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Climate Change Mitigation for Food Security: A Review of Soil and Water Resources Management

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ABSTRACT

Climate change effects on water availability has led to its scarcity in tropical regions with risk of agricultural droughts affecting crops and the entire ecosystem. Soil and man now face the threat of inadequate water and its resources on a regular basis. Sustainable soil management practices adapted to environmental conditions enhances interactions between soil water and plants which can mitigate the impacts of climate change. Soil and water resources management is sustainable to mitigate climate change through improved soil water storage, soil erosion control, improved soil structure from soil organic matter and soil carbon sequestration. Climate change now controls how plants and animals interact with the environment. These calls for concern for humanity as it threatens the natural ecosystem and have significant implications on food production. The increasing population will require more food and water thereby stressing water resources and the environment. There is the need to improve soil and water resources management on sustainability of the ecosystem. This could affect the quality of some foods and farmers ability to manage certain crops. This review identified the ecological dynamics of climate change, vulnerability, resistance and management interventions that may assist the ecosystem resilience. The consequences of global warming through human activities on soil and water resources was also highlighted. The paper concluded that climate change mitigation requires effective collaboration amongst different stakeholders that has contributed to its deteriorating effects. Recommendations were made based on recycling wastewater and integrated soil fertility management to boost food security within the increasing population.

***Keywords:* Climate change, Water management, Soil management, Ecosystem, Population**

INTRODUCTION: The combination of fossil fuels, oil and gas are major contributors to global warming as it has influenced climate change faster over the years. These has led to global rise in hunger and food insecurity. Climate change has also affected water availability as its scarcity in tropical regions poses high risk of agricultural drought and plant stress (IPCC, 2019). These has affected human beings and all forms of life in recent years. Sustainable soil management practices adapted to environmental conditions enhances interactions among soil water and plants, which can mitigate the impacts of climate change (Lal, 2013) and improve food security. Food security, human health, rural-urban migration and flourishing ecosystems are all climatic and water dependent within the tropical regions of the world. Sustainable agricultural growth is essential for economic and population development, poverty reduction and food security globally. These is because crops and livestock largely depend on water for development and growth. Water is a limiting factor in agricultural production and also essential for their value addition. The major water sources for agricultural production comes from rainfall, surface water and groundwater. Improving water resources management according to FAO (2021), are crucial steps aimed at boosting food security. It is key to the long-term agricultural viability of, global food production and its processing. Its management is essential to equitable water allocation, enhancing adaptation related to climate shock stresses, and addressing water scarcity (Baclig, 2022). These objectives requires working at the immediate local and national community level to implement laws, policies, planning and social practices. There is the need to extend access to effective irrigation technologies and encourage on-farm soil water conservation practices. Farmers require sufficient soil and water conservation practices to ensure moisture for crop growth and its availability at the cultivation periods. This can also enhance soil carbon storage thus contributing to climate change mitigation, the carbon added improves fertilizer efficiency and retain water for crop use.

CLIMATE CHANGE CHALLENGES AND THE ECOSYSTEM: Many plants and animals species are not able to survive these conditions and are becoming extinct as the ecosystem is losing balance. Many species of animals for which the climate where they live influences key stages of their annual life cycle migrate. Birds migrate in a particular season and when the season is delayed, the migration affects them. For instance, sparrows have become extinct in some regions. The ecosystem assist in the mitigation and adaptation to climate change. The magnitude and its rate depend strongly on near-term mitigation and adaptation actions, with the projected adverse impacts and damages. (Hasan, Desiere, D'Haese and Kumar, 2018). We need to take actions to help ecosystems adapt and reduce these effects through conservation and restoration approaches as reported by Wang, Vanga, Saxena, Orsat and Raghavan, (2018). Agencies that manage countries natural resources now consider climate change in polices and planning. Groups are preserving habitats, restoring damaged and disturbed ecosystems. For instance introducing new species and genes in crop production and animal husbandry within locations they will thrive explains conservation approach. Zimbabwe, Namibia and South Africa are among African countries that have adopted the cultivation of stress and water tolerant crops in response to periodic drought and heat waves. The cultivars released through various government interventions under various projects within Africa are positively impacting livelihoods through food security (Kondwakwenda, Mutari, Simango, Nchanji, Chirwa, Rubyogo and Sibya, 2022). Nature-based approaches such as vegetation cover, green roofs, green space and construction of structures that restore natural hydrologic functions mitigates climate change hazards. Continuous surveillance and integrated pest management are techniques that could be adopted to handle the pressure caused by insect pest and diseases associated with climate change (Batisani, 2014). Countries research council should carry out survey annually to determine the severity of pest and diseases of economic crops. Plant breeders must adopt conventional modern breeding techniques which should increase crop resistance to pest and diseases infestation. Improved breeding will introduce long-term solution and control for present time and historical pests and diseases (Sibiya, Tongoona, Derera and van Rij, 2012

