Impact of climate change on soil health

[*1,2]SHAMAL SHASANG KUMAR, OWAIS ALI WANI[2], JARABALA RADHA KRISHNA[2], NAZIR HUSSAIN[3]

Department of Soil Science and Agricultural Engineering, College of Agriculture, Fisheries and Forestry, Fiji National University, FIJI

Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, INDIA

Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, INDIA

Abstract: - Extrapolating concentrations of carbon dioxide with the increasing global population is a major concern worldwide. With time, this natural greenhouse gas menaces natural phenomena, ultimately leading to increased temperature rates, which causes variations in climate and weather patterns. The current scenario of rapid climate change is directly associated with agriculture throughout the world, mainly in soil health which is a necessary tool towards sustainability of soil and ultimately soil health which presently has a profound impact on human health. With the ever-changing climatic conditions, modifications in the temperature, precipitation and increased carbon dioxide levels in the atmosphere are the three major driving forces which highly alter soil properties (physical, chemical, biological) and its process that includes; soil organic matter decomposition, nitrogen mineralization, nitrification and denitrification, nutrient acquisition, erosion, soil salinity and acidity. Within the soil as a dynamic entity, climate change can be mitigated to some extent through appropriate agricultural mitigation tactics such as conservative agrarian practices, which include conservation tillage operations, cover cropping and crop rotation, Biochar and through the incorporation of organics and amendments that in turn would enhance soil fertility, processes and ultimately soil health.

Key-Words: - Climate change, carbon dioxide, agriculture, soil health, mitigation

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1 Introduction

It is projected that by 2030, the global population will rise to 8.5 billion [1]. Since the time of industrial revolution, mankind has proceeded to establish a disparity in the natural equilibrium of our world. With the ever increasing human population, there is a need to generate greater resource to meet the people's daily needs. This indicates to us that there is a need for increasing global food production along with land cultivation in a sustainable manner for meeting this required food demand. With 20-30 years lagging in our global climate network, international agreements on reducing emissions through reducing greenhouse gases at every attempt, the earth is expected to get warmer by 1.50°C in between 2020-2024 [2]. Forest conversions through deforestation by means of complete burning to support this expansion; while the property was repurposed for human use e.g. the Amazon rainforest approximately contributes 2 billion tonnes of carbon dioxide per year [3] accounting 5 percent of global emission. Global warming is no hoax [4] since it has been amply substantiated. Climate change clearly represents the increase in temperature in the soil and atmosphere, changes in the precipitation, declining groundwater, floods caused by heavy rainfall, earthquakes and increasing sea levels due to the glacial melting. With the alarming phenomenon of global warming there are basically two theories which are attributing towards the issue of climate change. The first theory clarifies that the main cause of the recent increment in global temperature rates is directed towards the increasing temperature due to the release of natural greenhouse gases mainly carbon dioxide (CO_2). While in some situations this is a natural process which is due to anthropogenic activities. “Anthropogenic” behaviors interact with the carbon cycle on a regular basis because it is one of the most essential components that affect almost any environment. With geological records, the climate is continuously changing and is a major concern around the world. There are no new phenomena in the world with regard to climate change [5, 6]. The factors that lead to climate change which releases mainly CO_2 are the result of various “anthropogenic sources” which encompasses; deforestation, extrapolating fossils, land transitions, intensive farming and the decomposition of natural soil biology, erosion and natural fires, increased population causing rapid industrialization [7]. Such anthropogenic activities have substantially increased nearly 35 percent of CO_2 concentrations since its “pre-industrial” concentrations along with its effects. Carbon dioxide is one of the most prevalent greenhouse gases that lead to global warming by trapping long wave radiation and returning it to the earth's surface. In comparison, the second theory says that it is the “Sun’s profound activity” that has led to recent warming and is thus considered to be included in the usual expected limits of physical temperature variation along the aeons. An assumption as to how the sun contributes to this climate is linked to the magnetic field and the solar wind which modulates the extent of increased energy cosmic radiation that are reflected on the earth. In turn this alters the lower altitude cloud covers and proportion of water vapors found in the atmosphere which allows it to regulate the climate [8]. Global warming creates several major challenges that have impact on human superficial comfort and endanger the basis of our survival [9, 10]. Climate change is just one of the challenges that we face. Some of the other consequences of changing climate are: sea level rise; ocean acidification; reduction in the cryosphere (glaciers, permafrost, and Greenland’s ice sheet); changes in fresh/saltwater; habitat size; increased disease and pest infestations; loss of coral reefs; changed hydrological cycles and variation in plant and animal life [11]. Global warming is nothing more than surface heating due to greenhouse gas emissions, which increases global air temperatures for a long term. Such surface temperature fluctuations and the consequent harmful effects on precipitation over a lengthy duration is called climate change. In the past the earth's atmosphere has changed significantly as seen by the historical indications of ice ages and shifts in sea level and the records of history since human civilization over several centuries. The reasons of historical variations are not always apparent. However, the changes of ocean tides, solar radiation, volcanic outbursts and other natural forces are widely understood to be associated. The distinction is that over the past few decades global temperatures have risen unusually quickly. Climate change is linked to agriculture and especially to the soil health as it controls soils vital processes and functions along with having intrinsic effect on crop productivity which contributes towards food security and sustainability. This paper gives us an overview of climate change, its implications towards soil health and measures that can be put in place for better management of the rapidly changing climate in relation to agriculture in the present context.

