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Influence of the Changes in Land-Use and Land Cover on Temperature over Northern and North-Eastern India

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Abstract: This study explores the influence of land-use and land cover (LULC) changes on the temperature over North India (NI) and North-Eastern India (NEI) during 1981–2006 by subtracting the reanalysis temperature from the observed temperature (observation minus reanalysis (OMR) method). The normalized difference vegetation index (NDVI) data of the AVHRR satellite for the period 1981–2006 were analyzed to understand the type of LULC changes during this period and their linkage with the temperature change over the two regions. The results from OMR indicated that the LULC change over NI during 1981–2006 resulted a warming of 0.03 °C, and that of NEI during this period resulted a cooling of 1.5 °C. The results from LULC changes during the said period indicated an increase of dry land/snow cover and agriculture/fallow land by ~0.1% of total area and a decrease of shrubs/small vegetation and dense forest over NI by about 0.1–0.2%. Over NEI, the areas under agricultural/fallow land, open forest and dense forest showed an increase by about 0.8–2.4% during this period, and the areas under dry/snow cover and shrubs/small vegetation indicated a decrease by ~0.7–3.6%. The comparison between the OMR analysis and LULC changes indicated that the warming over NI during 1981–2006 is due to the expansion of the dry land and the decline of dense forest. On the other hand, the cooling over NEI during the period is attributed to the decline of non-vegetated/small vegetated lands and the expansion of agricultural land/forest covers in that period. This study has an overall implication towards the modeling studies for the impact assessment of LULC changes in the present as well as future climate.

Keywords: land-use and land cover change; climate change; OMR; Northern India; North-Eastern India

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1. Introduction

Recent studies have revealed that anthropogenic forcing due to the changes in land-use and land cover (LULC) is one of the responsible factors for the temperature change in recent decades [1,2]. The changes in LULC largely modify the local level energy budgets through the underlying land surface processes such as roughness, conductivity, soil moisture, etc. and thus influence the temperate ecosystem [3–7]. In this context, India also has witnessed numerous changes in the LULC over the years [5,8–11] and its impact on the temperature trends [2,12–14]. In a recent study, Mukherjee and Singh [15] documented a steady rise in surface temperatures over two Indian cities due to possible urbanization during 2008–2016. Kayet et al. [7] reported that the surface temperature around Saranda forest in Jharkhand state has increased due to the decrease of vegetation cover during 1994–2014. Similarly, the changes in LULC resulted in warming over Western India due to a decrease in forest areas during 1975–2005 [16]. LULC change over Sundarban Biosphere Reserve in the West Bengal State of India resulted in an increase of temperature by 2.07 °C due to conversion of open forests into settlement during 1990–2014, while a decrease of temperature by 0.19 °C due to conversion of settlements into water bodies [17]. Similarly, LULC changes over Eastern India contributed towards warming at a rate of ~2 °C per decade during 1991–2006 due to conversion of small vegetation into bare lands, while it resulted in cooling during 1981–1990 due to an increase of dense forests and agricultural lands [18]. These studies clearly indicate that the impact of LULC changes on the temperature trends over Indian regions was not uniform and varied over time and region. Hence, to monitor climate hazards associated with the temperature trends over Indian regions for the adaptation interventions, understanding of the impact of LULC changes on the temperature over different regions of India have been a focus of many recent studies.

Northern India (NI), located in the north part of India, comprising the states of Jammu and Kashmir, Ladakh, Haryana, Punjab, Chandigarh, Uttarakhand, Uttar Pradesh, and the union territories of Delhi. North-Eastern India (NEI), located at the easternmost part of India, consists of eight states viz. Sikkim, Assam, Tripura, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, and Nagaland. A location map of the two regions viz. NI and NEI are depicted in Figure 1.

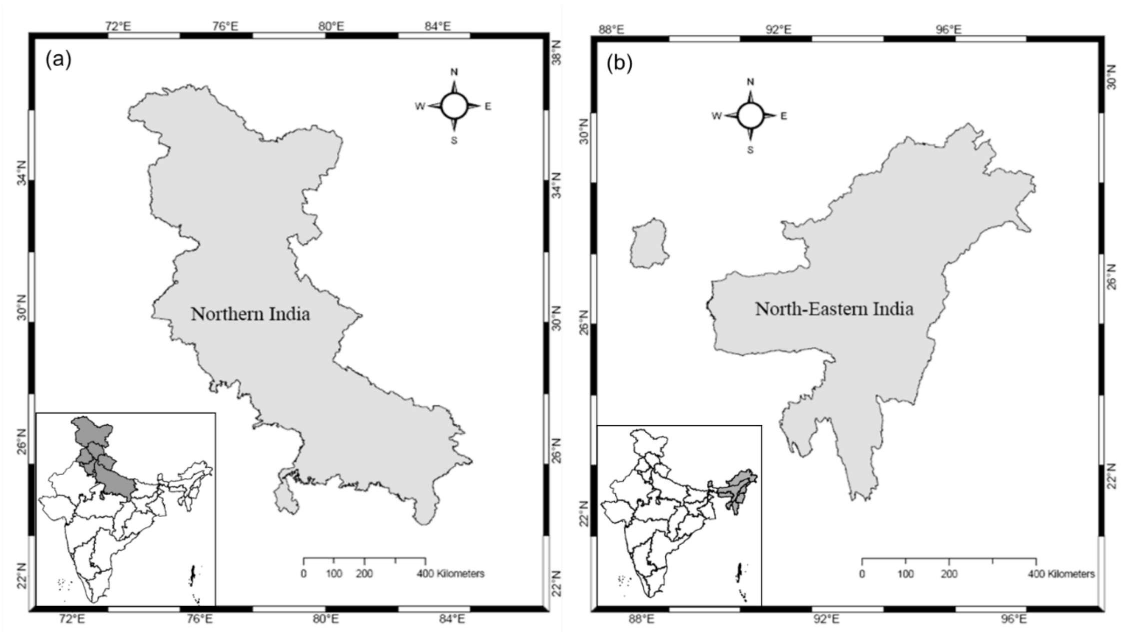

Figure 1. The location map of (**a**) Northern India (NI) and (**b**) North-Eastern India.

