

The Influence of Optimization of Soil and Water Resources on Environmental Sustainability

**Engr. Anene Ndubisi Kelvin, Ohanu Victor Chibueze
& Engr. Ademiju, Teslim. A.**

Department of Agricultural Education
Federal College of Education (Technical) Asaba
For correspondence, email: ndubisianene63@gmail.com

Abstract

This study investigates the Optimization of Soil and Water Resources for Environmental Sustainability by evaluating current global degradation trends, identifying sustainable strategies, examining the impacts of optimized resource management, and proposing innovative policy frameworks and technologies for integrated management. Utilizing a quantitative research design, data were collected from a purposive sample of 60 agricultural lecturers selected from six tertiary institutions in Southern Nigeria, including Delta State University, University of Delta, Dennis Osadebe University, Ogwashi-Uku Polytechnic, Nnamdi Azikiwe University, and Enugu State University of Science and Technology. A structured questionnaire was employed to elicit responses, and descriptive statistics were used for analysis. The findings reveal that while respondents recognize the transformative potential of technological innovations such as precision irrigation and remote sensing in enhancing soil and water use, there remains significant skepticism about the adequacy of current policy frameworks. Respondents strongly supported the need for policy reforms, community-based resource management, and increased government prioritization of sustainable practices. The study recommends comprehensive policy restructuring, increased investment in technological infrastructure, incentives for environmentally sustainable practices, and participatory resource governance. These measures are crucial for mitigating soil and water degradation and promoting long-term environmental resilience. The study contributes to the growing body of knowledge on sustainable environmental management and offers practical insights for policymakers, researchers, and practitioners focused on resource optimization and ecological balance.

Keywords: Soil and Water Optimization, Environmental Sustainability, Policy Frameworks, Technological Innovation, Resource Management.

INTRODUCTION

Soil and water are foundational elements of ecosystems, agriculture, and human well-being, functioning interdependently to maintain environmental health and productivity (FAO, 2020; Rockström, Falkenmark, Folke, Lannerstad, Barron, Enfors, & Gordon, 2017). Healthy soils support vegetation and act as natural water filters, while adequate and clean water is essential for sustaining plant life and soil microorganisms (IPCC, 2022). However, these resources are increasingly threatened by human-induced activities such as deforestation, urban sprawl, unsustainable farming, and climate change (Gao, He, Fan, & Li, 2023; UNEP, 2019). The resulting issues—soil erosion, nutrient depletion, salinization, desertification, and water pollution—underscore the urgent need for strategic and sustainable interventions to preserve and optimize soil and water resources (WWAP, 2020).

Integrated resource management approaches have been widely recommended to address the complex challenges of soil and water degradation (Huang, Zhan, & Zhang, 2019; Qadir, Noble, & Oster, 2020). Techniques such as conservation agriculture, agroforestry, integrated watershed management, and precision farming are recognized for their potential to enhance sustainability (Tittonell, 2020; Singh, Jain, & Chaudhary, 2022). Nevertheless, adoption rates remain low in many areas due to policy limitations, socio-economic barriers, and insufficient public awareness (Boretti & Rosa, 2019; Mbilinyi, Tumbo, & Mahoo, 2021). Moreover, many studies treat soil and water issues in isolation, missing the opportunity to explore their synergistic potential through integrated optimization—a notable gap that this study seeks to address.

International and national frameworks have emerged to combat soil and water degradation, including the UN Convention to Combat Desertification, the Global Soil Partnership, and Integrated Water Resources Management strategies (GWP, 2021; UN-Water, 2022). National initiatives such as Nigeria's National Water Resources Master Plan and India's Soil Health Card Scheme reflect growing governmental efforts. However, these programs often fall short due to weak enforcement, fragmented implementation, limited stakeholder involvement, and a lack of data-driven decision-making (Obalum, Buri, & Wakatsuki, 2020; Mwangi, Ndungu, & Ouma, 2023). As a result, soil and water degradation continues to threaten food security, livelihoods, and environmental stability, particularly in ecologically vulnerable regions like Sub-Saharan Africa and South Asia.

This study is timely and significant, aiming to empirically explore integrated, innovative strategies for sustainable soil and water optimization by using geospatial tools, modeling, and participatory methods (Kahil, Dinar, & Albiac, 2021; Zhang, Zhao, Xie, Zhu, & Yao, 2023). Its interdisciplinary framework merges ecological science, policy analysis, and socio-economic perspectives to examine trade-offs, synergies, and long-term implications of resource management. Emphasizing local knowledge and context-specific practices (Vanlauwe, Coyne, & Giller, 2017; Akinnifesi, Makumba, & Ajayi, 2022), the study intends to deliver practical, scalable solutions adaptable to various environmental and developmental contexts. In doing so, it contributes to more effective environmental governance and supports the broader pursuit of sustainable development.

Research Questions

1. What is the current global status of soil and water degradation, and what are the major contributing anthropogenic and natural factors?
2. What sustainable strategies are currently being implemented for the optimization of soil and water resources across different regions, and how effective are these strategies?
3. How does the optimization of soil and water management contribute to the achievement of environmental sustainability, particularly in relation to ecosystem health, biodiversity, and climate resilience?
4. What policy frameworks and technological innovations can be proposed to enhance integrated soil and water resource management for long-term sustainability?

Objectives of the Study

The study aims to:

1. Evaluate the current status of soil and water degradation globally.
2. Identify and analyze sustainable strategies for soil and water optimization.
3. Examine the impacts of optimized soil and water management on environmental sustainability.
4. Propose policy frameworks and technological innovations for integrated resource management.

