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Climate Change Effect on Soil Health its Mitigation and Adaptation

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Abstract: Climate changes are recognized as one of the major factors responsible for soil properties affecting sustained development. Soil health has been described as an integral part of the concept of sustainable agriculture. Climate change has a potential impact on soil health through the physical, chemical and biological properties of soil. The change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods. Soil health is a composite set of measurable physical, chemical and biological attributes related to functional soil processes, which can be used to evaluate soil health status as affected by management practices and climate change. Defining soil health in relation to climate change should consider the impact of a range of predicted global change drives such as rising atmospheric carbon dioxide levels, elevated temperature, altered precipitation and atmospheric nitrogen deposition on physical, chemical and biological functions of soil.

Key words: Soil Health · Soil Organic Carbon · Soil Properties · Management Practices

INTRODUCTION

Soil is formed by the action of climate and biota on parent material over a certain period modified by topography. Changes in any of the soil-forming factors, such as climate, will impact directly and indirectly on current soils with important implications for their development, use and management. Climate parameters such as temperature (T) and precipitation have changed with progressing earth history globally, regionally and locally. Human activities are leading to changes in the global environment at virtually unprecedented rates, with potentially severe consequences to our future life. Soil systems are fundamental to sustainable development due to their multifunctional role in providing services including biomass production (food, feed, fiber and fuel); habitats for living organisms and gene pools (biodiversity); cleaning of water and air; mitigation of greenhouse gas emissions; contributions to carbon (C) sequestration and provisions to cultural, recreational and human health assets [1-3].

The effects of climate change are associated with increases in temperature and extreme weather events such as heavy rainfall, droughts, frosts, storms and rising sea levels in coastal areas. These effects may also increase the threats to the soil such as soil erosion, soil compaction, reduced soil fertility and lowered agricultural productivity, which ultimately deteriorates food security and environmental sustainability [4]. These climate related risks raise major concerns regarding the future role of soils as a sustainable resource for food production. The interaction of nutrients, irrigation and seasonal climatic variability particularly at low input of irrigation has several implications. Farmers often achieve far less than 50% of the climatic and genetic yield potential for a given sowing date. In addition to cultivar choice, climate plays a major role while attaining potential yield or maximum yield [5] all other factors being optimal.

Climate change has an impact on the soil through its effect on increasing air temperatures which cause higher soil temperatures, which generally increase the chemical reaction rate and diffusion-controlled reactions [6]. Climate change can affect soil functions directly and indirectly. The direct effects include soil process changes in organic carbon transformations and nutrient cycling through altered moisture and T regimes in the soil or increased soil erosion rates due to an increased frequency of high-intensity rainfall events. Several studies have assessed the effects of climate change on soil functions [1, 7, 8]. The indirect effects of climate change on soil functions include those that are induced by climate change adaptation options.

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Agricultural management can mitigate climate change effects, for example, through increased soil organic carbon (SOC) sequestration [9]. Several scenario studies have investigated agricultural adaptation options in response to climate change, including the introduction of irrigation regimes in drought-prone areas, crop rotation changes, increased fertilization rates on cropland, amended soil tillage practices and cultivation of melting permafrost soils [10-12]. Farmers may implement adaptations as a result of multiple, intertwined driving forces, including market price changes, new technologies and improved knowledge in combination with climate change [13]. Given these facts, this review is made to climate change effect on soil health.

The Importance of Changing Climate: Climate determines the type and location of human-managed ecosystems, such as agricultural farmlands even residential areas. Climate affects the weathering of rock, the type of soil that forms and the rate of soil formation. Climate helps to determine the quantity and quality of water available for human use, determines the severity of droughts, storms and floods. Climate largely determines the nature of biomes (major terrestrial ecosystems, defined based on their plant communities). Climate change affects the net primary productivity in interactive effect with land management practices by affecting soil processes influences; the composite set of measurable physical, chemical and biological soil attributes which relate to functional soil processes [14-18]. Agricultural activities have a profound effect contributing to the potential effect of climate change on soil health resulting through organic matter supply, temperature regimes, hydrology and Acidity. Following are the major consequences of climate change on soil health.

