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Rice Production and Global Climate Change

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ABSTRACT

There is need to increase rice production to feed the world population from less land with degrading nutrient base by application of less inputs and energy and rice production is the cause of global climate change by heavy emissions of carbon dioxide, methane and nitrous oxide. These gases trap the infrared long waves emitted from earth's surface in atmosphere and increase the temperature of atmosphere. Increasing the total biomass of rice plant there can be higher grain yield. There is need of thorough modifications in present rice production practices which will be efficient to produce enough grains to feed to world population to sustain food security and minimise the emissions of greenhouse gases otherwise rice production and global warming will affect negatively each other and bring catastrophe in the world. Flooding irrigation, puddling and transplanting in rice production should be avoided. Direct seeded rice planting and zero tillage can be adopted with alternate wetting and drying of rice field. New rice varieties need to be developed with multiple stress tolerance to drought, flood, submergence, cold, salinity, iron and zinc toxicity and low soil fertility for evolving a smart agriculture system. All the nitrogenous fertilizers should release nitrogen slowly to manage the soil carbon and nitrogen (C: N) low ratio to avoid increased emission of nitrous oxides and carbon dioxide in the soil. The soil fertility could be improved by green manuring and use of compost.

The soil moisture and oxygen concentration should be managed to avoid more emission of nitrous oxides from soil. There should be convergence of efforts of all sectors to make our earth free from the anticipated difficulties of global climate change by allocation of fund and abiding the principle of carbon credits. The small-scale farmers should be helped by adequate fund, capacity building, technology and incentives to maintain their rice production with minimum greenhouse gas emissions.

Keywords: Greenhouse Gas; Global Warming; Nitrification; De-Nitrification; Carbon Dioxide; Methane; Nitrous Oxide; Direct Seeded Rice; Alternate Wetting and Drying; Smart Agriculture

Abbreviations: GWP: Global Warming Potential; GFDL: Geophysical Fluid Dynamics Laboratory; QTLs: Quantitative Trait Loci; AWD: Alternate Wetting and Drying; SRI: System of Rice Intensification; GHG: Greenhouse Gas; CCAFS: Climate Change, Agriculture and Food Security; BISA: Borlaug Institute for South Asia; EDF: Environmental Défense Fund; FAO: Food and Agriculture Organization; PNAS: Proceedings of the National Academy of Sciences; EDF: Environmental Defence Fund

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Introduction

There is need of an annual increment in global rice production at 1% to meet the growing demand for food [1]. This achievement cannot be accomplished by covering more area under crop or administering more fertilizers and pesticides in rice crop and the only option remained is to increase the total biomass of the crop plant which will ultimately produce more food grains [2]. Crop photosynthesis and respiration losses with an efficient combine determine the total biomass production and both of these two components are greatly affected by growing global temperature [3]. The increased CO_2 concentration, ozone gas and temperature of atmosphere will bear direct negative consequences on rice grain production in future [4-6]. The rice grain yield decreases by 10% for each 1°C increase in growing-season minimum night temperature in the dry season whereas the effect of maximum temperature on the crop yield is insignificant. This evidence states that increased night-time minimum temperature decreases rice grain yield is associated with global warming. In the past century daily minimum night temperature has increased at a faster rate than daily maximum temperature and is associated with steady increase in concentration of greenhouse gas emissions [7,8]. The erratic climate devastates the rice culture in Asia and rice cultivation contributes greatly to climate change. Drought, flood and extreme temperatures significantly damage crops and push the livelihoods of 144 million smallholder rice farmers into uncertainty every crop growing season.

The atmosphere of earth basically composes nitrogen (N_2) 78% and oxygen (O_2) 21% [9]. The maximum portion of long wave infra-red rays emitted from earth surface is absorbed by the atmosphere and rest of long waves are reemitted to the earth surface. This process is known as greenhouse effect which causes the atmospheric temperature to increase gradually and in intense situation of increasing atmospheric temperature on earth is known as global warming. CO_2 and water vapours are the most important greenhouse gases (GHG), but CH_4, N_2O, ozone, chlorofluorocarbons and aerosol can increase the atmospheric temperature [9]. Agriculture contributes significantly to the greenhouse gases (GHG) as carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O). The contribution of N_2O, CH_4 and CO_2 in the GHGs emission of agriculture is 60, 39 and 1% respectively [10]. The contribution of N_2O and CH_4 to global warming potential (GWP) is 25 and 298 times more than GWP of CO_2 [11]. The global annual production of raw rice is 755.45 million tonnes (Statistical Yearbook, World Food and Agriculture 2021) and for each kilogram of rice grain produced is accompanied by production of 1-1.5kg of straw [12]. It is estimated that about 755.4-1133.1 million tonnes of rice straw is produced per year globally and the total biomass production of rice crop which includes both weights of grains and straw is about 1510.8 – 1888.5 million tonnes globally per year.

The average plant organ carbon(C) contents are 45.0 % in reproductive organs, 47.9 % in stems and 45.6% in roots respectively [13] though these values are significantly lower than the widely employed canonical value of 50 %. Keeping this C content of plant organs to total biomass as 46% and excluding 14% moisture, the total quantity of carbon assimilated in rice crop globally will be 597.67-747.09 million tonnes. The atomic weight of CO_2 is 44.01g/mol and that of carbon is 12.011g/mol. Therefore, the net quantity of CO_2 sequestered by global rice production practices is about 2,189.96- 2,737.44 million tonnes. According to General Circulation Models [14] it has been predicted that during the time span of last century (20th century) the concentration in CO_2 has doubled and there has been an increase of 4°C in atmospheric temperature. Agriculture has been the most vulnerable component of human life in the verge of global climate change [15]. According to Geophysical Fluid Dynamics Laboratory (GFDL) there is an estimated yield loss of about 11% of total rice production in India [16] due to the effect of global warming. Flooding of rice fields and burning the rice straw in situ in traditional cultivation practices contribute nearly 10% of global man-made methane, which is a potent greenhouse gas. GHG emissions of CO_2, CH_4 and N_2O from the rice fields are large and very sensitive to management practices.

Therefore, rice production is an important target for mitigating GHG emissions [17]. Flooded rice culture with puddling and transplanting is considered one of the major sources of methane (CH_4) gas emissions. Methane gas emission has been shown in (Figure 1). because of prolonged flooding resulting in lack of oxygen (anaerobic) conditions in soil. It accounts for 10-20% (50-100 Tg/year) of total global annual CH_4 emissions [18]. The share of fresh water for agriculture is decreasing due to the depletion of water table, faulty

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irrigation systems, degrading quality of water, increasing demand for industrial sectors and increased cost of energy supply. There is scarcity of labour during the peak period of puddling and transplanting. Again, puddling is cumbersome, time taking, expensive and the cause of major CH_4 emission (anaerobic de-nitrification process) in rice cultivation. The methane gas emission from rice fields in selected countries such as US, Italy, Japan, China and India has been given below in (Table 1) with total amount of methane emitted in the country and methane gas emission from rice fields and its share in total greenhouse gas emissions: Climate-responsive solutions need to work with extension agents, local bodies, national research institutions, and governments across at the national and international level with compact co-ordination. There is need to address the effects of climate change on the production of rice and scaling up of climate smart practices for sustainable and intensive rice-based farming systems.

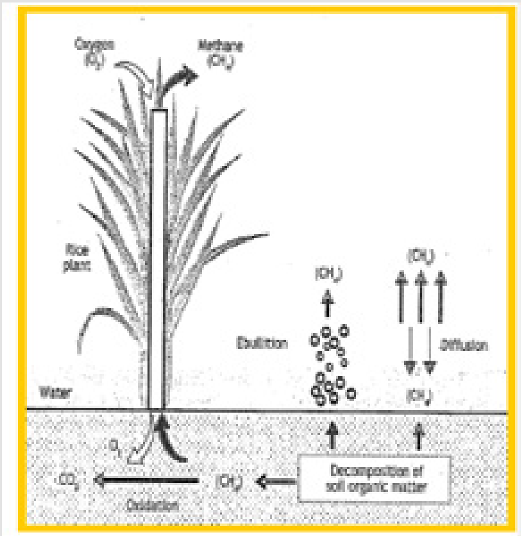

Figure 1: Schematic representation of methane emissions from flooded rice fields. Source: Rice Almanac (3rd Edn.)., p.39.

Table 1: Methane gas emissions from rice fields in selected countries.

