Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Science of the Total Environment 730 (2020) 139089

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

COVID-19 challenges to Pakistan: Is GIS analysis useful to draw solutions?

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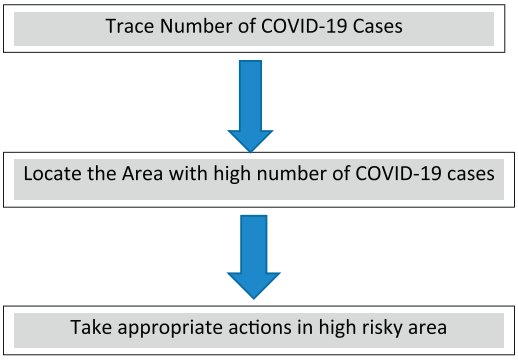
HIGHLIGHTS

- The outbreak of 2019 novel coronavirus disease (COVID-19) is a public health emergency of international concern.
- The ability to detect disease in their early stages is a key component of efficient disease control and prevention.
- The research focuses to develop a transparent user-friendly method to simulate spatial-temporal disease outbreak data.
- GIS techniques, resources, and methods can be used in Pakistan for more effective investigation of disease.
- It is quite easy for authorities to locate the highly effected area and take appropriate actions in that particular areas.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 19 April 2020
Received in revised form 25 April 2020
Accepted 27 April 2020
Available online 1 May 2020

Keywords:
COVID-19
Pakistan
GIS
Health

ABSTRACT

The outbreak of novel coronavirus (COVID-19) is a public health emergency that had caused disastrous results in more than 100 countries. The ability to detect disease outbreaks in the early stages is a key component of efficient disease control and prevention. With the increased availability of electronic healthcare data and spatial analysis techniques, there is great potential to develop algorithms to enable more effective disease surveillance. The research focuses to develop a transparent user-friendly method to simulate the outbreak data. The paper describes the GIS tools to identify and define the field of investigation which requires consideration of the strengths and limitations of data collection instruments, facility of locational data collection, accuracy of locational data, and pertinent attributes for understanding disease risk. Using such information, it is quite easy for authorities to locate the highly effected area and take appropriate actions in that particular areas. However, GIS techniques, resources, and methods can be used in Pakistan for more effective investigation of vulnerable geographical locations.

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https://doi.org/10.1016/j.scitotenv.2020.139089
0048-9697/

1. Introduction

The 2019–20 coronavirus pandemic is a continuous pandemic (COVID-19) caused by severe acute respiratory syndrome coronavirus (SARS-CoV-2) (World Health Organization, 2020a, 2020b). The epidemic is discovered in Wuhan, China, in December 2019, and announced to be a public health emergency of international concern on January 30, 2020 (World Health Organization, 2020a, 2020b). More than 1.8 million cases of COVID-19 have been reported in 210 countries and regions, resulting in more than 110,000 deaths. Over 412,000 people have recovered. The pandemic caused severe global socioeconomic chaos (The New York Times, 2020), such as postponement and cancellation of sports, religious, political and cultural activities (panic purchases have exacerbated the widespread shortage of supplies (Jade Scipioni, 2019). Schools or universities in 193 countries have closed national or local closures, and students worldwide 99.4% of the population (UNESCO, 2020).

