A Review of the Impacts of Climate Change on Soil Conditions and Global Food Security

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ABSTRACT
As people around the world increasingly feel the impacts of climate change, the collective call for action grows louder and louder. The effects of climate change on soil conditions and global food security food - often neglected in favor of tropical storms, and sea level rise - are receiving more and more mainstream attention. Soils are intricately linked to the atmospheric/climate system through the carbon, nitrogen, and hydrologic cycles. Because of this, altered climate will have an effect on soil processes and properties. Recent studies indicate at least some soils may become net sources of atmospheric c, lowering soil organic matter levels. Soil erosion by wind and water is also likely to increase. This brief seeks to summarize the relationship between climate change, soil conditions and food insecurity, highlighting suitable agricultural innovations for climate change adaptation for global food security..

Keywords: *Climate change, Temperature rise, Impacts, Soil conditions, Food security*

INTRODUCTION

The Food and Agriculture Organization (FAO) defines food security as a “situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life” **(**FAO, 2007). This definition comprises four key dimensions of food supplies: availability, stability, access, and utilization. The first dimension relates to the availability of sufficient food, i.e., to the overall ability of the agricultural system to meet food demand. Its sub-dimensions include the agro-climatic fundamentals of crop and pasture production (Tubiello*et al*., 2007) and the entire range of socio-economic and cultural factors that determine where and how farmers perform in response to markets (Joseph and Francesco, 2007).

` Soils are so important for food security (Pimentel, 2006; Lal, 2010; Blum *et al*., 2013; Brevik, 2013), and climate change has the potential to threaten food security through its effect on soil properties and processes (Erik, 2013; Pereek, 2017; Akamigbo and Nnaji, 2011). Despite the millions of acres of industrial cropland, satellite-guided tractors, and shining supermarkets in places like the United States, a large percentage of food worldwide is still produced on relatively small parcels of land by smallholder, subsistence farmers who rely solely on rainfall to water their crops and animals. These practices mean that long-term changes in climate intimately impact food production - perhaps more than any other sector of the global economy. Since the mid-1800s and the Industrial Revolution, surface air temperatures over Earth’s land area have warmed by an average of 1.5°C. Much of that warming has occurred since 1975 as concentrations of carbon dioxide and other greenhouse gases (GHG) in the atmosphere steadily accumulate(Christopher *et al*., 2013).

Climate change is a global phenomenon and occurring continuously since the earth came into existence. Climate change has become a major scientific and political issue during the last decade. There are well marled cold and hot cycles in the history of earth's climate, however, these changes have been observed relatively rapid in the last 150- 200 years around the world (FAO, 2002).Understanding these effects and what we may do to adapt to them, requires an understanding of how climate and soils interact and how changes in climate will lead to corresponding changes in soil. Therefore, this paper will focus on what we know about soil-climate interactions with a special view on global food security in the future.

GLOBAL CLIMATE CHANGE

The expression of the term "climate change" according to many people means the alteration of the world's climate as a result of human activities through fossil fuel burning, clearing forests and other practices that increase the concentration of greenhouse gases (GHG) in the atmosphere. this is in line with the official definition by the united nations framework convention on climate change that states that climate change is the change that can be 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 time periods*"(Raj Patel ET AL., 2007). The intergovernmental panel on climate change (IPCC) defines "climate change" as *"a change in the state of the climate that can be identified by changes in the mean and or the variability of its properties, and that persists for an extended period, typically decades or longer"* (FSIN, 2019).

Agriculture is considered both as a contribution to climate change and a victim as well. Agriculture is a contributor because it emits significant amount of greenhouse gases, and victim because climate change have considerable impact on agricultural production. The fourth assessment report of intergovernmental panel on climate change (IPCC) made is clear that the global average temperature has increase by 0.74^{o}C over the last 100 years and projected increase is about 1.8 to 4.0^{o}C by 2100. Climate change and agriculture are interrelated processes and global warming is projected to have significant impacts on agriculture by influencing through direct and indirect effects on crops, soil, livestock and pests. Apart from the probable decline in food production, nutritional quality of food may also be reduced raising a concern for nutritional security. Alarmed by the possible impact of the global climate change on the quality of life of human beings efforts are being made to develop strategies to mitigate its negative impacts. In light of these concerns, the impact of climate change on soils and its mitigation and adaptive strategies have been discussed.