Soil Physical Properties Affected by Climate Change: Soil physical properties form the foundation of several chemical and biological processes, which may be further governed by climate, landscape position and land use. Thus, a range of soil physical properties when altered by climate change can trigger a chain reaction that leads to soil environment, which may greatly influence the growth and production of crops [19]. High temperature, high and low extremes of rainfall, increase in CO_2 concentration and their interactions due to climate change are expected to influence several soil physical processes. These factors subject the soils to a significant risk of salinization, decreased water availability and changes in C and N dynamics, nutrient storage in soil and reduction in soil biodiversity [20]. The physical properties and processes of soil affect soil health by altering water movement through soil, root penetration in soil and water congestion. Some key soil physical indicators about climate change include Soil texture, soil structure, aggregate stability, porosity, infiltration and plant available water, bulk density and soil temperature.

Soil Texture: Soil texture is a physical soil property, a basic determinant of soil characteristics. It changes very slowly in the soil formation time scale, hence is not prone to be affected on the time scale relevant to climate change studies. However, among other features, it determines the sensitivity of soil to changes in climatic factors. The four potential climate scenarios (arid, semi-arid, sub-humid and humid) have a great impact on important soil processes as the texture differentiation in the soil profile. Regarding the cracking and shrinking phenomenon of clay soils, however, these soils appeared to be also sensitive to a changing climate if the number of wetting and drying in shrinking-swelling clay cycles increases. This in turn influences and facilitates greatly the formation of cracks in the soil. Deep cracks result from rapid, direct movement of water from the surface soil to permeable substrate or drainage installations through bypass flow. It can decrease the filtering function of the soil and increase the likelihood of nutrient losses and water pollution [21].

Bormann [22] indicated that changes in the seasonal soil moisture regime are strongly determined by the regional changes in climate and by climate-induced changes in capillary moisture transport from the groundwater to the root zone. The authors found that soils with the highest water retention capacity (silty soils) reacted most sensitively to changes in climatic parameters, whereas clay soils showed the least sensitivity also as a function of vegetation density, rooting depths and transpiration. Istanbulluoglu and Bras [23] also emphasized the importance of soil texture in controlling the magnitude and shape of climate-soil vegetation-landscape functions but did not analyze their sensitivity to climate change.

Soil Structure and Aggregate Stability: Changes to soil structure are hard to quantify because of the influence of land use and management. Changes to soil structure are hard to quantify because of the influence of land use and management. Soil structure is the unique property of the soil that has a fundamental effect on the behavior of soils, such as water holding capacity, nutrient transformations and movement, nutrient leaching and drainage [24]. Climate change deteriorates the soil structure.

The most important direct impacts of climate on the soil structure are the destructive potential of raindrops, surface runoff and filtrating water, due to extreme rain events [25]. The structure of the soil dictates organic C accumulation, infiltration capacity, movement and storage of gases, water and nutrients, the emergence of crops and root activity. It can also be used to measure soil resistance to erosion and management changes because it is a measure of aggregate stability, the resistance of soil aggregates to external energy such as high-intensity rainfall and cultivation are important [26]. Aggregate stability is considered a useful soil health indicator since it is involved in maintaining important ecosystem functions in soil including organic carbon accumulation, infiltration capacity, movement and storage of water root and microbial community activity. It can also be used to measure soil erosion and management changes [14, 26].

The nature and quality of the structure are strongly influenced by the amount and quality of organic matter present, inorganic constituents of the soil matrix, cultivation methods and natural physical processes such as shrink-swell and freeze-thaw behavior. A decline in soil organic matter levels leads to a decrease in soil aggregate stability, infiltration rates and an increase in susceptibility to compaction, run-off, furthermore susceptibility to erosion [5, 19]. Thus, managing soil structure through increasing soil organic matter content contributes to the maintenance of soil health.

