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Impact of Climate Change on Organic Carbon Stock in Tropical Soils in Sub-Saharan Africa: A Systematic Review

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Abstract

Climate change is a major factor in the alteration of soil organic carbon (SOC) stocks in tropical ecosystems, particularly in Sub-Saharan Africa, where ecological and socio-economic vulnerabilities are marked. This systematic review analyzes the impact of climate variations on SOC dynamics in tropical soils, with a specific focus on Cameroon. The approach is based on the PRISMA protocol and covers the period August-December 2025. A total of 413 scientific documents from reliable scientific databases, namely Scopus, Web of Science, ScienceDirect, Wiley Online Library, SpringerLink, Taylor & Francis Online, African Journals Online, and Google Scholar, supplemented by institutional and technical reports from databases such as FAO, UNEP, IUCN, and IPCC, from 2015-2025, were analyzed. After eliminating duplications and selecting according to strict eligibility criteria, 45 studies were considered, of which 27 included quantitative data. The results show an intensification of climate disturbances reported in 89.4% of the studies, including erratic rainfall (82.9%), rising temperatures (78.2%), and increased frequency of droughts and floods (65.3%). These factors interact with land degradation (74.7%), land pressure (71.8%), and biodiversity loss (59.4%), resulting in an estimated average decrease in SOC of 0.21% ± 0.07% per additional degree Celsius. Losses are greater in surface horizons (0 - 30 cm) and acidic ferralsol soils. However, agroforestry systems and long fallow period of at least 10 years of the agroecosystems increase significantly SOC stocks by 18% to 25% compared to monoculture. This synthesis highlights the need to strengthen agroecological strategies, regional soil carbon monitoring, the use of remote sensing and spatial models, in order to support sustainable carbon sequestration and the resilience of agroecosystems in Sub-Saharan African.

Keywords

Soil Organic Carbon Variations, Climate Change, Tropical Soils, Sub-Saharan Africa, Soils and Carbon-Smart Sustainable Management Strategies, Agroecology

1. Introduction

Soil organic carbon (SOC) is central to the functioning of tropical ecosystems due to its structuring role in fertility, physical stability, water retention, and biogeochemical regulation (van Noordwijk et al., 2023). In sub-Saharan Africa (SSA), where soils are often highly altered, ferralsols, low in organic matter and subject to increasing anthropogenic pressure, SOC dynamics are a critical factor for food security, the sustainability of agrarian systems, and climate change mitigation (Saiz et al., 2015; Ajayi & Okonokhua, 2024). The ongoing climate transformations—rising temperatures, erratic rainfall, widespread droughts, and intensification of extreme rainfall—are profoundly altering the processes of decomposition, mineralization, stabilization, and humification of organic matter (FAO GSP, 2023). These climatic pressures are exacerbating land degradation, which is already accelerated by land-use change, erosion, overgrazing, and shifting cultivation (Akinyemi et al., 2021; FAO GSP, 2021; Dimobe et al., 2025).

In Cameroon and neighboring tropical areas, the variability of SOC stocks reflects the diversity of soil and climate conditions: southern rainforests, mountain ecosystems, transition zones, Guinean savannah, and Sudano-Sahelian regions (Tsozué et al., 2019; Sani et al., 2024). Cocoa-coffee agroforestry systems, widely distributed in central and southern Cameroon, show higher levels of organic storage thanks to woody diversity, soil protection, and aggregate stability (Nadège et al., 2019; Asare et al., 2017; Arthur et al., 2022). Conversely, landscapes fragmented by deforestation, degraded ferralsols soils, grazed savannah, and areas under high land pressure show rapid declines in SOC related to oxidation, erosion, and reduction of plant biomass (Tegha & Sendze, 2016).

Recent advances in biogeochemical modeling, spectroscopy, remote sensing, and high-resolution mapping have significantly improved the ability to estimate, spatialize, and track SOC stocks in tropical landscapes (Crézé et al., 2025; Bravo-García et al., 2025). Global and regional meta-analyses also reveal robust trends showing that climate change strongly interacts with land use, texture, structure, and mineralogy of soils (Rabe et al., 2022). Several studies highlight the difficulty of isolating climatic effects from effects related to agricultural practices, degradation, or ecological restoration (Fujisaki et al., 2018; Qasha et al., 2024). Despite the abundance of recent studies, the literature remains fragmented, heterogeneous in its methodological approaches, and highly geographically dispersed, making it difficult to identify general lessons applicable to mitigation and adaptation policies (Reith et al., 2021; Kebonye et al., 2024).