Our study focuses on investigating the trend of COVID-19 and the use of spatial temporal analysis for the case of Pakistan, which is a developing economy with limited resources to fight against COVID-19. The deadly coronavirus 2019–20 declared as a global pandemic and the first case is reported in Pakistan on February 2020 (see, Fig. 1). The number of confirmed cases are over 5000 including 1026 recovered and 86 died up till April 2020. Punjab is the biggest province of Pakistan and has the highest number of cases with confirmed 2400 (Tribune.com.pk, 2020a, 2020b). To restrict unnecessary movements across the cities, the government has ordered rigorous instructions for the coming two weeks that will slow the spread of coronavirus. As the COVID-19 cases are reported in Karachi and Islamabad, the Punjab government started imposing restrictions all across the province as a precautionary measure. Similarly, after reporting two new cases in Karachi, the provincial government has also taken all the necessary action. Five advanced hi-tech scanners have been fitted at airports and import tax on items related to the disease treatment. Regardless of all the high level and extensive actions being implemented by the administrative bodies, the virus is now becoming a high risk situations for old age persons, as indicated in Fig. 2. Thus, mass education through print and electronic media has become extremely significant to alert the nation about the current and anticipated issues related to the coronavirus and other sufferings (Tribune.com.pk, 2020a, 2020b). However, the number of cases, linear trend and deaths are increasing, as mentioned in Fig. 3, which is an alarming situation for a developing country, like Pakistan. Fig. 4 points the cases the provincial level situation of COVID-19.

2. Challenges in using GIS

The spread of infectious diseases is one of the most dangerous problems in the world such as Influenza, SARS, MERS, and Ebola and now COVID-19 (Santos et al., 2019; Fung et al., 2019; Quwaider and Jararweh, 2016; Bernard, 2018). The infectious disease affects the people who are surrounding the patient or in direct touch with them (Ahmed et al., 2020). Health researchers are studying the reasons behind these diseases in order to find a way to discover it at an early stage and limit their spread (Allen et al., 2016; Ahmed et al., 2020; Al-Zinati et al., 2020). Public health agencies depend on traditional ways to control and monitor the expansion of infectious diseases. This way relies on the laboratory reports and doctor's diagnosis, but it takes a long time to detect if the disease spreads or not.

Identifying disease outbreaks early is critical for efficient infectious disease control. Currently, spatial data are collected but often not well utilized in routine infectious disease surveillance. As outbreaks are often characterized by the degree of spatial diffusion of cases, spatiotemporal surveillance algorithms are being developed in a number of countries. These spatiotemporal algorithms aim to facilitate the early detection of disease outbreaks which exhibit spatial clustering (Meng, 2017) such as those associated with person-to-person transmission of disease, or a localized source of infection.

Both historical and simulated outbreak data can be used to evaluate algorithms for public health surveillance. Evaluation is typically performed by comparing algorithm-derived outbreak indicators with predetermined criteria indicating the specific location of outbreaks in time and space. The following section outlines the benefits and limitations of using historical and simulated data for the evaluation of outbreak detection algorithms. The objective of this research is to focus on developing a transparent user-friendly method (i.e. GIS) to detect, collect and analyze outbreak data in Pakistan.

The paper discusses few challenges as well as responses associated with it, however, Pakistan need to work multiple dimensions: firstly, developing GIS capacity and using GIS Tools for controlling the pandemic. Secondly, Reveal the existence of an epidemic, identify and count cases. Thirdly, carry out convenient multi-scale dynamic mapping for epidemics. Fourthly, spatial segmentation of the epidemic risk and prevention level. Fifth, the tabulate and orient the data in terms of time, place, and person (Descriptive Epidemiology). Sixth, implement and evaluate control and prevention measures rapid estimation of the population flow and distribution. Seventh, develop, test hypothesis and plan the balancing of supply and demand of medical resources. Eighth, assessment of the supply

