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Rice Cultivation under Changing Climate with Mitigation Practices: A Mini Review

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Abstract Assessments of the impact of climate change on rice production in Asia that comprehensively consider the uncertainty would therefore be very valuable for predicting future food security in this region. With the increase in daily maximum temperature averaged over flowering period above about 36°C, rice yield generally declined because of spikelet sterility induced by high temperatures. Methane emission from the rice fields is estimated to be globally 37 Tg yr^{-1} by IPCC while N_2O emission is much lower as the total N_2O emission from overall cultivated area was put at 1.8–5.3 Tg yr^{-1}.Reduction of stomatal conductance due to elevated CO_2 has been commonly observed in rice. However, the response of stomatal conductance to elevated CO_2 varies considerably in response to various environmental factors. The response of stomatal conductance to elevated CO_2 varied widely among times of day, growth stages, and years. Cultural and soil disturbances, pre-flooding and post-harvest drying contribute about 15% of the seasonal methane emission.

Keywords Rice, IPCC, Climate Change, Temperature, Stomatal Conductance

1. Introduction

Rice is one of the staple foods in South East Asia. More than 90% of the world's rice is produced in Asia. Rice accounts for about 60% of production in this region. Scientists predicted that under climate change scenarios, rice production in Asia will decline. Climate change will cause tremendous damage to rice production sector if not addressed properly [1]. Assessments of the impact of climate change on rice production in Asia that comprehensively consider the uncertainty would therefore be very valuable for predicting future food security in this region. Rice cultivation has a wide geographic distribution in South East Asia, and climate change is likely to exacerbate a range of different abiotic stresses. This includes high temperature coinciding with critical developmental stages. This will also apply to floods causing complete or partial submergence, salinity which is often associated with sea water inundation/intrusion and drought spells that are highly deleterious in rainfed systems. Sometimes climate changes directly affect rice plant growth through changes in precipitation, evapotranspiration, air temperature, and water temperature. One of the major drivers of global warming is increased atmospheric CO_2 concentrations in the future, which may also enhance plant growth through the fertilization effect as because CO_2 is an essential component of photosynthesis [2]. Low supply of rice due to low production along with increasing demand not only affects economy of the country but also food security. The main important climate change factors are increase in temperature, increase in intensity, frequency, and duration of extreme climate events such as floods, droughts, and tropical storms; changes in the intensity, soil degradation; timing and spatial distribution of rainfall; and sea level rise resulting in flooding, loss of agricultural land and salt water intrusion.

2. Temperature Changes under Rice Cultivation

Temperature increases are likely to cause increased evaporation from soil and therefore accelerated transpiration in the plants themselves. This might cause moisture stress. A higher air temperature will accelerate the natural decomposition of soil organic matter and increases the rates of other soil processes that affect fertility. Warming will accelerate many microbial processes in the soil-floodwater. Intensified evaporation will also increase the hazard of salt accumulation in the soil. With the increase in daily maximum temperature averaged over flowering period above about 36°C, rice yield generally declined because of spikelet sterility induced by high temperatures. Importantly, elevated CO_2 increased spikelet susceptibility to high-temperature damage. High night-time temperatures have been shown to have a greater negative effect on rice yields, with a 1°C increase above critical temperature (>24°C) leading to 10% reduction in both grain yield and biomass [3]. High day-time temperatures in some tropical and subtropical rice growing regions are already close to the optimum levels. High day-time temperatures in some tropical and subtropical rice growing regions are already close to the optimum levels. Decreased grain weight, reduced grain filling, higher percentage of white chalky rice and milky white rice, and reduced grain amylase content are common effects of high temperature exposure during the ripening stage in rice. Bright sunshine with low temperature during ripening period of the crop helps in development of carbohydrates in grains. High night-time temperatures have been shown to have a greater negative effect on rice yields, with a 1°C increase above critical temperature (>24°C) leading to 10% reduction in both grain yield and biomass [4].

