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### Mapping Covid-19 incidence hotspots in Pakistan using spatial-statistical approach

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#### Keywords

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#### Abstract

COVID-19 pandemic is a top-level global emergency which has reduced the coping capacity several developed nations. The infected cases are growing very rapidly. The social interaction and travelling of people have further intensified the situation. Therefore, in this paper an attempt has been made to identify and assess COVID-19 hotspot in Pakistan and public health department to decelerate the exponential growth of patients. Point-level geo-coding technique is applied on patient's record (25/03/2020 to 20/04/2020) and the relative location was converted into absolute location. A total 468 confirmed cases were geo-coded. Getis-OrdGi\* statistical model is applied in ArcGIS10.2 to calculate Z-score and P-values for each location representing the COVID-19 incidence intensity. Then Inverse distance weighted (IDW) technique of spatial interpolation was applied on Z-score and spatial clusters of confirmed cases were geo-visualized in the form hotspot and cold spot. The spatial extent of hotspots and age group of infected persons is alarming. The study provides a suitable methodological framework for identification and analysis infectious disease hotspots. The results can also facilitate public health department and related authorities to win war against COVID-19 lethal outbreak. Similarly, it can help policy makers to restrict travelling and social interaction in hotspots.

#### 1. Introduction

Human history is observing a very strange time fighting an invisible enemy; the novel corona virus infectious disease 2019 (COVID-19). Initially observed in, now spreading swiftly around the world. In Pakistan, first case was reported on February 25, 2020. The main cause of COVID-19 pandemic in Pakistan is the entry of infected pilgrims from Iran, pilgrims and migrants from Saudi Arab. Similarly, infected people from UAE, Malaysia and China have also transmitted the virus. These infected migrants travelled and meet different people over different locations and transmit corona virus to healthy people. This transmission continues till the complete lock down. Currently, lock down has minimized the interaction of infected and healthy persons. Similarly, the quarantine facility across the country has decrease the exposure of healthy citizens. But still, the entire population in Pakistan is at high risk due to COVID-19 outbreak across the country (Mahmood 2022).

Globally, corona virus disease 2019 (COVID-19) pandemic became a biological disaster and tens of thousands of people have lost their lives; millions are infected and quarantined. Man has experienced various

pandemics throughout the history with different intensity and impact (Remuzzi & Remuzzi, 2020; Mahmood, 2022). Today we are observing and experiencing a very tough time by fighting once again with an invisible enemy; the COVID-19 (Sah et al. 2020; Bastola et al. 2020). As of today, 28th April, 2020, there are 3.06million confirmed Coronavirus cases, with 0.213 million deaths while 0.907million has been recovered. In the total Coronavirus patients died, very interestingly the highest number belongs to Italy i.e., 4,032 deaths. The death toll is followed by China (3,248), Iran (1,433) and Spain (1,044) Corona virus (COVID-19) started spreading in December 2019 and was noticed in early January 2020. It started spreading in China in mid- to late-January (The Economist, 2020). The impact of this public health emergency has affected countries and communities in terms of economic, socio-psychological issues, as well as international relations (Hua and Shaw, 2020).

Currently, a variety of human diseases is prevailing with unknown etiology (Rodriguez-Morales et al. 2020; Callaway 2020; Li et al. 2020). Viruses have been considered as cause of these diseases which has increased the continuous search for new viruses

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(Stohlman & Hinton, 2001; Jubelt and Berger, 2001; Shingadia et al. 2002; Rota et al. 2003). There are four human coronaviruses known to exist: human coronavirus 229E (HCoV-229E), HCoV-OC43, severe acute respiratory syndrome (SARS)-associated coronavirus (SARS-CoV) and Coronavirus. The coronaviruses have been identified in mice, rats, chickens, turkeys, swine, dogs, cats, rabbits, horses, cattle and humans, and can cause a variety of severe diseases including gastroenteritis and respiratory tract diseases (Martina et al. 2003; Harapan et al. 2020). Van der Hoek et al. (2004) reported the identification of a fourth human coronavirus, HCoVNL63, using a new method of virus discovery. The virus was isolated from a 7-month-old child suffering from bronchiolitis and conjunctivitis. Coronavirus has caused an ongoing outbreak of viral pneumonia in China. Person-to-person transmission has been demonstrated, but, to our knowledge, transmission of the novel coronavirus that causes coronavirus disease 2019 (COVID-19) (Bai et al. 2020; Leung and Wu 2020). It spreads by the mucous containing liquid present in the human body mainly droplets of saliva or discharge of nose. At this crucial time, vaccines or any obvious treatment had developed to cure COVID-19. After the first three months of this pandemic multiple epidemiological assessments in different countries from Asia, Europe, and North America have been published (Sah et al. 2020; Bastola et al. 2020). Nevertheless, there are countries, with a rapid increase and a high number of cases, with a lack of studies (Rodriguez-Morales et al. 2020; Arab-Mazar et al. 2020).

