Soil at The Nature Conservancy

A shared science agenda: activities and priorities

The Nature Conservancy

Soil is intrinsically connected to the wellbeing of people and the environment.

Contents

This document was prepared by Deborah Bossio and Stephen Wood in collaboration with staff at The Nature Conservancy.

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Introduction

Centuries of research and direct experience show that soil is intrinsically connected to the wellbeing of people and the environment. The Sustainable Development Goals (SDGs), adopted by United Nations Member States in 2015, established a clear mandate to manage the planet for both human and environmental wellbeing. This thinking is reflected in The Nature Conservancy's mission—to achieve a world in which "...the diversity of life thrives, and people act to conserve nature for its own sake, and its ability to fulfill our needs and enrich our lives." Any viable approach to achieving this—and hence achieving the SDGs—requires addressing soil as the foundation of both agricultural and healthy, natural ecosystems.

OVER THE PAST DECADE, soil has gained greater attention in research, practice and policy arenas. In 2012 the UN Food and Agriculture Organization launched the Global Soil Partnership, and then celebrated the International Year of Soil in 2015. At the 2015 UN Climate Change Conference in Paris we saw national governments engage with soil, as reflected in the 4 per 1000 initiative launched by the French government to build soil carbon for climate and food security.

In recognition of the importance of soil for global conservation work, and the need to accelerate progress, The Nature Conservancy (TNC) has decided to invest in soil science to improve how we manage land and scale up our conservation impact. This work aims to ensure that the best possible soil science is available to TNC and its partners and collaborators. TNC's audience for this science is TNC conservationists and scientists, and external partners in non-profits, government, and private enterprise who look to TNC for guidance on ways to meet their conservation, sustainability, and climate goals.

Having clear goals and priorities for soil science at the Conservancy is a prerequisite for ensuring that these partnerships achieve the greatest possible impact, and better alignment with broader Conservancy goals and science. This was the motivation behind developing the shared soil science agenda.

Here we present this shared soil science agenda. Our agenda is shared because it is the result of months of conversations with TNC staff, ranging from property managers to global leads, and therefore rooted in the priorities of staff across the Conservancy. It is built on our existing, extensive work to manage soils for conservation outcomes. And it is a soil science agenda as our priority is to catalyze and carry out science that directly and indirectly supports conservation implementation by facilitating and influencing decision-making by practitioners and investors.

We begin with an overview of the importance of soil for conservation and the relationship between soil management and TNC's conservation agenda. We also introduce current practice, give a snapshot of the regional distribution of soil-related projects at TNC, and summarize the range of conservation outcomes soil management can support going forward.

The final section presents the overarching conservation objectives and the science approach needed. We also lay out the types of actions that will be supported by this science agenda.

The shared soil science agenda provides the 'what' and the 'why'. With this in hand, specific initiatives to address the 'where', 'how' and 'with whom' will be developed moving forward.

Importance of soil for conservation

TNC's conservation priorities include tackling climate change, sustainable food production, and protecting habitat and biodiversity; soil is critical to all three.

1. Tackle climate change

Soil is the largest terrestrial stock of carbon, containing twice as much carbon as the atmosphere. Current land use degrades and threatens this important carbon pool, and future climate change will only amplify this. Retaining and building soil carbon is therefore important to a multi-pronged natural climate solution approach to mitigating climate change. Sequestering carbon in soils of crop and grazing lands, preserving it in peatlands and grasslands, and building soil carbon stocks through reforestation are all important pathways for land-based climate action. Soil is also an important source of methane and nitrous oxide, which are potent greenhouse gases. Reducing these non-CO_2 emissions is another key aspect of natural climate solutions.

2. Sustainable food production

Fertile soil is necessary for long-term, productive agriculture. The living ecosystem that is soil provides nutrients to grasslands and crops through the weathering of sediments and mineralization of organic matter. It retains water, which can support crop yield productivity, resilience, and stability. And the right mix of soil biodiversity is important to avoid damage from pests and pathogens. New science is even showing that soil management can impact the nutritional content and flavor of food. In grazing lands, changes in soil properties—like the dramatic loss of soil carbon or erosion—can be important indicators of land degradation.

3. Protect habitat and biodiversity

Soils regulate water cycles and control nutrients that pass through soil en route to water systems. Nutrients leave soil by leaching through the soil profile and into groundwater systems, and are lost when water flows on top of the soil surface, eroding surface soil particles (with nutrients attached), and depositing those sediments and nutrients in nearby water systems. Excess nutrients can lead to lower aquatic diversity, lower recreational value, and in some cases impact water quality for human consumption. Sediments can also clog components of hydroelectric dams and reduce the lifespan of reservoirs. Wind loss of soil sediments can create air pollution hazards.

Soil is also key to managing lands for biodiversity, which is core to TNC's work. Many of the practices that protect habitat and biodiversity—such as changing vegetation communities and fire regimes—have strong impacts on soil properties. These changes feedback and impact on habitat restoration efforts because many soil microorganisms exist in close association with plants and can give certain species a leg up by helping with nutrient and water acquisition.

