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GREENHOUSE GASEOUS EMISSION AND ENERGY ANALYSIS IN RICE PRODUCTION SYSTEMS IN GHANA

J.F. ESHUN, S.O. APORI and E. WEREKO
Takoradi Polytechnic, Takoradi, Ghana, P. O. Box 256, Takoradi, Ghana
Corresponding author: jfeshun@yahoo.com

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ABSTRACT

Agriculture in Africa is associated with low food production. The attempt to increase food productivity has the potential to generate some environmental concerns such as greenhouse emissions and energy impacts. The environmental impact of the rice production in the tropics, especially Africa, has not received much attention from the research community. Therefore, analysing the environmental performance of rice (*Oryza sativa)* production in Ghana provides an effective first step to develop, implement and improve its environmental management. The objective of this study was to assess greenhouse gas (GHG) emissions and energy impacts of rice production in Ghana. Among the three main components of greenhouse gases (GHGs), N_2O accounted for the highest value, followed by CO_2. Approximately, 477 kg CO_2-equivalents of greenhouse gas was emitted per hectare of rice production. Among the activities that generated greenhouse gases, fertiliser application ranked first (72%), with transportation to mills as the second with a relative emission of 10%. Fertiliser application and transportation were the major contributors to SO_2 emission. Energy used (mainly from diesel usage) in rice production amounted to 0.2 MJ per hectare. With regards to options to reduce environmental impact of rice production in Ghana, practices that recover investment cost and generate a profit in the short term are preferred by rice farmers over practices that require a long-term to recover investment costs. Practices that have a high probability associated with expected profits are desired over practices that have less certainty about their returns.

Key Words: Carbon dioxide, nitrous oxide, *Oryza sativa*

RÉSUMÉ

L'agriculture en Afrique est associée à une faible production alimentaire. La tentative d'augmenter la productivité alimentaire présente un risque de générer des problèmes environnementaux dont les émissions à effet de serre et les impacts énergétiques. L'impact environnemental de la production de riz dans les régions tropicales, spécialement en Afrique n'a pas reçu beaucoup d'attention de la communauté des chercheurs. Par conséquent, l'analyse de la performance environnementale de la production de riz au Ghana fournit une première étape efficace pour développer, exécuter et améliorer sa gestion environnementale. L'objectif de cette étude était d'évaluer les émissions de gaz à effet de serre et impact énergétiques de la production du riz au Ghana. Parmi les trois composantes principales de gaz à effet de serre, N_2O présente des valeurs les plus élevées suivi par le CO_2. A pproximativement, 477 kg CO_2-équivalents au gaz à effet de serre étaient émis per hectare du riz produit. Parmi les activités génératrices de gaz à effet de serre, l'application des fertilisants se rangeait premier (72%), le second étant le transport à l'usine avec pour émission relative de 10%. L'application de fertilisants et le transport constituaient des contributeurs majeurs à l'émission du SO_2. L'énergie utilisée (principalement le diesel) dans la production de riz s'élevait à 0,2 MJ par hectare. En ce qui concerne des options pour la réduction de l'impact environnemental de la production de riz au Ghana, les pratiques permettant de recouvrer le coût d'investissement et de générer un profit à court terme sont préférées par les producteurs de riz plutôt que les pratiques qui nécessitent un recouvrement à long terme des coûts d'investissement. Les pratiques ayant une forte probabilité associée à des bénéfices attendus sont souhaités par rapport à celles qui présentent moins de certitude en terme de profit.

Mot Clés: Dioxyde de carbone, oxyde nitreux, *Oryza sativa*

INTRODUCTION

Sub-Saharan Africa (SSA) has one of the world's fastest growing populations, but with very low growth rate of food production**.** Inadequate food production has over the years resulted in malnutrition and widespread poverty (WARDA, 2005) in parts of the region.

Rice (*Oryza sativa* L.) is an important staple food and is crucial to the economy of many countries in SSA. (Chandler, 1979). Rice is also a good source of energy for a majority of the populace in SSA and has been used consistently in meals.

According to Ghana's Ministry of Food and Agriculture (MoFA, 2009), the country estimated national rice consumption stands at 561,400 metric tonnes per *annum,* with local production at 107,900 metric tonnes per *annum* leaving a gap of 453,500 metric tonnes per *annum* for imports. Low productivity is the greatest challenge for development. Any attempt to increase rice production through high fertiliser inputs and other application has the potential of generating environmental concerns such as greenhouse gas (GHG) emissions and energy impacts (Holger and Conrad, 2007; Lianxin Yang and Yulong Wang, 2007; Zou and Huang, 2007; Connor and Comas, 2008; Fulu and Yousay, 2008; Maelinda and Noorlidah, 2008). Flooded rice paddies emit methane (CH_4), the second most important of the long-lived greenhouse gas (GHG) contributing with a potency of 21 times to global climate change relative to the main greenhouse gas carbon dioxide (CO_2) (IPCC, 2007).

