds were delineated at their outlet or nearest point on the nearest drainage channels. The delineated boundary was overlaid on Google Earth imageries[6], visually checked, modified and reprojected. In this method, deviation of micro watershed boundary from actual boundaries has been found to be less than 40 m (with few exceptions) and deviation in area by less than 20% (unpublished work of the authors). Watershed delineation was performed in ARC GIS 9.3. Boundary reported (provided by the project implementing agency) and boundary delineated using SRTM data were compared.

Advantage watershed

Let A_{c_pr} is the area of a particular land cover class on control + watershed under in pre-implementation condition, A_{c_po} is the area on control + watershed under a particular land cover class in post-implementation condition, B_{c_pr} is the area of a particular land cover class in watershed (reported) in pre-implementation condition, and B_{c_po} is the area in watershed (reported) under a particular land cover class in post-implementation condition.

Advantage watershed for the land cover class =

$$\{[(B_{c\_po} - B_{c\_pr})/B_{c\_pr}] - [(A_{c\_po} - B_{c\_po}) - (A_{c\_pr} - B_{c\_pr})]/(A_{c\_pr} - B_{c\_pr})\}*100.$$

Figure 1 represents the flow chart of image processing and watershed impact evaluation.

Results and discussion

Watershed boundary

The reported watershed showed slight deviation (5 to 35 m) from SRTM-derived watershed boundary in case of Asoli (Figure 2) and Buldhana, but substantial deviation in case of Dharampur (Amravati) and Wardha clusters (Dahegaon, Manda, Savad and Borkhedi). The slight deviation due to poor spatial resolution of elevation data

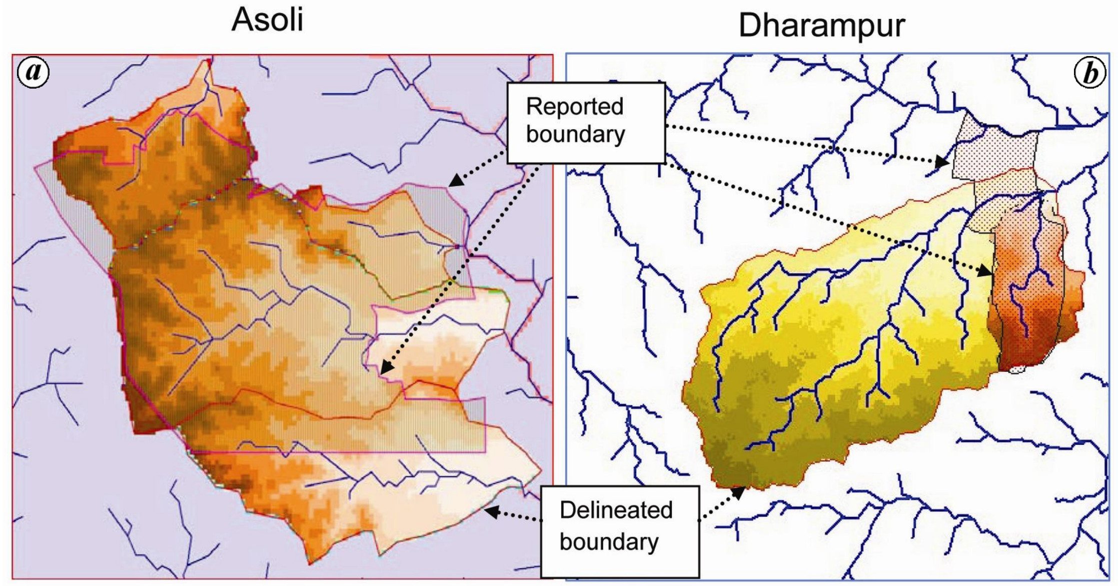

Figure 2. Reported versus delineated boundary (using SRTM 90 m resolution elevation data) of (***a***) Asoli–Yavatmal and (***b***) Dharampur–Amravati watershed clusters.

used may be ignored. Maximum deviation was found in the case of Dharampur cluster (Figure 2). The main reason for this is the use of poor-quality elevation data for watershed delineation. In plain areas some deviation can be allowed if it is done to facilitate people's participation and defining beneficiaries, but at the same time it should not be ignored as it defies the very basic concept of a watershed.

Biophysical impact

For impact analysis the reported boundary was used as watershed interventions. Area under three vegetation classes, namely vegetation (dark green), vegetation (green) and vegetation (poor/stressed) along with area under water body were used for comparison between pre- and post-implementation images.