Types of soil management practices

Many management practices have been identified and promoted to improve soil properties. Generally, these practices fall into groups that target soil physical properties, soil chemical properties, or soil biological properties, bearing in mind that many practices affect multiple types of properties.

Practices aimed at impacting physical properties, such as terracing, agroforestry windbreaks, or cover cropping, are usually designed to reduce erosion. Practices targeting soil chemical properties could include the adoption of leguminous crops to increase nitrogen, or the addition of organic amendments to increase carbon and other nutrients. Management practices designed to impact the biological properties are those that are aimed at influencing the biotic activity of soil, either by promoting organisms regarded as beneficial, such as mycorrhizal fungi, or by reducing the effect of harmful organisms, such as root pathogens.

Different practices—whether physical, chemical, or biological—can be adopted for different conservation goals (Table 1). Some soil management practices are well suited to addressing climate change and others to reducing sedimentation, while many fall into a 'happy coincidence' category where they impact several outcomes.

Similarly, many outcomes of soil management may contribute to multiple conservation priorities. For example, forest restoration contributes to protecting land and water at the same time as tackling climate change through carbon sequestration. Reduced nutrient loading to waterways can protect important aquatic habitats and improve drinking water quality.

Biophysical management practices

In this summary we focus on biophysical management practices that impact soil. Therefore Table 1 does not include decision-making practices, which are essential underpinning for many strategies and programs at the Conservancy. Decision-making practices, as embodied in TNC's Conservation by Design approach, drive planning and change processes in systems and include the concepts of adaptive management, continuous improvement, action planning and landscape planning.

Table 1. Types of biophysical conservation practices that could impact soil.

This is not an exhaustive list but a sample of common types of practices.

Practice	Conservation outcome		
	Climate	Food	Biodiversity
Agroforestry	✔	✔	✔
Biochar	✔		
Cover cropping	✔	✔	✔
Crop diversification		✔	
Fire management	✔	✔	✔
Grass strips		✔	✔
Grazing management	✔	✔	✔
Intermittent rice flooding	✔	✔	
Mangrove restoration	✔		✔
Nutrient management	✔	✔	✔
Organic matter input to agriculture	✔	✔	
Reduced tillage	✔	✔	
Reforestation	✔		✔
Terracing		✔	✔
Vegetation restoration			✔
Wetland and riparian restoration	✔	✔	✔
Avoided conversion	✔		✔

Implementation and outcomes

The Nature Conservancy is already implementing many of the practices highlighted in Table 1, but to date there has been no synthesis regarding where they are being adopted and for what goals. In this section, we capture a snapshot of soil projects and priorities at the Conservancy based on conversations with TNC staff and survey responses from project managers, regional conservation leaders and scientists.

Some Conservancy projects directly target soil outcomes, while others adopt management practices that impact soil outcomes but for non-soil reasons. An example of a direct soil project is the Northern Rangelands Trust partnership in northern Kenya (see soil project, page 13), which is using rangeland management to increase soil carbon, leverage carbon markets, and provide revenue for community rangeland trusts as part of efforts to improve rangeland productivity for both livestock and wildlife. An example of indirect impact is Matador Ranch in Montana, where TNC is protecting grassland biodiversity through grassbanks and indirectly preserving soil carbon by avoiding conversion to wheat agriculture. A greater number of TNC project managers identify as being involved with projects that are indirectly impacting soil, rather than directly targeting soil outcomes.

Priorities and practices related to soil

At the Conservancy, soil management practices are implemented to achieve a range of outcomes, including biodiversity restoration, carbon sequestration, crop productivity, and the others listed in Figure 1. According to the survey of TNC staff, the highest priorities are currently biodiversity restoration and protecting water quality by reducing nutrient loading and lowering sedimentation. Tackling climate change—through sequestering carbon and reducing greenhouse gases—is the next most important priority area, while agricultural productivity outcomes have a somewhat lower priority. The lower rankings of rangeland and crop productivity do not imply that productivity outcomes are not an important component of TNC projects, but that productivity outcomes are less often ranked as the most important. This reflects the mission of the Conservancy, and the role that agriculture plays as a part of strategies for achieving ecosystem services beyond production of food.

