

# GLOBAL WARMING - CAUSES, IMPACTS AND MITIGATION STRATEGIES IN AGRICULTURE

## ABSTRACT

Global warming- a new global challenge in front of agricultural scientists, affecting almost all the climatic parameters involving air temperature and rainfall intensity, and distributions. Elevated levels of green house gases (GHGs) viz. carbon dioxide, methane, nitrous oxide etc. are only because of faulty agricultural practices viz. intensive tilling, burning of crop residues, which further adversely affecting the both land and water productivity. As per one projection that global surface air temperatures may increase by 4.0–5.8 °C in upcoming few decades which offset the likely benefits of increasing atmospheric concentrations of carbon dioxide on crop plants. Over space and time, new environmental conditions created which might be responsible for frequent droughts, higher temperatures, flooding, salinity, increased carbon dioxide levels, rise in sea-level, irregular rainfall patterns and shifting of pest dynamics etc. Therefore, global warming cycle needs to break down through forestation, using crop residues on soil as mulch or in soils as biochar instead of burning, and adopting certain agricultural practices or developing new plant cultivars which responds to CO<sub>2</sub> under higher temperature conditions etc which helps to reduces rather mitigate the adverse effects of the global warming. Further, changes in diets, minimum tillage operations and reductions in food wastage will also serve the purpose. Present review highlighted the crucial reasons for global warming, its impacts on agriculture and finally on mitigation strategies, which helps to improve the agricultural productivity and finally livelihoods of the farmers.

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**KEY WORDS:** Global Warming, Green house gases, Biochar, Global population

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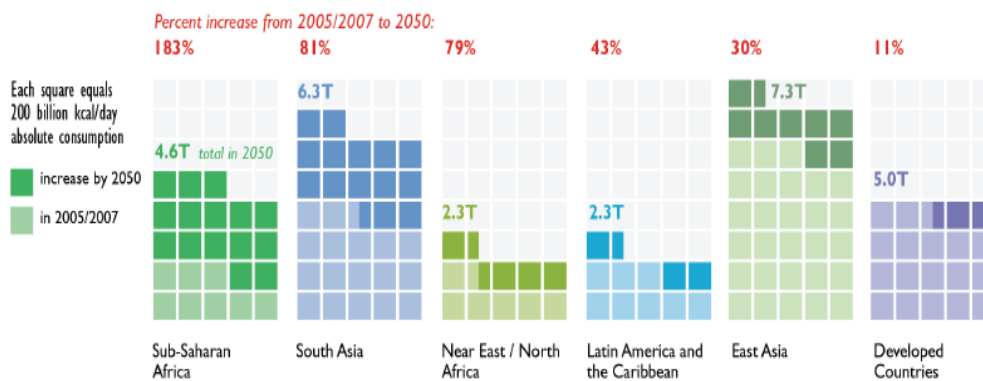
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## 1. INTRODUCTION:

Global temperature boost in basic words could be articulated as warming of the globe including earth's surface which is liable for raised degrees of air temperature and environmental CO<sub>2</sub>, undistributed and profoundly high rainfall liable for higher soil erosion, early liquefying of ice sheets, ascend in ocean levels, diminished capacity limit of the dams that brings floods in low lying zones [1]. Earth's air adjusts the interception of solar radiation as while earth's surface for the most part retains short wave radiations which reradiates by earth's surface as long wave radiations both back to environment and afterward again practical which further warmth up earth surface once more [2]. This prompted environmental change by one or other which speaks to a noteworthy change, that is, a change with significant monetary, ecological, and social impacts, in

the mean estimations of a meteorological component, for example, temperature and measure of precipitation during a specific period, for which the methods are figured over 10 years or more [3]. Various variables answerable for this, anyway agrarian exercises shared just 10–12% of the complete worldwide anthropogenic outflows of GHGs [4]. Two regular topics all through the survey incorporate A) tending to beef industry and consumption and B) escalation and expanded proficiency in the farming worth chain. Domesticated animals mostly used for beef industry represents approximately 70 percent of agrarian emissions, where India is far behind as significant portion is vegetarian. Changing diet habits from non-vegetarian to vegetarian will lessen methane emissions, and thereby reduces impacts of global warming both on agriculture and finally on the humans.

