SCIENCE–POLICY BRIEF

UNITED NATIONS CONVENTION TO COMBAT DESERTIFICATION

SCIENCE-POLICY BRIEF 01 — NOVEMBER 2015

Pivotal Soil Carbon

Environmental change and carbon are intrinsically linked. When contained in greenhouse gases, carbon is a part of the problem. But in its organic form in the soil, carbon represents a major part of the solution. The first metre of soil contains more than twice the amount of carbon than the amount in the atmosphere, and about three times the amount that resides in the world's vegetation. Increasing soil carbon builds a precious reservoir and helps to offset greenhouse gas emissions. It also contributes to the fertility of the soil, the foundation for all land-based natural and agricultural ecosystems which provide a major part of the world's food supply, natural resources and biodiversity. Moreover, ecological and societal resilience – the capacity to bounce back after disruptive change – is greater when and where soils are productive. This is a one-to-many relationship: the same molecule of carbon maintained or added to the soil leads to all of these benefits simultaneously. Sustainable land management (SLM) practices, such as mulching, zero tillage, green manuring and water harvesting, enhance soil carbon levels. Maximizing the potential return on investment in SLM practices requires a strategic, integrative approach across the efforts to respond to the grand environmental challenges of our time: climate change, land degradation and biodiversity loss. With carefully integrated policies, we have an extraordinary opportunity to help those using and managing land across the globe to optimize soil organic carbon, not only for their own well-being, but to that of the entire planet.

Building soil carbon through soil management is the most viable option for carbon sequestration in the biosphere

- Nowhere else in the biosphere do we have greater potential to effect substantive, positive change than in our soils because policies that support sustainable land management (SLM) practices focused on both maintaining (preventing loss) and increasing (storing even more) soil organic carbon produce far greater economic, social and environmental impact than the absolute amount of carbon sequestered.

The act of maintaining and increasing soil organic carbon provides multiple global benefits simultaneously

- Preventing soil loss (*preventing and combatting desertification and land degradation*) means less carbon escaping into the atmosphere, contributing significantly to closing the emissions gap in order to achieve the 2 °C target (*mitigating climate change*).

- Increasing soil organic carbon increases soil moisture as well as the fertility and productivity of the soil, leading to better returns on agricultural land and food security (*improving human well-being).*

- Improved productivity leads to more carbon stored in plants, and ultimately in soil when residues decompose (*mitigating climate change*).

- Sustaining land productivity reduces the pressure for land conversion, protecting the carbon stock (*mitigating climate change*), the services of the surrounding environment (*an ecosystem services benefit*) and the natural habitat (*a biodiversity benefit*).

- Taken together, all of this leads to the increased resilience of the overall system, meaning reduced vulnerability to the impact of environmental change (*a climate change adaptation benefit*).

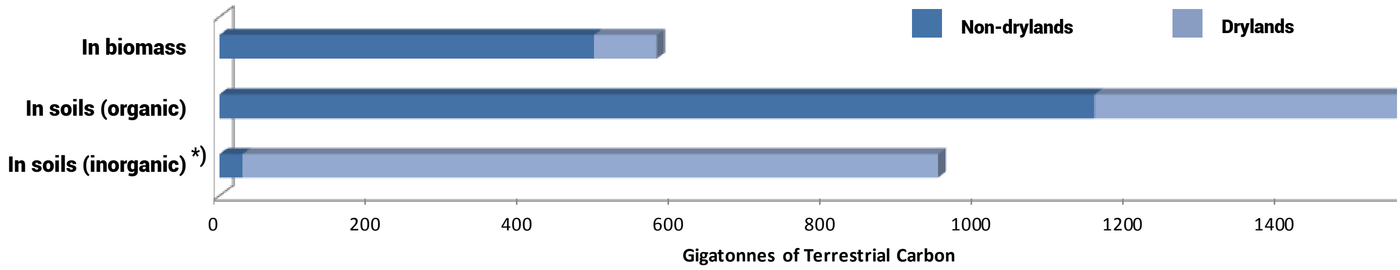
Ensuring full accounting of soil organic carbon as a terrestrial carbon sink under a future climate agreement is both essential and feasible

- Soil organic carbon as an indicator contributes an essential but elusive component to the measurement of progress towards the implementation of all three Rio conventions as well as meeting the Sustainable Development Goals (SDG) on Land Degradation Neutrality (LDN) and climate change.

