Satellite Based Approach for Assessing Land Cover Changes of Modhupur Sal Forest Regions in Bangladesh: Its Dynamics and Impacts on Surface Temperature

Ashrafunnahar Hena, Hafizur Rahman, Md. Shahjahan Ali

Abstract*: Land Use and Land Cover (LULC) changes have a significant impact on climate changes in the local to global scales. In this paper, we studied the impact of LULC changes of Modhupur Sal forest and its adjoining areas in Bangladesh on LST using multi temporal satellite data. Seasonal and temporal values of LST were determined for three decades from 1989 to 2019. It was seen from the LULC study that the Sal forest area has changed a lot over the time period. Through the long-term time series data, it is found that with the change of LULC, LST of the area has increased. An inverse correlation between the NDVI and LST has been observed from 1989 to 2009 in winter and 1993 to 2011 in summer. But in 2019, both in winter and summer, with the increase of NDVI value of the area, LST was seen to increase.

Keywords*: Land Surface Temperature, Land use/Land Cover, Vegetation Indices, GIS and Remote Sensing.

I. INTRODUCTION

Modhupur Sal forest, locally known as "Modhupur Garh", is located in the central part of Bangladesh. where Sal (Shorea robusta) is the principal plant species in this forest. This tropical moist deciduous forest is rich in biodiversity, and is now at risk of extinction. Except the largest Sal forest of Modhupur Garh, there are many other smaller Sal forests in the north and north-western parts of Bangladesh. For decades the Modhupur Sal forest has been a matter of great concern for because of deforestation or modification [1]. Anthropogenic activities such as settlement, agriculture, and commercial plantations are the main causes of this alteration [2,3,4]. Land Use Land Cover Change (LULCC) influences the local climate system through biophysical effects due to the modification of land surface traits such as surface albedo and land surface temperature (LST). These may affect the global atmospheric component of carbon dioxide and changes in the land surface, which affect regional and global climate [5-12]. LULCC analysis is important to quantify the changes at various spatial and temporal levels, which reflects the scale of human activities in a given environment [13-16].

Remote Sensing and Geographic Information System (GIS) are powerful and effective tools for analyzing LULC and LST changes. Landsat archives can be used for large-scale multi-decadal analysis [17]. In many cases, LULC changes have been investigated by using spectral responses to identify alterations have been occurred in large forest associated areas [18]. Since changes in land surface characteristics affect the energy and radiation on the Earth's surface, land surface temperature (LST) can be detected by the remote sensing data [19-22] through the analysis of LULCC [23-32]. In Bangladesh, LULCC and LST has been studied in recent times with great importance as these are considered as very important factor in climate change studies. However, most of the times the studies are mainly in urban areas [33]. The sea surface heatwave vulnerability of the coastal areas in Bangladesh shows that buildup areas have higher LST than in vegetated areas [34]. The warming effect may be caused by the decrease of forest area and expansion of buildup and agriculture. In this study, we provide a data driven assessment of LULCC in Modhupur Sal forest and its adjoining areas to observe its impacts on LST using Landsat data. In this work Landsat-5 and Landsat-8 data for the past three decades from 1989 to 2019 was utilized. The study was done taking yearly satellite data of two seasons (Winter and Summer) for observing the seasonal variations of the changing effects to improve the accuracy of the results and making the observations more consistent with time.

II. STYDY AREA

The Modhupur Sal forest, alias 'Modhupur Garh', is located at the greater Mymensingh and Tangail districts in Bangladesh which is the largest spot in the central part of the country. The Sal forest is the third largest forest ecosystem in Bangladesh and is classified as a tropical moist deciduous forest [35]. Compared with other forests in Bangladesh, the tropical moist deciduous Sal forest is considered to have greater environmental and economic significance [2,36]. As early as fifty years ago, most of the areas of Modhupur Garh were covered by forests, and Sal (*Shorea robusta*) was the main tree species.

