Risk Assessment of COVID-19 Pandemic By Deep Learning Model (DLM) In India: A District Level Analysis

Manzoor A Wani (manzoorwani8559@gmail.com)
University of Kashmir https://orcid.org/0000-0001-6727-7010

Junaid Farooq
National Institute of Technology Srinagar

Danish M Wani
Bharat Sanchar Nigam Limited

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Abstract

The intensity of Coronavirus Disease 2019 (COVID-19) pandemic is a horrible ongoing human disaster with high morbidity and mortality rates. Current epidemiological studies urge the need of implementing sophisticated methods to appraise the evolution of COVID-19. In the study we estimated 228 days of daily incidence of COVID-19 cases i.e. from 1st May to 15th December 2020- a district level analysis in the northern Himalayan belt of India. To determine the current & future trends of COVID-19 transmission, we used Deep Learning Model (DLM) with 60 days forecasting. The estimated values from deep learning not only indicated high cases of morbidity and mortality but forecasted high rise in the incidence of COVID-19 cases in different districts of the study region. Storing, analyzing, and presenting incidence of COVID-19 cases in Geographic Information System (GIS) will attribute in understanding, planning & implementing mitigating measures to tackle the current & future variant behavioral changes adopting COVID-19 virus. The remedial first-aid measures such as physical & social distance, use of masks, maintaining personal hygiene, recommended vaccinations & other Standard Operating Procedure (SOP) framed by World health organization (WHO) must be adhered till complete obliteration of COVID-19 virus.

Introduction

COVID-19 pandemic has been a tale of morbidity & mortality across the Globe. Ongoing pandemic has eventually urged the need of implementing sophisticated methods in the epidemiological studies to appraise the current and future trends of COVID-19 pandemic that is consuming human population at rapid rate and causing serious liquidity problems due to prolonged & unavoidable lockdowns oriented with normal human actions. Historical outbreaks of various infectious outbreaks have offered some disease ecological models to understand the spatial & temporal course of current infectious pandemic, that will be benefitted to estimate the current & future pattern of COVID-19 pandemic (J&K Advisory Committee Report, 2021). The pandemic of COVID-19 caused by Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been initially reported in patients with comorbidity such as pneumonia in the Wuhan city of China and was supposed to spread in the regions of Southeast Asia by epidemiological modeling center taking into consideration its (China) geographical proximity and substantial travel connections with these regions (Sajadi et al, 2020). Instead of Southeast Asia COVID-19 pandemic were diffused to other parts of the globe such as Europe, North America which became the largest COVID-19 epicenters with high cases of morbidity and mortality across the human planet (Sajadi et al, 2020).

Albeit, countries around the globe are striving hard to mitigate the spread of COVID-19 by formulating & executing various strategies such as country lockdown, closing schools, halting transports, curtaining borders of regional, national, international boundaries to break the deadly chain of COVID-19 strain virus (Subramanian et al, 2020). Developing and under-developed countries are at higher risk due to poor health care infrastructure, deprived socio- economic, lack of perception, poverty, low standard of living, illiteracy, poor housing environment resulted in the weak immune system. (Sahoo et al, 2020). Lessening approaches in social distancing, protective precautions & other SOP protocols recommended for COVID-19 may result in sharp increase in the incidence of COVID-19 cases is therefore, perquisite to adhere

social distance, use of masks, hand washes & other WHO recommended SOP's along with fast mass vaccination drive (Theeb et al, 2021).

Machine Learning (ML) and Cloud Computing can be used with more effectively and efficiently to track the progression of this pandemic across the globe by predicting future trends of COVID-19 that will be used in designing strategies and policies to manage its diffusion (Shreshth et al,2020). An artificial-intelligence technique based on a deep convolutional neural network (CNN) to detect COVID-19 patients using real-world datasets is currently used in detection of COVID-19 pandemic, that is increasing exponentially with almost 35 million confirmed cases globally (Moutaz et al, 2020). Forecasting the spread of COVID-19 pandemic requires ample historical data and it is also worth to mention that no prediction is certain as future seldomly repeats with the same intensity (Petropoulos et al, 2020). Understanding the early signs of dynamic nature of this infectious global pandemic and apprising the overall efficacy of current measures is very important in asserting the potential while adopting sustainable controlled measures in the newer areas (Samuel et al, 2020).

