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Traditional Rice Farming Accelerate CH_4 & N_2O Emissions Functioning as a Stronger Contributors of Climate Change

Imran[1,2*], Abdul Bari[3], Roshan Ali[3], Naeem Ahmad[3], Zulfiqar Ahmad[2], Muhammad Idrees Khattak[4], Akhtar Ali[3], Fayaz Ahmad[3], Inayatullah Khan[1] and Shahida Naveed[5]

[1]*Department of Agronomy, The University of Agriculture, Pakistan*

[2]*Climate Change Centre (CCC), The University of Agriculture, Pakistan*

[3]*Agriculture Research Institute Mingora Swat, Pakistan*

[4]*Department of Rural sociology, The University of Agriculture, Pakistan*

[5]*Associate professor of Botany, Govt. Girls degree college Karak, Pakistan*

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***Corresponding author :** Imran, Department of Agronomy, the University of Agriculture, Pakistan, Email: imranagrarian@aup.edu.pk

Abstract

Traditional methods of rice farming, like those practiced in the South Asian countries included Pakistan, contribute to greater GHG emissions than in other regions. These methods include constant saturation of rice fields (which depletes oxygen in the system), the addition of fertilizers (which provides nitrates that stimulate denitrification in bacteria), and increasing the acreage of rice fields which increases the area available for GHG emissions. Alternate methods such as modified irrigation and more efficient fertilizer use have proven to be effective in reducing GHG emissions. Another improved method of rice farming, Direct Seeded Rice (DSR) is also a step toward climate change and GHG mitigation strategy to be adopt and disseminate in the farming community of the rice growing countries. However it is a challenge to identify and improve ways of increasing rice yields while simultaneously reducing GHG emissions to widespread implementation of GHG-reducing practices due to limited outreach and awareness regarding the incentives and benefits of alternate methods of rice farming.

Keywords : Rice (*Oryza sativa L.*); Climate change; Greenhouse gases; Methane; Nitrous oxide

Introduction

Oryza sativa L is an important kharif crop of Pakistan and ranked second to wheat as a staple food. Rice is occupying a prime position in the agricultural economy of Pakistan. In Asia, more than 3.5 billion people prefer rice for food and this demand for rice will be increased up to 70 percent in 2025 [1]. In Pakistan the area under rice cultivation is 2.25 million hectares, thus becoming the country's third largest crop in terms of area. Rice cultivation has been playing an effective role in uplifting the economic conditions of the common famer community of the country. In Khyber Pakhtunkhwa rice is the second preferable cultivable crop to wheat and maize, grown under two different agro climatic conditions, i.e., plains and upper mountainous valleys. Out of the total rice cultivated area (64719ha), 81% comprised of cooler, high altitude areas of Malakand, Hazara and adjacent tribal areas of Khyber Pakhtunkhwa [2]. The Intergovernmental Panel on Climate Change (IPCC) has confirmed that anthropogenic emissions of greenhouse gases (GHGs), which are those emitted by human activity, contribute to climate change and are at their highest levels in history. GHGs contribute to the warming of the planet by trapping radiation and releasing it near the surface of the earth. Agricultural practices emit over 50% of global non-carbon dioxide GHG emissions. About 7% of these emissions are a result of rice farming, and over 80% of GHG emissions from rice farming are produced in South and Southeast Asia (India, China, Indonesia, Thailand, Vietnam, and Burma). The warming of the planet, combined with the growing population expected to exceed 9 billion by 2050, threaten advancements made to achieve global food security and environmental sustainability.

The earth's surface, like all planetary bodies, releases infrared radiation. While this radiation usually travels through the atmosphere and escapes the surface, greenhouse gases (GHGs) that are present in the atmosphere, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and even water (H_2O), can capture this radiation and release it back to the surface of the earth [3]. GHGs are emitted as a byproduct of many activities such as burning fossil fuels, generating electricity, and agriculture. While CO_2 is often the first one that comes to mind, CH_4 and N_2O are much stronger contributors of GHGs emissions. Rice farming is a significant source of human-produced non-CO_2 emissions. Because rice is grown in flooded systems, the soil remains waterlogged, preventing oxygen from entering the pores. Additionally, the decomposition of organic plant matter in the fields consumes and therefore, limits the amount of oxygen present. With limited oxygen in the soil, bacteria that can conduct anaerobic respiration, or "breathing" in the absence of oxygen, thrive. Two of the most common methods of such respiration in flooded rice fields are methanogenesis, the production of CH_4, and denitrification, the conversion of nitrates to nitrogen gas with N_2O as a byproduct. Paddy rice fields are particularly conducive to these processes not only because the soil is waterlogged and therefore lacks oxygen; but also because anaerobic bacteria rely on plant matter from rice for respiration.

