Letters in Spatial and Resource Sciences (2021) 14:129–140
https://doi.org/10.1007/s12076-021-00269-2

ORIGINAL PAPER

Land use and land cover change and their impact on temperature over central India

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Received: 10 September 2019 / Accepted: 17 April 2021 / Published online: 3 May 2021

Abstract
This study explored the land use and land cover changes (LULCC) during 1981–2006 over central India and their impact on the surface temperature over this region. The land use maps were prepared from the Advanced Very High Resolution Radiometer (AVHRR) datasets to investigate the LULCC during 1981–2006 and the impact of LULCC was investigated from the Observation Minus Reanalysis method. The overall analysis indicated a decrease in the small vegetation lands and open forests during 1981–2006 and an increase in the dry lands, agricultural lands and dense forests during this period. As a probable consequence, the temperature trend increased by 0.076 °C per decade due to the LULCC over central India.

Keywords Land use and land cover changes · OMR method · Central India

1 Introduction

The change in land use and land cover literally means the alternation of one or more land use and land cover types into another type. It is generally an interaction between human beings and the natural environment (Pielke and Avissar 1990). However, the use of land by the human beings has rapidly increased in recent decades and become one of the significant contributors to the recent change in climate (IPCC 2007, 2013). This is because any changes in the land use modify the underlying land surface process which alter the energy exchange rate between the land surface and lower atmosphere and thus influence the atmosphere (Jain et al. 2014; Gogoi et al. 2019; John et al. 2020). Previous researches (Pielke and Avissar 1990; Gallo et al. 1996; Viterbo 2002; Li et al. 2015) highlighted that even a small change in land use may modify

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the local climate. Studies over India also highlighted many changes in the land use and land cover types in past years. For example, Nayak and Behera (2008) examined different land use types over Pilibhit district in Uttar Pradesh. Babykalpana (2012) examined the land use and land cover changes (LULCC) over Coimbatore district and Rawat et al. (2013) explored the changes in the land use over Ramnagar town area in Uttarakhand and Jain et al. (2014) explored the LULCC over Dehi-Mumabi industrial corridor. However, few studies over India highlighted the impact of LULCC on surface temperature (e.g., Niyogi et al. 2011; Nayak and Mandal 2019a; Prijith et al. 2021). In a study, Nayak and Mandal (2012) reported a warming of 0.06 °C/10 years over western India mostly due to significant increase in the agricultural lands and subsequent decrease in forest lands during 1973–2009. Singh et al. (2017) documented an increase of 0.75 °C in the mean land surface temperature during 2002–2014 over Lucknow city of central India. In another study, Nayak and Mandal (2019a) documented a cooling (0.001 °C/10 years) over eastern India mostly due to the transformations of small vegetation and open forest into dense forest during 1981–2006. Their study also highlighted a warming (~0.2 °C/10 years) over eastern India due to the transformations from agricultural land and shrub into bare land during 1991–2006. Prijith et al. (2021) revealed a decrease of surface temperature by -0.14 ± 0.005 K over Northwest India due to conversion of barren land to vegetation land. These studies clearly indicated that LULCC over few regions of India mostly contributed to warming, while that of over some other regions resulted cooling. However, the impact of LULCC over many other regions of India are still unclear. Central India is one of them which comprise a variety of land covers including mountains in the east, deserts in the west and agricultural lands in the middle. Large portions of this region are rich in natural resources including biodiversity and minerals. However, due to the food demand and human development the land across the globe in recent decades have been significantly altered (Creutzig et al. 2019). So as a continuation to the above studies, an attempt was made to investigate LULCC over central India (Fig. 1) and their possible impact on temperature over this region by using the Advanced Very High Resolution Radiometer[1] datasets and Observation Minus Reanalysis[2] method.

2 Data and methods

For the land use map, the AVHRR Normalized Difference Vegetation Index (NDVI) images at 8 km spatial resolution were obtained from the Global Land Cover Facility (GLCF) for the years 1981, 1991, 2001, and 2006. The AVHRR data were classified into five land use types, viz., dry land (DL), small vegetation (SV), agricultural land (AL), open forest (OF) and dense forest (DF). Dry land covers the non-vegetation lands such as barren lands, settlements etc., small vegetation covers shrubs, grasslands etc., agricultural land covers the fallow lands, cultivable lands etc., open forest covers the green patches with 10–40% crown cover and dense forest covers those with more than

[1] AVHRR is a sensor onboard the National Oceanic and Atmospheric Administration (NOAA) satellite.

