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Assessment of Smog Pattern and its Effects on Visibility in Lahore Using Remote Sensing and GIS

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Abstract: In recent times, many parts of the world are experiencing drastic levels of air pollution, which includes smog, the mixture of fog and smoke, polluted air formed by human activities like burning of coal, excessive use of vehicles and many others. During November 2016, Lahore city also experienced the smog due to increased level of air pollutants. In earlier studies, very limited research work has been done related to smog, therefore, this research is aimed to study the pattern of smog in Lahore and its impact on visibility through remote sensing and GIS. Satellite images of MODIS and Landsat OLI, of November, 2016 is used to study the pattern of smog, whereas the visibility data was acquired from Pakistan Meteorological Department (PMD). For the processing and analysis of data ERDAS IMAGINE 14 and ArcGIS 10.1 software were used. The findings of this research reveal that the dense smog cover on 2nd, 3rd, and 4th November 2016 leads to the considerable reduction in visibility. As on 2nd November'16, it was only 111.6 meters (m) while during bright days it was recorded more than 300 m or 400 m.

Keywords: Air pollutants, visibility, MODIS (Moderate Resolution Imaging Spectroradiometer), Landsat OLI.

Introduction

Fog is the natural environmental phenomenon which is experienced by many areas in the winter months, but due to increase in population and the use of technology, air pollution is increasing day by day. This increase in pollution converted that fog into smog, the mixture of smoke and fog. (Allaby, 2014).

Smog affects the activities of people and health. According to World Health Organization (WHO), air pollution has caused acute diseases like asthma and respiratory diseases. Smog has also resulted in the itching of the eyes, dry cough, sneeze, breathlessness, chest discomfort. In 2012 it was estimated that 3.7 million premature deaths were because of air pollution. Since 2012 the smog issue has become a public event, and it has reported in weather forecast (Wang et al., 2016).

Smog in the atmosphere is caused by human activities and climatic conditions. Activities like the burning of coal in industries, vehicular smoke, crop burning, construction, firework and the smoke of brick kilns are the primary sources that add fundamental particles to the atmosphere for the smog (Barry, 2016). Smog is formed when the static weather and fine particles such as PM 2.5 (Particulate Matter with a diameter of less than 2.5 mm) and other air pollutants continue to accumulate, and chemical processes occurred (Wang et al., 2016). The most common air pollutants that affect the quality of air are SO_2 = Sulfur Dioxide, PM = Particle Matter, Pb = Lead, CO = Carbon Monoxide, NO_2 = Nitrous Dioxide, O_3 = Ozone (EPA, 2016).

The day by day increase in air pollution due to various human activities has changed the climate a lot and also became the primary reason of smog. Around the mid-2000's China became the world's capital for air pollution (Watts, 2005) and according to World Health Organization, some Indian cities atmosphere is also considered as the most dreadful for air pollution in the world. In 2016 New Delhi faced the outrageous smog at the time of Diwali because of so much smoke in the air.

The particular area does not experience smog it is endured in many parts of the world. According to Deutsche Welle, New Delhi is in the top ten countries with Lahore, others are Mexico City, Riyadh, Cairo, Ahwaz, Beijing, Ulan Bator, Moscow, and Dhaka (Welle, 2017). In 1952 Great London experienced the most notorious smog, which reportedly killed 3500-4000 people in the short term (Authority, 2002).

The global release of smoke from factories and vehicles plays vital role in smog formation which has caused the sever smog pollution in Los Angeles in 1950s-1960s (Boffey, 1968). In Bangkok, vehicles contributed 62% to the formation of photochemical smog (Zhang and Oanh, 2002). From early 2013 China has experienced violent episodes of smog due to the high concentration of ambient fine particles (Zhou et al., 2015).

Similarly, Lahore is one of the most crowded cities of Pakistan and facing the soil or road dust due to construction, industrial and vehicular release of gases. These all has increased the pollutants in the atmosphere, especially PM 2.5 that is recorded four times more in winter than in summer for the data

recorded over the years from November, 2005 to December, 2007 (Lodhi et al., 2009). Lahore experienced the smog for the first time in the month of November, 2016.

In Lahore annually 1,250 people lost their lives because of air pollution as the air pollution and human health have a strong relationship. The air pollutants responsible for smog are in gaseous forms like nitrogen oxide (NOx), carbon monoxide (CO), sulfur dioxide (SO_2), ozone (O3) and volatile organic compounds. The liquid or solid forms are particulate PM 10 (less than 10 µm) or PM 2.5 (less than 2.5 µm), and some air toxins. Vehicular emission played a vital role in adding carbon mono oxide in air pollutants. By quantification and controlled use of motor vehicles this increase can be minimized (Aziz and Bajwa, 2007).