Climate change most directly impacts food production through crop yield changes, typically from temperature increases and rainfall variability. a general rule of thumb in the equatorial tropics is that every 1°c rise in mean temperature is associated with a 10 percent drop in crop yields. Temperature spikes during critical phases of a plant's growth can lead to outright crop failure. Although impacts will vary considerably by crop and production system, some countries in sub-Saharan Africa and other low-latitude places will likely see yields from rain-fed maize, wheat, and rice fall considerably in the coming decades.

CAUSES OF GLOBAL CLIMATE CHANGE

According to Rajib*et al*., Pareek, 2017; Chase *et al*., 2019; Brevik, 2o13; Brouder and Volenenc, 2008; Akamigb and Nnaji, 2011, the following are the causes of climate change:

(i) Natural causes: there are a number of natural factors responsible for climate change. Some of the more prominent ones are continental drifts, volcanoes, ocean currents, the earth tilts, cornets and meteorites (Rajib*et al*., 2016).

(ii) Human (Anthropogenic) causes: these include industrialization, deforestation and pollution, etc., which have greatly increased atmospheric concentrations of water vapour, cabon-dioxide, methane and nitrous oxide, all greenhouse gases that help trap heat near earth's surface. Humans are pouring carbon-dioxide into the atmosphere much faster than plants and oceans can absorb it. These gases persist in the atmosphere for years, meaning that even if such emissions were eliminated today, it would not immediately stop global warming (Rajib*et al*., 2016).

(iii) Greenhouse Gases: our planet is made habitable by the presence of certain gases, which trap long-wave radiation emitted from the earth's surface, giving a global mean temperature of 15^0C as opposed to an estimated -18^0C in the absence of an atmosphere. This phenomenon is popularly known as the "Greenhouse" effect (Rajib et al.,). Four of the principal gases that create the "greenhouse effects" are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbon (CFCc)(WRI, 2006).

(iv) Local activities such as deforestation, land use change, etc.

SOILS AS A PART OF THE GLOBAL C AND N CYCLES

Soils are integral parts of several global cycles. The two that are the most important from the perspective of soils and climate change interactions are the carbon and Nitrogen cycles because C and N are important components of soil organic matter (Brady and Weil, 2008) and because carbon dioxide (CO_2), methane (CH_4), and Nitrous oxide (N_2O) are the most important of the long-lived greenhouse gases (Han et al., 2007). The global C and N cycles were in balance with inputs approximately equalling outputs prior to industrial revolution when low populations and levels of technology minimized the anthropogenic generation of greenhouse gases, but the burning of fossil fuels, tilling of soil, and other human activities have altered the natural balance such that we are now releasing more C and N into the atmosphere each years than is taken up by global sinks (Pierzynski*et al*.,2009). Human management of soils can have a profound impact on the balance of C and N gas emissions from those soils, and therefore influence global climate change (Brevik, 2012).

INFLUENCE OF CLIMATE CHANGE ON SOIL PROCESSES/CONDITIONS

Carbon and Nitrogen are major components of organic matter (Brady and Weil, 2008). Organic matter is important for many soil properties, including structure formation and maintenance, water holding capacity, cation exchange capacity, and for the supply of nutrients to the soil ecosystem (Brevik, 2013). Soils with an adequate amount or organic matter tend to be more productive than soils that are depleted in organic matter (Brevik, 2013), therefore, are of the biggest questions concerning climate change and its effects on soil processes and properties involve how potential change in C and N cycles will influence soils (Brevik, 2013).

Increased temperature is likely to have a negative effect on C allocation to the soil, leading to reductions in soil organic C and creating a positive feedback in the global C cycle (increased temperatures lead to increased CO2 released from soils to the atmosphere, which leads to more increase in temperature) as global temperatures rise (Gorrisen*et al*.,2004; Wan *et al*., 2011). Through climate change and anthropogenic activities, many or our world soils have become or are expected to become more susceptible to erosion by wind and/or water (Zhang *et al*., 2004). Simulations ran for Australia showed that increase rainfall due to climate change could lead to significant increase in runoff, with amplification greater in arid areas (up to five time more runoff than the percentage increase in rainfall) than in wet and temperate areas (twice as much runoff as the percentage change in rainfall) (Chiew*et al*., 1995).

