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A Calculation The Grey Forecasting Method of Maize Productivity In Indonesia

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Abstract : *The accuracy of forecasting is a crucial issue for decision-makers regarding planning. During the recent years, several techniques have used for forecasting in order to accurately predict the future demand. Although there are several forecasting techniques, selection of the most appropriate one is of paramount importance. The advancement of technology contributed to the improvement of maize plantation in Indonesia, and it shows increased expressively year by year and irregular cycles which bring suitable data series to accurate forecasting. This paper proposes a GM (1,1) forecasting method with time-series data to predict the maize productivity in Indonesia by this study delivers better forecasting performance. After assortment, the real data about the total production of maize in Indonesia from 1994 to 2015, then the result show the error from the actual data and the forecasting result have a positive correlation found between the actual data and the forecasting outcome from Grey forecasting method. This correlation related to previous research and study about Grey forecasting stated that with the Grey forecasting method suitable for short-term and long-term prediction.*

Keywords : *forecasting, GM (1, 1), grey, maize, productivity*

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I. Introduction

Presently is the best moment to export maize for Indonesia due to the increasing total production in a recent year. Boosting maize exports will undoubtedly benefit many parties involved in maize farming, including farmers. Indonesia also gets the benefit because will be able to generate more foreign exchange in the form of rupiah. Indonesian maize production from 1994 to 2017 shows an upward trend; this is in line with the increase in harvested area in the same period. However, the increase in domestic production has not been able to meet domestic needs so that sometimes the government must import maize from abroad. Furthermore, the Ministry of Agriculture claims that from this year maize production has a surplus with the intention of Indonesia has the opportunity to boost exports to several countries with a target of 300 thousand tons this year. After exporting to the Philippines, the next destination for Indonesian maize exports should be in Malaysia.

Moreover, based on data from the Ministry of Agriculture, national maize production in 2017 reached 27.95 thousand tons from the previous year of only 23.58 million tons. Maize production is the highest compared to previous years and this year is predicted to grow 7.34%. The area of maize harvested land last year increased by 20.95% to 5.3 million Ha from the previous year of 4.44 million Ha. Although the national maize productivity in 2017 reached 52 Quintal (Qu) / Ha decrease 1.98% from the previous year realization 53.05 Qu / Ha. However, the objective of this study is to predict the total of productivity maize in Indonesia using secondary data from Statistic Indonesia from 1994 to 2015.

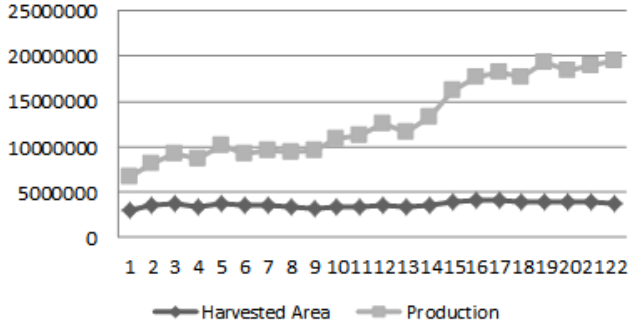

Fig 1. Total Harvested Area and Production of Maize in Indonesia

II. Literature Review

Grey System theory introduced in 1982[1], Professor Julong Deng's paper titled "The Control Problems of Grey Systems" the first paper on grey systems to be published in the Systems and Control Letters journal. In that same year, Professor Deng also published "Grey Control System" in Chinese and the paper published by the Journal of Huazhong University of Science and Technology.

The publication of these two seminal articles indicated that a new and cross-sectional discipline named grey system theory came into the world[2]. Furthermore, the result from Grey shows the significant error from the real data and the forecasting result have a positive correlation found between the real data and the forecasting outcome from Grey forecasting method[3]. Grey is suitable for short-term and long-term prediction[4]. Lately, the result from Grey method not only improve the forecasting accuracy of the original Grey models but also provide a valuable reference[5]. The Grey forecasting method has successfully applied in many areas of research including business[6], engineer[7], economics[8], technology[9] and management[10]. Therefore, this paper proposes a GM (1, 1) approach based on the extended GRA method.

III. Grey Forecasting Method

A grey number is a figure that represents a range of values rather than an exact value when the exact value for the said figure is not known. The range of a grey number can be an interval or a general number set. Grey numbers usually expressed as the symbol "⊗", which is called grey. A grey number represents the degree of information uncertainty in a given system. As the basis of grey systems theory, research on grey numbers and grey measures have attracted increased attention over the past years. Therefore, a large number of scholars have conducted in-depth research, such as optimization of background value, grey derivative, initial value, improvement of data smoothness and establishment the discrete GM (1,1) model to improve the model of simulation and prediction accuracy.

In consequence, an expression introducing the comparison of rolling modeling data and fundamental data of forecast results show as Fig. 1. The average residual error different rolling modeling GM (1,1). For instance, in method 1: Choose the first four continuous data to predict the 5th of the output value, 2nd to 5th serial data to predict the 6th output value and after that. Besides, in Method 2: forecast the 6th of the production value by adopting the first five following data, 2nd to 6th continuous data to forecast the 7th output value and henceforth. Furthermore, the study presents methodologies for projecting the most accurately predicts of the amount of maize productivity in Indonesia by testing the precision of the Grey forecasting model.

