Change Detection of Surface Temperature and its Consequence Using Multi-Temporal Remote Sensing Data and GIS Application to Tapi Basin of India.

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Abstract — The LANDSAT- TM Band-6 raw data is converted to black body temperature in degree Celsius by using IDRISI software model. Recent two decade data is used for detection of surface temperature change during 1990- 2010 to estimate increase rate of increase in temperature to understand the intensity of Global warming in the present and previous decades. It is evident that surface temperature of Tapi Basin in the Central part of India increased from 41.6 °C in May 1990 to 44.1 °C in May 2010.This fact proves the intensity of Global warming. The spatio-temporal change is also detected to classify the basin in micro-thermal zones. Recently, Tapi basin facing several problems attributed to this temperature change in river channel as well as in basin area. The prominent channel change is aggradations. Aggradations lead to the decreases of channel capacity causing high floods even in low to moderate rainfall. The basin is facing problem of depletion of water level in channel as well as water table and salinization of basin soil due to accelerated rate of evaporation with increase of the temperature. The Tapi basin is situated in core part of India. It extents between 20° 4' 33.2574" N to 22° 1' 3.2556" N lat and 72° 38' 11.8752" E to 78° 16' 41.865" E log and covers 65145 sq.km area with 724 km. east-west length of basin .The basin is underlined Deccan trap formations and comes under the tropical monsoon regime

Keywords — change Detection, GIS, Global Warming, Land surface Temperature, Remote Sensing

1 INTRODUCTION

The spatio- temporal Land surface temperature change detection in response to climatic change can be analyzed through hydrological regime in hydro-geomorphic physical entity like river basin, which could be affected by climatic variations in recent decades and may be resulted from the global warming. The hydrological regime covers the changing condition of water and sediment discharge positions in river channel as well as basin area. The prominent channel change is aggradations. Aggradations lead to the decreases of channel capacity causing high floods even in low to moderate rainfall. The basin also face the problems of depletion of water level in channel as well as water table and salinization of basin soil due to accelerated rate of evaporation with increase of the temperature This sort of change can be detected, monitored and predicted using GIS with renewed satellite information from remote sensing data .The remote sensing data is compared with 60 year(1950-2010) average recorded data.

This study is an attempt to use a GIS and Remote sensing Technique to approach change detection of Land surface temperature and its consequence using Multi-Temporal Remote Sensing (MTRS) Data and GIS application to Tapi Basin of India. Since the Tapi basin is one of the major river basin in the central part of India facing all above problems associated with change in temperature in response to global warming. The scope of this paper is confined to the following objectives only .The analysis of hydrological regime will be beyond scope of this paper.

2 STUDY AREA

Tapi is a centrally located basin forms graben between Satpura Mountain to the north and Anjanata–Satmala offshoot hills Of Western Ghat to the South. It extents between 20° 4' 33.2574" N to 22° 1' 3.2556" N lat and 72° 38' 11.8752" E to 78° 16' 41.865" E log. and covers 65145 sq..km area with 724 km. east-west length of basin. The basin is underlined Deccan trap formations of Eocene with extensive recent alluvial formation and comes under the tropical monsoon deciduous bioclimatic regime.

3 OBJECTIVES

1 To understand the overall temperature condition of Tapi Basin from recorded data

2 Estimation of Land Surface Temperature from Landsat TM Band 6 Data for Year 1990 and 2010.

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3 Land Surface Temperature change Detection in spatio-temporal context to understand Global Worming

4 METHODS AND DATA SOURCE

The raw data source is the USGS and NASA landsat TM band 6 imageries. The microcomputer based geographical information system is developed, mainly depending on information derived from remote sensing images from TM Satellite Band 6 during 1990-2010 as well as was geomorphic and environmental data available. The processes of the spatio- temporal surface temperature change detection of Tapi basin in response to climatic change associated with global warming is shown with quantitative evidence through spatial analysis function of GIS software IDRISI-Taiga and Arc GIS/Info 9.3.1. The following fig 1 flow chart explicates methodology of the present study.

Table 1 Landsat TM data Scene

Landsat Band	Year 1990		Year 2010	
	Path	Row	Path	Row
6	145	45	145	45
6	145	46	145	46
6	146	45	146	45
6	146	46	146	46
6	147	45	147	45
6	147	46	147	46
6	148	45	148	45

4.1 LST ANALYSIS: LST (Land Surface Temperature)

LST is derived from the following three processes.

4.1.1 Conversion from Digital Number to Radiance

All TM bands are quantified into 8-bit data. This digital data is stored in digital number (DN) which ranges between 0 and 255. The digital number is converted into cell value radiance CV_R using a linear equation as shown below:

$$CV_R = G\,(CV_{DN}) + B \qquad (1)$$

Where:
CV_R is the cell value as radiance
CV_{DN} is the cell value digital number
G is the gain (0.005632156 for TM)
B is the offset (0.1238 for TM)

4.1.2 Conversion from Radiance to Brightness Temperature

By applying the Planck's inverse function, thermal bands radiance values are converted to brightness temperature value by following formula.

$$T = \frac{K_2}{\ln\left(\frac{K_1}{CV_R} + 1\right)} \qquad (2)$$

Where:

T is degrees Kelvin
CV_R is the cell value as radiance
K_1 is calibration constant 1 (607.76 for TM))
K_2 is calibration constant 2 (1260.56 for TM)

4.1.3 LST Derivation

LST is derived from TM5 using model developed by Sobrino,et al (2004) and Jackson, et al (2004) for the use of spectral surface emmissivity and NDVI values of the particular scenes. The derivation of land surface temperature is as:

$$S_t = \frac{T}{1 + (\lambda \times T/\rho)\ln \varepsilon} \qquad (3)$$

Where,
S_t = LST
λ is wavelength of emitted radiance ($\lambda = 11.5$ µm),
$\rho = h \times c/\sigma$ (1.438×10^{-2} m K),
σ = Boltzman constant (1.38×10^{-23} J/K),
h = Planck's constant (6.626×10^{-34} J s), and
c = velocity of light (2.998×108 m/s)