Manuscript received on 21 January 2023 | Revised Manuscript received on 31 January 2023 | Manuscript Accepted on 15 May 2023 | Manuscript published on 30 May 2023.
*Correspondence Author(s)

Mist. Ashrafunnahar Hena, Department of Electrical and Electronic Engineering, Islamic University, Kushtia, Bangladesh. Email: henaashrafunnahar@gmail.com

Dr. Hafizur Rahman, Bangladesh Space Research and Remote Sensing Organization (SPARRSO), Dhaka, Bangladesh. Email: hafiz1961@yahoo.com

Dr. Md. Shahjahan Ali*, Department of Electrical and Electronic Engineering, NIslamic University, Kushtia, Bangladesh. Email: jahanshah.iu@gmail.com, ORCID ID: https://orcid.org/0000-0002-1522-8038

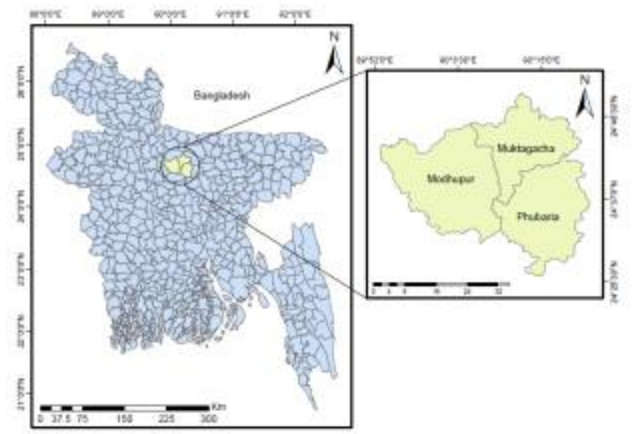

Fig. 1. Location of the study area.

The main part of the Sal forest is now located in Modhupur Upazilla, but a small part also resides in Mukatagacha and Fulbaria Upazila. Figure 1 shows our study area, which extends from N 24º3204400 to N 24º44042:700 and E 89º59049:500 to E 90º10034:600 and about 120 km north from the capital city of Dhaka. It has a tropical climate with an average rainfall of 205cm. The average temperature gradually increased from February and reached the highest temperature in April (around 35ºC).

III. DATA AND METHODOLOGY

A. Data

The study period was selected in a decadal way for both in winter and summer. For winter, the Landsat data of month January was collected for the years 1989, 1999, 2009 and 2019. Peak summer month in Bangladesh is April. In April the sky sometimes remains cloudy and so cloud and haze free images were not available in some years. This is why, the Landsat data for the month of April was collected for the year 1993, 1998, 2011 and 2019. These imageries were obtained from the United States Geological Survey website (http://earthexplorer.usgs.gov). Satellite data used this study is listed in Table I.

Table- I: Data Used in the study

Satellite	Sensor	Acquisition Date	Path/Row	Resolution
Landsat 5	TM	January, 1989	137/43	30 Meters
Landsat 5	TM	January, 1999	137/43	30 Meters
Landsat 5	TM	January, 2009	137/43	30 Meters
Landsat 8	OLI/TIRS	January, 2019	137/43	30 Meters
Landsat 5	TM	05-Apr-93	137/43	30 Meters
Landsat 5	TM	03-Apr-98	137/43	30 Meters
Landsat 5	TM	07-Apr-11	137/43	30 Meters
Landsat 8	OLI/TIRS	13-Apr-19	137/43	30 Meters

B. Image Processing

The Landsat 5 and Landsat 8 Images were collected and corrected geometrically and radiometrically to increase the quality of the overall accuracy of the study. Image preprocessing involves layer stack, image subset, atmospheric correction, and image resample before utilizing the images as the input to the models utilized. After resampling spatial resolution of Landsat data was 30 m by 30 m.

C. Methodology

The objective of this study is to analyze the effects of LULC changes on LST. The first method was to extract the types of land use and land cover of the study area. The second method was to identify the thickness of vegetation present in the form of NDVI. The third method was to retrieve the LST value from the thermal bands of Landsat data. Finally, the spatio-temporal variation of LST was analyzed with LULCC and NDVI. Also, statistical study of NDVI and LST was done to investigate the patterns of LST. All these methods were carried out using ArcGIS 10.5 and ERDAS IMAGINE 2015 software. The flow diagram of the methodology is presented Figure 2.

IV. RESULTS AND DISCUSSIONS

All data used in the study were individually processed and analyzed according to the methodology. Important outputs of the study are discussed in the following sections.

