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WINTERS EXPONENTIAL SMOOTHING AND Z-SCORE, ALGORITHMS FOR PREDICTION OF RAINFALL

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ABSTRACT

The detailed rainfall forecasting to districts in Indonesia are limited. The researches related to the rainfall forecasting are needed in order to support the development in different fields including agricultural areas. There is no one model or system integrating climatic classifications and the weather forecasting aiming at determination of the ideal cultivating season. This rainfall forecasting was developed by processing the previous rainfall data using the combination of Z-Score model, transformation function, and the Winters Triple Exponential Smoothing. The data resulted from the forecasting was used to determine the spatial-based climatic classification in Boyolali, Central Java, Indonesia using Oldeman method. The proposed model is able to predict the weather using climatic classification. The rainfall data resulted from the proposed forecasting model can be used for climatic classification using Oldeman method in the research area.

Keywords: *Climatic Classification, Forecasting, Model, Oldeman, Transformation, Winters, Z-Score*

1. INTRODUCTION

The climatic changes, i.e. the global phenomenon, have been increasing as a result of human activities such as the use of fossil fuels and the change in the land use. One of global climatic changes is the extreme rise of climatic frequency and intensity, such as storm, flood and drought. Some previous researches argued that there were many indicators in climatic changes like sea level rising, flood, drought, some problems in resources and water resources development [1]. In most Indonesian areas, climatic changes have become one of the serious threats towards agricultural sector and potentially caused new problems for the sustainability of food production and agricultural production system in general. The impact of climatic changes towards agricultural sector is multi-dimensional, from resources, agricultural infrastructures, agricultural production system, aspects of food self-sufficiency and sustainability, until the farming community welfare in general [2].

As the one of climatic elements, rainfall resulted from the atmosphere in tropical areas in general is in the form of the rainfall [3]. This rainfall has an important role in agriculture. However, it was not easy to get the description of rainfall concurrent in all tropical areas [3]. One of the roles of rainfall is as the main climatic element in providing information about seasonal climatic forecasting. This information was prepared in order to provide information about the seasonal climatic condition ahead that will hopefully happen in a particular predicted period [4]. There were less detailed rainfall forecasts to districts in Indonesia. The researches in the rainfall forecasting are needed to support the development in various areas, including agriculture [5].

There is no any model or system integrating climatic classification and weather forecast for determining the ideal cultivating system. Climatic classification aims to determine the type of climate viewed from the completely active element side, especially water and heat [6]. The newer understanding about climatic classification is by looking at the systematic relationship between climatic element and the world crop system. It was found the correlation between crops and heat or water element. Thus, temperature or water index has been used as the criteria for determining climate types. Climatic classification based on the crop system is usually associated with the forest, rain, desert, grasslands, and tundra.

In this research, the experiment will be done determining rainfall forecast model and emphasizing on the steps of data normalization or

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pre-processing data to develop the forecasting model with a good level of accuracy. The focus of experiment is on the algorithm design and algorithm testing for each step of prediction model making until the steps of climatic classification making. The rainfall forecasting model will produce rainfall forecasting data to be used to make climatic classification map, i.e. one of the main variables for determining the congruity of cultivating pattern to be developed on the following research. The expected result from the research is the rainfall forecasting model that can be integrated to the spatial-based climatic classification model in all Indonesia areas.

2. RELATED WORKS

Exponential smoothing forecast method uses different score for the past [7], and because its attribute is decreasing exponentially from the last data point until the first. There are three exponential methods, they are simple exponential method, (for data with stationer pattern), dual exponential using two different parameters for two used exponential smoothing and known as Holt method (for data with trend pattern), and different three parameters for three different smoothing, which are data smoothing, trend smoothing, and seasonal index smoothing for data with seasonal pattern with or without trend. Reference [7][8] said that exponential smoothing constitutes the short-term forecast method recommended by Food and Agriculture Organization to replace linear model such as regression, which is now still used for forecasting in agricultural cultivation. The downside of linear model is the short-term forecast inconsistency [9], for instance there was a fact of a decrease of crop production in one area caused by drought but the model still showed the rise of production.

Reference [10] in time series prediction, forecasting model like ARIMA has many sophisticated parameters to get high accuracy in time series prediction. Applying this sophisticated method will automatically face a lot of barriers and costs. To decrease this complexity in forecasting without decreasing the accuracy of resulted prediction, simple equation like exponential smoothing model for forecasting can be used. The research of time series data forecasting was done, that was comparing five exponential smoothing methods for dual seasonal forecasting (daily and weekly) the demand of electrical charge [11]. The best method found was double seasonal multiplicative Holt-Winters Exponential Smoothing method based on the resulted MAPE value, because it outperformed other exponential smoothing methods and modified exponential smoothing method. The length of forecasting period influences method accuracy [7].