Asoli cluster: Area under vegetation (dark green), vegetation (green), vegetation (poor/stressed) and water body was higher on 28 October 2010 compared to 20 October 2007 in control + watershed as well as in reported watershed area (Table 2). Overall increase in area under vegetation (total) in control area and reported watershed was 69.2% and 97.8% respectively. Therefore, advantage watershed was 28.6% for vegetation (total) and 1.7% for water body. In traditional approach 97.8% increase would have been attributed to the watershed ignoring the fact that even outside the watershed area, total vegetated area in post-implementation is higher by 69.2%, which is mainly because of better rainfall and late *kharif* rainfall during 2010 compared to 2007. The extra 28.6% (97.8%–69.2%) can be attributed to watershed activities.

Area under two categories of vegetation, i.e. vegetation (dark green) and vegetation (poor/stressed) along with water body was found higher on 1 February 2011 post-project compared to 24 January 2008 pre-project in control + watershed as well as in reported watershed (Figure 3). Advantage watershed was 75% for vegetation (total) and 51% for water body (Table 2). More increase in green cover area in watershed compared to the control was attributed to the increased water (surface and ground) availability for irrigation due to water harvesting and conservation measures taken in the watershed programme.

Dharampur–Amravati: Two pairs of imageries were compared for change detection as well as segregating non-watershed effects. Post-implementation area under vegetation of different greenness and area under water body were higher in control as well as watershed area (Table 3; Figure 4), with the exception of vegetation (poor/stressed). Area under vegetation (dark green) was marginally higher, but area under vegetation (green) was substantially higher on 29 September 2010 as compared to 20 October 2006. For this period watershed had advantage of 8.9% for vegetation (total) and 915.2% for water body. New water bodies formed during watershed project could be noticed. Similarly area under all categories of vegetation was higher on 27 January 2011 compared to 24 January 2007 in control area as well as in reported watershed (Figure 3). Water body decreased in control area but improved in watershed by 198.5%. Overall advantage of watershed in terms of total area under vegetation was 4.4%, but it was 241.5% for water body. The increase in area under water body within watershed substantiates the formation of new water bodies.

Table 2. Land cover (area in ha) in terms of vegetation of different greenness, water body, percentage change in control area (excluding watershed), in reported watershed and advantage watershed of Asoli–Yavatmal cluster of watersheds

	20 October 2007		28 October 2010		Change (%)		
Class	Con + Was	Was	Con + Was	Was	Con	Was	Adv. Was (%)
Vegetation (dark green)	4323.1	737.2	5110.4	797.0	20.3	8.1	–12.2
Vegetation (green)	2688.8	381.3	4933.6	874.3	75.9	129.3	53.4
Vegetation (poor/stressed)	1567.5	177.6	4843.5	892.0	184.3	402.4	218.1
Vegetation (total)	8579.3	1296.1	14887.5	2563.2	69.2	97.8	28.6
Water body	202.3	23.3	208.8	24.4	3.0	4.7	1.7
	24 January 2008		1 February 2011		Change (%)		
Class	Con + Was	Was	Con + Was	Was	Con	Was	Adv. Was. (%)
Vegetation (dark green)	955.1	58.8	3839.6	420.1	281.5	615.0	333.5
Vegetation (green)	1344.3	146.0	301.1	26.4	–77.1	–81.9	–4.8
Vegetation (poor/stressed)	319.5	47.6	1268.3	245.7	276.1	416.4	140.3
Vegetation (total)	2619.0	252.4	5409.0	692.3	99.3	174.3	75.0
Water body	133.8	12.2	180.4	22.1	30.2	81.2	51.0

Con, Control area around watershed; Was, Watershed; Adv. Was, Advantage watershed. (Relative change in watershed as compared to control area, expressed as percentage.)