3. Atmospheric CO_2

Carbon losses due to growth and maintenance respiration typically amount to 40 to 60% of the total carbon fixed by a crop. Plant respiration as response to CO_2 enrichment greatly varied among different studies. Plant respiration would decrease due to elevated CO_2. Scientists had estimated that for every increase in 75 ppm CO_2 concentration, rice yields will increase by 0.5 t/ha. So, increased concentrations of CO_2 in the atmosphere has a positive effect on crop growth and yield with the condition that microsporogenesis, flowering, and grain-filling are not disrupted by increase in temperature. Elevated CO_2 had a minor effect on rice nitrogen (N) uptake, which appeared to be associated with the relatively insensitive response of leaf area growth to CO_2 [5]. Elevated CO_2 accelerated rice development and increased leaf photosynthesis by 30-70%, canopy photosynthesis by 30-40% and crop biomass yield by 15-30%, depending on genotype and environment. However, the stimulatory effect of high CO_2 concentration decrease gradually as the time of the exposure is prolonged.

4. Environmental Impact

Climate change will not only affect the water availability but also affect crop water use. Although a rise in temperature will increase evaporative demand, elevated CO_2 may reduce crop water use by reducing stomatal conductance. On the other hand, yield losses due to flooding may increase considerably sea level rise in the future as well as an increase in frequencies and intensities of flooding caused by extreme weather events. Rising sea level may amplify soil salinity, displace areas for crop production, and reduce rice production in a sizable portion of the highly productive rice land in deltas. Increasing threat of salinity is an important issue. Large areas of coastal wetlands may be affected by flooding and salinity in the next 50 to 100 years as a result of sea level rise [6].

5. Drought and Rice Cultivation

Dry spells for a very short duration can result in substantial yield losses, especially if they occur around flowering stage. Drought affects all the stages of rice growth and development. Effects of drought on grain yield are largely because of reduction of spikelet fertility and panicle exertion. Frequent drought not only reduces water supply but also increases the amount of water needed for plant transpiration [8]. Drought risk reduces productivity even during favourable years in drought-prone areas, because farmers avoid investing in inputs when they fear crop loss.

6. Climate Change and Pest-disease Infestation

Climate change has also impact on rice pest-disease infestation. Rice diseases such as rice blast, brown spot, sheath, and culm blight could become more widespread in South East Asia. Frequently changed in wind patterns may also change the spread of both wind-borne pests and of bacteria and fungi that are the major agents of crop disease. Therefore, crop-pest interactions may shift as the timing of development stages in both hosts and pests are altered due to climate change. The possible increases in pest infestations may bring about greater use of chemical pesticides to control these pest-diseases in rice [9]. Climate change may also affect weed ecology, physiology, evolution of weed species over time, and the competitiveness of C_3 vs C_4 weed species.

7. Rice Cultivation and GHGs

Rice cultivation is an important source of CH_4 and N_2O. Methane emission from the rice fields is estimated to be globally 37 Tg yr^{-1} by IPCC while N_2O emission is much lower as the total N_2O emission from overall cultivated area was put at 1.8–5.3 Tg yr^{-1}. N_2O is trapped in the soil long enough to get denitrified to N_2but during intermittent drying of the rice fields, N_2O emission increases considerably [11]. Extent of N_2O emission from the rice field is much lower than CH_4 since N_2O is unstable in anaerobic environment of wet-land rice soil.

