Impact of Climate Change on Land use/land cover change at watershed level: Case studies from Rajasthan, India

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1. Introduction

The ecosystem is always believed to be frail in an arid region and the land cover changes often shows the most significant effect on the environment because ofanthropogenic activities or natural processes (Zhou et al., 2008). Land use/land cover change (LU/LC), associated with climatic changes, has become a focus of the study on the interaction between human activities and the natural environment. Land cover changes can be regarded as one of the most sensitive indicators that echo these interactions (Bisht and Tiwari, 1996).

Watershed management has acquired immense importance in the recent past years and involves the development and conservation of natural resources with the active participation of local people, institutions and organisations in harmony with the ecosystem. It 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. Watershed management programmes yield multiple benefits, such as sustainable production, resource conservation, groundwater recharge, drought moderation and employment generation.

Remotely sensed data because of its synoptic view and its ability to acquire images in a time series domain has extensively been utilised in LU/LC mapping and assessing change detection (JayaKumarand Arockiasmy, 2003).Since watershed data and watershed processes have spatial dimensions, GIS acts as a powerful tool for understanding these processes and managing the potential impacts of human activities.

2. Objective

In the current study, an attempt to correlate the changes in climatic conditions with land use and land cover has been made at the watershed level. Two watersheds namely Mithri Watershed and Jaggar watershed from Pali and Karauli district, respectively have been chosen for the present study.

3. Study Area

3.1 Mithri Watershed, Pali district (Western Rajasthan)

The Mithri watershed lies in the western part of Pali district, Bali block and covers an area of about 313 km^2. The watershed has maximum and minimum elevation of 1059 and 287 meters above mean sea level (MSL) respectively. Digital Elevation Model (DEM) derived from ASTER data reveals that higher elevations ranging from (838-1059 m) are encountered in the South-East part of the watershed represented by Hills and Ridges. The Mithri river is ephemeral in nature and flows from South East to North West direction.

3.2 Jaggar watershed, Karuli district (Eastern Rajasthan)

The main Jaggarriver flows almost south to North and joins the main Gambhirriver at 26°51' 29" North and 77°04'52" East. The area is mainly drained by the Jaggar river and its tributaries. A small check dam (called Jaggar bandh) is built in the central part of the watershed, which primarily serves as a source of irrigation for agriculture at the local level through the canal. The elevation information derived from ASTER shows maximum and minimum elevation of 388 and 202 meters above mean sea level (MSL) respectively.

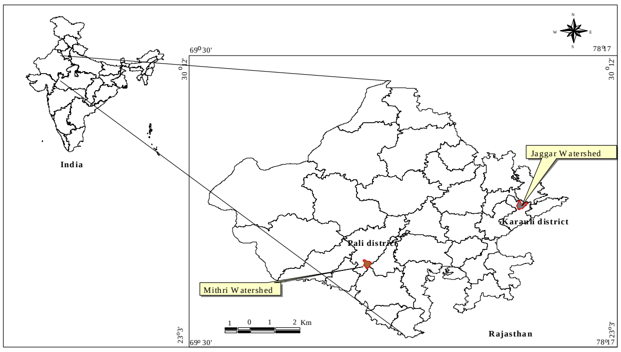

Figure 1: Rajasthan map showing the location of the watersheds

4. Methodology

Data sets used for the present study were derived from multiple sources and agencies, such as Survey of India Topographical Maps, Satellite Imagery from NRSA, Hyderabad. Moreover,meteorological data were collected from Indian Meteorological Department, Pune, ground data/GPS coordinates through field visits and secondary data from various government and non-governmental agencies.

Survey of India (SOI) topographic map numbers 54F/1 & 54 F/2, 54 F/5 for Jaggar watershed, Karauli district surveyed in 1968-1969 and 1983-1984 and 45 G/8 for the Mithri watershed, Pali district surveyed in 1971-72 on 1:50, 000 scale, were obtained from Survey of India, New Delhi, and Dehradun. For the purpose of demarcation of boundaries of the watershed, toposheets were used and slope, elevation and directions of drainage flow were taken as the basic inputs.

Geocoded Standard False Colour Composites (FCCs) of Indian Remote Sensing satellite IRS IA Data Linear Imaging Self Scanning (LISS II), (Path-Row: 29:49) of 30th May 1989; IRS-1C Linear Image Self Scanning (LISS III), (Path-Row: 96-52) of 13th May 1998; IRS-P6 (LISS III), (Path-Row: 98-52) of 27th May 2009 on1: 50,000were procured from National Remote Sensing Agency (NRSA), Hyderabad for the Mithri watershed.