Emissivity ε can be estimated by means of following equation considering the normalized vegetation difference index:

$$\varepsilon = f_v \varepsilon_v + (1 - f_v)\varepsilon_s \qquad (4)$$

Where εv and εs denote emissivity of vegetation and soil, while fv can be expressed as (Sobrino, et al (2004):

$$f_v = 1 - \left(\frac{NDVI_{max} - NDVI}{NDVI_{max} - NDVI_{min}} \right)^{\alpha} \qquad (5)$$

Where,
NDVI max = NDVI for complete vegetation cover,
NDVI min = NDVI for bare soil.
α = function of leaf orientation distribution with the canopy

After the atmospheric and radiometric calibration , the imageries were transferred into grid system and imported in to ARC GIS/Info 9.3.1 to gain LST derivation in each grid of pixel size 120Mx 120M using Grid Raster Calculator and finally surface temperature map yields. The estimated temperature difference map is prepared for the recent rise in temperature attributed to the global warming.

4.1.4 Land surface Temperature change detection

The LST data of year 1990 is deducted from LST data of year 2010 to obtain the land surface Temperature change detection mpa as shown in fig.12.for understanding the intensity of global warming in spatial context.

4.2 Recorded 60 years(1950 – 2010) temperature data analysis

The summer months(April and May) minimum, maximum and mean temperature maps prepared from 60 years (1950-2010) recorded data of various weather stations in Tapi Basin and near by areas by intorpolation method with ARCGIS software as shown in fig 3 – 8.The average annual temerature map also have been prepared for 60 years recorded data as shown in fig 9.These fig 2 -9 are compared with estimated Land surface temperature remote sensing data.

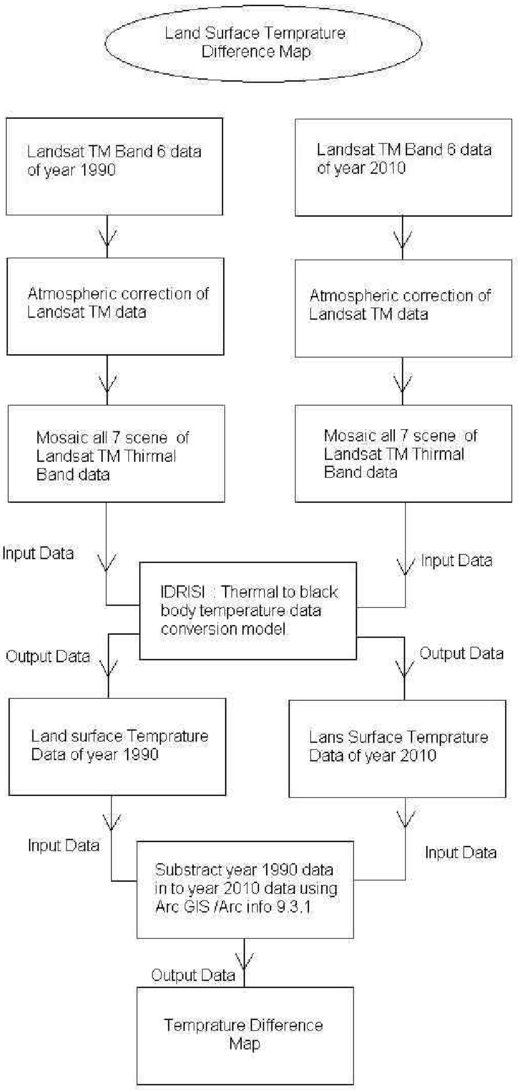

Fig 1 Methodology Flow Chart

5 RESULTS AND DISCUSSION

Table 2. Spatial Range of Average summer month temperature derived from the maps of 60 years recorded data during 1950-2010.

Months	Spatial Range of Temperature		
	Min Temp. .°C	Max. Temp °C	Mean Temp °C
April 60Year average)	17.4 – 25.3	31.6 – 41.1	24.5 – 32.7
May (60Year average)	19.1 – 28.2	32.0 – 42.7	25.6 – 35.4

The range of maximum ,minimum and mean temperature estimated from fig 3-8 as shown in table 2.

Table 3 The average of minimum, maximum and mean temperature derived from table 2

Months	Average of Spatial Range of Temperature		
	Min Temp °C	Max Temp °C	Mean Temp °C
April(60Year average)	21.35	36.35	28.6
May(60Year average)	23.65	37.35	30.5
Average of April & May	22.5	36.85	29.55

Average summer months minmum,maximum and mean temperature estimated from table 2.The average minmum,maximum and mean temperature is 22.5 °C,36.85 °C and 29.55 °C respectively for 60 years.

The average annual temperature of Tapi basin is shown in fig.9.This fig.9 indicates spatial range of average annual temperature of Tapi basin which ranges between 20.4 °C – 27.5 °C .This wide variation in average annual temperature is attributed the surface configuration landuse and antrhopogenetic activities. The average annual temperature of Tapi basin from recorded 60 year data(1950-2010) is 23.95 °C.

The LST for summer month in 1990 spatial ranges between 8.7 °C and 41.6 °C. The similar range of temperature in 2010 is 10.2 - 44.1 °C. The average LST of summer month for 1990 and 2010 is respectively 25.15 °C and 27.15 °C. The net rise LST from 1990 to 2010 is 2 °C. This increase in Land surface Temperature attributes Global Worming.