Globally, [5] delineated that total food consumption ( $\text{kcal day}^{-1}$ ) in 2005/2007 and total increase by 2050 shown in Fig. 1 where light colored boxes represent absolute consumption in



**Fig. 1. Growth in total food consumption by 2050, relative to 2005/2007 Source: Dickie et al., 2014**

2005/2007 and dark colored boxes represent the growth in absolute consumption from 2005/2007 to 2050 while Growth in food consumption by 2050, relative to 2005-2007 delineated in Fig. 2.

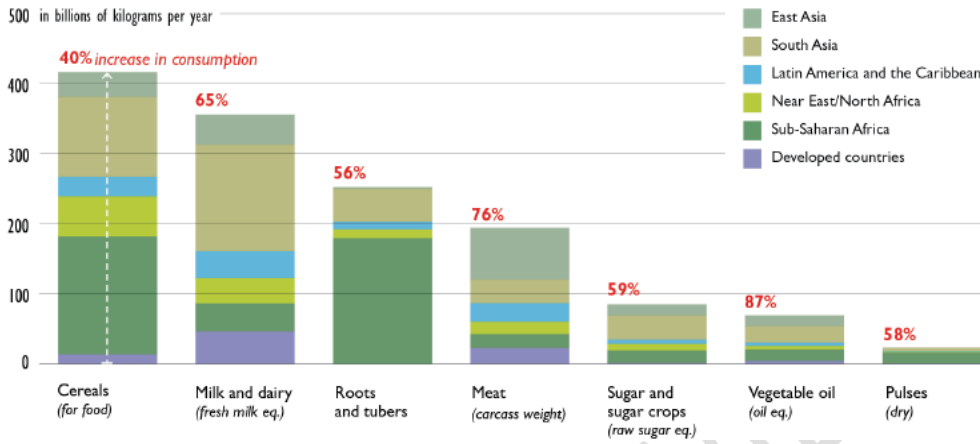


Fig. 2. Growth in food consumption by 2050, relative to 2005–2007 Source: Dickie et al., 2014

For deforestation, data is the average annual rate from 2000–2005 (by way of comparison, the rate of global deforestation by area has increased in recent years). Peat and fire emissions show the range of emissions for the years 2000–2008. Direct agricultural production emissions are from 2008. Other supply chain emissions are from varying years, mostly 2004–2010 (Fig. 3).

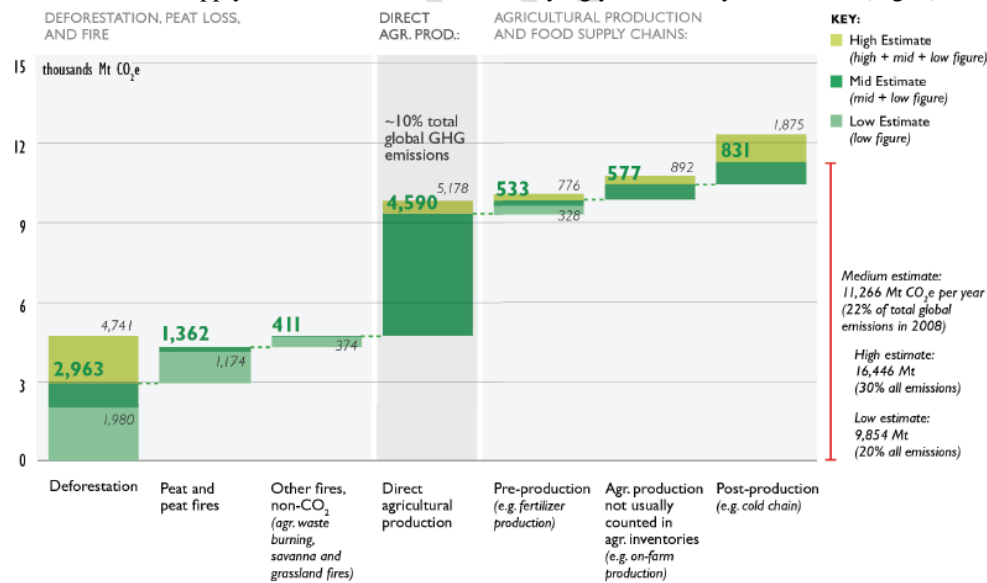
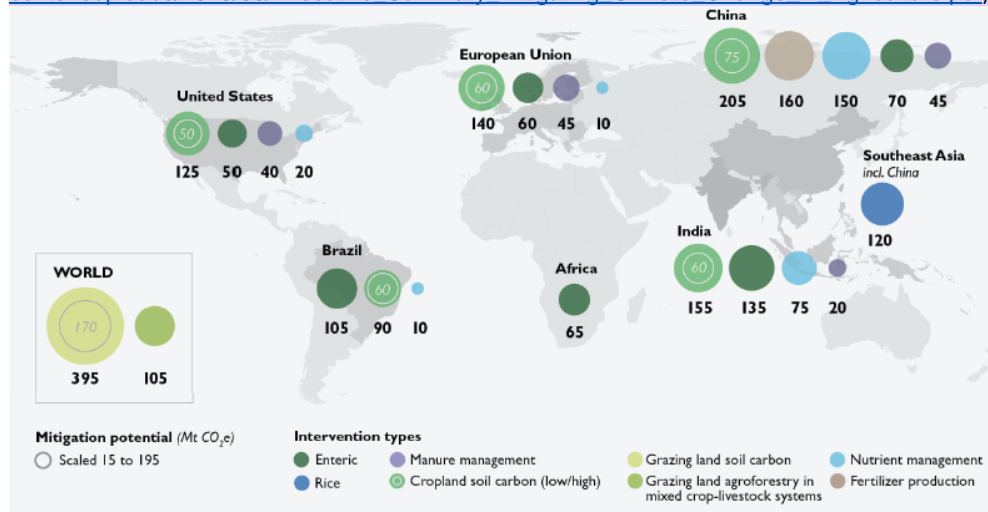