Geocoded Standard False Colour Composites (FCCs) of Indian Remote Sensing satellite IRS-1A Linear Image Self Scanning (LISS II), (Path-Row: 31-51) of 19th May 1990; IRS-1C (LISS III), (Path-Row: 98-52) of 28th April 1998; (IRS-P6) LISS III (Path-Row: 93-54) of 7th May 2010 on 1: 50,000were procured from National Remote Sensing Centre (NRSC), Hyderabad for Jaggar watershed.

Meteorological data observed and recorded for the annual average maximum and minimum temperatures and annual average rainfall for the period 1977 – 2007 for Karauli district and 1969-2008 for Pali district were obtained from India Meteorological Department (IMD), Pune.

5. Results and Discussion

5.1 Climate data analysis

Mithri Watershed, (Pali district) Western Rajasthan

Maximum daytime temperatures in summer and winter have been found to be increased by 0.2°C and 0.15°C respectively, whereas, for monsoon, it shows a decline of 0.06°C. The minimum night temperature also shows a decrease in summer, winter and monsoon seasons by 0.12, 0.19 and 0.13°C respectively. The rainfall data analysis shows a declining trend from 596 mm in 1969 to 455 mm in 2008 with a total decline of 141 mm with a standard deviation of 338.34% for 1969-2008. The steep plunge in rainfall graph in the years 1969, 1974, 1987, 2002 and 2008 points towards the years of severe droughts that occurred in the study area (Figure 2a).

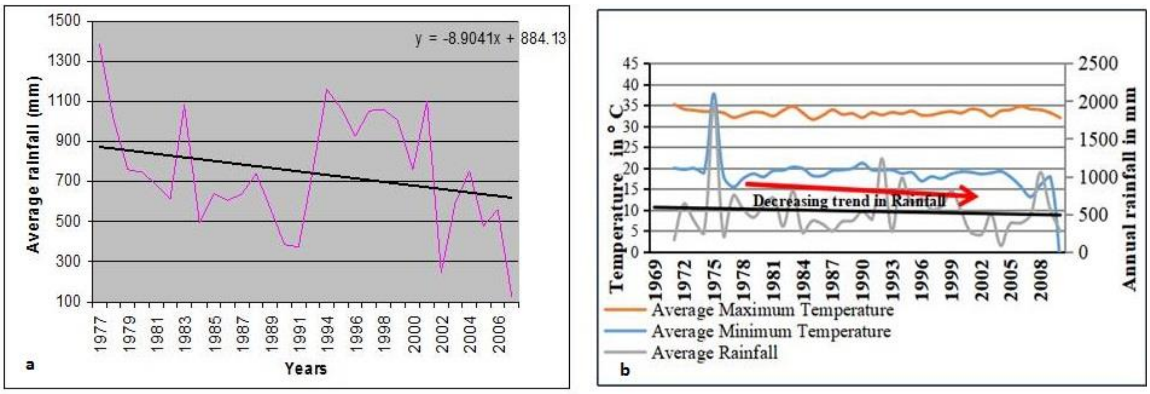

Figure 2: Graph showing variation and general declining trend of rainfall in two watersheds ((a) Mithri and (b) Jaggar).

Jaggar Watershed, Karauli district (Eastern Rajasthan)

The trends computed for the annual average maximum and minimum temperatures show an increasing trend from 1977 to 2007, for all three seasons, except for maximum temperature in the winter, which show a declining trend. Analyses of temperature data reveal that the maximum daytime temperature in the winter season has decreased by 0.06°C whereas temperatures in summer and monsoon seasons have increased by 0.03°C and 0.32°C respectivelyduring the period of 1977-2007. Minimum night-time temperature also exhibits an increasing trend by 0.03°C, 0.20°C and 0.23°C during winter, summer and monsoon seasons respectively. As per the analysis of rainfall data, a markedalteration in average annual rainfall has been indicated as illustrated by a zig-zag trend for the period of

1977-2007. The standard deviation of annual rainfall is about 288 mm with a coefficient of variation of 37.062% with a total declineof 269 mm (Figure2b).

5.2 Land use/Land Cover Change Analysis

Land use/land cover assessment is one of the most important parameters to meaningfully plan for land resource management. Remote sensing and GIS effectively assist in natural resource management by providing timely, accurate and up-to-date information obtained from satellite-based high-resolution remotely sensed data on a cost-effective basis.

