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Correlation of Rice Production and Greenhouse Gas Emissions in North Sulawesi Province

(Korelasi Produksi Beras dan Emisi Gas Rumah Kaca di Provinsi Sulawesi Utara)

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ABSTRACT

This study aimed to reveal correlation, calculate significance, and discover the regression equation of rice production to Green House Gas (GHG) emission in North Sulawesi Province. The data on GHG emissions from rice cultivation (Gg CO2eq) was obtained from the Ministry of Environment and Forestry of Indonesia. Data on rice production from wetland and dryland (Gg) was from the BP Statistical Review annual period of 2000-2021, both for North Sulawesi Province. Data analysis of correlation coefficient, F-test for Regression, and Simple Regression Analysis will be processed with the help application of MS Excel. The results show that the correlation between rice production and emission of rice cultivation in North Sulawesi Province is 0.53 and classified as a moderate correlation. The coefficient of determination stated that the emission of rice cultivation could be explained by about 28.6% from rice production. Therefore, rice production is statistically significant to the emission of rice cultivation with a 5% confidence level for North Sulawesi Province. Furthermore, this study found a regression equation, emission of rice cultivation is 112.67 + 0.516 times rice production.

Keywords: correlation coefficient, green house gas emission, rice production

ABSTRAK

Tujuan penelitian ini adalah untuk mengungkap korelasi, menghitung signifikansi, dan menemukan persamaan regresi produksi beras terhadap emisi gas rumah kaca (GRK) di Provinsi Sulawesi Utara. Data emisi GRK dari budi daya beras (Gg CO2eq) diperoleh dari Kementerian Lingkungan Hidup dan Kehutanan Indonesia dan data produksi padi dari lahan basah dan lahan kering (Gg) berasal dari Badan Pusat Statistik periode tahunan 2000–2021, kedua data untuk Provinsi Sulawesi Utara. Analisis data koefisien korelasi, uji F untuk Regresi, dan Analisis Regresi Sederhana diolah dengan bantuan aplikasi MS Excel. Hasil analisis korelasi antara produksi padi dengan emisi budi daya padi di Provinsi Sulawesi Utara adalah 0,53 dan tergolong korelasi sedang. Nilai koefisien determinasi menyatakan bahwa angka emisi budi daya padi dapat dijelaskan sekitar 28,6% dari produksi padi. Produksi beras secara statis signifikan terhadap emisi budi daya padi dengan tingkat kepercayaan 5% untuk Provinsi Sulawesi Utara. Penelitian ini menemukan persamaan regresi, yakni emisi budi daya padi sama dengan 112,67 + 0,516 kali produksi padi.

Kata kunci: emisi gas rumah kaca, koefisien korelasi, produksi beras

INTRODUCTION

Food is among many essential factors needed for a human to live and for every person to consume regularly. In the field of research, many studies and experiments to increase food production have been done (Deprá *et al*. 2022, He *et al*. 2021, Tian *et al*. 2021, Wu *et al*. 2018). Nevertheless, some research was conducted to increase food production in focus more to improve corps yield (Guo *et al*. 2022, Islam *et al*. 2022, Wei *et al*. 2022, Yue *et al*. 2022). FAO (2021) stated that crop production in 2019 reached 9.4 billion tonnes, an increase of 3.2 billion tonnes or 53% more than in 2000, with rice being 0.8 billion tonnes or 8% of total crop production in 2019. However, food accretion does not mean it goes without effect because of the increment in food production by crops; unfortunately also increases emissions released into the environment (Slamini *et al*. 2022, Sun *et al*. 2017).

