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RESEARCH ARTICLE

A SPATIO-TEMPORAL ANALYSIS OF LAND SURFACE TEMPERATURE (LST) IN BANKURA DISTRICT, WEST BENGAL (INDIA) USING LANDSAT IMAGES

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ABSTRACT

The Land Surface Temperature (LST) is reffered as the radiative skin temperature of ground. It depends on the albedo, soil moisture and vegetation covers. Land Surface Temperature (LST) is one of the key variables in climatological and environmental studies. Many scientists want to measure land's temperature for many important reasons e.g. in places where it is too cold or too hot food crops may die. Temperature also influences weather and climatic characteristics of a region. So, mapping the temperature of Earth's land is helpful for scientists as well as the planers to better understand our world. Due to complexity of landscapes the sampling was difficult to derive LST and environmental response relationships. The temporal data acquired through space borne remote sensors has bridged the gap of temporal data for the entire earth surface. In this study the general trend in the LST of Bankura district is trying to establish since 1991. Besides, the spatial characteristics of LST also denoted.

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INTRODUCTION

Land tunes song more preciously song of life (Das, 2015). Surface Temperature of Land is an important climate variable, related to surface energy balance and the integrated thermal state of the atmosphere within the planetary boundary layer (Jin, 1996). Traditionally, air temperature of the land surface was referred as Land Surface Temperature (LST), which was measured by a sheltered thermometer 1.5–3.5 m above a flat grassy, open and airy surface. With satellite technology, another type of LST, satellite-based surface temperature called skin temperature, is becoming available globally (Dickinson 1994). Satellite LST products provide an estimate of the kinetic temperature of the earth's surface skin (Norman & Becker, 1995). Skin temperature is inferred from the thermal emission of the earth surface and is generally some average effective radiative temperature of various canopy and soil surfaces (Hall *et al*., 1992; Betts *et al*., 1996). Intergovernmental Panel on Climate Change (IPCC, Houghton *et al*., 2001) and National Research Council (NRC, 2000) pointed out the urgent need for long-term remote sensing–based land surface skin temperature (LST) data in global warming studies.

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So LST is a key variable in climatological and environmental studies. Matsui *et al* (Matsui, 2002) found that there is relationship between LST and rainfall variability in the North American Monsoon. Skin temperature of land can be used to monitor vegetation water stress, assessing surface energy balance, detecting land surface disturbance, and monitoring condition suitability for insect–vector disease proliferation, among other uses (Pinheiro, 2006). In this connection the Landsat programme is the longest running project for collecting the imagery of the earth from space. The Landsat imagery that acquired millions of images is a unique resource for global change research and applications in agriculture, geography, geology, forestry, regional planning, education and environment. In this study I have tried to monitor the temporal trends as well as spatial characteristics of Land Surface Temperature of Bankura district, West Bengal (India) using Landsat images and Geographic Information System (GIS).

Study Area

Bankura district is one of the largest districts in W.B. carrying 6925.01 Sq km of geographical area and it is located in the western part of West Bengal in India. It is a part of Bardhaman Division of the State and included in the area known as "Rarh" in Bengal.

It ranks 4th according to Population and literacy rate of 2001 Census in the State. The District Bankura is bounded by latitude $22^0 38'$ -$23^0 38'$N and longitude $86^0 36'$ E to $87^0 47'$ E. River Demodar flows along the northern boundary of the district. The adjacent districts are Bardhaman in the north, Purulia in the west, Paschim Medinapure in the south and Hooghly in the south-east direction. The Survey of India (SOI) toposheets covering the districts are 73I, 73J, 73M and 73N (Fig.1).

Geographical Characteristics of Study Area

Bankura district has been described as the "connecting link between the plains of Bengal on the east and Chotanagpur plateau on the west." The areas to the east and north-east are low lying alluvial plains, similar to predominating rice lands of Bengal. To the west the surface gradually rises, giving way to undulating country, interspersed with rocky hillocks.

