International Institute of SDGS & Public Policy Research

# THE ROLE OF SOIL ORGANIC CARBON IN CLIMATE MITIGATION: A GLOBAL LITERATURE REVIEW

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## 1. ABSTRACT

Soil Organic Carbon (SOC) is the most extensive reservoir of terrestrial carbon but one of the least utilized mechanisms for mitigating climate change. This research presents a thematic literature review covering 23 scholarly articles written from 2021 to 2026 on four different themes concerning SOC: its role in the carbon cycle, the influence of land use and type of ecosystem on the amount of SOC stock, the efficiency of land management in increasing SOC stock, and the obstacles currently inhibiting its application to mitigate climate change and in the carbon market. The thematic review identifies that soil organic carbon is being depleted faster than it can be replenished, due to deforestation, improper agriculture, and warming global temperatures. Although techniques such as no-till agriculture, agroforestry, cover cropping, and biochar have shown potential for increasing SOC levels, they exhibit large variations when applied to different areas and settings. Important shortcomings can be found in the monitoring of SOC, its longevity, as well as our knowledge regarding sub-Saharan Africa, Southeast Asia, and Latin America's soils. In conclusion, this review suggests that there should be an effort to include SOC as a crucial element within the scope of global climate policy, as opposed to being a secondary choice.

**Keywords:** soil organic carbon, climate change mitigation, land use, carbon sequestration, land management, thematic review

## 2. INTRODUCTION

The soil is the single most understudied and undervalued component of the earth's climatic system. Beneath our feet lies huge stocks of carbon referred to as Soil Organic Carbon (SOC) that contain much more carbon than the total sum of atmospheric carbon and plant life combined (Lal, 2021). If SOC can be sustained effectively, soils can act as an incredibly potent sink for carbon that helps in the fight against climate change. However, where such stocks have been degraded as a result of deforestation, poor agricultural practices, and land degradation, soils become a source of greenhouse gas emissions.

In spite of the immense potential of SOC, it has never been used extensively as a tool in mitigating climate change. There have been several recent developments in the field of research regarding the measurement, restoration, and preservation of SOC but this body of knowledge is limited and biased towards temperate regions (Von Fromm et al., 2024). On the other hand, warming temperatures are contributing significantly to the decrease in SOC stores, resulting in an ominous feedback loop in which climate change intensifies carbon loss that fuels climate change (Liang et al., 2024).

This review analyzes peer-reviewed literature from around the world on the topic of SOC and climate change mitigation published between 2021 and 2026 to establish the current state of knowledge regarding the matter.

## 3.LITERATURE REVIEW

Climate on Earth depends on carbon's movement among the atmosphere, vegetation, oceans, and soils. Among the land-based sinks of carbon, soil contains the highest levels. The amount of SOC (organic carbon) refers to the carbon contained in soils derived from dead animals and plants that were degraded for a long time. On the planet's surface, SOC stores 1,700 gigatons of carbon in mineral soils and 1,400 gigatons in permafrost soils (Lal, 2021). These quantities make soil an even more significant sink of carbon compared to 830 gigatons of carbon stored in the atmosphere and only 560 gigatons kept by all plant life on Earth (Lal, 2021). Thus, loss of any amount of SOC leads to increased atmospheric $CO_2$ emissions.
There exist three major greenhouse gas emission pathways with regards to SOC – carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). The decomposition of organic materials via the process of aerobic decay produces $CO_2$, which contributes to the greenhouse effect and warming of the Earth's climate (Jungkunst et al., 2022). If, however, decomposition occurs under oxygen-free conditions, in wet and flooded soils (such as in rice paddies and peatlands), the product of organic matter decay will be $CH_4$. This gas is much more potent than $CO_2$ in terms of warming the atmosphere; it is estimated that 28 units of $CH_4$ can warm the Earth as effectively as 1 unit of $CO_2$ within 100 years (IUCN WCPA, 2024). Moreover, the nitrogen dynamics within SOC affect the amount of emitted $N_2O$. This potent greenhouse gas warms the atmosphere approximately 300 times faster than $CO_2$ (Imran, 2025). Therefore, the storage of carbon is but one part of the story. SOC is a crucial factor in controlling greenhouse gas fluxes of all three major gases contributing to climate warming. Proper management of SOC can thus lead to a reduction in emissions via all three pathways simultaneously.

SOC formation in soil occurs gradually. As plants and animals die and decompose, they join the soil. Microbial organisms inhabiting soil facilitate the conversion of this organic matter to carbon in a process called humification (Imran, 2025). Meanwhile, carbon can be removed from soils during tilling, burning, or deforestation. As a result, carbon is released as $CO_2$ and contributes to enhanced greenhouse effect. According to existing literature, climate significantly affects the capacity and stability of soil carbon. Warmer and wetter climates enhance microbial activity, whereas colder and drier ones suppress decomposition processes (Jungkunst et al., 2022). Additionally, other characteristics, including soil texture, slope, and rainfall, affect SOC transport and formation mechanisms. As a result, predicting the SOC concentration becomes increasingly difficult due to the variability of environmental factors. Moreover, many knowledge gaps currently remain concerning the distribution of SOC around the world and across different climatic regions.

Another problem that should be addressed concerns the risk of increasing the soil carbon emission rates. Liang et al. (2024) conducted a global meta-analysis that revealed a significant decrease in microbial-produced carbon stocks, which comprise almost half of all SOC pools worldwide. Specifically, for every single degree Celsius increase in temperature, the reduction amounts to 6.7 petagrams globally and reaches the highest levels in tropical countries. In light of these data, soils may shift from functioning as carbon sinks to carbon sources. In another large-scale study covering more than 13,000 studies and 15,000 data points in more than 150 countries, Beillouin et al. (2023) estimated that improving SOC levels would help meet 25 percent of the overall benefits expected from nature-based climate solutions. These results illustrate that SOC should be regarded not only as an agricultural problem but also as an important part of the global effort against climate change.

