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ASSESSMENT OF CARBON EMISSIONS UNDER THE UNCERTAINTY OF THE ENERGY USING FOR THE PRODUCTION OF PIG MEAT

Prayong Keeratiurai
Department of Civil Engineering, Faculty of Engineering, Vongchavalitkul University, Nakhon Ratchasima Province, Thailand
E-Mail: prayong_kee@yahoo.co.th

ABSTRACT

Carbon is an important element for humans because it is the primary element of both plants and animals and it cycles through living and non-living components. Pigs are energy using animals that are raised for their meat, and produce emissions of CO_2. The carbon footprint is also the alternative for consumers to choose products with the least release of greenhouse gases into the environment. Therefore it is important to study and understand the relationship between the carbon emissions and carbon transfer to pig' energy use to develop carbon footprints for meat production. The focus of this study was to develop carbon footprints for pig meat production. To accomplish this we studied the rate of the carbon emissions from electricity, petroleum, LPG used during meat production. The results shown that the carbon emission were 0.21±0.05, 1.22±0.13 and 0.24±0.05 kg.C/head/day from the using of electricity energy, transportation energy, and LPG, respectively. The carbon emission from the using of transportation energy was quite high in terms of energy using but low in the using of electricity and LPG activities. The results also shown that the carbon emission of the energy using from farms and slaughterhouses were 1.98±0.17 and 1.11±0.04 kg.C/head/day, respectively. The carbon footprint from energy using were 26.33±0.33 kg.CO_2.eq./1 kg.meat. Therefore, farmers should reduce emissions from energy consumption such as reduce electricity utilization in farms, slaughterhouses and reduce distance for animal feed transportation to farms, animals to farms and slaughterhouses. It is suggested that the use of fuel for transportation should be reduced because it creates the highest carbon emission.

Keywords: carbon emission, pig meat production.

INTRODUCTION

One of the environmental threats that our planet faces today is the long-term change in Earth's climate and temperature patterns due to global climate change, or the greenhouse effect. CO_2 and CH_4 from human activities are the most important greenhouse gases contributing to global climate change (IPCC, 1995) with CH_4 being 23 times more potent than CO_2 (IPCC, 2001). Ox and buffalo are herbivores while pig and chicken are energy-using animals that are raised for their meat, and produce emissions of both CO_2 and CH_4. Carbon is an important element for humans because it is the primary element of both plants and animals and it cycles through living and non-living components. The growth rates of human population drivers the demand of livestock production increase. Livestock animals meet a variety of food needs for people (Thornton *et al*., 2009). They are important nutrient sources of protein in the form of meat, milk, eggs, and processed products (Lauhajinda, 2006). Livestock productions have emitted some greenhouse gases from fertilization, feed production, transportation, energy use in housing, respiration and digestion of livestock (Thanee *et al*., 2009a). The effects of livestock productions due to the utilization and changes of natural resources and environmental factors on the global should be considered (IPCC, 1996). The productive processes should release the least greenhouse gases to avoid such problems and save the Earth. Life cycle assessment (LCA) is an environmental assessment tool for evaluating the impacts that a product has on the environment over the entire period of its life from the raw materials extraction which it was made through the manufacturing, packaging processes, and the use, reuse and maintenance of the product and on to its eventual recycling or disposal as waste at the end of the useful life (defined by the United Nations Environment Programmed (UNEP) 1999) (Thu Lan and Shabbir, 2008). Pigs are energy using animals that are raised for their meat, and produce emissions of CO_2. The carbon footprint is an alternative for consumers to select the products that release greenhouse gases emission into the environment (Thanee, Dankitikul and Keeratiurai, 2009b). Therefore, it is important to study the relevant factors concerning the entire production both physical and biotic environment (Thanee and Keeratiurai, 2010). The primary objective of this study was to investigate the carbon footprints from farms and slaughterhouses in fattening pig production. In addition, the carbon emissions in energy patterns from electricity, petrol, and LPG used in pig meat production in Ratchaburi, Nakhon Pathom and Nakhon Ratchasima provinces were also studied.