The other research of weather forecast was done to determine the length of rainy season, they proposed measuring the average of monthly rainfall in one area [12]. When the monthly rainfall is more than 150 mm, the length of rainy season will be 6 months and the length of dry season will be 6 months. If the result of rainfall measurement in one *dasarian* (10 days) is more than or the same as 50 mm, and the following *dasarian* has the similar rainfall, that *dasarian* will be the beginning of rainy season [4]. Reference [4][5] predicting the monthly rainfall in Purbalingga area using kalman filter method with predictor of SST 3.4. validacy towards last three years prediction (hindcast) 2006, 2007, 2008 showed correlation coefficient value up to 75%. To get predictor value of SST Nino 3.4, ARIMA method was used. Reference [5][13] their aim is developing forecasting accuracy using ARIMA model for monthly rainfall forecasting in Dhaka, Bangladesh.

Reference [14] investigated the change of rainfall in Iran focusing on determining the change of seasonal rainfall area, and yearly rainfall data from synoptic station for statistically 13 years period in 1999-2011 and the rainfall was studied to determine the change of rainfall in that area. The findings indicated that the annual trend of rainfall forecasting was the increasing trend and showed the increase of rainfall in the following years in those areas. Reference [15] was conducted to compare the performance of Holt-Winters forecasting method and double exponential smoothing, the findings showed that double exponential smoothing was more accurate for trend data than Holt-Winters method. However, in the prediction of land cost with the seasonal data and Holt-Winters model trend was better than double exponential smoothing method. The next review of literature and research about forecasting [16], from the research and review of literature conducted, it was concluded that score parameter estimation using the minimum squared in hybridizing exponential smoothing with neural network did not give optimum result.

The first difference of this research to the previous researches is the use of combination of Z-Score method, transformation function, and winters triple exponential method to increase the accuracy of forecasting model, meliorate data pattern and add forecasting time period. The second difference is this research integrated the climatic forecast model with the climatic classification model based

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on the resulted forecasting rainfall data. The third difference is the focus of the research that is on the algorithm design, method, and algorithm optimum testing. The accuracy level of resulted prediction was measured by MAD, the prediction middle error value using ME, and counting the resulted prediction data pattern.

The first contribution is the rainfall forecasting model with the level of minimum error and fulfills parsimony principal for forecasting the rainfall in one area in Indonesia. The second contribution is the rainfall forecasting model using the combination of Z-Score method, transformation function, and winters triple exponential method, can be integrated to spatial-based climatic classification according to oldeman method.

3. THEORETICAL BACKGROUND

Reference [17] the definition of forecasting can be distinguished with prediction. Forecasting is the process of estimating data value based on functional relationship model among data values. On the other hand, prediction is the process of estimating data value without considering about the relationships of data values. Reference [18] asserted that seasonal means the tendency of repeatedly movement pattern in one season period, typically one year for monthly data. Reference [19] stated that trend pattern and seasonal will be more accurate with the use of Winters Exponential Smoothing which consists of: (1) exponential smoothing series, (2) trend estimation, (3) seasonal estimation, and (4) the following period forecasting. According to Bob Jenkin in [20] for forecasting purpose, it is needed minimum 50 value of the past observation (historical).

3.1. Exponential Smoothing Forecasting Method

Winters triple exponential smoothing was used for seasonal data processing [7]. Holt-Winters model was based on the three smoothing equations, i.e. one stationer element, one for trend, and one for the seasonal with the equation [7]. The equation as follows, showed that winter whole smoothing is on the equation 1, trend smoothing is on the equation 2, seasonal smoothing is on the equation 3, and forecasting is shown in equation 4:

$$S_t = \propto \frac{X_t}{I_{t-L}} + (1-\propto)(S_{t-1} + b_{t-1}) \quad (1)$$

Trend Smoothing:

$$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1} \quad (2)$$

Seasonal Smoothing:

$$I_t = \beta\frac{X_t}{S_t} + (1-\beta)I_{t-L} \quad (3)$$

Forecasting:

$$F_t + m = (S_t + b_t m)I_{t-L+m} \quad (4)$$

Wherein:

S_t = Overall smoothing data in t period
b_t = Trend smoothing data in t period
I_t = Seasonal smoothing data in t period
∝ = Constant of smoothing is worth 0 to 1
β = Constant of trend is worth 0 to 1
γ = Seasonal constant is worth 0 to 1
X_t = Actual data of rainfall
m = Intended forecasting period
F_t+m = Forecasting data in t + m period

3.2. The Forecasting Method Accuracy

In periodically series modeling, parts of known data can be used to predict the next remaining data, thus it is possible to directly study forecasting accuracy [7]. For the users, the accuracy of following forecasting is the most important. For the creator of modeling, the goodness of model for the known facts (qualitative and quantitative) should be noticed.

