Spatial Distribution and Trend Analysis of Current Status of COVID-19 in Nepal and Global Future Preventive Perspectives

Ramesh Raj Pant

Tribhuvan University Institute of Science and Technology

Buddha Bahadur Bahadur (✉ budbsn.btechnep@gmail.com)

Nepal Academy of Science and Technology <https://orcid.org/0000-0003-1153-4860>

Kiran Bishwakarma

Nepal Environment and Development Consultant Pvt Ltd.

Sudip Paudel

Tribhuvan University Institute of Science and Technology

Nashib Pandey

Kantipur Dental College, Teaching Hospital and Research Center

Samir Kumar Adhikari

Ministry of Health and Population, Nepal

Kamal Ranabhat

Tribhuvan University Institute of Medicine

Research

Keywords: COVID-19, Spatial distribution, Future perspective, Outbreak, Nepal

Posted Date: August 11th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-54139/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background: Coronavirus disease (COVID-19) is a recently discovered severe and contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and has received worldwide attention. The risk of COVID-19 is serious for the infected persons of chronic diseases as well as vulnerable populations including elder group. Still, the present scenario of scarcity of effective treatment options and limited recovery rate of ongoing treatment are prevailed in Nepal. This study aims to analyze the spatial distribution and trends of COVID-19 with the help of geographic information system (GIS) software and outlook future preventive perspectives.

Methods: In this research work, we used GIS tool ArcGIS 10.4.1 to map the distribution patterns of population of COVID-19 cases. Federal, provincial and district level daily cases data of COVID-19 confirmed, cured and death from 23rd January to 13th July 2020 were obtained from the Ministry of Health and Population (MoHP), Government of Nepal. In addition, we reviewed several peer-reviewed research papers to summarize the global scenarios and preventive perspectives on COVID-19.

Results: In context to Nepal SARS-CoV-2 has spread throughout the country infecting 16,945 persons in all 77 districts, as of 13th July, 2020. Confirmed, cured and death cases experienced an upward trend up to 1st July, 2020 followed by downward trend as of 13th July, 2020. Over 70% of total confirmed cases of reported COVID-19 patients were from the lowland-plain area. Spatial clustering suggested that provinces 2 and 5 were at potentially increased risk of COVID-19, and Province 1 and Bagmati province could be grouped as future "hot spots". In addition, we proposed four strategies namely, identification of the key medical and social elements, discovery and development of treatment options for a future pandemic, investing in ethno-medicine research and epidemic preparedness of health care system to decrease the efficacy of calamities of future pandemics.

Conclusion: Our study demonstrates one of the best ways to protect; control and sluggish transmission of SARS-CoV-2 could be achieved by monitoring active ties using GIS spatial analysis. And, the severity of future pandemic could be minimized by integrative action on the abovementioned four different preventive master plans.

Introduction

Pandemic coronavirus disease 2019 (COVID-19) caused by SARS-CoV-2 outbreak is the worst respiratory disease outbreak of this decade, and currently crippling the entire global fabric of human socioeconomic and political life [1–3]. COVID-19 is the third coronavirus infection in the 21st century originated in Asia, after severe acute respiratory syndrome (SARS) in 2003 and Middle East respiratory syndrome (MERS) in 2012, probably all of them were of animal origin [4, 5]. Despite concerted worldwide efforts to maximally prevent, control and confine to the break the chain of transmission SARS-CoV-2, it remains a major public health problem with a high global health burden in virtue of highly infectious, no effective available till date [6, 7]. Few cocktails of approved antiviral drugs including hydroquinone, remdesivir, azithromycin, dexamethasone, have been trial for treating the critical COVID-19 patients worldwide. However, the results are not so promising [8–10]. In 2020 as per the data of July 13, there were over 13 million cases and the number of deaths has crossed 0.57 million worldwide over 213 countries and territories including 2 international conveyances. The SARS-CoV-2 virus originated in December 2019 in Wuhan city (the capital city of Hubei Province, China) causing infection and death of over 0.8 million and 3 thousand people, respectively in China (as per the data of July 13, 2020). And, the World Health Organization (WHO) declared the COVID-19 as a public health emergency of international concern (PHEIC) on 30th January of 2020 [11].

In Nepal the first confirmed case of SARS-CoV-2 infections was a native student, studying in Wuhan, with symptom onset on 3rd January 2020 confirmed as an index case on 23rd January followed by migrants from Middle East countries and majorly from India [12]. Over 16 thousands positive cases of SARS-CoV-2 from Nepal have been reported by the WHO

and MoHP as of July 13, 2020 [11] in all 77 districts in Nepal. Previous studies from Nepal focused on mental assessment of COVID-19 patients and normal people [13, 14] awareness, challenge and hospital disaster preparedness plans [15, 16], clinical profile [17, 18] and viral genome status [12].

The GIS and spatial mapping are emerging global health tools [19], widely used for knowledge, prevention, and treatment of various diseases. In relation to the spatial analysis of certain information, it is possible to evaluate the risks of disease, trends in outbreaks over time and space, and hotspots of infection. In addition, these methods may relate to the design, planning, and distribution of international health resources for treatment, control and prevention facilities and may help mitigate the impact of interference [20–23]. This study aimed to investigate the dynamics of the trend to predict the spread of diseases with the help of GIS software and spatial patterns of RT-PCR positive SARS-CoV-2 infected people at the provincial level in Nepal from 23rd January to 13th July, 2020.

