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Natural Disaster Risk Prediction in Indonesia: H-WEMA Approach

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ABSTRACT

Natural disaster is defined as any hazards caused by the meteorological and earth forces, with no human interference and involvement. Due to the huge social and economic impacts it can give, the threat pose by the natural disaster should not be taken lightly. Indonesia, as one of the countries in the ring of fire belt, had recorded almost half of the global death from natural disasters in 2018. Three out of ten deadliest disaster events happened in Indonesia in that year. Therefore, in this study, the natural disaster risk prediction in Indonesia will be conducted using a time series forecasting method, namely H-WEMA method. It was first introduced in 2016 and has been applied to numerous cases. From the forecasting results, three out of ten categories of natural disasters in Indonesia can be properly predicted by using H-WEMA. There is a declining trend in natural disaster events for those three categories, at least for a few future years ahead.

Keywords: H-WEMA, Indonesia, Natural Disaster Risk, Prediction.

1. INTRODUCTION

A natural disaster is defined as any hazards caused by the meteorological forces and earth forces, such as earthquakes, tsunami, volcano eruptions, floods, landslides, etc. [1]. There is no human interference and involvement in the occurrence of natural disasters, in contrast with man-made disasters, such as air-water-soil pollution, industrial and nuclear accident, or even terrorist attacks [1]–[3]. However, due to the huge social and economic impacts it can give, the threat pose by the natural disaster should not be taken lightly and need to be addressed properly.

According to the Centre for Research on the Epidemiology of Disasters (CRED) report, Indonesia recorded nearly half of the total death (4,535 of 10,733) from natural disasters in 2018 [4]. In fact, three out of the top ten deadliest disaster events during that year happened in Indonesia. One of the primary factors for this threat is the geographical location and geological conditions of Indonesia which is located at the confluence of four tectonic plates, i.e., Asia Continent, Australia Continent, Pacific Ocean, and Indian Ocean [5]. Fig. 1 shows the weekly disaster events map from 1-7 January 2019 [6].

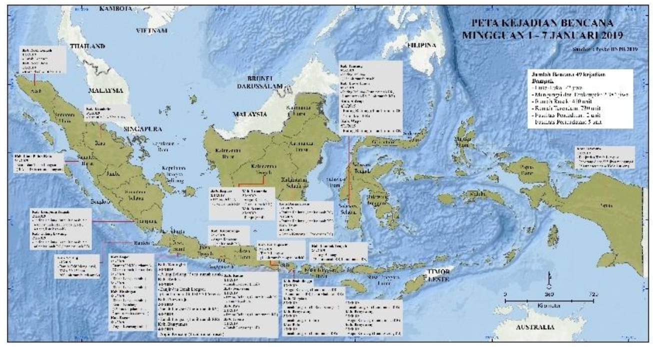


Figure 1: Disaster events map in Indonesia [6]

Prediction of natural disasters has become a popular issue in the research domain. Goswami et al. [7] argue that this task does not only involve the prediction of the natural disaster, but also the disaster's prone area, and different attributes contribute to the occurrence of the natural disaster. Miao and Ding [8] also have done an analysis of natural disaster's influence on the regional economy and found that the economy is affected dramatically by natural disasters. Moreover, Chen et al. [9] point out that research on the prediction, characteristics, and causes of natural disasters is of considerable significance and in urgent need.

Some researchers give their focus on the prediction of natural disasters. Ravikumar et al. [10]have tried to predict natural disasters based on fuzzy logic using hybrid Particle Swarm Optimization (PSO). Bande and Shete [11] have built an IoT based flood monitoring and Artificial Neural Network (ANN) based flood prediction system. Meanwhile, Rosellini et al. [12] have investigated and built the post-earthquake posttraumatic stress disorder prediction tool by using a machine learning approach.

In this study, the natural disaster prediction will be focused on Indonesia country. A relatively new hybrid forecasting method, known as Holt's Weighted Exponential Moving Average (H-WEMA), will be applied. It was introduced in 2016 [13] and since then has been applied to numerous cases, such as Forex forecasting [14], capital stock prediction [15], and domestic tourist arrivals forecasting [16]. Hence, it has been accepted as a promising forecasting method that can be used in different kinds of scenarios.

The structure of this paper as follows. Section 2 will briefly discuss H-WEMA as the main forecasting method applied, then Section 3 will present the natural disaster risk prediction results in Indonesia. Lastly, a concluding remark will be given in Section 4.

2. H-WEMA

As briefly explained in the Introduction, H-WEMA is a hybrid forecasting method, proposed by Hansun and Subanar in 2016 [13], that combines the procedure of Weighted Moving Average with Holt's Double Exponential Smoothing (H-DES). It is an improved version of the Weighted Exponential Moving Average (WEMA) method, which is preferred to forecast the future values of a time-series data with a trend pattern [14], [16]. As described in [16], the procedures of H-WEMA are as follows.

