INSTITUTE OF CURRENT WORLD AFFAIRS

GSH-7 Are Tropical Forests Sources or Sinks of Carbon Dioxide?

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San Jose, Costa Rica
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Dear Peter:

Man's increasing dependence on fossil fuels (coal, natural gas, petroleum and their derivatives) as energy sources has caused a measurable increase in the amount of Carbon Dioxide (CO_2) in the earth's atmosphere. The increase in atmospheric CO_2 is expected to cause an increase in the earth's temperature. As a resident of Hanover, New Hampshire, you might welcome some additional free warmth, but global warming would have disastrous consequences for mankind--melting of polar ice caps causing sea levels to rise, shifting of subtropical deserts poleward, and increasing the arid zones of the world, to name a few.

The increase in atmospheric CO_2 is not commensurate with the quantities released through the burning of fossil fuels--only about 50% of the increase has been retained in the atmosphere. To account for the "missing" CO_2 released into, but not remaining in the atmosphere, oceans and tropical forests have been proposed as major "sinks" (absorbers of atmospheric CO_2). Yet in the past few years, considerable disagreement (see Science 197:1352, 1977) has developed between oceanographers and terrestrial ecologists over whether oceans or tropical forests are the primary CO_2 sink. Oceanographic models indicate very slow mixing of oceanic surface waters with the deep, cold waters due to a natural barrier of rapidly decreasing temperature, called a thermocline. According to oceanographers, the slow mixing across the thermocline means that deep ocean waters are not a major sink of atmospheric CO_2.

The apparent limited capacity of oceanic waters to absorb the increasing amount of CO_2 in the atmosphere has led many scientists to assume that tropical forests, particularly the vast, forested Amazon Basin, are functioning as the major sink of atmospheric CO_2.

How do forests function as a CO_2 sink? Carbon, absorbed as CO_2 from the atmosphere, is a basic building block in the photosynthetic process in all green plants. Chlorophyll in plant cells reacts with solar energy to bring about synthesis of complex organic molecules such as sugar and cellulose. Long-living plants such as trees store this carbon in their wood, for example, and hence serve as a CO_2 sink. Short-lived plants also absorb atmospheric CO_2, but the stored carbon is soon released through consumption, decomposition, burning, etc., so non-woody plants are not considered CO_2 sinks.

As long as a tree, or more appropriately a forest, continues to increase its biomass (the total amount of living matter), it is a net sink of atmospheric CO_2. If the forest is cut down and burned, however, nearly all of the stored carbon is released into the atmosphere; thus that particular forest changed from a sink to a *source* of CO_2. Harvesting timber from the forest varies on the source/sink spectrum. If the timber is used to build a house, most of the stored carbon is not returned to the atmosphere. In contrast, burning newspapers releases the stored carbon to the atmosphere. (Those New York Times stored in the attic are not a source, however.)

Ecological theory tells us that a mature forest is in dynamic equilibrium such that there is neither a net increase nor decrease in the forest biomass. In other words, the death and decay of scattered trees in the forest is balanced by the growth of the living trees. This means that a mature forest is neither a source nor a sink of atmospheric CO_2.

The great bulk of tropical forests in the Amazon Basin are commonly assumed to be mature, hence they are neither sink nor source of atmospheric CO_2. The indigenous practice of shifting cultivation is an ecologically sound land use system that does not alter the CO_2 source-sink balance on a regional basis. Although shifting cultivators fell and burn a patch of forest, that CO_2 source is presumed to be roughly balanced by the rapid growth (and storage of carbon) of secondary forest on previously abandoned patches.

Consideration of the vastness of mature forests in the Amazon and the exponential increase of deforestation in the tropics in the past decade has led some ecologists to question the assumption of tropical forests being a CO_2 sink. George Woodwell, director of the Ecosystems Center of the Woods Hole Marine Biological Laboratory, Massachusetts, is an initiator and leading proponent of the idea that deforestation is a net source of atmospheric CO_2. (Though unclear, I believe Woodwell uses deforestation to mean the burning of forests.) He and his colleagues claim that the amount of CO_2 released by utilization or the burning of living plants is probably one to two times the amount currently released from the burning of fossil fuels (Science 199:143). Woodwell has thrown the ball back to the oceanographers, suggesting that the CO_2 released to the atmosphere but not retained in the atmosphere must be going down the oceanic sink.

Woodwell's deforestation thesis is based on admittedly skimpy data, but it has attracted numerous adherents. With increasing population and Brazil's push this decade to open up the Amazon Basin for colonization, it is easy for one to be comfortable with Woodwell's thesis. I was surprised by Woodwell's claim that deforestation is probably releasing as much or up to twice as much CO_2 to the atmosphere as is the burning of fossil fuels, so I decided to review his deforestation estimates. On close reading of his papers, I find several bothersome assumptions and generalities that suggest to me his estimate of 1-2% deforestation per year may be nothing more than a gross guess.