The average annual summer temperature for previous 60 years(1950-2010) recorded data is 23.95 °C .and average summer month Land surface temperature for previous two decades(1990-2010) from table4 is 25.65 °C. The net rise of temperature is 1.6 °C in previous sixty years. However, in the previous two decades remote sensing data in summer reveals the rise in temperature by 2 °C. This rate is certainly accelerated during previous two decades. This fact is certainly attributed to the global warming. There are several causes of global warming in Tapi Basin like deforestation, over exploitation of river and ground water, saline older alluvium aquifer characteristics and technogenic anthropogenesis. They all are responsible for increase in green house gases like CO2, CFC, SO2, NO2 and various salt accumulations due to high rate of evaporation in the soil.

Table 4 Estimated Land Surface Temperature & the rise of temperature estimated from fig 10 & 11

Land Surface Temperature (LST ° C)		Average LST °C		Average Temperature °C	Difference/ Rise in Temp. °C
Year 1990	Year 2010	Year 1990	Year 2010	1990 - 2010	1990 - 2010
8.7 – 41.6	10.2 – 44.1	25.15	27.15	25.65	2.0

5.1 Land Surface Temperature Change Detection in Spatial-Temporal Context during 1990-2010

Table 5 land surface temperature in a spatial context

LST Category for year 1990	Year 1990 (area in sq km.)	% Area	LST Category for year 2010	Year 2010 (area in sq km.)	% Area
Low (8.7-18 °C)	19087.51	29.3	Low (10.2-18 °C)	11454.06	17.58
Moderate(18-26.4 °C)	38480.27	59.06	Moderate(18-26.4 °C)	27788.85	42.65
High(26.4-34 °C)	6566.83	10.08	High(26.4-34 °C)	17288.94	25.53
Very High(34-41.6 °C)	1010.88	1.55	Very High(34-44.1 °C)	8613.65	13.22
Total Area	65145	100	Total Area	65145	100

The surface temperature was low to moderate in comparatively higher area in 1990 than in 2010.On the contrary very low area of Tapi basin experienced high and very high temperature in 1990. Conversely, comparatively higher area has experienced high and very high temperature in 2010. This fact clearly indicates increase in temperature in response to global warming in the spatio- temporal context. The table no.6 reveals the change in temperature with respect to the spatial extent.

Table 6 land surface temperature change detection in a spatial context

Temperature change (degree Celsius)	Area (sq.km)	% Area
-3 - -2	407.93	0.62
-2 - -1	7407.23	11.37
-1 - 0	24271.18	37.25
0 - 1	24814.50	38.09
1 - 2	7740.33	11.88
2 - 3	503.83	0.77

The Land surface change temperature detection map is prepared by subrastricting the LST data of 1990 from LST data of 2010.The Land surface change detection is obtained andshown in table 6.The range of LST change detection from 1990 to 2010 ranges between -3 and + 3.The minus value indicates decrease in LST.The Zero value indicates no change in LST and positive value indicates increase in LST in spatial context.

5.2 The Table 6 shows following key aspects

1. The hilly area of Satpura Mountain in middle Tapi basin and Western Ghat experience maximum positive LST change detection of temperature (Above +2 °C).It means that there is maximum rise in Land surface temperature.This is the most severly affected global worming area of Tapi basin.How ever it is relatively small area and severely affected by deforestations.The deforestation responsible for rise of CO_2 .Since the lack of natural vegetation .The vegetation absorbs CO_2 in the preparation of there own food during the photosynthesis and mentains the content of CO_2 in normal range.The CO_2 is one of the significant green house gas.The rise in temperature is attributed to increase of greenhouse gas CO_2
2. The water bodies in the basin cover comparatively small area and it shows minimum negative change detection of temperature.
3. The permanent irrigated area like orange tree plantation, banana plantations and vine yards have the surface temperature change detection in the range of -1 °C and -2 °C This area covers 11.37% of total basin area,
4. The existing forest area and some greenery patches of the basin have the surface temperature change detection in the range of -1 °C and 0 °C This area covers 37,25% of total basin area.
5. The dry farming area and seasonal irrigated area with saline tracts of the basin reveal the surface temperature change detection in the range of 0 °C and +1 °C This area covers 38.09 % of total basin area,
6. The urban and rural settlement areas and bare surfaces have the surface temperature change detection in the range of +1 °C and +2 °C. This area covers 11.88 % of total basin area. Recently building material of the house in rural area is also of cement concrete like urban areas. This region can be defined as concrete jungle in the global warming context. In summers this area is comparatively hotter than agricultural areas.

5.3 Major Consequences of Global Warming in Tapi Basin.

Considering dry summer months in which intensity of temperature is high and accumulated surface temperature responsible for accelerated rate of evaporation and transpiration. The water rises upward by osmotic pressure from beneath the water table and water table falls. .The raised water evaporates out and leaving salt accumulation in the surface soils. The summer irrigated crops also aids in accumulation of salts from direct evaporation of water. This problem of salinization especially found in alluvial soils middle Tapi basin. The deep older alluvium aquifer in this region is comparatively more saline The saline soils absorbs more heat than any other residual surface soils. This fact of Tapi basin is an added asset of the global warming. The major consequence of fall in water table and over exploitation of water for irrigation is drying up of Tapi river channel in summer. The overall global warming effect of rise in sea level reduces the energy head of the rivers. The consequent effect is the aggradations of channels and reduction of channel cross section area. This fact leads to increase in magnitude and frequency flood of floods in the river Tapi. The spill over water during the peak flood stage of high magnitude flood on the both side banks of river for a considerable distance and rebound water during falling stage of flood bellow bank discharge stage responsible for accelerated gully erosion on both the banks of river Tapi. The tremendous soil loss is experienced during high magnitude floods

6 CONCLUSION

This paper provides the methodology of determanation Land surface Temperature from Remote sensing data.The LANDSAT- TM Band-6 raw data is converted to Land surface temperature in degree Celsius by using IDRISI software model. Recent two decade data is used for detection of surface temperature change during 1990- 2010 to estimate increase rate of increase in temperature to understand the intensity of Global warming in the present and previous decades. The mean annual temperature for previous sixty year data is 23.95 ° C. The average estimated summer month's temperature from remote sensing data is 25.65 ° C. The net difference of rise of temperature is 1.6 ° C. However, in preceding two decades(1990-2010) the rise of temperature is 2 ° C It is evident that surface temperature of Tapi Basin in the Central part of India is increased by 2 ° C from 1990 to 2010. This fact certainly proves the increse in land surface temperature.