2 Climate change and its impact on agriculture

The climate is continuously changing when seen with geological records. This rapid rate at which this change is coming up and its magnitude are of great concern worldwide. In terms of climate change, India ranks as the 5th most vulnerable country to be affected due to enhancing attributes by the drastic factor [12]. In India, one meter rise in sea level is likely to displace approximately 7.1 million people; about 5764 km^{-2} of the land area will be lost along with 4200 km^{-1} of road as well. That is because various factors, such as: “anthropogenic- deforestation, land-use change, intensive farming practices” and “natural- soil organic matter decomposition, erosion, natural fires” are leading to climate change. Climate change has a very strong link with greenhouse gases of which a major contributor is CO_2. This gas being symmetrically aligned has the tendency to absorb long heat wave radiations from the sun. China along with India being the two large-scale nations having vast human race will continue to be sources of global C emissions. Thus efforts to minimize CO_2 emissions must be made [13]. At an increasing trend, the earth’s climate continues to warm up due to increasing temperature rate and the effect of this is considerably a major challenge to mankind especially for farmers and farming communities around the world. Climate and its variables have influence in many ways on all economic sectors, such as rainfall variations contribute to flooding intensity and frequency. Any rise in temperature may significate a spike mean level of seas, impacting vast populations, e.g. peninsular and coastal regions. It can increase precipitation by 15 to 40 percent and cause a 3-6 degrees Celsius annual average temperature increase. The rapid changing climate directly impacts agriculture throughout the world mainly in terms of food security i.e. food availability, food accessibility, food utilization, and food system stability; which will influence health, living resources and food production and distribution of the human race [14]. Climate changes can modify the distribution of species and at the same time affect organism interactions [15]. Moreover with the adverse impact of climate, agricultural yields are more prone and vulnerable to losses [16, 17]. Agriculture in fact is directly exposed to climate change since its necessary operations are dependent on climate. However, this effect on agricultural yields varies between countries and is dependent on crop type. There are some places which may benefit from actions of climate change e.g. when subjected to countries which are colder with increasing temperature or by carbon fertilization effect [18]. Alternatively, some countries may be affected negatively by the adverse effects of water stress, increased variability in yield and mainly reduced crop yield. Several other countries in both the combinations can exacerbate intrinsic vulnerabilities [19]. Suppose that temperature having both the positive and negative consequences on agricultural yields is then determined on the basis of a countries characteristics. Nevertheless, with high temperature implications on issues of water scarcity arises which may create unfavorable agricultural climate systems in all countries especially the semi-arid areas found in Southern European countries. With climate change drought is a recurring extremity which is known as less precipitation then normal and is associated mainly with warm temperature ranges over a time span from months to years. Agricultural droughts are mainly seen in tropical regions as compared to the temperate regions. Droughts substantially negatively affect the agricultural productivity, alter soils natural fertility gradient, threatening water supplies for irrigation of plants that will directly decrease crop production, whereas when increased precipitation with changing climate flooding would occur and wipe out crop yield causing direct damage as a source of finance drainage for farmers. This is a major threat to the global food security as the global population continues to increase. When looking on an overall perspective climate change affects crop production by means of directly and indirectly chelation [20-22], hence in order to achieve adequate predictions for the future scenarios, there is an essential need to consider soil properties.

3 Global warming, greenhouse effect and its influence on glaciers

Over the course of this century, global warming has caused the occurrence of increased global air temperatures near the earth's surface. Climate scientists have collected extensive measurements of the variety of weather cycles, temperatures, precipitation, associated climatic factors, and ocean current and chemical compositions of the atmosphere since the middle of the 20th century. This suggests that since the advent of geology and human activity the environment has changed all over the world and that since the Industrial Revolution those activities play an important role in climate change. During timeframe of 1880 to 2012, the IPCC recorded a global mean temperature increase of about 0.9 degrees Celsius. The rise is nearer to 1.1 degrees Celsius when measured by mean temperature since 1750 to 1800's. This estimate has also been endorsed in IPCC report 2018 [23], which states, since pre-industrial times, human and its behavior are responsible for average rise in global warming temperature to 1.2 degrees Celsius and that the greater part of warming could be due to human activities in the 20th century. Many climatologists agree that major social, economic and ecological loss will result if world average temperature increases by just 2 degrees Celsius. The extinction would grow, with changes in farm patterns and the increase in maritime levels of many animal and plant species. The above scenarios depend mainly on the concentration of some trace gases, referred to as greenhouse gases which, by burning fossil fuels for industry, transports, and home uses, have been injected into the lower atmosphere. The so-called greenhouse effect rises causing earth's surface heating up and the lower atmosphere is influenced by water vapors, CO_2, methane, nitrous oxides as well as other pollution from greenhouse gases. The IPCC confirmed in 2014 that the C, methane and nitrous oxide atmospheric concentrations exceed those of the 800,000-year ice core. Of all these gases, CO_2 is of the greatest importance both because of its greenhouse effect role and because of its role in the human economy. At the start of the industrial era of mid-18th century, atmospheric CO_2 levels were higher at about 280 ppm. Until mid-2018, fossil fuels had risen to 406 ppm, and the existing fuel consumption is projected to grow to 550 ppm by the middle of the 21st Century. The principle, CO_2 concentrations will be doubling in 300 years. The magnitude, intensity, and impacts of rising surface temperatures on human lives and need for actions to minimize and cope with future warming are still being studied by researchers worldwide. The amount of atmospheric CO_2 has increased from 280 ppm to 395 ppm and CH_4 from 715 ppb to 1882 ppb and N_2O from 227 ppb to 323 ppb from 1750 to 2012. The Global Warming Potential (GWP) of gases, i.e. CO_2, CH_4 and N_2O, amounts to 1, 25 and 310 respectively. Global warming scenarios are projected to indicate an increase by 1.4 to 5.8 degrees Celsius by 2100 of the global average surface temperature. The forecast warming rate in the last 10,000 years is unprecedented. Global warming indications are much more complex than rising temperatures around the world. The earth is warming from Northern to the Southern

