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Research Article

Modelling Early Pandemic of Novel Coronavirus in Nepal

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Abstract: COVID-19 disease has taken pandemic turn and has challenged the global community. The disease is sharply increasing in Nepal. In this present communication we would like to discuss the current epidemiological situation of COVID-19 in Nepal. We have developed a model to understand the current trend of the disease and forecast the burden in the future. Beside logistic model we have also predicted data using time series analysis (ARIMA process). The present model has forecasted the future trend of the disease if the prevailing situation persists.

सारांश: कोविड -१९ रोगले माहाब्यधि को रुप लिइ संसार लाइ नै ठुलो चुनौति भइ रहेको छ। यो रोग नेपालमा पनि असाध्य धेरै बढीरहेको छ। नेपाल मा कोविड -१९ रोगको हालको एपिडीमिओलोजिकल् अवस्था को बारेमा यो लेखमा चर्चा गर्नेछौ । हामिले एउटा नमुना बिकास गरि यो रोग को हालको अवस्था र भबिष्यमा कस्तो अवस्था हुनेछ सो कुरा बुझ्ने प्रयास् गर्नेछौ । लजिस्टिक् नमुना बाहेक अरिमा प्रक्रिया बाट पनि भबिष्य मा हुने सान्क्रमिण् को संख्या भबिश्यबाणी गरिनेछ । यस्तै अवस्था रहेमा भबिश्यमा कति सन्क्रमित् हुनेछन् सो को संख्या भबिश्यबाणी गरिनेछ ।

Keywords: *COVID-19, Modelling, Logistic Model, ARIMA Model*

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1. Introduction

The ongoing pandemic of SARS-CoV-2 was first initiated as a local outbreak of pneumonia of unknown etiology in Wuhan City of China during the end of December 2019 [Wuhan municipality health commission, 2019; WHO (2020a)]. The etiological agent responsible for this infection wasn't known in the beginning but at the end of December, it was identified as a novel coronavirus [WHO (2020b)]. In a week of time the infection spread rapidly and by the end of January 2020 it crossed national boundaries affecting more than 18 countries [WHO (2020c)]. On January 7 the Novel coronavirus was isolated and the whole genome sequence was shared with the World Health Organization (WHO) on 12 January. On February 11, 2020, the International Committee on Taxonomy of Viruses (ICTV) named the virus as SARS-CoV-2 while the WHO named disease caused by this novel virus as COVID-19 [WHO (2019a), Gorbalenya et al. (2020)]. The WHO declared the COVID-19 outbreak as a pandemic when the confirmed cases reached to 118,319 with 4,292 deaths worldwide on March 11, 2020 [WHO (2020d), WHO (2020e)]. It was also confirmed that the COVID-19 follows human-to-human transmission. [WHO (2020c), Li et al. (2020), Chan et al. (2020)]. By April 20, 2020 there have been 2,314,621 confirmed cases with 157,847 deaths around the world due to COVID-19 [WHO (2020f)]. In context of Nepal, the first infection was reported on 25 January. By April 20, 2020 there have been 31 confirmed case of infections. Out of these thirty-two confirmed cases four cases has recovered while other are under medical treatment and no deaths has been reported due to COVID-19 [MOHP (2020)]. All the reported COVID-19 cases were imported cases for Nepal until April 4, 2020 [Paudel et al. (2020), Marahattha et al. (2020)]. But on, April 4, 2020 an additional three cases were identified with one suspected to have local transmission and with this Nepal reached to second stage of COVID-19 infection [MOHP (2020)]. Though the first case was identified in January, the country-wide lockdown came into effect on 24 March under Article 2 of the Contagious Disease Act, 2020 (1953). In the initial phase, Nepal failed to capture the significance of this global problem as not much was done to prevent it [Marahattha et al. (2020)]. However by June 23, 2020 there are more than 10,000 cases and hence this is the time to apply mathematical modelling to understand the current trend.

