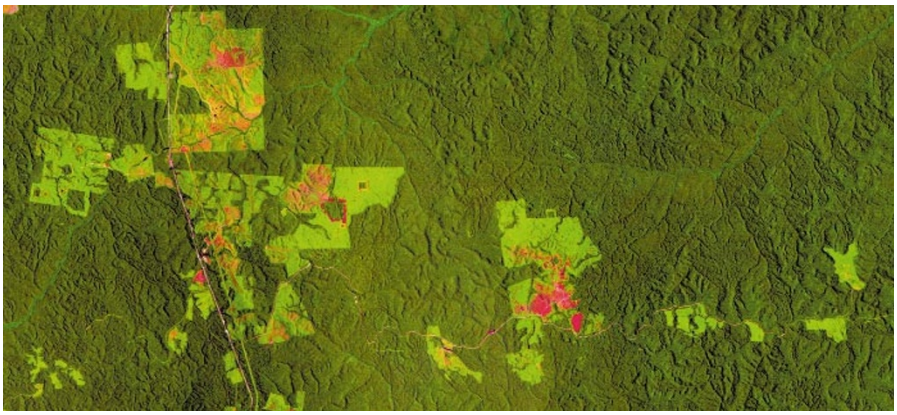

Figure 1 **Forest clearings in the Amazon, in an area north of Manaus, Brazil. Clearings show as pale green among the uncut, darker green forest. Within the clearings, square forest islands of different sizes remain. These, plus control plots within the continuous forest, constitute the forest-fragment experiment. The pink areas are bare soil or recently cleared areas, including those that must be repeatedly cleared around the experimental plots. The clearing at the far right of the image is about 3 km east to west and 5 km north to south.**

average years (W. Laurance; B. Williamson, Louisiana State Univ.).

The second controversial question raised by the project concerned the forest edges. The project could not have anticipated the recent history of forest clearing, and the relative amounts of forest islands and forest edges that it produced. Depending on definition, the Amazon basin has 3–4 million km$^2$ of lowland rainforest[5]. Brazil's Instituto Nacional de Pesquisas Espaciais (INPE) estimated Amazon deforestation at 21,000 km$^2$ per year[5] for the 1980s, and, since then, the annual estimates range from 50 to 150% of that amount[6]. INPE, however, does not include the amounts of forest left behind as islands, or the amounts near forest edges.

A study of satellite images by David Skole (Univ. New Hampshire) and Compton Tucker (NASA) broadly agrees with these rates of deforestation[6]. Deforestation has left little forest behind, and the laws on leaving a specified fraction uncut have not been widely respected. Skole and Tucker found that little of what does remain is in isolated forest islands — only about 1,000 km$^2$ per year. By comparison, the amount of forest edge is huge. Large roads bisect the forest, small roads feed off them perpendicularly at regular intervals, and yet-smaller tracks feed off these. Skole and Tucker asked how much forest was within 1 km of these numerous edges, and the answer was an area one and a half times larger than that of the cleared forest.

Results from the Manaus project show large changes in species composition, population dynamics and carbon flux along this huge area of new forest edge. There are sharp increases in tree mortality and damage because of greater exposure to wind, penetrating up to 300 m (perhaps further) from the forest edges. Fragments of less than 36 hectares are all 'edge', and, within them, about 10% of the plant biomass was lost within two to four years of isolation[7]. Laurance and colleagues reported that these changes accompany accelerated tree dynamics — species now grow faster and die younger than before. And although the abundance of lianas increases along the edges, this is not enough to compensate for the loss of tree biomass. As a result, up to 15 million tons of carbon are lost from the forest to the atmosphere from the newly created forest edges in the Amazon. Worldwide, the amount is perhaps ten times that.

With 20 years of hindsight, Lovejoy's second question, about edges, is more important than the first one about forest islands. Tropical deforestation has been so complete that forest islands constitute only a small area. It is understanding the extent to which edge effects penetrate uncut forest, and how these effects are modified by the nature of what surrounds them (secondary forests or cattle pastures), that constitute the pressing ecological questions for Claude Gascon, the project's lead scientist. Of course, at the current rates of deforestation, not even forest edges will remain a century from now. Only with a determined effort might some forest islands remain. If so, the results from this project would provide the best hope for informing their management. □

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**Daedalus**

## Gravity waving to us

**Physicists are still exasperated by the elusiveness of gravitational waves. Laser interferometers and resonating metal bars have so far failed to detect them. Einstein showed that a gravitational field can be detected by its bending of light. A distant galaxy in the same line of sight as a nearer one can form an 'Einstein ring' image around it; the light is deviated in passing through the nearer galaxy's gravitational field. If an Einstein ring is ever found around an empty patch of sky, a clump of dark matter will have been discovered. Similarly, says Daedalus, the light from a distant star or galaxy should be deviated in phase with any gravitational waves through which that light passes. An observer would see the object apparently vibrating back-and-forth in the sky, in time with the gravitational waves.**

**The effect would be extremely small, and is probably below the resolution of the best modern telescopes. But Daedalus is undismayed. He points out that phase-sensitive detection can extract a periodic signal from vastly greater amplitudes of noise, provided the frequency and phase of the signal are known. Several types of astronomical object, such as spinning pulsars and tightly orbiting binary neutron stars, should radiate gravitational waves at their own rotational frequency. So he wants to train a big telescope on such an object, and study the image of a distant star or galaxy close to it in the sky. The image should be vibrating ever so slightly in time with the rotation frequency of the gravitational source. Demodulate the position-signal of that star with a phase-sensitive detector locked to the rotating source, and the amplitude and direction of the vibration should slowly emerge out of the optical noise.**

**This elegant scheme only works with gravitational waves of known period. But once the method has been well worked out, it should be possible to select the image of a distant galaxy, and to try decoding its position-fluctuation with a whole range of likely frequencies and phases. The occasional positive result would indicate the presence nearby of some gravitational source with that frequency and phase. The real prize would be to detect several such objects, all vibrating in the same phase as some invisible central source of gravity waves. This would reveal dark matter in the form of two extinct neutron stars, dead and dark but still locked in each other's gravitational embrace, and still waltzing endlessly round each other.**

**David Jones**