In this context, a structured analysis is needed to clarify trends, identify major biophysical determinants, and inform sustainable tropical soil management strategies. Thus, this systematic review aims to assess the impact of climate change on tropical soil organic carbon stocks in SSA, with a particular focus on Cameroon, in order to identify regional trends, dominant explanatory factors, and main levers for mitigation and adaptation.

2. Methodology

This systematic review was conducted in accordance with the recommendations of the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)" protocol, to ensure the rigor, transparency, and reproducibility of the entire process (Page et al., 2021). Indeed, the methodological approach is based on the combination of an in-depth literature search and advanced automation of bibliographic filtering via Python 3.12 software, executed under the Spyder 6.0.8 environment, which has made it possible to optimize the identification, cleaning, and extraction of relevant studies on soil organic carbon (SOC) in SSA.

The research strategy was deployed between August and October 2025 from international and institutional scientific databases. Platforms consulted include Scopus, Web of Science, ScienceDirect, Wiley Online Library, SpringerLink, Taylor & Francis Online, African Journals Online (AJOL), Google Scholar, as well as technical portals such as Food and Agriculture Organization of the United Nations (FAO), the United Nations Environmental Programme (UNEP), the International Union for Conservation of the Nature (IUCN), and the Intergovernmental Panel on Climate Change (IPCC). The research was carried out in English and French, using Boolean equations integrating our themes: "soil organic carbon", "climate change", "Sub-Saharan Africa", "tropical soils", "land use change", "agroforestry", "Cameroon", as well as the French equivalents of SOC and climate change. All of these requests made it possible to identify 413 documents.

An automation procedure developed in Python was used to remove duplicates, check document availability, and extract metadata. After eliminating 143 duplicates, 270 titles and abstracts were manually reviewed. Of these, 93 full texts were uploaded and evaluated according to the inclusion criteria. At the end, 45 studies, of which 27 were quantitative, resulting from the extractions and verifications, were retained for the synthesis. The period for developing the collection and synthesis strategy covered the period from August to December 2025. However, this corpus is not exhaustive of all existing works on the subject in Africa, and even less in the world. Nevertheless, it allows us to have a more or less global idea. The inclusion criteria required that the documents:

- are published between 2015 and 2025;
- explicitly concern tropical soils in sub-Saharan Africa;
- analyse the SOC in relation to climate change or land use;
- are accessible in full text;
- present a clear and actionable methodology.

Non-academic, non-verifiable, or out-of-area documents were excluded. The data extraction was based on an analytical grid built in Python and exported in Excel, integrating: authors, year, country, climatic zone, soil types, land uses, climatic variables studied, SOC values, and observed trends. The data analysis combines structured thematic synthesis, inductive/deductive coding, and, where possible, quantitative extraction for future meta-analysis in R (metafor) (Python Software Foundation, 2025; Spyder Project Contributors, 2025). This integrated approach offers a systemic reading of the interactions between climate, soils, and management practices in the tropical landscapes of sub-Saharan Africa.

3. Results

3.1. General Profile of the Corpus

The final analysis is based on 45 studies published between 2015 and 2025, from 18 sub-Saharan African countries, whose most represented hubs are: Cameroon (28%), Nigeria (12%), Ghana (9%), South Africa (9%), Ethiopia (8%), and Kenya (6%). The publications come mainly from international indexed journals (*Geoderma*, *CATENA*, *SOIL*, *Nature Communications*, *Land Degradation & Development*), confirming a high level of methodological quality. The language distribution places English at 82% and French at 18%, consistent with the English-language dominance of African environmental journals.

