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RESEARCH ARTICLE

Application of Remote Sensing Technology for Impact Assessment of Watershed Development Programme

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Keywords Watershed · Monitoring and impact assessment · Remote sensing · GIS · Land use/land cover · NDVI

Abstract The current study was taken up to investigate the utility of remote sensing and GIS tools for evaluation of Integrated Wasteland Development Programme (IWDP) implemented during 1997-2001 in Katangidda Nala watershed, Chincholi taluk, Gulbarga district, Karnataka. The study was carried out using IRS 1C, LISS III data of December 11, 1997 (pre-treatment) and November 15, 2002 (post-treatment) covering the watershed to assess the changes in land use / land cover and biomass that have changed over a period of five years (1997-2002). The images were classified into different land use/land cover categories using supervised classification by maximum likelihood algorithm. They were also classified into different biomass levels using Normalized Difference Vegetation Index (NDVI) approach. The results indicated that the area under agriculture crops and forest land were increased by 671 ha (5.7%) and 1,414 ha (11.94%) respectively. This is due to the fact that parts of wastelands and fallow lands were brought into cultivation. This increase in the area may be attributed to better utilization of surface and ground waters, adoption of soil and water conservation practices and changes in cropping pattern. The area under waste lands and fallow lands decreased by 1,667 ha (14.07%) and 467 ha (3.94%), respectively. The vegetation vigour of the area was classified into three classes using NDVI. Substantial increase in the area under high and low biomass

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levels was observed (502 ha and 19 ha respectively). The benefit-cost analysis indicates that the use of remote sensing and GIS was 2.2 times cheaper than the conventional methods. Thus, the repetitive coverage of the satellite data provides an excellent opportunity to monitor the land resources and evaluate the land cover changes through comparison of images for the watershed at different periods.

Introduction

Watershed management is perceived by many as a viable approach for increasing agricultural production in rainfed marginal areas on sustainable basis. Many countries in the world including India are investing billions of rupees in treating several millions hectares of land on watershed approach. Unfortunately monitoring and evaluation has not got its share of attention and therefore it is very difficult to quantify and assess the changes which have taken place not only in natural resources but also in livelihoods of people due to these programmes and in the long run to justify the need for these schemes (Kallur, 1991; Ranadhir and Ravichandran, 1991; Anonymous, 1998). There is often not enough room for mid term adjustments in ongoing programmes due to lack of a proper monitoring system. The need therefore arises to identify a quick and cost effective technique for monitoring the impact of such schemes on a 'before project – after project' temporal scale as well as during project implementation stage (Agnohotri *et al.*, 1986; Singh *et al.*, 1989; Sabins 2000).

Taking the present day importance of impact assessment in watershed development programme and capabilities of remote sensing, GIS and GPS technologies in watershed management, a study was carried out on impact assessment of Katangidda Nala watershed in Gulbarga district of Northern Karnataka in peninsular India, using IRS 1C, LISS-III data of December 11, 1997 (pre-treatment) and November 15, 2002 (post-treatment) covering the watershed were used to assess the changes in land use / land cover and biomass that have changed over a period of five years (1997 – 2002). Similar studies were reported by Jaiswal *et al*. (1994), Serman *et al*. (2001) and Seto *et al*. (2002). The objective of the present study was to impact assessment of IWDP programme in Katangidda Nala watershed using remote sensing, GIS and GPS technologies.

Materials and methods

Location and climate

The Katangidda Nala watershed is located in northern part of Chincholi taluk of Gulgabrga district in Karnataka, India (latitude $17^0 26'$ to $17^0 36'$ N and longitude $77^0 30'$ to $77^0 38'$ E). The total area of the watershed is 11,847 ha. The location of the study area is depicted in Fig. 1. Gulbarga is located in the semi-arid tropical region of peninsular India. Nearly 70% of the total annual precipitation, i.e. 755 mm, is received during the monsoon season (June – September) and 18% during the post-monsoon season (October to November).

