Effect of Land-Use Intensity on Surface Temperature

A Study on Chittagong City Corporation Area

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***Abstract*—Heat and temperature is on the news of the air in the today's world. High temperatures in urban areas have a direct impact on human health and are associated with heat related problems and excess summer deaths. This study is carried out to know the trend of land surface temperature and assess the impact of land use intensity on temperature in the Chittagong City Corporation Area, Bangladesh. A general linear model was used to estimate surface temperatures using Landsat TM, ETM+ and OLI_TIRS are used in the year 1991, 2003 and 2015 the months of May. Land use and its environmental effects can be quantitatively defined by land-use intensity. In this study, land-use intensity metric was improved using a geographic mapping method. The results revealed the temperature increased when the land-use intensity increased via a hierarchical transition owing to forest land reductions of 26.25%, respectively; built-up land increased by 48.45%. The temperature increase was driven more by the external environmental degrades than by land use intensity changes. The temperature response to land-use intensity changes was more sensitive in low altitude areas than in high altitude areas.**

Keywords-Temperature; Intensity; Gravity; Landsat; Spatial

I. INTRODUCTION

Asian cities are most hurriedly growing regions of the world in recent few years. Sixteen of the world's 24 mega cities (cities with more than 10 million people) will be located in Asia by the year 2015 [1]. The rapid urban alteration in Asia involving a large volume of population with increased energy consumption and dense urban infrastructure is reported to significantly affect the quality of life of urban inhabitants as well as to worsen urban environment and urban climate [2]. Bangladesh is a third world country having a population of over 160 million [3]. The surrounding environment and natural resources are degrading for this reason. Dhaka and Chittagong are two most large cities in Bangladesh. People from other regions come to these cities for searching job, higher living standard and service facilities. Comparing with other cities, Chittagong has the ability to grow economically and contribute its growth around the country. But now this city is developed without any plan which spoiled its resources. Chittagong city has faces many environment related problems because of unplanned hill cutting, damaged forest areas and rapid urban growth. Landslide, water logging creates difficult situation to span life in this city for human and other habitat also [4]. People are not thinking about temperature impact and problems arising because of it. Chittagong city is also facing heat related problem like this. Temperature of the city is increasing day by day. Tall buildings are constructed without any green area for cooling environment. Loss of water-body like Chaktai Khal, Rajakhali Khal inside the city worsens this situation more [5]. In recent years urban heat risk (UHR) has become a topic of great interest. Researchers are interested in understanding the various aspects of this phenomenon including its causes, effects and complexity. There are some direct and indirect heat related health problem like early death, heat stroke, skin cancer etc. which waste money and energy who are capable in working. The indirect effects include slower economic growth [6]. The main objective of the research is to analyze the Temperature and land-use intensity in the study area, and establish a relationship between land use intensity and temperature.

To perform this type of analysis, it is important to select the satellite images of the same time interval. Again the spatial resolution of the images is important. For this research purpose, Landsat satellite images have been chosen that are only can be found in free public-domain. Another reason for choosing these images is that the time interval is found equal 12 years of interval (1991, 2003, and 2015).

II. STUDY AREA

Chittagong City is not only the principal city of the district of Chittagong but also the second largest city of Bangladesh. It is situated within 22°14' and 22°24' N Latitude and between 91°46' and 91°53' E Longitude and on the Right Bank of the river Karnafuli. According to the census 2011, the city has a population of 25, 92,459 distributed within the 41 wards of the city [8]. The total area of the Chittagong City Corporation is

42694.393 acre. 41 wards existed here among them South Pahartali is the biggest area coverage almost 6000 acres and Lowest area is Dewan bazar ward and its area coverage is 100 acre only. The city is growing. It grew at the rate of 4.527% per annum between the years 1991 -2001. The growth has slowed down between the years 2001 to 2011. The city grew at the rate of 2.81% per annum in average during the last decade [8] [9]. The government of Bangladesh has declared it the 'Commercial Capital' of the country [10].