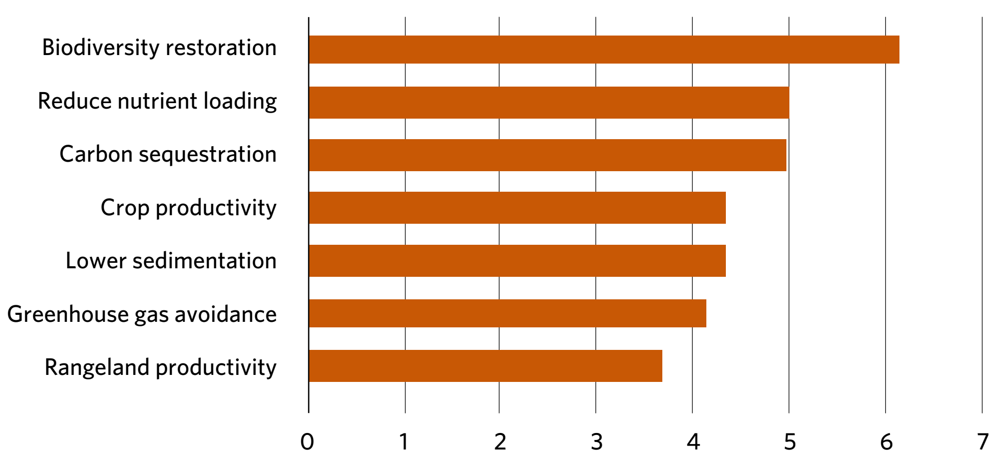
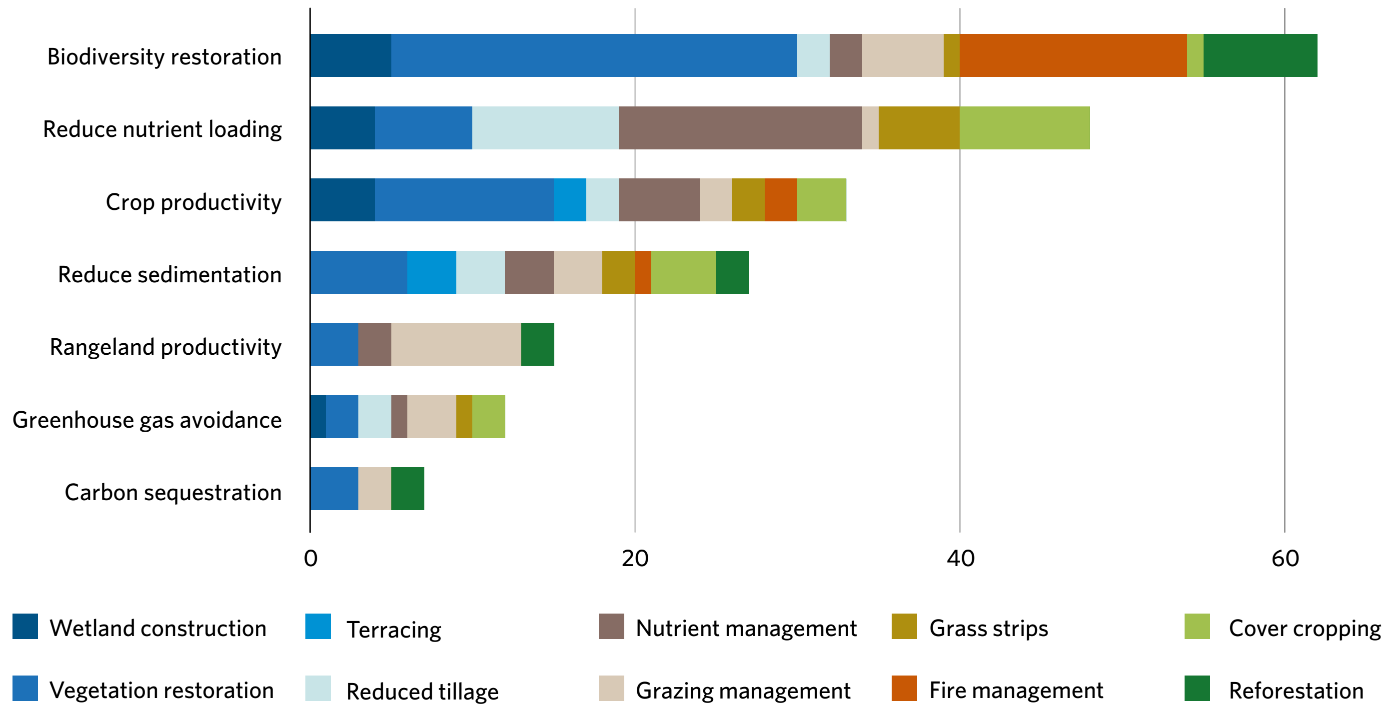


Figure 1. Average priority ranking of target outcomes in projects impacting soil; higher numbers indicate higher priority based on survey of TNC staff.

Figure 2. Relative importance of practices used for projects, with a particular priority ranked as most important by TNC staff.



