REMOTE SENSING AND GIS FOR DENGUE EPIDEMIC RISK MAPPING IN LAHORE, PAKISTAN

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ABSTRACT: Over the last two decades, dengue fever has become a major mosquito borne disease in Pakistan. Dengue outbreaks were reported in the major cities of Pakistan especially in Lahore where the number of dengue cases increased radically in 2011 making it the worst epidemic in the national history. It had been observed that dengue virus population increases in specific climatic conditions and there were some Environmental Factors EFs that promoted its growth. The objective of this study was to propose an advance approach to identify the risk prone areas by linking these factors with dengue outbreaks using satellite data and Geographical Information System (GIS) techniques. Information provided in terms of spatial and temporal distribution patterns of dengue fever outbreaks in Lahore and its relationships with EFs was helpful in developing dengue risk map. The results showed that most of the cases occurred in those areas which received heavy rainfall R^2 ranging from 0.66 to 0.8 followed by high temperature and low Normalized Difference Vegetation Index (NDVI).

Key words: Dengue fever, Epidemic Risk Mapping, Remote Sensing (RS), Geographical Information System (GIS) and Normalized Difference Vegetation Index (NDVI).

(Received 21-08-2015 Accepted 05-03-2016)

INTRODUCTION

Mosquito-borne diseases are a serious threat to human health in many parts of the world, especially in developing countries like Asia and Africa. Within next 20 years the mosquito-borne diseases of Asia and Africa, primarily dengue and malaria, are expected to spread in many other countries (WHO, 2006). Typical species of mosquitoes, flies, ticks and fleas are able to transmit viruses or parasites to humans (Lemon, 2008). There is a serious need to control spread of dengue virus at an early stage to save millions of people living in the hot and humid regions of the world (IPCC, 2014).

Dengue Haemorrhagic Fever (DHF) and Dengue Shock Syndrome (DSS) have become major global public health issue. According to World Health Organization report (WHO, 2006), dengue fever is present in at least 100 countries and due to this fever, approximately 40 percent of the world population is at risk in tropics and sub-tropic regions. The same report also states that 50 million infections are reported annually due to the DHF which is a leading cause of childhood mortality in several Asian countries.

In Pakistan, dengue fever is known since 1994 when first case was registered in the southern part of Karachi and epidemics were reported from almost all part of the country. In the Punjab province, especially in Lahore the number of cases are increasing since 2007 (Khan, 2011). The worst ever 2011 outbreak of dengue in Lahore occurred from March to December while in other parts of Punjab such outbreaks were mostly reported after the Monsoon season. The number of cases were on peak during the hot and rainy season i.e. August to October. According to Punjab Disaster Management Authority (PDMA, 2011) a total 17,330 dengue cases were registered in Lahore in 2011. By the end of the rainy season, these incidences lowered. Climatic conditions are considered to have a major influence on the distribution pattern of dengue outbreaks. Climatic change plays an important role on the mosquito breeding, especially dengue virus. The spread and extent of dengue fever may help to make connections between land use, climate, and public health (Rusch *et al*., 2011). Weather parameters are easy to monitor/observe and to ascertain the specific environmental conditions that support mosquito breeding (Gubler, 1988). A temporary variation in weather parameters, mainly precipitation, temperature and humidity can presumably be related to dengue outbreaks (CDC, 2012).

Geospatial techniques like Remote Sensing (RS), Geographical Information System (GIS) and other related technologies are used as a powerful tool to manage and analyze spatial and temporal data in various application fields. Among others, these techniques are currently used as a set of strategic and analysis tools for public health mapping. In other parts of the world these techniques are used effectively to rapidly map risk prone areas (Ali *et al*., 2003, Umor *et al*., 2007 and Anon, 2009). The mapping of disease in areas where outbreaks initiate not only help in better managing the epidemic within the affected neighbourhood but it can also assist in identifying other high risk areas in order to mitigate it before spreading.

MATERIALS AND METHODS

Present study was planned to develop dengue risk map using environmental factors by identifying potential high risk areas in Lahore. The factors selected for this study were; topography, vegetation cover, rainfall, humidity and land surface temperature (LST). These factors were tested for their significance in contributing to dengue outbreaks by relating them with distribution pattern of disease. The satellite data from Spot-5 and Landsat TM were used to derive these factors. Study Area was located within the latitude and longitude of 31°32′59″N and 74°20′37″E. The northern side of the city lied on the banks of river Ravi and the eastern side borders with India (Fig-1). Under the latest revision of Pakistan's administrative structure, promulgated in 2001(The Local Government System, 2001), Lahore was marked as a City District and divided into nine towns and one cantonment. Minimum hierarchy of administrative unit is Union Council defined by the City District Government Lahore (CDGL). Its Administrative towns are Ravi Town, Shalimar Town, Wagah Town, Aziz Bhatti Town, Data Gunj Bakhsh Town, Gulberg Town, Samanabad Town, Iqbal Town, and Nishtar Town. Each town consists of a group of Union Councils (UCs).

The methodology developed for dengue risk map is shown in figure (2). The four phases involved in the methodological workflow were; data collection, Geo-database development, Risk Score identification and GIS analysis. According to 1998 census, the population of Lahore was 6,318,745 and population for year 2010 was estimated to be 8,592,000 making it the second largest city of Pakistan after Karachi.

Data Collection: Weather data used for this study was provided by Pakistan Meteorological Department (PMD). The epidemic data was procured from Ministry of Health (MOH) and Punjab Disaster Management Authority (PDMA). Remote Sensing data was used to develop detailed maps of Land Cover and Land Use (LCLU), Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST) and topography. LCLU and NDVI were obtained from Spot-5 satellite data; LST from Landsat TM satellite data and elevation from Shuttle Radar Topography Mission SRTM data.

Geo-Database Development: A Geo-database was developed for the above mentioned data using the well known GIS software - ArcGIS 10.1. Geo-database was a common data storage and management structure for ArcGIS. Overlay Weighed Analysis tool of ArcGIS 10.1 was used in GIS analysis to generate maps of dengue risk.

Environmental Weights and Risk Scores: Environmental weight and risk score were determined for mapping distribution pattern of dengue outbreak through epidemical and environmental data analysis. This analysis was based on ranking the major factors that contributed to dengue occurrence. All factors were analyzed with real cases reported by hospitals in Lahore.