[2] OMR is a technique to investigate the LULCC impact on temperature.

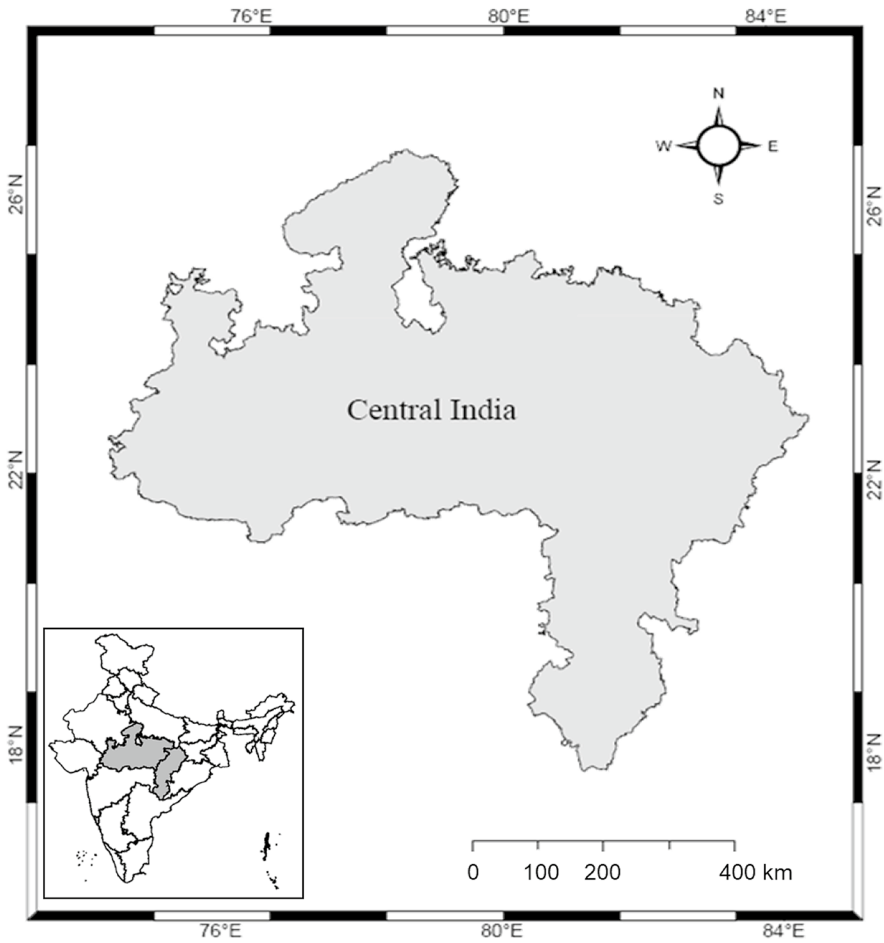

Fig. 1 Location map of central India

40% crown cover. The hierarchy approach of land use types was used to classify the NDVI images (e.g., Hansen et al. 2002). Multitude of previous studies also used this method to classify the AVHRR data over different regions (Nayak and Mandal 2018; Nayak and Mandal 2019a, 2019b). The hierarchy of land use types used in the present study is shown in Fig. 2. The AVHRR datasets were classified over central India for four time periods (1981, 1991, 2001, and 2006). The accuracy of the classification was validated against the very high resolution (30-60 m) Landsat images. The Landsat Multispectral Scanner (MSS at 60 m) images were used to validate the classified land use map for the year 1981, the Landsat Thematic mapper (TM at 30 m) images were used for the validation of the classified land use map for 1991, and the Landsat Enhanced Thematic Mapper (ETM at 30 m) and the ETM Plus (ETM+ at 30m) images are used to validate the classified land use maps for the years 2001 and 2006 respectively. All