Step 1. Find a base value, B_t, using Eq.(1)

$$B_t = \frac{\sum_{t=k-n+1}^{k} w_t A_t}{\sum_{t=k-n+1}^{k} w_t} \tag{1}$$

Step 2. Find the forecasting value using H-DES procedures as follows.

Set the initial values for L_t and T_t, i.e., the smoothed constant process value and the smoothed trend value respectively, as shown in Eq.(2) and Eq.(3).

$$L_{t-1} = B_{t-1} \tag{2}$$
$$T_{t-1} = B_t - B_{t-1} \tag{3}$$

Calculate the following values for both smoothed series using Eq.(4) and Eq.(5).

$$L_t = \alpha A_t + (1-\alpha)(L_{t-1} + T_{t-1}) \tag{4}$$

$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1} \tag{5}$$

Calculate the forecasted value by using Eq.(6).

$$F_{t+k} = L_t + kT_t \tag{6}$$

Step 3. Repeat Step 1 and 2 until each data point has been visited.

Fig. 2 shows the simple diagram of H-WEMA procedures.

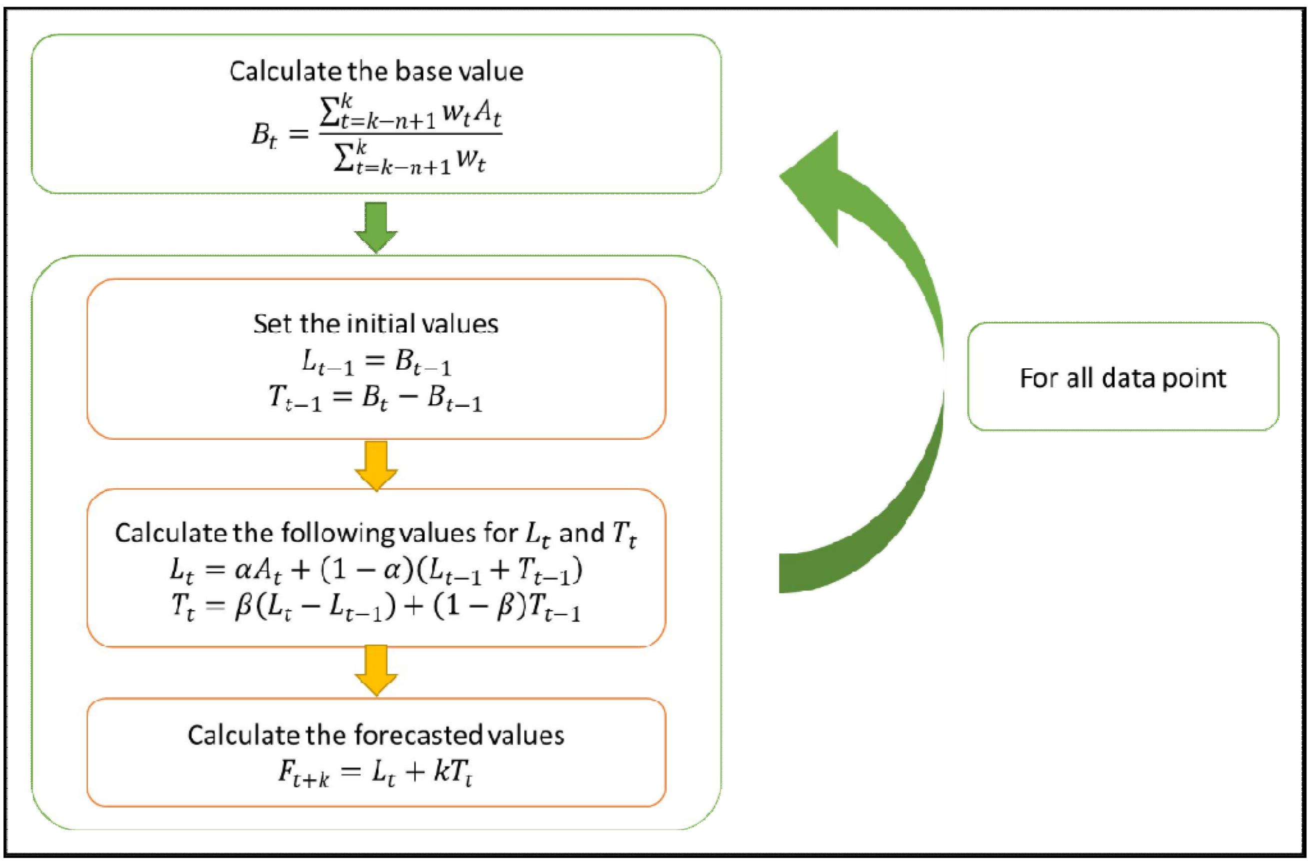


Figure 2: H-WEMA procedures

3. RESULTS AND ANALYSIS

3.1 Dataset

The natural disaster data being used in this study is collected from Badan Nasional Penanggulangan Bencana (National Disaster Management Agency) database, which can be accessed by the public through Data Informasi Bencana Indonesia (Indonesia's Disaster Information Data) [17]. There are ten natural disaster categories, namely flood, tornado, landslides, forest and land fires, drought, tidal wave/ abrasion, earthquakes, volcano eruptions, tsunami, and earthquakes and tsunami. Out of the ten categories, three of them have some missing or zero values, i.e., drought, tsunami, and earthquakes and tsunami. Therefore, for simplicity, those three natural disasters events will not be considered for the prediction in this study. Fig. 3 shows the natural disasters trend in the last ten years, while Table 1 presents the annual recapitulation of all of the natural disaster events for the last ten years in Indonesia.

