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Proficient strategies for climate smart agriculture production system: key to mitigate impending climate change

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Abstract : Studies on climate change have underscored two points; first that atmospheric commons, namely the earth's carbon absorbing capacity, is finite and depletable and that growth of GHG emissions, even at their present level pose a threat to humankind. Carbon pollution is causing the world's climate to change not only on the magnitude of the change but also on the potential for irreversibility, resulting in extreme weather, higher temperatures and more droughts. Our earth is undoubtedly warming. This warming is largely the result of emissions of carbon dioxide and other Greenhouse Gases (GHG's) from human activities including industrial processes, fossil fuel combustion, and changes in land use, such as deforestation etc. Day by day the cycle of climate on earth is changing. Global warming has led to season shifting, changing landscapes, rising sea levels, increased risk of drought and floods, stronger storms, increase in heat related illness and diseases all over the world. This has resulted due to emissions of Green House Gases (GHG's) from various anthropogenic activities. To protect ourselves, our economy, and our land from the adverse effects of climate change, we must reduce emissions of carbon dioxide and other greenhouse gases. By involving agriculture as mitigation tool particularly for non-CO_2greenhouse gas (GHG), this would not only help to curb the problems but also enhanced the agricultural system productivity. An international treaty known as "Kyoto Protocol" has come in to force in 2005 with an vision and mission to stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system and to achieve this goal the concept of Clean Development Mechanism (CDM) has come into inclination as an integral part of protocol with an objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Indian opportunity in global carbon credit (trade) is also discussed briefly in this article.

Key words:Strategies, Climate smart agriculture, Climage change.

INTRODUCTION

The greenhouse gases are the main culprits of the global warming and climate change. The greenhouse gases like carbon dioxide, methane, and nitrous oxide are playing hazards in the present times. An increase of temperature by 1°C would be equivalent to a 150 km Northward shift of isotherms (lines joining places with similar temperature) or about 150 m lower altitude. There is a 5 per cent decrease in rice yield of every °C rise in temperature above 32 °C. According to recent report by Inter Governmental Panel on Climate Change (IPCC) by 2100 AD, due to global warming the average global surface temperature is projected to increase by 1.1 to 4.0 °C above 1990 levels for low emission scenario of greenhouse gas (GHG). The reduce length of growing seasons as a result of climatic change is causing detrimental effects on agriculture, In south Asia, crop yield could decrease up to 50percent by 2050 if suitable measures are not taken. The most significant impact of climatic change is expected in respect of availability of water. Why is there a need for agriculture

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to aid in the mitigation of climate change and concurrently better adapt itself for change, despite of occupying 40-50 percentof the total land surface agriculture contribution is meager to the extent of 10-12percent of total global anthropogenic greenhouse gas (GHG) emissions. Agriculture contributes 47percent and 58percent of total anthropogenic emissions of (non-greenhouse gas).CO_2 has large annual exchanges between the atmosphere and agricultural lands but the net flux is estimated to be approximately balanced, so accounts for less than 1percent of global anthropogenic CO_2 emissions. Agricultural N_2O and CH_4 emissions have increased by nearly 17percent from 1990 to 2005and about 32 % of increase has been noticed from Non-Annex I countries (least developed countries) who were responsible for75 percentof all agricultural emissions.