The basin can be classified in to micro thirmal zones on the basis of LST for 1990 and 2010.The land surface change detection is obtained from LST difference of two decades.This gives the nature of change normal increased and decreased in spatial context.The nagative values indicates the decrease in LST and positive value reveals increase in LST.The Zero value indicate no change in LST.The change detection in LST is low to moderate in comparatively higher area of Tapi basin in 1990 than in 2010.The very low area of Tapi basin experienced high and very high change detection in LST in 1990.The higher area have experienced high and very high temperature in 2010. This sort of spatio-temporal change detection is attributed to change in surface conditions by the anthropogenic activities like over irrigation, over exploitation of ground water from saline aquifers, deforestation, urbanizations and changing pattern of house types.

The immediate suggestion is of aforestation and maintenance of greenery not only in urban areas but also in rural settlements. The over irrigation strictly avoided and water conservation practices should be adopted. The saline water should be used after proper treatments. The emissions of greenhouse gases should be stopped by allmeans.

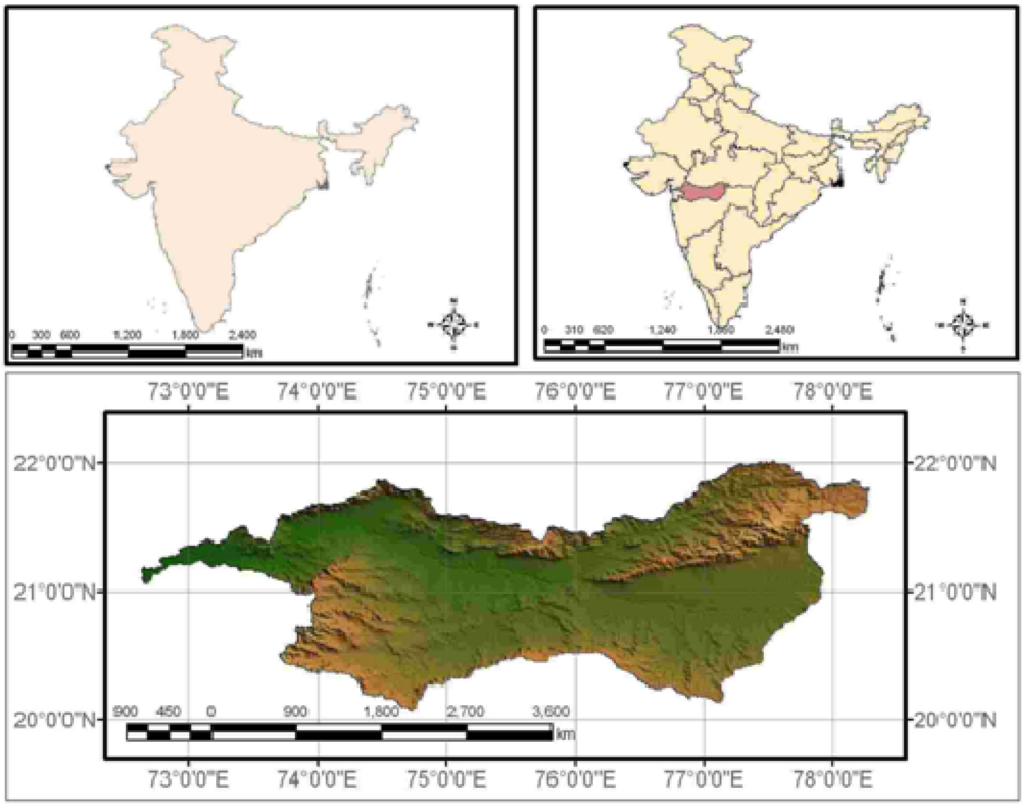

Fig. 2 Location Map of Tapi Basin

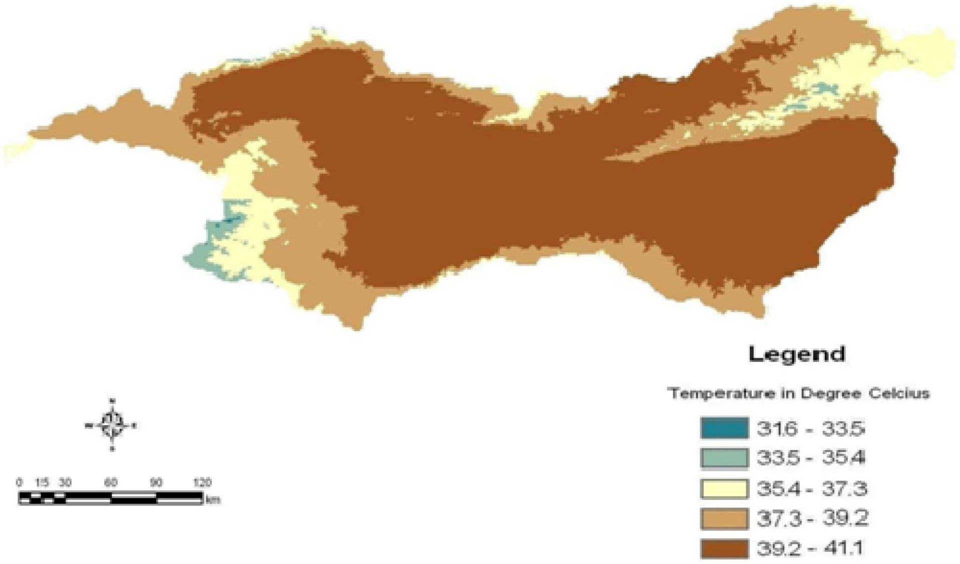

Fig. 3 Maximum Recorded Temperature in April (60 year Average 1950-2010)

