CIAT
International Center for Tropical Agriculture
Since 1967 / Science to cultivate change

BRINGING SOILS TO LIFE

For sustainable landscapes and prosperous societies

The status of soil has always profoundly shaped the fate of society. Yet, the modern world seems to have lost sight of this fact.

2015 International Year of Soils

Though essential for meeting our food needs, soils are often ignored or undervalued in agricultural development programs and investment strategies. Ironically, this lapse comes at a time when soil health is more important than ever for confronting enormous global challenges – such as rising food demand and climate change – and by implication, for meeting the Sustainable Development Goals that the United Nations is expected to launch in 2015.

The UN has declared 2015 the International Year of Soils, creating an opportunity to renew global awareness of the vital link between healthy, fertile soils and prosperous societies. “Dirt is not dirty; it is the source of life,” Indian activist Satish Kumar reminds us. But only if we bring degraded soils to life through better management, can they store water, deliver nutrients to crops, curb damage from natural disasters like floods, harbor biodiversity, capture carbon, and provide all the other ecosystem services that are essential for sustaining and improving life.

Deforestation in the Brazilian Amazon, near Manaus, Amazonas.

From FARM to whole PLOTS LANDSCAPES

The International Center for Tropical Agriculture (CIAT) has worked steadily and strategically to improve soil management over several decades. Engaging with many partner organizations, our researchers have achieved key advances – from highly diverse rural settings across Africa to remote upland areas of Asia and the hillsides and vast savannas of Latin America.

CIAT has the largest soils team in the CGIAR Consortium – the global research partnership of which the Center is a member – and also the most diverse, including not only soil scientists but also ecologists and anthropologists. Their job is mobilizing the expertise and generating the knowledge that decision makers need to promote sustainable, climate-smart management of rural land, so that it can deliver greater economic and social benefits. The work of our soils team is guided by *CIAT Strategy 2014–2020*, which envisions a critical role for this research in "building an eco-efficient future."

To radically alter current patterns of soil and land degradation, we need to act both locally and globally. For this reason, the Center has broadened the scope of its soils research to encompass not only individual farm plots but entire landscapes across the tropics. CIAT's pioneering soils research is organized around three interrelated themes: (1) restoring degraded land, (2) soils and climate change, and (3) sustaining soil fertility and health.

In the Tana River watershed, CIAT is working with partners to preserve the environment, while also improving farmers' livelihoods.

1. Restoring degraded land

The cost of land degradation worldwide has reached an estimated US$490 billion, according to the United Nations Convention to Combat Desertification (UNCCD), far higher than the cost of reversing it. The only affordable response now is investing in land restoration and soil rehabilitation, which have the potential to benefit millions of rural households in developing countries and all who rely on the ecosystem services that farm families help maintain.

To this end, environmental agencies, governments, and investors are joining forces to undertake major efforts, such as Initiative 20x20, which is supported by the World Resources Institute (WRI), CIAT, and other partners. This initiative aims to restore 20 million hectares of degraded land in Latin America by 2020.

The success of such efforts depends on long-term political and financial commitment but also high-quality science that addresses key issues, such as how rural people can achieve and benefit from land restoration, ensuring that investments deliver the expected payoffs.

Through decades of research on crop, soil, and land management, CIAT and its partners have developed and tested a wide range of sustainable soil and land management options, such as integrated soil fertility management, and slash-and-mulch agroforestry, which have proven effective for halting land degradation. Yet, adoption of these solutions is still limited, because of diverse social and economic factors as well as resource constraints.

In response, CIAT scientists design soil and land management options with local communities, using ecosystem services approaches. Going a step further, researchers help develop incentives for wider adoption of these options and target investments across landscapes, with the aims of restoring ecosystem services, intensifying crop production sustainably, and delivering tangible economic and social benefits – especially for marginalized groups and women.

Kenya's life blood

In the upper watershed of Kenya's Tana River, soil washing down from hillsides damages the water supplies of downstream users, including Nairobi's estimated four million inhabitants. Researchers have shown that in the last 10 years soil sediment in parts of the river has increased by more than 30%.

To find solutions, various organizations, including The Nature Conservancy (TNC) Kenya, are piloting a water fund with CIAT support, which brings together different users of the Tana River ecosystem – farmers, government agencies, hydropower companies, and breweries. Their joint aim is to create incentives for upstream communities to protect and better manage the watershed.

In support of this initiative, researchers have generated maps illustrating the dynamics of upland farming and modeled the hydrological impacts of land-use change. The results are used to target investment in solutions, such as reforestation and improved cropping systems, that increase farmers' incomes.

Partners that include the country's largest electricity and water provider together with businesses like Coca Cola have raised more than US$900,000, and these funds are already benefiting users of the upper watershed. The Nairobi Water Fund – a first for Africa – was launched in March 2015 and aims to be fully capitalized at $15 million by 2020.