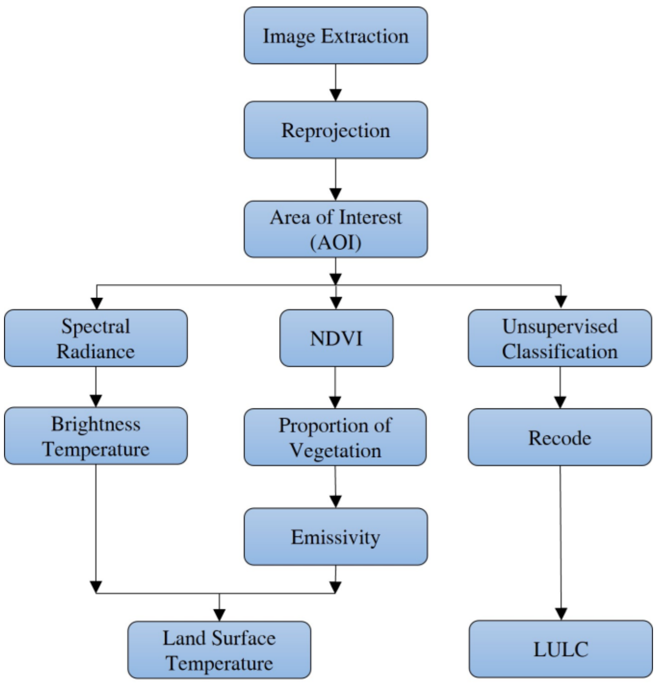

Fig. 2 Flow Diagram of the Method.

Table- II: LULC Types of the Study Area

Land Cover Types	Description
Waterbody	Waterbodies are mainly the area of inland water
Sal Forest	Sal Forest is the natural Sal forest occupied in the study area
Vegetation	Vegetation areas are the transformed rubber forest, agriculture and home shed vegetation in the study area.
Others	These areas are the bare soil, settlements, fallow land, industries, roads and other permanent structures.

Retrieval Number:100.1/ijee.A1841053123
DOI: 10.54105/ijee.A1841.053123
Journal Website: www.ijee.latticescipub.com

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Table- III: Statistical Summary of LULC Changes in Winter

Years	Waterbody		Sal Forest		Vegetation		Others		Total
	Hectors	%	Hectors	%	Hectors	%	Hectors	%	Hectors
1989	10398.5	8.4	30049.9	24.4	14016.7	11.4	68821.8	55.8	123287
1999	7624.44	6.2	22764.1	18.5	23739.6	19.2	69156.7	56.1	123287
2009	7275.42	5.9	18854.4	15.3	25967.3	21	71187.9	57.7	123287
2019	8002.35	6.5	13543.4	11	34321.5	27.8	67419.1	54.7	123287
	Total change=(-)1.9%		Total change=(-)13.4%		Total change=(+)16.4%		Total change=(-)1.1%		

Table- IV: Statistical Summary of LULC Changes in Summer

Years	Waterbody		Sal Forest		Vegetation		Others		Total
	Hectors	%	Hectors	%	Hectors	%	Hectors	%	
1993	6267.24	5.1	29952.2	24.3	28652.5	23.2	58392.8	47.4	123287
1998	3606.75	2.9	25939.3	21	38165.5	31	55563.8	45.1	123287
2011	2891.34	2.3	20469.4	16.6	46577.2	37.8	53335.1	43.3	123287
2019	4436.37	3.5	13781.5	11.2	46804.1	38	58265	47.3	123287
	Total change=(-)1.6%		Total change=(-)13.1%		Total change=(+)14.8%		Total change=(-)0.1%		

Table- V: Statistical Summary of NDVI in Winter (left) and Summer (right)

Winter				
Year	Min NDVI	Max NDVI	Mean NDVI	STD
1989	-0.21	0.4	0.16	0.12
1999	-0.08	0.47	0.17	0.13
2009	-0.07	0.32	0.1	0.08
2019	-0.04	0.33	0.13	0.07

Summer				
Year	Min NDVI	Max NDVI	Mean NDVI	STD
1993	-0.25	0.57	0.3	0.15
1998	-0.17	0.64	0.31	0.15
2011	-0.09	0.58	0.39	0.1
2019	-0.07	0.48	0.3	0.07

where Min = minimum, Max = maximum, Mean = Average value and STD = standard deviation.

