Jurnal Ilmiah KURSOR
Menuju Solusi Teknologi Informasi

Vol. 9, No. 4, Desember 2018

ISSN 0216 – 0544
e-ISSN 2301– 6914

THE IMPLEMENTATION OF GREY FORECASTING MODEL FOR FORECAST OF CAPTURED FISHERIES PRODUCTION

[a]Muhammad Shodiq, [b]Budi Warsito,[c]Rachmat Gernowo

[a] Magister of Information System, Diponegoro University, Semarang, Indonesia.
[b]Department of Statistics, Diponegoro University, Semarang, Indonesia.
[c]Department of Physics, Diponegoro University, Semarang, Indonesia.
E-mail: [a]Shodiqmuhammad13@gmail.com, [b]budiwrst2@gmail.com,
[c]gernowo@yahoo.com

Abstract

The increasing need for fish causes problems related to production in the fisheries sector. In fisheries production all information related to fishing ground is well known, but on the other hand it is not easy to predict the amount of production due to unclear information. This is also related to the number of ships that make trips, the length (time) of the trip, the type of fishing gear, weather conditions, the quality of human resources, natural environmental factors, and others. The purpose of this study is to apply Grey forecasting model GM (1,1) to predict fisheries production. Grey forecasting models are used to build forecast models with limited amounts of data with short-term forecasts that will produce accurate forecasts. This study employs the data of captured fish from 2010 to 2018 to analyze calculations using the GM model (1,1). The results showed that the Grey Forecasting Model GM (1.1) produced accurate forecasts with an ARPE error value of 9.60% or the accuracy of the forecast model reached 90.40%.

Key words: Fisheries Production, Forecasting, GM (1,1), Grey Forecasting..

INTRODUCTION

The Developments in the fisheries sector, especially captured fisheries are currently related to the problem of overfishing [1]. This activity will create a significant reduction in fisheries resources along with filling production needs and the rapid pace of the economy wheel. The Increasing number of life needs related to fisheries resources requires planning and decision making for evaluation of fisheries management policies in order to obtain optimal results [2]. Fishery products have an important contribution to the other production activities and food security and also provide jobs opportunities; there for a policy is needed to manage socio-economic sustainability of the fisheries sector [3]. By understanding the upcoming fish production, it is possible to take advantage from it and use it as reference for planning and making decision optimally.

Obtaining optimal results in forecasting fisheries production isn’t easy. It caused by unclear information obtained. One of the information related to the catch area is well-known, but it’s still difficult to forecast fisheries production. The difficulties are related to the number of ships sailing, sailing time, types of fishing gear used, weather conditions, natural environmental factors, engine strength used and the capacity of the vessels used [4].

Grey system is a system with partially known and partially unknown information. The theory of grey systems can be used in various fields to solve problems [5]. One of the grey system models is GM (1,1). The GM (1,1) model can be used for forecast with limited data samples. Compared to the time series analysis model the advantage of GM (1.1) model is it can be applied to limited data with short-term forecast that produce accurate forecast, besides this model also does not consider the statistical distribution of processed data [6].

Forecasting fish production can be applied as a first step to find the coming fisheries results, the implementation of grey forecasting will provide benefit if linked to the forecasting system. Using grey forecasting it is possible to develop an appropriate tool for forecasting systems that have important functions in planning and policy making [7]. In addition, grey forecasting has been used in forecasting the electric power’s price to produce very accurate forecast [8]. Forecasting of agricultural products using GM (1,1) show accurate forecast results [9], the forecast of the syphilis incidence in China using GM (1,1) shows that GM (1,1) produces accurate forecast [10], and the forecast of China's electricity consumption by comparing grey forecasting and ARIMA shows that grey forecasting has the smaller MAPE than ARIMA [11].

In previous researches, grey forecasting was widely used in cases to electricity forecasting, disease incidence, and agricultural products. In this research, grey forecasting was applied to the fisheries sector in the case of fisheries production. This research aims to find or help grey forecasting in fisheries production can produce high forecast accuracy, as in previous researches using grey forecasting.

Based on these problems, a fisheries production forecasting system is needed, so it can be used to find the information of fish production amount, one of the models used is GM (1,1). In this research, the implementation of GM (1,1) produced an information on fisheries production forecasts that could be used as input material and for the fish supply’s strategies of the following period.

