Tropical Plant Research
An International Journal
© Society for Tropical Plant Research

ISSN (E): 2349 – 1183
ISSN (P): 2349 – 9265
4(1): 115–125, 2017
DOI: 10.22271/tpr.2017.v4.i1.018

Research article

Evaluation of land-use land-cover change with changing climatic parameters of a watershed of Madhya Pradesh, India

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[Accepted: 09 March 2017]

Abstract: In this present study an attempt has been made to determine trend of climatic parameters (precipitation and temperature) as well as LULCC for the watershed located near the Achanakmar-Amarkantak biosphere reserve of Central India. For analyzing trends of LULCC, Remote Sensing technique is used and Landsat satellite data of five different years (1990, 2000, 2005, 2011, and 2013) are procured and eight LULC classes such as settlement, river, water bodies, high dense vegetation, low dense vegetation, fallow land, open land and agriculture are identified. The trend analysis carried out over the LULCC data which shows that the high dense vegetation and agricultural lands are decreasing while settlement, fallow land and low dense vegetation lands are increasing. Simultaneously, when both parametric and nonparametric methods of trend analysis are applied over the annual precipitation and temperature (maximum, mean and minimum) data for the period of 1981 to 2011, significant (p-value < 0.05) decreasing and increasing trends are observed, respectively. Although, the present study does not include an establishment of an empirical relationship of LULCC and climate change, result of this study is a strong indicator of decreasing high dense vegetation having local impacts of decreasing rainfall and vice-versa.

Keywords: Land-use land-cover - Remote Sensing - GIS - Precipitation & Temperature - Trend Analysis.

[Cite as: Soni S (2017) Evaluation of land-use land-cover change with changing climatic parameters of a watershed of Madhya Pradesh, India. *Tropical Plant Research* 4(1): 115–125]

INTRODUCTION

The anthropogenic activities of post Industrial era, have caused significant emission enhancement of greenhouse gases resulting the global warming. Subsequently, climate change has become the most important environmental plight of the present time (IPCC 2007 a,b,c,d). However, along with the climate change issue of present time, rapid land use and land cover change (LULCC) has also taken place throughout the world due to urbanization, deforestation and population growth (Duncan *et al.* 1993, Parker & Alexander 2002, Delang 2002, Duram *et al.* 2004, Fromard & Vega 2004). It is now presumed that LULCC and climate change are interlinked with each other (Turner *et al.* 2007). Since the global and hemispheric climate change can have direct impacts on temperature and precipitation (rainfall, snow etc.) distribution, enhancement of flood and avalanche frequency along with changes in the agricultural productivity of a country or region, impact assessments of climate change for a particular ecosystem or targeted land practices such as national parks, forests or river basins are necessary.

Simultaneously, LULCC is an important parameter contributing to local and regional climate change (Chase 1999, Pielke *et al.* 2002). A recent study estimated that 40% of the global temperature rise is due to world-wide change in land use (Kalne & Kai 2003, Munoz-Villers & Lopez-Blandco 2008). The LULCC of a region is so pervasive that, when aggregated globally, the LULCC significantly affects the key aspects of Earth system functioning (Muttitanon & Tripathi 2005). The LULCC is the primary source of soil and forest degradation (Tolba & El-Kholy 1992) which alters the ecosystem services of a particular land type and affect the ability of biological systems to support human needs (Sala *et al.* 2000, Vitousek *et al.* 1997). However, enough attention

Received: 20 November 2016

https://doi.org/10.22271/tpr.2017.v4.i1.018

was not provided to the LULCC during several climate studies which involve detection of climate controlling factors (Reddy & Gebreselassie 2011). According to the third assessment report of Intergovernmental Panel on Climate Change (IPCC), climate studies involving detection and attribution techniques of climate controlling factors have not taken into account the anthropogenic forcing such as changes in the Land use and Land cover (LULC) (IPCC 2001).

Several national and international research communities have studied the reason, trend and impacts of climate change at global, hemispherical and regional scale (Chase 1999, Joeri 2011, Paeth 2009). Temperature and precipitation are assumed to be one of the important climatic parameters that represent climate change on a long-term basis. Therefore, several explorations on climatic trends have been conducted by analyzing precipitation and temperature data at different periods of records throughout the world (Dessens & Bucher 1995, Serra *et al.* 2001, Marengo 2004, Longabardi & Villani 2009). Most of these studies have shown that the trend of temperature or precipitation distribution of a particular region is either decreasing or increasing. A recent study by Karl *et al.* (1993) have shown that the monthly minimum temperature, from countries comprising 37% of the global landmass, is increasing by 0.84^{o}C compared to only 0.28^{o}C increase in maximum temperature for the period 1951–1990. The IPCC (2007e) report has also demonstrated that the global surface warming is occurring at a rate of 0.74±0.18 °C during 1906–2005.