Materials And Methods

Study Area

Nepal, officially the “Federal Democratic Republic of Nepal”, lies in South Asia between two big countries of China in north and India in south, east and west. It is located mostly in the Himalaya region and also includes some low-land areas in the Indo-gangetic plain. Geographically, Nepal lies in between latitudes 26° N to 31°N and longitudes 80° E to 89° E, covering 1, 47, 516 sq. km. Total population of Nepal is 30 million according to the latest update released by the Central Bureau of Statistics, Nepal. Nepal is ranking in 49th and 93rd largest countries in terms of population and covering area respectively, in the world. It officially has seven provinces namely: Province 1, Province 2, Bagmati, Gandaki, Province 5, Karnali and Sudurpaschim. Kathmandu is the federal capital city of Nepal and other major cities include Janakpur, Biratnagar, Bharatpur, Pokhara, Lalitpur, Dharan, Birgunj, Butwal, Nepalgunj, Mahendranagar, etc. The country map with the population density distribution as spatial scale is presented in Fig.1.

Methodology

Spatial analysis approaches and the use of GIS tool are used in this study to assess the distribution pattern of COVID-19 disease transmission in the spatial level in Nepal .The statistics of SARS-CoV-2 infected cases, total cured and deaths from Nepal have been retrieved from WHO data center and MoHP website [11]. In addition, the data portal system of the MoHP was used to download the data of Nepal [24]. The statistics of COVID-19 as of 13th July of 2020 has been reported in present study. Population distribution of Nepal based on the province system was taken from the energy data information website [25]. In this research work, the distribution patterns of population COVID-19 total cases were illustrated with GIS tool ArcGIS 10.4.1. In addition, several peer-reviewed research papers of COVID-19 were downloaded from PubMed, MEDLINE, local journals of Nepal, including Journal of Nepal Health Research Council and reviewed to summarize the global scenarios and preventive perspectives on COVID-19.

Results And Discussion

Current Status

Total cases of COVID-19 in Nepal are 16945 as of 13th July 2020 with total cured and deaths are 10294 and 38, respectively. The district wise confirmed cases with cured and death due to COVID-19 in Nepal is presented in Table 1. The first COVID-19 index case was reported in Nepal on 23rd January 2020 when a 31-year-old student, who had returned to Kathmandu from Wuhan, China (epicenter of COVID-19), was also the first case reported in South Asia. The second case was confirmed on 23rd March 2020 in Kathmandu after two month later of the first case. Then the Federal Government of Nepal formally declared a nationwide lockdown from 24th March 2020. The first local transmission and

first death of COVID-19 was reported on 4th April 2020 in Kailali and on 14th May 2020 in Sindhupalchok district, respectively. Globally, as of 13th July 2020, over 11 million were confirmed in 213 countries with reported deaths and cured are 0.55 million and 4.45 million, respectively. The fatality rate and cured rate in Nepal due to COVID-19 were 0.21% and 60.75%, respectively while of the globe were 4.34% and 58.13%, respectively. As of 13th July, 2020, Nepal ranks on 61th position in global context, 23rd rank in Asia in number of infected cases. Moreover, on the South Asian Association for Regional Cooperation it ranks on 6th position on infected cases per million populations (Fig. 2).

The province wise total cases reported is highest in Province 2 (n = 4,348) followed by Province 5 (n = 4,071) and Sudurpaschim (n = 3,936) (Table 2). As depicted in Table 1, the confirmed cases of COVID-19 are distributed throughout the country with all the administrative districts. However, as of 13th July, 2020, 7 districts namely, Paachthar, Dhankutta, Bhojpur, Rasuwa, Manang, Mustang and Humla had no active cases. The total number of confirmed cases is highest in the Rautahat district (n = 1,453) followed by Kailali (n = 922) Dailekh (n = 812), and Kapilbastu (n = 765) and lowest in Manang (n = 1) and Mustang (n = 1) followed by Humla (n = 2) and Solukhumbu district (n = 2) districts (Table 1).

The detailed cumulative trend analysis of COVID-19 in Nepal is present in Fig. 3. The total number of recently confirmed cases in Nepal rapidly increased from 11th May to 1st July, 2020 then sluggish up to 13th July though ease in lockdown started from 11th June 2020. However, earlier studies showed an increasing trend with the ease in lockdown for the number of corona cases [27]. Moreover, only one hundred fifty-five new cases have been reported on 13th July 2020.

Age and gender wise distribution of confirmed COVID-19 cases are illustrated in Fig. 4 and Fig 5. The largest number of infected cases was reported in the age group 21-30 years, which accounted for 37.39% (n = 6337) followed by the age group of 31-40 years which accounted for 23.06% (n = 3909) over the study period. However, death rate was higher in age group 41-50 (n = 11), which contributed to 28.94% of total death cases. The age wise distribution of the disease, infected persons and death cases are contrasting to the many other countries around the globe, is one of the key finding of this study.

From Fig. 5, a higher proportion of male compared with females in the different age groups was infected. Among 16,945 confirmed cases, 14,588 were males and 2,357 were females, with a male-to-female sex ratio of ~6.2. Similar to our study one study by Jordan *et al.* (2020) concluded infection risk was higher among men than women however the ratio was comparatively lower than the present study [27]. In context to Nepal, the few reasons behind this may be a larger number of male immigrants from other countries, particularly from India due to cross country open borders. Further steroids, especially low levels of estrogen and X-linked gene activity are also attributed for high risk of COVID-19 in Male [28]. Importantly 97% of COVID-19 cases were immigrants from India [29], is one of the serious matters of concern for all levels of governing bodies in Nepal. In contrast to our study, the gender wise distribution pattern of COVID-19 cases in Italy stated the number of female cases to be slightly more than males [30], concluding heterogeneity in infection rates among gender in different countries. Higher numbers of infected cases were males of age group 21-30 years followed by age group 10-20 years. Likewise, females of age group 21-30 years followed by age group 31-40 years were infected. In context to the death cases male of age group 41-50 years (n = 9) and female of age group 21-30 years (n = 5) have major contributions. Overall, men's death was 3.75 times the death rate of women. The study by Jin *et al.* [31] and Shim *et al.* [32] also stated males are more at risk of mortality; however the death ratio was observed 2.4 and 2.75, respectively.