All forecasting models have different actual values, with the forecasting value known as residual. Reference [21] there are some techniques to measure the error or residual for each step of forecasting, mean absolute deviation (MAD), i.e. one technique to evaluate forecasting techniques. MAD was used to measure the accuracy level of forecasting by averaging the forecasting error (absolute value). The purpose of this MAD is that the analysts know about the forecasting error in the same unit as the original data, is shown in equation 5.

$$\text{MAD} = \frac{\sum_{t=1}^{n}(Y_t - \hat{Y}_t)}{n} \quad (5)$$

Wherein:

Y_t = Actual value in t period
$\hat{Y}_t$ = Forecasting value in t period
n = Amount of data

If X_i is the actual data for i and F_i period, it constitutes forecasting (fitted value) for the same period, thus the error is defined as follow:

$$e_i = X_i - F_i$$

Middle error value is when there is observation value and forecasting for n time period [7], there will be n gallic/error and the measure of standard statistic, is shown in equation 6.

$$\text{ME} = \sum_{i=1}^{n} e_i/n \quad (6)$$

Wherein:

e_i = Amount of rainfall data reduced by forecasting data

3.3. Data Normalization Method

Z-Score constitutes a normalization method achieved by subtracting the intensity of raw data for

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each of the rainfall to the overall average of rainfall intensity [22], then divided by standard deviation from the overall measured intensity, is shown in equation 7:

$$\text{Z-Score} = \frac{X_t - \bar{x}}{\text{StdDev}(x)} \quad (7)$$

Wherein:
X_t = Data that will be normalized
$\bar{x}$ = Mean of the overall data
StdDev = Standard deviation from the overall data

Transformation of functions, by applying certain transformations to the graph of a given function we can obtain the graphs of certain related functions [23]. This will give us the ability to sketch the graphs of many functions quickly by hand. It will also enable us to write equations for given graphs. Let's first consider about translations. If c is a positive number, then the graph of it is just the graph of shifted upward a distance of c units (because each y-coordinate is increased by the same number c). Likewise the value of at x is the same as the value of at (c units to the left of x). Therefore, the graph of it is just the graph of shifted units to the right (see figure 1). Vertical and horizontal shifts depend on the value of c > 0, to obtain the graph of :

- y = f(x) + c, shift the graph of y = f(x) a distance c units upward
- y = f(x) - c, shift the graph of y = f(x) a distance c units downward
- y = f(x – c), shift the graph of y = f(x) a distance c units to the right
- y = f(x + c), shift the graph of y = f(x) a distance c units to the left

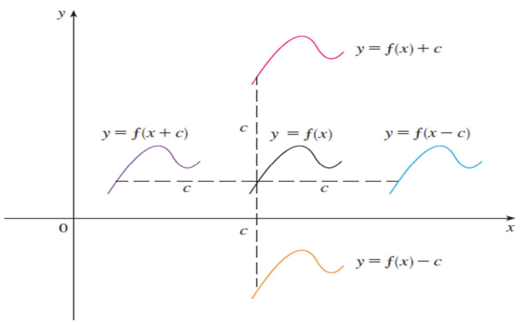

Figure 1: Translating The Graph Of f [22]

3.4. Climatic Classification of Oldeman Method

Oldeman method employs rainfall element as the basic of climatic classification [6]. This method emphasizes more on agricultural area, thus it is called as agricultural climatic classification. The amount of rainfall at 200 mm each moth is good enough to cultivate the rice field, 5 months rainy season is good enough to cultivate the rice field for one season. In this method, wet season was defined as the month that has the amount of rainfall at least 200 mm. Dry season was defined as the month that has the amount of rainfall less than 100 mm.