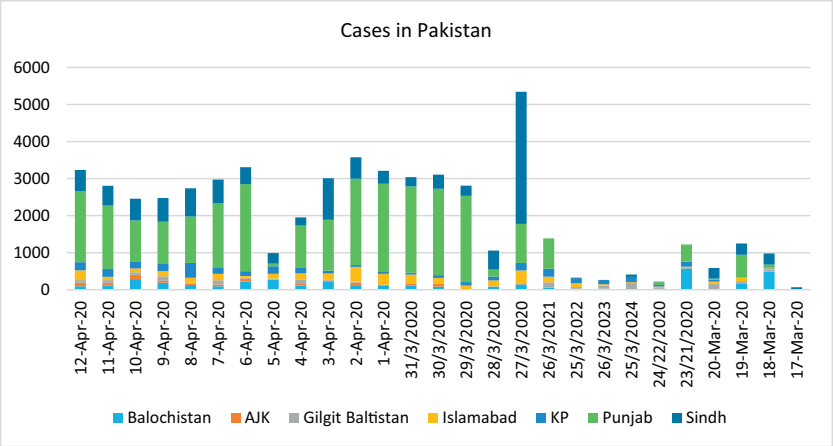


Fig. 1. Daily cases of COVID-19 in Pakistan (2020/03/17–2020/04/12).
Source: Government of Pakistan

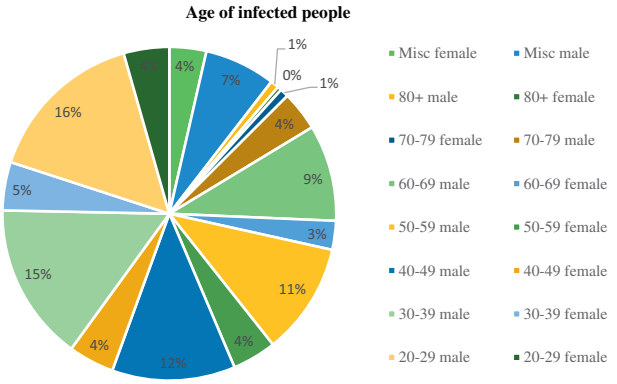


Fig. 2. Gender distribution w.r.t to age infected by COVID-19 in Pakistan.
Source: Government of Pakistan

of materials and transportation risk. Ninth, communicate findings, monitor the spatial spread of social sentiment and detection.

2.1. Developing GIS capacity and using GIS tools for controlling the pandemic

Successful collaboration with the GIS subject matter expert (SME) can be achieved through recommendations about maps relevancy, analysis plans, and accuracy of data. GIS SMEs are involved from the very start and GIS capabilities can be initiated between the field teams as well. Like, a collaboration of GIS SMEs team with the Global Health team of the Centers for Disease Control and Prevention on tasks related to geospatial research analysis and service plans in order to find out the most viable methods for gathering, storing, and examining locations. Workers played an active role (Vynnycky et al., 2019) in this collaboration and generated a plan that regulated the location of the survey, adopted a strategy of data collection, and conducted spatial data analysis that helped in producing an interactive tool for mapping.

Pakistani cities should focus on preparing general reference maps and sampling plans to educate the local community about updated situation of COVID-19 at regional to national level. The map can be helpful to determine the boundaries of the area to be surveyed. It is handy to map and analyze data that is available publicly, based on a specific interest, for instance, health outcome data and population. In this survey, image data is also helpful in providing information particularly if someone tries to examine the damage caused by natural calamities.

2.2. Reveal and identify the outbreak of an epidemic and count cases

The GIS packages of commercial and open-source, offer valuable software options (Lansley et al., 2019). It helps to produce spatiotemporal algorithms to detect the infectious disease outbreak at earliest. This suggests the status of performance evaluation of algorithmic increases during in that time. The assessment methodology checks the algorithmic time pattern and accuracy for recorded disease outbreaks which further allows the selection of a viable algorithm for individually specified observatory context. The evaluation methodology also allows fine-tuning of the algorithm parameters to boost performance for the specified applications.

2.3. Spatial segmentation and dynamic mapping for epidemics

The accurate vulnerable population must be determined when a particular health result is concluded. Often, estimating the population in a specific geographic area is involved in assessing the vulnerable population. GIS can assist in census data evaluation in identifying an appropriate number of populations at risk. Frequently, these pre-established geopolitical limits are enough for characteristics estimations of population. But this case does not remain same all the time. For example, wind forms may transmit a disease to only a small portion of a county or even across different census zones, resulting unusual forms (Ma et al., 2020). GIS tools can be used in calculating and creating the calculated percentage of the area to be surveyed in relation to identified geopolitical borders, as given in Figs. 5, 6 and 7.