DECISION MAKING UNDER UNCERTAINTY

The results of this study could analyzed environmental problems from the energy using of pig meat production. The analysis was based on pay of matrix principle by using all alternatives such as the energy sectors, carbon emission situations. Then make the decision follow theories and laws.

The applied analysis using Laplace Rule to choose the alternative of the energy using which cause the highest environmental problems by setting the probability of the equal situations. According to the Laplace Rule, it could be advised that the best alternative of the energy

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using in pig meat production cause more environmental problems.

The Maximax Rules was applied to indicate the problems of the alternative of the energy using in pig meat production by selection of situations which got the maximum result and then selected the maximum result from every alternatives again. It could be stated by this following mathematical model:

$$\max_i \left[\max_j P_{ij} \right] \tag{1}$$

Where, i = the alternative of the energy using
j = the situations
P_{ij} = Result from the application of the Maximax Rules

The Minimax Regret Rule was applied to avoid the regret that the decision was already made in taking the poor alternative. The maximum result of each situation was considered to minus the all alternatives in each situation. Then the results were set the matrix form and selected the maximum regret in each alternative. Each alternative was selected to find minimum value again and could be shown as:

$$\min_i \left[\max_j R_{ij} \right] \tag{2}$$

Where, i = the alternative of the energy using
j = the situations
R_{ij} = Regret value from take the maximum of each situation minus the all alternatives in each situation

According to theories and rules applied such as Pay off Matrix, Laplace Rule, Maximax Rules and Minimax Regret Rule in making the decision on environmental problems.

MATERIALS AND METHODS

The fattening pigs refer to the pigs' age between 1-6 months or the pigs' weight between 6.5-100 kilograms. This paper studied 4 type of fattening pigs were newly born pigs, small fattening pigs; grow fattening pigs, and large fattening pigs. Pig farms and slaughterhouses in Ratchaburi, Nakhon Pathom and Nakhon Ratchasima provinces were selected. The provinces had the highest intensity numbers of pig productions in Thailand as shown in Figure-1 (Department of livestock Development, 2009).

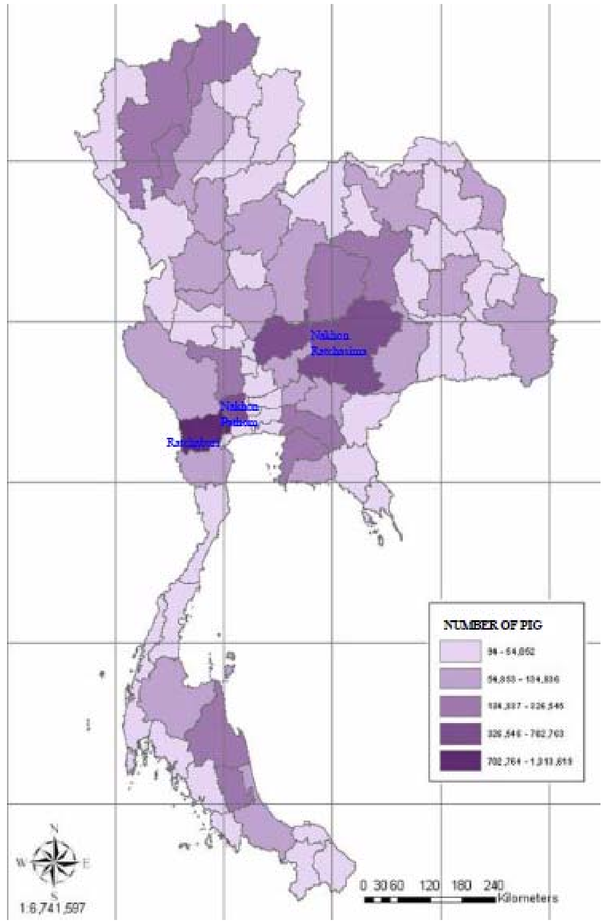

Figure-1. The study area in Ratchaburi, Nakhon Pathom and Nakhon Ratchasima provinces of Thailand.