Katangidda Nala watershed receives rainfall in almost all the months, except December, January, February and March. The mean annual rainfall of the watershed is 823.16 mm. The rainfall data of 1997 and 2002 reveals that the watershed received good rain during June to October with a total mean annual rainfall of 825 mm during 1997 and 618 during 2002. The mean monthly maximum temperature was recorded during May (32.10^0C during 1997 and 33.75^0C during 2002). The lowest temperature was observed in December (22.50^0C during 1997 and 21.5^0C during 2002). The rainfall pattern and temperature variations in Katangidda Nala watershed are depicted in Fig. 2.

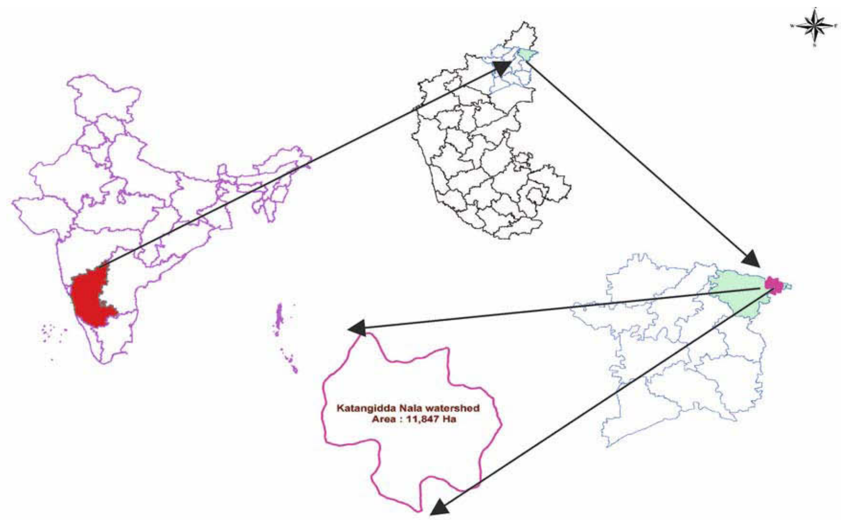

Fig. 1 The location map of Katangidda Nala watershed, Chincholi taluk, Gulbarga district, Karnataka, India

