CLIMATE CHANGE, FOOD SECURITY, NATIONAL SECURITY and ENVIRONMENTAL RESOURCES

GLOBAL ISSUES & LOCAL PERSPECTIVES

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PUPLISHED BY:

Society for Agriculture, Environmental Resources & Management (SAEREM)

SAEREM BOOK CHAPTERS2023: First published 2024: ISBN 978-978-60709-9-5

First published 2024

SAEREM World

Nigeria

Typeset in Times New Roman

Climate Change, Food Security, National Security and Environmental Resources

Global Issues & Local Perspectives

ISBN 978-978-60709-9-5

Printed at: SAEREM World

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Preface

This book adopts an exegetical approach as well as a pedagogic model, making it attractive agriculture and environmental economics teachers, professional practitioners and scholars. It is eschews pedantry and lays bars the issues in such clarity that conduces to learning. The book elaborates on contemporaneous climate change, food security, national security and environmental resources issues of global significance and at the same time, is mindful of local or national perspectives making it appealing both to international and national interests. The book explores the ways in which climate change, food security, national security and environmental resources issues are and should be presented to increase the public's stock of knowledge, increase awareness about burning issues and empower the scholars and public to engage in the participatory dialogue climate change, food security, national security and environmental resources necessary in policy making process that will stimulate increase in food production and environmental sustainability.

Climate Change, Food Security, National Security and Environmental resources: Global issues and Local Perspectives is organized in four parts. Part One deals with Climate Change with Six Chapters, Part Two is concerned with Food Security with Nine chapters, Part Three deals with National Security with Five Chapters, while Part Four pertains Environmental Resources, has Five Chapters.

Ahmed Makarfi / Eteyen Nyong

April 2024

SAEREM BOOK CHAPTERS2023: First published 2024: ISBN 978-978-60709-9-5

CHAPTER 13

Soil Conservation Management: Climate Change and Food Sufficiency

Eze, Kingsley Chijioke*, Obasi, Nnenna Patrick and Inyang, Otoobong Anwanabasi.

Abstract

Soil conservation involves proactive strategies for managing and safeguarding soil resources to prevent degradation and enhance long-term sustainability. This comprehensive survey explores the intricate relationship between soil conservation management, climate change impacts on soil health, and their collective influence on global food sufficiency. Exploring both traditional and contemporary soil conservation practices, the analysis navigates through the evolving strategies, emphasizing the importance of case studies for practical insights. The narrative culminates in a forward-looking discussion, offering recommendations for policymakers, farmers, and researchers. Emphasizing collaboration and adaptability, this assessment addresses the critical need to ensure soil resilience amidst climate change, ultimately securing global food sufficiency goals. Grounded in a synthesis of scientific literature, this synopsis provides a thorough understanding of the dynamic interplay between soil conservation, climate change, sustainable food production and food security.

Keywords: Soil Conservation; Climate Change and Resilience; Food Sufficiency; Sustainable Agricultural practices; Soil Health; Global Food Security.

Introduction

Soil conservation entails the proactive ways of managing, safeguarding and protecting the soil resources in order to prevent the soil from degradation while enhancing its sustainability (Sanju, Gajanand, and Choudhary 2021). It involves different practices that are aimed at maintaining and/or improving the soil quality, soil structure and soil fertility (Muhammad, 2023). Soil, a determinate and vital natural resource, supports global agricultural productivity besides the

delicate balance of ecosystem (Aniket, Prasad and Nihal 2023). In a way of navigating the challenges posed by climate change, as well as striving to ensure global food sufficiency, the role of soil conservation management arises as a key player in sustainable agriculture (Ingulsrud 2016). Here, we will be discussing the critical intersection of "Soil Conservation Management: Climate Change and Food Sufficiency," highlighting the intricate relationships between soil health, climate impacts with, the imperative of securing the supply of food. Soil that is frequently underestimated, is a complex and dynamic living system (IPCC, 2019). It functions as a basic substrate for plant to grow, provides water, nutrient and also gives structural support (Raghavendra, Raghavendra, Siva Prasad, Veeresh, Hanamant, Adilakshmi, Venkataravana,

Suresh, Sai Maheshwari, Prabhakara and Sudhir 2022). Soil that is healthy, is a prerequisite for a robust agricultural system, it influences crop production, carbon sequestration and water filtration (Chopra, Magazzino, Shah, Sharma, Rao and Shahzad 2022). Healthy soil is essential for agricultural production and food security. The FAO (Food and Agriculture Organization) accentuates that sustainable soil management practices are vital in ensuring resilient and productive agricultural systems (FAO, 2020).

