Rice Cultivation and Greenhouse Gas Emissions: A Review and Conceptual Framework with Reference to Ghana.

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ABSTRACT

Rice is an essential crop in Ghana. Several aspects of rice have been studied to increase its production; however, the environmental aspects, including impact on climate change, have not been studied well. There is therefore a gap in knowledge, and hence the need for continuous research. By accessing academic portals, such as Springer Open, InTech Open, Elsevier, and the Kwame Nkrumah University of Science and Technology's offline campus library, 61 academic publications including peer reviewed journals, books, working papers, reports, etc. were critically reviewed. It was found that there is a lack of data on how paddy rice production systems affect greenhouse gas (GHG) emissions, particularly emissions estimation, geographical location, and crops. Regarding GHG emission estimation, the review identified the use of the emission factor method in GHG level estimation in the tropics. The use of this method, however, has been variously found to be ineffective due to the use of temperate environmental conditions in its calibration. The calibration (emission factor method) leads to either an under or overestimation of emission levels in the tropics. On location, most research on rice GHG emissions have been carried out in Asia with little input from Africa. Regarding crops, there is paucity of in-situ emissions data from paddy fields in Ghana. Drawing on the review, a conceptual framework is developed using Ghana as reference point to guide the discussion on fertilizer application, water management rice cultivars, and soil for future development of adaptation strategies for rice emission reduction.

OBJECTIVES

To review research done on African smallholder rice – Greenhouse gas emissions and develop a conceptual framework to guide research in the field on the African continent especially sub-Saharan Africa

METHODOLOGY

The review was done by accessing and critically reviewing academic portals, such as Springer Open, InTech Open, Elsevier, and the Kwame Nkrumah University of Science and Technology's offline campus library, academic publications including peer reviewed journals, books, working papers, reports, etc. The review was used as a guide for the development of a conceptual framework to guide paddy-rice emission research.

RESULTS

Conceptual Framework

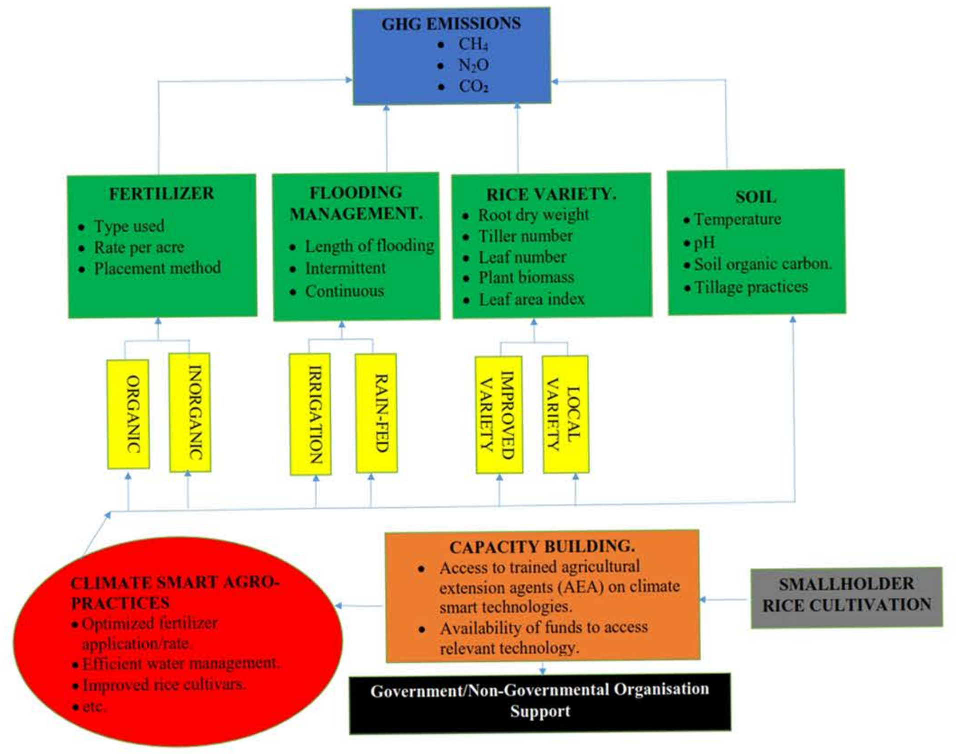

Figure 1

Figure one (1) shows the relationships that exist among the various factors at play at the smallholder rice paddy cultivation level. These factors account for the level of emissions that will be released from the paddy rice cultivation process.

Table 1. IDENTIFIED GAPS IN REVIEWED LITERATURE

Area	Identified Gaps
Emissions Estimation	Use of emission factors calibrated using temperate conditions which doesn't suit tropical conditions. Insufficient measurements for the development of a localized emissions database for continuous research on rice induced emissions in Ghana.
Location	Majority of studies on rice induced GHG emissions carried out in Asia with little to no input from African rice production.
Crops	Unavailability of emission data collected in-situ from paddy rice fields in Ghana.

