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**Research Article**

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# Risk assessment of dengue outbreak using geographic information system (GIS) in Rawalpindi

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**Abstract** About half of the world's population is at risk from the vector borne diseases including dengue and malaria. World Health Organization (WHO) has ranked Dengue fever as the most important mosquito borne viral disease in the world. The main objective of this research work is to study the spatial distribution patterns of dengue disease in Rawalpindi using spatial clustering techniques to identify the hotspots and the possible risk factor for those hotspots. Dengue disease data was collected from District Health Office, Rawalpindi. The climate data including average temperature, rainfall and relative humidity was collected from Pakistan Meteorological Department, Islamabad. ArcGIS version 10.1 was used for spatial statistical analysis. The results of this study indicated that incidence level of dengue disease varies according to geographic location and climatic conditions, showing significant spatial autocorrelation. Hotspots were identified using Getis-OrdGi* statistic. Temporal variations of disease cases show significant positive association with the meteorological variables including rainfall, relative humidity and temperature. So, this study highlights the usefulness of GIS in the epidemiological studies.

**Keywords** Epidemiological studies, Spatial Distribution, Getis-OrdGi* Statistic, Spatial Autocorrelation

## Introduction

Many diseases have been taken under control by applying biomedical sciences and health measures, however still there has been increase in the spread of viral diseases leading to disabilities and death through the whole world.

Dengue fever is fast growing vector borne viral disease having certain health impacts. In tropical and sub- tropical dengue outbreak is widespread in 100 countries generating challenges among government and international health authorities [1]. Dengue fever is transmitted through bites of infective female mosquitoes, most commonly the mosquito Aedesaegypti or yellow fever mosquito. Approximately 50 to 100 million cases of dengue fever have been anticipated globally, of which 500,000 cases result in dengue hemorrhagic fever per annum [2]. Usually it reproduces in water containers, tree holes , rock holes, roof gutter, tanks, water coolers, jars, drums, barrels, pots, buckets, flower vases, plant saucers, discarded bottles, used tyres and other places where rainwater collects or is being stored [3]. Since early nineties, outbreaks of dengue fever had been occurring in Pakistan but mostly it is occurring in populated areas of Sindh, Karachi, Hyderabad and Punjab since 2005. After heavy rains in 2011, there was a massive outbreak of dengue fever in and around Lahore and certain other areas of central Punjab and a large number of dengue fever cases were recorded during this outbreak with a considerable mortality [4].

Geographical Information System (GIS) is a tool that is used for any computer based capability for operating geographical data. Nowadays GIS applications are used by almost all sectors of life particularly for their planning activities. In medical sciences the usability of GIS extends with the expansion of epidemiological applications.

Human geography has a branch of Medical geography which deals with the geographic characteristics of health and healthcare facilities by carrying out studies on geographical allocation and causes of diseases associated with natural, environmental, manmade, interactions and the healthcare facilities provided in areas as whole [5].

Novel technologies and advances are being tested based on behavior of mosquito and disease transmissions and involve use of computers, GIS, satellite imagery, cartographic, demographic, socioeconomic, and environmental data to implement disease early warning and response system [6].

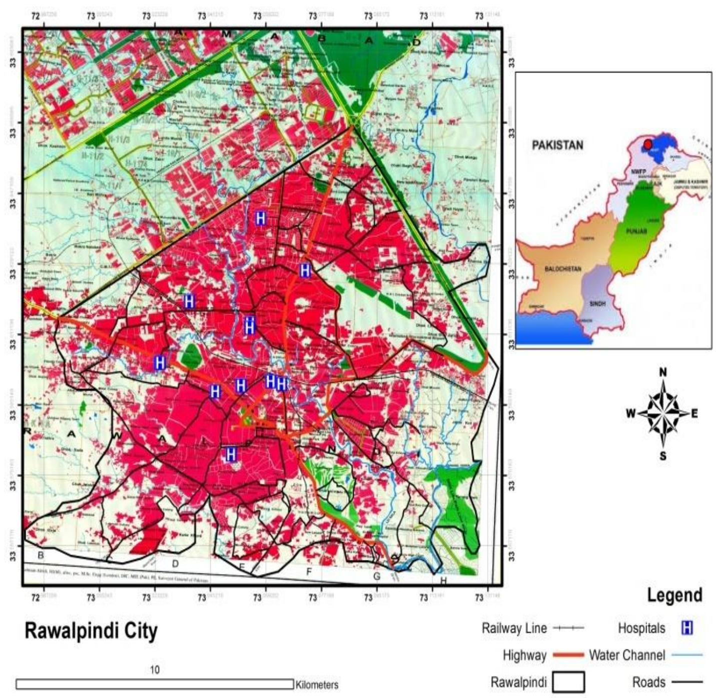
Geographic Information Systems and Remote Sensing technology have been used to visualize and analyze data related to vector borne diseases. There is great potential for the use of GIS and RS technologies in the prevention and control of vector borne and other infectious diseases [7].

