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Spatial Analysis of COVID-19 with Associated Multimorbidity and Environmental Dynamics using Google Earth Engine in Balochistan, Pakistan

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ABSTRACT: COVID-19 has caused a death toll of over 7 million. COVID-19 has proven to have hostile effects on human health, industrial production, the economy, social functioning, and international relations. The pandemic of the SARS-CoV-2 virus is also causing mismanagement of other diseases such as respiratory, cardiovascular, arboviral, metabolic, neural diseases, and hypertension. These alarming situations of multiple co-infections are the cause of serious public health concerns globally. The study aims to explore the effect of the COVID-19 pandemic on routine and emergency care for multimorbidity in Balochistan. This involves both primary and secondary data sources. Primary data was collected through a field survey, while secondary data was obtained from the World Health Organization, the government of Balochistan, and remote sensing. Density analysis was carried out to generate the density maps of COVID-19 cases with associated multimorbidity across all the districts of Balochistan in a geographic information system environment using ArcMap 10.8.2. Remote sensing data acquired from Sentinel 5P through Google Earth Engine was used to analyze environmental parameters such as nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone, and land surface temperature during the COVID-19 years. The findings of this study indicate that multimorbidity was a risk factor for COVID-19 severity and that the risk increased with the morbidity burden. This study also shows that urban populations are more vulnerable to the risk of multimorbidity with COVID-19 than those in rural areas. The results strongly recommend the implementation of modified tactics for patients with multimorbidity and a lack of facilities.

KEYWORDS: COVID-19, Geographic Information System (GIS), Remote Sensing (RS), Google Earth Engine, Balochistan

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Introduction

The COVID-19 outbreak led to a worldwide socio-economic crisis, especially impacting developing countries due to their weaker economic status. On January 20, 2020, the World Health Organization (WHO) declared it a pandemic (Zanke et al., 2020). COVID-19 resulted in more than 777 million COVID-19 cases and more than

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7 million deaths worldwide (Chodick, 2025). The virus attacked the respiratory system of humans, and people who already had respiratory problems were severely affected by the coronavirus, which ultimately resulted in their deaths. Researchers predicted that old-age households with multimorbidity are at high risk of infecting with COVID-19 (Lai et al., 2022). Therefore, the chances of dying from COVID-19-related conditions had affected the old age people as compared to the younger ones (Santesmasses et al., 2020). People with multimorbidity should be given priority and vaccinated as soon as possible (Agrawal et al., 2022). There is a dearth of information on the consequences of COVID-19 and managing multimorbidity in patients.

Long-lasting illnesses tend to group into patterns, with their specific consequences on the clinical outcome of infected patients (Cornell et al., 2008). These outcomes have pertinent inferences for organizational, precautionary, and clinical actions to help meet the needs of patients with COVID-19 (Carmona-Pírez et al., 2022). Outcomes of research on multimorbidity and antagonistic actions of COVID-19 vaccines in Hong Kong propose that patients who were not vaccinated had a higher risk of severe conditions than patients who were vaccinated (Lai et al., 2022). However, researchers also concluded that multimorbidity is associated with increased risks regardless of vaccination (Lai et al., 2022). The age groups of 60 and above had more chances of multimorbidity (Divo et al., 2014) and therefore, COVID-19 had more serious consequences for the older population (Abad-Diez et al., 2014). People having multimorbidity often experience more care issues as compared to those having a single illness (Noel et al., 2007). Most commonly experienced concerns were physician consultation (43%), diagnostic services (26%), transport (33%), and mobility constraints (21%) (Castro-de-Araujo et al., 2022). COVID-19 cases in Portugal in 2020 happened mostly in people aged 80 years or older (Nogueira et al., 2022). In New York City, the customary comorbidities included hypertension (56.6%), obesity (1737; 41.7%), and diabetes (33.8%) (Richardson et al., 2020).

Since Pakistan's border is connected with China and Iran, and our country has friendly relations with these countries, the chances of transmission of COVID-19 to Pakistanis are higher than in other countries (Javed et al., 2020). The first 2 confirmed cases of COVID-19 were reported on February 26, 2020, from religious travelers to Iran (Khan et al., 2020). The number of infected individuals reached 7,025 on 17 April 2020 throughout the country, with about 135 deaths (Noreen et al., 2020). The main reason for this increase was the Pakistani pilgrims returning to their cities without being tested for COVID-19. Pakistan, with less than 0.75% of the GDP allocation for the health sector, could not cope with COVID-19 shocks (Katper et al., 2020).

Air pollution is a complex and dynamic combination of gaseous pollutants, particle matter, and land surface temperature (LST) that varies daily and seasonally due to anthropogenic activity, changing land cover, and climatic circumstances. Urban climate change is a result of the city's increased air pollution levels, which increase the temperature of the atmosphere and the surface. Satellite-borne sensors collect the LSTs, which are then utilized for research on global change monitoring, climate modeling, and heat balancing (Pal & Ziaul, 2017). One of the main effects of urban expansion and increased energy emissions is the rise in LST, also known as the urban heat island effect (Rozenstein et al., 2014). This study aims to discover the impacts of COVID-19 on routine and emergency care for multimorbidity in Balochistan, with a focus on the analysis of environmental parameters such as nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and LST. The selected tools are the Geographic Information System (GIS), remote sensing (RS), and Google Earth Engine (GEE) techniques.