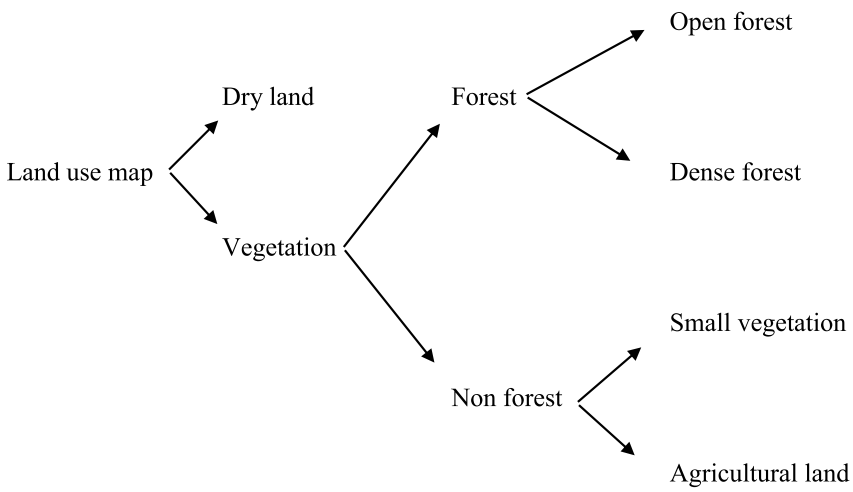

Fig. 2 Hierarchy of land use types

the satellite images used for this classification and validation are provided by National Aeronautics and Space Administration (NASA).

The observation minus reanalysis (OMR) method was applied to explore the LULCC contribution towards the surface temperature over central India. This method was originally given by Kalnay and Cai (2003) and later used in many studies across the globe (e.g., Frauenfeld et al. 2005; Fall et al. 2010). Although the OMR method associated with the errors which mostly due to the non-climatic biases that sometimes impact on the observation (e.g., Menne et al. 2010), and also existence of some uncertainties are still unclear, the studies based the OMR method have shown robust results specifically the LULCC impact on the surface temperatures. The daily surface temperature datasets were obtained from National Climatic Data Center (NCDC) for the period 1981–2006 at eight different stations and from the NCER/NCAR reanalysis (NNRP1) dataset for the same period. The NNRP1 dataset was selected based on the previous studies conducted over Indian regions (e.g., Maity et al. 2017a, 2017b; Nayak et al. 2019). The linear trends from the observation and that of from reanalysis datasets were computed for the whole period of 26 years (1981–2006). Finally, the OMR method was applied to investigate the LULCC contribution to the temperature trends over central India.

3 Results and discussion

3.1 Land use and land cover statistics

Figure 4 illustrates the NDVI AVHRR data (Fig. 3a), classified land use map (Fig. 3b), and the high resolution Landsat images (Fig. 3c) over central India.