FORECAST

There are several definitions of forecasts, one of them in the Great Dictionary of Indonesian Language (KBBI), which states that forecasting is estimating an event based on the results of rational calculations. While other definitions of forecasting, are:

a. Forecasting is a knowledge to predict future events carried out in a continuous sequence of studies [12].
b. Forecasting is an important tool for companies in planning and determining policies in their operational activities [13].
c. Forecasting is a tool that handles important problems in various fields including, economics, physics, and engineering [14].

Based on these definitions, forecasting is a tool that is used to make decisions on future events by involving historical data and projecting it into the future with a mathematical model. The obtained results could help on various fields in determining policy.

GREY SYSTEM THEORY

Grey system theory was introduced by Professor Deng Julong in 1982. Grey system theory is a system that has some known parameters or systems with less information.

The purpose of this theory and its application is to link the gap between natural science and social science. Therefore, grey system theory can be utilized in various fields to solve problems [5].

The name grey system was taken based on the color of the subject under study. In control theory, the level of color depth is used to explain the level of information clarity. One of well-known type of it is called black box. This concept is usually used if internal characteristics or mathematical equations that describe dynamics are completely unknown [15]. The word black describes unknown information, white for information that is completely clear or identified and grey shows information that is partly clear and partly unclear. Therefore, systems with completely unknown information are called black systems, systems that have clear information are called white systems, and systems with incomplete information are called grey systems [16].

GM type (1,1) is a type of grey system theory that is widely used in various fields because of its efficiency in terms of calculations rather than other grey system theories. The GM type (1,1) is usually known as Grey Model First Order One Variable which making predictions by using time series data [10].

GREY FORECASTING

Grey Forecasting Model or abbreviated as GM (1,1) is a method used for forecasting a limited and short-term amount of data that produces an accurate forecasting model with no need to consider statistical distribution of data processed [6]. This forecast can be used for line forecasting, natural disaster forecasts, interval forecasts, season forecasts and capital market forecast [5]. This general forecasting model is GM (*n*,*m*) where *n* is the order of differential equations and *m* is the number of variables in equation [15].

In the estimation stage of the grey model parameter, a technique is needed to change random raw data into regular data to form a grey model or known as grey generating. There are two grey generating techniques, namely:

a. AGO (Accumulated Generating Operation) is a generator function to accumulate historical data sequences to obtain a new line of historical data in differential equations.
b. IAGO (Inverse Accumulated Generating Operation) is used to obtain predictive values from original data that previously changed to AGO.

Grey forecasting is defined in the form of differential equations, in the model there are parameter values a and b that must be searched before by applying the grey generating technique for the original data.

Grey forecasting or GM (1,1) procedure can be done with the following steps [9]:

1. Compile original data series based on time sequence

$$x^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(k)\right), \quad k \geq 4 \qquad (1)$$

2. By taking the first order of accumulation to produce an operation (1-earlier) at $x^{(0)}$,, we can obtain a new data series of 1-AGO (Accumulated Generating Operation), namely:

$$x^{(1)} = \left(x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(k)\right), \quad k \geq 4 \qquad (2)$$

with

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{0}\,(i), k = 2, 3, \dots, n$$

3. Calculate the background value of $z^{(1)}$ built with the generation method based on the average value of two data $x^{(1)}(k)$ which contiguous.

$$z^{(1)}(k) = 0.5\left(x^{(1)}(k-1) + x^{(1)}(k)\right), \qquad (3)$$

$$k = 2, 3, \dots, n$$

4. Next for each pair of values of $x^{(0)}(k)$ dan $z^{(1)}(k)$ is formed to apply the differential grey equation in GM (1,1). But before forming GM (1,1) it is necessary to know the definition of the first *grey* order differential equation is

$$\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b.$$

If integrated

$$\frac{dx^{(1)}(k)}{dk} + ax^{(1)}(k) = b$$

at the interval

$$[k-1, k],$$

$$\int_{k-1}^{k} \frac{dx^{(1)}}{dk} dk + a \int_{k-1}^{k} x^{(1)} dk = b,$$

Then obtained

$$x^{(1)}(k) - x^{(1)}(k-1) + a \int_{k-1}^{k} x^{(1)} dk = b,$$

Namely:

$$x^{(0)}(k) + a \int_{k-1}^{k} x^{(1)} dk = b$$

dan and the difference equation shown as shadow equation:

$$x^{(0)}(k) + az^{(1)}(k) = b, \qquad (4)$$

With

$$z^{(1)}(k) = \int_{k-1}^{k} x^{(1)} dk, k = 2,3, \dots n.$$

With a is the developer coefficient, and b is the grey input variable.

