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CHALLENGES OF SOIL FERTILITY MANAGEMENT UNDER CHANGING CLIMATIC CONDITIONS: A REVIEW

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ABSTRACT

Climate change represents a serious threat to global food security, not because of its effects on soil, but also for its effect on crop production. Changes in temperature and rainfall patterns can have a great impact on the organic matter and processes that take place in our soils, as well as the plants and crops that grow from them. In order to meet the related challenges of global food security and climate change, agriculture and land management practices must undergo fundamental transformations. Improved agriculture and soil management practices that increase soil organic carbon, such as cover crop rotation, integrated soil fertility management, organic farming, conservation agriculture and agroforestry, bring multiple benefits. They produce fertile soils that are rich in organic matter (carbon), keep soil surfaces vegetated, require fewer chemical inputs, and promote crop rotations and biodiversity. These soils are also less susceptible to erosion and desertification, and will maintain vital ecosystem services such as the hydrological and nutrient cycles, which are essential to maintaining and increasing food production.

Soil fertility is declining as a result of climate change, which brings more extreme weather events such as flooding, drought and more unpredictable weather conditions. Some common farming practices such as burning crop residues, use of fertilizer, improper crop rotation, land clearing and deforestation are part of the problem. But there are many traditional and modern agricultural practices which can help boost soil fertility and assist farmers in making their farms more resilient to the changing climate. These include organic farming, using rather than burning crop residues, and other organic materials, planting nitrogen-fixing crops and trees, use of compost and other manures, and using practices which conserve soil and water.

INTRODUCTION

Climate change refers to some observable variations in the climate system that are attributable to human (anthropogenic) activities especially those that alter the atmospheric composition of the earth and ultimately lead to global warming. Climate change refers to the observed and/ or predicted changes in the interactions between the chemical and physical climates of the earth (IPCC, 2007). Climate change threatens to increase the potential for soil erosion, reduce soil quality, lower agricultural productivity and negatively impact food security and global sustainability, making it one of the most severe challenges we will face in the 21st century. Climate change leads to increased activity of soil microorganism that will cause a loss of organic matter and nitrogen in the soil, accelerated soil degradation, erosion as well as weakening in the capacity of the agricultural ecosystem to resist natural disasters (Lim, 2010). Climate is expected to bring more extreme weather events such as flooding, drought and more unpredictable weather. These changes will truly deepen problems with soil fertility (Farm Radio International, 2009). Global warming is the term used to describe the gradual increase in the average temperature of earth's atmosphere. Global warming is caused by increase in the emission of GHGs through the burning of fossil fuels (oils, natural gas and coal), burning of wood, wood products and solid wastes, raising of livestock and the decomposition of organic wastes in solid wastes landfills; combustion of solid wastes and fossil fuels in industrial and agricultural activities; bush burning; and deforestation. All these human (anthropogenic) activities contribute to alter the balance of the equilibrium between the natural GHGs (water vapour, carbon dioxide, methane and nitrous oxide) and the man-made GHGs (sulfur hexane fluoride- (SF_6); hydro-fluorocarbons-(HFCs); and perfluorocarbons (PFCs) in Earth's atmosphere thus promoting the warming of both the atmosphere and the oceans since they are heat-trapping gases (1PCC, 2005)

Soil fertility is defined as the capacity of the soil to supply nutrients to the plant required for the successful production of plant life (IFDC, 2010). It is also defined as the capacity of a soil to supply adequate and sufficient nutrients to plants (Usman, 2008). Soil fertility management involves sustaining and increasing soil fertility and maintaining food production in an economically, ecologically and socially acceptable way (Usman, 2008).

Agriculture is not only affected by climate change but also contribute to it (Niggli et al., 2008). Ten to twelve percent of global greenhouse gas emissions are due to human food production. In addition, intensive agriculture has led to deforestation, overgrazing and widespread use of practices that result in soil degradation. These changes in land use contribute considerably to global CO_2 emissions. Soil fertility management can boost the capacity of agricultural production to adapt to more unpredictable and extreme weather conditions such as droughts, and floods, reduce greenhouse emissions and reverse carbon losses from soils (Van Oost et al., 2004).