It is important to collect, store, manipulate, analyze and interpret COVID-19 data to disseminate necessary information & put forward rational strategies for mitigating the burden of COVID-19 pandemic (Ahmadi et al, 2021). COVID-19 which is an extreme current public threat enveloping all irrespective of region, social-cultural, religious, & economic backgrounds. COVID-19 pandemic with its extreme intensity in the spread and alarmingly high fatality rate is a huge global concern. Integration of mathematical modeling and GIS can play a decisive role in mitigating the diffusion and predicting the further growth of pandemic (Ankush 2020).

Geographical knowledge concerning with identifying the space (existence), structure and inter-relation of the phenomena can play a crucial role in understanding and mitigating of COVID-19 pandemic (ESRI 2020). Modern GIS technologies centre around web-based tools, improved data sharing and real-time information to support critical decision-making (Kamel et al, 2020). Dashboards exemplify those ideals and have been extremely popular in sharing and understanding the spread of SARS-CoV-2 coronavirus. Communication through map-based dashboards offers accessible information to people around the world eager to protect themselves and their communities. This tool type improves data transparency and helps authorities disseminate information (Kamel et al, 2020).

Spatial analysis of data, through geographic information system (GIS) have become an essential techniques and are in great demand in academic schools of public health, environmental health, and in public health agencies that are responsible for disease surveillance, control and health planning (Mayer 1983). In 2003, the international organization of health in Europe, projected the benefit of using geographic information system (GIS) for the identification of diseases that can be linked in understanding the features such as spatial variation of diseases, and their association to environmental factors and the health care system (Aghajani et al. 2017). With the advancement of analytical and computing power, GIS technology has boosted the importance of mapping epidemiological diseases

considerably (Malczewski 2004). The mapping of disease helps in interpreting the delineated area more effectively and efficiently that will be great asset for epidemiological planning (Anna et al, 2014).

The need of an hour is to get location by location risk assessment so that timely preventive measures can be taken. Countries across the globe incorporation with WHO are engaged in developing not only effective & efficient vaccines but its availability to every people in the World and so far WHO has effectively rolled 7 different vaccines across three formats to boost body's natural immune system (WHO 2021).

India which is the second largest populated and 7th largest in area was hit by the COVID-19 pandemic early 2020 with prolonged continuation & meager declined trend in the winter months, eventually proved a fairy tale fiction which developed a sense of unacceptable lethargy among people in general & to some extent the concerned administration. Till now country as whole has marked the second highest number of infected cases with nearly 2.83 crore infected cases reported & over 3.35 lacs deaths with non-stop going (https://github.com/CSSEGISandData). The union territory of Jammu & Kashmir following the foot step of national guidelines has also showed a high rise in daily cases & is expected to increase manifold in the coming months, keeping in view the nature of perpetual backwardness in terms of socio-economic, political instability, unique topographical identity, prevalent respiratory problems & current available health care infrastructure (Wani et al, 2020) might induce the new pandemic epicenter. The study might prove the limelight for future epidemiological studies in formulating, executing and implementing the mitigating strategies not only to the current ongoing biological disasters but might prove vital for the future studies to be prepared & respond any such biological disaster with the least reactive time bound.

Methods

2.1 Study area:

The present study has been carved in the north western region of the Himalayan surrounded by snow clad mountains, carpeted with lush green meadows, undulating topography, distinctive climate region, varied geo-physical environment and unique social cultural set up. Total human population of 12.27 million is residing in the area of 42241 km^2. The area with two administrative regions i.e. Jammu region covering 62 per cent of the total area and Kashmir region with 38 per cent of the total area. Both regions contribute almost equal share of population with high population density (432 sq.km) in the Kashmir valley region. The region has been demarcated into 20 districts with 10 from each region for administrative purposes. The variation in the topography, climate has not only affected the socio-cultural and economic conditions of the people but plays potent role in the overall health scenario (Wani et al, 2019). The geographical identity of the area with discrete physical, socio-economic and behavioral environment imposes a great challenge to overall respiratory health (Wani et al, 2020). Figure 1 shows the map of the study area. Insert figure I here.

2.2 COVID-19 Data:

Data of daily incidence cases of COVID-19 in the study region from 1st May 2020, to 15th December 2020 were obtained from the continuously updated department of information and public relations, Govt. of Jammu Kashmir (DIPR) from their official address. https://twitter.com/diprjk .

