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# CLIMATE CHANGE AND AGRICULTURAL SYSTEM: POTENTIAL IMPACTS AND SOIL MANAGEMENT STRATEGIES - A REVIEW

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## ABSTRACT

**Climate holds a key position in driving the agriculture of an area. The changing climatic conditions are becoming a big threat for safety of agricultural system and food security across the globe. In developing countries of Asia and Africa, declining soil fertility and drought are the major constraints in harvesting the potential yields. The average temperature around the globe is also expected to rise globally by 6°C in the coming century which is mainly due to uncontrolled emission of greenhouse gases. A prominent elevation in $CO_2$ and $CH_4$ concentration has been observed in the past centuries largely due to fossil burning and urbanization. Further upto 35 percent increase in the concentration of nitrous oxide is also expected due to injudicious use of nitrogenous fertilizers. According to the prediction of climate models the rise in temperature and frequent happening of severe drought are going to affect the agricultural productivity in 21st century. In order to sustain the agricultural productivity it is need of the hour to properly understand the impact of these changes on soil fertility and crop productivity. This review is aimed to highlight the potential impacts of rising temperature, shifting precipitation patterns and rising $CO_2$ concentrations on soil health and agricultural productivity. Soil organic carbon pool is also going to get negatively affected by these changing climatic conditions. It has also been tried to shed some light on the potential of various carbon sequestration strategies conservation tillage, cover crops, Proper nutrient management, proper irrigation management and restoration of degraded soils, in combating the devastating impacts of changing climate. In addition the nitrogen management strategies are also elaborated alongwith manure management to minimize the emission of greenhouse gases.**

**KEYWORDS:** **Climate change; global warming; carbon management; soil fertility; drought.**

## INTRODUCTION

Climate is usually regarded as the long term expression of short term weather. It is the usual behavior of weather conditions over a period of time. Climate can, therefore, be regarded as key element in driving the agricultural productivity of any area. In past decades climate has been subjected to the rapid changes as the result of natural factors being accelerated by the human activities (24). Global warming is further accelerating the anthropogenically induced climate change (40). A 0.6C° rise in global temperature was reported during the 20th century with 1990s being the warmest decade. It has also been reported that 1998 was the warmest year in last 150 years (11). It is expected that a rise of 1.1-6.4 C° in the average global temperature will take place in 21st century (6). Increase in emission of GHGs is expected to become the major cause of the rising global temperature. The concentration of carbon dioxide and methane raised upto 30 and 150 percent, respectively during past 250 years (72) and the situation is yet to get even worsen in following decades due to un-judicious use of agricultural inputs and fossil burning. The release of nitrous oxide is expected to rise by 35-60 percent by 2030 due to the increased use of nitrogenous fertilizers and manures (10). The rising carbon dioxide concentration in the atmosphere coupled with decrease in soil organic carbon (SOC) stock damage overall health and make it more prone to erosion. It affects biomass productivity, biodiversity and environment by influencing the major nutrient and water cycles (72). This rising temperature is also becoming the cause of snow and glacier melting which is going to influence the water resources in the coming years. In the last 500 years the Gangotri Glaciers in Nepal have reduced upto 600 m. In China the glacial ice of Tien Shien Mountains has reduced upto 25 percent in the last 40 years. The Dokriani Barnak Glacier reduced by 20m in 1998 only (60). This glacier melting is resulting in extreme climatic events like floods, cyclones, storm and uneven rains.

Pakistan has faced drastic floods in recent years causing great damage to the agricultural productivity. In addition changing precipitation patterns has also resulted in severe periods of the water shortage in certain parts of the world. Iraq, Turkey, Jordan and Middle East countries have faced severe drought since 2001 (60). All these climatic changes are proving hazardous for the agricultural productivity throughout the world especially in developing countries. It is need of the hour to adopt various mitigation strategies to minimize the hazardous effects of the changing climatic conditions on agriculture in the coming decades. The main emphasis of the this review is to highlight the potential impacts of these climatic changes in the climatic conditions on the agricultural system and mitigation and adaptation strategies which can be followed to cope with the devastating effects of the climate change.