Spatial distribution of COVID-19

Geographically, Nepal is divided into three distinct ecological regions, Mountain in north, Hilly in middle and lowland plain in South. The spatial distribution of COVID-19 confirmed cases is presented in Fig.6. The reported cases in the plain region are relatively higher than the Hilly and Mountain regions. More than 70% of total confirmed cases are reported from the lowland -plain areas. The main reason for the high number of confirmed cases in the lowland plain region is

most probably due to the open boundary with India [29] and major cities with high population density in the plain region [33, 34]. However, the numbers of death cases are higher in hilly regions compared to plain regions (Table 2; Fig. 6). One of the reasons behind the higher death cases in hilly regions may be due to lack of rapid access to health facilities [35]. While comparing the cases with India as of 13th July of 2020 was 0.9 million and ranked in the top three in the world. Huge numbers of Nepalese are in India for different purposes such as working, studying and other different business purposes. Large number of people entered Nepal without maintaining proper physical distance after declaring the lockdown in India which causes the outbreak of COVID-19 in Nepal.

Prospects for controlling future pandemics of SARS-CoV

With the global scenario of SARS-CoV in 2003 (SARS-CoV), 2012 (MERS-CoV) and 2019 (SARS-CoV-2), alarm world for the next outbreak sooner or later. Based on the progress made in medical sector, as well as science and technology to date, the experiences gained from numerous outbreaks of infectious diseases in the past few centuries and decades, we suggest the necessity of some future preventive perspectives to be initiated to stop or lessen the impact of upcoming pandemics. So, for the foreseeable future we must first deal with the ongoing pandemic and future threat by anticipating as far as possible catastrophic.

Identification of the key medical and social elements

One of the key determinants that profound the mortality and morbidity of people due to infection by SARS-CoV-2 is social and economic status [36, 37]. Some of the common sources could be the animal trafficking [38, 39], poor sanitation and hygiene of livestock workers [40, 41], reservoir intermediate animal sources [42] increase the risk of emergence of zoonotic disease. Anti-smuggling operations and close monitoring of rearing of wild and domestic animals and associated workers hygienic status is important to break transmission link of infectious agents. Cross country open borders have brought challenges of viral spread *via* immigrants in many countries around the world, and Nepal is one of the examples. The connection between socio-cultures, climate change, humidity and seasonal variability assume that the risk of transmission of SARS-CoV-2 does appear to be the greatest [43, 44]. Additionally, variation in food availability and food intake, age, and sex are important factors which could also play a role in the SARS-CoV-2 notification variability [45]. Ethnicity is another key player for increased risk of acquiring SARS-CoV-2 infection, for instance, studies have revealed that the Black, Asian and Minority Ethnic individuals are more prone and worsen clinical complications from COVID-19 compared to White individuals [46-48]. Further, good food practice strategies to boost immune responses with immunity eliciting (boosting) agents have positive impact in nullifying the severity of SARS-CoV-2 [49]. Assessments of global changes in present endemic/pandemic [50, 51] are crucial to identify impacts for future endemic/pandemic and their mitigation and management. Likewise, technologies and devices for effective tracking and tracing, rapid screening of infections [52-54] are important to identify the current epidemic, and eliminate the future outbreaks. Increasing prevalence of SARS-CoV-2 in non-communicable diseases conditions such as obesity, high blood pressure, chronic obstructive pulmonary disease, diabetes mellitus, cardiovascular diseases, and cancer can be a clue for safety of these vulnerable groups [55]. Intermittent trends and variation in genomic changes in corona strains of animals' analysis may have ideas for future. Pre collaboration, actions and awareness on the abovementioned social and medical determinants by government sectors, the private sector, civil society organizations non-governmental organizations, international organizations could have a positive effect on future prevention, spread and lessen the calamitous impacts of pandemic.

Treatment options for a future pandemic

SARS-CoV-2 is an enveloped positive sense, single-stranded RNA virus with 50–200 nanometers in diameter with four major structural proteins, spike protein, membrane protein, envelope protein and nucleocapsid protein together with several accessory proteins [56]. In addition, the close genomic relationship (>75% nucleotide identity) of SARS-CoV-2 with

SARS-CoV and MERS-CoV has been a good playground for similar therapeutic insights [57]. In the current face of tragic of unavailable clinically approved vaccines or drugs for SARS-CoV-2 treatment except few antiviral agents and others (remdesivir, favipiravir, hydroquinone, azithromycin, dexamethasone) to lessen the severity of complications of COVID-19 [10] paving a way to drugs/vaccine discovery is utmost. Antiviral agents could be discovered and developed by targeting, broadly various stages of the life cycle of virus (entry, attachment, replication, transcription, translation, maturation, release) [58, 59] by currently available methods, either computational or/and traditional. And/or, targeting molecular targets such as ACE2 of human, 3CL^{pro} protease, Nsp13 helicase of SARS-CoV-2, for instance [61, 62]. Basically, discover and/or test existing broad-spectrum antiviral drugs, screening of the all available molecular databases, based on the genomic, signaling and pathological information could lead to characterization of more effective therapeutics from present to future. Thus identifying, discovery, development of stockpile of antiviral and developing standard operating procedures for rapid deployment would be effective treatment options to cope with the disastrous impact of the future outbreak.

