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Stochastic Climate Model for Implementation in Rice Planting Planning

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Abstract

One of the essential problem in this research is the difficulty of prediction skill to analyze the recent characteristics of weather and climate. This condition is estimated due to impact of climate change that affect to change in variation of rainfall. However, along with the development of modeling technology, prediction of weather and climate has develop rapidly to approach the higher accuracy. The modeling is recently using stochastic and deterministic approach.

In this research, one of the climate model was developed and evaluated, namely stochastic approach and its implementation to determine rice planting time. The stochastic modeling used in this research is climate model using Fast Fourier Transform (FFT) and Non-Linier Least Squares methods. The FFT model was increased to 2 steps, namely initial model analysis and anomaly model analysis. In addition, this climate model also utilizes anomaly smoothing using Kalman Filter, to reduce the outlier data. The result of rainfall prediction was subsequently evaluated using observational data to show its validity. The validity was also performed in determination of rice planting time.

The research produced verification in all rainfall stations of Indramayu that was shown by average R-Skill reaching 0.73. The highest R-Skill was obtained in Bondan station, namely up to 0.82 with RMSE of 31.23. In this region, planting time in dry season can be started in the 1st dasarian of April 2013, while planting time in wet season can be started in the 3rd dasarian of October 2013. The result of rainfall prediction show the variation dominantly caused by local factors.

Introduction

In recent years, scientists indicate a climate change occurring in all parts of the world (Thomas, et al., 2006). One of the impacts of climate change on which this study is difficult to predict the weather anymore, meteorological data such as rainfall became lost in its periodic nature. This of course will affect many sectors, such as agricultural activities are highly dependent on the rainy season-dry cycle for early planting and harvesting.
To determine the climate variability that will occur in the future, be required to follow a model variation of meteorological data, so as to predict future weather behavior. The model in question is the mathematical

modeling, where the data is processed with mathematical methods to produce an equation or function that can follow the data (Farhamsa, et al., 2008). The model was created to make quantitative predictions (deterministic or probabilistic), which can be used both to test and refine the previous model, or for practical use (Howison, et al., 2005). Along with the development of modern technology, weather and climate prediction has developed rapidly, ranging from the nature of the stochastic approach such as time series and regression models, to deterministic approaches. In Indonesia, many developing general models of stochastic nature. Analysis techniques are used such as time series analysis, regression Fourier, fractal analysis, neural network (Dupe, 1999 and Boer, 2001). One advantage of stochastic climate models is the resolution depends on the number of observation points in the climate of an area being studied. The more observation stations, the higher the resolution of the predicted outcome. In this study will be developed and evaluated one of the stochastic climate models to be implemented in local area coverage. Stochastic model in question is the climate models using Fast Fourier Transform and Non-Linear Least Squares. This is a function of climate model predictions choose the function that has the smallest error factor. In this study the rainfall data will be enumerated by the method of Fast Fourier Transform (FFT) to see the periodic nature then modeled by non-linear least square method. FFT models in this study will be increased to 2 times the use of FFT, ie at the beginning of model analysis and model analysis anomalies are formed from the initial model. In addition, climate models also use a smoothing anomalies with Kalman filter methods, to reduce some outlier data from its periodic nature. Results of rainfall prediction using the FFT method will be evaluated against observational data to test their validity using correlation method.

Data and Method

The data used in this study is a secondary data obtained from observations of rainfall stations of the Meteorology, Climatology, and Geophysics Agency (BMKG). This data is in the form of daily rainfall observational data of 11 locations in the Indramayu district, over a period of 27 years (1982 to 2009). As for the implementation of the farm, the research also used a rice field maps in Indramayu region.

The climate model development using Fast Fourier Transform and Non-Linear Least Square method was processed by several steps that these measures are based on the inversion method to obtain the best model (Aster, et al., 2005). The daily rainfall data was set to be 10 days each months to be dasarian rainfall data and processed in the climate modeling.

Direct model analysis is the first step in modeling the climate. The goal is to find a stable and stationary initial model which this model reflects a pattern of weather data is pure without any interference and noise in the data. Rainfall data for one location was analyzed by least squares curve fitting to generate the corresponding function to the data. Function used as a fitting curve is taken out of the equation commonly used in modeling. Algorithms used in the Least Square method is Levenberg-Maquardt algorithm which is a standard algorithm for non-Linear Least Square processing.

The next step is to analyze the periodic characteristics of the climate and weather data anomalies. The goal is to get the information on the recurrence pattern of weather anomalies. This step is done with the assumption that the pattern is a periodic weather anomaly. Data anomaly is a deviation of weather data for weather models that are considered as pure pattern for the studied area. Weather models in question are early models produced in the first step. To get the values of frequency anomaly data, the method used is the discrete Fast Fourier Transform. This method serves to change the time domain of rainfall data into the frequency or period of rainfall data. The output of this step is the predominant frequencies of rainfall data that identifies an anomalous weather pattern that will recur.

The last step is to refine model that has been generated in the first step. With this refining, the model was able to reflect expected changes in weather patterns are non-stationary (Farhamsa, 2011).

Verification of the model will be two steps, namely verification using R-Square comparing of the predicted monthly rainfall results against observational data during 1982-2007 and verification using R-Skill comparing of the predicted monthly rainfall results against observational data during 2008.

To verify the results of monthly rainfall prediction, we used the method of R-Square and R-Skill computation on every rainfall prediction in the same station. If the results of R-Square has not met the criteria received an outcome prediction, the modeling will be iterated from an early step to obtain the results of acceptable R-Square and R-Skill. The experts generally stated that a higher correlation of 0.8 is the most good, and less than 0.5 is weak (McLean, 2006).