Pole. Since 1906, average global surface temperature in sensitive polar region substantially increased over 0.9 degrees Celsius. The impacts of rising temperatures do not look for a far-reaching future global warming is now having repercussions. The heat melts glaciers and sea ice, changes the pattern of precipitation, and moves animals. Most people see global warming as synonymous with climate change; however scientists tend to use "climate change" to describe the complicated changes that are adversely affecting our planet's climate. Average temperatures not only increase but also extreme weather, changes in population and habitat of wildlife, the rising seas and a number of other impacts are included as part of climate change. These changes are regulated by addition of greenhouse gases in the atmosphere as a result of man-kind. Warming of earth's surface and troposphere is attributed by high temperature elevations that are a result of various greenhouse gases which are water vapour, CO_2, methane and other gases in the air is known as Greenhouse effect. The greatest effect among these gases is due to water vapour. Greenhouse gas levels constantly are increasing mainly CO_2 and methane at a 0.4 percent Year since 1750 [24]. The French mathematician Joseph Fourier is sometimes regarded as the 1st individual who coined the term "greenhouse effect" in 1824. Svante Arrhenius a Swedish physicist and physical chemist is marked as the person who made it clear as how heat is captures in the atmosphere. The mechanism through which this process takes place is when the surface of the Earth is heated by sunlight, radiation in the form of energy is sent back to space as infrared waves. Unlike visible light, this radiation is absorbed by the atmospheric greenhouse gases thus causes temperature increment. In exchange, the warm atmosphere radiates infrared radiation out towards the surface of Earth. The Earth average surface temperature would be near to −18 degrees Celsius in the absence of heat due to greenhouse effect. Since greenhouse effect being natural phenomena possibilities of this effect could exacerbate the greenhouses gases to the atmosphere due to human activities. Atmospheric CO_2 concentrations have risen by nearly 30 percent, while methane levels have doubled by the end of the 20th century since the industrial revolution. By the end of the 21st century, man-kind could cause a global temperatures increase by 3-4 degrees Celsius. As a result of substantial increment at the following rate this would negatively affect the earth's climate causing extreme conditions such as drought and reduced food production affecting human lives. Intergovernmental Panel on Climate Change (IPCC) in the fifth assessment reported the systematic evaluation of the changes in global glaciers and permafrost over time. Since the early 1950s and 1960s glaciers found across the world have been retreating in length, shrinking in area, and decreasing its volume and this retreat has accelerated since the early 1990s. During 1980s, the permafrost temperature has increased and depth of seasonally frozen ground has become shallower [25]. Changes in the outer geometrical morphology of glaciers and permafrost, such as changes in the length, area, volume, and thickness of glaciers due to mass loss, have been the primary indicators of transition. With the overall increase in englacial temperature, its response to atmospheric warming can be seen in glacier mass losses, which are primarily caused by internal thermal and dynamic processes. Since 2000, seepage and permeation of melting water, as well as its refreezing, have increased significantly in the Swiss Alps Colle Gnifetti, resulting in a 6.8°C rise in englacial temperature between 1982 and 2008 due to latent heat release during the seeping and permeation of melting water [26]. Temperature shifts during the englacial period may also have a major effect on glacier mass balance [27].

