AN ASSESSMENT OF HEAT IMPACTS ON HEALTH USING THERMAL ZONATION TECHNIQUES

Aakanksha[1], Vinay Hudda[2], Nithiyanandam Y[3]

[1]Email: aakanksha.aakanksha@students.teriuniversity.ac.in
[2]Email: vinay.hudda@students.teriuniveristy.ac.in
[3]Email: nithiyanandam.y@teriuniversity.ac.in

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Abstract

Complex land use patterns in urban areas of India have significantly affected the land surface temperatures. High diurnal temperatures in urban areascan negatively influence the health of the population and therefore are imperative to study. Thus, an attempt has been made in this research to understand these impacts (both direct and indirect) on human health and well-being of the people of Gurugram city in state of Haryana using various indicators and reference from the previous indicative studies in this light. This study tries to investigate the association between the escalating temperatures of the city and increasing number of cases of heat related illness. The open source remotely sensed data (Landsat 5 and Landsat 8) of the summer season (April-June) is used to calculate the average land surface temperature (LST) of the city and further hotspots were identified to conduct primary health survey. Moreover, a primary level of medical data has been used to understand the spatial and health dynamics based on the LST. A total of 78 samples have been taken during the random sample survey to support the hypothesis. Moreover, cases with heat-related illness in most of the hotspots were positively correlated to the areas of higher land surface temperature. Acceptable agreements on the relationship between the two variables were obtained. The approach so applied in this study can be expanded at the national level to examine the impact of heat on human being. This information would help government to provide better living condition and quality of life. Also, the output may be interest of urban health care professional, law makers, planers and the social workers.

1. Introduction:

The rapid urbanization in most of the cities today has led to high diurnal temperatures. This can influence human health negatively. ‘The heat related illness can be understood as incapability of the human body to deal with the increasing and most importantly changing temperatures’ (**Joseph a. Grubenhoff et al., 2007).** The body’s metabolism increases with high heat input from the environment, but when the heat output from the body is not proportional to the heat input problems can occur. Heat related illness can range from minor syndromes to life threatening emergencies. ‘High temperatures cause the clinical syndromes of heat stroke, heat exhaustion, heat syncope, and heat cramps’ (Kovats, R. Sari et al, 2008). Summer heat waves pose a serious health risk. The study in this regard to understand these heat related illness hence becomes imperative. ‘The people majorly at risk are infants, children, elderly and patients with chronic illness’ (Queensland Health 2009). High mortality rates have been noticed in previous decades in the most of the urban areas.

2. Aim and Objectives:

The aim of this study is to identify a relationship between the escalating air temperatures of the Gurugram city in the state of Haryana and its impacts on human health. The objectives can be summarized as:

1. Multi-temporal datasets to study the land surface temperature of the Gurugram city using the thermal remote sensing
2. To identify the hotspots on the basis of land surface temperature.
3. To map the number of cases of heat related illnesses and viral/ bacterial infections in the identified hotspots.
4. To establish the relationship between the two parameters; land surface temperature and the number of cases of heat related illness in the hotspots

3. Study Area

Gurugram is a city in the Indian state of Haryana and is part of the National Capital Region of India. It is 32 kilometers southwest of New Delhi and 268 km south of Chandigarh. As of 2011, Gurugram had a population of 876,824. Witnessing rapid urbanization, Gurugram has become a leading financial and industrial hub with the third-highest per capita income in India