2.3 Mathematical Modeling

Predicting future and current trends in the epidemiological studies is an important problem for public health, and has gained an increasing attention in the data mining and machine learning communities (Yuexin et al, 2018). A modified model of Susceptible Infected Recovered (SIR), known as SIRD (Susceptible-Infected-Recovered-Deceased) Model, was used in this paper to simulate the transmission dynamic behavior of Covid-19 infection rates as described and validated by Farooq et al 2020a. This model is fatal unlike a typical non-lethal SIR model which means that there is a positive probability of an infected person succumbing to the disease. A typical SIR model assumes that the recovered group of patients gains full immunity from reinfection. However, this model accommodates the possibility of a recovered person being reinfected. The impact of new births and unrelated deaths in ignored and the total population is assumed to remain constant with random distribution. The problem of parameter estimation or learning for this model was solved by using a deep learning technique known as incremental learning as described and implemented by Farooq et al 2020b. Training data is needed before executing a learning algorithm or estimation technique. However, in an epidemic like situation, the training data becomes available only with the progress of disease with time. Thus, the model has to train and execute simultaneously while the model parameters keep varying with time. Further, the training data gets accumulated over time increasing the computational burden. Therefore, deep learning was used to train the model in an adaptive fashion such that the need to keep rebuilding the model whenever new training data sets are received is eliminated.

This model is an intelligent, non-intrusive, adaptive, real-time and online in nature, therefore it can be used for monitoring, forecasting and simulation of transmission dynamics and growth of any epidemic without any loss of efficiency, accuracy, fidelity or computational performance which generally arise due to long run-time, large size of training data, increasing computational complexity, change in virus behavior due to mutations, change in government policies etc. Even if the epidemic continues for decades in the whole world, the model will keep running accurately on daily basis without loss of performance.

In the study area, we run deep learning model to daily recorded COVID-19 cases i.e. (prevalence, recovery, and death rates) from 1st May to 15th December 2020, with 60 days forecasting in all district of the study area.

2.4 Statistical techniques:

Kendal’s rankings were assigned to the COVID-19 cases (prevalence, recovery and death rate) and composite index method was adopted to measure the intensity of COVID-19 cases (prevalence, recovery, & death rate) district wise to generate heat index map using GIS techniques.

2.5 Demographic data:

District wise demographic data i.e. total population, growth rate, density, literacy rate were obtained from current available source i.e. JK Statistical Digest 2016 and Census of India 2011.

2.6 Health care infrastructure:

It is important to appraise the health care infrastructure in the current scenario of COVID-19 pandemic as it raising several concerns about the capacity of the government to tackle the existing health care facilities (Atiqa et al, 2020). In this connection, an evaluation in the overall health care infrastructure was assessed to estimate the prepared measures to mitigate the incidence of COVID-19 pandemic at inter-district level.

2.7 Mapping:

Study area, and heat maps related to the incidence of COVID-19 cases (active, recovery and death rate) in the area were stored, manipulated, analysed and presented in Arc GIS 10.2 software.

Results

3.1 Evolution of COVID-19 cases

Diffusion of COVID-19 across the globe has taken a huge toll on human lives. This study pertains to appraise inter-district variation in the pattern of COVID-19 cases (active, recovery, and death rate). As see in the figures I & II sharp rise in the incidence of COVID-19 active cases and death rates from 60th day of data observation in the whole area. During this period (July- August) whole region experiences sharp rise in the air temperature, relative humidity which nullifies the role meteorological parameters on the incidence of COVID-19 in the region (Wani et al, 2020). In the study we found spatial temporal variation in the incidence of COVID-19 cases with high infectious & death rates in the districts of Kashmir division figure I (I-X). In comparison districts of Jammu division figure II (XI-XX) show low rates of infectious, death rates & high recovery rate during the given time period. Albeit, it is still imperfection to relate any major etiological cause in the spatial variation in diffusion of COVID-19 cases in these two different geographical proximities, the variation in the incidence cases can be asserted with the variation in the geographical identity these two regions possess which directly affects their mode of life (Wani et al, 2020). Figure III showing the total COVID-19 cases with prediction window & data validation of the whole region. In the figure III, it is clearly seen that area is witnessing sharp rise in the Covid-19 cases (active & death rates) with more people getting infected is strengthening the infection chain & adding burden to limited health care resources. DLM show high data accuracy with least mean absolute error (MAE = 1.1%). Kashmir region known for its personified natural landscape, bewitching climate is cynosure to every human eye and is witnessing high tourist flow throughout the year is thought to be the main reason for COVID-19 diffusion as high cases were linked to the virus of UK variant as compared to Jammu where virus of Indian variant was found more dominant (J&K Advisory Committee Report, 2021). Besides the variant nature of virus, spatial variation in seen in the socio-economic status as shown in table S1 is also attributing to the COVID-19 incidence such as high population, high population density, low literacy rate,