Table 1: Oldeman Climatic Classification [24]

Zone	Classification	Wet season	Dry season
A	A1	10 – 12 months	0 – 1 month
	A2	10 – 12 months	2 months
B	B1	7 – 9 months	0 – 1 month
	B2	7 – 9 months	2 – 3 months
	B3	7 – 8 months	4 – 5 months
C	C1	5 – 6 months	0 – 1 month
	C2	5 – 6 months	2 – 3 months
	C3	5 – 6 months	4 – 6 months
	C4	5 months	7 months
D	D1	3 – 4 months	0 – 1 month
	D2	3 – 4 months	2 – 3 months
	D3	3 – 4 months	4 – 6 months
	D4	3 – 4 months	7 – 9 months
E	E1	0 – 2 months	0 – 1 months
	E2	0 – 2 months	2 – 3 months
	E3	0 – 2 months	4 – 6 months
	E4	0 – 2 months	7 – 9 months
	E5	0 – 2 months	10 – 12 months

Oldeman divided five climatic zones and five climatic sub-zones that is shown in table 1. Climatic zone constitutes the divisions from the amount of consecutive wet season in a year. On the other hand, climatic sub-zone constitutes the amount of consecutive dry season in a year. The naming of zones are arranged alphabetically, which are zone A, zone B, zone C, zone D and zone while

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the naming of sub-zones are arranged numerically (sub 1, sub 2, sub 3 sub 4 and sub 5).

4. RESEARCH METHOD

The research has 7 steps, the diagram of research steps in figure 2 tells that the first step is conducting past rainfall data inventory with particular period and analyzing data pattern (for determining horizontal data pattern, cyclical, trend, or seasonal). The analysis of data pattern was needed to determine the suitable forecasting method referring to past data pattern [7].

The second step is data normalization in figure 2, counting statistical value from the data by processing actual rainfall data using the combination of Z-Score method and the function of transformation. The third steps is predicting rainfall data resulted from data normalization (y_t value). The forecasting step of y_t value is predicting the rainfall data for the following 12 periods using Winters Triple Exponential Smoothing method. The selection of forecasting method is based on the review of literature [7][21]. In this step, the experiment will be conducted by looking for the optimum value for the parameter of alfa, beta, and gamma in order to improve the forecasting accuracy.

Then the resulted prediction will be reconverted to be actual prediction data in the fourth step. Fifth step is choosing the appropriate forecasting model by measuring the accuracy of forecasting [21] (see figure 2). Mean Absolute Deviation (MAD) and Mean Error are used to estimate the accuracy of forecasting model, and the model with minimum MAD and ME can be preferred as the most appropriate model.

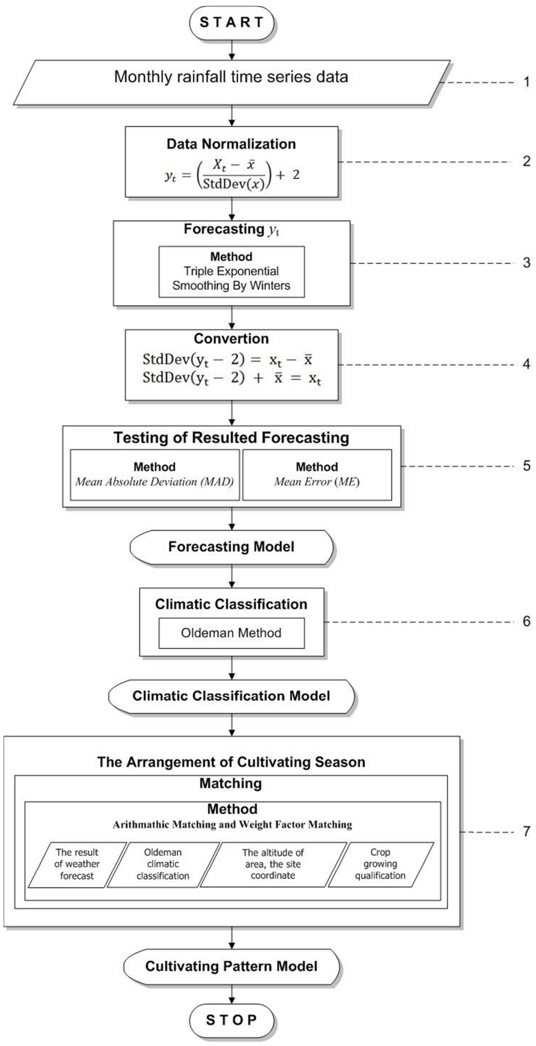

Figure 2: The Proposed Forecasting Data Integrated To Climatic Clasification

The proposed model preference is the pattern of resulted forecasting data should be seasonal with parsimony principal that prefers the simplest model. The proposed forecasting method will produce rainfall forecasting data for the next 12 periods will be used as the consideration to determine the climatic classification in research are. Winters Triple Exponential Smoothing method needs three smoothing parameters at 0 to 1 [7], the proposed pseudo code forecasting model is shown in figure 3.

