POLICY BRIEF

IS GHANA'S SOIL BREATHING TOO MUCH CARBON? UNDERSTANDING LAND-USE EMISSIONS

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KEY MESSAGES

- Forestry Commission and Ministry of Lands and Natural Resources (MLNR) should launch large-scale reforestation of degraded forest with community-based participation.
- Expand agroforestry to integrate trees into farms, boosting carbon storage and reducing emissions.
- Ministry of Environment, Science, Technology, and Innovation should invest in soil monitoring stations as permanent plots to track CO_2, CH_4, and N_2O emissions and sinks.
- Ministry of Food and Agriculture should subsidize eco-friendly techniques to enhance soil carbon and cut emissions.

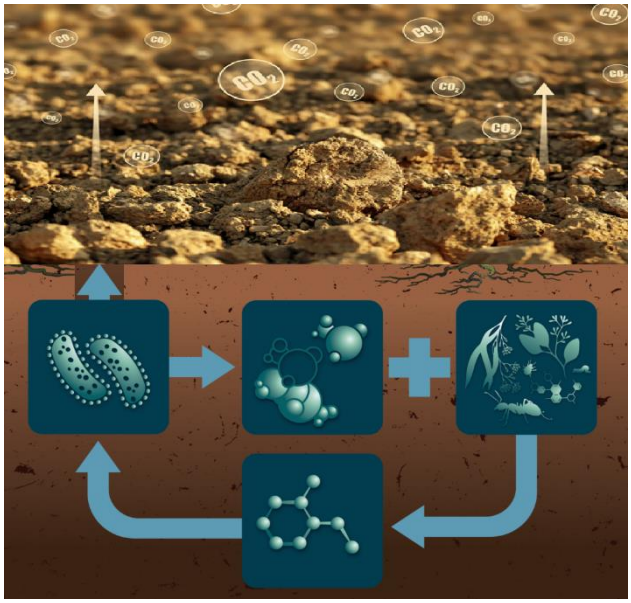
Soil respiration (SR), the release of CO_2 from soil due to microbial decomposition and root activity, is a major component of terrestrial carbon emissions. Yet, its dynamics across different land-use types in Ghana remain poorly understood.

Seasonal variations, land-use changes, and soil properties significantly influence soil respiration rates (SRR), making it a critical factor in Ghana's efforts to effectively manage greenhouse gas (GHG) emissions. However, limited long-term data capturing the interplay of these factors has hindered the development of informed mitigation strategies.

The Agriculture, Forestry, and Other Land Use (AFOLU) sector, which accounts for 38.3% of Ghana's total GHG emissions, is a key contributor to soil respiration. Activities such as deforestation, agricultural expansion, and land degradation release substantial amounts of CO_2, while also reducing the capacity of forests and soils to act as carbon sinks. Forested areas, with their undisturbed soils and high organic matter content, typically emit less CO_2 compared to agricultural lands, which are characterized by higher soil disturbances and intensive management practices. Despite this, ongoing deforestation and the conversion of forests to croplands in Ghana have significantly increased soil respiration rates, highlighting the need for sustainable land-use practices.

The Environmental Protection Agency (EPA) Ghana plays a central role in the country's climate efforts, including the reporting of Nationally Determined Contributions (NDCs) under the Paris Agreement. Accurate and comprehensive data on soil CO_2 fluxes across

various land-use types are essential for refining Ghana's GHG emission inventories and aligning them with international climate commitments.



Soil respiration describing carbon dioxide released from the soil due to decomposition of soil organic matter and plant litter by soil microbes and through plant roots and soil fauna.

This study addresses this need by investigating SRR across forests, fallow lands, and croplands (maize and rice) in Ghana's moist semi-deciduous forest zone. The findings aim to support Ghana's Natural Resource Management and Agriculture and Food Security priorities by promoting sustainable land-use practices that reduce emissions and enhance carbon sequestration. Integrating these insights into EPA Ghana's reporting framework can improve the accuracy of national inventories and strengthen Ghana's climate mitigation strategies.

How land use affects soil carbon emission: Insights from Ghana's semi-deciduous forest zone

This study examined soil respiration across four land-use types in Ghana's moist semi-deciduous forest zone: forest, fallow land, maize fields, and rice fields. Forest plots in the Bobiri Forest Reserve, managed since 1939, remain undisturbed, while fallow lands, left uncultivated for 7 – 15 years, were previously used for crops like maize and cassava. Maize fields have been cultivated for more than 15 years and rice fields, cultivated for over 20 years, rely on chemical fertilizers and pesticides.

A total of 14 plots were selected for measuring soil respiration from these land-use types for 13 months using a closed chamber method.

Equipment used for the study

Soil samples from the same plots were analysed for physical and chemical properties such as soil moisture, bulk density and texture) and chemical properties (pH, organic carbon and nitrogen). These parameters were assessed to understand their influence on soil respiration rates.

