Employing Geographic Information System and Spatiotemporal Analysis of Dengue Outbreaks in a Metropolitan Area in Pakistan

Shakeel Mahmood and Ahtisham Irshad

Abstract Dengue is endemic in Pakistan with its usual peak incidence in the post monsoon period. In the recent past dengue outbreaks have occurred in major urban areas particularly Karachi, Lahore and Peshawar affecting large number of population. This study is an attempt to analyze the spatial and temporal variation of dengue fever (DF) in Samanabad Town, district Lahore. The study is based on primary and secondary data. Primary data is acquired through semi-structured questionnaire. Secondary data have been acquired from concerned Government departments. Geographic information system (GIS) is used to perform spatial analysis. It has been found that temporally DF prevalence varies from month to month and year to year. Similarly spatial variation has been observed. Analysis reveals that DF is still a major threat to the area as socio-economic and geographic conditions favors mosquitoes breeding and transfers of disease from one person/place to another. This study presents useful information related to the dengue outbreak spatio-temporal patterns and may bring the attention of public health departments to plan strategies to control the spread of disease. Risk zones of DF have been delineated using Inverse Distance Weighted (IDW) technique of spatial interpolation. The methodology is general for spatio-temporal analysis and can be applied for other infectious diseases as well.

Keywords Dengue fever · Dengue hemorrhagic fever Aedes Albopictus · Aedes Aegypti · Spatial distribution · Temporal pattern · Risk zones · Geographic information system · Karachi · Lahore · Disease transmission

S. Mahmood (✉) · A. Irshad
Department of Geography, GC University Lahore, Lahore, Pakistan
e-mail: shakeelmahmoodkhan@gmail.com

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1 Introduction

Globally, dengue fever (DF) has become one of the most prominent mosquito-borne infectious diseases (Shaikh et al. 2014; Senthil et al. 2014). The global incidence of DF has been mounting and making large human population vulnerable particularly in tropical and sub tropical regions (Lin and Wen 2011; Jeefoo et al. 2011; Li et al. 2011). In the past 50 years, DF has amplified 33-fold with an increase of 50 million cases per annum (Fareed et al. 2016). Thousands of DF and dengue hemorrhagic fever (DHF) cases have been reported each year and became a leading factor of morbidity and mortality (Amarsinghe et al. 2011).This has made 2.5 billion people at risk in about 120 counteries (Raheel et al. 2010; Arshad et al. 2011; Mulligan et al. 2012; Naqvi et al. 2015). Dengue virus is transmitted to human by mosquito that is *Aedes Aegypti* and A*edes Albopictus* (Li et al. 2011).

The spatial distribution of DF is directly influenced by prevailing weather and seasonal conditions because its vector is sensitive to it (Hales et al. 2002). The temperature conditions have significant influence over mosquito feeding habits, virus development and population dynamics. Similarly, the developmental stages of mosquito life are controlled by temperature. The chance of female mosquito fertilization reduces when temperature falls below 20 °C and feeding activity ceases when temperature falls below 15 °C. Exposure to high temperatures results in increased mortality of adult mosquitoes. The temperature of water plays vital role in breeding and reproduction of mosquitoes (Balmaseda et al. 2006; Mahmood et al. 2019). *Aedes Aegypti* laid eggs in cooler water having shaded container. The *Aedes Aegypti* continues to live in a wide range of temperatures and humidity while *Aedes Albopictus* does not. This is the reason that *Aedes Aegypti* is dominant in urban environment and *Aedes Albopictus* likes better Peri-urban areas (Juliano et al. 2002). Rainfall makes available the favorable habitat for mosquito initial stage of life. The combine impact of higher temperature and rainfall increases humidity. The higher humidity causes higher feeding rates and better development of *Aedes Aegypti* (Scott et al. 2000).