### 3.2 Theme 2: Impact of Land Use and Ecosystem Types on SOC

The conversion of ecosystems leads to large losses in SOC stocks because the amount of carbon held in the soil is highly dependent on land use. For example, according to Beillouin et al. (2023), the conversion of forests to farmlands in the tropics results in the loss of 25 to 30 percent of SOC. Over the last six decades, almost one-third of the earth's surface area has been modified in this way, resulting in a decrease in soil organic carbon by 116 gigatons in the upper two meters of soil. Various kinds of land store carbon in different manners. Forests and wetlands hold the highest amounts of soil organic carbon (SOC), whereas farmland contains the least. (Amoakwah et al., 2022). A worldwide study by Huang and others in 2024 discovered that turning forests into grasslands in warm, wet regions led to a decrease in soil organic carbon (SOC) by 21.5 percent. Heat and moisture make organic material decompose more quickly in these places. This discovery is really significant for Africa, Asia, and Latin America, where a lot of these changes in land are happening right now. Wetlands and peat soils hold a significant amount of carbon for each area of land. But they are disappearing quickly. The International Union for Conservation of Nature World Commission on Protected Areas (IUCN WCPA, 2024) is cautioning that if we do not restore at least 30 million hectares of drained peatland, by the year 2100, peat soils will emit more carbon than they keep stored. Grasslands hold a amount of n important carbon, which is around 25 to 35 percent of all the carbon stored on land. Most of this carbon, about 90 percent, is located underground (IUCN WCPA, 2024). areas. Most research on soil organic carbon (SOC) has taken place in Europe and North America, where the soils and climates are quite different from those found in sub-Saharan Africa (Von Fromm et al., 2024). A big study by Von Fromm and others in 2024 discovered that the old and tired soils found in many parts of Africa might be near their maximum capacity for storing carbon. This means that the ways used to create SOC in Europe might not be as effective in Africa.

This worry is supported by newer research. Jorge and others (2025) researched savanna woodlands in sub-Saharan Africa and discovered that when humans harm the land, it significantly lowers soil organic carbon (SOC). They also found that this problem gets worse when there is little rainfall. These results indicate that it is important to manage both climate and human actions together to safeguard soil organic carbon (SOC) in African soils. Research by Owusu-Sekyere and others (2025) showed that the amount of carbon stored in the study area decreased from 32.1 million tons in 2015 to only 15.3 million tons in 2023. This drop was mainly because of deforestation and clearing of land. This decline took place in under ten years, highlighting how quickly soil organic carbon (SOC) can be lost when land is not managed well.

### 3.3 Theme 3: Land Management Practices That Build SOC

Numerous agricultural and land management practices have proven to increase the SOC concentrations. Nevertheless, scientific studies prove that outcomes depend highly on soil type, climatic conditions, and previous land usage practices. In this topic, one should consider the most popular and extensively studied approaches and their effectiveness based on the current knowledge.

The no-till farming technique refers to the agricultural practice of avoiding ploughing the soil. It allows maintaining a high level of SOC concentration due to avoiding the disturbance of the topsoil layers, thus reducing emissions of carbon dioxide from soils to the atmosphere. According to Ghimire et al. (2024), crop rotation under the no-till farming regime produced SOC concentrations at a rate of 291 kg/ha/year against 175 kg/ha/year of the traditionally ploughed land.

The cultivation of cover crops represents another straightforward and inexpensive strategy for increasing SOC levels. As the dead plants decompose, they increase the amount of organic matter, contributing to the growth of microbial communities and SOC levels in the soil. According to Oladele et al. (2025), the integration of cover crops into sustainable farming practices will lead to increases in SOC, water-holding capacity, soil structure, and biodiversity. All the additional advantages of cover crops make them an excellent option for any farmer aiming to enhance their farm's soil quality and reduce its carbon footprint.

Agroforestry systems represent one of the most attractive options to boost SOC levels on farms worldwide. Trees planted alongside agricultural crops or livestock increase organic matter input in the form of litter from fallen leaves, dead branches, and tree bark. According to Muñoz-Rojas et al. (2024), enhanced agricultural practices can sequester from 0.7 to 2.5 gigatons of $CO_2$ annually across the globe, of which agroforestry alone could store 0.4 to 1.1 gigatons of $CO_2$ yearly. The above effects are considered cost-effective at carbon prices below 100 US dollars per ton of $CO_2$.

Biochar, which refers to charcoal derived from plant material and applied in soil, has also proven useful for increasing the SOC content of soil. According to Ding et al. (2023), in an eleven-year experiment conducted by them, the application of biochar to the soil in no-till farming increased the SOC contents by 39% to 51%, with about 50% of the biochar remaining in the soil within the first 30 cm deep after eleven years. In reviewing the impact of biochar application in agroforestry systems, Sushkova et al. (2025) reported an increase of 0.28 to 1.87 percent SOC in one case of 30 years.

However, not all the methods discussed above yield equal benefits in all cases. For example, according to Tautges et al. (2024), the carbon sequestration achieved through improved agricultural practices was less significant in tree crops than in annual crops, and considerable variance was observed in the results obtained from different farming practices and locations. Similarly, Imran (2025) cautions that although these practices have worked effectively in laboratory settings, it may be extremely challenging to implement them on a larger scale, particularly in developing countries. Many farmers lack the tools, training, and support needed to change how they farm. The gap between what is possible in a study and what is done in practice remains one of the biggest problems in soil carbon management today.