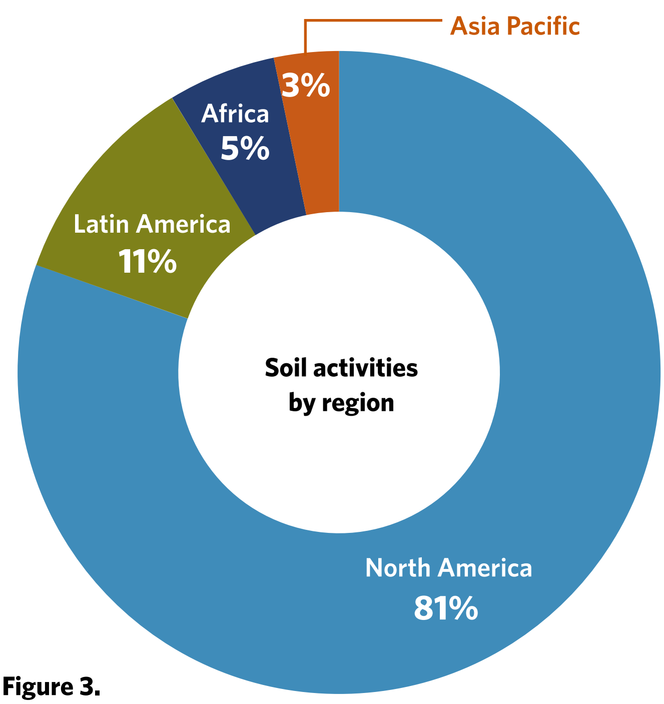


Figure 3.
Proportion of soil projects distributed by TNC region.

TNC has in its toolbox a diverse mix of management practices to achieve conservation priorities and many of these practices will affect the soil (Table 1). We asked TNC staff about which management practice types were used for specific projects. Projects varied both in the number of practices they used and the importance of different practices for different conservation priorities (Figure 2, page 8). Projects that identified biodiversity restoration as their most important goal used vegetation restoration the most, followed by fire management. Vegetation restoration emerged as the most important management practice across many conservation outcomes; terracing was the practice used in the smallest number of different projects.

Regional distribution of TNC soil projects

The majority of TNC's soil-related projects are in North America (Figure 3), reflecting the fact that North America has been the historical focal area of the Conservancy. However, the ecosystems or habitat types within which soil-related projects are taking place at TNC include forest, grassland, wetlands, and agricultural ecosystems, across all regions.

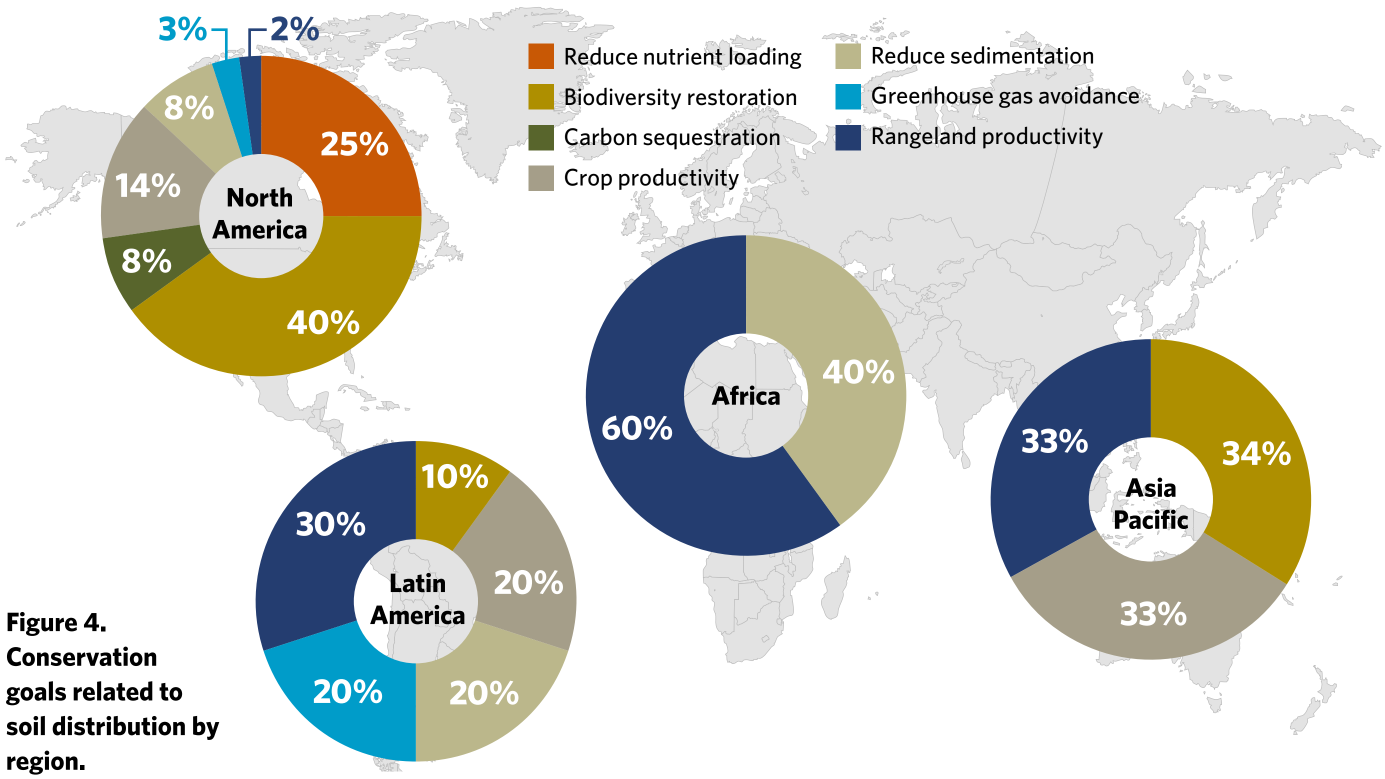


Figure 4. Conservation goals related to soil distribution by region.