Figure 3: Natural disasters trend for the last 10 years in Indonesia [18]

Table 1: Natural Disasters in Indonesia Period 2010-2019

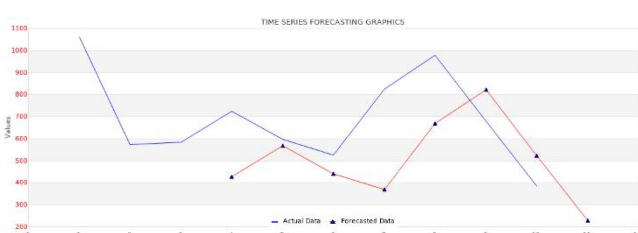
Year	Floods	Tornado	Landslides	Forest and land fires	Tidal wave/ abrasion	Earthquakes	Volcano eruptions	Drought	Tsunami	Earthquakes and tsunami	Total
2010	1,061	404	402	4	12	16	5	43	1		1,948
2011	574	441	329	24	17	14	4	219	1		1,623
2012	584	545	287	49	29	15	7	263	3		1,782
2013	725	502	294	26	36	10	8	66			1,667
2014	596	618	598	101	20	16	7	7	2		1,965
2015	525	571	502	46	7	26	10	7			1,694
2016	824	663	599	178	22	15	7				2,308
2017	979	887	848	96	11	23	6	19			2,869
2018	679	804	474	370	34	27	52	129	2	2	2,573
2019	385	568	355	55	8	13	4	33			1,421
Total	6,932	6,003	4,688	949	196	175	110	786	9	2	19,850

3.2 Forecasting Results

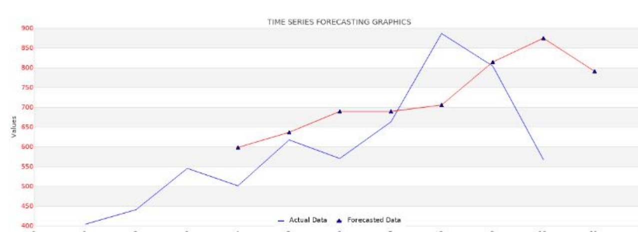
The forecasting results for seven categories of natural disasters are given in Fig. 4. The blue line represents the actual values, while the red line represents the predicted values using the H-WEMA forecasting method. Three of the forecasting results, i.e., forest and land fires, earthquakes, and volcano eruptions, show a linear trend that is not suitable for the data referenced, hence the forecasting method is not suitable to predict those data. In this study, the constant smoothing factor, α and β, will be increased iteratively on each loop, started from 0 to 1 with two decimal places to get the smallest forecast error. Table 2 shows the best α and β values for each disaster category used in this study.

Table 2: Best α and β for Each Category

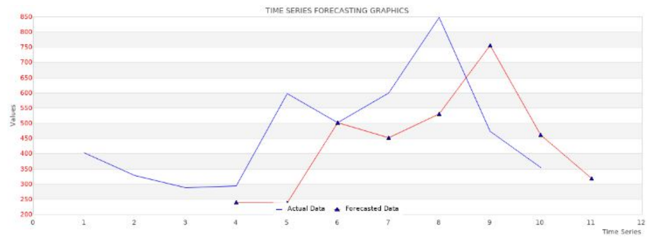
Category	Best α	Best β
Floods	1	0
Tornado	0.24	1
Landslides	0.87	0
Forest and land fires	0	0
Tidal wave/ abrasion	0.32	1
Earthquakes	0	0
Volcano eruptions	0	0.05