Environmental weight was assigned on amount of the influence each identified indicator contributed to dengue outbreaks. The risk score values were then ranked as high, medium and low i.e. 3, 2 and 1 respectively for each variable.

Remote Sensing and Geographical Information System Analysis: As mentioned earlier, the environmental factors selected for this study were; topography, vegetation cover and land surface temperature. The Normalized Difference Vegetation Index (NDVI) map was generated from the Spot-5 satellite data. NDVI map corresponded to the distribution pattern of vegetation cover. Identified environmental factors were overlaid in ArcGIS using Overlay Weighed Analysis tool. The Risk Map was generated for areas which had high dengue outbreaks.

RESULTS AND DISCUSSION

The factors were mapped using satellite data and GIS techniques and their influence on dengue outbreaks was analyzed. A detailed map of Land Cover Land Use LCLU was generated as part of this study using Spot-5 satellite data. Although LCLU map did not directly influenced the analysis but it was required to obtain the information about land cover and land use of the study area (Fig-3).

Topographical Influence: The elevation data or Digital Elevation Model DEM was obtained from Shuttle Radar Topography Mission SRTM to map topographical high and low land areas of Lahore. According to Pan American Health Organization (PAHO) (2010) the ideal conditions for dengue were reported at 2,200 m altitude beside other factors. But the study area was almost flat and there was no significant variation in the elevations of Lahore. Therefore there was no effect of topography on the distribution pattern of dengue outbreaks (Fig-4).

Statistical Analysis for Dengue Risk Assessment with Rainfall: Correlation and regression analysis were the statistical tools that were used in this study to calculate statistical significance in the relationship between the rainfall and dengue incidences occurred in Lahore during 2011. Rainfall and temperature were the major factors of climatic change and for the breeding of Aedes mosquitoes (WHO, 2009). According to Russell and Rao (1942), Relative humidity was the second important factor after temperature and higher degree of humidity i.e. 85 to 90 percent was very favourable for dengue outbreaks. Since dengue cases usually occurred after rainfall (Fig-5 and fig-6) and the life span of dengue from egg to complete larvae stage was 2-3 weeks depending upon the environmental conditions, a date wise comparison of the two variables cannot be possible. To find out the relationship between these two factors, the dengue cases were shifted 15 to 18 days back from their recorded dates of incidence.

Due to the data limitation, only three towns i.e. Data Gunj Baksh Town, Samanabad Town and Gulberg Town were selected as the sample cases to find out the relationship between the rainfall and dengue incidences. Results of linear regression showed statistically significant relationship between rainfall and dengue outbreaks in all sampled union councils with R^2 ranging from 0.66 minimum to 0.8 maximum (Fig-7).

Influence of Land Surface Temperature: The Land Surface Temperature (LST) maps were generated from Landsat-5 TM satellite data that represented the distribution pattern of surface temperature in the study area. Two LST maps were developed that represented pre-incidence and post-incidence temperatures. The LST maps were overlaid with the distribution pattern of dengue cases. According to the World Health Organization (WHO, 1997), temperature greater than 26°C and heavy rainfalls were significant parameters to determine the dengue transmission and to influence the transmission rate. Furthermore, slightly higher temperature i.e. 27°C required less time for the virus to reproduce and distribute in the mosquito (Kumarasamy, 2006). Therefore, comparison between LST and distribution pattern of dengue cases showed that the number of cases were influenced by the distribution pattern of LST. The distribution patterns of dengue outbreaks were high with high LST (Fig-8). The results showed that LST was an important environmental factor to determine the distribution pattern of dengue outbreaks and high values of LST had high risk of dengue outbreaks.

Correlation between Dengue Outbreaks and NDVI: NDVI was used to derive vegetation cover on a land surface. According to Umor *et al* (2007) mostly cases occurred in less vegetated areas. The regions that have large coverage of green areas had comparatively low number of cases as compared to the areas with low / no vegetation (Fig-9).

Dengue Risk Map for Lahore: A Weighed Overlay Analysis was done to develop Dengue Risk Map DRM from remotely sensed environmental data. Environmental factors were assigned weights and then classified as low, medium and high potential risk areas for dengue outbreaks (Table 1).

A dengue risk map was developed using LST, NDVI and LCLU layers and converting their pixel values into the above mentioned scale values. The risk map thus generated was verified with real dengue cases reported in the study areas. Dengue risk map showed a strong relationship with real dengue cases in risk prone areas (Fig-10 and 11).

The statistical accuracy of the findings was found to be very convincing since the relationship of dengue outbreaks with environmental factors rainfall, LST, and NDVI was statistically significant with R^2 values of 0.65 and more. The results showed that most of the cases occurred in those areas that received heavy rainfall ranging from R^2=0.66 to R^2=0.81 followed by high temperature and low NDVI.

Table 1. Environmental Weights and Scores of Dengue Outbreaks.

Dengue Outbreak Indicator	Influence Weight (%)	Field	Risk Score
LST	**33**	18° C – 21° C	Low (1)
		21° C – 24° C	Low (1)
		24° C – 27° C	Medium (2)
		27° C – 30° C	High (3)
		30° C – 34° C	High (3)
NDVI	**33**	Non-vegetated Area	High (3)
		Vegetated Area	Low (1)
LCLU	**34**	Water Bodies	Low (1)
		Urban Area	High (3)
		Barren Land	Low (1)
		Green Areas	Low (1)

LST: Land Surface Temperature, NDVI: Normalized Difference Vegetation Index and LCLU: Land Cover Land Use