Fig. 3. Global agriculture and land use change emissions Source: Dickie et al., 2014

Coming over to the global mitigation opportunities, [5] in their report highlighted that setting aside economic and political constraints, the greatest technical opportunities to reduce agricultural greenhouse gases from direct agricultural are centered on a few key geographies viz. U.S., E.U., China, India, and Brazil. **There is a high level of uncertainty in estimates of carbon sequestration on croplands and grazing lands. In this analysis we have provided an upper estimate and a lower estimate of mitigation potential based on different assumptions and/or different analyses. The two circles show the mitigation potential using the high and low estimates** (Fig.4).

([http://www.climateandlandusealliance.org/wp-content/uploads/2015/08/Executive\\_Summary\\_Mitigating\\_Climate\\_Change\\_in\\_Agriculture.pdf](http://www.climateandlandusealliance.org/wp-content/uploads/2015/08/Executive_Summary_Mitigating_Climate_Change_in_Agriculture.pdf))

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United States	Brazil	European Union	India	China	Southeast Asia (incl. China)
125. <b>Croplands:</b> Soil carbon sequestration (biochar), high	105. <b>All ruminants:</b> Enteric fermentation reduction	140. <b>Croplands:</b> Soil carbon sequestration (biochar), high	155. <b>Croplands:</b> Soil carbon sequestration (biochar), high	205. <b>Croplands:</b> Soil carbon sequestration (biochar), high	120. <b>Rice:</b> Water and rice straw management
50. <b>All ruminants:</b> Enteric fermentation reduction	90. <b>Croplands:</b> Soil carbon sequestration (biochar), high	60. <b>All ruminants:</b> Enteric fermentation reduction	135. <b>All ruminants:</b> Enteric fermentation reduction	160. <b>Supply chain:</b> Fertilizer production	Greater Horn of Africa
40. <b>All livestock:</b> Stored manure management	10. <b>All crops:</b> Nutrient management	45. <b>All livestock:</b> Stored manure management	75. <b>All crops:</b> Nutrient management	150. <b>All crops:</b> Nutrient management	65. <b>All ruminants:</b> Enteric fermentation reduction
20. <b>All crops:</b> Nutrient management		10. <b>All crops:</b> Nutrient management	20. <b>All livestock:</b> Stored manure management	70. <b>All ruminants:</b> Enteric fermentation reduction	World
				45. <b>All livestock:</b> Stored manure management	395. <b>Grazing Lands:</b> Soil carbon sequestration, high
					105. <b>Grazing Lands:</b> Agroforestry in mixed crop-livestock systems

Fig. 4. Global mitigation opportunities (technical potential) Source: Dickie et al., 2014