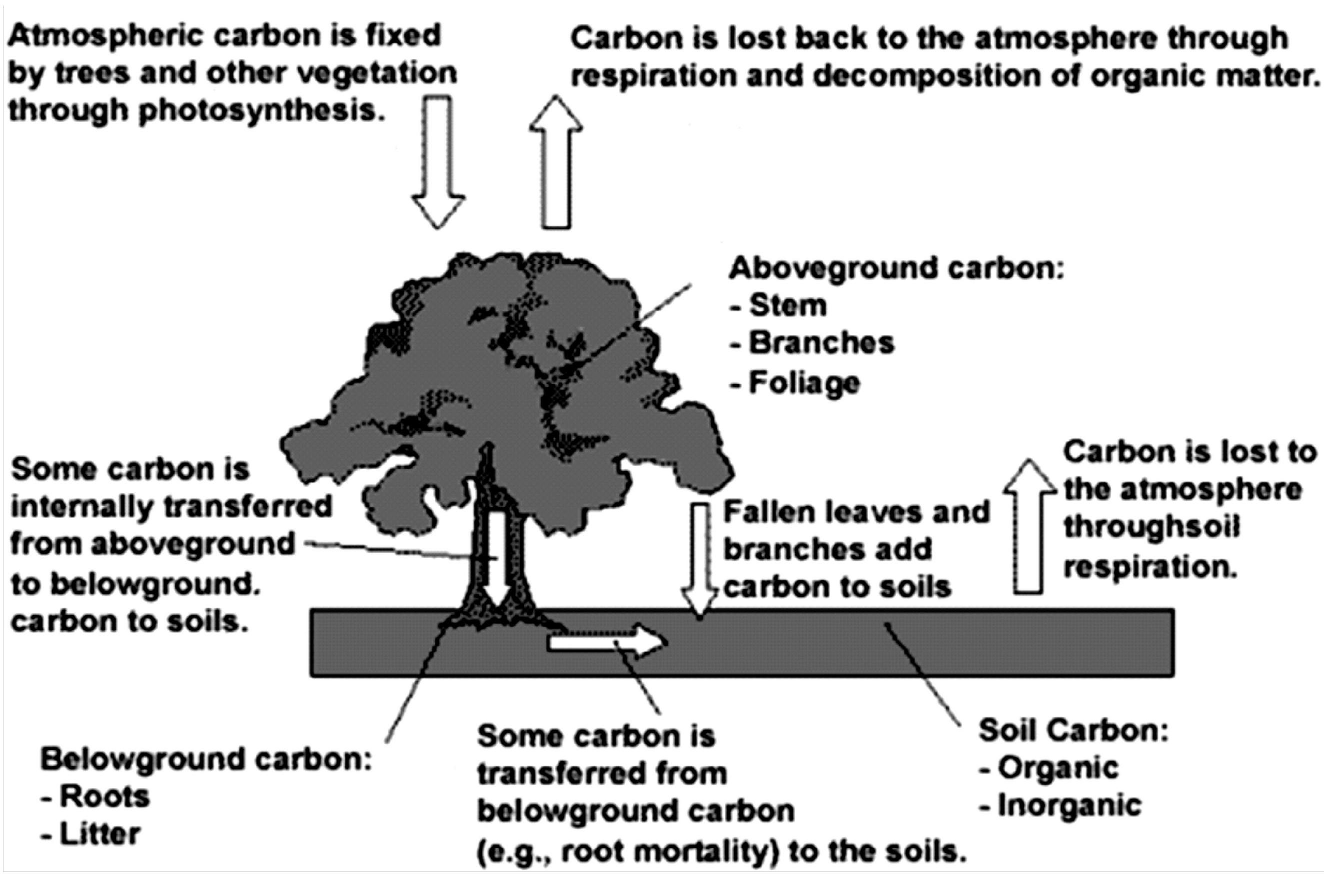
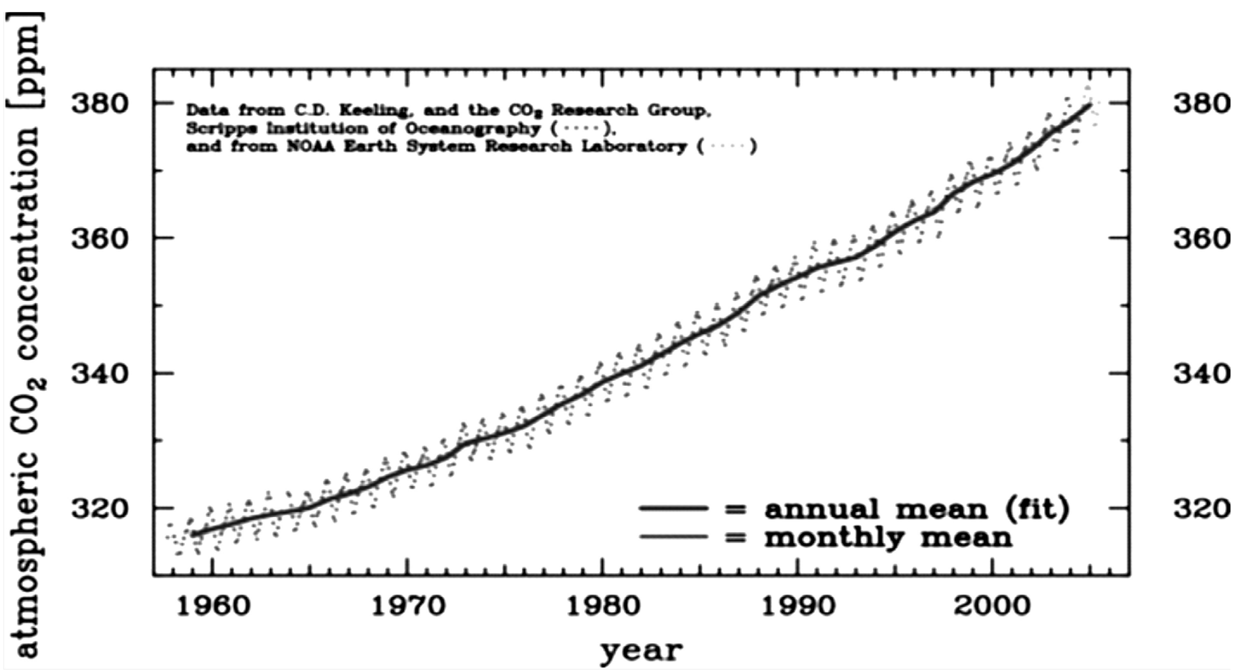


