The Contribution of Agriculture in a Local Greenhouse Gas Turnover

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Abstract

The general objective of this study is to analyze the contribution of agricultural sector in a local scale greenhouse gas turnover. It includes identification and quantification of the entire agricultural activities regarded as greenhouse gas sources as well as those concerned as greenhouse gas sink. The study was carried out in 2010 and based on a series of five years data compiled from a municipality in West Java Province as a case. The greenhouse gas sources were categorized into four sectors covering energy sector, solid waste, agricultural and animal husbandry sectors whereas the greenhouse gas sink was identified merely in agricultural sector. The amount of a single greenhouse gas emission was calculated by multiplication between a source unit and its corresponding emission factor. The total quantity of greenhouse gas emission generated by the municipality was summation of the whole sources from the entire sectors. The amount of the whole greenhouse gas sink was summation of the total sequestered carbon. The study result based on five years compiled data indicated that the average municipality greenhouse emission was in the order of 14.0 MT CO_2-e per year whereas the net sink was approximately 0.05 MT CO_2-e per year. The contribution of agricultural sector was merely 0.08 % of the total municipality greenhouse gas sources while its contribution on the greenhouse gas sequestration (as sink) was 2.39% of the emitted greenhouse gases. It can be concluded that based on the quantitative analysis, the local agricultural sector is a manner to sequester atmospheric carbon.

Keywords: agricultural sector, greenhouse gas, source, sink, turnover.

Introduction

Global warming, or more properly, global climate change (GCC), may be the most serious environmental challenge ever faced by mankind (Mackie and Cooper, 2009). There are many uncertainties surrounding the issue of global warming. However, several things about the phenomenon are certain. It is known that CO_2 and other greenhouse gases, such as CH_4, absorb infrared radiation by which earth loses heat. The levels of these gases have increased markedly since about 1850 as nations have become industrialized and as forest lands and grasslands have been converted to agriculture (Manahan, 2000). Global warming phenomenon which is nowadays concerned as a serious worldwide problem is essentially able to be mitigated locally based on the local governmental development program. The local governments can formulate action plans based on their local greenhouse gas (GHG) mass balance and database. A local GHG turnover is therefore necessary to estimate contribution of each sector involved in emitting the GHG. Greenhouse gases which deal with infrared-absorbing trace gases (other than water vapor) consist of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). CFC was excluded from this study case due to the lack of CFC distribution and consumption data. The objectives of this study are to quantify the entire agricultural activities regarded as greenhouse gas sources as well as those concerned as greenhouse gas sink and to analyze the contribution of agricultural sector in a local scale greenhouse gas turnover.

Materials and Methods

The study was carried out in 2010 and based on a series of five (5) years data compiled from a municipality in West Java Province, called City of X, as a case. The greenhouse gas sources were categorized into four sectors covering energy sector, solid waste, agriculture and animal husbandry sector whereas the greenhouse gas sink was identified merely in agricultural sector. The amount of a single greenhouse gas emission was calculated by multiplication between a source unit and its corresponding emission factor as indicated in Box 1. The total quantity of greenhouse gas emission generated by the municipality was summation of the whole sources from the entire sectors. The amount of the whole greenhouse gas sink was summation of the total sequestered carbon.

Box 1. General equation and the related emission factor for agricultural sector data source

CO_2, CH_4 and N_2O emission from wetland or dryland paddy field:
- Data source: Centre Agency for Statistics, City of X, 2005-2009
- Emission factor: IPCC Guidelines for National Greenhouse Gas Inventories, 1996
- GHG mass = wetland area x plantation day x emission factor

Carbon sequestration by city re-greening program and estate crops plantation:
- Data source: Centre Agency for Statistics, City of X, 2005-2009 and BPLH, City of X, 2009
- Emission factor: IPCC Guidelines for National GHG Inventories, 1996
- Carbon sequestration = area x emission factor