Name of Country	Total amount of emitted CH_4 ($GgCH_4$)	Contribution of rice methane to methane emission (%)	Contribution of rice methane to total greenhouse gas emission (%)
US (2005)	328	1.3	0.1
Italy (2005)	70	3.7	0.3
Japan (2004)	274	24	0.4
China (1994)	10182	30	5.9
India (2006)	6600	35	9.8

The farmers need to be helped by providing them with rice varieties which have proven inheritance to sustain the present shocks of climate change. There should be research for climate resilient products such as new technologies for cultivation to combat future climatic crises that may affect the rice production on world as a whole. The climate resilient new technologies in rice would reduce greenhouse gas emissions, increase input-use efficiency. Focus should be on development of climate smart rice varieties that could thrive with sustained yield in the changing climatic order. There is need of allocating more funds towards crop production in view of global climate change.

Promotion of Low Carbon Climate Smart Rice

The climatic situations are changing abruptly without following any pattern which pause problems to all activities related to agricultural farming. In Asian countries rice production is left the only way of income for the livelihood of poor and small farmers and due to uncertainty in climate poor farmers are unable to put more expenditure for inputs of rice cultivation which fingers towards the poor crop management situations of rice cultivation. Thirdly the high population pressure aimed at producing more rice grains from less area without adequate soil management practices which degrades the soil health. Production of healthy crops with enriched nutrients signals crops to grow in a degraded soil nutrient base that could fight all the adverse growing situations and could be fortified with all essential nutrients in adequate concentrations. This suggests that a rice variety for future cultivation must be with multiple capacities of withstanding different biotic and abiotic stresses in a poor resource base with high yield potential and high nutrient composition in rice grains. This seems quite difficult and non-conceivable, but we have to work hard to get this group of rice varieties and provide to all farmers without any shortcut to sustain the global food security. IRRI in collaboration with other rice research institutes in the world is working vigorously for the development of rice varieties that can tolerate adverse conditions forecasted more to occur and to be intense with global climate change.

These include drought, flood, cold, heat, soil problems of high salt, iron toxicity, Zn deficiency and different diseases and pests. IRRI has already developed different rice varieties with drought resilience, tolerance to submergence, cold, salinity, soil acidity and multiple resistances to different diseases and pests. In brief varietal development of IRRI in response with climate change has been enumerated below.

Drought Tolerant Rice: Drought affects about 23 million ha of rainfed rice in South and Southeast Asia causing yield loss up to 40%. The varieties developed by IRRI are Sahabhagi Dhan, Sahod Ulan and Sookha that could yield 0.8 to 1.2 tonnes/ha under drought. IRRI is working for incorporating the drought tolerant quantitative trait loci (QTLs) in leading high yielding rice varieties of different rice growing regions of the world.

Flood Tolerance or Submergence Tolerance Rice: Flood can affect rice crop at any stage and flood at crop maturity stage may give farmers zero yield due to complete crop damage. The floods may be short term, flash flood or long-term stagnant flood. Plant breeders have been successful in incorporating submergence tolerance single gene Sub1 into Indian leading rice variety Swarna and the submergence tolerant rice variety is Swarna Sub-1 and other varieties are IR64-Sub1, Ciherang Sub1, etc.

Salt Tolerant Rice: Millions of hectares of rice growing lands in world are now salt affected not suitable to traditional high yielding rice varieties. In salt affect areas the yield of rice goes below 1.5 tonnes/ha. IRRI has found that SUB1 and Saltol genes can be combined into the rice varieties for salt tolerance. Saltol has been incorporated to BRRI Dhan 11, 28, 29 varieties of Bangladesh and many salt tolerance rice varieties have been developed.

Heat Tolerant Rice: Increasing heat of atmosphere is the most devastating threat to rice crop due to the effect of global warming. Very less increase in atmospheric temperature may affect different growth stages of rice. Rice is more sensitive to high temperature during flowering and ripening stages. High increase in temperature (>35^{o}C) during reproductive period may cause emergence of sterile stamens, un-pollinated spikelet's, poorly filled grains or chaffy grains leading to yield and quality loss of rice. *Oryza glaberrima* a wild rice variety has been found to have early morning flowering and high transpiration which are suitable traits for avoiding heat stress.

Cold Tolerant Rice: Occurrence of frequent low temperatures may cause yield loss up to 50%. Cold tolerance involves a complex trait of many genes. Three regions in the rice genome have links with cold tolerance at the reproductive stage of the plant. Cold stress at reproductive stage decreases the formation of fertile pollens and finally there will be less grain yield due poor fertilization. Cold tolerant breeding line IR66160-121-4-4-2 has been developed from the cold tolerance gene donors Jim brug (tropical japonica variety of Indonesia) and Shen-Nung89-366 (temperate japonica variety of China).

Rice Variety for Poor Soils: Potassium and zinc deficiency and iron and aluminium toxicity are rampant in rice growing areas of Asia, Latin America, and Africa. IRRI has developed rice varieties/ lines Suakoko 8 (*Oryza sativa* L.) and CG 14 (*O. glaberrima*) tolerant to iron toxicity in Africa.

Sustainable Rice Straw Management: Rice straw could be collected and economically be used for bioethanol production, now which has very demand for green energy sources as reducing emission of GHG and also for other ethanol requiring industries. Rice straw could be used for production of farmyard compost as the CO_2 produced in this organic matter decomposition process does not have an effect on global warming because this kind of decomposition are called the short-term carbon cycles which includes plants grown, foods from plants and the associated waste of plant and food processes. There is sharp benefit of making composts from rice straw or plant wastes as there is no production of other gases than CO_2 (CH_4 and N_2O add 25 and 298 times more heat to atmosphere respectively with same quantities in consideration) which could reduce GHGs emission and the CO_2 emitting materials are stored as carbon for other use (as compost) in the phenomenon of sequestration.

Direct Seeded Rice

To make the rice cultivation technology more proficient to the present natural, edaphic, economic and demographic situations on global scale, rice should be cultivated in a low GHGs emission situation with minimum use of energy and minimum disturbance to the rice production ecosystems. Emission of CH_4 is high in conventionally puddled transplanted rice (CT-PTR) as compared to dry direct seeded rice (dry-DSR). The reduction in CH_4 emissions ranged from 30- 58% in dry-DSR compared with CT-PTR [19,20]. The efficiency of mitigation of GHGs (reduction of CH_4 emission) emissions of different rice cultivation practices are in the decreasing order such as dry-DSR> wet DSR with intermittent drainage or irrigation> Wet DSR > CT-PTR [18]. There is low emission of CH_4 in dry-DSR during early growth stages and wet-DSR until establishment of seedlings due to aerobic field conditions as anaerobic situation required for CH_4 gas emissions [21].

Alternate Wetting and Drying (AWD) in Rice Field

Emission of methane from anaerobic conditions of submerged rice fields account for 12% of total global emissions which is the key issue that directs towards the sustainability of rice production and food security. Alternate wetting and drying (AWD) of rice fields could reduce water use by 30% and methane emission by 48%. After the eye-opening result of system of rice intensification (SRI) practice of rice cultivation more naturally and organic way of adaptation with robust plant stand, high yield and environment friendly [22-24] the alternate wetting and drying (AWD) of rice field for better crop stand and higher yield has motivated the farmers to adopt this irrigation practice which has long term benefits for farmers and sustainability of environment. In wetting period, the soil gets sufficient water (75% of water holding capacity) necessary for growth and in drying period soil gets enough oxygen for growth of plant roots and microorganisms in root rhizosphere. The plant roots get aerobic condition in the total cropping period which facilitates better root growth and ultimately plant growth and high yield. In this aerobic situation N_2O gas is also formed (nitrification) in the soil having more organic matter, applied more N-fertilizers and high temperature. The soil moisture regime should be maintained so that the soil temperature will be maintained at optimum that is required for plant metabolism.

There is need to reduce the application of N-fertilizers by application of organic compost, organic manure to be used as need base, and to manage the soil moisture below saturation as the crop needs lest it will be reason for production of N_2O a GHG which is 298 times more able to create global warming effects. Alternate wetting and drying (AWD) is now accepted as a viable mitigation measure for reduction of greenhouse gas (GHG) emission in agriculture. By adapting AWD in rice, the farmers can help reduce methane gas emissions, reduce irrigation costs and enhance water use efficiency of their source. AWD is a climate-smart practice in rice production that has both mitigation and adaptation benefits, and it is crucial to address climate change in the world.

Adaptation Benefits of AWD in Rice

Studies have found that alternate wetting and drying rice field can halve emissions and save up to 30% of the water needed for irrigation. The following are the adaptation benefits of AWD in rice production system.

Production: AWD improves the quality of soil structure, and a better soil structure allows intercrop with rice or other agricultural crops in quick successions. This may lead to intensive cropping systems and provides multiple sources of income to the farmers. A better soil structure will always reduce the farm operation cost at every step.