Although regions outside North America have fewer projects, some of their activities align strongly with priorities related to soil. For instance, much of the work within the Africa program focuses on rangeland and water system management, which are directly related to soil through grazing management and reducing sedimentation (Figure 4, page 10). Projects in Latin America focusing on agricultural supply chains and water funds all impact soil management practices.

Because regions differ in their conservation priorities, they also differ in the relative importance of different practices (Figure 5). For example, terracing agricultural fields was not cited in any North America projects whereas it was promoted in Latin America and Asia. Some practices, like reforestation, are cross cutting.

It is notable that the ecosystems and habitat types within which soil-related projects are taking place at TNC include forest, grassland, wetlands, and agricultural ecosystems across all regions. Biodiversity restoration and rangeland productiviy are priorities in temperate grassland and prairie ecosystems around the world, exemplified by the Matador Ranch grassbank project in Montana and the Toson Hulstai Nature Reserve in Mongolia. Reducing sedimentation in waterways from soil erosion is a priority in upper watersheds near cities for our Water Funds projects globally (see soil project, page 13). An emphasis on reduction of nutrient loading and crop productivity has the greatest reach in agricultural ecosystems in the Corn Belt of the USA, with its deep, rich soils high in organic matter and intensive farming systems, including for example in the Mackinaw River watershed project in Illinois, and through the reThink Soil Roadmap (see soil project, page 12). The Oregon Forest program combines fire management and ecological thinning to restore temperate forest habitat, with strong indirect impacts on soil. Protection of tropical forests and grasslands, and their soil carbon stocks, is at the heart of TNC's new Collaboration for Forest and Agriculture for Brazil, Argentina and Paraguay.

