

Trend and Forecasting of COVID-19 Epidemic in Davao Region Using SIR Model

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Date received: October 7, 2021

Date accepted: December 20, 2021

Date published: December 31, 2021

ABSTRACT

This study provides analysis and forecast of COVID-19 epidemic in Davao Region, Philippines. The confirmed daily cases were used to estimate the main epidemiological parameters using SIR model. The results show that the infection rate is slowing down when the enhanced community quarantine was implemented as evident in the decreasing trend of basic reproduction number (R_0) and increase in epidemic doubling time. Furthermore, by the SIR model and if enhanced community quarantine (ECQ) will not be lifted, then the total epidemic duration is about 154 days.

Keywords: *COVID-19, SIR Model, Philippines*

The University of Mindanao

INTRODUCTION

The COVID-19 outbreak have shown enormous global impact as it both affect the health and economy of many countries. As reported in John Hopkins University Corona Virus Center, approximately 4.3 million people around the world contracted the disease with 297,197 total deaths (JHU, 2020). Moreover, the coronavirus pandemic provides unprecedented challenge to every country's economy. In fact, the Center for Strategic and International Studies (CSIS, 2020) reported that many countries are implementing financial measures such as Japan (\$9.6 billion, or 0.19 percent of GDP), South Korea (\$9.2 billion, 0.56 percent of GDP), and Italy (\$4.1 billion, 0.20 percent of GDP). However, the sufficiency will depend on how long the virus will be contained and eliminated.

In the Philippines, the outbreak started on the 30th of January that involved a 38-year-old Chinese woman who was confined in a Hospital in Manila. As of May 09, 2020, there have been a total of 10,610 confirmed cases in the country (DOH, 2020). Out of these cases, a total of 704 deaths and 1,842 recoveries were recorded. There has been a slowing down of turnout of result in the early month of outbreak at a rate of 200 to 250 patients per day due to limited testing kits (Magtulis,

2020). In late March, more testing kits have been availed and additional testing laboratories were accredited by Department of Health to increase the testing rate in the country (Modesto, 2020).

Davao Region being one of the affected areas in the Philippines recorded its first case in March 15 that involves a 21-year old female who had a travel history to United Kingdom and Manila (Lumawag, 2020). Subsequently, more spread of disease were recorded in the Region which were mostly associated to cockfighting derby in Matina Galleria in Davao City. On April 4, the Region was placed into enhanced community quarantine to control the movement of people in and out of the Region.

With the increasing daily number of positive cases, an evidence-based decision with the use of mathematical models is highly recommended by the World Health Organization to estimate the key epidemiologic parameters of COVID-19 (WHO, 2020). To respond to the challenge, this study provides data-driven forecast on the epidemic status of Davao Region using the Susceptibles-Infectives-Recovered (SIR) Model.

METHOD

The analysis was based on the publicly available data of the new confirmed daily cases reported for Davao Region from March 15 until May 09 (DOH, 2020). The confirmed daily cases were used to estimate the main epidemiological parameters using SIR model.

The SIR model can be written as the following differential equations:

$$\frac{dS}{dt} = -\frac{\beta}{N}IS,$$

$$\frac{dI}{dt} = \frac{\beta}{N}IS - \gamma I,$$

$$\frac{dR}{dt} = \gamma I,$$

where $N = S + I + R$ is the total population β is the contact rate, and $1/\gamma$ is the average infectious period. From the three equations, we obtain total population size N .

For the actual computation, the analysis utilized the codes of Batista (2020) in implementing susceptible-infected-removed (SIR) epidemic model for epidemic evaluation. The model is data driven which assumes a constant population, uniform mixing of the people, and equally likely removal of infected.

RESULTS AND DISCUSSION

Figure 1 displays an erratic trend of daily new COVID-19 cases in the month of May. More specifically, a sudden surge was observed in May 5 with 12 new cases from zero case the prior day. In the same way, the DOH reported a considerable increase from the previous day's tally on

May 08 with 9 additional cases. Although the recent daily growth rate are mostly within the 5 percent boundary, a sudden spike of new cases may suggest that the infection can still potentially spread in the population and likely to grow exponentially at any given time. Moreover, the results indicate that the disease can still spread to the susceptible population.

This continuing transmission of COVID-19 can be explained by the computed Basic Reproduction Number (R_0) as shown in Table 1. The R_0 is an indication of the transmissibility of the virus. For $R_0 > 1$, the number infected is likely to increase, and for $R_0 < 1$, transmission is likely to die out (Liu et al., 2020). In the Table, the recent R_0 values are is still above 1 which suggests that the infection will probably keep spreading.