Greenhouse Gas Source and Sink in Agricultural Sector

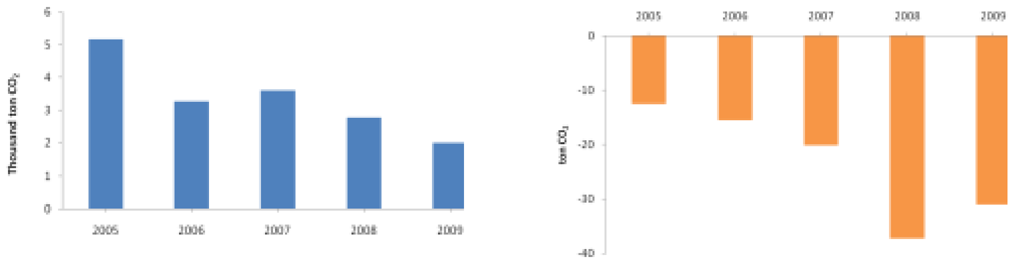
Agricultural activities regarded as greenhouse gas sources and sink in The City of X covers wetland paddy cultivation, dryland paddy cultivation, estate crops, and city re-greening program. The amount of the absorbed carbon was estimated simply from the area of the paddy cultivation. The similar case occurs in the estate crops as well. Therefore, the total amount of the absorbed carbon by those plant species was calculated directly based on the area of the cultivation.

Contribution of Agricultural Sector in the Local Greenhouse Gas Turnover

The identified agricultural activities occurred in The City of X mentioned above are compiled altogether as agricultural sector. The cultivated area by each of these activities was identified and recorded by Centre Agency of Statistics, City of X. It was then compiled for five (5) years (2005-2009), in order to calculate the GHG emission quantity generated by agricultural sector. Other sectors contributing greenhouse gases are energy sector, solid waste generation, and animal husbandry. The contribution of energy sector on the total greenhouse gas production was estimated by multiplying the amount of the energy source quantity by its corresponding emission factor. It covers all fossil fuel consumption for the city electricity, transportation, and industry. The amount of the generated solid waste is assumed in the order of 0.51 kg/capita/day (IPCC, 1966). By using the total population data of the City of X, the total amount of methane emission can be estimated. For the parameter nitrous oxide (N_2O), the estimation method is almost the same as those used in the CO_2 and CH_4 parameters, except for the emission factor. Global warming potential (GWP) of CO_2 is one, N_2O is 21 whereas for CH_4 is 310.

Results and Discussion

Estimation of the emitted CO_2 from the wetland paddy field and dryland paddy field is presented in Figure 1. It shows that in general there is tendency where the amount of emitted CO_2 from the wetland paddy field is decreasing with the year. This is due to the ongoing encroachment of the modern irrigated agricultural area that was converted to be industrial area and other land uses. In 2009 even, the total area of the wetland paddy field was less than a half of the total area in 2005 meaning that the amount of the emitted greenhouse gas becomes less than a half as well.



(a) (b)

Figure 1. CO_2 emission from wetland (a) and dryland (b) paddy field.

The amount of the sequestered GHG from dryland paddy field however, was not decreasing in the period of 2005-2009. It showed that the CO_2 sequestration from dryland paddy field in 2009 was almost threefold of that in 2005. This was simply due to the growing area of dryland paddy field in the City of X. The amount of methane emission from the wetland and dryland paddy field is presented in Table 1. It revealed that according to the paddy field area, the quantity of the emitted methane varies directly with the total paddy area. The more paddy field area, the higher amount of the methane emission, and vice versa. The generation of the methane in the wetland paddy area is initiated by anaerobic condition of the inundated paddy field as it was commonly practiced in conventional paddy cultivation system in Indonesia. As a result, methanogenic bacteria become more active to generate methane in such kind condition. The relative contribution of agricultural sector on total methane emission of The City X is presented in Figure 2. Agriculture contributes merely 0.01 % of the total methane emission where the largest portion was contributed by domestic solid waste due to the characteristic of the City X as an urban area. Another main issue of an urban area is the scarcity of agricultural land. Therefore, total methane emission generated by agricultural land is consequently relatively small.