Many scientists have geospatially analyzed different diseases in different regions of the world. Disease maps have been playing a key descriptive role in epidemiology and early warnings. Disease mapping can be used to pinpoint the areas where outbreaks originate and effectively target high-risk areas for early prevention and control. Recent studies have mapped risk areas over different defined time periods to describe the temporal dynamics of epidemics.

For controlling the transmission of dengue fever and outbreak of other vector borne diseases, it is important to identify the spatial and temporal patterns of climate and its impact on human health [8].

**Study Area**

The study area of this research work was Rawalpindi situated in the north, north-western part of Pakistan. Rawalpindi lies between 33.6000° N, 73.0333°E. Locally it is known as 'Pindi' in the north of province Punjab comprising area of 5,286 $km^2$ (2,041 sq mi). The City-District of Rawalpindi comprises seven Tehsils namely, Murree, Khutta, Kotli, Sattian, Gujjar Khan, KallarSyedan, Taxila and Rawalpindi. The city is located in the Potohar region of country the city is linked with city capital Islamabad. Rawalpindi covers a subtropical climate having long and very hot summers, monsoon and short, mild and wet winters [9].




**Objectives of Study**

The objectives of the research are:

- Analysis and clustering of dengue risk by applying Hotspot analysis.
- Interpretation of spatial distribution and spatial pattern of dengue disease to show the hot spot regions with the highest risk levels.
- To address the dengue disease surveillance for monitoring and mapping of dengue outbreak in Rawalpindi.
- To generate dengue risk assessment for applying preventive measures to control the dengue outbreak for different localities.

## Materials and Methods

**Data Used**

The data product required for the study included Islamabad- Rawalpindi guide map that was obtained from Survey of Pakistan.