Total emissions of Greenhouse Gases released into the atmosphere from agriculture in 2019 counted up to 10.7 billion tonnes of carbon dioxide equivalent (Gt CO_2eq) (FAO 2021). Meanwhile, in Indonesia, the agricultural sector contributed GHG emissions mainly from three main gases (CO_2, CH_4, and N_2O), which reached 105,301 Gg or 1.05×10^{-4} Gt CO_2eq in 2019 (Anwar *et al*. 2021). The opposite finding, research in

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Bangladesh discovered a negative link between agricultural productivity and CO_2 emissions; the decreased agricultural product increased CO_2 emissions in the longer term (Raihan *et al*. 2022). Another result from research in Nepal established that significant negative relation between agriculture and CO_2 emissions, implying that reducing the product of agriculture raises CO_2 emissions in the long term (Raihan & Tuspekova 2022).

North Sulawesi is one of 33 provinces in Indonesia, located north of Sulawesi Island, with the border with the Philippines in the north, by the Sulawesi Sea, the Maluku Sea in the east, Tomini Gulf in the south, and Gorontalo Province in the west (BPS-Statistics of Sulawesi Utara Province 2022). A strict policy in the local administration for converting productive land to annual crops and rice paddies is to control sedimentation in Lake Tondano (Walangitan *et al*. 2012). Another research in Lake Tondano found that nitrogen (from agricultural activity surrounding the lake) transformed into nitrate, nitrite, and ammonia, which made *Eichhornia crassipes* became an invasive species (Wantasen *et al*. 2012). Therefore, the local farmers need proper formal education and farming skill (Lubis & Langston 2015; Purba & Pratiwi 2020). Unfortunately, there is no study conducted about the correlation between rice production and GHG emission in North Sulawesi Province. Hence, this study aimed to reveal the correlation coefficient, calculate significance, and discover the regression equation of rice production to GHG emission in North Sulawesi Province. There are benefits from this study for the government as a source of information to make a policy about rice cultivation and GHG emission, for people as a piece of information to understand the correlation between rice cultivation and GHG emission, and for scientists to further research.

MATERIALS AND METHODS

The data used in this study was obtained from the Ministry of Environment and Forestry of Indonesia and the BP Statistical Review of North Sulawesi Province. This study used time series data with an annual period from 2000–2021 for Indonesia, especially for North Sulawesi Province. The data consist of GHG emissions from rice cultivation (Gg CO2eq) and rice production from wetland and dryland (Gg).

Many studies determined a correlation between multiple variables with the Pearson correlation coefficient equation (Balikai *et al*. 2022, Wang *et al*. 2022, Zeng *et al*. 2021). In this study, the two variables were rice production and emission from rice cultivation, determined with the same means. The F-Test of regression will calculate the significance of the independent variable on the dependent variable (Braun *et al*. 2016, Chakraborty & Choudhury 1999, Esfahanian *et al*. 2013, Marzouk 2021, Pieloch-Babiarz *et al*. 2021, Roca *et al*. 2020). Regression Analysis has been used in research to predict the impact of the independent variable on the dependent variable based on existing data to discover regression equations (Bondarchuk 2022, Brumercikova & Bukova 2020, Mchugh *et al*. 2016, Shin & Kim 2016, Yang *et al*. 2007). In this study, the independent variable is rice production, and the dependent variable is the emission from rice cultivation. Data analysis of correlation coefficient, F-test for Regression, and Simple Regression Analysis were processed using MS Excel.

RESULTS AND DISCUSSION

Correlation Coefficient

Table 1 shows the correlation between rice production and rice cultivation emission in North Sulawesi Province. Multiple R is the correlation coefficient with a value of 0.53 in positive correlation. Schober & Schwarte (2018) conducted a study and found a classification correlation coefficient of 0.53 classified as a Moderate Correlation. The correlation coefficient is 0.5–0.7, with both positive and negative values, concluding that those variables depend on each other (Balikai *et al*. 2022). An interesting finding recently by another study stated correlation coefficient of multiple R is overinterpreting if it is the only one that indicates the "strength" and "weakness" dependence of variables (Rusakov 2022). Based on the data result compared to other studies, it can be said that the rice production and emission from rice cultivation in North Sulawesi Province have a Moderate Correlation. Both variables depend on each other, and even though they cannot be determined, the correlation is weak or strong.