Greater runoff would be expected to cause increased erosion. Water erosion models in the United Kingdom predicted that a 10% increase in winter rainfall could increase annual soil erosion by as much as 150% during wet years, but that long-term averages of soil erosion would show a modest increase over current conditions (Faris and Boardman, 1995). Li *et al* (80) predicted changes in water erosion of 50% to 195% for conventional tillage and 26% - 77% for conservation tillage in China's Loess plateau region, while Zhang et al (Zhang *et al*., 2004) predicted increased erosion in Oklahoma, USA of 19% and 40% under conservation and compared to average annual erosion in the period from 1950 to 1999 (Brevick, 2013).for some people soil is felt as the soul, the backbone or the skin of the Earth, or the placenta of life (Akpabio and Nnaji, 2011). It is a product of five soil farming factors – parent materials, living organism, time and relief (Akpabio and Nnaji, 2011). The interaction between these factors of soil formation determines the type and nature of soil formed in any given area.

Climate which is the regular pattern of weather conditions of a particular place affects soil through such elements as temperature, rainfall, wind, relative humidity, solar radiation, etc. the climate of an area is generally noted to be stable, and that is with insignificant variation over a long period of time. For many years now, there have been reported cases of climate change across the globe. Climate change occurs when a situation in which a change in climate continues in one direction at a rapid rate and for an unusual long period of time (lasting for several years) (Anyadike, 2009, Akanigbo and Nnaji, 2011). In this case of the present condition which we are experiencing, the footprint of this change is a steady and general increase in temperature (Akamigbo and Nnaji, 2011).

Climate change is generally believed to be caused by three major causes – atsomoic, volcani eruptions and anthropogenic cause. The causes of climate change to a build-up of greenhouse gases. These gases absorb the terrestrial radiations from the earth and re-radiate the heat back to earth, thereby leading to a general increase in temperature often referred to as global warming (Ozor, 2009a; Akamigbo and Nnaji, 2011).

The impact of climatic variations and climate change on Nigerian soils could be examined in their implication on floods, droughts, desertification, soil erosion etc. (Akamigbo and Nnaj, 2011). Human activities that make our soils vulnerable to impacts of climate change include poor and inefficient irrigation practices, industrial/mining, road construction an sound excavation with lorries (Emenike, 1988) and other authorities without satisfactory measures for prevention of land degradation. Also, bush or forest fires and uncontrolled use of fire for hnting, agricultural clearing or for settling certain social conflicts, demographic pressure (human and livestock) and deforestation resulting from land clearance for agriculture and other land uses (including unplanned urbanization, overgrazing, uncontrolled and wasteful logging, illegal felling and excessive fuel wood collection) make our soils vulnerable to climate change (Akamigbo and Nnaji, 2011).

Soil seems to be more important for modern human society than ever before to meet the global demands for food and fibre for increasing population from limited soil resource. Climate change is threatening food security globally. Though, climate change is a slow process involving relatively small changes in temperature and precipitation over long period of time, nevertheless these slow changes in climate influence the various soil processes particularly those related to soil fertility. The effects of climate change on soils are expected mainly through alteration in soil moisture condition and increase in soil temperature and C)2 levels as a result of climate change.

The global climate change is projected to have variable effects on soil processes and properties important for restoring soil fertility and productivity. The major effect of climate change is expected through elevation in CO2 and increase in temperature.The impact of climate change factors specifically temperature, CO2 and rainfall on various soil properties is being discussed below to understand the relationship between climate change variable and various soil properties in order to evolve appropriate mitigation strategies (Table 1).

Table 1: Effects of climate change variable on soil processes

Climate change variables	**Effects**
1. Temperature	- Loss of organic matter - Reduction in labile pool of SDM - Reduction in moisture content - Increase in mineralisation rate - Loss of soil structure - Increase in soil respiration
2. Increase in CO2 concentration	- Increase in soil organic mater - Increase in water use efficiency - More availability of carbon to soil micro organisms - Accelerated nutrient cycling
3. 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 - Increased productivity in arid regions
4. Reduction in rainfall	- Reduction in soil organic mater - Soil salinization - Reduction in nutrient availability

Source: Pareek (2017).