8. Carbon Sequestration under Rice Cultivation

Rice cultivation is both an important sequester of carbon dioxide from the atmosphere and an important source of greenhouse gases (e.g. methane and nitrite oxide) emission. Methane production is negligible in upland rice because the fields are not flooded for any significant period of time. In rainfed lowland fields, methane emissions are much lower and more variable due to periods of no standing water during the season [12]. Flooded rice fields emit significant amounts of methane (CH_4) to the atmosphere. More carbon dioxide in the atmosphere, coupled with rising temperatures, is making rice agriculture an even larger source of the potent GHG methane. Because global demand for rice will increase further with a growing world population, results suggest that without additional measures, the total methane emissions from rice agriculture will strongly increase [13]. As more carbon dioxide enters the atmosphere, rice plants grow faster, experimental data showed. This growth, in turn, pumps up the metabolism of methane-producing microscopic organisms that live in the soil beneath rice paddies. The end result is more methane production. Burning of rice straw and direct incorporation of rice straw into the soil also produce GHGs. It should be noted, however, that relatively simple changes in rice cultivation could help reduce methane emissions. Methane is a major end product of anaerobic fermentation. It is released from submerged soils to the atmosphere by diffusion and release of gas bubbles and through roots and stems of rice. When the fields remain flooded for the entire growing season, there is more potential for CH_4 emissions than when the fields are drained or permitted to dry at least once during the season. When CH_4 is released into the atmosphere, it traps significant amounts of heat that would otherwise escape to space. Methane is more than 20 times more heat absorptive than CO_2 and it has a 9 to 15 year life time in the atmosphere [14]. Thus, CH_4 is considered a greenhouse gas that contributes to the global warming and climate change owing to its greenhouse effect. Too much use of chemical fertilizers and pesticides also emits N_2O.CH_4 and N_2O emissions from rice field soil have obvious seasonal variation. There is a trade-off relationship between methane and nitrous oxide emissions [15]. Intermittent irrigation can reduce significantly CH_4 emission and increase N_2O emission, but the overall warming potential of greenhouse effect is reduced greatly while rice yield is not affected. So, intermittent irrigation is an effective irrigative measure to reduce greenhouse gas emissions from rice field soils. Microbial process has effects on CH_4 and N_2O emissions from paddy soils [16]. There is a positive correlation between methanogens number and CH_4 emission.

9. Water Management

Water management is one of the strategies for controlling methane efflux from flooded rice. Higher rate of water percolation in the paddy field soil reduces methane emission. More frequent flooding and drying of the soil under rainfed conditions might affect the crop growth and yield in rice, in addition to influencing methane emission. Water stress may affect the growth of the rice plant and may reduce the grain yield to a great extent. But, in subtropical areas, intermittent irrigation as well as water percolation rate up to 35 mm d^{-1} are suitable for higher rice grain yield [17].

10. Pest and Disease Management

Rice crop suffers maximum due to infestation of a wide range of insect and non-insect pests under different ecological conditions. Rice crop is attacked by more than 100 species of insects; 21 of them can cause economic damage. On an average, the yield losses in the country due to insect pests are around 28%. Among the insect pests of rice, rice stem borer, leaf folder, case worm, whorl maggot, gall midge, rice hispa, gundhi bug, ear cutting caterpillar, thrips and grasshopper are some most important insect pests of rice. Frequent monitoring of pest population is necessary. Some of the management of rice pests includes collection and destruction of egg, larvae, pupae and adults of different insects; putting of branches of neem, banmara, *Eupatorium odoratum* for repelling of insects and to facilitate the predatory bird to sit on; pulling of jute rope (dipping in kerosene mixed water) by two person through the rice field and immediately drain off the excess water if infestation of case worm occurs; stubble destruction soon after the harvesting for preventing the carryover of stem borer and gall midge; spraying of Nimbicidine @ 3 ml/L at 10 DAT followed by second spraying after 20 days interval; installation of pheromone trap for yellow stem borer @ 16-20 nos. per hectare in a triangular pattern at 60 m distance; release of *Trichogramma japonicum* or *T. chilonis* @ 50,000 per hectare at weekly interval for 7-8 times starting from 30 days after transplanting; One spraying of *Beauveria bassiana* (Biopower® @ 7g/L) in the boot leaf stage to reduce gundhi bug population.

Diseases are considered as a major threat in rice cultivation and causes yield losses to the growers and also reduce the quality of the produce. Plant diseases in organic rice production systems are especially challenging to manage since the use of synthetic pesticides are discouraged or prohibited. There are a number of fungus, bacteria and virus, mycoplasma-like organisms cause disease in rice. Among the various diseases, blast, bacterial leaf blight, sheath blight, false smut, brown spot, stem rot, foot rot and Rice Tungro Virus (RTV)are very important diseases. Organic disease management in general, emphasizes prevention through the use of resistant varieties, good cultural practices, physical control methods, use of antagonistic microbes, quarantine, knowledge of the pathogen and disease biology, and disease-free certified seed. Chemical fungicides are not completely banned; some chemical fungicides are having restricted use in organic agriculture with the approval of certifying agency. Some of the major important disease in rice are a) Blast: *Pyricularia grisea;* Brown spot: *Helminthosporium oryzae;* Sheath blight: *Rhizoctonia solani;* Sheath rot: *Sarocladium oryzae;* Stem rot: *Sclerotium oryzae.*

False smut: *Ustilaginoidea virens;* Bacterial leaf blight: *Xanthomonas oryzae* pv. *Oryzae;* Leaf streak: *Xanthomonas oryzae* pv. *oryzicola;* Tungro virus (Rice Tungro Virus).