Another alternative to support the number shown on the correlation coefficient is with coefficient determination, which is part of the analysis correlation coefficient, shown with *R*-squares (R^2) in Table 1. The R^2 or coefficient determination was used to determine how much the independent variable explains the dependent in a study. The R^2 is 0.706, meaning independent 70.6% of the dependent variable (Carter *et al*. 2017). Another study found R^2 that is higher than 0.8 defined that the

Table 1 Correlation statistics between rice production and emission from rice cultivation

Multiple *R*	0.534420134
R-squared	0.28560488
Standard error	121.3236794
Observations	22

Description: Multiple *R* = correlation coefficient; *R*-squared = coefficient determination; Observation = number of observed data pairs; Standard errors distribution accuracy of observed data pairs.

independent variables explain 80% of the dependent variable (Sinkhonde 2022). In this study, the R^2 is about 0.286. In other words, the numbers of rice production explained or impacted about 28.6% of the emission from rice cultivation in the North Sulawesi Province. Moderate correlation with a correlation coefficient of only about 0.53 and 0.286 of coefficient determination, are those implied that both data have little to zero impact or are “statistically insignificant” to each other?

F-test for Regression

The F-test for Regression was done with Analysis of Variance (ANOVA) to discover the impact of rice production to emission form rice cultivation, is statically significance or insignificance. This study used the significance level of 0.05 or 5%, while Table 2 shows the value of F significance is 0,0104. The value of significance level which is 0,05 is higher than the value of F significance, this means that the rice production is statically significance to emission form rice cultivation in North Sulawesi Province. Same result from another study when the *F* significance is far less than the significance level of 0,05, that assumed the independent variable is significance to dependent variable (Sugiarti *et al.* 2022).

The *F*-test for regression was done with Analysis of Variance (ANOVA) to discover the impact of rice production on emission from rice cultivation is statically significant or insignificant. This study used the significance level of 0.05 or 5%, while Table 2 shows the *F* significance is 0.0104. The significance level value, which is 0.05, is higher than the value of *F* significance, meaning that rice production is statistically significant to emissions from rice cultivation in North Sulawesi Province. The same result from another study, when the *F* significance is far less than the significance level of 0.05, assumed the independent variable is significant to the dependent variable (Sugiarti *et al.* 2022).

Moderate correlation, and only 28.6% of emissions, can be explained by rice production. Nevertheless, this study found a significant statistical result of rice production to emissions. This odd result, fortunately, has some explanation. A study found that the emission, in this case, from rice cultivation, is not only from the plant process that produces rice but also from mechanization and chemical reactions from fertilizers (Wang *et al*. 2022). Another study found that technological improvements in agriculture still worsen emissions. Hopefully, more technological improvements in agriculture will reduce emissions in the future (Radwan *et al*. 2022). Another study even found that agricultural machines emit emissions that can ruin the ozone layer (Yu *et al*. 2023). Unfortunately, this study does not cover how many other aspects affect emissions besides rice production.

Simple Regression Analysis

The last calculation for this study is a simple regression analysis to discover the regression equation of rice production to emission in North Sulawesi Province. A regression equation can be used to predict the value of the dependent variable based on the value independent variable in the future (Ahmad & Mariano 2006). Table 3 gives the coefficients for the simple regression model for this study, $Y = 112.67 + 0.52X$ or emission from rice cultivation is 112.67 + 0.52 times rice production. In regression equations with positive calculation, the linear increases, while in negative calculation, the linear tends to decrease (Rodrigues *et al*. 2017). This study found that the regression equation is an increasing trend because positive calculation shown in Figure 1.