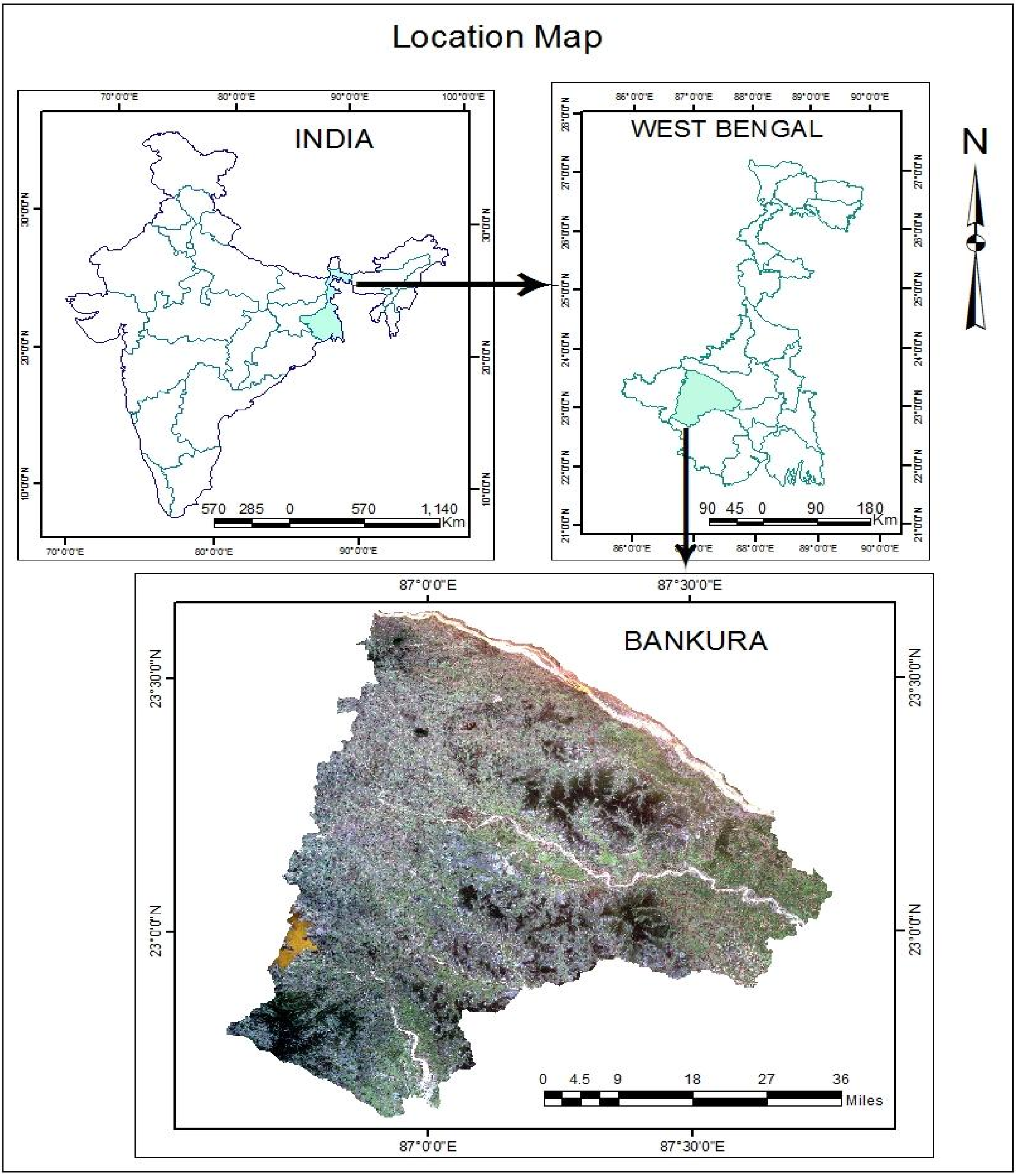

Fig. 1. Location map of Study Area

Much of the country is covered with jungles, having main concentration of *Sal, Teak* and *Mahua*. The lateritic terrain of this area is overlaid on Tertiary sedimentaries and it is a type of low level secondary laterites and detrital origin drifted from western plateau after Pleistocene Ice Age (Prakasam and Biswas, 2009). Bankura has a great historical as well as cultural back ground; it was ruled under the Gupta period by local Hindu kings who paid tribute to Samudra Gupta. The land is also called Mallabhum after the Malla rulers of this place who built the famous terracotta temples during the 17th and 18th century at this place. The terracotta temples here are the best specimen of the classical style of Bengal architecture (Wikipedia). The important rivers are Dwarkeswar, the Kasai, Silai, Sali, Damodar etc. The optimum physical environment of this area is responsible for dense forest growth which is distinct characteristic on Bankura district.