political instability & other related socio-economic problems were more common in the valley part (Kashmir) of region. With unique geographical identity people of the valley region are more prone to respiratory, cardiovascular diseases, hypertension, diabetes etc. (Wani et al, 2019). Heat index maps showing the intensity of COVID-19 cases (active, recovery and death rates) district wise as shown in the figure IV (a-c) spatial variation in the incidence of COVID-19 cases in the districts with high cases from urban areas & districts with high population concentration such as districts of Srinagar, Jammu, Budgam, and Baramulla that are showing high positivity & fatality rates. These hotspot areas need quick response in providing & managing COVID-19 health care facilities to tackle COVID-19 surges by strengthening the preparedness & mitigation measures. The heat index maps generated will be helpful in identifying hotspot areas & in proper response management in resource-allocation measures for COVID-19 during recovery phases. Insert figures I, II, III, IV here respectively.

3.2 COVID-19 health care facilities

COVID-19 pandemic has possessed serious challenges to the current health care infrastructure around the World. It seems virtually impossible for the administration to improve the objectives of various health and welfare program as propounded by WHO. In this study, we appraised the current scenario of COVID-19 health care amenities available at inter-district level. Albeit, administration has stepped towards the progression of health care infrastructure but are lacking far behind, keeping in view the magnitude and intensity of COVID-19 virus. As shown in the table SII, High inter-district disparities are seen in the current health care infrastructure such as isolation beds with and without ICU beds, availability of beds for confirmed and suspected cases, Oxygen supported and ventilators to cope COVID-19 severity. Scarcities in COVID-19 health care facilities were seen more in the districts of Kashmir division with continuous spike in the COVID-19 cases in the region. High patient ratio with available COVID-19 health facilities were seen in the entire region. Poor and insufficient health care facilities available in periphery districts of the region are also possessing challenges to the nodal health care institutions that is resulting immense burden while tackling COVID-19 infectious cases. The extent of inter-regional disparity of patient ratio and COVID-19 health facilities can be analysed by the looming scenario of current health care system available in the urban regions of the study area i.e. Srinagar sharing (1:6) and Jammu (1:3) isolation beds without ICU for confirmed cases. Even much worst scenario were seen in other districts of Kashmir division such as Bandipora with (1:10), Ganderbal (1:5), Jammu (1:5). Patient ratio increases with critical COVID-19 health care facilities in the entire districts of the study region i.e. high patient ratio seen in oxygen supported beds in the districts of Kathua (1:119), Srinagar (1:87), Rajouri (1:45) and Budgam (1:36). Sharing of life saving ventilators show an increasing burden i.e. 1:405 in the entire region indicating that 405 COVID-19 patients can avail one ventilator at a particular if the severity rate increases, this patient ratio is seen high in Srinagar (1:1546), Pulwama (1:1322), and Kulgam districts(1:962). It is clear from the preceding discussion that the whole region lacks basic COVID-19 health facilities; with extreme regional disparities prevailing in the region is adding more hurdles while mitigating this pandemic. With the current health care infrastructure available the study area as a whole is highly vulnerable to get exposed to this deadly virus with variant nature of Corona virus, if no proper measures will be done.

Conclusion

The threat possessed by the current COVID-19 pandemic in India seems to get accelerated in the coming months as seen in the variant behavior of SARS-CoV-2. It is expected that World might experience different waves of COVID-19 pandemic each of more severe intensity. Keeping in view the dynamic nature of corona virus, it is expected that positivity & fatality rate will surge. Little pause of dormancy, is actually dimming the responsive behaviour resulting in some loosening in the protective measures such as social distancing & other SOP guidelines recommended for COVID-19, might prove more fatal then the previous pandemic waves as seen in the variant nature of Corona virus that is gaining momentum & resistance with each variant & presently the threat of new delta variant is looming across the globe. The purpose of the present study was to estimate the current & future risk involved due to COVID-19 using two sophisticated & advanced tools i.e. DLM & GIS to understand and respond to the ongoing pandemic more effectively & efficiently. In the study area high cases of COVID-19 were seen in many districts & are expecting to increase manifold in the coming months with each escalation in COVID-19 wave, insufficient health care infrastructure, high population, illiteracy & lack of perception, misconception & lack of trust against the current vaccination drive makes it a huge concern for the administration & policy makers. It is worth to mention that country (India) has emerged and came out with two vaccines (COVISHILED, and COVAXIN) and has initiated nation mass vaccination drive across the country in various phase manners due to second largest human population, are facing unprecedented constraints while vaccinating people due to ambiguity whispered regarding the clinical validation of the rolled out COVID-19 vaccines, large population, lack of scientific perception, & traditional bound beliefs.