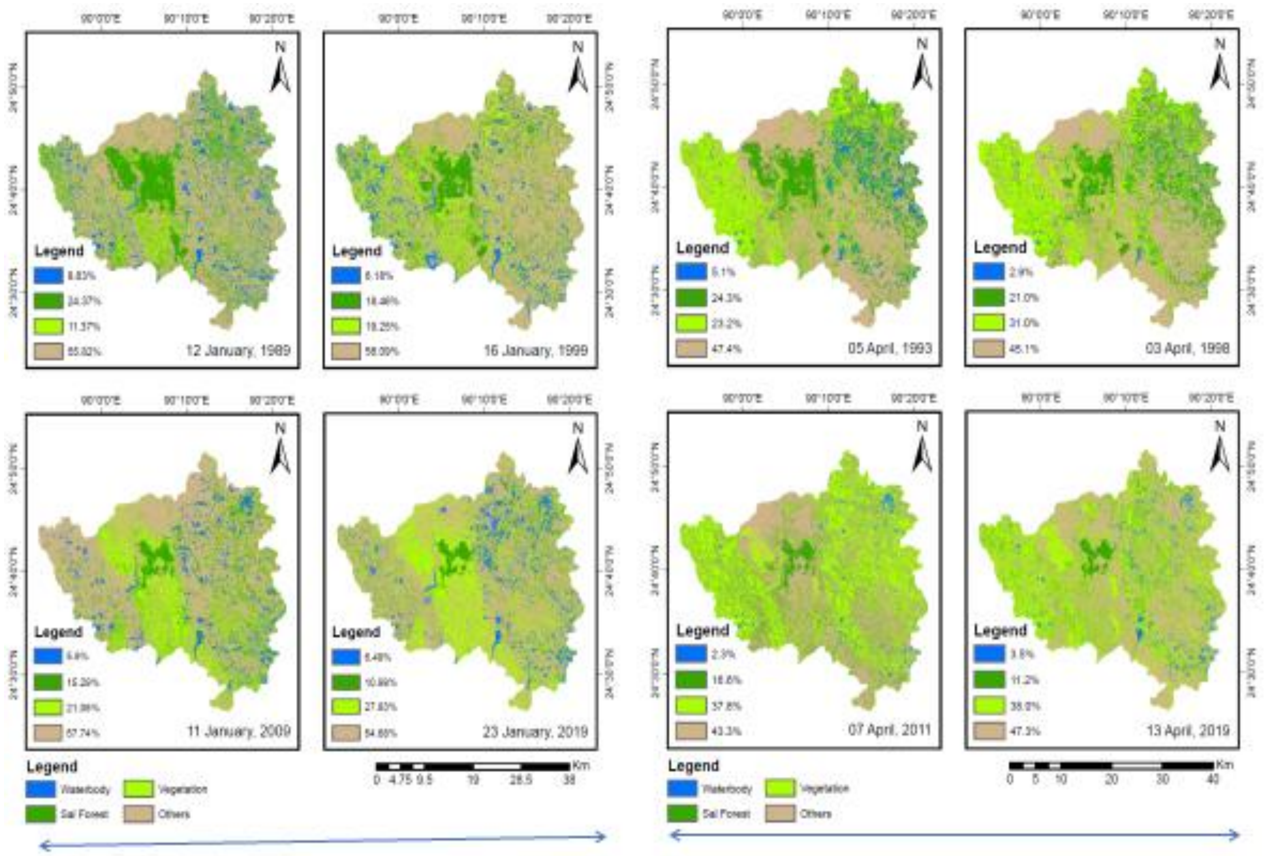


Fig. 3. Spatio-Temporal Pattern of LULC Change in Winter (left) and Summer (right).

A. LULC Change and Its Assessment

After preprocessing, the remote sensing data was classified to investigate changes happened in the past thirty years. In this study, LULC of Modhupur Sal forest and its adjoining areas was classified into four main classes (Table II). Landsat images were analyzed for the two seasons - winter (January) and summer (April). Table III shows the statistical summary of LULC dynamics of Modhupur Sal forest and its surrounding areas and the percentage (%) of changes in LULC in winter. Figure 3 shows the spatio-temporal pattern of LULC of study area over the period of study. From the multispectral response characteristics, it was observed that there was a very little area of waterbody in the study area. Waterbody covered 8.4%

Table- VI: NDVI Values for Different LULC Types in Winter (left) and Summer (right)