LITERATURE REVIEW

Conceptual Review

Soil Resource Optimization

Soil resource optimization involves the strategic and sustainable use of soil to enhance its productivity, ecological functions, and resilience while minimizing degradation. It incorporates ecological, agronomic, and technological approaches to maintain long-term soil health, which is crucial for food production, water filtration, carbon sequestration, and biodiversity (Lal, 2019; FAO, 2020). In response to global soil degradation caused by human activities like intensive farming and urbanization, sustainable soil management practices such as erosion control, nutrient recycling, organic matter enhancement, and conservation tillage are essential (Montanarella & Panagos, 2021). Soil optimization relies on integrating chemical, biological, and physical dimensions (Brevik, Cerdà, Mataix-Solera, Pereg, Quinton, Six, & Van Oost, 2022) and is theoretically grounded in agroecology, sustainable land management, and resilience frameworks (Altieri & Nicholls, 2018; UNCCD, 2021; IPCC, 2022). Technological advancements, including GIS, remote sensing and machine learning, further support precision land management (Li, Liu, & Zhao, 2020).

Effective soil optimization strategies include the use of organic amendments such as compost, biochar, and green manure to restore fertility and microbial activity (Lehmann, Bossio, Kögel-Knabner, & Rillig, 2019; Zhang et al., 2023). Conservation agriculture practices—minimal tillage, soil cover, and crop diversity—also enhance soil structure and reduce erosion (Kassam, Friedrich, Derpsch, & Kienzle, 2019), though their adoption is often hindered by socio-

economic and policy challenges in developing nations (Pretty, Benton, Bharucha, Dicks, Flora, Godfray, & Wratten, 2020). The emerging concept of "soil health" integrates various biological and chemical indicators to assess soil quality (Bünemann, Bongiorno, Bai, Creamer, De Deyn, de Goede, & Brussaard, 2018). Despite advancements, gaps persist in standardizing evaluation metrics, integrating indigenous practices, and ensuring coordinated policy support (Vanlauwe et al., 2017; UNEP, 2019). Addressing these challenges through interdisciplinary research and inclusive policies is critical to achieving land degradation neutrality and advancing SDGs 2, 13, and 15.

Water Resource Optimization

Water resource optimization is a multidimensional strategy aimed at ensuring the efficient, equitable, and sustainable use of water across agricultural, domestic, industrial, and ecological sectors. With global freshwater demand projected to rise by over 50% by 2050 (WWAP, 2020) and climate change altering hydrological patterns (UN Water, 2020), optimizing water resources has become crucial. This involves both supply-side measures—such as improved water harvesting, recycling, and storage—and demand-side interventions like reducing wastage, enhancing irrigation efficiency, and promoting sustainable consumption (FAO, 2020). Technological tools such as precision irrigation, smart water grids, and real-time monitoring further aid in minimizing water loss and enhancing decision-making (Díaz, Ramírez, & Guerrero, 2022; Kumar, Shukla, & Singh, 2024). These approaches support Sustainable Development Goal 6, which seeks universal access to sustainable water and sanitation. The framework is underpinned by Integrated Water Resources Management (IWRM), which emphasizes coordinated, inclusive, and ecosystem-sensitive water governance (GWP, 2021), as well as the water-energy-food nexus and concepts like virtual water and water footprints that guide policy and sustainable trade (Ringler, Bhaduri, & Lawford, 2018; Hoekstra & Mekonnen, 2019).

Nature-based solutions (NbS) such as wetland restoration and watershed reforestation play a vital role in enhancing groundwater recharge and reducing runoff, complementing traditional infrastructure (UNEP, 2019; Al-Ghamdi, Nasr, & Rehan, 2023). In agriculture, which accounts for nearly 70% of global freshwater withdrawals, water-saving practices like drip irrigation, soil moisture sensors, and drought-resistant crops are essential for resilience (Boretti & Rosa, 2019). Evidence from semi-arid regions shows that blending indigenous knowledge with modern tools improves water productivity and aquifer conservation (Kahil, Dinar, & Albiac, 2021). Community-led governance has also proven effective, especially where centralized systems fall short (Meinzen-Dick, Zwarteveen, & Domènech, 2018). However, major challenges persist: many water governance frameworks remain fragmented and reactive, lacking robust data systems (UNESCO, 2022), and often exclude gender perspectives, equity, and indigenous knowledge (Clement, Harcourt, Joshi, & Sato, 2020). Technological adoption is also hampered by cost, capacity deficits, and policy inertia, particularly in developing countries. This study seeks to bridge these gaps by exploring empirical, technology-driven, and community-based strategies for sustainable water optimization in the face of escalating global environmental pressures.

Environmental Sustainability

Environmental sustainability is a multidimensional concept focused on maintaining ecological health and resilience through responsible natural resource management, reducing environmental degradation, and supporting sustainable socio-economic systems (Goodland, 2017; Mensah, 2019). Evolving from a conservation-centric model, it now reflects a systems-thinking approach that integrates environmental, social, and economic dimensions, aligning with the UN's Sustainable Development Goals (SDGs), especially SDGs 13, 14, and 15 (Gupta et al., 2020; UN, 2022). At the heart of environmental sustainability lies the management of natural capital—resources like clean air, water, soil, and biodiversity—through practices that maintain ecological balance and avoid surpassing Earth's thresholds (Rockström et al., 2017). Strategies such as renewable energy, agroecological farming, green infrastructure, and circular economy models are widely adopted, along with regenerative methods like rewilding and soil carbon sequestration to restore damaged ecosystems (Müller, Burkhard, & Kroll, 2020; Kirchherr, Reike, & Hekkert, 2018; Lal, 2019).

Environmental sustainability is also institutionalized through international frameworks like the Paris Agreement and the Convention on Biological Diversity, which drive systemic reforms in energy, agriculture, water, and waste management to tackle global environmental threats (IPCC, 2022; EEA, 2020). However, implementation remains uneven, especially in lower-income nations due to limited institutional capacity and public awareness (UNEP, 2019). Innovations such as artificial intelligence, GIS, and participatory governance are increasingly used to bridge these gaps (Leal Filho, Salvia, Pretorius, Pacao, Lange Salvia, & Saari, 2021). The nexus approach, which emphasizes the interdependence of water, energy, food, and ecosystems, has offered a deeper, integrative perspective on sustainability challenges (Weitz, Strambo, Kemp-Benedict, & Nilsson, 2017). Nonetheless, critical gaps persist, including insufficient emphasis on social justice, indigenous knowledge, and local governance (Agyeman, Schlosberg, Craven, & Matthews, 2016), as well as inconsistencies in sustainability metrics that fail to capture qualitative aspects (Mayer, 2019). A holistic, inclusive, and context-sensitive model is thus essential, and this study contributes by exploring soil and water resource optimization as practical strategies for achieving environmental sustainability.

