The value of vegetation

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The day Brazil's voters chose Jair Bolsonaro as their new President wasn't a good day for efforts to mitigate climate change. During the election campaign, the declared populist and would-be strongman vowed to end the "environmental activism" of his predecessors. Previous Brazilian governments were not exactly zealous supporters of measures to combat climate change. But what Bolsonaro has promised to implement since his inauguration in January 2019 amounts to a full-scale attack on the international community's attempts to limit the effects of greenhouse gases on future temperatures.

Tropical rainforest accounts for more than 3 million square kilometers of the Brazilian interior, a huge area comprising largely pristine landscapes—and in the context of climate change, an enormous carbon sink. Trees take up carbon dioxide (CO2), convert it into biomass and store it for long periods. Some 10 percent of Brazil's primeval forest (an area the size of Germany) has been destroyed over the past 30 years or so. The primary culprits have been deforestation—at best, semilegal—and slash-and-burn land clearance for agriculture. The forest was replaced by cattle ranches and soybean fields. Bolsonaro's immediate predecessors had taken steps to reduce the rate of forest loss in recent years, but those efforts now appear doomed. As the German weekly Die Zeit put it, "Does our planet's green belt have a future?"

Julia Pongratz was appointed to the Chair of Physical Geography and Land-Use Systems at LMU last year, and her research is deeply concerned with this issue. She monitors the pace and extent of such "changes in land use" (the neutral term favored by climate researchers) in Brazilian rainforests and elsewhere around the globe—and tries to quantify the effects of the conversion of forest into cropland or pasture, or mixed woodland into monocultures. She wants to quantify the impact of such changes, and the interactions they can be expected to trigger on the greenhouse effect. But she would also like to know what forms of land use and forest management might help to reduce the rate of the global warming trend.

The trend is clear—up!

Pongratz holds up a graph that is not hard to understand. It shows a single red line, and although one can discern minor seasonal or annual variations, its import is clear and undeniable. Indeed, it would seem to imply that we can bid farewell to any hope of moderating the pace of global warming. The plot depicts the inexorable rise in the level of CO2 in the atmosphere. The trend is unmistakable—upwards. In the course of the past 50 years alone, the concentration of this greenhouse gas has increased by about 20 percent. "In spite of international agreements designed to protect the climate, there has been no discernible reduction in the rate of increase of CO2 in the atmosphere," says Pongratz. "But without these efforts, the slope of the curve would most probably be even steeper."

According to the analyses of historical records carried out by the Global Carbon Project, of which Pongratz is a member, human activities have resulted in the release of approximately 660 gigatonnes of carbon since 1750, which is some 2.4 teratonnes of CO2. But the really significant rise in CO2 levels began with industrialization, and it has since accelerated at a rapid rate. Only about 40 percent of these emissions remained in the atmosphere and contributed to the greenhouse effect—but this value is now closer to 45 percent. Of the rest, one half was taken up by the oceans and the other half by soils and vegetation.

These figures already point to the significance of vegetation—and the pre-eminent role of human activities—for the world's climate. Before moving to LMU, Julia Pongratz had worked on this topic for several years at what is probably Germany's leading center for climate research, the Max Planck Institute (MPI) for Meteorology in Hamburg, where she led an Emmy Noether Junior Research Group on "Forest Management and the Earth System," funded by the Deutsche Forschungsgemeinschaft (DFG).

Around three-quarters of the (ice-free) land surface on Earth is directly exposed to human influence. Over the course of history, people have wiped out the original vegetation on about a quarter of this area. About two-thirds of the remainder is now under various modes of cultivation. In addition, around a quarter of the Earth's annual net primary production (i.e., the amount of plant biomass generated annually) is consumed to meet the needs of

humans. This level of exploitation of the natural world has an impact on the climate. Around one-third of all the CO2 released by human activities up to today can be attributed to the destruction of the natural vegetation.

The moderating effect of transpiration

How significant then are the effects of the large-scale destruction of natural vegetation? In the context of climate change, attention has long been focused almost exclusively on the combustion of fossil fuels to provide energy for heating purposes, industrial processes and transport. Indeed, fossil fuels are currently the major source of carbon emissions. Changes in land use account for about 10 percent of the amount of CO2 annually emitted into the atmosphere," says Pongratz. That might not seem like much, but another factor comes into play here: Agricultural production is also associated with the release of greenhouse gases other than CO2—nitrous oxide (N2O) from fertilizers, methane (CH4) from cattle farming and rice cultivation. When these gases are included, land use accounts for almost one-third of total greenhouse gas emissions. In many low-income and poorly industrialized countries, land use makes a larger contribution to the greenhouse effect than does the burning of fossil fuels. And Brazil, with a surface area of 8.5 million km2, tops the list for emissions attributable to land use.

Thus, land clearance inevitably perturbs the carbon cycle. Moreover, not only do biochemical processes have an impact on the greenhouse effect, several purely physical mechanisms also play a role. For example, the planet's albedo (the fraction of sunlight that is reflected back into space) increases when the dense foliage of forests is replaced by wheat fields. This has a cooling effect, but it is more than compensated by the heating that accompanies the loss of transpiration owing to the reduction in leaf area. In a temperate woodland, the ratio of leaf area to surface area is 7 to 1, and in a tropical forest it can reach 12:1. Therefore, evaporation of water from the leaves of trees has a far greater cooling effect than transpiration from a field planted with a cereal crop.