Date of acquisition: 22 April, 2017 Source: earthexplorer.usgs.gov

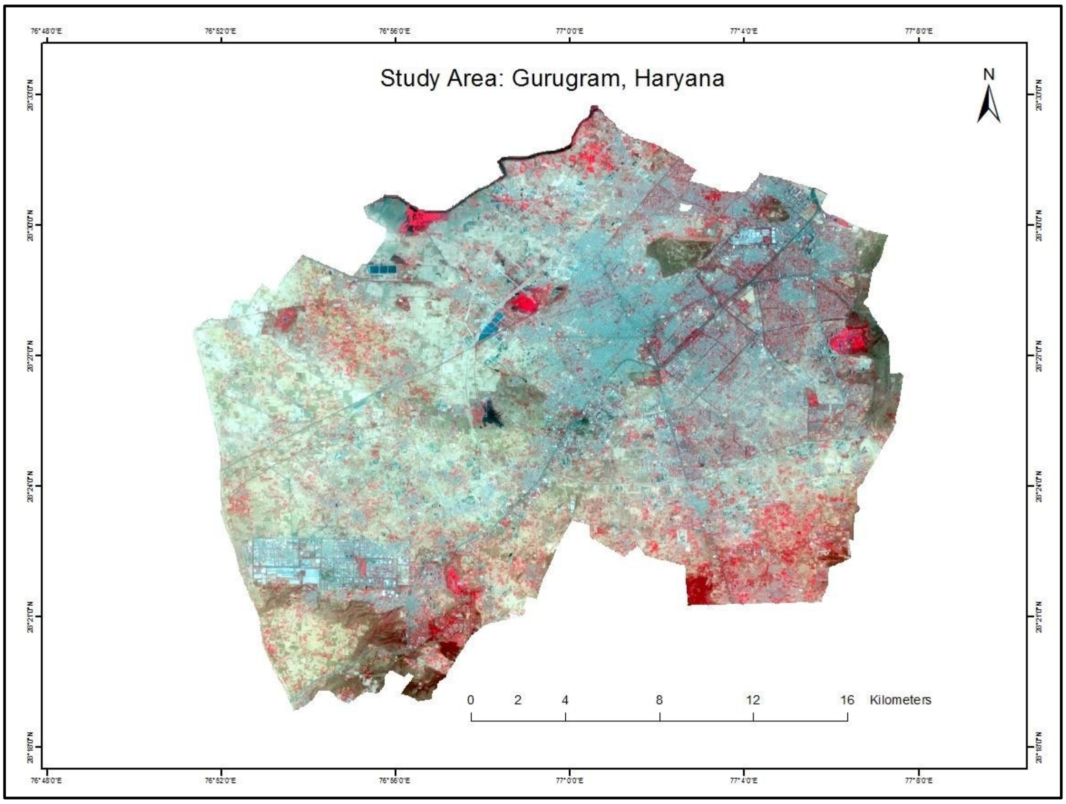

Figure 1: False color composite stacked image of Gurugram

4. Methods:

Multispectral and Multi - temporal data was collected for study area (Gurugam City). The satellite imageries of Landsat were obtained from USGS Earth Explorer (Freely Available). The data was obtained at 30m resolution. Nine images of Landsat – 5(Thematic Mapper) for years 2009, 2010 and 2011 and five images of Landsat – 8(Enhanced Thematic Mapper Plus) for years 2015 and 2016 were gathered. The details of the datasets used in the study are discussed below:

4.1. Medical data collection:

For this study, a primary level of health data was collected to further understand the types of heat related illnesses in a given locality. A random sample survey was conducted in heat pockets of Gurugram city. The survey questionnaire comprised of 17 questions. The questions were formed in such a way that they covered various aspects of the conditions that may be responsible for causing heat related illness. The survey presented data that proved valuable to the study and gave an insight to the problems that may be held responsible for the conditions that persist. The survey questionnaire is presented below:

4.2. Data Processing:

The satellite images were used to calculate the Land Surface Temperature (LST). The steps and formulas used for LST calculation[1] are discussed below:

- *DN to radiance conversion*

The formula to convert DN to radiance using gain and bias values is:

$$L_{\lambda} = gain * DN + bias$$

Where: L_{λ} is the cell value as radiance

DN is the cell value digital number

gain is the gain(multiplicative factor) value for a specific band

bias is the bias(additive factor) value for a specific band

- *Radiance to at-sensor Brightness Temperature*

The conversion formula for estimating at-sensor B^T from at-sensor spectral radiance is:

$$B^T = \frac{K_{A2}}{\ln(\frac{K_{A1}}{L_{\lambda}} + 1)}$$

Where B^T is at-sensor Brightness Temperature

$K_{A1}$and $K_{A2}$are Thermal Constants

A. Emissivity corrected LST

- *Emissivity Corrected LST*

The emissivity corrected LST (T_{ec}) are calculated using the following equation:

$$T_{ec} = \frac{B^T}{1+(\lambda * B^T/\rho)\ln\varepsilon_s}$$

Where:

λ is the peak response wavelength of emitted radiance B^T is the at-sensor brightness temperature

The flux density (ρ) = [h × (C /σ)] = 1.438× 10-2 m K Where, h is Planck's constant (6.626 ×10-34 J s),

C is the velocity of light (2.998 ×108 m s-1), σ is Boltzmann constant (1.38 × 10-23 J K-1) εsis the surface emissivity

- *Emissivity*

According to Kirchhoff's law of thermal radiation, R □ 1 - ε, the emissivity of an object is equal to its observance at the same temperature (Nicodomus, 1995). Since the emissivity values of objects on the earth cannot exceed one (the maximum emissivity for a blackbody), the reflectance, R, is calculated by subtracting the dimensionless emissive power from 1, i.e., ε = 1 - R.

Where, R is the Top of Atmosphere Reflectance Reflectance $(R_{\lambda}) = \pi * L_{\lambda *} d^2 / E_{sun,\lambda} * \sin\Theta_{SE}$ Where,

d = Earth sun distance on acquisition date $E_{sun,\lambda}$ = Exo-atmospheric solar irradiance $\sin\Theta_{SE}$ = Solar Elevation angle

(Source: Gain, Baisλ , d , E sun,λ and sinΘ SE collected from metadata)

Note:ESUN values are not provided for Landsat 8 data because they are not required for converting data to reflectance. For calculation of $R_{\lambda,}$

$R\lambda = M\rho Qcal + A\rho$

Where:

M_{ρ} = Band-specific multiplicative factor from the metadata

A_{ρ} = Band-specific additive rescaling factor from the metadata

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

4.3. Average Temperature Calculation

For the purpose of this study, to get the information about the temperature conditions that exists in various areas during the summers, the average temperature was calculated from the images. T All

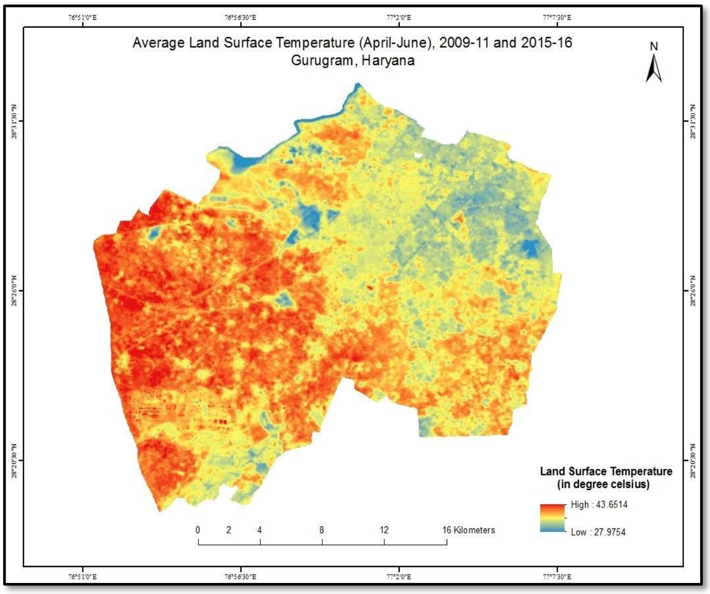

Figure 2: Average LST (April-June), 2009-11 and 2015-16

LST images were used and clubbed together to compose a single image that comprised of the average LST extracted from images

In order to make more sense of the data and identify the heat zones in the study area, the average LST image was classified into various severeness zones. Since the average land surface temperature for Gurugram city was in range 25℃ to 43℃ the zones were identified as shown below:

Category	Range
1	25 - 27
2	28 - 30
3	31 - 33
4	34 - 36
5	37 - 39
6	40 and above

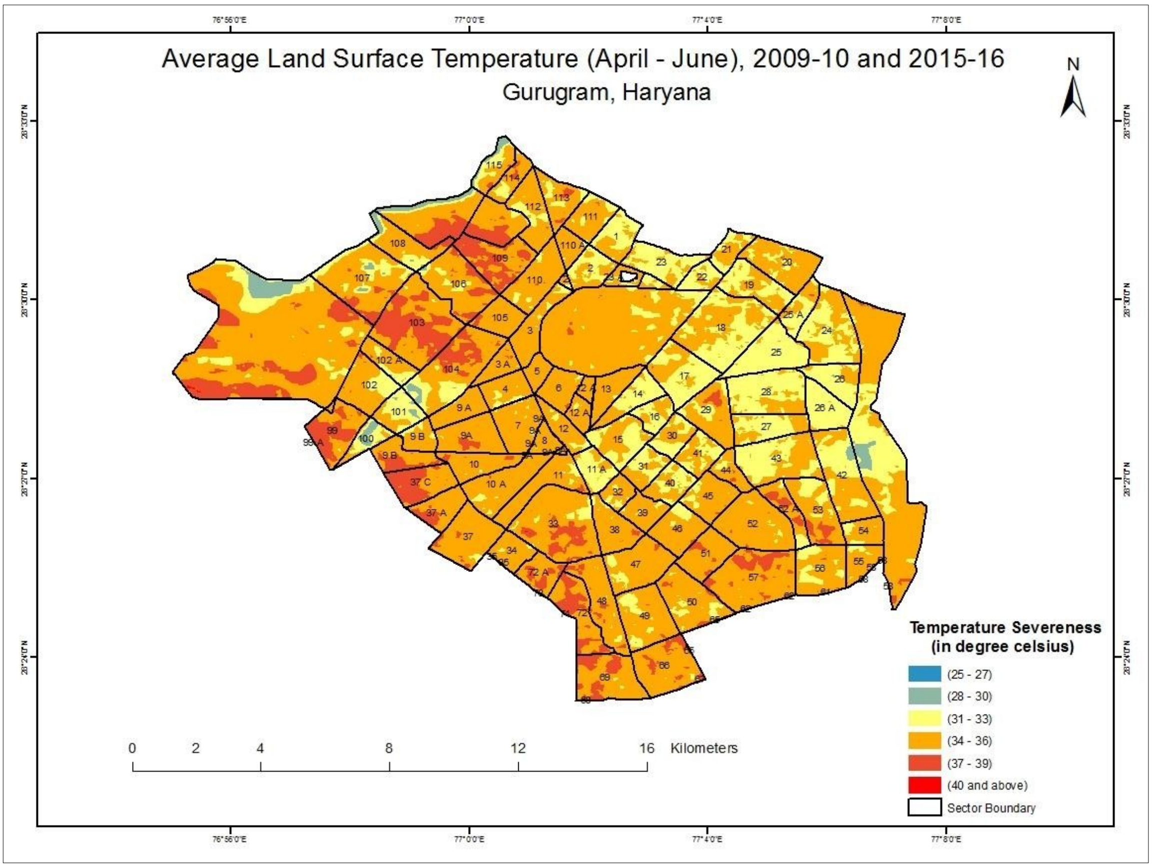

Figure 3: Average LST (Apr-Jun) for the year 2009-10 and 2015-16

This map shows the average land surface temperature for months of April-June for the combined five years, 2009-11 and 2015-16. As can be seen in this map, the average highest temperature for the city of Gurugram was observed to be in most of southern and north-western parts with the temperature range of 37℃ to 39℃. With this map, one can interpret that mostly the areas shown in red are zones of continuous high temperature and are more prone to heat related illnesses. While on the other hand the other areas lying in the lesser temperature ranges are less prone to heat related illnesses.