Fig.1: Natural carbon cycle involving higher plant

Changes in the Earth's climate are the result of both internal variability within the climate system and external factors, such as anthropogenic emissions of long-lived greenhouse gases like carbon dioxide, methane, and nitrous oxide. The greenhouse gases are the main culprits of the global warming and climate change. Carbon dioxide (CO_2) is the most important manageable driving agent for climate change. Since 1750, the atmospheric CO_2 concentration has been rising steadily. Most of the observed warming over the last 50 years is attributed to the increase in greenhouse gas concentration. CO_2 cycles among the atmosphere, the land, and the oceans.

Global warming potential (GWP):

Global warming potential (GWP) is the ratio of the warming that would result from the emission of one kilogram of a greenhouse gas to that from the emission of one kilogram of carbon dioxide over a fixed period of time such as 100 years. To standardize all gases for comparison in this paper, we use the global warming potentials (N_2O = 310 and that of CH_4 = 21). To calculate the effect of emissions on atmospheric forcing in terms of carbon dioxide equivalents (CO2e), values expressed as carbon dioxide equivalents (CO_2e) are calculated based on their global warming potential (GWP). Thus, for example, one tonnes of N_2 emitted will be equivalent to 310 tonnes of CO_2. It is particularly difficult to estimate actual GHG emissions from agriculture and other land uses because of the high degree of both spatial and temporal variability associated with the underlying causes of these emissions. The spatial variability has to do with both the variation in the biophysical environment and variation in farm management. This is particularly problematic for estimation of the non-CO_2greenhouse gases (GHGs) like nitrous oxide (N_2O) and methane (CH_4), both of which present large variation across landscapes and regions. Temporal variability is driven to a large extent by inter-annual variations in local weather and how farmers respond to these variations. Our best estimate is that agriculture accounts for about 10-12 percent of the total global anthropogenic emissions of GHGs or between 6 and 8 GtCO2e per annum, whereas contribution of Non-CO_2 GHGs from management operations is about 6.2 Gt CO_2e. More over energy related CO_2 emissions (including emissions from manufacture of fertilizer) = 0.6 Gt CO_2e.



Source: Energy Information administration's, Emission of Green House Gases in USA

Fig. 2: The rising atmospheric carbon dioxide concentration as recorded on Mauna Loa (Hawaii)

Non-CO_2 Greenhouse Gases

Agriculture accounts for between 59 and 63 percent of the world's non-CO_2 GHG emissions. This sector accounts for 84 percent of the global N_2O emissions and 54 percent of the global CH_4 emissions.These emissions are principally from six sources:

1. N_2O from soil
2. N_2O from manure management
3. CH_4 from enteric fermentation CH4 from manure management
4. CH_4 from rice cultivation
5. CH_4 from other sources

a. Savannah burning
b. Burning of agricultural residues
c. Burning from forest clearing
d. Agricultural soils (CH_4)