The maximum and minimum temperature datasets are important because minimum temperature alone is almost certainly not a good parameter to detect heat accumulation in the atmosphere associated with climate changes (Pielke & Matsui 2005). In addition, minimum temperature is much more sensitive to land use change than maximum temperature (Hale & Gallo 2008, Runnalls & Oke 2006, Walters *et al.* 2007).

In India, the climate change is expected to adversely affect forestry, agriculture, temperature, and rainfall distribution. Climate change is also expected to change the monsoon onset (Lal *et al.* 1994, Panigrahy *et al.* 2009) and increase extreme events such as floods (Booij 2005), droughts (Loukas *et al.* 2008) and devastating cyclonic storms (Knutson *et al.* 2010) which have direct consequences on the population and the economy of the country (Fulekar & Kale 2010). Therefore, climate change studies are of paramount importance and efforts are continuing to understand the trend of climatic regimes over the Indian subcontinent (Aggarwal *et al.* 2004, Mall *et al.* 2006, Rupa-Kumar *et al.* 2006, Joshi & Rajeevan, 2006, Samui & Kamble 2009). A study by Kothawale & Rupa-Kumar (2005) has indicated that the mean annual temperature of the Indian subcontinent has increased at a rate of 0.05°C per decade during 1901–2003 mostly due to the rise of maximum temperature (0.07°C per decade) rather than the increase of minimum temperature of 0.02°C per decade.

However, the LULCC has an inter-relationship with the temperature and precipitation distribution of an area, and depending on the feedback processes within land and atmosphere, impact of the climate change can be assessed. A study by Douglas *et al.* (2006) on the changes in moisture and energy fluxes due to agricultural land use and irrigation in the central Indian region has shown that the increasing agricultural land use has contributed significantly in increasing the vapor flux of this region which could modulate the local to regional scale cloud formation and subsequently, modulate the precipitation distribution. Therefore, it is important that we understand the LULCC of a particular river basin area or a targeted land practice area, so that the inter-relationships between the climate parameters and the LULCC can be explored (Turner *et al.* 1994, Knorr *et al.* 2011).

Therefore, the present study aims to explore the long-term land use land cover changes of a watershed with particular focus on investigating changes in the meteorological parameters of the area and their relationships with LULCC. The Chakrar watershed of Madhya Pradesh is chosen for this purpose. The Chakrar watershed is an important sub-tributary of the Narmada basin and constitutes part of the Achanakmar-Amarkantak Biosphere Reserve. The watershed has dominant Sal (*Shorea robusta* Gaertn.) forest and due to increasing human population in the last few decades, it is hypothesized that the forest area within this watershed is degrading. An in-depth analysis of land-use land-cover change of the watershed and subsequent analysis of meteorological parameters over the study area is, therefore, envisaged to provide (i) whether the underlying hypothesis of degrading forest cover over the watershed is true and (ii) enhanced understanding of the inter-relationships between climatic and LULCC drivers.

MATERIAL AND METHODS

Study Area

The study area is Chakrar Watershed of Dindori District, Madhya Pradesh, India (Fig. 1). The watershed has rich Sal (*Shorea robusta* Geartn.) dominant forest with altitudinal range 700–980 m. The watershed extends from 22°31' 12.24" to 22°52' 44.93" N latitude and 81°14' 41.23" to 81°28' 29.42" E longitude. Total catchment area of the Chakrar watershed is 415 km^2. The area falls under sub-tropical monsoon climatic region. Average annual precipitation of this watershed varies between 1200–1306 mm and annual temperature varies between 18–43 ºC. Maximum amount of rainfall occurs during monsoon season *i.e.* June to September.