Generally, carbon sequestration appeared to decrease with time in most rice based cropping sequences, such as rice-wheat systems [6]. For establishing paddy, more particularly on the coarse textured soils, extensive tillage operations performed in the standing water commonly termed as puddling which further decreased the carbon stored in the soil, deteriorated the soil

structure, seals the soil pores and hence, reduces the aeration after forming the plow pan [7]. Moreover, due to higher use of doses of chemical fertilizers, excessive disturbance of the soil and removal/burning of residues in the fields, reduces the carbon status and hence health of the soil [8]. Advanced agricultural managements viz. minimum soil disturbances and increased residue retention will increase soil carbon in the rice-based systems [9]. Further, farmers must be encouraged for the sustainable agriculture by improving the carbon inputs, soil health and reduces the emission of green house gases viz. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O through introducing the concept of zero tillage, minimum tillage and providing different economic and viable options for the residue management and mitigates the effects of rice-based cropping systems on climate change [10,11, 12, 13].

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Further, biogas production must be encouraged, as on one side it provides us kitchen gas while on other produces slurry which could be used in fields. Therefore, present agricultural research must be confined to production system with least production of green house gases and that might be by different approaches viz. use of slow nutrient release fertilizers viz. neem coated urea, polycoated urea etc., green manuring, farm yard manures, compost and by fermented paddy compost. Burning of crop residues particularly of paddy must be discouraged by providing different viable options viz. happy seeder, use of straw management systems (SMS) behind the combines, biogas production, electricity production, for mushroom cultivation etc.

## 2. CAUSES OF GLOBAL WARMING AND ITS EFFECTS

Green house gases viz. CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and in some cases chlorine and bromine containing compounds etc. are the major cause for the warming of our globe. Therefore, answer lies in its controlled emissions by one or other approach or either through an integrated approach. The accumulation of these gases responsible for the changed radiative equilibrium of the atmosphere (which ultimately responsible for the warming of our atmosphere) as greenhouse gases allowed entry of incoming short wave radiation but as they tried to go back as long wave radiation, GHGs absorbed them. **The net warming from 1850 to the end of the 20th century was equivalent to nearly 2.5 W/m<sup>2</sup> with carbon dioxide contribution about 60 % to this figure.** (<https://www.scribd.com/document/410293861/evs-term-paper-docx>) Decreased ozone levels over Antarctica was earlier reported [14] of the British Antarctic Survey and he published an article in whom response CFCs (used as aerosol propellants in industrial cleaning fluids and in refrigeration tools) were the cause of the problem. **Therefore, different programmes organized even at international levels to cut down production of GHGs responsible for global warming. Under ultraviolet light, these gases dissociate releasing chlorine atoms which then catalyses ozone destruction.** ([https://en.wikipedia.org/wiki/Ozone\\_depletion](https://en.wikipedia.org/wiki/Ozone_depletion)). Aerosols scattered and absorbed solar and infrared radiations and secondly alter the microphysical and chemical properties of clouds and perhaps affect their lifetime and extent. Absorption of solar radiation by aerosols warms the air directly instead of permitting sunlight to be absorbed by Earth's surface. Crop residue burning produces a mixture of organic droplets and soot particles. Many industrial processes produce a wide diversity of aerosols, while exhaust emissions from various sorts of transport produce a rich mixture of pollutants that are either aerosols from the outset or are transformed by chemical reactions in the atmosphere to form aerosols [14].

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Many natural processes that cause rain, snowfall, hailstorms, rise in sea levels is related to impacts of global warming. Further, predicting the size of emissions of greenhouse gases in the upcoming years is not an easy assignment. Under global warming, CO<sub>2</sub> concentration increased, global air temperature increased, extra water vapor converts in sudden and heavy rains which

leads to floods in various regions of the world. Higher the air temperature, higher will be the evaporation, thereby share of transpiration lessens which further reduces inflows of the nutrients in the plants and finally reduces the both water and land productivity. Higher evaporation losses further promoted to drought in the regions, which further had a negative impacts on the production level more particularly under critical growth stages.

Regions dependent on the melting water from snowy mountains may suffer drought and scarcity of water supply because the glaciers all over the world are shrinking at a very rapid **rate and melting of ice appears to be faster than previously projected.** (<https://www.coursehero.com/file/p2ge5dl/drought-in-the-regions-where-increased-evaporation-process-is-not-compensated/>) As per Intergovernmental Panel on Climate Change (IPCC), about one-sixth world population might suffer from this droughts. More heat waves, intensive and frequent rains, floods, hailstorms and thunderstorms, higher seas levels are the some end effects of the global warming. Global temperature might increased in the upcoming years if some immediate and urgent steps are not implemented (Fig. 5). Mainly, industrialization, setting up of power houses, intensive tillage, burning of crop residues instead of incorporating in the soil are the main factors which significantly enhances the intensity of global warming right from the 20<sup>th</sup> century.