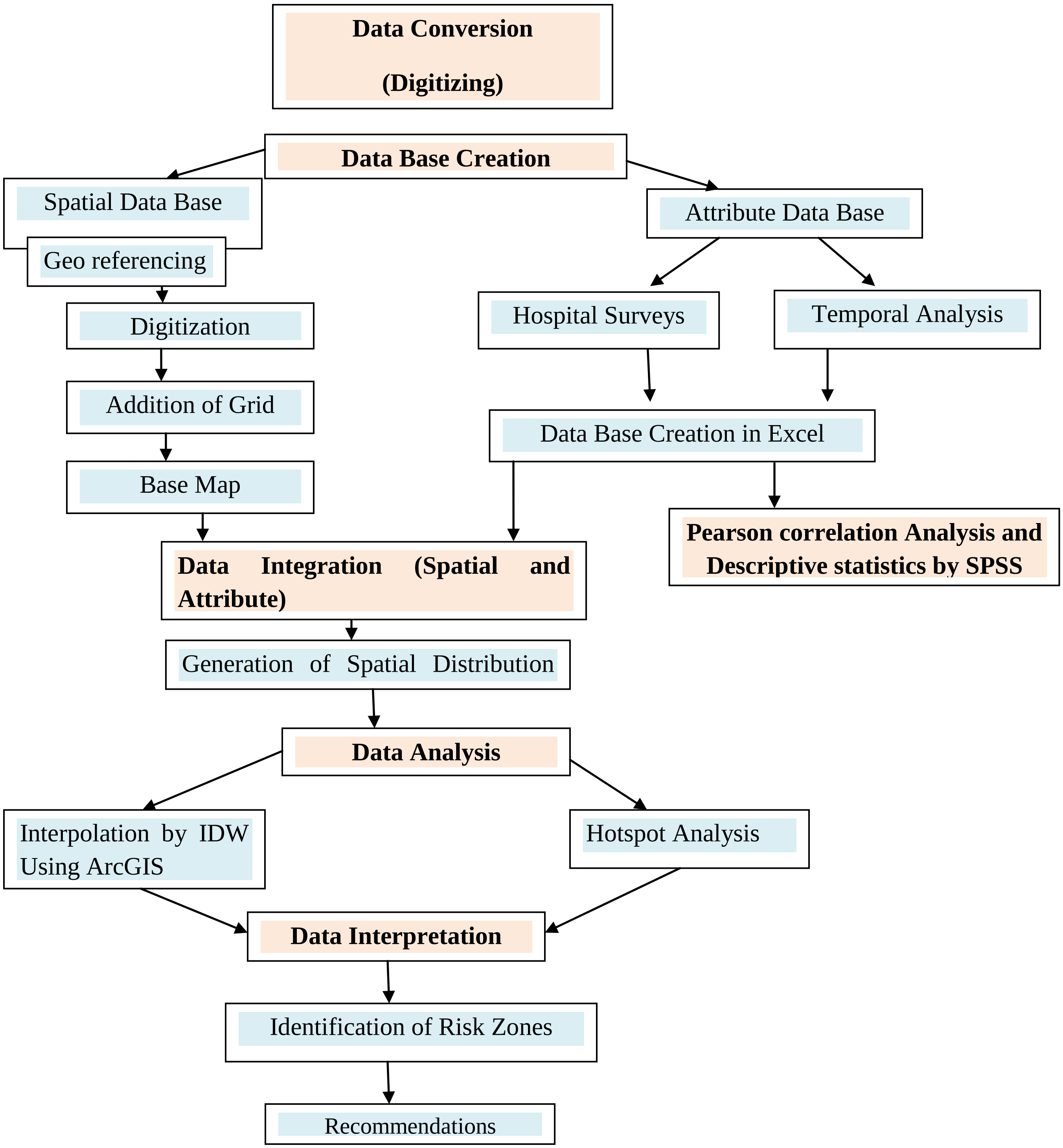



*Figure 1: Schematic Diagram of Methodology*

For the purpose of this study, dengue disease cases data reported during the years 2011 to 2013 was used which were obtained from Rawalpindi District Health Office, DHQ hospital, WAPDA Hospital, Railway General Hospital, Benazir Hospital and the dengue camp DhokeHassu. Location data of the study area was collected using Global

Positioning System (GPS) by visiting all the places. Longitude and latitude were both recorded for each location. Annually rainfall (mm), relative humidity (percent) and temperature ($^0$C) data from 2011- 2013 were collected from Pakistan Meteorological Department.

### Global Spatial Autocorrelation

Spatial autocorrelation or Global Moran's I statistic measures the correlation among the spatial observations and allows to find the characteristics of the global pattern (random, clustered, dispersed) and therefore was used to identify the global spatial pattern characteristics [10, 11]. Incremental spatial autocorrelation tool was used to measure the series of spatial distances or incremental distances. By calculating the distances, it was also used to create the line graphs between z- scores and the measured spatial distances. Aggregated incidence disease data was used for its calculation. It was also used to identify the threshold distances for hotspot analysis. Peak values (where the z- score is high) were identified by using this tool.

### Hotspot Analysis

The condition that indicates a form of clustering in spatial distribution is called Hotspot. Detecting hotspots is a valuable method of identifying areas with larger or smaller than expected concentrations of events. For statistical significant negative Z-score, smaller value of Z- score shows more intense clustering of low values (cold spots). For statistical significant positive Z-score, larger value of Z- score shows more intense clustering of high values (hot spots). High risk areas are at lower significance level in comparison to hot spots [12].