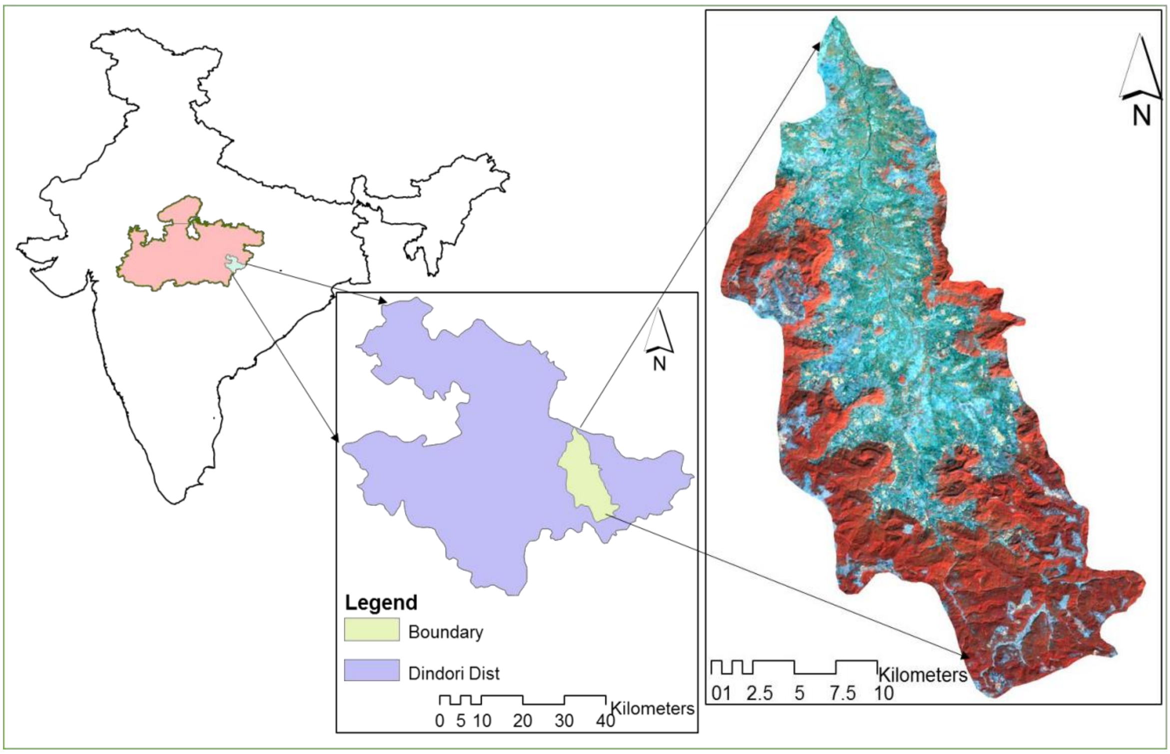

Figure 1. Location map of the study area.

Data Used

In order to investigate the LULCC of the study area, Landsat 5 TM (path 143, row 44) satellite data (Ioannis & Meliadis 2011) are used for the year of 1990 and Landsat 7 TM (path 143, row 44) satellite data are used for 2000, 2005, 2011 and 2013. Satellite data was procured from USGS websites (www.glovis.usgs.gov). Yearly continuous data of LULCC was unavailable from the Landsat products over the experimental area. Hence, only five years of LULCC of the study area was investigated. However, the Meteorological time series data of annual precipitation, mean temperature, maximum temperature and minimum temperature for 30 years (1981–2011) are acquired from India Water Portal (www.indiawaterportal.org/met_data/) for the study area.

Land-Use Land-Cover Change Analysis

Satellite data were processed using ERDAS IMAGINE 9.2 software for geometric corrections (image to image georectification) with the coordinate system *UTM WGS 84*, *Zone 44 North* to make these images compatible (Lillesand & Kiefer 1994). The images of 1990, 2000, 2005, 2011 and 2013, resampled to 30m x 30m pixel size using the nearest neighbor resampling technique (Serra *et al.* 2003, Jensen 2005). Pixel based supervised image classification with maximum likelihood classification algorithm was used to map the land-use land-cover classes (Lillesand & Kiefer 1994, Shalaby & Ryutaro 2007). Eight LULC classes *viz*., Settlement, River, Water bodies, High Dense Vegetation, Low Dense vegetation, Fallow land, Open land and Agriculture were identified for image classification.

The pre and post field visit was done with a GPS receiver and using a set of questionnaire designed for the purpose. GPS points were selected for ground truth validation and verification of location (latitude and longitude) and elevation. The accuracy assessments were performed for classified images of 1990, 2000, 2005, 2011 and 2013. A minimum of about 40 random points were generated per class using stratified random sampling approach for efficient accuracy assessment (Congalton & Green 2009). The corresponding reference class for each LULC type was collected from different data sources, including data from field visits, topographic maps, and raw images. Raw images were used for those visually visible classes, e.g., forests and water bodies

(Congalton & Green 2009). Topographic maps were utilized to collect reference samples for 1990 classified images while field visits data were mainly used for the 2013 classified image. Reference points for the 2000, 2005 and 2011 classified image were collected through visual interpretation of the raw Landsat TM 2000, 2005 and 2011 image. This was supplemented by field visits and discussion with elders in the study landscape that made it possible to establish reference points of different classes.

Trend Analysis

The trend is a significant change over time exhibited by a random variable, detectable by statistical non-parametric and parametric procedures. According to Önöz & Bayazıt (2003), parametric t-test has less power than the non-parametric Man-Kendall test when the probability distribution is skewed. With due trend detection and cross verification, both parametric and non-parametric statistical procedures are applied to the precipitation and temperature time series.