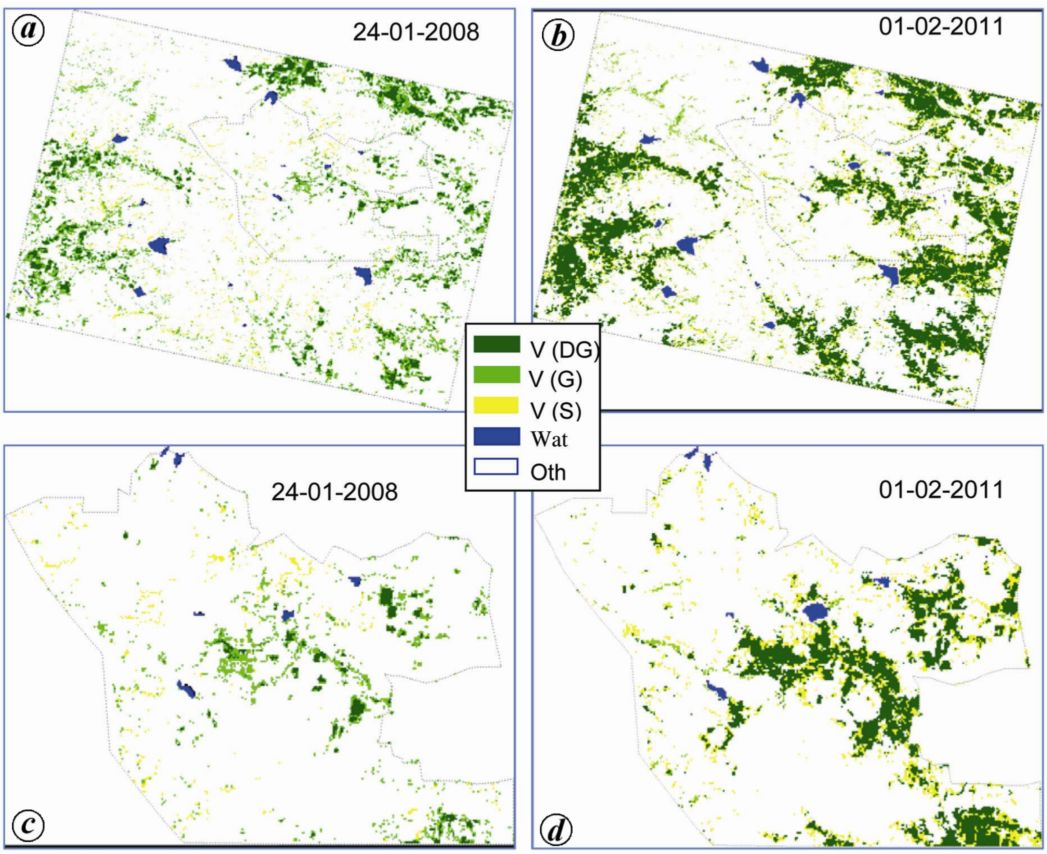

Figure 3. Vegetation of different greenness and water body spread as on 24 January 2008 and 1 February 2011 in control + watershed (***a***, ***b***) and reported Asoli–Yavatmal watershed cluster (***c***, ***d***).

Dudhlam–Akola: A pair of imageries (pre- and post-implementation) was compared. Post-implementation (27 January 2011) area under vegetation (dark green) and vegetation (green) was higher compared to pre-implementation (24 January 2007) in control as well as reported watershed (Table 4). Area under water body was9% less in post-project image compared to pre-project image in control area, but was high under watershed as a

Table 3. Land cover (area in ha) in terms vegetation of different greenness, water body, percentage change in control area (excluding watershed), in reported watershed and advantage watershed of Dharampur–Amravati cluster of watersheds

Class	20 October 2006		29 September 2010		Change (%)		Adv. Was (%)
	Con + Was	Was	Con + Was	Was	Con	Was	
Vegetation (dark green)	8368.3	584.2	8395.2	605.5	0.1	3.6	3.6
Vegetation (green)	10.5	0.3	4661.2	417.9	##	##	##
Vegetation (poor/stressed)	3735.3	372.9	2879.6	314.5	–23.7	–15.6	8.1
Vegetation (total)	12,114.1	957.4	15,936.0	1337.9	30.8	39.8	8.9
Water body	228.6	3.5	259.1	35.5	–0.7	914.6	915.2
Class	24 January 2007		27 January 2011		Change (%)		Adv. Was (%)
	Con + Was	Was	Con + Was	Was	Con	Was	
Vegetation (dark green)	2197.2	97.2	4060.4	166.8	85.4	71.5	–13.9
Vegetation (green)	0	0	2521.9	136.3	##	##	##
Vegetation (poor/stressed)	4804.5	320.5	4887.1	398.60	0.1	24.4	24.3
Vegetation (total)	7001.7	417.7	11,469.4	701.7	63.5	68.0	4.4
Water body	429.4	12.8	219.4	38.3	–56.5	198.5	255.1

Con, Control area around watershed; Was, Watershed; Adv. Was, Advantage watershed. (Relative change in watershed as compared to control area, expressed as percentage.) ##, Used was infinity or very high value due to zero or very small denominator.

new water body was formed (Table 4). For area under total vegetation, watershed had advantage of 7.7% and for water body, addition of 1.7 ha was noticed.