Porosity: Porosity is a measure of the void spaces in material as a fraction (volume of voids to that of total volume) and pore size distribution provides the ability of soil to store root zone water and air necessary for plant growth [27]. Pore characteristics are strongly linked to soil physical quality, bulk density, micro porosity and functions of the pore volume. While soil porosity and water release characteristics directly influence a range of soil indices including soil aeration capacity, plant available water and relative field capacity. Soil porosity and pore size distribution consequently soil functions are likely to be affected in unexpected directions [27]. Root development and soil microbe enzyme activities are closely related to soil porosity and pore size distribution [19]. Decreased microbial activity reduced root growth and exudates, reduce aggregate stability. Increased rainfall intensities which are the result of climate change, where rain droplets impact causes surface sealing on sodic soils leads to poor crop emergence, growth and increases chances of surface runoff [28].

Infiltration and Plant Available Water: The water availability for plant growth and important soil processes are governed by a range of soil properties including porosity, field capacity, the lower limit of plant-available micro pore flow and texture [27, 29]. Plant available water capacity has been used as part of integrative soil health tests to assess management impacts. Furthermore, the soil available water and distribution may respond rapidly to climate change. Its effect especially on variable and high-intensity rainfall or drought events and thus management strategies could be planting of cover crops, conservation tillage and incorporation of organic matter, which maintain or even enhance water infiltration and available water in the soil which help in mitigating the impact of severe rainfall and drought events or severe erosion events [30].

Bulk Density: Bulk density is routinely assessed to characterize the state of soil compactness in response to land use and management [31]. Bulk density in general negatively correlated with soil organic matter (SOM) content [32]. The loss of organic carbon from increased decomposition due to elevated temperature [33] may lead to an increase in bulk density and hence making the soil more prone to compaction vis land management activities and climate change stresses from variable and high-intensity rainfall and drought events [34] which results in decreased porosity and compact layer formation inhibiting root growth. Root development, as well as microbial activity, may be altered by climate change via changes in soil water and temperature regimes and changes in soil hydro-physical properties such as alterations in bulk density or the development of preferential flow paths [35].

Soil Temperature: The soil temperature regime is governed by gains and losses of solar radiation at the surface, the process of evaporation, heat conduction through the soil profile and convective transfer via the movement of gas and water Karmakar *et al.* [5]. Trends in soil temperature are important but rarely reported, indicators of climate change. Though not the same, there is a close relationship between air temperature and soil temperature and a general increase in air temperature will inevitably lead to an increase in soil temperature. As with soil moisture, the soil temperature is a prime mover/factor in most soil processes. Warmer soil temperature will accelerate soil processes, increase microbiological activity, cause rapid decomposition of organic matter, hasten nutrient release, increase nitrification rate and generally accentuate chemical weathering of minerals. However, soil temperatures will also be affected by the type of vegetation occurring at its surface, which may change itself as a result of climate change or adaptation management [5]. Increasing soil temperature harms climate change that disturbs soil health. To manage this soil cover (through mulching and plantation) is useful to keep soil temperature to the need of microorganisms and the growing plant's Insafe climate.

Soil Chemical Properties Affected by the Climate Change: The most important soil chemical properties are the soil pH, electrical conductivity, nutrient and carbonate contents and their distribution in the soil profile, cation exchange capacity (CEC) and rate of acidification or alkalization. While it is crucial to consider soil carbon cycling to obtain a better understanding of soil chemical responses to climate change, since the topics are too large for the present review paper; the focus is limited to some of the direct impacts on soil chemical properties.

Soil pH and Electrical Conductivity: Soil pH is a function of inherent parent material, time of weathering, vegetation and climate. It is considered an important indicator of soil health. Soil pH has thus been included in integrative soil health tests to assess impacts of land-use change and agricultural practices [28], it has much influence on nutrient solubility and availability. Increasing precipitation, however, can intensify leaching and lead to soil acidification. When the soil pH gets low some toxic elements like Al and Mn get solubilized and affect plant growth [36]. Soil acidification affects soil chemistry since low pH values promote the mobilization of potentially toxic elements (heavy metals). The decrease in pH can result in the depletion of basic cations through leaching in soil that is well-drained, structurally stable and receives high amounts of intense rainfall.

In a wetter climate, soil acidification could increase if buffering pools become depleted. Drivers of climate change will affect SOM status, nutrient cycling, plant available water and hence plant productivity, which in turn affects soil pH [37]. The Soil pH decreased with increasing elevation, due to increased leaching of basic cations in the higher elevations from greater precipitation and increased nitrification. Therefore, the pH of soil decreases when one moves from lower elevation to higher elevation [38].

