Indian Forester, 143 (9) : 921-927, 2017
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

APPLICATION OF REGIONAL CLIMATE MODELS IN ASSESSING CLIMATE CHANGE IMPACT ON FOREST OF KANHA TIGER RESERVE

RINKU MONI DEVI, BHASKAR SINHA, A.P. DIMRI[1] AND SAMEER SARAN[2]

Indian Institute of Forest Management, Nehru Nagar, Bhopal (Madhya Pradesh)
E-mail id-rinku.devi.fri@gmail.com

ABSTRACT

The current paper attempts to understand the possible impacts of climate change on the forest of Kanha Tiger Reserve, Madhya Pradesh using different climate models and remote sensing techniques. The aim of the study was to assess the response of natural vegetation to climate drivers. Different sources of climate data over a time period of 33 years and satellite images of the different time period were used for the study. Normalised Difference Vegetation Index (NDVI) and climate variables (rainfall and temperature) were analyzed for detecting the change in vegetation. The change in vegetation was correlated with change in variability of precipitation and temperature. The results showed that on an average there is variation in the vegetation status with the change in climate variables. Further, it can be recommended that integrating regional climate models and remote sensing techniques can better help in understanding the present and future impacts of climate change on forest ecosystems and can contribute in planning effective adaptation strategies in the forestry sector.

Key words: Forest, Climate change, Climate model, NDVI, Remote Sensing.

Introduction

Climate Change is a global concern as it is affecting physical and biological systems across the globe (INCCA, 2010; IPCC, 2014). Climate is possibly the most important factor in determining the type, composition of vegetation globally and has a significant influence on the distribution, structure and ecology of forests (Chaturvedi *et al*., 2011). Forests play a major role in the present and projected future carbon budget. The world's forests have absorbed 30% (2 petagrams of carbon per year) of annual global anthropogenic CO_2 emissions (Bellassen and Luyssaert, 2014). Thus, forests are important both from climate change mitigation as well as adaptation point of view. The distribution of vegetation is mostly dependent on rainfall and temperature which in turn are influenced by climate. It is increasingly being realized that natural ecosystem is becoming vulnerable to climate change and may bring changes in biodiversity, a shift in distribution pattern and productivity etc. (Ravindranath *et al*., 2006; Chaturvedi *et al.,* 2011). In the Indian context, climate change is inducing an additional stress on ecological and socioeconomic aspects. The poor and rural communities which are comparatively more dependent on ecosystem services are, therefore, likely to be more affected by deteriorating environmental conditions and factors limiting resource availability.

Climate change is one of the key drivers of the interannual variation in vegetation activity. Analysing the pattern of NDVI, temperature and rainfall over a long period would help in understanding the relationship between terrestrial ecosystems and climate system. Therefore, there is an immense need for research to investigate the correlation between NDVI and climate factors. Many studies have attempted to understand the relationships between NDVI and climate factors in different geographic regions and ecosystems. However, the mechanisms of the response of vegetation to climate change are still not clear (Wang *et al*., 2003). Most of these studies have related NDVI with climate factors during the growing season or examined their spatial changes (Suzuki *et al*., 2000). Some studies have focused on the relationships between change in NDVI and climate variables in different seasons to described their spatial patterns (Wang *et al*., 2003). However, there are no studies focusing on the study of vegetation change and relationship between NDVI and climatic parameters in tiger reserve which is a protected area having the least anthropogenic interference, therefore the study in this

Integrated approach involving application of different climate models, remote sensing techniques and field survey could help in planning the future adaptation strategies in forestry sector at state/regional/country levels.

[1]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India
[2]Indian Institute of Remote Sensing, Dehradun, India

area is of significance. This study was done with the aim to understand the variability of past climate data from different sources and to assess the change in the vegetation of Kanha Tiger Reserve.

Study area

Kanha Tiger Reserve (KTR) with coordinates 22.33^0 N, 80.63^0 E stretches over 940 km^2 in the two districts of Mandla and Balaghat (Fig.1). KTR is divided into buffer and core area with six ranges in each zone. The forest is mixed type and sal (*Shorea robusta)* is the dominant species. According to the Tiger Conservation Plan of KTR, the climate of the district is tropical monsoonal type with temperature ranging from -2°C (winter) to 45°C (summer). Average annual rainfall is around 1300mm with maximum precipitation in monsoon.