5. To get the parameter values a and b, use the least square estimate $\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix}$.

$$\hat{a} = (B^T B)^{-1} B^T Y \qquad (5)$$

With

$$Y = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \quad B = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(n) & 1 \end{bmatrix} \qquad (6)$$

6. Under the initial conditions such as $x^{(1)}(1) = x^{(0)}(1)$, the solution of the grey differential equation GM (1,1):

$$\hat{x}^{(1)}(k) = \left(x^{(0)}(1) - \frac{b}{a} \right) e^{-a(k-1)} + \frac{b}{a}, \qquad (7)$$

$k = 2, 3, \dots, n$

7. Use (IAGO) Inverse Accumulated Generating Operation to get the forecast value $\hat{x}^{(0)}(k)$

$$\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1), \qquad (8)$$

$k = 2, 3, \dots, n$

ACCURACY MODEL FORECASTING

In forecasting, it is necessary to measure how accurate the method that used. To find out the accuracy of the forecast used method, the measurement is done by using RPE (Relative Percentage Error) to determine the estimated error value by using the original value of both positive and negative errors. Then then using ARPE (Average Relative Percentage Error) to show the accuracy of the forecast method can be seen from the magnitude of the average percentage value of absolute error [15].

$$\in (k) = x^{(0)}(k) - \hat{x}^{(0)}(k) \qquad (9)$$

$$\text{RPE}(k) = \frac{|\in(k)|}{x^{(0)}(k)} \times 100\% \qquad (10)$$

$$\text{ARPE} = \frac{1}{n-1} \sum_{k=2}^{n} \frac{|\in(k)|}{x^{(0)}(k)} \qquad (11)$$

$$\text{Accuracy} = 100 - \text{ARPE} \qquad (12)$$

Annotation:
$x^{(0)}(k)$ = original data value
$\hat{x}^{(0)}(k)$ = forecast value
$|\in(k)|$ = absolute remnant value.

Table 1. Standard measure of the accuracy of forecast model [17].

RPE(k) and ARPE (%)	Forecast Potency
<10%	Very accurate
10-20%	Accurate
20-50%	Quite accurate
>50%	Innacurate

RESULT AND DISCUSSION

This research was conducted at Brondong Nusantara Fisheries Port, Lamongan using annual production data from 2010 to 2018 and this forecast system fisheries production is build using PHP and MySQL.

Table 2. Annual production data

Year	Production Data
2010	46569
2011	60769
2012	52249
2013	57198
2014	46432
2015	49278
2016	57763

2017	58145
2018	71626

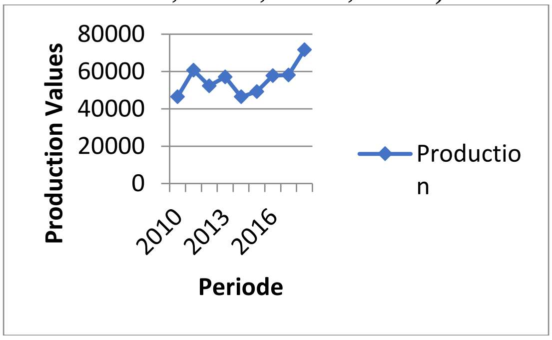
Based on table 2 production data, a grey forecasting model will be calculated. The first step in this calculation starts from:

1. Form the initial data series (equation 1).

Table 2. Initial Data (production)

k	Year	Production Data
1	2010	46569
2	2011	60769
3	2012	52249
4	2013	57198
5	2014	46432
6	2015	49278
7	2016	57763
8	2017	58145
9	2018	71626

$x^{(0)}$ = (46569, 60769, 52249, 57198, 46432, 49278, 57763, 58145, 71626)



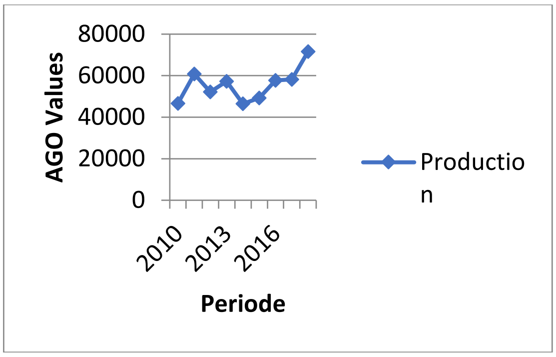
Picture 1. Production data chart

2. Set AGO sequence (Equation 2)

Table 3. Post-AGO Production data

k	AGO
1	46569
2	107338
3	159587
4	216785
5	263217
6	312495
7	370258
8	428403
9	500029

$x^{(1)}$ = (46569, 107338, 159587, 216785, 263217, 312495, 370258, 428403, 500029).