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```
Read the actual rainfall data
Save the actual rainfall data into array i
Give initials to smoothing value of α, β, γ by the range of 0 to 1
Read the average of rainfall data (MEAN)
Read standard deviation of the rainfall data(STD)
Read the predicted period n
// THE PROCESS OF DATA SMOOTHING
For each rainfall data
    Calculate the value of equation 7 added by equation 2
    Calculate the smoothing using equation 1
    Calculate the trend smoothing using equation 2
    Calculate the seasonal smoothing equation 3
End for
// THE PROCESS OF SEARCHING
For each n
    Load smoothing, trend smoothing, seasonal smoothing
    Calculate the forecasting value of transformation data using equation 4
    Calculate the value of actual data forecasting, which is the value of transformation data forecasting minus 2, multiplied by STD and plus MEAN
End for
Finish
```

Figure 3: The Proposed Pseudo Code Rainfall Forecasting

The sixth steps is making the climatic classification using oldeman method based on the need of water for the plants especially for the grains. The arrangement of climatic type is based on the number of wet month and dry month in order. The steps for classifying climate using oldeman method are as follows : the first step is determining and converting spatial and temporal data which encompasses coordinate, boundaries, and digital rainfall data. The second step is conducting climatic classification for attributive data based on the oldeman method followed by the interpolation of monthly rainfall and reclassification. The result of this classification was the dissemination map of wet and dry month oldeman classification per month. Finally, overlay and reclassification are done in order to generate the oldeman climatic map based on the predicted data. The seventh step is the arrangement of cultivating season using arithmatic matching and weigth factor matching. The seventh step will be conducted in the future research.

5. EXPERIMENTAL RESULTS

5.5. Rainfall Data

This sub chapter will discuss data visualization and rainfall data analysis. The data used in this research was the monthly rainfall of each sub-district (19 sub-districts in Boyolali) in the period of 2001 – 2012 (12 years, 144 periods). The data was taken from Climatology Meteorology and Geophysics Agency of Central Java province and from Dinas Pertanian, Kehutanan, dan Perkebunan (Disperhutbun) Boyolali district. The use of monthly data for rainfall forecasting was based on the review of literature [5][12][13][25]. The more monthly periods used by the data pattern, the easier to determine the appropriate forecasting method.

The monthly data is the most appropriate data for determining the climatic classification according to the oldeman climatic classification, dividing climatic areas by the amount of wet and dry month in a year. The rainfall data pattern in 2001 – 2012 is depicted in figure 4.

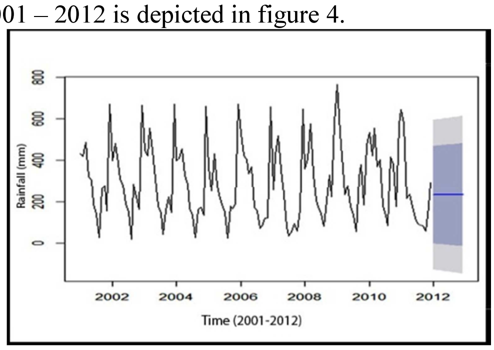
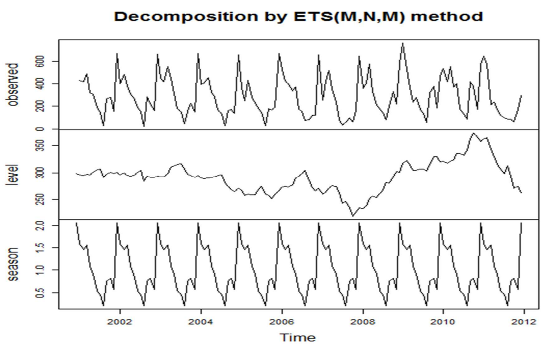


Figure 4: The Graph Of Monthly Rainfall In Boyolali Based On The Data In 2001 – 2012