Next powerful weapon to combat SARS-CoV-2 at present and for future outbreak is vaccination, which has worked spectacularly well in many cases. As the structural and genomic information have been available characterization and development and distribution of vaccine for possible vaccine production strategy that undermined the ability to treat severe cases effectively could be highly counterproductive [62]. In addition, technical support, capacity building and technology transfer for SARS-CoV-2 vaccines and diagnostics to developing countries to prepare stockpiles of vaccines. Moreover, genome sequence SARS-CoV-2 displayed nucleotide identity (>75%) to the previously identified coronavirus SARS-CoV, MERS-CoV, for instance, could be very helpful in developing broad-spectrum monoclonal antibodies against the plethora of coronavirus strains [63] despite of several hurdles on the counter parts. So, for the current and foreseeable future we must deal with the ongoing antiviral agent and vaccine development side by side to counter the sudden abrupt outbreak.

Epidemic preparedness of health care system

Besides non-pharmaceutical interventions, healthcare facilities and their staffs are key players in epidemic preparedness for outbreak response. The lack of progress in controlling the current pandemic of SARS-CoV-2 revealed poor settings of public health systems and services together with limited contact tracing, poor setting of quarantine, disobeying physical distancing rule and so on. Inspiring statements about bold policy changes for health system strengthening must be urgently translated into action with efficient collaboration and coordination among state, local, and territorial national and international public health agencies for full protection against the evolving catastrophic direct and indirect cost of illness [64-68]. Addressing all barriers (Fig.7) is a tall order and will require political will on the highest level, stimulated by forceful grassroots demands [69].

Investing in ethno-medicine research

Calamitous outbreaks have been recorded from ancient periods in the history of human civilization, including Spanish Flu, Hong Kong Flu, SARS, H7N9, Ebola, Zika, to name a few. These viruses explode informally as endemic, epidemic and pandemic, in some cases remaining as a seasonal flu and infecting millions of people and thousands of deaths each year [3, 70, 71]. Based on the historical records, despite of some drawbacks, herbal drugs has been used in the traditional medicine for treatment of different disease including COVID-19, *Astragali Radix*, *Glycyrrhizae Radix Et Rhizoma*, *Lonicerae Japonicae Flos* and *Fructus forsythia*, to name few [72-73]. The era of antiviral therapy can be traced back to the 1960s, since then over 60 clinically efficacious antiviral compounds have been discovered till date. However, mostly, if not all have some limitations, ranging from poor bioavailability to toxic side effects and drug resistance with some virus where no effective drugs or vaccines exist [74]. After some period (1990-2010s AD) of pace dawn of discovery of drugs from plants origin there is again resurgence of research in ethno-medicine-based drug

discovery. In the current era, in many developed countries research institutes, universities and pharmaceutical laboratories as well as in the clinics thereof priorities have been given to scientific research on medicinal plants. In present scenario about 35 percent of western medicines originated directly from natural products or their derivatives {plants (approx. 25%), microorganisms (approx. 13%), animals (approx. 3%) and derive from natural products (approx. 14%)} [75-77]. Therefore, medicinal plants and their bioactive metabolites are the main focus of interest and have several advantages over the synthetic drugs due to their broad therapeutic potency, limited side effects and their ongoing human trial for a long time. Thus, the research on ethno-medicine is a key step for transferring antiviral agents from the impatient to the patient. To catalyze this transformation and pave the way for future research crucial priority for scientific investment is unavoidable. Ensuring full and continued funding and implementation of all components of the SARS-CoV-2 is the highest priority for all countries for better, wise and wider use of existing technologies to dissect the antiviral drugs from natural products.

Conclusions

This study was conducted to assess the impacts of COVID-19 focusing on the pattern of spatial distribution in Nepal. Descriptive statistics and GIS-based spatial techniques are feasible and helpful to clarify, quantify and identify the areas for intervention. Therefore, knowledge of spatial distribution of COVID-19 is expected to provide accurate and easily accessible information for implementation of preventive measures in community health. The study revealed spatial analysis of COVID-19 incidence and clustered pattern is in the low-land plain region, mostly in province 2 and province 5 as of 13th July 2020. The age and gender wise infection, and the death due to COVID-19 are the some interesting finding from this study, where major contributors are male and age group for the both male and female is 21 – 50. Furthermore, the study has also heightened the medical and social determinants, discovery of broad-spectrum vaccines or/and antiviral drugs, empowerment and upgrading of health care systems and re-investigation of pre-approved ethno-medicine and search for new herbal and or medicinal plants. All the aforementioned findings could be necessary and important for public health policymakers to promote strategies for COVID-19 control and management for infrastructure for global community including Nepal. More importantly, the results of this study could be useful to the government bodies and concerned authorities to take the appropriate decisions and carry out a comprehensive assessment of the spread of the virus and effective public health measures in the different provinces and districts in Nepal. Overall, the findings could be directly applicable to other countries around the globe to cope with the current and future possible outbreak.

Declarations

Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

No fund was received to conduct this research.

Author's contributions

RRP conceived and designed the study, collected the data, authored or reviewed drafts of the paper, and approved the final draft.

BBB conceived and designed the experiments, drafted manuscript, revised figures and/or tables, and approved the final draft.

KB and SP prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.

NP drafted future perspective sections in the manuscript, reviewed drafts of the paper, and approved the final draft.

SKA and KR collected the data, reviewed drafts of the paper, and approved the final draft.