Table 1. CH_4 emission from wetland paddy field

Area type	Year	Area (ha)	Plantation day (day/year)	Emission factor[1] (kg/ha/day)	kg CH_4[2]	ton CO_2-e
Wetland	2005	1959	200	0.096	37,613	790
	2006	1242	200	0.096	23,846	501
	2007	1364	200	0.096	26,189	550
	2008	1055	200	0.096	20,256	425
	2009	758	200	0.096	14,544	305
Dryland	2005	40	100	0.063	252.0	5
	2006	50	100	0.063	315.0	7
	2007	65	100	0.063	409.5	9
	2008	120	100	0.063	756.0	16
	2009	100	100	0.063	630.0	13

Data source: Centre Agency of Statistics, City of X (2005-2009)
[1] IPCC Guidelines for National Greenhouse Gas Inventories, 1996
[2] $kgCH_4$ = area x plantation day x emission factor

It is estimated that approximately 5 to 20 percent methane produced and released into the atmosphere is a by-product of the anaerobic decomposition of waste. A significant source of this type of methane production is solid waste disposal in landfills, where methanogenic bacteria break down organic matter in the waste under anaerobic conditions to produce methane (Anonymous, 2002). The landfilling of municipal solid waste is a significant source of atmospheric methane (CH_4), contributing to10–20% of anthropogenic methane emissions (IPCC, 2001 in Einola et al., 2008). This is in line with the findings of Papageorgiou et al. (2009) stated that disposal of waste in landfills generates methane that has high global warming potential.

The third concerned parameter of GHG in agricultural sector is nitrous oxide (N_2O) where its theoretical emission quantity was determined by areas of the wetland and dryland paddy field that were multiplied by their corresponding emission factors. Relative contribution of agriculture sector on total nitrous oxide emission was very small, i.e. merely 0.1 percent. Agricultural sector was not an important source of GHG from the viewpoint of the generated nitrous oxide (N_2O).

Table 2. CH_4 emission per sector expressed in ton CO_2 equivalent (CO_2-e)

Sector	Average (ton CO_2-e)
Fossil fuel consumption	2,9E+05
Domestic solid waste	8,2E+06
Agriculture	5,2E+02
Animal husbandry	6,6E+02
CH_4 Total emission	8,4E+06

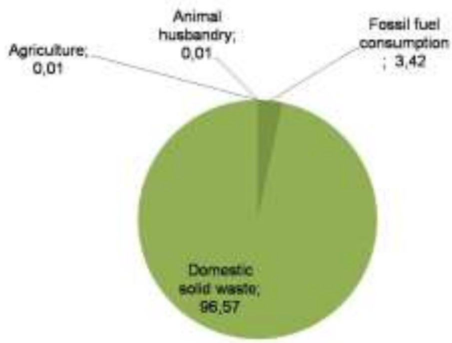
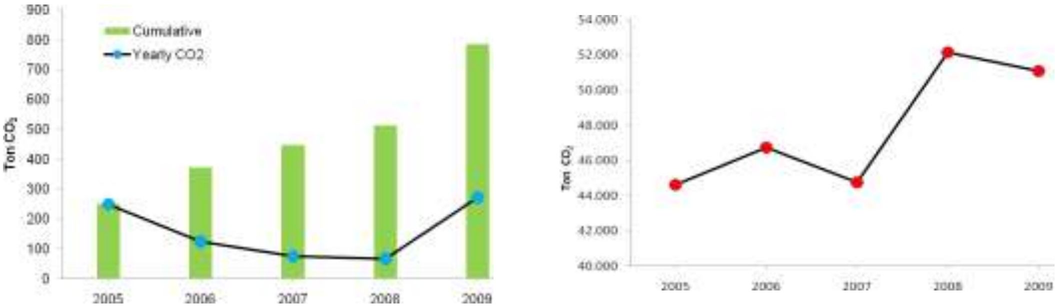


Figure 2. Relative contribution of agricultural sector on total methane (CH_4) emission.