According to Koppen's classification, NI consists of climatically diverse regions. The temperature on the plains in NI goes above 35 °C during summer and becomes below 5 °C during winter. Some states in NI experience below the freezing point during winter, while few states receive heavy snowfall and heavy fogs (Oliver and Wilson, 1987). On the other hand, NEI consists of a humid climate with hot summer (go up to 28 °C) together with mild winters (within 14–16 °C) and severe monsoons [19]. As these two regions comprise many high mountains, so the climate over these regions greatly affected due to the features associated with mountains, such as height. Nevertheless, the surface of the earth has been significantly altered, primarily attributing to humanoid activity since immemorial times. The use of land by humankind led to an observable pattern in the LULC that has a profound effect on the natural environment. The footprint of human activities is rapidly increasing, leading to consequences on climatic variables such as temperature. The mountain areas across the globe, in recent decades, have also been increasingly affected by LULC change due to the demand for human development.

Previous studies [12–18] highlighted the impact of LULC changes on the temperature over various regions of India. However, the impact of LULC changes on the temperature over mountainous rich regions, particularly over NI and NEI, is not well explored. Thus, comprehending the effects of LULC changes over these two regions on temperature should add new knowledge in the context of climate risk management. In this study, we explored the impact of LULC changes on the temperature over NI and NEI during 1981–2006 by subtracting the reanalysis temperature from the observed temperature [observation minus reanalysis (OMR) method] [20]. We also attempted to investigate the changes in LULC over these two regions during 1981–2006 from the advanced very high-resolution radiometer (AVHRR) satellite datasets to understand the type of LULC changes and their linkage with the temperature change over NI and NEI.

2. Materials and Methods

The reanalysis daily temperature datasets were obtained from the NCER/NCAR Reanalysis (NNRP1) over NI and NEI regions, and the observed daily temperature was taken from the National Climatic Data Center (NCDC) at 16 different stations for the period 1981–2006. The geographical locations of each station are given in Table 1. The reanalysis temperatures were first interpolated at the corresponding observed stations by using the inverse distance formula from four corner points of the grid that confined the observation station. The inverse distance formula used in this study is given as:

$$T_s = \frac{\sum_{i=1}^{4} d_i \times T_{g_i}}{\sum_{i=1}^{4} d_i} \qquad \left\{ i = 1, ..4 \right\}$$

where T_s is the reanalysis temperature at the station, ${d_i}^{-1}$ is the Euclidean distance from the station to the corner point g_i, Tg_i is the reanalysis temperature at point g_i.

Table 1. List of observation stations.

Sl. No	Station Name	Longitude (E)	Latitude (N)
1	Agartala	91.250	23.883
2	Agra	77.967	27.150
3	Allahabad/Bamhrauli	81.733	25.450
4	Amritsar	74.867	31.633
5	Bareilly	79.400	28.367
6	Dehradun	78.033	30.317
7	Dibrugarh/Mohanbar	95.017	27.483
8	Gauhati	91.583	26.100
9	Gorakhpur	83.367	26.750
10	Hissar	75.733	29.167
11	Imphal	93.900	24.667
12	Lucknow/Amausi	80.883	26.750
13	New Delhi/Safdarjun	77.200	28.583
14	Patiala	76.467	30.333
15	Srinagar	74.833	34.083
16	Tezpur	92.783	26.617

The temperature trends over the regions are then estimated from the linear trends in the reanalysis and observed temperature anomalies during 1981–2006 with respect to their 26 years means. Finally, we subtracted the reanalysis temperature trend from the observed temperature trend to calculate the contribution of LULC changes towards the temperature over the regions. This method of estimating the impact of LULC changes on the temperature is known as the observation minus reanalysis (OMR) method [20]. The OMR-based studies have been conducted over various regions across the globe [11,18,21–24] and appear to be successful in capturing the LULC impact on the temperature trends.