There are many models to study the novel coronavirus which causes a disease called COVID-19 as it has stocked more than 50% of the population of the world inside their homes. This is the pandemic which has affected highest number of populations of the earth in our lifetime. It started from Wuhan city of Hubei province of China in December 2019 which has now spread into 213 countries [WHO (2020f)] and currently there are more than 9.3 million world's population infected by this COVID-19 and more than 480 thousand people have died due to this pandemic by June 24, 2020.

Because of its effects to human beings' huge number of people is studying the disease. As of June 24, 2020, there are at least 1.19 million articles were found when we searched the word "COVID 19" in google scholar. This shows that global community is very active in exploring to understand the various aspects of the disease.

Modeling a pandemic of Novel Coronavirus is a challenging task. Its nature generally changes by time. Still we can model it and try to find the way it will go for next few weeks/months. Exponential growth is always expected in the beginning of such pandemic [Pujari and Shekatkar (2020), Ranjan (2020), Dudala et al. (2020)]. However, the exponential growth always gives only the growing nature of the disease which is not correct as in reality it levels off after some time. Other models like Logistic, Susceptible-Infection-Recovery (SIR) give results which capture the final stages of the pandemic. In section 2 we discuss about the models and in section 3 we present and discuss our models with the available observed data of Nepal. Finally we close with conclusions and providing the outlook.

2. Model

As huge number of people are studying COVID-19 in different ways there are many people trying to apply already well-developed models to the number of cases in the world and their countries/region etc. At any case at the beginning generally exponential model works. However, it has a drawback that it does not represent the decreasing number of the COVID-19 (or any other such disease like SARS, MERS, Ebola etc.) cases after saturation. In Nepal first case was appeared on January 23. The person recovered and second case was appeared on March 23, 2020. The Government of Nepal started locked down on March 24th. Therefore, relatively few cases have been appeared in Nepal. However now it has crossed 10,000 (as of June 23 it is 10,099).

For further growth of the cases and if the number of cases is higher one can use "Logistic model" [18]. In mathematical epidemiology, when one uses a phenomenological approach, the epidemic dynamics can be described by the following variant of logistic growth model [Batista (2020a)]

$$\frac{dc}{dt} = rc(1-c/K) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where c is the cumulative number of cases, r is infection rate and K is the final epidemic size. After a bit algebra it can be written as

$$Number\ of\ Cases = c/(1+\exp(-(x-b)/a)) \ldots\ldots (2)$$

In equation (2) *c* is related to total number of cases after saturation whereas *b* gives the number of days in which the number of cases per day will be maximum. *a* is a constant. Before we used exponential model to model it (results not shown here). Now we believe that we are in the second to third phase of the logistic model [Batista (2020a), Batista (2020b)] and hence we use logistic model. Most of the cases have been modeled by SIR (Susceptible – Infected- Recovered) model [Batista (2020b)]. SIR model considers the rate by which disease is transferred from one infected person to others and the contact rate of the infected person. Many authors use it to predict future cases. Batista has shown that Logistic model and SIR both give similar results if the number of cases is relatively high [Batista (2020a), Batista (2020b)]. The scope of the present paper is just to give guidelines the way number of cases is increasing in Nepal at present time and predict the cases for immediate future. We focus our study in Logistic model (equation (1)). Also, we juxtapose our results of logistic model with time series analysis - Auto Regressive Integrated Moving Average (ARIMA) process.

3. Results and Discussion

As of June 23, 2020, there are 10,099 cases reported in Nepal. In our model, we consider cases from March 23 as on that day there were two cases even though one was reported a bit earlier.

The cases in Nepal are very few in comparison to other neighboring countries (China, India, Bangladesh etc.). This could be because of lockdown. We consider number of cases for first 68 days and fit a logistic model equation (1). The fitted curve is shown in figure 1.