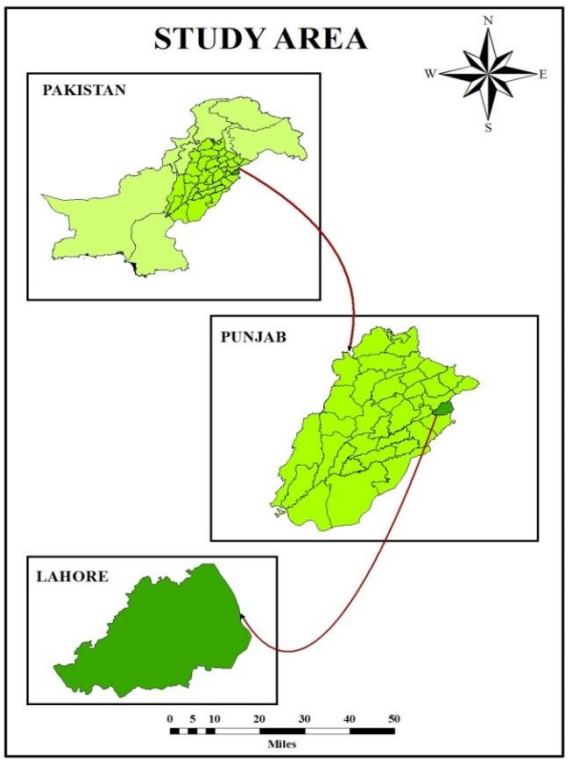

Fig. 1 Study area, Lahore.

The air pollutants are more in urbanized area due to the industries and vehicles and compared to the National Air Quality Index these air pollutants are recorded high in Lahore (Ali, 2013). For this reason, now Lahore experiences the smog and this research is carried out to highlight the pattern of smog in Lahore through remote sensing and GIS techniques. Another objective of this research is to investigate the effect of smog on visibility. The impacts of smog on visibility were also examined in India with the help of remote sensing (Sati and Mohan, 2014).

Earlier studies have shown that this phenomenon of smog is experienced in many parts of the world, affecting the health and activities of people, but very few researches are done in Lahore as the experience of smog in Lahore is not very old. In 2012 the meteorological data, ASTER and Landsat images were used to investigate the presence of smog shown as a dark gray inversion layer (Qureshi *et al.,* 2012). Therefore, this study is carried out to focus the patterns of smog in Lahore predominantly in November, 2016 as it was reported that the concentration of smog was high in this time period.

Materials and Methods

The accuracy of the research depends on the data collected for that it is very imperative to select reliable tools and techniques. The selected study area, Lahore is the capital of Punjab and the second largest city after Karachi. It covers 1772 sq. Km and located on Lat. 31º 15' and 31º 43'N and Long. 74º 10' and 74º 39' E (Figure 1). April, May, and June are hot months and winter stays from November to March in the study area. The formation of fog is usually the phenomenon of the winter season, which Lahore experience in the months of November and December mostly. July to September are monsoon months.

For this research the secondary data sources were selected for the collection of necessary information related to smog patterns in Lahore. Figure 2 briefly explains the methodological framework of the study.

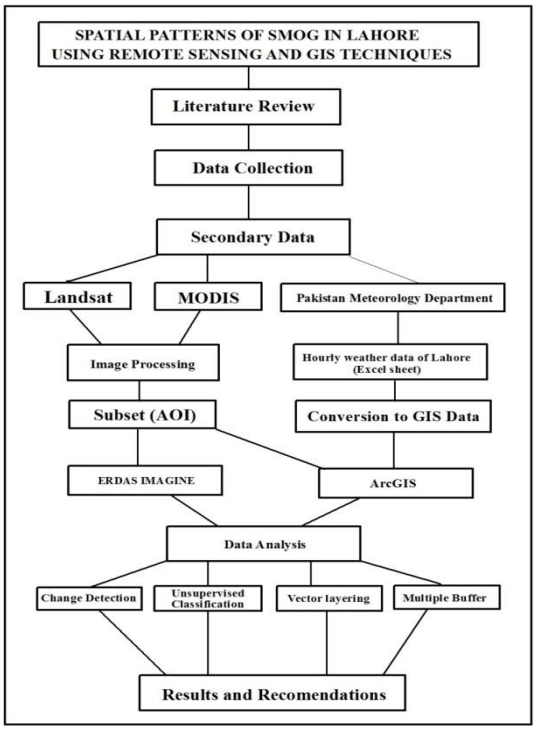

Fig. 2 Methodological framework.