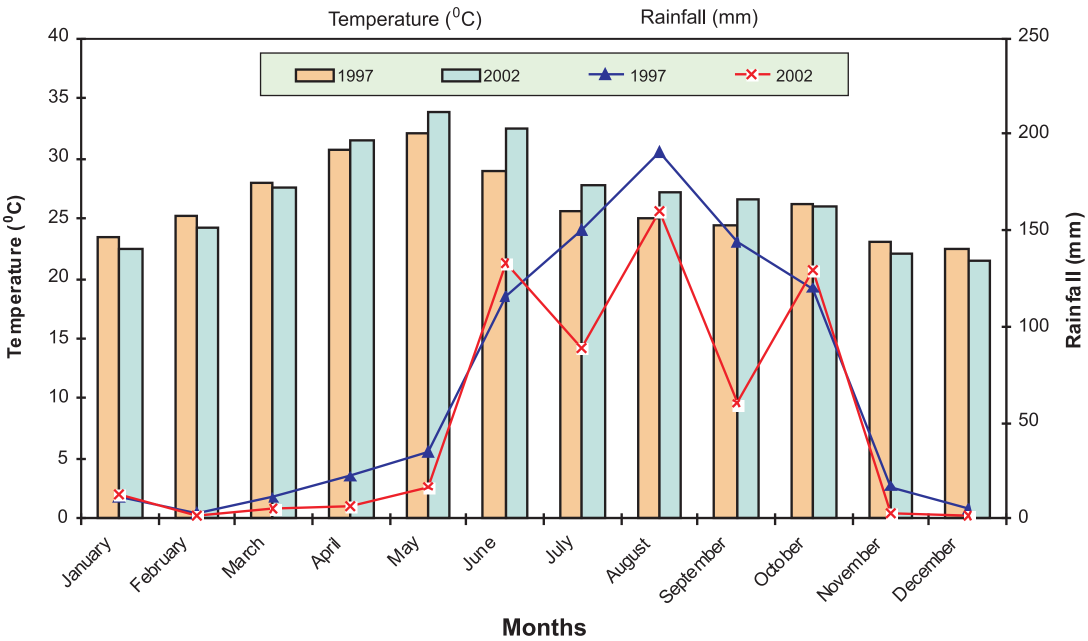

Fig. 2 Rainfall pattern (mm) and temperature variation (^{0}C) in Katangidda Nala watershed, Chincholi taluk, Gulbarga district (1997 and 2002)

Database used

The Indian Remote Sensing satellite (IRS) data of LISS III sensor with a spatial resolution of 23.5 m resolution were used for the study. IRS-IC data of December 11, 1997 and IRS-ID data of November 15, 2002 covering the watershed were analyzed to assess the changes in land use / land cover biomass that have occurred over a period of five years. The watershed is covered in satellite path and row of 99 and 60. The satellite data digital analysis was carried out at Karnataka State Remote Sensing Applications Center (KSRSAC), Bangalore using the state-of-art IBM RS6000 computer system and EASI/PACE image processing software. The satellite imageries used for the study are depicted in Fig. 3.

Ancillary data like SOI (Survey of India) map of 1: 50,000 scale was procured from SOI office, Hyderabad. The watershed is covered in the Survey of India topomaps 56 G/10 and 56 G/11 on 1: 50,000 scale. The ground site should be permanent features, so that the control points can be identified easily on the satellite imagery. Nearly around 13 control points are selected for the study area and are presented in Table 1.

Generation of land use/land cover maps

The classification of images was done using gaussian maximum likelihood algorithm (MXL). The MXL quantitatively evaluates both the variance and covariance of the category spectral response pattern while classifying an unknown pixel. This algorithm assumes Gaussian (normal) distribution and each pixel is considered as a separate entity, independent of neighbors. Using multivariate sample mean vector and interband variance co-variance matrix, the probability of every pixel was calculated for each class and the pixels were assigned to that class which had the highest probability. Those pixels not

