Real-time Forecasting of the COVID-19 Epidemic using the Richards Model in South Sulawesi, Indonesia

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A B S T R A C T

This paper discussed Real-time Forecasting of the COVID-19 Epidemic using daily cumulative cases of COVID-19 in South Sulawesi. Our aim is to make model for the growth of COVID-19 cases in South Sulawesi in the top 5 provinces with the largest COVID-19 cases in Indonesia and predict when this pandemic reaches the peak of spread and when it ends. This paper used the Richards model, which is an extension of a simple logistic growth model with additional scaling parameters. Data used in the paper as of June 24, 2020 were taken from the official website of the Indonesian government. Our results are that the maximum cumulative number of COVID-19 cases has reached 10,000 to 12,000 cases. The peak of the pandemic is estimated to occur from June to July 2020 while continuing to impose social restrictions. The condition in South Sulawesi shows a sloping curve around October 2020, which means that there are still additional cases but not significant. When entering November, the curve starts to flat which indicates the addition of very small cases until the pandemic ends. The results of the pandemic peak prediction are the same as the Indonesian data; what is different is the prediction of when the pandemic will end. In the best-case scenario, the current data will tend to slow down, with the COVID-19 pandemic in South Sulawesi expected to end in November 2020. Our modeling procedure can provide information about the ongoing COVID-19 pandemic in South Sulawesi that may facilitate real-time public health responses about future disease outbreaks.

A R T I C L E I N F O

1. INTRODUCTION

The COVID-19 pandemic has spread evenly in almost all regions in Indonesia. The positive cumulative cases of COVID-19 in Indonesia reached 49,009 patients with a total of 2,573 thousand deaths (https://www.ecdc.europa.eu/en/publications-data/ download-todays-data-geographic-distribution-covid-19-cases-worldwide).

COVID-19 cases in South Sulawesi were detected since March 20, 2020, which began with 2 positive cases that have continued until now with a total of 4,185 cases as of June 24, 2020, with a total of 155 deaths and 1,272 cases recovered (https://covid19.go.id/ peta-sebaran). The number of cases increases every day with the largest addition of cases reaching 211. COVID-19 pandemic in South Sulawesi entering June began to experience a increase in cases per day, namely only an average of 111 cases per day. The Indonesian government has made various efforts to control the epidemic including social distancing, physical distancing, and working from home. In addition, in some areas, the government even imposed stricter social restrictions for the so-called "red zones". In the South Sulawesi Province, only a few cities have implemented social restrictions including Makassar City which has the most cases in South Sulawesi. Meanwhile, other regions carried out independent quarantines in their respective regions.

Modeling of COVID-19 cases has been carried out with a variety of models ranging from research conducted by Arino and Portet (2020) as well as simple modeling of COVID-19 using SIR model (Chen *et al.,* 2020) and SEIR model (Putra and Abidin, 2020). In addition to modeling COVID-19, researches have also been undertaken on the impacts that occur due to COVID-19 both in the field of education (Mulyanti *et al.,* 2020) and in the field of health (Paranjay and Rajeshkumar, 2020).

Here, this paper used the Richards model, which has been successfully applied to describe previous epidemics such as the procedure for predictions of SARS outbreak (Hsieh, 2009), a study on the rapid parameter estimation and the grey prediction in Richards Model (Wang *et al.,* 2016) and real-time forecasting about influenza pandemic (Nishiura, 2011). This model has several limitations and only applies to several stages of an outbreak, or when sufficient data points are available. Thus, in the initial analysis, a model with the number of cases reported in the COVID-19 epidemic in Indonesia was used. Then, the scenario that fitted the case in South Sulawesi was evaluated to make similar modeling to realistic. Our analysis examines the development of the epidemic in Indonesia and the impact of preventive actions by the government. Our research used simple models quantitatively documenting the impact of COVID-19 spread prevention measures, and provided informative implications for the upcoming pandemic in South Sulawesi in the form of information when the peak of the epidemic occurs and when it ends.