The Flow diagram (Fig. 2) shows that the images of the Landsat and MODIS were taken to study the patterns of smog. Here, the image of Landsat 4 TM was taken to show the area from where the visibility data were collected in the days of smog at Allama

Iqbal International Airport. The Landsat processed image shows the surroundings of data site very well like built up land, vegetation cover and vacant land (Fig. 3).

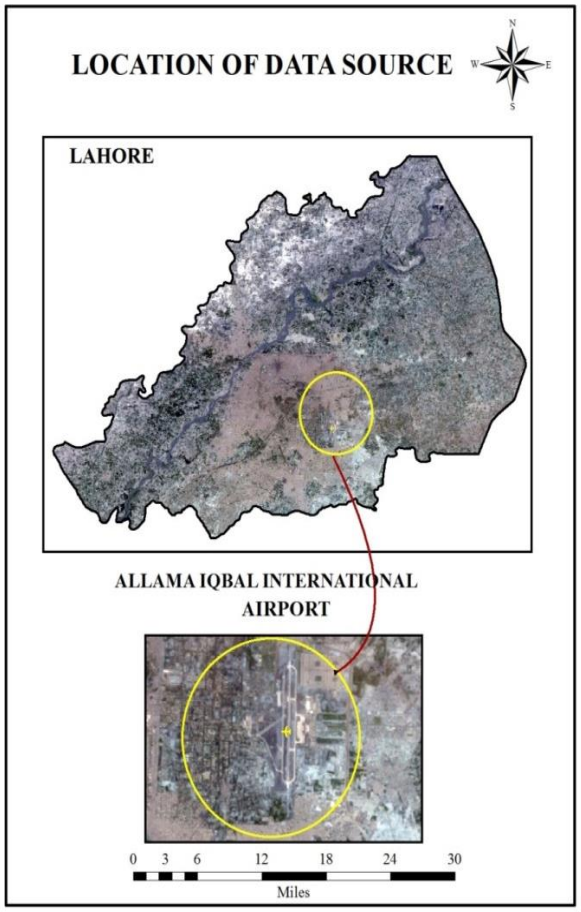

Fig. 3 Location of data source, Allama Iqbal International airport.

For the study, the MODIS images are used as MODIS was the best easily available source. MODIS satellite is a low-resolution satellite, but the data like cyclones, cloud cover and sand dunes can be well represented by this satellite. To fulfil the second objective of research for the visibility data the weather data was taken from Pakistan Meteorological Department (PMD), Lahore.

As the phenomenon of smog was experienced at the start of November 2016 so to study the smog patterns in Lahore the images and PMD data of 1st to 10th November 2016 were selected. For the processing and analysis of data Arc Map 10.1 and ERDAS IMAGINE 2014 is used. The analysis of classification and change detection is performed in ERDAS IMAGINE 2014 and for vector layering and Buffer analysis Arc Map 10.1 is used.

Results and Discussion

The Figures 4 and 5 shows that whole area of Lahore is covered with smog as it is within the boundary line of different colors.