MATERIALS AND METHODS

In the present study the surface temperature measurement of land in Bankura district was carried out with the help of Landsat images which collected from the website of Earth Resources Observation & Science Center (EROS) where as the administrative map are collected from National Atlas & Thematic Mapping Organization (NATMO), Kolkata.

Table 1. Details of the Satellite data that are used in the study

S. No.	Satellite	Sensor	Path	Row	Bands	Date of acquisition	Cloud Cover (%)
1	Landsat	TM	139	44	3,4,6	30/04/91	0
2	Landsat	TM	139	44	3,4,6	01/04/04	0
3	Landsat	OLI/ TIRS	139	44	4,5,10,11	29/04/14	0

Derivation of LST from Landsat Images

The above mention data are used in the study. All the work has been done in GIS environment (ArcGIS10). To achieve the goal I used following algorithms. At fast NDVI (Normalized Difference Vegetation Index) is calculated using Near-Infrared (NIR) band and red band. The algorithm stands as-

NDVI = (NIR – Red) / (NIR + Red)

Next the DN value of thermal bands that is band-6 in case of Landsat TM and band-11/12 for Landsat OLI/TIRS are converted into TOA radiance using following algorithm-

$$\mathbf{L_\lambda = M_{L*}Q_{cal} + A}$$

Where,

L_λ = TOA spectral radiance (Watts/(m2 * srad * µm))
M_L = Band-specific multiplicative rescaling factor from the metadata RADIANCE_MULT_ BAND_x, where x is the band number)
A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

In the next stage is conversion from TOA spectral radiance to brightness temperature (T) using following formula provided by USGS website-

$T=K2/[Ln\{(K1/ L_\lambda)+1\}]$

Where - T= At-satellite brightness temperature (K), L_λ=TOA spectral radiance (Watts/(m2 * srad * µm)), K_1= Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the band number, 10 or 11), K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the band number, 10 or 11).

Here the output is in Kelvin unit I converted it into degree centigrade by sub ducting 272.15. Then in case of Landsat OLI/TIRS I made average of calculated brightness temperature of Band 10 and band 11 with the help of cell statistics in Arc-Toolbox.

The land surface temperatures (LST) were computed as follows (Artis & Carnahan, 1982):

BT/{1+w*(BT/p)*Ln(e)}

Where BT= At satellite Temperature, w= wavelength of emitted radiance (11.5 Am), q = h*c/j (1.438_10_ 2 m K), j = Boltzmann constant ($1.38*10^{-23}$J/K), h = Planck's constant ($6.626*10^{-34}$ J s), and c = velocity of light ($2.998*10^8$ m/s).
e= Land Surface Emissivity

There is another important things before LST calculation i.e. calculation of Land Surface Emissivity (e). The following equation was used to calculate Land Surface Emissivity (e):
E=0.004*Pv +0.986

Pv is the Proportion of Vegetation that can be derived according to Carlson and Ripley (1997), using NDVI image equation below:

$Pv= [(NDVI-NDVImin)/(NDVImax-NDVImin)]^2$

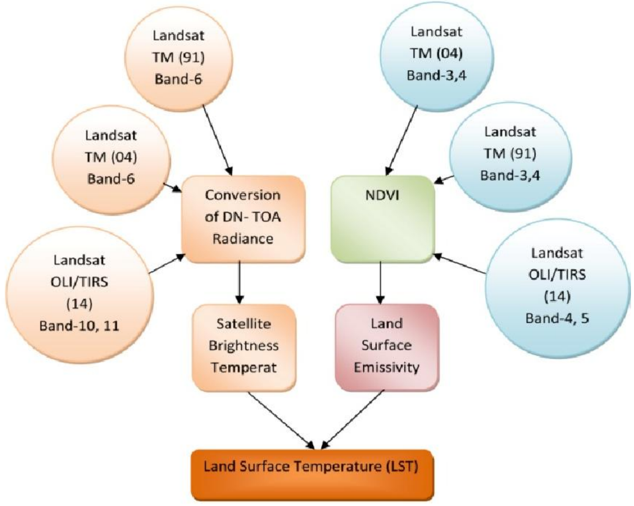

Figure 2. Method followed for LST analysis

RESULTS AND DISCUSSION

Following the above stated methodology the LST map of Bankura district is prepared in different time (1991, 2004, 2014) (Fig-3).

Land Surface Temperature is enumerated at landscape level for both Landsat TM and OLI/TIRS thermal bands as elucidated earlier. The minimum and maximum temperature from Landsat TM data and OLI/TIRS data are given in Table 2. Figure-3 shows the LST map of Bankura district from 1991, 2004 and 2014