The normalized difference vegetation index (NDVI) images from AVHRR products are classified into different LULC types at 8 km resolution for the years 1981, 1991, and 2006 by using the hierarchy approach of LULC types [25]. Here the AVHRR is a sensor onboard the National Oceanic and Atmospheric Administration (NOAA) satellite series 7, 9, 11, 14, 16, and 17 and the global inventory modeling and mapping studies (GIMMS) processed these data to provide geometrically corrected NDVI images, hereafter referred as AVHRR products which are available two times per month at 8 km spanning from 1981 through 2006. The NDVI was computed from the near-infrared (NIR) and red band (Red) data in the electromagnetic spectrum and determined to provide a numerical indicator for each pixel to understand whether the target region has green vegetation. Mathematically it can be written as:

$$\mathrm{NDVI} = \frac{NIR - Red}{NIR + Red}$$

The hierarchy approach refers to categorizing the whole LULC into two groups based on the NDVI values and then to categorize each individual into another two groups and to continue the process [26]. The NDVI values vary between −1 and +1. The higher NDVI values indicate the land type with green vegetation cover, e.g., forest covers, and the lower positive NDVI values refer to the land type with non-vegetation cover, e.g., dry land. Following this way, we categorized the whole region into a vegetated and non-vegetated LULC type. The non-vegetated LULC type includes barren rock, barren land, settlement, sand and snow, etc. and is referred to as the dry land/snow cover (DL/SC) category. The green vegetation covers are next categorized into forest areas and non-forest areas based on higher and moderate NDVI values. In this way, the forest areas are classified into the open forest (OF) and dense forest (DF) categories and non-forest covers are categorized into shrubs/small vegetation (S/SV) and agricultural/fallow land (A/FL). Figure 2 shows a schematic diagram of the hierarchy of the LULC types used in this study.

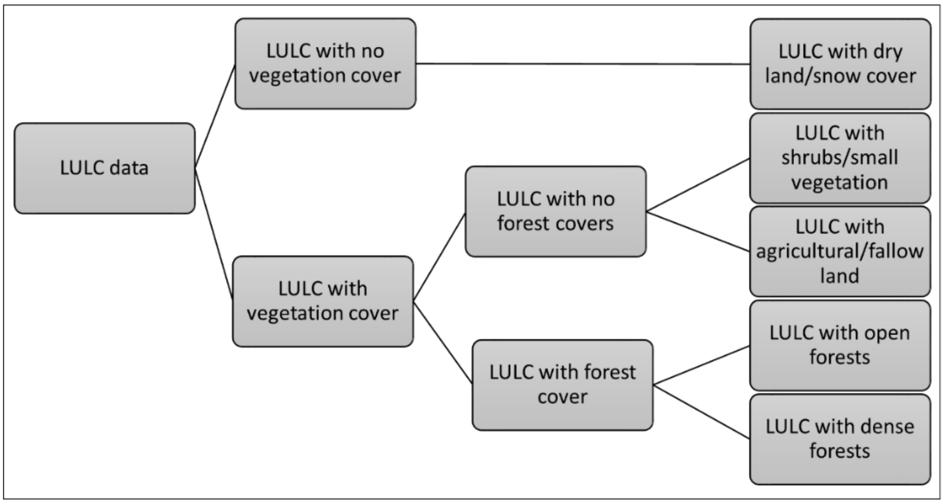

Figure 2. Hierarchy approach used for classification.

The accuracy assessment of the classified LULC maps was conducted against the very high-resolution (30–60 m) NASA Landsat images through the user's accuracy, producer's accuracy and overall accuracy by using 50 randomly selected sample points over each region. The satellite images of NASA Landsat MSS at 60 m, Landsat TM at 30 m and Landsat ETM+ at 30 m are obtained from Earthsat and United States Geological Survey (USGS). These satellite images are then composited with the bands of 4, 3, and 2 for Landsat MSS and those with the bands of 7, 4, and 2 for Landsat TM and Landsat ETM+.

The producer's accuracy corresponds to the possibility that an individual LULC type is categorized as such in the reference map (or ground truth). User's accuracy corresponds to the probability that an individual LULC type is categorized as such in the classified map (derived by the user). The overall classification accuracy corresponds to the number of samples were classified as such in both reference and classified map and dividing this by the total number of samples.

3. Results

3.1. Temperature Trends and Contribution from LULC Change

The temperature anomalies over NI and NEI during the period 1981–2006 from reanalysis and that of observation and OMR are shown in Figure 3. The results indicated warming trends in the reanalysis at the rates of 0.157 and 0.572 °C per decade during 1981–2006 over NI and NEI, respectively, while that in the observation showed a warming trend at a rate of 0.17 °C per decade over NI and a cooling trend at a rate of 0.014 °C per decade over NEI. This implied that during 1981–2006 the reanalysis temperature showed a warming of 0.4 °C over NI and 1.48 °C over NEI, whereas the observed temperature indicated warming of 0.44 °C over NI and cooling of 0.036 °C over NEI. Thus, the OMR, observed temperature minus reanalysis temperature, indicated warming at a rate of 0.013 °C per decade over NI and cooling at a rate of 0.586 °C per decade over NEI during 1986–2006, implying 0.034 °C warming contribution from the LULC change over NI and 1.5 °C cooling contribution from the LULC changes over NEI during this period.