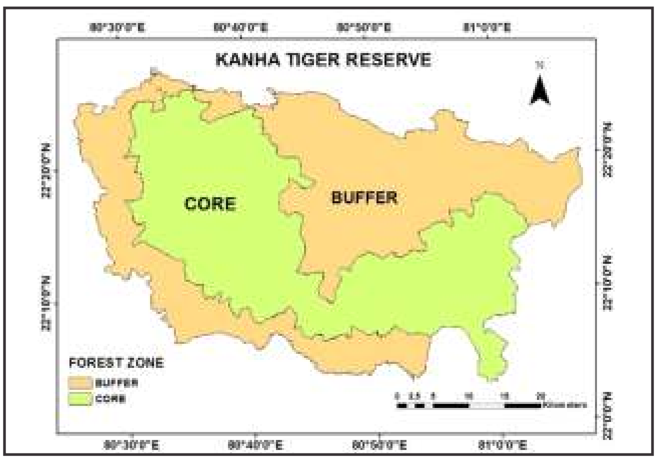

Fig. 1: Kanha Tiger Reserve.

Data and Methodology

Dataset used

Brief details of datasets (Table 1) and grid points (Table 2) used in the study are given below.

To understand the variability of past climate data, precipitation datasets of IMD1 (0.5^0 X 0.5^0) for the time period (1972-2005), IMD2 (0.25^0 x 0.25^0) and REMO (0.5^0X 0.5^0) for the time period (1972-2015) were used. Local weather station data for the time period (1998-2008) was taken from forest range office which would support in investigating the local climate trend of buffer and core areas. An intercomparison and evaluation of two existing IMD precipitation datasets along with climate model (REMO) was done for the given study area. Correlation is calculated for intercomparison of different datasets within different grids. Further for objective 2, ArcGIS and ERDAS software was used for analyzing the remote sensing data. Satellite images of different time period Landsat-5 (1990) and Landsat-8 (2016) of January along with post monsoon images of Landsat-7 (2000) and Landsat-5 (2008) of November was acquired from USGS server. The images were processed, compared and interpreted along with calculation of NDVI. Change detection was done by supervised classification in ERDAS for calculating the change in forest cover in the core and buffer zones of Kanha Tiger reserve. The flowchart of the methodology is given in Fig.2.

Results and Discussions

Climate data analysis

Annual Precipitation and total number of rainfall days: Average annual precipitation of three sources of datasets IMD1 (0.5^0X0.5^0), IMD2 (0.25^0X0.25^0) and REMO (0.5^0X0.5^0), are represented in the graph (Fig.3) showing variation in the precipitation pattern with a decrease in annual precipitation. There was an increase in annual precipitation in 1994 (1813mm) and decrease in annual precipitation *i.e.* 873mm in the year 2000 in IMD1. REMO showed highest precipitation 1922mm in 2008 and lowest 742mm precipitation in 2003. IMD2 indicated 2962mm

Table 1: Brief details of datasets used in the study

Data sets	Short name used in the study	Spatial resolution (lat x lon)	Data period
IMD	IMD1	0.5^0 X 0.5^0	1971-2005
IMD	IMD2	0.25^0 X 0.25^0	1971-2015
REMO	REMO	0.5^0 X 0.5^0	1971-2015
Local weather station	LWS		1993-2014

Table 2: Brief details of grids used in the study.

IMD1-0.5^0 X 0.5^0 (Year-1972-2005) (Rajeevan *et al*., 2009)	IMD2-0.25^0 x 25 (Year-1972-2015) (Pai *et al*, 2014)	REMO (0.5^0 X 0.5^0) (Year-1972-2015)	Local Weather Station (Core, Buffer range) Year-1994-2008
Grid1-80.25E-21.75N	Grid1-80.52E-22.31N	Grid1-80.25E-21.75 N	Grid1-80.93E-22.17 N
Grid2-80.75 E-22.25 N	Grid2-80.56E-22.18N	Grid2-80.75E-22.25 N	Grid2-80.54E-22.29N
Grid3-81.25E-22.75N	Grid3-80.79E-22.22N	Grid3-81.25E-22.75N	Grid3-80.93E-22.17 N
	Grid4-80.67E-22.15N		
	Grid5-80.80E-22.19N		