4.4. Medical Data:

A random sample of 78 was taken for the study. The two of the locations which fell under high temperature zones (category 3 and category 5) were Sector 14 and Sector 15. Other than this, one of the most susceptible populations in case of heat related diseases were the auto-drivers. As the survey conducted in sector 14 and 15 could not result in any pattern oriented information, a general survey was conducted with the auto-drivers. The data hence generated is random and represents an occupational section of the society. The data that collected through the survey was entered into ArcGIS. All the heat disease cases were mapped with their locations shown. The cases were divided into two categories: Heat Disease and Bacterial/Viral Infections. The maps of diseases are shown below:

Table 1 : Cases of Heat Diseases

S.No.	**Place**	**Number of Cases**
1	Jharsa	1
2	South City	1
3	Wazirabad	1
4	Tau Devilal Stadium	1
5	Badshahpur	4
6	Sector 45	1
7	Sector 52	1
8	Sector 11	1
9	Sector 14	2
10	Sector 15	2
11	Krishna Colony	1
12	Shanti Nagar	1
13	Sadar Bazar	1

Table 2: Cases of Bacterial/Viral Infections

S.No.	**Place**	**Number of Cases**
1	South City	1
2	Sohna	1
3	Sector 48	1
4	Sector 45	1
5	Sector 14	2
6	Wazirabad	2
7	Tau Devilal Stadium	1
8	Badshahpur	3