Soil electrical conductivity (EC) is a measure of salt concentration. It indicates trends in salinity, crop performance, nutrient cycling and biological activity and quality [39]. Along with pH, it can act as a surrogate measure of soil structural decline, especially in sodic soils [40]. Increasing temperatures and decreasing precipitation increase the electrical conductivity under climate change scenarios [38]. According to Pariente [41], the dynamics of soluble salts concentration in soils from four climatic regions (Mediterranean, semi-arid, moderately arid and arid) and found a non-linear relationship between the soluble salts content and rainfall, with sites that received $<$200 mm rainfall contained significantly high soluble salt contents and vice versa.

Cation Exchange Capacity: Cation exchange capacity (CEC) refers to the total amount of cations exchanged on soil colloidal surfaces such as clay mineral and organic matter surfaces. The CEC of soilsis also considered as an important soil chemical property particularly the retention of major nutrient cations $Ca2^{+}$, Mg^{2+}, K^{+} and adsorption of organic molecules that potentially toxic cations $Al3^{+}$ and Mn^{3+} [28]. These properties can thus be useful indicators of soil health informing a soil's capacity to absorb nutrients as well as pesticides and chemicals [42]. The CEC of coarse-textured soils and low-activity clay soils is attributed to that of SOM, the increasing decomposition and loss of SOM due to elevated temperatures which may lead to the loss of CEC of these soils [33]. Low CEC of soil may result in increased leaching of base cations in response to high and intense rainfall events, thus transporting alkalinity from soil to waterways.

Acidification: Soil acidification is a natural process that usually occurs as a consequence of nitrate leaching in high-rainfall areas [43]. Large areas of acidified soils in most countries become a primary problem for agricultural soils, where land management practices modify and aggravate the process [44]. Climate determines the dominant vegetation types, their productivity, the decomposition rate of their litter deposits and influences soil reaction in this indirect way. An increase in the extent of acidification depends on both temperature and rainfall, i.e. regulated by climate. Significant increases in rainfall will lead to increases in leaching, loss of nutrients and increasing acidification, depending on the buffering pools existing in soils [28], whereas a decline in rainfall reduces the intensity and extent of acidification [45].

Acid sulfate soils are examples of acidification as they suffer from extreme acidity as a result of the oxidation of pyrite when pyrite-rich parent materials are drained. Changes in soil pH that may be associated with climate change can influence colloidal surface charge and adsorption capacity of the colloidal material. The increase in temperature and precipitation because climate scenarios have great contribution to the acidification of the soil.

Plant Available Nutrients: Nutrients are another important constituent of soil and the concentration of soil nutrients varies from one geographical region to another. Soil nutrient quantity is often affected by climatic factors. Changes in temperature and precipitation could affect soil nutrient levels in numerous manners. Increasing temperatures could act to assert nutrients within the soil because of raised evaporative forces and abbreviate leaching [46]. Downward movement of water in soil leads to loss of soil nutrients; hence to a great extent affects the soil nutrient level. Moreover, a decrease in rainfall may cause upward movements of nutrients and thus lead to salinization. In tropical and subtropical countries, the loss of soil nutrients is an increasing problem [47, 48]. Measurement of extractable nutrients may indicate a soil's capacity to support plant growth; conversely, it may identify critical or threshold values for environmental hazard assessment [14]. Nutrient cycling especially N is intimately linked with soil organic carbon cycling [32] and hence drivers of climate change such as elevated temperatures, variable precipitation and atmospheric N deposition are likely to impact N cycling and possibly the cycling of other plant-available nutrients such as phosphorus and sulfur.

Response of Soil Biological Properties to Climate Change: The soil biota is adaptive to changes in environmental circumstances. Under conditions of climate change, biological indicators form an integral component in soil health assessment. Key biological indicators selected for the scope of this review include soil microbial biomass, soil respiration, enzyme activity, potentially mineralizable C and N, Soil carbon, C:N ratio and soil organic matter.