## 1. Potential impacts of climate change

Climate is one of the most important driving forces for agricultural productivity. It is an obvious fact that changing climatic conditions under the present scenario are going to affect the agricultural productivity globally and thus have a great impact on worlds food supply. Whether it relates to higher temperature and drought or to elevated levels of carbon dioxide and decreasing soil fertility; agriculture around the globe is being badly affected by fluctuations in these environmental variables.Some of the key climatic changes are highlighted in Table 1.

**Table 1. Key climatic changes an over view**

| Indicator | Changes |
|---|---|
| $CO_2$ concentration | 30 % rise in $CO_2$ concentration has been observed in the last 250 years |
| $CH_4$ concentration | 150 % rise in methane concentration has been observed in last 250 years |
| $O_3$ concentration | On an average nearly 35 to 40 % rise in $O_3$ concentration has been observed in last 250 years |
| Temperature | Nearly 0.6 C$^{\circ}$ rise in global temperature over 20$^{th}$ century |
| Drought | In both Asia and Africa the severity as well as the frequency of drought has increased |
| Snow cover | 10% decrease in the snow cover over the last 50 years |
| El Nino event | In previous 20 to 30 years more frequency and intensity has been observed as compared to last 100 years |

[Adopted from Jameel (60)]

***(a) Effects of higher temperature:*** The rising global temperature and the increasing drought incidence is becoming a major threat to agriculture and food security especially in developing countries (15). Climate models predict that in 21$^{st}$ century the temperature averages in Asia, Africa and South America are expected to rise further by 2-4C$^{\circ}$ (105). However, crop responses to the higher temperature in changing climate are yet not properly understood (82). The effect of rising temperature on the crop growth usually depends upon the moisture availability in certain areas. If enough irrigation water or precipitation is available the rising temperature could have a net positive effect on the yield by increasing the physiological activities (122), prolonged growing period (62) and decreasing the damage caused by frost in temperate regions (91). Within the arid regions, the higher temperature is going to influence agriculture by reduction in soil moisture as the result of higher evapotranspiration losses (18).

Various morphological and phonological changes are caused by high temperature in the plants resulting in affected plant growth and productivity (128). Higher temperatures may results in delayed seed germination or loss of vigor (130). Shoot dry weight and net assimilation rates are also significantly reduced in certain crops in response to higher temperature (12, 128). High temperature may also result in hastened maturity, causing a considerable reduction in the yield (1, 95, 126). A five percent reduction in the yield of wheat and maize is expected with every 1 C$^{\circ}$ increase in the temperature without any significant shift in the precipitation pattern (60). Rising temperature has significant effects on wheat yield in various parts of the world (2, 78). A yield reduction of 1 to 9 percent had been observed in wheat with 1 to 2 C$^{\circ}$ rise in temperature (81, 131). A negative relation between the rice productivity and the rising temperature has been observed (106). In dry season the rise of minimum temperature by one percent is expected to cause a ten percent decline in rice productivity (97). Alongwith its hazardous effects on the growth of crop and agricultural productivity, higher temperature also affects the quality of final produce. The elevated temperature coupled with drought caused a decrease in the starch concentration in the grain while increasing the protein content (35, 51). However, the rising temperature has a positive correlation with the micro nutrient concentration in the grains (63).

***(b) Drought and floods:*** The rising atmospheric temperature as a result of global warming has resulted in shifted precipitation patterns. Due to reason the frequency and severity of drought is rising in Asia and Africa (60). In the late 20$^{th}$ century, large scale crop failure in Sub-Saharan Africa as a result of drought resulted in mass starvation and the condition is expected to become more severe in the 21$^{st}$ century (21, 58, 108). Increasing intensity and duration of the drought events are expected to reduce the yield of rain fed agriculture in Africa upto 50 percent by 2020 (6) . Agricultural productivity in Asia is also expected to decline significantly due to increased incidence of drought and flood events (9). Asian monsoon regions alongwith the west Asian countries are expected to face severe drought conditions in upcoming years during spring and summer months (67). Conditions are expected to get even worse by 2030 in developing countries of South Asia and South Africa where increased drought incidence will have negative effects on many important crops and food security (80). Soil moisture is an important driving force for plant and microbe population. Drought can negatively influence the biological populations (88) resulting in drastic effects on plant community (25, 59). Introduction of the artificial irrigation was a great innovation in the agricultural system to mitigate the effects of water deficit. However, due to changing climatic conditions the quality and quantity of fresh water resources are being influenced and thus this adaptation seems limiting in the developing countries (30, 64).