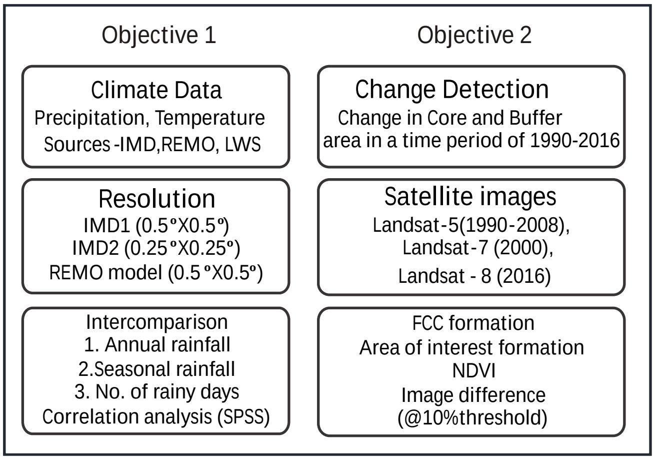

Fig 2: Methodology flowchart

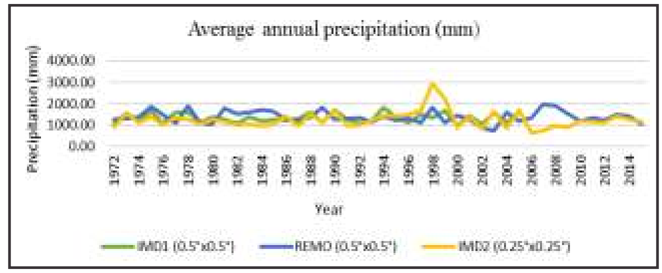

Fig. 3: Average annual precipitation

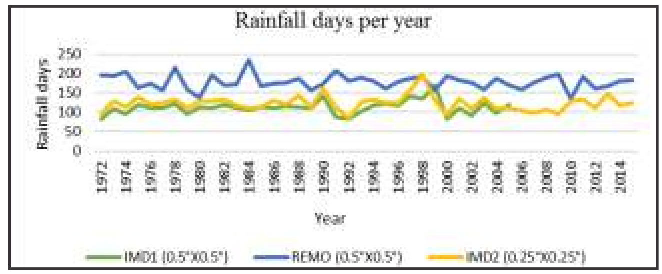

Fig. 4: Total number of rainfall day.

precipitation in 1998, which is highest precipitation and 608mm as lowest precipitation in 2006. A total number of rainfall days varies in all the three datasets (Fig.4) representing a decrease in a total number of rainfall days. with IMD1 having 193 as highest rainfall days in 1999 and lowest 83 rainfall days in 1972. Moreover, REMO showed 235 rainfall days in 1984 and lowest 129 rainfall days in 2010. In IMD2, highest and lowest rainfall days are 197 in the year 1998 and 85 days in the year 1992.

Seasonal variability: For analyzing the seasonal variability, months are categorized into seasons namely, summer which spans from March to May, monsoon (June to Sep), post monsoon (Oct to Nov) and winter (Dec to February). During MAM, there is similar precipitation trend in IMD1 and IMD2 whereas REMO results in overestimation [Fig 5(a)]. Moreover, during monsoon season (JJAS), IMD1 and REMO showing similar trends whereas IMD2 indicated an abrupt increase in precipitation 2383mm during 1998 and decrease in precipitation *i.e.* 530mm during 2006 [Fig 5(b)]. During October-November, REMO displayed overestimation in precipitation results, in comparison to IMD1 and IMD2 [Fig 5(c)] while in winter months (DJF) all the three data sources displayed similar precipitation trend showing decrease in rainfall [Fig 5(d)].

There is an increase in average annual temperature as seen in figure 6(a) reaching upto 24°C in 2014 in comparison to previous years. Figure 6(b) showed the trend of seasonal variations in temperature. There is an increase in temperature reaching upto more than 30°C during MAM while monsoon months (JJAS) indicated slight fall in temperature *i.e.* 28°C and low temperature during Oct-Nov. Model overestimates the values of temperature during winter months (DJF). It is to be noted that while computing correlation analysis taking into account for 33years (1972-2005) in SPSS it is seen that among all the three gridded datasets, IMD1 and IMD2 are positively correlated (N=33, Correlation=0.561, Sig=.001) and IMD1 and REMO didn't have significant correlation.

Local weather station data

For detail investigation of climate data in core and buffer areas, it is of great importance to analyze the local weather station data, as it will support the study and help in determining the variations in climate variables at regional/local level. Kanha range indicated a decline in

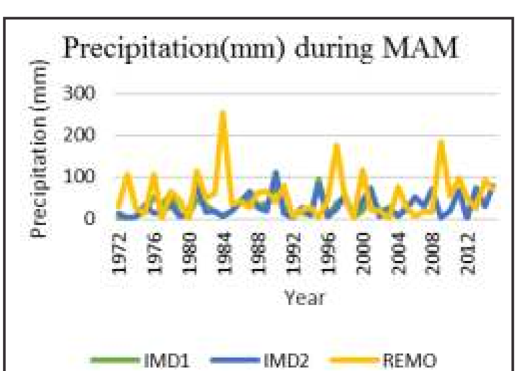

Fig. 5(a): Precipitation during March to May.

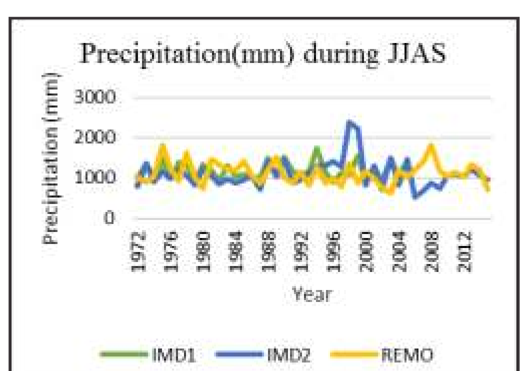

Fig. 5(b): Precipitation during Jun to September.

