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Scenario on Environmental Management to Reduce Green House Gas Emission Due To Low Land Rice Cultivation under Paddy Soils

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Abstract
As an important staple food crop rice production needs to be increased by 40% by the end of the 2030s to meet the increasing demand for food due to the expanding population. In this regard countries like Ethiopia having reasonable potential of rice production in various areas, mainly in rainfed lowland, upland and irrigated ecosystems are the major targets. But such Agricultural activities contribute to approximately 18.4% of to the present concentrations of GHGs emission followed by energy sector that are considered as one of the major sources of emissions however, this warming potential is a cumulative effect of 100 years horizon. CH_4 gas is produced under flooded or anaerobic soil conditions by the process of methanogenesis while N_2O gas is produced through nitrification and denitrification processes. Consequently predicting the dynamic changes in emission of GHGs and rice yield in paddy fields and keeping the possible solution should be considered. From the scenarios of rice and green house gas emissions water managements on paddy soils as well as organic and inorganic fertilizations under plenty mass production of rice on paddy soils are top most considerable's. Therefore conducting researches to fills the gap by determining the effect of nutrient and water management on rice yield and greenhouse gas emission should be developed and in lined with the mass production for the future.
Keywords: Paddy Soils; Fertilization; Water Management; Green house gases
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1. Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop and the essential food source for more than half of the world's population. The world average paddy rice productivity is about 4.6 tons ha^{-1}. Globally, paddy rice production covers an area of 162.1 million hectares with 755.5 million tons of grains (FAOSTAT, 2018). Rice has sufficient nutritional content and if the cultivation is expanded in various parts, it could play a crucial role in easing food insecurity. According to FAOSTAT (2018), the production share of paddy rice in the world is 90.6% in Asia, 5.2% in America, 3.5% in Africa, 0.6% in Europe, and 0.1% in Oceania. As indicated by Food and Agriculture Organization of the United Nations (FAO) agricultural outlook , rice production needs to be increased by 40% by the end of the 2030s to meet the increasing demand for food due to the expanding population (Vázquez and Cuevas, 2019),which necessitates global efforts to increase rice production to ensure food security.

In Ethiopia, rice production started in the early 1970's as the country has reasonable potential of rice production in various areas, mainly in rainfed lowland, upland and irrigated ecosystems (Mulugeta and Heluf, 2014). The area coverage by rice crop has been increase from 10,000 ha in 2006 to over 63,000 ha in 2018 (CSA, 2019). The increased area for rice production is considerably linked with expansion of production in the wetland and upland areas with the introduction of suitable rice varieties for the different agro-ecologies (CSA, 2019). Rice production increased from 71,316.07 tons in 2008 to 171,854.1 tons in 2018 (CSA, 2019). Rice production has brought a significant change in the livelihood of farmers and created job opportunities for a number of citizens in different areas of the country. However, the research revealed that Rice productivity in Ethiopia is still estimated at 2.8 t ha^{-1}, which is much lower than the World's average of 4.6 t ha^{-1}(FAOSTAT, 2018). As MoARD indicated, Amhara, Southern Nations Nationalities and Peoples Region (SNNPR), Oromiya, Somali, Gambella, BeniShangul Gumuz, and Tigray regions are the current rice producing areas in Ethiopia (Tilahun, 2020). Amhara region takes the lion's share and accounted for 65-81% of the area coverage and 78-85% of the production in the years 2016-2018 (CSA 2018 and 2019). The potential rainfed rice production area in Ethiopia is estimated to be about 30 million hectares.

Rice production systems contribute to global climate change through emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4) and Nitrous oxide (N_2O) gases to the atmosphere; simultaneously the rice production is also affected by the change in climatic variables (Ali e*t al*., 2019). Agricultural activities contribute to approximately 18.4% of to the present concentrations of GHGs emission followed by energy sector that are considered as one of the major sources of emissions. The global warming potential (GWP) of CH_4 and N_2O is 28 and 265 times higher than that of carbon dioxide, respectively, on a 100-year time horizon (IPCC, 2014).

Rice requires a high amount of water as compared to the other crops. In paddy rice production systems, a large quantity of water is lost through evapotranspiration, surface runoff, seepage, and deep percolation (Linquist, 2015). Rice paddies have attracted considerable attention due to share of 1.3% global greenhouse gas emission from the agriculture sector. At the global level, agricultural share in freshwater is about 70% to 80% of the total irrigated fresh water resources, from this 90% of that consumed by rice cultivation in Asia (Wu *et al*., 2017). Thus, producing more rice at lower environmental cost is required for future development, i.e., the use of less water and the production of fewer greenhouse gas (GHG) per unit of rice.