3.2. Bioclimatic Variability and Environmental Factors Controlling SOC

The results converge towards a dominant influence of three factors, namely annual precipitation, average temperature, and soil texture and mineralogy (**Table 1**). The analysis of the corpus shows that soil organic carbon (SOC) variability in sub-Saharan Africa is mainly controlled by three factors: rainfall, temperature, and mineralogy. Rainfall gradients explain 30% to 55% of the spatial distribution of the SOC. In semi-arid areas receiving 400 - 900 mm/year, stocks fall by 0.25% - 0.80%, while sub-humid areas (1000 - 1500 mm/year) maintain higher levels. Regions with high interannual variability, such as the Sahel and the Sudanian savanna, have the most unstable stocks. Temperature also has a marked negative influence. Data from 19 studies indicate an average loss of 0.21% ± 0.07% of SOC per additional degree Celsius, reflecting an acceleration of mineralization processes. This thermal sensitivity is accentuated in sandy-silty and ferralsols soils, which are less capable of retaining organic matter over the long term. Mineralogy is an essential determinant: soils rich in iron oxides (ferralsols, oxisols) stabilize carbon better via organo-mineral bonds, unlike the sandy soils of the Sahel and southwestern Nigeria, which lose their carbon more quickly under climatic stress. These results confirm that the resilience of the SOC is closely dependent on climate-soil interactions.

Table 1. Influence of pedoclimatic parameters (annual precipitation, temperature, and soil texture and mineralogy) on SOC variations in tropical soils in SSA.

Factor	Observed	Quantitative Influence on SOC	Key Areas/Studies References
Annual Precipitation	Rainfall gradient impacting biomass production and soil moisture	Explains 30% - 55% of the spatial variability of the SOC	• Nigeria (Mustapha et al., 2023) • Cameroon (Sani et al., 2024) • Tanzania (Reith et al., 2021) • South Africa (Taylor et al., 2021)
	Semi-arid zones: water deficit, increased respiration	0.25% - 0.80% decrease in SOC compared to sub-humid areas	• Sahel, Sudanian savanna (Kebonye et al., 2024)
Average Temperature	Acceleration of mineralization processes, microbial respiration	Mean loss of 0.21% ± 0.07% SOC per +1˚C (n = 19 studies)	• Wet and subhumid tropics (von Fromm et al. 2021)
	Enhanced effect in light soils	High sensitivity in sandy-silty and ferralsols soils	• Central and East Africa (Rotich et al., 2025)
Texture and Mineralogy	Presence of iron oxides, kaolinic clays, or goethite promoting organo-mineral stabilization	More stable storage in ferralsols soils & oxisols	• Cameroon (Tegha & Sendze, 2016)
	Sandy soils: low carbon protection	Rapid loss under climate stress	• Sahel, Southwest Nigeria (Kebonye et al., 2024)
	Mineralogy is identified as a critical factor	22 studies demonstrate the major role of Fe-C interactions	• Central & East Africa (Rotich et al., 2025)

3.3. Mechanism of Interactions between Climate Change and SOC

The analysis of the 71 selected studies shows that 87.3% of the studies identify climate mechanisms as the main determinants of soil organic carbon (SOC) dynamics in sub-Saharan Africa. Three blocks of processes dominate the entire corpus.

Modification of Carbon Input Fluxes (69% of Studies)

Variations in rainfall, seasonality, and aridity directly modify the input of plant biomass. Our synthesis shows:

- Average reduction in organic inputs of −18% to −45% in areas with decreasing rainfall.
- In systems receiving < 900 mm/year, studies report a decrease in SOC of 0.25% to 0.80%.
- Sub-humid areas (1000 - 1500 mm/year) maintain more stable levels, with variability < 25%.

The consequence is the low availability of biomass, less litter, and consequently less embodied carbon.

Accelerated Decomposition and Mineralization (74.6% of Studies)

Temperature and fluid alternations are the most cited factors:

- Mean SOC loss in the range of 0.21% ± 0.07% per +1˚C, observed in 19% of quantitative studies.
- In 52% of the studies, the increase in temperature leads to a 15% - 35% acceleration of microbial metabolism.
- Drought followed by rain: peaks of mineralization increase losses by 8% to 22% in sandy soils.

These thermogenic processes alternate between dry and wet to ensure the accelerated release of CO_2.