2. THEORY

One of the advantages of using the Richards model for mathematical modeling is to fit the accumulative case number, which helps to smooth out the stochastic variations in the epidemic curve owing to variations in data collection (Hsieh, 2010; Richards, 1959). The Richards model also extends the simple logistic growth model through a scaling parameter a, which measures the deviation from the symmetric simple logistic curve (Lee *et al.,* 2020; Pearl and Reed, 1930; Roosa *et al.,* 2020). The Richards model is defined by the differential equation

$$C'(t) = rC(t)\left[1 - \left(\frac{C(t)}{K}\right)^a\right]$$

The addition of the parameter a provides a measurement of flexibility in the curvature of the S shape exhibited by the resulting solution curve. As a model for the growth of an epidemic outbreak, $C(t)$ is the

cumulative number of infected cases at time t in days, K is the carrying capacity or total case number of the outbreak, r is the per capita growth rate of the infected population, and a is the exponent of deviation from the standard logistic curve.

The basic premise of the Richards model is that the daily incidence curve consists of a single peak of high incidence, resulting in an S-shaped epidemic curve and a single turning point of the outbreak. These turning points, defined as times at which the rate of accumulation changed from increasing to decreasing, can be easily located by finding the inflection point of the epidemic curve, the moment at which the trajectory begins to decline. This quantity has obvious epidemiologic importance, indicating either the beginning (i.e., the moment of acceleration after deceleration) or end (i.e., the moment of deceleration after acceleration) of a phase (Gao *et al.*, 2013).

The analytic solution of the Richards model is as follows:

$$C(t) = \frac{K}{[1 + e^{-r(t-t_m)}]^{1/a}}$$

It is trivial to show that t_i is the only inflection point (or turning point denoting deceleration after acceleration) of the S-shaped epidemic curve obtained from this model. Moreover, the equation can be re-expressed as

$$t_m = t_i + \frac{\ln a}{r}$$

where t_i is equal to the inflection point when $a = 1$, and approximates t_i when a is close to 1.

3. MATERIALS AND METHODS

We used a data source from the official Indonesian government website about COVID-19, which reports cumulative cases for all provinces in Indonesia, including South Sulawesi. Data were taken from (https://covid19.go.id/peta-sebaran). Data were collected on cases reported every day at 4 pm (GMT +8) from the initial date of reporting, March 20 until June 24, 2020.

Then, the trajectory of the epidemic in South Sulawesi, which according to the latest data will lead to the peak of the epidemic, was estimated.

Phenomenological models were used, in which these have previously been applied to various other infectious disease outbreaks, namely the Richards Curve, which is an extension of a simple Logistic Growth Model with additional scaling parameters.

The Richards model used several parameters including K, r, a, and t_m. To determine the four assumptions, the cumulative data of positive patients with COVID-19 were used.

The value of r that is the growth rate per capita of the infected population is calculated using the following equation.

$$P_t = P_0 e^{rt}$$

where P_t is the cumulative number of positive COVID-19 cases at the end of the observation period, P_0 represents the number of cases at the beginning of the pandemic, and t is the time.

4. RESULTS AND DISCUSSION
4.1. COVID-19 cases modeling in Indonesia

At present, the COVID-19 case in Indonesia has not shown a significant decline. In some regions, there are still quite numerous cases where one of which is East Java and South Sulawesi. We calibrated each of the models to the number of daily cases reported in Indonesia. We fitted the model to an "incidence" curve while presenting the cumulative curves for visualization. Reported data were available beginning March 02, 2020, so the calibration period includes daily data from March 02 to June 24, 2020. We estimated the best-fit solution for each model using the nonlinear least square, which is a process that produces model parameters that minimize the number of squares of errors between models and data. In the beginning, it was modeled for Indonesia, and then subsequently was used for evaluating cases that were similar to what happened in South Sulawesi. Indonesian

data plots using the Richard model is shown and explained in **Figures 1** and **2**.

From the results of the predicted COVID-19 cases in Indonesia, it was found that COVID-19 in Indonesia was at the peak of the pandemic, namely in June 2020. The analysis results showed that the estimate for the maximum number of cases is between 124,000 and 125,000 cases. The peak of the pandemic is estimated to occur in the middle of June 2020 until the end of July 2020. The end of the pandemic is expected to occur at the end of April 2021. This will happen if the Indonesian people implement the government's recommendations.

