MIT Climate & Sustainability Consortium

Transforming Past Agricultural Landscapes into Carbon Sinks

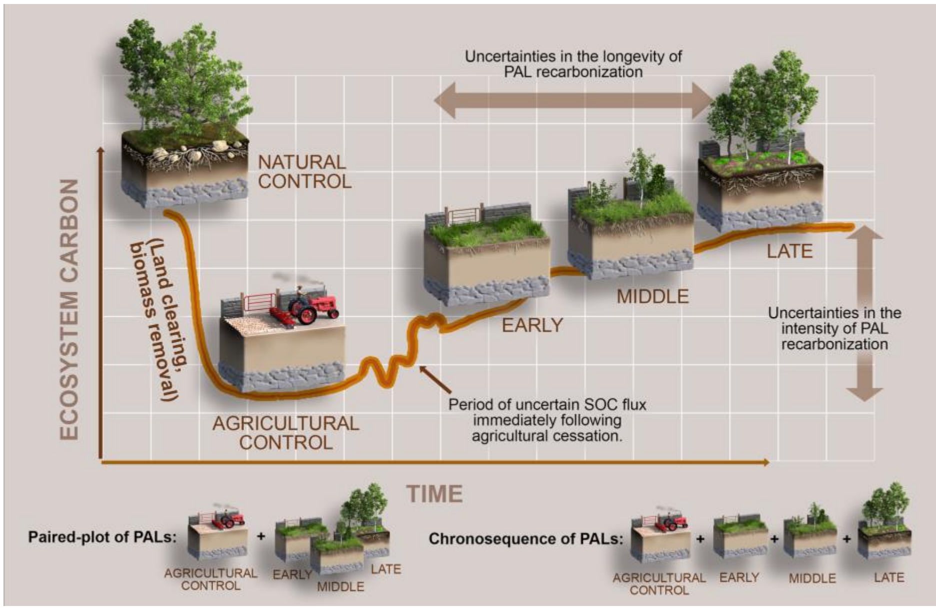
Project Overview

How can we accurately protect, monitor, and utilize post-agricultural landscapes as carbon sinks?

César Terrer

This project, led by MIT Professor César Terrer (Civil and Environmental Engineering), explores the challenges and opportunities in conceiving of post-agricultural landscapes (PALs) as carbon sinks. When these PALs are allowed to regrow with native vegetation, the growth of the vegetation metabolizes CO2 and converts it to organic matter, some of which remains in the soil and becomes mineralized for long-term storage. Despite their worldwide prevalence, they have significant untapped potential. To assess their role in rebuilding the planet's natural carbon stocks through ecosystem restoration, it is important to more fully understand their impact.

For millennia, agriculture has depleted terrestrial carbon stocks at the expense of natural ecosystems. PALs often signify the return of ecosystem properties, such as carbon, towards pre-disturbance states or new equilibria through secondary succession, which is when the plants recolonize their habitat after a major disturbance has altered the area but has not rendered it lifeless. They appear in every agricultural region of the world and can drawdown carbon with or without human involvement. If commitments to halt gross forest area loss by 2030 succeed, recarbonizing PALs – actively adding carbon back into the soil – will play a key role in reversing global land use change from being a net carbon source to a net sink.



The main challenge with PALs, however, is that they are insufficiently represented in terrestrial carbon models, both spatially (as a poorly mapped land cover class) and temporally (as uncertain carbon sinks), which hinders the ability to monitor, quantify, and leverage them strategically. This MIT research team explore some of the reasons behind these challenges and what can be done to address them so that the role of PALs can be properly evaluated.

The project aligns closely with the MCSC's Nature-based Solutions pathway.

Findings & Outcomes

PALs can diversify the global land sink and provide timely support for the UN Decade of Ecosystem Restoration (2021–2030) by fulfilling local- to global-level commitments to reverse ecosystem degradation. However, they need an immediate, concerted effort by researchers to appraise their role in the terrestrial carbon cycle through better data, maps, and models. This MIT team's results quantify the role of soils to sequester carbon in restored croplands, and suggest that cropland restoration is likely one of the most effective nature-based solutions for total carbon sequestration potential.