CLIMATE CHANGE MITIGATION MEASURES AND SOIL WATER MANAGEMENT: Climate change mitigation consists of human activities required to reduce greenhouse gases emissions and exploiting carbon sinks to reduce the accumulation of CO_2 in the atmosphere. It may involve large area of land and regions over a long period of time. The climate change mitigation measures influences soil water resources and their management when developing and evaluating different options as reported by Adesina and Odekunle (2011) within the ecosystem. These complements soil and water resources. The management policies and measures can have a direct effect on greenhouse gas emissions and the respective mitigation measures. The global trend most often affects water through droughts, floods and irregular rainfall that influences erosion, saturated and unsaturated zones. Researchers are observing changes in evaporation, humidity, snow accumulation and melt.

Improved access and use of soil water controls climate change. It requires cutting-edge land farming procedures such as Integrated Soil Fertility Management (ISFM), Conservation Agriculture (CA) and land restoration technology. ISFM judiciously integrates inorganic and inorganic fertilizers and improves germplasm (Nkonya, Koo, Kato and Guo, 2013). Application of organomineral fertilizer boosts returns by 58% compared to applying chemical fertilizers alone. The Alliance for a Green Revolution in Africa (AGRA) has shown that the adoption of ISFM can be significantly boosted. Agroforestry systems adopts shallow-rooted crops with deep-rooted trees and utilizes soil moisture Reverse-slope terraces and water-harvesting innovations are integrated water management solutions with regards to climate-change mitigation. (Amadu, McNamara and Miller, 2020).

Water management in our cities should now be more important than it was. Urban water supplies are particularly vulnerable to climate change. By the year 2050, six hundred and eighty five (685) million people residents in about 570 cities will likely be exposed to additional 10 per cent reduction in water availability as a result of climate change. Some major cities such as Jordan, Cape Town, and Melbourne, may experience reduction of between 30 and 49 per cent. Santiago and Chile, with a decline of over 50 per cent (IPCC, 2019). We need to protect our water sources, efficient in water use and infrastructural development. These approaches need to be intensified in many cities. Establishment of more urban green space and wetlands can reduce storms and flooding in cities as these will absorb irregular water, reduce runoff and improve water quality. This will filter and absorb nutrients and pollutants. There should be tendency to reduce water scarcity through augmentation of water supply by increasing surface and groundwater storage. This tendency should focus on reducing water demand by minimizing the losses in conveyance and distribution systems through implementation of adequate tariff. This will encourage lower water demand and change water use technologies in domestic, industrial, and irrigation systems. Water demand reduction also controls other activities that are not directly related to water, but are equally important (Cosgrove and Cosgrove, 2013). This could be through demographic growth control, increasing the efficiency and use of food products that consume water during production and supply process. Water managers need to be familiar and interact with various disciplines and stakeholders. They should have sufficient skills to be able to engage affected stakeholders where improved water management is required.

Nature-based solutions (NBS) bring multiple benefits through restoring wetlands, coastal mangrove forests and natural floodplains. They are important to water conservation as well as climate change mitigation strategies as they act as carbon sinks and absorbs greenhouse gas emissions. Peatlands store at least twice as much carbon as all of Earth's forests, while mangrove soils hold over 6 billion tonnes of carbon and can sequester up to four times more carbon. These approaches are nature-based and should attract attention and funding. Currently, UNEP and the FAO are supporting the Democratic Republic of Congo in the development of a program to protect and sustainably manage the Cuvette Centrale Peatlands, which is estimated to be the largest continuous tropical peatland complex in the world (IPCC, 2019). It contains the equivalent of two years of global greenhouse gas emissions (Dargie, Lawson, Mitchard, Page, Bocko and Ifo, 2017) which might be released if the peatlands were altered or drained by human interference or continuous periods of drought.These solutions to societal challenges are emerging as an integrated approach that can reduce climate change effects (Seddon, Turner, Berry, Chausson and Girardin, 2019) at reduced cost and providing multiple benefits for people and nature. Planting trees and increasing green space helps initiate cooling and flood reduction, carbon storage, air pollution mitigation, and provides recreation and health restoration advantages in urban cities. The NBS are ways to connect economic development with the ecosystems, and means to enable sustainable development (Calliari, Staccione and Mysiak, 2019). They are aimed to address broad goals within the society as they differ from the traditional biodiversity conservation management. These solutions must be implemented to support biodiversity and people (Lewis, Wheeler, Mitchard and Kock, 2019).