Mann-Kendall Test

Mann-Kendall test is a non-parametric statistical test used to assess the significance of trends in climatic time series data such as precipitation and temperature (Mavromatis & Stathis 2011). Non-parametric tests are thought to be more suitable for non-normally distributed data which are encountered in climatic time series (Yue *et al.* 2002). Man-Kendall test was suggested by Mann (1945) for randomness against time, which constitutes a particular application of Kendall's test for correlation commonly known as the 'Mann-Kendall' or the 'Kendall t test' (Kendall 1962). The test has been extensively used with environmental time series (Hipel & McLeod 1994, McLeod *et al.* 1990). Let X_1, X_2,……………X_n represents data points over time, in the test null hypothesis H_0 is tested where the random variables are independent and identically distributed. The alternative hypothesis H_A, is that the data are not identical. Under H_0, the Mann-Kendall test is calculated by using following equations (Lazaro *et al.* 2001, Önöz & Bayazit 2003, Kahya & Kalayci 2004).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i)$$

Where,

$$Sgn(x_j - x_i) = \begin{cases} +1, & x > 0 \\ 0, & x = \mathbf{0} \\ -1, & x < \mathbf{0} \end{cases}$$

Under the hypothesis of independent and randomly distributed random variables, when n ≥ 8, the S statistics is approximately normally distributed with the mean.

$E[S] = \mathbf{0}$

The variance statistic is given as

$$Var[S] = \frac{\{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j(t_j - 1)(2t_j + 5)\}}{18}$$

Where, p is the number of tied groups in the data and t_j is the number of data values in the j^{th} tied group. As a consequence, the standard test statistic Z is computed as follows

$$Z = \begin{cases} \dfrac{S-1}{[Var(S)]^{\frac{1}{2}}} , & if\ S > 0 \\ 0 , & if\ S = 0 \\ \dfrac{S+1}{[Var(S)]^{\frac{1}{2}}} , & if\ S < 0 \end{cases}$$

The test statistic Z is used a measure of significance of trend and used to test the null hypothesis, H_0. The test statistic Z follows a standard normal distribution. A positive (negative) values of Z signifies an upward (downward) trend.

Spearman's Rho

Spearman's Rho is a rank based test to determine the significance of correlation between two variables that can be used to test for a correlation between time and the data series (Siegel & Castellan 1988). This test evaluates the degree to which individuals or cases with high rankings on one variable were observed to have similar ranking on another variable (Sprent 1989).

The test statistic ρ_s is the correlation coefficient, which is obtained in the same way as the usual sample correlation coefficient, but using ranks:

$$\rho_s = \frac{S_{xy}}{(S_x S_y)^{0.5}}$$

Where,

$$S_x = \sum_{i=1}^{n} (x_i - \bar{X})^2$$

$$S_y = \sum_{i=1}^{n} (y_i - \bar{Y})^2$$

$$S_{xy} = \sum_{i=1}^{n} \left(x_i - \bar{X}\right) \left(y_i - \bar{Y}\right)$$

and xi (time), yi (variable of interest), $\bar{X}$ and $\bar{Y}$ refer to the ranks ($\bar{X}$, $\bar{Y}$, S_x and S_y have the same value in a trend analysis).

For time series, the quantity $\rho_s\sqrt{n-1}$ is normally distributed mean of 0 and variance of 1.

Linear Regression

Linear regression is a parametric test which is one of the most common trend test and in its basic form assumes that data is normally distributed. The test statistic for linear regression is the regression gradient. The test is used to test for linear trend by the linear relationship between time and the variables of interest. The linear regression gradient is calculated by

$$b = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

And the intercept is estimated as

$$a = \bar{y} - b\bar{x}$$

The test statistic S is

$$S = {}^{b}/_{\sigma}$$

Where,

$$\sigma = \sqrt{\frac{12\sum_{i=1}^{n} (y_i - a - bx_i)}{n(n-2)(n^2-1)}}$$

The application of this test assumes that the errors (deviations from the trend) are independent and follow the same normal distribution with 0 mean.

RESULTS AND DISCUSSION

Accuracy assessment of the supervised classification of the satellite imagery was derived by using a reference template from the margining data with 40 randomly selected samples on the latest imagery, from which overall accuracy and Kappa statistics were derived. The Kappa statistics incorporated the diagonal elements of the error matrices (Yuan *et al.* 2005). Satellite imageries of 1990, 2000, 2005, 2011 and 2013 were classified (Fig. 2) and validated using error matrix and Kappa statistics. The overall accuracy was found to be 91 percent whereas overall Kappa statistics was 0.8898. The statistics shows that the result was overall good.