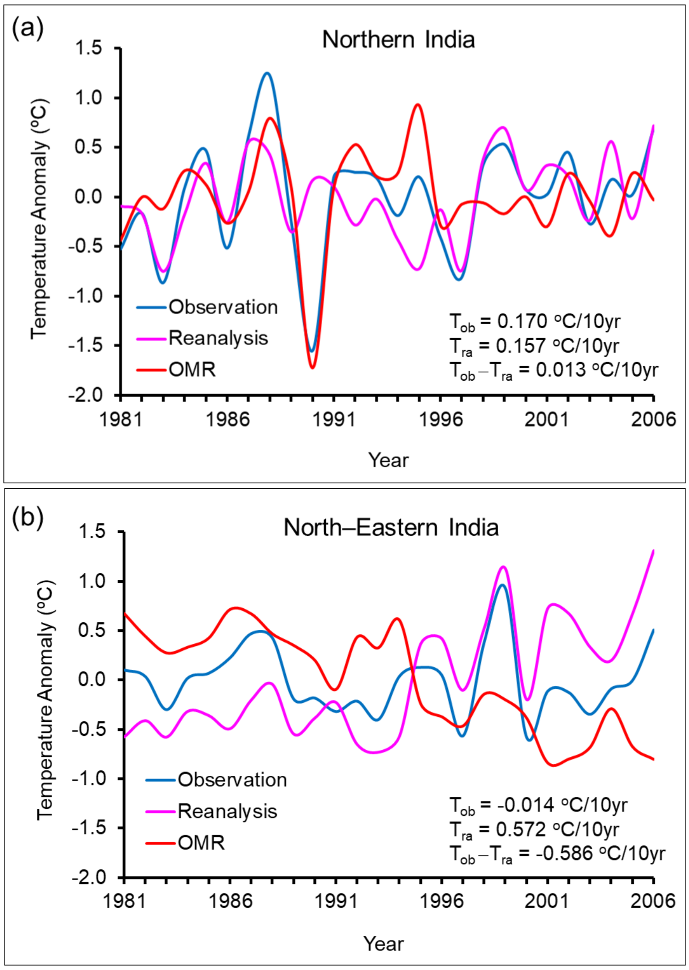

Figure 3. The temperature anomalies over (**a**) NI and (**b**) NEI for the period 1981–2006 derived from the observation, reanalysis and observation minus reanalysis (OMR).

Closer investigation of the temperature in the reanalysis data indicated nearly cooling over NI in most of the years during 1989–1997 and warming in most of the years after the year 1997 (Figure 3a). On the other hand, over NEI, the reanalysis data showed cooling in all years before the year 1995 and warming after the year 1995 (Figure 3b). However, the observed temperature showed warming over NI and cooling over NEI in most of the years. This implied LULC change contributed towards warming over NI and NEI during 1989–1997 and 1981–1995, respectively and cooling NEI after the year 1995. There are negligible contributions from LULC changes that are noticed over NI after the year 1997.

3.2. LULC Map

Figure 4 represents the NDVI images of AVHRR satellite data and LULC map after classification over NI and NEI for the years 1981, 1991 and 2006. It shows the five different LULC types viz. dry lane/snow cover, shrubs/small vegetation, agricultural/fallow land, open forest and dense forest those categorized from the NDVI images. The classified LULC map indicated that most of the regions over NI were covered with dry land/snow cover, agricultural/fallow land and dense forest during 1981–2006, while most of the regions over NEI were covered with open forest and dense forest during this period.