From figure 1, it is seen that the logistic model developed from the data of first 68 days fits very well. In figure 1, x-axis is the number of days starting from March 23 whereas y-axis is the number of cases. Orange line is the model fitted to the data. The total number of cases estimated to be around (64,346±15,192) from logistic model. The daily peak value will occur on (111±15) days. The number of cases on 111th day will be around 30,000±6,000. The advantage of applying logistic model is that it not only predicts the number of cases in such pandemic more correctly than exponential for long time but also it helps us to predict number of cases in one day. Figure 2 shows the number of cases per days. From figure 2, the daily highest number of cases will be 1570. The error in the daily cases is 460. Here again we fitted the model from first 68 days.

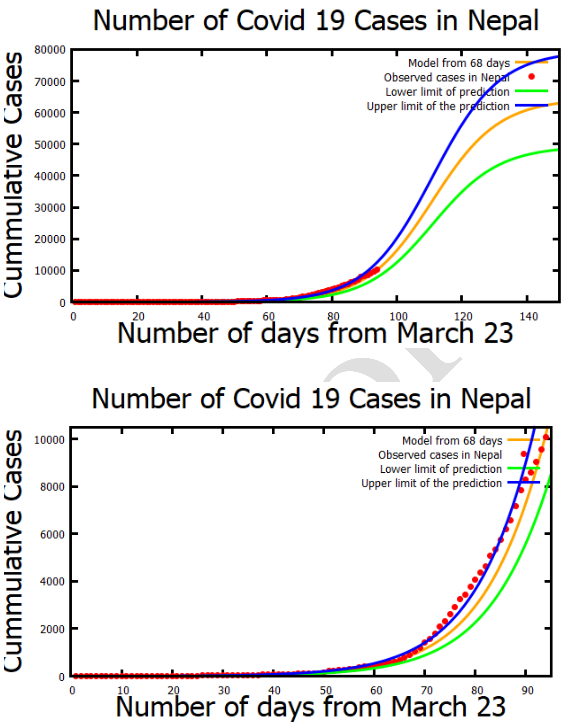

Figure 1 (color online): (Upper panel): The number of cases in Nepal fitted to logistic model developed from first 68 days only. Orange line is model, green and blue lines denote the lower and upper limit of the model that is they define the error in our fitted model. The Red dots are the observed number of cases. (Lower panel): Same as upper one, only the scale is changed to make it more visible.

From Figures 1 & 2 both we see that we developed the model from first 68 days data. It fits very well with the cumulative number of cases till date (June 23, 2020). The number of cases per day also agrees within error bar. We hope it will be helpful to make policy by taking these predicted number of cases.

We also use Time Series analysis ARIMA model [Box et al (2016)] to predict the cases for next few weeks. For forecasting a Time Series, ARIMA modeling is one of the best modeling techniques.

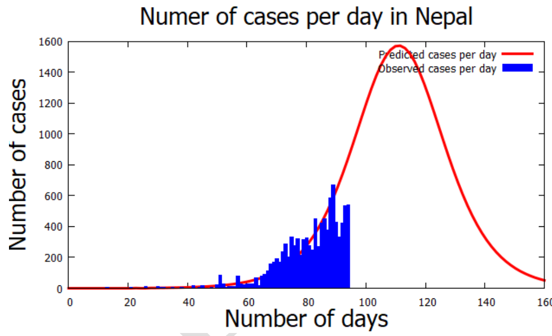

Figure 2: (Color online); Number of novel coronavirus (COVID 19) daily cases versus number of days starting from March 23 in Nepal. The blue boxes are observed data and red line is predicted from logistic model.