With threat of still looming new COVID-19 strain, it is important and utmost priority to follow cost free approach to cope COVID-19 pandemic i.e. follow the guidelines and policies set by the World Health Organization (WHO) in general and local administration i.e., maintaing physical distance, proper hygiene, use of masks to avoid the further transmission. It is also mandatory that government administration must take urgent initiatives to upgrade health care infrastructure especially in the hotspot districts to mitigate and lessen the burden of this COVID-19 pandemic in future.

Declarations

Ethical Approval and Consent to participate: Not Applicable

Consent for publications: Not Applicable

Data availability: COVID-19 data are provided by department of information and public relations, Govt. of Jammu Kashmir (DIPR); Data link: DIPR-J&K (@diprjk).Twitter. https://twitter.com/diprjk.

Demographics data: can be downloaded from www.censusindia.gov.in; www.ecostatjk.nic.in.

Competing interests

The authors declare that there is no conflict of interest.

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Authors contribution:

MAW and DMW have designed the work. MAW, JF, and DMW collected the required data. Data analysis and interpretation is done by MAW, JF. MAW, JF, and DMW drafted the manuscript.

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Figures

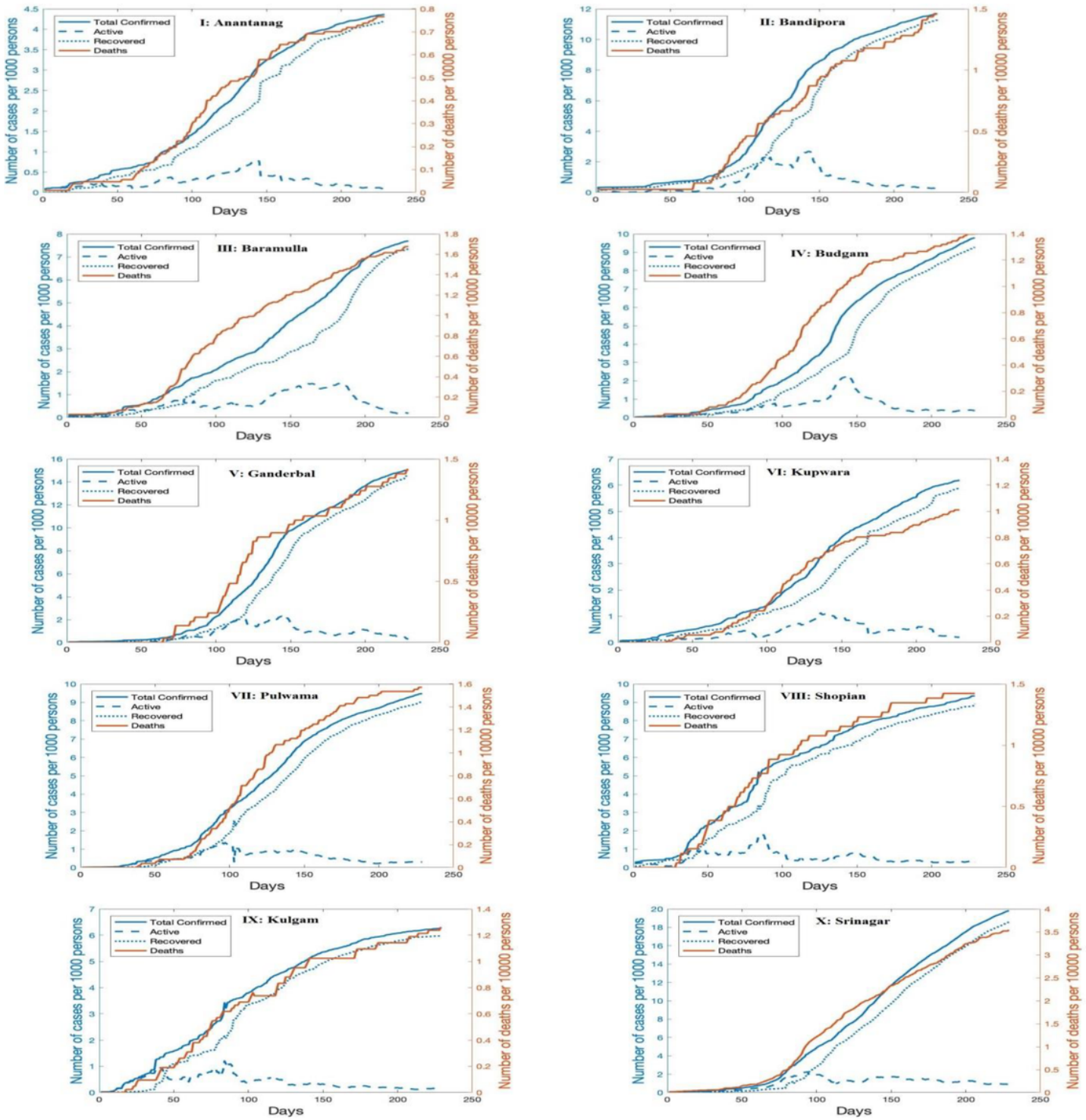

Figure 1

(I-X): COVID- 19 casses (active, recovery, deaths) in the districts of Kashmir dvision from 1st May- 15 December 2020