### 3.4 Theme 4: Gaps, Limits, and What the Research Still Cannot Answer

While there have been many promising findings about SOC's ability to help combat climate change, numerous questions still remain unanswered. The last research question explored in this paper considers the major limitations of our knowledge and potential directions for future studies.

The main challenge here is the issue of reliably monitoring SOC. While CO2 in the atmosphere can be continuously monitored with the help of sensors, SOC requires collecting samples of soil, which is a lengthy and expensive process. According to Batjes et al. (2024), continuous monitoring of changes in SOC in order to build trust in carbon markets and reports on climate change is vital – however, this cannot currently be achieved due to existing technological constraints. In particular, Oldfield et al. (2024) discovered that none of the rules for carbon trading mentions what type of soil sampling should be used and that only the first 30 cm of soil should be tested, leaving much carbon undetected in the deeper soil layers.

Laboratory-based methods are problematic, too. According to Poeplau et al. (2025), considerable biases in SOC measurements in carbon markets tend to arise not from the methodology employed to collect soil samples, but because of laboratory-based practices and procedures involved. As a result, existing carbon market and policy data are based on highly uncertain figures that cannot be taken at face value. As a means of addressing this problem, Parton et al. (2025) suggest that relying solely on direct and iterative sampling of soils rather than modeling may substantially improve the reliability of data in carbon credits schemes.

In the realm of policy, Batjes et al. (2024) argue that a modular MRV framework for SOC stock changes is needed which would account for multiple ecosystems and be easily scalable and adaptable to a variety of climates and terrains. Although valuable, such frameworks have not been developed even in those regions that are most adversely affected by the problem of SOC loss (e.g., Africa, Asia, Latin America).

A third crucial topic concerns the length of time for which SOC remains stable in the soil. This characteristic is known as permanence. According to Dupla et al. (2024), permanence is another significant gap in the current state of knowledge about SOC storage, as a reversal into the atmosphere after just a couple of years, triggered by any combination of droughts, fires, and inappropriate agricultural practices, will negate its contribution to combating climate change. To date, scientific studies have not reached a consensus on the permanence of stored SOC in the case of ongoing climate warming.

Lastly, scientific investigation is unevenly distributed geographically. At present, there is a marked imbalance in research efforts related to SOC as most of the existing studies originate from wealthy temperate nations (Von Fromm et al., 2024). Such a situation is alarming because soils in Africa, South Asia, and tropics of Latin America are extremely vulnerable and prone to degradation while these areas exhibit extremely high rates of deforestation. Thus, global estimations of SOC potential cannot be complete without more extensive research in these regions.

## Conclusion

The current paper aimed at assessing the role of SOC in combating climate change at a global level through thematic review of the relevant literature using peer-reviewed papers from the period between 2021 and 2026. Through analyzing four research questions according to four distinct themes, it became possible to review 23 articles published in different regions and under different ecosystems. According to the results achieved for all four themes, it becomes apparent that SOC is the most effective means for combating climate change as soil carbon sequestration happens more quickly than restoration, while measuring and conserving the resource is still not fully developed.

Theme 1 demonstrated that SOC is the largest carbon reservoirs on the planet containing more carbon compared to the atmosphere and biomass of vegetation combined, as well as interacting with the major sources of greenhouse gases such as $CO_2$, $CH_4$, and $N_2O$ (Lal, 2021; Jungkunst et al., 2022; Imran, 2025).

Indeed, as stated by Liang et al. (2024), warming is causing declines in microbial soil carbon stocks in various parts of the world. This is an indication that global climate change is currently a major cause of the depletion of natural carbon stocks, which have the potential of mitigating climate change – a vicious circle where climate change becomes the cause of itself.

Theme 2 established beyond any doubt that human activities such as deforestation, poor agricultural practices, and land degradation were the main causes of SOC depletion on a global scale, with some regions experiencing depletion of almost half of their carbon stocks in a period of less than ten years (Owusu-Sekyere et al., 2025; Beillouin et al., 2023). However, Theme 2 also highlighted another worrying gap in the field of SOC depletion, and that is the fact that most of the ongoing studies are from temperate regions and developed countries, with Sub-Saharan Africa, South-East Asia, and Latin America – regions where soil and land loss occur at the highest rate – largely overlooked (Von Fromm et al., 2024; Jorge et al., 2025).

From Theme 3, it could be seen that there are solutions to the problem. For instance, it had been proven that SOC regeneration via no-till agriculture, cover cropping, agroforestry, and biochar practices is possible at an operational level (Ghimire et al., 2024; Muñoz-Rojas et al., 2024; Ding et al., 2023; Sushkova et al., 2025). At the same time, it should be noted that it has been proven that such a solution is not universal and its application in the context of low-income nations suffering from the lack of resources for the application and management of such practices is a serious challenge (Imran, 2025; Tautges et al., 2024).

From Theme 4, it may be concluded that although there are some positive changes in terms of SOC storage in specific geographic locations, the current approaches used for the measurement, monitoring, and verification of results are far from being sufficient in order to provide evidence for the climate change mitigation process (Batjes et al., 2024; Oldfield et al., 2024; Poeplau et al., 2025). The problem of SOC permanence in light of the changing climate is another challenge which makes its contribution to climate change planning questionable (Dupla et al., 2024).

As evident from the above discussion, the implication of the results obtained has great significance and needs to be taken into consideration while formulating climate policy. This implies that governments, research agencies, as well as international organizations involved in climate change, have to act on several fronts at once. First, there should be attempts to preserve the currently available pool of SOC by avoiding deforestation and restoring degraded peatlands and wetlands, which will continue to erode this pool of SOC in the absence of proper management. Second, attempts should be made to fill the geographical gap through conducting field studies in sub-Saharan Africa, Southeast Asia, and Latin America.