Generally, CH_4 gas is produced under flooded or anaerobic soil conditions by the process of methanogenesis, while N_2O gas is produced through nitrification and denitrification processes depending on the soil redox potential condition (Ali *et al*., 2019).

Thus, predicting the dynamic changes in emission of GHGs and rice yield in paddy fields and keeping the possible solution for the scrnario in the future is important for formulating agricultural management measures to save water, increase yield, and promote sustainable development. Therefore to formulate and recommend best agricultural management practices for environmentally friend and better rice productivity reviewing of previous works will be very important.

2. Rice and Greenhouse Gas Emissions

Rice is the staple crop for the majority of the world's population (FAO, 2014a), and rice production is the sector where the majority of the peoples get employment and used as a source of income, especially in developing countries. In 2013, farmers harvested rice on 165 million hectares worldwide and flooded ("paddy") rice achieved a global average yield of 4.5 tons per hectare (FAO, 2014a). Roughly, 20 million of those hectares in Asia produce two or three crops of rice per year (Fischer *et al*., 2014).

According to the different researches, paddy rice generates methane roughly 500 million tons of emissions of carbon dioxide equivalent (CO_2e) per year. For the coming of 100 years, methane is a cause for global warming, which implies that rice methane may be equivalent to around 800 million tons of carbon dioxide equivalent per year. Generally, paddy rice methane contributes at least 10 percent (and possibly more) of emissions from global agricultural production, and 1 percent or more of total human-generated GHG emissions. For most rice-growing countries in Southeast Asia, rice contributes around 50 percent of agricultural emissions and from 2.5 percent to more than 20 percent of total emissions (UNFCC, 2014).

Unfortunately, climate change threatens to decrease rice yields and to increase its GHG emissions. Most of the rice is currently cultivated in regions where temperatures are above the optimal for growth (31/22°C) (Wang *et al*., 2018). Any further increase in mean temperature or episodes of high temperatures during sensitive stages may reduce rice yields drastically. Millions of hectares of high quality, low-lying rice lands in Asia affected by sea-level rise, increasing the risks of salinity and flooding. In addition, higher concentrations of carbon dioxide in the atmosphere appear directly to increase methane emissions by increasing the supply of carbon to the microorganisms that produce methane. The CH_4 emissions are the main source of GHG from rice paddy fields. In waterlogged paddy fields, CH_4 is generated by anaerobic decomposition of organic matter in the soil (Lee *et al*., 2010).

3. Water Management influence on Paddy Rice yield and Greenhouse Gas emission

Water management used, together with other crop management practices such as crop variety selection and fertilizer management, affects the magnitude of GHG emissions. Manure amendment in the soil increased grain yields and water productivity by 7.7% and 15.8%, respectively in wet season compared to those in the no-manure treatment. However a biogeochemical model, Denitrification-Decomposition (DNDC) simulation, require to enhance its capacity of predicting the dynamic changes in greenhouse gas (GHG) emissions and yield in the future from the typical nutrient and water management paddy rice ecosystems.

In Ethiopia, water and nutrient management effect on rice production and greenhouse gas emission has not yet studied. Similarly, no efforts were investigated to increase the yield of paddy rice, simultaneously with less greenhouse gas emissions in the study area as well as in Ethiopia. However, the 26% of yield increment was obtained due to draining and re-flooding the water from 15-days to one-month interval as compared to continuous flooding. The integrated use of nitrogen-phosphorous fertilizer (NP) and FYM gave higher yields than application of either NP or FYM alone in rice production (Tilahun and Zelalem, 2019).

Several types of water management practices (i.e., continuous, full-season flood, intermittent flooding, or mid-season drain) are currently used globally for rice production. The most common type, both historically and currently, is the continuous, full-season flood.

In the flood of rice field, the more methane-producing bacteria grow and the more they generate methane. The drawdown of water accomplished by temporarily halting irrigation, allowing water levels to subside through evapotranspiration, percolation, and seepage. Interrupting flooding even with occasional draw downs has a dual effect: it quickly drives down the populations of methane producing bacteria, and it stimulates the breakdown of methane by other bacteria. Although the drop-in methane emissions are not necessarily proportional to the duration of the drawdown, studies have found that almost any means of reducing or interrupting this flooding reduces methane emissions (IPCC, 2007). LaHue *et al*. (2016) reported a reduction of 57–78% in annual CH_4 emissions from rice fields maintained under the AWD system. However, N_2O emissions might increase under AWD method due to an enhancement in nitrification and denitrification processes resulting from constantly changing soil conditions between anaerobic and aerobic and related changes in redox potential (Oo *et al*., 2018). Pandey *et al*. (2014) reported that 64% less global warming potential (GWP) with Alternate wet and dry (AWD) from organic amended paddy field. Tirol-Padre *et al*. (2017) recorded a 21–38% reduction in CH_4 emissions with a 4% increase in rice grain yield with AWD compared to continuous flooding. Despite the benefits of reduced GHG emissions and increased rice yield from improved water management practices, farmers often face practical and technical constraints in implementing these systems.