Land use land cover maps from Landsat imageries of 1990, 2000, 2005, 2011 and 2013 were produced and trend analysis of LULCC were carried out. Regardless of proportion of changes in the size and type of land cover, significant changing trends were observed between 1990 and 2013. The major land cover classes such as: settlement, fallow land, and low dense vegetation show increasing trend in land cover areas (Fig. 3A,B,C) having r^2 of 0.90, 0.89 and 0.72, respectively. Settlement area was found to increase by 1.87%, whereas the fallow land and low dense vegetation were found to increase by 8.99% and 4.78%, respectively. Significant decreasing trends were observed for high dense vegetation and agriculture classes. High dense vegetation, which was spread over 139.83 km^2 area in 1990, degraded to only 95.85 km^2 in 2013 (Table 1) and remaining proportion of lands were found to transform to low dense vegetation and fallow land (Fig. 2A–E). A significant decrement of 10.60% is observed in high dense vegetation with r^2 of 0.84 (Fig. 3A–F). Agriculture land which were spread over 53.38 km^2 during 1990 reduced to 31.29 km^2 in 2013 showing a decreasing trend with r^2 = 0.54 and loss of 5.32%. A trend relationship between high dense vegetation with rainfall and agriculture with rainfall shows a decreasing trend (Fig. 4A, B).

Table 1. Land use land cover changes in Chakrar Watershed during 1990–2013. [Reproduces from Soni *et al.* 2015]

Class	1990		2000		2005		2011		2013	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Settlement	4.91	1.18	6.41	1.54	10.96	2.64	12.29	2.96	12.69	3.06
River	2.67	0.64	2.71	0.65	2.73	0.66	2.73	0.66	2.72	0.66
Waterbodies	0.24	0.06	0.26	0.06	0.34	0.08	0.43	0.10	0.48	0.11
High Dense Vegetation	139.83	33.69	132.15	31.84	131.73	31.74	96.25	23.19	95.85	23.10
Low Dense Vegetation	54.54	13.14	58.46	14.09	54.92	13.23	75.55	18.20	74.37	17.92
Fallow Land	143.04	34.46	141.15	34.01	159.25	38.37	162.56	39.17	180.33	43.45
Open Land	16.40	3.95	11.83	2.85	17.74	4.28	16.63	4.01	17.29	4.17
Agriculture	53.39	12.86	62.07	14.95	37.35	9.00	48.60	11.71	31.29	7.54
Total	415.03	100.00	415.03	100.00	415.03	100.00	415.03	100.00	415.03	100.00