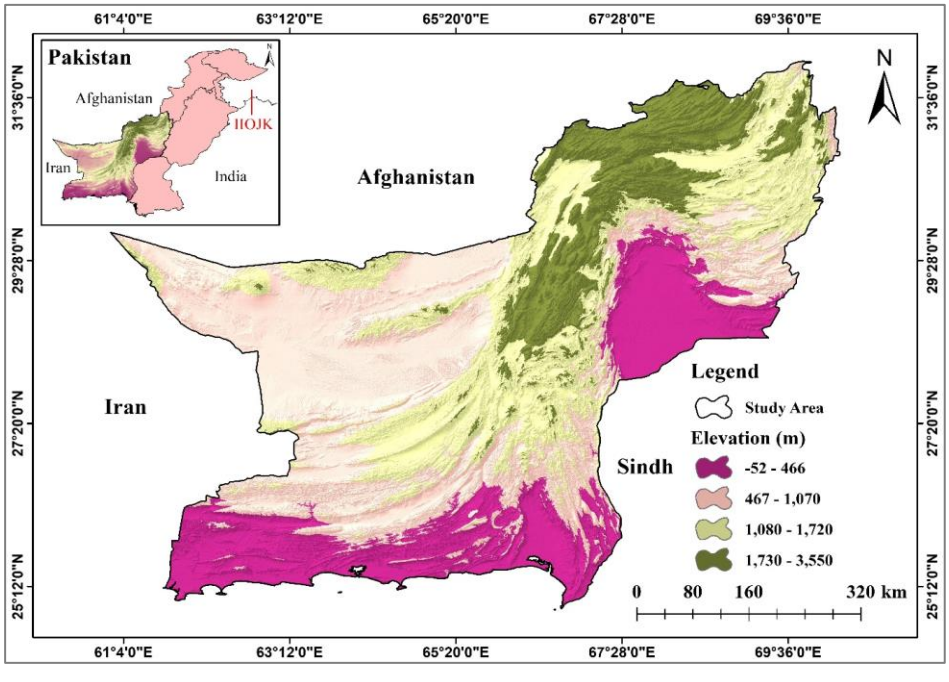
Method and Materials

Study Area

Balochistan is the largest province of Pakistan in terms of total land area, with an extent of 347,190 km2, or 43.6% of Pakistan's total land area. The province coordinates span from 22.0o N to 32.0o N latitudes and 66.0o E to 70.0o E longitudes and it is situated in the southwest region of the country (Ullah et al., 2025), bordering the Arabian Sea to the south, Iran to the southwest, and Afghanistan to the north and northwest (Fig. 1). According to the 7th Population and Housing Census the population of the province is 14.89 million (male 52.1% and female 47.9%), with population density of 42.90 people per km2 (PBS, 2023). A majority (10.28 million or 69%) of the population in Balochistan lives in rural areas, while only 4.61 million (31%) people live in urban areas. Balochistan is home to diverse communities; the Pashtuns make up the majority in the north of the province, while the Baloch make up the majority in the south and east. Quetta is the most populous and capital of the province (Ullah et al., 2024), with a majority of Pashtun tribes and minorities of Baloch, Hazara, and Punjabi tribes (PDMA, 2025). Approximately 80% of the region of the province is intermountainous. Coastal plains and flood plains make up the remaining 20%. Sulaiman, Toba-Kakar, Central Brahui, Kirthar, Chagai, Raskoh, the Central Makran, and Makran coast are the major mountain ranges of the province. Balochistan has a continental semi-arid Mediterranean climate, with 200-350 mm of annual rainfall, with a variable proportion of that amount falling as rain and snow in the middle of winter or as heavy summer showers (PDMA, 2025). Mineral production is the main driver of the province's economy, while agriculture and livestock also play an important role, especially in the eastern areas of the province.

Figure 1

Study Area Map with all the Districts of Balochistan



However, challenges still exist in Balochistan province, such as a large percentage of the population's lack of access to basic facilities like electricity, natural gas, clean drinking water, and education facilities (Ullah et al.,

2025). Balochistan as a study area was carefully chosen based on research and literature review. This study area also faces a problem because of the lack of management during the COVID-19 pandemic, whether it is related to infrastructure, logistics, or the economy. In this study, all districts of Balochistan were monitored to find the hotspots during an epidemic.

Data Collection

COVID-19 & Multimorbidity data have been used in this study to process and explore the condition of COVID-19 with multimorbidity. Geostatistical data is sorted in Microsoft Excel, and only relevant diseases were selected to correlate with COVID-19 and then processed to import into ArcGIS 10.8.2 in CSV format. Table 1 shows the datasets used during this research, the source from which the data is gathered, and the processes for this study.

Table 1

Datasets used in this study with data sources

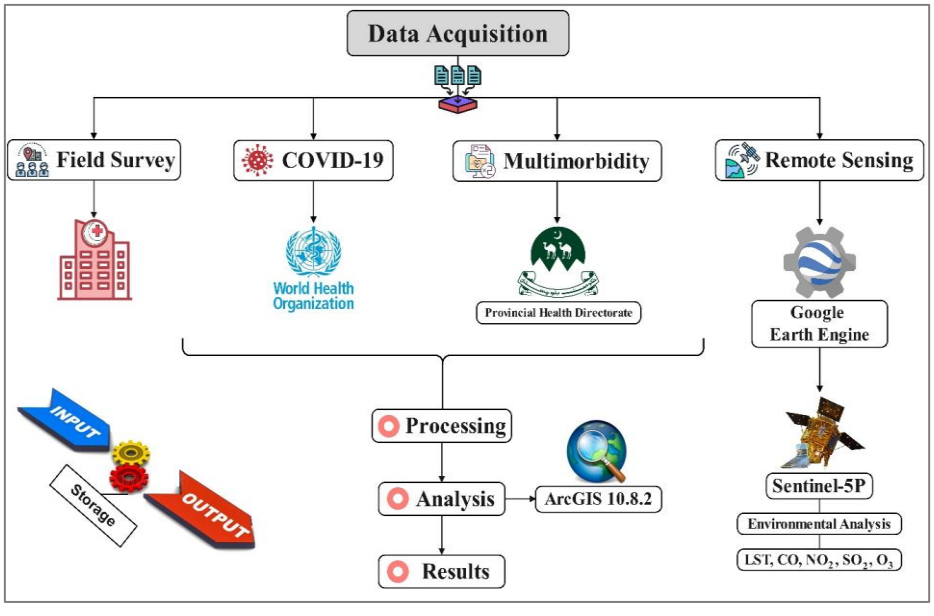
S.No	Dataset	Source	Process
1	COVID-19	WHO	Density map and Statistical analysis
2	Multimorbidity	DG Health Balochistan	Density map
3	Sentinel 5P	GEE Data Repository	Environmental Change Detection
4	SRTM DEM	USGS Earth Explorer	Elevation
5	Availability of Facilities	Main Hospitals of the Provincial Capital	Field Survey

Methodology

After going through different literature on global studies of COVID-19 with different diseases, it is logical and scientifically proven that there is a connection between COVID-19 with Multimorbidity. This study adopted the following flow of work (Fig. 2) to explore multimorbidity and the COVID-19 situation, specifically in Balochistan, and how directly or indirectly the environment is affected across the study area during the lockdown.