Yield: Implementation of AWD increases the yield of crops by improving soil quality and fertility helps the soil to absorb adequate quantity of zinc and nitrogen. AWD facilitates the reuse of organic nutrients present in soil for next crops in succession in the field. It can reduce the incidence of certain pests and diseases and help in maintaining health of crops.

Human Health: AWD avoids swampy or stagnant situations in crop field and reduces the breeding place of mosquitoes and other water borne diseases. Increasing Zn content of soil AWD benefits the zinc-deficient people around the world.

Environment: Rice production in Asia consumes almost half of the fresh water supply. By implementing AWD in rice production there is decrease in water consumption and saving of fresh water could be materialized which could be used for other processes. Adapting AWD in rice field will decompose rice straw better than other irrigation practices.

Socioeconomics of Farmers: AWD is more beneficial for farmers having small water sources. This promotes efficient utilization of available water bodies. This method is a boon to poor farmers who generally rely on rainwater and has low fund to irrigate the crop. With respect to factors responsible for emission of greenhouse gases, there is an inverse relationship between CH_4 and N_2O in rice farm. Management of water and organic matter reduces methane emissions and increases nitrous oxide emissions. In particular, nitrous oxide is a long-lived greenhouse gas that traps many folds (298 times more than CO_2) more heat in the atmosphere than methane over more than 100-year time frames. Therefore, it is utmost necessary to manage rice field so that net effective emission of GHG would be managed to minimum instead of adopting only a specific technology for demonstration per se.

Laser Land Levelling

It is a most logical and important activity of crop production which enhances the production efficiency and is eco-friendly. Laser land levelling a potent operation can save water by minimising the total requirement of irrigation water and in reducing greenhouse gas emission. It requires making the plots on the contour and levelling by laser guided machines or land levellers for getting levelled tabletop surface of plots. On flat surfaces irrigation water moves quickly to rear ends of the plot within less time with less quantity of water and the irrigation cost is reduced. Thus laser land levelling enables non-stagnation (avoid water logging) of irrigation water in the field and to maintain water below saturation quickly which improves aeration in soil and facilitates better microbial activities in root zone and hence enables better crop growth and yield, better soil structure and decreases the emission of greenhouse gases (CO_2, CH_4, N_2O, etc.,). It has been predicted that for every rise of 1°C in temperature of arid and semi-arid regions of Asia there will be an increase of 10% in demand of irrigation water. The findings of the International Maize and Wheat Improvement Centre (CIMMYT), Borlaug Institute for South Asia (BISA) and CGIAR Research Programme on Climate Change, Agriculture and Food Security (CCAFS) on impact of laser land levelling has been briefed below:

- Laser land levelling significantly reduces irrigation time for rice by 47-69 h/ha per season.
- It enhances yield by an average of 8 percent for rice and helps to food security.
- It saves electricity about 755 kWh per hectare per year for rice.
- It is cost effective. As demand increases, a group of farmers could avail the equipment on rent and share the costs.
- It reduces greenhouse gas emissions from saving on energy, reducing cultivation time and increasing input efficiency.
- With higher yield farmers get more revenue.

Threat of Climate Change on Rice Farming

Now we see that more than half the world population is dependent on rice as staple food and perceive a long-term threat for rice production from global climate change especially the earth's increasing temperature. At present rice is vulnerable to many adverse climatic situations and what global warming would cause to the world's future rice culture is not predictable efficiently by the scientists. The concern is that global climate change will pave difficulty in the attainment of food security in the world. So in this context Louis Verchot, Head of the land restoration group at International Centre for tropical Agriculture said, " It is really a bit of wake-up call, We are going to need to really rethink how we organize our food systems."

Increase of Global Temperature

Increase in temperature due to GHG emissions leads to increased soil temperature, soil drying, and plant stress which impacts adversely on agriculture even where there is large change in precipitation has not happened. With the present pace of greenhouse emissions, it is expected that towards the end of this century one third of agricultural land will suffer from moderate drought. In general rice is maximally grown in low lying lands of high temperature areas. So for each increase in night temperature above 35°C will directly decrease 10% yield of rice and increase in sea levels will submerge the rice growing lands which will decrease the net global rice production.

Uncertainty in Seasonal Weather

An increase in the frequency and severity of hot weather would reduce in the yield of rice up to 40% by the end of 21st century as reported in the Archives of Agronomy and Soil Science, 2018. Rice could be grown up to the temperature rise of 40°C, heat stress decreases efficiency of pollination by impairing the ability of flowers to pollinate and temperature more than 35°C can significantly decrease rice yield. According to IRRI the cultivated crop rice is the most vulnerable to future global climate change. There will be high degree of migration of agricultural laborours or farmers due to crop loss and yield loss resulted due to global warming. By principle a carbon sink absorbs CO_2 from the atmosphere and a carbon source releases CO_2 into the atmosphere. The largest carbon sinks of world are ocean, soils and forests and the carbon sources are burning of fossil fuels such as coal, oil and gas, deforestation and volcanic eruptions. If there will be more deforestation and loss of wetlands climate change will roll back and would create catastrophe in the entire globe. Verchot told on global climate change from the International Center for Tropical Agriculture that the transformation on global landscape is going to the total civilization and its economy is at risk and it is pushing forty years back in many places and it is going to aggravate the vulnerability of the poor sections of people.

To get out of the possible threats of global climate change, researchers are engaged to make food systems more resilient by decarbonizing irrigation systems and development of rice varieties which could withstand high temperatures or flooding. There is need to develop seed varieties that have higher tolerance to drought or heat or submergence or cold. The traditional varieties need to be identified having strong resistance to salt water.

Rice Production and Greenhouse Gas Emission

Rice has a very high carbon footprint, but there is still very less investments and rice crop deserves greater attention than other crops as it is the most important staple food and produces more GHGs that may devastate the rice crop itself and the world in future. Improved farming techniques also can cut emissions of methane, the potent planet-warming gas. According to the Environmental Défense Fund (EDF) rice production is releasing greenhouse gases into atmosphere as much as 1,200 average power stations fuelled by coal globally. Half of the global rice production (770 million tonnes) in 2018 (Figure 2) is shared by China and India (UN Food and Agriculture Organization (FAO)). Flooding the field is the predominant conventional irrigation method for growing rice crop. Stagnant water is never necessary for growing rice crop. Flooding is only efficient to prevent the spread weeds in the crop field. Otherwise flooding requires huge amount of water, needs continuous irrigation, its energy cost is high, creates anaerobic situation in the field which affects root growth and reduces yield. Due to anaerobic condition of rice field decomposition of organic matter through de-nitrification process creates marshy gas methane (CH_4) which is a powerful greenhouse gas contributes significantly to global warming. Rice is the second-largest source of methane from agriculture after livestock. Rice farmers cannot imagine this truth as flooding has been so general in rice production.

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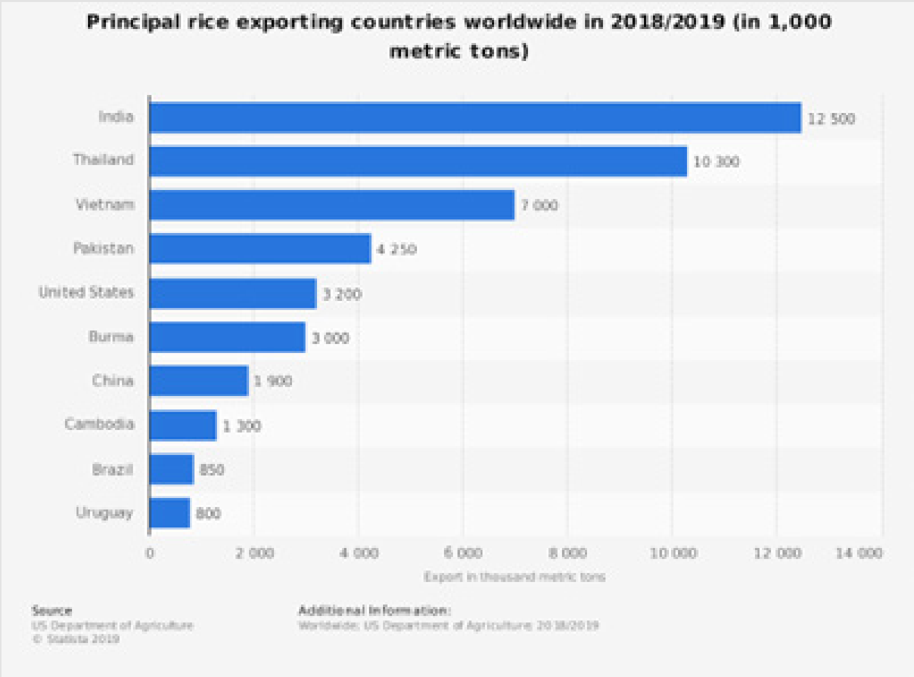

Figure 2: Principal rice growing countries worldwide 2018-19, Source: US Department of Agriculture, Statista 2019.