Nitrous oxide emission from soils is the most important emission for the sector, followed by CH_4 from enteric fermentation. CH_4 from rice cultivation is the third largest source. The driver of emissions from this sector is production, which will increase in the near future to keep pace with the growing population, particularly in tropical developing countries. A change in diet preferences and increased consumption of meat as societies become more affluent is also an important driver, particularly for emissions from enteric fermentation. By 2030, non-CO_2greenhouse gases (GHGs) emissions from agriculture are expected to be almost 60 percent higher than in 1990. There are numerous opportunities for mitigating non CO_2 GHGs in agriculture. Greenhouse gases (GHGs) emissions can be reduced by managing carbon and nitrogen more efficiently in agricultural ecosystems. Carbon can be sequestered from the atmosphere and stored in soils or in vegetation, for example in agroforestry systems. Crops and residues from agricultural lands can be used as a source of fuel to displace fossil fuel combustion, either directly or after conversion to fuels such as ethanol or diesel. In the following sections we examine some promising options.

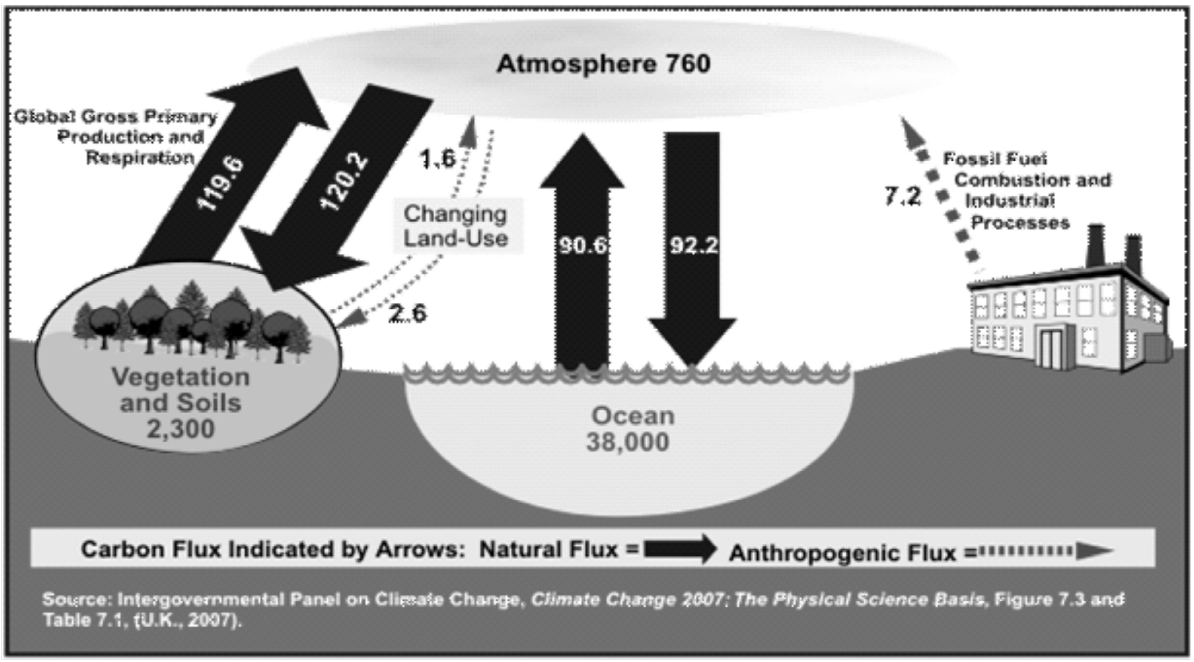
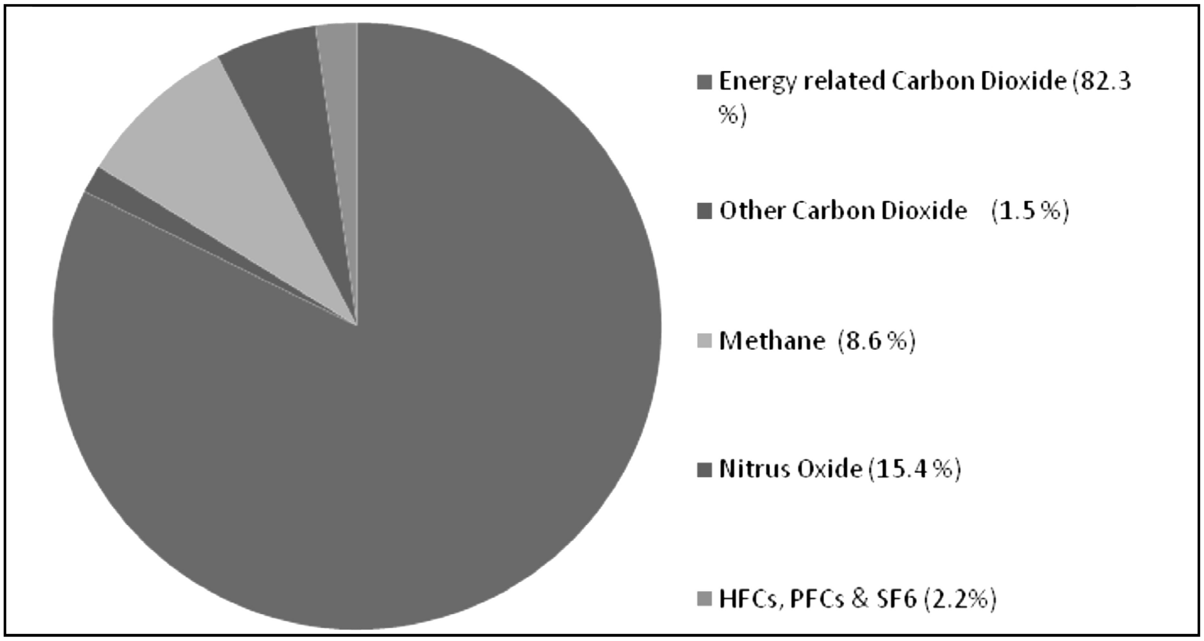