Winter				
Year	Mean value of NDVI			
	Waterbody	Sal Forest	Vegetation	Others
1989	-0.07	0.24	0.20	0.09
1999	-0.04	0.29	0.30	0.12
2009	-0.05	0.15	0.21	0.06
2019	-0.02	0.11	0.14	0.17

Summer				
Year	Mean value of NDVI			
	Waterbody	Sal Forest	Vegetation	Others
1993	-0.13	0.32	0.44	0.17
1998	-0.08	0.26	0.36	0.15
2011	-0.02	0.41	0.48	0.14
2019	-0.02	0.31	0.30	0.11

Table VII: Mean LST (°C) for each type of LULC in Winter (left) and Summer (right)

LULC	Mean value of LST (°C)			
	1989	1999	2009	2019
Waterbody	16.64	18.1	18.16	21.09
Sal Forest	16.12	17.06	18.02	21.24
Vegetation	16.43	17.67	17.89	19.81
Others	17.45	19.22	19.81	22.2

LULC	Mean value of LST in °C			
	1993	1998	2011	2019
Waterbody	26	26.55	26.21	29.45
Sal Forest	28.34	26.67	26.81	29.66
Vegetation	26.2	26.2	25.31	30.77
Others	30.25	29.94	27.44	30.58

Table VIII: Statistical Summary of LST (°C) value in Winter (left) and Summer (right)

Winter				
Year	Min LST	Max LST	Mean LST	STD
1989	14.1	19.2	16.9	1.02
1999	14.8	22.8	18.5	1.52
2009	16.7	22.5	18.7	1.05
2019	19.6	25.6	22	0.91

Summer				
Years	Min LST	Max LST	Mean LST	STD
1993	21	34.99	27.99	2.89
1998	21.4	32.2	26.8	2.02
2011	23.8	34.5	29.2	1.85
2019	26.4	35.6	30.5	1.23