LCA methodology applied in this study

The Society of Environmental Toxicity and Chemistry (SETAC) are generally credits for the current LCA methodological framework. Recent standard by the International Organization for Standardization (ISO) have defined LCA as the study related to the environmental aspects and potential impacts throughout the life of products from raw materials acquisition through production, use and disposal (Leng, *et al*., 2008). The International Organization for Standardization (ISO) of 14000 series was formed to accept as providing a consensus framework for LCA (Rebitzer, *et al*., 2004). Inventory analysis involves data collection and calculation procedures to quantify the relevant input and outputs of a product system. These inputs and outputs may include the use of resources and releases to air, water and land associated with the system (Thu Lan, 2007). Life cycle study, data collection represented a time consuming task and it was important to obtain quantitative information concerning various processes in the product system. A significant part of data associated with pig meat life cycle was collected from pig farms and slaughterhouses. Data for energy consumption, resources and material were obtained directly from pig farms and slaughterhouses. A

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useful instrument facilitating the estimation of gas emissions was the emission factor, which was a representative value attempts to link the associate with the system output. The process of impact assessment analyzes the environmental burdens associated with the material and energy flows determined in the inventory analysis phase though successive steps listed as follow classification, characterization, normalization and weighting (Curran, 1996). The study of life cycle assessment to evaluate carbon footprint for the pig meat production was shown in Figure-2.

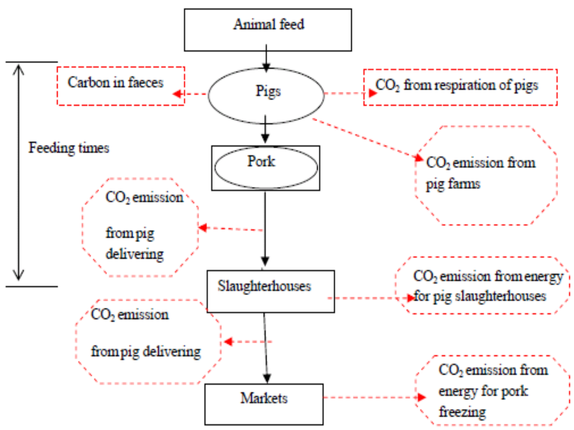

Figure-2. Life cycle assessment to evaluate carbon footprint for the pig meat production.

Site sampling and analytical methods

The numbers of farms and pigs in each district of selected provinces were calculated by determining the numbers of farms and fattening pigs in the provinces (Yamane, 1973; Cavana *et al*., 2001). Therefore, the sample groups were calculated by Taro Yamane's formula (Yamane, 1973) as follows;

$$n = \frac{N}{1 + Ne^2} \tag{3}$$

Where, n = Sample size
N = Population size
e = Error of sampling

The calculation showed that there were 400 pig farms, comprised of 226 pig farms in Ratchaburi, 117 pig farms in Nakhon Pathom and 57 pig farms in Nakhon Ratchasima. The numbers of pig slaughterhouses in Ratchaburi, Nakhon Pathom and Nakhon Ratchasima provinces were 12, 21 and 7, respectively. Animal feed, pork, entrails and faeces were collected and transferred to the laboratory at Suranaree University of Technology for further analyses. Carbon dioxide was measured from living pigs at the farms. The evaluation of carbon emission from energy sectors in pig meat production was calculated with the software of Department of Livestock Development as shown in Figure-3 and the analytical methods are as follows:

a) Moisture contents were measured by weighing sample after oven drying at 103-105°C for 24 hours (Manlay *et al*., 2004 a).
b) Carbon contents were measured by CNS-2000 Elemental Analyzer (Manlay *et al*., 2004 b).
c) CO_2 was detected by Gas Analyzer (Kawashima, Terada and Shibata, 2000).
d) Volatile solids and ash were analyzed by weighing the known weight of the sample after burning at 550°C for 30 minutes (APHA, AWWA and WEF., 1992).
e) Weight of pig by weighing or using pig weighing tape (Bunyavejchewin *et al*., 1985, Vudhipanee *et al*., 2002).