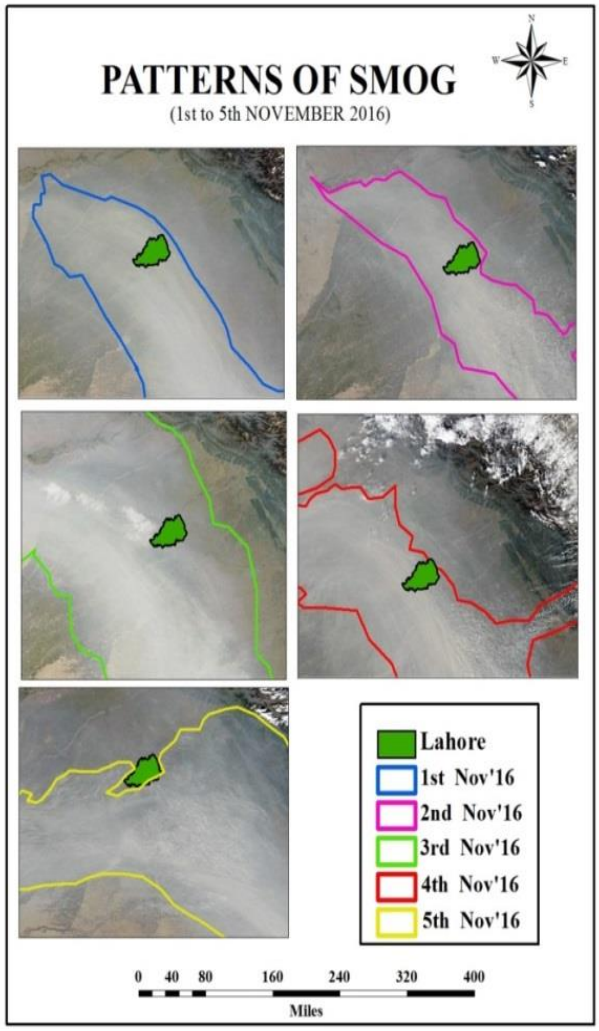

Fig. 4 Individual Vector layers from 1st to 5th November 2016 showing smog patterns.

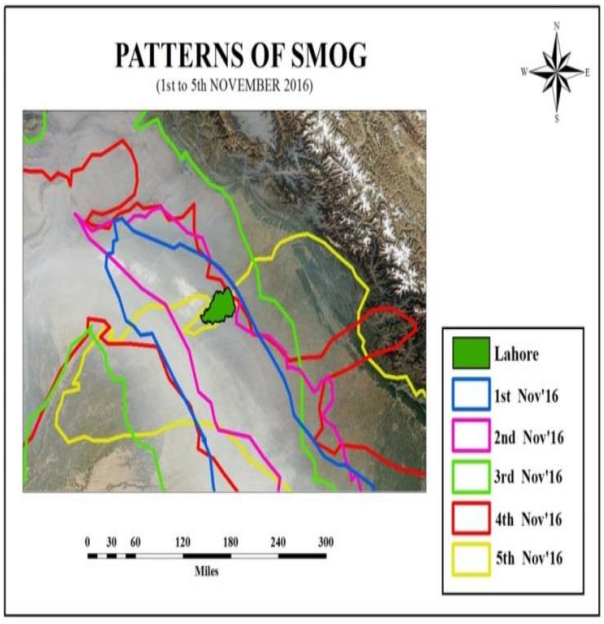

Fig. 5 Combined vector layers of smog from 1st to 5th November 2016.

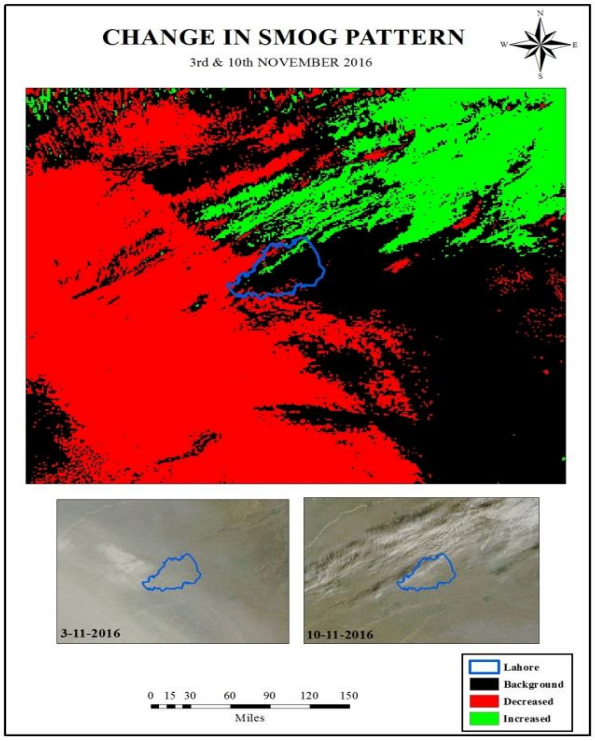

Fig. 6 Smog patterns through change detection.

