Forecasting of Field Rat Attacks Using Transfer Function Model

Antoni Ahmat, I Made Sumertajaya, Anik Djuraidah

Abstract— Field rat (*Rattus argentiventer*) is one of the major plant-disturbing organisms categorized by Directorate General of Food Crops, Indonesian Ministry of Agriculture. As an island with a large number of rat species, the agriculture in Sulawesi is susceptible to field rat attacks. In Sulawesi, there are more than 51 species of Muridae family. This precautions was needed in order to suppressed the field rat attacks, which can be done by forecasting. By forecasting the expected decision can be made more effective and efficient. The transfer function model is a combination of regression analysis characteristic with ARIMA time series characteristic (Autoregressive Integrated Moving Average). This thesis described the procedure of formation of transfer function model and its application to predict the field rat attacks on rice. The explanatory variable used in the modeling is the area of rice planting.

Index Terms— area of rice planting, field rats, time series, transfer function.

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1 Introduction

THIS study will predict the attack of field rats on rice in Sulawesi. Field rat (Rattus argentiventer) is one of the rice pests that cause considerable damage and losses in Asian countries in generally and especially Indonesia. Losses caused by field rats have been counted since in the nursery, vegetative phase, generative phase, until the storage. Based on Singleton's (2003) report in Sudarmaji et al. (2009), rice yields lost due to field rat attacks in 11 Asian countries, including Indonesia reached 5-10%. If the calculated loss of 5% is equivalent to the production of 30 million tons of rice. According to Maryanto and Yani (2009) reports, 18% of the total 2050 species of mice live in the archipelago and more than 51 species of the *Muridae* family are on the island of Sulawesi.

Basically time series forecasting is univariate data analysis. But in reality most observations are multivariate data. If forecasting analysis is based solely on responsive data only without regard to the factors that influence it then the information to made the desicion became incomplete, so the aim of forecasting becomes not achieved accurately. The ARIMAX model or transfer function was a model that included explanatory variables in the model. The uniqueness of the transfer function method was that there was an element of causality in the model. Therefore, the transfer function was often called dynamic regression with time series approach (Fathurahman 2009).

The data used was the proportion of rice planting area affected by field rats on the total area of rice planting in Sulawesi. As explanatory variable, the data used was the area of rice planting (hectare) in Sulawesi. The aim of this study is to build a model for forecasting field rat attacks on rice in Sulawesi by transfer function model and checking the accuracy of forecast result.

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2 RESEARCH METHOD

2.1 Data

The data used in this study were secondary data that obtained from Directorate General of Food Crop, Ministry of Agriculture, those are data of field rat attacks on rice and data of rice planting area (hectares) in six provinces in Sulawesi period 2010-2016. The variables used in this study are the proportion of field rats attack on rice plants as the response variable and the area of rice planting as explanatory variables.

2.2 Method of Data Analysis

Steps in analyzing data:

1) Checking the stationarity of both X and Y variables from each location using Augmented Dickey Fuller (ADF) test.
2) Divide data into 2 sets of training data (72 first data) and data testing (last 12 data).
3) Identifies the prewhitening input and output series to determine the initial order of the model for each location.
4) Calculate the cross correlation form prewhitening input and output series.
5) Determine the order (b, s, r) for the transfer function model based on the cross correlation of input and output series.
6) Estimated residual series
7) Estimated of model parameter of transfer function with conditional least square estimation method.
8) Perform a diagnostic checking of the transfer function model by checking the residual model autocorrelation and calculate the cross correlation between the residual series with the prewhitening input series.
9) Checking the accuracy of transfer function model based on RMSE and MAPE value. The smaller RMSE and MAPE values indicated better model.

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3 RESULT AND DISCUSSION

3.1 Stationarity Test

According Makridakis (1993) stationarity has the meaning that there is no growth or decline in data. In other words, the fluctuations of the data are around constant mean values, irrespective of the timing and variety of those fluctuations. Time series data is said to be stationary in an average if the average does not change from time to time. If a time series data is not stationary on average then it can be overcome by doing differentiation (differencing). The differentiation represents the reduction of certain data with the previous data. In addition, a stationary time series data is in variance, if the time series plot does not show any significant change in variation over time. If the data is not stationary in variance, then the transformation is necessary. The test that can be done to know the stasionarity is Augmented Dickey Fuller (ADF) test. The ADF test is based on unit root test.