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CLIMATE CHANGE; ITS CAUSES AND EFFECTS

Phenomenon of climate change

According to IPCC (2007), climate change refers to the observed and/ or predicted changes in the interactions between the chemical and physical climates of the earth. The current change in the global climate is a phenomenon that is largely due to the burning of fossil energy (coal, oil and natural gas) to the mineralization of organic matter as a result of land use. These processes have been caused by man's exploitation of fossil resources, clearing of natural vegetation and use of these soils for arable cropping (Kotschi and Muller, 2004).

According to NETI (2010), the primary gases that contribute to the greenhouse effect include:

1. Carbon dioxide (CO_2): it is an important component of the atmosphere. Carbon dioxide is released through natural processes such as respiration, volcanic eruptions and through human activities such as deforestation, land use changes, burning fossil fuels and land clearing for agriculture, which leads to an increase in the decomposition of organic matter in the soil transferring the stored carbon in the organic matter into carbon dioxide, which also increase the carbon dioxide concentration in the atmosphere (Daniel and Edward, 1998).
2. Methane: a hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills and water dumps, agriculture and especially, rice culture as well as ruminant digestion (cud-chewing) and manure management associated with domestic livestock.
3. Nitrous oxide: a powerful greenhouse gas produced by soil cultivation practices, especially with the use of commercial and organic fertilizers, leguminous plants, fossil fuel combustion, nitric acid production and biomass burning

Causes of climate change

The Agricultural sector contributes to the emission of these greenhouse gases through the following ways:

1. Land clearing for agriculture leads to an increase in the decomposition of organic matter in the soil, transferring the carbon stored in the organic matter into CO2 which increases the CO2 concentration in the atmosphere (Daniel and Edward, 1998).
2. Deforestation
3. Paddy rice cultivation
4. Enteric fermentation (Ruminant production)
5. Manure management and fertilizer application
6. Biomass burning (slash and burning agriculture)

According to Edu-green (2010), the Energy sector contributes to the emission of these greenhouse gases through the following ways:

1. Electricity is the main source of power in urban and rural areas. All our gadgets run on electricity generated mainly from thermal power plants, which are run on fossils fuels, and are responsible for the emission of huge amounts of greenhouse gases and other pollutants.
2. Cars, buses and trucks which transport goods and people are run mainly on petrol of diesel, both are fossil fuels.

3. Timber is used for construction of houses, and in paper making, which means that large area of forest has to be cut down.
4. Industrial fertilizer production and fertilizer uses result in more emission of nitrous oxide.

Effects of climate change

According to Environment and Greener Living (2010), the effects of climate change are:

1. Sea level rise: global warming leads to sea level rise with its attendant consequences that include increased frequency and intensity of storms, floods, poverty and malnutrition.
2. Rising temperature: the global temperature will rise as a result of greenhouse gas emission. This could make some species of plants and animals extinct, and there are already changes to the way plants and animals live. Further changes in temperature will affect many animals and plants species around the world, resulting to inability of them to adapt quickly and habitats might not be available for them to move into resulting in an increased risk of extinction.
3. Reduced crop yield: as temperature increases and rainfall pattern changes, crop yields are expected to drop significantly. Water availability for irrigation and drinking will be less predictable because rain will be more variable. It is also possible that salt from rising sea level may contaminate underground fresh water supplies. Droughts are likely to be more frequent (Wikipedia, 2010). Global warming leads to excessive evapo-transpiration which is the process by which plants lose water usually from leaves through the stomata and partly from the water surface and soil. This has increasing impact on crop productivity and reduce crop yield (Wikipedia, 2010)
4. Higher carbon-dioxide (CO^2): the burning of fossil fuels (coal, oil, gas) releases the CO^2 that are absorbed and that has accumulated over a long period. This raises the CO^2 content of the atmosphere. This increase in CO^2 content brings about changes in crop yields. It increases growth rates in some plants.
5. Increased pest and diseases: climate change will also impact negatively on agriculture due to disruption of seasonal cycles and ecosystems which will in turn lead to increase in migratory pests. It is pertinent to note that any significant changes in temperature could affect the incidence of pest and disease, alter the plants we could keep.
6. According to LUMEN (2010) August Edition, climate change will lead to flooding which could cause, the disappearance of islands and low-lying regions with consequent human migration and loss of fertile lands for crop production. Climate change will lead to flooding of agricultural lands, which consequently result to washing away of soil nutrients through erosion. Flooding also affect the activities of microorganisms such as decomposition and mineralization of nutrients.
7. Drought: climate change results to drought which affects land for agriculture. This results in suppression in decomposition of organic matter and makes the soil susceptible to wind erosion.