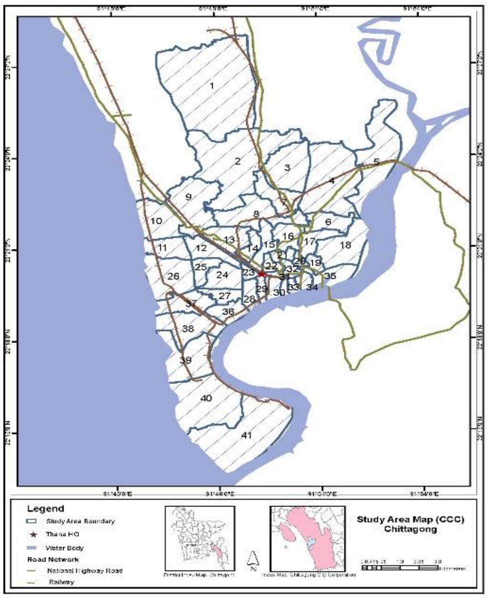

Figure 1. Study Area Map

In the Chittagong city most of the road is paved and it radiates heat and increase temperature. In 1989 vegetation cover was 47% in the Chittagong city which is almost half part of the total area and buildup area was 9%. But in the 2001 due to urbanization vegetation area reduced 10% and buildup area increase 12% [11]. In the recent time vegetation land-use is reduced more and it is existed in 31% and buildup area exists 27% [11]. Among the built-up area, the pucca structure occupies 29.82%, semi pucca-58.16% and the rest 12.02% is kutcha structure. Low lying area between Raja khali khal and the river Karnaphuli is about 14.49 hectares and occupies 24.69% of the study area. The Built-up area is about 56.57% of the study area, and Khals and water bodies occupy the remaining 18.74% of the study area [4]. Maximum uses identified by Chittagong City Corporation are agricultural uses which comprises 39.56 percent [10].

III. METHODS

A. Retrieval of land surface temperature (LST) from the Landsat TM Images

A two-step process was followed to derive temperature from the Landsat TM Images in this research [12]. In the first step, the digital numbers (DNs) of band 6 were converted to radiation luminance (RTM6) using the following formula:

$$T_{TM6} = \frac{V}{255}\left(R_{MAX} - R_{MIN}\right) + R_{MIN} \qquad (1)$$

Where, V represents the DN of band 6, and

R_{MAX} = 1.896 (mWcm^{-2}sr^{-1})

R_{MIN} = 0.1534 (mWcm^{-2}sr^{-1})

In the second step, the radiation luminance was converted to at-satellite brightness temperature in Kelvin, T (K), using the following equation:

$$T = \frac{K1}{\ln\left(\frac{K2}{\frac{R_{TM6}}{b}} + 1\right)}$$

(2)

Where, K_1 = 1260.56 K and K_2 = 607.66, which are pre-launch calibration constants under an assumption of unity emissivity; b represents effective spectral range, when the sensor's response is much more than 50%, b = 1.239 (μm).

B. Retrieval of land surface temperature (LST) from the Landsat ETM+ Images

In this research, a two-step process was also used to retrieve brightness temperature from the Landsat 7 ETM+ images [7]. In the first step, the DNs of band 6 were converted to radiance based on the following formula

$$T = \frac{LMAX - LMIN}{QCALMAX - QCALMIN} \times (QCAL - QCALMIN) + LMIN$$

(3)

Where, information can be obtained from the header file of the images, $QCAL_{MIN}$ = 1, $QCAL_{MAX}$ = 255, QCAL = DN, and L_{MAX} and L_{MIN} are the spectral radiances for band 6 at digital number 1 and 255 ($QCAL_{MIN}$ and $QCAL_{MAX}$), respectively [7].