Water resources management as part of climate action plans benefits the right of man to safe drinking water and sanitation as it directly tackles the impacts of climate change (Oki, 2016) It also contributes to achieving the Sustainable Development Goals (SDGs) of the United Nations. In 2020, countries reviewed and implemented their contributions under the Paris Agreement. The great opportunity will improve water management practices and allow communities make decisions which will aid climate resilience. This will allow countries great opportunities to improve on broader development and climate programs effectively. This initiative will solve world water issues and implement adequate synergy with climate adaptation through Integrated Water Resource Management (IWRM).Water resources and its management must be an action plan. The 2020 World Water Day awareness highlighted that every individual has a role to play. Steps should be taken to mitigate climate change and channeled towards water conservation. Humans may need to take short showers in place of baths and prevent letting taps run during hand washing and teeth brushing. Installation of water-efficient taps and toilets should also be considered. Water intensive products and services can also be reduced, services like power generation and transportation (Döll, Jimenez-Cisneros, Oki, Arnell, Benito, Cogley, Jiang, Kundzewicz, Mwakalila and Nishijima, 2015). Water management approaches such as fog capture and wetland protection will make it possible to improve soil structure, organic matter and moisture with irregular rainfall as a result of climate change effect

Carbon dioxide (CO_2) capture and storage (CCS) within the soil separates it from industrial and energy sources through retention of crop residue on soil surface with reference to its isolation from the atmosphere. It's injection into soil pore spaces dissolves it in soil water and is being trapped with and transported by the regional groundwater flow. This may degrade the quality of groundwater. Deep-sea storage (below 3,000 m water depth and a few hundred meters of sediment) are safe options. About 33% of the global soils have been degraded and have lost their organic carbon through agricultural expansion, land grazing (FAO, 2019) and other land-use to arable land. This has led to soil structural loss increment, soil exposure to erosion, reduced water retention and nutrient supplies for crop use. These has been a major threat to food security in developing countries as they can continue without carbon input within the soil. Maintaining soil organic carbon stocks will reduce soil degradation by increasing organic matter supply at best management practices and close crop yield gaps (Lal, 2018). These has the potential to reduce 32%, 66% and 5–7% yield gap of maize, wheat and fertilizer needs respectively (Oldfield, Bradford and Wood, 2019) and other agricultural food potentials. These priorities through transformation to increase soil carbon sequestration should be considered in Africa and south west Asia.

Wastewater treatment is a contributor to climate change. It contributes 3% to 7% of all emissions. They are sourced from the energy involved in treating wastewater and biochemical processes adopted. However, untreated wastewater contains soil organic matter and a major source of methane, a powerful greenhouse gas. It accommodates lots of energy than is needed for its treatment. It is estimated that about 80% of wastewater is released into the environment without any form of treatment. Water resources management in this case will involve treatment techniques which will extract methane from organic matter present in wastewater and then use it to generate the energy needed to run the process. Water-scarce countries such as Jordan, Mexico, Peru and Thailand have adopted this principle. These techniques will also reduce CO_2 emission and improve the quality of life within the ecosystem. Recycling and partially treating wastewater for crop production will also boost food security. The understanding of local knowledge and science involved in wastewater treatment is important for climate change adaptation strategies (White, Storey, Owen, Bell, Charters, Dickie and Zammit, 2017). The effluent from wastewater will influence climate change and will depend on the design and type of its treatment processes (Lawrence, Blackett and Cradock-Henry, 2020). The key implications arising from wastewater flooding and odour from wastewater is reduced resilience of waterways and mental health of residents within the community. Exposure to untreated wastewater threatens public health and deteriorates water quality which is a source of illness associated with respiratory disorder. These impacts are already evolving and actions are required to reduce them. Concerned authorities therefore need to be aware of the risks so as to make important decisions related to wastewater infrastructures. Their decisions should be considered with other current and future laws relating to land use (Signh, Rahman, Srinivas, Bazaz, 2018)