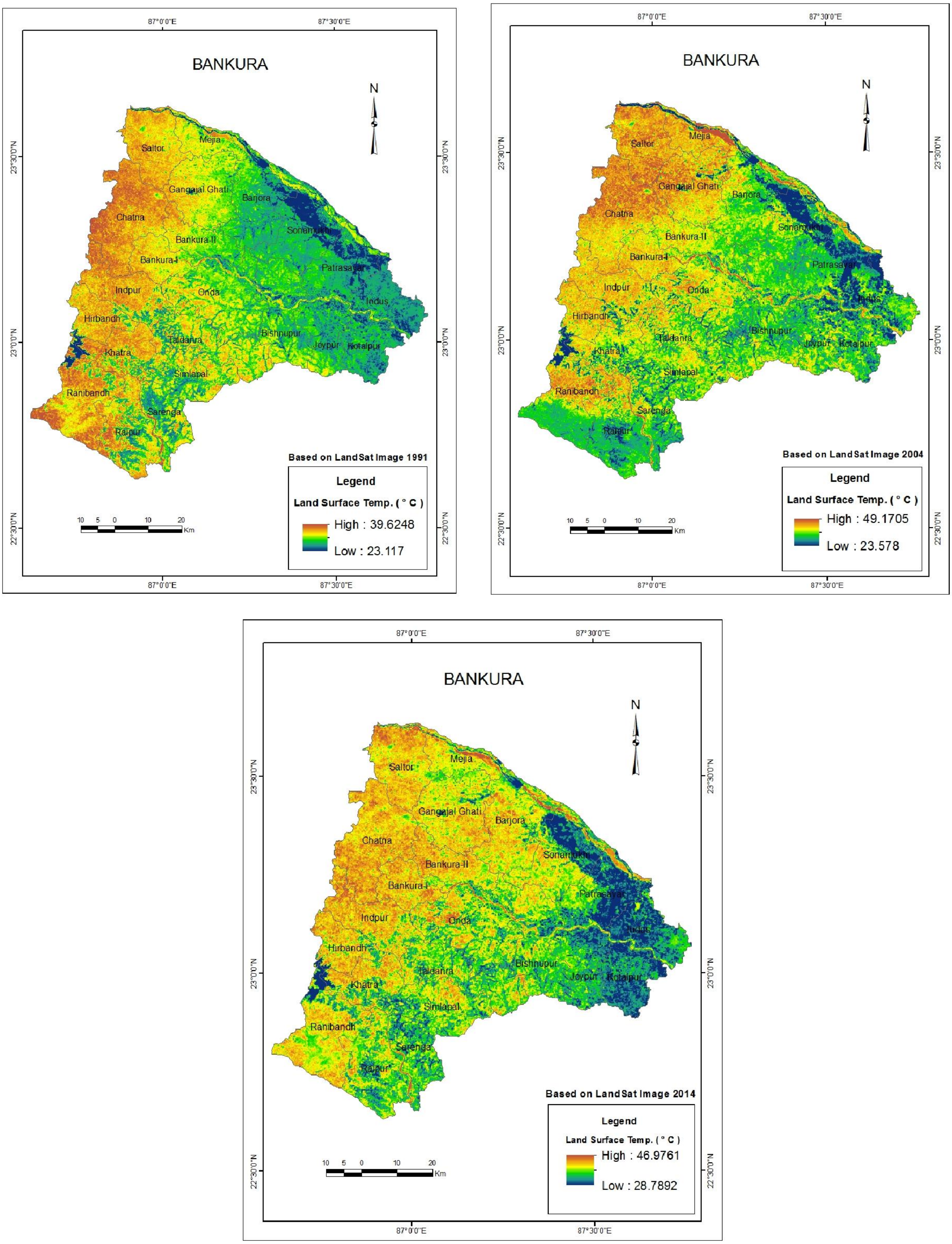

Fig. 3. LST from 1991 to 2014

Table 2. LST Analysis

Year	Min (°C)	Max (°C)	Range of Temperature (°C)	Average Temperature (°C)
1991	23.12	39.62	16.5	31.37
2004	23.58	49.17	25.59	36.38
2014	28.79	46.98	18.19	37.89

The higher temperature can be seen especially in western part of the district mainly the undulating plain area due to higher proportion of barren land in both pictures. The south-eastern part is still maintaining relatively lower surface temperatures. The region's maximum temperature has increased from 39.62°C to 49.17°C in between 1991 and2004; which may be the most eye catching things but another important thing is that the temperature has decreased from 49.17°C to 46.98°C in between 2004 and 2014. Minimum temperature increases with time and the rate become too high from 2004 to 2014. The range of temperature is fluctuating with time. The average temperature shows the most vulnerable picture. Average temperature increases 6.5°C from 1991 to 2014. The cause may be anthropogenic or effect of global warming. The picture will be cleared by consulting Table 2 as well as Fig. 3 and Fig. 4.

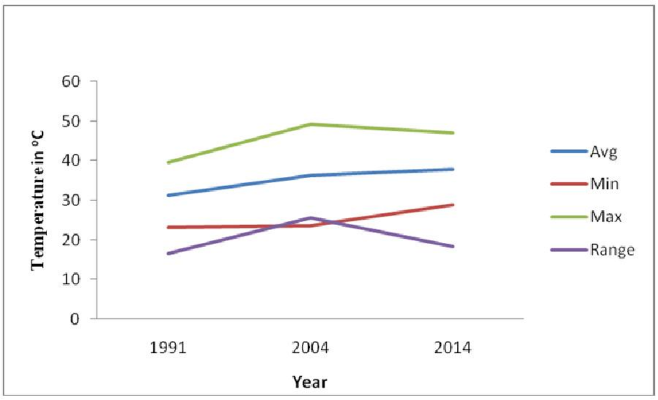

Fig.4. Trands of LST

The trends of spatial characteristics of LST shows that Barjora, Bankura-II, southern portion of Gangajalghati and Sonamukhi, south-western part of Patrasayar Block experience remarkable increase of LST. On the other hands LST decreased in some block namely Indus, Kotalpu, and north-eastern part of patrasayar. Southern portion of Ranibandh and Raipur experienced decrease of LST in the year of 2004.

Conclusion

Remote sensing based LST are determined from thermal emission at wavelengths in Infrared band. In the research the potential of remote sensing to study the Land Surface Temperature (LST) in Bankura Disrict, West Bengal is presented by estimating the spatial distribution and intensities of geo-physical parameters. The study has related to the changing characteristics of land surface temperature at a temporal as well as spatial scale. The picture arise from the study indicates that there is an increase of average land surface temperature from 31.37°C to 37.89°C over 23 years. Although Census of India (2011) shows that the total forest cover of Bankura is increased (125851.68 to 143040 hectare) in between 2001 and 2011 that means the temperature should not likely. I think more research needed in these fields. But it is hurtfully true that if these changes are not addressed then there will be future drought to be occurring under warmer temperature conditions as climate change progresses, which will enhance the potential extent of drought-induced vegetation die-off and the effect will also keep it hands on agricultural sector.

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