Soil Microbial Biomass: Microbial biomass is the living component of SOM. It is considered as the most labile C pool in soils and a sensitive indicator of changes in soil processes with links to soil nutrient and energy dynamics including mediating the transfer between SOC fractions. Soil microbial biomass is responsive to short-term environmental changes [15, 49]. Studies by Rinnan *et al.* [50] revealed a significant decline in the soil microbial biomass during long-term simulated climatic warming experiments. The relative abundance of bacterial phyla was impacted by the precipitation treatment, which led to shifts in the relative abundance of proteobacteria and acido bacteria. Carbon dioxide and temperature didn't create a major impact on the distribution of these groups. The relative abundance of proteobacteria was greater in the wet relative to the dry treatments, whereas acido bacteria abundance was greater in dry treatment. Because acido bacteria is a ubiquitous phylum in soil, they required aerobic conditions for their metabolism, proteobacteria required anaerobic conditions for their metabolism [51].

Soil Respiration: As soil respiration positively correlated with SOM content it is used as a biological indicator for soil health. Soil respiration, particularly its temperature response is widely acknowledged to be a critical link between climate change and the global C cycle [51]. Studies have also shown that soil respiration is relatively responsive to changes in the seasonal timing of rainfall/soil moisture, which is predicted to change according to global and regional climate models [52].

Enzyme Activity: Soil enzyme activities show a rapid response to changes in soil management [53, 54]. Its activities may serve to indicate change within the plant-soil system since these are closely linked to the (1) cycling of nutrients and soil biology, (2) are easily measured, (3) integrate information on both the microbial status and the physicochemical soil conditions and (4) show rapid response to changes in soil management [54]. Studies of individual enzyme activities report strong temporal and spatial variability, often leading to conflicting results [53-55] showed that by altering the quantity and quality of belowground C input by plants, elevated CO_2 may stimulate microbial enzyme activities [51]. Furthermore, altering the quantity and quality of belowground C input by plants, elevated CO_2 may stimulate microbial enzyme activities, an abundance of microbial enzymes and C turnover possibly affecting microbial community functioning in soil. It is still to be known how soil microbial enzyme activities are involved in organic C turnover, nutrient cycling and greenhouse gas emissions.

Potentially Mineralizable C and N: Mineralizable organic matter acts as an interface between autotrophic and heterotrophic organisms during the nutrient cycling process [56]. However, mineralizable organic matter is useful to assess soil health under climate change, since it can affect nutrient dynamics within single growing seasons. These processes are closely connected with the soil moisture regime and with the abiotic and biotic transformation phenomena (fixation, immobilization/ release, mobilization; changes in solubility and redox status, etc.). High precipitation increases leaching, filtration loss (potential groundwater pollution) and reductive processes. Low precipitation (dry conditions) may reduce the solubility, mobility and availability of available elements and compounds. Groffman *et al.* [57] reported that the rates of in situ net mineralization and nitrification increase with soil moisture content in summer. The rates of in situ net mineralization and nitrification are faster in summer than in winter and in high elevation plots than in lower elevation plots. Net nitrification is particularly slow on the lower valley low elevation plot. Castro *et al.* [51] reported that potential mineralization and nitrification is more in the case of ambient carbon dioxide treatment compare to elevated conditions.

Soil Carbon and C: N Ratio: Rosenzweig and Hillel [35] and Lal [58] reported that increased temperature and episodic rainfall stimulate microbial activity (mineralization/decomposition). This leads to reduced biomass accumulation, depletion of soil carbon and decrease C: N ratio. Increased atmospheric CO_2 increases plant water use efficiency (WUE). It in turn increases biomass production per mm of available water [59]. A decomposition rate is greater than net primary production under an increased water deficit. This process causes the drier condition favorable for organic carbon reduction. Drought-induced losses of biomass; which reduces the annual and perennial vegetation. Its mitigation management strategies include conservation tillage practices, crop residues management, green manuring and intercropping.

