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Research Paper

IMPLEMENTATION OF WATERSHED MANAGEMENT PROGRAMMES IN KANERA WATERSHED, A CASE STUDY USING REMOTE SENSING AND GIS

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The present study utilized remote sensing data to analyze land use changes in Kanera watershed of Guna district, Madhya Pradesh, Central India, during 2001 – 2011 for implementation of watershed management programmes. Multi-spectral and multi-temporal data have been used for generating of thematic maps. Survey of India (SOI) topographical map was used for preparation of base map which was overlaid on FCC for land use/land cover mapping through visual interpretation, which led to the identification of 8 land use/land cover categories. The maps were finalized after the ground truth verification was conducted in key areas. The precipitation data for the period from 1986 to 2011 were statistically analyzed over a period of 25 years to know the variation of annual precipitation. The maximum and minimum precipitation recorded in watershed is 1677.5 mm in 2011 and 83.1 mm in 1996, respectively. The comparative analyses of 2001 and 2011 satellite data reveals that significant positive changes have occurred within rain-fed watershed in land use/land cover categories like cultivated land, uncultivated land, open forest, open scrub, culturable wasteland and water body, whereas, negative change has been observed only in built up class. The transformation of land use from one pattern to another is due to the increase in annual precipitation. The changing trends form negative to positive change is the result of implementation of different watershed development/management government programs in Kanera watershed.

Keywords: Land use/land cover, positive and negative change, land transformation and watershed development/ management programs

INTRODUCTION

The concept of watershed management based on integrated land use planning has been in vogue for the past two decades. Watershed management has emerged as a new paradigm for planning, development and management of land, water and biomass resources with a focus on social and environmental aspects following a participatory approach. Watershed management is considered a philosophy of comprehensive

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integrated approach to natural resources management, which also takes into account the social resources. It involves judicious use of natural resource with active participation of institutions, organizations and community in harmony with the ecosystem (Anon, 2004). However, one of the major gaps in watershed development programme has been the inadequate database on various parameters for planning and lack of research on the methodology and its implementation (Dhruvnarayana *et al*., 1990; Sarkar and Singh, 1997; Vidyanathan, 1991). The need for watershed management is because of the pressure on nature resources, increasing conflicts of interest and complex river systems represent a huge challenge. The small-scale, sectoral structures of water management are now reaching their limits. The integrated management of natural resources in the catchment area/watershed allows efficient and targeted natural resource management through regional coordination, transparent balancing of interests and clear priority setting.

Land use can be referred as human's activities which are carried on over land, usually with emphasis on the functional role of land in economic activity. Land use deals with the use of land surface and describes how a parcel of land is involved in forest, agriculture crops, grazing ground, water resources, waste disposal sites, habitation etc. In contrast, land cover is the assemblage of biotic and abiotic component on the earth's surface which describes the material that is present on the earth's surface (Turner *et al*., 1994). Land use/land cover pattern of a region is an outcome of natural and socio- economic factors and their use by man in time and space (Singh and Khanduri, 2011). Land cover indicates the visible evidences of land use which include both vegetative and non vegetative features like dense forest, plowed land, grassland, urban structures, parking area, water, snow (Sabins, 2000; Campbell, 2002; Gupta, 2003; Prakasam, 2010). Every parcel of land on the Earth's surface is unique in the cover it possesses (Moshen, 1999). Information regarding existing land use/ land cover is an important input parameter for agricultural, hydrological and ecological models which constitute necessary tools for better understanding of land utilization aspects, besides plays an important role in development, planning, management of natural resources and monitoring environmental changes (Dhinwa *et al*., 1992; Wilkie and Finn, 1996; Shetty *et al*., 2005). Changes in land cover may be brought by natural events such as weather, flooding, fire, climate fluctuations, and ecosystem dynamics. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Riebsame *et al*., 1994).

Application of remote sensing data, because of its repetitive and synoptic coverage capabilities, made it possible to study the changes in land cover in a time and cost effective manner in association with Geographical Information system (GIS) which provides suitable platform for data analysis, update and retrieval (Andersen *et al*., 1976; Kachhwaha, 1985; Nayak *et al*., 1985, 1986, 1989; Rasch, 1994; Green *et al*., 1994; Kam, 1995; Star *et al*., 1997; McCracker *et al*., 1998; Chilar., 2000; Luque, 2000, Maselk *et al*., 2000; Yang and Lo, 2002). Application of remote sensing data Remote sensing and GIS provides efficient methods for land use planning and management.