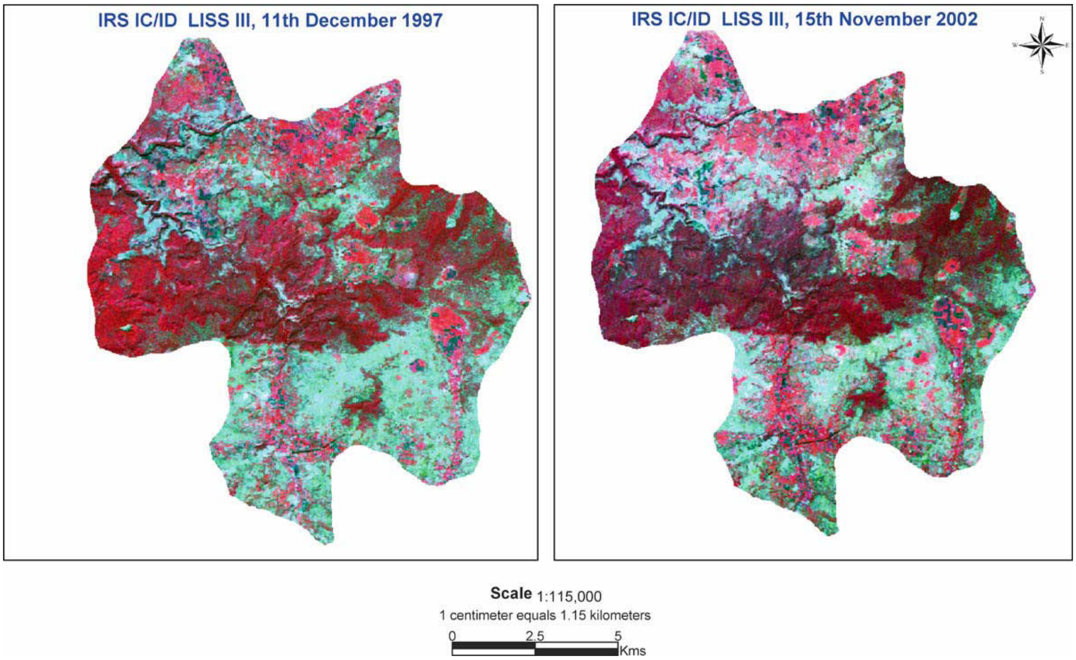

Fig. 3 Satellite imageries used for the impact assessment of Katangidda Nala watershed, Chincholi taluk, Gulbarga district, Karnataka, India

Table 1 List of ground truth sites selected in Katangidda Nala watershed, Chincholi taluk, Gulbarga district

Sl. No.	Control point	Nearest village	Land feature	Latitude	Longitude
1	Road junction	Shadipur	Land with scrub	17^{0}27' 26.20" N	77^{0}32' 42.90" E
2	Road bend	Seri	Fallow	17^{0}29' 54.74" N	77^{0}32' 35.23" E
3	Settlement	Sangapur	Tank corner	17^{0}27' 50.56" N	77^{0}33' 50.20" E
4	Road intersection	Jeelavarsha	Agriculture	17^{0}28' 22.28" N	77^{0}34' 27.67" E
5	Settlement	Chindanur	Fallow	17^{0}29' 25.60" N	77^{0}34' 10.10" E
6	Road junction	Lachmasagar	Agriculture	17^{0}26' 50.45" N	77^{0}35' 25.30" E
7	Drainage origin	Venatapur	Agriculture	17^{0}28' 35.40" N	77^{0}33' 45.20" E
8	Road junction	Sangapur	Agriculture	17^{0}27' 10.50" N	77^{0}33' 20.50" E
9	Settlement	Dharmasagar	Temple	17^{0}30' 36.40" N	77^{0}36' 50.10" E
10	Settlement	Chindanur	Road bend	17^{0}32' 35.10" N	77^{0}35' 32.30" E
11	Settlement	Linganagar	Road junction	17^{0}34' 10.25" N	77^{0}35' 40.42" E
12	Settlement	Antawaram	Tank	17^{0}32' 50.15" N	77^{0}33' 46.24" E
13	Settlement	Shadipur	Road junction	17^{0}27' 20.12" N	77^{0}32' 40.50" E

meeting the probability criteria were assigned to reject class as suggested by Lillesand and Kiefer (2000).

Generation of normalized difference vegetation index (NDVI) maps

The NDVI is highly correlated with vegetative parameters such as green leaf biomass, leaf area and is an indicator of photosynthetic activity; hence it is of considerable value for vegetation discrimination and seasonal monitoring. NDVI has been used to describe vegetation dynamics and monitor the seasonal growing conditions for making primary productivity analysis. NDVI is computed by using the infrared (IR) and red reflectance data as given below:

$$\mathrm{NDVI} = \frac{\mathrm{IR} - \mathrm{R}}{\mathrm{IR} + \mathrm{R}}$$

The values for NDVI range from -1.0 to +1.0. Vegetated areas generally yield high values of NDVI because of their relatively high NIR reflectance and low visible reflectance. Water, snow and clouds have negative IR radiation. Rocks and bare soil have NDVI values around zero since they have similar reflectance in both the bands and represent areas without any vegetation cover. Only green vegetation has positive NDVI values and high values being associated with higher densities / vigour of any given healthy biomass (Sabins, 2000 and Lillesand and Keifer, 2000). NDVI maps were generated by using the above equation for the study area for both the periods. The study area was classified into the following different biomass levels like High, Medium and Low, the area under each class was calculated.