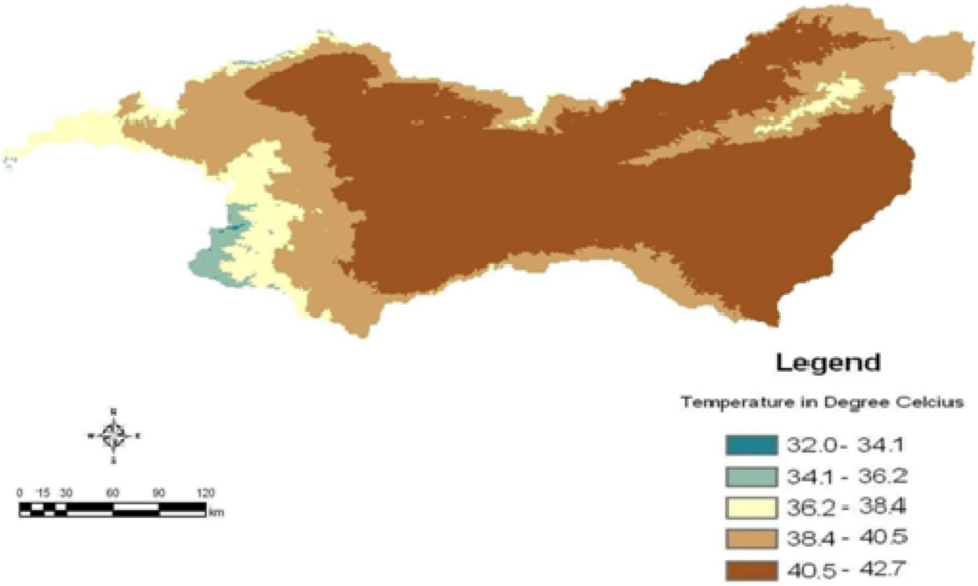

Fig. 4 Maximum Recorded Temperature in May (60 year Average 1950-2010)

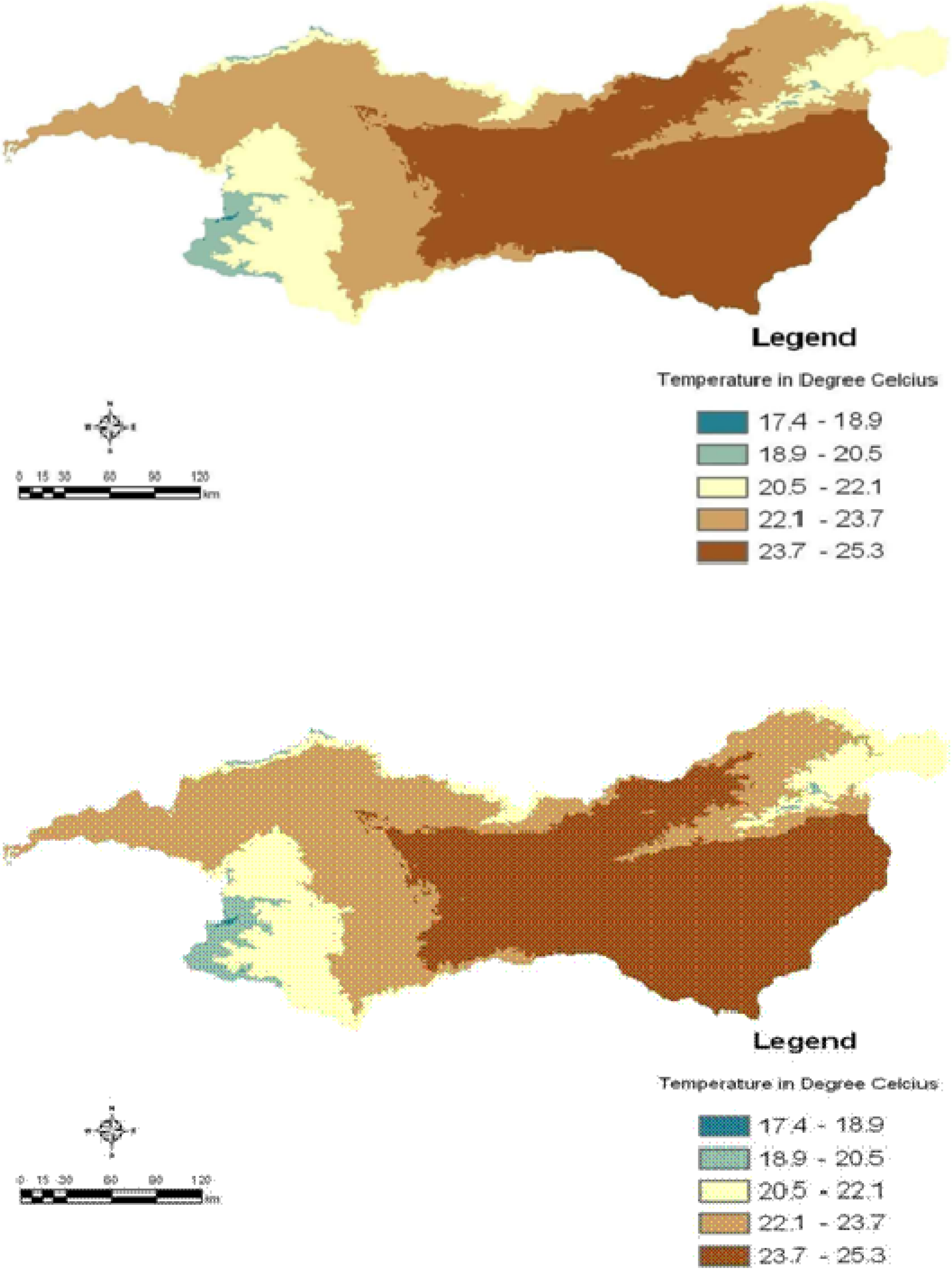

Fig. 5 Minimum Recorded Temperature in April (60 year Average 1950-2010)