The pattern of monthly rainfall data in 2001 – 2012 will subsequently be analyzed and interpreted to determine the data pattern (see figure 4). One of conducted analysis is the decomposition analysis as depicted in figure 5. This analysis showed that this research used seasonal data pattern.



ure 5: The Decomposition Graph Of Rainfall In Boyolali Based On The Data In 2001 – 2012

The rainfall dissemination in Boyolali based on the rainfall data in 2001 – 2012 is depicted in figure 6.

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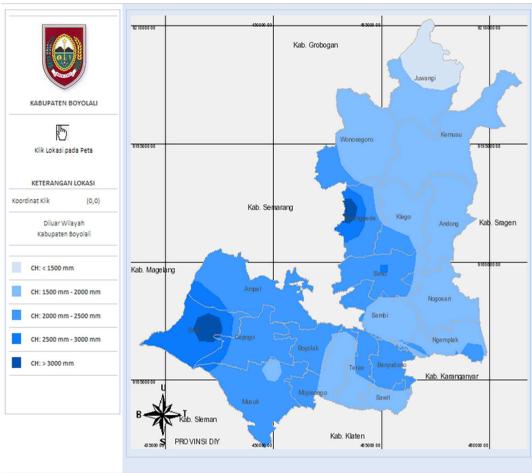

Figure 6: The Map Of Rainfall Dissemination In Boyolali Based On The Data In 2001 – 2012

The preliminary finding showed that there was the peak of rainfall shifting pattern in the period of 1969 -1979, 1979 – 1989 and 2000 – 2010 (see figure 7).

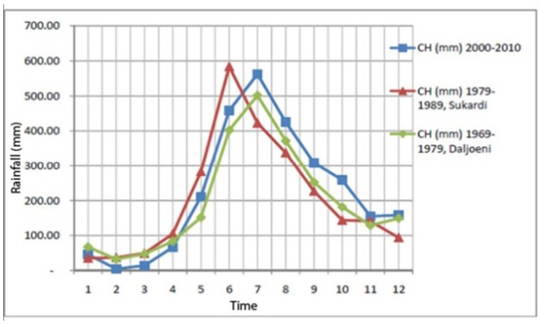

Figure 7: The Shifting Pattern Of Rainfall In 1969 – 2010 [26]

Figure 8 showed that there was a change on the amount of monthly rainfall and the peak of rain shifting in the period of 2000 – 2010 compared to the period of 1969 – 1979 and 1979 – 1989. This condition ensured that there will be the influence to cultivating season (land cultivation time, seedling time, growing time to harvesting). In rainfed farming areas, the characteristic change of the rainfall leads to both the failure and success of farming, especially for grain cultivation that needs great amount of water.

The next step is conducting data normalization. It was done by subtracting raw data intensity for each month to the overall mean data, and then divided by standard deviation from the overall measured intensity (Z-Score method) before added by 2 function of transformation. The aim of normalization process is eliminating the winded data gap.

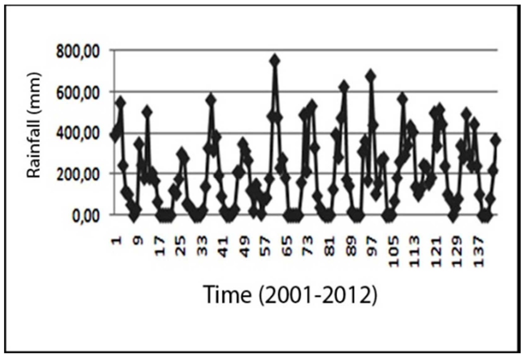

Figure 8: Data Value And Data Pattern Before Normalization

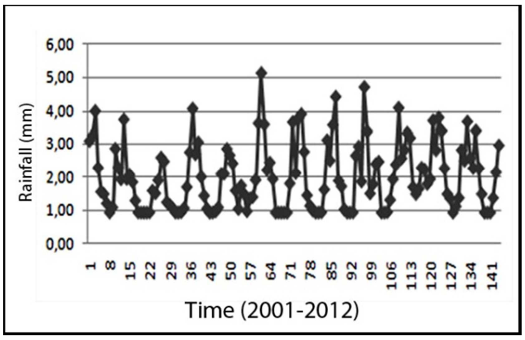

Figure 9: Data Value And Data Pattern After Normalization

In was shown in figure 8 and figure 9 that there is similarity of data pattern before and after normalization. On the other hand, the difference of both graphs is that before normalization process, the highest rainfall level was 756 mm of rainfall in January 2006 and the lowest level was 0 mm of rainfall in some months. After normalization using Z-Score and function of transformation, data gap was smaller, as depicted in figure 10. And the level of rainfall was 5, 11 mm at the highest and 0, 91 mm at the lowest. The result of normalization data will be predicted using winters triple exponential smoothing method.

5.6. Experiment and Discussion

This sub chapter will discuss the comparison result of Winters rainfall forecasting model and rainfall forecasting using proposed model. The next discussion is the result of Oldeman climatic classification using rainfall forecasting data. Forecasting was conducted by using winters triple exponential smoothing method.

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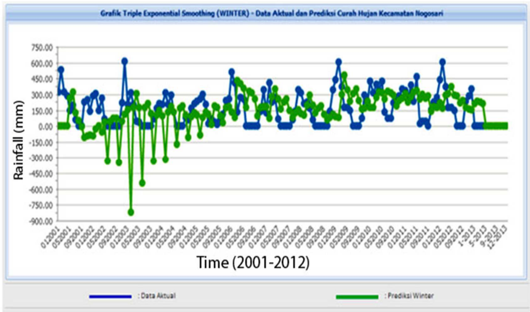

Figure 10: The Graph Of Rainfall Forecasting In Nogosari Sub-District Without Normalization Data