Remotely sensed data includes aerial and satellite photographs or data can be collected by satellites sensors orbiting around the earth and this process is another resource of GIS data (Camargo et al., 2019). Remote sensing techniques help in identifying primary topography or observe alteration with time fluctuations. Satellite or aerial photographs can be particularly useful to create responses to natural climatic events by providing the top view of calamities caused by environment and infrastructure and how people are stranded across the area.

GIS is useful for the imagery evaluation of disease growth, altering concentrations, or spreading of threats across time (Tosepu et al., 2020). This imagery evaluation and visualization include number of techniques, like static map series, animations, and linked interactive micro maps. Moreover, number of advanced tools are used to create animated and visualized curve of an epidemiology for all the spatial units

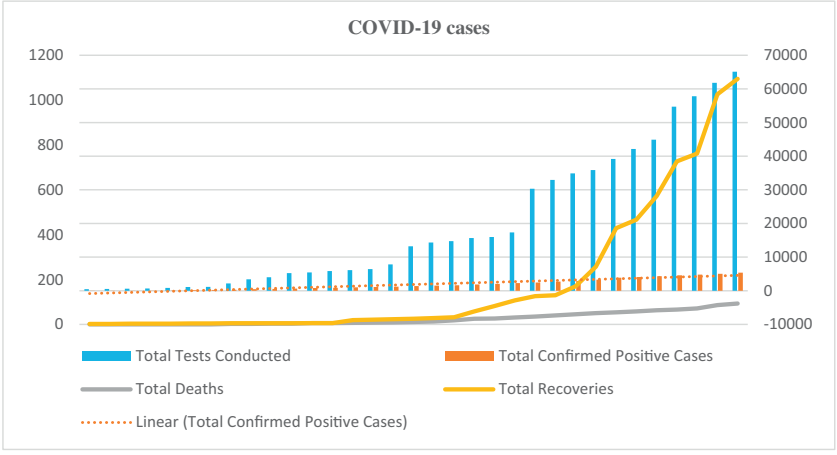
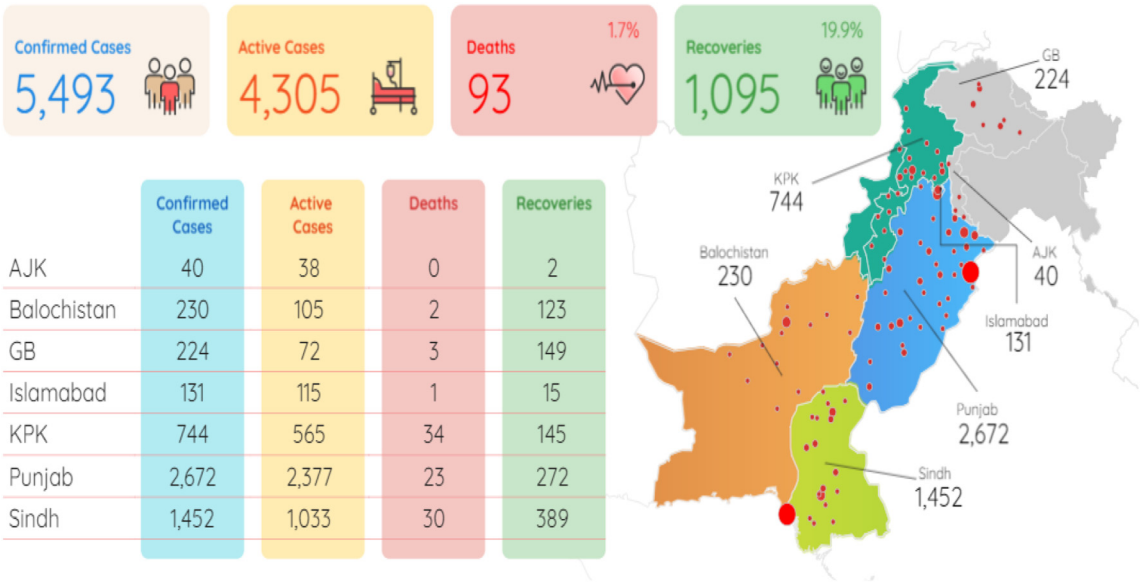


Fig. 3. Trend of COVID-19 in Pakistan (2020/03/15–2020/04/14).