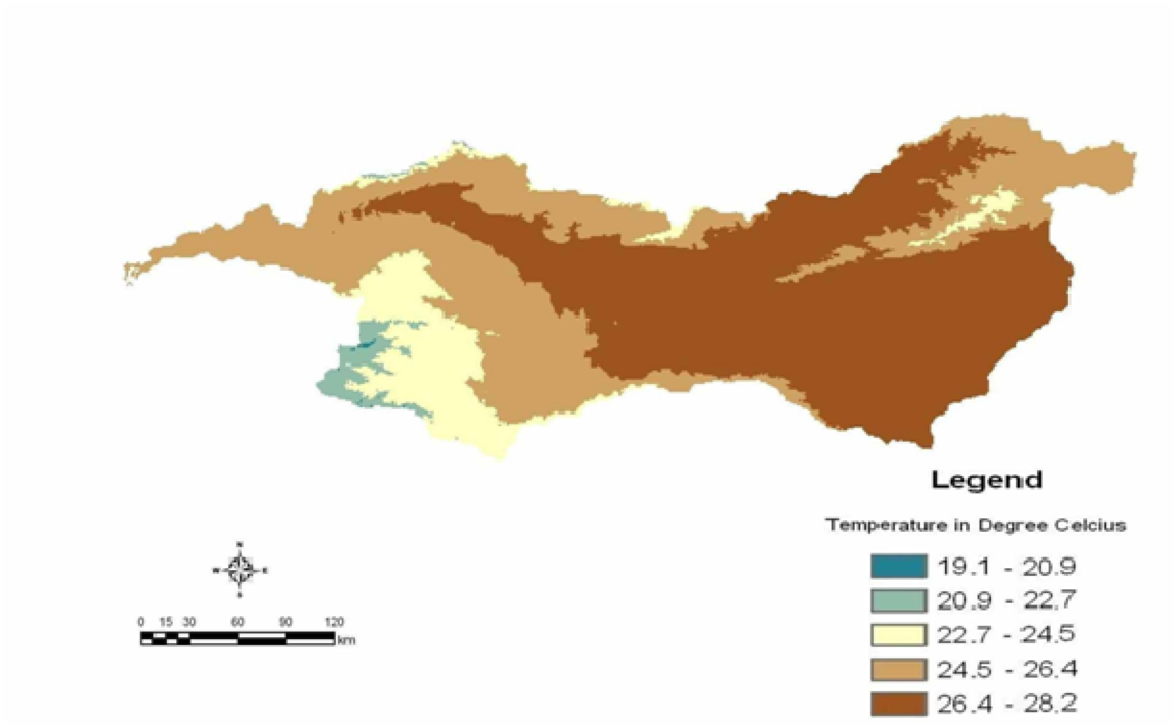

Fig. 6 Minimum Recorded Temperature in May (60 year Average 1950-2010)

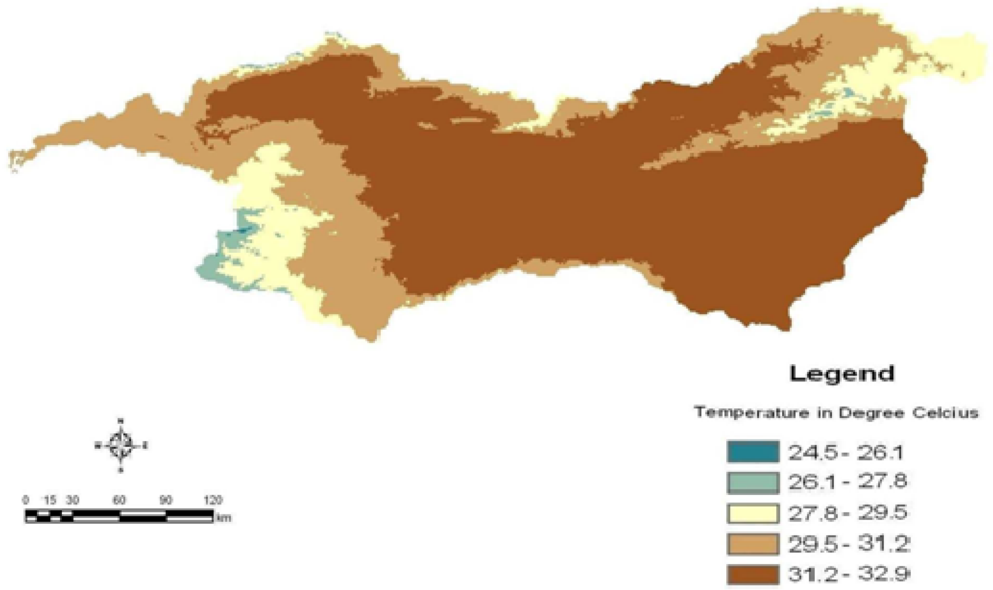

Fig. 7 Mean Recorded Temperature in April (60 year Average 1950-2010)