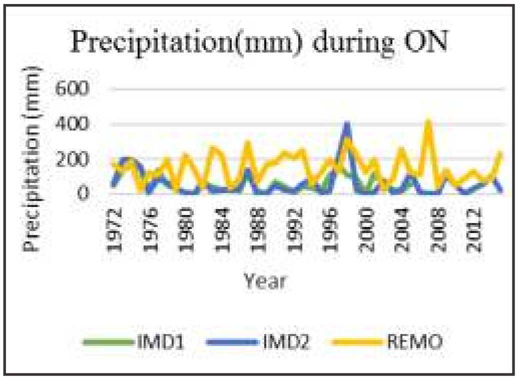

Fig. 5(c): Precipitation during October to November.

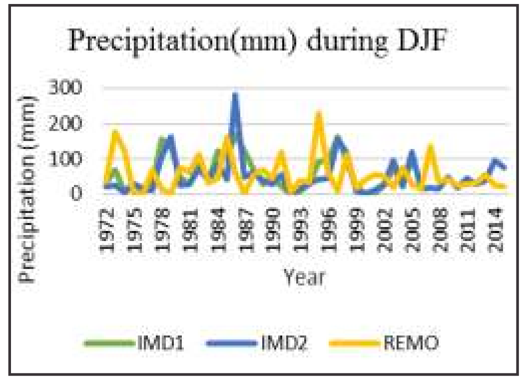

Fig. 5(d): Precipitation during December to February.

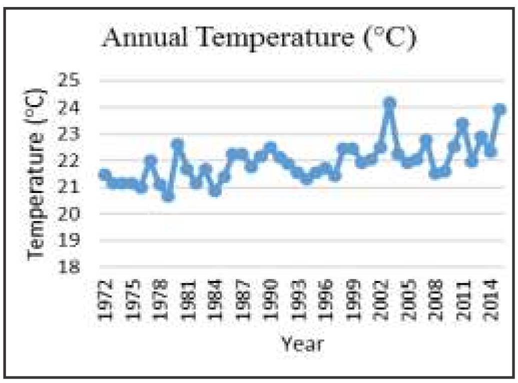

Fig. 6(a): Annual average temperature.

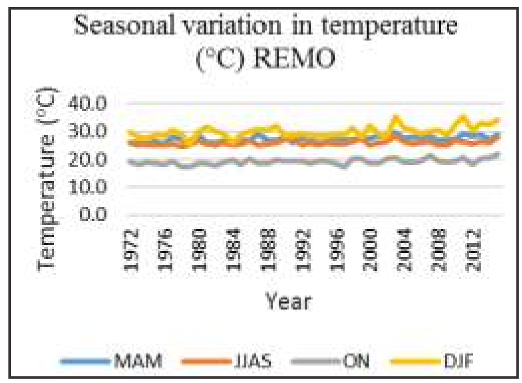

Fig. 6(b): Seasonal variation in temperature.

precipitation in all seasons [Fig.7(a)] with the lowest precipitation during DJF. There was a rise in precipitation during monsoon months from 1997 to 1999 and a slight decrease in precipitation afterwards 1999. In Supkhar range precipitation was decreased during 1995 to 1999 and increased during 2006 to 2013 [Fig. 7(b)]. Kisli range showed a continuous decrease in precipitation after 1997 during all seasons [Fig.7(c)]. All the three ranges showed maximum temperature reaching upto 35^{0}C in a year and 12^{0}C to15^{0}C as minimum average annual temperature[Fig. 7(d)].

Impact on forest of KTR

For analysing the change in forest cover, Landsat-5 (1990) and Landsat-8 (2016) and Landsat-5 (2000, 2008) was analyzed. NDVI is a technique used to measure and monitor plant growth, vegetation covers and biomass production which is calculated by using visible and near infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that falls on it, and reflects a large portion of the near infrared light. Unhealthy or sparse vegetation reflects more visible light and less near infrared light. NDVI varies from -1 to +1. On comparing the NDVI difference images of two time period, there is a significant change in NDVI with values varying from -0.51 to 0.87 during 1990 [Fig 8(a)] and -0.96 ot 0.89 during 2016 [Fig 8(b)]. Furthermore, during 2000-2008, NDVI ranges from 0.79 to -0.2 in buffer and 0.82 to -0.2 in the core.