To encourage future investment, CIAT researchers are working with Kenya's Water and Resource Management Authority and TNC to implement a monitoring program that provides evidence on the effectiveness of various interventions in retaining soil and reducing sedimentation in rivers. This will provide businesses with proof that investments in cleaner water are yielding returns.

Digging terraces to curb soil erosion in northern Tanzania's Lushoto District.

2. Soils and climate change

Farming is highly vulnerable to climate change impacts, which can depress crop yields and reduce the suitability of whole areas for staples like beans and maize. Climate change further undermines agriculture by putting greater pressure on soils. Rising temperatures speed the loss of organic matter, and more intense rainfall increases soil erosion. At the same time, agriculture contributes significantly to climate change through greenhouse gas emissions (GHGs).

Emissions from agriculture have steadily increased in recent decades, as crop production has intensified. Better soil management is thus critical for enabling agriculture to both mitigate and adapt to climate change impacts.

CIAT conducts research that informs the investments of the International Fund for Agricultural Development (IFAD) and other partners in climate-smart agriculture. Our scientists quantify GHGs from diverse production systems (especially the big emitters like irrigated rice and livestock) and work with partners to design and assess win-win solutions. The results are used to guide investments aimed at fast-tracking the transition to low-emissions agriculture and nationally appropriate mitigation actions. CIAT soil scientists also quantify soil organic carbon stocks under various land uses to assess the mitigation potential of different systems.

Potential solutions include enhancing soil organic matter; optimizing rainfall infiltration and retention; and integrating trees with crops, including legumes, to enhance ecosystem services, such as carbon sequestration and nutrient cycling. These options show great potential for strengthening food security and nutrition, adapting to climate change impacts, and keeping emissions within safe boundaries – the three pillars of climate-smart agriculture.

Down-to-earth data in Tanzania

The landscape in Lushoto District, nestled in northeastern Tanzania's Usambara Mountains, is highly diverse but also highly vulnerable to climate change. The organic carbon content of the soil – a key indicator of soil health – varies dramatically over short distances, making clear the need for locally adapted management options.

Research conducted by CIAT and its local partners, including the Selian Agricultural Research Institute (SARI) in Arusha, shows that current cultivation practices have caused a sharp decline in soil organic carbon, which translates into lower crop productivity and increased vulnerability to climate change.

To help reverse the decline, researchers are using the Land Degradation Surveillance Framework – developed by CIAT and the World Agroforestry Centre – for monitoring soil health and quantifying ecosystem services. On this basis, researchers develop maps that reflect the complexity of soils within the landscape, and also examine how land and soil health metrics are linked with crop productivity and socio-economic indicators. The maps help guide the design of strategies to achieve climate-smart agriculture, which our partners use with farmers to develop site-specific recommendations for managing and protecting soils. Science-based information also helps local government make better decisions about land-use planning.

Farmers who have adopted the Quesungual slash-and-mulch agroforestry system in Nicaragua's Estelí Department.

3. Sustaining soil fertility and health

Maintaining healthy soils and reversing soil fertility decline are critical for achieving sustainable intensification of crop production, which is vital for ensuring future food security. A key starting point for research aimed at achieving these ends involves the use of cost-effective diagnostic techniques to determine soil characteristics, measure threats to soil health, and identify the drivers of soil fertility loss.

With this information, CIAT scientists assess the potential for enhancing and sustaining the productivity of specific farming systems (such as conservation agriculture, maize-bean intercropping, and crop-livestock systems) through more efficient use of inputs and natural resources. Working with a new initiative of the German government called "One World No Hunger," for example, CIAT is conducting research on soil rehabilitation in Africa and Asia. The results help identify improved management practices for specific conditions, with the aim of curbing soil degradation.

In recent years, our scientists have focused on developing tools that help farmers achieve a better fit between soil management technologies and the specific land and economic conditions in which these options can be adopted.

To help sustain soil fertility and health for future generations, CIAT researchers use biophysical models and indicators of soil-based ecosystem services (e.g., disease and pest suppression), drawing on results from long-term experiments to determine the impacts of farm and landscape management. Researchers then analyze scenarios to help identify best options as well as the locations where these are likely to prove economically viable and socially acceptable, while also reducing agriculture's impact on ecosystems.

An alternative farming system from Central America

Some improved approaches to soil management result from the fusion of traditional knowledge with new insights from science. Such is the case with the Quesungual slash-and-mulch agroforestry system, which was originally developed in the early 1990s by the Food and Agriculture Organization of the United Nations (FAO) with community-based organizations in Lempira Department, Honduras, as an alternative to slash-and-burn cultivation.

The system includes many species of trees scattered across cropland at a density of up to 1,000 per hectare. The roots act as anchors, stabilizing hillsides, minimizing soil erosion, and improving nutrient uptake from deeper soil layers. Farmers regularly prune most of the trees and use the cuttings as mulch to provide nutrients, increase soil organic matter, improve soil structure, and retain moisture – giving crops and soils some protection against dry spells, heavy rains, and climate change impacts. In addition to capturing carbon dioxide, many of the trees in the system fix nitrogen, thus improving soil fertility.