Acknowledgements

This work was not funded by any organization. COVID-19 statistics were obtained from MoHP website in accordance with a specific confidentiality protocol.

Author information

Affiliations

¹Central Department of Environmental Science, Institute of Science and Technology, Tribhuvan University, Kirtipur, Kathmandu, Nepal

²Faculty of Science, Nepal Academy of Science and Technology, Khumaltar, Lalitpur, Nepal

³Nepal Environmental and Development Consultant Pvt. Ltd., Babarmahal, Kathmandu, Nepal

⁴Kantipur Dental College, Teaching Hospital and Research Center, Basundhara, Kathmandu, Nepal

⁵Ministry of Health and Population, Ramshahpath, Kathmandu, Nepal

⁶Central Department of Public Health, Institute of Medicine, Tribhuvan University, Maharajgunj, Kathmandu, Nepal

Abbreviations

COVID-19: Coronavirus Disease

GIS: Geographic Information System

SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2

MoHP: Ministry of Health and Population

SARS: Severe Acute Respiratory Syndrome

MERS: Middle East Respiratory Syndrome

SAARC: South Asian Association for Regional Cooperation

WHO: World Health Organization

PHEIC: Public Health Emergency of International Concern

RNA: Ribonucleic Acid

ACE2: Angiotensin-Converting Enzyme 2

References

1. WHO. Coronavirus disease (COVID-19) pandemic, <https://www.who.int/emergencies/diseases/novel-coronavirus-2019>, Date accessed: July 13, 2020.
2. Keni R, Alexander A, Nayak PG, Mudgal J, Nandakumar K. COVID-19: Emergence, spread, possible treatments, and global burden. *Front in public health*. 2020;8:216.
3. Morens DM, Daszak P, Taubenberger JK. Escaping Pandora's box-another novel coronavirus. *N Engl J Med*. 2020 (published online Feb 26).
4. Guarner J. Three emerging coronaviruses in two decades. *Am J Clin Pathol*. 2020;153:420–21.
5. El Zowalaty ME, Järhult JD. From SARS to COVID-19: A previously unknown SARS- related coronavirus (SARS-CoV-2) of pandemic potential infecting humans - Call for a One Health approach. *One health*. 2020;9:100124.
6. Zheng J. SARS-CoV-2: an emerging coronavirus that causes a global threat. *Int J Biol Sci*. 2020;16(10):1678–85.
7. Contini C, Di Nuzzo M, Barp N, Bonazza A, De Giorgio R, Tognon M, Rubino S. The novel zoonotic COVID-19 pandemic: An expected global health concern. *J Infect Dev Ctries*. 2020;14(3):254–64.
8. Chemical Entities of Biological Interest (ChEBI). Entity of the Month www.ebi.ac.uk/chebi/entityMonthForward.do, Date accessed: July 13, 2020.
9. Yu J, Chai P, Ge S, Fan X. Recent understandings toward coronavirus disease 2019 (COVID-19): From Bench to Bedside. *Front Cell Dev Biol*. 2020;8:476.
10. Jin Z, Du X, Xu Y, Deng Y, Liu M, Zhao Y, Zhang B, Li X, Zhang L, Peng Y, Yu J, Wang L, Yang K, Liu F, Jiang R, Yang X, You T, Liu X, Yang X, Bai F, Liu H, Liu X, Guddat LK, Xu W, Xiao G, Qin C, Shi Z, Jiang H, Rao Z, Yang H. Structure of M^{pro} from SARS-CoV-2 and discovery of its inhibitors. *Nature*. 2020;582:289–93.
11. Worldometer. COVID-19 coronavirus pandemic, <https://www.worldometers.info/coronavirus>, Date accessed: July 13, 2020.
12. Sah R, Rodriguez-Morales AJ, Jha R, Chu DKW, Gu H, Peiris M, Bastola A, Lal BK, Ojha HC, Rabaan A, Zambrano A, Costello L, Morita A, Pandey K, Poon BD. L., LM.: Complete genome sequence of a 2019 novel coronavirus (SARS-CoV-2) strain isolated in Nepal. *Microbiol ResourAnnounc*. 2020;9(11):e00169-20.
13. Chalise HN. COVID-19 situation in Nepal. *Arch Psychiatr Ment Health*. 2020;4:33–4.
14. Sharma P, Joshi D, Shrestha K. Mental health and COVID-19 in Nepal: A case of a satellite clinic. *Asian J Psychiatr*. 2020;53:102175.
15. Marahatta S, Paudel S, Aryal N. COVID-19 Pandemic: What can Nepal do to curb the potential public health disaster? *JKAHS [Internet]*. 2020;3(1):1–4.
16. Pokharel S, Raut S, Rijal KR, Adhikari B. COVID-19 pandemic, public health preparedness in Nepal and one health approach. *Disaster Med Public Health Prep*. 2020; 2020:1–3.
17. Joshi J, Mishra P, Kamar SB, Sharma ND, Parajuli J, Sharma S, Pandey HR. Clinical profile of cases of COVID-19 in far western province of Nepal. *JNHRC*. 2020;18(1):135–37.