In early December 2019, an outbreak of coronavirus disease 2019 (COVID-19), caused by a novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), occurred in Wuhan City, Hubei Province of China (Harapan et al. 2020). The World Health Organization (WHO) declared COVID-19 as Public Health Emergency of International Concern (PHEIC) on 31<sup>st</sup> of January 2020, and finally a pandemic on 11<sup>th</sup> March 2020 (Li et al. 2020). As of March 24<sup>th</sup>, 2020, the virus has caused a casualty of over 16,600 people worldwide with more than 380,000 people confirmed as infected by it, of which more than 10,000 cases are serious. Then on April 28<sup>th</sup>, 2020, there were 3.06 million confirmed Coronavirus cases, with 0.213 million deaths while 0.907 million has been recovered. In the total Coronavirus patients died, very interestingly the highest number belongs to Italy i.e., 4,032 deaths. The death toll is followed by China (3,248), Iran (1,433) and Spain (1,044) Corona virus (COVID-19) started spreading in December 2019 and was noticed in early January 2020. Worldwide, the impact of this pandemic has affected countries and communities socially, economically and psychologically as well as international relations (Hua and Shaw, 2020). At present, COVID-19 pandemic is hot topic globally.

In Pakistan, first case was reported on February 25, 2020. As of 28<sup>th</sup> April, 2020. The total confirmed cases are 14612, active cases 11067, deaths 312 and recovered cases 3233 (NIH, 2020). The main cause of COVID-19 pandemic in Pakistan is the entry of infected pilgrims from Iran, pilgrims and migrants from Saudi Arab. Similarly, infected people from UAE, Malaysia and China have also transmitted and spread the virus. These

infected migrants travelled and meet different people over different locations and transmit corona virus to healthy people. This transmission continues till the complete lockdown. Currently, lockdown has minimized the interaction of infected and healthy persons. Similarly, the quarantine facility across the country has decrease the exposure of healthy citizens. The COVID-19 is still a biological hazard and the entire population is at high risk in Pakistan. Therefore, the aim of this pioneer study is to summarize the current situation of COVID-19 and model incidence hotspot using spatio-statistical approach.

## 2. Method

This study is based on secondary data. The data regarding registered COVID-19 confirmed cases were acquired from National Institute of Health (NIH) of Pakistan website. The data were classified in MS Excel. Point-level geo-coding technique is applied to geo-code 492 confirmed COVID-19 cases of past 30 days i.e. 15/03/2020 to 15/04/2020. The hotspots is determined by applying Getis-OrdGi\* (G-i-star) statistical model in GIS environment to quantify Z-score and P-values. Finally, Inverse Distance Weighting (IDW) technique of spatial interpolation is implemented to generate a spatial layer depicting hotspots and coldspot zones by utilizing Z-score as input data. In the current study, Getis-OrdGi\* geo-statistical model has utilized due to its better predictive validity and spatial clustering that fits the study area as definition of hotspot than other models. The Gi\* statistic is more interested in assessing incident intensity than in analyzing the spatial clustering of any particular value associated with COVID-19 incidence. Similarly, Gi\* statistic examines the individual locations, enabling hotspots to be identified based on a comparison with the neighboring samples and has been successfully applied in hotspot identification and mapping.

### 2.1. Hotspot Analysis

The geo-coded COVID-19 cases records were imported into ArcGIS10.2 and geo-visualized in the form of point feature class as spatial layer (Fig. 2). The layer was added as input data to perform hotspot analysis. The hotspot analyst, identifies spatial clusters of high values (hotspots) and low values (cold spots) by implementing Getis-OrdGi\* statistical model. It converts the geo-coded COVID-19 cases record into a new output feature having attributes of the z-score, p-value, and Gi-Bin confidence level ranging from -3 to +3. High counts of cases close together have +ve z-score indicating hotspot and vice versa. The z-score range +/-3 reflect statistical significance with 99-percent confidence level, +/-2 bins reflect 95-percent confidence level, and +/-1 bins reflect 90-percent confidence level, whereas 0 bin is not significant (Fig. 3). Then the IDW technique of spatial interpolation is implemented to generate the raster spatial layer depicting COVID-19 cases intensity as hotspot or coldspot. The z-score values are utilized as input data in spatial interpolation. The COVID-19 incidence intensity is categorized into five classes namely very low (-2.1 to -3), low (-1.1 to -2), moderate (+1 to -1), high (1.1 to 2) and very high (2.1 to 3). Linear regression analysis is applied on daily COVID-19 confirmed cases.