Unfortunately, there is a flaw in this regression equation because both data start pairing up in hundreds (far from zero of *x* and *y* axis, shown by the value of Intercept in Table 3, which is 112.67). The data prediction below a hundred is biased. For example, we want to predict emission data; if the rice production is 1, 10, and 100 Gg, the regression equation results are 112.516; 117.16; and 163,6, respectively. The predicted data from 1, 10, and 100, that supposedly close to exponential order, now only range closely by addition. Fortunately, there is no way that the North Sulawesi Province only produces 1 or even 100 Gg of rice per year these days unless there is an extraordinary phenomenon such as war or extreme natural disaster that will render this regression equation useless anyway. A study found no unbiased regression model for estimation (Krizsan *et al*. 2014).

Table 3 Simple regression analysis statistic

	Coefficients
Intercept	112,6967888
Rice production (in Gg)	0,515994617

Description: In simple regression model Y=a + bX; Intercept = number of a; Rice production (in Gg) = number of b.

Table 2 Analysis of variance of regression model*

ANOVA					
	df	SS	MS	F	F Significance
Regression	1	117692,4	117692,4	7,995712	0,0104
Residual	20	294388,7	14719,44		
Total	21	412081,1			

Description: df (degree of freedom); SS (Sum Square); MS (Mean Square); *Significance level 5%.

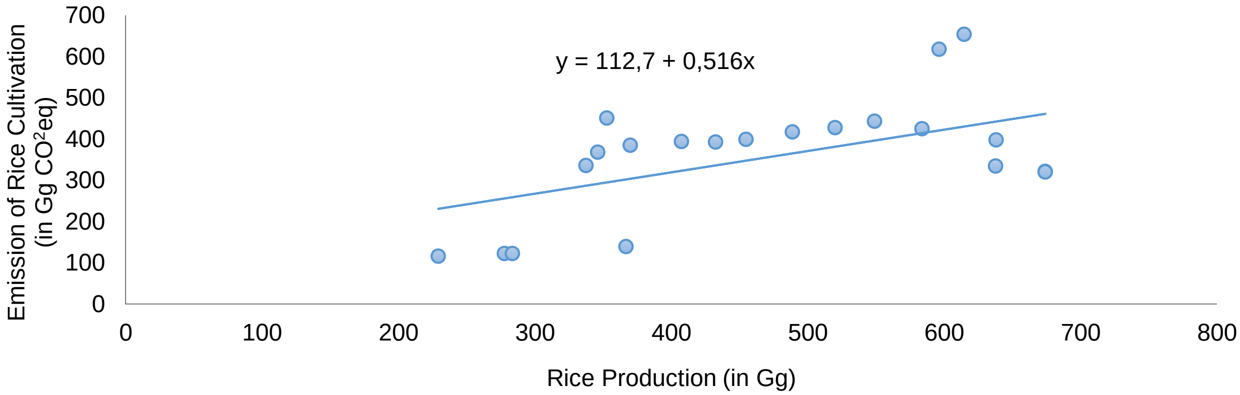

Figure 1 Simple regression analysis of *y* = Emission of rice cultivation, *x* = Rice production.

CONCLUSIONS

Based on the analysis, we conclude that the correlation between rice production and the emission of rice cultivation in North Sulawesi Province is moderate. The value of coefficient determination stated that the level of emission of rice cultivation could be explained by about 28.6% from rice production. This study found that even with moderate correlation and 0.286 value of coefficient determination can still achieve statistical significance with 5% confidence level from rice production to the emission of rice cultivation in North Sulawesi Province. This study found a regression equation, the emission of rice cultivation is 112.67 + 0.516 times rice production.

The benefit of this study to the government as a policymaker is that policies need to be stipulated to reduce emissions from rice cultivation because this study found some correlation between rice production and emission from rice cultivation. People now can understand from this study that rice production correlates with emissions from rice cultivation, so consuming rice should be efficient considering the enormous emission yielded in the process. Scientists can base more studies in the future on the correlation between rice production and emission by rice cultivation.

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