Remote sensing data is a valuable source from which land use/land cover change information can be extracted efficiently (Singh, 1989). Identifying difference in the state of an object or phenomenon at different time is known as change detection. Change detection is major application of remote sensing obtained from multi date data sets of Earth-orbiting satellites (Anderson, 1977; Singh, 1984). Change detection and monitoring involve use of multi-date images to evaluate differences in land use/land cover from time varying image sequences (Coppin and Bauer, 1996). Detection of changes in the land use/ land cover involves use of at least two period data sets which are superimposed (Jensen, 1996). Land use/land cover change is critically linked to the interaction of natural and human influences on environmental change. The change in the state of biosphere and bio-geochemical cycle are driven by heterogeneous changes in land use and continuation of those uses (Tuner *et al*., 1994).

The present study has been carried out in Kanera watershed to analyze spatial and temporal changes in land use/land cover pattern and land transformation as a consequence of climate change and human interference during past 10 years. The main objective of the study is to analyze land use/land cover change and its causes using remote sensing and GIS.

DESCRIPTION OF STUDY AREA

Kanera watershed is bounded between 77^o 22’ to 77^o 29’ E longitudes and 24^o 40’ to 24^o 37’ N latitudes located in Guna district of Madhya Pradesh, Central India, and covers an area of 69.01 km^2. The main Kanera stream flows almost west to east and joins the Sind river at Kothia (77^{o}29' E and 24^{o}30' 45" N). A small check dam is built in the western part of the watershed, which primarily serves as a source for irrigation. Apart from this structure, there is no other source of irrigation, and agriculture is mainly rain-fed. The maximum and minimum elevations encountered in the watershed are 532m and 472m above MSL, respectively. The area is represented by shallow to deep black soils, developed on gentle to moderately gentle sloping lands. The clay content varies from 35-50%, showing clayey to clayey loamy texture, sometimes with gravely, stony or rocky phase. Alkalinity ranges from slight to strong. Soils of the area respond to management and support a variety of crops under rain-fed and irrigated conditions. Geologically, the area is represented by recent alluvium. However, a few deeply weathered exposures of Deccan traps are reported in the watershed. The drainage in the area is dendritic to sub-dendritic. Locally parallel to sub-parallel pattern has also been developed. The climate of the study area is warm and semi-arid with an average annual rainfall of about 860.9 mm. The maximum temperature rises up to 42^o C in June while minimum temperature can be as low as 17.5^o C in January. Kanera watershed represents a typical rain fed watershed, representing a gentle and uniform slope from west to east, defined by the course of Kanera trunk stream.

MATERIAL AND METHODS

The Survey of India (SOI) topographical map of 1982-83 was used for preparation of base map. Geocoded false color composites (FCC) IRS 1C LISS III (Path-Row: 97-54) of 27 February, 2001 and IRS P6 LISS III (Path-Row: 97-54) of 27 February, 2011 of band combinations (234) green, red and near IR used for deriving land use/land cover status of the watershed. Data available of the same season gives uniform spectral and radiometric characteristics and minimize the seasonal variation. The climate data (rainfall) of the district Guna from 1986 to 2011 has been procured from Indian metrological department (IMD) Pune. Besides, secondary information on the study area was collected from published and unpublished government sources and ground truth data was also taken as one of the inputs in the final analyses.

The multi temporal satellite data of (2001 and 2011) were registered with topographical map to minimize geometric errors. Base map of the area having details such as settlement, road, railway line network, rivers and water bodies etc were superimposed on geocoded false colour composite (FCC) data for the identification of various land cover categories in the study area. Visual interpretation technique is the effective method to monitor and classifying land use/land cover from satellite data. Visual interpretation uses skill that were originally developed for interpreting aerial photographs, and takes into consideration various photographic and geotechnical elements such as tone, texture, shape, size, association, drainage, landform and relationship with other objects to identify different land cover classes (Lillesand *et al*., 2004). Land use/land cover change information can be obtained by either image-to-image comparison or map-to-map comparison (Green *et al*., 1994). Map-to-Map comparison was used for land use land cover change detection. Land cover were classified into 8 classes namely open forest, open scrub, cultivated land, uncultivated land, culturable waste land, Barren/rocky area, Built up land and water body. The ground truth verification was done in the key areas to rectify the errors in the land use/ land cover categories. The data base of land use/ land cover has been generated using on screen digitization in ArcMap 10 software for land use/ land cover change analyses. The steps followed for analyses are digitization, creation of polygon topology assigning unique id for each polygon and editing. Area statistics of each land use category have been calculated in sq.km as well as in percentage. The change in extent of different land use categories during the period from 2001 - 2011 was analyzed and computed. Land transformation map were prepared by overlay analysis of land use map of the year 2001 and 2011.