18. Hamal PK, Chaurasia RB, Pokhrel N, Pandey D, Shrestha GS. An affordable videolaryngoscope for use during the COVID-19 pandemic. *Lancet Glob Health*. 2020;8(7):e893–4.
19. Nykiforuk CIJ, Flaman LM. Geographic Information Systems (GIS) for health promotion and public health: A review. *Health Promot Pract*. 2011;12(1):63–73.
20. Comber AJ, Brunsdon C, Radburn R. A spatial analysis of variations in health access: linking geography, socio-economic status and access perceptions. *Int J Health Geogr*. 2011;10:44.
21. Tsai P, Lin M, Chu C, Perng CH. Spatial autocorrelation analysis of health care hotspots in Taiwan in 2006. *BMC Public Health*. 2009;9:464.
22. Uthman OA, Yahaya I, Ashfaq K, Uthman MB. A trend analysis and sub-regional distribution in number of people living with HIV and dying with TB in Africa, 1991 to 2006. *Int J Health Geogr*. 2009;8:65.
23. López-Abente G, Aragonés N, Pérez-Gómez B, Pollán M, García-Pérez J, Ramis R, Fernández-Navarro P. Time trends in municipal distribution patterns of cancer mortality in Spain. *BMC Cancer*. 2014;14:535.
24. Nepal, Government. Ministry of Health and Population, COVID-19. <https://covid19.mohp.gov.np/#/> Date accessed: July 13, 2020.
25. Nepal - Population density. (2015). <https://energydata.info/dataset/nepal-population-density-2015> Date accessed: July 13, 2020.
26. Wong D, Yuan L, Perlin S. Comparison of spatial interpolation methods for the estimation of air quality data. *J Expo Sci Environ Epidemiol*. 2004;14:404–15.
27. Jordan RE, Adab P: Who is most likely to be infected with SARS-CoV-2? *Lancet Infect Dis*. 2020;S1473-3099 (20): 30395-99.
28. Meng Y, Wu P, Lu W, Liu K, Ma K, Huang L, Cai J, Zhang H, Qin Y, Sun H, Ding W, Gui L, Wu P. Sex-specific clinical characteristics and prognosis of coronavirus disease-19 infection in Wuhan, China: a retrospective study of 168 severe patients. *PLoS Pathog*. 2020;16:e1008520.
29. Rijal A 99% COVID-19 Cases in Nepal asymptomatic, 97% imported. *The rising Nepal* (2020, July 19) <https://risingnepaldaily.com/main-news/99-covid-19-cases-in-nepal-asymptomatic-97-imported>.
30. <https://www.statista.com/statistics> Date accessed: July 5, 2020.
31. Jin J-M, Bai P, He W, Wu F, Liu X-F, Han D-M, Liu S, Yang J-K. Gender differences in patients with COVID-19: Focus on severity and mortality. *Front Public Health*. 2020;8:152.
32. Shim E, Tariq A, Choi W, Lee Y, Chowell G. Transmission potential and severity of COVID-19 in South Korea. *Int J Infect Dis*. 2020;93:339–44.
33. Olsen H. The United States might have a secret weapon against coronavirus. *The Washington Post*, (2020, March 19). <https://www.washingtonpost.com/opinions/2020/03/19/united-states-might-have-secret-weapon-against-coronavirus/>.
34. Rosenthal B. Density is New York City's big "enemy" in the coronavirus fight. *The New York Times*, (2020, March 23). <https://www.nytimes.com/2020/03/23/nyregion/coronavirus-nyc-crowds-density.html>.
35. Hamidi S, Sabouri S, Ewing R. Does Density Aggravate the COVID-19 Pandemic? *JAPA*. 2020.
36. Abrams EM, Becker AB, Szeffler SJ. Paradigm shift in asthma therapy for adolescents: Should it apply to younger children as well? *JAMA Pediatr*. 2020;174(3):227–28.
37. Wu D, Wu T, Liu Q, Yang Z. The SARS-CoV-2 outbreak: what we know. *Int J Infect Dis*. 2020;94:44–8.
38. Lam TT, Jia N, Zhang Y, Shum MH-H, Jiang J-F, Tong Y-G, Shi Y-X, Ni X-B, Liao Y-S, Li W-J, Jiang B-G, Wei W, Yuan T-T, Zheng K, Cui X-M, Li J, Pei G-Q, Qiang X, Cheung WY-M, Li L-F, Sun F-F, Qin S, Huang J-C, Leung GM, Holmes EC, Hu