Sustainable Strategies for the Optimization of Soil and Water Resources

The sustainable optimization of soil and water resources is a critical component of environmental management aimed at securing long-term ecosystem productivity, biodiversity, and human well-being, especially amid challenges like climate change, soil degradation, and water scarcity (FAO, 2020; IPCC, 2022). Central to this effort are conservation-based agricultural practices such as agroforestry, cover cropping, conservation agriculture, and integrated nutrient management, which collectively improve soil health, enhance water retention, and reduce erosion, thereby supporting both short-term crop productivity and long-term ecosystem sustainability (Lal, 2019; Paustian, Lehmann, Ogle, Reay, Robertson, & Smith, 2019). In addition, Integrated Water Resource Management (IWRM) offers a holistic framework for water sustainability, combining innovative technologies like drip irrigation and wastewater reuse with participatory governance and policy integration to ensure balanced water

use across sectors (GWP, 2021; UN-Water, 2023). Precision agriculture tools such as remote sensing and soil moisture sensors further enable targeted, efficient use of inputs, reducing environmental harm while maximizing yields (Zhang et al., 2023).

Beyond technical approaches, ecological restoration and landscape-based planning play vital roles in optimizing soil and water use. Strategies such as reforestation, wetland rehabilitation, and buffer zone establishment improve hydrological regulation, soil stability, and groundwater recharge (Chazdon & Brancalion, 2019; Djenontin et al., 2020). Nature-based solutions (NbS), including green infrastructure and watershed restoration, have emerged as cost-effective, adaptive responses to climate-related challenges (Seddon et al., 2021). Integrating traditional ecological knowledge (TEK) with scientific methods enhances these efforts, fostering community-based and culturally grounded conservation outcomes (Reed et al., 2020). However, significant barriers remain, especially in low- and middle-income countries, where limited financial and institutional capacity, weak regulatory systems, and fragmented governance structures inhibit the widespread adoption of these practices (UNEP, 2019). To address these issues, there is a pressing need for integrated policy frameworks that align efforts across scales and sectors through inclusive stakeholder participation, infrastructure investment, and support for sustainable farming initiatives (OECD, 2021). This study advances conceptual insight by synthesizing innovative strategies and proposing inclusive, adaptive pathways for harmonizing environmental and socio-economic goals.

Theoretical Review

This study employs a multi-theoretical approach to guide its empirical investigation into optimizing soil and water resources for environmental sustainability, drawing from the Sustainable Livelihood Framework (SLF), Integrated Water Resources Management (IWRM) Theory, and Systems Theory. The SLF, formulated by DFID (1999), positions natural resources like soil and water as vital livelihood assets, especially in developing regions where these resources underpin agricultural productivity and poverty reduction (Scoones, 2015). It emphasizes sustainable resource management to enhance resilience, reduce environmental vulnerability, and promote long-term socio-economic well-being. The framework enables the assessment of how soil and water optimization can strengthen community asset bases and adaptive capacities, underscoring the social dimensions of sustainability.

Complementing this, the Integrated Water Resources Management (IWRM) Theory—first introduced by the Global Water Partnership (GWP) in the late 1990s—offers a coordinated, multi-sectoral framework for managing water resources by integrating economic, environmental, and social priorities (GWP, 2021; UN-Water, 2023). It highlights the necessity of stakeholder collaboration, transboundary governance, and institutional adaptability to address the interconnectedness of water, soil, land use, and ecological systems (Rahaman & Varis, 2020). Systems Theory, as articulated by Capra and Luisi (2017), reinforces this by offering a holistic framework that recognizes the cascading effects of environmental degradation across ecological domains. By aligning with the concept of planetary boundaries (Steffen et al., 2018), Systems Theory supports the development of integrated models and cross-sectoral policies that address environmental complexity and interdependence. The

Anene, Ohanu & Ademiju. The influence of optimisation of soil & water resources

integration of these three theories provides a robust foundation for empirical analysis and policy development aimed at sustainable environmental management through the joint optimization of soil and water resources.

Empirical Review

Several empirical studies have been conducted globally to investigate strategies for optimizing soil and water resources toward environmental sustainability. For instance, Ayele and Seifu (2019) in their study titled *"Sustainable Soil Management Practices and Their Effects on Agricultural Productivity in Ethiopia"* employed a quasi-experimental research design involving 180 farmers selected through stratified random sampling across three agro-ecological zones. Using descriptive statistics and regression analysis, the study found that conservation tillage, crop rotation, and organic manure application significantly improved soil fertility and crop yields. The authors recommended that extension services be strengthened to scale up these practices among smallholder farmers and suggested further research on context-specific adaptation of sustainable soil practices.

Similarly, Kariuki, Otieno, and Mwangi, (2020) conducted a study titled *"Impact of Integrated Water Resource Management on Water Efficiency in Kenyan Watersheds"*, using a mixed-method design with 250 respondents (households and water managers) selected through purposive and cluster sampling techniques. The study employed SPSS for descriptive statistics and ANOVA for inferential analysis. Findings revealed that communities practicing IWRM recorded improved water availability during dry seasons, reduced conflicts over water use, and enhanced community participation in water governance. The authors emphasized policy support for decentralized water governance and recommended investments in water-harvesting infrastructure.