Hotspot analysis is followed by IDW (Inverse Distance Weight age). This method uses defined and selected set of sample points for estimating the output grid cell values. It determines the cell value using a linearly weighted combination of set of sample points and controls the importance of the known points upon the interpolated values based on their distance from the output points there by generating a surface grid. Hence surface grids were generated using spatial analyst tool bar. These surface grids are actually showing the spatial distribution of dengue disease in Rawalpindi.Bi-variable correlation analysis was applied to identify attributable risk factors for vector borne dengue disease. The analysis was calculated by using SPSS 20.0 version.

### Results and Discussion

Data related to vector borne dengue disease was collected from year 2011 to 2013 from District Health Office of Rawalpindi. Total patients of dengue fever reported in Rawalpindi in three tears from 2011 to 2013 were 1684, of which 482 cases reported in 2011, 110 cases reported in 2012 and 1092 cases were reported in 2013.

Temporal analysis of the dengue disease cases with the climatic variables was used to show the temporal variation of the dengue disease with yearly temperature, humidity and precipitation. Results indicated that as the average annual temperature, rainfall and humidity increases, the number of dengue cases also increase. Butas the rainfall decreased in year 2012, the number of dengue cases also reduced. Lowest numbers of patients were observed in 2012, while highest numbers of patients were observed in 2011 and 2013.

### Impact of Climatic Factors

Temperature, precipitation and humidity are significant factors for disease spread. Bi- variable correlation analysis indicated that the dengue disease cases area are significantly positively associated with these variables (temperature, rainfall and humidity). During the warmer season the incidence of dengue increases and similar is the case with rainfall and humidity.

Pearson's correlation was used to correlate incidence of dengue disease with climatic variables. Bi-variable correlation was applied between dengue disease incidence and the independent variables (temperature, humidity and rainfall). Analysis showed that variables are in positive relation with dengue disease incidence and it showed the positive association.

### Spatial Distribution of Dengue

Spatial distribution of dengue disease cases were visualized by using the incidence map as shown in figure 2. Highest number of cases was seen in 2011 and 2013, while the lowest was in 2012.