- The necessary local, national and global soil organic carbon assessment methods and models currently under development need to be implemented in a coordinated, harmonized fashion, and contributing data collection, analysis and reporting networks need to be established.

- Even though the approaches to monitoring and assessment of each of the three Rio conventions differ, the integrative potential of soil organic carbon has been demonstrated, and achieving that integration is operationally feasible.

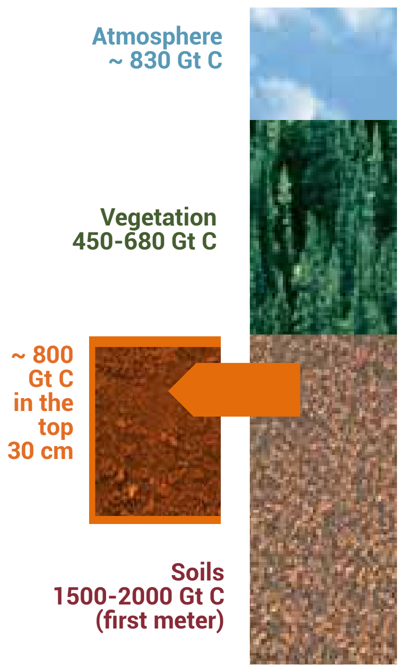
How important are soils for storing carbon and what is the contribution of drylands?



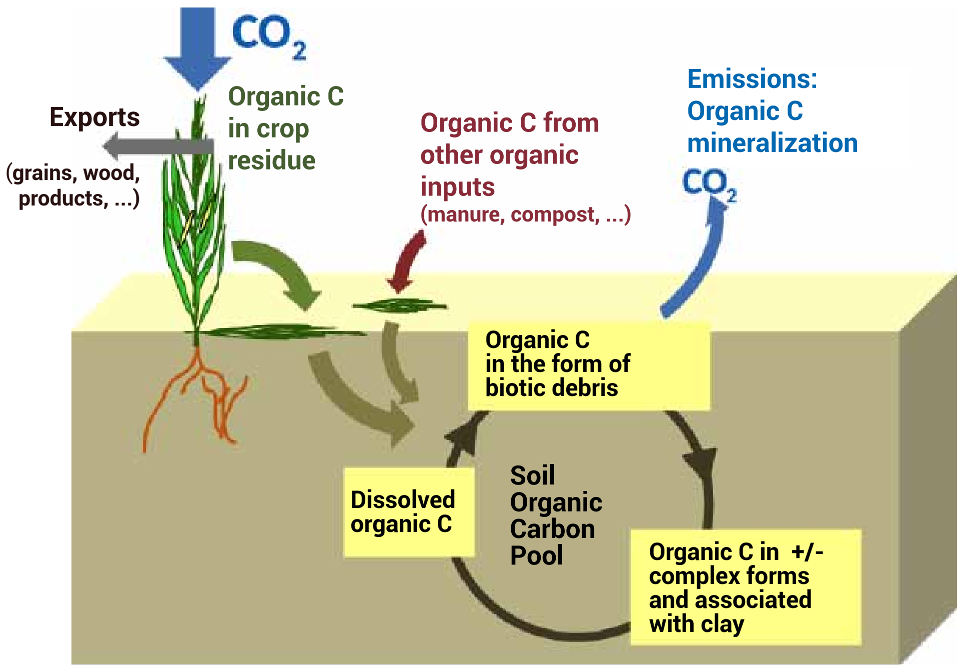
*) Inorganic carbon, commonly present as carbonate in dryland soils, is relatively stable carbon reserve, but dissolved inorganic carbon (DIC) can be a significant export from some soils undergoing degradation.[1]