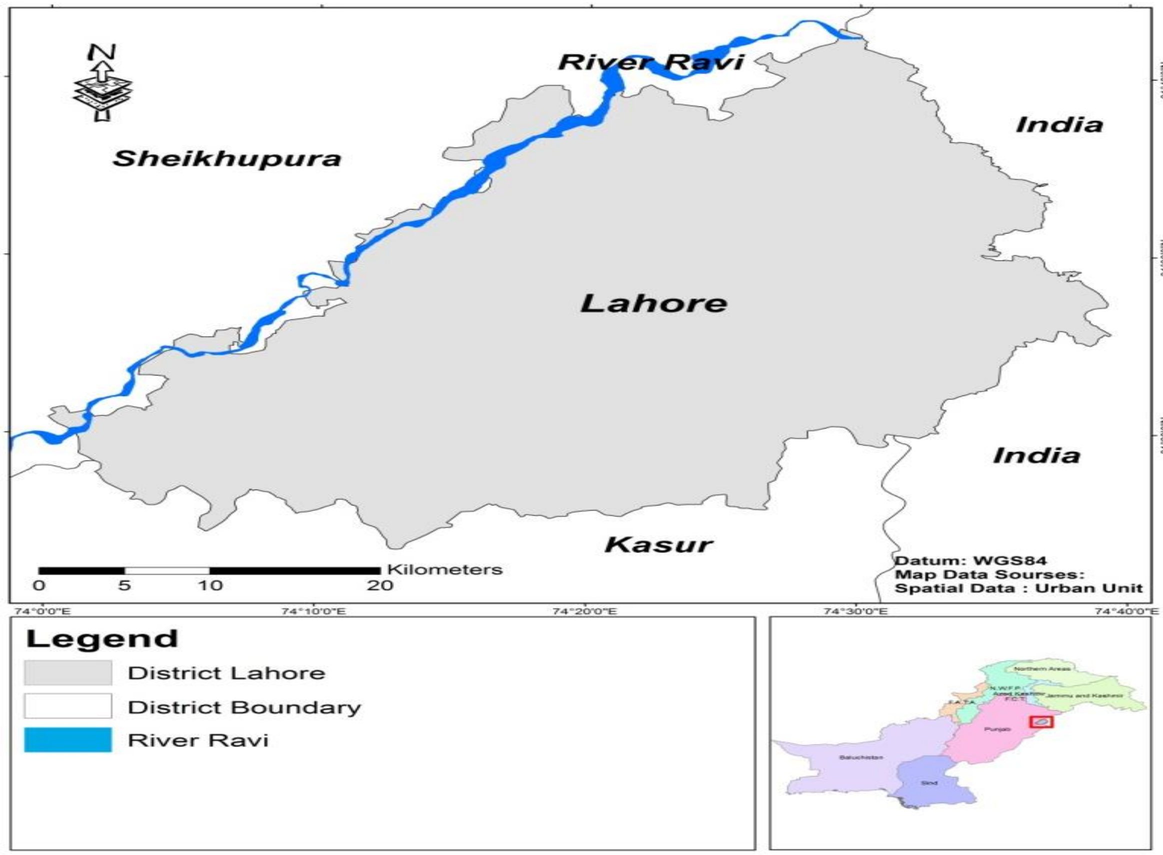

Fig-1: Study Area

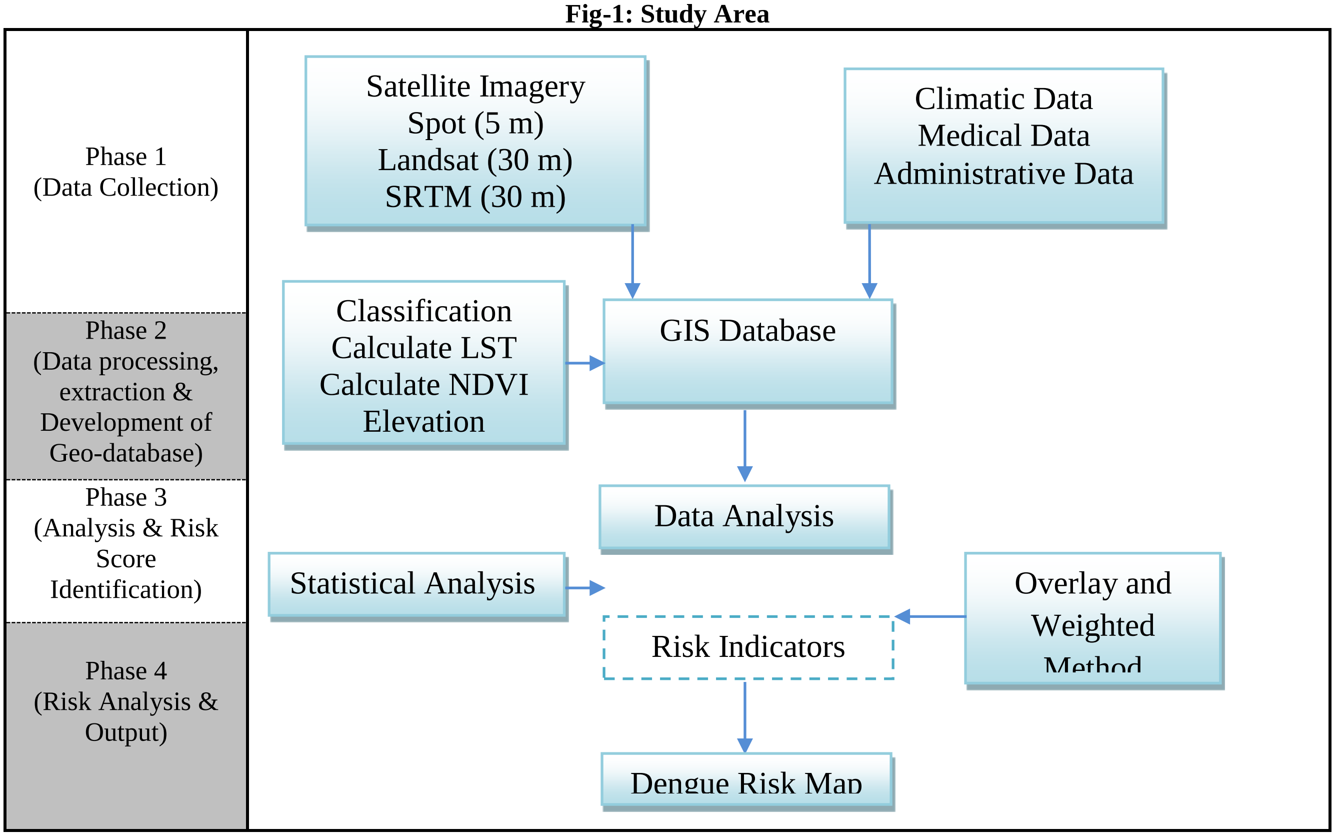

Fig-2: Flow Chart for Methodological Concept

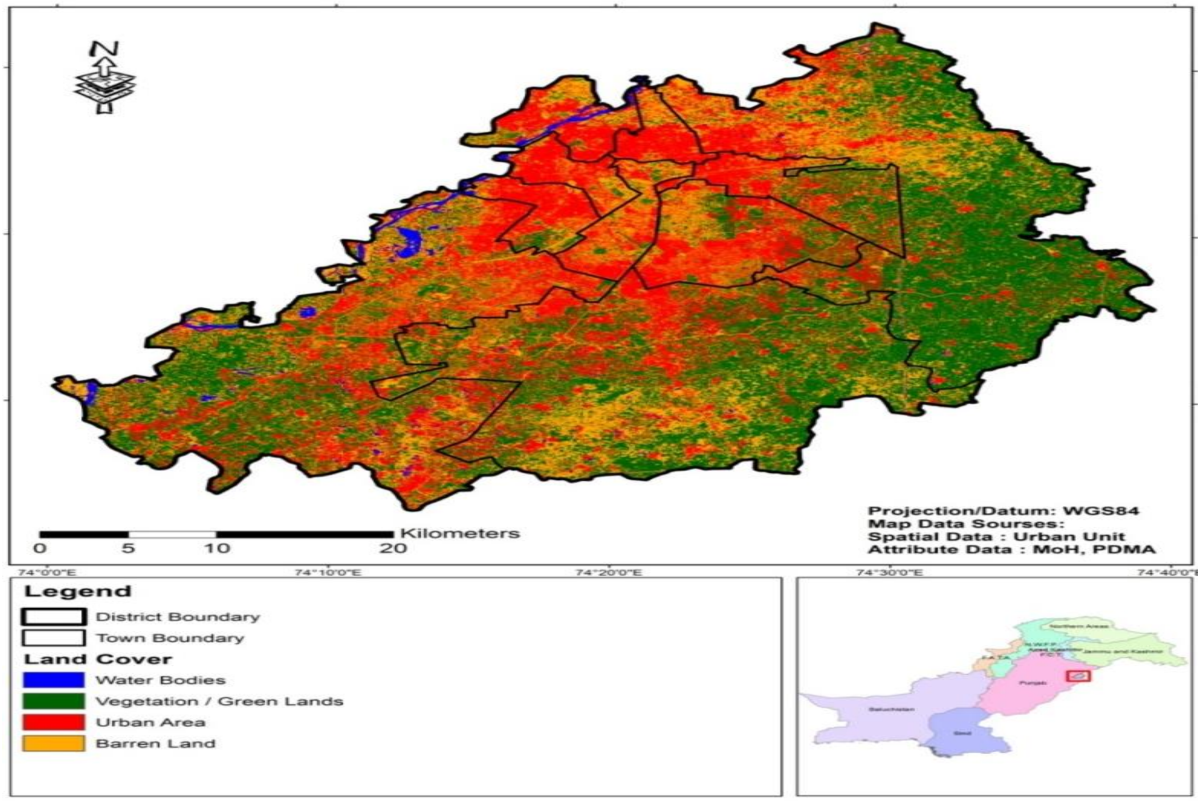

Fig-3: Land Cover and Land Use (LCLU) Map of District Lahore

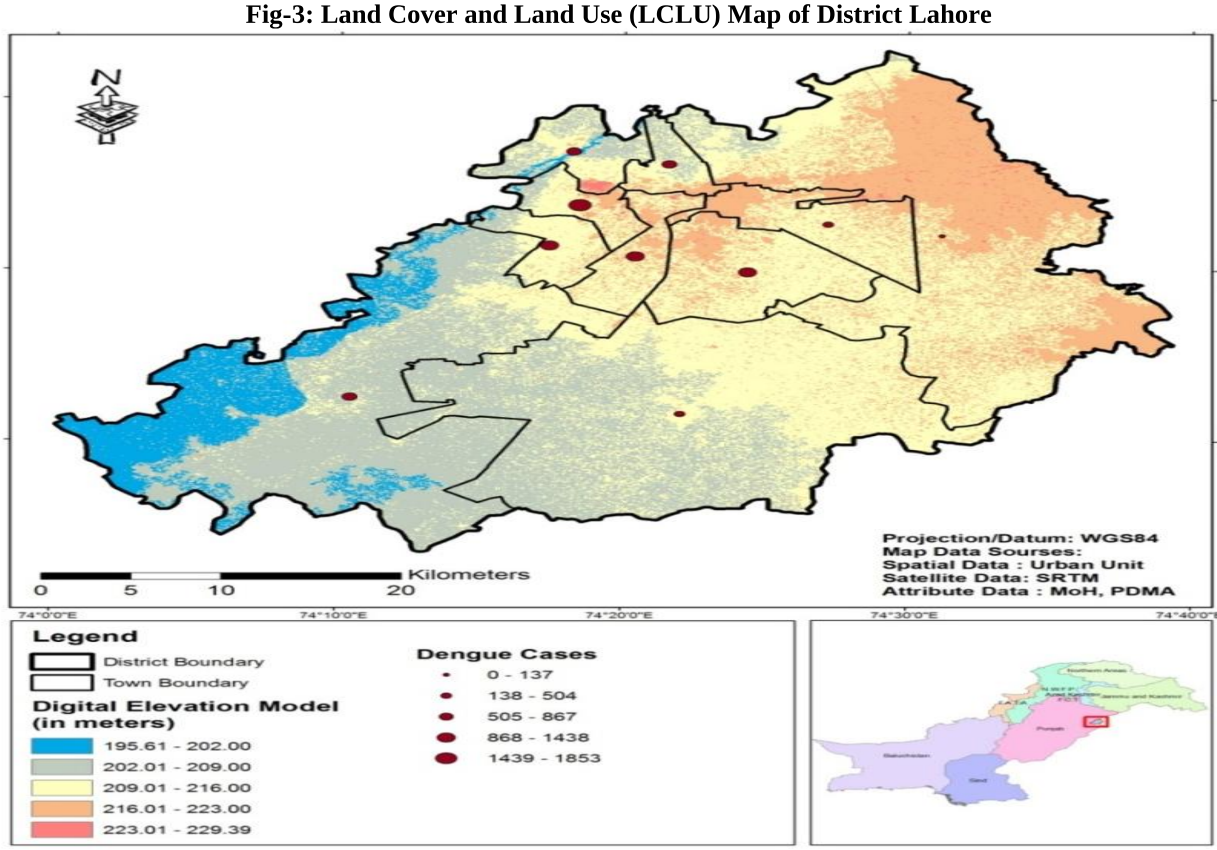

Fig-4: Elevation Map and Dengue Cases

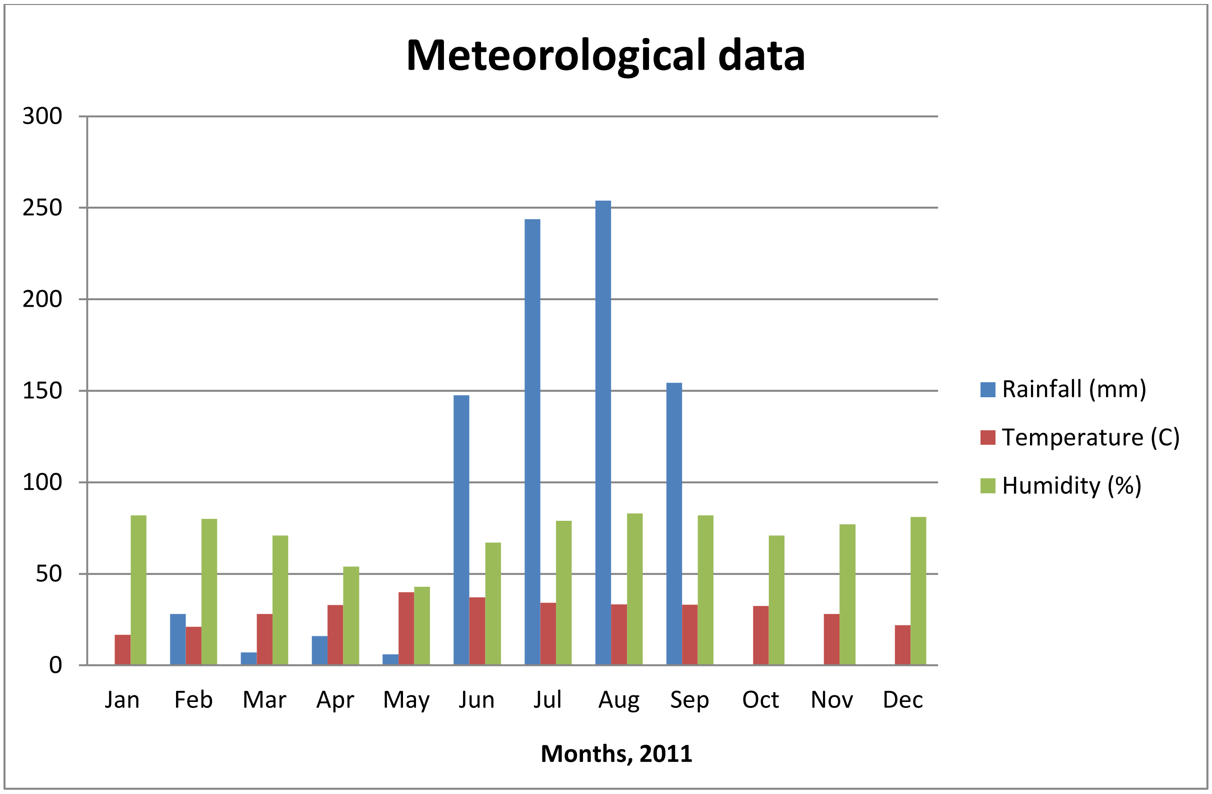

Fig-5: Meteorological data of District Lahore in 2011