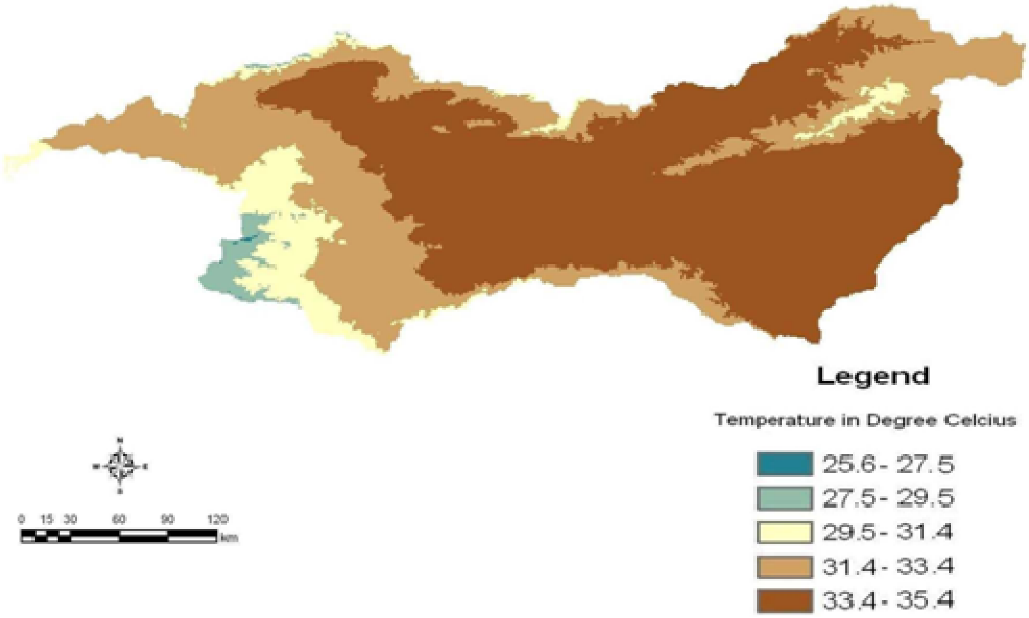

Fig. 8 Mean Recorded Temperature in May (60 year Average 1950-2010)

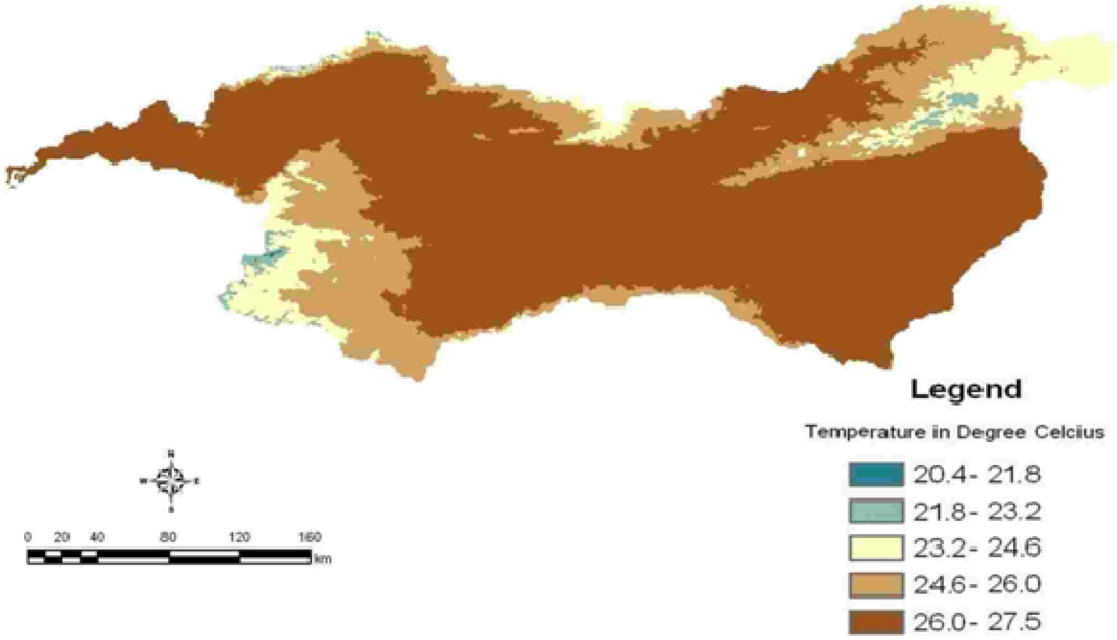

Fig. 9 Mean Recorded Temperature of Whole year (60 year Average 1950-2010)