There is need of appropriate extension activities for farmers to make them understand the situation and the real looming problem. Microorganisms produce methane gas about 12% of annual global emissions by the process of decomposition of organic (plant) matter in rice fields. Increased level of oxygen in soil is also an atmospheric threat that this increased concentration of oxygen in soil will react with soil nitrogen and produces nitrous oxide (N_2O) which is generally known as laughing gas and has very high GWP.

Rice production in water saturated (puddled or continuously irrigated or submerged or water stagnant) field is a challenge which could not be carried out with sustainability and with happy living in the world. Standing water in rice field encourages production of methane and too little water in the form of fluctuations in planned flooding (AWD) produces N_2O. So for a sustainable rice production we have to choose the water level in rice field as 5cm above the rice field (water saturation with standing water) and 5cm below surface of rice field (where there is difficult of irrigation). Water table 5cm above the surface of rice field will discourage anaerobic reaction of microbes so production of CH_4 will reduce and when water table will be 5cm below the surface of rice fields, due to capillary rise of water to the surface of soil will restrict atmospheric O_2 to interact with soil-N and decreases N_2O formation.

Impacts of Climate Change on Rice Production

It is all research findings loudly pronounce that climate change has a net negative impact on rice production all over the world. The general impacts of climate change is fluctuations in temperature and precipitation that leads to frequent requirement of flooding, scarcity of water and increased menace of weeds, pests and pathogen that adversely affect the rice production and productivity. Small farmers are more prone to the negative impacts of climate change in rice production as they lack the necessary knowledge, support and resources. Due to the effects of climate change the distribution pattern of rainfall has been disturbed, which is very erratic, and the intensity of rainfall has increased and often happen out of rainy season. Due to this kind of high intensity rainfall there is continuous flooding and there is heavy damage to the crop in the field before harvest and also it damages the crop after harvest in threshing yard in case of poor farmers as they are unable to afford adequate protection measures. Increase in temperature has resulted in hotter days and it leads to quick evaporation of irrigation water and poor farmers are unable to provide adequate irrigation. Due to water shortage and high temperature there are problems in rice growth and production such as panicle development, panicle emergence, pollination, grain filling and finally reducing yield of rice.

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Occurrence of heavy winds is also due to the effect of climate change. Excess rainfall causes flooding and submergence and heavy wind lodge and submerge the crop in flooding water, and this brings heavy loss in rice production. Flooding could affect very seriously at any stage of rice production which is maximum at seedling or seed germination stage and before harvest of crop which may damage 100% crop with zero yield. The farmers can do nothing to avoid heavy winds. With increase of temperature and high soil moisture the rice field microclimate become very suitable for growth and development of different disease, pests and pathogens which ultimately affect negatively the growth and production of rice crop. The better plant growth is conceived with soil capillaries containing 60% water and 40% air. So there is need to avoid continuous flooding of rice fields to decrease the emission of GHGs and to have better plant growth and crop productivity. To mitigate the global climatic change farmers need to use new rice varieties or seeds that can tolerate drought, high temperature, submergence, cold, salinity and low nutrient soil conditions; to adjust planting dates, use slow nitrogen releasing fertilizers, maintain proper plant populations that will cover the field and maintain the soil temperature low so that there will be less emission of N_2O gas in dry soil.

Management of N_2O Emissions from Soil

It has already been stated that increased level of oxygen in soil in interaction with non- limiting soil-N produces nitrous oxide (N_2O) in aerobic condition (Figures 3 & 4) which has very high GWP. Total global annual N_2O emission reached about 17.7 Tg of N, which was 6.7 Tg (37.8%) from anthropic sources. Agricultural lands emitted 2.8 Tg of N per annum or 15.3% of total greenhouse gas emissions or 41.8% of the anthropic emissions [25]. N_2O emissions decrease in cases of small availability of N in the soil [26]. Application of excess N-fertilizers more than the crop requirement is the main cause N_2O emission in agricultural field. In soil with water saturation condition when KNO_3 was applied in splits, the emission of N_2O decreased as compared to a single application [27]. In general soils containing more nitrogen produce more nitrous oxide (N_2O). N_2O is produced in the soil both by the processes of nitrification and de-nitrification by micro-organisms present in the soil where nitrification occurs in presence of sufficient oxygen and de-nitrification is an anaerobic situation. Increased soil organic C content increases the N_2O production [28]. The soil moisture and soluble C content show a significant positive correlation with N_2O emissions, during organic residue decomposition [29]. C content in soil influences nitrification and denitrification reactions [30] because it provides organic carbon to soil denitrifying microorganisms and stimulate microbial growth and activity [31,32] reported that emission of N_2O increased initially and later decreased with increasing soil moisture.

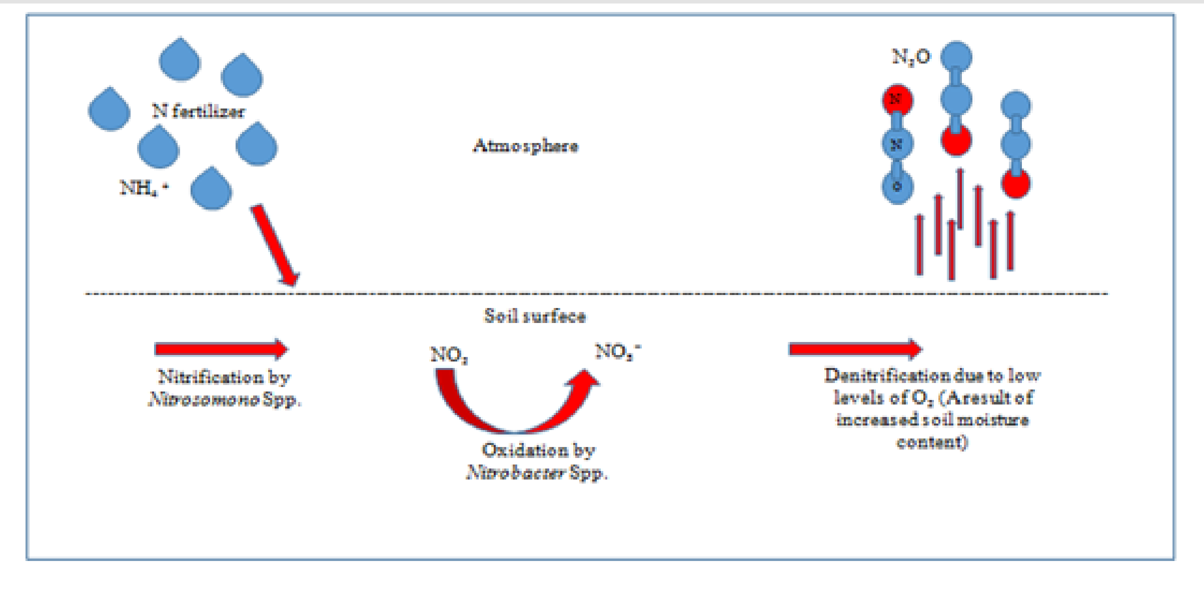

Figure 3: Schematic diagram of emission of nitous oxide(N_2O).

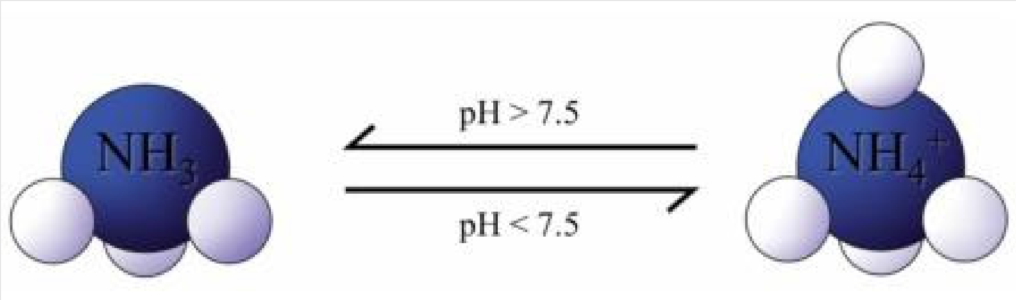

Figure 4: The pH dependency of ammonia or ammonium.