In the second step the effective uniform emissivity obtained by the following equation:

$$T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)}$$

(4)

Where, T is the effective brightness temperature in Kelvin; K_1 = 666.09 (watts/ (meter2 × ster × μm)) and K2 = 1282.71 (Kelvin) are calibration constants; and L_λ is the spectral radiance in Watts meter^{-2} ster^{-1} μm^{-1}.

C. Retrieval of land surface temperature (LST) from the Landsat OLI_TIRS Images

OLI and TIRS band data can be converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata file [7]:

$$L_\lambda = MLQcal + AL \qquad (5)$$

Where,

L_λ = TOA spectral radiance (Watts meter^{-2} ster^{-1} μm^{-1})

ML = Band specific multiplicative rescaling factor from the metadata

AL = Band-specific additive rescaling factor from the metadata

Qcal = Quantized and calibrated standard product pixel values (DN).

D. Conversion to Satellite Brightness Temperature of land surface temperature (LST)

TIRS band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file [7].

$$T = \frac{K2}{\ln(\frac{K1}{L_\lambda}+1)} \quad (6)$$

T = Satellite brightness temperature (K)

L_λ = TOA spectral radiance (Watts meter^{-2} ster^{-1} μm^{-1})

K1 = Band specific thermal conversion constant;

K2 = Band specific thermal conversion constant.

The temperature values derived in Kelvin (A) from the above two processes were converted in to Degree Celsius (B) using the following equation,

B=A − 273.15

E. Conversion to At-Satellite Brightness Temperature of land surface temperature (LST)

Land use intensity varies according to the various land-use type. Built-up land has the highest intensity. Therefore, the land-use intensity was classified into four grades where each grade was assigned a specific value [13]. Using the grades the land-use intensity forms a continuous distribution composite index that ranges from 1 to 4 [13]. For the convenience of geographical index calculations the values were multiplied by 100. However, the land-use intensity is equivalent to the Weaver index. The expression of land-use intensity is as shown in:

$$Lindex = 100 \times \sum_{n=1}^{\infty}(A_i \times C_i) \quad (7)$$

Lindex is the comprehensive index of land-use intensity. For Lindex [100, 400] A_i is the classification index of land use at the ith degree, C_i is the percentage of land-use intensity at the ith grade, and n is the classification number of the land-use intensity. [13]. A Geographical radiative units was developed based on this expression. However, the weight coefficients mainly radiate outward from the basic units of A and B. The radius is one unit, and *A* and *B* represent the average land-use intensity of the region (3×3). Therefore the average land-use intensity of the radiated areas in *A* and *B* was 363 and 241, respectively. This expression shows the influence of the surrounding land types and the continuity in geographical space. However, this method can effectively express the continuous characteristics of land-use intensity. The unit value could also reflect the characteristics of the land-cover. As example, a value within [200, 300] indicates that fallow land and vegetation provided the greatest contribution, so fallow land and vegetation was the dominant land-use type. To calculated intensity selected unit size was 90m× 90m. The value of each unit represented the average land-use intensity within an area. The total number of units was 1523.

$$x = \frac{\sum_{i=1}^{n} x_i \times M_i}{\sum_{i=1}^{n} M_i} \quad (8)$$

$$y = \frac{\sum_{i=1}^{n} y_i \times M_i}{\sum_{i=1}^{n} M_i} \quad (9)$$

Where x and y are represents the Centre's of gravity of particular attributes in a region. x is the longitude, y is the latitude, x_i and y_i are the central longitude and latitude of the ith unit, respectively, and M_i is a particular attribute in the unit.

IV. ANALYSIS AND DISCUSSION

A. Annual Temperature rising

Annual historical temperature recorded by BMD appraises the pattern of change that happened during the last 70 years. Annual mean temperature is found to have in general increasing trend in Chittagong. The overall mean annual temperature is found to be +0.21 per decade for year 1947 to 2007 [15]. In winter season, average temperatures are 29°C with a minimum at 13°C. In the pre-rainy season (summer) and the early months of the wet seasons, the highest temperatures are reached. The monthly average temperature can rise up to 34°C. In the wet season more than 85% of the total annual rainfall occurs. Monthly average temperatures remain high with an average of 31°C.