Picture 2. Post-AGO Data chart

Based on picture 2 the original data graph, it appears that the data pattern is not monotonous, while in picture 3 the post-AGO graph shows that the data pattern is monotonically go up.

3. Determine the background value of two data $x^{(1)}(k)$ that are contiguous, the results of the average will be used to calculate the matrix formation parameters a and b (Equation 3).

Table 4. Rows of background values

k	Background Values
1	46569
2	76954
3	133463
4	188186
5	240001
6	287856
7	341377
8	399331
9	464216

$z^{(1)}$ = (46569, 76954, 133463, 188186, 240001, 287856, 341377, 399331, 464216)

4. Calculating least square estimate to find out the parameter values a and b, done by specifying the matrix B and Y (Equation 6).

$$Y = \begin{bmatrix} 60769 \\ 52249 \\ 57198 \\ 46432 \\ 49278 \\ 57763 \\ 58145 \\ 71626 \end{bmatrix}, \quad B = \begin{bmatrix} -76954 & 1 \\ -133463 & 1 \\ -188186 & 1 \\ -240001 & 1 \\ -287856 & 1 \\ -341377 & 1 \\ -399331 & 1 \\ -464216 & 1 \end{bmatrix}$$

After B and Y matrix are formed, then calculate the multiplication of the B *transpose* matrix with matrix B (B^TB), the result of multiplying the B matrix *transpose* with B will be converted to inverse matrix $B^TB)^{-1}$, then calculates the *B transpose* matrix with the *Y* matrix *Y* (B^TY).

a. Calculate multiplication of matrix $B^T B$

$$B^T B = \begin{bmatrix} 691108865040 & -2131382 \\ -2131382 & 8 \end{bmatrix}$$

b. Calculates inverse multiplication of matrix $[B^TB]^{-1}$

$$[B^T B]^{-1} = \frac{1}{986E+09} \begin{bmatrix} 8 & 2131382 \\ 2131382 & 691E+09 \end{bmatrix}$$

$$= \begin{bmatrix} 8.11292E-12 & 2.16147E-06 \\ 2.16147E-06 & 0.700E+06 \end{bmatrix}$$

c. Calculate multiplication of matrix $B^T Y$

$$B^T Y = \begin{bmatrix} -123930164540 \\ 453460 \end{bmatrix}$$

5. Calculate parameters *a* and *b*, parameters *a* and *b* can be known after doing calculations with matrix multiplication ($[B^T B]^{-1} * B^T Y$) (Equation 5).

$$\hat{a} = \begin{bmatrix} 8.11E-15 & 2.16E-09 \\ 2.16E-09 & 0.700E+06 \end{bmatrix} \begin{bmatrix} -1.23E+13 \\ 453460 \end{bmatrix} = \begin{bmatrix} -0.02529693 \\ 49942.82367 \end{bmatrix}$$

Since $\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix}$, Then gained parameter value α = -0.02529693 dan $b = 49942.82367$

6. Apply GM differential grey equation (1,1) Based on the equation of GM model (1,1) with the known parameters are Equation 4:

$$\frac{dx^{(1)}(k)}{dk} + -0.02529693 \quad z^{(1)}(k) = 49942.82367$$

And the response function at $(k+1)$ and first-order original data is (Equation 7):

$$\hat{x}^{(1)}(k) = \left(x^{(0)}(1) - \frac{b}{a}\right) e^{-a(k-1)} + \frac{b}{a}$$

$$\hat{x}^{(1)}(k+1) = \left(46569 - \frac{49942.82367}{-0.02529693}\right) e^{-(-0.02529693)(k)} + \frac{49942.82367}{-0.02529693}$$

$$= (46569 + 1974264.603)e^{0.02529693(k)} - 1974264.603$$

$$= 2020834e^{0.02529693(k)} - 1974264.603$$

From the operation above, the obtained forecast value is $\hat{x}^{(1)}(k)$ a few steps ahead:

$\hat{x}^{(1)}(2) = 98341.96365$
$\hat{x}^{(1)}(3) = 151441.3303$
$\hat{x}^{(1)}(4) = 205901.0819$
$\hat{x}^{(1)}(5) = 261756.0709$
$\hat{x}^{(1)}(6) = 319042.0428$
$\hat{x}^{(1)}(7) = 377795.6589$
$\hat{x}^{(1)}(8) = 438054.5195$
$\hat{x}^{(1)}(9) = 499857.1885$
$\hat{x}^{(1)}(10) = 563243.2176$
$\hat{x}^{(1)}(11) = 628253.1719$

7. Apply (IAGO) Inverse Accumulated Generating Operation to get the forecast value $\hat{x}^{(0)}(1)$ (Equation 8).

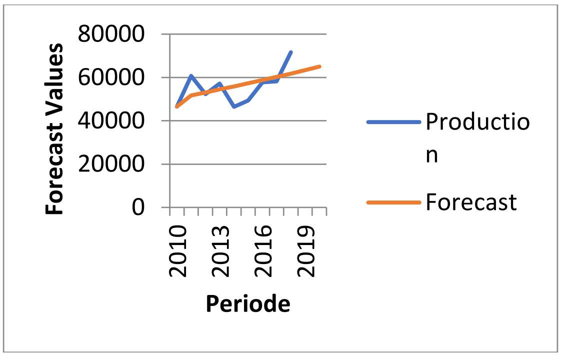
$\hat{x}^{(0)}(2) = 51772.96365$
$\hat{x}^{(0)}(3) = 53099.36665$
$\hat{x}^{(0)}(4) = 54459.75158$
$\hat{x}^{(0)}(5) = 55854.98904$
$\hat{x}^{(0)}(6) = 57285.97193$
$\hat{x}^{(0)}(7) = 58753.61605$
$\hat{x}^{(0)}(8) = 60258.86062$
$\hat{x}^{(0)}(9) = 61802.66898$
$\hat{x}^{(0)}(10) = 63386.02910$
$\hat{x}^{(0)}(11) = 65009.95428$

From the results of IAGO, the value of the original data obtained is obtained, $\hat{\boldsymbol{x}}^{(\mathbf{0})}(\mathbf{10})$ dan $\hat{\boldsymbol{x}}^{(\mathbf{0})}(\mathbf{11})$ is the result of forecasts for the next 2 years. After forecast value is obtained, the next step is to measure forecast errors. This step is used to measure the accuracy of the model that used (equations 9, 10, 11, and 12).

The difference between the original value and the forecast value is as Table 5 and Picture 3.

Table 5. Grey forecasting calculation results

Year	Production	Forecast	Error	RPE
2010	46569	46569	0	0
2011	60769	51773	8996	15
2012	52249	53099	-850	2
2013	57198	54460	2738	5
2014	46432	55855	-9423	20
2015	49278	57286	-8008	16
2016	57763	58754	-991	2
2017	58145	60259	-2114	4
2018	71626	61803	9823	14
2019		63386		
2010		65010		



Picture 3. Forecast chart.

From the table 5 grey forecasting calculation results obtained ARPE value of 9.60% with accurate forecasting power, as well as the accuracy of the forecast model reaches 90.40%.

After the results of forecast are obtained, the next step is to test the accuracy of the GM (1,1) model. Testing is done by comparing the GM (1.1) model with traditional time series models is single moving average (SMA) and single exponential smoothing (SES). Tests are done using ARPE error calculations, as in Table 6.

Table 6. Comparison of accuracy results

	GM (1,1)	SMA	SES
ARPE (%)	9.60	14	12
Accuracy (%)	90.40	86	88

Based on Table 6, the GM model (1.1) is more optimal than the traditional time series model. In addition, based on research using GM (1,1) in fisheries production, obtained the value of accuracy at 90.40%, whereas in previous research, GM (1,1) was applied in several cases including forecast of electric power prices resulting 92% value of accuracy [8], forecast of agricultural products have an accuracy of 90% [9], forecast of the incidence of syphilis in China have an accuracy of 88.5% [10], and forecast of electricity consumption by comparing GM (1,1) and ARIMA produce GM (1.1) 96.25% accuracy value and ARIMA at 95.38% [11], it can be said that the GM (1.1) model can be applied in case of fish production forecast and has optimal performance because the accuracy isn't far away different from previous research.