Wardha cluster: Four distinct watersheds made the cluster that was subjected to impact evaluation. Two post-implementation LISS III imageries were used for comparison with two pre-implementation imageries. In control as well as watershed, total vegetated area in post-implementation (15 December 2010 and 1 February 2011) was less than pre-implementation (25 October 2006 and 5 January 2007). Area under vegetation (dark green) and vegetation (green) was 65.5% and 14.8% lower respectively, in control area on 15 December 2010 compared to 25 October 2006 (Figure 5 and Table 5). Area under water body was also lower by 3.7% in control area and 1.6% in watershed. Comparing other pairs of images also revealed similar changes as area under vegetation (dark green) and vegetation (green) was less by 58.8% and 46.2% respectively on 1 February 2011 compared to 5 January 2007 in control area.

Though the area under different categories of vegetation in the reported watershed was also low in post-implementation compared to pre-implementation, the magnitude of difference was less than the same in control area. Area of vegetation (dark green) in reported cluster was lower by 64.6% on 15 December 2010 compared to 25 October 2006 and 69.6% lower on 1 February 2011 compared to 5 January 2007. Watershed advantage for vegetation area (total) and area under water body was 3.9% and 2.1% respectively, on 15 December 2010 as compared to 25 October 2006, and 3.2% and 17% on 1 February 2011 compared to 5 January 2007.

In the conventional method, interpretation would have been based on change within the watershed, which is negative in this case. The negative (reduction in vegetation and area under water body) change would have been attributed to the watershed project, which is not true. The lower vegetation area and area under water body in post-implementation condition was mainly due to difference (20–25 days) in the date of the imageries compared. As the number of days from previous *kharif* season increases, the reduction in greenness, area under green cover and water body is anticipated.

The advantage watershed scenario shows seasonal difference. The watershed advantage for *kharif* season and for the beginning of *rabi* season (October) is more likely to be the result of soil moisture conservation measures like bunding, trenching, levelling, etc. The watershed advantage for mid-*rabi* season and later period is more likely to be the result of water harvesting, groundwater recharge and irrigation facilities created in watershed projects. A suitable weightage can be given to the seasonal 'advantage watershed' and a composite index may be computed, which has not been attempted in this article.

Positive response of watershed project was visible in terms of improved vegetation area as well as water body in all watersheds. Further quantification for crops, irrigated area and area under plantations are desired, but this requires well-structured, three-season pre- and post-implementation ground data.

Possible modification in the proposed methodology

The control area approach helps minimize several biases of the common approach, but subtle difference between control area and watershed and relative change trend in pre-implementation condition may have a bearing on the final figure. To minimize such effects the relative change