According to Eshun *et al.* (2011), the environmental system analysis of tomatoes production in Ghana revealed that approximately 8,544 kg CO_2-equivalents of greenhouse gas was emitted per hectare of tomato production in Ghana.

The effects of greenhouse gas emissions and the consequent climate change exemplify systemic global climate change (Walker and Schulze, 2007). Climate change presents a profound challenge to food security and development, especially where poverty is pervasive and social safety nets are weak. There is an urgent need and effort to conduct greenhouse gas inventory studies in order to lay strategies for reducing the greenhouse gases emission impact from rice production in Ghana.

Current estimates of greenhouse gases emission from rice cultivation from most countries are based on measurements performed under Asian conditions (IPCC, 2007).

The environmental impact of rice production in the tropics, especially in Africa has not received much attention from the research community. If capacities are not built in tropical countries to develop local competence in Life Cycle Assessment (LCA) techniques, tropical rice production risks being inadequately represented in the international market. To date, there have not been extensive studies on the environmental performance of rice production in Ghana.

The objective of this study was to assess the greenhouse gases emission and energy use in rice production systems in Ghana and to identify technical options to reduce its impact in rice production system in Ghana.

METHODOLOGY

This study was done in the northern region of Ghana, from February to May 2011. Data were collected using questionnaires and computations for inventory datasets.

(i) Survey. Questionnaires were administered to thirty selected rice farmers based on their volume of rice production per year to provide data about the inputs and outputs of their activities for resources, material uses and energy requirements per hectare per year. The assessment covered land preparation, planting, fertiliser application, harvesting and transportation to milling plants. The system boundary, as illustrated in Figure 1, provides a process flow of the system, representing the linkages between processes

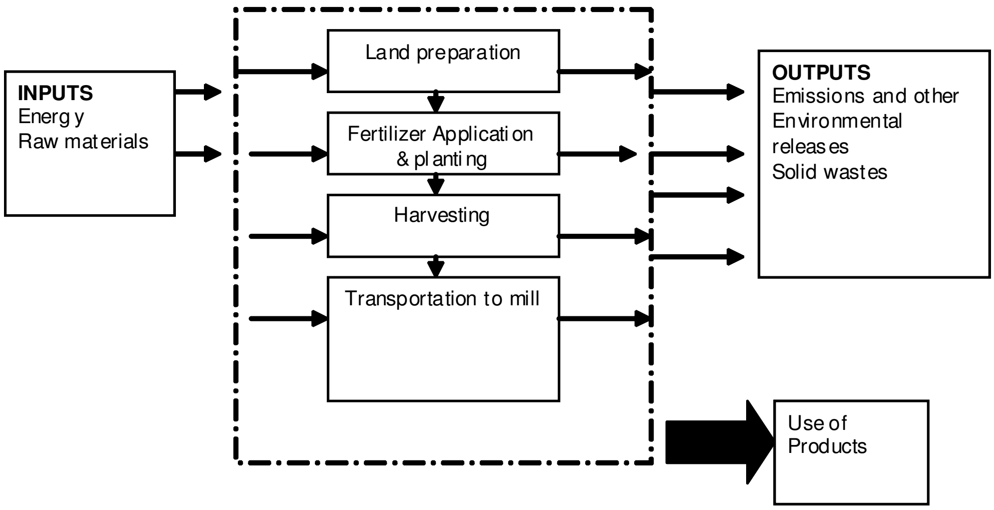

Figure 1. Life Cycle Assessment (LCA) of both upland and paddy rice production systems in Ghana-Product life Cycle Stages.

involved in the product life cycle, supports data collection and facilitate reporting and transparency of the LCA.

(ii) Computation. Computation for inventory datasets consisted of emissions and energy of the activities associated with rice production in Ghana per hectare per year. Emission inventory data were not available in Ghana; thus, they were calculated as a function of production activities and the emission factors (Table 2) using the following equation:

Emission = Activity x Emission Factor
.... (Equation 1)

We made the resulting emissions as local as possible by calculating them as function of production volumes, as provided by the survey. When the activities which generate the pollutants could be quantified, emission was calculated using the emission factor related to the production capacity. In this context, the production capacity was virtually thought of as an activity. The emission factor is emission per unit activity for a certain compound, which was obtained from references. The results of emission calculations are expressed in tonnes of pollutant either emitted or generated from rice production system in tonnes per year. The activity data and emission factors (Tables 1 and 2) used to quantify the emissions, were considered to be the best data available. The values which were not available were obtained from sources which are commonly used and widely accepted such as emission factors described by the IPCC (2006). However, some data could not be obtained directly from one source and the use of integrated information from multiple sources was adapted.