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### 3. IMPACTS OF GLOBAL WARMING ON AGRICULTURE:

Agriculture being dependent on the weather parameters viz. ambient temperature, green water status, relative humidity etc. affected by the outcomes of global warming [15]. Weather change assumes a critical job in a country's nourishment security and economy, particularly in a India [16]. All farming products are delicate to environmental change or atmosphere inconstancy [17]. As a result of climate change, decline in rice yields to a level of 15% and a subsequent 12% increase in rice prices, is forecasted by International Food Policy Research Institute (IFPRI) by 2050 in developing countries like India. **IFPRI, 2010 forecasted a 31.2% price hike for rice even in the optimistic scenario from 2010 to 2050. Reduction in 48.63% of land productivity by the year 2100 was estimated by Kumar et al., 2016, based on simulation techniques considering the effects of climate change.** ([https://www.researchgate.net/publication/327364260\\_Crop\\_improvement\\_strategies\\_for\\_mitigation\\_of\\_methane\\_emissions\\_from\\_rice](https://www.researchgate.net/publication/327364260_Crop_improvement_strategies_for_mitigation_of_methane_emissions_from_rice)). The rising temperature and CO<sub>2</sub> and vulnerabilities in precipitation related with worldwide environmental change have genuine immediate and aberrant ramifications for crop creation and nourishment security [18]. Future agrarian methodologies/technologies subsequently need to be invented, tested and thus recommended for different soil textural class under different agro-climatic conditions on efficiency, maintainability, benefit, security, and values which thusly would prompt improved nourishment security, employments, and ecological security [19]. The impacts of changes in temperature, CO<sub>2</sub> levels, and precipitation on crop production have been concentrated broadly utilizing crop renewal models [20]. The joined impacts of environmental change may have suggestions for dryland and irrigated conditions and cultivation in India by 2080–2100 because of a worldwide alteration in CO<sub>2</sub> levels, temperature and rainfall [21, 20, 22, 23]. Further effect of global warming viz. of higher CO<sub>2</sub> and temperature on the agriculture could be well understood through the following discussion

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#### 1. Impact elevated levels of CO<sub>2</sub> on agriculture:

CO<sub>2</sub> is basic inputs for photosynthesis and hence for plant development. An expansion in environmental CO<sub>2</sub> focus influences crop creation through modifying photosynthetic and transpiration rates. Evaluation of joined impacts of raised CO<sub>2</sub> and environmental change on the efficiency of a prevailing yields [24]. The immediate impacts of expanded CO<sub>2</sub> levels are valuable to vegetation, particularly for C-3 plants, as raised fixations upgrade absorption rates and increment stomatal obstruction, which bring about a decrease in transpiration and improved water-use proficiency in crops [25] though a few reproduction aspects too. In northwestern India, for instance, yields of rice and wheat expanded by 15% and 28%, individually, at raised CO<sub>2</sub> fixations [26,27]. The impacts of raised CO<sub>2</sub> on land productivity of wheat discussed in Table 1 [28].

**Table 1. Variation in simulated wheat yield due to varying CO<sub>2</sub> concentration under differential moisture regimes (Source: Pandey et al., 2007)**

CO <sub>2</sub> Concentration (ppm)	Stimulated grain yield (Kg ha <sup>-1</sup> )		Change (%) from base suboptimal and optimal yields	
	Sub-optimal	Optimal	Sub-optimal	Optimal
330 (Base value)	3112	3837	---	---
440	3695	4630	19	21
550	4327	5687	39	48
660	4876	6465	57	68

With the slow increment in CO<sub>2</sub> focus from 440 to 660 ppm, yield expanded from 21% to 68% under ideal conditions, though, under problematic conditions, comparable reactions were seen with somewhat lower sizes (19–57%). Hundal and Kaur [29] showed that with an expansion in CO<sub>2</sub> from 330 to 600 ppm, an increment as high as 11, 8 and 9% improvements recorded in LAI, biomass and grain yield, respectively. Rice developed under raised CO<sub>2</sub> had fundamentally higher land productivity [30]. Panicle dry load in the raised CO<sub>2</sub> treatment was essentially higher than other conditions all through the grain-filling period [30]. In cotton, an expansion in CO<sub>2</sub> levels, brought about a critical increment in final cotton yields [31] (Table 2), primarily owing to expanded boll dry weight and build up dry weight per boll. Therefore, it could be concluded that elevated CO<sub>2</sub> levels favored higher grain yields.