Figure 2

Methodology Workflow for the Present Study



To examine the current state of the COVID-19 epidemic preparedness along with other diseases, the present facilities, publicly available data, and documents were collected from the government of Balochistan.

ArcGIS

Multimorbidities that are selected to be mapped against epidemics are hypertension, road traffic accidents, depression cases, fever due to other causes, diarrhea, pneumonia, tuberculosis, asthma, acute upper respiratory infection (ARI), and typhoid for the years 2019 and 2020. District density maps are generated across all the diseases and for COVID-19 cases. Geostatistical analysis has been done on COVID-19 data to statistically spot the districts that are reporting a large number of cases. This analysis is done for the years 2020 and 2021. The ground truth data of COVID-19 and other diseases is exported to ArcGIS after being preprocessed in Microsoft Excel. The district dataset of multimorbidity is processed through density analysis, and then COVID-19 data is statistically analyzed to calculate the hotspot areas in Balochistan during the epidemic. COVID-19 point data is aggregated into polygons to represent the high-risk zones of the epidemic.

Field Survey

A survey study is implemented in the hospitals of Quetta, Balochistan, to study the on-ground realities of COVID-19 and the availability of facilities for other diseases. Selected hospitals are the Civil Hospital, Bolan Medical College, Benazir Hospital, TB Sanatorium, and Shaikh Zaid Hospital. Survey forms are filled out by on-duty medical staff in charge of COVID-19 monitoring wards of the mentioned hospitals.

Environmental Analysis

This part of the study consists of four main steps. In the first step of Data acquisition, the satellite Imageries are taken from USGS, and air quality data from Sentinel 5P TROPOMI. In the second & third steps, Land surface temperature and Air Quality Index are calculated. In the fourth step, the overall analysis is visually interpreted to analyze the results and fulfill the research objectives. The atmospheric air quality data are obtained from Sentinel 5P TROPOMI. The data on suspended air particles such as particulate matter (PM2.5 and PM10), Nitrogen dioxide (NO2), ammonia (NH3), Sulfur dioxide (SO2), Carbon monoxide (CO), and Ozone (O3) were collected and used to measure the air quality index (AQI). During the COVID-19 pandemic, there has been a major change in the atmosphere, according to different research, due to the decrease in human movement or quarantine. In this study, environmental analysis was done to monitor the change in atmospheric components. Google Earth Engine (GEE) is used for environmental change detection as it is a platform with fine satellite datasets and a JavaScript coding-based implementation. Atmospheric elements selected for environmental analysis processing are NO2, SO2, CO, and O3 from the remote sensing satellite Sentinel 5P.

Results and Discussion

Multiple Disease Analyses

This epidemiological research study, exploring COVID-19 with different diseases and environmental analysis of Quetta throughout the lockdown, includes secondary data and primary information from hospitals in

Quetta City. Statistical and density analysis are applied to identify multimorbidity profiles and investigate their impact on the risk of hospitalization and mortality during 2019 and 2020. Remote sensing environmental data sets are used to identify the changes that occur in different elements present in the atmosphere. Our results showed that multimorbidity was a risk factor for COVID-19 severity and that this risk increased with the increase in morbidity. Individuals with advanced cardio-metabolic profiles frequently presented the highest infection risk.

Multimorbidity density maps for the years 2019 and 2020 are shown in Figs. 4, 5, and 6. Multimorbidity is a global health issue impacting the quality of life of all ages. Multimorbid patients represent a special population of vulnerable individuals who suffer from two or more long-term conditions. In the scenario of Balochistan, the results represent that most urban area populations are more endangered to risk of multimorbidity with COVID-19. Whereas people living in rural areas are a very non-prevalent group with a low risk of death from COVID-19. All the morbidity maps show that the districts with rural settings, like Nukkundi, Dalbandin, Kharan, and Awaran, etc. show fewer diseases than the districts with urban settings, such as Quetta, Pishin, etc. The pattern with the highest severity is associated with cardiovascular, respiratory, and metabolic diseases. The disease sensitivity maps of 2019 for the districts of Balochistan showed that asthma, tuberculosis, typhoid, and acute upper respiratory infections (AURI) were prevalent in the northeastern and some districts situated in the southern parts of Balochistan (Figure 3). The disease density maps of the same districts for 2019 for patients less than 5 years old and more than 5 years old for Pneumonia showed that pneumonia was more prevalent in older patients than in children. This may be because the older population has less immunity than the children. However, the data for the same period for diarrhea showed almost the same pattern for patients less than 5 years old and more than 5 years old, with a negligible increase (Figure 4). This may be because both the children and the elderly population had received enough facilities for diarrhea. The disease density maps of 2019 for fever from road accidents outnumbered those of depression, hypertension, and fever due to other causes (Figure 5). When the disease density map for Asthma, tuberculosis, typhoid, and AURI of 2019 and 2020 were compared, the results showed that Asthama and T.B. cases were more in 2019 and reduced in 2020, but the cases of AURI and Pneumonia either remained the same or showed a very minor increase in the districts (Figure 6). This may be because the people who had asthma or T.P were seriously affected by covid-19 and died. Respiratory disease and fever-related diseases are showing occurrence in 2020 as well, maybe because these diseases have similar symptoms to COVID-19. The processed maps on the selected diseases show that in 2019, diseases were present in almost every district of Balochistan, but in 2020, the number of diseases was scattered, showing results in Quetta, Khuzdar, Sibi, and Killa Saifullah. Road accident data decreased in 2020 because of imposing lockdown by the government. This study investigated the association between multimorbidity among patients hospitalized with COVID-19 and their subsequent mortality risk. These findings strongly recommend the implementation of modified tactics for patients with multimorbidity and SARS-CoV-2 infection, especially in populations with a high morbidity burden and a lack of facilities.