In Nigeria, Olayemi and Adesina (2021) explored *"The Role of Agroforestry in Soil and Water Conservation in Southwestern Nigeria"* using a survey design. The study sampled 120 rural households using a multi-stage sampling technique and analyzed data with simple percentages, chi-square tests, and correlation analysis. Results indicated that agroforestry practices, including alley cropping and live fencing, significantly reduced soil erosion and enhanced groundwater recharge. The study recommended increased awareness and training for rural farmers on agroforestry techniques and called for government incentives to promote tree planting in agricultural landscapes.

Moreover, Zhang, Zhao, Xie, Zhu, and Yao, (2023) examined *"Precision Irrigation Technologies and Water Resource Sustainability in Chinese Agricultural Zones"*. Using an experimental design and a sample of 45 farms, selected via systematic sampling, the study applied ANOVA and regression analysis to assess the effects of drip irrigation systems. The findings showed a 30% increase in water-use efficiency and a 20% reduction in fertilizer runoff compared to traditional irrigation methods. The authors concluded that integrating sensor-based irrigation technologies can significantly reduce water wastage and recommended national subsidies for precision farming tools to accelerate adoption among small-scale farmers.

Lastly, González, Silva, and Vargas. (2023) conducted a cross-national study titled *"Evaluating Soil Health and Environmental Outcomes under Conservation Agriculture in South America"*. Adopting a longitudinal research design, the study surveyed 320 farmers in Brazil, Argentina, and Chile using random sampling and employed panel data analysis and multivariate regression. Findings highlighted that conservation agriculture practices, such as no-till farming and cover cropping, significantly improved soil organic matter and biodiversity. The researchers advocated for harmonized regional policies to support conservation agriculture and proposed the integration of sustainability metrics into national agricultural development plans.

These empirical studies collectively underline the multifaceted benefits of optimizing soil and water resources through sustainable strategies. However, they also reveal gaps in policy integration, technology diffusion, and farmer education—areas this current study aims to address, providing practical insights for policymakers, agricultural stakeholders, and environmental planners.

METHODOLOGY

This study adopted a quantitative research methodology anchored on the descriptive survey research design, which is appropriate for obtaining data that describe the characteristics, opinions, and perceptions of a population through the use of structured instruments. The target population for this study consisted of 180 lecturers drawn from the Departments of Agriculture across six tertiary institutions in Nigeria: Delta State University (DELSU), Abraka; University of Delta (UNIDEL), Agbor; Dennis Osadebay University, Asaba; Delta State Polytechnic, Ogwashi-Uku; Nnamdi Azikiwe University, Awka; and Enugu State University of Science and Technology (ESUT), Enugu State—each contributing 30 lecturers to ensure institutional parity and academic diversity. To scientifically determine an appropriate sample size, the Taro Yamane formula (Yamane, 1967) was employed:

$$n = \frac{N}{1+N(e)^2}$$

Where:

n = sample size

N = population size (180)

e = margin of error (0.10 for 90% confidence level)

Thus, a sample size of 60 lecturers was determined. From this scientifically derived sample, participants were selected using a simple random sampling technique to ensure that each lecturer had an equal chance of being chosen. This approach enhanced the representativeness and generalizability of the study findings across the selected institutions. The research instrument was a structured, self-administered questionnaire developed based on the objectives of the study, and its reliability was ensured through a pilot study and subsequent refinement. Data collected were analyzed using descriptive statistical tools, including frequency counts, percentages, means, and standard deviation, to succinctly summarize the responses and provide meaningful interpretation. This methodological approach facilitated a systematic and objective

examination of the research problem, allowing for empirical insights grounded in numerical evidence.

ANALYSIS OF RESULTS AND DISCUSSION

Table 1: Mean and Standard Deviation Scores of Response on Current Global Status Of Soil And Water Degradation, And The Major Contributing Anthropogenic And Natural Factors (N=60)

S/N	STATEMENT ITEMS	SA	A	D	SD	X	SD
1	The current state of soil and water degradation globally is highly alarming	30	20	6	4	3.27	0.85
2	Anthropogenic factors such as industrialization and deforestation significantly contribute to soil and water degradation.	35	18	5	2	3.43	0.72
3	Natural factors, including climate change and drought, play a substantial role in the degradation of soil and water resources.	25	22	8	5	3.12	0.91
4	There is a significant global awareness regarding the causes and effects of soil and water degradation.	18	25	10	7	2.90	0.97
5	Soil and water degradation is primarily caused by human activities rather than natural processes.	28	20	7	5	3.18	0.88
	Grand Mean/SD					3.18	0.87

The interpretation of Table 1 reveals a strong consensus among respondents on the severity and causes of global soil and water degradation. The overall grand mean of 3.18 and a standard deviation of 0.87 indicate a high level of agreement and moderate variability in responses, reflecting a generally shared perspective on the issue. The highest mean score of 3.43 (Item 2) underscores the critical role of anthropogenic activities—particularly industrialization and deforestation—in accelerating degradation, while the relatively high score for Item 1 (3.27) confirms the global alarm over the deteriorating state of soil and water resources. Natural factors like climate change and drought also garnered significant acknowledgment (Mean = 3.12), though less emphatically than human-induced causes, supporting the assertion in Item 5 (Mean = 3.18) that human activities are the primary drivers. Notably, the lowest mean score (2.90) for global awareness (Item 4) suggests a potential gap in public knowledge or effective communication strategies about these environmental challenges. These findings are highly relevant to the study as they validate the urgency of addressing soil and water degradation through evidence-based policies.