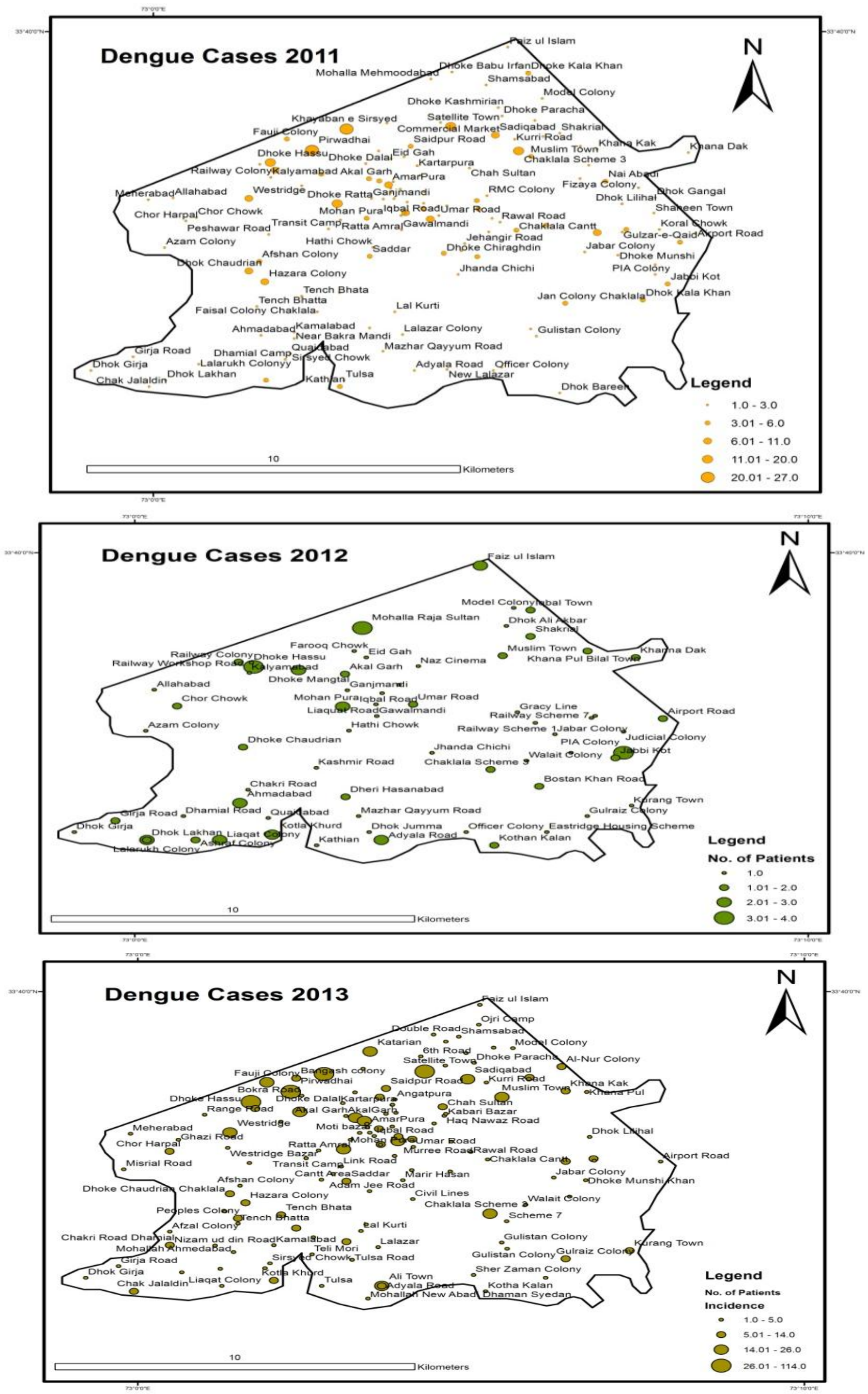



*Figure 2: Spatial distribution of dengue cases in Rawalpindi in 2011, 2012 and 2013*

**6.3. Incremental Spatial Autocorrelation Analysis**

The possible spatial autocorrelation of dengue disease cases was estimated by calculating Moran's I Statistics. Spatial clustering was observed for all years (2011- 2013).