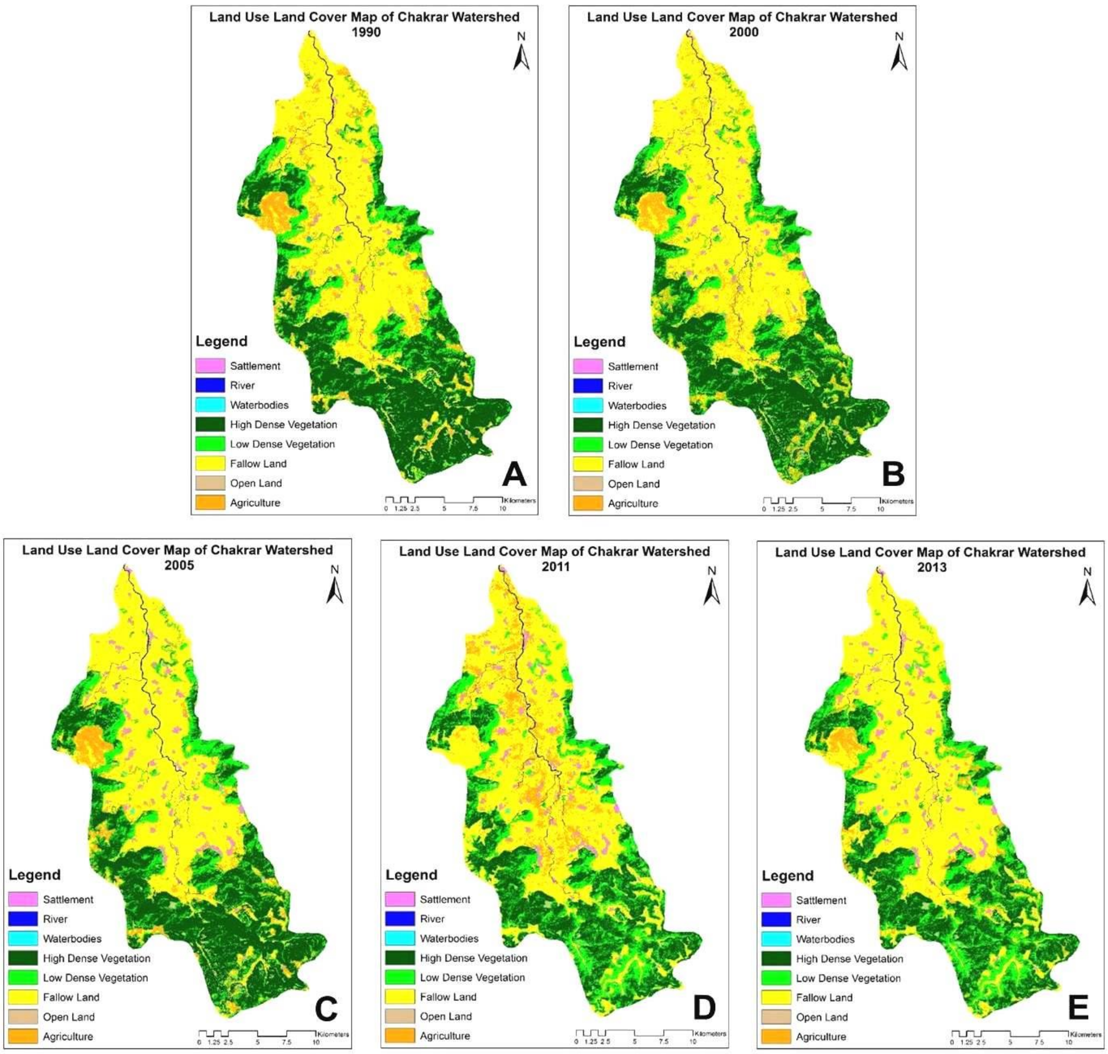

Figure 2. Land use land cover map of Chakrar Watershed during: **A,** 1990; **B,** 2000; **C,** 2005; **D,** 2011; **E,** 2013. [Reproduces from Soni *et al.* 2015]

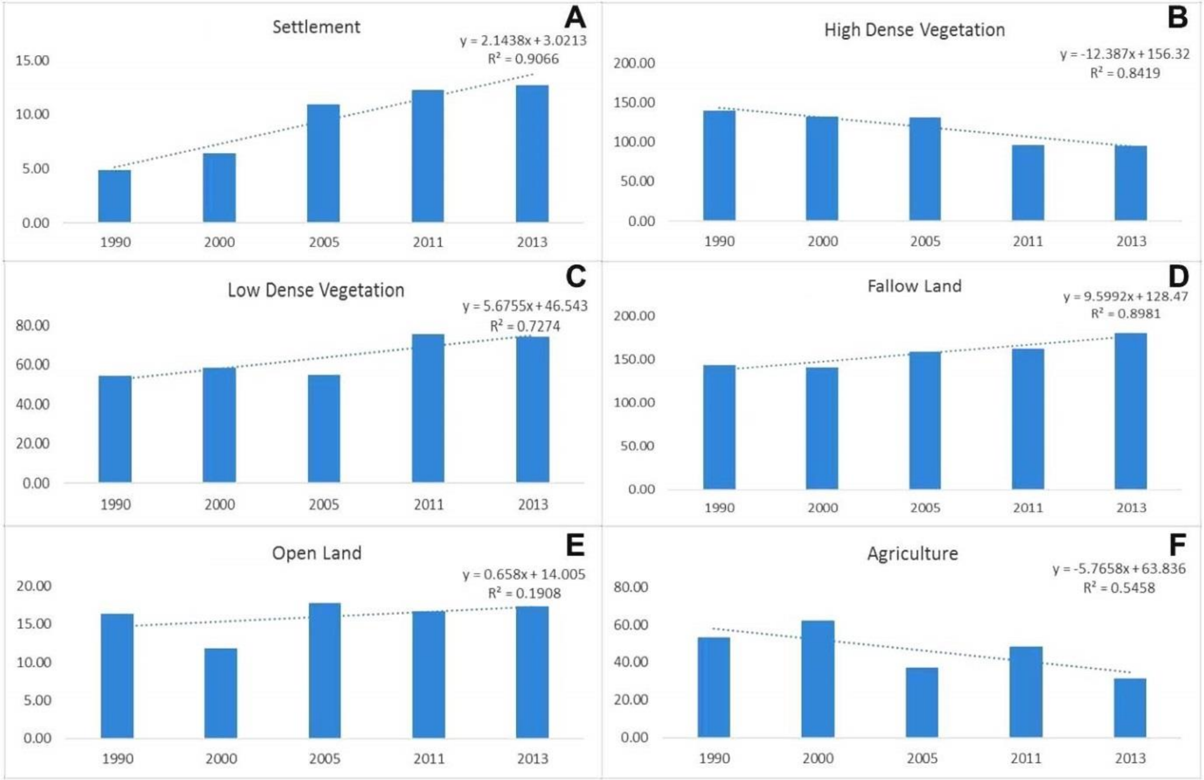

Figure 3. Graph of trend analysis of land use/cover classes: **A,** Settlement; **B,** High dense vegetation; **C,** Low dense vegetation; **D,** Fallow land; **E,** Open land; **F,** Agriculture land. [Reproduces from Soni *et al.* 2015]