- Y-L, Guang Y, Cao W-C. Identifying SARS-CoV-2-related coronaviruses in Malayan pangolins. *Nature*. 2020;583:282–85.
39. Zheng J. SARS-CoV-2: an emerging coronavirus that causes a global threat. *Int J Biol Sci*. 2020;6(10):1678–85.
 40. Kimman T, Hoek M, de Jong MC-M. Assessing and controlling health risks from animal husbandry NJAS -. *Wageningen Journal of Life Sciences*. 2013;66:7–14.
 41. Cunningham AA, Daszak P, Wood JLN. One Health, emerging infectious diseases and wildlife: two decades of progress? *Philos Trans R Soc Lond B Biol Sci*. 2017;372(1725):20160167.
 42. Shi J, Wen Z, Zhong G, Yang H, Wang C, Huang B, Liu R, He X, Shuai L, Sun Z, Zhao Y, Liu P, Liang L, Cui P, Wang J, Zhang X, Guan Y, Tan W, Wu G, Chen H, Bu Z. Susceptibility of ferrets, cats, dogs, and other domesticated animals to SARS–coronavirus 2. *Science*. 2020;368(6494):1016–20.
 43. Qi H, Xiao S, Shi R, Ward MP, Chen Y, Tu W, Su Q, Wang W, Wang X, Zhang Z. COVID-19 transmission in Mainland China is associated with temperature and humidity: A time-series analysis. *Sci Total Environ*. 2020;728:138778.
 44. Ward MP, Xiao S, Zhang Z. The role of climate during the COVID-19 epidemic in New South Wales, Australia. *Transbound Emerg Dis*. 2020;00:1–5.
 45. Butler MJ, Barrientos RM. The impact of nutrition on COVID-19 susceptibility and long-term consequences. *Brain Behav Immun*. 2020;87:53–4.
 46. El-Khatib Z, Jacobs GB, Ikomey GM, Neogi U. The disproportionate effect of COVID-19 mortality on ethnic minorities: Genetics or health inequalities? *Eclin Med*. 2020;23:100430.
 47. Pareek M, Bangash M, Pareek N, Pan D, Sze S, Minhas JS, Hanif W, Khunti K. Ethnicity and COVID-19: an urgent public health research priority. *Lancet*. 2020;395(10234):1421–22.
 48. Pan D, Sze S, Minhas J, Bangash MN, Pareek Nilesh, Divall P, Williams CML, Ogagioni MR, Squire IB, Nellums LB, Hanif W, Khunti K, Pareek M. The impact of ethnicity on clinical outcomes in COVID-19: a systematic review. *Eclin Med*. 2020; 23.
 49. Boretti A, Banik BK. Intravenous Vitamin C for reduction of cytokines storm in acute respiratory distress syndrome. *Pharma Nutrition*. 2020;12:100190.
 50. Gössling S, Scott D, Hall CM. Pandemics, tourism and global change: A rapid assessment of COVID-19. *Journal of Sustainable Tourism*. 2020.
 51. Sigala M. Tourism and COVID-19: Impacts and implications for advancing and resetting industry and research. *J Bus Res*. 2020;117:312–21.
 52. Gozes O, Frid-Adar M, Greenspan H, Browning PD, Zhang H, Ji W, Bernheim A, Siegel E. Rapid development cycle for the coronavirus (covid-19) pandemic: Initial results for automated detection & patient monitoring using deep learning ct image analysis. *arXiv*. 2020;2003:05037.
 53. Green K, Graziadio S, Turner P, Fanshawe T, Allen J. Molecular and antibody point-of-care tests to support the screening, diagnosis and monitoring of COVID-19. *Oxford COVID-19 Evidence Service*. 2020.
 54. Nguyen T, Duong Bang D, Wolff A. 2019 Novel Coronavirus Disease (COVID-19): Paving the road for rapid detection and point-of-care diagnostics. *Micromachines*. 2020;11(3):306.
 55. The OpenSAFELY Collaborative. Williamson E, Walker AJ. OpenSAFELY: factors associated with COVID-19-related hospital death in the linked electronic health records of 17 million adult NHS patients. *medRxiv*. 2020.
 56. Pal M, Berhanu G, Desalegn C, Kandi V. Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2): An update. *Cureus*. 2020;12(3):e7423.
 57. Wang H, Li X, Li T, Zhang S, Wang L, Wu X, Liu J. The genetic sequence, origin, and diagnosis of SARS-CoV-2. *Eur J Clin Microbiol Infect Dis*. 2020;1–7.

58. Qureshi A, Thakur N, Tandon H, Kumar M. AVPdb: a database of experimentally validated antiviral peptides targeting medically important viruses. *Nucleic Acids Res.* 2024;42:D1147–53.
59. Qureshi A, Kaur G, Kumar M. AVCpred: an integrated web server for prediction and design of antiviral compounds. *Chem Biol Drug Des.* 2017;89:74–83.
60. Prajapat M, Sarma P, Shekhar N, Avti P, Sinha S, Kaur H, Kumar S, Bhattacharyya A, Kumar H, Bansal S, Medhi B. Drug targets for corona virus: A systematic review. *Indian J Pharmacol.* 2020;52(1):56–65.
61. Wu C, Liu Y, Yang Y, Zhang P, Zhong W, Wang Y, Wang Q, Xu Y, Li M, Li X, Zheng M, Chen L, Li H. Analysis of therapeutic targets for SARS-CoV-2 and discovery of potential drugs by computational methods. *Acta Pharm Sin B.* 2020;10(5):766–88.
62. Flower DR, Macdonald IK, Ramakrishnan K, Davies MN, Dovtchinova IA. Computer aided selection of candidate vaccine antigens. *Immunome Res.* 2010;6:1.
63. Amanat F, Krammer F. SARS-CoV-2 vaccines: Status report. *Immunity.* 2020;52(4):583–89.
64. Khan Y, O'Sullivan T, Brown A, Tracey S, Gibson J, Genereux M, Henry B, Schwartz B. Public health emergency preparedness: a framework to promote resilience. *BMC Public Health.* 2018;18:1344.
65. Toner E. Healthcare preparedness: Saving lives. *Health Secur.* 2017;15(1):8–11.
66. WHO. 2009. Pandemic influenza preparedness and response, <https://www.who.int/influenza/preparedness/en>, Date accessed: July 13, 2020.
67. NCBI. The impacts of the affordable care act on preparedness resources and programs, <https://www.ncbi.nlm.nih.gov/books/NBK241389>, Date accessed: July 13, 2020.
68. CDC. Public health emergency preparedness cooperative agreements. <http://www.cdc.gov/phpr/archive.htm> Date accessed: July 13, 2020.
69. Clancy CM. Emergency departments in crisis: implications for disaster preparedness. *Am J Med Qual.* 2007;22(2):123–26.
70. Morens DM, Folkers GK, Fauci AS. The challenge of emerging and re-emerging infectious diseases *Nature.* 2004;430(6996):242–49.
71. Global Health Security Is National Security
Date accessed: July 13, 2020
Diseases NCBI, Influenza P, Resistance A. Global Health Security Is National Security
<https://www.ncbi.nlm.nih.gov/books/NBK458470/> Date accessed: July 13, 2020.
72. Yang Y, Islam MS, Wang J, Li Y, Chen X. Traditional Chinese medicine in the treatment of patients infected with 2019-New coronavirus (SARS-CoV-2): A review and perspective. *Int J Biol Sci.* 2020;16(10):1708–17.
73. Luo E, Zhang D, Luo H, Liu B, Zhao K, Zhao K, Zhao Y, Bian Y, Wang Y. Treatment efficacy analysis of traditional Chinese medicine for novel coronavirus pneumonia (COVID-19): an empirical study from Wuhan, Hubei Province, China. *Chin Med.* 2020;15:34.
74. De Clercq E, Li G. Approved Antiviral Drugs over the Past 50 Years. *Clin Microbiol Rev.* 2016;29(3):695–47.
75. Cragg GM, Newman DJ. Natural products: a continuing source of novel drug leads. *Biochim Biophys Acta.* 2013;1830(6):3670–95.
76. Katiyar C, Gupta A, Kanjilal S, Katiyar S. Drug discovery from plant sources: An integrated approach. *Ayu.* 2012;33(1):10–9.
77. Li F, Wang Y, Li D, Chen Y, Dou QP. Are we seeing a resurgence in the use of natural products for new drug discovery? *Expert Opin Drug Discov.* 2019;14(5):417–20.

