

Descriptive Modeling for Methane Emission from three Major Livestock in Sarawak

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Abstract

Rising concerns of methane emission, especially from natural enteric fermentation process of livestock, has caused the implementation of 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines Tier 1 methodology, which is the simplest method in quantifying greenhouse gases emissions, for quantification of methane emission from three major livestock in Sarawak. Lack of specific country-specific emission factor has led to prediction of future emission. Fitness functions are the inputs used in coding for producing forecasted emission, and can be obtained from the Statistical Package for the Social Sciences (SPSS) software. SPSS is then employed to access the correlation between amount of livestock and methane emission generated. Linear regression model is applied in SPSS software which generates three important tables namely Model Summary Table, Analysis of Variance (ANOVA) Table and Coefficients Table for result analysis. Fitness functions produced from the Coefficients table generated by SPSS illustrated strong correlation between livestock quantity and methane emitted.

Keywords: *fitness function, linear regression, livestock, methane, SPSS.*

1 Introduction

Methane, which is a type of greenhouse gas (GHG), can be emitted either directly or indirectly. Sources of methane emission include rice cultivation, manure management of livestock as well as enteric fermentation process of livestock [1]. This methane emission is higher in Asia than in other continents [2]. In Malaysia alone, domestic enteric fermentation are categorized as key categories for agriculture sector both in initial and second national communication (NC2) of Malaysia. Net increment of 13% in methane emission proved the emission is rising steadily throughout the period of initial national communication (NC) to second national communication (NC2) [3]. As stated in second national communication (NC2) of Malaysia, methane emission from enteric fermentation contributed 2% of total methane emission with highest contribution from landfill, followed by rice production at values of 47% and 4% respectively [7].

The United Nations Framework Convention on Climate Change (UNFCCC) divided countries into three main groups according to different commitments namely Annex I Parties and Non-Annex I Parties [8]. Annex I Parties include the industrialized countries such as Australia, Germany, Japan and United Kingdom [9]. Non-Annex I Parties are mostly developing countries such as Brazil, Cambodia, Myanmar and Thailand [10]. Even though Malaysia belongs to non-Annex I country which is not committed to reduce GHG emissions by any specific percentage, Prime Minister of Malaysia has made an announcement during Copenhagen Summit 2009. It is a conditional voluntarily target of 40% reduction in CO₂ intensity of Malaysian Gross Domestic Product (GDP) by 2020 from a 2005 baseline, subject to availability of technology and finance from Annex I countries.

This conditional volunteer is applicable for all sectors in Malaysia namely energy, industrial processes, agriculture, land use, land use change and forestry (LULUCF) and waste [3]. This paper aims to generate fitness function from the SPSS software which can be used as coding equation to predict future emission from three major livestock in the state of Sarawak. As shown in Table 1, major livestock in Sarawak, namely cattle, goat and swine are experiencing abrupt change in population and hence, methane emission from these livestock has been calculated.

2 Definitions

Enteric fermentation is defined as digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream of herbivores. Throughout this process, methane is generated. Ruminant livestock such as cattle and sheep are major sources of methane while only moderate amount of methane is generated from non-ruminant livestock such as swine and horse [4]. In other words, ruminants are herbivorous mammals with

a four-chambered stomach while non-ruminants are monogastric animals that digest food in one stomach, similar to humans.

2.1 Livestock farming in Sarawak

Table 1 exhibits population of major livestock in Sarawak at 4 years interval [5].

Table 1: Amount of major livestock in Sarawak

Year	1998	2002	2006	2010	2014
Cattle	8,495	9,532	12,918	14,364	12,096
Goat	10,214	9,078	11,146	16,433	15,021
Swine	504,850	461,289	423,858	393,694	681,068

As inferred from table above, change in livestock population at different time frame for sure will cause effect on methane emission. It will be appropriate to initiate the future emission prediction by obtaining objective function of livestock.

2.2 Overview of 2006 IPCC Guidelines methodology

As stated in the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines, there are three tier choices for quantifying GHG emissions namely Tier 1, Tier 2 and Tier 3. The Tier 1 method is the simplest to use as it employs default factors. The Tier 2 method uses the same fundamental equations as Tier 1 but with location or country-specific parameters instead of defaults. The Tier 3 method is more sophisticated, including empirical and process models that can be used to estimate or predict carbon stock changes or CO₂ emissions and removals. In the study, tier 1 method is employed such that only readily-available animal population data are needed to calculate emissions since country-specific emission factors are not available. Default emission factors are recommended for each of the livestock, as shown in equation (1) below [4]:

$$\text{Emissions} = \text{EF} \cdot (\text{N} / 10^6) \quad (1)$$

Where: emissions = methane emissions from enteric fermentation, Gg CH₄ yr⁻¹;
 EF = emission factor for the defined livestock population, kg CH₄ head⁻¹ yr⁻¹;
 N = number of head of livestock species.