Figure 3

Maps for the Year 2019 Representing the Disease Density of Every District. Exhibited Diseases are Acute Upper Respiratory Infection, Tuberculosis, Typhoid, and Asthma

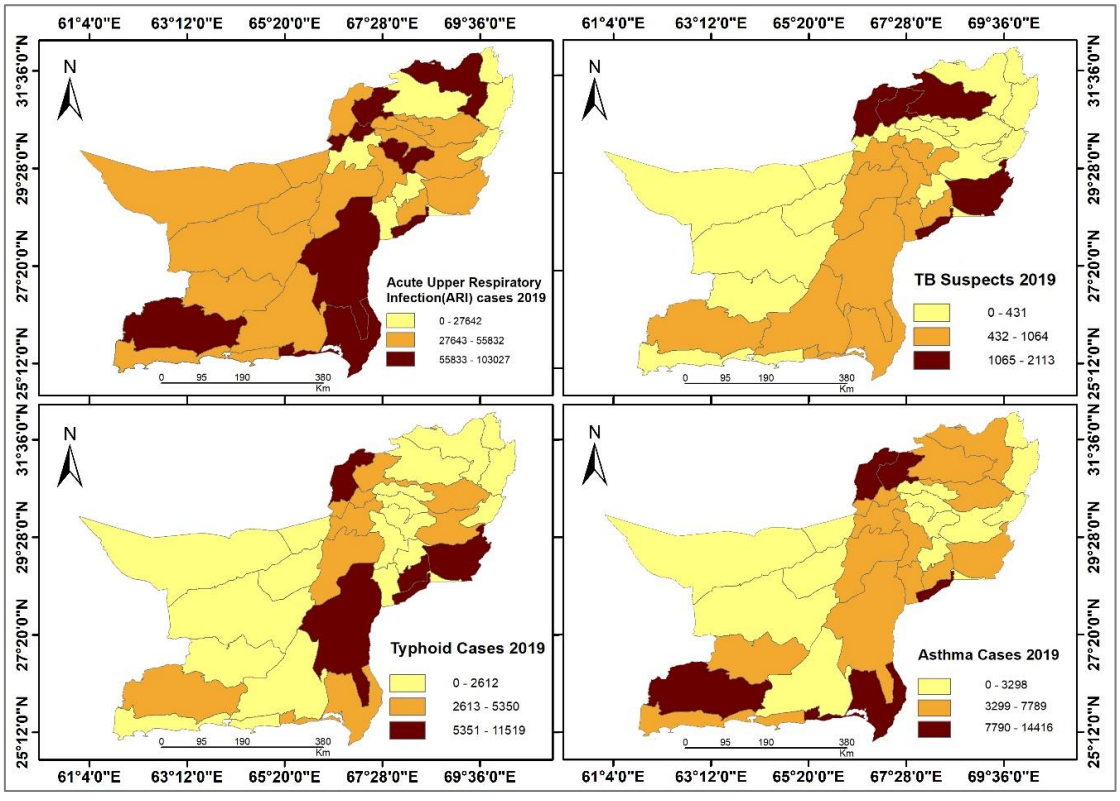


Figure 4

2019 Disease Density Map for Pneumonia and Diarrhea

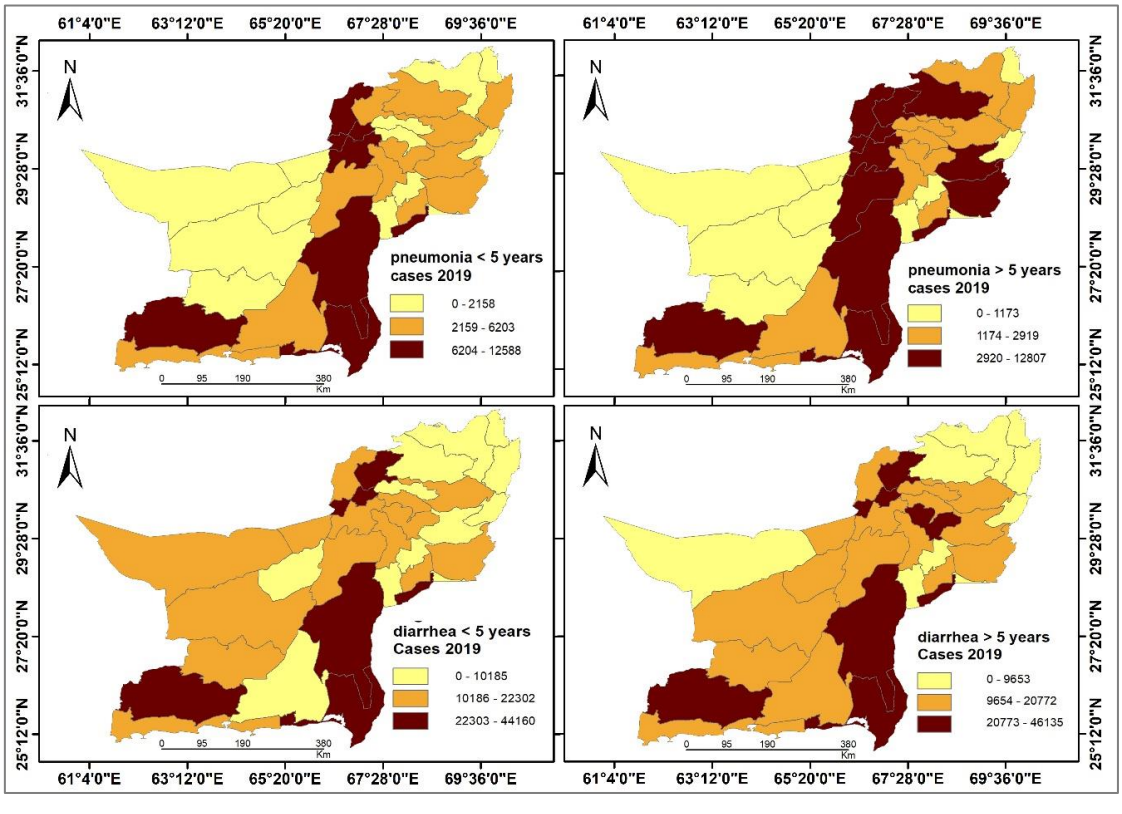


Figure 5

This Data Frame Represents the Disease Density of Fever due to Other Causes, Hypertension, Depression, and Road Traffic Accidents in the Year 2019.