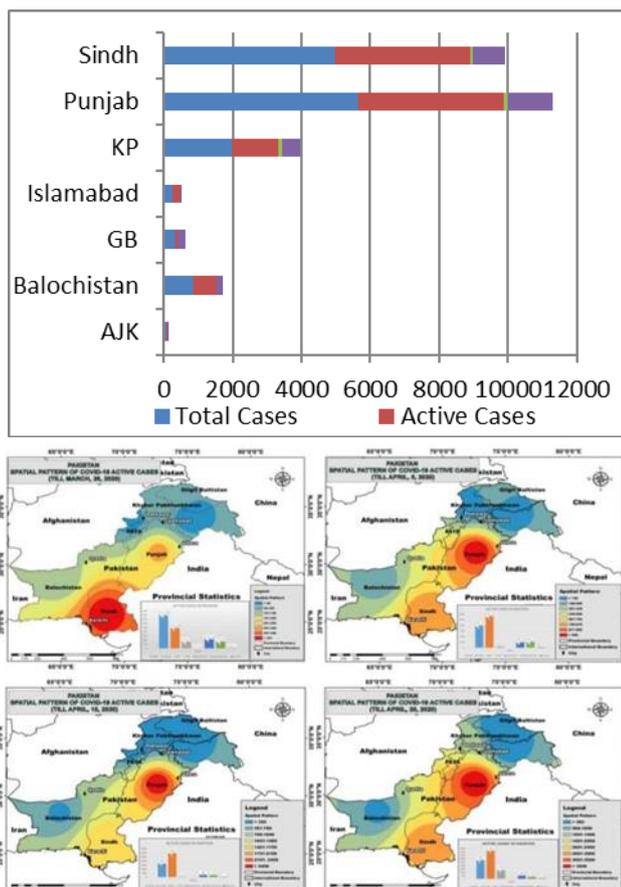
### 3. Results and Discussion

The results obtained from processed data are explained in the following sections.

#### 3.1. Spatial Analysis

The spatial pattern of COVID-19 confirmed cases is variable across the country. The number of confirmed cases decreases towards north. The province Sindh becomes hotspot whereas northern areas including northern parts of Khyber Pakhtunkhwa and GB form coldspot. The spatial extent of hotspot seems to extend towards Punjab. In this regard, research on emergency bases is highly needed to minimize the spread of COVID-19 pandemic.

The spatial pattern of COVID-19 confirmed cases is variable across the country. The number of confirmed cases decreases towards north. Currently (26/03/2020) province Sindh is the hotspot whereas northern areas including northern parts of Khyber Pakhtunkhwa and GB form a coldspot (Fig. 1). The spatial extent of hotspot seems to extend towards Punjab. In this regard, research on emergency bases is highly needed to minimize the spread of COVID-19 pandemic.



**Figure 1.** Hotspots and coldspots of COVID-19 active cases from 26/03/2020 to 20/04/2020 in Pakistan

Moreover, this study attempts to investigate the spread of corona Virus, a deadly pandemic infectious disease. The Province Sindh has highest concentration of infected patients due to several reasons. Karachi is the capital of Province Sindh and largest city of Pakistan. Karachi has the largest stock exchange market in

Pakistan, which attracts the world international economist.

It is also the hub of international businesses around the world. Moreover, Jinnah International Airport is one of the Pakistan's largest and busiest international and domestic airports. The passengers coming from international flights such as students of Pakistan's went over to other countries to seek knowledge might be already infected. These are reasons from which international people attract towards the Sindh. Karachi has a port, which is South Asia's largest and busiest deep-water seaports.

Almost Pakistan's 60% cargo is hand by this port, which means it can also be the major hotspot region of this infectious virus. It is because goods are being imported from the world and there is a probability that these goods are already had infected by the corona virus. Political instability in Sindh region and poverty rate can also be a major reason of this pandemic spread.

After Sindh Province, Punjab leads because the carelessness of people. Mostly the people who had infected by this virus are in age group of 21 -50 years. Lahore is second largest city of Pakistan's and hub of many industrial and domestic level markets. A large proportion of commuters daily travel this and infect other people.

Figure 1. demonstrated the spatial distribution of COVID-19 in Pakistan's province. Moreover, this study attempts to investigate the spread of corona Virus, a deadly pandemic infectious disease. The province Sindh has highest concentration of infected patients due to several reasons. Karachi is the capital of Province Sindh and largest city of Pakistan. Karachi has the largest stock exchange market in Pakistan, which attracts the world international economist.