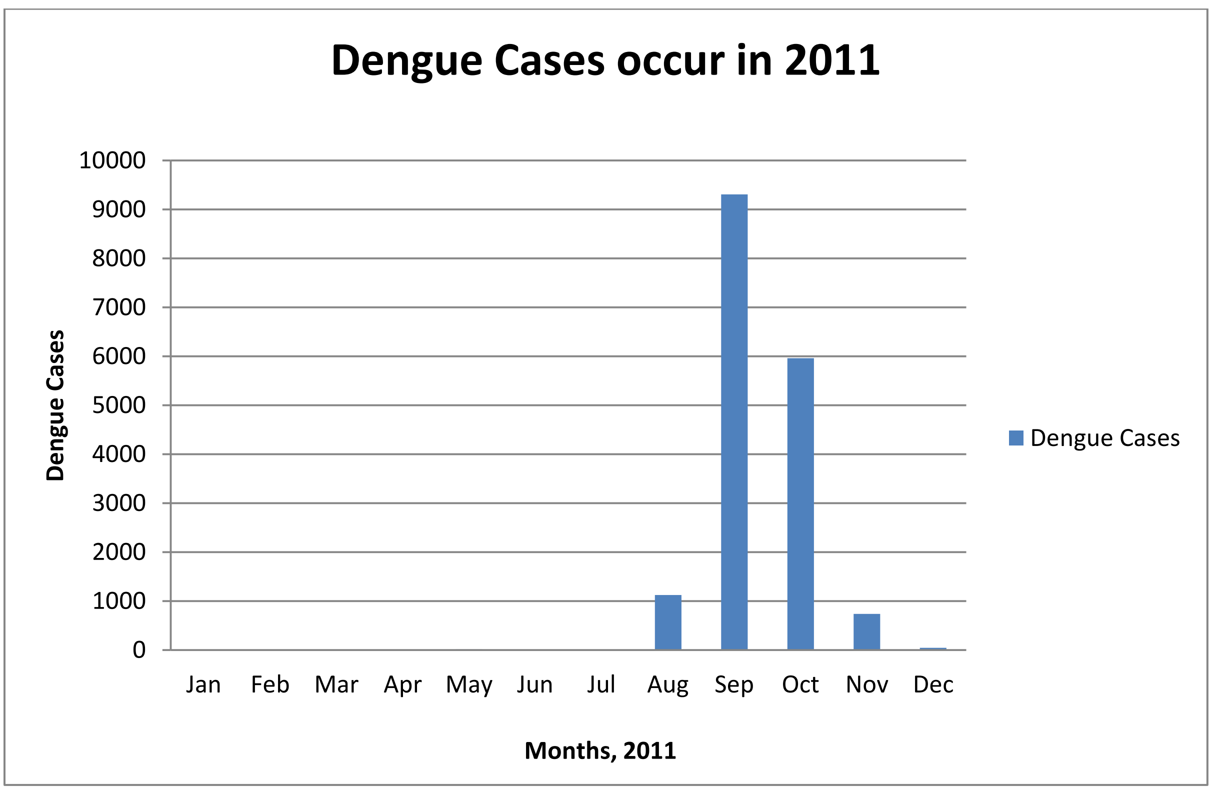

Fig-6: Dengue Incidences in District Lahore during 2011

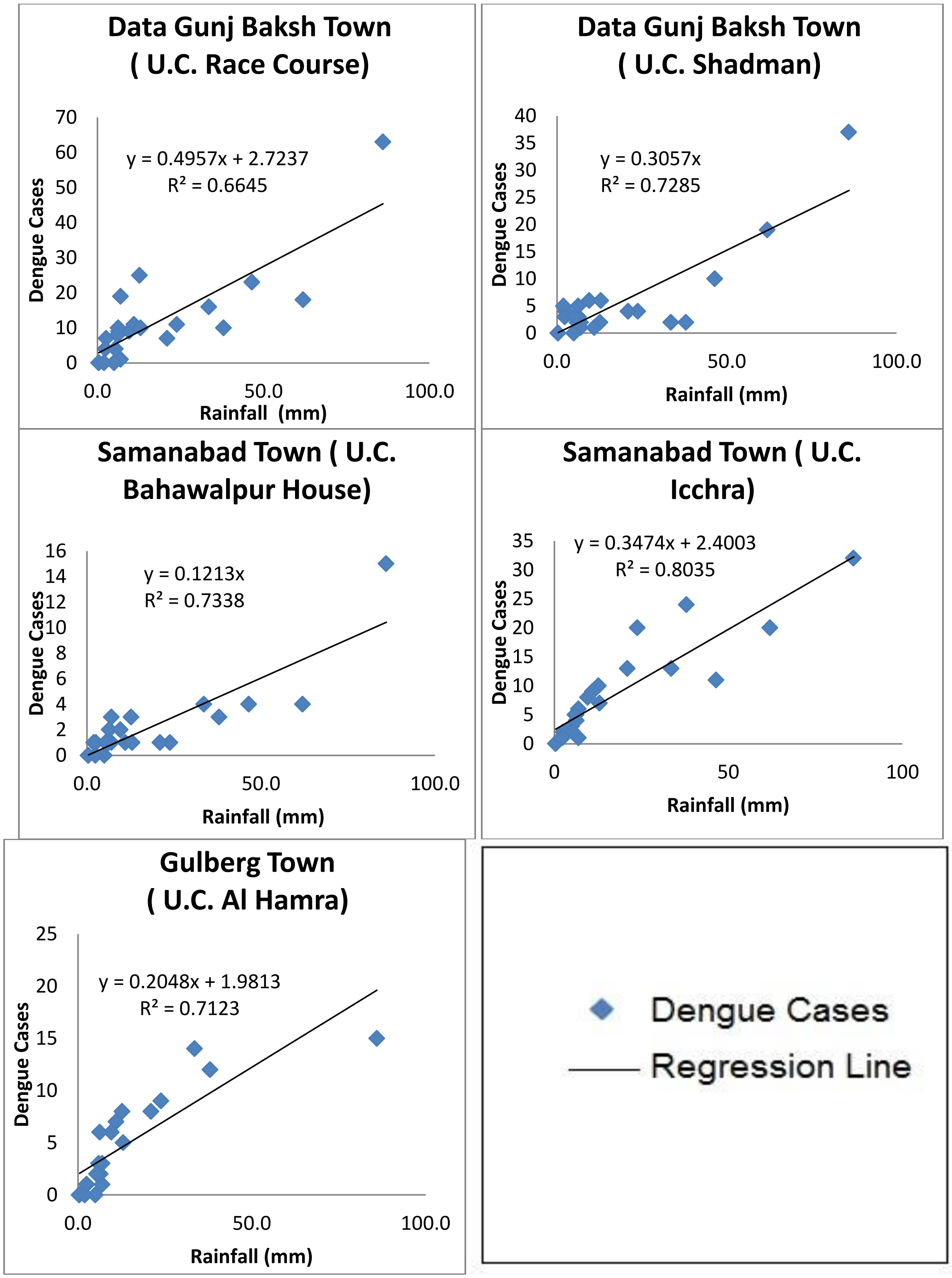

Fig-7: Scatter Plot and Regression Line between Rainfall and Dengue cases

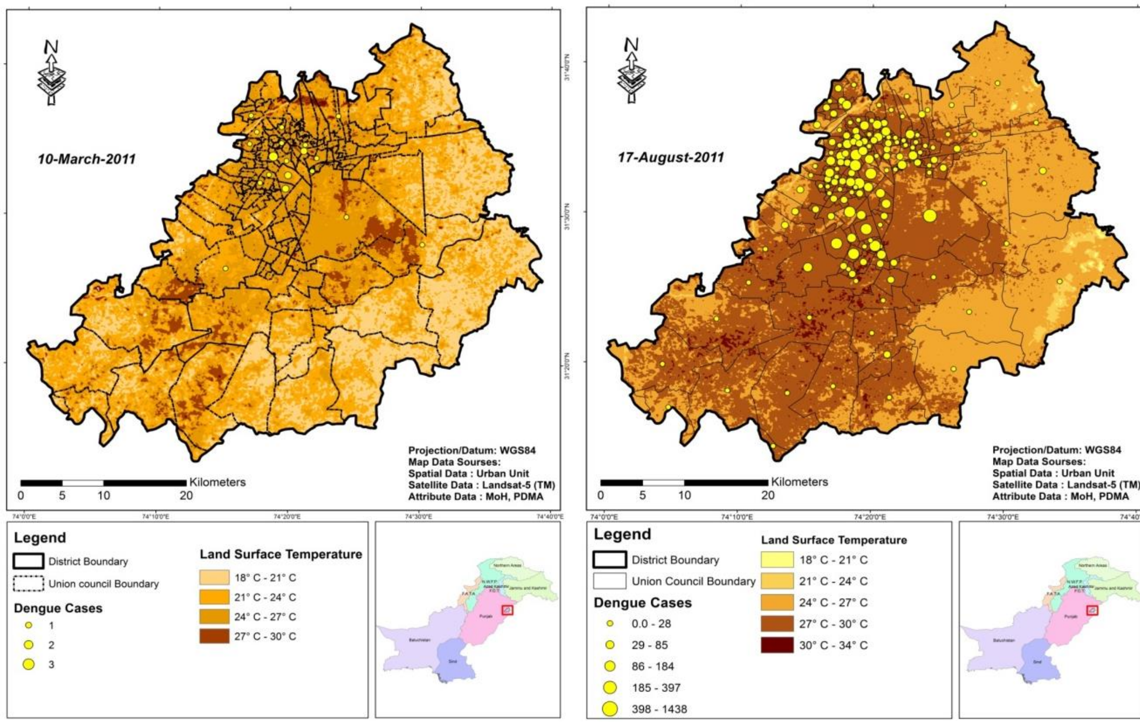

Fig-8: LST and Distribution Pattern of Dengue – Pre and post Incidence Map

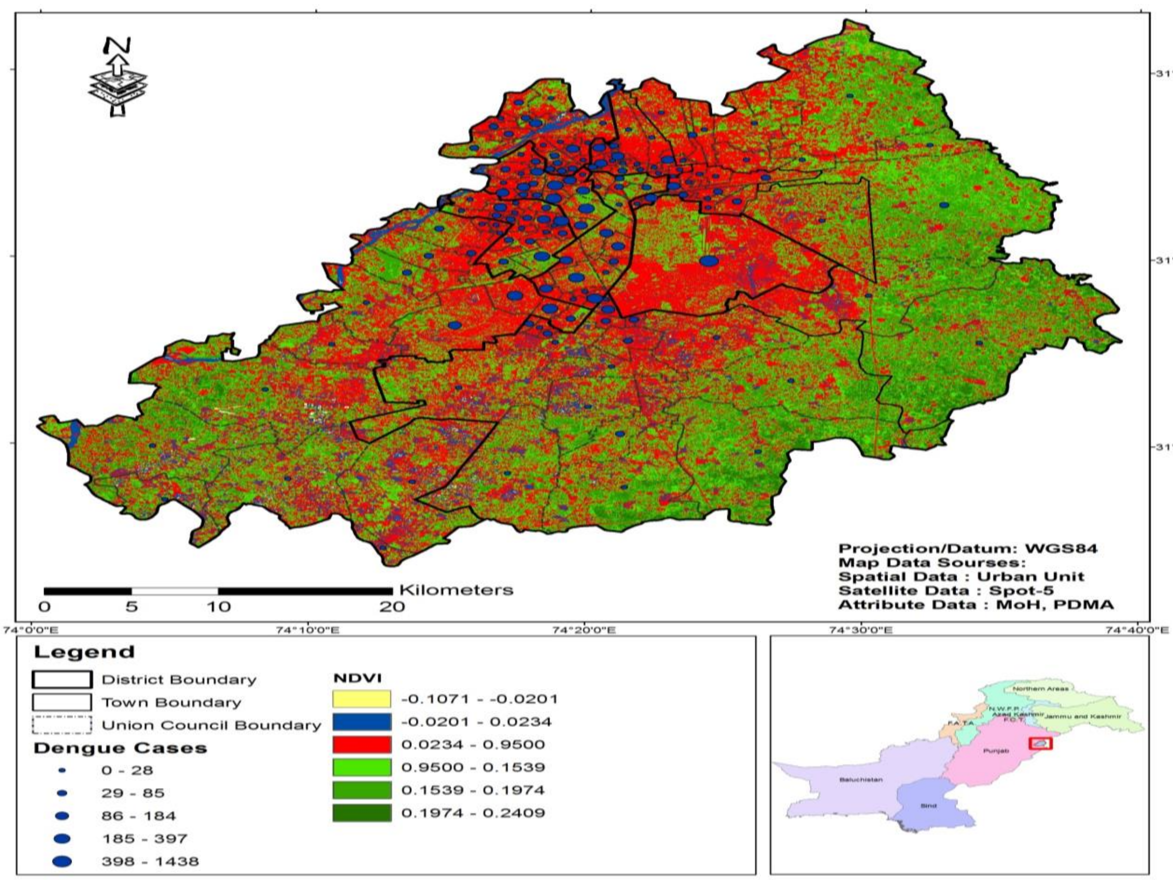

Fig-9: NDVI and Distribution of Dengue Cases

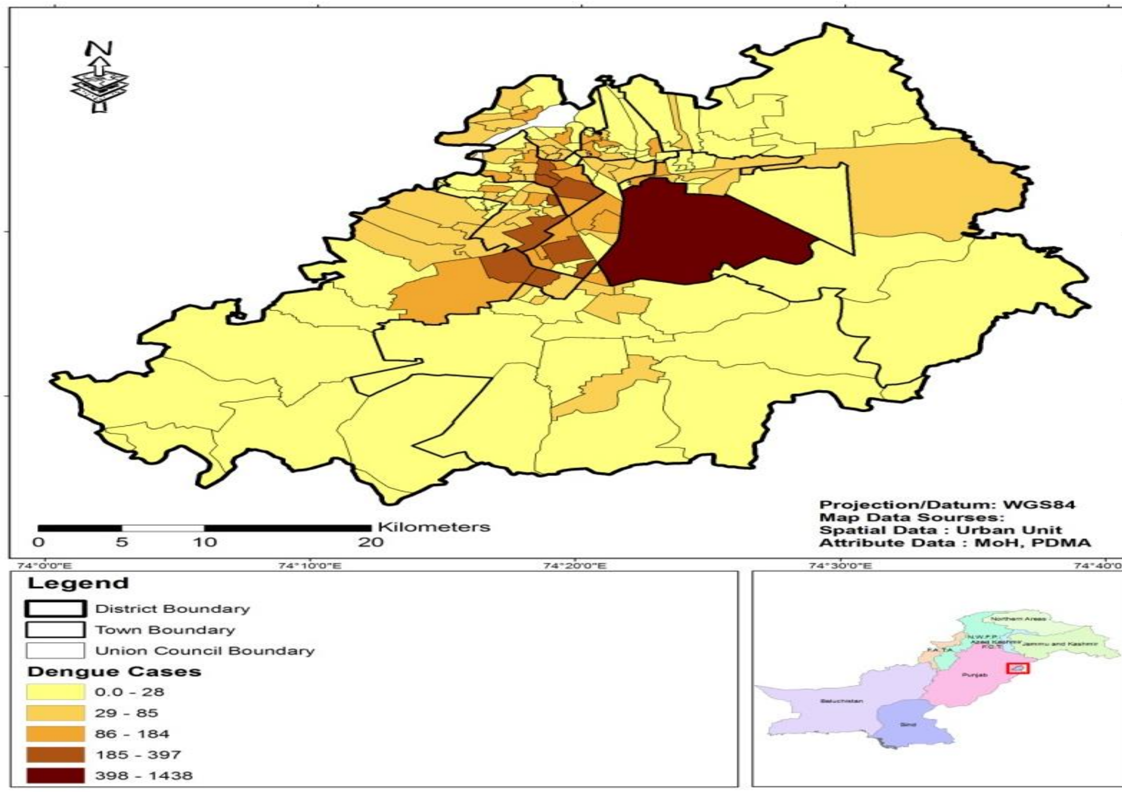

