Footprints in the *forest*

Researchers are tracking just how much impact ancient peoples had on the Amazon.

BY JEFF TOLLEFSON

Crystal McMichael first led a crew into the Amazon jungle in 2007, looking for signs of ancient human disturbances. Armed with machetes, they hacked their way through thick vegetation while fending off spiders, mosquitoes and bees. They were exploring around Ecuador's Lake Ayauchi, which McMichael knew held the earliest record of maize (corn) cultivation in the Amazon from around 6,000 years ago. But the jungle hid its secrets well. "If you looked at the forest you wouldn't realize there was any ancient disturbance," says McMichael, now a research scientist at the Florida Institute of Technology in Melbourne. "You have to dig."

Scientists have struggled for decades to uncover humanity's historical footprint in the forest and determine what kind of an impact people had centuries to millennia ago. Their goal is to understand the evolution of the rainforest and just how much of the landscape we see today is 'natural' versus how much has been shaped by human hands.

Studies dating back to the 1950s suggested that small indigenous tribes merely scratched out a living in primitive villages before the arrival of Europeans. But more recently, researchers have proposed that the Amazon hosted complex societies that turned swathes

of the forest into farms and orchards. Some estimates place the prehistoric population of the Amazon as high as 10 million — a huge number considering that the current population is around 30 million. The debate is heated. When McMichael and her colleagues reported¹ last year that indigenous occupations might have been rare in the most-remote parts of the jungle, their paper outraged archaeologists.

The topic evokes strong emotions in part because it touches on the sensitive issue of indigenous land claims and goes to the heart of conservation philosophy. If prehistoric human populations were limited and today's Amazon is relatively pristine, then one might assume that this otherwise stable and natural ecosystem would be altered by any human disturbance — let alone the clearance of vast tracts of forest for agriculture (in Brazil alone, an area greater than Germany has been cleared over the past 25 years). By contrast, if the primeval Amazon was filled with people who managed the landscape, then the forest might be capable of absorbing further human impacts. Encouraging indigenous practices, even on a large scale, might allow people to live in balance with the rainforest.

"The people who refuse to accept the human role are never going to understand how the environment that we appreciate today came to

Indigenous populations may have long maintained plantations of palms and bananas.

be," says anthropologist Clark Erickson of the University of Pennsylvania in Philadelphia, who believes that people were widespread throughout the Amazon. "And if you don't understand that, you will never know how to manage it."

HOSTILE LAND

When researchers started studying the Amazon, they entered what had long been viewed as an impenetrable and hostile environment. Scientists such as the late Betty Meggers, an archaeologist at the Smithsonian Institution in Washington DC, argued in the 1950s that the region's lush flora grew atop a layer of poor

RICKEY ROGERS/REUTERS/CORBIS

Networks of roads connect villages in the virgin forest.

TON KOENE/VISUALS UNLIMITED/CORBIS

soil that was unfit for cultivation and therefore large-scale civilization². This theory fitted neatly within an old colonial paradigm that portrayed the Amazon as a largely empty jungle open to occupation and exploitation. Meggers documented pottery shards, burial sites and a network of defensive mounds on the island of Marajó at the mouth of the Amazon River. But, she argued, this community was short-lived owing to environmental limitations such as poor soil. This probably prevented large-scale development throughout the basin, she wrote: “Its levelling effect appears to be inescapable.”

This view came under attack in the 1980s, first by Anna Roosevelt, an archaeologist at the University of Illinois at Chicago. On the island of Marajó, her work revealed a culture that had endured for nearly 1,000 years until about 400 AD — more than long enough to put theories about environmental limitations in doubt³. By the time Roosevelt published a detailed book⁴ about her work on Marajó in 1991, the tide of opinion had begun to turn.

While Roosevelt was studying Marajó, William Balée, an anthropologist at Tulane University in New Orleans, Louisiana, was spending time with the Ka’apor tribe in the southeastern Amazon. In 1993, he documented the group’s knowledge and use of a forest region that contained an unusually

high concentration of useful species⁵. Tribal members referred to neighbouring patches of forest, by contrast, as wild and undisturbed. For Balée, this was a sign that many parts of the landscape were at one point cultivated as complex orchards. “Part of this was a backlash against the idea that natives tiptoed through the forest and left no footprints,” says Erickson.

Since then, researchers working across the eastern and central Amazon have found deposits of ‘*terra preta*’ (literally ‘black earth’ in Portuguese), which are fertile soils that are thought to have been created through cycles of fire and cultivation. Further earthworks, including mysterious systems of ditches and mounds, were uncovered throughout the 1990s in the western Amazon. By the mid-2000s, researchers had come to believe that prehistoric people once occupied large areas; built networks of roads, canals and bridges; cultivated crops such as maize and manioc (cassava); and maintained plantations of useful trees such as bananas and palms⁶. “These societies were fully on par with small to medium-sized populations anywhere on the globe in the 1400s,” says anthropologist Michael Heckenberger at the University of Florida, Gainesville. “They weren’t backward in any way.”

After such a radical shift in thinking, it was perhaps inevitable that the scientific pendulum would swing back the other way. In June 2012, a team of researchers led by McMichael and Mark Bush at the Florida Institute of Technology published a paper¹ arguing that human civilization was sparse across the wetter forests of western and central Amazonia. The team had collected 247 soil cores from dozens of sites and found charcoal in many locations — a sign of human fires. But none of the sites held human artefacts or *terra preta* (see ‘Signs of life’). The team documented maize cultivation in only one instance, and just a couple of other sites revealed signs of grasses that suggested repeated clearing of the land. Bush concluded that others had been too quick to extrapolate evidence of dense populations in the eastern Amazon across the entire basin. “We don’t believe in a virgin system, but we don’t believe in a completely exploited system either,” he says. “We cannot assume that Amazonian forests were resilient in the face of heavy pre-Columbian disturbance.”