Global land temperatures in the past decade, 2006–2015, were 1.0°C (1.8°F) warmer than the twentieth-century average (NOAA, 2016). Under a moderate greenhouse gas emissions scenario, referred to as representative concentration pathway (RCP) 4.5, atmospheric CO_2 concentrations would continue their rise from a 280-ppm preindustrial baseline, beyond the present 400-ppm levels, and on to values of 540 ppm by 2100 (Prather *et al*., 2013). Climate simulations indicate a further land warming of 1.9–4.0ºC (3.4–7.2°F) [90% confidence interval (CI)] (Collins *et al*., 2013; 7IPCC, 2014; NOAA, 2016). Under the higher emission scenario, known as RCP8.5, CO_2 concentrations would reach 940 ppm by 2100 and result in land warming of 4.0–6.8°C (7.2–12.2°F) (IPCC, 2014; NOAA, 2016). Even a moderate emissions scenario is expected to result in average summer temperatures that exceed the most extreme temperatures currently experienced in many areas of the world (Battisti, 2009).

The availability of water resources for agriculture will be influenced by climate change in a multitude of ways, including shifting precipitation patterns, loss of glaciers and earlier seasonal snow melt, and intrusion of saltwater into coastal aquifers (Jimenez *et al*., 2014).

Climate model projections generally indicate less precipitation in currently arid and semiarid regions and greater precipitation in the polar latitudes (Collins *et al*., 2013). Rainfall events are expected to become more intense, likely increasing runoff and flooding (Collins *et al*., 2013).

A typical example of the impact of climate change, among other factors, is the formation of gully erosion (Figure 1).

Figure 1: Gully erosion site in Uyo
Source: Udoumoh *et al*.(2019)

Crop yields are highly sensitive to changes in temperature and water availability (Lobell, 2012)(see figure 3). Optimal growing temperatures vary depending on cultivars and other environmental variables, but air temperatures above approximately 30°C (86°F) are generally associated with reduced yields for rain-fed crops (Carlson, 1990, Schlenker, and Roberts, 2009). High temperatures can depress yields by accelerating crop development and can induce direct damage of plant cells (Sanchez *et al*., 2014). Exposure to damaging temperatures will generally increase as global temperatures rise (Gourdji*et al*., 2013), although these trends will vary regionally and can be locally tempered by irrigation or other changes in agricultural practices (Bonfils, 2007; Davin*et al*., 2014; Mueller *et al*., 2012).Crop water stress is also a major driver of yield loss and is generally coupled with high temperatures both because low soil moisture leads to a decrease in evaporative cooling from the landscape (Mueller and Binder, 2015) and because high temperatures increase crop water loss (Lobell, 2012).

Based on (FAO, 2019); (FAO et al., *2019)*, there has been evidence of increase in global temperatures that has led to climate change at global, regional and national levels over the past 100 years. increase in global temperatures experienced over the past century is as a result of accumulation of greenhouse gases in the atmosphere leading to global warming. using complex climate models, the "intergovernmental panel on climate change" in their third assessment report has forecast that global mean surface temperature will rise by 1.4^0c to 5.8^0c by the end of 2100. Multiple datasets show essentially the same global warming trend over the past 100 years, with the steepest increase in warming in recent decades. The evidence of human-induced climate change goes beyond observed increases in average surface temperatures; it includes melting ice in the arctic, melting glaciers around the world, increasing ocean temperatures, rising sea levels, acidification of the oceans due to excess carbon dioxide, changing precipitation patterns, and changing patterns of ecosystem and wildlife functions. Reduced agricultural productivity with the resultant food shortages has been experienced. Studies have shown that with higher concentrations of co_2, plants can grow bigger and faster. However, the effect of global warming may affect the atmospheric general circulation and thus altering the global precipitation pattern as well as changing the soil moisture contents over various continents.

- There has been an increase in sea level observed in some parts of the world due to excess heating of air - which has caused large scale melting of ice covers. Large scale flooding of California in 1999 and parts of western coast in India in the last 5-8 years are testimonies to effects of sea level rise. if the sea level rises by 80-90 cm, perhaps many of coastal cities of the world will be washed away besides great changes in harbours and their facilities, in sea routes and in fishery industry (FAO, 2019). Loss of fertile agricultural land occasioned by flooding impacts on food security and livelihoods at household and national level. There has been an increase in drought and floods globally. Ironically, changes in the climate due to excess greenhouse gases are causing both increased drought and increased flooding. Violent storm activity increase as temperatures rise and more water evaporates from the oceans. This includes occurrence of more powerful hurricanes, pacific typhoons, and an increased frequency of severe localized storms and tornadoes. These storms often result in flooding and farmland damage hence causing food insecurity. Warming also causes faster evaporation on land leading to drought induced famine.
- Change/shifts in seasons and seasonal characters have been experienced throughout the globe due to change in air temperature and rainfall patterns. Some seasons have either been shortened or prolonged. Winters have extended in many places, while summer is more severe in other places. The degree of dependability has reduced and an element of uncertainty has increased. This disorientates the farmers in the rural community who have hitherto depended on indigenous knowledge in predicting weather patterns in food production.
- Major changes have occurred in water resources of the world due to disturbances in hydrological cycles. Heavy rainfall tracts are gradually converted into low rainfall tracts with many humid areas being transformed into arid areas. Similarly, ground water depletion is high and recharging is very low.
- There has been a shift in disease/pest cycles of plants and animals. Many insignificant pests/diseases are attaining major proportions because composition of microbial population is affected by shift in temperature and hydrological cycles. These have impacted on food production output and post-harvest loss occasioning food shortages and loss of livelihoods(Christopher*et al*., 2013).

