

Impact of climate change on plant nutrient dynamics and soil forming process

M L Dotaniya¹, Harvir Singh, M D Meena and R L Choudhary

ICAR-Directorate of Rapeseed Mustard Research Sear, Bharatpur 321 303, India

Over the past few decades, acceleration in the human-induced changes in the climate of the Earth has become the focus of scientific and social scrutiny. The gaseous composition of the atmosphere has undergone a significant change mainly through increased industrial emissions, fossil fuel combustion, widespread deforestation and burning of biomass as well as changes in land use and land management practices. These anthropogenic activities have resulted in an increased emission of radiatively active gases, e.g., carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), popularly known as the 'greenhouse gases'.

Key words: Greenhouse gases, Global warming potential, Nutrient dynamics

HUMAN existence on the Earth is affected by ecosystem functions. Growing population is pulling more pressure on natural resources to produce more food stuffs to feed the hungry mouth. With progressive Earth history, growing population may need 333 million tonnes (MT) food by 2050 from 283 MT in the year 2018-19 (3rd advance estimates). This situation is more pathetic in developing countries like India, Pakistan, Bangladesh and most of the African countries. This situation may worsen in coming years. Another side, natural resources exhausted their potential and polluted over the period. Ecosystem services are adversely affected by contamination level, type of pollutant, vulnerability of the process, gas composition of the atmosphere and their reactivity. Atmospheric temperature increasing with the time due to the increasing concentration of the greenhouse gases (GHGs). Most of the GHGs are CO₂, CH₄,

Table 1. Composition of major GHGs

Gas	Formula	Contribution (%)
Water vapour	H ₂ O	36-72
Carbon dioxide	CO ₂	9-26
Methane	CH ₄	4-9
Ozone	O ₃	3-7

N₂O, CFCs, water vapour and ozone gas (Table 1). In May 2018, CO₂, CH₄ and N₂O concentration in the

atmosphere were 414 ppm, 1859 ppb and 330 ppb, respectively. These gases have the capacity to trap the long-wave radiation emitted from the Earth and enhance the atmospheric temperature. These adverse effect changes the global cycles of water and mineral. Food web and chain is disturbed due to the increasing contamination of pollutant and loss of biodiversity.

What is global climate change?

In the atmosphere, concentration of GHGs is increasing from the pre-industrial era to the present time and their adverse effect on ecosystem functions has increased. Anthropogenic activities enhance the gases emission rate due to more consumption of fossils fuel and industrialization. Short-wave radiation coming from the Sun towards the Earth convert into long-wave radiation and part of it reflect back to space as an Albedo. It is almost 30% of total

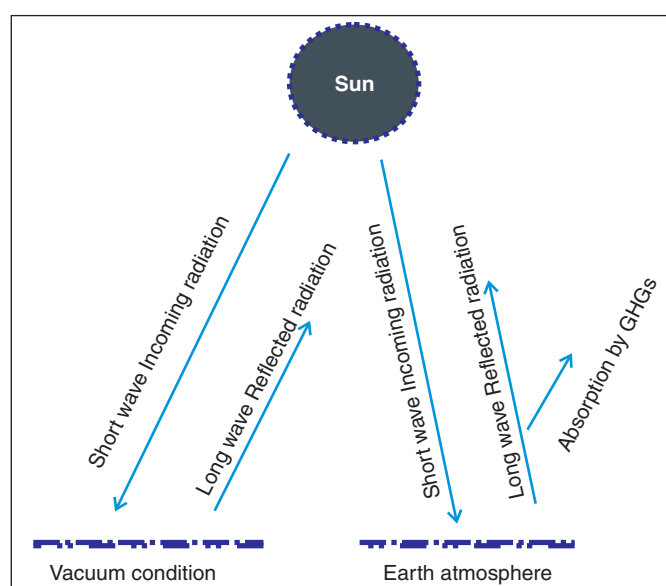


Fig. 1. Schematic diagram of GHGs effect on atmosphere

Table 2. Global warming potential of major GHGs

Gas	Chemical composition	GWP (Time Horizon)
Carbon di oxide	CO ₂	1
Methan	CH ₄	21
Nitrous oxide	N ₂ O	310
HFC-23	CHF ₃	11,700
HFC-32	CH ₂ F ₂	650
Sulphur hexafluoride	SF ₆	23,900

incoming radiation from the Sun. Part of the reflected radiation is absorbed by the GHGs and enhance the atmospheric temperature (Fig. 1). This process is known as global climate change. Global warming potential (GWP) of a gas decided the intensity of warming the atmosphere. It is calculated with respect to CO₂ global warming potential (Table 2).

The Intergovernmental Panel on Climate Change (IPCC) provides the generally accepted values for GWP, which changed slightly between 1996 and 2001. An exact definition of how GWP is calculated, is given in the IPCC's 2001 Third Assessment Report. The GWP is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kg of a trace substance relative to that of 1 kg of a reference gas:

$$GWP(x) = \frac{\int_0^{TH} a_x \cdot [x(t)] dt}{\int_0^{TH} a_r \cdot [r(t)] dt}$$

where TH is the time horizon over which the calculation is considered; a_x is the radiative efficiency due to a unit increase in the atmospheric abundance of the substance (i.e., Wm⁻² kg⁻¹) and $[x(t)]$ is the time-dependent decay in abundance of the substance following an instantaneous release of it at time $t=0$. The denominator contains the corresponding quantities of the reference gas (i.e. CO₂). The radiative efficiencies a_x and a_r are not necessarily constant over time. While the absorption of infrared radiation by many greenhouse gases varies linearly with their abundance, a few important ones display non-linear behaviour for current and likely future abundances (e.g., CO₂, CH₄, and N₂O). For those gasses, the relative

radiative forcing will depend upon abundance and hence upon the future scenario adopted. Carbon dioxide has a GWP of exactly 1 (since, it is the baseline unit to which all other GHGs are compared).