CONCLUSION

In this research, grey forecasting model GM (1.1) cann't only be applied in the case of electricity forecasting, disease incidence, and agricultural products, but this research applied the GM (1.1) model in the case of fisheries production. According to results of the research on the implementation of grey forecasting models in the fisheries production forecasting system, it can be concluded that grey forecating model has high accuracy in fisheries production reached 90.40%, it can be said that the GM (1.1) model can be applied in case of fish production forecast and has optimal performance because the accuracy isn't far away different from previous research.

ACKNOWLEDGMENT

The authors would like to thank Brondong Nusantara Fisheries Port, Lamongan for providing data for this research.

REFERENCES

[1] R. G. Felthoven and C. J. Morrison Paul, “Directions for productivity measurement in fisheries,” *Mar. Policy*, vol. 28, no. 2, pp. 161–169, 2004.

[2] I. C. Kaplan and J. Leonard, “From krill to convenience stores : Forecasting the economic and ecological effects of fisheries management on the US West Coast,” *Mar. Policy*, vol. 36, no. 5, pp. 947–954, 2012.

[3] D. Belhabib, U. R. Sumaila, and P. Le Billon, “The fisheries of Africa: Exploitation, policy, and maritime security trends,” *Mar. Policy*, vol. 101, no. July, pp. 80–92, 2019.

[4] H. Boesono, D. R. Setiawan, K. E. Prihantoko, B. B. Jayanto, and A. R. Malala, “Productivity Analysis of Mini Purse Seine in PPI Pulolampes Brebes, Central Java, Indonesia,” *Aquat. Procedia*, vol. 7, pp. 112–117, 2016.

[5] L. Sifeng, J. Forrest, and Y. Yingjiel, “A Brief Introduction to Grey Systems Theory,” pp. 1–9, 2011.

[6] S. Wang, W. Wang, C. Huang, and S. Chen, “Journal of Strategic Information Systems Improving inventory effectiveness in RFID-enabled global supply chain with Grey forecasting model,” *J. Strateg. Inf. Syst.*, vol. 20, no. 3, pp. 307–322, 2011.

[7] S. Ding, K. W. Hipel, and Y. guo Dang, “Forecasting China's electricity consumption using a new grey prediction

model," *Energy*, vol. 149, pp. 314–328, 2018.

[8] M. Lei and Z. Feng, "Electrical Power and Energy Systems A proposed grey model for short-term electricity price forecasting in competitive power markets," *Int. J. Electr. Power Energy Syst.*, vol. 43, no. 1, pp. 531–538, 2012.

[9] S. Ou, "Forecasting agricultural output with an improved grey forecasting model based on the genetic algorithm," *Comput. Electron. Agric.*, vol. 85, pp. 33–39, 2012.

[10] L. Wu, S. Liu, L. Yao, and S. Yan, "The effect of sample size on the grey system model," *Appl. Math. Model.*, vol. 37, no. 9, pp. 6577–6583, 2013.

[11] C. Yuan, S. Liu, and Z. Fang, "Comparison of China ' s primary energy consumption forecasting by using ARIMA (the autoregressive integrated moving average) model," *Energy*, vol. 100, pp. 384–390, 2016.

[12] Hyndman, R.J., 2014, Forecasting : Principles & Practice, Edition 23th September 2014, University of Western Australia.

[13] J. Yeong, H. Chul, H. Kim, and S. Kang, "Forecasting the monthly abundance of anchovies in the South Sea of Korea using a univariate approach," *Fish. Res.*, vol. 161, pp. 293–302, 2015.

[14] J. Cui, S. feng Liu, B. Zeng, and N. ming Xie, "A novel grey forecasting model and its optimization," *Appl. Math. Model.*, vol. 37, no. 6, pp. 4399–4406, 2013.

[15] E. Kayacan, B. Ulutas, and O. Kaynak, "Expert Systems with Applications Grey system theory-based models in time series prediction," *Expert Syst. Appl.*, vol. 37, no. 2, pp. 1784–1789, 2010.

[16] J. Zhou, "The Application Of Grey Forecasting Model Based On Excel Modeling And Solving In Logistics Demand Forecast," pp. 362–365, 2013.

[17] A. Muqtadir, S. Suryono, and V. Gunawan, "The Implementation of Grey Forecasting Model for Forecast Result's Food Crop Agricultural," *Sci. J. Informatics*, vol. 3, no. 2, pp. 159–166, 2017.