Q&A: Can disused croplands help mitigate climate change?

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Abandoned croplands represent an opportunity for carbon sequestration, but more research is needed to identify the most promising areas. Credit: Tangopaso/Wikimedia Commons

As the world struggles to meet internationally agreed targets for reducing greenhouse gas emissions, methods of removing carbon dioxide such as reforestation of cleared areas have become an increasingly important strategy.

But little attention has been paid to the potential for abandoned or marginal croplands to be restored to natural vegetation as an additional carbon sink, say MIT assistant professor of civil and environmental engineering César Terrer, recent visiting MIT doctoral student Stephen M. Bell, and six others, in a recent open-access paper in the journal *Nature Communications*.

Here, Terrer and Bell explain the potential use of these "post-agricultural" lands to help in the fight against damaging climate change.

Q: How significant is the potential of unused agricultural lands as a carbon sink to help mitigate climate change?

Bell: We know of these huge instances of land abandonment and post-agricultural succession throughout history, like following the collapse of major cities from ancient Mesopotamia to the Mayans. And when the Europeans arrived in the Americas in the 15th century, so many people died and so much forest grew back on abandoned farmland that it helped cool the entire planet and was potentially a driver of the coldest part of the so-called "Little Ice Age" period.

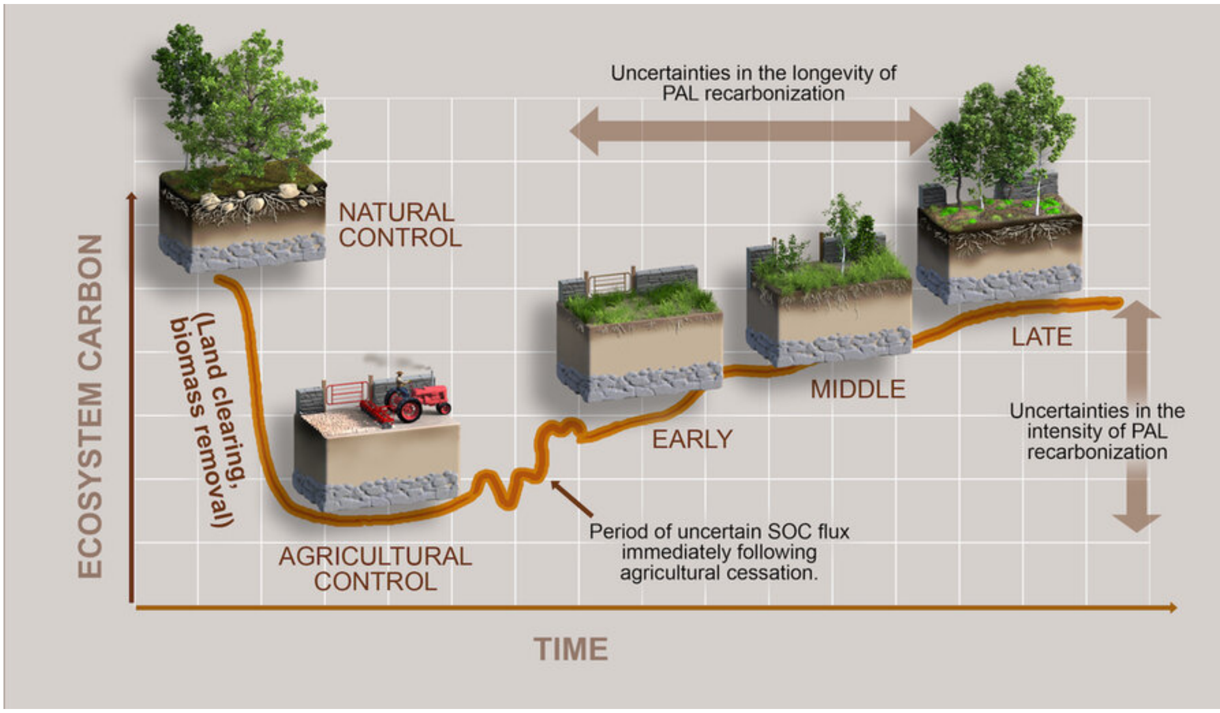
Today, we have abandoned farmland all over the Mediterranean region, where I did my Ph.D. field work. As young people left rural areas for the cities throughout the 20th century, farmers couldn't pass on their land to anyone, and the land succeeded back into shrub lands and forests. The biggest recent example of abandonment is for sure the collapse of the

Soviet Union, where an estimated 60 million hectares of forest regrew when support for collective farming stopped, resulting in one of the largest carbon sinks ever attributed to a single event.