The integrative potential of monitoring trends in soil carbon stocks

Changes in carbon stocks in biomass and soil reflect the integration of processes affecting plant growth and losses from terrestrial organic matter pools. Thus they reflect trends in ecosystem function, soil health and climate, as well as land use and management. This helps detect trends in the processes leading to and the management of climate change, desertification / land degradation and biodiversity loss. Change in soil organic carbon is largely influenced by anthropogenic activities, such as land-use change, and management practices that influence the productive potential of soil. Soil organic carbon is an indicator of overall soil quality associated with soil nutrient cycling, soil aggregate stability and soil structure, with direct implications for water infiltration, vulnerability to erosion and ultimately the productivity of vegetation, and in agricultural contexts, yields. The soil carbon pool plays the role of both a source and a sink of carbon and thus is relevant to the estimation of the carbon balance. Soil carbon stocks reflect the balance between organic matter inputs (dependent on plant productivity) and losses due to decomposition through action of soil organisms and physical export through leaching and erosion. On seasonal timescales, carbon stocks of natural and managed systems may be explained largely by changes in plant biomass (known as a "fast variable"), but over several years, soil carbon stocks (a "slow variable") become a more relevant indicator of the functioning of the system, its adaptive capacity and resilience to perturbations (e.g. drought), and thus its capacity to provide ecosystem goods and services in the long term.



Soils represent the largest organic carbon pool of the biosphere.[2]



Sustainable Land Management (SLM) can both reduce emissions and help us store more carbon in future.

What can policy makers do right now?

Capitalize on land-based approaches to climate change mitigation and adaptation

■ Develop policies, ideally integrated at the global and national levels, that promote the adoption of sustainable land management (SLM) as well as restoration / rehabilitation practices that preserve or maximize soil organic carbon, thereby simultaneously supporting efforts to prevent and combat desertification, prevent biodiversity loss, and both mitigate and facilitate the adaptation to climate change.

Incentivize SLM

■ Encourage the development of incentives for the awareness, acceptance and adoption of SLM practices at different scales and that include the local knowledge of land users.

Ensure a full and integrated accounting of soil carbon

■ Realize the integrative potential of soil carbon as an indicator within the combined contexts of the monitoring and reporting approaches of the three Rio conventions. This will require assembling a small team of experts in monitoring and assessment that represent the scientific bodies of each of the three Rio conventions, as well as representatives from those organizations that are currently working to make datasets and methodologies behind terrestrial observations and land-based indicators both accessible and applicable.

■ Encourage an integrated and harmonized approach to local, national and global monitoring of trends in soil carbon stocks, as well as the development of contributing networks for data capture, analysis and interpretation. This should build on the momentum of each of the Rio conventions, and leverage the capabilities of relevant global observatories (for example the Global Earth Observation System of Systems, the Global Climate Observing System, the Global Biodiversity Observing System, UNEP Live).

What are the consequences of inaction?

Without sustainable land management, negative 'feedback loops' can develop through land degradation, biodiversity loss and climate change, whereby the loss of soil organic matter and vegetation increases greenhouse gas emissions and vulnerability to climate change, leading to further land degradation and biodiversity loss. Loss in productivity drives further land use conversion for agriculture (all types), which can lead to increased pressure on the natural environment and land conversion, a negative self-enhancing feedback with respect to the well-being of those using the land, carbon emissions and biodiversity loss.

The cost of inaction is significant:

Recent estimates of the global loss of ecosystem service values (ESV) due to land degradation and desertification are estimated at USD 6.3 - 10.6 trillion annually.