In Pakistan, DF is endemic with its usual peak in the post-monsoon season affecting urban and sub-urban areas (Mahmood et al. 2019). The very first DF outbreak was reported in 1994–1995 in Karachi with 4500 registered cases (Khan and Hassan 2011; Khnanani et al. 2011). During 2005–2006, there was an unprecedented increase in DF with more than 3640 reported cases and 40 deaths (Shakoor et al. 2012). In Lahore, few DF cases were reported in 2006–2007 and epidemic occurred in 2008 (Jahan 2011). The total number of reported cases was 17,493 with 290 deaths in year (Rasheed et al. 2013). The dengue epedmic has been occuring every year since 2006 and extended to most of the cities in Pakistan (Rasheed et al. 2013). It has badly affected the major cities of Karachi, Lahore, Multan, Fasilabad and Rawalpendi (Laghari et al. 2015). Naqvi (2015) found that transportation is the main factor of dengue spread from Karachi to Lahore.

Currently, in Peshawar (The capital city of Khyber Pakhtunkhwa) the registered cases of DF is maximum in the entire country and is spreading to the surrounding districts very rapidly.

Geographic information system (GIS) is a strong geographical tool for spatial and temporal analysis (Mahmood et al. 2019) and have been applied in epidemiological and public health studies for many years (Mondini and Chiaravalloti-Neto 2008) to assess and identify potential risk factors involved in disease transmission (Twumasi and Merem 2005; Jeefoo et al. 2011). This study involved micro-level detailed investigation of DF spatial pattern at union council (UC; the smallest electoral unit) which made it different from past studies. Similarly, there are few studies regarding the dengue outbreak and it spatial pattern in the study area. The main objective of this research is to employ GIS and Spatiotemporal Analysis of Dengue Outbreaks in a Metropolitan Area in Pakistan.

2 Study Area

Lahore is the second largest city of Pakistan and capital of the province Punjab (Shirazi and Kazmi 2014). Geographically, it is extended from is 31° 15′ to 31° 45′ N latitude and 74° 01′ to 74° 39′ E longitude with total area of 2260 km^2. The population density is 2778 person/km^2 (Shirazi and Kazmi 2013). Administratively, Lahore is divided into nine towns with one cantonment area. Iqbal Town is the largest covering 476.79 km^2 and Shalimar town is the smallest with 26.88 km^2 area. Climate of the study area is sub-tropical. In January and February the temperature remains low and in June and July temperature remains high (Shirazi 2012). It is located in the lucky monsoon region of south asia with plenty of rainfall which is significant factor for dengue growth. In July and August the study recienves maximum rainfall (Naqvi et al. 2015).

Samanabad Town has been selected for detail and micro-level investigation regarding the spatio-temporal trend of DF. It was severely affected by dengue outbreak in 2008. Out of the total reported cases in Lahore, 62% were registered from the study area (Fig. 1). The severely affected Union Council (UC; smallest electoral unit) were Samanabad, Ichra and Gulshan-e-Ravi (Mushtaq et al. 2010). In the Northwest of the study area River Ravi is flowing. Waste water drain (locally Ghanda Nalla) is flowing from north to south of the town and make it favorable for the breeding and growth of mosquito.

2.1 Data Acquisition and Analysis

To achieve objective of the study, seven UCs were selected as sample sites, out of nineteen in the study area by random means of sampling namely Babu Sabu, Abu Bakar Siddque, Gulshan-e-Ravi, Samanabad, New Samanabad, Ichra, and Sikander Block (Fig. 1).