	Confirmed Cases	Active Cases	Deaths	Recoveries
AJK	40	38	0	2
Balochistan	230	105	2	123
GB	224	72	3	149
Islamabad	131	115	1	15
KPK	744	565	34	145
Punjab	2,672	2,377	23	272
Sindh	1,452	1,033	30	389

Fig. 4. Recent cases of COVID-19 in Pakistan (2020/03/15–2020/04/14).
Source: covid.gov.pk

within the case study area. Curve magnitude and direction are shown in maps which help in visualizing the outbreak stage, magnitude, and geographic distribution.

2.4. Arrange data in terms of individuals, time, and area

Usually, the initial data is used to create a mapped visualization of the disease distribution with number of points. These points are shown in the maps displaying each case study area or depict the geographic distribution rates across time or fluctuations in the counts distribution (Cromley et al., 2018). The data of rate and count census can be assessed to different terrestrial units (e.g., counties, census tracts, or postal codes). Choropleth mapping technique visualizes the counts extent or rates by using borderline aggregations (Morrison and Bryan, 2019). Selection of classified divisions and color themes are of primary considerations. The mapped accumulated cases from houses within a

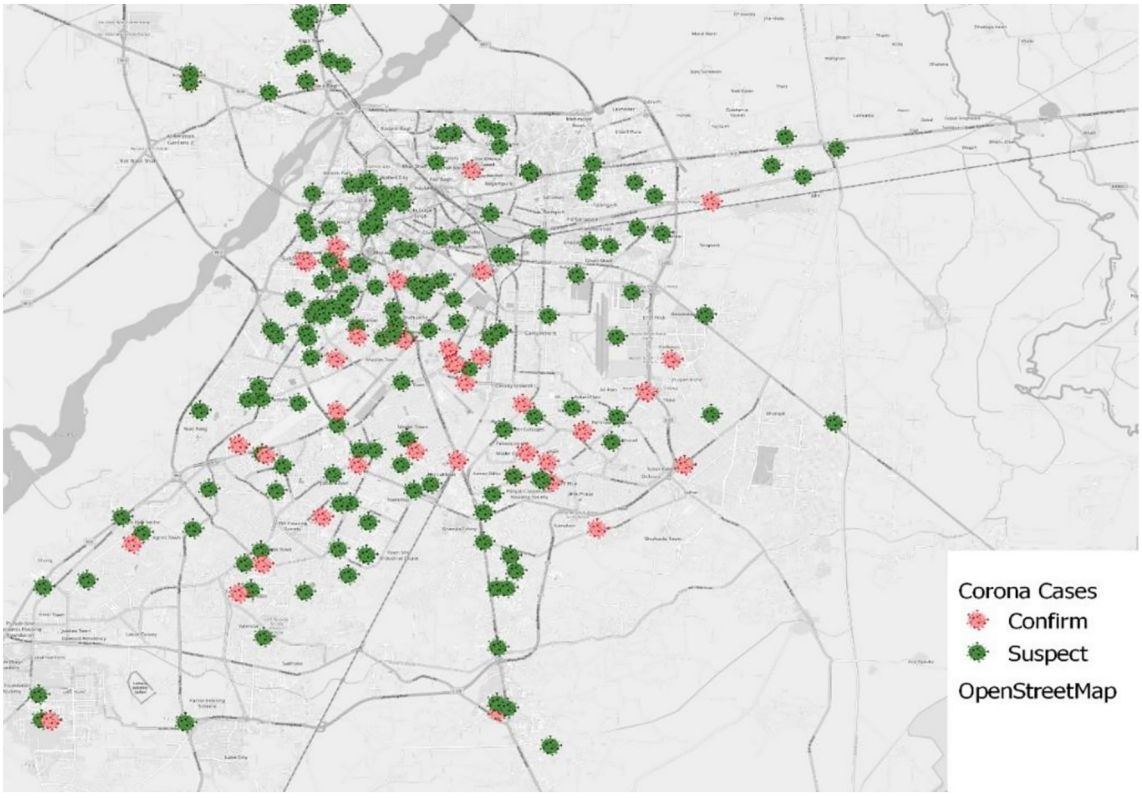


Fig. 5. COVID-19 cases.
(Source: Urban unit, Government of Punjab, Institute of Planners of Pakistan Urban)

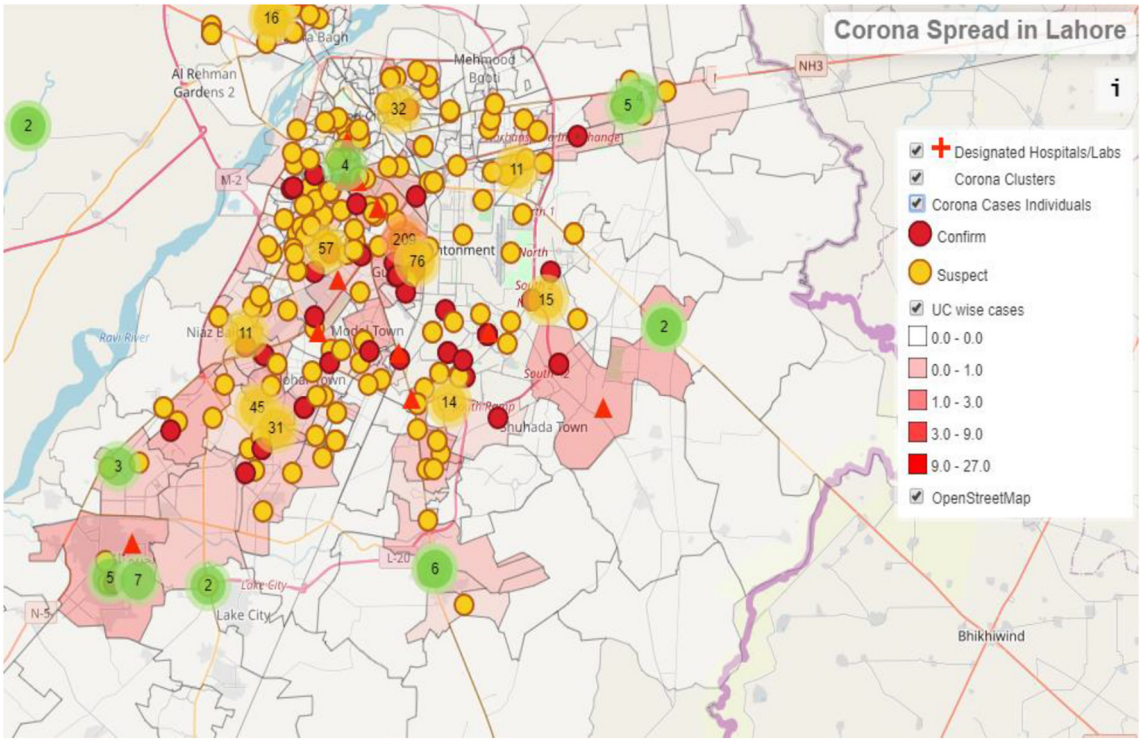


Fig. 6. Cases in Lahore, 2020/03/15–2020/04/14.
(Source: Urban unit, Government of Punjab, Institute of Planners of Pakistan)

village that is also quite useful. This information, choropleth maps of the recorded homes cases or rates, can be compared with the quantity in other homes within the whole case study area. Additionally, map is also used to display the location of cases within rooms of a building, such as in a hospital, dispensary, or nursing home (Ahmed et al., 2020).