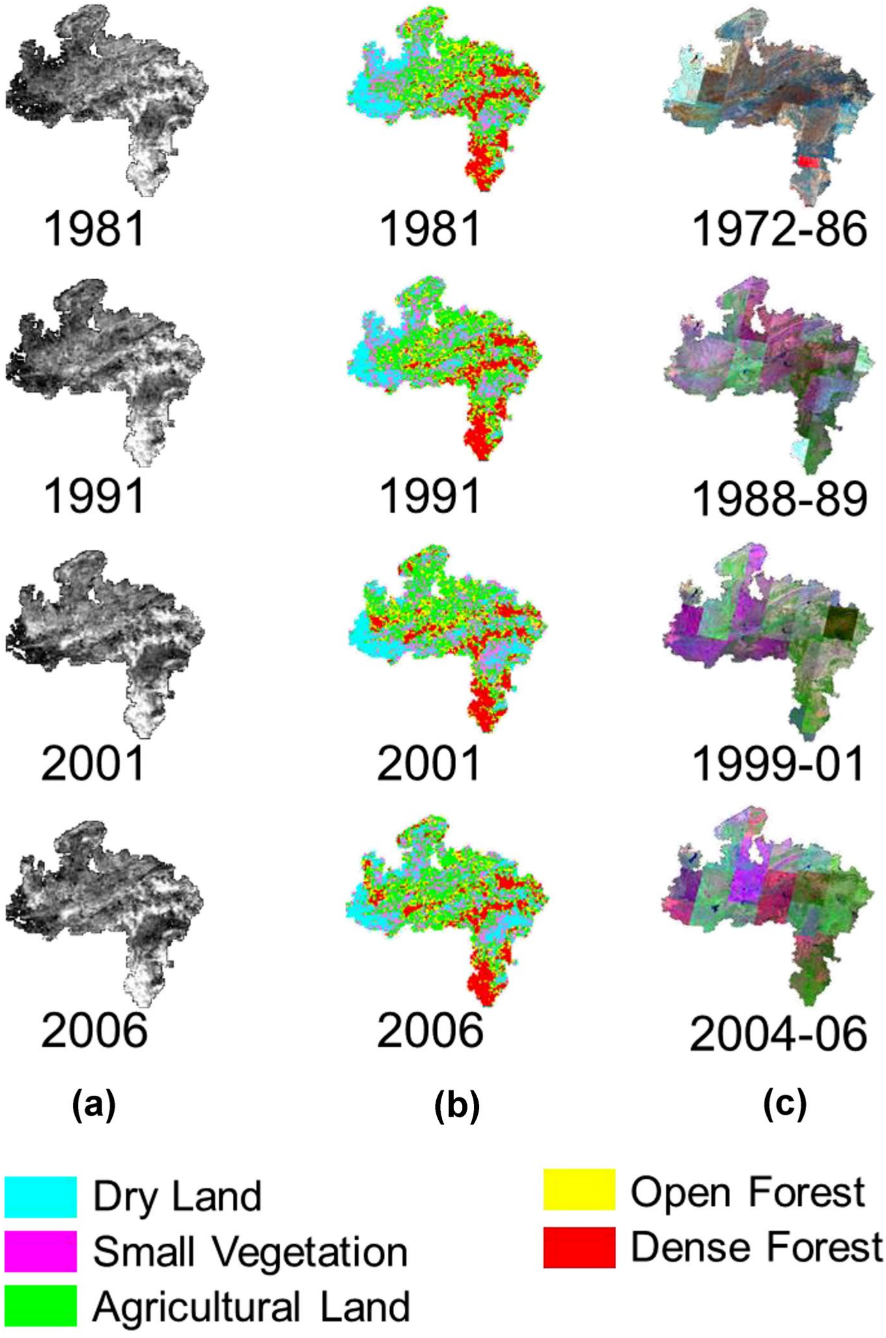

Fig. 3 **a** NDVI Images, **b** classified land use maps, and **c** high resolution satellite images over central India

The classified land use map showed that during 1981–2006 large areas in western regions of central India were mostly covered by dry land and small vegetation, while large areas in eastern regions of central India were covered by forests and the central regions were mostly covered with agricultural lands. The accuracies of the classified land use maps were calculated with fifty randomly sampled locations from the Landsat images for each year separately. Overall accuracy of the classified land use map was found as 88% for the years 1981 and 1991, and 90% and 92% for the years 2001 and 2006 respectively (Table 1). The areas under each land use type during 1981–2006 are shown in Fig. 4 and Table 2. It was noticed that the dry land over central India covered ~ 13.5–15.5% (> 64,000 km^2) of total areas in each time period, while the small vegetation covered about 21–22.5% (> 100,000 km^2). The maximum area was covered by agricultural land of more than 150,000 km^2 (~ 32.5–34.5%) in each time period, while the minimum area was covered by open forest with more than 61,300 km^2 (~ 13–14%). The dense forest covered about 16.5% (> 78,000 km^2) of total areas in each time period. It is worth to mention that the areas under each land use type in 1991 showed some deviated values compared to other years (see Table 2). It was found that the areas under dry land and open forest were found less during 1991 in comparison to other years. The areas under agricultural land and small vegetation also showed higher values in 1991 compared to other years. The area under dense forest was found to be equal in 1981 and 1991. The reason for the deviated results in 1991 could be attributed to the industrial development and rapid growth of urbanization during the decade 1991–2000 (e.g., Singh et al. 2017). Another reason could be due to the misrepresentation of some sub-category types of land use which are not distributed to their parent land use types. Thus the classification with more number of land use types, e.g., separating small vegetation into grasslands and shrubs, agricultural land into cropland and irrigated cropland, dry land into desert and semi-desert etc., is required to improve the classification accuracy which is planned as our future research.