In the case of R-Square and R-Skill is accepted, map of spatial predictions for rice planting time will be created based on criteria that monthly rainfall is greater than 50

No	Rainfall Station	R-square (1982-1007)	R-Skill (2008)	RMSE (2008)
1	Anjatan	0.77	0.74	65.44
2	Bondan	0.76	0.82	31.23
3	Bugel	0.72	0.73	35.10
4	Cidempet	0.76	0.79	49.55
5	Cikedung	0.77	0.68	43.43
6	Gabuswetan	0.79	0.76	34.55
7	Indramayu	0.80	0.77	50.86
8	Jatibarang	0.74	0.70	46.03
9	Jutinyuat	0.82	0.65	65.11
10	Kedokan Bunder	0.81	0.73	44.60
11	Krangkeng	0.81	0.63	53.56
	Average	**0.78**	**0.73**	**47.22**

Table 1. Verification result of dasarian rainfall prediction in 2008

mm per dasarian (Oldeman, et al, 1980). If the monthly rainfall is more than that amount, then the region has been allowed to start rice planting.

Result and Discussion

Table 1 show the result of verification at all stations indicated by R-Square, R-Skill, and RMSE. R-Square indicates the accuracy of backward model prediction to the historical rainfall data during 1982 to 2007. The highest R-square was obtained in Jutinyuat, namely 0.82. While R-skill indicates accuracy of the forward prediction model to the rainfall data in the same year. In this experiment, the rainfall data in 2008 was tested to the dasarian predicted rainfall, where the highest R-skill is obtained in Bondan station reaching 0.82. RMSE was also considered to indicate the error of predicted rainfall value to the rainfall data. The lowest RMSE is obtained in Bondan station, about 31.23.

In general, there are three causes of local rainfall in Indonesia, namely orographic, convective, and convergence. An orographic rain occur due to the high topographic structure. A convective rain occur due to heating by the sun on the oceans. And, convergence rain occur due to air mass meeting at the center of low pressure.

Of the three types of causes rain because the local effects, there are two possibilities that occur in Indramayu district, namely convective and convergence, because Indramayu district does not have characteristics of a high topography variation.

Actual rainfall patterns in the area of Indramayu was normally only affected by monsoonal pattern (Estiningtyas, et al., 2011). There are two possible causes of the rainfall occurs in Indramayu district, namely convective and convergence factors. Because along the boundary line of Indramayu region bordering the ocean, this condition causes the rain is raised by the presence of convective clouds due to dominant solar heating to ocean. Mostly in the first 6 months (January to July), Indramayu region always occurs rain started in the north and further to the south. Shift in rainfall from north to south is also due to the high air pressure differences between land and ocean causing the sea breeze especially in the afternoon, the sea

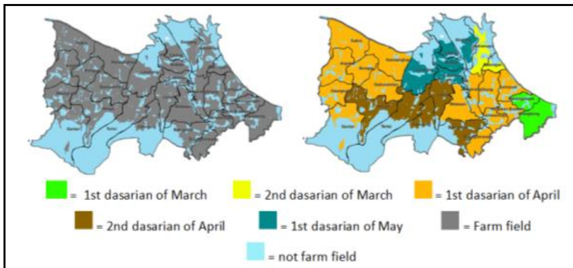

Figure 1: Prediction map of rice planting in the dry season 2013 in the Indramayu district: (a) farm field map of Indramayu, (b) map of Indramayu + rice planting predictions

breeze blowing from sea to land and bring moist air mass to the mainland Indramayu. But as a whole, the Indramayu region occur a three wet month from December to February and four dry month from July to October (Slamet, et al., 2001).

The following is a map of the rice planting prediction in the district of Indramayu in the dry season 2013 showed in Figure 1. In the dry season 2013, the Indramayu district is divided into 5 time of planting. At 1st dasarian of March 2013, the beginning of the rice planting can be done for at Krangkeng and Karangampel. 2nd dasarian of March, the region can start planting in Balongan and Indramayu district. 1st dasarian of April 2013, the region can start planting in Sukra, Anjatan, Bongas, Haurgeulis, Gabuswetan, Gantar, Kandanghaur, Widasari, Jatibarang, Sliyeg, Jutinyuat, Kertasemaya, Sukagumiwang, and Kedokan Bunder. 2nd dasarian of April 2013, the region begin planting in Kroya, Terisi, Cikedung, Lelea, and Bangodua. 1st dasarian of May 2013, the region could begin planting in the district of Losarang, Lohbener, Arahan, Cantigi, and Sindang.

Conclusions

Based on the analysis, some conclusions can be drawn as follows: (1) the results of the verification of rainfall prediction suggests that climate models is valid for use in Indramayu areas that have achieved average R-Skill of 0.73, (2) the highest R-skill achieved in the station Bondan, amounting to 0.82 with a RMSE of 31.23. At this region, the planting season in the dry season 2013 will begin on 1st dasarian of April 2013 and in the rainy season 2013 will begin in 3rd dasarian of October 2013, (3) dasarian rainfall prediction shows that average rainfall variability in the district of Indramayu will be more dominant caused by local factors, ie differences in land and sea, especially those occurring in the northern area of Indramayu, and (4) early planting of rice in Indramayu district is generally done after the collection of rainfall during the 2-3 dasarian with rainfall amount of 50 mm per dasarian.

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