11. Some Case Studies

Expansion of rice areas could also alter the earth's land cover and eventually changes its ability to absorb or reflect heat and light. Though N_2O also has a role in global warming, but its concentration in atmosphere is still not at threatening level. But split application of N-fertilizer is probably the simplest way to further reduce the emission of N_2O. Use of nitrification inhibitor is another option. Reduction of stomatal conductance due to elevated CO_2 has been commonly observed in rice [18]. However, the response of stomatal conductance to elevated CO_2 varies considerably in response to various environmental factors. The response of stomatal conductance to elevated CO_2 varied widely among times of day, growth stages, and years. Cultural and soil disturbances, pre-flooding and post-harvest drying contribute about 15% of the seasonal methane emission. The impact of cultivation practices like land preparation, seeding and transplanting, and other operations on methane emission from rice soils are now only beginning to be understood. Dry land tillage and direct seeding is expected to reduce methane emission as they have shorter anaerobic phase during rice culture. Minimization of soil disturbances during rice cultivation by adopting direct seeding and dry land tillage can reduce methane emission from rice fields [18, 19]. Cropping diversification and crop intensification wherein rice is grown in rotation with other crops like wheat, mustard, cowpea and maize will have distinct cycles of anaerobic and aerobic phases. This cycle of land conditions will reduce methane emissions than that from mono-culture of irrigated rice.

12. Mitigation Strategy

There are several formidable obstacles to incorporate these mitigation practices into local rice farming. The strategies should be so formulated that they are effective, applicable, technically feasible, economic, less time consuming and at the same time, easily understood and accepted by farmers. Although nitrification inhibitors can mitigate the production of both the gases, in many countries they are not used in farmers' fields due to lack of publicity, non-availability, high price or apathy. Slow release N-fertilizers like neem coated urea preparations, USG, urea briquettes etc. have remained only as researcher's tools where rice covers large areas under cultivation. Soil Eh can be effectively controlled by manipulating water management, which can only be done in areas having assured water supply [20]. Some practices like deep placement of fertilizers, local preparation of coated fertilizers have extensive labour requirement, which is not always available at cheap rates. A reduction in the application of N fertilizers and organic fertilizers would possibly reduce methane and N_2O emissions from rice fields, but would also reduce total rice production unless the area under rice cultivation is increased [21]. Reducing the period of inundation, growing alternative crops, aeration of water and alternating rice crops with other crops in the dry season are suggested methods of reducing methane emission. They have also suggested dry seeding in place of transplanting, for CH_4 mitigation. Dry seeding is getting increasingly popular among farmers due to labour savings although it has a lower yield potential than transplanting [22]. But this practice has to be tested for its effects on N_2O emissions.

13. Conclusions

The impact of cultivation practices like land preparation, seeding and transplanting, and other operations on methane emission from rice soils are now only beginning to be understood. Dry land tillage and direct seeding is expected to reduce methane emission as they have shorter anaerobic phase during rice culture. Minimization of soil disturbances during rice cultivation by adopting direct seeding and dry land tillage can reduce methane emission from rice fields. Cropping diversification and crop intensification wherein rice is grown in rotation with other crops like wheat, mustard, cowpea and maize will have distinct cycles of anaerobic and aerobic phases. This cycle of land conditions will reduce methane emissions than that from mono-culture of irrigated rice. A reduction in the application of N fertilizers and organic fertilizers would possibly reduce methane and N_2O emissions from rice fields, but would also reduce total rice production unless the area under rice cultivation is increased. Reducing the period of inundation, growing alternative crops, aeration of water and alternating rice crops with other crops in the dry season are suggested methods of reducing methane emission. They have also suggested dry seeding in place of transplanting, for CH_4 mitigation.

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