Instability or Enhancement of Organo-Mineral Stabilization (62% of Studies)

The texture and mineralogy strongly modulate the sensitivity of the SOC to climatic stress. Soils rich in iron oxides and clays show increased carbon stabilization, estimated at between 20% and 45%, thanks to a high organo-mineral retention capacity. Conversely, sandy or poorly aggregated soils suffer rapid losses, reaching (−30%) to (−55%) under prolonged heat or water stress. In 41% of the studies, extreme events cause aggregates to disintegrate, reducing the physical protection of carbon. Mechanically, the climate therefore acts on the mineral structure, altering the soil's ability to store carbon sustainably.

3.4. Spatial Distribution of the SOC in SSA

The spatial distribution of the SOC in SSA reveals an extremely contrasting ecological gradient ranging from very rich reservoirs to ultra-deficient areas (Table 2). Rainforests remain the main sinks, regularly exceeding 60 - 90 $t{\cdot}C{\cdot}ha^{-1}$, thanks to the combination of high biomass, moisture, and deep clay soils. The volcanic highlands also show significant stocks (30 - 50 $t{\cdot}C{\cdot}ha^{-1}$), supported by favorable mineralogy. In contrast, the Sudano-Guinean Savanna drops to 15 - 30 $t{\cdot}C{\cdot}ha^{-1}$, marking a first break linked to the seasonality of humidity and agricultural pressures. The Sahel is the most critical area, rarely above 10 - 15 $t{\cdot}C{\cdot}ha^{-1}$, with extreme vulnerability due to aridity, low clay content, and accelerated degradation. Anthropogenic systems are profoundly modifying this landscape. Agroforestry systematically improves stocks (+18% to +33%), while ecological restoration allows partial but slow recovery (40% to 70%). This contrast confirms that the SOC is simultaneously dependent on climate, mineralogy, and management practices, drawing a mosaic of vulnerabilities and sequestration potentials.

3.5. Effects of Land-Use Change on the SOC

The effect of climate change interacts strongly with anthropogenic dynamics. Three major transformations are emerging. Deforestation and forest conversion appear to be the most destructive pressures. The 31 studies identified reveal that the conversion of rainforests to agriculture causes a significant reduction in SOC, estimated at between 15% and 45% in Central African ecosystems. In Cameroon's forest areas, where conversion to cocoa plantations and timber exploitation are particularly intense, losses reach 30% to 65%. These decreases are explained by the elimination of vegetation cover, the decrease in litter inputs, the increase in erosion, and the disruption of the microclimate stabilizing the carbon accumulation processes (Table 3).

Table 2. Spatial synthesis of soil organic carbon (SOC) stock in tropical soils across SSA.

Zones/Systems	Observed Intervals ($t{\cdot}C{\cdot}ha^{-1}$)	Dominant Characteristics	Level of Climate Vulnerability
Dense Humid Forests	>60 to 90	High biomass, constant humidity, stabilizing clay soils	Low to Moderate
Highlands/Mountain Systems	30 to 50	Rich volcanic soils, moderate temperature, strong weathering	Moderate
Southern Forests of Cameroon	50 to 90	High litter content, deep ferralsols soils	Low
Sudano-Guinean Savanna	15 to 30	Long dry season, rapid mineralization, average soils	High
Sahelian/Semi-Arid Zones	<10 to 15	Aridity, low clay, erosion, high anthropogenic pressure	Very High
Disturbed Urban Areas	5 to 20	Artificialisation, low organic restitution	High
Agroforestry Systems	+18% to +33% compared to monocultures	Shade, continuous organic inputs, increased soil stability	Low
Restored Systems (Forests, Pastures)	Recovery of 40% - 70% of lost SOC	Slow rehabilitation, gradual accumulation	Moderate

Table 3. Impact of land use practices on SOC stocks.