Table 2: Mean and Standard Deviation Scores of Response on Sustainable Strategies Currently Being Implemented For The Optimization Of Soil And Water Resources Across Different Regions, And Their Effectiveness (N=60)

S/N	STATEMENT ITEMS	SA	A	D	SD	X	SD
6	Sustainable agricultural practices such as no-till farming and crop rotation are effectively improving soil health and water retention in my region.	25	20	19	5	3.08	0.89
7	Integrated water management approaches are successfully reducing water wastage and improving water distribution in agricultural areas.	22	26	8	4	3.10	0.85
8	The implementation of reforestation and afforestation practices has contributed to improving soil conservation and water quality.	18	28	10	4	3.00	0.84
9	The adoption of water-saving irrigation technologies, such as drip irrigation, has been highly effective in optimizing water usage.	30	20	7	3	3,28	0.78
10	Governments and stakeholders have made significant efforts to implement sustainable soil and water management practices in my region.	20	22	10	8	2.90	0.95
	Grand Mean/SD					3.07	0.86

The results presented in Table 2 reveal that respondents generally perceive sustainable strategies for optimizing soil and water resources as moderately effective across various regions, as indicated by the grand mean score of 3.07 and a standard deviation of 0.86, suggesting a fairly high level of agreement with relatively low variability in responses. Among the strategies evaluated, the adoption of water-saving irrigation technologies such as drip irrigation ($\bar{X} = 3.28$, $SD = 0.78$) received the highest level of endorsement, reflecting its recognized impact on efficient water usage. Similarly, integrated water management approaches ($\bar{X} = 3.10$) and no-till farming and crop rotation ($\bar{X} = 3.08$) were also viewed favorably, indicating that respondents acknowledge their roles in improving water distribution and enhancing soil health, respectively. However, the statement on government and stakeholder efforts scored the lowest mean ($\bar{X} = 2.90$), highlighting a perceived deficiency or inconsistency in institutional commitment toward sustainable practices. These findings are significant to the study as they underscore the practical effectiveness of certain environmentally sustainable

strategies already in place, while simultaneously drawing attention to areas requiring enhanced policy intervention.

Table 3: Mean and Standard Deviation Scores of Response on Optimization Of Soil And Water Management Contribution To The Achievement Of Environmental Sustainability, Particularly In Relation To Ecosystem Health, Biodiversity, And Climate Resilience (N=60)

S/N	STATEMENT ITEMS	SA	A	D	SD	X	SD
11	Optimizing soil and water management plays a critical role in enhancing ecosystem health and biodiversity.	30	20	7	3	3.28	0.80
12	Effective soil and water resource management practices contribute significantly to climate resilience by mitigating the impacts of extreme weather events.	28	22	6	4	3.23	0.84
13	The restoration of degraded soils through optimized management practices improves the overall ecological balance and biodiversity.	26	25	5	4	3.22	0.81
14	Proper soil and water management practices have long-term positive effects on ecosystem sustainability and resource availability.	32	20	5	3	3.35	0.78
15	Optimizing soil and water resources helps in reducing the vulnerability of ecosystems to climate change.	29	23	5	3	3.30	0.77
	Grand Mean/SD					3.28	0.80

The data presented in Table 3 reveal a consistently high level of agreement among respondents regarding the critical role of optimized soil and water management in advancing environmental sustainability, particularly in relation to ecosystem health, biodiversity, and climate resilience. The mean scores for all five items range from 3.22 to 3.35, with a grand mean of 3.28 and a relatively low standard deviation of 0.80, indicating strong consensus and minimal variability in responses. Specifically, the highest agreement was recorded for the statement that proper soil and water management practices have long-term positive effects on ecosystem sustainability and resource availability ($\bar{X} = 3.35$), followed closely by the view that optimizing these resources reduces ecosystem vulnerability to climate change ($\bar{X} = 3.30$). These findings underscore the strategic importance of adopting sustainable soil and water management

practices as a pathway to enhancing ecological resilience, restoring degraded ecosystems, and mitigating the adverse effects of climate change.

Table 4: Mean and Standard Deviation Scores of Response on policy frameworks and technological innovations proposed to enhance integrated soil and water resource management for long-term sustainability (N=60)

S/N	STATEMENT ITEMS	SA	A	D	SD	X	SD
16	Existing policy frameworks adequately address the need for integrated soil and water resource management.	15	20	18	7	2.55	0.98
17	The implementation of modern technologies, such as precision irrigation and remote sensing, is critical for improving the management of soil and water resources.	28	22	7	3	3.25	0.79
18	Policy reforms that promote community-based water management are essential for achieving long-term sustainability.	24	25	6	5	3.13	0.85
19	Technological innovations in soil and water resource management have significantly improved agricultural productivity and environmental sustainability.	26	23	8	3	3.20	0.81
20	Governments should prioritize the development and implementation of policies that incentivize sustainable practices in soil and water management.	30	21	5	4	3.28	0.78
	Grand Mean/SD					3.08	0.84

The interpretation of Table 4 reveals that respondents generally acknowledge the importance of policy frameworks and technological innovations in enhancing integrated soil and water resource management for long-term sustainability. The highest mean score ($\bar{X} = 3.28$, $SD = 0.78$) was recorded for the statement that governments should prioritize the development and implementation of policies that incentivize sustainable practices, indicating strong agreement among respondents and highlighting a critical policy direction. Similarly, high mean scores for statements on the role of modern technologies ($\bar{X} = 3.25$) and technological innovations in improving productivity and environmental sustainability ($\bar{X} = 3.20$) suggest a widespread belief among agricultural lecturers in the transformative potential of precision irrigation, remote sensing, and other technological solutions. Notably, the item concerning existing policy

frameworks received the lowest mean score ($\bar{X} = 2.55$), reflecting respondents' relative dissatisfaction or skepticism about the adequacy of current policies in addressing integrated soil and water management needs. The grand mean of 3.08 and a moderate standard deviation of 0.84 indicate overall positive perceptions with moderate variation in responses.

Discussion of Findings

The first key finding reveals a strong consensus among respondents regarding the seriousness and causes of global soil and water degradation. Participants identified anthropogenic activities such as industrialization and deforestation as major contributors, consistent with research by , Kariuki, Otieno, & Mwangi, (2020), who noted that these human-induced factors significantly worsen soil erosion, contamination, and water depletion. Climate change and drought were acknowledged as additional but less dominant drivers. This recognition highlights the dual necessity of addressing both human and environmental contributors to degradation, calling for comprehensive and adaptive interventions.