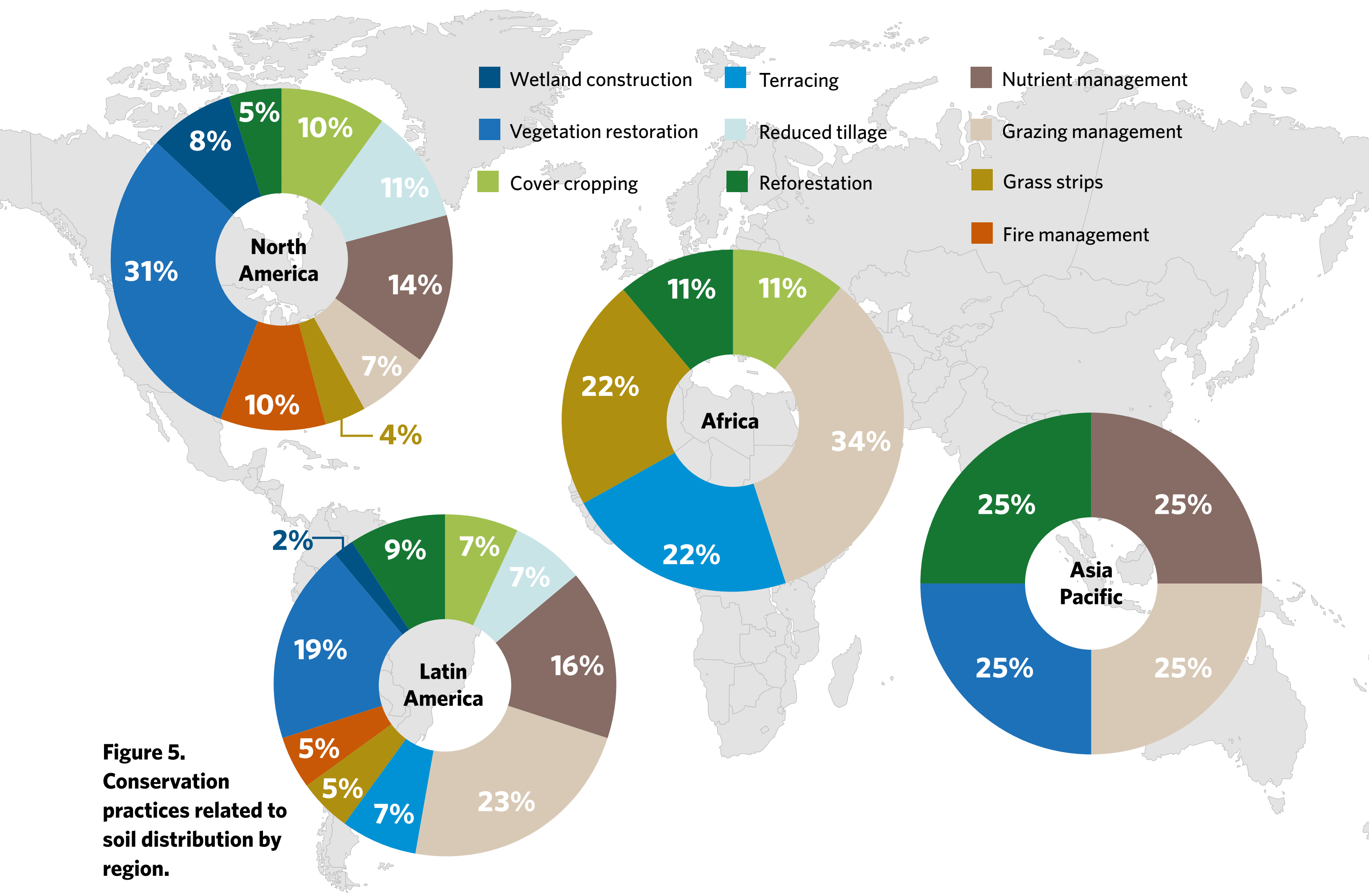


Figure 5. Conservation practices related to soil distribution by region.

Ground level: TNC soil projects

reThink Soil Roadmap

In 2016 The Nature Conservancy launched its roadmap outlining reforms of United States corn, soy and wheat crops to encourage the adoption of practices that improve environmental and conservation outcomes.

The initiative promotes three practices: reduced tillage; cover cropping; and targeted nutrient use. The aim of the project is for 50 percent of arable land in the US to be under these practices by 2025. To achieve this 'soil health' goal, the project is partnering with two other initiatives active in North America—the Soil Health Institute and the Soil Health Partnership. The work blends data collection at around 135 demo sites, the development of new assessment and indicator protocols, communications and outreach, and strategic work with supply chain actors. Though new, the reThink Soil Roadmap is the largest single project related to soil in the Conservancy and is beginning to expand to other regions of TNC's work.

Northern Rangelands Trust partnership

The Northern Rangelands Trust (NRT) is a community-led, non-governmental organization in northern Kenya set up by a coalition of local leaders, politicians and conservation interests. Its mission is to develop resilient community conservancies, which transform people's lives, secure peace and conserve natural resources.

NRT includes 14 member conservancies that work across 2.2 million hectares, support and empower communities to develop locally-led governance structures, run peace and security programs, take the lead in natural resource management, and manage sustainable businesses linked to conservation. One aspect of NRT's rangeland conservation program is to economically incentivize sustainable rangeland practices by tapping into soil carbon market funding and provide conservancies with revenue based on the carbon sequestered. This partnership is one of the most important TNC projects, putting in place long-term efforts to manage ecosystems for soil outcomes, in addition to other aspects of rangeland health.

Water Funds projects

Water Funds are projects that use terrestrial conservation to protect aquatic resources. Because terrestrial and aquatic systems are linked, the degradation of terrestrial habitat can lead to erosion and nutrient loss that can lower water quality and aquatic biodiversity, and damage infrastructure like hydro-electric dams.

The Conservancy is involved in dozens of Water Fund projects—from China to Kenya to Minnesota—that share similar broad goals but are being implemented based on geographically-specific needs. Because most of the impacts on aquatic systems are related to agricultural soil management—erosion of sediment, leaching of soluble nutrients—there are growing efforts to couple Water Fund projects with efforts to improve the health of soils in surrounding areas. For example, the Nairobi Water Fund around the Tana River is working closely with farmers to promote soil management practices, like terracing and agroforestry, that can reduce sedimentation into the Tana River. By adding a focus on farm-level soil health through the introduction of climate-smart agriculture practices, Water Funds efforts will also increase agricultural productivity and farmer income.

A first soil science agenda for TNC

Here we present The Nature Conservancy's first shared soil science agenda. It is truly a shared agenda because it is the result of months of dialogue with TNC staff, ranging from property managers to global leads, and therefore rooted in the priorities of staff across the Conservancy. It is built on the ongoing extensive work being done by TNC on four continents to manage soils for conservation outcomes, as described above. It is a soil science agenda and our priority is to catalyze and carry out science that directly and indirectly supports conservation goals.