CLIMATE DATA ANALYSIS

The climate data for the period 1986 - 2011 procured from India Metrological Department, Pune, was statistically analyzed in respect of annual rainfall. The annual rainfall data was computed and analyzed for 1986 to 2011 period to know the variation during the period of 24 years. The variation in average annual rainfall were calculated in R software by plotting the annual rainfall against the years, a trend line was drawn and difference in the y value give the variation in the rainfall during the whole period of study. The standard deviation and co-efficient of variation was also calculated to know the deviation and variation from the mean value by applying formulas, as

Standard deviation = $\sqrt{(\Sigma / N)}$

Coefficient of variation =

$$\frac{\text{Standard Deviation}}{\text{Average}} \times 100$$

The rainfall data analysis has shown a significant variation in average annual rainfall as indicated by zig - zag trend of 1986 - 2011 period. The following regression relationship was established between average annual rainfall and year:

Average rainfall (y) = 3.9928 × + 807.09

The equation indicates an increase in trend of average annual rainfall. Its slope of 3.9928 would translate into a total increase of about 93 mm in average annual rainfall during the 1986 - 2011 periods. The maximum and minimum rainfall recorded in watershed is 1677.5 mm in 2011 and 83.1 mm in 1996, respectively (Table 1). The standard deviation of annual rainfall is about 310.9 mm with a coefficient of variation of 36.11%. 1996 might have been a drought year because the year has recorded lowest rainfall of 83.1mm (Figure 1). Annual average rainfall is about 861 mm with July and August being the wettest months. Almost 92% of the annual rainfall is received during the monsoon month's viz., June to September. 6.5% and 1.5% of the annual rainfall takes place during winter and summer seasons, whereas, 8% of the annual rainfall occurs from October to May (Khanday and Javed, 2008).

RESULTS AND DISCUSSION

Land use/land cover maps from Geocoded (FCC) IRS 1C LISS III (Path-Row: 97-54) of 27 February, 2001 (Figure 2) and IRS P6 LISS III (Path-Row: 97-54) of 27 February, 2011 (Figure 3) of band combinations (234) were generated to know the significant change in land use/land cover status and land transformation matrix during last 10 years period in watershed. Area statistics of each land use/land cover category of 2001 and 2011 generated in Arc GIS 10 has been determined to analyze change in their spatial distribution (Table 2). By comparing the land use/land cover maps of 2001 and 2011 a change detection map has been generated in Arc View 3.2 to assess the major changes and land transformation in the watershed during 2001 - 2011 (Table 3) (Figure 4).

Table 1: Variation in Average Annual Rainfall (1986-2003)

Years	Rainfall (mm)	X - X'	(X - X')²
1986	805.60	-55.40	3068.73
1987	1024.40	163.40	26700.82
1988	818.30	-42.70	1822.96
1989	734.80	-126.20	15925.47
1990	1338.70	477.70	228200.96
1991	672.40	-188.60	35568.51
1992	679.00	-182.00	33122.60
1993	1043.00	182.00	33125.40
1994	1286.00	425.00	180628.27
1995	1123.00	262.00	68646.02
1996	83.10	-777.90	605122.43
1997	371.50	-489.50	239606.48
1998	679.00	-182.00	33122.60
1999	901.00	40.00	1600.31
2000	960.00	99.00	9801.76
2001	910.00	49.00	2401.38
2002	478.00	-383.00	146686.05
2003	877.00	16.00	256.12
2004	791.90	-69.10	4774.28
2005	911.10	50.10	2510.40
2006	993.90	132.90	17663.43
2007	765.80	-95.20	9062.31
2008	980.60	119.60	14305.08
2009	677.30	-183.70	33744.28
2010	803.00	-58.00	3363.55
2011	1677.50	816.50	666678.53
Total	22385.90		
Average (X')	861.00		"=2417508.8