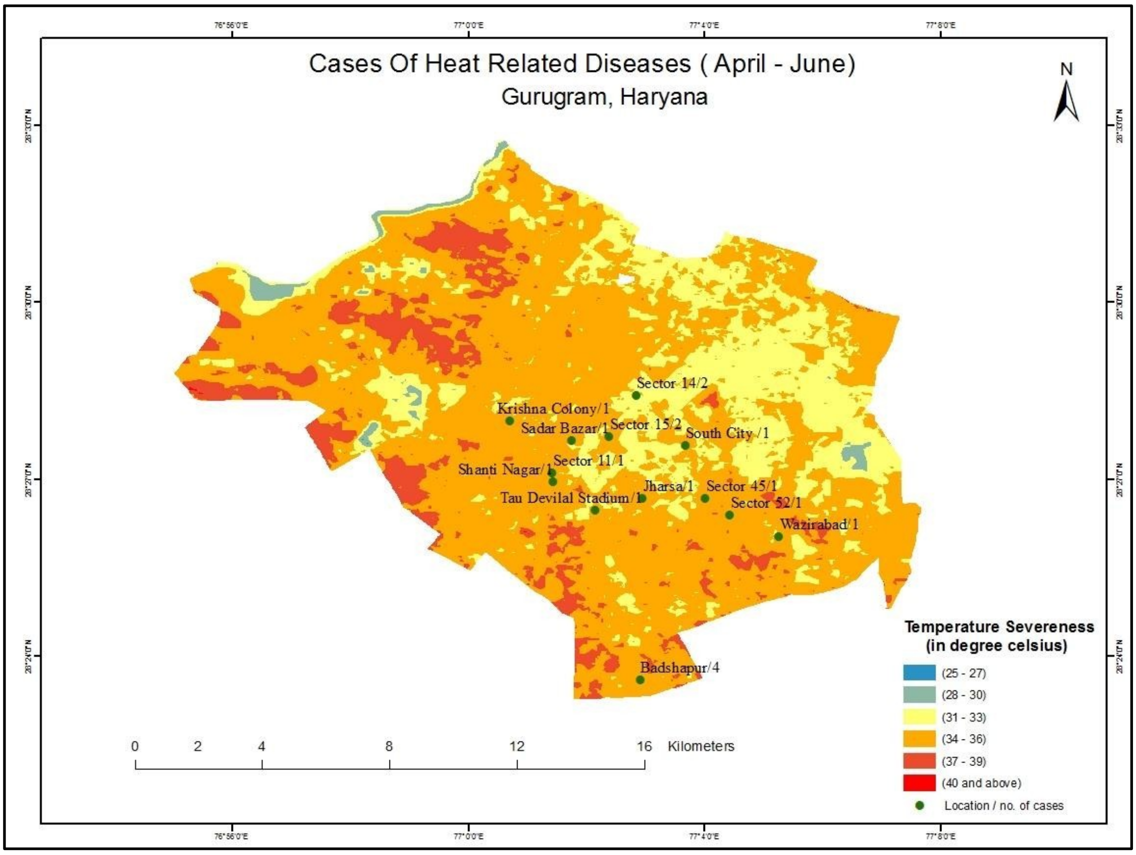

Figure 4: Cases of heat related diseases (Apr-Jun)

This map explains how the number of cases of heat related diseases are distributed spatially using a random sample survey. The highest number of cases is observed in Badshapur with an average land surface temperature of 34℃ - 36℃. Most of the recorded cases are found in 31℃- 36℃. The population living in these zones is more prone to heat related diseases. Moreover, the highest temperature zones of 36℃ and above are sparsely populated.

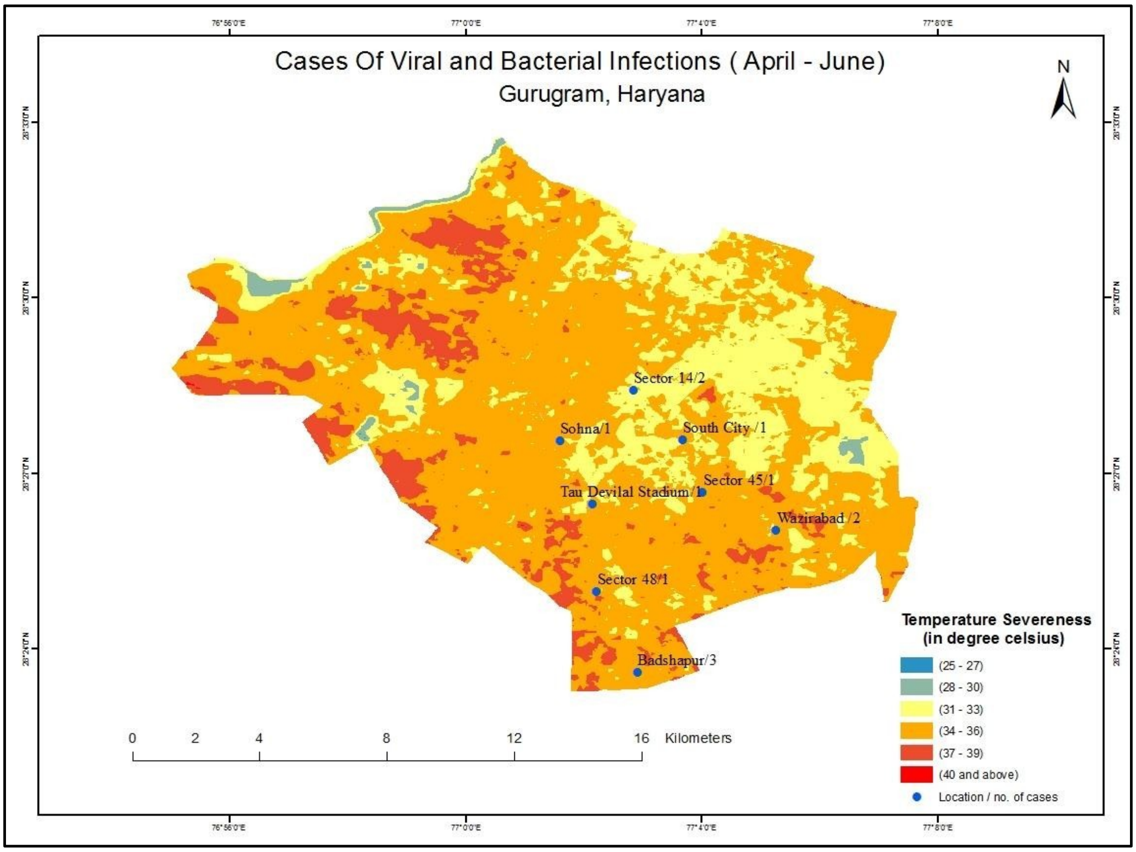

Figure 5: Cases of viral/ bacterial infections (Apr-Jun)

This map shows the distribution of number of cases of viral and bacterial infections in random sample surveyed areas. The highest number of cases observed is in Badshapur with the average land surface temperature of 34℃ - 36℃.