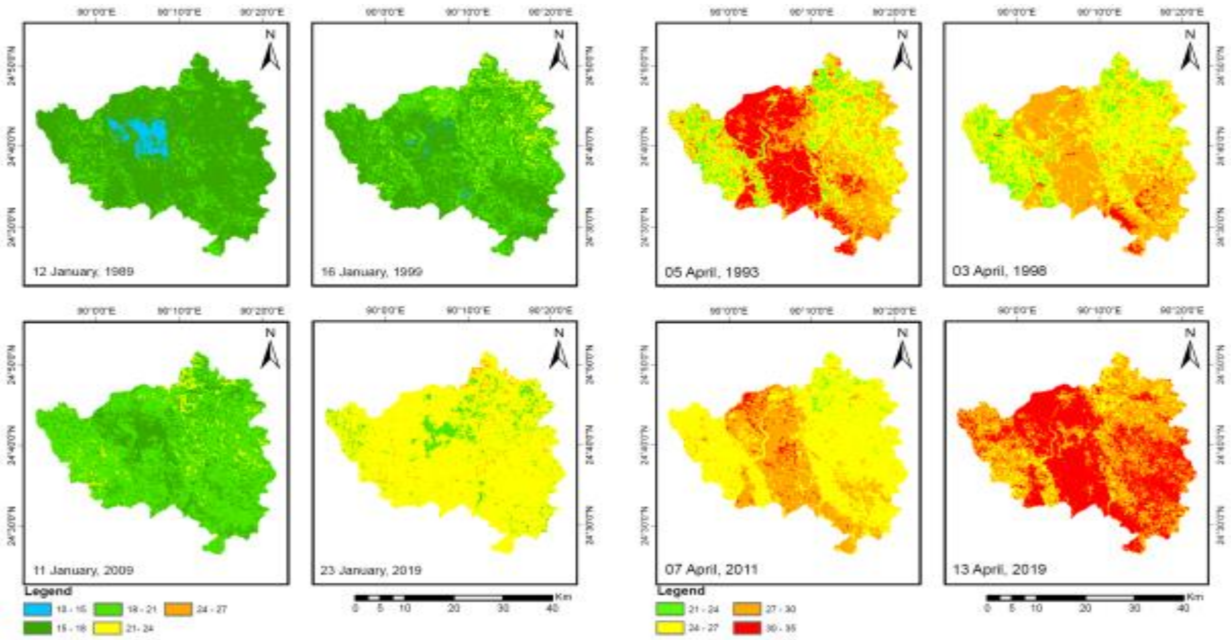
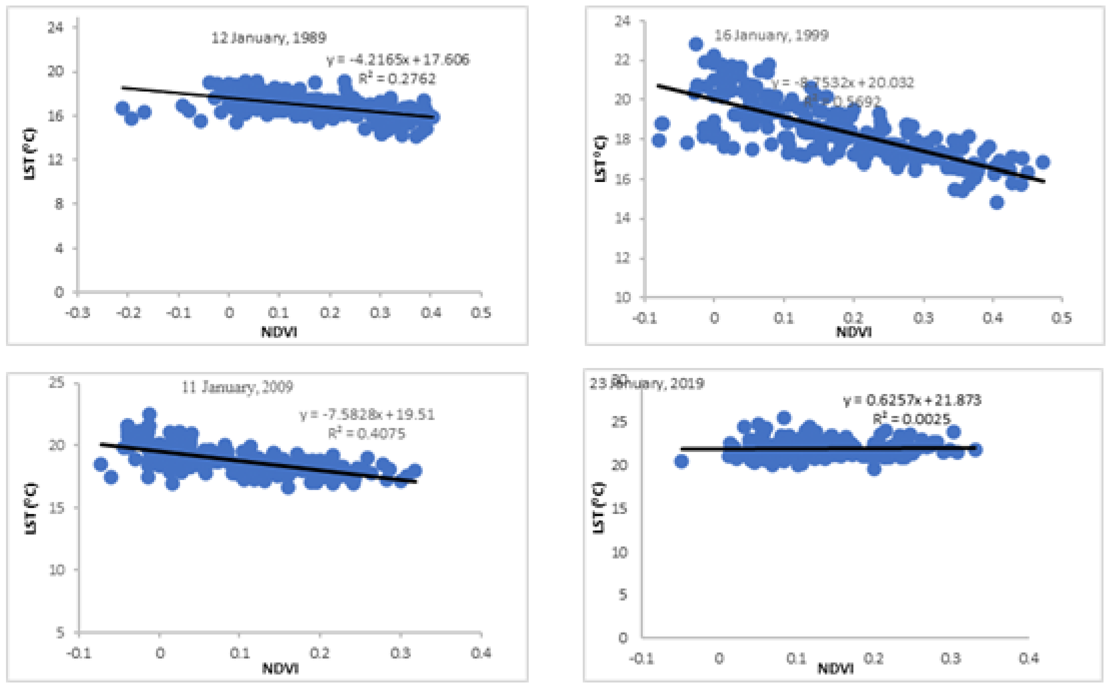
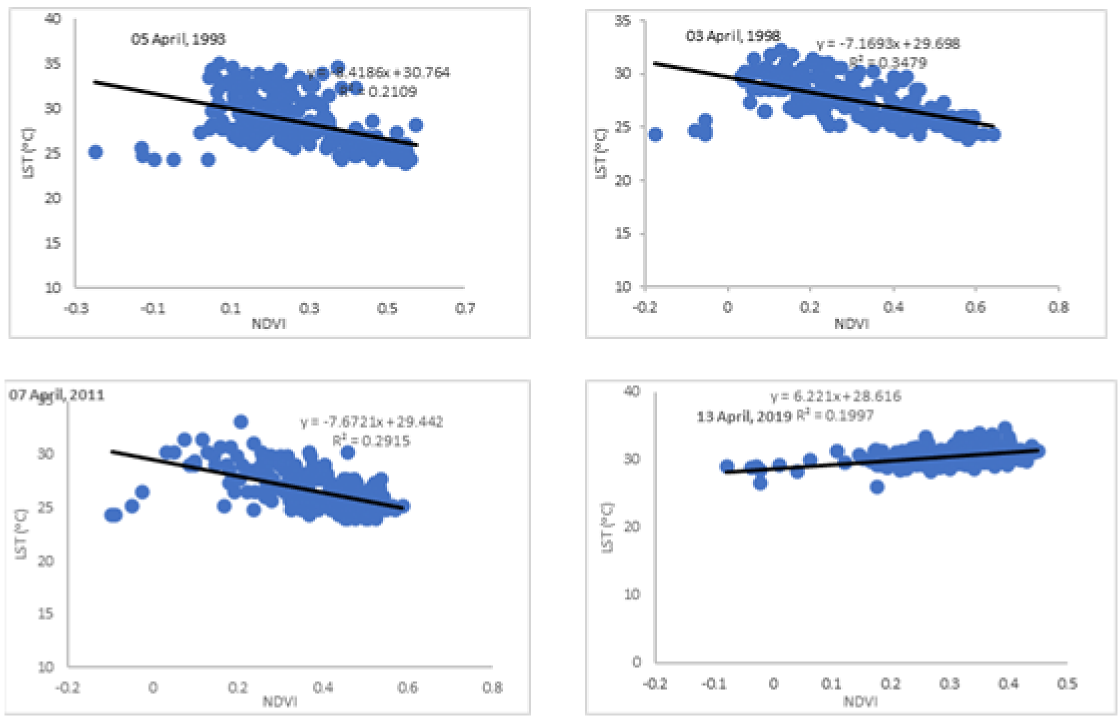