A significant reduction in seed germination and stand establishment is reported as a result of water limiting conditions (65). Yield determining processes are also very much responsive to water limitation. Time to anthesis is reduced in response to drought applied at pre-anthesis while the induction of water stress at post-anthesis stage reduced the grain filling duration in triticale genotypes (36). Coincidence of drought with flowering, pollination and grain filling stages has been found drastic for various crops like wheat and corn (66, 110).

Global changes in the climatic conditions also cause the intensification of the hydrological cycle resulting in extreme weather events like floods (75). The floods in Pakistan during the past few years (2010-2014) have resulted in heavy crop and life losses. According to an estimate 500000 tons of stocked wheat, 28340 hectares of standing cotton, 121000 hectares of fodder and 81000 hectares of rice and sugarcane each were destroyed only in 2010 in Pakistan as a result of flood. More extreme events are expected in the upcoming decades as result of melting glaciers and other climatic changes.

**Table 2. Extreme weather events in the recent past**

| Year | Extreme event |
|---|---|
| 1991 | A devastating cyclone in Bangladesh resulting in the death of over 100000 people |
| 1992 | Flood in river Jehlum, regarded as the worst flood of $20^{th}$ century |
| 1998 | Flood water occupying nearly 2/3 of the area of Bangladesh resulting in great agricultural losses as well as the movement of nearly 20 million people |
| 1999 | Coastal areas of Southern Sindh were hit by a severe cyclone; 25 % decrease in rainfalls in Iran since 1999. |
| 1999-2001 | A worst drought was experienced by Pakistan |
| 2001 | Record 621 mm rainfall in Islamabad in a period of only 10 hour in the month of July |
| 2002 | Eastern Europe was hit by intensive floods |
| 2003 | Violent forest fires in Australia ; Death of 35000 people in Europe due to unexpected heat wave. |
| 2004 | During the month of July, very intense rainfalls and the rising levels in the revers caused the worst floods in South Asia. Water covered about two third of the area of Bangladesh; In September Bangladesh again got flooded due to continuous rainfall of 5 days. |
| 2010-2014 | Worst floods in Pakistan causing a lot of damage to agricultural, economy as well as to human lives. |

(Adopted from Jameel (60);

***(c) Elevated levels of carbon dioxide:*** The sole source of carbon for the plants is the atmospheric carbon dioxide. In $C_3$ plants, $CO_2$ assimilation at present $CO_2$ concentration is limiting. However, increasing $CO_2$ concentration to 800-1000 ppm will stimulate photosynthesis (5). Normally the elevated $CO_2$ effects are studied in non-limiting availability of nutrient and water supply, and temperature conditions are kept as close to the optimum conditions as possible. Under these conditions the elevated $CO_2$ levels resulted in 10 to 15 percent rise in wheat yield and 28 percent increase in tuber yield in potato (68). However, $C_4$ species showed less response to elevated $CO_2$ levels. Under nutrient limiting conditions the elevated $CO_2$ levels showed only 7 percent increase in yield (68). It has been found that under water limiting conditions the effects of water shortage can be compensated by stimulation in grain yield of wheat by elevated $CO_2$ (5). The effects of increased $CO_2$ concentration are also temperature dependent. $CO_2$ and $O_2$ show different solubility at different temperatures, therefore it is expected that rising temperature would improve the affinity of RUBISCO toward $CO_2$ and thus increasing the rate of photosynthesis with temperature (83). Higher atmospheric concentration of $CO_2$ can result in closing of stomata through which vapors are released. So under enriched concentrations of $CO_2$ the crops might use less water and produce more carbohydrates. Water use efficiency is thus expected to be increased as a result of this dual effect (23). In short we can say that $C_3$ plants are much more responsive to elevated $CO_2$ concentration as compared to $C_4$ plants and these responses are dependent on various factors like temperature, changing precipitation patterns and extreme metrological event.