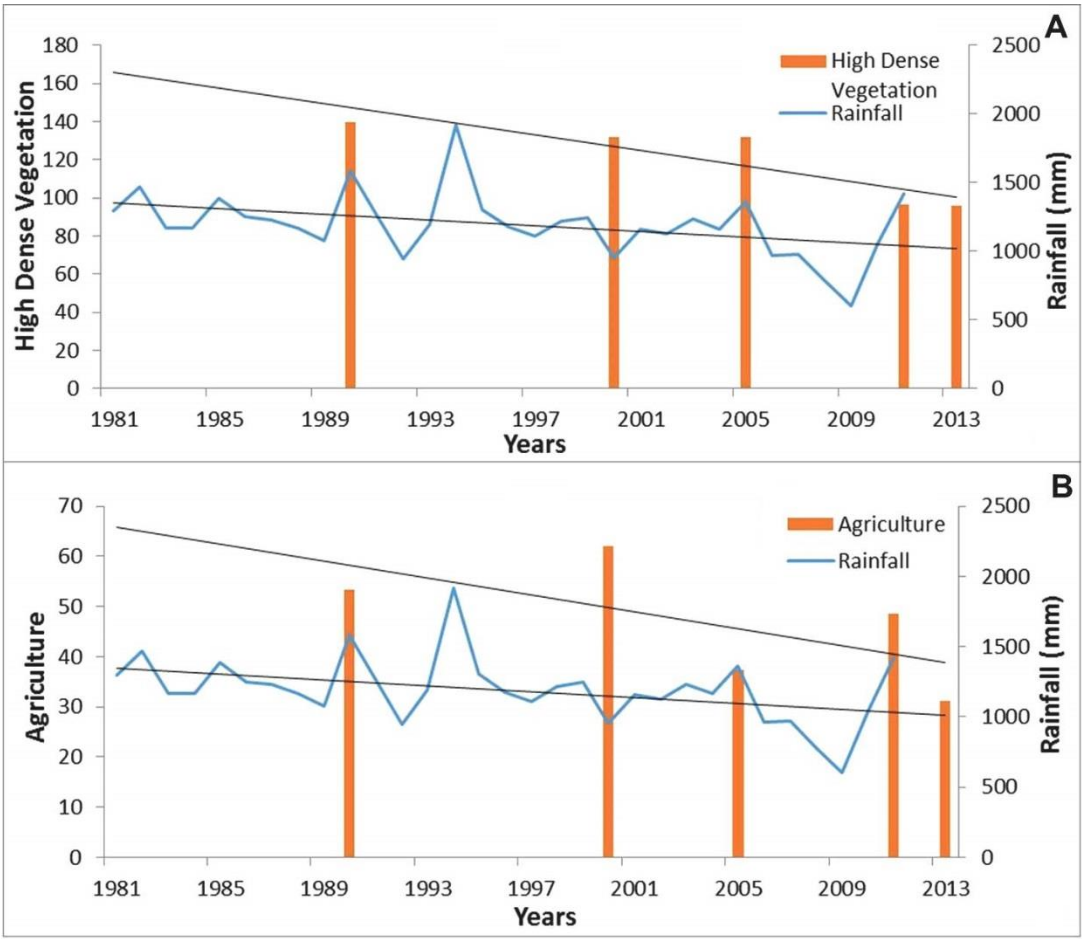

Figure 4. Trend relationship between: **A,** High dense vegetation and rainfall; **B,** Agriculture and rainfall with respective years.

Since, it is hypothesized that a major proportion of this LULCC is associated with changing climatology of the area; trends of two major climatic indicators (precipitation and temperature) were also computed. Along with the non-parametric Mann-Kendall test for identifying trend of rainfall and temperature for 30 years over the study area, parametric Linear Regression test for trend analysis and Spearman's Rho test for correlation analysis with time were also carried out for the climatic indicators. In the Mann-Kendall test, Z statistics and S score for annual rainfall revealed negative trend at p-value < 0.05 (Table 2A). For annual maximum temperature, mean temperature and minimum temperature positive trend at p-value < 0.1 were observed (Table 2B,C,D). In Spearman's Rho test, correlation coefficient value for total annual rainfall was found to be negative (-0.42) at a p-value < 0.05. However, for annual maximum temperature, mean temperature and minimum temperature correlation coefficient values were found to be 0.16, 0.19 and 0.26, respectively, with p-values < 0.1. In order to compare the trend analysis results from the nonparametric methods with parametric method, linear regression tests were also performed over the climatic parameters. Sign of slopes of the linear regression tests for all the climatic parameters were found to be comparable with the Mann-Kendal method. However, the magnitude of slopes was found to vary marginally within an error range of ±10%.