Figure 1: Increasing Trend of Average Annual Rainfall During 1986-2011

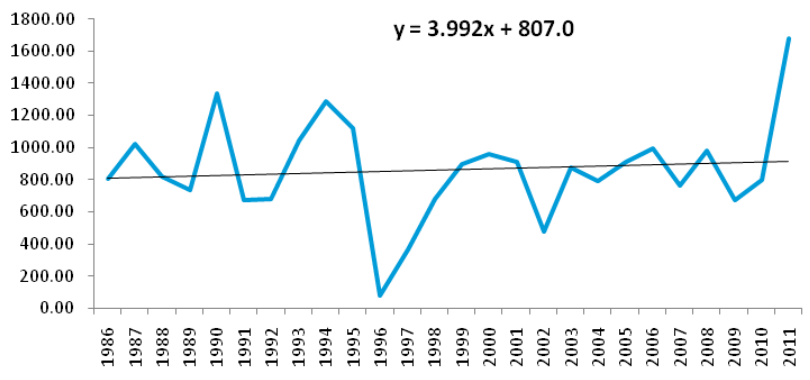
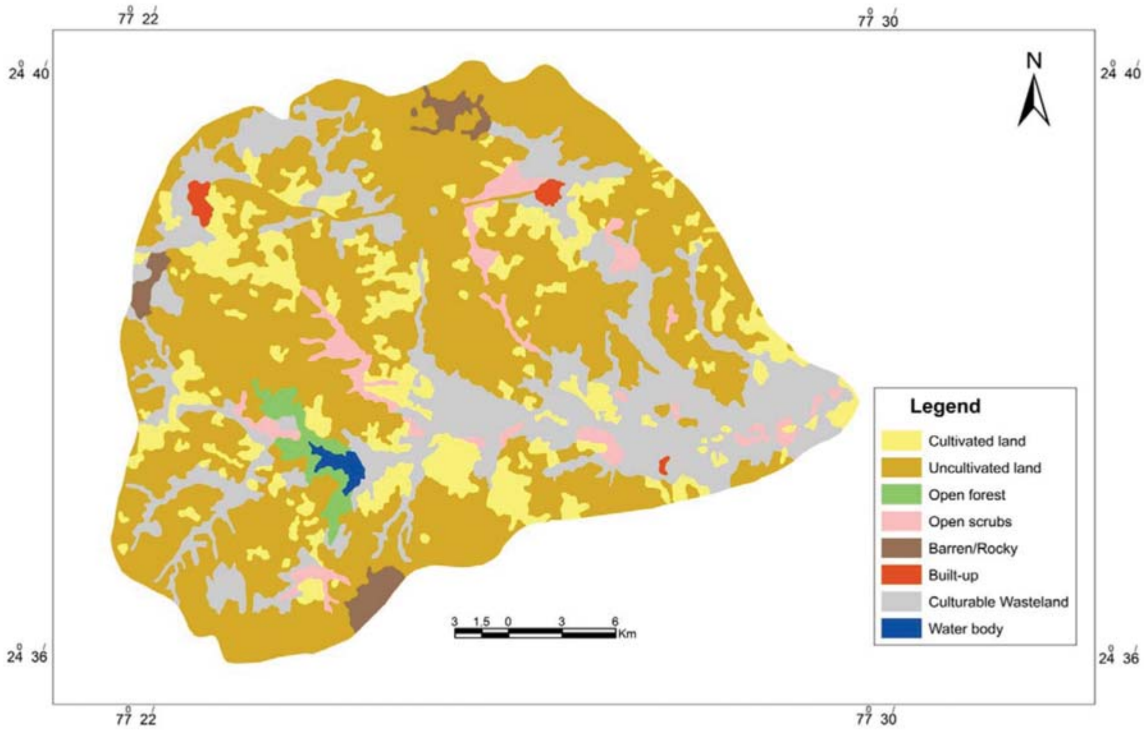


Figure 2: Land UseiLand Cover Map of Kanera Watershed (2001)



The significant positive changes within a typical rain-fed watershed has been observed during 10 years in major land use/land cover categories like cultivated land, uncultivated land, open forest, open scrub, culturable wasteland and water body, whereas, negative change has been observed only in built up class. The transformation of land use from one pattern to another is due to the climatic responses.