5. Results and discussion

Moreover, the data collected during the primary level health survey revealed these observations. The localities of Sector 14 and Sector 15 which were surveyed randomly, a total of 40 samples were collected. The localities seemed to be well-planned. The most of the samples in these heat pockets belonged to upper middle or high income group measured in terms of number of cooling appliances in the family (3 air-conditioners on an average per household). Also, there were no problems of water or electricity as well. Among 40 samples, more than half of them were not directly exposed to heat, hence lesser prone to heat related diseases.

The next observation made was of the dispersed samples. The 38 samples taken from the various localities comprised mostly of lower middle income groups measured in terms of number of cooling appliances each household had (1 cooler on an average per household). The localities like Wazirabad, Badshapur, and Sohna were not well planned residential areas. The localities had water and electricity issues. The samples taken from these localities were observed to be exposed to heat more in terms of number of hours outdoors. The average number of hours that an auto-driver was outdoors was 8 hours per day. These are comparatively very high when compared to the other sampled population group of Sector 14 and Sector 15. Hence, this set of sample consisting of lower middle income group was more prone to heat related diseases

6. Conclusion:

A relationship between temperature and heat diseases was identified. It was uncovered that the areas having the average land surface temperature in the range of **32^0C to 36^0C** were the areas in which people suffer from indirect and direct heat diseases. During the course of this study, it was found that out of **78 people** that were surveyed, **30 people** suffered from direct or indirect heat disease. To be precise, **18 people** out of **78 people** suffered from heat diseases. Moreover, it was observed that other factors like occupation type and financial capabilities also affects such illnesses. If the occupation type is outdoors as seen in the case of auto-drivers, there can be larger implications of such diseases. Planning of the residential areas in cities also play an important role. Most of the unplanned areas yielded greater number of cases of heat illnesses.

It can be inferred that heat has adverse effects on the health of people and serves as a medium for the spread of heat diseases. This calls for a study on a larger scale to identify other reasons behind the spread of heat diseases so that efforts to minimize the spread of these diseases can be taken in the rapidly developing areas like Gurugram where population and development are increasing at a rapid rate.

7. References:

1. Nichol et.al. 2016. '*A Simple and Effective Retrieval of Land Surface Temperature Using A New Reflectance Based Emissivity Estimation Technique'*
2. Suresh. S et al, *2016.'Estimation of Land Surface Temperature of High Range Mountain Landscape of Devikulam Taluk Using Landsat*8 data'
3. Rajeshwari. A, Mani N D, 2014. '*Estimation of Land Surface Temperature Of Dindigul District Using Landsat 8 Data*'
4. Md. Shahid latif, 2014. '*Land Surface Temperature Retrieval of Landsat- 8 Data Using Split Window Algorithm- a Case Study of Ranchi District*'
5. Javed mallick et al., 2008. '*Estimation of Land Surface Temperature over Delhi Using Landsat-7 ETM+*'
6. Joseph a. Grubenhoff et al., 2007, '*Heat-Related Illness*'
7. Parker, Jenifer, 2011, '*Contemporary issues of heat illness'*
8. Heaviside, Clare, et al, 2003, *'Heat-related health impacts associated with the urban heat island and climate change in the West Midlands, UK'*
9. Climate Council, 2016, *'The silent killer: Climate change and the health impacts of extreme heat'.*
10. Hajat et.al. 2008, '*Heat Stress and Public Health: A critical review',* Annual Review of Public Health.
11. Kjellstrom et.al. 2009, '*Public health impact of global heating due to climate change: potential effects on chronic non-communicable diseases'*