The analytical study of point-level cases provides the impression of disease spread levels. This data also helped to evaluate the spatial clusters. Likewise, activity space analysis or service areas are helpful in characterizing the extend of disease spread on temporal and relative scale. As stated earlier, another valuable benefit of GIS is adding information

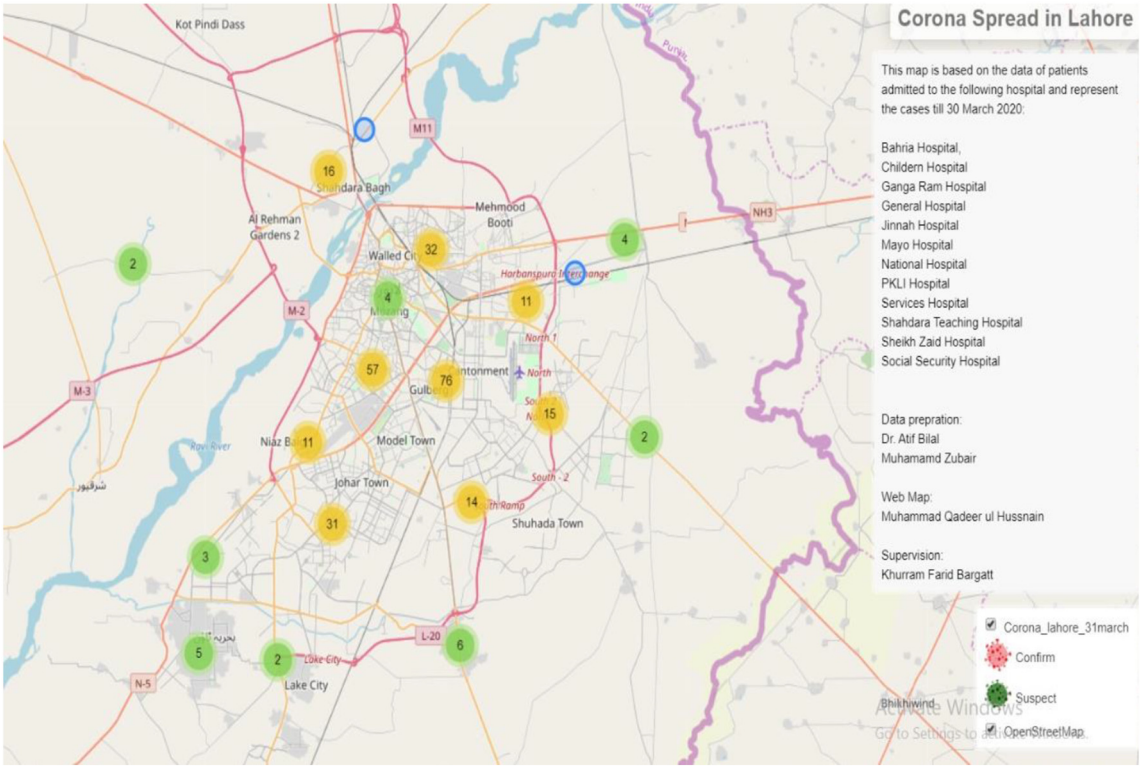


Fig. 7. Cases in Lahore, 2020/03/15–2020/04/14.
(Source: Urban unit, Government of Punjab, Institute of Planners of Pakistan)

related to spatial form into the main analysis which helps in depicting ranges of disease patterns and insights relevant to risk factors at various locations.