Socio-economic study

The standard questionnaire was prepared and used to collect the socio-economic information of the beneficiaries of IWDP programme in Katangidda Nala watershed. Random sampling design was adopted. The list of respondents was prepared by selecting 100 farmers from 10 villages and 12 tandas (hamlets) of Katangidda Nala watershed. The farmers were selected based on the required information 10 farmers in each village/tanda and among these 10, two each belonged to a different section *i.e*. large, medium, small and marginal land holdings and one from SC/ST community. Every care was taken to give proper representation in the sample by making use of village panchayat register and the voters' list. Finally the collected information was compared with the 1997 (pre-treatment) data, which was traced from the IWDP project master plan.

Results and discussion

Land use/land cover changes during 1997 and 2002

The land use land cover maps of the both the periods (pre-treatment and post-treatment) indicated the following changes. The area under agriculture and forest increased marginally and reduction in the area under follow land and wastelands were noticed, which is similar to the study conducted by Blum *et al.* (1989), Rao *et al.* (1996) and Hajare *et al.* (2001). Table 2 shows the statistics of the area under different land use/land cover categories of the periods indicating transformations Fig. 4.

In northern and southern parts of watershed, vast stretches of agriculture cropped area covered about 6,137 ha during 1997 and 6,808 ha in 2002, indicating an increase of 671 ha during the study period (5.7 per cent of total geographical area). This increase in area may be attributed to better utilization of surface and groundwater, and changes in cropping pattern, the area under fallow decreased by 467 ha (3.94 cent of total geographical area). This change was due to conversion of fallow lands in to croplands, horticultural plantations and transformation of marginal and wastelands. Significant reduction in the area under fallow was observed.

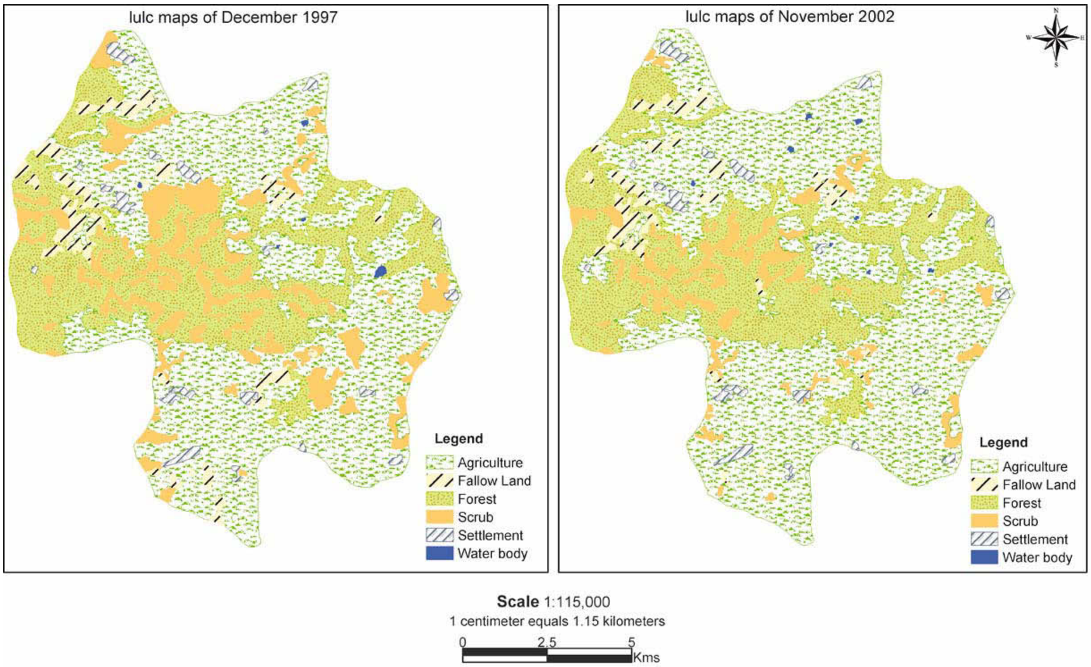

Fig. 4 Comparison of land use/land cover maps (1997 and 2002) of Katangidda Nala watershed, Chincholi taluk, Gulbarga district, Karnataka, India.