Fig. 4. Spatio-Temporal Pattern of LST in Winter (left) and Summer (Right).



(a) Winter



(b) Summer

Fig. 5. Correlation Between the Pattern of NDVI and LST for (a) Winter and (b) Summer.

of the study area in 1989 and it reduces to 6.5% in 2019. Sal forest area was 30049.9 hectors in 1989 and reduced to 13543.4 hectors in the year 2019.

There were 14016.7 hectors of other vegetation area that was 11.4% of the total area in 1989. In the year 2019 this area was increased to 34321.5 hectors that was 27.8% of the total area in 2019. Little change was observed in the other areas. As April is the hottest month in Bangladesh, we have chosen the Landsat images of April (1993 – 2019) for understanding the effect in summer. From the results it was observed that Sal forest area remains same as winter. The vegetation area was seen to increase from 23.2% to 38% during three decades in the summer period. Other area remains almost same that covered about 47% of total area.

The reason of increasing vegetative area may due to natural Sal forest has been replaced by other forest type like-rubber plants, wood plants and crop cultivation [15]. Also, in the winter in Bangladesh, many fields remain fallow that comes under cultivation in summer. The increased level of vegetation in summer period may be the outcome of this seasonal crop pattern especially in the high lands.

Retrieval Number:100.1/ijee.A18410531123
DOI: 10.54105/ijee.A1841.053123
Journal Website: www.ijee.latticescipub.com

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B. NDVI Dynamics with LULC Types

NDVI values are important to identify the thickness or health of vegetation. The NDVI values generally varies between -1.0 to +1.0. In the study area, the values above 0.3 were indicated as healthy vegetated category and the value between 0.02 to 0.03 were categorized as less healthy vegetated area. The values below 0 were waterbody, between 0.01 and 0.10 was non-vegetated area, and between 0.10 to 0.20 for poorly vegetated area.

The NDVI values were retrieved from the Landsat data of the Modhupur Sal forest and its adjoining areas. Table V and Table VI show the statistical summary of NDVI and NDVI values for different LULC types respectively. From the tables it was seen that NDVI values were in the range of -0.21 to 0.40, -0.08 to 0.47, -0.07 to 0.32 and -0.04 to 0.33 in 1989, 1999, 2009 and 2019, respectively in winter. Average values of NDVI in the respective years were 0.16, 0.17, 0.10 and 0.13. The average NDVI values in summer were 0.30, 0.31, 0.39 and 0.29 in 1993, 1998, 2011 and 2019, respectively. Thickness of vegetation as well as NDVI values was seen to decrease from 1989 to 2019. In summer, a higher level of NDVI was noted. As April, in Bangladesh, is just the end of Spring and starting of Summer, trees take new leaves and all agriculture fields remain full with growing crops, this may be caused that NDVI value in summer is higher than in winter.

C. LST vs LULC Change

Analysis of LST variations with LULC: Vegetative lands absorb adequate amount of heat through transpiration and release low radiations resulted in the decrease in surface radiant temperature. The topography and surface types of the study area exhibited noticeable differences in the LST values. Table VII shows the mean temperature of different LULC type and Table VIII presents the maximum, minimum and mean values of LST for the study period.

In this study, surface temperature shows an increasing trend during 1989 and 2019. Maximum, minimum and mean temperatures were seen to increase in both winter and summer. From Table VII it is seen that the mean surface temperature for each LULC types has increased. Yearly average increment of minimum, maximum and mean temperatures are about 0.18 ºC, 0.21 ºC and 0.17 ºC respectively in winter. In summer, the yearly average increment of minimum, maximum mean temperatures are about 0.18 ºC, 0.02 ºC and 0.08 ºC respectively.