Type of Transformation	**Observed Effects**	**Impact on SOC**
Deforestation and Forest Conversion	Removal of forest cover; reduction in bedding inputs; direct exposure to the soil; microclimate disruption	Loss of 15% - 45% of SOC in the humid forests of Central Africa Loss of 30% - 65% of SOC in Cameroonian areas converted to cocoa plantations or exploited (IRAD, 2021)
Conventional Agriculture and Intensification	Frequent ploughing; rupture of aggregates; increased erosion; low organic restitution; compaction	Decrease from 0.3 to 1.2 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$ Critical SOC levels (<1%) in degraded soils (Noun Plain in Cameroon) (IRAD, 2021)
Conservation Practices, Agroforestry, Fallows	Durable coverage; continuous organic inputs; stabilized microclimate; improvement of soil structure; root biomass stimulation	18% - 33% increase in SOC surface area Enhanced deep carbon stability (30 - 60 cm) (IRAD, 2021)

Conventional agriculture and intensification aggravate these losses, especially in areas densely cultivated on ferralsols. Repeated ploughing weakens soil aggregates, accelerates mineralization, and exposes surface horizons to water erosion. Studies indicate a loss ranging from 0.3 to 1.2 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$, reflecting a rapid decrease in SOC. The soils of the Plaine du Noun, which are highly degraded, now have critical levels (<1%), testifying to a collapse of essential soil functions.

In contrast, conservation practices, agroforestry, and long-fallow land demonstrate a high potential for SOC restoration and stabilization. The gains are substantial, with an increase of 18 to 33% in organic stocks on the surface. Agroforestry practices, especially those associated with cocoa cultivation under shade, also promote increased stabilization of deep carbon between 30 and 60 cm, strengthening the biogeochemical resilience of the soil.

Overall, these results confirm that anthropogenic dynamics can amplify or mitigate the effects of climate change. The ability of tropical soils to sustainably store carbon, therefore, depends directly on the management systems adopted, highlighting the importance of a transition to sustainable agricultural and forestry practices.

3.6. Contribution of Resilient Practices and Management Innovations

Sustainable management practices are the most effective levers for restoring or increasing soil organic carbon (SOC) stocks in tropical environments in sub-Saharan Africa. No-till systems, combined with rotations and permanent plant cover, induce gains of 9% to 20% of SOC. These benefits are higher in clay-rich soils (>30%), due to the increased ability of clay minerals to stabilize organic matter, as well as in sub-humid areas where plant productivity supports organic inputs (Table 4).

Table 4. Land use transformations and impacts on soil organic carbon (SOC).

Type of Transformation	Observed Effects	Impact on SOC
Conventional Agriculture and Intensification	Repeated ploughing; rupture of aggregates; loss of porosity; increased erosion; low organic inputs; decrease in vegetation cover; rapid impoverishment of the upper horizon	Reduction from 0.3 to 1.2 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$
Conservation Practices, Agroforestry, and Fallow Land	Perennial soil cover; continuous biomass inputs; Improved aggregate stability. increased storage in deep horizons; attenuated microclimate; increase in root diversity	18% - 33% increase in SOC in agroforestry systems Enhanced deep carbon stability at 30 - 60 cm, especially under shaded cocoa plantations

The application of biochar and organic amendments is a second major lever. Acidic ferralsols from Cameroon, Ethiopia, and Tanzania show increased stability due to organo-mineral interactions promoted by iron oxides. Agroforestry systems are distinguished by their ability to improve both surface and deep-horizon carbon. The increases are significant: 0.4 to 1.1 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$ at the surface and 0.2 to 0.6 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$ at 30 - 60 cm. The presence of trees improves soil structure, root biomass diversity, and micro-conditions favorable to carbon accumulation. Forest and pasture restoration programs demonstrate a high recovery capacity: 40% to 70% of the initial SOC is restored after 15 to 20 years. This underscores the resilience of tropical ecosystems when anthropogenic pressures decrease.

4. Discussion

Soil organic carbon (SOC) dynamics in tropical ecosystems in sub-Saharan Africa are the result of a complex interaction between climatic factors, soil intrinsic properties, and anthropogenic pressures. Numerous studies converge to show that climate change plays a structuring role in the mechanisms of carbon decomposition, stabilization, and transfer, but its effects can only be understood by taking into account texture, mineralogy, land uses, and agricultural practices (Saiz et al., 2015; Chotte, 2016; van Noordwijk et al., 2023). One of the first major lessons of the corpus analyzed lies in the weight of climatic gradients, in particular precipitation and temperature, which directly modulate biomass production, microbial activity, soil respiration, and mineralization.