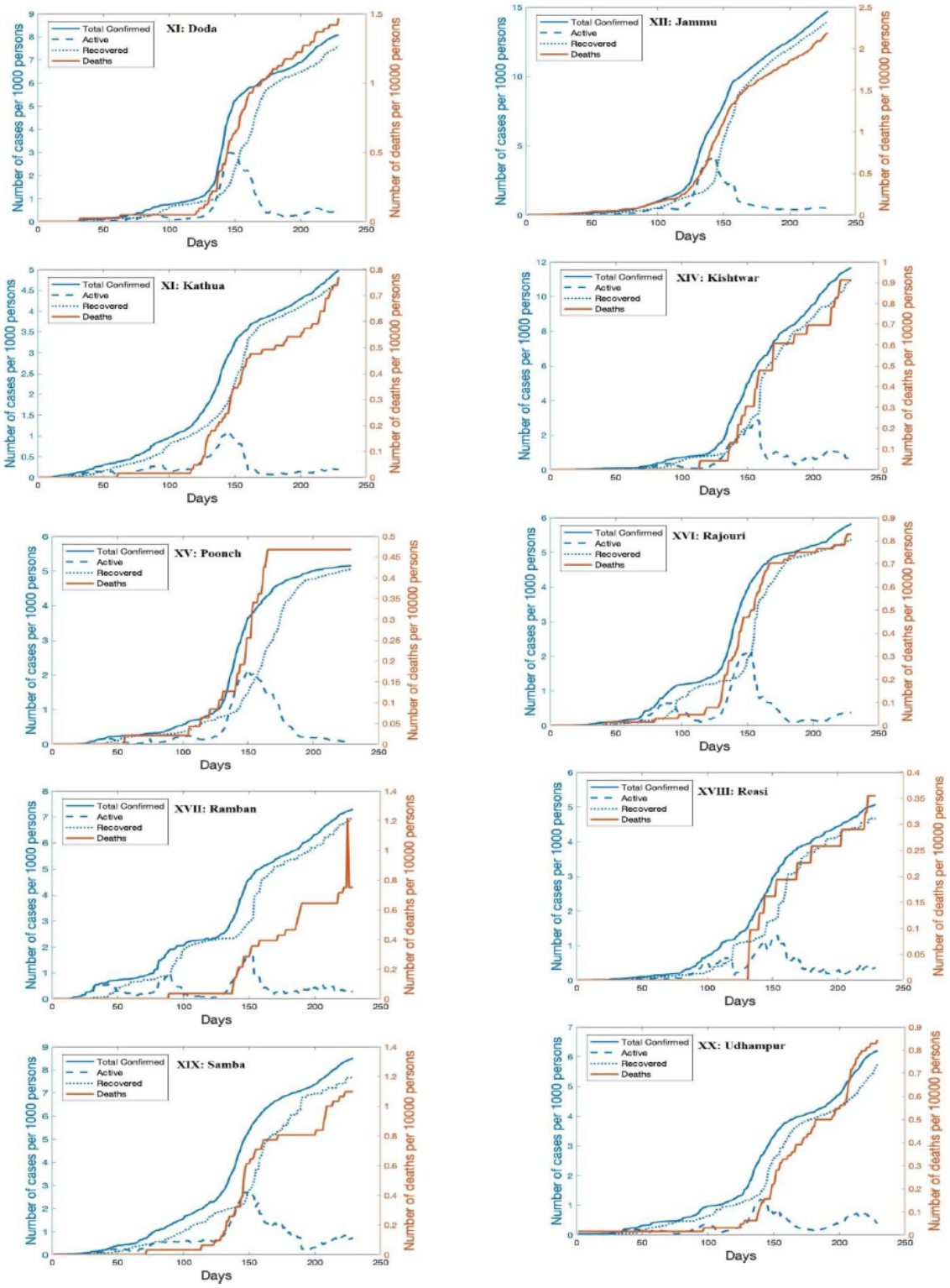

Figure 2

(XI-XX): COVID- 19 casses (active, recovery, deaths) in the districts of Jammu dvision from 1st May- 15th December 2020