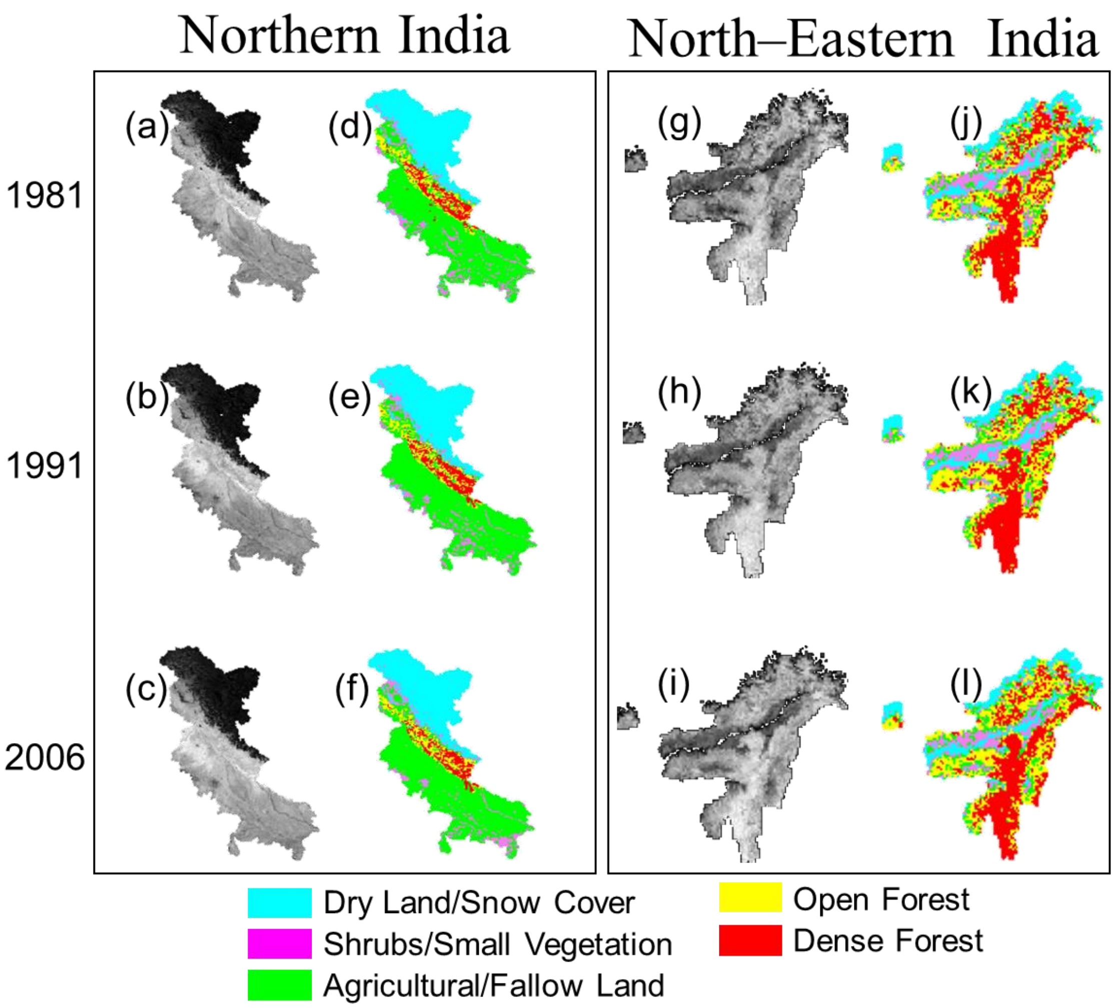

Figure 4. Spatial representation of land-use over NI (left panel) and NEI (right panel) for the years 1981, 1991 and 2006 from (**a**–**c**,**g**–**i**) advanced very high-resolution radiometer (AVHRR) normalized difference vegetation index (NDVI) images and (**d**–**f**,**j**–**l**) land-use and land cover (LULC) classification.

Before proceeding with further statistics, the LULC classification was first subjected to an accuracy assessment using the controlled cluster technique against the high-resolution Landsat images. The resolution of classified LULC maps was kept the same as of NDVI images at 8-km and was compared against the Landsat MSS, which was at 60 m resolution, and TM and ETM+ images, which were at 30-m. We selected 50 sample points randomly over each region of NI and NEI from the LULC classified map and the high-resolution satellite images for the years 1981, 1991 and 2006 separately. These sample points were put to randomized controlled trials in a group of LULC types by using ERDAS Imagine software to examine the overall accuracy based on the user's accuracy and producer's accuracy. Table 2 represents the sample analyzed accuracy assessments of the five LULC types over NI and NEI for the years 1981, 1991 and 2006. The overall accuracy of the classified LULC maps was obtained within the range of 90–92% over NI (Table 2) and 88–90% over NEI (Table 2).

Table 2. Accuracy assessment of LULC types for 1981, 1991 and 2006; (**a**) Northern India, (**b**) North-Eastern India.

(**a**) Northern India

LULC Type	1981		1991		2006	
	Producers Accuracy (%)	**Users Accuracy (%)**	**Producers Accuracy (%)**	**Users Accuracy (%)**	**Producers Accuracy (%)**	**Users Accuracy (%)**
DL/SC	100.00	80.00	90.00	90.00	90.00	90.00
S/SV	75.00	75.00	60.00	75.00	66.67	100.00
A/FL	90.91	96.77	96.43	96.43	100.00	96.88
OF	100.00	66.67	75.00	75.00	66.67	66.67
DF	66.67	100.00	100.00	75.00	66.67	66.67
Overall classification accuracy	90.00%		90.00%		92.00%	

(**b**) North-Eastern India

LULC Type	1981		1991		2006	
	Producers Accuracy (%)	**Users Accuracy (%)**	**Producers Accuracy (%)**	**Users Accuracy (%)**	**Producers Accuracy (%)**	**Users Accuracy (%)**
DL/SC	80.00	80.00	75.00	75.00	100.00	83.33
S/SV	80.00	100.00	88.89	88.89	100.00	75.00
A/FL	100.00	60.00	75.00	75.00	62.50	100.00
OF	94.12	94.12	84.62	91.67	94.44	94.44
DF	93.33	93.33	95.00	90.48	93.75	88.24
Overall classification accuracy	90.00%		88.00%		90.00%	

The area statistics under each LULC type over NI and NEI for the years 1981, 1991 and 2006 are shown in Figure 5 and Table 3. Results indicated that the area occupied by agricultural/fallow land over NI corresponds to nearly 49% (about 349,000 km^2) of the total area during 1981–2006, and the area occupied by dry land/snow cover showed nearly 31% (~220,000 km^2) of the total area during this period. The forest areas and the shrub/small vegetation covers over NI accounted for ~11% and ~9% of the total area, respectively. On the other hand, nearly 55% (about 160,000 km^2) of the total areas over NEI were the open or dense forest lands during 1981–2006, and nearly 12–16% (about 30,000–40,000 km^2) of total areas are occupied each with dry land/snow cover, shrubs/small vegetation, agricultural/fallow land during this period. The areas under dense forest over NEI accounted for 31–32% of total areas, and the areas under open forest correspond to 25–27% (Table 3). Dry land/snow covers occupied 15–16% of total areas of NEI, and shrubs/small vegetation and agricultural/fallow land accounted for 12–16% and 13–14% of total areas, respectively.