The second finding emphasizes a concerning gap in global public awareness about soil and water degradation. Respondents indicated that current education and communication efforts are insufficient, a concern echoed by FAO (2019), which has criticized the limited scope of awareness campaigns. The apparent neglect of public engagement in policy strategies may be impeding the advancement of sustainable practices. These findings suggest an urgent need for regulatory reforms and increased advocacy to promote sustainable land use, while fostering a culture of shared responsibility across different levels of society and governance.

It was observed that while respondents support sustainable soil and water resource management strategies like drip irrigation and crop rotation, there is a perception of weak institutional and governmental support. Practices advocated by Adeoye and Olofin (2019) and Lal (2019) are recognized for their environmental benefits, yet their broader implementation is hampered by policy gaps. As earlier noted by Nwankwo et al. (2018), many agricultural policies in Nigeria suffer from poor funding and lack of grassroots involvement. This reveals that despite technical readiness, the absence of strong institutional backing hinders widespread adoption, highlighting the need for cohesive, well-funded, and participatory governance systems.

Finally, findings stress the importance of robust policy frameworks and technological innovations in advancing integrated soil and water management. Respondents called for proactive policies that support modern tools like precision irrigation and data-driven farming, reflecting global trends as advocated by Olaniyan and Adeyemi (2018). However, skepticism toward existing policies points to a disconnect between policy design and practical realities, as noted by Ojo and Adeyemi (2019). This underscores the need for inclusive, adaptable, and community-based approaches that ensure environmental sustainability is achieved through technology-enabled, locally grounded, and policy-supported strategies.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this study has critically examined the role of policy frameworks and technological innovations in enhancing integrated soil and water resource management for long-term sustainability, drawing insights from a sample of agricultural lecturers across six

tertiary institutions in Southern Nigeria. The findings reveal a strong consensus among respondents on the indispensable role of modern technologies such as precision irrigation, remote sensing, and community-based management approaches in driving sustainable agricultural practices. However, a significant gap was identified in the adequacy of existing policy frameworks, indicating the need for comprehensive reforms that align with emerging environmental and technological demands. These insights resonate with broader literature affirming the necessity of aligning policy with innovation to ensure ecological resilience and food security. Therefore, this study underscores the urgent imperative for policymakers to prioritize the development and implementation of forward-looking, incentive-based policies and to invest in technological infrastructure that supports efficient resource management. Such strategic actions are vital for achieving environmental sustainability, promoting agricultural productivity, and meeting the long-term developmental goals of the agricultural sector.

Based on the findings of the study, the following four recommendations were proposed:

1. *Implement Integrated and Adaptive Environmental Management Policies:* Governments and environmental agencies should develop and enforce comprehensive, multi-level policies that address both anthropogenic and climatic causes of soil and water degradation. These policies must integrate adaptive strategies—such as reforestation, afforestation, erosion control measures, and sustainable industrial practices—to mitigate the cumulative effects of human activity and climate change.
2. *Strengthen Public Awareness and Environmental Education Campaigns:* There is an urgent need to enhance public education and awareness campaigns regarding the causes, impacts, and solutions to soil and water degradation. These efforts should target diverse audiences—including rural communities, schools, farmers, and policymakers—using both traditional and digital media, and be backed by institutions like the Ministry of Environment and international bodies such as the FAO.
3. *Promote Community-Based and Grassroots Participation in Policy and Practice:* Sustainable land and water resource management requires inclusive participation. Governments and NGOs should involve local communities, farmers, and indigenous groups in decision-making processes and implementation. Policy frameworks should be decentralized and participatory, ensuring alignment with grassroots realities and encouraging a culture of environmental stewardship.
4. *Increase Institutional Support and Investment in Sustainable Agricultural Practices:* To overcome policy and funding gaps, there must be deliberate investment in institutional frameworks that support sustainable technologies like drip irrigation, crop rotation, and precision agriculture. This includes funding for training, equipment, and research, as well as capacity-building initiatives for local institutions to support implementation at scale.

Anene, Ohanu & Ademiju. The influence of optimisation of soil & water resources

REFERENCES

- Adeoye, A. O., & Olofin, E. A. (2019). *Adoption of Climate-Smart Agricultural Practices among Smallholder Farmers in Nigeria: Constraints and Policy Implications. Journal of Sustainable Agriculture and the Environment*, 6(2), 45–57.
- Agyeman, J., Schlosberg, D., Craven, L., & Matthews, C. (2016). Trends and directions in environmental justice: From inequity to everyday life, community, and just sustainabilities. *Annual Review of Environment and Resources*, 41, 321–340. <https://doi.org/10.1146/annurev-environ-110615-090052>
- Akinnifesi, F. K., Makumba, W., & Ajayi, O. C. (2022). Integrated soil fertility and water conservation practices in sub-Saharan Africa. *Agricultural Systems*, 197, 103347.
- Al-Ghamdi, S. G., Nasr, P., & Rehan, R. (2023). Nature-based solutions for water management: A holistic approach to sustainable development. *Sustainability*, 15(1), 112.
- Altieri, M. A., & Nicholls, C. I. (2018). *Agroecology: Scientific basis of sustainable agriculture*. CRC Press.
- Ayele, G. A., & Seifu, G. S. (2019). Sustainable soil management practices and their effects on agricultural productivity in Ethiopia. *Journal of Soil and Water Conservation*, 74(5), 233-240. <https://doi.org/10.1111/j.1467-4949.2019.00359.x>
- Boretti, A., & Rosa, L. (2019). Reassessing the projections of the World Water Development Report. *npj Clean Water*, 2(1), 1-6.
- Bossio, D., Cook-Patton, S. C., Ellis, P. W., Fargione, J., Sanderman, J., Smith, P., & Griscom, B. W. (2020). The role of soil carbon in natural climate solutions. *Nature Sustainability*, 3(5), 391–398. <https://doi.org/10.1038/s41893-020-0491-z>
- Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J., & Van Oost, K. (2022). The interdisciplinary nature of soil. *Soil Science Society of America Journal*, 86(1), 1–9.
- Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., & Brussaard, L. (2018). Soil quality—A critical review. *Soil Biology and Biochemistry*, 120, 105–125.
- Capra, F., & Luisi, P. L. (2017). *The Systems View of Life: A Unifying Vision*. Cambridge University Press.
- Chazdon, R. L., & Brancalion, P. H. (2019). Restoring forests as a means to many ends. *Science*, 365(6448), 24–25.
- Chivenge, P., Mabhaudhi, T., Modi, A. T., & Mafongoya, P. (2019). The potential role of neglected and underutilised crop species as future crops under water scarce conditions in Sub-Saharan Africa. *International Journal of Environmental Research and Public Health*, 16(1), 156. <https://doi.org/10.3390/ijerph16010156>