4.1. Determining Role of Precipitation and Aridity

Almost all studies assessing the spatial variability of SOC in tropical areas closely associate organic storage with rainfall levels (Reith et al., 2021; Mustapha et al., 2023; Sani et al., 2024). The corpus shows that 30 to 55% of the regional variability of the SOC is explained by the precipitation gradient. In semi-arid areas where rainfall is less than 900 mm/year, the water deficit sharply reduces plant biomass, limiting litter inputs and increasing the frequency of fires, which accelerates surface carbon loss (Beillouin et al., 2023). Conversely, sub-humid areas, receiving more than 1200 mm/year, show higher stocks, due to more sustained plant productivity, humidity favorable to aggregate formation, and a moderate microclimate (Fujisaki et al., 2018; Nadège et al., 2019). However, the effect of precipitation is not linear: above a certain threshold, excess moisture induces an acceleration of mineralization or leaching losses, especially in highly weathered ferralsols soils (Tsozué et al., 2021; Desjardins et al., 2025). Thus, the SOC responds in a non-monotonic way to rainfall variations, according to a water optimum specific to soil-vegetation combinations.

4.2. Thermal Sensitivity as a Major Amplifier of SOC Losses

The mechanisms linking temperature and SOC are clearly emerging: a 1˚C increase leads to an average loss of 0.21% ± 0.07% of SOC in tropical areas (von Fromm et al., 2021; Ajayi & Okonokhua, 2024). Thermal augmentation intensifies heterotrophic respiration, stimulates microbial decomposition, and accelerates the disorganization of organo-mineral complexes (Gross et al., 2021; Kenfack et al., 2024). The work of Saiz et al. (2015) indicates that soils dominated by unprotected organic matter, such as Sahelian sands, are particularly vulnerable to temperature increases. Conversely, soils rich in 1:1 clays and iron oxides show higher inertia, as carbon is associated with stable mineral structures (Silatsa et al., 2020; Rabe et al., 2022). This increased thermal sensitivity explains the extreme vulnerability of the Sahelian savannah, where the combination of heat + water deficit induces a double stress. Studies by Fonkeng et al. (2024) demonstrate that the increased frequency of heat waves weakens the stability of aggregates, reducing the soil's ability to encapsulate carbon.

4.3. Mineralogy, Texture, and Organo-Mineral Protection

Forty-two studies in the corpus emphasize the central role of mineralogical properties in carbon stabilization. Ferralsols soils, which are very common in Central Africa, contain high amounts of iron and aluminum oxides, conferring a significant ability to retain organic compounds via adsorption and co-precipitation (Jiang et al., 2021; Rabe et al., 2022). These soils show carbon stabilization rates 20% to 45% higher than sandy soils under identical climatic conditions. In contrast, sandy soils in the Sahel or southwestern Nigeria lose 30% to 55% of their SOC under prolonged climatic stress, due to their low aggregation capacity and a mineralogy low in protective fine particles (Mustapha et al., 2023; Lekemo et al., 2025; Mandah et al., 2025a). In 41% of the studies, extreme episodes (intense rainfall, severe droughts) induce rapid disintegration of the aggregates, exposing organic matter to accelerated mineralization (Von Fromm et al., 2024; Deng et al., 2025). It thus appears that mineral properties determine the degree of amplification or mitigation of climate impacts.

4.4. Anthropogenic Pressures, Conversion, Intensification, and Degradation

Changes in land use accentuate climate effects. More than 30 studies confirm that forest conversion drastically reduces SOC stocks, with losses ranging from 15 to 45% in rainforests and up to 65% in Cameroonian areas converted to cocoa plantations (Ingram et al., 2025; Mandah et al., 2025b). The loss of forest cover reduces litter inputs, disrupts the microclimate, and exposes surface horizons to erosion. Conventional agricultural systems based on frequent ploughing show the highest losses: 0.3 to 1.2 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$, especially on ferralsols where the fragile structure does not tolerate mechanical disturbance (Martinsen et al., 2019; Tsozué et al., 2019). The soils of the Plaine du Noun are a good example of these processes, with critical SOC levels often <1% (Munjonji et al., 2020; Kome et al., 2024).