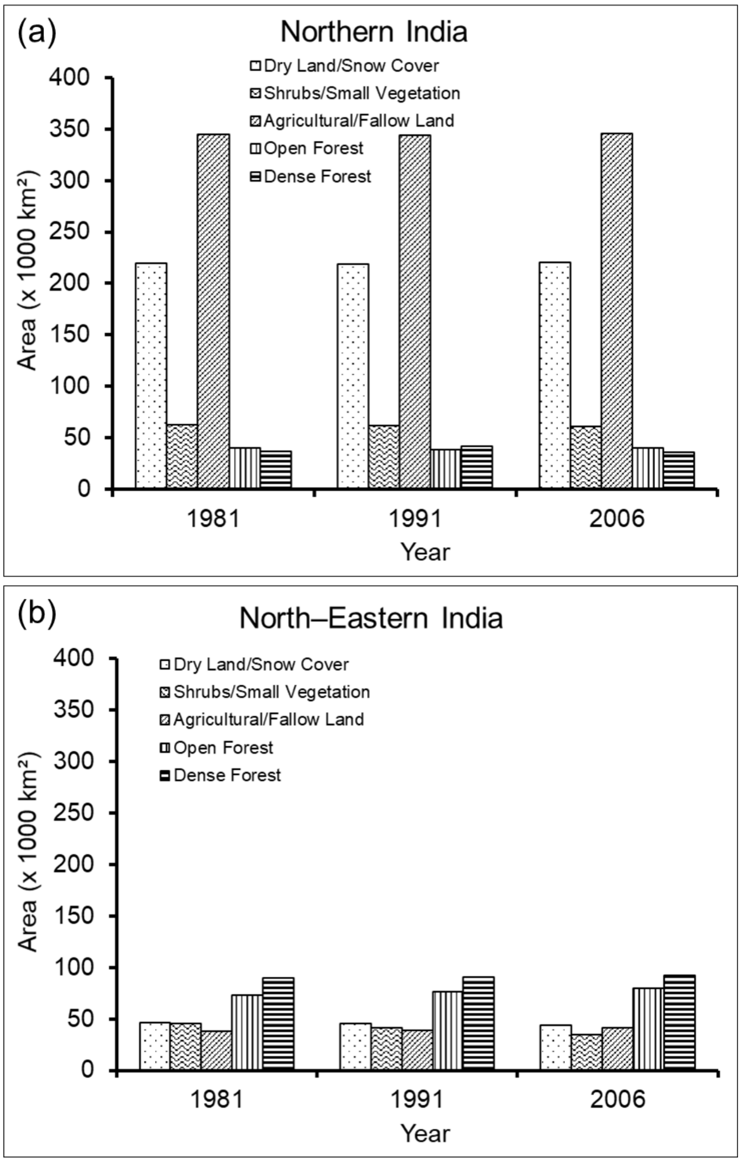

Figure 5. Areas under each LULC type over (**a**) NI and (**b**) NEI.

Table 3. Area estimation under each LULC types; (**a**) Northern India, (**b**) North-Eastern India.

(**a**) Northern India			
LULC Type	**1981 (%)**	**1991 (%)**	**2006 (%)**
Dry land/snow cover	31.18	31.06	31.34
Shrubs/small vegetation	8.85	8.76	8.63
Agricultural/fallow land	49.00	48.83	49.15
Open forest	5.73	5.46	5.75
Dense forest	5.25	5.88	5.14
(**b**) North-Eastern India			
LULC Type	**1981 (%)**	**1991 (%)**	**2006 (%)**
Dry land/snow cover	15.80	15.52	15.12
Shrubs/small vegetation	15.56	14.09	11.92
Agricultural/fallow land	12.95	13.31	14.03
Open forest	24.97	26.06	27.40
Dense forest	30.71	31.02	31.52

3.3. LULC Change

Figure 6 represents the changes in each LULC type over NI and NEI during the three periods viz. 1981–1990, 1991–2006, and 1981–2006. The LULC changes over NI during 1981–1990 indicated that except dense forest, all LULC types were decreased by nearly 0.1–0.3% each of total area and during 1991–2006 shrubs/small vegetation continued to decrease by ~0.1 and dense forest were decreased by ~0.9%, while other LULC types were increased by ~0.4% each. Shrubs/small vegetation and dense forest showed an overall reduction of ~0.1–0.2% of total area over the period 1981–2006, while dry land/snow cover and agricultural/fallow indicated an overall increase of about 0.1% of total area over this period (Figure 6a). On the other hand, the areas under agricultural/fallow land, open forest and dense forest over NEI are increased during both the periods 1981–1990 and 1991–2006, while the areas under the other two LULC types are decreased during these periods (Figure 6b). It is noticed that the area under dry land/snow cover over NEI decreased by ~0.3% of the total area during 1981–1990 and continued to decrease by ~0.4% during 1991–2006. Nearly 1.5% of the total area was decreased under shrubs/small vegetation during 1981–1990, and an additional ~2.1% of the total area was decreased during 1991–2006. The area under agricultural/fallow land was increased by ~0.4% of the total area during 1981–1990 and further increased by ~0.7% during 1991–2006. An increase of ~1% of the total area was noticed under open forest during 1981–1990 and an additional increase of 1.4% during 1991–2006. Over the period 1981–2006, dry land/snow cover and shrubs/small vegetation indicated an overall decrease, while other LULC types showed an overall expansion during this period.