Changes detected in forest/vegetation cover for buffer and core area is displayed in figure 8(c, d). Vegetation types are classified as poor (> 10%), low (10 – 40%), moderate (40-60%) and dense (>60%) (FSI) and is represented in figure 8(e,f)]. There is a significant decrease in dense, moderate and low forest cover types in the buffer during 2016 in comparison to the year 1990 while there is an increase in poor forest cover types in the buffer during 2016[Fig 8(e)]. This may due to many factors like human settlement nearby the buffer areas, tourists and influenced by other human activities etc. Further, there is a slight decrease in dense and low forest cover types while moderate and poor forest cover types have increased in the core during 2016 [Fig 8(f)]. The reason may be due to the presence of intact forest and non-interference of any anthropogenic sources within core area. Moreover, suitable microclimatic conditions in protected area encourage the vegetation to grow and develop successfully. Fig. 9(a,b) gives a clear picture of significant change in forest cover in the buffer and core during 1990-2016 at 10% threshold showing enormous decrease in vegetation cover in the buffer [Fig.9(a)] in comparison to core with a slight change in vegetation cover [Fig.9(b)].

Conclusion

The results of the study illustrate the response of different climate drivers i.e. precipitation and temperature

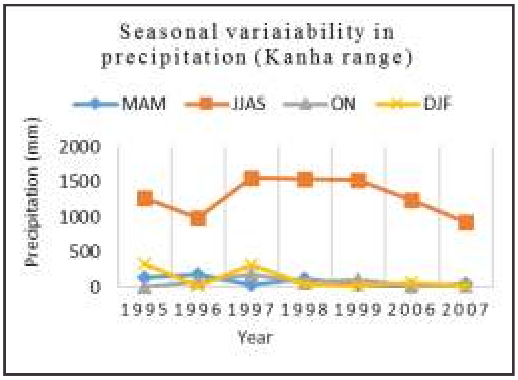

Fig. 7(a): Seasonal variability in precipitation Kanha range.

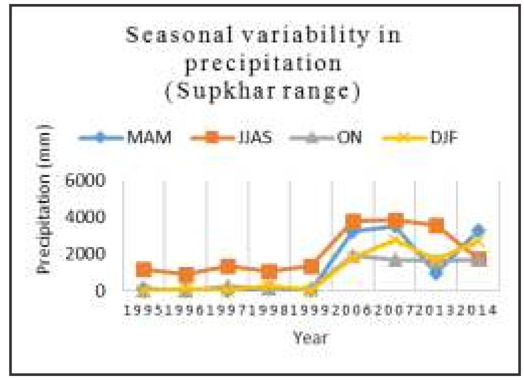

Fig. 7(b): Seasonal variability in precipitation at Supkhar range.

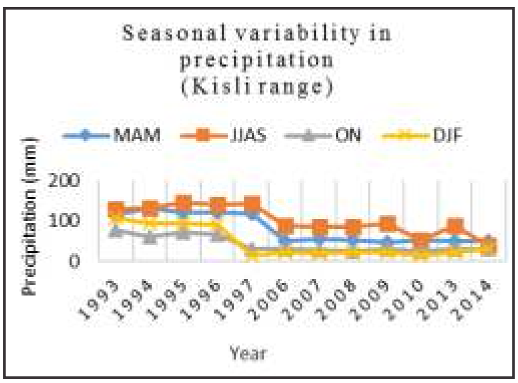

Fig . 7(c): Seasonal variability in precipitation at Kisli range.

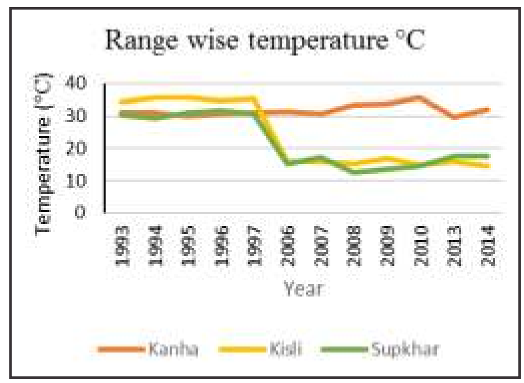

Fig. 7(d): Temperature at Kanha, Kisli and Supkhar range.

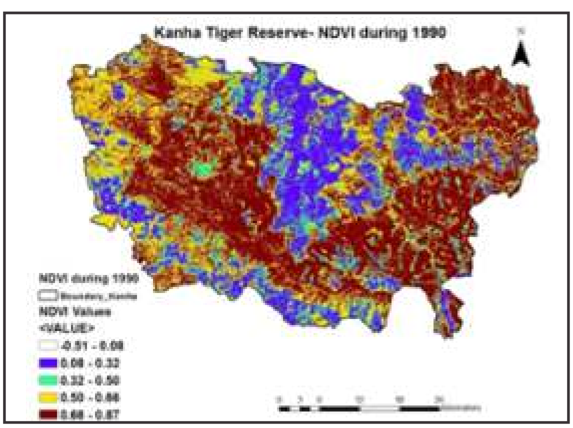

Fig. 8(a): NDVI at Kanha Tiger Reserve during 1990.