Terrer's research team asserts that better data, as well as better use of existing data, is desperately needed to clarify underlying relationships, to model PAL impacts in all agricultural regions of the world, and to predict potential carbon sinks and sources through time. Currently, researchers remain limited in their ability to promote PALs as components of sustainable land management strategies – but integrating better maps and bigger time-stamped datasets with new approaches in artificial intelligence-driven modeling will allow for the investigation of the carbon cycle impacts of PALs with more accuracy than ever before. The preliminary results from Terrer and his team will help enable researchers, at MIT and beyond, to include cropland restoration in the portfolio of nature-based climate solutions.

Preliminary Results

The team's results quantify the role of soils to sequester carbon in restored croplands, and underscore that soils have been an overlooked carbon sink and climate solution. They found that cropland restoration leads to significant increases in soil carbon density over time across different ecosystems, regardless of the type of restoration (active or passive). For example, in areas that naturally transition to grassland or forest from croplands, soil carbon can increase by >100% over 100 years. In the long-term, soils can sequester equivalent amounts of carbon or even more than vegetation – and carbon sequestered in soils is more long-lasting and permanent than in vegetation biomass.

This team's findings suggest that cropland restoration is likely one of the most effective nature-based solutions for total carbon sequestration potential. Globally, restoring abandoned croplands can sequester 2-5 times more carbon than regenerative agriculture, grazing management, or wetland restoration.

The researchers have developed a high-resolution map of abandoned croplands and marginal lands that could be used for restoration. In absolute terms, Africa has the largest amount of abandoned croplands ready for restoration and climate mitigation. In relative terms, Europe and European Russia have the largest percentage of land that can be leveraged for climate mitigation. This analysis will allow the team to assess the areas of opportunity for carbon sequestration.

The team's results are based on a unique field-based dataset of >3,000 soil chronosequence data pairs that allows, for the first time, to quantify the rates of soil carbon accrual following cropland restoration (transition from cropland to forest, or cropland to grassland). Their analysis maps the areas with higher potential for carbon sequestration: soil carbon sequestration is higher in colder and wetter than in warmer and drier climates.

Journal Publication: *Nature Communications*

The team's explorations were published in *Nature Communications*, in a paper titled Quantifying the recarbonization of post-agricultural landscapes. The paper's authors are Stephen M. Bell, Samuel J. Raymond, He Yin, Wenzhe Jiao, Daniel S. Goll, Philippe Ciais, Elsa Olivetti, Victor O. Leshyk, and César Terrer.

Opportunities for Implementation

Research

- The team's paper in *Nature Communications* highlighted the need to better understand the spatial and temporal legacies of PALs.
- Collect and use existing information and data.
    - Review previously published paired-plots and chronosequences studies of PALs featuring carbon data, as well as secondary soil physicochemical properties (e.g., nitrogen, phosphorus, particulate and mineral-associated organic matter, etc.) for modeling drivers of SOC dynamics.
    - Explore time-stamped data points, crucial for understanding what factors determine if and when a PAL will act as a carbon sink or source following agricultural cessation.
- Produce better data where there are gaps.
    - Produce reliable, up-to-date, spatial estimates of past, present, and predicted instances of agricultural cessation, since one major roadblock to protecting, monitoring, and utilizing PALs as carbon sinks is finding them.
    - Generate data using higher spatial, temporal, and spectral resolution remote sensing.
- Focus future discussions about promoting PALs as carbon sinks, particularly at the international level, on accounting for potential conflicts with food production, biodiversity, rural socioeconomic needs, and other sustainable development goals.

Implementation

- The research team will work to accurately protect, monitor, and utilize PALs as carbon sinks through better maps, datasets, and models.
- The team's high-resolution map of abandoned croplands and marginal lands could be used for restoration.