The results describe that ***Cultivated land***

Figure 3: Land UseiLand Cover Map of Kanera Watershed (2001)

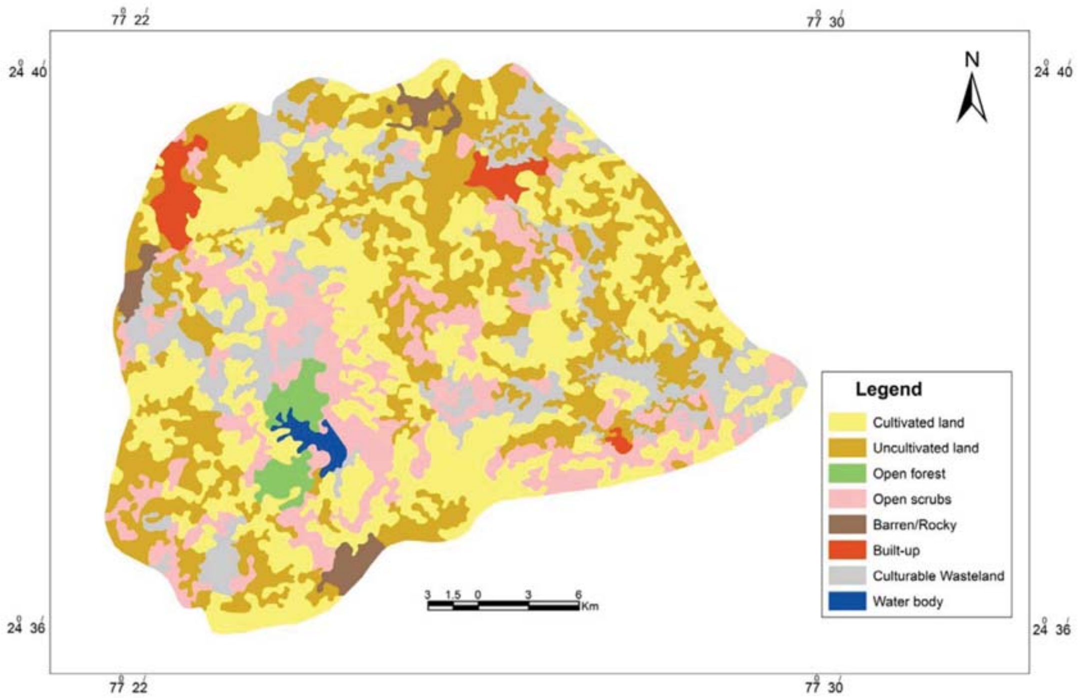


Table 2: Land use/land cover statistics of 2001 -2011 and change matrix (area in km²)

LULC	LULC 2001		LULC 2011		2001 – 2011 Change	
	Area in Km²	Area in %	Area in Km²	Area in %	Area in Km²	Area in %
Cl	9.67	13.98	28.62	41.36	18.95	27.39
UCL	37.70	54.48	21.59	31.19	-16.11	-23.29
OF	0.98	1.41	1.24	1.79	0.26	0.38
OS	2.64	3.82	6.91	9.98	4.26	6.16
B/RK	1.14	1.64	1.14	1.64	0.00	0
BL	0.43	0.62	1.50	2.16	1.07	1.54
CWL	16.38	23.67	7.75	11.21	-8.62	-12.46
WB	0.26	0.38	0.46	0.66	0.19	0.28
TOTAL	69.19	100	69.19	100	49.46	