Soil properties: Key drivers of soil respiration dynamics

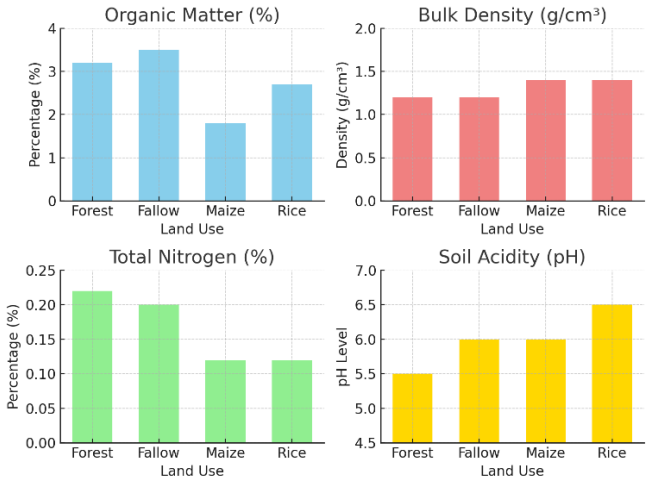


***Figure 1**: Soil properties across land-uses: Insights on Organic matter content (OM), Bulk density (BD), Total nitrogen (N) and pH Levels"*

Key soil properties across land-use types show forests and fallow lands recording higher organic matter and nitrogen levels, indicating healthier soils, while maize and rice fields have lower values, reflecting soil degradation due to continuous cultivation. Bulk density is higher in maize and rice fields, indicating soil compaction, which can hinder water infiltration and root growth, whereas forest and fallow lands have better soil structure. Forest soils are more acidic, while rice fields have the highest pH as observed in Figure 1. These findings emphasize the need to preserve forests for soil health and to improve agricultural practices, such as adding organic inputs, to reduce soil compaction in maize and rice fields.

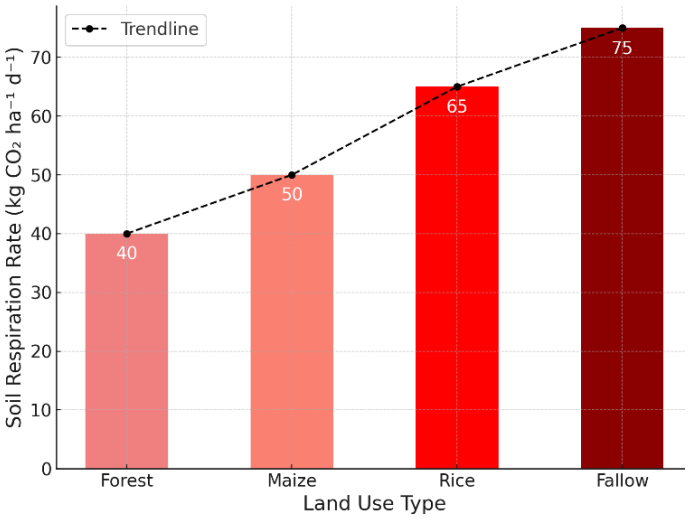


Figure 2: "Rising Emissions: variation of soil respiration rates across land-use types

The graph on Figure 2 shows that soil respiration rates increase across land-use types, from forest to fallow land. Forests have the lowest soil respiration rates, while fallow lands have the highest. This trend reflects the differences in soil properties across these land uses, such as organic matter, pH, nitrogen, and bulk density. For example, higher respiration rates in fallow and cropland soils may be linked to lower organic matter and higher compaction compared to forest soils. These findings highlight the impact of land use on soil carbon emissions and the importance of targeted management practices.

The findings highlight the critical role of forest conservation in reducing carbon emissions and preserving soil health, as forests recorded the lowest soil respiration rates. Conversely, agricultural practices in maize and rice fields significantly contribute to carbon losses due to continuous cultivation and soil disturbance, while unmanaged fallow lands exhibit the highest emissions due to organic matter decomposition.

Policy recommendations for climate actions

These findings emphasize the need for targeted policies to protect forests, reduce soil compaction in agricultural lands, and sustainably manage fallow lands to mitigate carbon emissions and improve soil health.

For the Ministry of Food and Agriculture (MoFA)

- MoFA should subsidize organic fertilizers and eco-friendly farming techniques to boost soil carbon and reduce emissions.
- Develop targeted training programs to educate farmers on sustainable farming practices, including reducing soil disturbances and improving soil organic matter. Deploy extension officers to monitor compliance.

For Forestry Commission (FC) and Ministry of Lands and Natural Resources (MLNR)

- FC and MLNR should implement large-scale tree-planting programs to restore degraded forests and expand forest cover, with incentives for private and community participation.
- MoFA should encourage agroforestry systems to integrate trees into agricultural lands enhancing carbon sequestration.

For Ministry of Environment, Science, Technology, and Innovation (MESTI) and the Environmental Protection Agency (EPA)

- MESTI should allocate funds for research to establish a network of soil monitoring stations across dominant land-use types across ecological zones (permanent plots) to collect data on soil respiration including both net emission and sequestration of CO_2, methane (CH_4) and nitrous oxide (N_2O). Equip these stations with automated sensors for real-time monitoring and accurate data collection.
- Alternatively, EPA should partner with research institutions to collect high-quality, long-term soil respiration data, improving GHG inventories and Ghana's NDC reporting accuracy.

REFERENCES:

- Anokye, J., Logah, V., and Opoku, A., 2021. Soil carbon stock and emission: estimates from three land-use systems in Ghana. Ecological Processes, 10(1). https://doi.org/10.1186/s13717-020-00279-w
- EPA., 2024. Ghana's Fourth Biennial Update Report to the United Nations Framework Convention on Climate Change (Issue March). www.epa.gov.gh

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