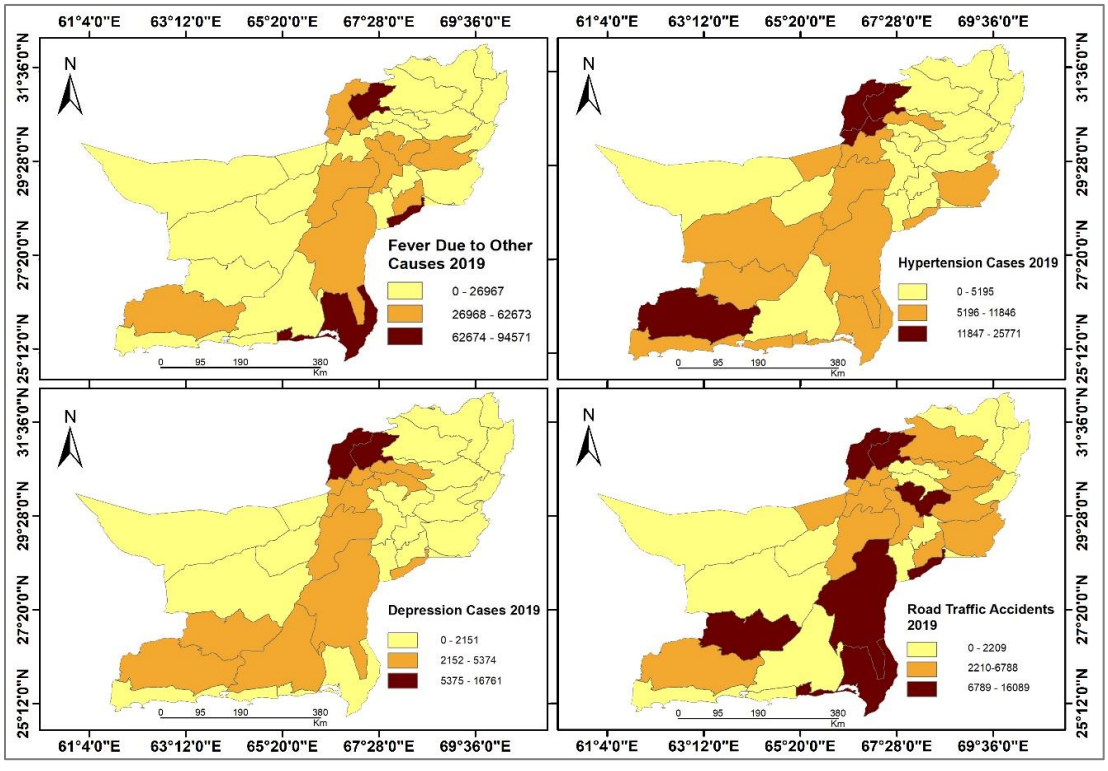


Figure 6

Maps for the year 2020 representing the Disease Density of every District. Exhibited Diseases are Acute Upper Respiratory Infection, Tuberculosis, Typhoid, and Asthma