EFFECTS OF CLIMATE CHANGE ON SOIL FERTILITY

Soil fertility simply is defined as the capacity of the soil to supply necessary nutrients to the plants, and then only with macronutrients, usually nitrogen and phosphorus and sometimes, potassium (IFDC, 2010). According to Agbede (2009), soil fertility is the capacity of soil to provide enough nutrients to support plant growth. According to Mutegi *et al*, (2018), fertile soil has the following properties:

- It is rich in the essential plant nutrients, including N, P and K.
- It contains trace elements which are also critical for plant nutrition, but are needed small quantities than NPK. These included boron, copper, iron and several others.
- It contains good levels of organic matter which improves soil structure and its ability to hold water.
- The soil pH (an indicator of acidity or alkalinity) is balanced
- It has good structure, so it drains well.
- It contains a range of microorganisms (earthworms, termites etc) that help support plant growth and health.

Climate change can affect soil fertility through the following ways:

1. **FLOODING**: Flooding in soil results in waterlogged and or anaerobic situation is soil. This situation results in the conversion of nitrate ions to gaseous forms of nitrogen which is lost in atmosphere (denitrification), absence of soil organisms, because of the anaerobic condition created by flood (Brady and Weil, 1999), reduces organic matter decomposition (Brickman and Sombroek, 2010), destruction of soil structure, thereby closing the soil pores, and the accumulation of salts (salinization), through the evaporation of water, still retaining the amount of salt, increased acidity of the soil through the reaction of Aluminum and Iron in flooded area and loss of exchangeable bases in leaching (Hossner and Juo, 1999).
2. **CARBON DIOXIDE**: Increasing CO_2 Concentration results in increase in soil organic matter, increase in water use efficiency, more availability of carbon to soil microorganisms, and accelerated nutrient cycling. (Pareek, 2017). Higher CO_2 partial pressure in soil air and CO_2 activity in soil water increased microbial and root activity in the soil, hence, increased rates of plant nutrient release (e.g, K, Mg, micronutrients) from weathering of soil minerals. The increased production of root material tends to raise soil organic matter content, which also entails the temporary immobilization and cycling of greater quantities of plant nutrients in the soil. Increased microbial activity due to higher CO_2 concentration produces greater amount of polysaccharides and other soil stabilizers. Increase in litter or crop residues, root mass and organic matter content tend to stimulate the activity of soil macro fauna including earthworms and consequently, improved infiltration rate and by pass flow by the greater number of stable biopores (Brickman and Sombroek, 2010).
3. **HIGHER TEMPERATURE**: According to Kolay (1999), soil microbial activities are increased at high temperature, such as decomposition of organic matter and mineralization of nutrients. The higher the temperature, the higher the decomposition of organic matter to release the nutrient especially nitrogen contained in it in the soluble form which is absorbed by plant roots. Increased temperature would induce a greater rate in the production of plant minerals, loosening the soil organic matter due to increase in the activities of microorganisms, resulting in the production of greater amounts of polysaccharides and other soil stabilizers (Brickman and Sombroek, 2010). Increased temperature results in loss of soil organic matter, reduction in moisture content, increase in mineralization rate, increase in soil respiration rate, and loss of soil structure. (Pareek, 2017)