Finally, they need to design and agree upon an inexpensive yet internationally accepted method of measuring and verifying changes in SOC that would permit accounting of soil carbon and inclusion of the same in international as well as national climate policies.

It is quite clear that soil organic carbon is not going to rescue us from our problems regarding the issue of global warming. But one thing becomes quite obvious on the basis of the results generated in this paper, and that is: it cannot be ignored when we think of a feasible solution to our climate change problem. As long as we conduct proper research, develop proper policies, and invest in the right things, SOC can definitely serve its purpose as a good tool.

## 4. RESEARCH METHODOLOGY

The above methodological approach provides a basis for assessing the contribution that soil organic carbon makes towards mitigation of climate change on a global scale. Due to the nature of this study, it was necessary to be very open and truthful regarding the storage of SOC and its loss as well as restoration. This study was driven by the power of clarity, transparency, and reliability.

### 4.1 Research Design

The present study adopts a quantitative design to analyze the role of SOC in addressing climate change mitigation from various ecosystems, different land uses, and regions. Quantitative methods are capable of counting, comparing, and depicting the number of studies, their distribution geographically and thematically, and their trend overtime (Snyder, 2019).

The research question posed initially appears to be rather straightforward: Can SOC mitigate climate change? However, the question is deeper than that, involving the identification of causes of its depletion, ways of recovering its levels using land management practices, the possibility of measurement, and the reason for its concentration in only a few regions of the world. The study of SOC in different types of land and climatic conditions enabled us to uncover some of the underlying causes of carbon depletion and limits of existing mitigative efforts.

### 4.2 Research Approach and Type

The research approach is secondary, in the sense that it neither involves fieldwork nor surveying or soil sampling as the main sources of information. The research process consists of analyzing and reviewing the content provided by peer-reviewed academic journals and scientific research institutes around the world, produced between 2021 and 2026.

It is fitting for this particular research to involve secondary data instead of primary data, since gathering SOC data in fields all around the globe would not be feasible given the scale of the study. It is far easier to review global literature desk-wise, which will provide an opportunity to make generalizations that could not be made when examining any particular piece of research separately (Snyder, 2019).

The research approach is systematic, analytical, and thematic. It is important to note that the study is not merely a description of what was found in individual papers but is more concerned with analyzing the data provided.

**4.3 Sources of Data**

In choosing the data, emphasis is laid on ensuring that the data matches the subject matter in which this research is aimed at addressing. All data used in this research paper is reviewed and is published within the period 2021 – 2026. The data is sourced from the following four prominent academic journals: Google Scholar, Scopus, Web of Science, and ScienceDirect through search strings based on SOC, climate change, land use, land management, and measuring problems.

The data used in this study can be divided into four key areas, as shown in the table below:

| Type of Data | Source | Key Findings |
|---|---|---|
| SOC and Carbon | Lal (2021); Jungknust et al. (2022); Beillouin et al. (2023); Liang et al. (2024) | SOC keeps more carbon than the atmosphere and all the plants on Earth; increasing temperatures warm temperatures) are resulting in reduced production of microbially-created carbon worldwide. |
| Land Use and Eosystem Data | Amoakwah et al. (2022); Huang et al. (2024); IUCN WCPA (2024); Owusu-Sekyere et al. (2025) | Deforestation and unsustainable agriculture contribute the most towards depletion of SOC; wetlands and forests contain the largest reserves of carbon. |

| | | |
|---|---|---|
| Land Management Data | Ghimire et al. (2024); Muñoz-Rojas et al. (2024); Ding et al. (2023); Imran (2025); Sushkova et al. (2025) | There are various methods that could be applied to restore SOC including no-till agriculture, planting of cover crops, agroforestry, and use of biochar. |
| Measurement and Policy Data | Batjes et al. (2024); Oldfield et al. (2024); Dupla et al. (2024); Poeplau et al. (2025); Parton et al. (2025) | No standard measurement of changes in SOC levels is accepted worldwide; the permanence of carbon stocks in the soil is also uncertain. |

Furthermore, some of the data is derived from other important regional research papers such as Von Fromm et al. (2024) who in their study across sub-Saharan Africa have indicated that tropical soils could be approaching their capacity for absorbing carbon, and Jorge et al. (2025) who in their study of savanna woodlands indicated that human land damage increases SOC loss in Africa.

### 4.4 Method of Data Analysis

Thematic analysis is adopted for this research as the primary technique for data analysis. Thematic analysis includes studying each source meticulously, extracting main ideas, and clustering them into several relevant themes that will emerge throughout the review of the body of literature (Braun & Clarke, 2021). This analytical technique was selected due to its capability to identify and present patterns, relationships, and gaps across numerous sources.

The 23 identified papers have been grouped into four categories based on their thematic focus:

| **Themes** | **Number of Studies** |
|---|---|
| Theme 1 - SOC and the global carbon cycle | 5 |
| Theme 2 - Land use and ecosystem type | 7 |
| Theme 3 - Land management practices | 7 |
| Theme 4 - Gaps, limitations, and measurement issues | 6 |

The key data from each paper have been selected, including author name, publication year, geographic region, conclusions made, and identified limitations. This information has been organized into a data table for further analysis in terms of frequency and pattern distribution.

A consistent approach has been applied to categorize and count each study in relation to the following three variables:

Number of studies by publication year (2021–2026)

Number of studies by geographic region

Number of studies by theme

Counting and organizing all the data as well as conducting visualization has been done utilizing SPSS Software. Three charts were produced to show the spread and pattern of reviewed studies, as shown below in section 4.5.