B. Land Surface Temperature

The LST distribution for 1991, 2003 and 2015 are present in Figure 2. High temperatures mainly occurred in urban centers, densely area which is known as the heat island effect. Over the few decades the average temperature showed an increase ranged from 0.471°C to 4.48°C. The temperature rise was higher in the center area. The minimum, maximum, and average temperatures were 19.411°C, 30.602°C, and 26.048°C in 1991 and 22.611°C, 34.302°C, and 30.140°C in 2003 and 23.849°C, 36.983°C, and 32.422°C in 2015. Over the twelve years (1991 to 1993) the average temperature increased 03.374°C/12a (12a indicates 12 years), and the maximum and minimum temperatures increased 03.381°C/12a and 02.438°C/12a, and for 1993 to 2015, the average temperature increased 03.836°C/12a (12a indicates 12 years), and the maximum and minimum temperatures increased 03.327°C/12a and 02.872°C/12a, respectively. While minimum temperature increased, it played a key role on the average temperature changes.

C. Characteristics of Temperature Changes and Land-Use Intensity Changes

The results of the land-use classification and intensity expression in 1991, 2003 and 2015 presents in Figure 3. Built-up land increased gradually, whereas vegetation area decreased due to a transition to built-up land. The value of the land-use intensity in the Chittagong City Corporation Area varied between 100 and 400. A comparison of the land-use classification and intensity revealed that the land-use intensity varied with the land-use type and that was manifested as a continuous transitional feature. The color gradually darkened from the water to the vegetation and built-up land.