Fig. 3: Global Carbon Cycle (Billion Metric Tons Carbon)

Agricultural Option:

There are useful opportunities for mitigating non-CO_2greenhouse gas (GHG) and soil carbon emissions in agriculture. Emissions can be reduced by managing carbon and nitrogen more efficiently in agricultural ecosystems. The most promising option for the continent is carbon sequestration from the atmosphere and storage in soils or in vegetation. Sequestration offers the most significant and cost effective means of reducing atmospheric concentrations of GHGs. There are large potentials in a number of practices in agriculture. Total costs for sequestration were on the order of $10 per t CO_2 e and the estimates of global feasibility are between 0.7 and 2.1 Gt CO_2 e per year. Abatement costs are significant compared to current and projected rates of global investment in agriculture. Improved abatement options likely require increases in public research funding. Investments, particularly in developing Countries, need to increase.Options to mitigate Carbon Dioxide emissions is agriculture include reducing emissions from present sources, and creating and strengthening **carbon sinks.** Options for increasing the role of agricultural land as a sink for CO_2 include carbon storage in managed soils and **carbon sequestration** after reversion of surplus farm lands to natural ecosystems. However, soil carbon sequestration has a finite capacity over a period of 50-100 years, as new equilibrium levels of soil organic matter are established. Efforts to increase soil carbon levels have additional benefits in terms of improving the productivity and sustainability of agricultural production systems. Soils of croplands taken out of production in permanent set-asides and allowed to revert to native vegetation eventually could reach carbon levels comparable to their pre-cultivation condition. However, a large-scale reversion or reforestation of agricultural land is only possible if adequate supplies of food, fiber, and energy can be obtained from the remaining area. Retaining high organic carbon in tropics is also a challenge.



Source: Energy Information Administrations, Emissions of Greenhouse gases (USA)