3. Organic Fertilizer Effect on yield and Greenhouse Gas Emission from Paddy field

Researchers revealed that replacing of chemical fertilizer with organic manure significantly decreased the emission of Greenhouse Gas emissions (GHGs) and pointed out that organic farming can reverse the agriculture ecosystem from a carbon source to a carbon sink (Liu *et al*., 2015). The substitution of chemical fertilizers with organic fertilizers has become a common practice in agricultural systems. Thus, Liu *et al*. (2015) investigated mitigating GHG emissions through the replacement of chemical fertilizer with organic manure in temperate farmland. The research results revealed that replacing chemical fertilizer with organic manure significantly decreased GHG emissions without crop yield losses which reversed the agriculture ecosystem from a carbon source (+2.7 t CO_2-eq. hm^{-2} y^{-1}) to a carbon sink (-8.8 t CO_2-eq. hm^{-2} y^{-1}).

Ren *et al*. (2017) combined data from 379 observations results showed that N_2O, CO_2, and CH_4 emissions were significantly affected by Organic manure compared to mineral fertilizer (percentage change: −3, +15 and +60%) and non-fertilizers (percentage change: +289, +84 and +83%). Methanogenic activities in soils treated with organic manure were obviously higher than chemical fertilizers. Among the organic manure fields the maximum methane emission from green manure, biogas residue and beef manure treatment were 52, 20 and 19 times, respectively of that given by control, and among chemical fertilizers (Traore *et al*., 2017). It was also reported that a significant amount of N was lost as N_2O emission and NO_3^--N leaching under current intensive manure application. CH_4 emissions were positively correlated with the organic fertilizer rate, the straw returned fraction, the tillage depth and the soil organic carbon (SOC) content and negatively correlated with the soil clay fraction (Zhao *et al*.,2020). It is believed that the combination of organic and inorganic sources is one of the efficient measures for achieving high rice yield and reducing chemical fertilizer application and GHG emissions. Studies have been indicated that organic fertilizer has a positive impact on yield, yield component of crops as well as on the chemical properties of soil. The application of 15 t FYM ha^{-1} significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density, creating a good soil condition for enhanced growth of the rice crop. A research papers also revealed that, the farmyard manure incorporation of organic residues significantly affected crop yield. Retention of crop residues for less than three years led to a significant increase of 4.7% in rice yield. Furthermore, yield responses to crop residue retention were significantly higher at experimental duration of 3–10 years (7.2%) and >10 years (9.7%) than those at experimental duration <3 years of 4.7%, while no significant difference was found between the duration of 3–10 and >10 years (Huang *et al*., 2013). Crop straw and green manure contain many nutrients and are important organic fertilizer resources, which can increase soil organic matter content, replenish soil nutrients, and maintain farmland fertility. Methanogenic activities in soils treated with organic manure were obviously higher than those with chemical fertilizers. Among the organic manure fields the maximum methane emission from green manure, biogas residue and beef manure treatment were 52, 20 and 19 times, respectively of that given by control.

4. Inorganic Fertilizer effect on Greenhouse Gas Emission and Paddy Rice yield

Greenhouse gas emission levels and grain yield of paddy rice is associated with fertilizers applied. Rice paddies are one of the largest agricultural greenhouse gas (GHG) sources due to the application of large quantities of nitrogen (N) fertilizers to the plants. Therefore, the application of nitrogen (N) fertilizer to increase crop yields has a significant influence on soil methane (CH_4) and nitrousoxide (N_2O) emission/uptake. CH_4 emissions is stimulated at low N application rates (<100 kg N ha^{-1}) while, it inhibited at high N rates (>200 kg N ha^{-1}) as compared to no N fertilizer. The same results were reported by response of CH_4 emissions per kg N fertilizer was greater with the rate < 140 kg N ha^{-1} than > 140 kg N ha^{-1} indicating that substrate switch from CH_4 to ammonia by Methanotrophs may not be a dominant mechanism for increased CH_4 emissions. Thus, the rate of N were not >140, but reported a contradicted result by cumulative seasonal methane flux was highest in urea 36.3 (kg ha^{-1}) followed by control 35.2 (kg ha^{-1}) and ammonium sulfate 28.5 (kg ha^{-1}). The same contradicted reported on CH_4 and N_2O emissions reduced and rice grain yield increased significantly with application of 80 kg N ha^{-1} while, Yield based CH_4 and N_2O emission intensities were highest at 120 kg N ha^{-1} . A significant increase in paddy rice yield had been reported with a higher application of fertilizes to paddy fields, which can lead to increased methane emission to the atmosphere.