4 Effect of climate change on soil properties

The three climate change forces that influence different soil properties and processes are used as a medium for plant growth and plant production, namely, temperature, precipitation and increased CO_2 levels in the atmosphere. The concentration of atmospheric CO_2 is now at 418.21 ppm and will rise more in the coming years [28]. The air temperature is closely linked to the soil surface temperature and an increase in the air temperature typically leads to an increase in soil temperature. In addition, soil temperature is controlled by surface radiation gains and losses, evaporation processes, heat transmission via the soil profile, and convective transmission through the movements of the gas and the water. Higher temperature of soil intensify soil processes that lead to higher decomposition rates for organic matter, increased microbiological activity, rapid nutrient release, increased nitrifying rates and faster chemical mineral weathering. Through changes in precipitation, temperature drives evapotranspiration and vegetation changes caused by climate change, plant growth rate, extraction rates of soils and the impact of higher CO_2 levels on the transpiration of plants, climate change can directly influence soil moisture levels leading to drought conditions. Precipitation changes have swift repercussions on soil water regimes as the reaction time in the earth normally lasts within a couple of hours. The fluctuations in the soil water levels are dictated by a combination of microbiological soil processes, the nutrient supply in soil, the absorption of plants and the depletion of soil nutrients. Changes in the state of soil humidity can also affect climate itself which can lead to drought by decreasing available humidity, changing patterns of circulation and rising air temperatures.

4.1 Soil physical properties

Soil physical properties are described as the processes of soil air, water, dissolved chemicals, germination, root development and erosion. Soil facial attributes form the basis for a variety of chemical and biological processes which can be further determined by the climate, plants and the utilization of the soil. The soil composition, water penetration rate, bulk density, rooting depth and soil surface are some of the main physical indicators of soil in relation to climate change. The soil composition regulates organic C accumulation, penetration potential, movement and preservation of gases, water and nutrients, the production of seed and root and microbial activities. It can be used to measure soil erosion resistance and it measures aggregate stability, soil aggregation resistance, such as high precipitation and cultivation [29]. The structure of the soil is dependent on its quantity and consistency and the inorganic components of the soil matrix and soil culture processes, and soil aggregates may reduce stability, increase compaction-sensitive, or reduce soil aggregates stability. The soil aggregates can decrease in soil levels during the climate change. Soils of high clay, especially those with smectitical mineralogy can shrink when they are dry and cause large cracks. The fractures close as the soils rebound. The extent and scale of crack forming should be increased under drier climatic conditions. An increasing soil drying would lead to more difficulty in managing clay soils with a high shrinkage swelling potential. The importance of soil structure is important factors to be addressed in the future management of soil and water, the transport of nutrients in soil and landscape within the climate change framework. The distribution of soil pores is an indicator of the soil's capacity to store the water and air required for plant growth in the root zone. Soil porosity and water release characteristics influence some soil physical measures, such as soil aeration capability, available plant water capacities and relative field capacity [30]. In future climate scenarios involving high CO_2 and temperatures and variable and intense precipitation events can alter not only the distribution of porous soil porosity and the distribution of pores, but also root and soil biological activity, and thus affect soil function in unexpected directions [31]. The water and distribution of soil available can rapidly react to climate change, particularly varying and heavy rainfall and drought and can thereby mitigate the effects of extreme precipitation and drought events with management strategies such as the preservation of the laying of organic manures that keep or even increase the water penetration available and soil water [32]. Bulk density is adversely related to organic soil [33]; reduction of organic C due to higher temperatures [34] will thus lead to a rise in bulk density, thus increasing the risk that soils may be more compact by land management or climate change stress such as variable and high rainfall and drought occurrences [35].

4.2 Soil chemical properties

Soil pH is a critical component of soil that is strongly affected by biological and chemical functions of parent material type, weather severity, vegetation type and climatic variables [36]. Climate change drivers affect the status of organic matter, nutrient cycles, available water status for plant use and therefore plant productivity in turn is affected the pH level of soil [37]. Soil electrical conductivity is associated to salinity, crop performance, nutrient cycling and bioactivity levels with pH as sub-situational soil structural measures can decrease especially in soil. As a substitute for temperature increase and precipitation decrease, [38] used elevation gradient in climate change scenarios and found that electro-conductivity decreased in a semiarid areas but the soil pH increased. The conservation and the immobilization of potentially harmful aluminum and toxic cations are in particular important determinants of the soil chemical contents of significant nutrient cations such as Ca, Mg and K. Since soil organics is largely determined for cation exchanges in coarse textured soils and soils of low-activity clay [39], increasing decomposition and loss of soil organic substance at elevated temperatures can contribute to the loss of cation exchange capability of these soils [40]. Plant nutrient cycling is consistent with organic C cycling, which makes N cycling likely to affect the mechanisms of climate change such as rising temperatures, precipitation and atmospheric N deposition [41].