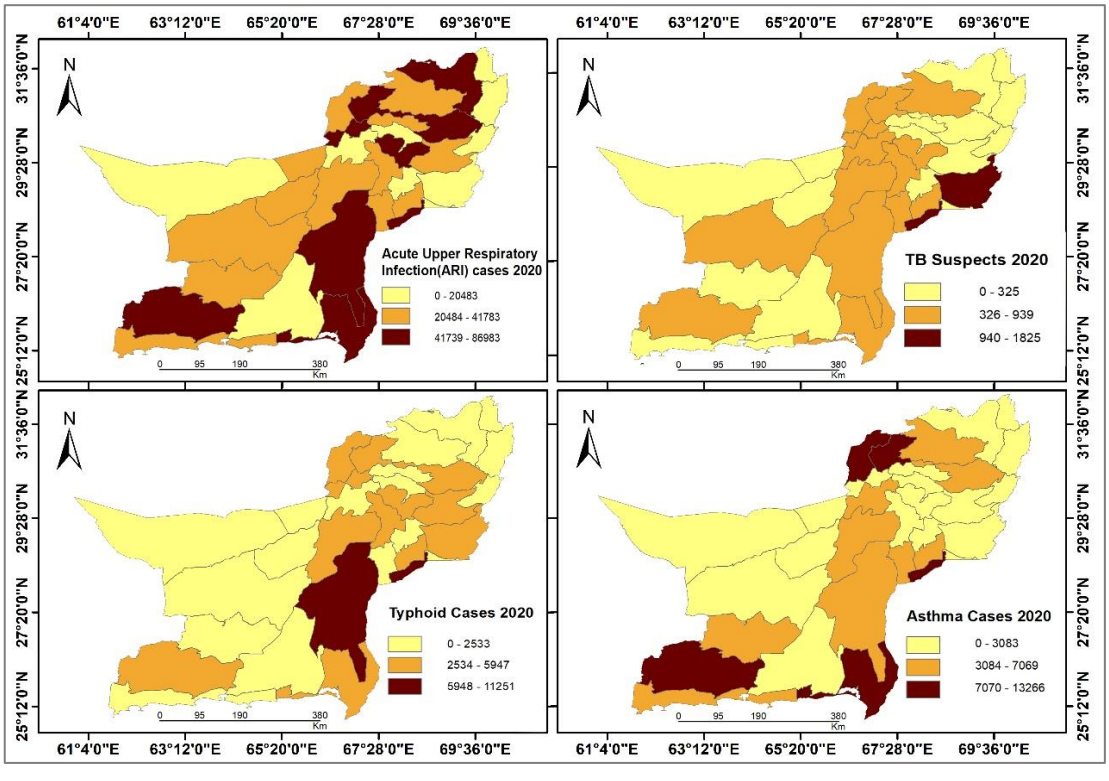


Figure 7

2020 Disease Density Map for Pneumonia and Diarrhea (Below and Above 5 years).

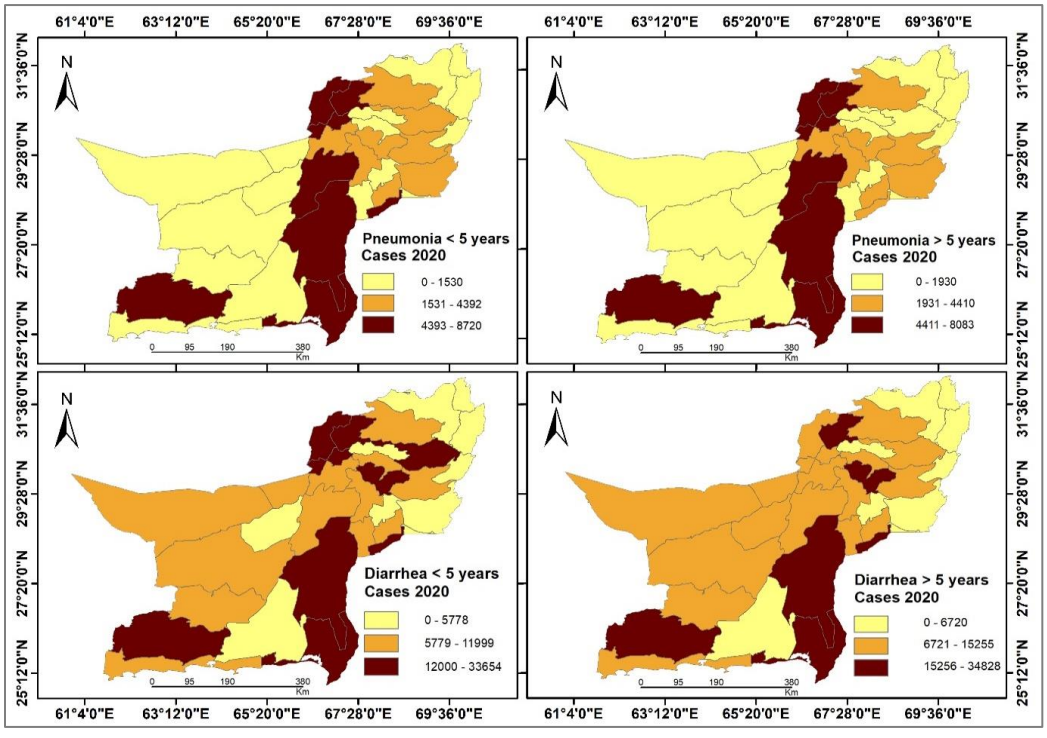
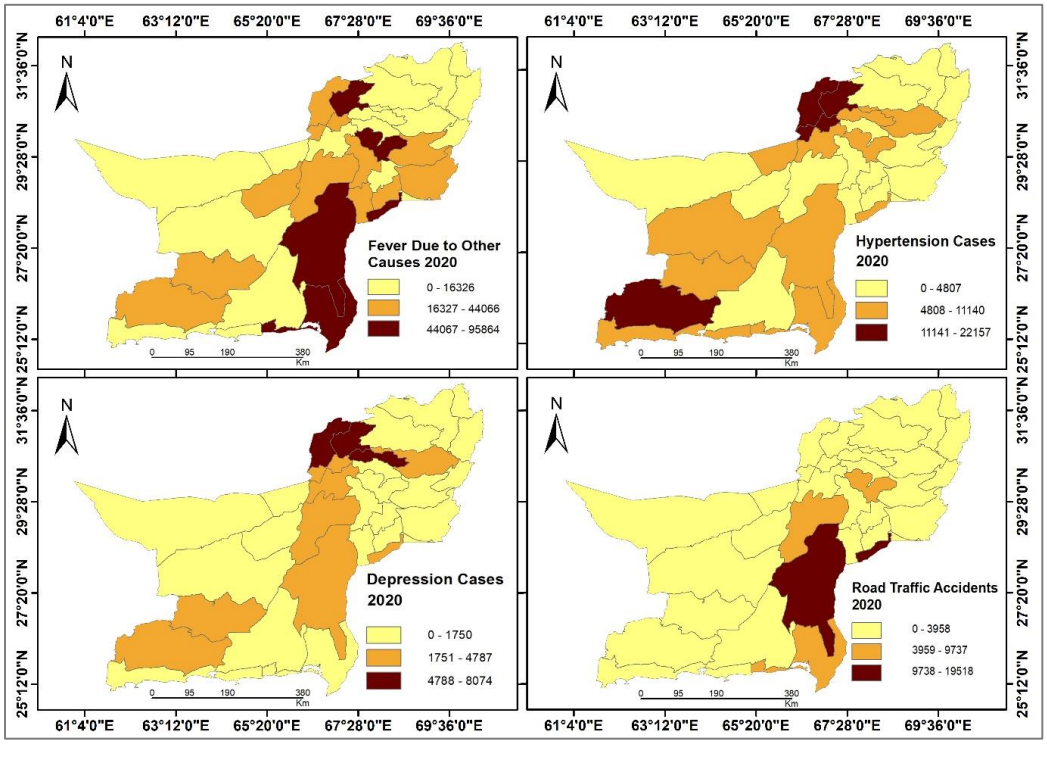


Figure 8

This Data Frame Represents the Disease Density of Fever due to Other Causes, Hypertension, Depression, and Road Traffic Accidents in the Year 2020

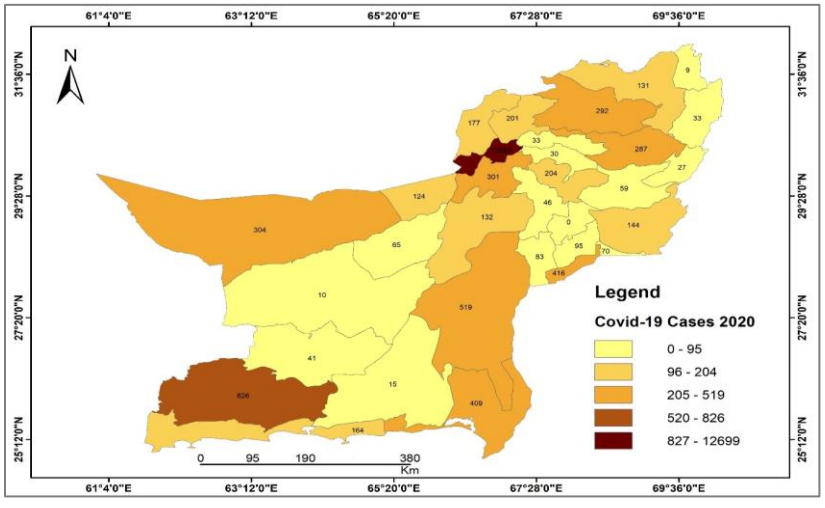


Multiple disease analyses also revealed that people living in urban residences have higher challenges than the rural population. Patient activation for self-care, multimorbidity, literacy, and technology-enabled

teleconsultation could be explored as potential interventions. Future studies should qualitatively explore the challenges of physicians as well as garner an in-depth understanding of multimorbidity management in such situations as the COVID-19 pandemic. Chronic diseases tend to cluster into patterns, each with its particular effects on the clinical outcome of infected patients. GIS-based statistical analysis for Balochistan revealed that not all cardiovascular and respiratory patterns have the same risk of COVID-19 hospitalization or mortality and that this risk depends on the pattern of multimorbidity. These results have relevant implications for organizational, preventive, and clinical actions to help meet the needs of COVID-19 patients.