Soil Organic Matter: Soil organic matter is arguably the most important soil component, influencing as it does soil structure, water/pore space holding capacity, soil stability, nutrient storage and turnover and properties that are fundamental in maintaining and improving soil quality. A decline in organic matter content increases the susceptibility to soil erosion. Organic matter is a particularly important prime habitat for immense numbers and variety of soil fauna and microflora, which play a critical role in the health and productivity of soils. Soil organic matter comprises an extensive range of living and non-living components; it is one of the most complex and heterogeneous components of soils that vary in their properties, functions and turnover rates [32]. It provides and/or supports including the contribution to the charge characteristics of soils, a sink for and source of C and N and to a variable extent regulates phosphorus and Sulphur cycling. It provides microbial and faunal habitat and substrates, as well as affects aggregate stability, water retention and hydraulic properties [15, 32]. As SOM drives the majority of soil functions, decreases in SOM can lead to a decrease in fertility and biodiversity, as well as a loss of soil structure, resulting in reduced water holding capacity, increased risk of erosion and increased bulk density and hence soil compaction. Conversely, the addition of organic materials like vermicompost improves soil water holding capacity, soil pH and reduces toxic elements solubility which is very important to enrich the organic carbon content of the soil [60].

Generally, an increase in temperature has been reported to enhance SOM decomposition, but rising temperature, precipitation, CO_2, fertilization and atmospheric N deposition may support high plant productivity and OM input to soil and consequently increase SOM. Davidson and Janssens [33] reported that accessibility and availability of SOM to micro-organisms govern SOM losses rather than rate-modifying climate factors (i.e. temperature). The rate of decomposition exceeds the rate of humus formation when moving from cold to hot climates. Higher biomass production of wild plants, as well as more crop residues as a consequence of higher crop yield, increases the nutrient offer for soil organisms. Higher soil temperatures also stimulate the activity of soil organisms. Here, aerated soils of the lower and middle latitudes higher humus contents can be expected. In contrast, in the soils of higher latitudes smaller humus contents will occur. Wet soils with low air content, even in humid tropical areas, will be characterized by increasing humus contents. Higher soil temperatures will also stimulate the activities of aggregate forming and soil mixing animals among the soil organisms, in fact mainly the activities and efficiency of earthworms [61].

The impact of climate change factors, specifically temperature, CO_2 and rainfall on various soil properties is being discussed below to understand the relationship between climate change variables and various soil properties to evolve appropriate mitigation strategies (Table 1).

Table 1: Summary of expected effects of individual climate change variables on soil processes.

Climate change factors	Soil properties affected
Increasing Temperature	Loss of soil organic matter and soil structure
	Reduction in labile pool of SOM, moisture content
	Increase in mineralization rate
	Increase in soil respiration rate
Increasing CO_2 Concentration	Increase in soil organic matter and water use efficiency
	More availability of carbon to soil microorganisms
	Accelerated nutrient cycling.
Increasing Rainfall	Increase in soil moisture or soil wetness
	Enhanced surface runoff and erosion
	Increase in soil organic matter
	Nutrient leaching
	Increased reduction of Fe and nitrates
	Increased volatilization loss of nitrogen
	Increase in productivity in arid regions
Reduction in Rainfall	Reduction in soil organic matter
	Soil salinization
	Reduction in nutrient availability

Mitigation and Adaptation of Adverse Effects of Climate Change on Soil Health: The direct and indirect effects of climate change on our soil demand strong efforts to prevent additional adverse impacts, efforts to adapt to the impacts already occurring should be made. Oladipo [62] stated that a variety of options for mitigation (reduction of greenhouse gases) exists in agriculture; they fall into three broad categories (a) reducing emission of CH_4, CO_2 and nitrous oxide through efficient management of the flows of these gases in agricultural and other ecosystems (b) enhancing the removal of CO_2 through improved management of forestry and agroecosystems and (c) avoiding (or displaying) emissions.

Adaptation can be both autonomous and planned [62]. Autonomous adaptation is the ongoing implementation of existing knowledge and technology in response to changes in climate experienced and planned adaptation is the increase in adaptive capacity by mobilizing institutions and policies to establish or strengthen conditions that are favorable to effective adaptation and investment in new technologies and infrastructure. Adaptation should be properly targeted to avoid negative impacts, such as increasing competition on existing resources [63]. To minimize the negative impacts of climate change, several mitigation and adaptation measures need to be taken. Such adaptation measures would vary from one country/region/state to another and from one socioeconomic sector to another. Following are several practices that can help producers adapt to or mitigate the impacts of climate change.