3.2 LULCC

Figure 3b clearly indicated that large areas in western regions of central India were covered by dry land and small vegetation in the years 1981 and 1991, while some of these areas were converted to agricultural land and dense vegetation in the years 2001 and 2006. An increase of dense forest and a subsequent decrease of dry land and small vegetation were also noticed over central regions in the years 2001 and 2006. Similarly, large areas in the eastern regions of central India were covered by small vegetation in the years 1981 and 1991, some of which was converted to dry land in the years 2001 and 2006. The LULCC statistics for the periods 1981–1990, 1991–2000 and 2001–2006, and the entire period 1981–2006 are shown in Fig. 5. It indicated that the dry land decreased during 1981–1990 and 2001–2006, but significantly increased in 1991–2000 which resulted an overall increase of dry land of about 0.5% during 1981–2006. The significant increase of dry land during the period 1991–2000 was possibly due to the

Table 1 Accuracy of the classification of the land use map

Land use type	1981		1991		2001		2006	
	Producers accuracy (%)	Users accuracy (%)	Producers accuracy (%)	Users accuracy (%)	Producers accuracy (%)	Users accuracy (%)	Producers accuracy (%)	Users accuracy (%)
DL	77.78	87.50	60.00	75.00	88.89	100.00	88.89	100.00
SV	80.00	88.89	78.57	84.62	81.82	90.00	81.82	100.00
AL	100.00	93.75	94.44	89.47	84.62	84.62	100.00	87.50
OF	66.67	100.00	100.00	100.00	100.00	87.50	83.33	100.00
DF	100.00	76.92	100.00	91.67	100.00	90.91	100.00	83.33
Overall Classification Accuracy	88.00%		88.00%		90.00%		92.00%	

Producers refer to the samples taken in the Landsat images and users refers to samples represented in the classified map)

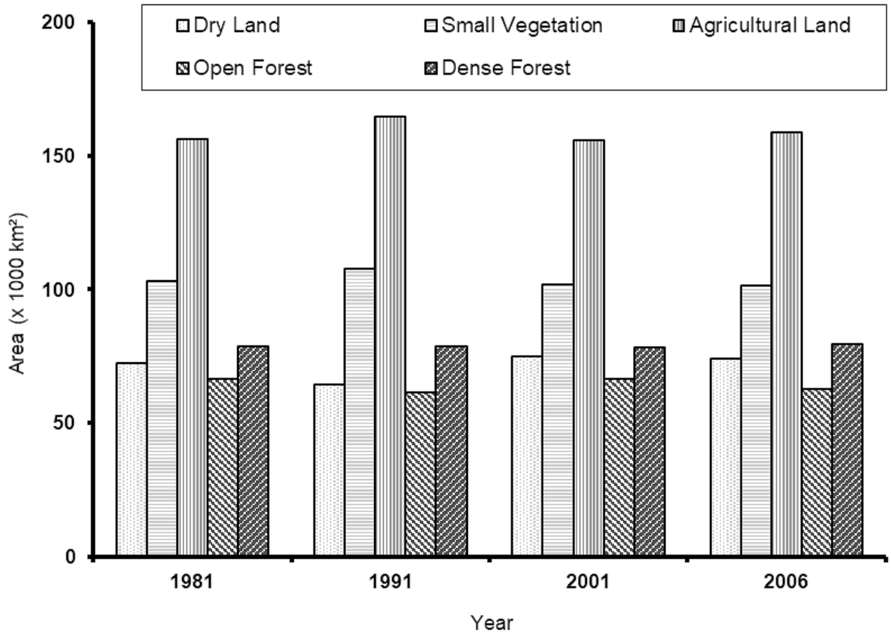

Fig. 4 Area estimation under each land use types

Table 2 Area under each land use types over central India in different time periods

Land use type	1981 (%)	1991 (%)	2001 (%)	2006 (%)
Dry land	15.20	13.48	15.69	15.52
Small vegetation	21.63	22.63	21.35	21.30
Agricultural land	32.77	34.53	32.65	33.27
Open forest	13.91	12.87	13.92	13.18
Dense forest	16.49	16.49	16.38	16.73

urbanization and more settlements in that period (Singh et al. 2017). The small vegetation was increased during 1981–1990, but decreased during 1991–2000 and 2001–2006, indicating a decrease of small vegetation since 1991. Agricultural land was increased during 1981–1990 and 2001–2006, while decreased during 1991–2000. However, the agricultural land during 1981–2006 was increased by ~ 0.5%. Open forest was increased during 1991–2000, but decreased during the periods 1981–1990 and 2001–2006. There was no change in dense forest during 1981–1990, however a small decrease of dense forest was noticed during 1991–2000 and an increase was noticed during 2001–2006. Overall, dense forest, agricultural land and dry land were increased during 1981–2006, while open forest and small vegetation were subsequently decreased over central India. These changes in land use were perhaps due to more demand for food production and settlements over central India during this period (Creutzig et al. 2019).