CIAT is conducting research on slash-and-mulch systems with local partners and farmers to explore their considerable potential in Latin America for rehabilitating degraded soils and landscapes, enhancing ecosystem services, and improving rural livelihoods. The results inform planning and policies on sustainable land use, biodiversity conservation, and soil fertility restoration.

As a result of this work, farmers have taken up silvopastoral and agroforestry systems in El Salvador and Nicaragua. In the latter country, spontaneous dissemination of these systems through farmer-to-farmer exchange has helped increase maize and bean productivity. Similar efforts are underway in Paraguay as well as the Colombian and Peruvian Amazon.

Soil testing at the source of the Tana River. Soil erosion washes away valuable top soil, affecting communities downstream.

Better choices for greater benefits

A key feature of CIAT's research on soil and land management is that it integrates science with the knowledge of multiple actors – including farmers, other land users, public and private investors, and policy makers – through a transformative approach that increases the likelihood of sustainable outcomes.

Many of the decisions that must be made – whether by farmers or policy makers – revolve around economic issues. What are the costs of change, who benefits, and who pays? How can societies achieve more equitable sharing of benefits from ecosystem services (such as carbon sequestration and water quality regulation) to improve human well-being? How can we create stronger incentives for improved land management? What are the best ways for smallholder farmers to restore degraded land and create environmental benefits, while also boosting incomes and food security? And how can these farmers afford to maintain soil fertility and agricultural productivity, and also enhance the resilience of farming in the face of climate change?

CIAT's research seeks answers to these questions, which are being brought into sharp focus by recent developments, such as large external investments in agricultural growth corridors. While creating new market opportunities for smallholder farmers, these investments could also have negative impacts, including land degradation, habitat conversion, water scarcity, land tenure concentration, and the replacement of diverse production systems with large-scale monoculture. CIAT scientists are working with the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) to help improve land-use planning, provide information in support of investment decisions, and monitor social and environmental conditions.

Inside the soil science toolbox

Since tropical landscapes and the socio-economic circumstances of those who manage them vary greatly, CIAT scientists and their partners need to use a wide array of cost-effective tools and methods:

Land assessment and digital soil mapping – Involving rigorous sampling design, modern terrain analysis software, rapid soil testing, geographic information systems, and expert knowledge, these approaches are used to create maps of key features (such as soil organic carbon stocks and erosion risks) that are relevant to climate-smart agriculture and land restoration.

Long-term and strategic agronomic trials – Replicated and networked on-farm trials are a powerful tool for testing new soil management practices with farmers and other decision makers. Long-term trials provide data on spatial patterns in soil quality and ecosystem services, which inform choices about how soil quality can be sustained in the future.

Crop models and yield gap assessment – These tools help determine drivers of change in soil fertility over the long term (in response to current or expected management practices) and to explain yield gaps. With this knowledge, we can design practices for testing with farmers and assess the impacts of climate change on crop productivity and future soil health.

Ecosystem services assessment – This approach combines participatory mapping with biophysical modeling of ecosystem services in landscapes to analyze both the on- and off-site impacts of farm-scale interventions on people, institutions, and ecosystems.

Rapid appraisal of climate-smart agriculture – This method involves gathering information through workshops and interviews with farmers to assess various aspects of farming systems (land health, agricultural production, rural livelihoods, and climate impacts) for the identification of locally appropriate solutions.

Land degradation economics framework – This set of tools is used to design economic incentives for equitable, effective, and sustainable land management interventions.

Land-use planning and trade-off analysis – Applicable to farming systems and landscapes, these methods facilitate choices about land management by assessing the social, economic, and environmental costs versus benefits of adopting particular practices and investment portfolios.

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To support our own work and meet clients' needs, CIAT maintains laboratories in Cali, Colombia, and Nairobi, Kenya, for digital soil mapping and land assessment; soil chemical, physical, and biological analysis; and greenhouse gas analysis.

About CIAT

The International Center for Tropical Agriculture (CIAT) – a member of the CGIAR Consortium – develops technologies, tools, and new knowledge that better enable farmers, especially smallholders, to make agriculture eco-efficient – that is, competitive and profitable as well as sustainable and resilient. With headquarters near Cali, Colombia, CIAT conducts research for development in tropical regions of Latin America, Africa, and Asia. Its pioneering soils research contributes importantly to several CGIAR research programs.
www.ciat.cgiar.org

CGIAR is a global research partnership for a food-secure future. Its science is carried out by the 15 research centers who are members of the CGIAR Consortium in collaboration with hundreds of partner organizations.
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Donor support

CIAT's research is made possible by the multi-donor CGIAR Fund as well as by grants from many organizations, some of which are also Fund donors. We are grateful to all who support our efforts to build an eco-efficient future for tropical agriculture through high-quality science that reduces hunger and poverty while enhancing natural resource management.

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April 2015