Fig. 4: Green House Gases share in global warming and climate change

C_4 plants are specially equipped to combat an energetically costly process, known as photorespiration, which can occur under conditions of high temperature, drought, high salinity, and its relevance to these latest findings–low carbon dioxide levels. Although a combination of any of these factors might have provided the impetus behind the evolution of the various C_4 lineages. To assess how environmentally efficient the various production systems are with respect to GHG emission. A Carbon to Productivity Ratio (CPR) is a suitable measure. Yield data of a long-term experiment at Pantnagar with NPK fertilizers at 50, 100 and 150 per cent of the recommended dose when analyzed after constructing annual greenhouse gases (GHGs) budgets individually for CO_2, CH_4 and N_2O indicated that CPR values of 0.45 to 0.48 were possible with zero tillage (ZT) and retention of crop residues at all three levels of N fertilizer use as against 0.54 for control, (without fertilizer). Zero tillage practices and crop residue retention can reduce GHG emission and curb global warming. Positive changes in agronomic practices like tillage, manuring and irrigation can help reduce greatly the release of greenhouse gases. Adoption of ZT and controlled irrigation can drastically reduce the evolution of CO_2, and N_2O. Reduction in burning of crop residues reduces the generation of CO_2, N_2O and CH_4 to a significant extent. Saving on diesel by reduced tillage and judicious use of water pumps have major role. Each liter diesel burning generates 2.6 kg CO_2. About 3.2 Mt CO_2/ annum (about 0.8 MMTCE) can be reduced by zero tillage in the 12 million ha under rice - wheat systems in the IGPs alone. Intermittent irrigation and drainage will further reduce CH_4 emission from rice fields by 28% to 30%. Use of calcium nitrate or urea instead of ammonium sulphate and deep placement of N through ZT machines can increase its efficiency and plant uptake thereby reducing N_2O emission. ZT systems on one hectare of land would save up to 100 liters of diesel and approximately 1 million liters of irrigation water. Using a conversion factor of 2.6 kg of CO_2 per liter of diesel burned, this represents a quarter ton less emission per hectare of CO_2, a principal contributor to global warming.

Why is there a need for Agriculture to aid in the mitigation of climate change and concurrently better adapt itself? The following list adds to those. (i) A first consideration is Agriculture's contribution to climate change. Agriculture, though occupying 40-50% of the Earth's land surface, contributes "only" 10-12% of total global anthropogenic GHG emissions (5.1 to 6.1 $GtCO_2$-eq/yr during 2005). However, agriculture contributes 47% and 58% of total anthropogenic emissions of N2O and CH_4, respectively; particularly important as it is known is that CH_4 and N_2O have 21 and 310 times the "global warming potential" of CO_2. CO_2 has large annual exchanges between the atmosphere and agricultural lands but the net flux is estimated to be approximately balanced, so accounts for less than 1% of global anthropogenic CO_2 emissions. Agricultural CH_4 and N_2O emissions have increased by nearly 17 percentfrom 1990 to 2005; 32% of the increase from Non-Annex I ("least developed countries") countries who were responsible for ~75percentof all agricultural emissions. The Annex I countries, collectively showed a decrease of 12 percent in GHG emissions. (ii) In terms of food security, FAO estimates put the number of people suffering from chronic hunger worldwide in 2003-5 at 848 million, an increase of 6 million from the 842 million in 1990-211. Soaring food, fuel and fertilizer prices have exacerbated the problem. Food prices rose 52percent between 2007-08, and fertilizer prices have nearly doubled over the past year. (iii) The diets of large sections of the world's population are changing, particularly in developing countries 12 where there has been a pronounced shift away from staples such as cereals, tubers and pulses towards more livestock products, vegetable oils, fruits and vegetables. Total meat production in developing countries increased 5-fold (27 million tonnes to 147 million tonnes) between 1970 and 2005, and, although the pace of growth is slowing down, global meat demand is expected to increase by more than 50% by 2030. One report13 states that by 2020, developing countries will consume 107 million metric tons (MMT) more meat and 177 MMT more milk than in 1996-8, dwarfing developed-country increases of 19 MMT for meat and 32 MMT for milk in the same period. These increases require more feed (coarse grains and oilseed meals). One projection sees that this increase in livestock production will require annual feed consumption of cereals to rise by nearly 300 MMT by 2020 with concurrent increased demand for fertilizers. Conversion of grain areas to vegetable and fruit production will also translate into greater fertilizer demand as average application rates for the latter is about double those for grain crops.