Plate 1 General View of the Watershed

Plate 2 Check dam constructed under IWDP

Plate 3 Storage of water in a Check dam

Plate 4 Water Usage for Irrigation

Table 2 Land use / land cover statistics during 1997 and 2002 along with the changes in Katangidda Nala watershed, Chincholi taluk, Gulbarga district

Sl.No.	Category	Pre-treatment 1997		Post-treatment 2002		Changes	
		Ha	Per cent	Ha	Per cent	Ha	Per cent
1	Agriculture crop	6,137	51.80	6,808	57.50	+ 671	+ 5.7
2	Fallow land	853	7.20	386	3.26	- 467	- 3.94
3	Forest area	2,014	17.00	3,428	28.94	+ 1,414	+ 11.94
4	Waste land	2,488	21.00	821	6.93	- 1,667	- 14.07
5	Settlements, roads and streams	355	3.00	404	3.37	+ 49	+ 0.37
	Total	11,847	100	11,847	100	—	—

Significant increase in area under forest was observed. The area under forest increased by 1,414 ha (11.94 per cent of total geographical area). This change was due to the conversion of wastelands into forest.

Due to the project, considerable amount of wastelands were transformed to forest and croplands. The area under wastelands decreased by 1,667 ha (14.07 per cent of total geographical area). These wastelands were reclaimed for productive use by adopting suitable treatment measures like better soil and water conservation practices. Similar results of decreased wastelands were observed by Kachhwaha (1990), Kant and Badarinath (1998) and Rao *et al.* (1998). Also a similar increased in forest area was observed by Seto *et al.* (2002) and Wentzel (2002). It was also observed that the area under settlement, roads and streams increased by 49 ha (0.37 per cent of total geographical area). This was because of increase in population, and construction of new houses / buildings, water harvesting and storage structures etc.

Normalized difference vegetation index (NDVI) of 1997 and 2002

The Normalized Difference Vegetation Index (NDVI) map indicates, that the vegetation increased considerably during the project period from 1997 to 2002 (Fig. 5). The increase may be due to adoption of soil and water conservation practices, better utilization of surface and ground water and changes in cropping pattern. Significant increase in the area under low and high biomass levels was also observed during the period. Table 3 shows the

Plate 5 Domestic use of stored water

Plate 6 Improved agricultural cropping systems

Plate 7 Domestic use of stored water

Plate 8 Agro-based jaggery preparation unit due to IWDP

statistics of the study area under different biomass levels during period 1997 and 2004. The area under low and high biomass levels increased by 19 ha (0.15%) and 502 ha (4.14 %), respectively. The reduction in the area under medium biomass level was to the extent of 521 ha (4.29 %). Similar results were noticed by Inoue *et al.* (1993), Arun (1998) and Patel *et al.* (2001).

Changes in socio-economic parameters during 1997-2002

Agriculture is the main occupation of people in the watershed. About 80% of the farming families depend upon agriculture for livelihood. Majority of the inhabitants of Katangidda Nala watershed are small and marginal scale farmers. Majority of them (90%)