In the recent decades, there has been extraordinary changes in climate pattern, with increase in temperatures, alteration in precipitation, with a rise in extreme weather events (IPCC 2022). The changes here exert profound impacts in soil health, that triggers concern in nutrient depletion, soil erosion and disruption of the microbial communities (IPCC, 2019). Consequently, the resilience of our agricultural systems and food security globally, are threatened (Chopra *et al.*, 2022). But this research aims to explore and illuminate the intricate interplay between soil conservation management, the adverse effects of climate change on soil, and their collective impact in ensuring a secured and sustainable global food supply. The quest for effective soil conservation strategies becomes paramount as we navigate a future where, climate uncertainties challenge conventional agricultural practices (Uday, David, Peter, Mark, John, and Anton, 2022).

The climate change impact on soil can be explained in the aspect of the increasing frequency of extreme weather events and shifts in precipitation patterns that pose significant threats to soil health (IPCC 2022). According to IPCC (Intergovernmental Panel on Climate Change), rising temperatures and altered precipitation patterns can exacerbate soil erosion and degradation (IPCC, 2019). In the aspect of the challenges in climate change, effective soil conservation management

is imperative for sustaining agricultural productivity as well as achieving global food sufficiency goals (Aryal, Sapkota, Khurana, Khatri-Chhetri, Rahut and Jat 2019)

This research explores the intricate relationship amid soil conservation practices, the impact of climate change on soil, and its collective influence in ensuring a secured and sustainable food supplies. Climate change has multifaceted effects on soil health, including changes in temperature, precipitation pattern, and extreme weather conditions. The changes can disturb soil structure, microbial communities and nutrient cycles (Smith and Johnson 2021). Warmer temperature accelerates soil organic matter decomposition thereby, affecting the availability of nutrient and the structure of the soil (Schimel, Balser and Wallenstein 2017). Changes in Precipitation Patterns leads to soil erosion, water-logging, and changes in soil moisture levels, absorption of nutrient and impacting plant growth (FAO, 2020). To fully understand this connection, we will explore soil conservation practices, starting with ancient traditions to the contemporary sustainable innovations (Costa Junior, Favarin and Da Rocha 2017). Examining case studies from different regions provides valuable insights into successful strategies, lessons learned, and their adaptability to various contexts (Dymond and Schipper 2018).

Furthermore, the exploration of global initiatives and governmental policies will shed more light on the concerted efforts at both international and national levels in order to address soil conservation challenges (United States. Department of Agriculture 2020). The integration of technological innovations in soil management will be scrutinized for its potentials in revolutionizing sustainable agricultural practices (Smith and Johnson 2022).

Finally, this review will culminate and help in a forward-looking discussion on future prospects of soil conservation management (Muhammad, 2023). Recommendations for policymakers, farmers, and researchers will be proposed, emphasizing the critical need for a collaborative and adaptive approach to ensure the resilience of our soils against the backdrop of climate change, ultimately securing our global food sufficiency goals (Gabriel, Olajuwon, Klauser, Blessing and Mara 2023).

Soil Conservation Practices

Soil conservation practices classified into traditional and modern practices are discussed in this chapter. The Overview of Traditional Soil Conservation Methods have been passed down through generations and it involves simple and locally adapted techniques which include the following: contour plowing, Terracing and cover cropping as shown in Figure 1.

*Contour Plowing***:** This involves plowing along the contour lines of the soil and this reduces water runoffs and also minimizes soil erosions.

*Terracing***:** Constructing terraces on hilly land can help in slowing down water runoffs and preventing soil erosion as well.

Cover Cropping: Planting of cover crops during the off-season will help to protect the soil from erosion, thereby enhancing nutrient retention, and improving soil structure.

The Modern and Sustainable Practices of soil conservation focuses on sustainability, minimizing environmental impact while maximizing agricultural productivity. This modern practice includes: No-Till farming, Agroforestry and Precision Agriculture.