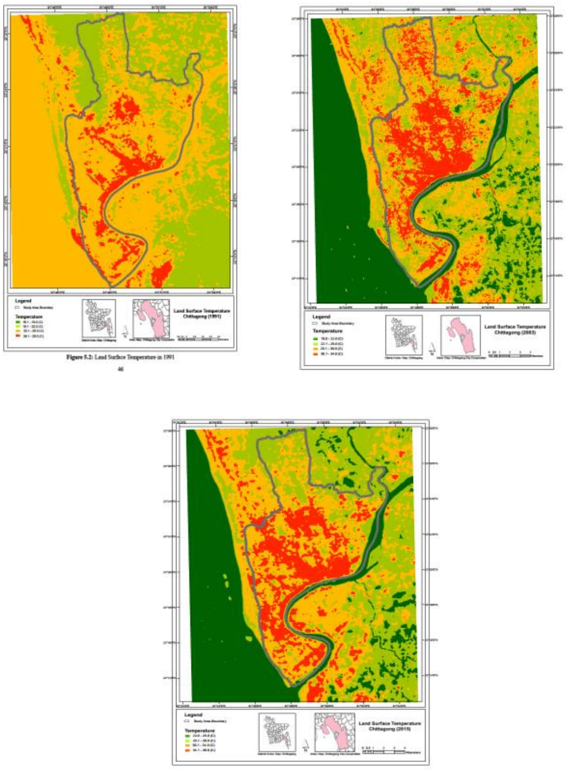

Figure 2. Land Surface Temperature in 1991,2003,2015

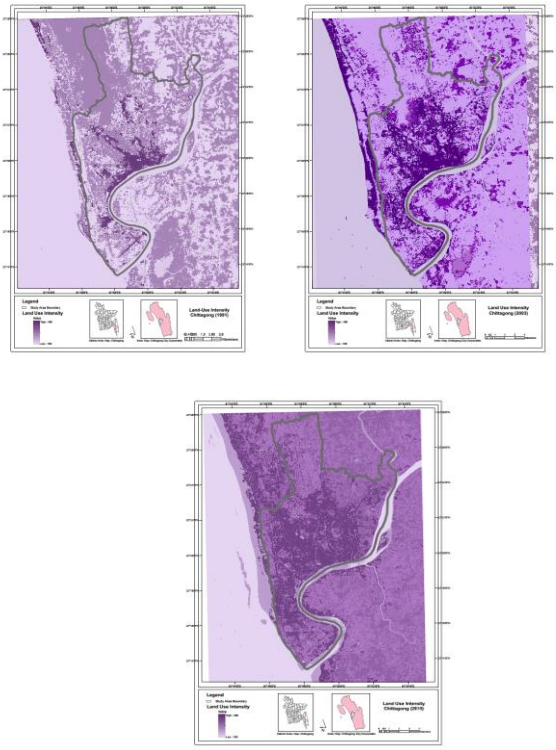

Figure 3. Land Use Intensity in 1991,2003,2015

The land-use intensities are higher in locations close to urban centers. As represented by the scattered pattern from the urban centers to the suburbs, the land-use intensity gradually increased towards urban centers. The rapid urbanization of the region is consistent with human activities. The characteristics of the relationship between area and temperature at different land-use intensity levels are summarized in Table I. The values of the land-use intensity were divided into three intervals (low, moderate, and high).The low level was [100, 200], in which unused land and water bodies were the dominant land-use types. The moderate level was [200, 300], in which fallow, water bodies, were the dominant types. The high level was [300, 400], in which built-up land was the dominant land-use types. The overall temperature presented an increase; therefore, a significant difference was observed among the three land-use intensity levels in 1991 to 2003 and 2003 to 2015. As the difference in 1991 to 2003, the low level land area decreased by 6.71 km^2 (5.2%), which represented the best instance land-use intensity level however, the temperature in the low-level land increased by 01.929°C (3.2 %). The moderate-level land area increased by 4.69 km^2 (9.3 %), whereas the corresponding temperature increased by 2.397° C (1.3%).The high-level land area decreased by 16.8 km^2 (34.9%), whereas the temperature increased by 2.481°C (2.7%). In 2003 to 2015 the low-level land area decreased by 20.92 km^2 (17.9%), which represented the best case land-use intensity level, and the temperature in the low-level land increased by 1.522°C (1.9%). The moderate level land area increased by 7.89 km^2 (- 11.9 %), whereas the corresponding temperature increased by 1.372° C (2.2%).The high level land area decreased by 29.3 km2 (47.2%), whereas the temperature increased by 2.419°C (3.2%). The results suggest that the increased land area of the moderate level and the decreased land area of the low level were the primary causes of the temperature rise.

D. Relationship of the Temperature to Changes in the Land-Use Intensity

The study area was divided into 1523 units, where each unit was 90m × 90m in size. The temperature and land-use intensity within the units were analyzed with spatial statistics (see table 5.3). The coefficient was -8×10^{-8} in 1991, -6×10^{-8} in 2003 and -3×10^{-8} in 2015. The results suggest that the sensitivity of temperature to the land-use intensity increased over the twelve years. The inflection point appeared when the land-use intensity was 200 or 300 and the warming acceleration was relatively low when the land-use intensity was [100, 200] or [300, 400]; however, the temperature increased rapidly within [300, 400]. The scatter distribution shows that the temperature rise was concentrated within [200, 300], which suggests that the land-use intensity within [200, 300] was a high influence on the rise of temperature. Therefore, the land-use intensity changes due to variations in fallow land, water bodies, and vegetation were the primary causes.