Several major cities in Indonesia, implementing different policies according to the conditions of their respective regions and the number of COVID-19 cases that spread in their area .

4.2. COVID-19 cases modeling in South Sulawesi

Based on modelling using the Richards model on positive case data in Indonesia, we also made the same illustration on the South Sulawesi data. In the initial step, the selection of initial assumptions is based on the actual data available.
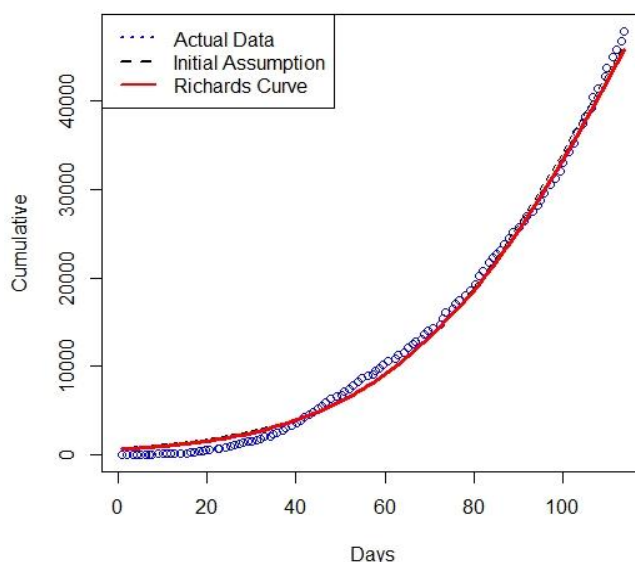
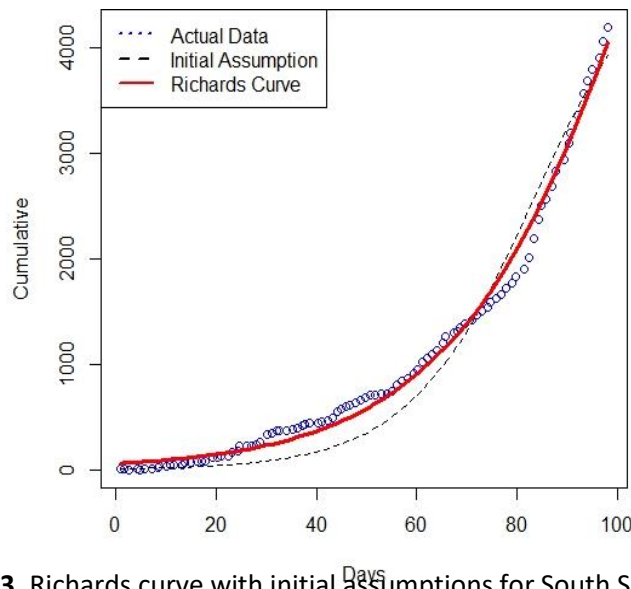**Figure 1.** Richards' curve with initial assumptions in Indonesia
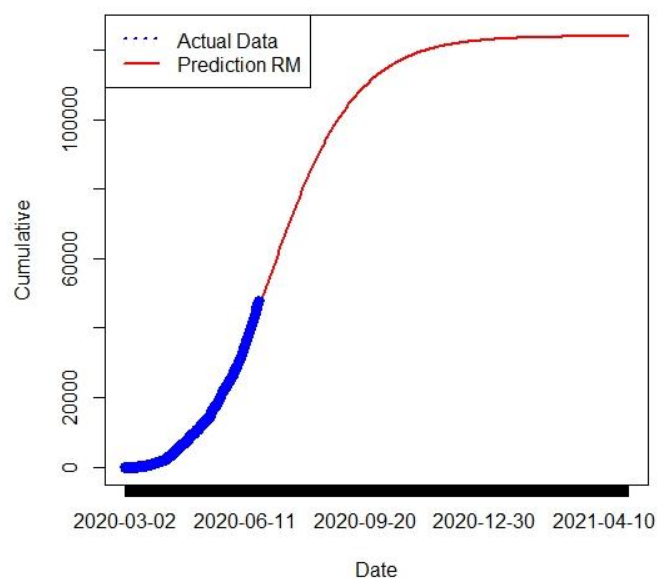
Figure 2. The prediction of COVID-19 in Indonesia with the Richards curve

The plot of data from the initial assumptions and Richards curve for South Sulawesi data is presented in **Figure 3**. It is shown that the Richards curve created can represent the actual data available. Then, a prediction was made using the cumulative data of COVID-19 positive cases in South Sulawesi from March 20, 2020, to June 24, 2020, in which the plot is shown in **Figure 4**.