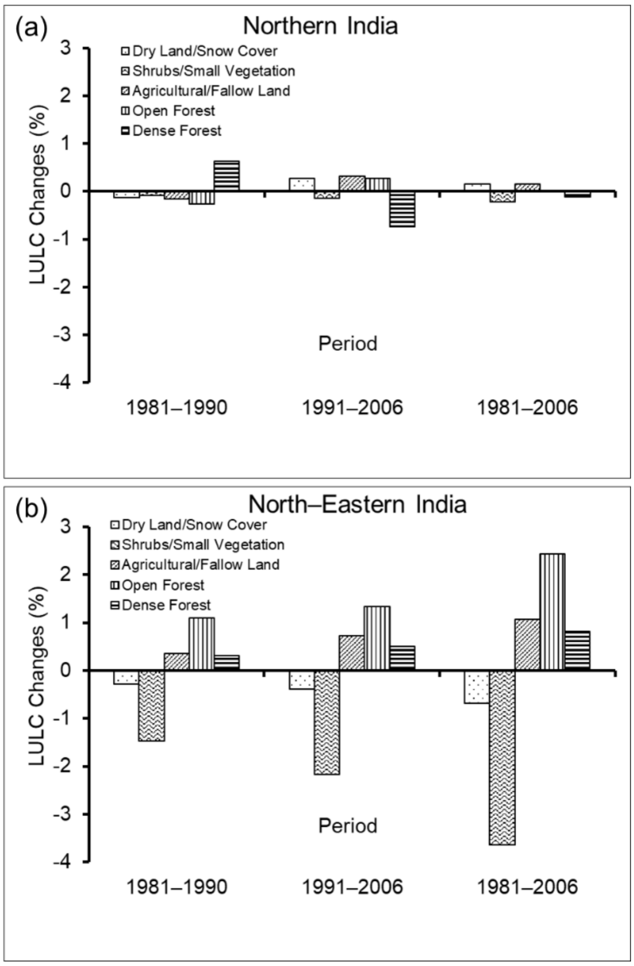

Figure 6. LULC changes over (**a**) NI and (**b**) NEI.

3.4. LULC Change versus Temperature Trends

In this section, we investigated the conversion of each LULC type from one type to another over NI and NEI during 1981–2006 (Figure 7) and compared their overall changes with OMR analysis (Figure 3) to understand the impact of LULC changes on the temperature trend.

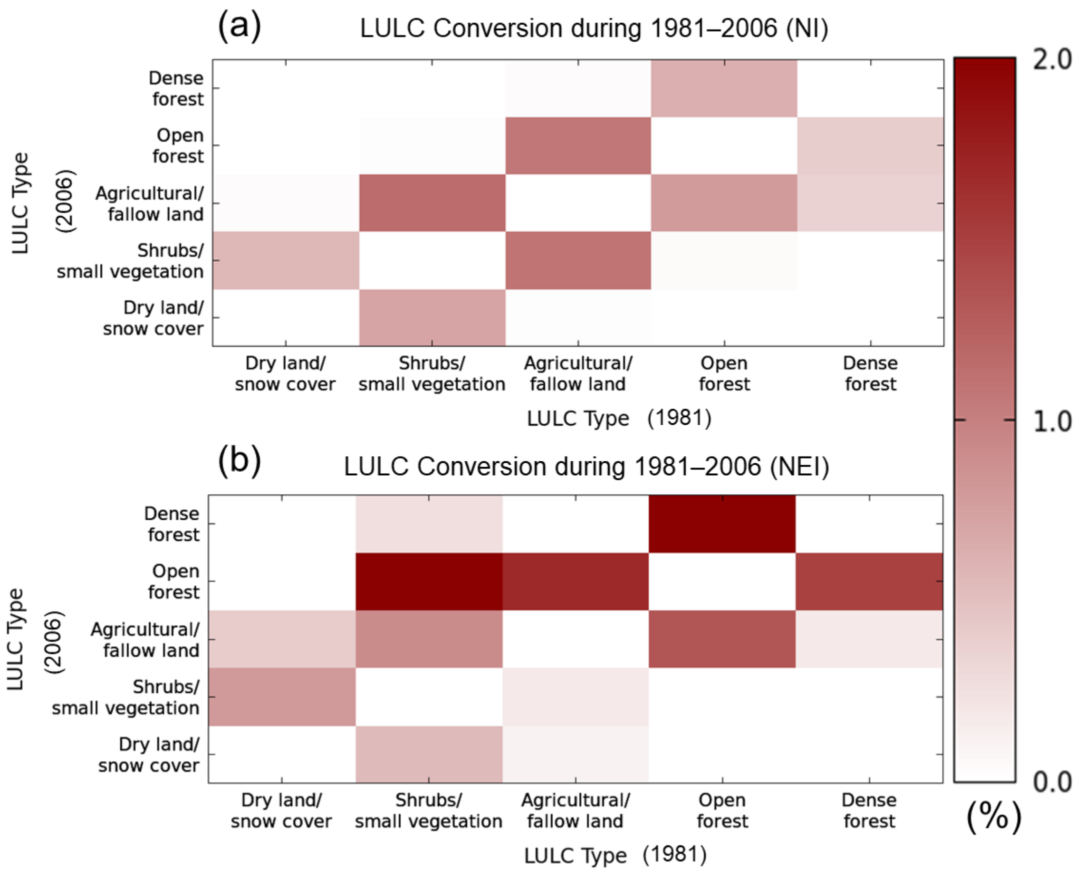

Figure 7. LULC change matrix analysis (in %) during 1981–2006 over (**a**) NI and (**b**) NEI. Conversion direction is from 1981 to 2006.