***(d) Influence of ozone:*** Various studies have suggested that rising $O_3$ levels caused a reduction in the yield of certain crops (44). This negative effect is actually due to reduction in photosynthetic carbon assimilation and due to limited activity of RUBISCO (37, 77, 96) coupled with increased rate of leaf senescence (52). Impaired assimilate translocation to the sink has also been reported as a result of increased $O_3$ concentration which results in limited plant growth (53). $O_3$ has also been reported to influence the quality of produce. For example increased $O_3$ resulted in improved N concentration in grain (98), however, a negative impact was observed on tuber quality in potato (124). A relation has also been observed in $O_3$ concentration and elevated $CO_2$ levels (90). Elevated levels of $CO_2$ can reduce the $O_3$ stress by reduction in the leaf conductance and improved antioxidant defense (100). Further $CO_2$ enriched atmosphere will also result in the exclusion of $O_3$ (38, 89).

Water plays an important role in the transport of nutrients to the plants either by diffusion in case of short distances or by mass flow of water soluble nutrients such as nitrates, sulphate, Ca, Mg, and Si over longer distance. The drought can greatly impact the movement of these nutrients (14, 85). Drought not only affects the crop growth but also affects the availability and uptake of nutrients. Drought increases the loss of nutrients from the soil as a result of erosion (55). In an effort to uptake less mobile nutrients like phosphorus; roots change their architecture by increasing their length and surface area (84). Drought impairs the growth and functions of the roots and thus influences the uptake of less mobile nutrients (87). Root-microbe interaction plays an important role in the nutrient uptake. The nitrogen accumulation in the root nodules is reduced in drought and thus affects the nitrogen fixation in legumes (13, 50, 69). The drought can also affect the activity of microbial communities, for example, the drought can affect the activity of the nitrifying bacteria (120). Under the drought conditions the positive effects of mycorrhizae fungi on plant have also been reported through the improved nutrient availability to roots (4, 49).

Very intense rainfall can also result in the loss of nitrogen through leaching of nitrates (121). In the poorly drained soils the intense rainfall can result in water logged soils producing hypoxic conditions. This oxygen deficiency in the water logged soils can result into the elemental toxicities of Mn, Fe, Al and B (107). The active transport of the ions into the roots is driven by the ATP synthesized through the electron transport chain which is oxygen dependent (33). Thus this hypoxia condition can also result into the nutrient deficiency in the plant. The nitrogen deficiency also occurs in the hypoxic conditions because in reduced environment the nitrates can be used as electron acceptors by the microorganisms.

A 100 to 300 percent increase in nutrient uptake can be resulted by rising soil temperature primarily due to the change in the roots architecture and increased rate of nutrient movement and water influx (85). The movement of the nutrient such as nitrates, sulphate, Ca and Mg, which are water soluble is driven by transpiration dependent mass flow (14).

**Table 3. Interaction of various climate changes with mineral stresses**

| **Processes** | **Effecting Climatic agent** | **Mineral stresses** |
|---|---|---|
| Soil erosion | Intense precipitation and drought | Loss of soil nutrient and decline in SOC pool |
| Transpiration dependent mass flow | Drought, higher soil temperatures, CO2 levels | Mobile nutrients such as Ca, Mg, Si, nitrates and Sulphates |
| Root growth | Drought, soil temperature and CO2 concentration | Effects almost all nutrient in general and K and P in special |
| Soil microbes | Drought and temperature | Nitrogen |
| BNF | Drought and temperature | Nitrogen |
| Leaching | Intense precipitation | Ca, Mg, nitrates and sulphates |
| SOC status | Soil temperature, moisture and $CO_2$ | Almost all nutrients |
| Soil salinity | Precipitation, temperature | Mg, Ca, Na, k |

Adopted from Clair and Lynch, (26)

Soil organic carbon (SOC) is another very important indicator of soil health as it plays an important role in improving the fertility status of the soil alongwith improving its structure and moisture holding capacity (70). SOC stocks are actually the sum of the organic plant inputs added to the soil (roots exudates, leaves and other plant parts) and the organic loses taking place from the soil as a result of erosion and respiration. It has been predicted by the simulation models that within the 21st century the SOC stocks will be decreased greatly due to decrease in the organic inputs as a result of dwindling agricultural productivity and increase organic loses due to changes in climatic conditions (61, 112). Evidence also suggest that the dry soil conditions coupled with higher temperature will also increase the loss of SOC stocks due to enhanced rates of wind erosion (76).