McMichael says that she gleaned something similar from Lake Ayauchi. She found significant amounts of charcoal and tiny fossilized structures from maize crops around the lake, but evidence of occupation fell away just a kilometre from the waters⁷. “People were there, but their impact was very localized,” she says.

FIERY DEBATE

The paper by McMichael *et al.* was attacked by both sides. Meggers criticized them for accepting existing evidence of large-scale civilization in eastern and central Amazonia. But the strongest criticism came from a dozen scientists who commented on the *Science* paper online. They argued that the paper underestimated signs of civilization by relying too heavily on soil data, which cannot reveal signs of manioc cultivation or other agroforest management. “Soils tell you one part of the story, but they don’t tell you everything,” says Susanna Hecht, a historical ecologist at the University of California, Los Angeles. She notes that the Inca had established a military outpost in the Putumayo region of western Amazonia by the end of the fifteenth century, just before the arrival of the Europeans, presumably to protect against, or trade with, populations in that region. “Why would you do that if you felt that there were just a bunch of naked people running around?”

In November 2012, a team led by Charles Clement, a horticulturist at the National Institute of Amazonian Research in Manaus, Brazil, countered with a paper⁸ arguing that human influence on the forests was pervasive. His study showed that trees that are considered useful for humans — including palms and Brazil nut trees — are more common near rivers, where populations would have been highest. Given that many of these species have different ecological preferences and would not necessarily grow together, the team argued that people

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must have had a hand in creating these bounteous patches. But their results also came under fire. Critics questioned both the strength of the statistics and the fact that the team did not attempt to establish a baseline for what might be expected in the absence of humans.

For researchers on either side of the debate, part of the problem is the sheer scale of the Amazon basin and the difficulty in reaching remote study sites. To get a clearer image, researchers are focusing on the view from space.

After her time in the field with Bush, McMichael joined a team of remote-sensing scientists

It suggests that about 3% or 4% of the basin might yield *terra preta*, compared with earlier, broader estimates of 0.1–10%. McMichael is now building a similar model to predict the extent of major earthworks such as those found on Marajó and in western Amazonia.

PAST AND FUTURE

It might take a much broader view — in time as well as space — to get the full picture of human impact on the Amazon. People were living there long before pre-Columbian times, and could have been shaping and determin-

Edinburgh, UK, suggests that dense rainforest might have given way to savannah and more open vegetation in many areas around 4,000–8,000 years ago thanks to a warmer climate and the use of fire by humans¹⁰. Mayle wrote that humans might have been “the key agents of disturbance” in the early forest.

Hecht's own work has focused on the more recent past: the 1880s to the 1920s, an era in which massive industrialization and globalization drove a boom in rubber extraction in the Amazon. Hecht compiled data on rubber sales and production and then teamed up with Sassan Saatchi, a remote-sensing expert at NASA's Jet Propulsion Laboratory in Pasadena, California, to map out the impact of rubber production across the basin. Their as-yet-unpublished analysis suggests that a million rubber trees were felled annually for 30 years, with each towering giant bringing down perhaps another ten trees as it fell. Saatchi suspects that the forest is still recovering from this sudden pulse of destruction, and he is trying to see whether signs of regrowth can be detected in the satellite data.

If many areas of the Amazon have been regrowing since the early 1900s, that could have temporarily boosted how much carbon dioxide the region is absorbing from the atmosphere, says Saatchi. If true, as that disturbance fades, the forest's role as a carbon sink could shrink.

Determining the full extent of human influence on the forest will take time. But Heckenberger says that what we know already offers some lessons for today. The evidence of ancient *terra preta* and cultivated ‘orchards’ in the forest demonstrates that indigenous peoples knew how to manage life within the Amazon long before the days of chainsaws and artificial fertilizers. Future efforts to develop the kind of agroforest systems that are being uncovered from the past, says Heckenberger, would help modern communities to both preserve the Amazon and carve out a living. “These are solutions that are quite intelligent and palatable,” says Heckenberger — for all of the Amazon's population. “I think they can learn a lot from themselves.” ■

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at the University of New Hampshire in Durham in an attempt to identify *terra preta* through satellite imagery. Their unpublished analysis suggests that it is possible to spot *terra preta* from space by seeking fertile regions where leaves absorb high amounts of nutrients and water.

McMichael has also developed a model that uses ecological factors such as distance from a river, elevation and forest type to predict where *terra preta* might be expected, which has helped field scientists to narrow their search. When tested against 2,900 sites where *terra preta* has been confirmed as either present or absent, the model predicts 89% of them correctly.

ing the composition of the forest for millennia through hunting and foraging.

The arrival of humans in the Amazon region coincided with — and perhaps contributed to — the widespread extinctions of megafauna, such as giant sloths and a cousin of the modern elephant, towards the end of the last glacial period some 12,000 years ago. A recent study⁹ suggests that these extinctions decreased the availability of the important nutrient phosphorous in the forest, and that might explain why the forest is still limited in phosphorous today.

An analysis of pollen and charcoal records led by Francis Mayle at the University of

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