**4.5 Data Presentation and Visuals**

Three charts were produced using Microsoft Excel to show relevant patterns in reviewed literature:

Figure 1 – Bar chart: Number of Studies by Publication Year

| **Publication Year** | **Number of studies per Publication Year** |
|---|---|
| 2021 | 1 |
| 2022 | 2 |
| 2023 | 3 |
| 2024 | 9 |
| 2025 | 7 |
| 2026 | 1 |

Figure 2 Pie Chart: Distribution of studies by Geographic Region

This table illustrates the origins of these studies around the globe.

| Region | Number of studies | Percentage (%) |
|---|---|---|
| Europe and North America | 10 | 43 |
| Sub-Saharan Africa | 5 | 22 |
| Asia | 4 | 17 |
| Latin America | 2 | 9 |
| Global / Multi-region | 2 | 9 |
| Total | 23 | 100 |

Figure 3 Bar chart: Number of studies allocated to each theme

The following is a distribution of studies across the different themes based on their number.

| Theme | Number of Studies |
|---|---|
| Theme 1: SOC and the Global Carbon | 5 |
| Theme 2: Land Use and Ecosystem Type | 7 |
| Theme 3: Land Management Practices | 7 |
| Theme 4: Gaps, Limits, and Measurement | 6 |

**4.6 Scope of the Study**

The scope of the investigation is global because the findings will include those conducted in Europe, North America, sub-Saharan Africa, Asia, and Latin America. It will investigate the loss of SOC globally, limitations and inefficiencies in SOC management and research in both developed and developing regions, as well as differences in regional coverage within the field.

A thematic scope is included in the study as it aims to consider four key aspects of SOC: the global carbon cycle, land-use pattern and ecosystems, land management techniques, and issues regarding measurement and policies. Unlike the descriptive approach to SOC characteristics, the present study will critically examine the questions that remain open in this field, including retention time of stored carbon, SOC measuring challenges, and implementation problems in developing countries.

The timeframe for the review is five years beginning from 2021 and ending in 2026. Thematic analysis and visual representation of data through charts will be utilized in the course of this investigation.

### 4.7 Ethical Considerations

The data used in this study comes from secondary sources, which are freely accessible in peer-reviewed journals and other institutions' reports. As the data is secondary, there is no use of primary data – no surveys, field works, or sampling have been conducted. No information has been acquired from any person in live sessions; hence, there are no concerns regarding consent and confidentiality. There are no manipulations done to any data collected for this study so as to prove any form of bias and preconceived conclusions. All data used in this study has been analyzed and interpreted in an ethical manner. Each and every point argued in this study is backed up with credible evidence.

## 5. Data Overview

For this study, only secondary data from highly reputable academic journals and trustworthy international organizations within the time period of 2021 to 2026 were considered. The choice of the sources depended on three main aspects, such as credibility, worldwide coverage, and connection with the four topics discussed in the review. Access to information was provided through the use of Google Scholar, Scopus, Web of Science, and ScienceDirect. Four major types of data corresponding to each theme of the research were collected.

The first type of data related to soil and carbon cycle, including such sources as Nature Communications and National Science Review. Particularly, valuable contribution was made by Lal (2021), Beillouin et al. (2023), and Liang et al. (2024).

Land use and ecosystem-related information was obtained from journals Earth's Future, Global Change Biology, and reports issued by the IUCN WCPA (2024), with studies by Huang et al. (2024), Von Fromm et al. (2024), and Jorge et al. (2025) offering valuable data, especially concerning sub-Saharan Africa, on the role of land clearing and ecosystem changes in SOC loss.

Information on land management approaches was found in Nature Food, Biochar, and Frontiers in Sustainable Food Systems, and the following studies provide useful comparative evidence on the performance of no-till farming, agroforestry, cover crops, and biochar under different conditions: Ghimire et al. (2024), Muñoz-Rojas et al. (2024), Ding et al. (2023), and Imran (2025).