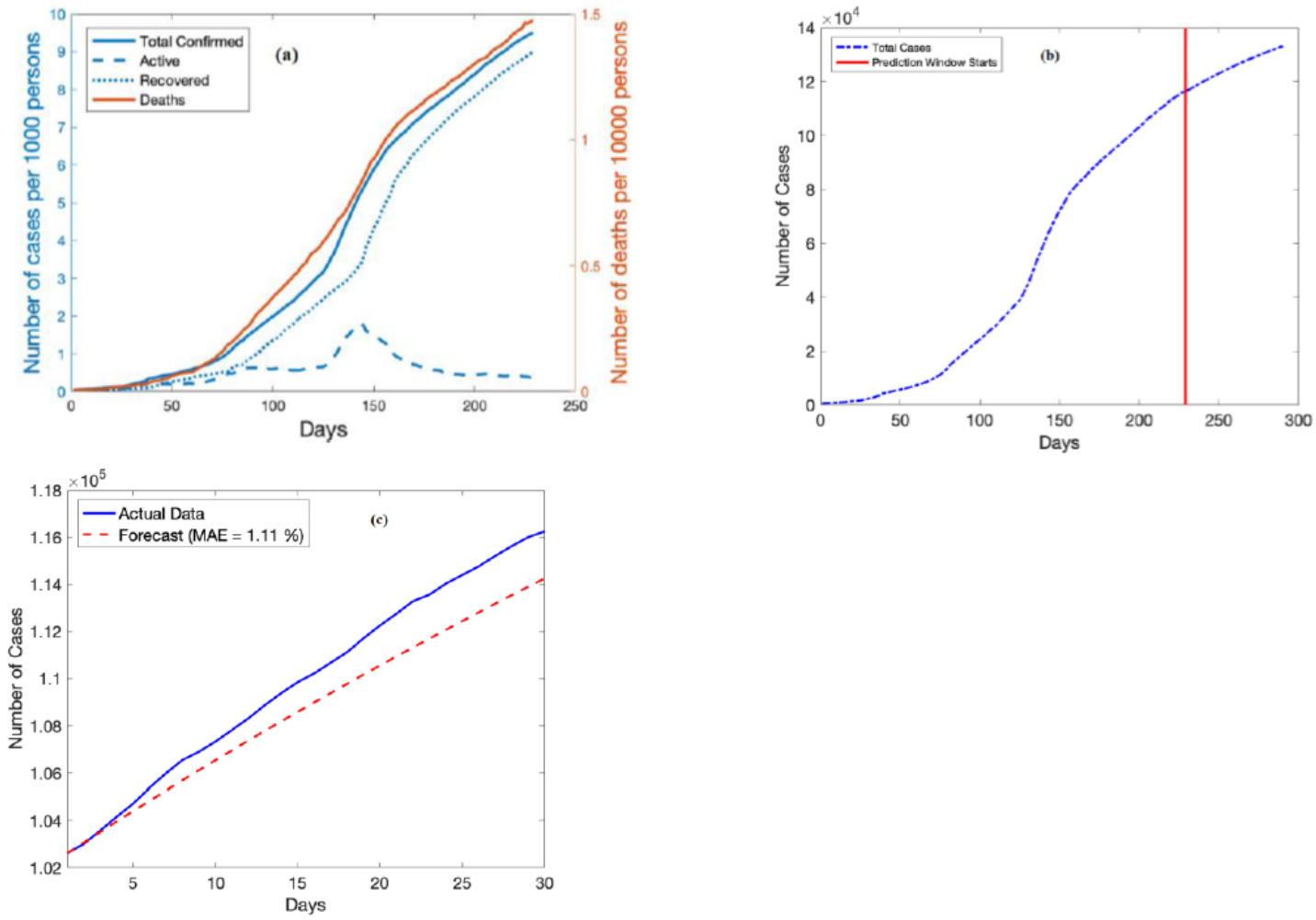

Figure 3

Total COVID- 19 casses , prediction window & data validation (1st May- 15th December 2020)