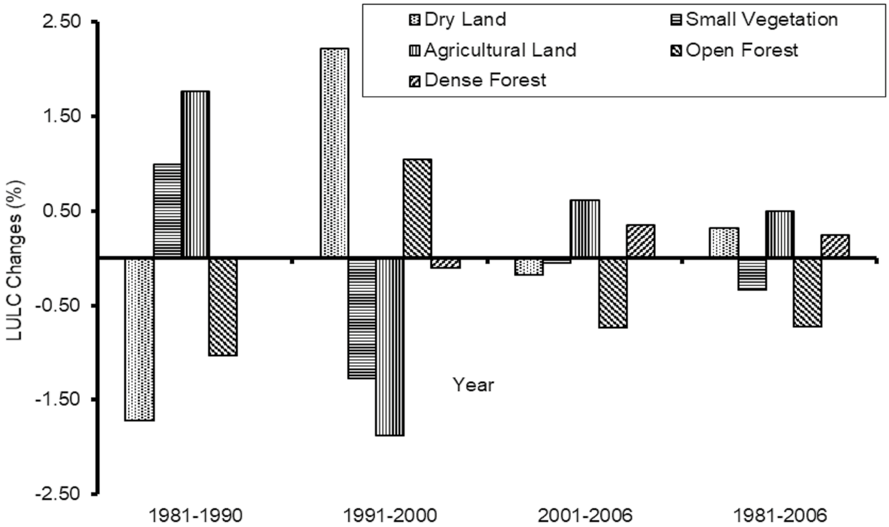

Fig. 5 LULCC during 1981–1990, 1991–2000, 2001–2006 and 1981–2006

3.3 Impact of LULCC on temperature trend over central India

Figure 6 represents the temperature anomalies and linear trends from observation and that of from reanalysis datasets for the periods 1981–2006 (Fig. 6). The equations of each trend line are shown also in the figure also. It indicated that central India was getting warmer at ~ 0.12 °C/10 years during the period 1981–2006. The rate of increase of temperature from reanalysis during the same period also indicated

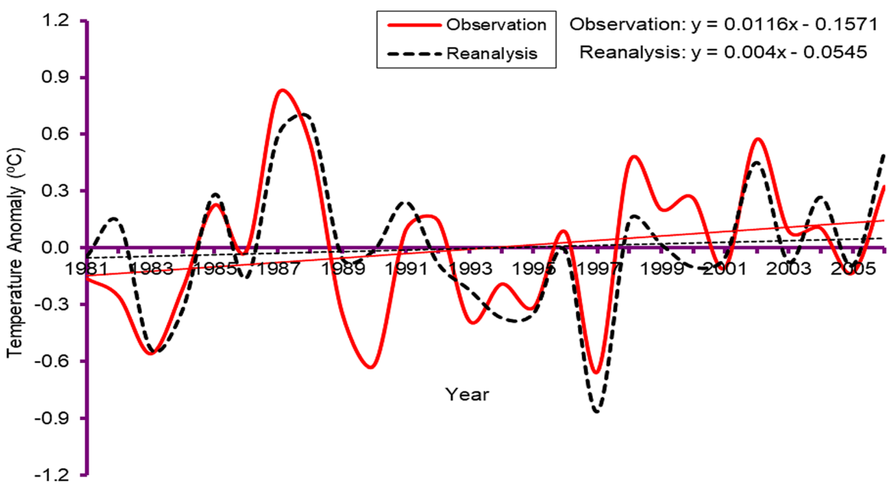

Fig. 6 Temperature anomalies and the linear trends from observation and reanalysis dataset during 1981–2006