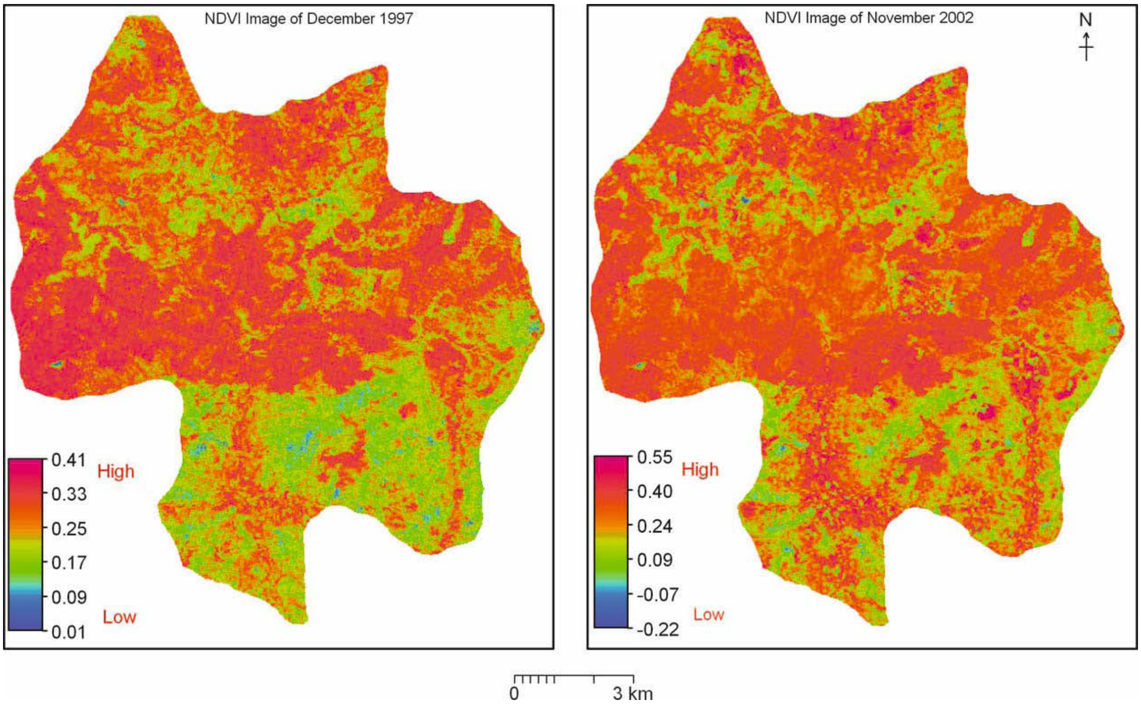

Fig. 5 Comparison of NDVI maps (1997 and 2002) of Katangidda Nala watershed, Chincholi taluk, Gulbarga district, Karnataka, India.

Table 3 Biomass variation in Katangidda Nala watershed, Chincholi taluk, Gulbarga district

Sl.No.	Category	NDVI values	Pre-treatment 1997 (ha)	Post-treatment 2002 (ha)	Changes	
					Area (ha)	Area (%)
1	Low	- 0.21 – 0.00	00	19	+ 19	+ 0.15
2	Medium	0.0 – 0.25	4,658	4,137	- 521	- 4.29
3	High	0.25 – 0.54	7,189	7,691	+ 502	+ 4.14
	Total		11,847	11,847	—	—

belong to SC / ST groups. Cattle population is very poorly maintained. Low productivity is also one of the factors for poor socio-economic status. It is a very neglected backward border area of Chincholi taluk in Gulbarga district. Most of the people are below poverty line. The number of landless labourers is considerably high and engaged mainly in agriculture. The major cropping system followed in the watershed is single crop / monocropping, employment to the people of watershed is seasonal. Thus migration of labourers is observed. There are about 1505 agricultural labourers in the watershed. A number of artisans like carpenters, black smiths, pot makers, rope makers, basket makers etc. are working. They were also assisted in the project for improving their expertise and purchase of implements.

The Integrated Wasteland Development Program project was implemented in Katangidda Nala watershed, Chincholi Taluk of Gulbarga District, during 1997-98 to 2000-2001 with a total investment of Rs. 473.88 lakhs. The area of the watershed is 11,847 ha. The reported arable land during pre-treatment period was 9,478 ha. Of which, only 6,137 ha of land was cultivated. During the project initiation, the reported cropping intensity was 110% and percentage of irrigated land was hardly 1.54 per cent. The fertilizer consumption was 10.5 kg/ha in *kharif* and 7.2 kg/ha in *rabi.* Drought occurrence is a recurring feature of the watershed. Table 4 shows the socio-economic parameters of Katangidda Nala watershed during 1997 and 2005.