*No-Till Farming***:** To avoid plowing or tilling will reduce soil disturbance then, enhance water retention, and preserve the soil structure (Somasundaram, Sinha, Dalal, Rattan, Mohanty, Naorem, Hati, Chaudhary, Bswas, Patra and Chaudhari 2020).

Agroforestry: To integrate shrubs and trees with crops will enhance biodiversity, improve soil fertility, and check erosion (Jose, 2019).

*Precision Agriculture***:** The use of technology in optimizing inputs, such as water and fertilizers, will minimize waste and environmental impacts (Brent, Jaenisch, Munaro, Krishna and Romulo 2022).

Case Studies Highlighting Successful Soil Conservation Projects: There are some case studies where we have soil conservation projects that are successful. An in-depth examination of these regions or countries that implement successful soil conservation strategies include China, Kenya, Australia etc as discussed below.

*China's Grain for Green Program***:** This large-scale initiative involved converting cropland to forest and grassland, reducing soil erosion and improving ecological conditions (Naresh, Singh, Sachan, Mohanty, Sahoo, Pandey and Singh 2024).

The Landcare Movement in Australia**:** Community-led efforts focusing on sustainable land management practices have improved soil health and biodiversity (Somasundaram, Anandkumar, Yash, Kathryn and Dalal 2021).

*Kenya's Terracing Project***:** Implementation of terracing and agroforestry practices in Kenya has successfully reduced soil erosion and improved water retention (Hilchey, 2017).

Ethiopia's Sustainable Land Management Program: By using integrated approaches such as terracing, afforestation and community engagement, Ethiopia's program has reduced soil erosion effectively and also soil fertility has improved (Nyssen, Descheemaeker, Poesen, Vanderkerckhove, Haile, Moeyersons and Haregeweyn 2019).

*Brazil's No-Till Revolution***:** In Brazil, there is a widespread adoption of no-till farming system, that is supported by the government's incentives, and this has minimized soil disturbance, enhanced overall soil health as well as improved water retention (Costa Junior *et al*., 2017).

*New Zealand's Riparian Planting Initiatives***:** New Zealand's efforts in planting of riparian buffers along waterways has reduced sedimentation, soil runoff mitigation and preserves water quality (Dymond *et al*., 2018).

Importance of Soil Conservation in the Context of Climate Change and Food Sufficiency

*Climate Change Impact on Soil***:** Increasing frequency of the extreme weather conditions and changes in precipitation forms pose important threats to the health of the soil. Intergovernmental Panel on Climate Change (IPCC) says that, increase in temperatures and changed precipitation forms can exacerbate soil erosion and degradation (IPCC, 2019).

*Food Sufficiency***:** Healthy soil is crucial for agricultural production and food security. FAO (Food and Agriculture Organization) emphasizes that sustainable soil management practices are vital to ensure resilient as well as productive agricultural systems (FAO, 2020).

Examples of Specific Climate-Related Challenges

Increased Erosion Risk: Intense rainfall events caused by climate change elevates the risk of erosion, affecting arable land and also reduces soil fertility (IPCC, 2019).

Drought Stress: Continued drought contributes to depletion of soil moisture, hinders crop growth and leads to degradation of soil structure (Wang, Sheffield, Schubert, Pan and Luo 2018).

*Extreme Weather Events***:** Floods, cyclones and hurricane can cause disturbance to soil, loss of nutrient, and increase in vulnerability to invasive species, thereby posing challenges to sustainable agriculture (Hossain, Raihan, Rafiq and Alam 2021).

Salinization: Alterations in precipitation pattern and rise in sea level contributes to soil salinization, hence, affecting the viability of land used for agriculture (Ehlers, Fleckenstein, Leuschner, Huth and Huwe 2019).

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*Shifts in Soil Microbial Communities***:** Induced climate change can change the compositions and activity of soil microbial communities, impacting nutrient cycles and the overall soil health (Kardol, Camenzind, Hempel, Homeier, Horn, Velescu and Scheu 2018).

Explanation of Climate Change Effects on Soil Health: Change in climate has many-sided effects on soil health such as, changes in temperature, precipitation pattern and extreme weather conditions. The changes could disrupt the structure of soil as well as nutrient cycles, and microbial populations. Temperature Increase: Higher temperature accelerates the decomposition of soil organic matter, it affects availability of nutrient and soil structure (Schimel, Balser and Wallenstein 2017).