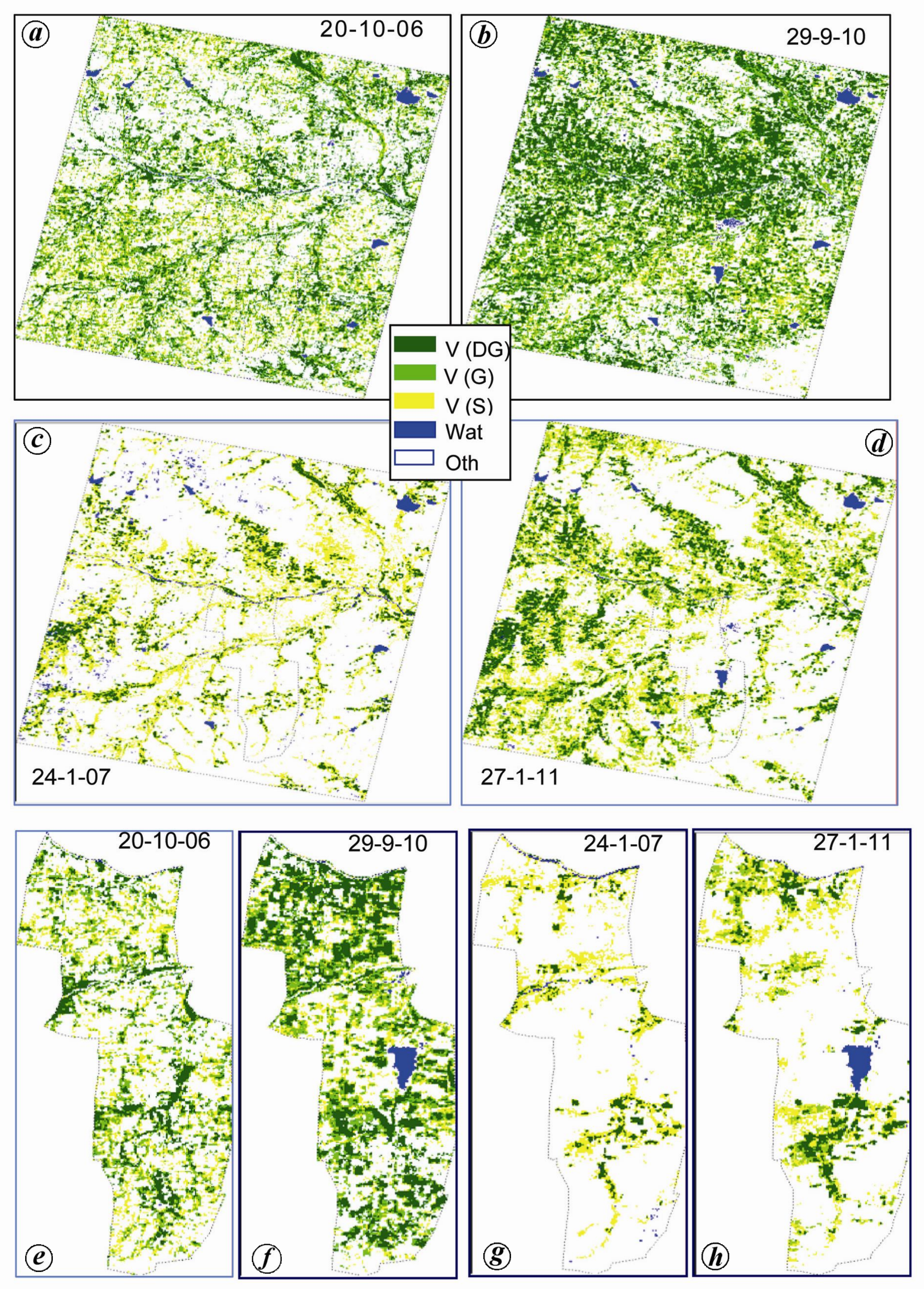

Figure 4. Vegetation of different greenness and water body in control area that includes reported watershed (***a–d***) and Dharampur–Amravati watershed cluster (***e–h***) as on 20 October 2006, 24 January 2007, 29 September 2010 and 27 January 2011.

(just like advantage watershed discussed earlier) analysis may be performed for watershed compared to the control area over a span of 4–5 years in pre-implementation period as well. In this case minimum three satellite imageries are required, i.e. (i) past (4–5 years before the beginning of the watershed project), (ii) pre-implementation (just before the beginning of the watershed), and (iii) post-implementation (usually 3–4 years after completion of the project). Relative change analysis needs to be performed for two sets of imageries.