an increase at ~ 0.04 °C/10 years. Thus the OMR trend (trend in observation—trend in reanalysis) revealed that the LULCC contributed 0.076 °C/10 years to the warming over central India. This result is found to nearly coincide with the contribution from LULCC to the warming over western India (0.06 °C/10 years) (Nayak and Mandal 2012). Previous studies over a city in central India also highlighted an increase of 0.75 °C in the mean land surface temperature during 2002–2014 (Singh et al. 2017). Multitude of previous studies (Mohan and Kandya 2015; Gogoi et al. 2019; Mukherjee and Singh 2020) also showed qualitatively comparable results over parts of India. The LULCC contribution to the temperature trend over eastern India is documented relatively low (−0.001 °C/10 years) during this period, but significantly high (~ 0.2 °C/10 years) during 1991–2006 (Nayak and Mandal 2019a). Kayet et al. (2016) documented a warming in land surface temperature during 1994–2014 due to LULCC around the Saranda forest in Jharkhand. Mukherjee and Singh (2020) highlighted an increase in mean surface temperature at a rate of ~ 2 °C/10 year over Surat and Bharuch urban area of western India. The contributions from LULCC towards warming over many regions across the globe are also documented in previous researches (Mushore et al. 2017; Roy et al. 2020).

According to previous studies (e.g., Nayak and Mandal 2019b), the major changes over India have occurred between the pairs DL & SV, SV & AL, AL & OF and OF & DF. So it is speculated to follow the similar tendency of LULCC over central India. This implied that the increase of DL over central India during 1981–2006 was mainly due to the decrease of SV which tended to warming. On the other hand, the increase of AL was mainly due to the decrease of OF which resulted cooling. DF was also increased during 1981–2006 and again resulted cooling. Closer investigation on the LULCC during 1981–2006 (Fig. 3) indicated that larger areas were converted to AL and DF which accounted for cooling in comparison to the areas converted to DL which accounted for warming. Conceptually, this indicated an overall cooling over central India during 1981–2006 which contradicted our results of OMR that LULCC contributed towards warming over central India (Fig. 6). The reason could be associated with the contribution of LULCC in intermediate periods. For instance, it was noticed that the temperature trends in both observation and reanalysis showed warming from the year around 1995. Thus the contribution from LULCC to the temperature trends also indicated warming from the year around 1995. This could be a consequence of the major change in land use types during the associated decade, i.e., 1991–2000 which is discussed in Sect. 3.1 (Table 2). Another reason for not agreeing the LULCC impact with OMR during 2001–2006 could be associated with the magnitude of the rate of change of temperature from one land use type to another (Nayak and Mandal, 2019b). For example, the conversation of AL to OF results warming at a very high rate, while conversion from OF to AL results cooling significantly in low rate. Similarly, the rate of contribution from the conservation of DL to SV is not the same as that of SV to DL. Moreover, as it is mentioned earlier, the results may be associated with the OMR method limitation, therefore, more research is suggested to understand the LULCC impact on other climatic variables through modeling studies after improving the representation of the land use map over central India with more land use categories.

4 Conclusions

In this study the changes in land use and land cover were explored over central India during the periods 1981–1990, 1991–2000 and 2001–2006, and the entire period 1981–2006 from the AVHRR NDVI images. It was found that during 1981–2006 about 50% areas of central India were covered with small vegetation and agricultural land, while about 30% areas were covered with forest and about 15% areas with dry land. It was further noticed that the agricultural land and dry land were significantly increased over central India during this, while the open forest and small vegetation were subsequently decreased. As a probable consequence, the LULCC over central India resulted warming at a rate of 0.076 °C/10 years during the period 1981–2006. It was also noticed that central India was getting cooler until the year 1995 and then started warming from the year 1995. The OMR trend indicates that the LULCC contributed towards cooling until 1995 and warming since 1995, indicating adverse effects of LUCCC in recent decades. Our overall results thus have an implication to undertake the future LULCC strategies over central India. Hence, the findings of this study may add value to the current knowledge in monitoring the adaptation to the temperature variations due to LULCC over central India.

Acknowledgement Authors sincerely acknowledge NASA, Global Land Cover Facility (GLCF) and Global Inventory Modeling and Mapping Studies (GIMMS) for providing the LULC data, National Climatic Data Centre (NCDC) and NCEP/NCAR for providing observed and reanalysis temperature datasets respectively. Indian Institute of Technology Kharagpur is acknowledged for providing the required facilities for conducting the research work.

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