Figure 9

Map Representing the Number of COVID-19 Cases all Over Balochistan in 2020

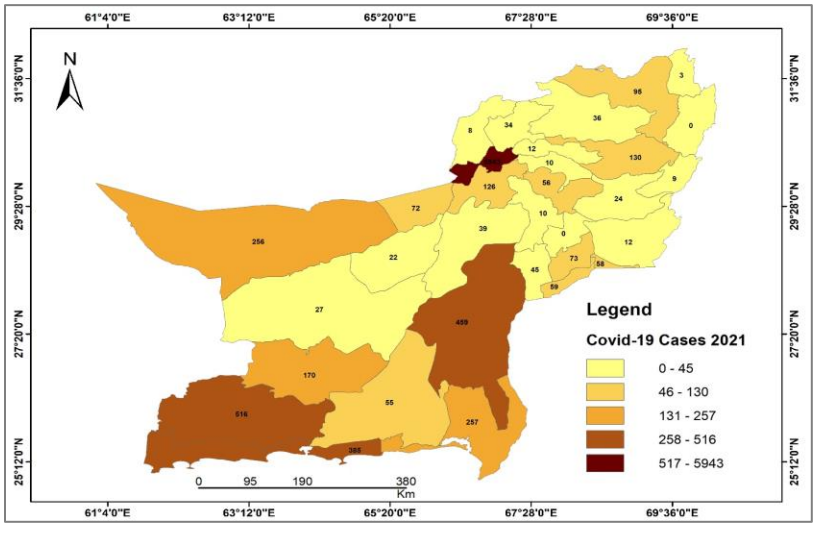


Field Survey

Additionally, a survey was conducted to assess the frequency of occurrence of hospital admissions before and after the mandatory lockdown. Following the implementation of the lockdown, hospital admissions among diabetic patients significantly decreased, while in-hospital mortality slightly increased. These findings highlight the shortcomings of the Balochistan health system and the significance of ensuring continued care as part of the response strategy during times of crisis.

Figure 10

Balochistan COVID-19 Cases in the Year 2021



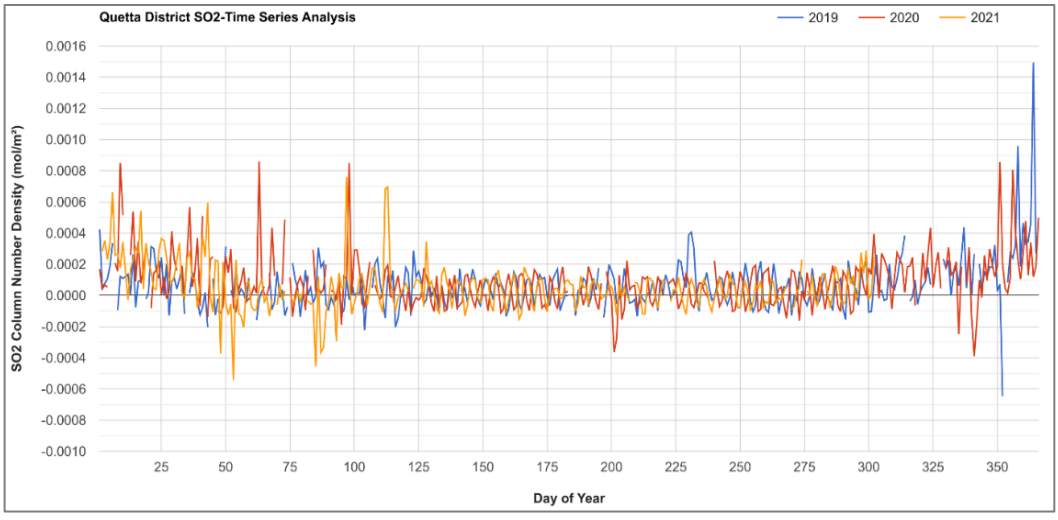
Environmental Analysis

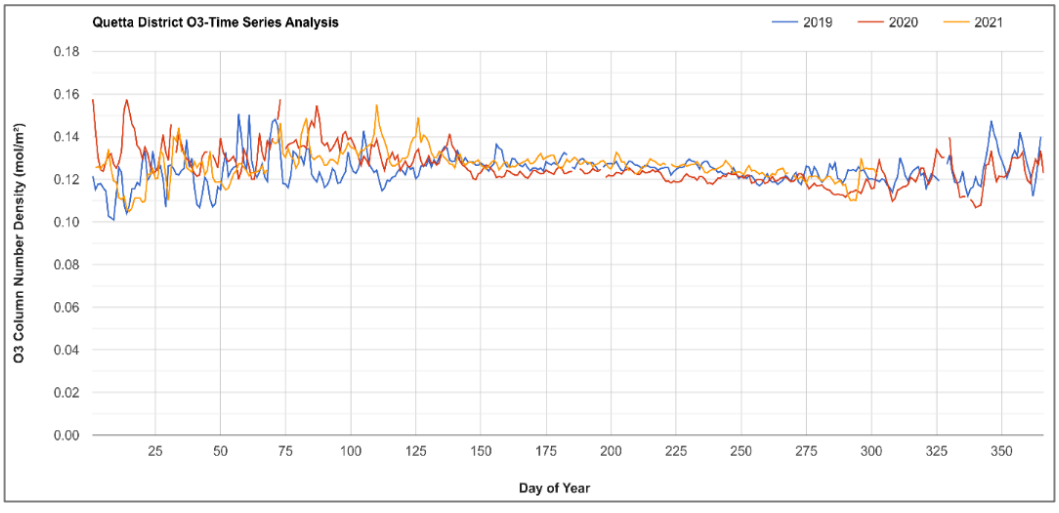
Significant changes in environmental parameters were noted during the COVID-19 pandemic worldwide, including in Pakistan, where lockdowns reduced human activity, which in turn resulted in notable reductions in air pollutants, including sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO). The COVID-19 lockdowns significantly reduced air pollution levels around the country. According to (Hassan et al., 2021), satellite data found that during the lockdown, concentrations of NO_2, CO, and ozone (O_3) decreased by around 28.88%, 15.81%, and 8.41%, respectively, throughout Pakistan. These decreases are due to fewer automobile traffic and industrial operations. Subsequent investigation revealed that NO_2 emissions in Pakistan's largest cities dropped by around 30% during the lockdown, and emissions from coal-based power plants dropped by 40%. This emphasizes how urban activity and energy production affect air quality (Abbas et al., 2022).