4.3 Soil biological properties

Dynamic adaptive pathways incorporating the most critical processes are involved in the soil biological properties. Kibblewhite *et al.* [42] reports that soil biota gives an account for the chemistry and physics of the soil structure and it is suited to the environmental changes. Climate change can influence the primary biological parameters soil organic matter and its constituent parts and soil microbial biomass. Soil organic matter mostly arises from carbon dioxide in the atmosphere, is photosynthesized into biomass in plants and ultimately emitted to soil by plants residues. Since organic soil build-up is basically a biological process, moisture, temperature, biological activity type and intensity, vegetation and land utilization are regulated. Soil organic matter reservoirs, roots and related species have separate reactions to environmental drivers and the drivers of climate change, but the supply of C substrates can control both reactions [43]. The soil organic matter is one of the most complex soil components, separated into various pools with a special phase of degradation; rapidly (active, labile, or microbial), slowly (intermediate and unprotected), or not at all (passive, recalcitrant, and protected). The C and N sink and source, and variable P and S cycling regulations, create complexes of multifunctional ions and organic agents that provide microbial and faunal habitat and mediums as well as affect aggregate stability, trafficability, water retention and hydraulics both contribute to the characteristics of soil. Reducing soil organic matter will lead to loss of soil structure, reduced fertility status of soils and lowering soil microbial biomass that will be leading to reduction in soil water contents, erosion and increased bulk density leading to soil compactness. Global warming and increased CO_2 levels may to some extent increase plant growth which in-return can provide more organic matter for the soil. But in contrary to, an increase in temperature it will cause more decomposition and loss of soil organic matter. The availability of organic soil to microorganisms controls their losses instead of the climate factors which change rates like temperature [44, 45]. In several experiments, higher CO_2 stimulates net primary production, but the fate of this C in particular the portion under the earth is largely unknown [46]; partly due to problems relating to measuring a small increment of soil organic matter against a large background. Also with increase in plant growth it will not be as large as originally thought [47] owing to the negative effects of increased levels of ozone and temperature rates on plant growth that may cancel out any CO_2 fertilization that occurs [48]. Thus making the soil eventually loses its organic matter in the form of CO_2 [49]. Too much organic matter depletion affects the physical, chemical and biological properties of the soil [50]. Recent studies have shown a decline in soil microbial biomass in simulated experiments with climate warming [51]. Microbial biomass is usually sensitive to elevated temperature but it is particularly peculiar to CO_2 [52]. Castro *et al.* [53] observed that in warm treatments the abundance of fungus increases and in warm plots the abundance of bacteria increases with atmospheric CO_2 increase, but in warm plots it decreases under ambient atmospheric CO_2 frequencies. The changes in precipitation alter abundance of *Proteobacteria* and *Acidobacteria*. In relatively moist soil environments, *Acidobacteria* is reduced with concomitant increase in *Proteobacteria*.

5 Influence of climate change on soil processes

Soils are closely linked to the C, N and hydrological cycles to the global atmosphere. Anthropogenic activities directly through agriculture as well as indirectly through climate change have greatly disrupted the soils natural C cycle [54]. Soils being the heart "sensitive region- organ" of earth, the small outermost portion on which humans depend mostly in day to day need [55, 56]. Soils contain three times the volume of C currently in atmosphere and in the vegetation C pool [57]. Any change in temperature will therefore affect soil processes and their related characteristics. Global warming has a dramatic impact on the dynamics of soil carbon [58]. As the climatic changes it impacts the natural C and N cycles, different processes related to soil organic matter affect the natural fertility of soils [59].

5.1 Soil organic matter decomposition

Soil organic matter consists of degrading residual debris contained in the soil. It is extremely heterogeneous and ranges from roots to ancient humidified material over thousands of years [60]. Soil organic matter is used as a soil efficiency measure and soil respiration is used as a proxy for soil quality. The more degradation the healthier soil is according to Janzen [61]. With increased soil biota the more ecological reward and ultimately productive soil. The degree to which the rate of decomposition of organic matter can be changed depends in part upon the physiological reaction of soil microorganisms to changes in temperature and precipitation. Increased temperature increases the microbial degradation rate which contributes to the organic soil degradation. This increase in respiration does not however continue to rise with temperature. Melillo *et al*. [62] found a 28 percent CO_2 flux rise over the first six years of warming over influence of the soils in a 10-year soil warming trial, followed by a substantial CO_2 decrease in following years and no substantial warming responses in the last experiment year. This may be due to higher temperature rates that induce physiological changes in microbes that lead to lower C usage efficiency [63]. The soil organic matter is potentially very vulnerable according to Pendall *et al.* [64], to the overt and indirect effects of high CO_2 and high temperature. The pools, roots and associated organic soil rhizospheral communities have various responses to climate change drivers. High CO_2 increases C supply below the layer meanwhile the temperature is expected to increase the rate of respiration and decomposition. Indirect influences on the availability of soil humidity and on the supply of nutrients can therefore change processes in unpredictable directions [65]. Temperature increase in the atmosphere may similarly enhance microbial operation but it may be eliminated if rainfall shifts contribute to drier conditions or a reduction in the litter amount, consistency, and turnover [66]. According to Kirkham [67], increased CO_2 levels are released as plant tissues grown under high atmospheric CO_2 degrade.

5.2 Nitrogen mineralization

Mineralization of organic matter is essential in order to supplement crop plants with essential nutrients [68]. Therefore, if N mineralization is decreased, plant growth will be adversely affected. As the C-N ratio of soil is increased by CO_2, soil organic matter decomposition needs further N by which microbes consume it in this breakdown, which will decrease the mineralization of N [69]. N limitation of CO_2 fertilized plants has been reported [70]. Even-though elevated temperatures stimulate the N availability of the soil, decomposition in SOC is still the net outcome. With increase in N mineralization [71] it has a positive impact on plant growth parameters. An *et al.* [72] observed that the N mineralization was increased in the first year because of the warming, but then decreased.