The cropping intensity due to IWDP project has increased from 110% to 119%, and the productivity of the watershed has also increased from 5.0 q/ha to 7.5 q/ha. Development activities along with sustainable utilization of natural resources have raised the living standards of watershed inhabitants and improved ecological balance. Various soil and water conservation activities implemented in arable and non-arable land have resulted in in-situ moisture conservation, recharge of ground water and productivity.

Table 4 Socio-economic parameters of farmers during 1997 and 2002 of Katangidda Nala watershed, Chincholi taluk, Gulbarga district (n=100)

Sl. No.	Particulars	Percentage of farmers	
		1997	2002
1.	**Annual income**		
	a) Less than Rs. 10,000	35	7
	b) Rs. 10,000 to 50,000	32	41
	c) Rs. 50,000 to 1,00,00	25	38
	d) More than Rs. 1,00,000	8	14
2.	**Education level**		
	a) Illiterate	49	14
	b) Lower primary (1st to 5th standard)	26	36
	c) Higher primary (5th to 10th standard)	16	31
	d) Matriculation and above (10th and above)	9	19
3.	**Property**		
	a) House (owned)	80	84
	b) Land (both irrigated and rainfed)	32	37
	c) Livestock (more than 2)	36	45
	d) Vehicles (2 wheelers, 4 wheelers, etc.)	16	23

One Veterinary Hospital and a Raita Bhavan were built under IWDP programme. MYRADA, a NGO took active role in conducting vaccination campaigns, awareness programmes and social developmental activities.

The following changes were noticed during 1997 to 2002:

- Number of electrified villages have increased from 30.0% to 34.5%
- Number of Primary schools available in the watershed has increased from 7 to 14
- Number of primary health centers available per lakh of population has increased from 6 to 10
- Sugarcane cultivation encouraged jaggery preparation units, which created additional employment opportunities to the people of the watershed

Benefit – cost analysis of remote sensing and GIS

Study indicates the benefits and costs of using remote sensing and GIS to monitor the land use and biomass changes in the watershed over the conventional / manual methods. The cost of each IRS IC / ID LISS III image covering an area of 141 km × 141 km was Rs.20,000/- and it needed another Rs.10,000/- for processing. Thus the total cost of monitoring of land use and biomass changes worked out to Rs.30,000/- per imagery and the cost per ha comes to Rs. 0.0315 only for each season.

Out of the imagery area of 19,88,100 ha (141 km × 141 km), Katangidda Nala watershed covered an area of only 11,847 ha. The cost of monitoring land use and biomass changes worked out to Rs. 7.30/ha for processing the two imageries of 11.12.1997 and 15.11.2002. The same work, if done manually by engaging surveyors would amount to Rs. 16/ha, assuming a team of two persons covering an area of 50 ha per day with wages @ Rs. 200 per person per day. Thus, the use of remote sensing and GIS was cheaper by 2.2 times than that of conventional methods. Similar results were noticed by Dueker and Kjerne (1989), Liu and Negron (2001) and Schmidt and Skidmore (2001). But, one great advantage was that no manual surveying could be done for the past period (pre-treatment) and it is possible only through remote sensing and GIS by processing the imageries of past periods. Another advantage was the reduced time required for monitoring. The manual or conventional methods need 328 man-days, where as the same work was done in 30 man-days; and this in really is the greatest advantage.

Conclusion

The present was undertaken the use the frontier technologies like remote sensing, GIS and GPS in monitoring and evaluation of watershed development project. It was observed that the monitoring and evaluation of watershed using remote sensing data is cheap, rapid, accurate and release with the repetitive coverage. Thus the remotely sensed data potentially offers a rich source of information for planning, management and developments on the earth's surface that change cover time.

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