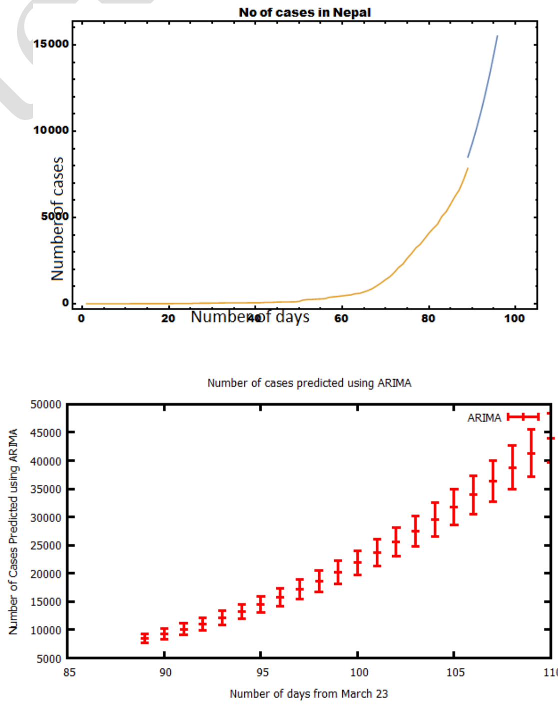

Figure 3 (Color online): (Upper panel): available cases and predicted cases by ARIMA model. (Lower panel): Only predicted cases from ARIMA model.

ARIMA models are always represented with the help of some parameters and the model is expressed as ARIMA (p, d, q). Here, p stands for the order of auto-regression, d signifies the degree of trend difference while q is the order of moving average. We have applied an ARIMA model to the Time Series data of confirmed COVID-19 cases in Nepal.

From all the available data till June 18, 2020 we performed Time Series analysis (ARIMA process). From our analysis we obtained ARIMA (2,2,2) model best fitted to the cases in Nepal. The obtained function is $Y(t) = -0.545X_{t-1}-0.381X_{t-2}+0.242Z_{t-1}+0.098Z_{t-2}+Z_{t}$. It gives number of cases on 111th day (July 11) to be around 40,000±7,000. It is higher than the number of cases predicted by logistic model. It should be noted that the Time Series analysis provides very good prediction when we are very close to available data. Here we must predict for more than 3 weeks. It could be the reason why ARIMA and Logistic differ a bit. Still within error bars both the models predict almost similar number of cases.

Basic Reproduction number R0:

The basic reproduction number (R0) gives number of people infected in average by one infected person. It is considered one of the most important parameters to estimate any predicted cases in future. It depends upon two parameters β and γ by the formula $R0= \beta/\gamma$ where β is the contact rate of infectious person to non-infectious person and γ is the average infectious period. When R0>1 the infection will be able to start spreading in a population, but not if R0<1. Higher the value of R0 higher the risk that uninfected person gets infected.

To estimate R0 we need two parameters β and γ. To estimate γ we considered average number of days infected person in Nepal take time to recover it. It is different for different person. However, we considered in average asymptotic person get recovered in 7 days and symptotic take 21 days. From this information by taking weighted average we estimated γ to be $1/9.8$ day^{-1}. Then from the time taken to double the cases we estimated β. In 68-75 days, the value (R0) was 1.9 to 2.4. However, its value is decreasing now, and it is 1.7 to 2.2. This can be seen from the number of days required to double the cases also. It was 6.5 days during 68-75 days whereas it is 11 days on June 23, 2020.

4 Conclusions and Outlook

We have studied COVID 19 cases in Nepal from March 23 to till date – June 23, 2020. The data fit well with the logistic model from data of 68 days. Also, to predict the cases in future we applied logistic model. From the model we predicted the total number of cases to be around 64,000 and the highest number of cases around 1500 on 111th day from March 23 (July 11). This is valid if the scenario remains as it is. Nepal has observed relatively low number of cases which is mostly due to lockdown and the social distancing measures adopted by the Nepalese citizens. But these strategies cannot stand alone as the lockdown is a blanket approach which helps to by some time to apply strong public health measures such as active case detection, quarantine, isolation and treatment. In the context of recent COVID-19 pandemic there are many uncertainties influencing the rate of transmission which are mostly govern by the community behavior and response. In presence of these certainty of dynamic change, once the number of cases changes the logistic model also need to be fitted and we may get other results. We hope that those results will not differ significantly from the number we predicted in this model. Also the present value of R0 is 1.7 to 2.2.

Authors' Contributions: NPA carried out all the modelling stuffs whereas SBM carried out the Epideomeological part of the paper.

Conflicts of Interest: The authors declare no conflicts of interest.

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