2.5. Develop and test hypothesis and plan studies including spatial dynamic balancing of supply and demand of medical resources

Resultant maps from the descriptive analysis can help in producing models about anticipated chances of linkage of the vulnerable populations with the risk factors. These results and maps of the descriptive analysis can lead to the hypothetical development of disease-causing factors, exposure locations, and the transmission mode. This information will help the field team to determine the requirement for doing more analytical studies in which to apply various advanced and modern spatial statistics to comprehend the geographic associations in different time periods and between disease and alleged dangers. Risk maps are used to examine and calculate data in an unchecked area or geographic regression practices by using interpolation methods and spatial overlays are deployed to deeply comprehend geographically distributed disease patterns or major risk aspects (Kaplan et al., 2019). Researchers deployed cluster analysis for the calculated, statistical evaluations to assess either same results appear near each other or these incidences are unusual. Cluster analytical results can be highly valuable for generating hypotheses and risk factor evaluation regarding time and place.

2.6. Assessment of the supply of materials and transportation risk

Particularly, rates graphics according to localities can highlight the areas where controlling measures are fairly effective (Ogen, 2020). Detection of such areas and disclosing the main factors which are affecting the effectiveness of these procedures are beneficial to determine, if these changes are fruitful to control measures. In addition, it is more important to determine that how and where these changes are important to incorporate. Researchers can record the fluctuations in the opioid-related fatality rates across various areas to check where working is going on effectively (Briceno et al., 2019).

The spatiotemporal analysis helps researchers in advanced techniques to check and quantify complex relations in prevention activities, expected disease factors and vulnerable areas. It also helps in assessing impression of placement where prevention measures are being taken (e.g., prescription, recovery causes, or treatment location, etc.). Afterward, we have to deploy time-series visualization, animations, map series, linked micro maps, and timeliness of geographic forms to evaluate these changing patterns. Later, healthcare analysis and temporals are analytical studies that expose the missed prevention opportunities or mark location where various intrusions are proved effective. This data is beneficial to depict the necessary areas for more resources and controlled procedures.

2.7. Communicate findings, monitor the spatial spread of social sentiment and detection

Among many effective methods, the topmost effective and quickest way to spread current situational information is through visualizing maps that also help in communicate area-pointed data about infrastructural, climatic, incidental, and prevalence influences with additional relevant geographic information. Weekly maps are quite significant to visualize incidences and geographic shifts of the disease during major disease outbreak like COVID-19. For instance, during 2017, the overwhelming Puerto Rico Hurricane live visualizations were carried out to access current data of the situation at hospitals, pharmacies, nursing homes and other health related places with potential targeted locations. These visualizations provide adequate information to determine the top areas where medical resources can serve best. Maps are helpful for the communicational findings to respond to local authorities and agencies and spread situational awareness. Moreover, victims can get the information right on hand. Similarly, the Pakistani government have to study the precautionary measures which had been taken by the different governments during previous pandemic situations.

3. Conclusion

The aim of this research is to introduce a technology for simulating disease outbreaks which can produce realistic case distributions, and be easily adapted for different locations and to represent different underlying population distributions in order to evaluate outbreak detection algorithms. The approach described facilitates the comparison of algorithms for early detection within a spatially relevant context. It is envisaged that the software will be developed further to include more detailed consideration of modes of disease spread, and to incorporate case detection and disease control processes. The implementation of the GIS environment, although not the most efficient approach, provides significant advantages including access to a large number of spatial functions, and is suited to the rapid development and prototyping. However, this approach is useful to trace and treat the patients timely, as well to take preemptive measure in that particular area to stop spreading COVID-19. For this reason, the local authorities need to quarantine that area, instead of lock down the whole country. Moreover, the GIS approach is useful to alert others about the COVID-19 spread precisely.

Data availability and command

All relevant data is included in the paper and it's supporting information files with added command.

Funding

This paper is produced without any funding from Institute/University.

CRediT authorship contribution statement

Suleman Sarwar: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing.**Rida Waheed:**Formal analysis, Writing - original draft.**Sahar Sarwar:**Writing - original draft, Data curation.**Aisha Khan:**Methodology, Formal analysis, Writing - review & editing.

Declaration of competing interest

The authors have declared that no competing interest exists.

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