## 2. Adaptation strategies to the changing climatic conditions

Various management strategies both in the field and off-site can be used to mitigate the adverse effects of changing climate on the agriculture. Various aspects of carbon and nitrogen management coupled with conservation practices have the potential to contribute in adapting to the changing climatic conditions and mitigating its hazardous effects on agricultural system (74). Described below are some of the key management strategies that can be employed to minimize the effects of changing climate and ensure food security in the coming years.

***(a) Carbon management:*** The carbon present in the terrestrial pool has remained the major source of the carbon dioxide present in the atmosphere since the start of settled agriculture on this planet (102). Various activities such as deforestation, cultivation of the soil and burning of biomass has resulted in the loss of terrestrial carbon. The carbon recovery in agricultural ecosystem is less as compared to that in the natural ecosystem (74). It has been reported that most of the soils lose about 50 percent of their SOC stock from the upper 6 inch portion within 25 to 50 years of conversion from natural to conventional agricultural ecosystem in temperate regions and within 5 to 10 years in the tropical areas (72). About 3.5 billion hectare area has been affected by various soil degradation processes such as salinity, erosion, etc. These degradation processes markedly decrease the SOC pool. Through the reclamation of salt affected and restoration of eroded soils, depletion in the SOC level can be avoided (71). Agricultural system can also be used to improve the SOC pool and to minimize the emission of certain greenhouse gases by adopting certain land management practices. Following are some of the key soil and agricultural management practices to improve the SOC pool.

***(b) Conservation tillage:*** The conventional tillage practices coupled with erosion results in depleting SOC stock in the agricultural soils. Thus by shifting from the plow farming to no till farming or to conservation tillage including minimum soil disturbance, minimizing the fallow period and introducing the cover crops in the rotation can improve the soil carbon level (72). By avoiding the fallowing in arid areas during the summer season and by introducing the no till farming alongwith residue incorporation or mulching can result in improving the soil structure and enhance the infiltration capacity (108). However, the benefits of no till approach is usually site specific and magnitude of the soil carbon improvement can be inconsistent in the soils having fine texture and poor drainage (129). More emission of $N_2O$ has also been reported in no till farming (86). The positive impacts of no till farming on the soil carbon levels have been observed in European soils along with those of North and Southern America (73, 103,113, 114). It has also been reported that the conservation tillage has the potential of adding 23 Tg C/year in European soils. In addition 3.2 Tg C/year can also be prevented from fossil fuel emissions by turning to conservation tillage. Complete shifting from the conventional to no till farming could mitigate all carbon emission from agriculture in Europe (116).

*Cover crops:* The benefits obtained from no-till farming can be increased to many folds by introducing the cover crops in rotations (72). Growing cover crops from the leguminous group can improve the quality of residual input and can enhance the soil carbon level (45, 111). It has also been reported that the cropping system including the leguminous crops can also reduce the losses of N and C from the soils (34). In Georgia, USA it has been reported that practicing no till farming alongwith growing hairy vetch as cover crop and managing the forage crops can greatly enhance the SOC pool (43, 104). However, if the cover crops are grown as green manures for short period then they may not enhance the soil carbon level. The benefits of cover crops have been reported in Hungary, United Kingdom, Holland and other European countries (16, 45, 115, 123).

*Nutrient management:* The introduction of the fertilizer responsive crops has accelerated the injudicious use of fertilizers in the modern agriculture. Therefore, it is the need of the day to use the fertilizers judiciously to ensure the environmental safety. Proper nutrient management can play an important role in soil carbon sequestration. The application of the organic fertilizers coupled with different composts has more capacity of improving the SOC pool as compared to that of synthetic fertilizer (54). Adequate supply of N and other nutrients can enhance the biomass production which will ultimately add to the soil carbon level when returned to the soil (124). Application of the organic matter on long term basis can also enhance the SOC levels and improve soil structure (48, 119) that may cause long lasting effects (27). The potential of no till or minimum till farming to improve the SOC stock can be increased by many folds if the soils are properly supplied with the organic manures (56).