E. Land-cover changes Effects

Table II presents the dynamic changes in the land-use type and temperature from 1991 to 2003 and 2003 to 2015. As the difference in 1991 to 2003, the area of built-up land increased

TABLE I. DYNAMIC CHANGES IN LAND-USE INTENSITY AND TEMPERATURE

Year	**Low level [100, 200]**		***Moderate level [200, 300]***		***High level [300, 400]***	
	Area (km^2)	***Temperature (°C)***	***Area (km^2)***	***Temperature (°C)***	***Area (km^2)***	***Temperature (°C)***
1991	79.2	26.15	66.1	28.43	31.7	29.9
2003	73.9	28.2	60.7	29.7	47.5	32.7
2015	43.1	29.7	69.3	31.1	71.6	34.1
Change rate % (1991-2003)	5.2%	3.2%	9.3%	1.3%	34.9 %	2.7%
Change rate % (2003-2015)	17.9 %	1.9%	-11.9%	2.2%	47.2 %	3.2%

by 27%, and the areas of water bodies decreased by 7.6%. However, Vegetation, fallow land, decreased by 16%, and 21%, and sandy area increase by 8 % respectively. The highest to lowest temperature increases were as follows: built-up land (02.383°C), vegetation (01.352°C), water body (0.349°C), fallow land (2.108°C) and sandy area (2.011°C). As difference in 2003 to 2015, the area of built-up land increased by 45%, and the areas of water bodies increased by 2.8%, respectively. However, Vegetation and fallow land, decreased by 22% and 11% and sandy area increase by 13 % respectively. The highest to lowest temperature increases were as follows: built-up land (03.625°C), vegetation (01.762°C), water body (0.489°C), and fallow land (1.808°C) and sandy area (2.011°C).

TABLE II. LAND-USE AND TEMPERATURE CHANGES

Year	**Buildup Area**		**Vegetation**		**Fallow land**		**Water body**		**Sandy Area**	
	Area (km2)	***Av (T)***	***Area (km2)***	***Av (T)***	***Area (km2)***	***Av (T)***	***Area (km2)***	***Av (T)***	***Area (km2)***	***Av (T)***
1991	39.6	29.1	79.8	23.3	51.8	24.1	12.3	24.2	4.9	30.5
2003	61.2	31.2	66.2	24.8	43.9	26.3	9.8	24.9	4.1	32.4
2015	98.8	34.1	57.3	26.1	36.2	28.1	7.7	25.6	6.1	34.1
Change (1991-2003) (%)	27	2.4	-16	1.2	-21	2.6	7.9	1.9	8	1.7
Change (2003-2015) (%)	45	4.8	22	1.9	11	2.1	2.8	1.6	13	1.9

The temperature increase over vegetation was lower than that over water bodies. The results exhibits that the temperature rise primarily resulted from the expansion of built-up area and the reduction of vegetation area and fallow land. Accordingly, transitions to different land-cover may lead to changes in land-use intensity. As example, when vegetation area was transformed to built-up area then the land-use intensity level may have changed in conjunction with an increase in temperature.

F. Centre of Gravity Effects

The changes in the centers of gravity of temperature and land-use intensity revealed the extent of interference by human activities [16] [17]. From the geographical perspective, a high correlation was observed when both changes were consistent, whereas a weak correlation was observed when they were not consistent; consistency mainly refers to changes in the same direction. $A1$, $B1$, C1, D1, E1, and F1 are the variations in the center of gravity of the temperature in Figure 4. $A2$, $B2$, C2, D2, E2 and F2 are the variations in the center of gravity of the land-use intensity. $A1$ and $A2$, E1, E2, F1, F2 were highly consistent in terms of the direction of the change, whereas the directions of change for $B1$ and $B2$, $C1$ and $C2$ were inconsistent, and D1 and D2 are highly inverse directional. These results exhibits that a direct correlation exists between landuse intensity and temperature change in central part (Agrabad, Alkaran, Halishahar), whereas the relationship was not obvious in the eastern parts (Mohora, panchlish, chadgoan) of the study area. These results reveal that the center of gravity shift displayed a spatial difference that did not always vary consistently, and it could be due to other environmental factors, such as inter annual and seasonal changes, global warming and sensible heat exchanges [18]. Therefore, the shift in the temperature's center of gravity was affected by both land-use intensity and other environmental factors.