The procedure of this method can be designated as follows:

Step 1. Form the row matrix $X^{(0)}$ for the historical time data as

$$X^{(0)} = \left\{ X^{(0)}_{(1)}, X^{(0)}_{(2)}, \ldots, X^{(0)}_{(n)} \right\} \tag{1}$$

Step 2. Form a row matrix of $X^{(l)}$ by Accumulated Generating Operation (AGO) as

$$X^{(1)} = \left\{ X^{(1)}_{(1)}, X^{(1)}_{(2)}, \ldots, X^{(1)}_{(n)} \right\} \tag{2}$$

where

$$X^{(0)}_{(k)} = \left\{ \sum_{i=1}^{k} X^{(0)}_{(i)}, k = 1, 2, \ldots, n \right\} \tag{3}$$

Step 3. Form the Grey differential equation

$$X^{(0)}_{(k)} + a.2^{(1)}_{(k)} = b \qquad k = 1, 2, 3, \ldots, n \tag{4}$$

where

$$Z^{(1)}_{(k)} = \alpha . X^{(1)}_{(k)} + (1 - \alpha) . X^{(1)}_{(k-1)} \tag{5}$$

which can write as

$Yn = B.a$ where (6)

$$B = \begin{Bmatrix} -Z^{(1)}{}_{(2)} 1 \\ -Z^{(1)}{}_{(3)} 1 \\ \\ -Z^{(1)}{}_{(n)} 1 \end{Bmatrix} \tag{7}$$

$$Y_n = \begin{Bmatrix} X_1^{(0)}{}_{(2)} \\ X_1^{(0)}{}_{(3)} \\ \\ X_1^{(0)}{}_{(n)} \end{Bmatrix}; \bar{a} = \begin{Bmatrix} a \\ b \end{Bmatrix} \tag{8}$$

Step 4. *a* and *b* coefficients are found by solving

$$\bar{a} = \begin{Bmatrix} a \\ b \end{Bmatrix} = \left(B^T B\right)^{-1} B^T Y_N \tag{9}$$

Step 5. From the Grey differential equation

$$\frac{\partial X^{(1)}}{\partial t} + a.X^{(1)} = b$$

is solved by using the initial condition

$$X_{(1)}^{(1)} = X_{(0)}^{(1)} \tag{10}$$

The AGO Grey prediction equation can obtain as

$$\hat{X}_{(k+1)}^{(1)} = \left(X_{(1)}^{(0)} - \frac{b}{a} \right).e^{a.(k)} + \frac{b}{a} \tag{11}$$

where ^ denotes Grey prediction value.

Step 6. The consumption forecast value is obtained by

$$X_{(k+1)}^{(0)} = X_{(k+1)}^{(1)} - X_{(k)}^{(1)} \tag{12}$$

The prediction value is

$$\hat{X}_{(k+1)}^{(0)} = \left(1 - e^{a}\right).\left(X^{(0)}{}_{(1)} . \frac{b}{a} \right) e^{a.(k)} \tag{13}$$

IV. Results

Data collected from Statistic Indonesia used to forecast the maize productivity in Indonesia. This study created results that corroborate the findings of several previous studies in this field. What is noteworthy in Table 1 is that the raw data of the household electricity consumption in Indonesia from 1994 to 2015. Likewise, in Table 1 showed the average residual error from the Grey forecasting. Relating the results, it could see that the result from Grey forecasting to predict the maize productivity in Indonesia have a low error. Interestingly, on an average residual error, only one has a more significant error which is in 4 years prediction about 3.41 % error. The calculation of GM (1,1) method in this study referred to predict the maize productivity in Indonesia from 1994 to 2015. The results indicated that the average accuracy of the forecasting model exceeds relatives' low error expressively.

Table 1. Real Data and Average Error Analysis.

Year	Real Data $x^{(0)}(k)$	Average Error $\Delta_k = \frac{\lvert\varepsilon(k)\rvert}{x^{(0)}(k)}$	Year	Real Data $x^{(0)}(k)$	Average Error $\Delta_k = \frac{\lvert\varepsilon(k)\rvert}{x^{(0)}(k)}$
1994	22.1600	-	**2005**	34.5400	0.0098
1995	22.6400	-	**2006**	34.7000	0.0273
1996	24.9700	-	**2007**	36.6000	0.0301
1997	26.2600	-	**2008**	40.7800	0.0828
1998	26.4900	0.0732	**2009**	42.3700	0.0362
1999	26.6300	0.0308	**2010**	44.3600	0.0359
2000	27.6500	0.0296	**2011**	45.6500	0.0122
2001	28.4500	0.0120	**2012**	48.9900	0.0305
2002	30.8800	0.0466	**2013**	48.4400	0.0566
2003	32.4100	0.0003	**2014**	49.5400	0.0196
2004	33.4400	0.0384	**2015**	51.7800	0.0432

Data Source: (BPS) Statistics Indonesia and authors calculation

Table 2. Average Residual Error

Year	Total Error
4	3.41%
5	3.32%
6	3.09%
7	3.08%
8	3.26%
9	3.11%
10	2.90%
11	2.89%
12	3.19%

What is noteworthy in Fig 2 is that 3.41 % average error precisely in several years is nearly matching with the real data. The model thus clearly has high prediction validity and is a sustainable goal for forecasting the maize productivity in Indonesia. Substantial evidence of Grey forecasting found when in the fourth year's prediction such shows in Fig. 2. It is apparent from Fig. 2 that very few average errors indicate.