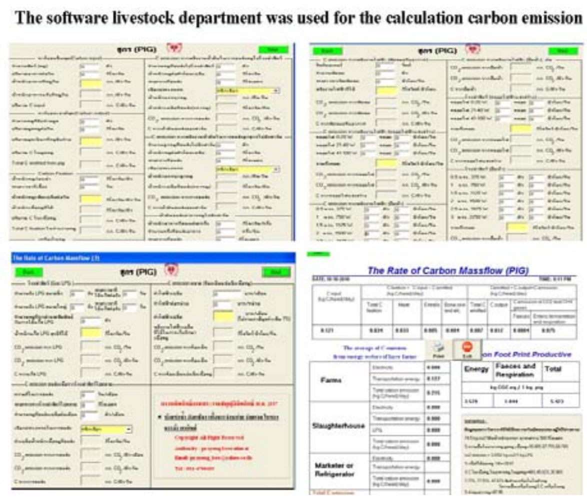

Figure-3. The software was used to calculate the carbon emission in energy sectors.

RESULTS AND DISCUSSIONS

Carbon emission from energy sectors

Carbon emission from the using of energy in each province was different because each province had different farm management. Moreover, the distances in transporting animals and animal feed to farms and transporting animals from farms to slaughterhouses were different. Most fattening pigs in Ratchaburi and Nakhon Prathom provinces were transported to slaughterhouses in Bangkok, resulting in carbon emission values of these two provinces were higher than in Nakhon Ratchasima province (0.524, 0.513 and 0.435 kg.C/head/day) as shown in Table-1. The results also shown that the carbon emission from the using of electricity energy was 0.21±0.05 kg.C/head/day, the carbon emission from the using of transportation energy was 1.22±0.13 kg.C/head/day, and the carbon emission from the using of LPG was 0.24±0.05 kg.C/head/day. Table-1 also shown that the carbon emission of the energy using from farms in three provinces was 1.98±0.17 kg.C/head/day and slaughterhouses was 1.11±0.04

kg.C/head/day. The results also showed the percentage of carbon emission from energy sectors of pig meat production as shown in Figure-4. Figure-4 showed that the carbon emission from the using of transportation energy was 72.86%, the carbon emission from the using of electricity energy and the carbon emission from the using of LPG was 12.56% and 14.58%, respectively. This study showed that the carbon emission from the using of transportation energy was quite high in terms of energy using but low in electricity and the using of LPG activities.

Table-1. Average of carbon emission from energy sectors at farms and slaughterhouses.

Average carbon contents from energy sectors (kg.C/head/day)		**C emission of fattening pigs**				
		Nakhon Pathom	**Ratchaburi**	**Nakhon Ratchasima**	**Average**	**Standard deviation**
Farms	Electricity*	0.02	0.01	0.09	0.04	0.05
	Transportation energy**	2.02	2.10	1.70	1.94	0.21
	Total carbon contents	2.04	2.12	1.79	1.98	0.17
Slaughterhouses	Electricity*	0.34	0.35	0.44	0.38	0.05
	Transportation energy**	0.51	0.52	0.44	0.49	0.05
	LPG	0.29	0.24	0.20	0.24	0.05
	Total carbon contents	1.15	1.12	1.07	1.11	0.04

*CO_2 emission = 0.18 kg.C/kWh and CO_2 emission from LPG = 3.0102 kg.CO_2/1kg. LPG (Pollution Control Department, 2003)
**CO_2 emission = 74.5 kg.CO_2/1 Ton/500 km (National Transportation Statistics, 2000)

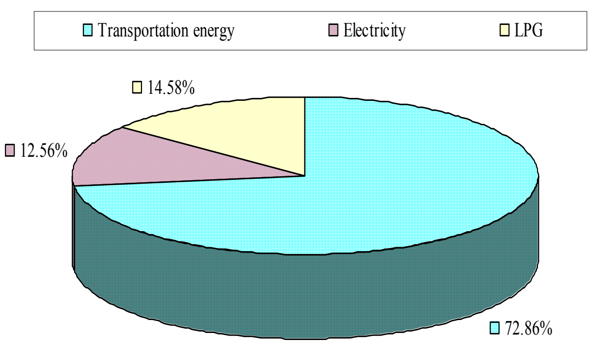

Figure-4. The evaluation of carbon emission from energy sectors for the pig meat production.