Mithri Watershed, Pali district

From the satellite data (Figure 3 a,b,c), cultivated land, uncultivated land, wasteland, forest, settlement, waterbody, and the dry river was clearly delineated. Pali district has faced several drought years, which has resulted ina reduction in cultivated land due todecreased net sown area. Additionally, due to the drying up of the surface water and the reduction in water by 12 to 15 m in the deep wells in the region, the cultivated landshave alsoendured a setback due toinsufficient irrigation facilities. It covered an area of 60.23 km^2 (19.36%) in 1989, which reduced to 37.31 km^2 (12.36%) in 1998. Dense forest-covered 112.38 km^2 (35.86%) in 1989, but decreased to 90.09 km^2 (28.75%) in 1998. In a span of another 12 years, it has further decreased to 72.94 (23.87%) in 2009.

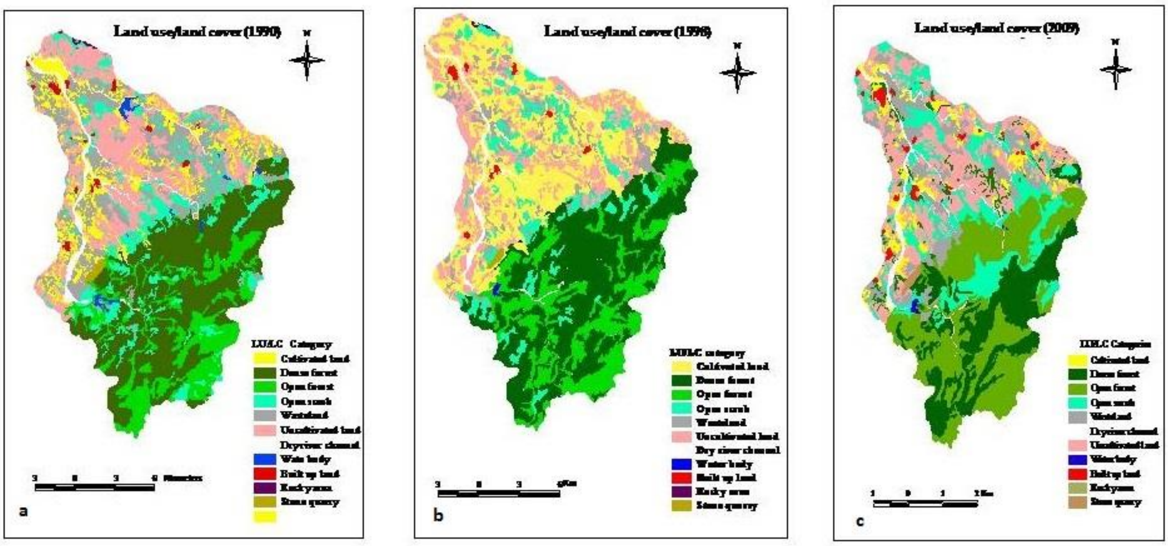

***Figure 3**:* Land use/ land cover maps for Pali District of the derived from IRS data of (a) 1990, (b) 1998 and (c) 2009

Open forest occupied 20.35 km^2 (4.93%) in 1989, which increased up to 25.12 km^2 (11.42%) and further increased to 32.74(11.42%) in 2009. The area under uncultivated land in 1989 was 30.35 km^2 (9.75%), which increased to 38.36 km^2 (13.97%) in 1998 and augmented to 49.23 km^2 (16.56%) in the year 2009. As the water resource in the region is dependent on scanty and erratic rainfall, the duration of availability of water in water bodies gets drastically reduced in the drought years. For the last 10-11 years, Mithririver has been witnessed to be dried in the Pali district. Shallow wells dry up fast and deep wells become deeper. The quality of groundwater depreciates and the concentration of undesirable constituents e.g. fluoride and nitrate reach toxic levels. Dry river channel area increased from 7.08 km^2 (2.25%) in 1989 to 7.42 km^2 (2.36%) in 1998 and to 8.10km^2 (2.5%) in 2009. Surface water body, however, shows an increase by 0.86 km^2 (0.2%) in 1998 because of the construction of a check dam in the northern part of the watershed. However, the water body area decreased to 0.70 km^2 (0.22%) because of the drying up of dam and other surface water bodies.