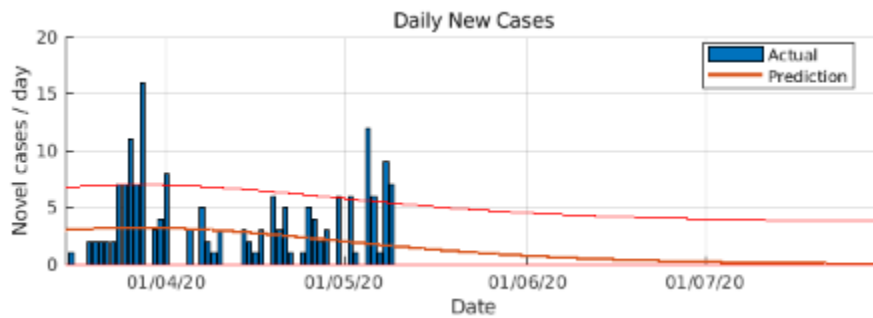


Figure 1. Infection Rate Status in Davao Region

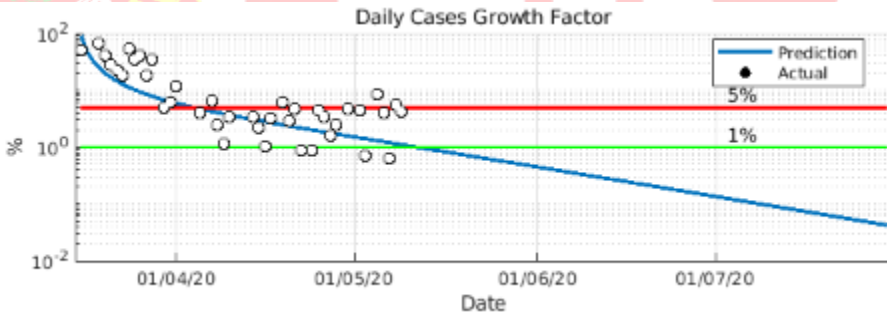


Figure 2. Growth Rate of COVID-19 in Davao Region

Nevertheless, the R_0 values have drastically dropped from April 4 ($R_0=2.8$) before the start of ECQ), to almost nearly 1 in May 09. The decline in the Basic Reproduction Number would signify the effectiveness of ECQ in lowering down the infection rate in the Region. This supports the research of Fang et al. (2020) that government interventions in China such as lockdown measures and decreased frequency of exposure resulted to decline in susceptible population and slower rate of increase in infected population.

Table 1. Basic Reproduction number (R_0) estimates

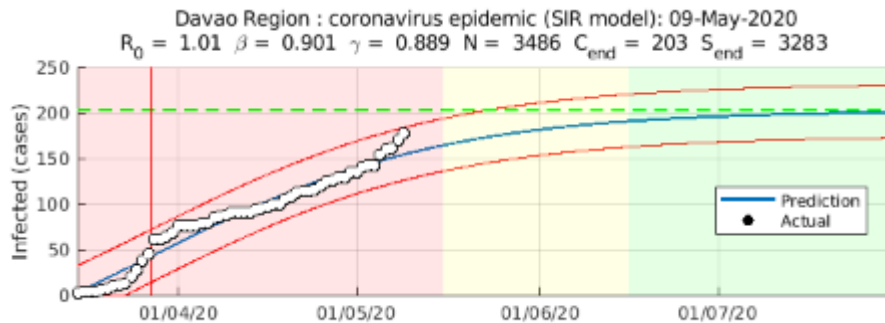
Date	Basic Reproduction Number
28-Mar	2.74
4-Apr	2.85
5-May	1.021
6-May	1.015
7-May	1.006
8-May	1.006
9-May	1.014

Furthermore, an epidemic doubling time was computed as another test to capture the trajectory of the outbreak (see Table 2). This metric determines the sequence of intervals at which the cumulative incidence doubles (Vynnycky & White, 2010). The results show an increase in the doubling time from 3 days (before ECQ) to 11 days (with ECQ) suggesting a slowdown in transmission when the ECQ was implemented.

Table 2. Epidemic Doubling Time

Date	Doubling Time
Before ECQ (till April 4)	3 days
With ECQ (till May 9)	11 days

Using the SIR Model Analysis (See Figure 3), the epidemic stage of the Region is at fast growth phase (RED). Subsequently, if the government intervention will not be changed (ECQ) and the situation will remain stable, then by the SIR Model, the predicted final size of epidemic is about 203 cases. However, we need to take note that there are projected 3,486 total susceptible individuals, which can likely be infected in the entire epidemic duration. Meanwhile, if the enhanced community quarantine (ECQ) will not be lifted, then the total epidemic duration is about 154 days which is expected to end on Aug 17, 2020.



Color coding representing epidemic phases:

Red - fast growth phase

Yellow - transition to steady-state phase

Green - ending phase (plateau stage)

Figure 3. Forecast of COVID-19 Epidemic in Region 11 using SIR Model

CONCLUSION

The enhanced community quarantine (ECQ) have been effective in controlling the spread of COVID-19 in Davao Region as evident in the reduced Basic Reproduction Number (R_0) and epidemic doubling time. However, since the R_0 is still above 1 then the disease can still spread in the population. The final size computation by SIR is fitted on the current status of the Region while under the ECQ, where there is lockdown between provincial borders and limited movement of people. However, the lifting of ECQ would most likely increase the contact rate that can also change the forecast.

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