3 Material and Methods

Statistical Package for the Social Sciences (SPSS) is employed in this study in order to generate equations which would be used as fitness function or objective

function in future coding part. Raw data are obtained from Sarawak's Chief Minister's Department, State Planning Unit, and Publication of Sarawak Facts and Figures [5]. Tier 1 methodology of 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines are applied for emission calculation due to difficulties in moving to higher tier methodology resulting from lack of detailed specific local data and emission factors.

3.1 Selection of regression model

Fitness functions are inputs used in coding process, and can be obtained from the Statistical Package for the Social Sciences (SPSS). This study employed SPSS Statistics for Windows, Version 20.0 [11]. The multiple regression methodology is usually applied to investigate the relationship between the independent and dependent variables. A multiple regression equation can be used to fit three different models of equation based on the experimental data as follows:

Second-order polynomial model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2 \quad (2)$$

First-order polynomial model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 \quad (3)$$

Linear Equation

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \quad (4)$$

For the second-order polynomial model, y represents the predicted response, β_0 is the model intercept, and $\beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$ are the regression coefficients for the linear, quadratic, and interactive effects of the model, respectively.

The regression coefficients that have a statistically significant effect on response should be considered in the equation. Therefore, if quadratic terms are not statistically significant, those coefficients are removed and equation will be linear [6].

Based on the above three model, equation used to calculate methane emission from enteric fermentation of livestock makes use of linear equation model. This is because there is only one independent variable (amount of livestock) and one dependent variable (emission). In other words, independent variable is the cause while dependent variable is the effect. Hence, x_1 will be the variable while y will be the emission. Hence, regression equation will take the form:

$$y = \beta_0 + \beta_1 x_1 \quad (5)$$

Each of the other coefficients are β variables, or the slope of the line. For each 1-unit change in x , y will change by β units. Since we only have one variable in this case, we just have a β_1 (the slope) and a x_1 (the value of X).

3.1.1 Statistical analysis

There are three tables which can be generated from Statistical Package for the Social Sciences (SPSS) namely Model Summary table, Analysis of Variance (ANOVA) table and Coefficients table. The coefficient of determination (R^2) from Model Summary table is used to evaluate the general predictive capability of the fitted model (more than 80% or 0.8). The p-value indicate whether a term in a model is significant or not. The smaller the P-value, the more significant the corresponding coefficient. Meanwhile the Fisher test (f-value) shows the level of significant in the model term [6]. Once significant, the equation will be used as the fitness function in coding.

4 Results and discussions

Table 2 illustrates the fitness function generated for cattle, goat and swine. The results of Model Summary table, Analysis of Variance (ANOVA) table and Coefficients table of these livestock are illustrated in Fig. 2-10.

Table 2: Fitness function generated for livestock

<i>Livestock</i>	<i>Fitness Function</i>
Cattle	$1.110E - 16 + 4.700E - 5 (x)$
Goat	$-6.939E - 18 + 5.000E - 6 (x)$
Swine	$5.551E - 17 + 1.000E - 6 (x)$

From the table above, for every increase in amount of cattle, goat and swine, a $4.700E-5$, $5.000E-6$ and $1.000E-6$ unit increase in methane emission is emitted from cattle, goat and swine respectively. Hence we can infer that cattle occupies a huge part in releasing methane emissions, followed by goat and swine. The ensuing section provides explanation on Model Summary, ANOVA and Coefficients table generated for cattle, goat and swine respectively.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000 ^a	1.000	1.000	.000000002

a. Predictors: (Constant), animal

Fig. 2 Model summary table for cattle.

Fig. 2 provides the R and R² values. The R value represents the simple correlation and is 1.000 (the “R” column). This indicates a high degree of correlation. On the other hand, the R² value (the “R square” column) shows how much of the total variation in the dependent variable, in this case, amount of methane generated from enteric fermentation of cattle, can be explained by the independent variable, amount of cattle. In other words, methane production is 100% explained by quantity of cattle.

ANOVA^a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.118	1	.118	.	. ^b
	Residual	.000	10	.000		
	Total	.118	11			

a. Dependent Variable: Enteric

b. Predictors: (Constant), animal

Fig. 3 Analysis of Variance (ANOVA) table for cattle.

The second table of interest is the Analysis of Variance (ANOVA) table. This table reports how well the regression equation fits the data (prediction of dependent variable). The above table shows that the regression model predicts the dependent variable significantly well. The proof is by checking out the “Regression” row and go to the “Sig.” column. This shows the statistical significance of the regression model. Here, $p < 0.0005$, which is less than 0.05. Since the significance is .000, we can reject the null hypothesis that “the model has no predictive value.” This proves that the regression model statistically significantly predicts the outcome variable. Therefore, it is a good fit for the data.