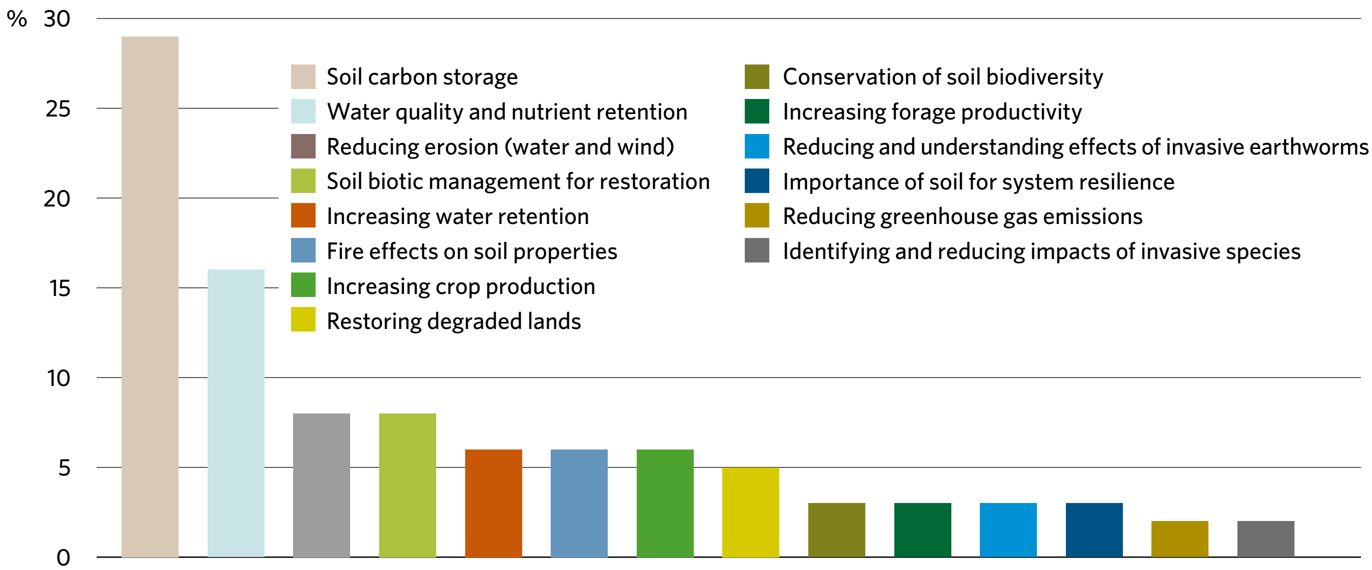
Direct support comes through our partnerships with universities, NGOs, research organizations and institutions that are the primary vehicle through which we can implement research work and strengthen our scientific approach. Having clear goals and priorities for soil science at the Conservancy will help us make the most of these partnerships for the greatest impact. Indirect support comes through advancing global narratives that influence higher-level decision-making and investment in conservation. For this we work in coalition with other NGOs, political actors, UN bodies, and public and private entities.

We see the need for three broad types of applied science related to soil (see Box, page 15): i) translational research that converts fundamental knowledge into actionable knowledge; ii) empirical studies that expand current knowledge on how to effectively conserve and restore the environment; and iii) tools for measuring and monitoring the impact of our work and the work of our partners.

TNC staff have identified a broad range of areas in which soil is important in achieving the Conservancy's conservation objectives (Figure 6, page 15). This range of impacts reflects understanding of the important role of soil biota in ecosystem processes, strong awareness of the role that soil can play in carbon sequestration for climate benefit, and the emerging emphasis at the Conservancy on natural climate solutions. These natural climate solutions are defined as conservation, restoration, and improved land management actions that increase carbon storage and/or avoid greenhouse gas emissions across global forests, wetlands, grasslands and agricultural lands.

Finding ways to increase carbon storage is by far the highest priority area for action on soils from TNC's perspective, whether that is for strict mitigation reasons, because of co-benefits of productivity and clean water, or because of interest in potentially leveraging carbon markets. Improving water and air quality—through reducing both nutrient loss and sediment loss—are also important. Other interests revolve around promoting biodiversity. In some cases, this means using soil to restore degraded lands, in other cases it means leveraging soil organisms for improving restoration success, the conservation of soil biodiversity itself, or even the management of invasive soil biodiversity, such as invasive earthworms.

Figure 6. Areas of impact in which soil is relevant to conservation objectives going forward, with relative importance based on TNC staff survey.



Science approaches

Translational research is a systematic effort to convert basic research knowledge into practical application. It may involve review, synthesis, assessment or meta-analysis of existing published research. The products may be papers, communication outputs, or policy briefs. A well-recognized example of this is the IPCC (Intergovernmental Panel on Climate Change) Assessment Reports. These reports assess the current state of scientific, technical and socio-economic knowledge on climate change and provide a clear statement of confidence surrounding the estimates. University partnerships and the Science for Nature and People Partnership (SNAPP) projects are important tools for translational science.

Empirical studies requires partnering with universities and other research partners that are actively engaged in expanding fundamental science. Empirical and modeling studies are required when new knowledge or location-specific information is required. It may involve replicated, time series, or ecosystem experiments to generate new data on empirical relationships, e.g. between management practices and their impacts. Modeling is often used when we want to simplify the complexity of a system to better understand, define, quantify, visualize or simulate an aspect of that system. These studies can test hypotheses around biophysical systems or socio-economic systems. Scores of partnerships are already in place at the Conservancy to pursue this model of science, including the NatureNet Science Fellows Program.

Tools for measurement and monitoring underpin research science as well as application. In the last two decades, there has been an explosion of new activity in this arena on soils, facilitated by advances in remote sensing, GIS and informatics. Setting goals and monitoring progress are vital components of progressing towards conservation outcomes. Standardized tools and metrics can be a powerful accelerator of scientific progress, allowing comparable data to be collected across space and time, and are crucial to aggregating progress toward higher-level goals, such as TNC's conservation goals, the SDGs and NDCs (Nationally Determined Contributions to climate mitigation).

