

domesticated sunflower remains at San Andrés, which date to 4700 years ago. Some archaeologists have argued that the sunflower was domesticated in eastern North America (4). The new data challenge this idea [the complete details are due to appear soon (9)]. This is all the more interesting because molecular studies of extant wild sunflower populations from several different regions of North America, including ones near the archaeological sites in question, could not identify the wild progenitor (9). However, additional studies using different genetic markers are needed.

We could resort to the unsatisfying explanation that, although other wild sunflower varieties are common in the United States, the wild ancestor may be extinct. But perhaps molecular biologists have not yet sampled the right spot. Wild Mexican sunflowers are distributed a few hundred kilometers directly north of San Andrés but were not included in the molecular analyses (see the figure). If future work identifies them as credible ancestors to the domesticated species, this would provide strong support for Pope *et al.*'s hypothesis for a Mexican origin of sunflower, but a separate origin in North America would still be possible.

The Mexican sunflower data clearly bear importance for the question of whether eastern North America was an independent center of plant domestication. During the past 10 to 15 years, scholars have been building a case for such a scenario (4). Eastern North America stands in dramatic contrast to the other independent centers because it arose much later, about 5000 years ago, with sunflower and squash (*Cucurbita pepo* L.) consistently among the oldest components of the plant assemblages (4).

Now that a North American origin for sunflower is under reexamination, attention will also turn to what seems to be the earliest plant in the complex, squash. Some controversy already surrounds it because, as with sunflower, investigators are not willing to rule out the possibility that squash was a product of Mexico, where evidence for the domestication of *C. pepo* is 10,000 years old (10). The story is more complicated because of the probability of two separate domestication events of the *C. pepo* variety of squash (4), but again, molecular studies indicating where these events most likely took place remain to be carried out. A more complete answer will rest on such molecular studies and their convergence with fu-

ture archaeological work in northeastern Mexico and the eastern United States.

Students of prehistoric agriculture have proposed numerous explanations for its beginnings, many of which rely on either the influence of the ecological changes that occurred globally at the end of the last Ice Age or processes operating from within human social systems involving the emergence of power and prestige (2). Identifying the regions where plant domestication arose independently, and regions where it did not, is crucial for our understanding of why and how agriculture emerged. More surprises are sure to come our way.

References

1. D. R. Harris, Ed., *The Origins and Spread of Agriculture and Pastoralism in Eurasia* (Smithsonian Institution Press, Washington, DC, 1996).
2. D. R. Piperno, D. M. Pearsall, *The Origins of Agriculture in the Lowland Neotropics* (Academic Press, San Diego, CA, 1998).
3. D. R. Piperno, K. V. Flannery, *Proc. Natl. Acad. Sci. U.S.A.* **98**, 2101 (2001).
4. B. D. Smith, *The Emergence of Agriculture* (Scientific American Library, New York, ed. 2, 1998).
5. G. J. Fritz, *Curr. Anthropol.* **35**, 305 (1994).
6. K. O. Pope *et al.*, *Science* **292**, 1370 (2001).
7. M. B. Bush *et al.*, *Nature* **340**, 303 (1989).
8. D. M. Pearsall, *J. Archaeol. Sci.*, in press.
9. D. L. Lentz *et al.*, *Econ. Bot.*, in press.
10. B. D. Smith, *Science* **276**, 932 (1997).

PERSPECTIVES: CLIMATE CHANGE

Where Has All the Carbon Gone?

Steven C. Wofsy

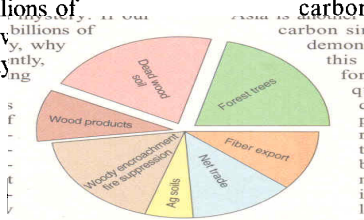
Emission rates of CO₂ from combustion of fossil fuel have increased almost 40 percent in the past 20 years, but the amount of CO₂ accumulating in the atmosphere has stayed the same or even declined slightly. The reason for this discrepancy is that increasing amounts of anthropogenic CO₂ are being removed by forests and other components of the biosphere (1). It is estimated that more than 2 billion metric tons of carbon (2 Pg C)—equivalent to 25 percent of the carbon emitted by fossil fuel combustion—are sequestered by forests each year. Inverse models for studying atmospheric concentrations of CO₂ suggest that mid-latitude forests in North America and northern Eurasia (2, 3) are crucial carbon sinks that remove this CO₂ from the atmosphere. But analyses of forest inventories (which measure forest areas and

timber volume) seem to indicate that forests sequester much smaller amounts of carbon (4, 5). Thus we have a mystery: If our forests are sequestering billions of tons of carbon annually, why can't we find it? Evidently, we have not been looking in the right places.

One place to look is in the organic matter of forests that is not considered commercially valuable and so is not normally reported in forest inventories. Such organic matter includes woody debris, soil, wood products preserved in landfills, and woody plants that have encroached on grasslands because of the long-term suppression of natural fires (see the figure, this page). According to Pacala *et al.* on page 2316 of this

issue (6), more than 75 percent of the carbon sequestered in the United States is found in organic matter that is not inventoried. When all major sequestration processes are counted, the range of values for uptake of CO₂ by U.S. forests is 0.3 to 0.7 Pg (10¹⁵ g) of carbon per year. This number is similar to that calculated from inverse models, and is compatible with direct carbon flux measurements and ecological data.

Asia is another place to look for forest carbon sinks, as Fang *et al.* (7) demonstrate on page 2320 of this issue. They report that forests in China have sequestered substantial quantities of CO₂, despite population pressure, rapid expansion of industry, and a relatively small base of forest land (~100 million ha with 4.5 Pg C in China, versus 250 million ha with 12 Pg C in the continental United States) (8). Reforestation and afforestation (the planting of new forests) have been national policies in China since the late 1970s, motivated by the desire to restore degraded ecosystems for flood and erosion con-



The fate of sequestered carbon. Uptake of atmospheric CO₂ by vegetation and soils in the United States, partitioned according to the ultimate fate of the sequestered carbon in the environment [adapted from (6)]. The total uptake of carbon in the continental United States is between 0.3 and 0.6 Pg C per year, equivalent to 20 to 40 percent of fossil fuel emissions worldwide.

The fate of sequestered carbon. Uptake of atmospheric CO₂ by vegetation and soils in the United States, partitioned according to the ultimate fate of the sequestered carbon in the environment [adapted from (6)]. The total uptake of carbon in the continental United States is between 0.3 and 0.6 Pg C per year, equivalent to 20 to 40 percent of fossil fuel emissions worldwide.

Enhanced online at
www.sciencemag.org/cgi/content/full/292/5525/2261

The author is in the Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02139, USA. E-mail: scw@io.harvard.edu