Perdomo, et al. [33] found that there was largest N_2O flux after rain and during the period of high soil temperature. Liu, et al. [34] revealed that large N_2O emissions were due to rain or irrigation events and confirmed that the diffusion of N_2O from soil to the atmosphere increased significantly immediately after rain and back to normal after three days. Effective nutrient monitoring is the safe standard of a sustainable growing operation and reducing the N_2O emissions. Drip irrigation systems are more adaptable for crop management with less water and limiting N_2O production in soil. Also, ferti-irrigation by drip systems is potent to reduce the total quantity of N-fertilizer need to be put in soil for better crop yield and by reducing the total Nitrogen in soil eventually it will help in managing the N_2O production in soil. Micro sprinklers and surface drip systems could be relied on to give a check to large N_2O emissions. Slow-release nitrogen fertilizers and N-fertilizers coated with nitrification inhibitors could release ammoniums or nitrate to plants slowly and the excess nitrogen in soil will reduce. Application of anhydrous ammonia (AA) increases soil pH and increases the soil nitrate and N_2O production. So application of N-fertilizer as urea is better to control N_2O emissions in rice fields. The ammonium fertilizers should be applied such that the plant could uptake in the form of ammonia, and in late situation ammonia will be converted to nitrate and it will be a source of N_2O emission.

Crops having high C:N ratio could be used as cover crop to minimize N_2O emission which is a very complex system to understand [35]. Crops with low C:N ratio increase the soil N and to minimize the available soil N could lead to N_2O emissions. N_2O is produced both by nitrification and de-nitrification by microbes. Nitrification is the conversion of ammonia/ammonium (NH_3/NH_4^+ into nitrate (NO^{3-}) by nitrifying microbes. These microorganisms consume ammonia or ammonium and take oxygen in breathing. The ammonia or ammonium are used interchangeably and the soil pH it decides the form of ammonia or ammonium in soil, i.e., ammonium will predominate in acidic situations (pH<7.5) and ammonia in alkali conditions (pH> 7.5). Actually de-nitrification is the process of conversion of NO^{3-} to elemental nitrogen (nitrogen gas N_2) by microbes in the soil but the microbes are always not able to convert all NO^{3-} to N_2 and N_2O is an intermediary product of this microbial process and N_2O being a gas gets released from soil before being converted to N_2. De-nitrification is an anaerobic situation and nitrification is an aerobic situation, means N_2O is produced in soil both in aerobic or anaerobic situations. Synthesis and emission of nitrous oxide (N_2O) by microbial decomposition processes results from complexes interactions of several factors, i.e., temperature, structure, texture, and pH of soil, available N in content of organic material and water [36].

Emission of N_2O from soil is greatly influenced by soil mobilization, crop rotation, sources of N in soil, type of N-fertilizer application, depth and time of N-fertilizer application, etc. [34,37,38]. Application of excess N-fertilizers in soil with high soil temperature increases nitrous oxide (Figure 5).

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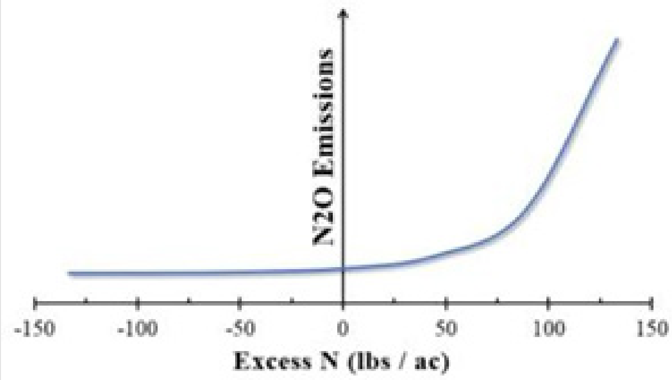

Figure 5: Nitrous oxide (N_2O) emissions by excess N-fertilization. From Groenigen, et al. [39].

Threats to Climate, Biodiversity and Food Security

Now we have not met the foremost necessity of food security completely globally. At the same time global climate change has posed impediments in the way of securing food security. It is a complex nature of our man made activities that when we tried to build up our economy we have left the environment, what it could be affected to which extent and whether it will disadvantage our main goal of food security and development. It is understood now though in late that without progress in biodiversity there cannot be a stable achievement in food security. Now we in Asia are facing the most important threats of Food insecurity, biodiversity loss and climate change and this is easily comprehended that these are very complexly correlated. If we do not address all these threats with equal importance for our survival, now we will conclude that we are not really interested in solving the problems of food security rather it will prove that simply we do not know how to secure food security.

We must acknowledge the impact of every action we make on earth; how much it will affect our climate, biodiversity and natural resources directly by use or indirectly by its effect. We should know that agriculture uses 70% of world's fresh water, covers 50% of habitable land and causes loss to biodiversity to the tune of 80% and it adds significantly to global warming by emission of CH_4 and N_2O.The food supply chains should be overhauled with revisiting the establishment of strong infrastructure to make it climate resilient. We need to establish sufficient infrastructure such as cold storages, warehouses, rural connectivity and digital services at places accessible to farmers and that the farmers could afford. The entire food production system should be climate smart such as field atmosphere, input use, product processing, by-product reuse or disposal, efficient use of natural resources, use of non-carbon energy sources such as wind energy, solar energy, etc. and at last use of climate resilient seeds for food production which will have very low emission of GHGs.

At last we need to follow nature and its principle to protect biodiversity for crop production to the extent it must be and it could be operationalized. We need to conserve natural ecosystems or create ecosystems in the way nature builds or modified or artificial ecosystems by development of community-based agroforestry, developing local plantations in pasture lands, reducing soil tillage intensity, etc. Our behaviour change is the greatest factor to materialize and sustain the food chain, climate and biodiversity. Our consumption pattern needs a thorough revision to diversify food and diet which would reduce the production load of a specific crop. Animal based food production contributes 57% of total greenhouse gas (mainly N_2O) emission from food production, so there is a need to shift to plant based food diet from diet of animal base.

Greenhouse Gas Emissions from Indian paddy Fields

India grows rice in about 43 million ha of land which is largest in the world and produces about 125 million tonnes of rice (UN Food and Agriculture Organization [40] (Figure 6) and rice shares 43% to the national food grain production. On the other hand rice contributes in emission of GHG mainly releasing CH_4 a potent greenhouse gas. Due to the vast diversity of geographical location of rice cultivation in India, such as variation in temperature, water depth, season, soil conditions, etc. bring big regional variations in GHG emis-

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sion. The UN-Intergovernmental panel on Climate Change (IPCC) 2007, 4th assessment report on Agriculture status for GHG contribution rice fields is

(i) Agriculture accounts for 10-12% of total global man made GHG emissions,

(ii) Agriculture accounts for 50% of methane emissions,

(iii) Rice production accounts for 11%of total methane (CH_4) emission and

(iv) South and East Asia accounts 82% of total methane emissions from rice production of total non-CO_2 emissions from agriculture.