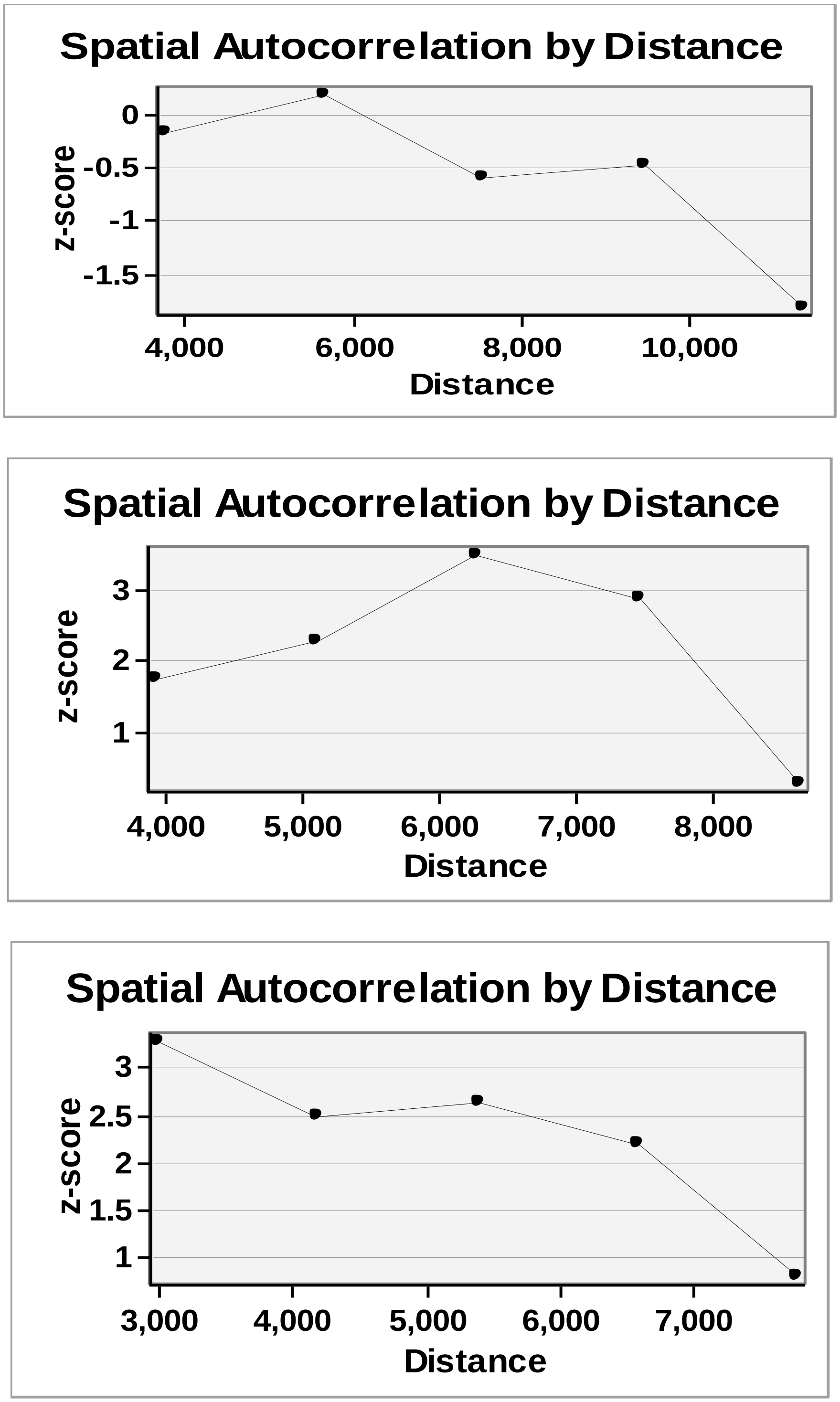



*Figure 3: Graphs Showing Spatial Autocorrelation of Dengue Disease Cases for years 2011, 2012 and 2013*

### 6.4. Hotspot Analysis

In disease mapping studies, often there is interest in identifying high risk areas in order to find out the causes of disease surveillance. Here, we focus on identification of locally isolated high risk regions termed 'local hotspots' or 'emerging hotspots', defined as regions with elevated risks, with respect to their neighbors. Identification of hotspots is crucial for disease surveillance.

Hotspot analysis works by generating p-value and z-score in its output feature class, which shows the hot and cold spots clustering in the random data. As the hotspot are the areas having clustering of incidence. The areas with high clustering of dengue cases are the hotspot regions, which are shown by the shades of red color in figure 4. These areas show the high dengue outbreak in Rawalpindi.