5.3 Nitrification and denitrification

Due to climate change affecting nitrification and denitrification, the various immersive environmental and biological causes are expected to change. The oxygen diffusion within the soil system greatly affects the nitrification-denitrification equilibrium, when the pore space with water is larger than 50 percent, under anaerobic conditions [73]. Increased ammonium (NH_4^+) abundance at intermediate pH ranges and in aerobic soil conditions supports the nitrification process, although it is limited as soils are very dry. The temperature response at nitrification is almost bell-shaped and has an optimal temperature of 20-35°C [74]. The high abundance of labile C as an energy source and of NO_3^- as an electron acceptor normally favors denitrification. It is favored in poorly ventilated areas and responds to near-nitrification temperatures but may be higher maximally [75]. Nitrification and denitrification both lead to the emission of a strong greenhouse gas (N_2O) of almost 300 times the global warming potential of CO_2 over 100 years [76]. Since N fertilizers are the best foretellers of N_2O soil emissions [77], soil moisture, soil temperature, oxygen partial pressure, organic carbon available and soil C/N ratio play significant roles in emission rates [78]. Since processes such as denitrification are sensitive to temperature, warming soils caused by climate change may have a strong beneficial impact on N_2O emissions [79]. In a global model, Riddick *et al.* [80] introduced climate dependency to predict N manure and fertilizer trajectories applied on the surface of the soil in changing climate conditions, and found N tracks to be highly heterogeneous both in terms of space and time. It was calculated from 14 percent in developed countries, to 22 percent in the developing countries, spatial and time volatilization of the NH_3 amount of agricultural fertilizer and manure was room. The highest NH_3 volatilization with heavy fertilizer and manure application in tropics, in India and China, was considered to be the best outcome of temperature dependency.

5.4 Nutrient acquisition

Soil moisture content deficit is expected not merely to affect crop production in many global warming scenarios but also to decrease the yields by their effect on soil nutrient supply and transport. The diffusion of nutrients over short distances and water soluble nutrient mass transfer over longer distances provide a deficit in soil humidity. Drought changes soil microbial composition and activities which estimates the C and N transformations governing soil fertility and nutrient cycles [81]. Intensive rainfall events associated with certain climate change scenarios negatively affect the food acquisition of lowly dry soils in fields, which could be hypoxic [82]. Bassirirad [83] notes that rhizosphere temperature gains may also promote the acquisition of nutrients by raising the intake of nutrients by rapidly diffusing the ion and increasing roots metabolism. However, the favorable impacts of warmer temperatures often rely on sufficient ground moisture. Extreme vapor pressure deficit is due to dry conditions that have increased temperatures which affects leaf stomatal closure [84] and reduces nutrient acquisition [85].

5.5 Soil erosion

Nearly each year, 75 billion tonnes of topsoil worldwide is lost through erosion (wind and water) and also by agriculture which costs approximately $400 (US) billion/year [86]. In a country like India topsoil is mainly lost by means of water erosion accounting 132 million ha^{-1} with 16.4 million in the form of terrain deformation [87] climate change by increased rainfall rate, soil erodability, vegetative cover and land use trends will most likely influence soil erosion. In a comprehensive study Pruski and Nearing [88] found that there is fluctuations in the rainfall intensity which has greater implications on soil erosion and runoff than being a result of storm frequencies. With the general circulation models it is still difficult to simulate the regional distribution of monsoon rainfall, the processes driving the monsoon, its seasonal cycles and modes of variability [89]. Garcı´a-Fayos and Bochet [90] revealed that correlations exists between climate change and soil erosion having negative effect on aggregate stability of soil, bulk density, water-holding capacity, pH, organic matter content, total N, and soluble P. With the adoption conservation practices it can result in an increase in organic concentration at surface soil leading to reduced soil erosions [91].

5.6 Soil acidity and salinity

Soil acidification is a phenomenon normally caused by the leaching of both essential cations and nitrate in areas receiving high rainfall. With increase in precipitation it may contribute to more leaching of basic cations (Ca^{2+} and Mg^{2+}) leading to soil acidification, whereas reduction in rainfall reduces soil acidity. Mainly the soil types found in semi-arid and arid zones can potentially be affected by acidification. Soil salinization is linked to changes in catchment hydrology resulting from land use and climate change. Hydrological changes in landscape leads to increase in the water tables thus increasing mobility of salts that are particularly stored in landscapes [92]. Climate change has the potential to change the hydrology of catchments by changes in precipitation, plant growth, runoff and seepage flows but this change will depending upon catchment characteristics. With less precipitation in the form of rainfall and increased evapotranspiration it may contribute to inadequate water flows that'll keep catchments flushed, evaporation and drying of some wetter areas may cause and outbreak of problems related to salinity. Regions that are mostly depending on irrigation for crop production are already susceptible to soil salinity problems [93] and with increase in temperature it will be affected more. An increase in the soils temperature substantially increases salinity accumulation particularly at depths of10–15cm in soil [94]. With proper soil and water management practices it can aid in mitigation of soil salinity problems. Brady and Weil [95] in a study portrayed that conservation agricultural practices that includes; reduced tillage, residue retention, crop rotations can influence the location and accumulation of salts by reducing evaporation and upward salt transport in the soil.