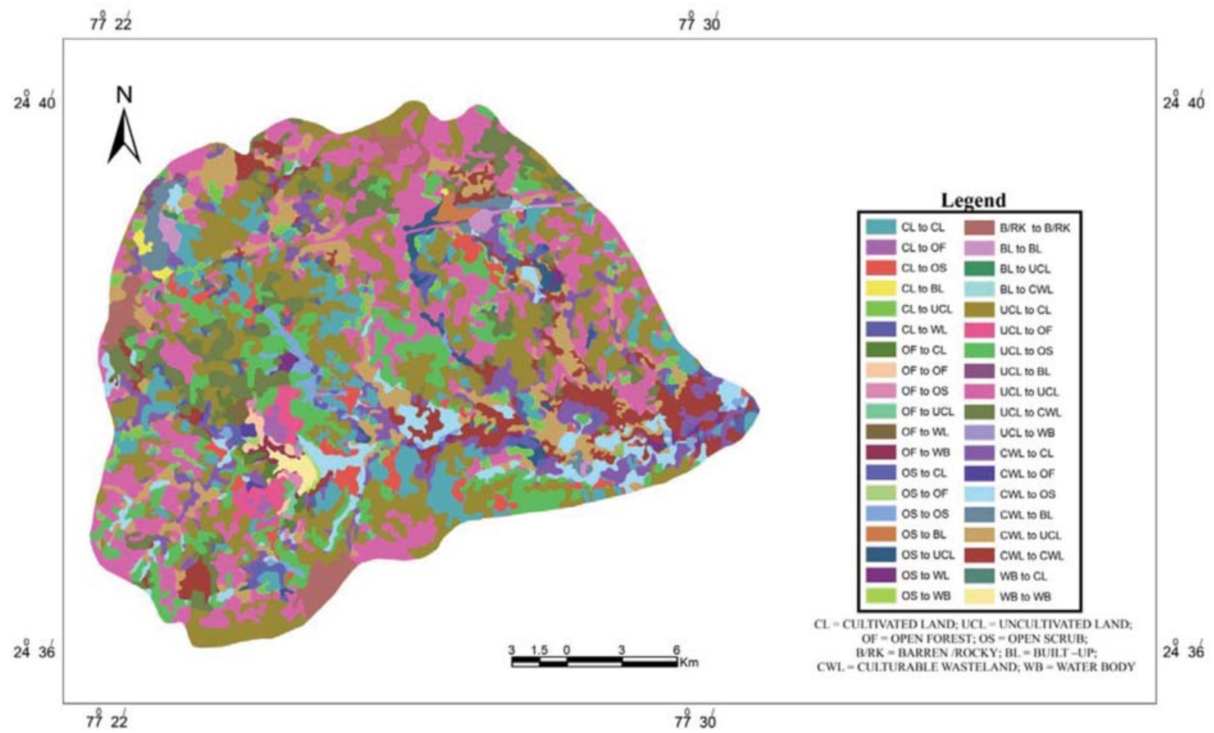
shows rapid increase of 18.95 km² (27.39%), from 9.67 km² (13.98%) in 2001 to 28.62 km² (18.95%) in 2011, however major portion has been added from uncultivated land (17.71 km²), culturable wasteland (4.08 km²) and small contribution by open forest, open scrub and water body. ***Uncultivated land*** shows a total decline in its areal extent by 16.11 km² (23.29 %) area from

Table 3: Land Transformation Statistics from 2001 – 2011 (area in Km^2)

LULC	CL	UCL	OF	OS	B/RK	BL	CWL	WB	2001
CL	5.62	1.74	0.26	1.20	0.00	0.14	0.72	0.00	**9.67**
UCL	17.71	14.29	0.71	2.30	0.00	0.15	2.48	0.06	**37.70**
OF	0.44	0.05	0.17	0.15	0.00	0.00	0.03	0.14	**0.98**
OS	0.76	0.63	0.02	0.69	0.00	0.20	0.33	0.01	**2.64**
B/RK	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	**1.14**
BL	0.00	0.06	0.00	0.00	0.00	0.36	0.01	0.00	**0.43**
CWL	4.08	4.81	0.09	2.57	0.00	0.65	4.18	0.00	**16.38**
WB	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.24	**0.26**
2011	**28.62**	**21.59**	**1.24**	**6.91**	**1.14**	**1.50**	**7.75**	**0.46**	**69.19**

Note: CL = CULTIVATED LAND; UCL = UNCULTIVATED LAND; OF = OPEN FOREST; OS = OPEN SCRUB; B/RK = BARREN / ROCKY; BL = BUILT –UP; CWL = CULTURABLE WASTELAND; WB = WATER BODY.

Figure 4: Change Detection Map of Kanera Watershed (2001)