The integrated environmental impact of the emissions was calculated using classification factors as illustrated in Table 3 (Heijungs *et al.*, 1992; Jawjit *et al.,* 2006).

Impact = Emission x Classification Factor
.... (Equation 2)

In this analysis, classification factors based on global warming were applied.

RESULTS AND DISCUSSION

Greenhouse gas emission. Approximately 477 kg CO_2-equivalents of greenhouse gas was emitted per hectare of rice production in Ghana (Table 4). Among the three main components of greenhouse gases, CO_2, CH_4 and N_2O; N_2O accounted for the highest value, followed by CO_2. Among the activities that generate greenhouse gases, fertiliser application ranked first, with a share of 72% (Table 4). Generally, it is believed that agricultural soils represent a large, and

TABLE 1. Activity data for the calculation of greenhouse gas emissions in rice production systems in Ghana

Source	Activity	Emission value	Unit (ha^{-1})
Land preparation	Diesel use	9.4	kg fuel
Planting	Diesel use	12.5	kg fuel
Pesticide application	Pesticide use (propanil)	3.87	kg
Fertiliser application	N fertiliser use	37.05	kg
	P fertiliser use	37.05	kg
	K fertiliser use	37.05	kg
	$(NH_4)_2SO_4$ fertiliser use	25.93	kg
Weedicides application	Chemical use (glyphosate)	0.1	kg
Harvesting	Diesel use	8.8	kg fuel
Transportation	Diesel use	15.4	kg fuel

TABLE 2. Emission factors as used in Equation (1) used to calculate greenhouse gaseous emission in rice production systems in Ghana

Source	Compound emitted	Emission factor	Unit	Reference
N-fertiliser use	N_2O	0.03	kg N_20-N kg^{-1} N	(IPCC, 1997)
	NO_X	0.025	kg N_20-N kg^{-1} N	(IPCC, 1997)
P-fertiliser use	PO_4^{-3}	0.2	kg PO_4^{-3}-P kg^{-1} P	(IPCC, 1997)
Transportation use in farm operation	CO_2	3150	g kg^{-1} fuel	(Schwaiger and Zimmer, 1995)
	N_20	0.02	g kg^{-1} fuel	(Schwaiger and Zimmer, 1995)
	CH_4	6.91	g kg^{-1} fuel	(Schwaiger and Zimmer, 1995)
	NO_X	50	g kg^{-1} fuel	(IPCC, 1997)
	NMVOC	6.5	g kg^{-1} fuel	(IPCC, 1997)
	CO	15	g kg^{-1} fuel	(IPCC, 1997)
Transportation to mill	CO_2	3180	g kg^{-1} fuel	(Schwaiger and Zimmer, 1995)
	N_20	0.1	g kg^{-1} fuel	(Schwaiger and Zimmer, 1995)
	CH_4	0.2	g kg^{-1} fuel	(Schwaiger and Zimmer, 1995)
	NO_X	29.8	g kg^{-1} fuel	(IPCC, 1997)
	NMVOC	4.7	g kg^{-1} fuel	(IPCC, 1997)
	CO	14	g kg^{-1} fuel	(IPCC, 1997)
	SO_2	20	g kg^{-1} fuel	(IPCC, 1997)

TABLE 3. Classification factors used in Equation (2) for emissions of greenhouse gases, in rice production systems in Ghana

Compounds	Classification factors	Reference
CO_2	1 kg = 1CO_2-eq	(IPCC, 1997)
CH_4	1 kg = 21CO_2-eq	
N_2O	1 kg =310CO_2-eq	

growing, global source of nitrous oxide. Nitrous oxide emissions from agricultural soils occur through nitrification and denitrification in soils, particularly that from mineral or organic fertilisers (Velthof *et al.*, 2002). Emissions are very dependent on local management practices, fertiliser types, and climatic and soil conditions. With a rapid increase in population growth, and the consequent need for more food production, both the area of agricultural soils and the