Table 2. Trend analysis: **A,** Total annual rainfall; **B,** Minimum temperature; **C,** Mean temperature; **D,** Maximum temperature.

A. Total annual rainfall		**Test statistic**	**(Statistical table)**			**(Resampling)**			**Result**
		Z statistics	**a=0.1**	**a=0.05**	**a=0.01**	**a=0.1**	**a=0.05**	**a=0.01**	
Mann-Kendall	Total S score = -135	-2.278	1.645	1.96	2.576	1.615	1.819	2.583	Statistically significant trend (at a < 0.05). Decreasing trend.
Spearman's Rho	Rho = -0.416	-2.279	1.645	1.96	2.576	1.645	1.997	2.474	Statistically significant trend (at a < 0.05). Decreasing trend.
Linear regression	Sigma = 4.439	-2.345	1.699	2.045	2.756	1.687	1.968	2.708	Statistically significant trend (at a < 0.05). Decreasing trend.

B. Minimum temperature		**Test statistic**	**(Statistical table)**			**(Resampling)**			**Result**
		Z statistic	**a=0.1**	**a=0.05**	**a=0.01**	**a=0.1**	**a=0.05**	**a=0.01**	
Mann-Kendall	Total S score = 68	1.139	1.645	1.96	2.576	1.7	2.057	2.549	No statistically significant trend (at a = 0.10). Decreasing trend.
Spearman's Rho	Rho = 0.258	1.411	1.645	1.96	2.576	1.743	2.061	2.754	No statistically significant trend (at a = 0.10). Decreasing trend.
Linear regression	Sigma = 0.005	1.558	1.699	2.045	2.756	1.682	2	2.974	No statistically significant trend (at a = 0.10). Decreasing trend.

C. Mean temperature		**Test statistic**	**(Statistical table)**			**(Resampling)**			**Result**
		Z statistic	**a=0.1**	**a=0.05**	**a=0.01**	**a=0.1**	**a=0.05**	**a=0.01**	
Mann-Kendall	Total S score = 52	0.867	1.645	1.96	2.576	1.666	1.989	2.515	No statistically significant trend (at a = 0.10).
Spearman's Rho	Rho = 0.187	1.025	1.645	1.96	2.576	1.756	2.085	2.516	No statistically significant trend (at a = 0.10).
Linear regression	Sigma = 0.005	1.247	1.699	2.045	2.756	1.754	2.091	2.99	No statistically significant trend (at a = 0.10).

D. Maximum temperature		**Test statistic**	**(Statistical table)**			**(Resampling)**			**Result**
		Z statistic	**a=0.1**	**a=0.05**	**a=0.01**	**a=0.1**	**a=0.05**	**a=0.01**	
Mann-Kendall	Total S score = 42	0.697	1.645	1.96	2.576	1.649	1.904	2.481	No statistically significant trend (at a = 0.10).
Spearman's Rho	Rho = 0.159	0.872	1.645	1.96	2.576	1.778	2.116	2.783	No statistically significant trend (at a = 0.10).
Linear regression	Sigma = 0.006	0.966	1.699	2.045	2.756	1.756	2.096	2.779	No statistically significant trend (at a = 0.10).

CONCLUSION

The primary aim of this present study was to evaluate the changing land use and land cover and climatic parameter of a watershed area near a biosphere reserve of the central India. It was hypothesized that the land use and land cover change of an area is interlinked with the local climate. Therefore, trend analysis of LULCC and major climatic parameters were carried out. It was observed that the high dense vegetation and agricultural land are decreasing for the study area since 1990, while low dense vegetation, settlement and fallow land are increasing. Simultaneously, trend analysis of the climatic variables for the period of 1980-2011 over the study area are revealed that the annual rainfall trend is decreasing whereas, trend of annual maximum temperature, mean temperature and minimum temperature is increasing. It should be noted that the present study does not include establishment of a direct relationship between LULCC and climatic control, albeit, an indication of decreasing high dense vegetation with decreasing rainfall is noted. Therefore, this present study lays the foundation of a future land use land cover – climate model scenario for testing sensitivity of both climate and LULC to each other.

ACKNOWLEDGEMENTS

Author is thankful to the Vice Chancellor of MGCGV University M.P. India to provide Remote Sensing and GIS laboratory.

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