Carbon sequestration process reduces the adverse impact of climate change and improves the environment health. At international level carbon food print and carbon trading is in common to evaluate the mitigation of climate change effect across the globe by the Intergovernmental Panel on Climate Change (IPCC). This agency promotes the countries to lower emission of GHGs from industrial and agricultural sectors and use green technology for economic development.

Effect on soil forming process

Global climate change affects the different ecosystem services by modifying the plant nutrient cycles like water cycle, carbon cycle and other plant nutrient cycles. These cycles are the key to plant growth and the base of vegetation existence on the Earth. The rising CO₂ concentration directly and indirectly affects the soil process like organic matter dynamics, nutrient dynamics especially nitrogen and biological parameters (soil biodiversity and enzyme activities) modifications in

chemical reactions (pH, salinization and alkalization, physical process), soil water dynamics, run off, variability in rainfall pattern and intensity, soil erosion, soil structure etc. All process directly and sometimes playing an indirectly crucial role in plant growth and biomass production on beautiful Earth. Some of the soil process affects by the elevated CO₂ concentration, can be broadly classified into structural (physical) and hydrological processes, and biogeochemical processes. The soil is a complex system, in which many changes operates simultaneously and influence soil health or soil quality. Increasing the concentration of CO₂ into the soil enhances the soil weathering process by mediating the carbonic acid (H₂CO₃) formation in soil. It also enhances the removal of silica from upper layer to the lower layer of soil. Soil pH is not affected directly by the increasing concentration of CO₂ and temperature, but indirectly affected by the root exudation and other associated plant nutrient dynamics. Doubling of atmospheric CO₂ concentration under continuous phosphorus deficiency condition increased wheat root activity by 30-40%, thus increasing the phosphorus availability enhance the plant growth. Heavy rain for shorter duration



Fig. 2. Photo Impact of climate change on natural resources

increase the run off rate and thereby nutrient loss from the crop field. Increasing the temperature reduces the mineralization rate, growth of plants, availability of water, biodiversity enhance the soil degradation process.

Effect on nutrient dynamics

Increasing the atmospheric temperature enhance the transpiration rate and more water uptake from the soil. Scarcity of moisture in the soil affects the plant nutrient kinetic in the soil. It reduces the mineralization rate of soil organic matter and adversely affects the plant nutrient availability in soil. Increasing temperature reduce the water uptake by plant and may suffer from nutritional deficiency. Low molecular organic acid secretions from the plant roots also reduced the soil microbial activities drastically. Siderophore production from plant roots decreased, and plants will face the deficiency of iron and zinc in deficient soils. Elevated CO₂ could alter the biochemical composition of plant tissue above and below ground, which will affect soil microorganisms. Different soil and plant parameter are affected by elevated CO₂ concentration in the atmosphere, but the effect is not same

in all parameters, it varied in a wide range. Elevated temperature enhances the nitrogen volatilization rate from crop field and reduces the nitrogen efficiency. These processes deteriorate the environmental quality and reduce the ecosystem health.

Effect on crop productivity

Increasing temperature in tropical and subtropic areas enhanced the respiration rate of the crop plants, which enhance the consumption of energy for completion of metabolic process. This mechanism reduces the conversion rate of source to sink and ultimately reduce the crop yield. However, in temperate areas or temperature limiting areas it enhances the crop yield. Elevated CO₂ elicited a 47% average increase in mycorrhizal abundance and that mycorrhizae were stimulated disproportionately more than roots (percentage colonization increased by more than 30%). These microorganisms are enhanced the microbial decomposition rate and availability of plant nutrients in the soil may increase. These nutrients improve crop yield and soil health.

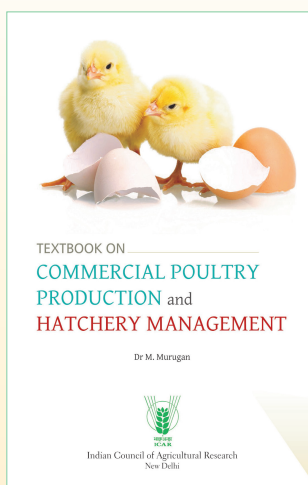
Conclusions

Industrial growth is an important

activity for the economic growth of a country. Most of the developing countries have old or poor technology to tackle CO₂ emission and safe use of modern tools and techniques related to environmental health to reduce the atmospheric GHGs emission. It requires a huge amount of investment, which can be supported by the developed countries. The rising atmospheric CO₂ concentration affect vigorously, but their clear cut effects are complex due to mixed interaction of the climate-soil-plant system. Due to many uncertainties in global climate changes (direction, rate, seasonal and geographical distribution) and the prediction of their environmental, ecological, economical and even social consequences, integrated multidisciplinary studies are required to give an exact scientific basis for the adaptation or mitigation of the unfavourable consequences of climate change. Use of integrated approach is needed to reduce the global temperature with the help of mass social based sustainable activities at National and International level.

¹Scientist. *Corresponding author e-mail: mohan30682@gmail.com

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