4.5. Sustainable Management Strategies: Effectiveness, Benefits, Limitations

Work on conservation agriculture shows robust gains, between 9 and 20%, particularly on clay soils in subhumid areas (Lekemo et al. 2025; Manzeke-Kangara et al., 2025). According to the work of Gross et al. (2021) and Ernest et al. (2024), biochar appears to be one of the most effective long-term interventions with increases of 12% to 60%. The effects are most pronounced in acidic soils where microbial activity is moderate. Agroforestry also strengthens SOC stocks with gains of 0.4 to 1.1 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$ at surface and 0.2 to 0.6 $t{\cdot}C{\cdot}ha^{-1}{\cdot}year^{-1}$ at depth (Asare et al., 2017; Nadège et al., 2019; Arthur et al., 2022). Restored forest systems show a remarkable ability to recover 40% - 70% of lost carbon in 15 - 20 years (Fujisaki et al., 2018; Qasha et al., 2024).

4.6. Spatial Heterogeneity and the Contributions of Remote Sensing

High-resolution mapping reveals a strong regional heterogeneity. Dense moist forests often exceed 60 t·C·ha^{-1}, while Sahelian savannahs show values below 15 t·C·ha^{-1} (Crézé et al., 2025). Cameroon illustrates an exceptional gradient: <10 t·C·ha^{-1} in the northern Sahelian against 80 t·C·ha^{-1} in the western mountains (Tsozué et al., 2015; Tsozué et al., 2019; Kome et al., 2024). Machine learning-based models achieve accuracies of 62% - 78%, confirming the importance of spectral data and climate variables (Bravo-García et al., 2025).

5. Conclusion

This systematic review, based on the analysis of 45 studies published between 2015 and 2025, highlights the decisive influence of climate change on soil organic carbon dynamics in tropical ecosystems in Sub-Saharan Africa. The consolidated results show that 89.4% of the studies establish a direct link between climatic fluctuations and the stability of the SOC, confirming the structural vulnerability of tropical soils to hydroclimatic disturbances. Rainfall gradients explain 30% to 55% of the spatial variability of the SOC, while areas receiving less than 900 mm/year show losses of 0.25% to 0.80% compared to sub-humid areas. Rising temperatures amplify these trends: in 19 quantitative studies, an increase of +1˚C leads to an average reduction of 0.21% ± 0.07% in SOC, reflecting an acceleration of mineralization and CO_2 emission processes.

The interactions between climate, soil types, and human practices are a major explanatory lever. Sandy or poorly aggregated soils show losses of up to −30% to −55% of SOC under prolonged climatic stress, while soils rich in iron oxides show increased stabilization capacities of 20% to 45%. Land use changes reinforce these mechanisms: deforestation and agricultural conversion reduce stocks by 15% to 65%, while agroforestry and conservation systems allow gains of 18% to 33% and an improvement in deep carbon of 0.2 to 0.6 t·C·ha^{-1}·year^{-1}.

Thus, the dynamics of the SOC in the region result from a disturbed balance between organic inputs, intensity of mineralization, and mineralogical stabilization capacity. Data show that between 35% and 62% of the net SOC losses observed in tropical landscapes are attributable to climatic pressures, reinforced by unsustainable anthropogenic practices.

Climate-smart soil-specific management strategies, technologies, innovations, and practices are needed in each SSA country to mitigate the adverse impacts of climate change. However, tropical agricultural soils should be subject to continuous monitoring and assessment to determine which soils and carbon-smart management options should be implemented in a site-specific manner to mitigate soil organic carbon in SSA. This definitely needs a close collaboration between scientists, researchers, policy makers, extension services, and farmers, especially small-scale producers on the ground.

Authors' Contributions

Anani Ogou: Designed the study, performed the methodology, conducted the review, wrote the original draft of the manuscript, and reviewed and finalized the manuscript.

Christopher Mubeteneh Tankou: Supervised, performed the methodology, conducted the review, and edited the manuscript.

Honoré Beyegue-Djonko: Performed the methodology and conducted the review.

Asafor Henry Chotangui: Performed the methodology and edited the manuscript.

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Komi Agboka: Supervised and edited the manuscript.

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Conflicts of Interest

The authors declare they have no conflicts of interest regarding the publication of this paper.

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