Altered Precipitation Patterns: Alterations in precipitation leads to soil erosion, changes in soil moisture contents and waterlogging, making impact in plant growth and absorption of nutrient (FAO, 2020).

Relationship between Soil Conservation and Food Sufficiency

*Connection between Healthy soil and Crop productivity***:** There is a connection that exist between healthy soil and crop productivity as discussed below. Healthy soils are fundamentals to crop productivity based on the role they play by providing essential nutrients, supporting root development, and in promoting a favorable microbial environment. Soil health influences factors such as water retention, nutrient availability and overall plant growth directly (Gabriel *et al.*, 2023).

Analysis of How Soil Conservation Contributes to Food Security:This can be explained using Figure 3.

*Enhanced Soil Fertility***:** Soil conservation practices, like the use of cover cropping and organic matter combination, contributes to improve soil fertility thereby supporting higher yields (Kathryn, Yash and Ram 2020).

*Reduced Erosion***:** Terracing and contour-plowing are soil conservation practices that minimizes erosion, preserves topsoil and also prevents nutrient loss, and are crucial in sustaining agricultural productivity (Ingulsrud, 2016).

*Water Management***:** Conservation practices such as precision agriculture and agroforestry helps in managing water resources efficiently and ensures optimal moisture levels for crops, most especially in regions that are prone to droughts (FAO, 2019).

Potential Challenges and Opportunities: Here, we will discuss two challenges and two opportunities that are associated with soil conservation.

Challenges: The challenges associated with soil conservation are discussed below.

Implementation Barriers: This is one of the challenges seen in soil conservation. The adoption of soil conservation activities might face resistance because of economic constraints, inadequate infrastructure and lack of awareness (Somasundaram *et al*., 2021).

Climate Change Impacts: Changes in climatic patterns pose challenges, while soil conservation practices need continuous adaptation in order to remain effective (Lorenza & Andrea 2024).

*Opportunities***:** The opportunities that one can gain in soil conservation are essential as discussed below.

*Technology Integration***:** Technological advancements like precision agriculture and satellite monitoring offers new tools for effective management of the soil (Okuduwor, Manureh and Amadi 2023).

Policy Support: Some government policy promotes sustainable farming methods and incentivizing soil conservation efforts could enhance food security (Gabriel *et al*., 2023).

Global Initiatives and Policies: Here, we will be discussing about the overview of international efforts in addressing soil conservation. International organizations and other collaborations lay emphasizes on the importance of soil conservation in actualizing sustainable agriculture. Efforts span research, awareness campaigns, and capacity-building initiatives:

FAO's Global Soil Partnership (GSP): They promote sustainable soil management through research coordination, knowledge exchange and also capacity development on a global scale (FAO, 2015).

United Nations Convention to Combat Desertification (UNCCD): They focus on how to combat desertification and soil degradation thereby, promoting sustainable land management practices all over the world (UNCCD, 2024).

European Union Common Agricultural Policy (CAP): They integrate soil conservation measures, laying emphases on sustainable farming practices as well as supporting agro environmental initiatives (European Commission, 2024).

China's Soil Tenure System Reform: The government of China have implemented some policies that are used to address degradation of soil, such as land tenure reforms, in order to encourage sustainable practices of land use (He, Li and Zhang 2019).

United States Conservation Reserve Program (CRP): They incentivize farmers in adopting soil conservation practices, like cover cropping and buffer strips, in order to improve soil health as well as reduce erosion (USDA, 2020).

Technological Innovations in Soil Management: Technological innovations in soil management can be explained briefly using Figure 2 where we talk about the emerging technologies and their impacts as explained below.

Exploration of Emerging Technologies in Soil Conservation: Innovations in soil conservation managements are used and they include precision agriculture, sensor-based soil monitoring and satellite imaging as discussed below.

*Precision Agricultur***e:** The use of technologies such as sensors, GPS, and drones in optimizing the use of resources, enables farmers to tailor inputs such as pesticides, water and fertilizers precisely (Liu, Li, Huang and Jia 2018).

Sensor-Based Soil Monitoring: The advanced sensor provides real time data in soil condition thereby, helping the farmers to make knowledgeable decisions of nutrient applications, irrigation as well as the general soil health (Ameur, Begue, Jones, Mora and Inglada 2018).