The integrated approaches of combining organic and inorganic fertilizers were effective in delivering higher yields than the inorganic fertilizer management alone. A sustainable production system in terms of emissions is the ability of that system to produce less emission per kilogram of yield. A combined application of FYM and inorganic N and P fertilizers improved the chemical and physical properties, which leads to enhanced and sustainable production of rice in the study area (Tilahun, *et al*., 2012). The integrated use of NP and FYM gave higher yields than application of either NP or FYM alone for many crops production. Organic manure reduced N_2O emission by 15% in paddy soils but increased the emission by 8% in upland soils (Ren *et al*., 2017). Given same amount of N inputs between different fertilization treatments, manure application significantly reduced soil N_2O emission by 3% and CO_2 emission by 36%, but increased CH_4 emission by 84% compared to mineral fertilizer in paddy soils (Ren *et al*., 2017). Application of manure instead of chemical fertilizer helps to reduce nitrogen input rate need to be highly considered, and mitigate GHGs emission.

Under controlled irrigation and flood irrigation, N fertilizers could significantly increase N_2O emissions, but the CH_4 emissions of each N treatment showed few differences (Nie *et al*., 2019). The appropriate N application under flooded water management could significantly increase grain yield in rice cultivation. Maximum amounts of CH_4 and N_2O fluxes were observed upon high-level fertilizer application in the plots. Therefore, reducing the high rate of fertilizer application is a feasible way of attenuating the global-warming potential while maintaining the optimum yield for the studied paddy fields (Zhang *et al*., 2020). Higher nitrogen fertilization rate may decrease the overall emission of CH_4 and N_2O under mid-season drainage. The increasing drainage times or applying organic fertilizer under mid-season does not change the overall emission rate of CH_4 and N_2O. Different research papers reported different contradicted results on the relationship between inorganic fertilizers with greenhouse gas emission. Therefore, further studies required to reveal the effects of inorganic fertilizers on greenhouse gas emission.

5. Possible recommendations

Sustainable food supply in the future will require reductions in GHG emissions from agriculture even as the world produces substantially more food. The production of rice, the staple crop for the majority of the world's population, emits large quantities of methane. Global rice production emits between 500 and 800 million tons of CO equivalent per year, 10 percent of total agricultural GHG emissions and 1 percent of global GHG emissions (Searchinger *et al*., 2015).

Methane from rice farming causes 3% of anthropogenic global warming (Evelyn, 2019). The greenhouse gas emissions from rice production vary in different factors, but they all agree that rice production is a significant contributor to overall emissions. Rice crop produce GHG emissions four times per ton of crop as compared to wheat or maize mostly in the form of methane and nitrous oxide.

Therefore different researches to fills the gap by determining the effect of nutrient and water management on rice yield and greenhouse gas emission should be developed and in lined with the mass production for the future. Farmer's nutrient and crop management influences on greenhouse gas emissions should be estimated and helps to document the baseline data. The agricultural management techniques like, water saving and fertilizer managements to save water, increase yield, and promote sustainable development were not adequately studied so it should be studied sufficiently. Thus, a well-developed production practices to be connected with the farmers for increasing crop yield, minimizing production cost and adopt climate-friendly farming practices in production of paddy rice is necessary.

6. Conclusion

The fact from addressed research articles showed rice production has given special consideration because of its global importance for food security. Due to this in Ethiopia it has been cultivated mainly in rain fed for lowland, upland and some extent irrigated ecosystems. Since this production is linked with wet land and upland areas the exploitation of all potential production areas will be highly important. On the other hand this productivity system contributes for plenty amount of green house gas emission. Therefore, to investigate the water management influence, fertilization effect should be studied and potential recommendation should be done for wel developed production practices.

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Affectionately Dedicated
To
My Beloved Brother
Late Dr Tegegnework Gebremedhin
Who was youngest age with outstanding wisdom on Climate smart agriculture!!
`` May God rest his soul in peace``

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