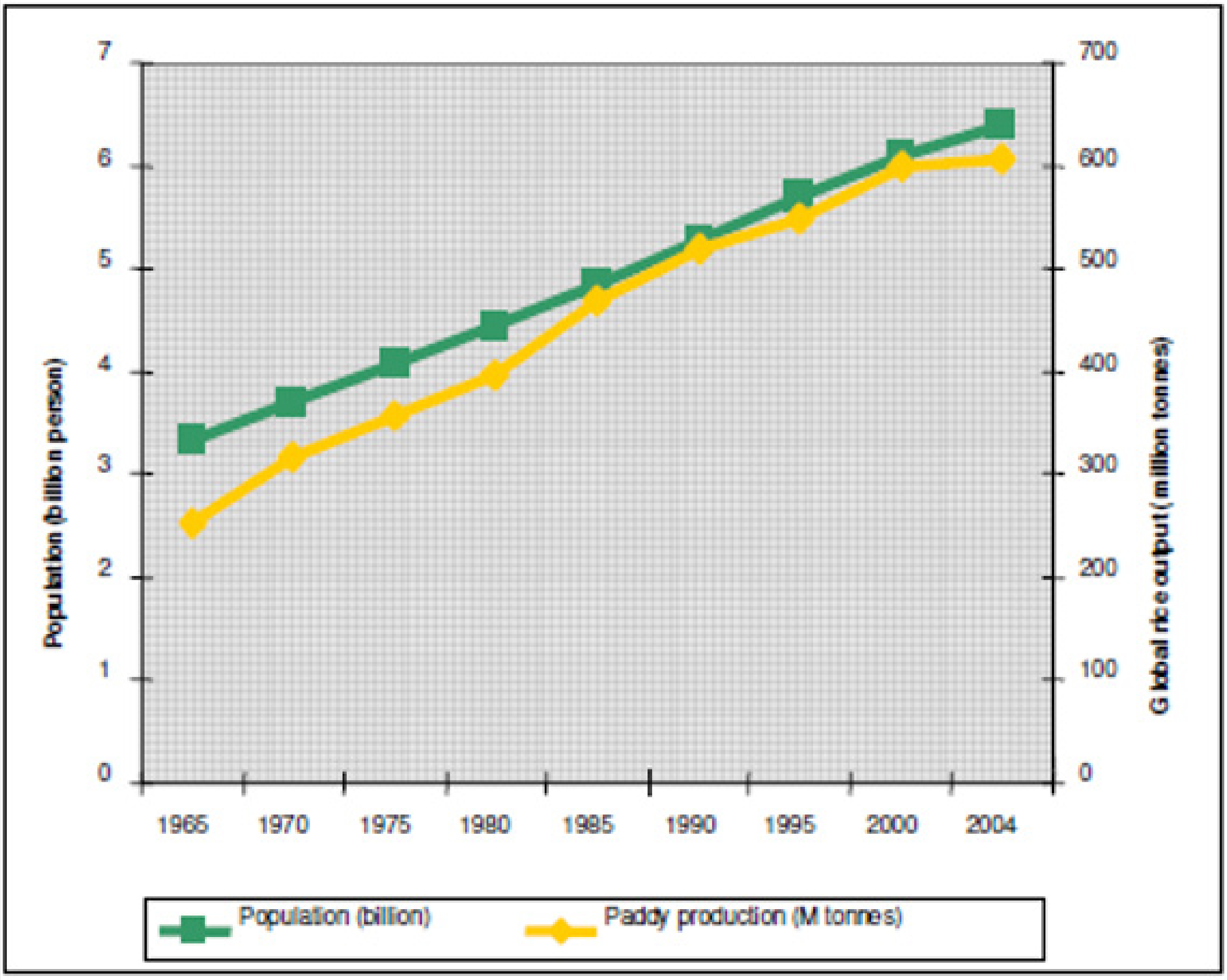

Figure 6: World population and global rice output, 1965 to 2004 [41].

The agriculture sector in India in 2007emitted a total of 334.41 million tonnes of CO_2 equivalents. This estimate of GHG emission comes from rice cultivation, manure management, agricultural soils and burning of crop residue. On an average of 3.33 million tons of CH_4 (69.87 million tons of CO_2 equivalents) is emitted from rice cultivation. This quantum of emission sums up all forms of water management for rice production followed in India such as irrigated, rain-fed, deep water and upland rice. To mitigate this problem of GHG emission in rice fields in India, there are many opportunities available such as alternate wetting and drying of rice fields, maintaining of mid-season aeration, improvement in organic matter management, promoting aerobic decomposition of crop residues, improving N-fertilizer application efficiency by applying N-fertilizer that matches crop demand, proper management of manure and animal waste, adoption of principle of minimum tillage and cover crops. According to a study investigated in India and published in The Proceedings of the National Academy of Sciences (PNAS), reported that AWD in rice farms could emit 45 times more N_2O in comparison with the maximum emission of methane from continuously flooded farms. The climate impact of rice fields has been underestimated by neglecting the production of N_2O from AWD rice fields. Environmental Defence Fund (EDF) in US reported that global effect of rice fields by CH_4 and N_2O is equivalent to that of 600 coal plants.

An investigation by researchers found in South India that N_2O emissions can contribute 99% of total climate impact of AWD rice cultivation of same area (Figure 7) [42].

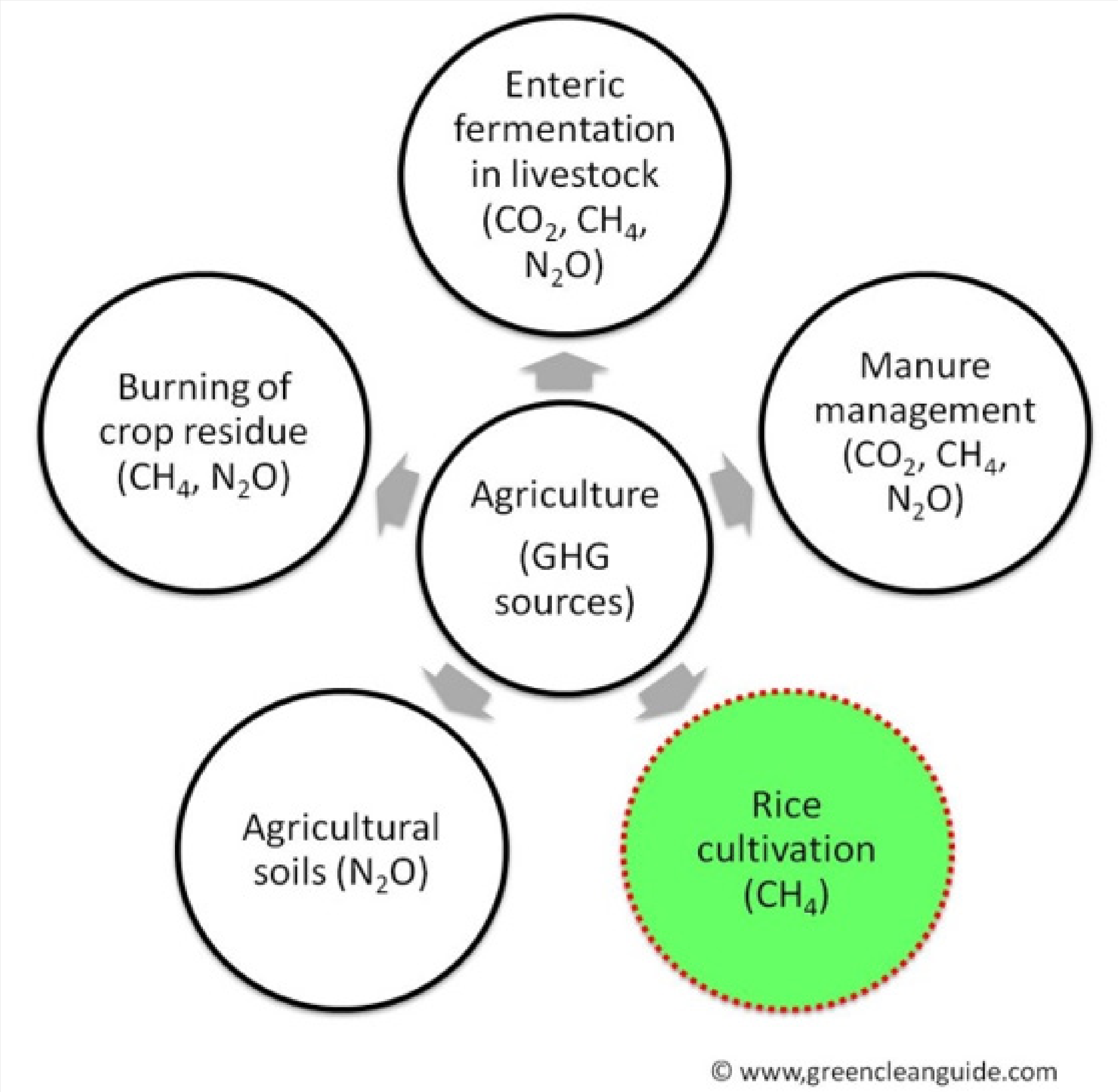

Figure 7: Sources of greenhouse gas in Agriculture. Source: www.greencleanguide.com [42].

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Growing of Climate Friendly Rice

Growing of rice crop is a resource-intensive essential enterprise. Rice cultivation covers about 11 % of the Earth's arable land and uses one-third of irrigation water. At the same time rice culture is tremendously responsible for releasing greenhouse gases to earth's atmosphere that creates the threat of global warming which is itself detrimental to rice production and human establishment. Contribution of rice production to total global methane emissions is 12% which is mainly due to anaerobic decomposition process during rice production process. Devising carefully chosen green house reducing techniques in farms reduced greenhouse gas emissions from rice cultivation by as much as 90% by integrating shallow (mild-intermittent) flooding with co-management of nitrogen and organic matter. Rice farmers can reduce about 60% of global climatic impact by adopting shallow flooding instead of continuous or intense forms of intermittent flooding. According to Zitouni Ould-Dada, deputy director of the climate and environment division at the UN Food and Agriculture Organization (FAO), said that 50 million smallholder farmers feed 50% of world population and due to this focus should be concentrated on these small holder farmers and fund should be earmarked for management of rice production. As rice is the most important food component of human life and in general rice is mainly produced by small holder farmers.