THE THREAT FROM DROUGHT

Of all the impacts from climate change on agriculture and food security, drought may be the most harmful for smallholder farmers and other vulnerable populations. Given improved early warning and humanitarian responses, large-scale deaths from famine are increasingly a thing of the past, but drought in the horn of Africa, southern Africa, and Central America has been long associated with famine. in these places where rain-fed agriculture is prevalent, over 80 percent of a drought's economic impact is felt in the agricultural sector(Alex de Waal, 2018; FAO *et al*., 2019).

Multi-year drought is especially devastating for subsistence farming families. Each year without a good harvest pushes the hunger season further ahead and diminishes seed stock for next year's planting. Long-term drought also destroys precious topsoil, allowing it to blow away in high winds or wash away during heavy rains(FAO *et al*., *2019*).

Major Water Sources Like Lake Chad Are Disappearing

Figure 2: Effect of climate change on Lake Chad
Source: "How climate change can fuel wars, Economist, May 23, 2019, https://www.economist.com/ international/2019/05/23/how-climate-change-can-fuel-wars.

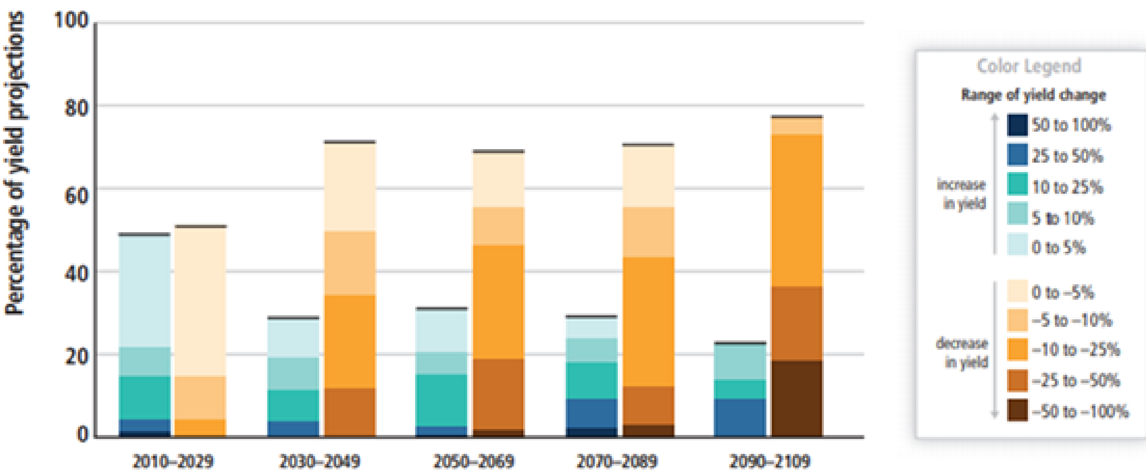

Fig.3:crop yields change projections due to climate change
Source: Andrew J. Challinor et al., Climate Change 2014: Impacts, Adaptation, and Vulnerability (New York: IPCC, 2014), https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap7_FINAL.pdf.