Decision making under uncertainty

The results of this study could analyzed environmental problems from the energy using of pig meat production. The analysis was based on pay of matrix principle by using all alternatives such as the energy sectors, carbon emission situation as shown in Table-2. Then make the decision follow theories and laws.

Table-2. The analysis under uncertainty was based on pay of matrix principle.

Alternative of the energy using	**Situation of carbon emission** (kg.C/head/day)	
	C emission from farms	**C emission from slaughterhouses**
Electricity	0.04	0.38
Transportation energy	1.94	0.49
LPG	0.00	0.24

The applied analysis using Laplace Rule to choose the alternative of the energy using which cause the highest environmental problems by setting the probability of the equal situations (n=2), results as in Table-3. According to the Laplace Rule, it can be advised that the best alternative of the energy using in pig meat production of the transportation energy cause more environmental problems.

Table-3. Result from the application of Laplace Rule.

Alternative of the energy using	**(C emission from farm + slaughterhouses)/n**
Electricity	0.21
Transportation energy*	1.22
LPG	0.12

Note: *Selected the alternative of the energy using which create maximum environmental problem

The Maximax Rules is applied to indicate the problems of the alternative of the energy using in pig meat production by selection of situations (Table-2) which get the maximum result and then select the maximum result from every alternative again. The results are shown in Table-4 which showed that the transportation energy of the pig meat production was the worst alternative among these three alternatives of the energy sectors.

Table-4. Result from the application of the maximax rules.

Alternative of the energy using	$\frac{\max Pij}{i(x)}$
Electricity	0.38
Transportation energy*	1.94
LPG	0.24

Note: *Selected the alternative of the energy using which create maximum environmental problem

The Minimax Regret Rule was applied to avoid the regret that the decision was already made in taking the poor alternative. Consideration of the maximum result in each situation was set in the matrix as shown in Table-5. And select the maximum regret in each alternative. Each alternative is selected to find minimum value again. The results were in Table-6 which showed that the electricity and LPG energy for pig meat production were recommended but transportation energy cause more environmental problems.

Table-5. Regret value of each alternative of the energy sectors.

Alternative of the energy using	Situation of carbon emission (kg.C/head/day)	
	C emission from farms	C emission from slaughterhouses
Electricity	1.90	0.11
Transportation energy	0.00	0.00
LPG	1.94	0.25

Table-6. Maximum regret value of each alternative of the energy using.

Alternative of the energy using	$\frac{\max Rij}{j}$
Electricity	1.90
Transportation energy*	0.00
LPG	1.94

Note: *Selected the alternative of the energy using which create maximum environmental problem

According to theories and rules applied such as Pay off Matrix, Laplace Rule, Maximax Rules and Minimax Regret Rule in making the decision on environmental problems, it could be concluded that LPG was the best alternative but transportation energy for pig meat production caused highest environmental problems among these three alternatives of the energy sectors.

Carbon footprint

The carbon footprint values of three provinces were similar or not significant difference ($P \leq 0.05$). This study showed that the release of carbon dioxide from the animals and animal activities was very low compared to the release of carbon dioxide form of energy consumption. The carbon footprint from pigs was 1.279, 1.33, and 1.371 kg.CO_2.eq./1 kg. meat in Nakhon Pathom, Ratchaburi and Nakhon Ratchasima provinces, respectively but the carbon footprint from of energy consumption was 26.071, 26.235, and 26.698 kg.CO_2.eq./1 kg. meat and the total of carbon footprint was 27.442, 27.514, and 28.028 kg.CO_2.eq./1 kg. meat in Nakhon Ratchasima Nakhon Pathom, and Ratchaburi provinces, respectively as shown in Figure-5. This study showed that the carbon footprint of fattening pigs were quite high in terms of energy use but low in animal activities, consistent with the studies on the comparison of carbon emitted from ox, buffalo, pig, and chicken farms and slaughterhouses in meat production (Thanee, Dankittikul and Keeratiurai, 2009b) and carbon massflow and greenhouse gases emissions from egg production using life cycle assessment in Nakhon Ratchasima province, Thailand. (Thanee and Keeratiurai, 2010). Therefore, if we want to reduce the carbon footprint value we should reduce the emissions from energy consumption such as reduce electricity in farms, slaughterhouses and reduce distance for transportation of animal feed and animals to farms and slaughterhouses.