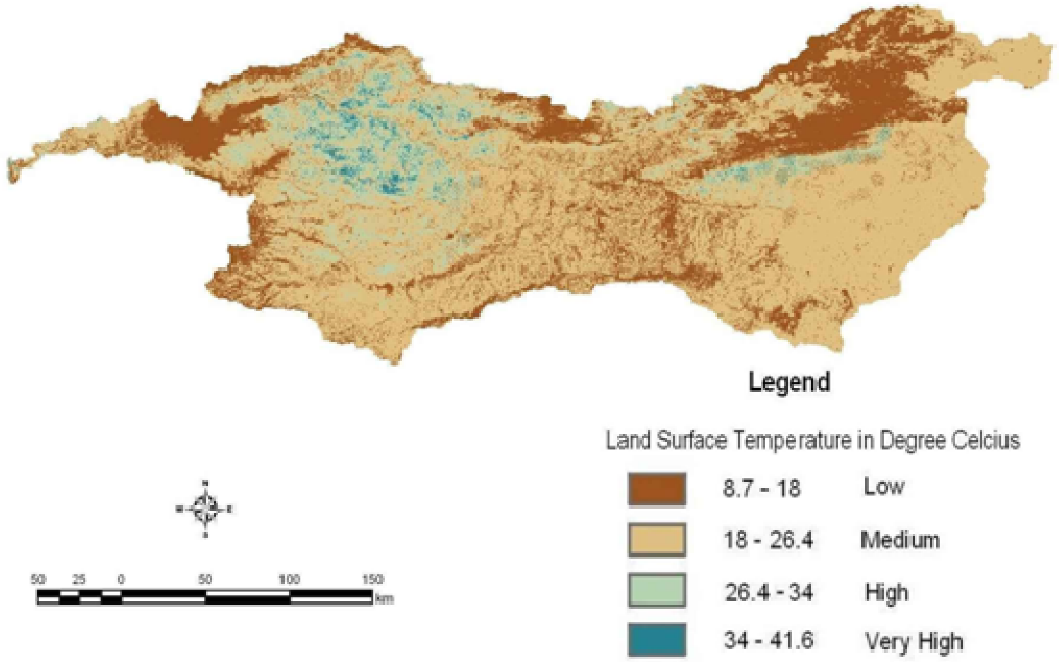

Fig. 10 Land Surface Temperature of Year 1990

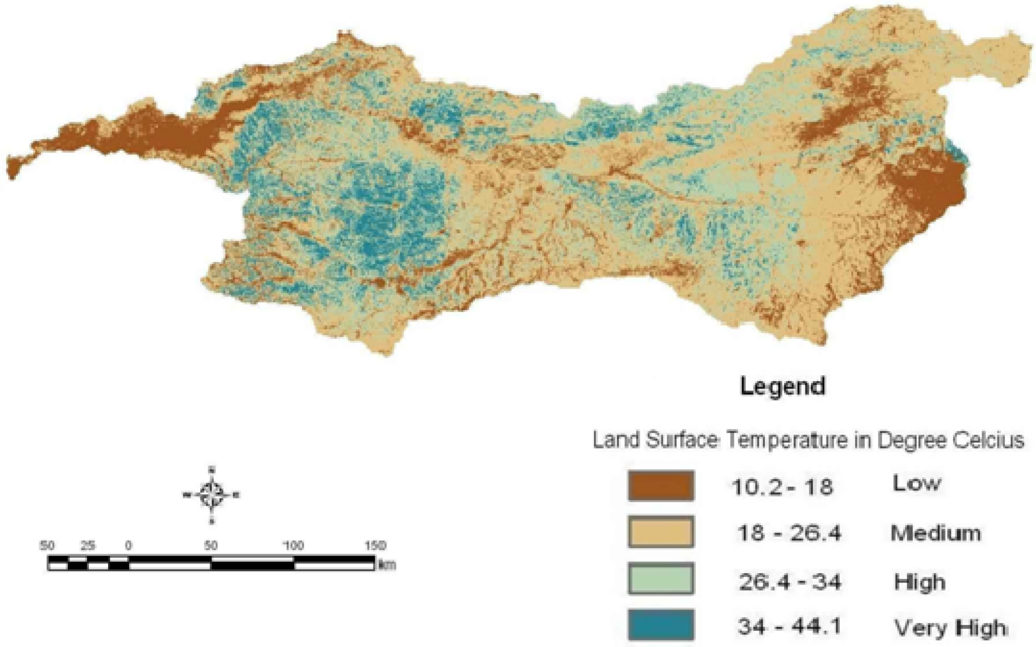

Fig. 11 Land Surface Temperature of Year 2010

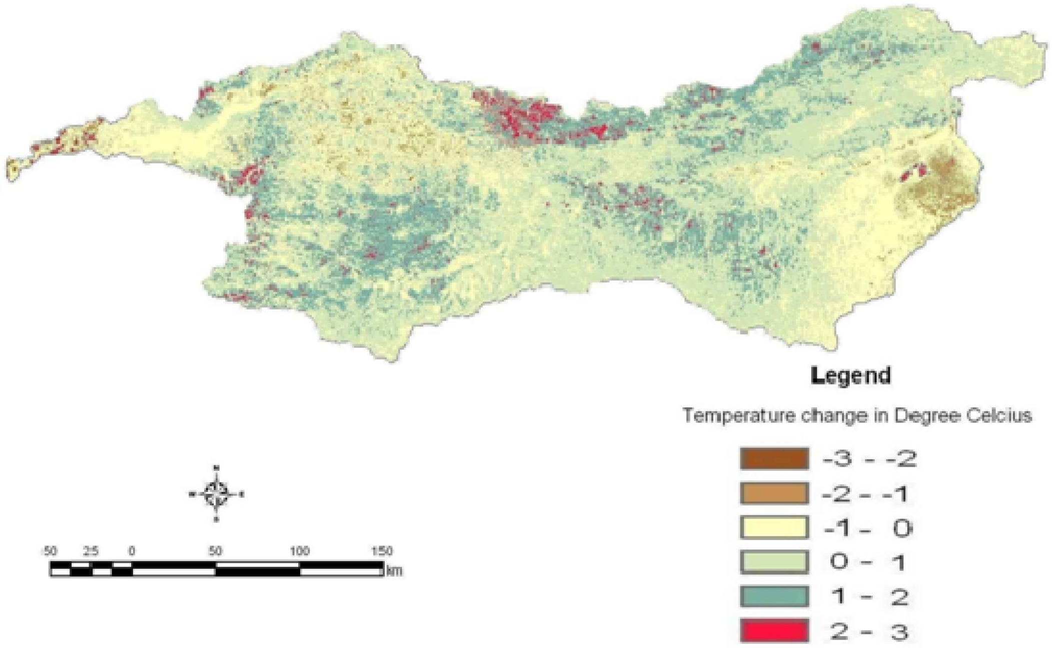

Fig. 12 Land Surface Temperature Change Detection Map

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