On the ground, the potential economic returns of SLM are promising:

For example, economic rates of return from 12 to 40% have been found for a number of projects including soil and water conservation (Niger), farmer-managed irrigation (Mali), forest management (Tanzania), farmer-to-farmer extension (Ethiopia) and valley-bottom irrigation (northern Nigeria and Niger). Returns of over 40% are on record for small-scale, valley bottom irrigation.

The economic incentives for taking action are very strong:

The adoption of sustainable land management practices could contribute to closing yield-potential gaps. Reaching 95% of potential maximum crop yields could create an additional 2.3 billion tonnes of crop production per year, equivalent to a potential gain of USD 1.4 trillion.[3]

Facts and figures: The link between soil carbon and climate change

Building soil carbon can help to mitigate climate change while increasing agro-ecosystem resilience through improved soil quality, which increases the capacity of those dependent on the land to adapt to environmental change[4]. Mitigation occurs as plants sequester atmospheric carbon, captured through photosynthesis in their shoots and roots as they grow. Eventually this plant material decomposes through the action of soil macrofauna and microorganisms, becoming soil organic matter. Soil microorganisms break down this organic matter, respiring carbon to the atmosphere. To build soil carbon, organic matter must be added at a faster rate than decomposition. Higher soil carbon leads to greater productivity, especially due to the role of organic matter in increasing the soil water holding capacity, which increases resilience to climate change.

- **The atmosphere constantly exchanges carbon with the biosphere. Globally, soils capture (via organic matter inputs from plants) more CO_2 than they release (via microorganisms), thus generating a potential carbon sink of about 1-3 Gigatonnes (Gt) per year[5], which contributes significantly to mitigating global warming and hence global climate change.**
- **At the global scale, soils store more than double the carbon (2,529 Gt) of the combined total of atmosphere (830 Gt) and biomass (576 Gt)[5, 6].**
- **Land use is a significant contributor to greenhouse gas emissions. The Agriculture, Forestry, and Other Land Use (AFOLU) is the largest greenhouse gas emitting sector after energy, accounting for 24% of total emissions or 10-12Gt of CO_2 equivalent per year, including 5-5.8 $GtCO_2e$/yr from agricultural production and 3-5.5 $GtCO_2e$/yr from Land Use, Land-Use Change, and Forestry (LULUCF) activities[7, 5].**
- **Soils of the world's agroecosystems (croplands, grazing lands, rangelands) have lost 25–75% of their original soil organic carbon pool, depending on climate, soil type, and historic management[8], amounting to 42 to 78 Gt of carbon[9], of which 18 to 28 Gt were lost through desertification[10].**
- **This loss provides an opportunity: the recoverable carbon reserve capacity of the world's agricultural and degraded soils is estimated to be between 21 to 51 Gt of carbon[9].**
- **Though exploiting the pivotal role of soil carbon would require a vigorous and coordinated effort at a global scale, the challenge can be met through sustainable land management practices which can improve agricultural yields and increase soil carbon[11].**
- **The potential impact is considerable. Increases in agricultural productivity explain as much as a quarter of the observed changes in atmospheric CO_2 during the growing season[12].**
- **Recommended management practices designed to increase the soil carbon pool in the world's agricultural soils could theoretically sequester 0.6 to 1.2 Gt C/yr. This includes 0.4 to 0.8 Gt C/yr in croplands (1350 Mha), 0.01 to 0.03 GtC/yr in irrigated soils (275 Mha), and though more difficult to estimate, 0.01 to 0.3 GtC/yr through improvements of rangelands and grasslands (3700 Mha)[13, 14].**
- **Small variations in the global soil organic carbon have high impact on the global carbon cycle and the CO_2 atmospheric concentration. As an example, even a relatively small annual increase in global soil carbon stocks (e.g., 1% of the carbon stocks in the top meter of the soils) would more than offset the annual anthropogenic CO_2 emissions from fossil fuel burning.**
- **Dryland soils represent a significant portion of the pivotal role carbon can play as they contain more than a quarter of global organic carbon stores and nearly all the inorganic carbon[6].**
- **The economics of taking action are very encouraging: the adoption of sustainable land management practices could contribute to closing yield-potential gaps. Reaching 95% of potential maximum crop yields could create an additional 2.3 billion tonnes of crop production per year[15], equivalent to a potential gain of USD 1.4 trillion[3].**