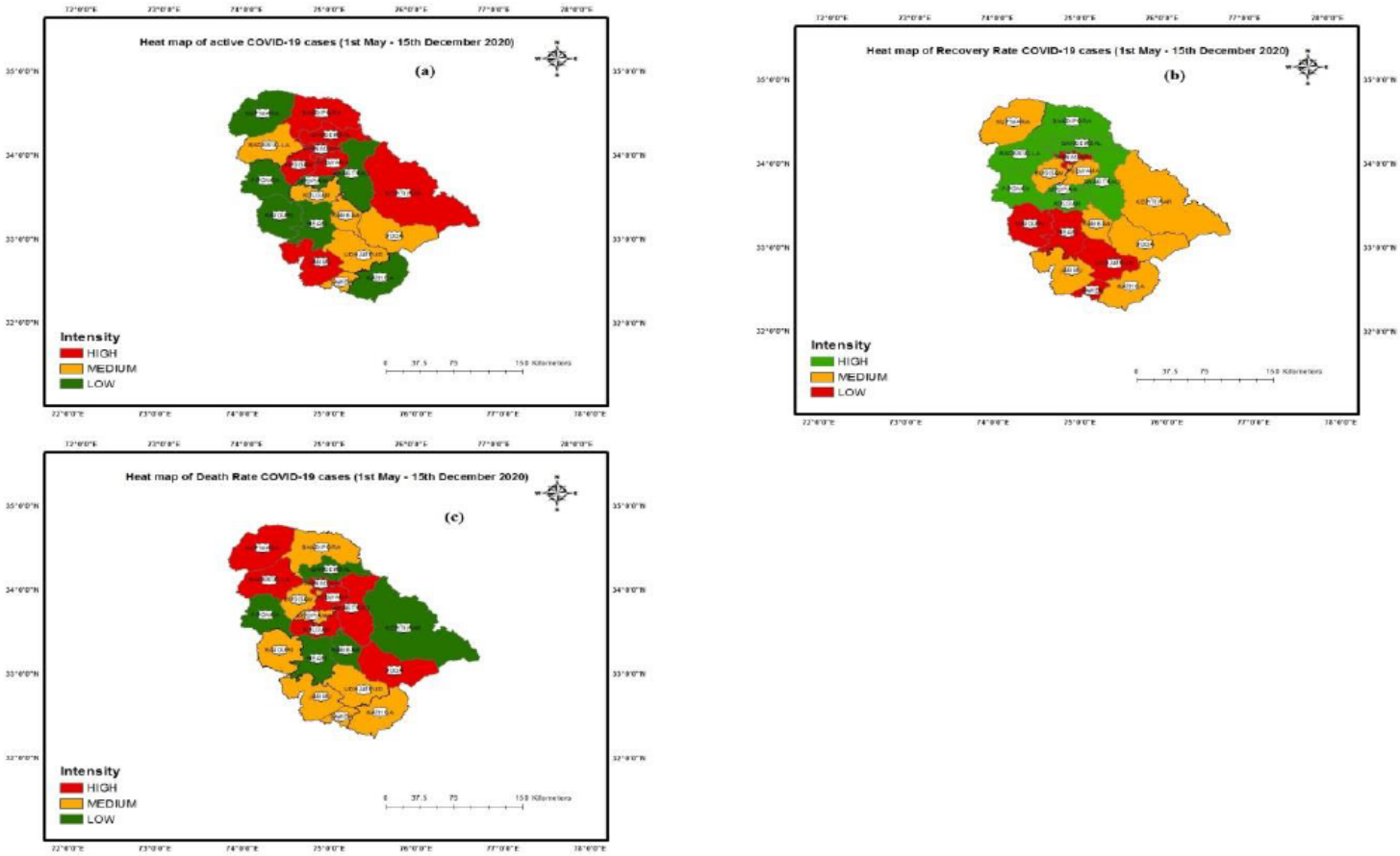

Figure 4

(a-c): Heat index intensity of COVID-19 incidence (active, recovery & deaths) from 1st May to 15th December 2020

Supplementary Files

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- Supplimentarfile.docx