Mitigation of Non-CO2 Green House Gases through Improved Agricultural Production Technologies:

There are a large variety of mitigation options for agricultural gases. In many cases there are production or cost tradeoffs that need to be understood in order to design proper incentives for uptake of these practices. Mitigation measures include agronomic measures such as improved crop varieties, fertility management, erosion control, irrigation management, and increased use of cover crops and crop rotation. Some soil management measures including improved nutrient management and reduced tillage will reduce emissions and sequester carbon. Better residue and water management in rice can yield significant reductions of CH_4 emissions. For livestock, there are wide ranges of practices associated with grazing land management, manure management, and feeding that can reduce emissions and increase carbon sequestration.Emissions of N_2O from croplands are often associated with applying fertilizer in excess of crop demands. One mitigation goal might be to reduce excess fertilizer application while maintaining high yields. Several mitigation options could be considered:

a) Split fertilization: Application of the same amount of fertilizer as in the baseline, but divided into three smaller increments.
b) Fertilizer reduction to match crop needs.
c) Application of nitrification inhibitors and the use of slow release fertilizer formulations reduce the conversion of ammonium to nitrite and limit N_2O emissions.

The composition of manure can influence the amounts of N_2O emitted. Up to 90 per cent of the CH_4 emitted by anaerobic manure management systems can be captured and combusted. In rice systems, water management can reduce soil CH_4 emissions. Different strategies of flooding and draining the field such as pre-harvest drainage, early single or dual drainage, midseason drainage, late dual drainage and alternate flooding/drainage all reduce emissions. Management of organic inputs can reduce emissions through the use of composted rice straw, mulching, and removal of rice stubbles from the fields. Mineral inputs can also be used to reduce emissions through the application of phosphogypsum, ammonium sulphate, and tablet urea. Direct seeding is also recommended for establishing rice fields with reduced methane emissions.

Cost of Non-CO_2 Green House GasesMitigation:

Costs included capital, or one-time costs, and operation and maintenance costs, or recurring costs. The calculation included a tax rate of 40% and used a 10% discount rate. Benefits included the intrinsic value of CH_4 as either a natural gas or as fuel for electricity or heat generation, non-GHG benefits of abatement (e.g. improved nutrient use efficiency), and the value of abating the gas given a GHG price. The breakeven price calculations do not include transactions costs. All calculations were in US$ from the year 2000. More details on the construction of these curves can be found in the report.

Mitigation through Carbon Sequestration:

Agricultural ecosystems have significant potential to increase carbon storage, thereby reducing atmospheric concentrations of CO_2 by sequestering C in soils and vegetation. Agricultural lands also remove CH_4 from the atmosphere by oxidation, though less than forests, but this effect is small compared to other GHG fluxes. Increased carbon stocks can be achieved through a change in land use to one with higher carbon stock potential, usually revealed by a change in land cover or through management practices. The IPCC Special Report on Land Use, Land-Use Change and Forestry identified a number of categories of activities on agricultural lands that generate benefits:

a) Conservation tillage to maintain higher levels of soil organic matter. This practice promotes sequestration of soil carbon, but tends to increase N_2O emissions. The carbon sequestration potential of this practice is controversial.
b) Improved grassland management (including improved grazing management, fertilization, irrigation and use of improved species and legumes).
c) Restoration of severely degraded lands (including salt-affected soils, badly eroded and desertified soils, mine spoils, and industrially polluted sites).

Costs of Carbon Sequestration in Agricultural Landscapes:

A rigorous analysis of costs and mitigation potential does not presently exist in the literature and there is no basis to develop this at the moment. For conservation tillage, there is generally a savings to farmers due to reduced use of tractors to till soils. These are somewhat offset by higher herbicide costs to reduce weed problems. However, since the carbon benefits of this practice remain doubtful, we will not pursue this further here. Clearly in developing countries, the greatest potential for climate change mitigation in rural landscapes are associated with reducing deforestation emissions and creating sinks through community forestry and agroforestry practices. Others have reviewed the costs to farmers of reducing deforestation and forest degradation emissions and these costs are around US$1 to 5 per t CO_2e. In this paper, we will provide a novel analysis of the potential costs of community forestry and agroforestry options.Individual countries present very different institutional situations and institutional costs associated with setting up monitoring and verification services, extension services to farmers and transparent benefit and risk sharing services will vary from country to country. Assessing these costs and the sources of variation in these costs is beyond the scope of this paper. However, we can assess the likely costs to farmers in very approximate terms asa means of establishing a likely "farm-gate price" for carbon sequestration.

International Protocol to encourage mitigation:

International Protocol to encourage mitigation of climate change caused by global warming due to emission of Greenhouse Gases (GHG's) through Carbon Sequestration.To protect ourselves, our economy, and our land from the adverse effects of climate change, we must reduce emissions of carbon dioxide and other greenhouse gases.