Facts and figures: The link between soil carbon and biodiversity

Soil organic carbon is necessary for life, both within the soil and for all organisms benefiting from the soil. Sustainable land management that helps maintain or increase soil organic carbon not only contributes to safeguarding biodiversity in general, but directly supports soil biodiversity that underpins the supporting ecosystem service of nutrient cycling, carbon sequestration, and atmospheric carbon fixation. These in turn make possible the supporting ecosystem service of primary production, central not only to the productivity of overlying vegetation cover and habitat, but also the ecosystem service of creating biological products of economic value that provide both food and income that benefit all.

- **Human activities, especially the conversion and degradation of natural habitats, are causing global biodiversity declines with accelerated species losses on the scale of the five mass extinctions in the geological record[16, 17].**
- **Across the globe, average species richness has declined since 1500 by 13.6% and total abundance by 10.7%, while the worst affected habitats have experienced reductions of 76.5% in species richness and 39.5% in total abundance[18].**
- **Drylands are home to an estimated 10,000 mammals, amphibian and avian species, and account for over a third of the global biodiversity hotspots (where a significant reservoir of biodiversity is under threat) and a third of all Endemic Bird Areas[19].**
- **Drylands are the original genetic source of numerous livestock breeds and over 30% of the world's cultivated plants, including a number of unique, high value medicinal plants and gums[6].**
- **Dryland ecosystems have plant diversity which in some cases is higher than more humid biomes[20], and are also characterized by highly diverse soil microbial communities[21].**
- **This biodiversity is fundamental to vital ecosystem functions such as nutrient cycling and the production of soil organic matter, which is essential to both productivity and carbon sequestration. Above-ground plant diversity leads to a diversity of carbon inputs below ground, and that heterogeneity in the soil subsequently supports belowground biodiversity[22].**
- **Plant diversity in drylands has been found to be positively correlated with the ability of dryland ecosystems to maintain multiple functions and services simultaneously, or their multifunctionality[23].**
- **Sustainable land management approaches in croplands are designed to influence common soil management practices (fertiliser application, zero tillage, cultivation, fallowing and crop rotations) in a way that will optimize the soil nutrient balance and soil microbial community diversity, which in turn supports the diversity of flora/fauna that rely on the supporting ecosystem services underpinned by these microbes[24].**
- **The cost of inaction is significant: recent estimates of the global loss of ecosystem service values (ESV) due to land degradation and desertification are estimated to be between USD 6.3 and 10.6 trillion annually[3].**

For further reading:

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Credits:

Photos page 1 — left: Integrating local knowledge: farmer participating in an exercise of ranking indicators for the evaluation of land management and restoration options commonly applied in degradation prone Kalahari rangelands of South Africa. Copyright © N. Dreber.

Middle: Integrated Soil Fertility Management For Food Security (ISFM) training, Dschang, Cameroon, Copyright © F. Oben Tabi.

Right: Landscape showing erosion control systems in the region of Bas-Limbé in the north of Haïti. Nearly all the slope is managed. Date: 14 May 2014. City: Bas Limbé, Haïti. © IRD – M. Bernoux

Photos page 3 — left: Traditional stone wall terraces for soil and water conservation in an Almond orchard in South East Spain. Copyright © J. de Vente.

Middle: Preparing a Zaï field in the province of Yatenga, Burkina Faso. The Zaï is a traditional technique of soil preparation which consists of holes to get some runoff water and then sow the millet or sorghum seeds to make them less sensitive seedlings case of irregular rainfall. Date: 5 January 2007. Copyright © IRD – E. Hien.

Right: Planting native trees to stabilize sand dunes in Kubuqi, China. Date: July 2015. Copyright © A. Erlewein.

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