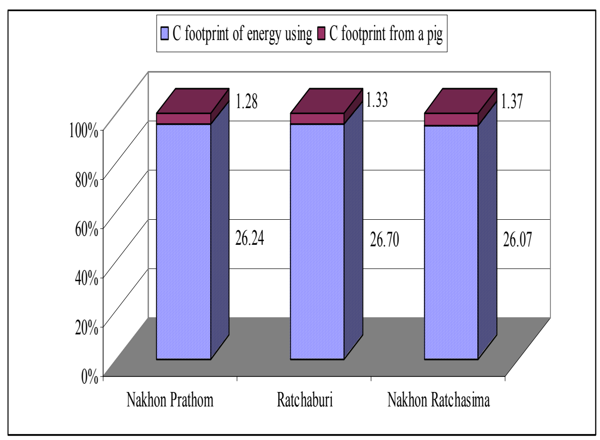

Figure-5. Carbon Footprint of fattening pigs in Nakhon Prathom, Ratchaburi and Nakhon Ratchasima provinces.

CONCLUSIONS

This study showed that the carbon footprint for pig meat production of fattening pigs were 27.44, 27.54 and 28.03 kg.CO_2.eq./1 kg.meat, in Nakhon Ratchasima, Ratchaburi and Nakhon Pathom provinces, respectively. The study also showed that carbon emission from fattening pig farms and slaughterhouses in Nakhon Ratchasima, Nakhon Pathom and Ratchaburi provinces were 0.98, 1.09 and 1.17kg.C/head/day, respectively. The results shown that the carbon emission were 0.21±0.05, 1.22±0.13 and 0.24±0.05 kg.C/head/day from the using of electricity energy, transportation energy, and LPG, respectively. The carbon emission from the using of transportation energy was quite high in terms of energy using but low in the using of electricity and LPG activities. The results also shown that the carbon emission of the energy using from farms and slaughterhouses were 1.98±0.17 and 1.11±0.04 kg.C/head/day, respectively. Most of carbon dioxide emission was from the use of fuel transportation of animal feed to farms and transportation of animals to farms and slaughterhouses, therefore the reduction of fuel use should be taken into account.

The rate of carbon emission showed that the fattening pig production contributed to environmental problems. Therefore, we need to reduce the environmental problems in pig meat production, the manufactures should reduce greenhouse gases emissions especially CO_2 from energy consumption such as reduce electricity utilization in farms, slaughterhouses and reduce distance for transportation of animal feed to farms, animals to farms and slaughterhouses. The carbon footprint is also the alternative for consumers to choose the products with the least release of greenhouse gases into the environment.

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REFERENCES

APHA AWWA, WEF. 1992. Standard Methods for the Examinations of Water and Wastewater. 20th Ed. American Public Health Association, Wash. D.C., USA. p. 445.

Bunyavejchewin P., Rompopak W., Vechabusakorn O., Khumnerdpetch W., Pikulthong P. and Chantalakhana C. 1985. Comparative Efficiency of Tapes for Estimation of Weight of Swamp Buffaloes and Cattle. Annual Report 1985. The National Buffalo Research and Development Center Project. Bangkok, Thailand.

Cavana R.Y., Delahaye B.L. and Sekaran U. 2001. Applied Business Research: Qualitative and Quantitative Methods. 3rd Ed. John Wiley and Sons, NY. p. 472.

Center for Agricultural Information, Office of Agricultural Economics. 2004. Agricultural Statistics of Thailand 2004. Agricultural Statistics No.410. Ministry of Agriculture and Co-operatives, Bangkok.

Curran M. A. 1996. Environmental Life-Cycle Assessment. McGraw-Hill Companies Inc, USA.

Department of Livestock Development. 2009. Livestock Statistics Data. [On-line], Available: http:// www.dld.go.th/index.html. Accessed date: December 2006.