Such local, small-scale changes in water and heat budgets can also have an impact on much larger scales, because atmospheric circulation can transport them to more remote regions.

Pongratz's group recently developed a way to distinguish between local and remote effects. "Until now, the remote effects have often been ignored because observational data only provide information about local variations. ¬– And that's not all. The climate system does not react in a linear fashion, as Pongratz points out. "In terms of the change in local temperatures, it makes a difference whether the first 10 percent or the last 10 percent of the trees in a forest have been cut down."

How then can the impact of changes in land use be incorporated into climate models? "When I finished my undergraduate studies in 2005, it had just become possible to simulate the carbon cycle and related processes that are relevant to climate in large-scale global models. "These were the first true "Earth System' models, which are now commonplace. But in the early days, they were revolutionary," Pongratz explains. The MPI in Hamburg developed its own model, in which the interactions between the atmosphere, the oceans and vegetation could be realistically simulated. "This type of coupled global model is particularly complex and computationally expensive," she adds.

Parish registers supply data for climate models

CO2 remains in the atmosphere for a very long time and, unlike methane, it is not chemically degraded there. So much of the CO2 emitted over the past several thousand years is still there, and must be added to the current emissions. Up until 2005, nobody had seriously attempted to reconstruct the historical dimension of the process. In her Ph.D. thesis, Julia Pongratz quantified the growth in land use on a global scale, as a proxy for CO2 release, over the period from 800 to 1850. The work relied on secondary sources of documentation, using records such as parish registers to estimate population levels prior to the era of accurate census data. Given that global trade was negligible, these data allow one to estimate the total area of land under agricultural use, and the amount of woodland lost to deforestation. Pongratz arrived at an emissions burden of some 100 gigatonnes for the millennium prior to the onset of large-scale industrialization.

In 2014, she contributed to a project that caused climatologists to rethink their models. The study demonstrated that deforestation and land management actually affect climate to very similar extents. "Keeping a forest, but managing it, altering its species composition, can alter local temperatures as much as wholesale deforestation does. That's something that had been ignored by climate scientists up to that point," says Pongratz. Last year, a further report in which she was involved appeared in the leading journal Nature. That study measured the effect of the same factors on carbon storage capacity. The authors concluded that, in the absence of anthropogenic influence, standing vegetation could sequester approximately 900 gigatonnes of carbon. The present figure is on the order of 450. The difference can be attributed more or less equally to changes in land cover and land management. "In a third paper, we confirmed these order-of-magnitude estimates in modeling studies. We therefore must extend our global models to include the impact of land management." But that's a difficult task—not only because it is hard to disentangle local from remote effects, but also because more data on smaller scales are needed to adequately reflect the patchwork nature of land use on the ground.

A team of climate scientists brought together under the auspices of the United Nations is now engaged on the Global Carbon Project, an ambitious attempt to construct a detailed and accurate picture of the distribution of global emissions. Pongratz is coordinating its efforts to estimate the level of emissions attributable to land use. In one study, the researchers plan to calculate the size of biomass stocks in Europe based on remote sensing data. The goal is to use these observational data to construct high-resolution models.

Pongratz is also associated with the International Panel on Climate Change (IPCC) – as a co-author of the IPCC's reports and as coordinator of two projects on the workings of the carbon cycle and on changes in land use. The punning title she chose for her inaugural lecture at LMU reflects the extent of her personal commitment: "Ackern für den Klimaschutz" (roughly translatable as "Arduous Field Work for Climate Change Mitigation"). But her talk actually dealt with the question of whether specific forms of land use could help to limit the negative impact of climate change sufficiently to bring the process under control.

A down-to-earth variant

Meanwhile, what are called negative emission technologies, which aim to withdraw carbon from the atmosphere by storing it in various reservoirs, have come into prominence. One truly 'ground-based' variant of this approach is simply to plant trees on a massive scale. A model developed by Pongratz and her Hamburg colleague Sebastian Sonntag suggests that, if this were done solely in areas which are no longer needed for agricultural production, the increase in atmospheric CO_2 levels projected for the year 2100 could be reduced by a much greater extent than previously thought. A 'plausible scenario' indicates that it would reduce the mean global temperature by about 0.3 degrees C.

As Pongratz now sees it, the issue is as clear as it is urgent. Current global efforts to mitigate climate change are inadequate to the task. Only some of the goals set out in the Kyoto Protocol can be achieved. The Paris Agreement of 2015 is even less effective, because it allows countries to set their own emissions targets. Unless the world's population, industrialists and politicians fundamentally change their approach to the management and utilization of natural resources, these measures will fail—by a large margin—to meet their defined goal of limiting the rise in average global temperature (relative to pre-industrial levels) to 1.5 degrees C. "Based on current trends, the rise will be closer to 3 degrees C," says Pongratz.

"We don't have much time to fundamentally modify the system," she warns. The various scenarios that researchers around the world have tested in their computer models all agree on one point: net global CO_2 emissions must be reduced to zero by the middle of the century, and be further reduced, to negative values, thereafter. In order to achieve this goal, "emissions must reach their peak well before the year 2030."

"When I entered the field of climate research," Julia Pongratz recalls, "simply understanding the workings of the system was the primary goal. Now, with 1.5° target in question, my work has become far more urgent." The policies favored by Jair Bolsonaro are only one of the many obstacles that stand in the way of an effective response to climate change.

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