**Table 2: Total dry matter, boll dry weight, lint dry weight and seed dry weight of cotton viz-a-viz. differential CO<sub>2</sub> concentration (Source: Reddy et al., 2004)**

CO <sub>2</sub> concentration	Total dry weight (g plant <sup>-1</sup> )	Boll dry weight (g)	Lint dry weight (g boll <sup>-1</sup> )	Seed dry weight (g boll <sup>-1</sup> )
Sub-ambient (180ppm)	165	5.6b	1.8b	2.7b
Ambient (360 ppm)	233b	5.8a	1.8ab	2.8ab
Elevated	309a	5.9a	1.8a	2.9a

(720 ppm)

\*Means with different letters within column are significantly different at  $p=0.05$

## 2. Impact of increased temperature on agriculture

Increased temperature affected the overall plant development and grain yields in its own way. An expansion in temperature by 20°C, achieved a 3–10% decline in grain/seed yield of kharif crops viz. rice, groundnut and soybean and a 29% reduction in grain yield of rabi crops viz. wheat [32]. Further, Pandey et al. [29] utilizing the CERES-wheat model delineated a continuous reduction in yield from 3546 to 2646 kg ha<sup>-1</sup> under higher temperature varied from 1–3°C which varied to, yield declined from 2841 to 2398 kg ha<sup>-1</sup> under problematic conditions, which might be because of decrease in the anthesis length and in grain loading up with an increase in temperature [33]. Under constant weather parameters, a temperature increment of 0.5, 1.0, 2.0, and 3.0 °C, would propel the development of wheat by 3, 6, 12, and 17 days, separately [34] (Table 3). Temperature hike of 1 °C not affected the heading of rice while if this increment promoted to 3 °C then heading and development extended by 4 and 5 days, respectively. Blossoming in soybean was postponed as long as 4 days and its development were deferred by 2 days (Table 3). An investigation shown a quadratic connection between rice yield and least temperature over the scope of 22.1–23.7 °C as yields declined by 10% with each 1°C temperature increment in least temperature and this yield declined further by 15% with each 1°C temperature increments in mean temperature [35].

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**Table 3. Crop phenology as affected by the temperature increase (Adapted from Kaur and Hundle, 2010)**

Crop and Phenological stages	Deviation from the normal temperature (days)				
	Normal	+0.5 °C	+0.5 °C	+0.5 °C	+0.5 °C
Chicken					
Flowering	08	-4	-7	-19	-23
Maturity	99	-5	-8	-16	-24
Wheat					
Anthesis	41	-3	-6	-12	-16
Maturity	82	-3	-6	-12	-17
Soybean					
Flowering	239	+1	+2	+3	+4
Maturity	294	+1	+1	+2	+2
Rice					
Heading	223	0	0	+1	+4
Maturity	263	+1	+1	+1	+5

<sup>a</sup>Julian days (Calendar day)

Therefore, it could be concluded that increments in temperature increment crop-breath rates; lessen crop length, the quantity of grains shaped, and crop yield; repress sucrose osmosis in



grains; influence the endurance and dissemination of nuisance populaces; rush supplement mineralization in soil; decline manure use effectiveness; and increment vanishing.

#### **4. MITIGATION STRATEGIES FOR THE GLOBAL WARMING:**

Upto now, it is clear that global warming is affecting the plants and agricultural growth by one or other way. Therefore, scientists come out with some technologies which is recommended for mitigating the adverse effect of the global warming, which are discussed below