Table 1 Resuly of Augmented Dickey-Fuller test

Province	Input	Series	Output	Series
	Rho	p-value	Rho	p-value
North Sulawesi	-83.39	0.0007	-61.20	0.0007
Gorontalo	-43.60	0.0007	-53.84	0.0007
West Sulawesi	-52.71	0.0007	-44.60	0.0007
Central Sulawesi	-38.86	0.0007	-20.53	0.0064
South Sulawesi	-41.84	0.0007	-36.00	0.0007
Southeast Sulawesi	-31.22	0.0007	-34,21	0.0007

Table 1 shows that the input and the output series can be said to have been stationary. The p-value was always smaller than the significant level of 0.05.

3.2 Establish Transfer Function Model

The steps in established the transfer function model for each location, which one was North Sulawesi. First, it would identify the input series and output series that has been stationary form ACF and PACF plot. The next step was to calculated the cross correlation between the input series and the output series. The cross correlation plot was used to determined the order of the transfer functions of order b, s, r. The order b stated as the first lag the input series began to give effect to the output series. The order s stated how long the input series gave effect to the output series. While the order r indicated how long the output series continued to be affected by the previous value.

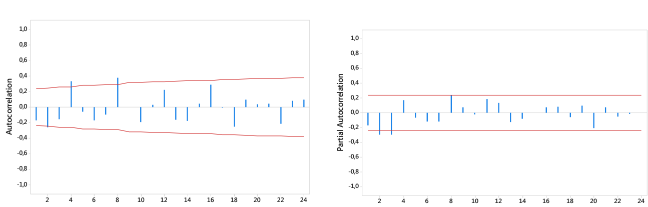

Figure 1 ACF and PACF of planting rice area of North Sulawesi

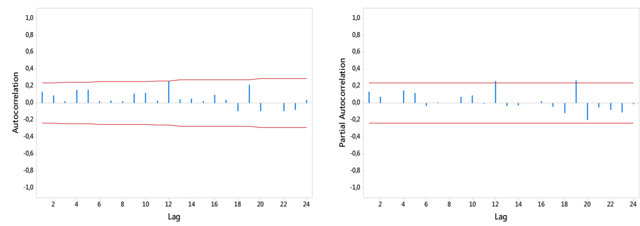

Figure 2 ACF and PACF of field rat attack proportion of North Sulawesi

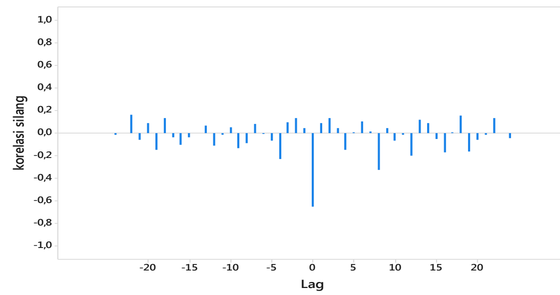

Figure 3 Cross correlation between input series and output series of North Sulawesi

The next step will be identified the residual series of the order that has chosen before. The residual assumption that has to be fulfilled was the nonsignificantly residual autocorrelation in each lag. In addition, the cross-correlation test between the input series and the residual series was not significant. From the examination, it can be concluded that the residual series didn't give any more effect. Thus it can be concluded that the transfer function model is feasible to be used for forecasting.

Table 2 Residual autocorrelation test

Lag	Chi Square	Degree of freedom	P value
6	5.64	4	0.2278
12	10.25	10	0.4187
18	14.58	16	0.5557
24	18.01	22	0.7051

Table 3 Corss corelation between input series and residual

Lag	Chi Square	Degree of freedom	P value
5	0.96	6	0.9872
11	7.60	12	0.8157
17	8.07	18	0.9776
23	9.94	24	0.9948

Table 2 and 3 showed that the otocorrelation of residual was not real. In addition, the cross-correlation test between the input series and the residual series is not real until lag 23. It can be concluded that the residual series did not give any significant effect anymore. Thus, it can be said that the obtained transfer function model is feasible.