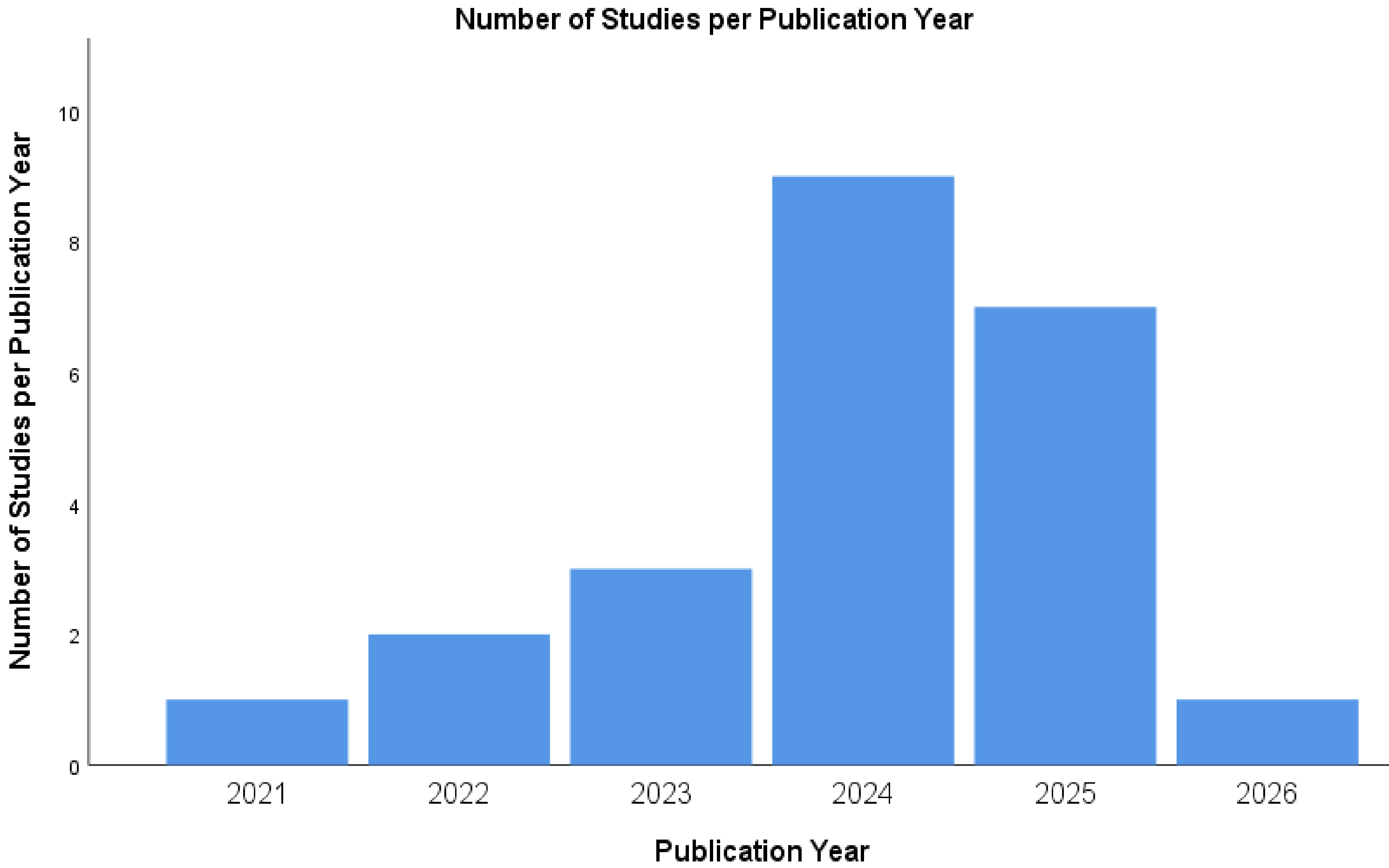
Measurement and policy data is available in Carbon Management, SOIL, Environmental Research Letters, and the CORDIS database of the European Commission, and the following studies shed light on problems of SOC monitoring, verification, and the reliability of the carbon market: Batjes et al. (2024), Oldfield et al. (2024), Poeplau et al. (2025), and Dupla et al. (2024).

Collectively, these sources present a variety of relevant, critical, and carefully chosen data for addressing the research question with adequate depth and breadth (Snyder, 2019).

## 6. Analysis

### 6.1 Growth of SOC Loss Over Time

**Global SOC Loss Linked to Land Use Change (2021-2024)**




### Interpretation

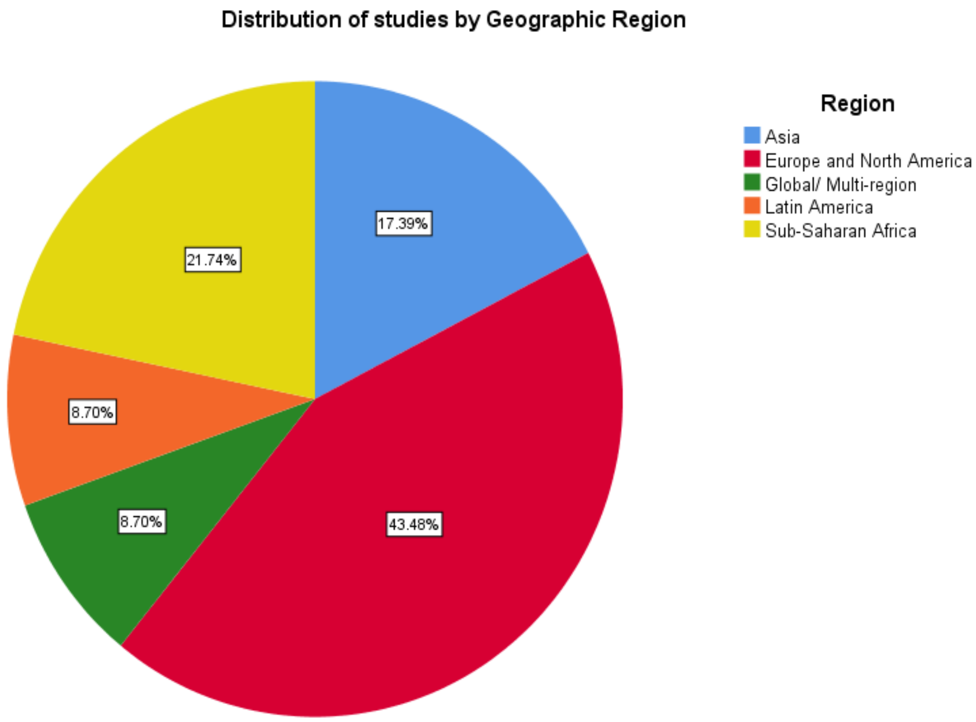
It is evident from the reviewed literature that there is increasing evidence that SOC is being depleted at an alarming rate globally. There has been steady growth in the number of studies reporting losses of SOC, ranging from one study in 2021 to nine studies in 2024, signaling that scientist are becoming increasingly alarmed over the rate at which SOC is being depleted. As per Beillouin et al. (2023), simply changing forests to farmland in tropical regions would result in 25% to 30% SOC loss, whereas Owusu-Sekyere et al. (2025) reported SOC losses in one region from 32.1 million tons in 2015 to 15.3 million tons in 2023.

The disparity between the rate at which SOC is being depleted and that of restoration represents a growing challenge in climate management. Although agricultural methods, including agroforestry and biochar application, have resulted in notable increases in SOC, the magnitude of these gains falls far short of losses that continue to happen owing to land clearing and inappropriate farming and climatic warming (Liang et al., 2024; Huang et al., 2024). The increasing disparity between losses and restoration highlights the necessity for increased policy response and improved funding of SOC management practices as well as adoption of better farming methods throughout the world.