REGIONAL IMPACTS OF CLIMATE CHANGE ON GLOBAL FOOD SECURITY

Africa

Agriculture is a particularly important sector in Africa, contributing towards livelihoods and economies across the continent. On average, agriculture in Sub-Saharan Africa contributes 15% of the total GDP. Africa's geography makes it particularly vulnerable to climate change, and 70% of the population relies on rain-fed agriculture for their livelihoods. Smallholder farms account for 80% of cultivated lands in Sub-Saharan Africa. Many re Nelson et al., 2009; Beddington et al., 2012). Researchers agree that agricultural innovation is essential to addressing the potential issues of climate change. This includes better management of soil, water-saving technology, matching crops to environments, introducing different crop varieties, crop rotations, appropriate fertilization use, and supporting community-based adaptation strategies (Sindhu, 2011; Nelson *et al*., 2009; Beddington*et al*., 2012).

On a government and global level, research and investments into agricultural productivity and infrastructure must be done to get a better picture of the issues involved and the best methods to address them. Government policies and programs must provide environmentally sensitive government subsidies, educational campaigns and economic incentives as well as funds, insurance and safety nets for vulnerable populations(Sindhu, 2011; Nelson *et al*., 2009; Beddington*et al*., 2012).In addition, providing early warning systems, and accurate weather forecasts to poor or remote areas will allow for better preparation; by using and sharing the available technology, the global issue of climate change can be addressed and mitigated by the global community (Beddington*et al*., 2012).

East Africa

In East Africa, climate change is anticipated to intensify the frequency and intensity of drought and flooding, which can have an adverse impact on the agricultural sector. Climate change will have varying effects on agricultural production in East Africa. Research from the International Food Policy Research Institute (IFPRI) suggest an increase in maize yields for most East Africa, but yield losses in parts of Ethiopia, Democratic Republic of Congo (DRC), Tanzania and northern Uganda (Wikipedia, 2021).

Southern Africa

Climate change will exacerbate the vulnerability of the Agricultural sector in most Southern African countries which are already limited by poor infrastructure and a lag in technological inputs and innovation.Maize accounts for nearly half of the cultivated land in Southern Africa, and under future climate change, yields could decrease by 30%. Temperatures increases also encourage a wide spread of weeds and pests. In December 2019, 45 million peoples in southern Africa required help because of crop failure. The drought reduces the water stream in Victoria Falls by 50%. The droughts became more frequent in the region (Rosane, 2019).

West Africa

The region has already experienced a decrease in rainfall along the coasts of Nigeria, Sierra Leone, Guinea and Liberia.This has resulted in lower crop yield, causing farmers to seek new areas for cultivation (Asenso-Okyere, 1997). Staple crops such as maize, rice and sorghum will be impacted by low rainfall events with possible increase in food insecurity(Wikipedia, 2021).

Central Africa

Higher rainfall intensity, prolonged dry spells and high temperatures are expected to negatively impact cassava, maize and bean production in Central Africa. Floods and erosion occurrence are expected to damage the already limited transportation infrastructure in the region leading to post harvest losses (Wikipedia, 2021).

Asia

In East and Southeast Asia, IPCC (2007:13) projected that crop yields could increase up to 20% by the mid-21st century. In Central and South Asia, projections suggested that yields might decrease by up to 30%, over the same time period. Due to climate change, livestock production will be decreased in Bangladesh by diseases, scarcity of forage, heat stress and breeding strategies (Chowdbury, 2016)

Australia and New Zealand

Without further adaptation to climate change, projected impacts would likely be substantial: By 2030, production from agriculture and forestry was projected to decline over much of southern and eastern Australia, and over parts of eastern New Zealand. In New Zealand, initial benefits were projected close to major rivers and in western and southern areas (Hennessy *et al*., 2007)

Europe

With high confidence, IPCC (2007) projected that in Southern Europe, climate change would reduce crop productivity. In Central and Eastern Europe, forest productivity was expected to decline. In Northern Europe, the initial effect of climate change was projected to increase crop yields. The 2019 European Environment Agency report "Climate change adaptation in the agricultural sector in Europe" again confirmed this. According to this 2019 report, projections indicate that yields of non-irrigated crops like wheat, corn and sugar beet would decrease in southern Europe by up to 50% by 2050 (under a high-end emission scenario). This could result in a substantial decrease in farm income by that date (Wikipedia, 2021).

Latin America

The major agricultural products of Latin American regions include livestock and grains, such as maize, wheat, soybeans, and rice (Jones, 2003; Baethgen, 1997) Increased temperatures and altered hydrological cycles are predicted to translate to shorter growing seasons, overall reduced biomass production, and lower grain yields (Mendelsohn, 1999; Baethgen 1997). Brazil, Mexico and Argentina alone contribute 70-90% of the total agricultural production in Latin America. In these and other dry regions, maize production is expected to decrease (Jones, 2003; Baethgen, 1997). A study summarizing a number of impact studies of climate change on agriculture in Latin America indicated that wheat is expected to decrease in Brazil, Argentina and Uruguay.Livestock, which is the main agricultural product for parts of Argentina, Uruguay, southern Brazil, Venezuelaand Colombia is likely to be reduced (Jones, 2003; Baethgen 1997).