Satellite Imaging: The use of satellite technology permits for large scale monitoring of crop health, soil and land use forms, which aids in assessing soil cmoistureonservation efforts (Ramoelo, Cho, Mathieu, Madonsela, van der Kervhove, Kaszta and Odindi 2018).

Impact of Technology on Sustainable Agriculture Practices: The impact of technology in sustainable agriculture practices can be seen in different ways as explained in this work.

*Resource Optimization***:** Precision agriculture technology contributes efficiently in the use of resource, to reduce waste and minimize environmental impact (Brent *et al*., 2022).

Data-Driven Decision Making: Real-time data from sensor and satellite imagery enables farmers to make knowledgeable decisions that leads to improved soil management and increase in productivity (Sanju *et. al.*, 2021).

Enhanced Monitoring for Conservation Practices: Technology enables continuous monitoring of the efficacy of soil conservation events, permitting timely adjustments and also improvements (Naresh *et al.,* 2024).

Lessons Learned and Applicability to Different Contexts: In different contexts, there are different lessons learnt and the ways of application of the soil conservation method as discussed below.

*Community Involvement and Ownership***:** Ethiopia's success in soil conservation has highlighted the importance of involving local communities in soil conservation practices, thereby fostering a sense of ownership and a lasting commitment (Deininger, Ali, Alemu and Tekie 2016).

Government Support and Policy Alignment: The Brazil's no-till revolution has emphasized the crucial role of government in the support and policy alignment of promoting and scaling up the sustainable soil management practices (Séguy, Barthes, Bouzinac, Duwig, Gabrielle, Makowski and Nicolardot 2017).

Tailoring Strategies to Local Conditions: The New Zealand's riparian planting initiatives showcased the need for context-specific approaches, recognized that effective soil conservation practices may differ depending on ecological and geographical conditions (Costanza, de Groot, Sutton, van der Ploaeg, Anderson, Kubiszewski and Turner 2017).

Future Prospects and Recommendations: Discussions on the future of soil conservation management is very important so that we don't use methods that will affect food supply and climate change negatively. They include the following:

Integration of Digital Technologies: Continued advancements in digital technologies such as Artificial Intelligence (AI) and machine learning, could enhance precision in soil conservation methods and providing real-time insights for adaptive management (Sanju *et. al.,* 2021).

Climate-Resilient Strategies: Efforts in future soil conservation should prioritize strategies that addresses the impacts of climate change, like developing crops resilient to changing conditions and implementing adaptive soil management practices (Okuduwor *et al*., 2023).

Recommendations for policymakers: Policymakers should implement and incentivize sustainable agricultural policies that will promote soil conservation practices (Gabriel *et al*., 2023).

They should also invest in researches and extension services to disseminate knowledge on effective soil management methods.

Recommendation for farmers: Farmers should adopt and adapt sustainable soil conservation methods depending on local conditions and needs of farmers (Somasundaram *et al*., 2021).

Farmers should also participate in training programs and also take advantage of available support mechanisms in implementing conservation measures *Recommendation for researchers*: Researchers should prioritize researches on the development of climate-resilient crops and innovative soil management techniques (Liu *et al*., 2018).

Researchers should also collaborate across disciplines in addressing knowledge gaps and also facilitate the integrations of cutting-edge technologies in soil conservation.

Conclusion: The effects of climate change on soil health, such as increased erosion risk, drought stress, and changes in soil microbial communities, necessitates attention urgently. Traditional methods and modern innovations such as precision agriculture offers effective solution in mitigating soil degradation and promoting sustainable soil management. Healthy soil is vital for crop productivity and it also plays a pivotal role in ensuring food security by enhancing soil fertility, minimizing erosion and enhancing use of resource.

Sustainable soil conservation is not only a critical response to climate change impacts on soil health but also a linchpin for achieving global food sufficiency. As climate change continues to pose challenges to agriculture, adopting and scaling up effective soil conservation practices is imperative. It not only ensures the resilience of ecosystems but also contributes to the long-term viability of agriculture. Policymakers, farmers, and researchers must collaborate to prioritize sustainable practices, integrate technological innovations, and enact policies that promote soil health. By recognizing the intricate links between soil conservation, climate change, and food security, we can pave the way for a more resilient and sustainable future in agriculture.

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