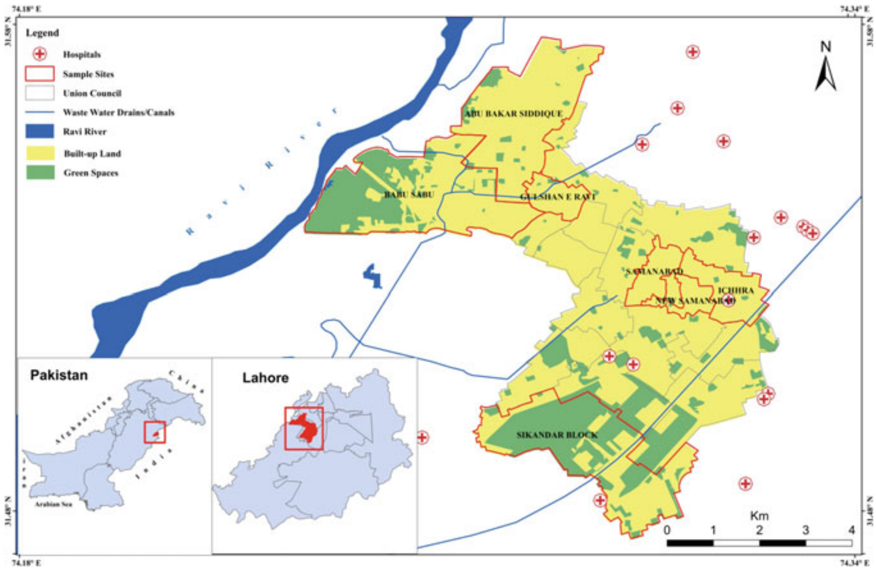

Fig. 1 Location of the study area and sample UCs

The required data were collected from concerned Government Departments. Population record was collected from Pakistan Statistical Bureau, Lahore. Rainfall, temperature and humidity data were collected from Pakistan Meteorological Department (PMD), Lahore. Data regarding the confirmed DF cases for the years 2012–15 were obtained from Governments Hospitals and Health Departments, district Lahore. The data comprised of patient's age, gender and postal address. Google Earth image was downloaded as base layer to develop land use and land cover map of the selected area. Spatial data regarding the administrative boundaries of the study area was collected from Punjab Provincial Disaster Management Authority (PPDMA), Lahore.

Relative location of the dengue affected person was converted to absolute location by applying Point Level Geo-coding technique to visualize the record on map. Then location data was converted KML using ArcGIS10.2 and geo-visualize the record on Google Earth for validation purpose. The data were validated using GPS-based questionnaire surveys using stratified purposive sampling techniques with sample size of 22%. The validity of the data was 83%. Simultaneously, GPS survey was also conducted to acquire the geographic location of health units including hospitals and Basic Health Units (BHU). MS excel was used for data processing and descriptive statistical analysis.

3 Results and Discussion

Analysis reveals that out of the 7 sample sites (Fig. 1), *Samanabad*, *Ichhra and Gulshan-e-Ravi* were the most affected with high prevalence. Sikandar Block and Abu Bakkar Siddique were less affected with low prevalence (Table 1). DF, DHF, and DSS are three serotypes with 394 registered cases in 2012, 388 had DF, 5 has DHF and 1 had DSS, 905 cases were registered in 2013, 887 had DF, 17 had DHF and 1 had DSS while in the 2014 registered cases were 130 of only DF. In the selected time DF cases were maximum and 2013 was severely affected by DF outbreak (Table 2). The total registered cases of dengue from 2007–15 were 2793.

Samanabad, *Ichhra and Gulshan-e-Ravi* are the densely populated sample sites. Most of the sample households have medium (7–9 members) family size. Similarly 44% of the surveyed households have monthly income ranges from 16 to 50 thousand (Pakistani Rupees). The age of confirmed DF patient ranged from 3 to 84 years with a median of 28 years. There were 725 males and 311 females out of the total affected persons and among them 131 (12.6%) were children (15 years or below), 579 (55.8%) were of 16–30 years; this was the most affected age group in the selected spatial and temporal dimension. Approximately 67%, 83% and 71% of these cases were confirmed during post Monsoon season in 2012, 2013 and 2014 respectively. In the mentioned season the rainfall decreases and relative humidity increases which favor the breeding and growth of mosquitoes. The number of DF cases increases from July onward, reached to its highest recorded peak in September, and then decreases. Out of the total patients, male patients were more than female (Fig. 2). In selected dengue outbreaks registered male patients were about 60%. Based on age, 16–30 years age group is most affected where as the elder persons are least affected (Fig. 3).