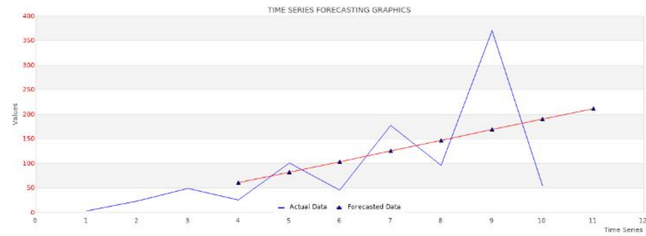
(a) Floods



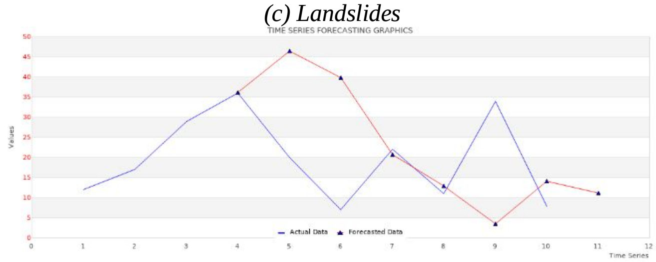
(b) Tornado



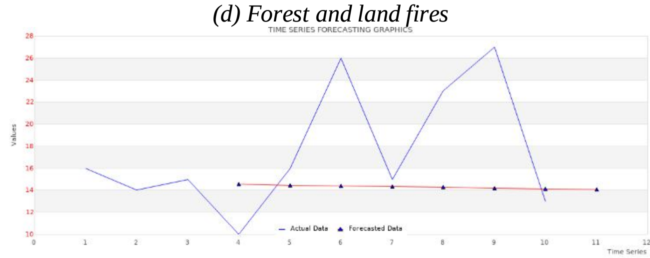
(c) Landslides



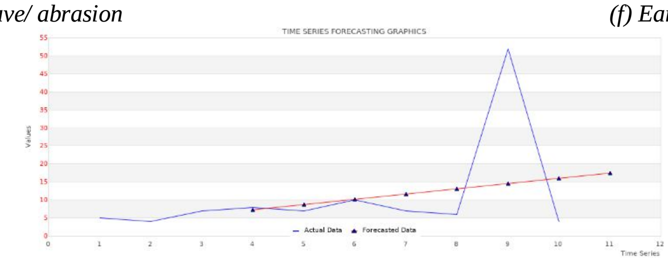
(d) Forest and land fires



(e) Tidal wave/ abrasion



(f) Earthquakes



(g) Volcano eruptions

Figure 4: Natural Disasters Risk Prediction

3.3Analysis

From the graphics of forecasting results, it can be drawn that three out of seven natural disasters events are not suitable to be predicted by using the H-WEMA method. This statement can be justified by calculating the forecast error measurement. One of the popular forecast error measurements is the Mean Absolute Percentage Error (MAPE). It is a scale-independent measurement and has a formula as shown in Eq.(7) [19].

$$MAPE = \left(\frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|\right) \cdot 100\% \qquad (7)$$

where n denotes the total number of data, A_t denotes the observation at time t, and F_t is the forecasted value of A_t. Table 3 shows the MAPE values for each natural disaster category, which has been predicted by using H-WEMA method.

Table 3: MAPE for Each Category

Category	MAPE
Floods	29.40397
Tornado	17.55780
Landslides	32.92472
Forest and land fires	94.53801
Tidal wave/ abrasion	113.21728
Earthquakes	28.29612
Volcano eruptions	85.01055

From Table 3, it can be clearly seen that forest and land fires and volcano eruptions have quite a significant number of forecast errors. Moreover, tidal wave/ abrasion also has a great MAPE value of over 100 which means that the errors are much higher than the actual values. Therefore, H-WEMA is not preferred to be used in the prediction for those categories of natural disasters.

For the first three categories of natural disasters in Indonesia (Table 1), i.e., floods, tornados, and landslides, which also have the highest number of occurrences, can be predicted well using H-WEMA due to their low MAPE values (Table 3). It can be inferred from the forecasting results that there is a declining trend of natural disasters of those three categories, at least for the near future.

4. CONCLUSION

In this study, the natural disaster risk prediction in Indonesia has been successfully conducted by using the H-WEMA method. Out of ten categories of natural disasters collected from BNPB (National Disaster Management Agency), seven were further processed using the H-WEMA method. However, from the forecasting results, only three categories, namely floods, tornado, and landslides, that can be adequately predicted by using the method. In the near future, the results can be analyzed for proper disaster strategy and management, focusing on those three disaster categories as can be seen in [20]. A comparison with other forecasting methods, such as deep learning framework [21], can also be done to get a more comprehensive result of natural disaster risk prediction in Indonesia.

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