##### **1. Planting date modifications:**

Modification in planting dates is a basic yet useful asset for adjusting with the impacts of potential a worldwide temperature alteration. Krishnan et al. [36] exhibited potential results by modifying the planting time of rice at two destinations by recreating crop development under various environmental change situations. Control of planting dates helped in decreasing yield unsteadiness by shielding blooming from agreeing with the most sizzling developing season [37]. On a few events in the most recent decade, South Asia saw unfavorable impacts of climatic varieties, that is, terminal warmth worry, on wheat efficiency. For instance, regardless of good climate conditions throughout the winter of 2009–2010, an unexpected ascent in night temperature during the grain-filling stage in wheat unfavorably influenced wheat efficiency in the Indo-Gangetic Plains (IGP) and other northern conditions of India [38]. Already, in Punjab scientists shifted the date of nursery sowing from mid May to almost mid June, which helps to saved a significant portion of irrigation water as in June transplanted rice, upcoming months has monsoon rains, which further increases the air humidity and vapour lifting capacity of ambient air decreased and ultimately lesser number of irrigations has to be applied as compared to May transplanted paddy seedlings without much loss to overall land productivity rather water productivity increased [39].

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##### **2. Mulching-Spreading of crop residue on the bare soil surface:**

Instead of burning crop residues viz. paddy straw in open, it is recommended to use it as mulch under which crop residues spread on the bare soil surface. Mulch acts in the following ways- by hindering hot sunrays from striking at the bare soil surface, reduces surface temperatures, reduces vapor pressure gradient and hence upcoming of water vapors, reduces wind speed and thereby its vapor lifting capacity, finally improved the overall both land and water productivity [40]. Zero tillage is an important resource conservation technology [41, 42], but its performance too decreased even from conventional tillage, if previous practiced after removing all the mulch loads from the soil [43, 44]. Hence practice of mulching mitigate the adverse effects of the global warming and maintains the land productivity one and in all [45, 40, 46, 47].

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##### **3. New crop cultivars**

As CO<sub>2</sub> concentration increased in the atmosphere, which further had a significant effects on the plants by affecting its different physiological processes viz. photosynthesis. Therefore, here is the job for the plant breeders to develop cultivars that could profit by the high temperature CO<sub>2</sub> treatment impact. As per one estimate, the vegetation will be decidedly profited by expanded CO<sub>2</sub> focus [26]. This gainful impact will be increasingly articulated for C3 plants, for example, wheat, rice, grain, oats, nut, cotton, sugar beet, tobacco, spinach, soybean, and most trees. In C3 plants, the raised centralizations of CO<sub>2</sub> will prompt higher absorption rates and an expansion in stomatal opposition, bringing about a decrease in transpiration rate and improved water-use productivity in crops.

### 3. Need to change feeding habits:

In current period, a significant portion of population shifting from vegetarian diet to non-vegetarian diet and it is estimated that interest for animal items is probably going to increment more than 70 percent internationally between 2005 and 2050. Meat production must also be discouraged by changing the food habits of the nationalists. Enteric aging is stomach related procedure in herbivorous creatures ('ruminants', for example, cows, wild oxen, goats, and sheep). These creatures have a rumen, an enormous four-compartment stomach with a complex microbial population which processes complex sugars with an end product as CH<sub>4</sub>, which is a GHG having high global warming potentials. The discharges decrease potential in Brazil, India, U.S. furthermore, E.U. alone adds up to 350Mt CO<sub>2</sub>e per year. Some interventions viz. Improving the nature of scrounges, preparing feeds to improve absorbability, and adding grain-based concentrates to domesticated animals, Enhancements and added substances decrease methane by changing the microbiology of the rumen, for the most part, Improving the wellbeing and conceptive limit of crowds will certainly limits the evaluation of CH<sub>4</sub>.

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### 4. Reduces food wastage:

Food wastage is an important but mostly unattended issue, will be certainly useful in mitigating the challenges as it reduces the set targets for the global food production. Reduced targets will certainly reduces the pressure to produce more from less agricultural lands, which further helps to implement different approaches of the conservation agriculture for practicing the sustainable agriculture in the region. As per FAO gauges, around 33% of all nourishment proposed for human utilization is lost. Food wastage started at the purchaser point through decay, spilling or other unintended results The carbon impression of nourishment wastage is assessed at 3.3 Gt CO<sub>2</sub>e. Cereals include the best portion of misfortunes by calorie and discharges (53 percent and 34 percent, individually), while leafy foods involve the best portion of misfortunes by weight (44 percent) and the second most noteworthy portion of outflows (21 percent). Although meat wastage is liable for a generally low level of misfortune by calorie and weight (7 percent and 4 percent). In the UK, 64 percent of nourishment wastage is "avoidable." [48]. Measure must be taken to reduce the food wastage as saved food will reduce the target of grain production which further reduces the use of different fertilizers. In India, particularly in Punjab, numbers of marriage palaces are there and all are full during the peak marriage seasons, where a number of marriage functions being organized and ever time, new food items (non-vegetarian, vegetarians followed by sweets, ice-creams etc.) being prepared served to the guests and remainder of the earlier functions disposed off (Bhatt 2020, personal observation). People must be aware of that and may come forward by organizing two to three marriages at a same time, which decrease personal financial loads on individual parents and on other hand reduces the food wastage. Further, NGOs may come forward to redistribute the left-over food of these functions to the poor who otherwise could not afford it.