2001 to 2011, it occupies 37.70 km^2 (54.48 %) in 2001 which has come down to 21.59 km^2 (31.19 %) in 2011. Major portion of the uncultivated land has transferred to cultivated land (17.71 Km^2), open scrub (2.30 km^2), culturable wasteland (2.48 km^2), whereas, small portion has shifted to open forest, built up and water body. ***Natural vegetation*** i.e. Open forest has gained 0.26 km^2 (0.38 %) and open scrub shows increase of 4.26 km^2 (6.16 %) from 2001 to 2011. ***Open forest*** area occupies 0.98 km^2 (1.41 %) in 2001 and 1.24 km^2 (1.79 %) in 2011, major land has come from uncultivated land (0.71 km^2), cultivated land (0.26 km^2), however, small portion from culturable wasteland and open scrub. ***Open scrub*** has increased from 2.64 km^2 (3.82 %) in 2001 to 6.91 km^2 (9.98 %) in 2011. Land use categories which shifted towards open scrub are uncultivated land (2.30 km^2), culturable wasteland (2.57 km^2), cultivated land (1.20 km^2) and small portion from open forest. ***Culturable wasteland*** shows a decline of 8.62 km^2 (12.46 %) area from 16.38 km^2 (23.67 %) in 2001 to 7.75 km^2 (11.21 %) in 2011. The culturable wasteland has shifted to cultivated land (4.08 km^2), uncultivated land (4.81 km^2) and open scrub (2.57 km^2) while small portion to open forest and built up. ***Water body*** the only source of surface water in the south-western part of the watershed registering an increase of 0.19 km^2 (0.28%) from 0.26 km^2 (0.38%) in 2001 to 0.46 km^2 (0.66%) in 2011. Water body gain most of the land surface from open forest 0.14 km^2, uncultivated land 0.06 km^2 and small portion from open scrubs.

The negative change has been observed in ***built-up land*** which shows increase by 1.07 km^2 (1.54 %) during the period of 10 years (2001-2011). The major land has shifted from culturable wasteland (0.65 km^2), open scrubs (0.20 km^2), uncultivated land (0.15 km^2) and cultivated land (0.14 km^2) to build – up land. No change has been observed in the barren/rocky land use class.

The Kanera watershed as a whole presented a grim scenario as the land use/cover changes from 1989 to 2001 period indicated degradation of land and other natural resources (Javed *et al*., 2009). The analysis from 2001 to 2011 depicts significant positive changes such as increase in cultivated land, natural vegetation and water body and decrease in uncultivated land, culturable wasteland are considered as the positive change in the Kanera watershed, where agriculture is the prime land use activity supporting the livelihood of the local people. The same land use classes show negative change during 1989 – 2001 like cultivated land has decreased by (12%), uncultivated land has increased by (24%), decrease in the natural vegetative cover, i.e. open forest by 4% and open scrub by 3% has been observed (Javed *et al*., 2009).

The change in trend form negative to positive changes is the result of implementation of watershed development or watershed management of government programs and increase in average annual precipitation from 2000 to 2011, in the Kanera watershed. The watershed development programs sanctioned by department of land resources are Drought Prone Areas programme (DPAP), Desert Development Programme (DDP) and Integrated wasteland development programme (IWDP), and these were implemented in Guna district in 72 micro watersheds covering an area of 116414 ha (http://dolr.nic.in/dolr/downloads/spsp/Madhya%20Pradesh_SPSP.pdf) and other projects sanctioned by other ministries of government of India cover 43 micro watershed like Rajiv Gandhi mission for watershed management (RGMWM) cover an area of 65113 ha , National watershed development project for rainfed area (NWDPRA) cover 34371ha for rehabilitation of degraded land in the district Guna (http://www.indiawaterportal.org/sites/indiawaterportal.org/filesMP_Watershed_Forward.pdf). Implementation of above watershed management schemes have direct effect on the land use categories of the Kanera watershed which shows negative changes during 1989 to 2001 and results reclamation, rehabilitation of degraded and unproductive land, which now depicts positive change in the land use categories from 2001 to 2011. Annual average precipitation (902.18 mm) from 2000 to 2011 has also increased from the original annual average precipitation, which also helps in bringing up all those positive changes in the watershed during 2001 to 2011.

CONCLUSION

The remote sensing and GIS techniques provide an excellent opportunity to create and manage database on spatial and non-spatial data for integrated watershed development. The data thus generated could be helpful to formulate site specific action plans for watershed management. The present study demonstrates that remote sensing data provides repetitive coverage of same area with multiple data sets is more effectively utlised to monitor the changes within a particular land use/land cover class. The positive change which results in the reclamation of cultivated land, uncultivated land, open forest, open scrubs, culturable wasteland and increase in waterbody is due to the increase in annual average precipitation from 1986 to 2011 and implementation of different watershed management/development programme sanctioned by department of land resources and other ministries of Government of India which cover over 115 micro watersheds in the Guna district, Madhiya Pradesh. More such programmes must be started by the government in such rain-fed watersheds to manage the water resources for reclamation of depleted natural resources which results positive change and will probably uplift environmental, economic and social standards of the people.

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