1) The average temperature increased from 26.048°C to 30.422°C and 30.45°C to 32.456°C in the Chittagong City corporation area between 1991, 2003 and 2015. This temperature rise was slightly higher than the background global warming. The area of built-up land increased by 27 % and 45 %, in 1991 to 2003 and 2003 to 2015, respectively, leading to an increase of 34.9 % and 47.2 % in moderate and high-level land uses in 1991 to 2003 and 2003 to 2015 respectively. These changes resulted in an increase in the land-use intensity, Built-up and for the temperature increase. Therefore, the influence of human activities can be quantitatively expressed based on the land-use intensity.

(2) An increase in the land-use intensity generally corresponds to a temperature increase such as the effect of heat island. However, the results of this study suggest that the temperature increase was primarily caused by the change in the landuse intensity. This finding may be interpreted as land-cover change owing to a hierarchical transition of temperature changes in the central area (Agrabad, Alkaran, Panchlaish, Enayet Bazar).

(3) The center of gravity of temperature is highly consistent with the land-use intensity in most of the central area (Agrabad, Alkaran, Panchlaish). The shift in the temperature's center of gravity was affected by both the land-use intensity. The center of gravity of the temperature is consistent with the land-use intensity in the southern part of the city, and this could confirmed that the land use and cover change strongly correlated with temperature in the south (Patenga).

V. CONCLUSION

Though Chittagong is one of the vegetative areas with a destined of natural landscape in Bangladesh, temperature of the city rises alarmingly.

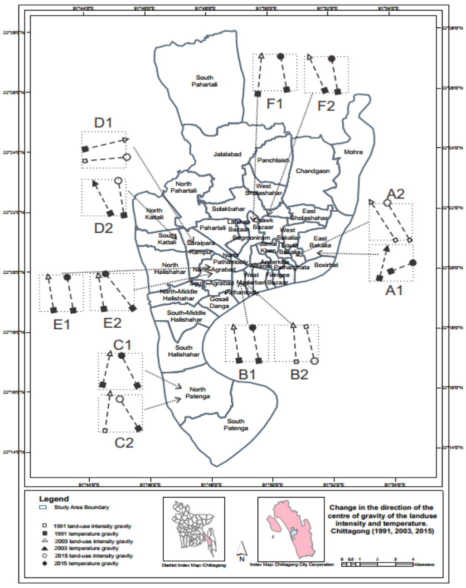

Figure 4. Change in the direction of the center of gravity

Causes of temperature rise relate habitually with population increase. People from other side of the country migrated Chittagong city for searching job. To fulfill the job demand a lot of commercial center, office, industry and to circulate this population bituminous road is constructed every year. Also to fulfill the housing demand and to accommodate large size city resident a lot of high rise building constructed. For constructing residential building, office and road government destroy vegetation areas and cut the hill areas. So, the temperature of the city increases more rapidly. In the land use intensity analysis it shown that 1991-2003 low (100,200) is 5.2%, medium (200,300) is 9.3% and high (300,400) is 34.9%. But in 2003-2015 low is 17.9%, medium is 11.9% and high is 47.2%. From the analysis it is shown that in 1991 minimum temperature was 19oC, maximum was 30 o C and average temperature was 26oC. In 2003 minimum is 22, maximum is 34 and average is 30. And in 2015 minimum 23, maximum 36 and average is 32. It is clear from the result that vegetation area decreases and build up area increases which result as temperature rise. The current trend of temperature has the most obvious environmental impacts on the surrounding ecosystems, land resources, structure and urban pattern and quality of human life. The study may assist environmentalist and planners to consider the impacts of temperature by identifying the current trend of urban land use. Land-use change over time is the response of combined effect of the social, economic, demographic and environmental variables as well current heat risk in the city. Understanding the characteristics, extent and pattern of change in temperature is vital element for efficient planning, managing and decision making activities and health impact of the city residents. In the absence of basic information about the current temperature rise, land-use and land-cover, it would be difficult to determine future improvements.

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