4. **RAINFALL INTENSITY**: Increased intensities of rainfall and rainfall totals would increase nutrient leaching rate in well drained soils with high infiltration rates and would cause water saturation, hence reduced organic matter decomposition, greater risks of soil erosion, but at the same time, provide soil with better hydration, (Brinkman and Sombroek, 2010), runoff of

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phosphorus either by eroded sediment or dissolved in the water runoff and increase in soil organic matter, increased reduction of Fe and nitrates, increased volatilization loss of nitrogen, and increase in productivity in arid regions (Pareek, 2017)

5. **DROUGHT**: According to Rosenzweig and Hillel (2010), drought results to drier soil conditions which suppress the decomposition of organic matter, causing low organic content in soil and which increases the vulnerability of soil to erosion. It also results to absence or inactivity of microorganisms or even their death. Dry soils have low nutrient holding capacity and high potential for nutrient leaching (MAFRA, 2009). Reduction in Rainfall results in Reduction in soil organic matter, Soil salinization, and Reduction in nutrient availability (Pareek, 2017).

IMPACTS OF CLIMATE CHANGE ON SOIL FERTILITY MANAGEMENT PRACTICES

The maintenance of an adequate nutrient supply to plant root is essential for maximum growth and quality of crops. Several factors control soil fertility which include parent material, soil structure, soil depth, presence of toxic elements, soil organisms, soil texture and cation exchange capacity (IFDC, 2010). According to Bierman and Rosen (2005), the aims of soil fertility management are:

1. Reducing nutrient losses through leaching, runoff and volatilization.
2. Maintaining or increasing nutrient storage capacity.
3. Promoting recycling of plant nutrients.
4. Applying additional nutrients in appropriate amounts.

These aims of soil fertility are affected by climate in the following ways:

❖ Climate effects like flood, higher temperature and increased rainfall intensity increase nutrient losses through leaching, volatilization of nutrients in gaseous forms and runoff. Flood causes nutrient loss through runoff and also volatilization of soil nutrient in gaseous form (denitrification) in an anaerobic condition. Higher temperature increased microbial activity such as decomposition, which lead to lower organic matter contents in the soil as a result of increased quantity of plant nutrients cycling through soil organisms (immobilization). Increased rainfall intensity causes loss of nutrient through runoff. Such nutrient like phosphorous.

❖ Climate change affects nutrient capacity of the soil through leaching, and water erosion, which remove the top soil, which is the richest layer of soil in organic matter content. This is as a result of the destruction of soil aggregate thereby closing the soil pores.

❖ Recycling of soil nutrients through the use of crop residues, mulching and organic manure are affected by climate change through its effects on soil organisms and their activities such as decomposition which would release the nutrient in them.

❖ Additional nutrients through the use of fertilizers and organic manure are affected by climate change through runoff nutrients in solution, and volatilization of the nutrients. Flood affects the decomposition of the organic materials by microorganism.

The following soil fertility management practices are affected by changing climatic conditions in the following ways:

1. **CROP ROTATION**: This is a planned sequence of growing crops, including legumes, in a regularly recurring succession on the same piece of land (Brady and Weil, 1999). Crop rotation decreases soil and nutrient loss from runoff and erosion, increases soil organic matter and favors stable aggregation of soil, add organic matter to the soil, stimulate a greater variety of soil microorganisms which enhance carbon and nutrient cycling (Bierman and Rosen, 2005).The extended growth period obtained with cover crops also extends the duration of root activity and the ability of root-exuded compounds to release insoluble soil nutrients (Lim, 2010).Flooding decreases the amount of oxygen in soil, thereby affecting the respiration of the roots of the cover crops, causing the lodging or even death of these crops and the nitrogen fixed by these legumes is converted to nitrous oxide. Drought conditions have effect on them because they also cannot survive without moisture, which can cause their death.
2. **SOIL CONSERVATION PRACTICES**: Such practices include reduced tillage and use of crop residues. Surface residues limits erosion impacts by reducing detachment of soil particles by wind or raindrop impact and restricting water movement across the soil. Tillage practices manage the amount of crop residues left on the soil surface and break down soil aggregate, increase soil aeration, which accelerate organic matter decomposition. Reduced tillage or no-till maximizes residues coverage. Extreme climate change results in drier crop residues, therefore, inhibiting microbial activity on them. Higher rainfall intensity causes destruction of soil aggregate, thereby exposing the soil particles to erosion and runoff of dissolved nutrients.
3. **MANURE AND OTHER AMENDMENTS:** Returning manure to crop fields recycles a large portion of the plant nutrients removed in harvested crops. Such manures like farm yard and green manures even compost manure. Application of these manures to the soil returns plant nutrients. However, nutrients can be lost from manure during storage, handling and application (Bierman and Rosen, 2005).

   Nitrogen is readily lost through volatilization of ammonia in an anaerobic soil condition as a result of flood through the process of denitrification. Manure adds organic matter to the soil which can improve soil structure and increase CEC (Farm Radio International, 2009). Nutrients in organic manure are lost through volatilization in an anaerobic soil condition and erosion as a result of flood. Higher temperature also results in higher rate of decomposition of these manures by soil organisms, leading to loss of nutrients through immobilization. Higher temperature results in higher evaporative demand on the manure, causing dryness of this material, therefore restricting the activities of microorganisms on these organic materials. Drought conditions also restrict microbial activities resulting to their death.

4. **FERTILIZER APPLICATION**: Fertilizer is referred to relatively soluble nutrient sources with a high concentration. They supply essential elements in a variety of chemical forms. They have high water solubility, immediate availability to plants, high concentration, accuracy and uniformity with which specific amounts of available nutrients can be applied (Bierman and Rosen, 2005). They supply Nitrogen, phosphorus, potassium and other nutrients.

   Due to the high solubility of fertilizer in water, it can be leached out beyond the root zone, washed away through erosion and runoff as a result of flood and high rainfall intensity. Denitrification can occur also. Acidification also occurs through the loss of exchangeable bases

(Ca, Mg, K, and Na) in leaching and acid production during Aluminum hydrolysis (Hossner and Juo, 1999). In drier soil, the release of nutrients in fertilizer applied is inhibited.

5. **PLANTING OF LEGUMINOUS CROPS**: Legumes add nitrogen to the soil, mostly falling leaves and their nitrogen-rich root nodules decompose underground. The organic matter produced by legumes is rich in nitrogen, which improve soil fertility (Farm Radio International, 2009). Leguminous crops also serve as green manure and cover crops, which all help in improving soil fertility (Russel, 1977). Such legumes as groundnut, peanut, cowpea, Lima beans, Mucuna and African yam beans. According to Ibeawuchi et al, (2008), Mucuna beans fixed 65.8mg N, Lima beans fixed 47.5mg N and African yam beans fixed 54.2mg N. Leguminous crops are affected by climate change in the following ways:
   - Drought condition does not allow germination of the leguminous seed, and even offer germination, it suppress their growth and can even cause death.
   - Flooding decreases the amount of oxygen in soil, thereby affecting the respiration of the roots of the cover crops, causing the lodging and even of the death.
   - These legumes survive under an optimum temperature, and beyond that, it affects their growth. They cannot survive without moisture. The nitrogen fixed by these legumes are converted to nitrous oxide in water logged condition through the process of denitrification.
6. **AGROFORESTRY**: Growing trees and shrubs together with food crops reduces the loss of soil nutrients, because the trees and shrubs usually have developed root systems, which absorb and store many nutrients which are unavailable to crops with shallow root systems (Farm Radio International, 2009). In this way, they reduce nutrients losses through leaching, runoff and erosion. After the leaves and cuttings fall to the ground and decompose, the nutrients once again become available to the crops. The trees and shrubs form hedges that protect crops and soil from wind and heavy rains which runoff over the surface of the soil. Also, the leguminous trees such as Acacia increase the supply of nutrient within the rooting zone of annual crops through N input by biological N fixation (Hossner and Juo, 1999). Flooding causes lodging of the plants and respiration of carbon dioxide due to anaerobic condition. Drought affects the growth of these plants because absence of moisture leads to wilting of the plants and even their death.