- Ensuring that the soil is protected all the time through mulching (i.e. live, plastic and plant residue mulch). The unprotected soil surface is exposed to the direct impact of raindrops, causing disruption of soil aggregates and sealing and crusting effects. Sealing effects cause sharp decreases in water infiltration rates under wet conditions. Crusting effects refer to seals that have dried and hardened, resisting seed emergence.
- Changing input such as crop varieties and/or species and using inputs with increased resistance to heat shock and drought; altering fertilizer rates to maintain grain or fruit quality consistent with the climate and soil condition and altering amounts and timing of irrigation and other water management practices [64, 65].
- Making wider use of technologies to harvest water, to conserve soil moisture (e.g. crop residue retention) and to use water more effectively in areas where there is a decrease in rainfall [66].
- Reduction of deforestation and promotion of afforestation/reforestation (planting of trees). This will increase biological carbon sequestration. Carbon sequestration implies transforming atmospheric carbon dioxide into long-lived pools and storing it securely so it is not immediately re-emitted [58]. Currently, the biosphere constitutes a carbon sink that absorbs about 2.3 gigatons (Gt) of carbon per year, which represents about 30% of fossil-fuel emissions. Forests usually regulate stream flows,

protect the land from erosion, reduce flooding in adjacent areas, minimize silting of rivers, canals and dams and contribute to stable hydrology essential for providing a stable source of water for human need and irrigated agriculture [67]. The increasing atmospheric carbon dioxide concentration stimulates photosynthesis and consequently plant growth [68]. Forests stimulate more than pastures and crops in the proportion of 60% to 14% respectively. Forest trees/plants can take up carbon for 20-50 years after establishment. Research on carbon sequestration is therefore suggested as an adaptive measure for the different agroecological zones.

- Increased application of fertilizers and inoculation of beneficial organisms into the soil. Some organisms' i.e. N-fixing organisms when inoculated into the soil improve N supply to crops. When appropriate organic and inorganic fertilizers are applied to the soil, the fertility of the soil increases and plant growth is enhanced thus promoting carbon sequestration.
- Effective erosion and desertification control. This could be affected through any of the following methods. Closure of most footpaths inside gullies; banning illegal entry into gullies in search for stones, marbles, clay, firewood, animal feeds, fruits, etc; construction of sumps and lateral drainage gutters diagonally off all roads and major paths in towns and villages. Construction of drainage systems on both sides of major roads leading to villages in the gully erosion section of the town; making it mandatory on all homes/compounds to provide at least one deep well to trap rain flood emanating from the compound. Construction of concrete roads and concrete drainage systems in the worst sections of towns whose soils are severely prone to erosion; arranging for all citizens of any given town or community (whether local or abroad) to undertake maintenance/construction/extension work on their roads, drainages, sumps at least twice each year; grassing lawns and open spaces [4].

The conservation tillage and residue management also help in the following ways in influencing some of the soil properties and mitigating the adverse effects of climate change on soil health [69]. Conservation agricultural practices help in improving soil organic matter by way of Regular addition of organic wastes and residues, use of green manures, legumes in the rotation, reduced tillage, use of fertilizers and supplemental irrigation, Drilling the seed without disturbance to soil and adding fertilizer through drill following chemical weed control. Maintaining surface residue, practicing reduced tillage, recycling of residues and inclusion of legumes in crop rotation [70]. It is necessary to spare some residue for soil application, which will help in improving soil tilth, fertility and productivity. Conservation tillage reduces soil compaction and erosion and increases soil organic matter and infiltration capacity all of which reduce runoff and increase drought resilience [71]. Tilling the field exposes soil organic matter/carbon to oxidation and makes the soil more susceptible to erosion, both of which result in carbon depletion and, as a consequence, less productive soils. Advances in seed technology, pest control and farm machinery are making no-till and reduced-till practices more acceptable to producers.

Reducing Bulk Density and Increasing Porosity: Bulk density and porosity are inversely related. Tillage layer density is lower in plowed than unploughed (area in the grass, low tillage area, etc.). When residues are involved, tilled soils reflect lower density. Mechanization with heavy machinery results in soil compaction, which is undesirable and is associated with increased bulk density and decreased porosity. Natural compaction occurs in soils, which are low in organic matter and requires loosening. But practicing conservation tillage to offset the compaction is effective only when there is adequate residue, while intensive tillage may adversely influence the soil fauna, which indirectly influences the soil bulk density and porosity.