TABLE 4. Greenhouse gases emission from rice production activities in Ghana

Activity/source	CO_2 emission		CH_4 emission		N_2O emission		Total	
	kg ha^{-1}	kg CO_2-eq ha^{-1}	kg ha^{-1}	kg CO_2- eq ha^{-1}	kg ha^{-1}	kg CO_2- eq ha^{-1}	kg CO_2-eq ha^{-1}	%
Land preparation	29.6	29.6	0.06	1.26	0.0001	0.031	30.89	7
Fertiliser application					1.1	345	345	72
Planting	20.5	20.5	0.045	0.95	0.0001	0.031	21.48	5
Harvesting	27.7	27.7	0.061	1.28	0.0001	0.031	29.01	6
Transportation	48.5	48.5	0.106	2.23	0.0003	0.09	50.82	10
Total	126.3	126.3	0.272	5.72	1.1006	345.183	477.2	100

intensity of their use is likely to continue to rise rapidly in the coming decades. The use of slow and controlled release fertilisers and/or stabilised fertilisers has been successful in serveral agro-environmental conditions, particularly in rice (Carreres *et al*., 2003; Tang *et al*., 2007); and in agricultural and horticultural crops, especially on sites with a high precipitation, intensive irrigation and/or light sandy soils (Pasda *et al*., 2001). Reducing emissions from non-carbon dioxide greenhouse gases, such as nitrous oxide, could deliver short-term climate change mitigation results as part of a comprehensive policy approach to combat climate change.

Energy consumption. According to Table 1, energy usage in rice production in Ghana were mainly attributed to diesel fuel use. The main processes that used diesel were land preparation, planting, harvesting and transportation. According to the activity data illustrated in Table 1, the total diesel usage was 46.1 kg of fuel per hectare, and its energy equivalent was 0.2 MJ per hectare. Energy production and use have various environmental implications. Since energy represents about 65% of global anthropogenic greenhouse-gas emissions, reducing emissions must necessarily start with actions geared to reduce fuel combustion (IPCC, 2007). To limit emissions from this sector, policy makers should first and foremost consider measures to encourage improved vehicle efficiency so as to reduce emissions from combustion.

Options to reduce the greenhouse gases and energy impacts. Technologies for mitigation of greenhouse gases are very important in rice production systems. The potential decrease in emissions of CO_2, CH_4 and N_2O (Table 4) are the equivalents carbon emission reductions for CO_2 and N_2O based on their respective ratios of global warming potential. From the total possible reduction in radiation forcing (CO_2 equivalents), approximately 72% could result from reduction in N_2O emissions and 26% from reduction in CO_2 emissions (IPCC, 2007).

Estimates of potential reductions range widely, reflecting uncertainty in the effectiveness of recommended technologies and the degree of future implementation globally (IPCC, 2007). To satisfy global food requirements, and acceptability by rice farmers, technologies and practices should be sustainable, provide additional benefits to farmers and consumer acceptance. Rice farmers have no incentive to adopt GHG mitigation techniques, unless they improve profitability. Some technologies, such as no-till agriculture or strategic fertiliser placement and timing, are already being adopted for reasons other than concerns for climate changes.

Options for reducing emissions, such as improved farm management and increased efficiency of nitrogen fertiliser use, will maintain or increase agricultural production with positive environmental effects. These multiple benefits will result in high cost effectiveness of available technologies. Practices that recover investment cost and generate a profit in the short term are preferred over practices that require a long-term to recover investment costs. Practices that have a high probability associated with expected profits are desired. When human resource constraints or knowledge of the practice prevent adoption, public education programmes can improve the knowledge and skills of the work force and managers to help advance adoption. Comprehensive national and international programs of research, education and technology transfer will be required to develop and diffuse knowledge of improve technologies. Crop insurance or other programs to share the risk of failure due to natural disaster are needed to aid the adoption of improved practices.

CONCLUSION

Fertiliser application and transportation are responsible for most greenhouse gases and energy impacts of rice production systems in Ghana. Approximately 477 kg CO_2-equivalents of greenhouse gas is emitted per hectare of rice production in Ghana. The total diesel usage is 46.1 kg of fuel per hectare, and its energy equivalent was 0.2 MJ per hectare of rice production. It is clear that with a rapid increase in population and the consequent need for more food production especially rice, both the area of agricultural soils and the intensity of the use of fertiliser is likely to continue to rise rapidly in coming decades. There is need to develop technologies for mitigation of **g**reenhouse gases in rice production systems and the potential decreases in emissions and energy use. Good policies on improved farm management, increased efficiency of nitrogen fertiliser use and vehicle efficiency will maintain or increase rice production with positive environmental effects.

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