Fig-10: Union Council-wise Distribution Pattern of Dengue Incidences in District Lahore

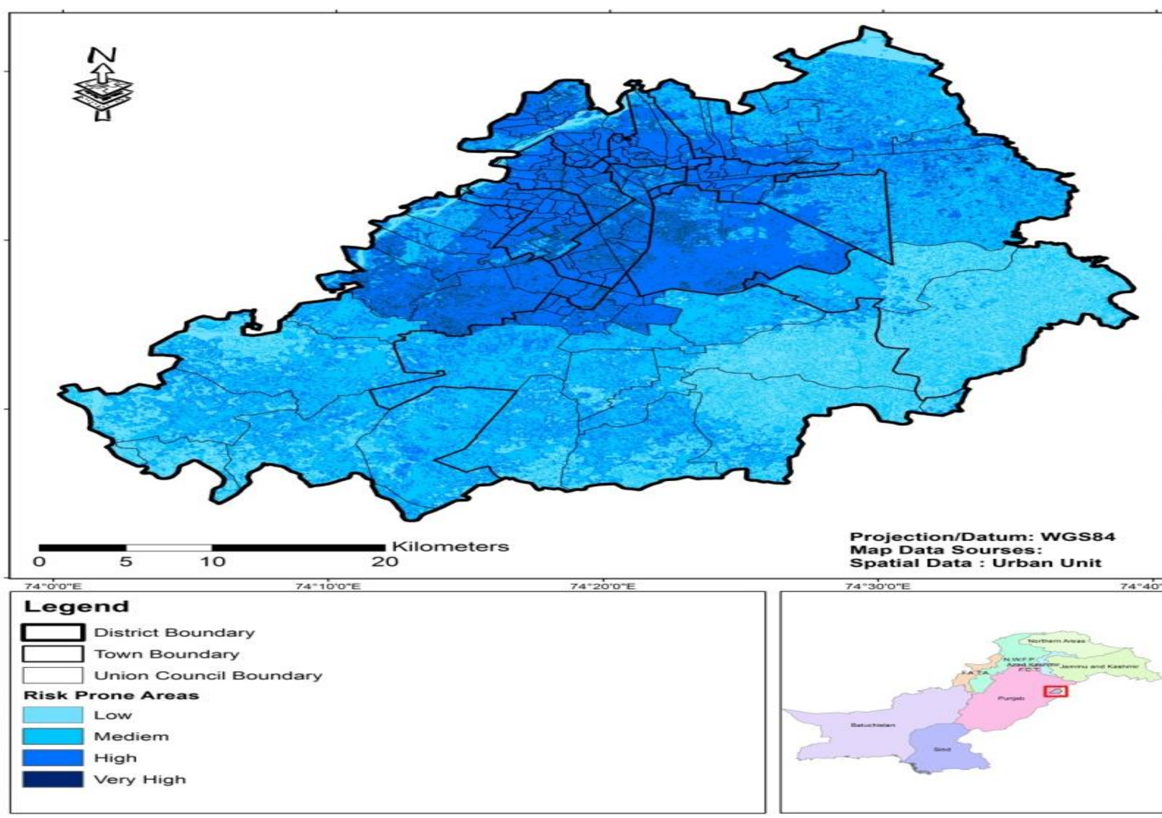

Fig-11: Dengue Risk Map of District Lahore

Conclusions: The study verifies the impact of environmental factors on the distribution pattern of dengue outbreaks in Lahore city. Dengue Outbreaks varies with the season and climatic changes. The highest outbreaks were recorded in the month of August followed by September due to high temperature and precipitation in these months. Precipitation was an important factor that increases the breeding habitats of mosquitoes during monsoon season in the months of July and August. High rainfall in the monsoon season also increases the vegetation cover. This type of seasonal changes provides better probability to dengue breeding and as a result the outbreaks were also high where the concentration of vegetation is high. After September when temperature falls along with low precipitation, the dengue cases decrease drastically.

The results of the analysis showed a strong influence of vegetation coverage and land surface temperature on dengue outbreaks. Since Lahore has a flat landscape therefore topography does not affect the distribution pattern of dengue outbreaks in the study area. Temperature was one of the confirmed influencing factors in combination with rainfall events. Most of the cases occurred in areas that have high LST with rainfall.

Acknowledgement: The authors would like to thank Member SAR, Pakistan Space and Upper Atmospheric Research Commission (SUPARCO), Director Pakistan Metrological Department (PMD), Director General (DG) Punjab Disaster Management Authority (PDMA) and Director The Urban Unit for providing data for this research work.

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