They belong to socio-economically poor sections. It is quite irrelevant to think that they could grow crop and qualify for carbon credits, because this requires more care, knowledge, interest and the most importantly fund for which they struggle day and night. Correction in global climate change is a genuine collective task and only could be achieved by cooperation of all categories or sections of people in the world. So rice production should given due care at all stakeholders level. There should be a strong autonomous body to govern the climate smart operations in every sector to which all energy consumers must abide and be hold responsible. All research on industry and agriculture must fulfil the criteria of minimum greenhouse emission guidelines with principle and action. Capacity building of farmers is the foremost necessity of this climate friendly rice cultivation. They should be provided with high yielding short duration rice seeds in sufficient quantity at right time so that farmers could grow crop early to avoid drought or flood or submergence or salinization of crop. There should be adequate full time irrigation facilities which will not compel farmers to flood the rice plot whenever water is available. All nitrogenous fertilizers must be slow release and it will release the N-fertilizers as the plant needs at a particular time. There should be safety measures for crop production which includes installation of crop production implements in cooperative basis, financial assistance for crop harvest and processing with installation of different postharvest hubs in different localities according to the crop of the area, credit linkage facilities for agricultural operations at low interest rate, government procurement of farmers' produce and easy and viable crop insurance and development of farmers learning schools with necessary aids and appropriate training incentives to all trainee farmers, etc.

Mind set of eating from farmers and cheating to farmers should be eradicated completely with giving them due recognition in society.

Global Emissions by Gas (Figure 8)

At the global scale, the most navigating greenhouse gases emitted by human action are:

Carbon dioxide (CO_2): Primary source of CO_2 is fossil fuels and CO_2 is also emitted from direct human-induced impacts on forestry and other forms of land use, i.e., deforestation, land cleaning for agriculture and soil degradation.

Methane (CH_4): Agricultural activities, energy use, biomass burning, and waste management contribute to CH_4 emissions.

Nitrous oxide (N_2O): Agricultural activities, i.e., N-fertilizer use, dry rice field with non-limiting N- content in soil are the primary source of N_2O emissions. Combustion of fossil fuel generates N_2O.

Fluorinated gases (F-gases): Industrial activities, refrigeration units, and use of some consumer products contribute to emissions of F-gases, such as perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6).

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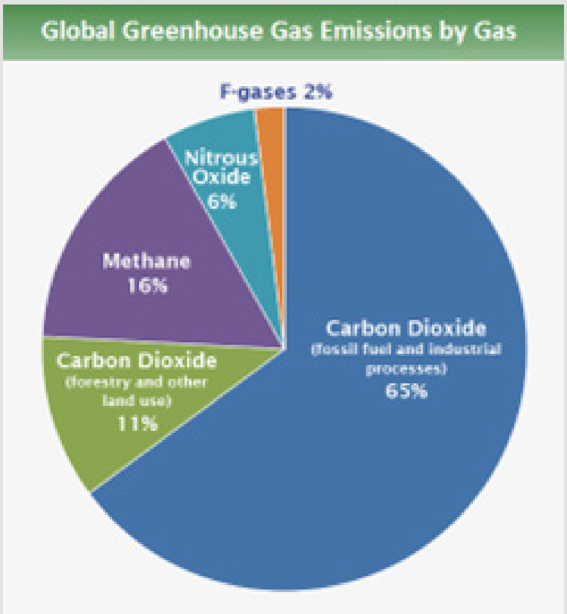

Figure 8: Global emission of greenhouse gas emission by gases. (Source: IPCC (2014) based on global emissions from 2010. The details about the sources included in these estimates can be found in the Contribution of working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate change.).

These greenhouse gases stay in the atmosphere for different time periods ranging from a few years to thousands ofyears. The GWP is a measure of the energy that will be absorbed over a given time period by 1 tonne of greenhouse emission into atmosphere. For better comparison the emissions are converted into the GWP equivalent of CO_2. Gases with higher GWP will absorb more energy per unit of gas emitted. Therefore, gases with lower GWP will give more warmth to earth and contribute more to global warming and climate change. Carbon dioxide is constantly exchanged in the atmosphere, ocean, and land surfaces. As CO_2 is both produced and absorbed by plants, microorganisms and animals. Emissions and removal of CO_2 by the natural processes tend to balance, absent anthropogenic impacts; after industrial revolution more production of CO_2 in industries resulted in global warming caused due to CO_2. Some carbon dioxide (CO_2) is absorbed quickly (for example, by the ocean surface) and some CO_2remains in atmosphere for thousands of years, due to very slow process of CO_2 to be transferred to ocean sediments. The lifetime of methane in the atmosphere is much shorter than carbon dioxide (CO_2), but CH_4 traps radiation more efficiently than CO_2. The GWP comparative impact of CH_4 is 25 times more than CO_2, but within few years CH_4 reacts with other chemicals in the atmosphere and breaks down to other new compounds.

Nitrous oxide (N_2O) is also naturally present in the atmosphere as part of nitrogen cycle of earth and it has a variety of natural sources. Nitrous oxide (N_2O) stays in the atmosphere for about 114 years before being removed by a sink or degraded through chemical reactions. The GWP impact of N_2O on warming the atmosphere is almost 298 times that of carbon dioxide (CO_2).

Global Emissions by Economic Sector (Figure 9)

Global greenhouse gas emissions can be classified by the economic activities by which they are produced:

Electricity and Heat Production sectors contribute to 25% of global greenhouse gas emissions in 2010. Burning of coal, oil and natural gas for electricity production and heat generation is the largest source of global greenhouse gas emissions. Industry: Industries produce an average 21% of global greenhouse gas emissions in 2010. Here is also the primary source of GHG emission is burning of fossil fuels. In this sector the emissions are from chemical, mineral and metallurgical transformation processes. Agriculture, Forestry, and Other Land Use activities produce 24% of global greenhouse gas emissions in 2010. Agriculture mostly contributes to emission of GHG in this sector which includes crop cultivation and livestock management. Transportation sector contributes about 14% of total global greenhouse gas emissions in 2010. This sector

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primarily include emissions from burning of fossil fuels for road, rail, air, and marine transportation. Buildings and house hold sector produced 6% of global greenhouse gas emissions in 2010. It includes cooking in homes, onsite energy generation and burning fuels for heat in buildings. Other Energy use sectors such as fuel extraction and refining, processing and transportation, etc. produced about 10% of 2010 global greenhouse gas emissions in 2010.

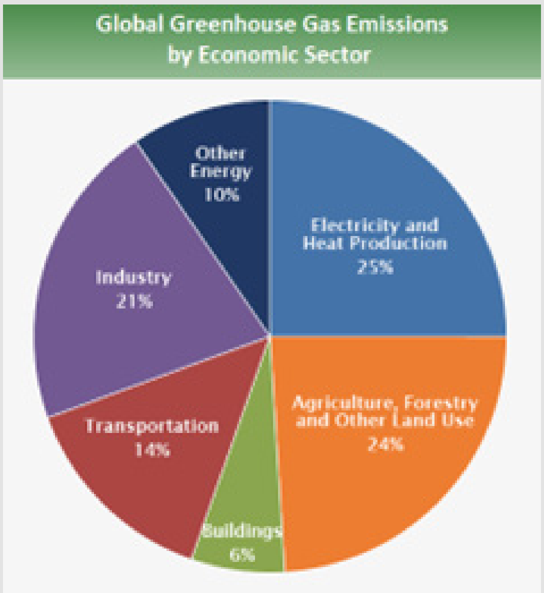

Figure 9: Global greenhouse gas emission by economic sector (Source: IPCC (2014) based on global emissions from 2010. The details about the sources included in these estimates can be found in the Contribution of working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate change.)

Global Carbon Emissions from Fossil Fuels, 1990-2014 (Figure 10)

From the above figure it is clear that carbon emissions from fossil fuels have significantly increased globally since 1900. CO_2 emissions have increased 90%, with that from fossil fuel combustion and industrial processes contributed about 78% of the total GHG. Agriculture, deforestation, and other land-use changes contribute to GHG emissions as the second-largest one [11] (IPCC, 2014) (Figure 11) [43].