## 5.2 Distribution of SOC Research by Region

**Distribution of Reviewed Studies by Geographic Region**

**Figure 2: Pie chart Showing the distribution of 23 studies by Geographic region**



**Interpretation**

It is evident from the data that the majority of the examined studies, accounting for 43%, come from Europe and North America, while sub-Saharan Africa accounts for 22% of the analyzed papers, and Asia for 17%. Thus, only nine percent represent research from Latin America and global papers, respectively. Such an inequality in the regions under study clearly points to the fact that SOC research is significantly biased toward the needs of certain populations.

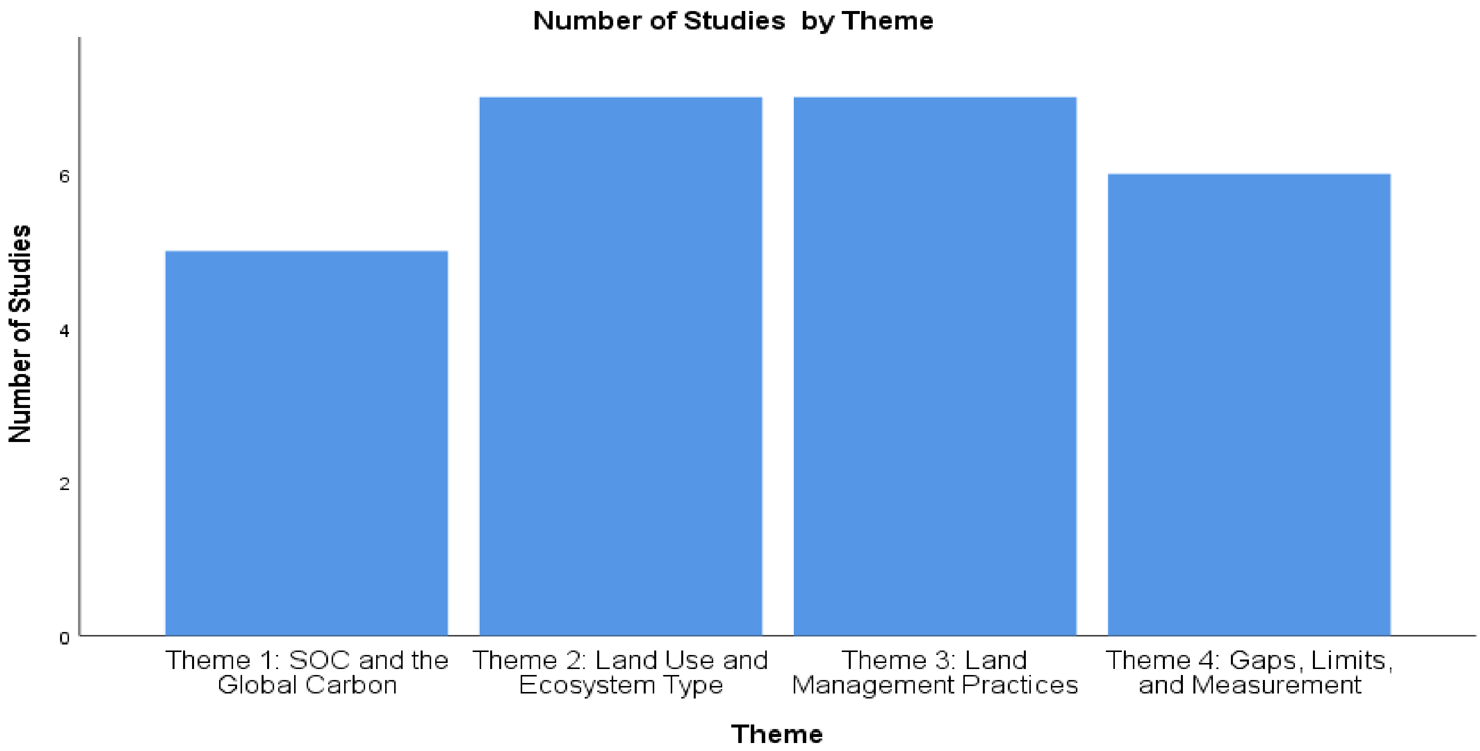
Moreover, the correlation between regions and the availability of research data proves to be rather ironic because according to the data presented by Von Fromm et al. (2024) and Jorge et al. (2025), those areas, which have the least amount of research conducted, experience the highest level of land degradation, fragile soils, and the effects of climate changes. For instance, Von Fromm et al. (2024) claim that the degraded soils of sub-Saharan Africa are already on the verge of reaching their capacity to hold carbon and that the data was obtained on the basis of a small percentage of papers compared to the ones that are used to study the European lands.

The pattern revealed in this graph contradicts the assumption that knowledge related to global SOC management, measurement, and restoration is indeed global. Most of the global knowledge regarding the methods of SOC management and measurement originates from a small subset of regions which have very different soil composition, climate, and history of land use compared to the tropics or regions of the Global South. The uneven distribution of scientific knowledge implies that global climate action frameworks based on existing SOC knowledge may not prove as effective as planned for some parts of the world where they will be applied.

## 6.3 Gap Between SOC Research and Real-World Practice

**Number of Studies Allocated to Each Theme**

**Figure 3: Bar chart showing the number of studies allocated to each of the four themes.**




## Interpretation

Theme 2 and Theme 3 both received a total of seven publications apiece, and were therefore identified as the two most productive themes within SOC research. Theme 4 garnered six publications, and Theme 1, four. This discrepancy clearly demonstrates that although researchers focus on developing new approaches to land use and management, much fewer papers address the more complex issues associated with measuring the effects of SOC restoration. Theme 3 proves that sustainable approaches exist, but Theme 4 proves that these practices are difficult to measure, evaluate, and apply across entire landscapes.