- Clement, F., Harcourt, W., Joshi, D., & Sato, C. (2020). Feminist political ecologies of the water crisis: Exploring gendered vulnerability and adaptation in water-scarce regions. *Geoforum*, 115, 69–80.
- DFID. (1999). *Sustainable Livelihoods Guidance Sheets*. Department for International Development, UK.
- Díaz, J., Ramírez, J., & Guerrero, J. (2022). Smart water management systems in agriculture: A review of recent developments. *Computers and Electronics in Agriculture*, 193, 106645.
- Djenontin, I. N. S., Zulu, L. C., & Ligmann-Zielinska, A. (2020). Integrated landscape approaches for natural resource management in Africa: A review. *Land Use Policy*, 90, 104299.
- Ezeaku, P. I., & Eze, P. N. (2019). *Conservation Agriculture and Soil Quality in the Humid Tropics of Nigeria: An Overview*. Nigerian Journal of Soil and Environmental Research, 17, 91–100.
- Falkenmark, M., & Molden, D. (2017). Addressing the water scarcity challenge. *International Journal of Water Resources Development*, 33(1), 3–13.
- FAO. (2020). *State of the World's Land and Water Resources for Food and Agriculture*. FAO Publishing.
- Gao, B., He, D., Fan, Y., & Li, Y. (2023). Effects of land-use changes on soil quality and ecosystem services: A meta-analysis. *Ecological Indicators*, 146, 109765.
- Garg, K. K., Wani, S. P., & Singh, A. K. (2021). Watershed management in India: Evolving paradigms and lessons learned. *Journal of Environmental Management*, 284, 112034.
- González, M. F., Silva, R. P., & Vargas, M. L. (2023). Evaluating soil health and environmental outcomes under conservation agriculture in South America. *Soil Use and Management*, 39(4), 412-426. <https://doi.org/10.1111/sum.12640>
- Gupta, J., van der Grijp, N., & Kuik, O. (2020). *Climate change, development and sustainability: From science to practice*. Routledge. <https://doi.org/10.4324/9780429490841>
- GWP. (2021). *Integrated Water Resources Management Toolbox*. Global Water Partnership. <https://www.gwp.org>
- Hoekstra, A. Y., & Mekonnen, M. M. (2019). The water footprint of humanity. *Proceedings of the National Academy of Sciences*, 109(9), 3232–3237.
- Huang, J., Zhan, J., & Zhang, Y. (2019). Integrated watershed management practices and their effectiveness in China. *Water*, 11(5), 984.
- IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Cambridge University Press.

Anene, Ohanu & Ademiju. *The influence of optimisation of soil & water resources*

Jägermeyr, J., Pastor, A., Biemans, H., & Gerten, D. (2020). Reconciling irrigated food production with environmental flows for Sustainable Development Goals implementation. *Nature Communications*, 11(1), 1–9.

Kadyampakeni, D., Morgan, K. T., & Sharma, S. (2021). Advances in precision irrigation for water and nutrient optimization. *Agronomy Journal*, 113(4), 3565–3580.

Kahil, M. T., Dinar, A., & Albiac, J. (2021). Improving water-use efficiency in agriculture: A multi-regional analysis of policy options. *Water Resources and Economics*, 36, 100184.

Kariuki, M. J., Otieno, J. N., & Mwangi, M. (2020). Impact of integrated water resource management on water efficiency in Kenyan watersheds. *Environmental Management Journal*, 62(7), 1253-1269. <https://doi.org/10.1016/j.envman.2020.02.012>

Kassam, A., Friedrich, T., Derpsch, R., & Kienzle, J. (2019). *Overview of the worldwide spread of conservation agriculture*. Field Actions Science Reports. The Journal of Field Actions, (Special Issue 19), 1–11.

Kassam, A., Friedrich, T., Derpsch, R., & Kienzle, J. (2019). Overview of the worldwide spread of conservation agriculture. *Field Actions Science Reports*, (12), 1–12.

Kirchherr, J., Reike, D., & Hekkert, M. (2018). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, 221–232. <https://doi.org/10.1016/j.resconrec.2017.09.005>

Kumar, M., Shukla, A., & Singh, P. (2024). Optimizing water resources through IoT-enabled precision irrigation: A review of trends and opportunities. *Journal of Environmental Management*, 337, 117695.

Lal, R. (2019). Accelerated soil erosion as a source of atmospheric CO₂. *Soil and Tillage Research*, 188, 35–40.

Leal Filho, W., Salvia, A. L., Pretorius, R. W., Pacaa, L., Lange Salvia, A., & Saari, U. (2021). The role of governance in the implementation of the Sustainable Development Goals. *Sustainability*, 13(3), 1132. <https://doi.org/10.3390/su13031132>

Lehmann, J., Bossio, D. A., Kögel-Knabner, I., & Rillig, M. C. (2019). The concept and future prospects of soil health. *Nature Reviews Earth & Environment*, 1(10), 544–553.

Li, J., Liu, Y., Liu, R., & Zhao, Y. (2020). Spatial-temporal monitoring of soil properties using remote sensing: A review. *Catena*, 190, 104512.