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Table 4 Transfer Function model structure of each provinces

Province	Input Series	Output Series	Order b,s,r	Residual Series
North Sulawesi	ARMA(3,8)	AR(12)	(0,0,0)	ARMA(12,2)
Gorontalo	ARMA(1,3)	AR(1)	(0,1,1)	MA(2)
West Sulawesi	ARMA(13,12)	ARMA (1,1)	(0,0,1)	AR(1)
Central Sulawesi	ARMA(1,3)	ARMA (1,1)	(9,0,0)	AR(1)
South Sulawesi	ARMA(9,12)	ARMA (1,12)	(0,2,0)	AR(1)
Southeast Sulawesi	ARMA(1,12)	ARMA (1,8)	(0,3,0)	MA(1)

Table 5 Parameter estimation of Transfer Function model

Provinces	Parameter	Estimate	p-value
North Sulawesi	ω_0	-1.292	<.0001
	θ_2	-0.256	0.034
	ϕ_{12}	0.344	0.010
Gorontalo	ω_0	-1.079	<.0001
	ω_1	-1.222	<.0001
	δ_1	0.905	<.0001
	θ_2	-0.131	0.298
West Sulawesi	ω_0	-0.644	0.049
	δ_1	0.588	0.002
	ϕ_1	0.355	0.007
Central Sulawesi	ω_0	0.644	0.015
	ϕ_1	0.737	<.0001
South Sulawesi	ω_0	-0.888	<.0001
	ω_1	-0.204	0.003
	ω_2	-0.132	0.083
	ϕ_1	0.886	<.0001
Southeast Sulawesi	ω_0	-0.943	<.0001
	ω_1	-0.644	0.004
	ω_2	-0.511	0.021
	ω_3	-0.514	0.026
	θ_2	-0.431	0.001

Table 6 Transfer Function model of six provinces in Sulawesi

Provinsi	Mdel Fungsi Transfer
North Sulawesi	$y_t = \omega_0 x_t + \frac{1-\theta_2 B^2}{1-\phi_{12} B^{12}} a_t$
Gorontalo	$y_t = \frac{\omega_0 - \omega_1}{1-\delta_1} x_t + (1-\theta_2 B^2) a_t$
West Sulawesi	$y_t = \frac{\omega_0}{1-\delta_1} x_t + \frac{1}{1-\phi_1 B} a_t$
Central Sulawesi	$y_t = \omega_0 x_{t-9} + \frac{1}{1-\phi_1 B} a_t$
South Sulawesi	$y_t = (\omega_0 - \omega_1 - \omega_2) x_t + (1-\theta_1 B) a_t$
Southeast Sulawesi	$y_t = (\omega_0 - \omega_1 - \omega_2 - \omega_3) x_t + (1-\theta_2 B^2) a_t$

From the order above, it can be determined the transfer function model to be used for each provinces which presented in Table 6. Table 5 showed that all parameters that used in each models gave significant value (p value <0,05). The next step was checked the accuracy of forecasting for each model. The precision of forecasting is evaluated using the MAPE. MAPE is used in order to know the percentage of error rate. The smaller value of MAPE indicated to be best model. Table 7 shows the comparison of MAPE values from transfer function model and ARIMA.

Table 7 RMSE and MAPE values of transfer function model

Provinces	MAPE ARIMA	MAPE FT
North Sulawesi	170.348	182.032
Gorontalo	191.487	121.115
West Sulawesi	489.128	471.442
Central Sulawesi	743.476	124.369
South Sulawesi	34.616	78.912
Southeast Sulawesi	111.762	73.776

Based on Table 7 it can be seen that forecasting using transfer function model yields less MAPE values than the ARIMA model. Thus, it can be argued that the transfer function model is better for forecaste the proportion of field rat attacks in Sulawesi. Although some provinces such as South Sulawesi and North Sulawesi gave smaller MAPE in ARIMA, transfer function model gave consistent smaller MAPE value for other provinces. This is relevant with the theory that add explanatory variables give good influence in forecasting.

4 Conclusion

Based on the aim of study, over all it can be concluded that transfer function models was able to predicted the arrival of rice field rat attack of 6 provinces in Sulawesi better than ARIMA model. However this model has not been able to predicted how big the attack rate, marked by the MAPE value is high enough.

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