Fossil fuel combustion, industrial operations, and vehicle emissions are the main causes of air pollution in Quetta. Environmental analysis shows very interesting variations in Quetta, the provincial capital of Balochistan (Figure 11). Although the study is not very vast, the variation that occurs in three years for the selected elements is quite interesting. The carbon monoxide (CO) dataset did not show any drastic variation. As land surface temperature, NO_2, and SO_2 represent seasonal variations.

Figure 11

Quetta District CO, NO_2, So_2, And O_3 Time Series Analysis Graphs





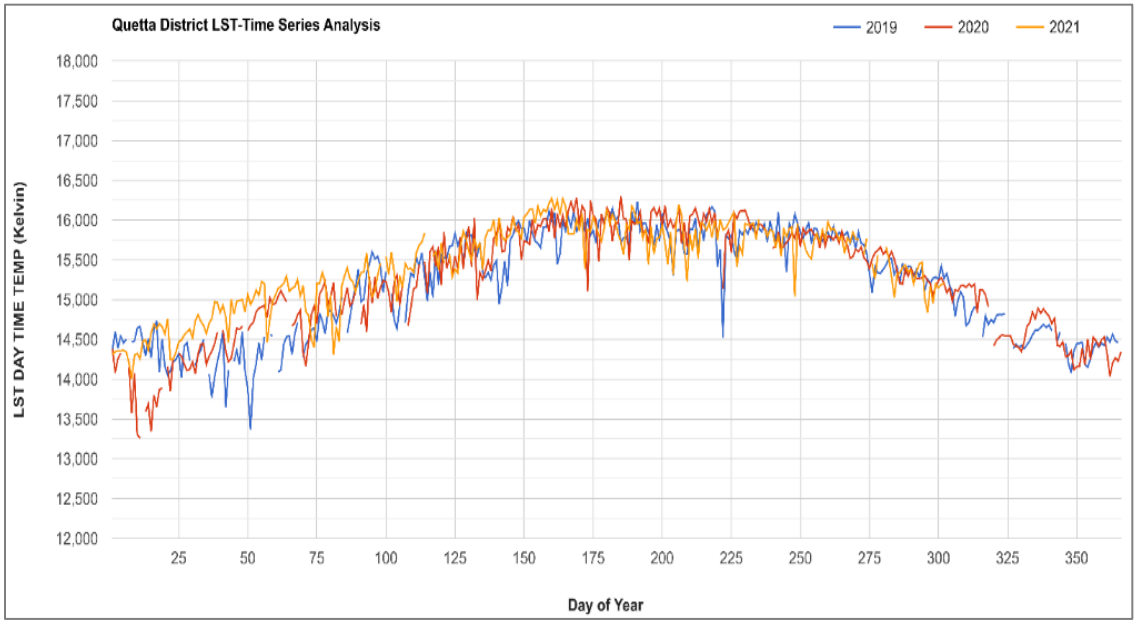
Land Surface Temperature

Globally, the COVID-19 epidemic and the lockdowns that followed had a significant effect on environmental factors, such as Land Surface Temperature (LST), in urban areas. Several studies conducted in Pakistan have shown that lower anthropogenic activity during shutdown times results in lower LST. For example, studies found that during the shutdown, LST decreased by around 5.42% in India's largest metropolitan agglomerations, which was ascribed to a decline in industrial and traffic activity (Nanda et al., 2021). Similarly, in Pakistan, the Surface Urban Heat Island (SUHI) impact, especially in megacities, significantly decreased as a result of constraints on industrial and transportation activities (Ali et al., 2021).

Although there isn't much research specifically on Quetta, the urban dynamics of the city imply that comparable trends may have happened (Figure 12). Rapid urbanization in Quetta has resulted in a rise in built-up areas and a decrease in plant cover, both of which are known to raise LST. Similar to patterns seen in other metropolitan areas, the brief drop in LST during the lockdown was probably caused by a slowdown in human activity. It is essential for environmental management and urban planning to understand these changes. The brief increases in air quality and decreases in LST during the lockdown demonstrate how much human activity affects urban settings. Strategies for mitigating climate change and promoting sustainable urban development can benefit from these ideas.

Figure 12

Quetta District LST-Time Series Analysis Graph



Conclusion

This study provides detailed sociodemographic and clinical information on all relevant morbidities with COVID-19 in Balochistan during 2019, 2020, and 2021, showing complex and extreme levels of morbidity dynamics during the first year of the pandemic. This study indicates that the prevalence of precautionary behaviors is different in the districts of Balochistan and does not show any serious precautionary performance. To guarantee the adoption of preventive actions against COVID-19, public health messaging and actions must continue to be disseminated among persons with multimorbidity, and more awareness campaigns should be organized for future crises. Based on the results of this study, it has been noted that there are connections between COVID-19 and other infectious diseases, and the environment is affected too. These changes affect human life in different ways, economically, socially, mentally, and physically. The results of this research work will not only help the researchers in the field of health sciences but also help to improve management strategies for the health sector and governmental administration. As COVID-19 does not have any major number of cases after 2021, we should mentally and physically be equipped for future cases, as the climate is changing and trends in living styles have also changed a lot. Low literacy rates and a general lack of awareness are leading to people not seriously adopting social distancing and hand hygiene. The high population density in major cities of Pakistan can facilitate the spread of the virus. The three-pronged approach of trace, test, and treat needs to be aggressively implemented to halt community transmission leading to exponential increases in cases. The findings of the study are helpful for policymakers to develop public health strategies, healthcare resource allocation, and future risks of diseases. To make policies for preparedness against future pandemics, there is a need for proper screening of travelers at the entry and exit points. Infected people should be quarantined. Social distancing should be followed at each place where crowds are expected, such as Banks, NADRA, and other offices where people rush for employment opportunities.

Credit Authorship Contribution Statement

Niamat Ullah and Shafi Ullah: Conceptualization, Methodology, Supervision, Writing - review & editing. Sabiha Mengal and Shanila Azhar: Software, Formal analysis, Validation. Said Qasim: Writing, review & editing. All the authors have made contributions to the paper and approved the submitted version of the manuscript.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests.

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Data Availability Statement

The data can be requested from the corresponding author.

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