Temporal analysis reveals that dengue distribution varies from month to month and year to year. Year wise 2013 was severely affected with maximum reported cases (905), in 2012 the reported cases were 394 and in 2014 of 130. Monthly distribution of dengue is also variable. January to May the incidence is minimum then from Jun incidence rises, in September maximum cases were recorded in 2012 and 2013. Incidence of dengue decreases from October to November. In the year 2013 two outbreaks occurred in September and November (Fig. 4).

Spatial analysis reveals that dengue distribution is not uniform. Samanabad, Ichhra and Gulshan-e-Ravi were the most affected sites with incidence rate; number of patients/1000 persons of 5.8, 4.2 and 2 respectively. The dengue incidence were high in Ichara followed by Samanabad in 2012 and 2013 whereas in Kashmir

Table 1 Serotype prevalence of Dengue in study area

Dengue type	Year 2012	Year 2013	Year 2014
DF	388	887	130
DHF	5	17	0
DSS	1	1	0

Source Health department and Arfa Kareem tower, Lahore

Table 2 Spatio-temporal distribution of dengue incidences in studied area

Sample UC	2012	2013	2014
Abu Bakkar Siddique	6	8	2
Gulshan-e-Ravi	49	109	16
Babu Sabu	17	11	2
Ichhra	89	301	34
New Samanabad	16	61	2
Samanabad	98	213	24
Sikandar block	0	1	2

Source Health department, Lahore

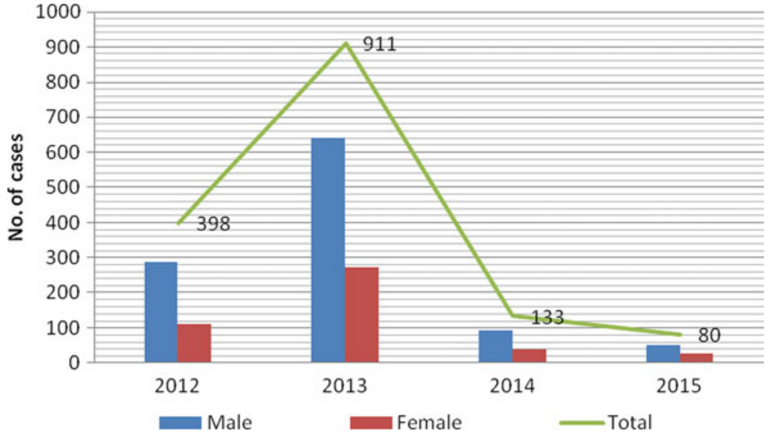

Fig. 2 Annual distribution of dengue occurrence in study area. *Source* Health department, Lahore

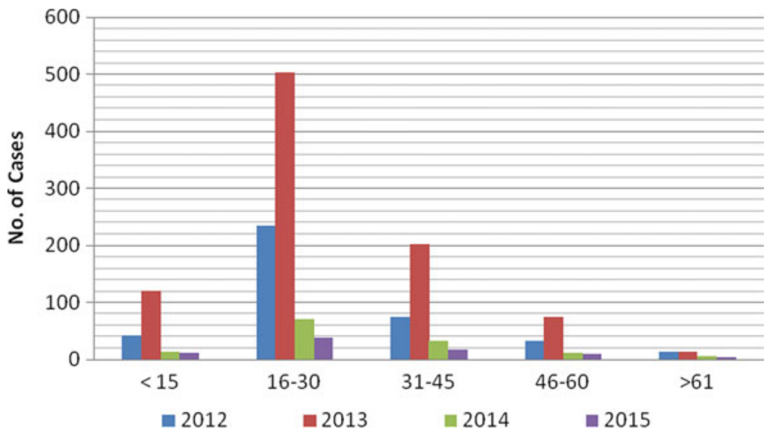

Fig. 3 Age wise distribution of dengue occurrence in study area. *Source* Health department, Lahore