6 Agricultural management str ategies to mitigate climate change

Some of the best management practices that can enable mitigation are as below:

6.1 Tillage

The primary objective of tillage is physical destruction top soil layer for seed bed preparation, introduction of fertilizers and likewise weeds management. Various soil types, temperature, rainfall, management and technology in different regions lead different tillage operations. For sequestration of C in agricultural soils, interaction between tillage, SOM dynamics and composition of soil is necessary. Tillage practices like conventional tillage (CT) causes reduction in soil carbon accounting 35-60 percent and as low as 15 percent globally. Due to intensive tillage operations SOC oxidation occurs that causes emission of CO_2 into the atmosphere. Among the best tillage practices the 2 known tillage practices that causes positive impacts on soil carbon sequestration are; no-till, and reduced till and conventional tillage systems. No tillage increases soil quality and aggregation amounts, while conventional tillage acts against the structure of soil, which enhances the decomposition of the SOM. Conservation tillage practices hold more crop and crop residue on the soil surface and thus providing a higher SOC concentration at surface layer as compared to conventional tillage. Both tillage operations with cropping systems cause fluctuations in behavior and activities of microbial that eventually affect dynamics and stability of SOC. Also by decreasing soil tillage and increasing crop strength, soil mineralization may be minimized. Decrease in soil temperature by using surface mulches and no-till strategy is necessary to maintain soil organic matter stocks mainly in the tropical soils. Higher biota and especially microorganism density usually occur in no-tilled soils. Most of the studies indicate that no-till can quickly increase soil C, especially on the earth's surface, in conjunction with improvements in aggregation. In order to stabilize atmospheric C, the introduction of conservation tillage is expected to sequester 25 Gt C globally for the coming 50 years.

6.2 Cover crop

Cover cropping is mainly done for soil advantages rather than crop production. Cover cropping improves soil quality by increasing SOC biomass, improving soil aggregations and fertility and retaining soil against water erosion. C sequestered through cover cropping is subjected to different types of soil, management, elevations and the climate [96]. Past studies evaluate the amount of 0.22 tonnes per acre per year for cover crops emitting carbon in soil [97]. In-situ application of green manures increases biomass added to the soil, which allows increased C sink in the soil to be established. The benefits of introducing conservative tillage for SOC sequestration are greatly enhanced with growing cover crops during the rotation cycle. Increase growth of leguminous cover crops increase biodiversity, residue feed efficiency and SOC pooling [98]. Ecosystems having large biodiversity are known to consume and sequestrate more C than those with reduced or decreasing biodiversity. Drinkwater *et al.* [99] has reported that legume based cropping systems decrease soil C losses and nitrogen. Sainju *et al.* [100] observed that adoption of no till with hairy vetch will increase SOC. Also Franzluebbers *et al.* [101] found that forage management increases the SOC stream. Berzseny and GYearffy [102] documented the beneficial impact of increasing cover crops on enhancing SOC pool in Hungary. Adoption of cover cropping systems with intensive row cropping rotations with varying tillage treatments can mitigate climate change and sequester more SOC.

6.3 Crop rotations

Crop rotation implies series of crops cultivated on the same region of land in frequently repeated successions. Successive crops can last two or more years. The sequestration of C is influenced to a great deal by crop rotations, climate, soil and multiple crop management activities. Various legume crops, like lentils, peas, sesbania, alfalfa, chickpea and other known may serve as C and N sources. Implementation of crop rotations, in particular by leguminous cover crops containing C compounds are considered more resilient to microbial metabolism, will render soil C stable. The annual cropping rotations sequestered 27–430 kg C-ha−1/Year. As compared over bare fallow crop rotations [103]. SOC sequestration is more likely in sub-humid than in drier conditions with crop rotations without bare fallow. Various types of cropping systems can indeed be helpful in carbon sequestration, namely the, ratoon cropping, cover cropping, and companion cropping system. Intercropping that involves intercropping of rows, mixed cropping, and intercropping of relays may raise revenue, and can improve soil quality. Nayak *et al.* [104] that the rotating rice-weat system in the Indo-Gangetic Plains is the most effective cultivation system. A few of the intercropping examples include cotton and peanut, wheat and mustard, wheat and chickpea, peanut and sunflower. Thus long term organic agriculture can indeed increase organic carbon in soil compared with conventional agriculture [105]. Taking into account economic factors, choosing optimal rotation of cropping systems accordingly with soil-environmental factors may be helpful in C sequestration that not only increases plant productivity, fertility of soils but often lowers CO_2 emissions into the atmosphere.