The Kyoto Protocol:

Kyoto Protocol is an agreement made under the

United Nations Framework Convention on Climate Change (UNFCCC). The treaty was negotiated in Kyoto, Japan in December 1997 and the protocol came into force on February 16, 2005. The aim is to lower overall emissions of six greenhouse gases - carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, HFCs (Hydrofluro Carbon), and PFCs. It has been established that per capita GHG emission is strongly correlated with economic prosperity. Further, it is recognized that without increase in GHG emissions or access to appropriate alternative technology options, developing countries would not be able to pursue their socio-economic goals. Kyoto Protocol is a global cooperative attempt to address both these issues. To achieve this goal the concept of Clean Development Mechanism (CDM) has come into vogue as a part of Kyoto Protocol.

Carbon Credits Indian Scenario:

Carbon credits are a key component of national and international attempts to mitigate the growth in concentrations of greenhouse gases (GHGs). One Carbon Credit is equal to one ton of Carbon. Carbon trading is application of emissions trading approach. Carbon offsets enable individuals and businesses to reduce the CO_2 emissions they are responsible for by offsetting, reducing or displacing the CO_2 in another place, typically where it is more economical to do so. Carbon offsets typically include renewable energy, energy efficiency and reforestation projects. Carbon emission offsetting can be used to offset the inevitable CO_2 pollution after you have done your best to try to avoid the pollution in the first place. There are two distinct types of Carbon Credits:

Carbon Offset Credits (COC's) and Carbon Reduction Credits (CRC's): Carbon Offset Credits consist of clean forms of energy production, wind, solar, hydro and biofuels.

Carbon Reduction Credits: It is consists of the collection and storage of Carbon from our atmosphere through reforestation, forestation, ocean and soil collection and storage efforts. Both approaches are recognized as effective ways to reduce the Global Carbon Emissions crises.

The cost of greenhouse gas reduction activities is usually much lower in a developing country than developed country. The developed country would be given credits (Carbon Credits) for meeting its emission reduction targets, while the developing country would receive the capital and clean technology to implement the project. Carbon credits are certificates issued to countries that reduce their emission of GHG (greenhouse gases) which causes global warming. Carbon credits are measured in units of certified emission reductions (CERs). Each CER is equivalent to one tonnes of carbon dioxide reduction. Their rates fluctuate and it was noticed that it was as high as 22 Euros in April, as low to below 7 Euros, before stabilizing at 12-13 Euros. Under IET (International Emissions Trading) mechanism, countries can trade in the international carbon credit market. Countries with surplus credits can sell the same to countries with quantified emission limitation and reduction commitments under the Kyoto Protocol. Developed countries that have exceeded the levels can either cut down emissions, or borrow or buy carbon credits from developing countries. India comes under the third category (Non-Annex I countries "least developed countries"),signatories to UNFCCC, have no immediate restrictions under the UNFCCC. This serves three purposes. India signed and ratified the Protocol in August, 2002 and has emerged as a world leader in reduction of greenhouse gases by adopting Clean Development Mechanisms (CDMs) in the past few years. According to Report on National Action Plan for operational sing Clean Development Mechanism(CDM) by Planning Commission, Govt. of India, the total CO_2-equivalent emissions in 1990 were 10, 01, 352 Gg (Gig grams), which was approximately 3% of global emissions. If India can capture a 10% share of the global CDM market, annual CER revenues to the country could range from US$ 10 million to 300 million (assuming that CDM is used to meet 10-50% of the global demand for GHG emission reduction of roughly 1 billion tonnes CO_2, and prices range from US$ 3.5-5.5 per tonnes of CO_2). India is well ahead in establishing a full-fledged system in operational sing CDM, through the Designated National Authority (DNA).

Summary:

Efficient carbon sequestration *vis-a vis* mitigation of ill effects of global warming and imminent climate change more importantly boosting of productivity of whole agriculture system through and improved production technologies having twin advantage by improving

agricultural production.As per the provisions made in "Kyoto Protocol" to achieve goal set and to promote the concept of Clean Development Mechanism (CDM), Indian position is so favorable that we can earn foreign exchange handsomely through carbon credit tradeas well as alsocontribute significantly towards slowdown of horrific impact of climate change beyond the geographical boundary forwelfare of humanity.

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