Graphical observation indicated the result of historical forecasting data was inaccurate (see figure 10). Data forecasting of the highest level of rainfall was 478, 26 mm and -822, 37 mm at the lowest. Data pattern of forecasting result for historical data without normalization indicated discrepancy to actual data pattern. However, data pattern of forecasting result indicated trend result. Winters forecasting indicated the effectiveness for short-term. Indicated that the result of forecasting was not more than 4 periods while the following 8 periods indicated 0 value (see figure 10).

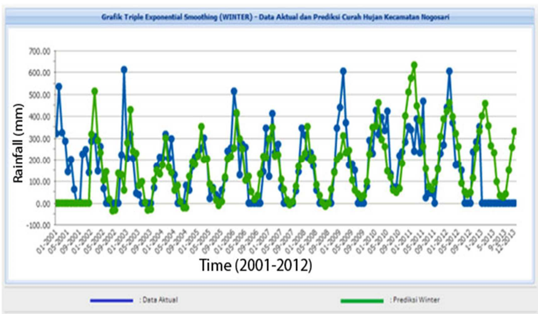

Figure 11: The Graph Of Rainfall Forecasting In Nogosari Sub-District With Normalization Data

The result of forecasting for historical data indicates significant increase of accuracy compared to forecasting without normalization process (see figure 11). The actual rainfall data was 0 mm at the lowest and 613 at the highest and forecasting data was -35 at the lowest and 632 at the highest. Data pattern of forecasting result for historical data through the normalization process indicated that there was congruity to actual data pattern. However, data pattern of forecasting result indicated that seasonal crop was in accordance with the rainfall data attributes. The forecasting using proposed model was able to perform forecasting result up to the 12 following periods.

Table 2: The Measurement Of Forecasting Accuracy In Nogosari Subdistrict

Period	Actual Data	Winters Forecasting Method	Proposed Forecasting Method
.	.	.	.
.	.	.	.
Jan-2012	439	216,524	420,933
Feb-2012	606	169,887	460,228
Mar-2012	370	294,027	395,766
Apr-2012	175	309,042	318,113
Mei-2012	178	369,971	259,588
Jun-2012	150	289,706	89,52
Jul-2012	0	282,866	51,226
August-2012	0	222,943	35,912
Sep-2012	0	240,244	47,363
Oct-2012	235	174,762	116,029
Nov-2012	282	161,01	251,507
Dec-2012	351	152,973	331,146
Jan-2013		212,83	402,083
Feb-2013		234,619	458,124
March-2013		224,157	352,988
Apr-2013		212,417	261,477
May-2013		0	230,191
Jun-2013		0	96,579
Jul-2013		0	33,916
August-2013		0	27,001
Sep-2013		0	40,543
Oct-2013		0	148,721
Nov-2013		0	254,879
Dec-2013		0	328,341
ME		22,248	-1,539
MAD		173,986	78,818

To identify the effectiveness of rainfall forecasting model, the calculation to estimate the forecasting model accuracy using MAD and ME. The model with minimum MAD and ME is proposed to be applied. Table 2, column 1 performs forecasted data period. Column 2 is the actual rainfall data, column 3 is the rainfall data from the result of winters forecasting method, and column 4 is the rainfall data from the result of proposed forecasting model.

Table 2 depicts the measurement result of rainfall forecasting data accuracy for Nogosari sub-district using MAD and ME score. The result indicated that ME score for winters forecasting was

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22,248 and MAD score was 173,986. On the other hand, ME score for proposed model was -1,359 and MAD score was 78,818. From the accuracy and error measurement conducted, it can be concluded that monthly rainfall data forecasting in 12 years in Nogosari sub-district for 12 upcoming periods (the forecasting from January 2013 to December 2013) using proposed method can average increase the accuracy by 63,851 %.