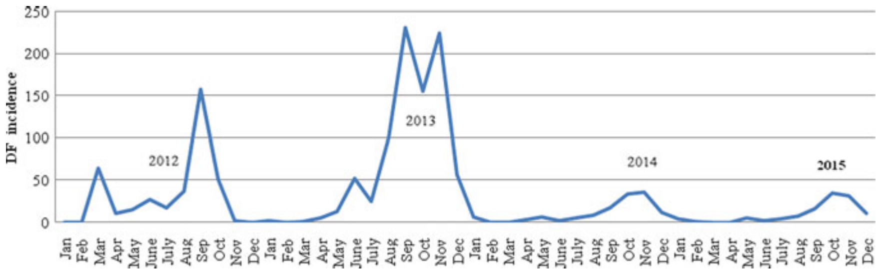

Fig. 4 Dengue fever outbreaks in district Lahore after Punjab Health Department, 2015

Block, Paki Thatti and Abu Bakar Siddique Colony the incidence was lowest (Fig. 5). Dengue incidence maps were developed for the year 2012, 2013 and 2014 using the layers of DF, population density and landuse. Different themes were combined in one layout to compare and identify most affected sample site (spatial) and year/moth (temporal) as well as to identify incidence relationship with study area attributes. Spatio-temporal analysis of the dengue reveals that prevalence is high in *Samanabad*, *Ichhra and Gulshan-e-Ravi,* where more than 90% land is built up with high population density while prevalence was low in *Babu Sabu, Abu Bakar Siddque, New Samanabad, and Sikander Block* where green spaces are more with comparatively low population density (Fig. 6). High risk zone are spatially located in north-western parts of the study area because over there no vegetation cover and high population density (Fig. 7).