**Table 4. Comparison of traditional and recommended strategies for improving the SOC stock**

| Traditional practices | Recommended practices |
|---|---|
| Residue burning and removal | Residue Incorporation and mulching |
| Conventional tillage | Minimum tillage, zero tillage (Conservational tillage ) |
| Fallowing | Cover crops |
| Mono cropping | Proper crop rotation |
| Extensive use of the chemical fertilizers | Integrated nutrient management |
| Flood irrigation | Drip and sprinkler irrigation |
| Intensive use of pesticides | Integrated pest management |
| Intense cropping | Integration of forestry and livestock with agriculture |

Adopted from Lal, (72)

*Irrigation management:* Just like the judicious application of fertilizers and the organic manures in the nutrient deficient soil, well managed application of the irrigation water can play an important role in increasing the biomass production which in turn will improve the SOC stocks (72). In Texas it has been reported that the SOC stocks in plots having irrigated sorghum and wheat improved with time (20). Proper irrigation management has also been reported to improve the SOC levels in the grasslands (28).

*Restoration of degraded soils:* Restoration of the degraded soils can play an important role in the soil carbon sequestration. By adopting certain land use practices we can restore a large portion of the SOC pool that has been lost in the degraded soils. CRP has been found much effective in restoring the SOC level. The SOC sequestration rate of 600 to 1000 kg C/ha/year can be achieved by adopting the CRP. In UK it has been reported that the SOC stocks increase @ 0.78 percent within four years of adapting grass ley system (45).

***(b) Nitrogen management:*** Nitrogen is very important for the living system and one of the basic components of proteins and nucleotides in all the living organisms, hence playing an important role in regulating various ecological processes. In the recent past an increase in the demand of N has been observed in agriculture as well as industry. This has been followed by the increased combustion of the fossil fuels resulting in a rapid increase in the concentration of the biologically available nitrogen (29, 46). Further, the inefficiencies in nitrogen use have resulted in the significant rise in the loses of $NO_3$, NO, $N_2O$ and $NH_3$ (93, 94), which is becoming a major contributor towards the environmental issues like eutrophication, soil and aquatic system acidification and atmospheric degradation (7, 29, 46). This situation is also coupled with the problem of nitrogen leaching which is resulting in contamination of the ground water (42, 79) causing negative impacts on the human health and biodiversity (19, 41). It is a well-known fact that the production of synthetic N fertilizers and their introduction into the agricultural system has resulted in increased productivity and thus helping a lot in ensuring the food security (101) but at the same time these inputs have also resulted in increased N loses and are one of the main contributor towards the rising concentration of the $N_2O$, a potential greenhouse gas (7, 94).

Various management strategies have been proposed to minimize the nitrogen loses. These can be grouped simply in following categories.

-  The first and foremost strategy can be to use the cropping system tools. For example the introduction of the legumes in existing cropping systems and to make more use of the crops having deep root systems for better soil resources utilization.
-  The soil-plant hydrological cycle should be properly understood for better management of the N and irrigation water i.e. the computer models can be used for site specific application of the N and irrigation and as a result the N and water use efficiencies can be improved.
-  While applying the N inputs care should be taken that these are added in right quantity, at right time and in right place so that it allows the quick utilization by the crop. The simple key is to use the 4Rs (117).
-  Nitrification Inhibitors and the slow release fertilizers can also be used to improve the soil retention of the applied N fertilizer and to decrease the emission of nitrous oxide (31, 118).

***(c) Manure management:*** The relationship among the application of manures and the emission of greenhouse gases is not clearly understood. When we talk about the conservation agriculture the manure injection is commonly regarded as the best practice. However still a lot of study is yet to be done to estimate the total losses of greenhouse gases in manure injection method. More research in this sector is also needed to estimate the potential of bio-char in reducing emission of the GHGs emission from the fields where manures are applied.

## CONCLUSION

The rising global population and changing climatic conditions alongwith their impacts on agricultural productivity has made the food security questionable in most parts of the world. In this review potential impact of the climate change on agricultural system has been summarized with reference to nutrient management and has tried to elaborate the fact that the proper management of soil should be one of our most important tools for mitigating and adapting to the changing climatic conditions. The way we manage and conserve our present soil and water resources is going to have a great impact on the resources available to the next generation for combating the food security issues. In addition carbon sequestration is an important strategy in fighting with the adverse effects of climate change. It generally helps improve the organic matter content in the soil as well as to maintain a good water holding capacity which can improve the performance of crops in drier conditions. In addition, use of nitrification inhibitors and slow release fertilizers the emission of $N_2O$ can be reduced to certain extent which will help to minimize the greenhouse gases emission and contribute to managing the climate change. Therefore, we can conclude that both on-site and off-site management practices can play an important role in mitigating the adverse effects of climate change.

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