North America

A number of studies have been produced which assess the impacts of climate change on agriculture in North America. The IPCC Fourth Assessment Report of agricultural impacts in the region cites 26 different studies(Field *et al*., 2007) with high confidence, IPCC (2007)projected that over the first few decades of this century, moderate climate change would increase aggregate yields of rain-fed agriculture by 5–20%, but with important variability among regions. Major challenges were projected for crops that are near the warm end of their suitable range or which depend on highly utilized water resources(Wikipedia, 2021).

CONCLUSION

Climate change poses a considerable threat to soil conditions, agriculture, and global food security, with potentially existential economic, political, and social outcomes for humanity. As climate impacts worsen and further stress an already hungry world, all stake holders should take responsibility in responding to the impacts of climate change, double down on domestic efforts to promote climate-smart agriculture.

RECOMMENDATIONS FOR MAKING SOILS LESS SUSCEPTIBLE TO EFFECTS OF CLIMATE CHANGE

According to Akpabio*et al*., 2011; Lal, 2004, Pla, 2008, IPPC, 2007, the adaptation measures to climate change in relation to soil condition includes:

i. Protection of the soil at all time through mulching; live, plastic and plant residue can be used to protect the soil against direct impact of rainfall with its attendant disruption of soil aggregates, sealing and crusting effects. Sealing effects lowers the water infiltration rates under wet soil condition, while crusting effects refers to seals that have dried and hardened thereby offering resistance to seed emergence.
ii. Ensuring land use and land use change, including the adoption of new seed and ensuring good cultivation practices.
iii. Ensuring effective erosion and desertification control: This could be achieved through any of these methods: banning illegal mining around gullies, ravines or water bodies; construction of drainage diagonally off all roads and major paths in towns and villages; grassing lawns and open spaces.
iv. Promotion of afforestation, reforestation and discouragement of deforestation: These practices help increases biological carbon sequestration (carbon sequestration – simply means transforming atmospheric carbon sequestration into long-lives pools and storing it securely so it is not immediately reemitted, currently, the biosphere constitutes a carbon sink that absorbs about 2.3 gig tonnes of carbon per year, which represents about 30% of fossil-fuel emissions. Also, forests help regulate the flow of runoff, protect land from erosion, reduce flooding in adjacent areas, minimize silting of rive, and contribute to a stable hydrology necessary for providing stable source of water for human need and irrigated agriculture.
v. Ensuring proper water management to prevent water logging, erosion as well as nutrient leaching in areas that usually experience torrential downpour of rainfall.
vi. Appropriating wide use of technologies to harvest water, and moisture (e.g. crop residue retention) and to maximize or optimize water use in areas where there is decrease in rainfall.
vii. Promoting the use of input or crop varieties and /or species with increased resistance to heart shock or drought; altering fertilizer application rates to maintain grain or fruit quality consistent with the climate and soil condition, as well as altering amounts and timing of irrigation and other water management practices.
viii. Construction of big and small water channels and gutters, damming to create artificial lakes in a number of the gullies, concrete wall embankments and road constructions with appropriate drainage.
ix. Formation of an Anti-Erosion committee and subcommittees for purposes of planning and interaction with federal Ministry of Environment and Housing and other agencies connected with erosion control in each city, village or community.

x. Enactment of laws or policies for sustainable development, with a mandate to deal with all climate change issues e.g. ensure ban on gas flaring, develop technology to convert this gas for domestic use e.g. cooking gas.

xi. Embracing emerging technologies such as biotechnology, and nanotechnology. According to WBGU (2003), and Akamigbo (2011), the use of specifically designed genetically modified organisms could be a way to improve the physical and chemical condition of our soils hence making soils less susceptible to effects of climate change.

xii. "Going Green" is another good adaptation measure to climate change in relation to soil condition. This entails the use of environmentally-friendly equipment, machines, infrastructures, and technology that produce less of the GHGs. For instance, improvement in rail transport, use of bio-fuels, and energy-saving devices among others.

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