OVERCOMING CHALLENGES OF SOIL FERTILITY MANAGEMENT UNDER CHANGING CLIMATIC CONDITION.

International Crops Research Institute for the Semi-Arid Tropics (ICRISTAT) (2010) suggested the methods to counter negative effects of climate change on soil fertility, to include:

1. **WATER MANAGEMENT AND CONSERVATION**: Climate change will put greater pressure on water resources as increasing volatile rainfall patterns force farmers to rely more on irrigation. IWMI (2010) suggest measures that enhance water management to include:
   a. Drip irrigation: here, water flows from raised pipes with emitters scattered throughout the plot, which discharge the water into the soil near the plant root by means of a slow-release mechanism.
   b. Water harvesting: this is a better management of rainfall which involves diversion of scare rainfall from source into small parcels containing crops and trees.

c. Mulching: Mulching the soil surfaces with crop residues or plant litter add organic matter, encourage soil organism activities and protects soil aggregates from beating rain (Brady and Weil, 1999). It reduces the loss of water by evaporation and reduces runoff (Wild, 1996).

2. **ORGANIC FARMING**: Organic agriculture is a holistic production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, cultural, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system (FAO/WHO, 1999). Organic farming is a form of agriculture that relies on techniques such as crop rotation, green manure, compost manure, and biological pest control to control pest in the farm and to maintain soil productivity (Wikipedia, 2010). Organic farming increase soil organic matter content and improves water holding capacity (Benaning, 2010).

   According to Zamora (2010), organic farming addresses emission reduction, reduces carbon emissions from farming system inputs such as fertilizers and pesticides, methane, and CO2. This is because organic farming relies on the use of compost, and other organic materials, use of green manures, the legume based crop rotation and agroforestry system for soil fertility enhancement. Organic farming can be used to mitigate global warming by decreasing fossil fuel emission by Thirty-three percent because of the elimination of synthetic nitrogen in the organic systems (Wikipedia, 2010). Organic agriculture helps farmers adapt to climate change because high soil organic matter content and soil cover help to prevent nutrient and water loss. This makes soils more resilient to floods, droughts, and land degradation processes.

3. **CARBON SEQUESTRATION**: Carbon sequestration refers to the removal of carbon dioxide (CO_2) from the atmosphere into a long lived stable form that does not affect atmosphere chemistry (Perry et al, 2004). It also implies transferring atmospheric CO_2 into a long-lived pools and storing it securely, so it is not immediately remitted (Lal, 2004). A soil which is well managed has the capacity to store more carbons and also prevents the release of carbon from it in the form of CO_2 which will lead to a decrease of greenhouse gas emissions in the atmosphere. Most of the carbon dioxide in the atmosphere comes from biological reactions that take place in the soil (Seidu and Sanjay (2016). Management practices that can lead to soil organic carbon (SOC) sequestration are mulch farming, conservation tillage, agroforestry, cover cropping and integrated nutrient management including the use of manure, compost, biosolids, water management and conservation, irrigation and crop rotation (Jan-Peter. 2008). According to Benaning (2010), SOC sequestration helps in mitigating climate change by introducing carbon into the soil. The carbon stored in soils may help to improve soil and water quality, decrease nutrient loss, reduce soil erosion, increase water conservation, increase the soil capacity to oxidize methane, especially under no-till farming and greater crop production (Perry et al 2004). SOC sequestration also, can be promoted through organic farming which reduces biomass mineralization, decrease oxygen availability and increase soil organic carbon concentration and reduce evaporation by minimizing exposed soil on the surface (Zamora, 2010)