6.4 Nutrient management

The sequestration of C in soil requires integrated nutrient management (INM). The lack of N, P, S and other building blocks of humus would severely limit the process for humification [106]. The effectiveness of sequestration is lowered when C and N are not managed properly [107]. The SOC sequestration level is also strengthened with an increase in biomass C application [108]. Chemical fertilizers, particularly N_2O, are a source of GHG emissions. In addition to this, the manufacturing of fertilizer and its transport are both correlated with GHG pollution. Through application doses of 50 percent NPK + 50 percent N through FYM in rice and 100 percent NPK in wheat consequently sequestered 0.39, 0.50, 0.51 and 0.62 Mg C ha^{-1} $Year^{-1}$ [109]. Adopting rice-rice system (RRS) under reduced tillage (RT) or no- till (NT) with INM is recommended for enhancing the productivity, C and N sequestration in paddy soils [110]. Liebig *et al.* [111] found that, relative to unfertilized samples, high N dose treatments improved SOC sequestration concentrations.

6.5 Organic manures and amendments

Another significant SOC sequestration technique is the use of manures and other organic amendments. Long-term studies in Europe revealed that with application of organic manures the intensity of SOC sequestration is larger than chemical fertilizers [112]. The rise of 10 percent over 100 years in Denmark [113], 22 percent over 90 years in Germany [114], 100 percent over 144 years in Rothamsted, UK [115] and 44 percent over 31 years in Sweden [116] in the SOC reservoir through long-term manuring at 0–30 cm depth. Manure application is essential for conserving soil health and it is a basis of C even its usage in various crop fields has an impact on C content. Use of organic amendments as substitution and additional nutrients has a beneficial impact on soil C sequestration and is often used as a C sink. In soils that have paddy cultivation, high clay content has ability to sequester more C [117]. Maltas *et al.* [118] reported that organic amendments viz. green manure, cereal straw , fresh cattle manure in 2 doses 35 and 70 t ha^{-1} and cattle slurry has the potential to supply 25-80 percent more C input to the soil. Uhlen & Tveitnes [119] stated that manure applications could increase the sequestration of SOC at a pace of 70–227 Kg ha^{-1} $Year^{-1}$ over 37–74 years. In contrasted to just NPK application, FYM along with NPK applications improves C sequestration in rice-wheat cropping method, whereas in green manuring, relative to applying FYM along with green manure, sequestered more C in Maize-Wheat crop rotation. In addition to increasing net primary production, composting also enhances the soil C quality. This all means that, along with other inorganic fertilizers, the usage of livestock waste, compost is advantageous for both plant health and climate.

6.6 Biochar

Biochar development is based on a process initiated thousands of years ago in the Amazon

Basin, where the indigenous people produced islands of thick, fertile soils called terra preta ("dark earth"). Anthropologists assume that the intended placement of coal in soil through cooking fires and middles led to a high productivity and C content in soils, sometimes with pieces of broken soil pottery. Biochar is enhancing soils by transforming crop waste into a fertile soil enhancer that preserves carbon and fertilizes fields. It is widely regarded as an effective means of C sequestering. It can successfully be used in concrete constructions as a C sequestering admixture to also help waste recycling [120]. Production of Biochar in association with soil preservation has been proposed as one potential way of decreasing CO_2 amount in the atmosphere [121]. Biochar climate change-mitigation ability derives mainly from its extremely recalcitrant nature that delays the process of return to the atmosphere of photosynthetically-fixed C [122]. Several studies have shown that Biochar use decreases polysaccharide / C co-location by decreasing C metabolism due to C fixation in organic soils. Combining Biochar with manure can decrease CO_2 and N_2O as comparing to manure sandy loam soil but not from the clay loam soil. However, higher amounts of application of Biochar (> 10 Mg ha^{-1}) and long-term monitoring are needed to assess the impact of Biochar on GHG emissions from the soil surface. Transformation of all sustainably produced crops to increase bioenergy, rather than Biochar, output will even mitigate up to 10 percent of global anthropogenic CO_2-Ce emissions. Biochar and bioenergy's relative climate-mitigation capacity depends on productivity changed soil and fuel intensity C being compensated with forms of biomass [123]. Under all other cases, the Biochar's climate-mitigation capacity is greater.

7 Conclusion

In conclusion, industrial revolutionization has caused the climate of the world to change to unexpected levels due to fluxes of greenhouse gases in the atmosphere. Climate change and global warming are a result of increased greenhouse gases in the atmosphere of which carbon dioxide is a major precursor of this changing scenario that all individuals around the world are encountering especially the agricultural sector. Climate and weather patterns have a direct influence on agriculture in terms of food security, sustainability of the soil that having profound effect on human health. With such gradual changes in climatic conditions it can modify the distribution of species and affect beneficial organism interactions in the soil-plant continuum. Temperature, precipitation and increased carbon dioxide levels in the atmosphere are hence considered the three major driving forces that influence soil properties (physical, chemical, biological) and its process which are soil organic matter decomposition, nitrogen mineralization, nitrification and denitrification, nutrient acquisition, erosion, soil salinity and acidity. There are several efficient mitigation measures that can reduce the brunt of climate change with the adoption of sustainable management practices such as following conservative agricultural practices that includes tillage operations, cover cropping and crop rotation, Biochar and through incorporation of organics and amendment that in turn would enhance soil processes and soil health without contributing to climate change.

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