Methanogenesis

Rice is grown in flooded systems, the soil remains waterlogged, preventing oxygen from entering the pores. Additionally, the decomposition of organic plant matter in the fields consumes and therefore, limits the amount of oxygen present. With limited oxygen in the soil, bacteria that can conduct anaerobic respiration, or "breathing" in the absence of oxygen, thrive. Two of the most common methods of such respiration in flooded rice fields are methanogenesis, and we call that the production or emission of methane gas (CH_4) from rice field [3]. Methane in rice paddies is produced by microscopic organisms that respire CO_2, like humans respire oxygen. More CO_2 in the atmosphere makes rice plants grow faster, and the extra plant growth supplies soil microorganisms with extra energy, pumping up their metabolism. Increasing CO_2 levels will also boost rice yields, but to a smaller extent then CH_4 emissions. As a result, the amount of CH_4 emitted per kilogram of rice yield will increase [4].

Denitrification

The conversion of nitrates to nitrogen gas with N_2O as a byproduct. Simply stated, when sufficient oxygen is not available in soil. Some microorganisms use oxygen from the nitrate ion (NO-). When oxygen is removed from nitrate, it leaves N gas, which can then be lost to the atmosphere. This is denitrification. Soilconditionsthatleadtodenitrificationtypicallyoccurwhen moisture is high or there is standing water, and conditions are warm enough to encourage microbial activity. Loss due to denitrification can be significant, especially in a wet year. When the soil microorganisms need oxygen, they'll take it from the air or from nitrate if the water in the soil prevents them from getting it from the air. The soil does not have to be completely saturated for denitrification to occur in this way (Figure 1).

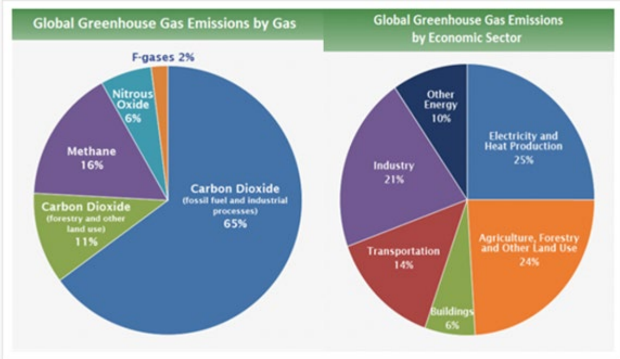

Figure 1: Graph showing GHG emission percentage ,Source: Mitigation related agreements, Koyoto Protocol, Paris agreement.

Denitrification chemistry and occurrence

Denitrification is a microbial process in the soil that reduces N-containing compounds into their simplest forms. Nitrification makes N available to the plant. Denitrification is one of the primary ways in which nitrogen is lost. Denitrification occurs when soil microorganisms use oxygen from the nitrate ion (NO-) rather than from air in the soil (oxygen) for respiration. This happens most often when soils are saturated and temperatures are warm enough to encourage a high level of microbial activity. Both fertilizer and organic sources of nitrogen are affected. A soil does not have to be completely saturated for denitrification to occur. When it does occur, nitrous oxide gas (N_2O) and other N gases are produced and lost into the atmosphere [3] (Figure 2).

Figure 2

When soils are warm and wet, Nitrate is easily lost as gas. Long period of wet condition can result tremendous fertilizer losses.

Flooded rice cultivation contributing Climate Change through CH_4 and N_2O emission. When soils are warm and wet, Nitrate is easily lost as gas. Long period of wet condition can result tremendous fertilizer losses which economically and environmentally unfriendly. Beside this CH_4 production increases in wet rice cultivation due to anaerobic respiration of the soil

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microbial population due to water logged condition and they can't not take oxygen. Therefore organic matter degradation and other plants residues decomposition take place in oxygen limited condition and proportionally produce methane CH_4 (Figure 3).

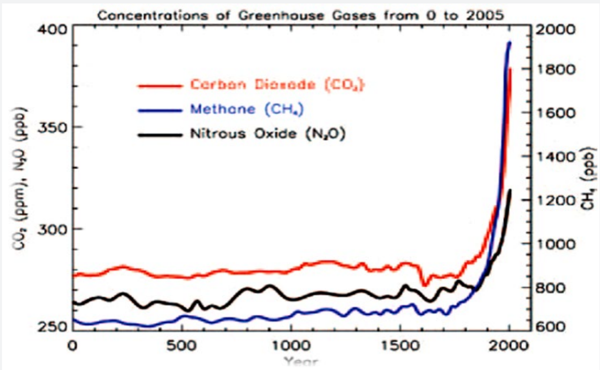

Figure 3: Concentration levels of different greenhouse gases: A trend over the past (Source: U.S. Global Climate Research Program, National Research Council of The National Academies of Sciences, (2011) (Imran 2017).