Minimizing Soil Crusting and Erosion, to Increase Infiltration: Tillage influences crusting, hydraulic conductivity and water storage capacity. It is understood that the textural influences and changes in the proportion of sand, silt and clay occur due to inversion and mixing caused by different tillage instruments, tillage depth and mode of operation and effect of soil erosion. Soil crusting which severely affects the germination and emergence of the seedling is caused due to aggregate dispersion and soil particles resorting and rearrangement during rainstorm followed by drying. Conservation tillage and surface residue help in protecting the dispersion of soil aggregates and helps in increasing saturated hydraulic conductivity. Increased hydraulic conductivity in conjunction with increased infiltration resulting from conservation tillage allows soil profile to be more readily filled with water. Further, less evaporation is also supported by conservation tillage and the profile can retain more water. Which have great contributions to minimize runoff [63].

Increasing the amount of rain that infiltrates into the soil and the soil water-holding capacity or available water content can reduce the impacts of both drought and extreme rainfall events. As more water infiltrates, more can be stored in the soil and less runs off to occur, which also reduces the probability of nutrient and sediment loss. One way to increase soil water-holding capacity is to increase the amount of soil organic matter in the soil profile.

Cover Crops/Crop Rotations: Cropping sequences that include a fallow period tend to reduce soil carbon levels as compared to continuous cropping, which tends to increase soil carbon levels. Cover crops and nitrogen-fixing legumes are often recommended to enhance fertility and increase the soil organic matter content. Cover crops help to ensure that soil is protected during intense rainfall events by absorbing raindrop impact, which reduces erosion and nutrient removal through runoff; they also protect the soil during periods of drought, when wind erosion can remove topsoil. A greater number of rotations in any given crop rotation cycle can also help to reduce pest pressure, thus enhancing a field's productive capacity [63].

Improving Irrigation Efficiency: Irrigation during some portions of the growing season is essential in certain regions and it is expected that the reliance on irrigation will increase substantially both in traditionally irrigated crops and in those that will need to be irrigated due to increased temperature stress. This coupled with increasing per capita water demand will result in even greater stress on water resources. Thus, increasing irrigation efficiency will enable producers to irrigate more land with fewer resources. Practices such as regular system maintenance, frequent system audits, using recycled water, using drip or subsurface-drip irrigation systems and incorporating soil moisture sensor networks to refine timing and target regions of a field are some common ways to improve irrigation water use efficiency [63].

Improving Nitrogen Use Efficiency: Excessive rainfall can result in the leaching of valuable nitrogen from the crop root zone. If nitrogen applications are optimized based on actual crop need and to the extent possible applied when there is a low potential for leaching, yields and profits can be increased. Nutrient management tools that improve the timing, method of application and amount of nitrogen applied should be used when possible. Some examples of these tools include nitrogen-content-sensing fertilizer applicators (e.g., Green Seeker and many others), incorporating short and long-term meteorological forecasts into fertilizer scheduling (e.g., evolving software tools such as Adapt-N) and utilizing soil moisture sensor networks to optimize timing. These strategies also decrease the amount of nitrogen that is lost to the environment [63].

CONCLUSION

The quantitative evaluation of predicted climate change effect on soil health is a difficult task due to uncertainties in the weather forecast. Climate change and land degradation are closely linked issues and conservation farming has shown promise in minimizing land degradation. Hence, the potential of conservation agriculture in minimizing the impact of climate change needs thorough investigation. Agricultural practices that have a contribution to increasing organic carbon in the soil; agricultural water management that keeps soil moisture to an optimum level and the number of inputs added to increase the crop productivity are better considered in line with soil health aspects. The adoption of conservation tillage and residue management, necessitate a complete package of practices used based on intensive research results for each agroecology. However, the site-specific management practices for soil and water conservation, crop improvement and integrated nutrient management need to be identified to overcome the impact of climate change on the physical, chemical and biological properties of soil.

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