Jaggar Watershed

Eight major land use/land cover identified and delineated on the imageries based on photographic and geotechnical elements include open forest, ravenous land with open scrub, open scrub, agricultural land, wasteland, exposed rock with open scrub, water body and built-up land (Figure 4). Area statistic of major land-cover categories hasbeen calculated for the year 1990, 1998 and 2010. Comparative analysis has shown significant changes in land-cover during 1990 to 1998 and 1998 to 2010 period. Comparative analysis of land use/land cover maps derived from satellite imagery has revealed the vulnerability of the watershed towards the changing climatic conditions. Change analysis shows a decrease inagricultural land at the expense of increase in open scrub and wasteland. The situation calls for immediate adaptation measures to counter the effects of climate change, which has threatened the ecosystem and the livelihood of the local population. Jaggar watershed has lost 5% of its forest cover in a decade. In the year 1998, the area under open forest was 49.98 km^2 (14.19%), which decreased to 33.60 km^2 (9.52%) by the year 2010. The area under open scrub has increased from 46.55 km^2 (13%) in the year 1998 to 67.78 km^2 (19%) in the year 2010. Agricultural land in the watershed has decreased from180 km^2 (51%) to 120 km^2 (34.2%) from 1998 to 2010. Two majorscereals normally grown are wheat and Bajra, but for the last several years, wheat has almost vanisheddue to the decline in rainfall and most of the farmers have switched to Bajra.

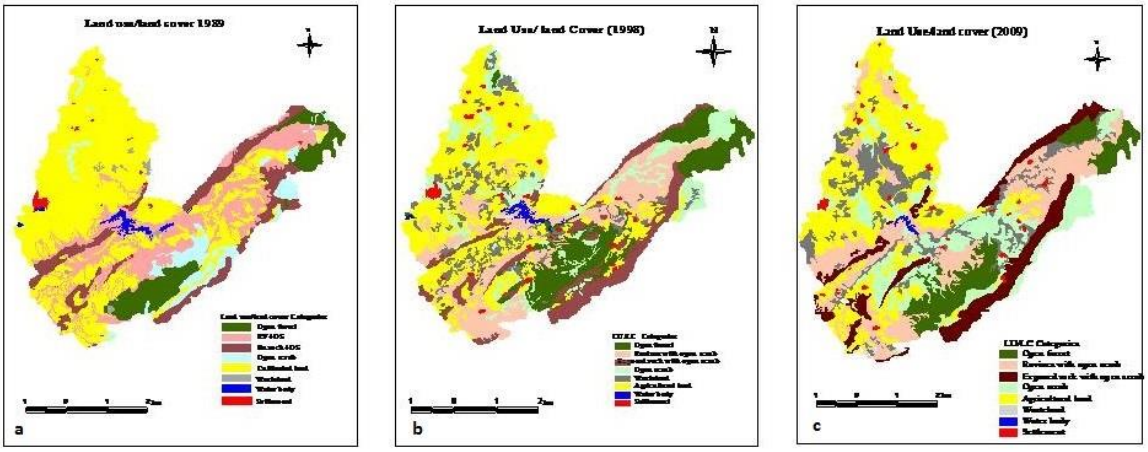

***Figure 4**: Land use/ land cover maps for Karauli District of the derived from IRS data of (a) 1990, (b) 1998 and (c) 2010*

6. Conclusion

In the present case studies, it is clearly suggested thatthe climate change has significant role in impacting availability of natural resources at watershed level in the state of Rajasthan. The two watersheds are under great stress as far as change in climate and availability of resources is concerned.

The satellite data analysis further proves that the land use/land cover changes, which have taken place in the two watersheds are the result of climatic changes and anthropogenic activities. The major land cover changes in a short period of 20 years reflect the prevailing climatic conditions and depletion of vegetative cover. The present study has proved the utility of remote sensing data in monitoring the land cover changes in space and time at a watershed level.

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8. References

Jayakumar.S. and Arockiasmy D.I. (2003). Land use/land cover Mapping and changes detection in parts of Eastern Ghats ofTamil Nadu using Remote Sensing and GIS. Journal of the Indian Society of Remote Sensing, Vol. 31, No. 4. 251-260.

Bisht, B.S and Tiwari, P.C(1996). Land-use planning for sustainable resource development in Kumaun Lesser Himalaya- a study of the Gomti watershed. International Journal of Sustainable Development and World

Zhou, Q., Li, B and Kurban, A., 2008. Trajectory analysis of land covers change in arid Environment of China, International Journal of Remote Sensing, 29(4), pp. 1093-1107.

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