So, when we look back at the past, we know there's potential. Of course, these are huge events, and no one is proposing to replicate anything like that. We need to use land for multiple purposes, but looking back at these big examples, we know there is potential for abandoned or restored agricultural land to be carbon sinks. And so that tells us to dig deeper into this question and get a better idea of realistic scenarios, a better understanding of the climate change mitigation potential of agricultural cessation in the most strategic places.

Terrer: More than 115 billion tons of carbon have been lost from soils due to agricultural practices that disturb soil integrity—such as tilling, monoculture farming, removing crop residue, excessive use of fertilizers and pesticides, and over-grazing. To put this into perspective, the amount of carbon lost is equivalent to the total CO_2 emissions ever produced in the United States.

Our current research synthesizes field data from thousands of experiments, aiming to understand the factors that influence soil carbon accrual in abandoned croplands transitioning back to forests or natural grasslands. We're working to quantify the potential for carbon sequestration in these soils over 30-, 50-, and 100-year time frames and mapping the areas with the greatest potential for carbon storage. This includes both increases in soil carbon and in vegetation biomass.



This illustration shows a typical post-agricultural landscape (PAL) trajectory involving land clearing from the primary forest (natural control) for agricultural use (agricultural control) and ecological succession following agricultural cessation (shown here as early-, middle-, and late-stage PALs). Credit: Massachusetts Institute of Technology

Q: What are some of the key uncertainties in evaluating this potential for unused cropland to serve as a carbon sink, and how could those uncertainties be addressed?

Bell: We use this word uncertainties in two ways. Specifically, the longevity of potential recarbonization, and the intensity of the potential recarbonization. Those are two factors, two aspects that we need to quantify to reduce our uncertainty.

So, how long will the land recarbonize, regardless of the intensity? If the carbon level is going up, that's good. If there's more carbon increasing in the soil, we know that it came from somewhere, it came from the atmosphere. But how long does that happen? We know soil can get saturated. It can reach its carbon capacity limit, it won't continue to increase the carbon stock, and the recarbonization curve will flatten out. When does that happen? Is it after a hundred years? Is it after 20 years?

But the world's soils are very diverse and complex, so what might be true in one place is not true in another place. It may take a longer time to reach saturation for more fertile soils in the Midwest U.S. than less fertile soils in the Southwest, for example. Alternatively, sometimes soils in drier areas like in the Southwest may never reach true saturation if they are degraded and have stalled recovery following abandonment.

The second uncertainty is intensity: How high on the y-axis on the chart of recarbonization does saturation occur? With the analogy comparing U.S. soils, you might have a relatively huge carbon increase on an abandoned farm in the Southwest, but because the soil is not very carbon-rich it's not a large increase in absolute terms. In the Midwest, there might only be a small relative increase, but that increase could be much more in total than in the Southwest. These are just nuances to keep in mind as we look at this at the global scale.

These nuances are essentially uncertainties. Soil carbon responses to agricultural land abandonment is complicated, and unfortunately it hasn't been studied in much detail so far. We need to reduce those uncertainties to get a better understanding of the recarbonization potential. This is easier said than done because not only do we have these temporal data uncertainties, but we also have spatial uncertainties. We don't have very good maps of past and present post-agricultural landscapes.

Q: Can this potential use of post-agricultural lands be

implemented without putting global food supplies at risk? How can these needs be balanced?

Terrer: As to whether utilizing post-agricultural lands for carbon sequestration can be implemented without jeopardizing global food supplies, and how to balance these needs, our recent research provides valuable insights.

The challenge, of course, lies in balancing cropland restoration for climate mitigation with food security for a growing global population. Abandoned croplands represent an opportunity for carbon sequestration without impacting active agricultural lands. However, the available area of abandoned croplands is insufficient to make a substantial impact on climate mitigation on its own.

Thus, our proposal also emphasizes the importance of closing yield gaps, which involves increasing crop production per hectare to its theoretical limits. This would enable us to maintain or even increase global crop yields using only a fraction of the currently cultivated area, allowing the remaining land to be dedicated to climate mitigation efforts. By pursuing this strategy, we estimate that over half of the amount of soil carbon lost so far due to agriculture could be recovered, while ensuring food security for the world's population.

More information: Stephen M. Bell et al, Quantifying the recarbonization of post-agricultural landscapes, *Nature Communications* (2023). DOI: 10.1038/s41467-023-37907-w

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