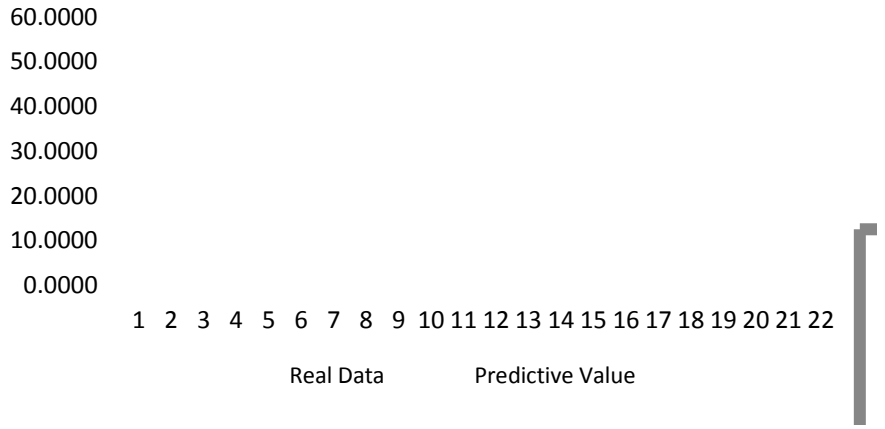

Fig 2. Grey forecasting rolling model

An optimum number to forecast of maize productivity in Indonesia has developed with α = 0.4, data series length m = 4, and data series step △ = 1. Slightly worse prediction results obtained with α = 0.4, *m* = 4 and △= 12, that is with the prediction from the previous years. Additionally, the results for a four years period the total error ranges start from 3.41 % to 3.19% in the different years and periods as we can see in Table 2. Also, the lower error is 2.89 % for the 11 years. Focus on 10 and 11 years prediction the total error only 2.90 % and the highest error 3.41% in 4 years prediction. Furthermore, there was a significant dissimilarity between the two conditions real data for the total supply and demand for the maize productivity in Indonesia. The total consumption data is fluctuating seems to increase slowly. Overall, the average error in the maize productivity in Indonesia measures that Grey forecasting accurately observed.

V. Discussion And Conclusion

The evaluation of the GM (1,1) method in this study referred to predict the maize productivity in Indonesia from 1994 to 2015. The results indicated that the average accuracy of the forecasting model exceeds relatives' low error significantly. The model thus clearly has high prediction validity and is a sustainable goal for forecasting the maize productivity in Indonesia. Substantial evidence of Grey forecasting found when in the fourth year's prediction such shows in Fig. 1. It is apparent from Fig. 1 that very few average errors indicate. What is noteworthy in Fig. 1 is that 3.41 % average error precisely in several years is nearly matching with the real data. The maize productivity in Indonesia will continue to increase, and it will drive to make a new plan for mapping in the future, and from the forecast, the result can count the total production and harvested area from Indonesia to prepare a better strategy in the future. The consequences also agree with our earlier observations, which demonstrated that result could explain and forecast for instance, in method 1: choose first four continuous data to predict the 5^{th} of the output value, 2^{nd} to 5^{th} following data to predict the 6^{th} output value.

Grey system modeling from GM (1,1) usually exhibits maximum accuracy for = 0.5. Focus on Fig. 2, the result of forecasting the total of maize productivity in Indonesia depends on the original data. The essential structures of the Grey forecasting technique are to determine data series to acquire upcoming prediction numeral using previous numbers such as, in this study using dataset about the household electricity consumption in Indonesia since 1994 to 2015. In this paper, the Grey system modeling based on the experimental results for

forecasting the maize productivity in Indonesia were examined and showed the number about 3.41% total error to predict range one to four years. Interestingly, in 11 years the total error is relatively small about 2.89 %. That indicates the Grey forecasting method not permanently have a real total error in the range of fourth years but in another range of the year might have the small total error. Furthermore, the maize productivity in Indonesia illustrates the small residual average error. As a result of the test that conducted that the maize productivity in Indonesia increased year by year according to the real data and the Grey forecast method. Indicates Indonesia could be the fifth largest economy in the world by 2030 based on purchasing power parity and the fourth largest by 2050. Achieving those levels will require significant investment in infrastructure, including agriculture, to drive higher GDP growth. In summary; it implies that Indonesia government should make the action plan for the future to develop agriculture sectors.

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