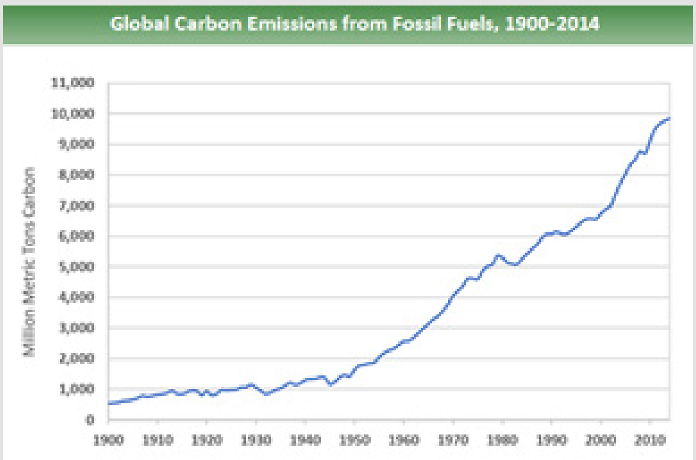

Figure 10: Global carbon emission from fossil fuels, 1900-2014 [40].

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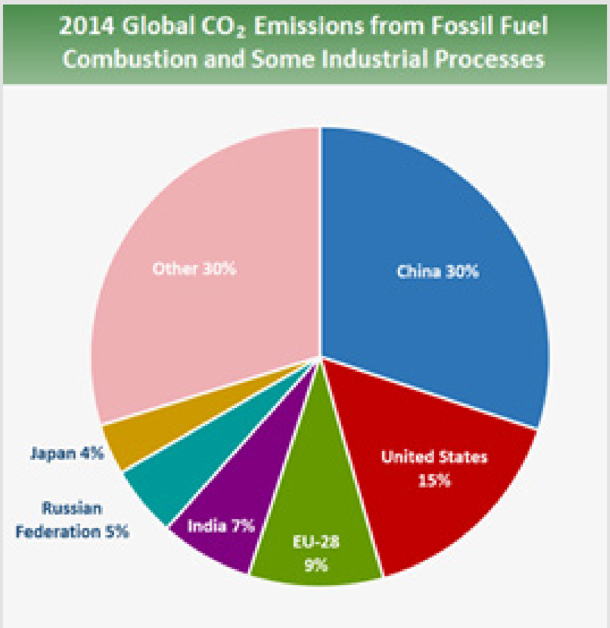

Figure 11: 2014 Global CO_2 emissions from fossil fouel combustion and some industrial process (Source: Boden TA, Marland G, and Andres RJ (2017).

Greenhouse Gas emissions by Countries

According to a statistical analysis in 2014, the top carbon dioxide (CO_2) emitters were China contributed maximum CO_2 for global GHG emissions and then followed by the United States, the European Union, India, the Russian Federation, and Japan. These data comprise CO_2 emitted from fossil fuel combustion, gas flaring and cement manufacturing industry. This represents a large proportion of total CO_2 emissions. Emissions caused due to agriculture, forestry and other land use [40] estimates indicated over 8 billion metric tons of CO_2 equivalent which is about 24% of total global GHG emissions [11].

Status of Greenhouse Gases in Atmosphere

Gases that trap heat in the atmosphere are called greenhouse gases. There are many kinds of greenhouse gases are present in atmosphere. Among them carbon dioxide (CO_2), methane (CH_4), nitrous oxide(N_2O) and fluorinated gases contribute considerably to the global warming. The anthropogenic greenhouse gases such as methane and nitrous oxide contribute about 17%and 6% respectively to the overall increase of global warming [43]. These are briefed below:

Carbon dioxide (CO_2): Carbon dioxide comes to the atmosphere through burning of fossil fuels (coal, oil and natural gas), trees, solid waste, and other biological materials, and a part of it results from certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is sequestered or removed from the atmosphere being absorbed by plants for photosynthesis.

Methane (CH_4): Methane gas is emitted into atmosphere during the production and transport of coal, oil and natural gas, agriculture, livestock, land use and decay of organic wastes products. The total global annual methane emissions are 576 (range 550–594) Tg [44]. Of this emission estimate, anthropogenic methane emissions were estimated [45] to be around 360 Tg, which includes 200 Tg emitted by agriculture activity, and 100 Tg emitted by the fossil fuel industry. However, isotopic evidence [46] reported with isotopic evidence that fossil fuel industry could emit a maximum of 150–200 Tg methane annually. Two-thirds of methane emissions are product of human activities and this portion of CH_4 emission is targets for mitigation. Methane is naturally destroyed by both chemical and biological processes, which includes reaction with atmospheric hydroxyl [OH] and chlorine, and by methane-consuming bacteria (methanotrophs) in soil and water. This results in the lifetime of methane in the air of 8-10 years [47].

Nitrous Oxide (N_2O): Nitrous oxide is emitted to atmosphere during combustion of fossil fuels and solid waste;

industrial activities; agricultural, land use, and during treatment of wastewater.

Fluorinated Gases: Perfluorocarbons, hydrofluorocarbons, nitrogen trifluoride and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted in smaller quantities from commercial, household, and industrial applications and processes. Hydrofluorocarbons are sometimes used as ozone-depleting substance substitute for stratosphere. Fluorinated gases are sometimes referred to as high-global warming potential (GWP) gases as for a given amount of mass, they trap substantially more heat than CO_2.

Basic Rules to Qualify for Carbon Credits

1) A practice must result in avoidance or reduction in releases of greenhouse gasses or sequestration of carbon into the soil.
2) A practice must be new and different from conventional, business as usual.
3) The practice has to be recognized by an official organization such as the Chicago Climate Exchange.
4) The practice must maintain appropriate monitoring and accounting methods.
5) No "cherry picking" allowed: a large company or municipality can't just list their carbon friendly activity. The activity has to be part of a larger carbon accounting that covers the company or municipalities carbon footprint (this is not the case for smaller organizations or businesses).

Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) is an innovative approach that helps people who manage agricultural systems to respond to climate change effectively. The CSA aims to achieve the triple objectives or anyone or more objectives of adapting to climate change, sustainably increasing productivity and incomes, and reducing GHG emissions. Climate smart agriculture targets to reduce trade-offs and promote synergy based on the objectives to disseminate decisions from the local to the global platforms and over short and long time periods, to find out locally acceptable solutions. Generally most of the poor people of the world live in rural villages and their livelihood is dependent on agriculture. Production of food crops, management of livestock, rearing of fish and forest production systems are potential to increase productivity and incomes of poor rural households. Developing countries are more vulnerable to the climate change and its impact which includes increasing temperature, changes in precipitation patterns, rising of sea levels and more frequent occurrence of unpredicted extreme weather events. All these climatic change situations risk agriculture, food and water supplies.

The CSA Approach

Different elements of climate-smart agricultural systems include: Management of agricultural farms, crops, livestock, aquaculture and fishery to achieve short-term food security and livelihoods needs according to the priorities for adaptation and mitigation. Conservation management system of ecosystem and landscape isto conserve ecosystem services which are found most important for food security, development and sustainability of agriculture, adaptation and mitigation of global climate change. Better services for farmers and land scape management teams to enable better management of climate change risks or its impacts and mitigation actions. Changes in the wider food system region base which includes demand-side measures and value chain initiatives that enhance the benefits of CSA.

Actions to Implement a CSA Approach Include

1) Expanding the evidence base: It needs to collect all such events of vulnerability of current and projected effects of climate change in a country in the agricultural sectors and for food security and identification of effective adoption objectives and estimates of potential reduction in GHG achieved by different adaptation strategies.
2) Policy support frameworks: Development of relevant policies, plans, investments and coordination across processes and institutions related to agriculture, climate change, food security and land use should be done in a participatory approach.
3) Strengthening national and local institutions: Active involvement of all institutions starting from local, state level, national and international level to address the climate change and a potent CSA with the participation of policy makers in building capacity of the personals engaged with global climate change.
4) Enhancing financing options: There should be innovative financial mechanisms that need to be engaged to

finance for change in agriculture and climate change for implementing CSA from public and private sectors.

5) Implementing practices at field level: farmers are the ultimate user of CSA at agricultural field level and they should be engaged with the CSA approach with supplementing necessary input, knowledge, fund with encouraging incentives and promotions.

The climate is changing at all the time, but today's concern is that we are unsafe in this world due to the actions of the affluent sections as well as poor sections. The wealthy states or countries or people use more resources and leave the world in the verge of devastation, and they do not too mind it. The poor or the middle people understand the consequences of global climate change, but they are unable to stand with a solution to this anticipated grave situation due to their poor stand of resources and socioeconomic conditions. If this shame less legacy will continue, all in the earth will suffer with drastic livelihood and development limitations. It would be thought our intellectual bottleneck that we say global climate change, global warming, food security and biodiversity all are in danger, and we cannot go with a strategy to save our biodiversity and food security. So all need to come and fight together with a planned effort to address the problems of current global climate change that would happen in future and find strategic solutions at national and international level with adoption of different mitigation technologies and allocation of none limiting funds to execute them with heart and will so that earth will sustain with food security and happy life [48-54].

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