Intergovernmental Panel on Climate Change. 1995. Climate Change 1995, The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Syndicate of the University of Cambridge, Cambridge, U.K. p. 572.

Intergovernmental Panel on Climate Change. 1996. IPCC Guidelines for National Greenhouse Gas Inventory. [On-line]. Available from: http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm. Accessed date: March 2008.

Kawashima T., Terada F. and Shibata M. 2000. Respiration experimental system, pp. 1-21. In: Japan International Research Center for Agricultural Sciences, Japan and Department of Livestock Development, Thailand, (Eds.), Improvement of cattle production with locally available feed resources in Northeast Thailand.

Lauhajinda N. 2006. Ecology: Fundamentals of Environmental. 2nd Ed. Kasetsart University, Bangkok.

Leng R., Wnag C., Zhang C., Dai D. and Pu G. 2008. Life cycle inventory and energy analysis of cassava-based Fuel ethanol in China. Cleaner Production Academic Publishers. pp. 374-384.

Manlay Raphaël J., Ickowicz Alexandre, Masse Dominique, Floret Christian, Richard Didier and Feller Christian. 2004a. Spatial carbon, nitrogen and phosphorus budget of a village in the West African savanna-I. Element pools and structure of a mixed - farming system. Agricultural Systems. 79: 55-81.

Manlay Raphaël J., Ickowicz Alexandre, Masse Dominique, Feller Christian and Richard Didier. 2004b. Spatial carbon, nitrogen and phosphorus budget in a village of the West African savanna-II. Element flows and functioning of a mixed-farming system. Agricultural Systems. 79: 83-107.

National Transportation Statistics. 2000. C-emission from petrol used for transporting. [On-line], Available: http://www.vcacarfueldata.org.uk/downloads, http://www.gdrc.org/uem/CO_2-Cal/CO_2-Calculator.html. Accessed date: March 2007.

Pollution Control Department. 2003. Acid Deposition Control Strategy in the Kingdom of Thailand. Japan International Cooperation Agency.

Rebitzer G., *et al*. 2004. Review Life cycle assessment. Part 1: Framework, goal, and scope definition, inventory analysis, and application. Environmental International Academic Publishers. pp. 701-720.

Tamminga S. 2003. Pollution due to nutrient losses and its control in European animal production. Livestock Production Science. 84: 101-111.

Thanee N., Dankitikul W. and Keeratiurai P. 2009a. The study of carbon massflow in ox, buffalo, and pig meat production from farms and slaughterhouses in Thailand. Thai Environmental Engineering. 23(2): 37-51.

Thanee N., Dankitikul W. and Keeratiurai P. 2009b. Comparison of carbon emitted from ox, buffalo, pig, and chicken farms and slaughterhouses in meat production. Suranaree Journal of Science and Technology. 16(2): 79-90.

Thanee N. and Keeratiurai P. 2010. Carbon massflow and greenhouse gases emissions from egg production using life cycle assessment in Nakhon Ratchasima province, Thailand. Proceedings of the 5th GMSARN International Conference 2010 on "Sustainable Development and Climate Change: Challenges and Opportunity in GMS" 17-19 November 2010, Luang Prabang City, Lao PDR. pp. 1-5.

Thornton P. K., Van de Steeg J., Notenbaert A. and Herrero M. 2009. The impacts of climate change on livestock systems in developing countries: A review of what we know and what we need to know. Agricultural Systems. 101: 113-127.

Thu Lan T. N. 2007. Life cycle assessment of bio-ethanol as an alternative transportation fuel in Thailand.

Thu Lan T. N. and Shabbir H. G. 2008. Life Cycle Assessment of Fuel Ethanol from Cassava in Thailand. Spinger-Verlag Academic Publishers. pp. 147-154.

Vudhipanee P., Lortae K. and Imvatana S. 2002. Comparative efficiency of weight prediction equations of swamp buffalo. Animal Husbandry Division: DLD. Available from: www.dld.go.th/research-AHD/Webpage/2545/45(3)-0406-147.pdf. Accessed date: June 2007.

Yamane Taro. 1973. Mathematics for Economists: An Elementary Survey. 2nd Ed. Prentice-Hall, New Delhi, India. p. 714.