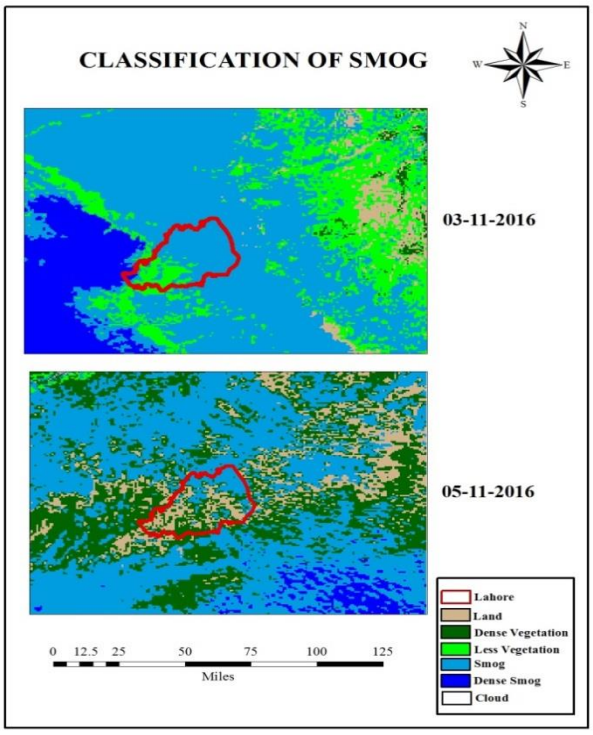

Fig. 7 Unsupervised classification of smog.

On 1st, 2nd and 3rd November the area is completely covered with smog, but as the time passed the smog cover seemed to disperse on 4th, and 5th November as the yellow line shows that it is totally out of the dense zone of smog.

With the help of change detection Figure 6 significantly illustrates the variation in the pattern of smog as the red color prominently shows the decrease.

The decline in the smog from 3rd November to 10th November can clearly be seen in Figure 6. The green color indicates the increase, which is due to cloud cover and not smog. Moreover, this cloud cover, separately in the image of 10th November 2016 which shows the northeastern side with the dense cover of darkness.

In Figure 7, not only the smog, but the land area and vegetation cover are also visible by unsupervised classification. It is reflected in the illustration below that on 3rd November 2016 the areas of Lahore are mostly covered with smog as it is entirely covered with light blue color while in the image of 5th November 2016 the land area and vegetation cloud be seen which means this day was more clear day than that of 3rd November, 2016.

Figures 4 to 7 show that the days of 2nd, 3rd and 4th November 2016 were covered by smog. By relating the patterns of smog and visibility data given in Table 1, which shows visibility data, direct relation between smog and visibility is indicated. This shows that the smog days had less visibility as compared to the clear days.

Table 1 visibility data of smog.

Date	Visibility (meters)
01-11-2016	262.5
02-11-2016	111.6667
03-11-2016	240
04-11-2016	117.9167
05-11-2016	307.9167
06-11-2016	220
07-11-2016	100
08-11-2016	394.5833
09-11-2016	414.5833
10-11-2016	347.9167

Source: Pakistan Meteorological Department (PMD)

With the help of buffer analysis, the Figure 8 shows the concentric circles with different ranges of visibility. The dark green color is showing less visibility zone, which was on 1, 2, 3, 4, 6 and 7th November 2016. While the red circles show the maximum visibility range, which was on 9th November'16. This means, it was the clearest day without any smog while the days of green shades were smog days.

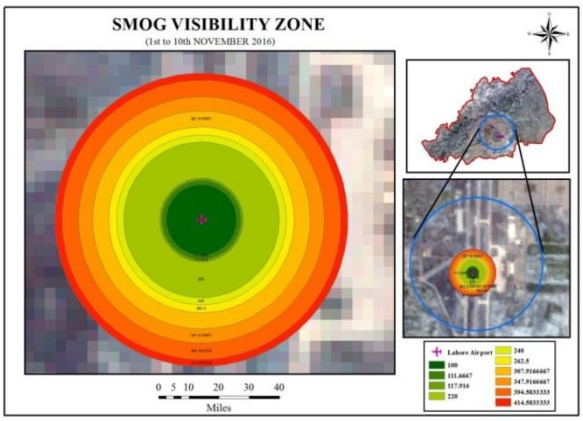

Fig. 8 Multiple buffer analysis showing smog visibility.

Conclusion

This study shows the significant findings; the smog was experienced in the month of November when the wind was static and calm. The smog days were 2nd, 3rd, and 4th November 2016. It has been also concluded that smog disappeared with the passage of time as no smog covering was found in the image of 5th November 2016. Now Lahore is experiencing more pollution due to the more use of vehicles, industries and construction so the smog effect on the visibility was also experienced, as the visibility was very low that is 111.6 m on 2nd November2016. While on a bright day, 10th Nov 2016 it reached up to 347.9 m to its highest.

Acknowledgement

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