The comparison of MAD and ME score using both winters and proposed models for 19 sub-districts in Boyolali, is shown in table 3, indicates that the proposed model has higher level of accuracy and relatively lower level of error. The average increase of rainfall forecasting accuracy in Boyolali was 64,374 %.

Table 3: The Comparison of MAD and ME Value in Boyolali District

No	Sub-district	Measure-ment Method	Winters Forecasting Model	The Proposed Forecasting Model
1	Ampel	ME	53,199	2,465
		MAD	225,819	96,74
2	Andong	ME	124,912	-1,022
		MAD	241,983	79,976
3	Boyolali	ME	-24,238	0,315
		MAD	174,975	101,903
4	Cepogo	ME	399,252	-3,4
		MAD	476,004	122,033
5	Juwangi	ME	244,869	-10,632
		MAD	390,753	76,058
6	Karanggede	ME	-32,263	-10,44
		MAD	218,61	118,226
7	Mojosongo	ME	209,601	7,082
		MAD	371,47	92,265
8	Musuk	ME	124,394	4,882
		MAD	413,745	122,071

The result of forecasting data from the proposed model can be used for the spatial-based climatic classification using Oldeman method depicted in figure 12.

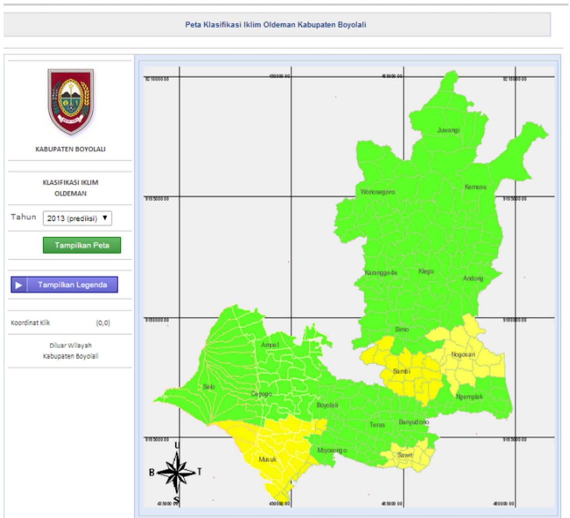

Figure12: The Map Of Spatial-Based Climatic Classification In Boyolali Using Rainfall Forecasting Data

The result of climatic classification using Oldeman method in Boyolali is shown in table 4. Ampel, Andong, Banyudono, Boyolali, Cepogo, Juwangi, Karanggede, Kemusu, Klego, Ngemplak, Selo, Simo, Teras, Wonosegoro and Mojosongo are included in D3 zone. D zone is cultivable for once cultivating season in a year whereas Sambi sub-district is included in C2 zone; Nogosari and Sawit are included in C3. C zone is cultivable for two times harvesting in a year, wherein grain growing when the level of rainfall is below 200 mm per month was done by *gogo rancah* system.

Table 4: The Oldeman Climatic Classification In Boyolali Using Rainfall Forecasting Data

Sub-district	Classification	Wet Month	Dry Month
Ampel	D3	4	5
Andong	D3	4	4
Boyolali	D3	4	5
Cepogo	D3	4	4
Juwangi	D3	4	4
Karanggede	D3	4	5
Mojosongo	D3	3	5
Musuk	C2	5	3

6. CONCLUSION AND FUTURE WORK

There had happened the shifting pattern of peak rain between 1969 -1979 period, 1979 – 1989 periods and 2000 – 2010 periods in Boyolali, Central Java, Indonesia. It ensures that this condition will have an effect on cultivating season.

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The proposed model has higher forecasting accuracy level and relatively lower level of error compared to Winters forecasting model. The average increase of rainfall forecasting accuracy in Boyolali district was 64,374 %. The rainfall data resulted from proposed model can be integrated to climatic classification model using Oldeman method in the research area.

We will improve the accuracy of the weather forecasting result using spatial forecasting. Developing Oldeman climatic classification map with the basis of coordinate location of climatic station in every sub-district using isoyet method. Developing spatial cultivating pattern model through the use of forecasting data resulted and Oldeman climatic classification, and making forecasting model for other areas in Indonesia in the future research.

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