Tables

Table 1 District-wise COVID-19 cases statistics in Nepal

SN	District	Confirmed	Cured	Death	SN	District	Confirmed	Cured	Death
1	Rautahat	1459	1096	1	40	Chitawan	105	75	1
2	Kailali	921	305	4	41	Nawalparasi W	115	60	0
3	Dailekh	799	689	2	42	Parbat	95	51	0
4	Kapilbastu	751	692	0	43	Udayapur	77	50	0
5	Mahottari	778	546	0	44	Jumla	43	63	0
6	Sarlahi	717	604	0	45	Lalitpur	75	29	2
7	Dang	571	426	1	46	Lamjung	71	15	0
8	Achham	629	63	1	47	Sindhupalchok	64	27	2
9	Bajura	617	266	1	48	Makawanpur	31	46	0
10	Doti	578	214	0	49	Kalikot	61	22	0
11	Palpa	556	205	1	50	Rolpa	50	38	0
12	Dhanusha	519	364	0	51	Bhaktapur	45	17	0
13	Surkhet	510	306	1	52	Ramechhap	35	22	0
14	Kanchanpur	447	174	0	53	Rukum West	33	12	0
15	Kathmandu	233	283	3	54	Myagdi	28	14	1
16	Banke	464	351	2	55	Nuwakot	26	18	0
17	Gulmi	361	184	3	56	Darchula	20	14	0
18	Arghakhanchi	339	176	2	57	Kabhrepalanchok	18	15	0
19	Pyuthan	329	120	0	58	Sindhuli	18	9	0
20	Saptari	324	246	0	59	Ilam	18	8	0
21	Rupandehi	332	250	1	60	Jajarkot	16	11	0
22	Jhapa	311	204	0	61	Sankhuwasabha	6	13	0
23	Nawalparasi E	290	46	0	62	Khotang	17	12	0
24	Dadeldhura	282	60	0	63	Rasuwa	11	11	0
25	Baitadi	277	137	0	64	Taplejung	11	7	0
26	Siraha	229	113	0	65	Dolakha	11	8	1
27	Baglung	224	179	1	66	Dhankuta	8	8	0
28	Syangja	209	191	2	67	Panchthar	7	7	0
29	Salyan	260	137	0	68	Bhojpur	6	6	0
30	Bardiya	197	115	0	69	Mugu	6	3	0
31	Morang	186	165	0	70	Okhaldhunga	6	5	0
32	Parsa	193	163	1	71	Dolpa	5	0	1

33	Bajhang	168	18	0	72	Rukum East	5	3	0
34	Tanahu	161	55	0	73	Terhathum	5	4	0
35	Dhading	136	113	0	74	Humla	2	2	0
36	Kaski	88	103	0	75	Solukhumbu	2	1	0
37	Bara	128	91	2	76	Manang	1	1	0
38	Sunsari	104	84	0	77	Mustang	1	1	0
39	Gorkha	114	74	1	Total		16945	10294	38

Table 2 Province-wise COVID-19 cases statistics in Nepal

Province	Total Cases	Cured Cases	Death
Province No.1	766	583	0
Province No.2	4348	2390	4
Bagmati	814	331	9
Gandaki	1274	360	5
Province No.5	4071	2363	10
Karnali	1736	1298	4
Sudurpaschim	3936	1267	6
Total	16945	10294	38

Figures

Figure 1

Map showing major cities of provinces and spatial distribution of population density

Figure 2

Status of Nepal of SAARC on the basis of infected cases/million population

COVID-19, Nepal

Total Cases: 16945
 Total Cured: 10294
 Total Death: 38
 Cured Rate: 60.75%
 Fatality Rate: 0.20%

COVID-19, Global

Total Cases: 13 M
 Total Cured: 7.6 M
 Total Death: 0.57 M
 Cured Rate: 58%
 Fatality Rate: 4%

Figure 3

Cumulative trend of COVID-19 cases in Nepal

Figure 4

Age wise distribution of infected and death cases of COVID-19

Figure 5

Gender wise distribution of infected and death cases of COVID-19

Figure 6

Spatial distributions of COVID-19 cases. (a) Total confirmed cases, (b) recovery/cured cases, and (c) total death

Figure 7

Potential preventive actions in health care setting of current and future pandemics