More greenhouse gas per grain of rice production

Rice production in many regions of the world has accelerated greenhouse gas emission. Rice produces methane gas by methenogenesis process by standing of water in their growing periods. Mostly other gases are also contribute by rice in the form of nitrification and methenogesis [5]. More carbon dioxide in the atmosphere and rising temperatures cause rice agriculture to release more of the potent greenhouse gas methane (CH_4) for each kilogram of rice it produces, new research published in this week's online edition of Nature Climate Change reveals [6]. Mosier et al reported that "Our results show that rice agriculture becomes less climate friendly as our atmosphere continues to change (Figure 4). Direct seeded rice (DSR) technology is one of the approach mitigating greenhouse gas (GHG) emission.

Figure 4

This is important, because rice paddies are one of the largest human sources of methane, and rice is the world's second-most produced staple crop," said (DrKees Jan van Groenigen), Research Fellow at the Botany Department at the School of Natural Sciences, Trinity College Dublin, and lead author of the study [7]. Van Groenigen, along with colleagues from Northern Arizona University and the University of California in Davis, gathered all published research to date from 63 different experiments on rice paddies, mostly from Asia and North America. The common theme in the experiments was that they measured how rising temperatures and extra carbon dioxide in the atmosphere affect rice yields and the amount of methane that is released by rice paddies [8]. The research team used a technique called meta-analysis, a statistical tool for finding general patterns in a large body of experimental data. "Two strong patterns emerged when analysed all the data: first, more CO_2 boosted emissions of methane from rice paddies, and second, higher temperatures caused a decline in rice yields," explained Professor Bruce Hungate of Northern Arizona University and co-author of the study. Rising temperatures were found to have only small effects on CH_4 emissions, but because they decrease rice yield, they also increase the amount of CH_4 emitted per kilogram of rice. "Together, higher CO_2 concentrations and warmer temperatures predicted for the end of this century will about double the amount of CH_4 emitted per kilogram of rice produced." explained Professor Chris van Kessel of the University of California in Davis and co-author of the study [9]. They reported that global demand for rice will increase further with a growing world population, our results suggest that without additional measures, the total CH_4 emissions from rice agriculture will strongly increase [3]. However, the authors point out that there are several options available to reduce CH_4 emissions from rice agriculture. For instance, management practices such as mid-season drainage and using alternative fertilizers have been shown to reduce CH4 emissions from rice paddies. Moreover, by switching to more heat tolerant rice cultivars and by adjusting sowing dates, yield declines due to temperature increases can largely be prevented, thereby reducing the effect of warming on CH_4 emissions per yield [10,11]. These findings, together with our own results really stress the need for mitigation and adaptation measures to secure global food supply while at the same time keeping greenhouse gas emissions in check. van Groenigen concluded.

Increased atmospheric CO_2 and rising temperatures are expected to affect rice yields and greenhouse-gas (GHG) emissions from rice paddies [12]. This is important, because rice cultivation is one of the largest human-induced sources of the potent GHG methane (CH_4) and rice is the world's second-most produced staple crop. The need for meeting a growing global food demand argues for assessing GHG emissions from croplands on the basis of yield rather than land area [3]. Such that efforts to reduce GHG emissions take into consideration the consequences for food production [13]. However, it is unclear whether or how the GHG intensity (that is, yield-scaled GHG emissions) of cropping systems will be affected by future atmospheric conditions [3,14,15]. Here we show, using meta-analysis, that increased atmospheric CO_2 (ranging from 550 to 743ppm) and warming (ranging from +0.8 °C+6 °C) both increase the GHG intensity of rice cultivation. Increased atmospheric CO_2 increased GHG intensity by 31.4%, because CH4emissions are stimulated more than rice yields. Warming increased GHG intensity by 11.8% per 1 °C, largely owing to a decrease in yield [16]. This analysis

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suggests that rising CO_2 and warming will approximately double the GHG intensity of rice production by the end of the twenty-first century, stressing the need for management practices that optimize rice production while reducing its GHG intensity as the climate continues to change [17-22].

Conclusion

The adverse impact of climate change is not limited to food security and water availability but also uneven rainfall distribution through which intensify floods leads to dampen soil. Various agronomic crop yields declining and most of the minor crops going to vanish and thus the food security problem a rising. Therefore, a well-coordinated program is necessary to create awareness among the society including the policy makers, general citizen & public, various organizations, industrialists and farmers to sustain the food security and the environment, whereas climate change has to be experienced round the world.

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