Mayer, A. (2019). *A review of the literature on sustainability indicators and indices*. In Filho, W. L. (Ed.), *Sustainable development research at universities in the United Kingdom* (pp. 131–147). Springer. https://doi.org/10.1007/978-3-030-01929-1_9

Mbilinyi, B. P., Tumbo, S. D., & Mahoo, H. F. (2021). Challenges in the adoption of soil and water conservation technologies in semi-arid Tanzania. *International Journal of Agricultural Sustainability*, 19(2), 152–169.

- Meinzen-Dick, R., Zwarteveen, M., & Domènech, L. (2018). Water rights and decentralized water governance: Contributions and challenges. *Water*, 10(6), 666.
- Montanarella, L., & Panagos, P. (2021). The relevance of sustainable soil management within the European Green Deal. *Land Use Policy*, 100, 104950.
- Müller, F., Burkhard, B., & Kroll, F. (2020). *Ecosystem restoration as a public good: Strategies for balancing ecological and socio-economic demands*. *Ecological Indicators*, 113, 106232. <https://doi.org/10.1016/j.ecolind.2020.106232>
- Mwangi, J. K., Ndungu, C. W., & Ouma, G. (2023). Review of the efficacy of soil and water conservation policies in Kenya. *Land Use Policy*, 131, 106507.
- Nwankwo, C. F., Nnadi, F. N., & Chikaire, J. U. (2018). *Constraints to the Implementation of Sustainable Agriculture Policies in Nigeria: The Roles of Stakeholders*. *Journal of Agricultural Extension*, 22(3), 104–113.
- Obalum, S. E., Buri, M. M., & Wakatsuki, T. (2020). Soil and water management practices for enhancing productivity of inland valley ecosystems in West Africa. *Agricultural Water Management*, 228, 105911.
- OECD. (2021). *Policy Coherence for Sustainable Development 2021: Empowering People and Ensuring Inclusiveness and Equality*. Organisation for Economic Co-operation and Development.
- Olayemi, J. B., & Adesina, A. O. (2021). The role of agroforestry in soil and water conservation in southwestern Nigeria. *Sustainable Agriculture and Environmental Science*, 56(3), 94- 103. <https://doi.org/10.1016/j.jes.2021.03.002>
- Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G. P., & Smith, P. (2019). Climate-smart soils. *Nature*, 532(7597), 49–57.
- Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., ... & Wratten, S. D. (2020). Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability*, 3(1), 41–51.
- Qadir, M., Noble, A. D., & Oster, J. D. (2020). Sustainable management of saline and sodic soils. *Soil Use and Management*, 36(4), 576–590.
- Rahaman, M. M., & Varis, O. (2020). Integrated water resources management: Evolution, prospects and future challenges. *Sustainability*, 12(13), 5505.
- Reed, M. S., Stringer, L. C., Fazey, I., Evely, A. C., Piran, C. L., Raymond, C. M., Akhtar-Schuster, M., Barral, M. P., Bours, D., Chanza, N., Cowling, R. M., Davies, J., De Vente, J., Esler, K. J., Folke, C., Gonzalez, D., Iwanaga, S., Kanninen, M., Lavorel, S., & Hubacek, K. (2020). A synthesis of the conservation evidence for nature-based solutions and ecosystem-based approaches for climate change adaptation and disaster risk reduction. *Environmental Science & Policy*, 112, 171–189. <https://doi.org/10.1016/j.envsci.2020.06.016>

- Anene, Ohanu & Ademiju.** *The influence of optimisation of soil & water resources*
- Ringler, C., Bhaduri, A., & Lawford, R. (2018). The nexus across water, energy, land and food (WELF): Potential for improved resource use efficiency? *Current Opinion in Environmental Sustainability*, 5(6), 617–624.
- Rockström, J., Falkenmark, M., Folke, C., Lannerstad, M., Barron, J., Enfors, E., & Gordon, L. (2017). *Water resilience for human prosperity*. Cambridge University Press.
- Scoones, I. (2015). *Sustainable livelihoods and rural development*. Fernwood Publishing.
- Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., & Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, 27(8), 1518–1546. <https://doi.org/10.1111/gcb.15513>
- Singh, R. K., Jain, V., & Chaudhary, S. (2022). Application of geospatial tools for soil and water conservation planning. *Geocarto International*, 37(13), 10782–10797.
- Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., Summerhayes, C. P., Barnosky, A. D., Cornell, S. E., Crucifix, M., Donges, J. F., Fetzer, I., Lade, S. J., Scheffer, M., Winkelmann, R., & Schellnhuber, H. J. (2018). Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences*, 115(33), 8252–8259. <https://doi.org/10.1073/pnas.1810141115>
- Tittonell, P. (2020). Ecological intensification of agriculture—Sustainable by nature. *Current Opinion in Environmental Sustainability*, 45, 1–7.
- UNCCD. (2021). *Restoring Life to the Land: The Role of Sustainable Land Management in Ecosystem Restoration*. United Nations Convention to Combat Desertification.
- UNEP. (2019). *Global Environment Outlook – GEO-6: Healthy Planet, Healthy People*. Cambridge University Press..
- United Nations. (2022). *World Water Development Report*. UNESCO Publishing.
- Vanlauwe, B., Coyne, D., & Giller, K. E. (2017). Integrated soil fertility management in Africa: An overview of principles and practices. *Agricultural Systems*, 161, 1–12.
- WCED. (1987). *Our Common Future*. Oxford University Press.
- Weitz, N., Strambo, C., Kemp-Benedict, E., & Nilsson, M. (2017). Closing the governance gaps in the water–energy–food nexus: Insights from integrative governance. *Global Environmental Change*, 45, 165–173. <https://doi.org/10.1016/j.gloenvcha.2017.06.006>
- WWAP (World Water Assessment Programme). (2020). *The United Nations World Water Development Report 2020: Water and Climate Change*. UNESCO.
- Zhang, X., Zhao, X., Xie, Y., Zhu, H., & Yao, M. (2023). Enhancing soil microbial diversity and resilience with biochar and organic inputs. *Applied Soil Ecology*, 189, 104969.