4. **CONSERVATION FARMING**: Conservation farming is a method which involves the restoration of farmland to forest and grassland, no-till or less-till farming and returning straw and stalk to the field (Lim, 2010). It includes a set of practices which conserve the soil, water, and soil

moisture, enhance fertilizer and seed use, and finally, saves time and money. Conservation farming has three main principles which help in biodiversity and environment protection and are Minimum soil disturbance, Crop residue management (leaving of previous crop residue in the field or planting a cover crop) and Crop rotation practices (Powlson et al, 2015). Besides conservation tillage and cover crops, conservation farming combines various farm practices in crop production, such as direct planting, green manure, agroforestry, and integrated and organic pest protection. Conservation farming increases the permeation of natural precipitation and reduces ground flow and evaporation, therefore improving the operation endurance against drought and water conservation, thus mitigating the negative effects of climate change. Conservation farming can adjust to changes in the temperature and moisture in the field, reduce the respiration of crops while increasing the retention of carbon. It can also prevent erosion by wind or water while providing protection from sand storms (Lim, 2010).

5. **INTEGRATED SOIL FERTILITY MANAGEMENT (ISFM)**: ISFM refers to a set of soil fertility management practices that include the combined use of fertilizer, organic inputs and improved planting materials coupled with the knowledge on how to adapt them to local conditions for improved nutrient use efficiency and crop productivity (Ruttan et al., 2010). They include, rotation of cereals with legumes, intercropping of cereals with legumes, manure applications, fertilizer application and various other forms of soil nutrient management practices coupled with use of appropriate planting materials and good agronomic management. For example, intercropped or rotated cereals benefit from nitrogen that is fixed by the preceding or rotated legumes in addition to sustaining better ground cover which reduces soil water and nutrient losses through evaporation and soil erosion. Ground cover also decreases the compacting and crusting effects of raindrop, thereby helping in maintenance of soil porosity, water infiltration, soil water retention and rain water use efficiency (Pareek,2017)). Integrated soil fertility management technologies can therefore improve the soil physical, chemical and biological characteristics (soil health), and support adaptation of agro-ecosystems to the changing climate and climate variability (Havlin, et al, 2005). Combining fertilizers and organic inputs benefits the conservation and build-up of soil C stocks, hence mitigating CO_2 emissions from soils

CONCLUSION

Climate change represents a serious threat to global food security, not because of its effects on soil, but also for its effect on crop production. Changes in temperature and rainfall patterns can have a great impact on the organic matter and processes that take place in our soils, as well as the plants and crops that grow from them. In order to meet the related challenges of global food security and climate change, agriculture and land management practices must undergo fundamental transformations. Improved agriculture and soil management practices that increase soil organic carbon, such as agro-ecology, organic farming, conservation agriculture and agroforestry, bring multiple benefits. They produce fertile soils that are rich in organic matter (carbon), keep soil surfaces vegetated, require fewer chemical inputs, and promote crop rotations and biodiversity. These soils are also less susceptible to erosion and desertification, and will maintain vital ecosystem services such as the hydrological and nutrient cycles, which are essential to maintaining and increasing food production

Soil fertility is declining as a result of climate change, which brings more extreme weather events such as flooding, drought and more unpredictable weather conditions. Soil fertility has been affected by global warming. The warmer atmospheric temperature observed over the past decades is expected to lead to a more vigorous hydrological cycle, including extreme rainfall events. Erosion and soil degradation is more likely to occur. Some common farming practices such as burning crop residues, use of fertilizer, improper crop rotation, land clearing and deforestation are part of the problem. But there are many traditional and modern agricultural practices which can help boost foil fertility and assist farmers in making their farms more resilient to the changing climate. These include micro-dosing of fertilizer, using rather than burning crop residues, and other organic materials, planting nitrogen-fixing crops and trees, use of compost and other manures, preventing wind and water erosion, and using practices which conserve soil and water.

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