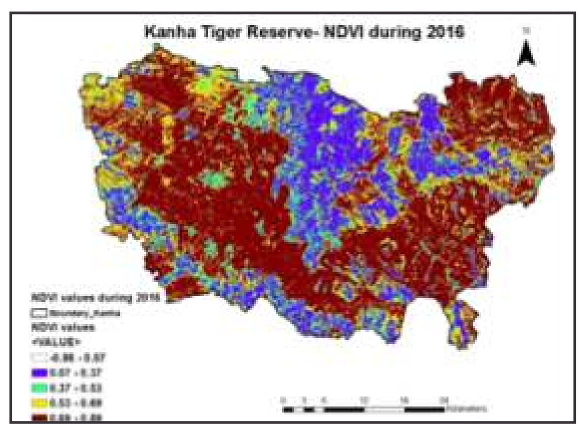

Fig. 8(b): NDVI at Kanha Tiger Reserve during 2016.

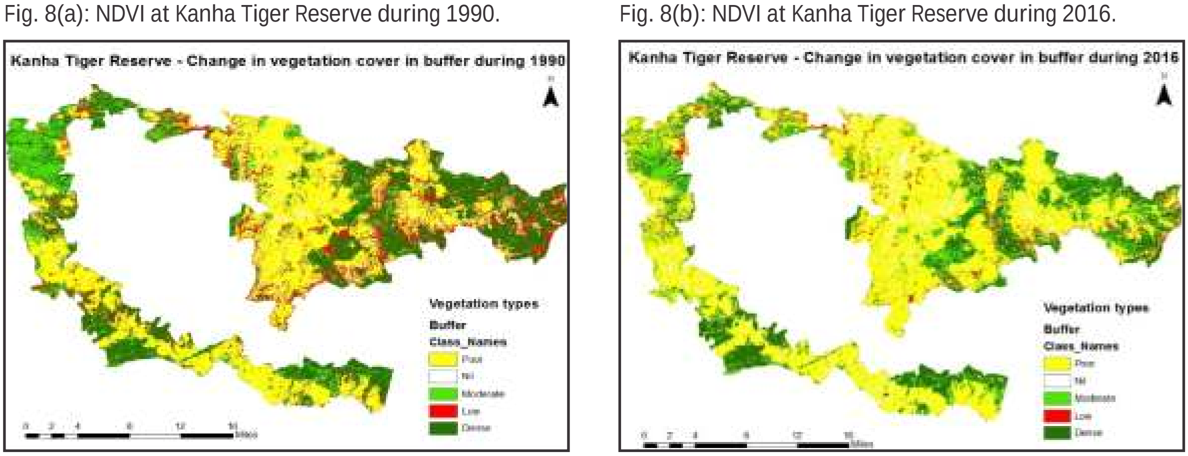

Fig. 8(c): Change in vegetation cover between 1990 and 2016 in buffer.

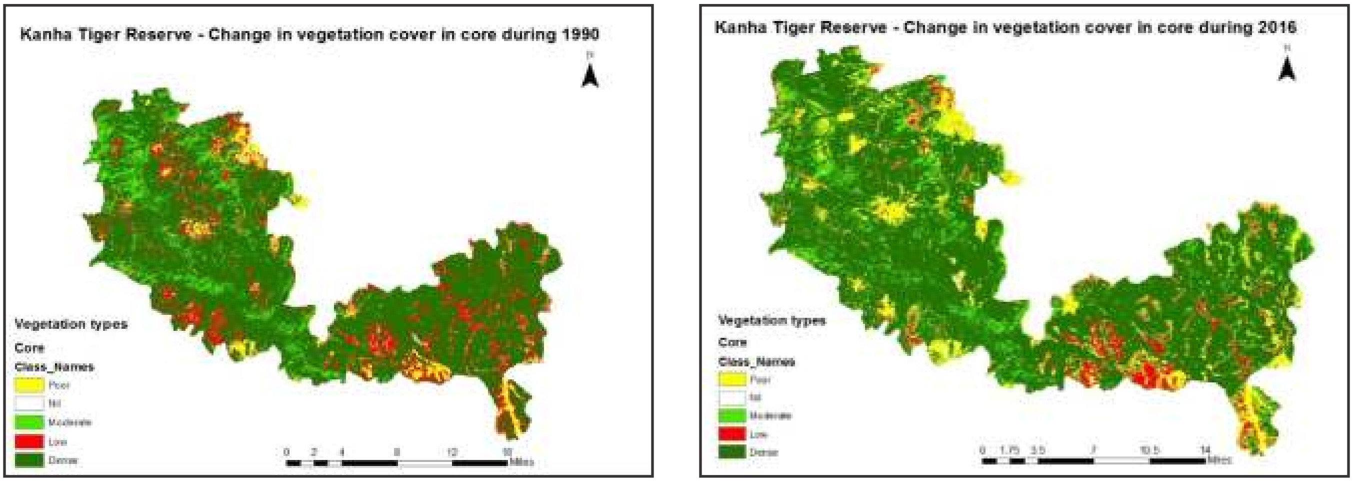

Fig. 8(d): Change in vegetation cover between 1990 and 2016 in core.