Coefficients^a

Model		Unstandardized Coefficients		Standardized	t	Sig.
		B	Std. Error	Coefficients Beta		
1	(Constant)	1.110E-16	.000		.000	1.000
	animal	4.700E-5	.000	1.000	150059981.800	.000

a. Dependent Variable: Enteric

Fig. 4 Coefficients table for cattle.

The most important table is the Coefficients table. This table provides the necessary information to predict methane emission of enteric fermentation from amount of cattle. It also serves to determine whether amount of livestock contributes statistically significantly to the model (by looking at the “Sig.” column). The significance level of .000 indicates that we can reject the null hypothesis that x does not predict y. The beta coefficient indicates how strongly the independent variable is associated with the dependent variable. Lastly, regression equation will take the form as shown in equation (2). In this case, regression equation is presented by using the values in the “B” column under the “Unstandardized B” column, as shown below:

Emission of methane from cattle’s enteric fermentation = $1.110E-16 + 4.700E-5(\text{amount of cattle})$

The first coefficient, “(Constant)”, is the intercept term. That is, before accounting for the dependent variable(s) – or, putting it another way, when x is zero – this is the value of y. In this case, the intercept is $1.110E-16$, so when $x=0$, y will equal $1.110E-16$.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000 ^a	1.000	1.000	.000000000

a. Predictors: (Constant), goat

Fig. 5 Model summary table for goat.

From figure shown above, the R column again shows the value of 1.000 to prove that both amount of goat and generated methane emission are highly related. As a result, R square demonstrated a 100% conformation such that dependent variable is connected with independent variable.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	.	. ^b
	Residual	.000	10	.000		
	Total	.001	11			

a. Dependent Variable: Enteric

b. Predictors: (Constant), goat

Fig. 6 Analysis of Variance (ANOVA) table for goat.

Regression model predicts the dependent variable well, illustrated in Fig. 6. We can see that the significance is .000, and infer that “the model has predictive value.” This shows that the regression model statistically predicts the outcome variable, making it a good fit for the data. As for the fifth column, it gives the F ratio, also known as the F-statistic in which the p-value associated with it. The F-statistic is the “Regression” divided by the “Residual”. In this case, it is $0.002/0.000 = 0.000$.

Model		Unstandardized Coefficients		Standardized	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-6.939E-18	.000		.	.
	goat	5.000E-6	.000	1.000	.	.

a. Dependent Variable: Enteric

Fig. 7 Coefficients table for goat.

Fig. 7 also presented the significance level of .000 for emission from goat. Consequently, fitness function used in coding will be $\text{emission} = -6.939\text{E-}18 + 5.000\text{E-}6$, multiplied by the amount of goat. Note that the first row named “Constant” shows the predictor variables (number of goat). It is also known as the y-intercept, height of regression line when it crosses the y-axis. In other words, this is the predicted value of goat when all the other variables are zero.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000 ^a	1.000	1.000	.000000000

a. Predictors: (Constant), swine

Fig. 8 Model summary table for swine.

Perfect correlation between quantity of swine and emission produced is highlighted by the number “1.000” as well as zero standard error of estimate. This boosts confidence since the model will be used for projection of future emission in the later part of research stage.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.050	1	.050	.	. ^b
	Residual	.000	10	.000		
	Total	.050	11			

a. Dependent Variable: Enteric

b. Predictors: (Constant), swine

Fig. 9 Analysis of Variance (ANOVA) table for swine.

Good fit for the swine data is proven by significance of .000, which is as expected. As for sum of squares, they are associated with three sources of variance namely Total, Residual and Regression. The Total variance is split into variance that can be explained by independent variables (Regression) and variance that is not explainable by independent variables (Residual).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.551E-17	.000		.	.
	swine	1.000E-6	.000	1.000	.	.

a. Dependent Variable: Enteric

Fig. 10 Coefficients table for swine.

From Fig. 10, the “Unstandardized B” shows values for regression equation for predicting dependent variable from independent variable. Hence, objective function for swine will be emission = 5.551E-17 + 1.000E-6(multiplied with

amount of swine). Meanwhile, the coefficient for deer is 1.000E-6. This means that for every increase in amount of swine, a 1.000E-6 unit increase in emission is emitted while all the other variables are held constant.

5 Conclusion

In this paper, it can be concluded that Statistical Package for the Social Sciences (SPSS) is a useful and powerful tool which acts as basic for objective function generation. The software showed it is capable in proving significant relationship between amount of livestock and methane emission generated. Production of fitness function for the major livestock in Sarawak proved these functions can be used to predict future emission, which is the scope of next research stage.

In conclusion, even if we in this developing country faces uncertainties on activity data collected, methods of data processing, methods of data and information presentation to the public, it is our responsibilities to pursue on these GHG quantifications for a better sustainable future. It is hoped that fitness functions obtained is going to yield accurate and reliable results in predicting future methane emissions that are helpful in aiding the policy decision process by the state government of Sarawak.

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