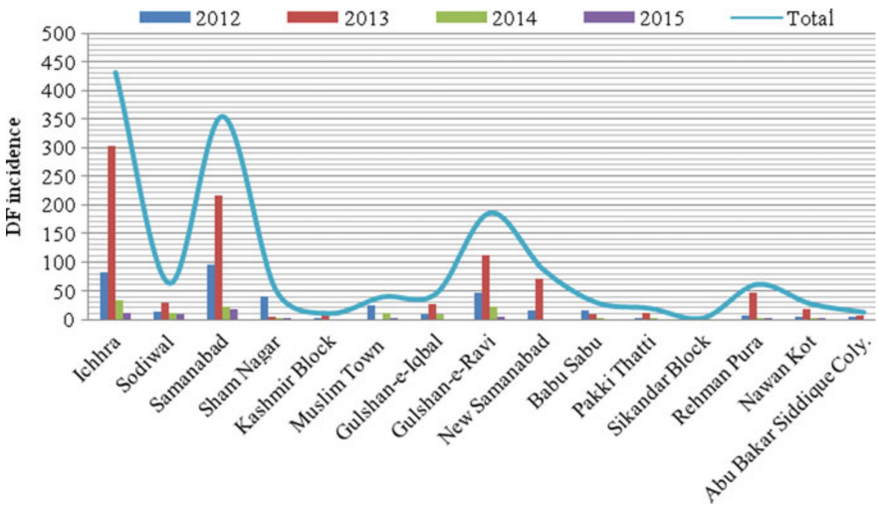

Fig. 5 Spatio-Temporal distribution of dengue incidences in studied area

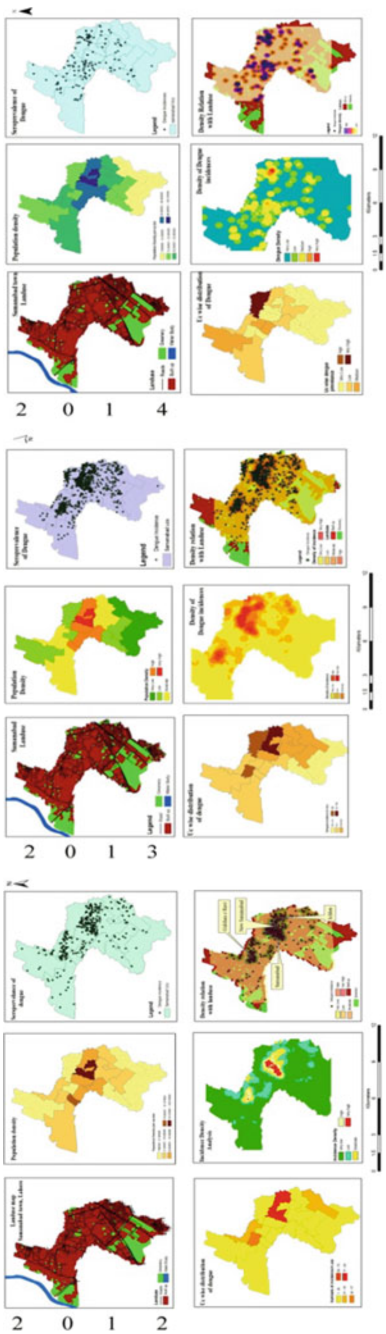

Fig. 6 Land use, population density, dengue prevalence from 2012–14

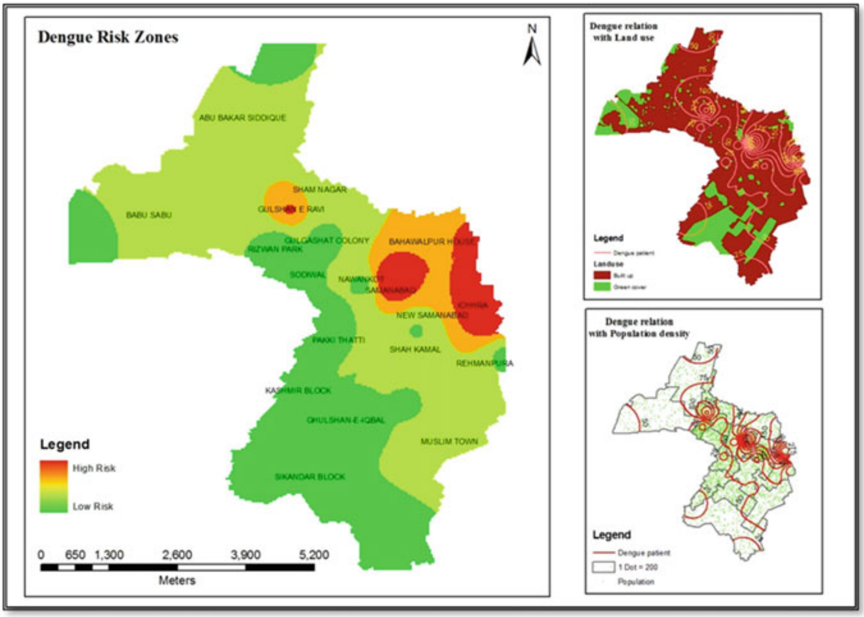

Fig. 7 Risk zones of Dengue

4 Conclusion

The study concludes that temporally dengue distribution varies from month to month and year to year. Dengue prevalence was high in 2013 with 905 reported cases followed by 2012 with 394 cases. Monthly prevalence also varies; from December to May minimum incidence recorded and from Jun it gets momentum and then in September attains recorded peak. In 2013 two outbreaks occurred in September and November. Spatio analysis reveals that prevalence is high in those UCs where green spaces are rare and more than 90% land is built up with high population density. On other hand where green spaces are more prevalence the incidence is low. Spatially, high risk zone is located in the North-Western areas. Finally, it is concluded that dengue fever infected person are more in those areas where population density is high with no green spaces or greenery.

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