SOIL MANAGEMENT: The world population is expected at 9.2 billion people by year 2050 and agricultural food production must increase by 70% to meet the increasing food demand from the soil (FAO, 2000). Climate change is expected to impact at least 22% of cultivated soils of economic crops by 2050 (Alun, 2020). Effective soil management with wise use of organic manure (fertilizers) and indigenous land farming methods such as Integrated Soil Fertility Management (ISFM) will however improve soil water management as it enhances soil carbon and boost crop yield to support food security (Vanlauwe, Bationo, Chianu, Giller, Merckx, Mokwunye, Ohiokpehai, Pypers, Tabo, Shepherd, Smaling and Woomer, 2010).The manure if digested anaerobically produces methane (biogas) which is a power source. Fertilizer application to soil through integration reduces environmental impacts, decomposition rate and carbon emission into the atmosphere. Soil conservation practices through ISFM has potentials to mitigate climate change as soil carbon sink capacity is enhanced when soils are exposed to it unlike treatment with organic or inorganic nutrient directly (John, Kapukha, Wekesa, Heiner and Shames, 2014). Zero tillage increases soil organic matter level and influences more water storage and retention within the soil. Reduced tillage prevents soil runoff which increases soil water retention capacity. These tillage methods reduces CO_2 emission through limited fossil fuel use into the environment. Soil is less disturbed as oxidation of its organic matter is low from the effect reduced atmospheric CO_2 emissions. Irrigated soils when covered with crop residues and other soil conservation practices increases soil carbon sequestration which will as a result increase crop yield (FAO, 2015). Irrigation water sources from burning fossil fuels require significant high energy, this contributes to emission. Also, groundwater is required to irrigate over 30 percent of irrigated lands. It has been projected that modernized irrigation will reduce water consumption in the tropics by 21 percent. The use of solar energy in irrigation practices is a good option which reduces emission from burning fossil fuels. This is a reliable and clean energy solution for water use and management especially in locations with high solar radiation. Awareness of solar radiation on climate change reduces greenhouse gas emission. As a result of low cost of installation and operating solar system in irrigation practices, farmers tend to overuse available groundwater. There is the need to put in place appropriate policies and rules to ensure effective water use and its management.

Methane emission from agricultural practices accounts for more than 50 percent of methane in the atmosphere (FAO, 2020). Transformation of wetland to irrigated land in rice cultivation releases methane into the atmosphere. This emission can be reduced through several soil water management practices such as: cultivating aerobic rice, avoiding water saturation in periods when rice is not grown and by reducing continuous flooding period during rice growing season. These approaches helps in soil water management and reduces methane emission (Reay, Smith, Christensen, James and Clark, 2018). Legumes cultivation diversifies pasture species and reduces animal density as low as possible on grazing and pasture land. This reduces methane emission. Farmers do not support this method because of the opportunity cost they tend to loose according to Thorton, Ericksen, Herrero and Challinor, 2014. Increasing the intake of tannin rich vegetables and cultivating moringa plants on rangelands have been reported to reduce methane emissions from livestock (Moyo, Masika, Hugo and Muchenje, 2011). Livestock methane emissions reduction through the use of feed additives during processing will suppress methane fermentation in ruminants and cattle diets. Large, non-ruminant herbivores replacement by domestic ruminant grazing livestock will result in changes in vegetation as it reduces methane emission and have a net mitigating effect on climate change. The use of adapted breed and hybrids of native and foreign breeds according to Taruvinga, Muchenje and Mushunje, 2013 is now been considered to be a smart strategy for improving livestock resistance to the harsh effects of climate change. Afforestation and agroforestry influences soil use and management. This will also lead to reduced stream flow and groundwater especially in the arid and semi-arid regions. This system combines shallow rooted crops with deep rooted trees.

AGRICULTURAL PRACTICES: Greenhouse gas emission from agricultural practices have doubled over the years and it's been projected to increase further by 2050 (FAO, 2014). Climate change mitigation measures in agricultural practices will also have both positive and negative effects on soil water resources (Thornton, Jones, Alagarswamy, Andresen and Herrero, 2010). Climate induced susceptibility in tropical agriculture is due to variations and extremes in weather conditions. The factors that influences agricultural practices vulnerability to climate change include: Higher reliance on crop production systems sensitive to climate change.Delayed access to crop production input and market output. Lower and declining soil productivity.Soil degradation and a declining natural resource base.Tropical African agriculture is most susceptible to climate change extremes, all parts of her food security (availability, accessibility, utilization and stability) are influenced by climate change. The food prices increment is as a result of uncertainty in food production from climate change effects and increasing food demand through population growth. Climate smart agriculture is gradually been recognized as solution to climate change effects on agriculture (Brohm and Klein, 2020; Chandra, McNamara and Dargusch, 2018) It encourages innovation agriculture system. Climate smart agriculture will contribute to sustainable improvement in agricultural productivity, increase income and food security. It will help improve farmer's ability to adjust to long term climatic shocks and reduce climatic change effects on food value chain. However, its promotion and adoption is still not enough, small holder farmers generally are not exposed to it.

CONCLUSION: Climate change mitigation will require radical and significant transformations across all sectors. Water management approach and better management of the water cycle is well recognized but not being conveyed into reality. It has not really appeared in international climate agreements. Paris agreement goal aimed at reducing global warming below 2 °C is a promising approach as it will help conserve biodiversity. The agreement continue to exist as general in nature, without proposing specific water management plans. Countries recognize water in their action plans, not all of them have actually calculated the costs of these actions and even fewer have put forward specific projects. The chances for collaboration between adaptation and mitigation measures for functional ecosystem services and food security are often neglected. The compliance level of implementation of the mitigation strategies varies also per sector. Comprehensive policy packages with financial incentives over a long period of time will drive climate actions around the world and is therefore a responsibility of all stakeholders.

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