In Figure 7, the horizontal axis shows the LULC types in 1981, and the vertical axis shows the LULC types in 2006. The conversion of each LULC type to another type is directed from the year 1981 through the year 2006. For example, the shaded cell in the first column in Figure 7a shows that about 0.4% of dry land/snow cover has converted to shrubs/small vegetation during 1981–2006; the shaded cells in the second column in Figure 7a show conversions from shrubs/small vegetation to dry land/snow cover and agricultural/fallow land during this period; and so on. It is noticed that the conversion pattern is the same over both regions, with an exception for the conversion from shrubs/small vegetation to open forest in NEI. Dry land over both regions was mostly converted to shrubs/small vegetation during 1981–2006, while shrubs/small vegetation was converted to dry land/agricultural/fallow land. It was noticed that agricultural/fallow land was converted to shrubs/small vegetation/open forest/dense forest during this period, while the open forest was converted to mostly dense forest/agricultural/fallow land. Similarly, conversion from dense forest to open forest/agricultural/fallow land was also observed during 1981–2006 over both the periods. The comparison between the LULC changes and OMR analysis over NI indicated that dry land/snow cover/agricultural/fallow land and expansion of shrubs/small vegetation/dense forest caused overall warming during 1981–2006.

Closer investigation in the changes in LULC over the region showed an overall expansion of less vegetation cover, and an overall reduction of dense vegetation over was responsible for the overall warming over NI during this period. On the other hand, the combined effect from the increased agricultural/fallow land/forests and the decreased dry land/snow cover/small vegetation caused an overall cooling over NEI during 1981–2006. It clearly indicated that a large decrease of less vegetation cover and a substantial increase of dense vegetation were responsible for the overall cooling over NEI during this period.

4. Discussion

In this study, we explored the impact of LULC changes on the temperature over NI and NEI during 1981–2006 by subtracting the reanalysis temperature from the observed temperature (observation minus reanalysis (OMR) method). We found that the LULC change during 1981–2006 resulted warming of 0.034 °C over NI, while it caused cooling of 1.5 °C over NEI during this period. Our results over NI were found to be qualitatively comparable with the previous studies conducted over other regions of India [2,7,14–17]. For instance, LULC change caused warming over Western India during 1973–2009 [16], surrounding areas of Saranda forest in the Jharkhand state of India during 1994–2014 [7] and Sundarban areas of West Bengal of India during 1990–2014 [17]. Our results over NEI were accounted to be consistent with LULC change resulted cooling during 1981–2006 over India as a whole [11] and Eastern India during this period [18]. It is also noticed that the temperature trend over NEI showed an overall cooling rate (0.014 °C per decade). This finding is coherent with the previous study over the region [27].

We further attempted to investigate the changes in LULC over NI and NEI during 1981–2006 from the AVHRR satellite datasets to understand the type of LULC changes and their linkage with the temperature change over these two regions. Analysis indicated that the warming over NI during 1981–2006 could be due to expansion of the areas under dry land/snow cover and reduction of areas under dense forest during this period. The cooling over NEI during 1981–2006 could be due to the decline of non-vegetated/small vegetated lands and the expansion of agricultural land/forest covers in that period. It is noticed that the dry land/snow cover and shrubs/small vegetation are largely decreased over NEI during 1981–2006. The reason for the decreased areas under these categories over NEI could be attributed to the snowmelt [28] and an expansion of monoculture farming [29]. The cooling over NEI could also be associated with the large increase of dense forest. The areas under dense forest over NEI were increased by ~0.3% during 1981–1990 and again increased by ~0.5% during 1991–2006, because dense vegetation land covers to control the increase in temperature over a region more effectively than the land with less vegetation cover [17].

These results will be useful for enhancing the knowledge in the context of climate risk over the NI and NEI region. The contribution from LULC changes towards the surface temperature in recent decades is of great concern across the globe. Several studies (discussed in earlier sections) also highlighted that the LULC changes largely regulate the lower atmosphere and thus influence the climate over a region. Hence, we believe the findings from this study will add value to the present state of knowledge in monitoring the adaptation to the temperature variations due to LULC changes over NI and NEI regions. It is worth noting here that the OMR method may be limited due to the errors introduced by the non-climatic biases, which sometimes affects observation [30–32]. The error may also be introduced due to the interpolation method used because four corner points of the grid that confined the observation station are not enough to accurately represent the state of air temperature within each region [33]. However, OMR-based studies have so far shown strong evidence on the impact of LULC changes on the regional climate, particularly surface temperature trends, even though few indicators of uncertainty still remain unclear. Hence, further investigation on the impact of LULC changes is suggested on other climatic variables through modeling studies for which the LULC map prepared in this study at different times would be of an advantage.

5. Conclusions

This study explored the influences of LULC changes on the temperature trend during 1981–2006 over two regions (NI and NEI) of India. The reanalysis temperature over each region was subtracted from the observed temperature over the corresponding region. The so-called "observation minus reanalysis" (OMR) method was used to quantify the impact of LULC changes on the temperature over both regions. The results indicated that due to the LULC changes during 1981–2006, NI experienced a warming of 0.034 °C, while NEI experienced cooling of 1.5 °C during this period. AVHRR satellite images were deployed to recognize the LULC changes occurring during this period over NI and NEI and to understand their linkage with the surface temperature change. Overall analysis inferred an expansion of the areas under dry land/snow cover over NI during 1981–2006 and a reduction of areas under dense forest over the same region in that period. This may lead to warming over NI during 1981–2006. On the other hand, a decline of non-vegetated/small vegetated lands is noticed over NEI during this 1981–2006 and an expansion of agricultural land/forest covers is seen over the same region in that period. This may lead to the cooling over NEI during 1981–2006.

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