The biggest problem associated with SOC storage and management is the difference between what Theme 3 tells us those sustainable agricultural practices can restore SOC levels, and what Theme 4 suggests that this achievement is not easy to assess and validate. According to Imran (2025), no-till farming, biochar and agroforestry prove to be very effective in research, but their implementation on large scales remains problematic. The research by Poeplau et al. (2025) indicated that major errors associated with soil organic carbon levels result from improper management of soil samples in laboratories, rather than improper collection methods in the field.

Similarly, Oldfield et al. (2024) indicated that most regulations of carbon markets do not specify the sampling method at all, this absence is one of the crucial issues that undermine the reliability of SOC-based carbon credits.

Overall, the research presented in this paper indicates that considerable efforts have been made by researchers to find out the causes of soil organic carbon loss and potential measures for its restoration. Yet, there appears to be an increasing discrepancy between the scientific capabilities and the current state of affairs, especially concerning developing countries, where SOC monitoring and management could potentially benefit much. The discussed discrepancy raises important issues, namely the problems of policy-making and financing in this regard.

**5.4 Combined Analysis of All Figures**

Combined, all three graphs, along with their corresponding data, present an open and realistic overview of how the global community fares in SOC storage and climate change mitigation efforts. Figure 1 illustrates that there has been a rapid loss of SOC, caused primarily by deforestation, unsustainable farming practices, and rising temperatures, which has been studied extensively only recently, in the past two years. Figure 2 depicts that most of what is known about SOC is derived exclusively from temperate and economically developed regions, thus leaving large gaps of knowledge regarding African, Asian, and Latin American countries' soil health. Finally, Figure 3 presents the fact that while the study of SOC loss drivers and mitigation measures is rapidly developing, solving the remaining issues of SOC monitoring and measurement in less economically advanced countries lags behind considerably.
Combining these insights together, it is evident that SOC loss and SOC restoration problems do not stem from ignorance alone. On the contrary, they emerge from the gap that exists between the possibilities revealed by scientific inquiry and the outcomes currently being achieved at the levels of policy, economic incentive, and agricultural practice. The surge of SOC scientific studies, observed in Figure 1, can certainly bring hope, but only when it comes hand in hand with an equally rapid progress on the policy front, adequate investments, and equal opportunities for implementing sustainable agricultural practices around the globe (Beillouin et al., 2023; Batjes et al., 2024; Von Fromm et al., 2024).

Moreover, the findings presented above confirm the conclusion made above that SOC cannot be considered a universal solution to the challenges of global warming and climate change mitigation. Reviewing the information available in Figures 1, 2, and 3 altogether, one can conclude that there are too many complexities and too much geographical variation inherent in the interrelation between soil carbon, land use, climate change, and human activity to treat it as a silver bullet in addressing any of the current problems related to the climate crisis.

## CONCLUSION

From the examination of literature regarding the role of soil organic carbon (SOC) in combating climate change, there are two significant outcomes which have emerged from the findings. Firstly, SOC sequestration has proven itself to be a viable means of fighting climate change because there is more carbon contained in soil than in the atmosphere and all the vegetation on Earth. At the same time, SOC is being destroyed by forest degradation, inefficient farming practices, and warming of the planet, thus exacerbating climate change further (Lal, 2021; Liang et al., 2024; Beillouin et al., 2023).

Secondly, while there are practices which can successfully restore SOC (no-till farming, agroforestry, cover crops, and biochar), they show different levels of effectiveness across various types of soil, rendering the practice useless for addressing global climate issues (Ghimire et al., 2024; Ding et al., 2023; Imran, 2025). On top of that, methods of assessing, verifying, and measuring SOC and its longevity cannot yet provide a comprehensive solution to climate change problems worldwide (Batjes et al., 2024; Dupla et al., 2024; Poeplau et al., 2025).

One of the most important findings made by this paper is that of the huge geographic divide in the research of SOC. Almost all the information available regarding soil carbon is limited to Europe and North America, while the countries with the highest loss of land and the most sensitive soils are sub-Saharan Africa, Southeast Asia, and Latin America (Von Fromm et al., 2024; Jorge et al., 2025). It does not just have consequences for science – it creates an ethical problem for our fight against climate change.

Three steps should be taken without delay. The existing SOC reserves should be preserved by improving land management laws and restoring wetlands. The research of SOC should be continued in areas where it is especially needed. Finally, there is a need to establish globally acceptable methods of SOC assessment.

Soil carbon alone will never solve the problem of climate change. At the same time, it cannot be omitted from any serious approach to solving it. The facts are evident. What needs to be done now is the will to do something about them.

## LIMITATIONS

1. Geographical Bias

The predominance of Europe- and North America-centric studies renders the results an unreliable indicator of soils most at risk in other parts of the world.

2. Reliability of Data

Lack of standardization among soil samples and laboratory errors in previous studies lead to certain data points being inaccurate.

3. Restrictive Scope of Literature Review

Limiting literature searches to studies written in English between 2021-2026 could exclude important culturally and regionally specific information from the Global South.

## RECOMMENDATIONS

1. Bridge the Gap in Tropical Soils Research

Continued support of SOC research in sub-Saharan Africa, Southeast Asia, and Latin America is necessary for the credibility of any climate strategy in the future.

2. Establish Global Standards for SOC Measurement

There must first be a reliable, universal, and accessible standard for measuring SOC gains before carbon can be traded on the market.

3. Educate Farmers on Effective Land Management Practices

Current methods exist that would improve SOC but require political and financial support to become widespread.

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