Cumulative and yearly rate of carbon sequestration by means of city re-greening program is presented in Figure 3. The lowest part of the graph occurred in 2008 as a consequence of the re-greening program that achieved 10.0 hectares merely whereas the average area of the re-greening program normally was 23.8 hectares per year. In contrast however, the best success of the city re-greening program was reached in the last year (2009) where The City of X showed their commitment to reduce the greenhouse gas emission as re-greening area covered 41.2 hectares in a year.

Another way of carbon sequestration mode that was contributed by the city was through estate crop plantation (Figure 3). The identified crops in The City of X were papaya, banana, durian, manioc, mango, corn, sweet potato, and others. Total area of the estate crop plantation was in the range of 3049-3849 hectares per year that is spread over the sub-city area. By opening more plantation area, the amount of the captured atmospheric carbon dioxide would become higher. According to de Nevers (1995), the only methods we now know to slow or stop the buildup of CO_2 in the atmosphere are to reduce the use of fossil fuels (gas, oil, coal, peat, lignite) and to stop the deforestation of the tropical rain forests.



(a) (b)

Figure 3. Carbon sequestration by city re-greening program (a) and estate crop (b).

An important illustration of the emission profile of The City of X is an outline of the GHG emission and the related carbon sequestration quantity. Analysis on the compiled data revealed that agricultural sector plays a minor role in emitting greenhouse gas (GHG) as indicated in Table 3. Percentage of the CO_2 emission from agricultural sector was merely 0.17% whereas its contribution on CH_4 and N_2O emission were only 0.01% and 0.06%, respectively. On the other side, however, agriculture contributes about 2.39% (Table 3) sequestration process of the emitted carbon dioxide back to the earth through photosynthesis process. It indicated that agriculture plays a significant role in the greenhouse gas turnover in the local scale.

The quantity of the emitted methane (CH_4) and nitrous oxide (N_2O) were significantly higher than the amount of emitted carbon dioxide (CO_2). Such condition should be noticed carefully since the warming effect of CH_4 and N_2O are much stronger than CO_2. According to Jones (1992), although increasing atmospheric CO_2 is often assumed to be the major contributor to warming, the combined effect of a number of trace gases, principally methane, nitrous oxide and chlorofluorocarbons (CFCs), though present at concentrations that are two to six orders of magnitude lower than CO_2, can rival the effect of CO_2 because, per molecule they absorb infrared radiation much more strongly.

Table 3. Outline of the GHG emission of The City of X and the carbon sequestration

Emission/ sequestration	GHG	Sector	Average quantity (2005-2009) [ton CO_2-e]	%
Emission	CO_2	Paddy field	3.3E+03	0.17
		CO_2 Total emission	2.0E+06	99.83
	CH_4	Agriculture	5.2E+02	0.01
		CH_4 Total emission	8.4E+06	99.99
	N_2O	Agriculture	2.2E+03	0.06
		N_2O Total emission	3.6E+06	99.94
	Grand total emission (source)		14E+06	0.24
	Average contribution of agric. sector		2.0E+3	0.08
Sequestration	CO_2	Sequestration by:		
		• Estate crops	4.8E+04	2.38
		• City re-greening program	1.6E+02	0.01
	Grand total sequestration (sink)		4.8E+04	2.39

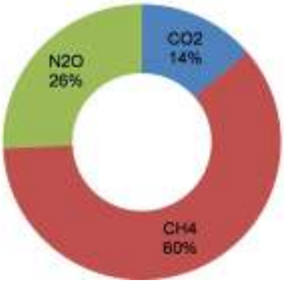


Figure 4. Relative emission of The City of X based on GHG component (2005-2009).

More severe condition occurred in The City of X where GHG parameters of CH_4 and N_2O were absolutely much higher than CO_2 (Figure 4). As a consequence, the warming effect on the atmosphere would be much higher too. The main potential reason for such condition was that the people of The City of X generated solid wastes higher than the other Indonesian urban population.

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