RICE CULTIVAR (VARIETY) IMPACT ON GHG EMISSIONS

Rice varieties have been found in various field studies to affect GHG emissions, especially methane [1,2]. The physiology of rice plants regulates methane emissions by making available sources of methanogenic substrates through carbon in the roots, including exudates, and also by transporting CH_4 emissions through the aerenchyma [3, 4-7]. Several studies have confirmed variations in the emission levels of different rice cultivars [8-9]. Findings from the studies demonstrate the possibility of employing biological mitigation strategies to control methane emission from rice production systems.
Typical among smallholder farmers in sub-Saharan Africa, access to improved and high yielding rice cultivars is a challenge. Therefore, if progress is to be made regarding the reduction of GHG emissions via improved seeds, access to seeds which are high yielding and low on emissions must be improved and made affordable.

RICE PRODUCTION MANAGEMENT PRACTICES INFLUENCE ON GHG EMISSIONS

The management practices that are employed in rice cultivation are key to the emission of greenhouse gases. Methane and nitrous oxide emissions are impacted directly by water management and fertilizer application respectively. Studies done by various authors confirmed that the majority of the practices that are carried out during the growing phase of rice cultivation affect GHG emissions and that they can be manipulated to reduce emissions [5-9]. A lot of work has been done to study the mechanisms through which these management practices influence GHG emissions.

OPTIMIZATION OF FERTILIZER APPLICATION EMISSIONS

The use of organic fertilizers may reduce emissions, but there is the need to determine their performance on a large scale as well as their economic viability. There is also the need for effective farmer education to gradually wean them off chemical fertilizers which have guaranteed yields for years.

Optimized fertilizer application will ensure efficient utilization of nutrients by the rice plant, thereby leaving very little residue for nitrification/denitrification and thereby reducing N_2O emissions. For smallholder farmers with limited access to farm inputs, optimized fertilizer application will not only help in the reduction of N_2O emissions but will also make it possible for the farmers to make savings for other farm activities and their families

It is important to note that different soils may produce different reactions to different fertilizer amendments, and so for rice fields in Ghana it will be important to study the effects of different fertilizer combinations on GHG emissions with a view of making organic fertilizers an integral part. Studies on emissions from both conventional and organic fields have not been carried out in Ghana or most other rice producing countries in Africa. This makes it difficult to assess the effect of synthetic and organic fertilizers on GHG emissions under tropical conditions.

Table 2. EMMISION LEVELS FROM VARIOUS STUDIES

	Location	Emission	Emission level	Reference
1	India	CH_4	18.63 g/m^2	[10]
		N_2O	14.33 g/m^2	
2	China	N_2O	23.10^a,40.10^b,71.10^c mg /m^2	[11]
3	China	CO_2	*0.45 - 8.62 μmol.m^{-2}.s^{-1}	[12]
4	China	N_2O	0.089-0.21 kgNha^{-1}	[13]
5		CH_4	34.6-51.7 kgCha^{-1}yr^{-1}	
6	China	N_2O	0.11 -0.68 kgNha^{-1}	[14]
		CH_4	135-467 kgCha^{-1}	
7	India	N_2O	1.09–1.64 kgCha^{-1}	[15]
8	Philipines	CH_4	75.55-86.81 kg CH_4–C ha^{-1} s^{-1}	[16]
		N_2O	0.64-0.0.90 kg N_2O– Nha-^{1} season-^{1}	
9	Italy	CH_4	0.16-0.38g CH_4/m^{2}d^{-1}	[17]
10	Indonesia	CH_4	19 -123 mg CH_4 m^{-2} d^{-1}	[18]
11	Indonesia	CH_4	-399.63 to 459.94 kg CH_4/ha	[19]
12	USA	N_2O	90-171 g N ha^{-1}	[20]
13	USA	CO_2	2.4-21.1 kg·C·ha–^{1}·d^{-1}	[21]
		N_2O	0.20-6.7 g·N·ha–^{1} d–^{1}	
		CH_4	–0.97-0.04 g·C·ha–^{1}·d–^{1}	

^{a}, ^{b} and ^{c} represents low, medium and high nitrogen fertilizer application respectively

CONCLUSIONS AND RECOMMENDATIONS

There is a chronic lack of data on rice cultivation and GHG emissions in Ghana and other African countries and as such the net effects of emissions are not known. This makes the design of mitigation measures to suit local conditions difficult. It emerged from this review that, in most cases, management practices of rice production systems played a critical role in the emission of greenhouse gases, especially fertilizer and flooding regimes. Rice cultivar/variety as a biological means of mitigating GHG emissions from rice cultivation systems is essential, but it should be used in collaboration with emission reduction proven water and fertilizer regimes to get the expected results. The conceptual framework had presented a visual representation of how various factors such as fertilizer application, water management practices, crop variety, and soil type inter-relate to explain the factors that influence the level of greenhouse gas emissions from rice fields. It is concluded that research in sustainable rice cultivation should be given attention in Ghana and other African countries to ensure continuous generation of knowledge and an understanding of the potential methods that can contribute to intensify rice cultivation and reduce greenhouse gas emissions.

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DISCLAIMER

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