Priority areas for soil science

We've classified priority soil-related objectives in Table 2, and highlighted the most exciting soil research and information needs for TNC to succeed across all of its activities. How to read these tables? If you are not a soil or conservation scientist, you may want to focus only on the objectives and conservation linkages. If you want to delve deeper, explore the specific priorities and needs column.

Table 2. Overall priority areas.

Conservation objectives	Science priorities and needs	Science approach		
		TR	ES	MM
Build and protect soil carbon	Estimate the potential for soil carbon sequestration at various scales, in different ecologies and socio/political systems	✔	✔	
	Quantify the effectiveness of various land management practices for building and maintaining soil carbon	✔	✔	✔
	Develop the value proposition of building soil organic matter for farmers	✔		
	Develop technical basis for valuing bundled benefits of soil carbon in watershed and landscapes	✔	✔	✔
	Estimate avoided soil carbon loss from conservation activities such as forest, grassland, and peatland protection	✔		
	Resolve barriers to soil carbon projects and jurisdictional approaches, e.g. permanence, commitment periods, leakage and variability	✔		✔
	Identify and promote market-based mechanisms to achieve soil carbon sequestration	✔		✔
Reduce nutrient loss and sedimentation	Quantify how on-field practices impact greenhouse gases	✔	✔	
	Quantify co-benefits of building soil carbon for nutrient run-off and leaching	✔	✔	
	Predict and monitor the effect of land management on reducing soil erosion	✔		✔
Promote biodiversity	What is the impact of microbial management on native species restoration?		✔	
	What is the impact of efforts to build soil carbon—through compost—on native biodiversity?		✔	
Restore and optimize soil fertility	How do agrochemicals impact soil biological and chemical properties?	✔	✔	
	Quantify the co-benefit of building soil carbon for productivity and resilience	✔	✔	
	Quantify the relationship between land management and soil water retention	✔		
Achieve implementation at scale	What limits adoption of soil management practices?	✔	✔	
	Identify rapid and/or low-cost tools for measuring soil fertility, soil carbon and other properties	✔		✔
	What is the needed scale of adoption of on-field practices to have landscape-scale impact?	✔		
	How do effects of land management depend on contextual factors, like soil texture and climate?	✔	✔	
Advance global narratives	Elucidate how soil carbon sequestration benchmarks against other climate mitigation approaches	✔		
	Recommend how soil health should be defined and measured for croplands, grazing lands, forests	✔		

KEY

Science approach

TR: Translational research that converts fundamental knowledge into actionable knowledge

ES: Empirical studies that expand current knowledge on how to effectively conserve and restore the environment

MM: Tools for measuring and monitoring the impact of our work and the work of our partners

Emerging topics

The six objectives listed in Table 2 have been established because many people within the Conservancy prioritize them highly. However, other knowledge needs were identified that we find exciting and/or that represent areas of specialized interest to scan forward, and which are presented in Table 3. These are most strongly associated with the conservation strategies of tackling climate change, sustainable food production, and protecting habitats and biodiversity.

Table 3. Emerging priority areas.

Conservation objectives	Emerging science priorities and needs
Harness soil biology for habitat restoration	What are the effects of invasive species, loss of canopy trees, conversion of native prairie, and other disturbances of soil biota and soil function?
	What are the feedback processes between soil biota, e.g. forest fungal associations, and disturbance through clearing, erosion, fires, and restoration of habitat?
	How to restore degraded and polluted soils, such as mine reclamation
Build soil health for human health	What would be the cascading effects of broad-scale consumer diet or policy change on soil properties?
	What are the strengths of linkages between soil health and human health?
Promote greening of cities	What are the effects of urbanization on soils and urban forests?
	How to engineer or restore urban soils for greening cities
Advance global narratives	Articulate connections between soil health, food quality and human health
	Understand benefits of increased soil biodiversity

Soil science agenda: impacts

Introducing a clear soil science agenda will strengthen TNC's partnerships and help to improve and scale up our land management and conservation impact across all regions and conservation priority areas. Actions that will be supported by the soil science agenda reflect the high priority TNC places on restoring soil health and increasing carbon storage by soils, and include:

- Land protection efforts that keep carbon in the soil
- Habitat restoration efforts
- Agricultural practice change that, builds productivity, improves water quality and sequesters carbon
- Restoring degraded forest, grasslands and croplands
- Agricultural mitigation options through reduced greenhouse gas emissions
- Target setting and monitoring at various scales for soil health and soil carbon projects
- Developing carbon market projects for conservation activities in agriculture, grasslands and wetlands
- Building awareness and partnerships for nature climate solutions.

By setting clear goals and priorities for soil science at the Conservancy, this agenda will allow us to coordinate our engagement in this crucial field across all of these diverse actions and to catalyze soil science that supports TNC's mission to achieve a world in which the diversity of life thrives.

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