#### 3.2. Temporal Analysis

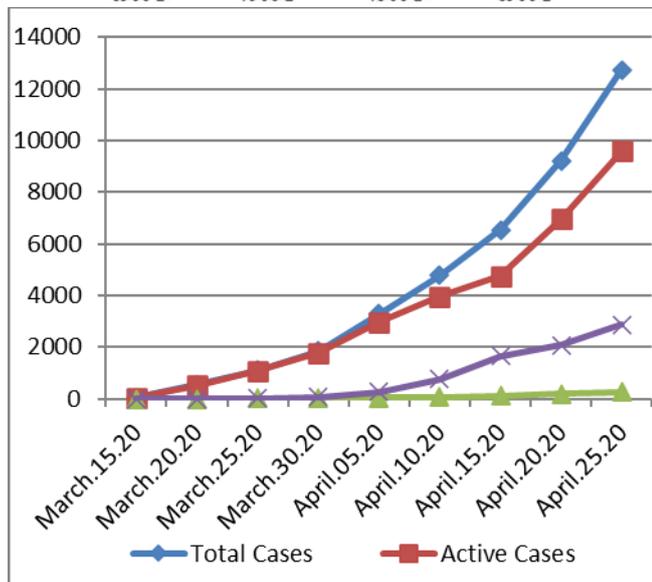
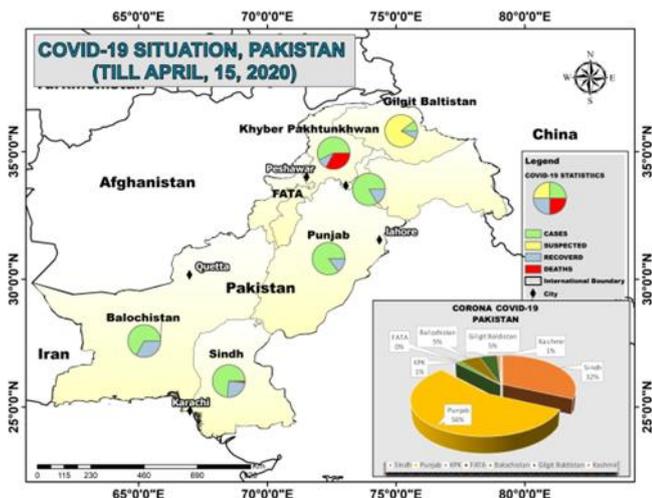
On February 25, 2020, first case was reported in Pakistan. The total number of confirmed cases in in Pakistan are 1,415 in which 1,374 are active cases. Total deaths from corona Virus in Pakistan are 13. The seven patients are critical in their health. Only 29 patients had recovered from this deadly disease. It has been estimated that the probability of number of cases per 1 Million population is 6 whereas, Deaths in per million population is 0.05.

In 31 days from February 25, 2020 to March 26, 2020, 915 patients caught by deadly disease of Corona Virus. The Sindh province having the total area of 140,914 km<sup>2</sup> and considered second largest province by population (47.88 M). The province Sindh is leading with the 399 patients found with the COVID-19 and Punjab Province is on second number having 246 patients. Other provinces including Baluchistan, Gilgit Baltistan and Khyber Pakhtunkhwa have 110, 81 and 78 patients respectively.

### 4. Conclusion

It is concluded from the study that Pakistan is still in a good position than many other countries to react to the current outbreak. The aggressive and systematic approach taken by the Government of Pakistan has

played a crucial role in lockdown, quarantine facilities and awareness campaigns across the country. Similarly, care of the critically COVID-19 patient has recovered more than 2500 infected persons. The existing health system is responding under enormous pressure and accommodating the new cases. The established quarantine centers are supporting the health system. It is predicted in the study that if the exponential trend continues for the next few weeks, then the health system will be not able to respond. The measures taking by the government in the right direction, but prediction tells us that they need to be implemented without delay. Otherwise, a substantial number of unnecessary deaths will become inevitable.



**Figure 2.** COVID-19 Situation, Pakistan (till April, 15, 2020).

Spatially, the COVID-19 incidence is very high (Hotspot) in central and south west of district Lahore whereas the surrounding of hotspots are covered by high incidence areas. The incidence is moderate in the south

and west. Towards north incidence is decreasing forming cold spot with low incidence of COVID-19. The spatial extent of hotspot seems to extend towards the borders of Lahore. In this regard, research on emergency bases is highly needed to minimize the spread of COVID-19 pandemic.

Most importantly, the prediction suggests that maximum number of infected persons that will be reached in Pakistan. The maximum number of patients will require intensive health care units. The spatio-temporal pattern and prediction of COVID-19 is of crucial importance to plan for new facilities in Pakistani hospitals and to calculate the time period in which they need to be available. Finally, lock down has minimized the interaction of infected and healthy persons. Similarly, the quarantine facility has decreased the exposure of healthy citizens to COVID-19. But still, the entire population in main cities particularly in Lahore is at high risk due to the rapidly growing COVID-19 confirmed cases. Identification of hotspot is highly needed for all major cities because the incidence is very high in all capital cities of Pakistan. This will provide a base for policy regarding people traveling and interaction.

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