As for South Sulawesi, the positive cases of COVID-19 will continue to grow, so predictions need to be made when the peak of the epidemic and when it ends. The analysis results show that the estimate for the maximum number of cases is between 10,000 and 12,000 cases. The peak of the pandemic is estimated to occur in the middle of June 2020 until the end of July 2020. The end of the pandemic is expected to occur at the end of November 2020.

From **Figure 3**, it is shown that the curve begins to slope around October, there are still additional cases but not significant. When entering November the curve starts to flat which indicates the addition of very small cases until the pandemic ends. while, if seen from **Figure 2** in the case of Indonesia in general the curve begins to slope around October, there are still additional cases but not significant. When entering December the curve starts to flat which indicates the addition of very small cases until the pandemic ends.

Figure 3. Richards curve with initial assumptions for South Sulawesi
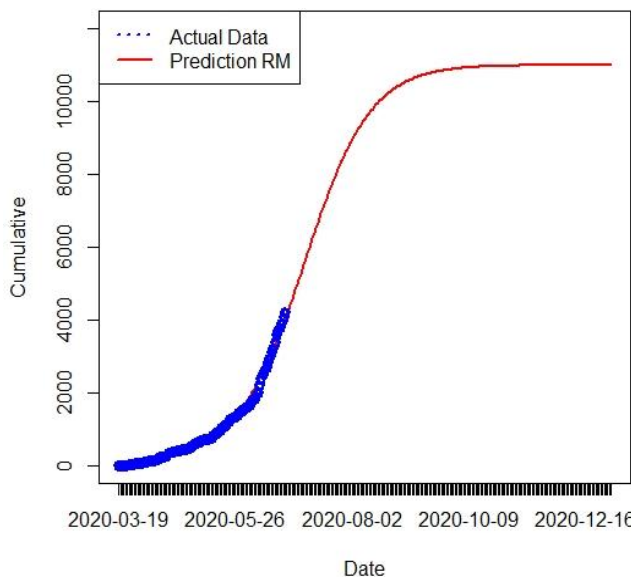
Figure 4. Prediction Results from Richards Curve for South Sulawesi

The results of the pandemic peak prediction are the same as the Indonesian data; what is different is the prediction of when the pandemic will end. This is because the region in Indonesia consists of several islands so that the policies of each region might also greatly affect the duration of the spread of the virus accompanied by a disciplined attitude of its citizens.

Predictions about when the COVID-19 pandemic will end in South Sulawesi using the Richards Model can occur more quickly if the government implements stricter regulations on the large-scale social restrictions or by locking up areas. This is in line with the research conducted by Putra and Abidin (2020) on the effect of lockdown on the addition of COVID-19 cases. In the research it is mentioned that with a lockdown, COVID-19 cases in Southeast Asia will decrease in June 2020. However, to carry out a lockdown in an area or country requires a careful preparation of various aspects of life, especially in the economic field.

5. CONCLUSION

The conclusion of this paper is that the Richards Model fitted all the data well. The Richards curves generated from Indonesian and South Sulawesi data have some similarities, namely the same in predicting when the peak of a pandemic occurs. For the COVID-19 case in Indonesia and South Sulawesi, the peak of the pandemic occur at the middle of June to July 2020. This will happen if the Indonesian people implement the government's recommendation to work from home. In the best scenario in South Sulawesi, the current data will tend to slow down where the COVID-19 pandemic is expected to end in November 2020 with a total number of cumulative cases between 10,000 until 12,000 cases.

6. ACKNOWLEDGEMENTS

7. AUTHORS' NOTE

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article. The authors hereby confirm that the data and the paper are free of plagiarism.

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