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### 5. Reducing methane emissions from rice cultivation

Rice cultivation plays a major role in global warming by green house gas emissions [49,50]. Matthews et al. [51] identified that 55% of the annual methane emission over rice growing areas is concentrated into four months, from July to October i.e. the predominant rice cultivation season. The average methane emissions varied from 0.65 to 1.12 mgm<sup>-2</sup>h<sup>-1</sup> [52]. Increased atmospheric CO<sub>2</sub> and 1<sup>0</sup>C degree rise in temperature have been shown to increase GHG intensity by 31.4% and 11.8% respectively and decreases rice yield [53]. It was reported

that, transport of over 90% of methane to the atmosphere, is through rice plants [54]. During the production of 1 kg of rice grain, 100 g of methane is emitted. The default methane baseline emission factor is 1.3 kg CH<sub>4</sub> ha<sup>-1</sup> day<sup>-1</sup>, in continuous flooding rice cultivation [55]. A major source of methane emissions is the decomposition of fertilizers and crop residues in flooded rice cultivation. The most effective option to reduce these emissions would be to prevent submergence of rice fields and to cultivate upland rice or other upland crops. (<http://ciesin.org/TG/AG/riceprod.html>). Following approaches should be introduced to the field level [56], so as get controlled release of the CH<sub>4</sub> to the farmers for sustainable rice production and mitigating greenhouse gas emissions such as

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1. Direct seeded rice represents an economically attractive option for the farmers to reduce CH<sub>4</sub> production along-with reducing overall production costs, but care should be taken for selecting fields with heavy textured soils [13].
2. Practicing alternate wetting and drying in rice fields reduces the CH<sub>4</sub> production alongwith saving a significant portion of irrigation water, which could be then used for other purposes viz. industrial etc.
3. Poultry manure and urea application reported to reduce the CH<sub>4</sub> production to the atmosphere
4. Paddy straw compost reported to be effective in reducing the CH<sub>4</sub> production than that of the fresh organic matter.
5. Use of the gypsum (as an amendment) and sulphate containing fertilizers in N, P and K deficient soils, reduces the CH<sub>4</sub> production due to the inhibitory effects of SO<sub>4</sub><sup>-2</sup> ions

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#### CONCLUSIONS AND FUTURE PLANS/POLICIES:

Comment [M19]: Discussion needed

Global warming is a reality. Raised CO<sub>2</sub> fixation may build crop development and yield because of expanded photosynthesis, diminished photorespiration, and diminished stomatal conductance. Further, enhanced CO<sub>2</sub> concentration might improve the soil N and P availability because of higher mineralization and phosphatase enzyme activity in the plant root area. On other hand, global warming might reduces the land productivity of rice and wheat because of the shorter length of harvest development. Different approaches viz. timely transplanting, short duration cultivars, forestation, use of residues as mulch on the soil or as biochar in the soil instead of burning, use of gypsum or polycoated fertilizes, new crop cultivars, minimum tillage operations instead of intensive tillage operations, double zero tillage, split application of the fertilizers, change in feeding habits, reduction in food wastage etc. are some of the recommended techniques to reduce the impact of global warming on agriculture. Further, it is recommended that different agricultural disciplines viz. plant reproducers, soil scientists, crop physiologists, agrometeorologists, and agronomists need to work in collaboration to find some integrated approach to reduce global warming effects and that too varied as per texturally divergent soils and under different agro-climatic conditions. Further, policy makers must provide some financial encouragements to the individuals practicing climate smart agricultural techniques. Further, different awards/incentives might be constituted by state government/NGOs/universities for farmers, who practice smart agricultural technologies to mitigating the adverse effects of the global warming,

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#### COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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