Carbon emissions from warming soils could trigger disastrous feedback loop

26-year study reveals natural biological factors kick in once warming reaches certain point, leading to potentially unstoppable increase in temperatures

Researchers examined plots of soil in the Harvard Forest, Massachusetts. They heated some of the plots with underground cables to 5C above normal levels, leaving others as a control. Photograph: Audrey Barker Plotkin/Science

Warming soils are releasing more carbon into the atmosphere than previously thought, suggesting a potentially disastrous feedback mechanism whereby increases in global temperatures will trigger massive new carbon releases in a cycle that may be impossible to break.

The increased production of carbon comes from the microbes within soils, according to a report in the peer-review journal Science, published on Friday.

The 26-year study is one of the biggest of its kind, and is a groundbreaking addition to our scant knowledge of exactly how warming will affect natural systems.

Potential feedback loops, or tipping points, have long been suspected to exist by scientists, and there is some evidence for them in the geological

record. What appears to happen is that once warming reaches a certain point, these natural biological factors kick in and can lead to a runaway, and potentially unstoppable, increase in warming.

Other tipping points posited by scientists include the disappearance of ice in the Arctic, which creates areas of dark water that absorb more heat, and the release of methane, a powerful greenhouse gas, from thawing permafrost.

In the Science study, researchers examined plots of soil in the Harvard Forest in Massachusetts, a mixed hardwood forest in the US. They experimented by heating some of the plots with underground cables to 5C above normal levels, leaving others as a control.

The long-term study revealed that in the first 10 years there was a strong increase in the carbon released from the heated plots, then a period of about seven years when the carbon release abated. But after this second calmer period, which the scientists attribute to the adjustment of the soil microbes to the warmer conditions, the release of carbon resumed its upward path.

In the last three years, the release of carbon has once again dropped back, which scientists attribute to another reorganisation of the microbes present. They suggest an increase in the number of microbes that can feast on the hard-to-digest organic matter, such as plant-based lignin, which gives clues to the possible cyclical nature of the process.

From 1991, when the experiment began, the plots subjected to 5C warming lost about 17% of the carbon that had been stored in the top 60cm of the soil, where the greatest concentration of organic matter is to be found.

Scientific understanding of the complexities of soil microbial activity is still limited, but the long-term nature of the study provides valuable insights into what might be happening, and is likely to happen in future, to vast swaths of forest soils across the world.

While deforestation has been the focus of most research into forests' effects on climate change, with a recent study suggesting tropical forests are turning into carbon sources rather than carbon stores as a result, the impact of warming soils has remained much of a mystery. Soils are one of the world's biggest natural carbon sinks, along with trees and the oceans.

Daniel Metcalfe, of Sweden's Lund University, said: "If these findings hold more widely across major terrestrial ecosystems, then a much greater portion of the global soil carbon store could be vulnerable to decomposition and release of carbon dioxide under global warming than previously thought."

The study was carried out by scientists at the US Marine Biological Laboratory, led by Jerry Melillo, with contributions from the universities of Massachusetts and New Hampshire.

Melillo, who holds the position of distinguished scientist at the MBL, said: "Each year, mostly from fossil fuel burning, we are releasing about 10bn metric tons of carbon into the atmosphere. The world's soils contain about 3,500bn tons of carbon. If a significant amount of that is added to the atmosphere, due to microbial activity, that will accelerate the global warming process. Once this self-reinforcing feedback begins, there is no easy way to turn it off. There is no switch to flip."

He added: "The future is warmer. How much warmer is the issue." While emissions from fossil fuels can be cut back, the reactions of the natural world to a warming climate may be impossible to control.

Some recent work has suggested that the warming of the globe may be progressing at a slightly slower rate than the upper range of previous studies estimated. However, feedback loops and tipping points have the potential to create sudden disruptions that are hard to take account of in standard climate modelling, and these could mean much greater changes and far higher rates of warming in the future.

Separately, research from Stanford Woods Institute for the Environment, and other institutions, published in the Annual Review of Ecology, Evolution and Systematics, and Global Change Biology, called for more work on how soil could be used as a carbon store. When agricultural soils are well-managed, they can store more carbon than they emit, which would allow them to be used as potential carbon sinks.

But the scientists warn that "we still don't have a strong understanding of the interactions among biological, chemical and physical processes regulating carbon in soils". They say much more research is needed, particularly as there are dangers in soils in Siberia that are rapidly warning, and could release vast quantities of carbon. They also warn

that there may be 25-30% less organic matter in some soils than previously estimated.

“Soil has changed under our feet,” said Jennifer Harden, a visiting scholar at Stanford. “We can’t use the soil maps made 80 years ago and expect to find the same answers.”