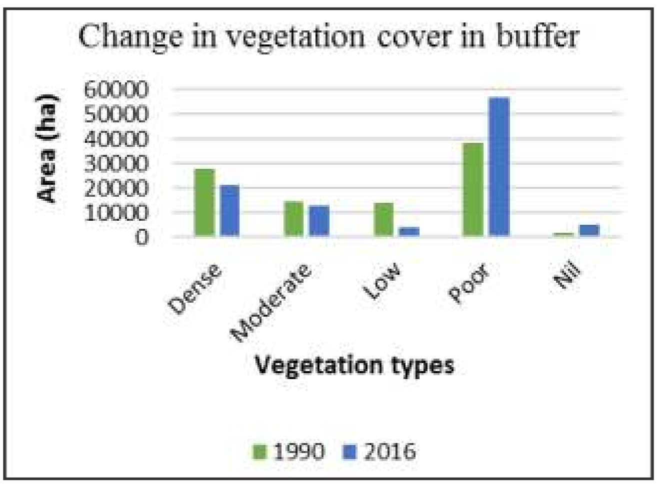

Fig. 8(e): Buffer: Change in vegetation cover.

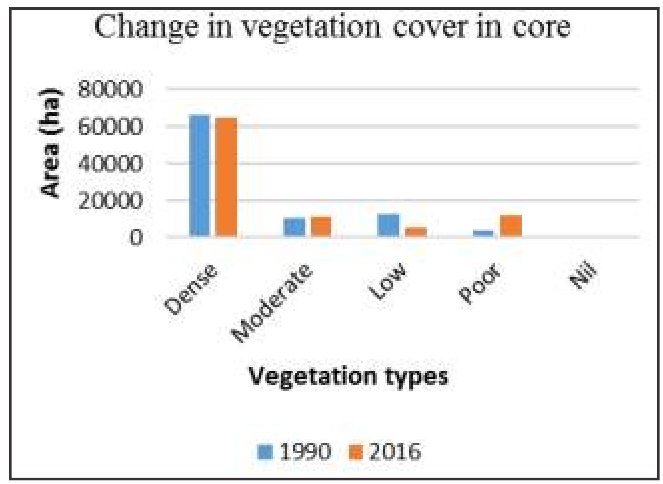

Fig. 8(f) :Core: Change in vegetation cover.

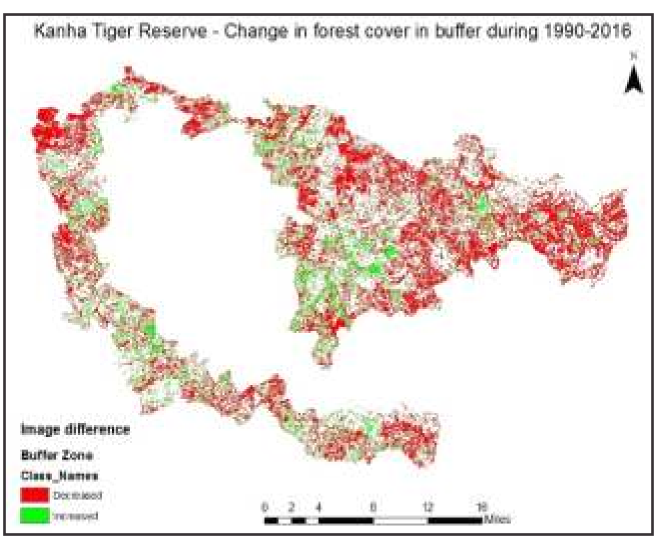

Fig. 9 (a): Change detection in buffer (1990-2016).

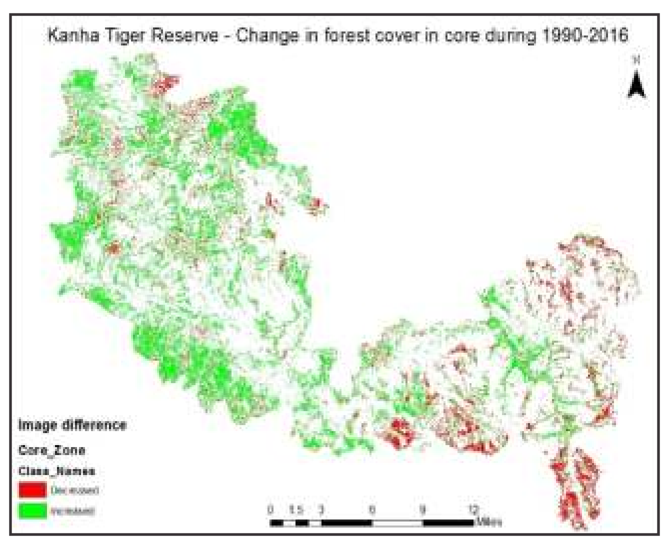

Fig. 9 (b): Change detection in core (1990-2016).