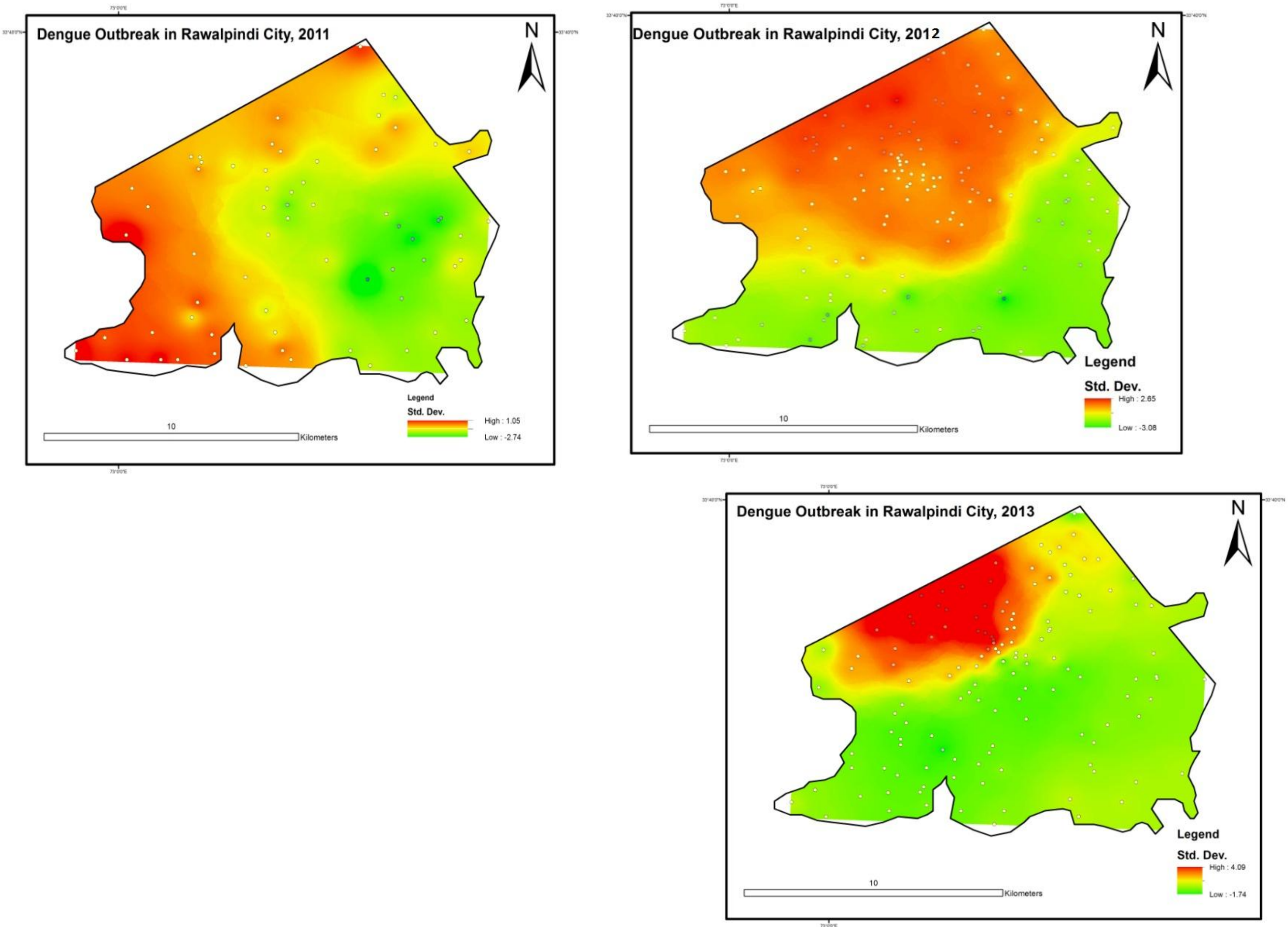



*Figure 4: Mapping of dengue hotspots, high risk and cold spots using Getis- OrdGi* statistics in Rawalpindi for years 2011, 2012 and 2013*

Calculated p-value and the z-score show statistically significant values in the data. Figures show that high (hot) clustering was found where the p-value is low and the z-score is high while high p-value and less z-score result in low (cold) clustering. In 2011, most areas of Rawalpindi were found hot. In 2012, there was relatively less clustering; only few areas of Rawalpindi had high clustering. While in 2013, there was high clustering and most areas of Rawalpindi were found hotter.

**Conclusion and Recommendations**

This study describes the spatial pattern of dengue disease distribution Rawalpindi using routinely collected individual patient morbidity data from health care facilities. The results of this study showed that the temporal variation in the incidence of dengue in Potohar Town, Rawalpindi exhibits a significant dependence on meteorological variables. The Global Moran's I test statistics show significant clustering (spatial autocorrelation) of dengue in the study area. Hotspots or location of clusters were identified using Getis- OrdGi* statistic. Climatic factors including temperature, rainfall and relative humidity indicated that variation in dengue cases in study area were highly associated with the increase or decrease of these factors. Based on the results obtained, the study recommends that intervention should be made by the relevant organization in high risk areas.

On the basis of these results it is recommended that studies should be conducted on mapping to identify the mosquito breeding grounds and risk prone areas. As well as disease surveillance system should be improved by educating the disease investigators of disease and public to increase awareness of vector borne disease outbreaks.

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