Spatio-temporal pattern of LST is shown in Figure 4. Differences in temperature for different LULC types are clearly observed in the figure. The Modhupur Garh area has undergone a major deforestation or modification due to several causes [1, 2, 15, 36]. It is reported that the natural Sal forest area has decreased and become 75%, 64% and 31% in 1989, 2010 and 2015 respectively from its original extent in 1972. The increment of surface temperature of that region may be the sequel of this deforestation or modification of the area.

Correlation between the pattern of NDVI and LST: Due to different human induced reasons the natural forest is replaced by other types of vegetation. This transformation of forest area actually did not make any important NDVI shift of the Sal area. However, the LULC of the area has changed significantly and from the NDVI it has been seen that the thickness of vegetation has been decreasing in the other vegetated areas. Therefore, the mean NDVI for both in winter and summer has decreased for each LULC types. The relationship between NDVI and LST of the study area has shown in figure 5 for winter and summer.

From the NDVI versus LST graph, it is seen that there was negative relationship in 1989, 1999, 2009 and 2019 in winter. This means that the higher the NDVI value the lower the LST of the study area. From the scattered plots of NDVI and LST it is found that NDVI has a negative correlation with LST in summer in 1993, 1998 and 2011. And in 2019 relationship between NDVI and LST has reversed. From 1993 to 2011, the LST decreases with increase in NDVI and in 2019, though the vegetated areas have been increased, LST has increased.

V. CONCLUSIONS

The study reveals the drastic changes in land use land cover in the study area. Surface energy budget of the study experienced modification considerably in response to large scale LULC changes. One of the distinct LST changes was observed in the Sal forest areas where unprecedented damage is happened. Another important change was observed in the vegetation areas as the encroachment or other modification. From the study, a negative relationship was found between NDVI and LST from 1989 to 2009 in winter and 1993 to 2011 in summer. But, in 2019 an inverse correlation between NDVI and LST was observed. More study is needed to reveal this shifting. Alteration of LULC by humans has a negative impact on climate and socio-economic dynamics on a global and local scale. Although Modhupur Sal forest area is a comparatively small region, however, studying LULC changes at regional scales may be important for assessing LST in larger scales.

ACKNOWLEDGMENT

This work has been done in the Laboratory of SPARRSO, Agargaon, Dhaka. We are grateful to the SPARRSO authority for providing Laboratory facilities to perform the research work over there.

DECLARATION

Funding/ Grants/ Financial Support	No, we did not receive.
Conflicts of Interest/ Competing Interests	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	These imageries were obtained from the United States Geological Survey website(http://earthexplorer.usgs.gov).
Authors Contributions	Mst. Ashrafunnahar Hena has done the experimental work, Dr. Hafizur Rahmanor made the research plan and guided the Mst. Ashrafunnahar Hena in executing the experimental works, Dr. Shahjahan guided the first author in data processing, data analysis and prepared the manuscript.

Retrieval Number:100.1/ijee.A1841053123
DOI: 10.54105/ijee.A1841.053123
Journal Website: www.ijee.latticescipub.com

Published By:
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AUTHORS PROFILE

Mst. Ashrafunnahar Hena has been serving as an Assistant Professor in the department of Electrical and Electronic Engineering at Islamic University, Bangladesh. She received her M.Sc. degree from the same department in 2007.

Dr. Hafizur Rahmanor was a chief scientific officer and member of Bangladesh Space Research and Remote Sensing Organization, Bangladesh. He received M.Sc. degree in Applied Physics and Electronics from Rajshahi University, Bangladesh, and PhD from Universite de Paul Savatier, Toulouse, France in 1992.

Dr. Shahjahan Ali has been serving as a professor in the Department of Electrical and Electronic Engineering at Islamic University, Bangladesh. He received M.Sc. degree in Applied Physics and Electronics from Rajshahi University, Bangladesh in 1993 and PhD in Engineering and Technology from Dhaka University, Bangladesh in 2011.

Retrieval Number:100.1/ijee.A1841053123
DOI: 10.54105/ijee.A1841.053123
Journal Website: www.ijee.latticescipub.com

Published By:
Lattice Science Publication (LSP)