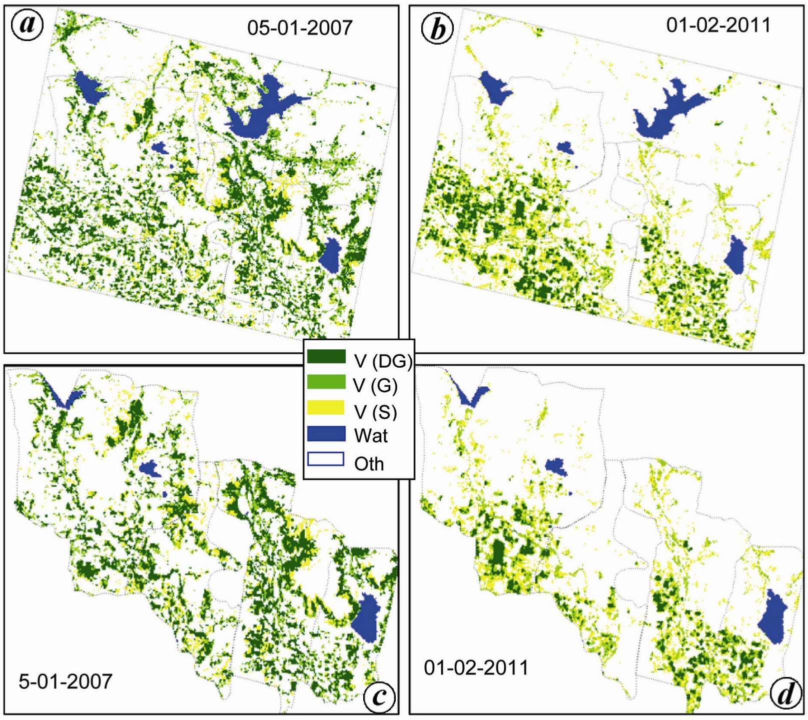

Figure 5. Vegetation of different greenness and water body in control area in and around the reported Wardha watershed cluster as on 5 January 2007 and 1 February 2011.

Table 4. Land cover (area in ha) in terms vegetation of different greenness, water body, percentage change in control area (excluding watershed), in reported watershed and advantage watershed of Dudhlam–Akola cluster of watersheds

	24 January 2007		27 January 2011		Change (%)		
Class	Con + Was	Was	Con + Was	Was	Con	Was	Adv. Was (%)
Vegetation (dark green)	900.3	166.4	1112.2	241.5	18.6	45.2	26.6
Vegetation (green)	0.0	0.0	870.7	139.9	##	##	##
Vegetation (poor/stressed)	1709.9	238.9	906.6	93.5	–44.7	–60.9	–16.1
Vegetation (total)	2610.2	405.2	2889.5	475.0	9.5	17.2	7.7
Water body	47.4	0.0	44.9	1.7	–9.0	##	##

Con, Control area around watershed; Was, Watershed; Adv. Was, Advantage watershed. (Relative change in watershed as compared to control area, expressed as percentage.) ##, Used was infinity or very high value due to zero or very small denominator.

Table 5. Land cover (area in ha) in terms vegetation of different greenness, water body, percentage change in control area (excluding watershed), in reported watershed and advantage watershed of Wardha cluster of watersheds

	25 October 2006		15 December 2010		Change (%)		
Class	Con + Was	Was	Con + Was	Was	Con	Was	Adv. Was (%)
Vegetation (dark green)	3267.6	1527.0	1140.2	540.3	–65.5	–64.6	0.9
Vegetation (green)	1505.2	574.0	1375.3	581.9	–14.8	1.4	16.2
Vegetation (poor/stressed)	682.5	268.5	1638.3	630.4	143.5	134.8	–8.7
Vegetation (total)	5455.2	2369.6	4153.9	1856.4	–25.5	–21.7	3.9
Water body	316.7	97.5	307.1	95.9	–3.7	–1.6	2.1
	5 January 2007		1 February 2011		Change (%)		
Class	Con + Was	Was	Con + Was	Was	Con	Was	Adv. Was (%)
Vegetation (dark green)	1472.2	647.3	537.1	197.1	–58.8	–69.6	–10.8
Vegetation (green)	725.7	323.0	508.2	291.5	–46.2	–9.7	36.5
Vegetation (poor/stressed)	417.4	237.6	784.6	377.7	126.4	58.9	–67.4
Vegetation (total)	2615.3	1207.9	1829.9	866.2	–31.5	–28.3	3.2
Water body	285.3	75.8	262.0	79.0	–12.7	4.3	17.0

Con, Control area around watershed; Was, Watershed; Adv. Was, Advantage watershed. (Relative change in watershed as compared to control area, expressed as percentage.)

Conclusion

There is need of improvement in delineation of micro-watershed for proper implementation of soil and water conservation measures in watershed management. The approach of control area around the watershed helps segregate the non-watershed effect from watershed effect at preliminary watershed impact evaluation without any additional cost. Therefore, it is essential for impact evaluation of planned interventions, including watersheds. All four watersheds implemented showed advantages in terms of vegetation and water body. Impact evaluation using remote sensing, if necessary, should be done after 4–5 years of completion of a project. Well-planned training site data collection using GPS thrice a year during preparatory phase of watershed project (density one point per 10–20 ha area) is essential for accurate mapping, planning and impact evaluation. There is need to explore microwave remote sensing data, viz. RISAT data for land cover during *kharif* season on watershed scale. A synergic use of microwave and optical remote sensing has the potential to be utilized for proper watershed planning, hydrological monitoring, hydrological modelling and impact evaluation.

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