leading to significant change (increase or decrease) in forest cover of Kanha Tiger Reserve. Different climate data sources IMD1, IMD2, REMO and local weather station data were used for comparing the climate variables to obtain perfect results at the regional level and the climate trend was analyzed. Among all the three gridded datasets, IMD (0.25X0.25) and IMD (0.5°X0.5°) are positively correlated (N=33, Correlation=0.561, Sig=.001) while IMD and REMO showed a negative correlation. Change in the trend of vegetation growth and response of dominant climatic drivers, would help to better estimate and predict the cause of change in climate. However, the interannual variation of vegetation growth cannot be fully explained by changes in climatic drivers, and further studies on the relationships and feedbacks between vegetation growth and carbon and nitrogen cycles are needed. Furthermore, there is a need for more *in-situ* observations for detailed analysis at the local level. Integrated approach involving application of different suitable climate models, remote sensing techniques and field survey could generate accurate information at a scale, which could help in planning the future adaptation strategies of the forestry sector at state/regional/ country levels.

Acknowledgement

The authors would like to thank Director IIFM, for providing the necessary facilities and infrastructure for the study. The authors would also wish to extend their gratitude to the faculties. Special thanks to Maneesh Kr. Patasaraiya for his valuable inputs and encouragement.

कान्हा बाघ रिजर्व के वनों पर जलवायु परिवर्तन प्रभाव का मूल्यांकन करने में क्षेत्रीय जलवायु मॉडलों का अनुप्रयोग

रिंकू मोनी देवी, भाष्कर सिन्हा, ए.पी. डिमरी एवं समीर सरन

सारांश

कान्हा बाघ रिजर्व, मध्य प्रदेश के वन पर जलवायु परिवर्तन के संभावित प्रभावों को समझने में विभिन्न जलवायु मॉडलों और सूदूर संवेदी तकनीकों के उपयोग का पुनरीक्षण करने हेतु वर्तमान शोधपत्र में प्रयास किया गया है। अध्ययन का उद्देश्य जलवायु संचालकों के प्रति प्राकृतिक वनस्पति की अनुक्रिया का मूल्यांकन करना था। अध्ययन के लिए 33 साल की समयावधि के जलवायु आँकड़ों के विभिन्न स्रोतों और विभिन्न समय अवधि के सैटेलाइट इमेजों का उपयोग किया गया। वनस्पति में परिवर्तन को खोजने के लिए सामान्यीकृत विभिन्नता वनस्पति तालिका और वर्षा परिवर्ती (वर्षा एवं तापमान) का विश्लेषण किया गया। वनस्पति में परिवर्तन को वर्षण एवं तापमान की परिवर्तनशीलता में परिवर्तन के साथ सहसंबंधित किया गया। परिणामों ने दर्शाया कि औसतन जलवायु परिवर्तियों में परिवर्तन के साथ वनस्पति स्तर में विभिन्नता है। इसके अलावा, यह संस्तुति की जा सकती है कि क्षेत्रीय जलवायु मॉडलों और सूदूर संवेदी तकनीकों का एकीकरण वन पारितंत्रों पर जलवायु परिवर्तन के वर्तमान एवं भावी प्रभावों को समझने में बेहतर सहायता कर सकते हैं और वानिकी सेक्टर में प्रभावी अनुकूलन रणनीतियों की योजना बनाने में सहयोग कर सकते हैं।

References

Bellassen V. and Luyssaert S. (2014). Carbon sequestration: Managing forests in uncertain times. *Nature*, 506(7487), 153-155.

Chaturvedi R.K., Gopalakrishnan R., Jayaraman M., Bala G., Joshi N.V., Sukumar R. and Ravindranath N.H. (2011). Impact of climate change on Indian forests: a dynamic vegetation modeling approach. *Mitigation and adaptation strategies for global change*, 16(2), 119-142.

IPCC (2014). *Fifth Assessment Report*. Geneva, Intergovernmental panel on climate change secretariat.

INCCA (2010). Indian Network for Climate Change Assessment. Report 2. Climate Change and India: A 4x4 Assessment - A sectoral and Regional Analysis for 2030s, Ministry of Environment and Forest, Government of India.

Ravindranath N. H., Joshi N. V., Sukumar R. and Saxena A. (2006). Impact of climate change on forests in India. curr. sci., 90(3), 354-361

Suzuki P., Tanaka S. and Yasunari T. (2000). Relationships between meridional profiles of satellite-derived vegetation index (NDVI) and climate over Siberia. *International J. Climatology*, 20:55–697.

Wang J., Rich P.M., and Price K.P. (2003). Temporal responses of NDVI to precipitation and temperature in the central Great Plains, USA. *Inter. J. Remote Sensing,* 24: 2345–2364.