Woodwell *et al.* (1978) state "The question of harvesting and clearing is especially important for the tropical forests of South America because the *Amazon Basin* (my italics) contains the most extensive primary rain forest remaining in the world." (p. 142). The authors cite two reports as original sources of data on tropical deforestation. One is a study by Veillon (appendix in Hamilton 1976) of deforestation in the western Llanos of Venezuela between 1950 and 1975. Veillon reports a loss of 12,890 km^2 of forest from the 39,625 km^2 of forest extant in 1950. Woodwell *et al.* use the 32.5% reduction in forest area over the 25 year period to calculate an average rate of deforestation of 1.3% per year. However, the total area studied by Veillon is 88,518 km^2, so actually only 14.6% of the study area was deforested during the 25 year period, or an average of 0.58% per year. Most of the western Llanos is tropical dry life zone (in the Holdridge system) and very popular for cattle ranching.

The other original source of data on deforestation cited by Woodwell *et al.* (1978) is a 1977 paper in Science by Adams *et al.* that provides deforestation data for two Brazilian states, Sao Paulo and Parana. Adams and his colleagues use state forestry data to show that in the state of Sao Paulo the area in mature forest decreased from 60% in 1910 to 20% in 1950, which is an average of 1% per year. In the state of Parana between 1953 and 1963, an average of over 3% of the 1953 forest area of 65,000 km^2 was cleared each year. Adams *et al.* do not provide the real rate of deforestation in Parana, but I calculate an average deforestation rate of slightly less than 1% per year in Parana for the period 1953 to 1963.

The state of Sao Paulo is the most industrialized and economically dynamic of the Brazilian states, hence it is not surprising that substantial deforestation of the state has occurred. The state of Parana is covered by some of the world's richest soils that are excellent for wheat and soybeans, hence the rapid deforestation of such productive agricultural soils is understandable.

I believe Woodwell and his colleagues have erred in using these data to estimate a 1-2% per year rate of deforestation in the Amazon Basin. First of all, not one of the three study areas is actually in the Amazon Basin. All three study areas have climates and soils more favorable to agriculture than occur in the Amazon Basin. I would not be surprised if the rate of deforestation in the Amazon Basin is more than an order of magnitude less than Woodwell's guess.

Woodwell *et al.* (1978) cite a paper by Bolin, in support of the deforestation thesis. Bolin (1977) uses FAO (Food and Agriculture Organization of the United Nations) statistics on timber harvest to calculate the net release of CO_2; however, it is not clear how the calculations are made nor the assumptions underlying the calculations. It appears that the timber harvest data of FAO are used to estimate the amount of forest land converted to non-forest land. Most, if not nearly all of the tropical timber harvest reported in FAO statistics refers to export timber. Since most export timber is of high quality, it is unlikely that it becomes an immediate source of CO_2. It is more likely to be stored as paneling, cabinetry, etc. An example of storage is the mahogany wood being converted to tables in Bolivia that I reported in GSH-5.

Furthermore, the selective harvest of one or a few species changes the mature forest to a forest with net positive growth as young trees fill the holes left by the harvested trees. Selective logging of high quality tropical timbers changes the exploited forests to a net sink of atmospheric CO_2. It is presently impossible to say how extensive are selectively logged forests nor how quickly they are converted to non-forest, that is from a CO_2 sink to a CO_2 source. Under relatively stable economic conditions--if such a condition exists in any tropical country--I suspect that the selective-logging "front" advances into mature forest at a rate roughly comparable to the rate of advance of the deforestation front into the selectively-logged forest. If my assumption is valid, we would only need to know the rates at which the two fronts are advancing, the lag time between fronts, and the rate of carbon storage in the recovering forest in order to make much more accurate estimates of the CO_2 source-sink relations of tropical forests. I don't believe such data exist for a single tropical forest.

In summary, I find the data base on timber harvest, forest recovery and even tropical deforestation to be woefully inadequate to answer the question: Are tropical forests sources or sinks of carbon dioxide? It is encouraging to know that Dr. Norman Myers is actively collecting information on tropical deforestation for the Natural Resources Defense Council. His study will hopefully provide a much stronger base for evaluating tropical deforestation.

Sincerely,

Gary

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BIBLIOGRAPHY

Adams, J.A.S., M.S.M. Mantovani and L.L. Lundell. 1977. Wood versus fossil fuel as a source of excess carbon dioxide in the atmosphere: A preliminary report. *Science* 196:54-56.

Baes, C.F., Jr., H.E. Goeller, J.S. Olson and R.M. Rotty. 1977. Carbon dioxide and climate: The uncontrolled experiment. *Amer. Scientist* 65(3):310-320.

Bolin, B. 1977. Changes of land biota and their importance for the carbon cycle. *Science* 196:613-615.

Botkin, D. 1977. Forests, lakes, and the anthropogenic production of carbon dioxide. *Bioscience* 27(5):325-331.

Hamilton, L. 1976. Tropical rainforest use and preservation: A study of problems and practices in Venezuela. Sierra Club, Int. Ser. No. 4.

Kerr, R.A. 1977. Carbon dioxide and climate: Carbon budget still unbalanced. *Science* 197:1352-1353.

Siegenthaler, U. and H. Oeschger. 1978. Predicting future atmospheric carbon dioxide levels. *Science* 199:388-395.

Stuiver, M. 1978. Atmospheric carbon dioxide and carbon reservoir changes. *Science* 199:253-258.

Woodwell, G.M. 1978. The carbon dioxide question. *Sci. American* 238(1):34-43.

Woodwell, G.M., R.H. Whittaker, W.A. Reiners, G.E. Likens, C.C. Delwiche and D.B. Botkin. 1978. The biota and the world carbon budget. *Science* 199:141-146.