CARBON SEQUESTERED, CARBON DISPLACED AND THE KYOTO CONTEXT

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ABSTRACT

The integrated system that embraces forest management, forest products, and land-use change impacts the global carbon cycle - and hence the net emission of the greenhouse gas carbon dioxide - in four fundamental ways. Carbon is stored in living and dead biomass, carbon is stored in wood products and landfills, forest products substitute in the market place for products made from other materials, and forest harvests can be used wholly or partially to displace fossil fuels in the energy sector. Implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change would result in the creation of international markets for carbon dioxide emissions credits, but the current Kyoto text does not treat all carbon identically. We have developed a carbon accounting model, GORCAM, to examine a variety of scenarios for land management and the production of forest products. In this paper we explore, for two simple scenarios of forest management, the carbon flows that occur and how these might be accounted for under the Kyoto text. The Kyoto protocol raises questions about what activities can result in emissions credits, which carbon reservoirs will be counted, who will receive the credits, and how much credit will be available? The Kyoto Protocol would sometimes give credits for carbon sequestered, but it would always give credits when fossil-fuel carbon dioxide emissions are displaced.

If a forest grows on land not previously in forest, carbon will accumulate in the growing biomass and there will he a decreased accumulation of the greenhouse gas carbon dioxide in the Earth's atmosphere. This is a common vision of how afforestation can be used to mitigate the accumulation of carbon dioxide in the atmosphere and the potential importance of carbon sinks is acknowledged in The Kyoto protocol to the United Nations Framework Convention on Climate Change [I]. If ratified, the Kyoto Protocol would permit the country responsible for afforestation to use the accumulating carbon as a credit against it's commitments to reduce greenhouse gas emissions - if the afforestation occurred since 1990 and the change in carbon stocks is reported in a "transparent and verifiable manner". Although the Kyoto Protocol is not explicit, we expect that this offset credit should include all carbon stocks in the forest, including the carbon in the forest soil.

In Figure 1 we use the output from our carbon accounting model to illustrate the accumulating carbon credits for a simple afforestation scenario. The figure shows that over time carbon will accumulate in the forest stand, including in the forest soil and forest litter, but that eventually trees approach maturity and the stand is unable to accumulate additional carbon. It approaches a steady-state carbon stock.

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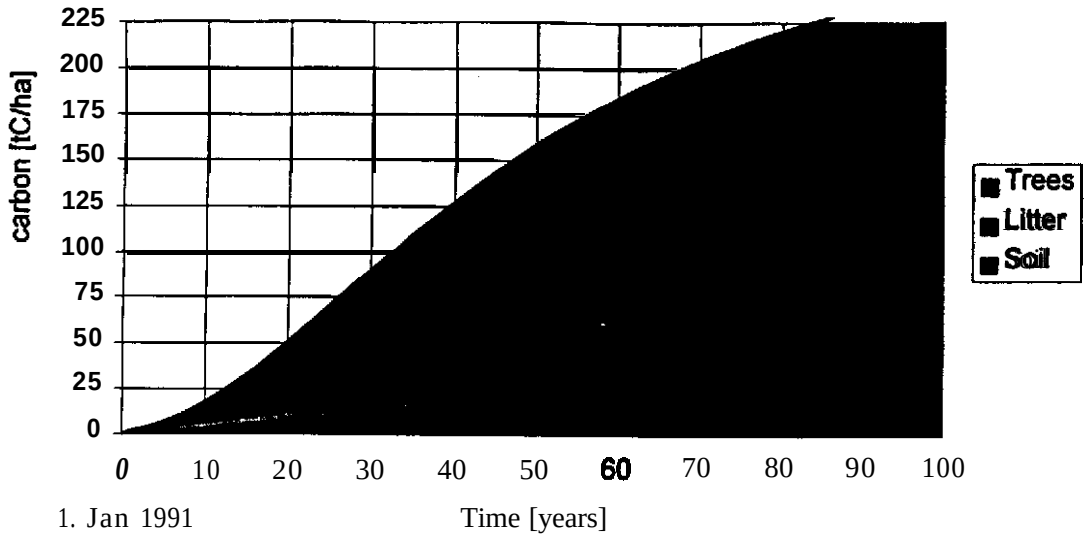

Figure 1: Cumulative carbon-stock changes for an afforestation scenario.

There are, of course, many land-use and forest management practices that could impact the net emission of carbon dioxide to the atmosphere. Our focus here is on analyzing these impacts and on the way in which changes in carbon stocks will be measured, monitored, and credited in international efforts to "prevent dangerous anthropogenic interference with the climate system" [2]. The model GORCAM (Graz/Oak Ridge Carbon Accounting Model) has been developed to try to examine the full system that is impacted by forest management decisions and to illustrate the effect that these decisions have on net carbon dioxide emissions. Protection of a growing forest stand, for example, can not only prevent the emission of its carbon stocks to the atmosphere, but can permit continuing accumulation of carbon from the atmosphere until the stand approaches maturity. If the same stand is harvested to produce a conventional mix of forest products, there will be an initial loss of carbon in the forest, but there will be an increase in carbon in forest products and an increase in the substitution of forest products and bioenergy for other products and other sources of energy. (This is under the assumption that increased harvest is coupled with an increased demand for wood products).

In Figure 2, output from GORCAM illustrates the net impact on atmospheric CO_2 if the forest stand from Figure 1 is harvested after 40 years and the harvest is used for a conventional mix of forest products. The numeric details of Figure 2 depend on the exact values for many input parameters in the model so the diagram presented here should be taken to illustrate the nature of the flows rather than to demonstrate their values. Nonetheless, the figure shows that when the forest is harvested carbon is sequestered in harvested materials (including, eventually, landfills) and that harvested materials substitute for other products that are generally more energy intensive to produce. Details of GORCAM can be found in Schlamadinger and Marland [3] and a sensitivity analysis of the importance of some of the principal model parameters is in Marland and Schlamadinger [4]. Whereas the carbon lo the protected forest stand of Figure 1 can be expected to approach some steady state value over time, the carbon displacement of Figure 2 can be expected to continue to increase over time. Note that the expected carbon sequestration after 50 years amounts to 128 tC / ha.

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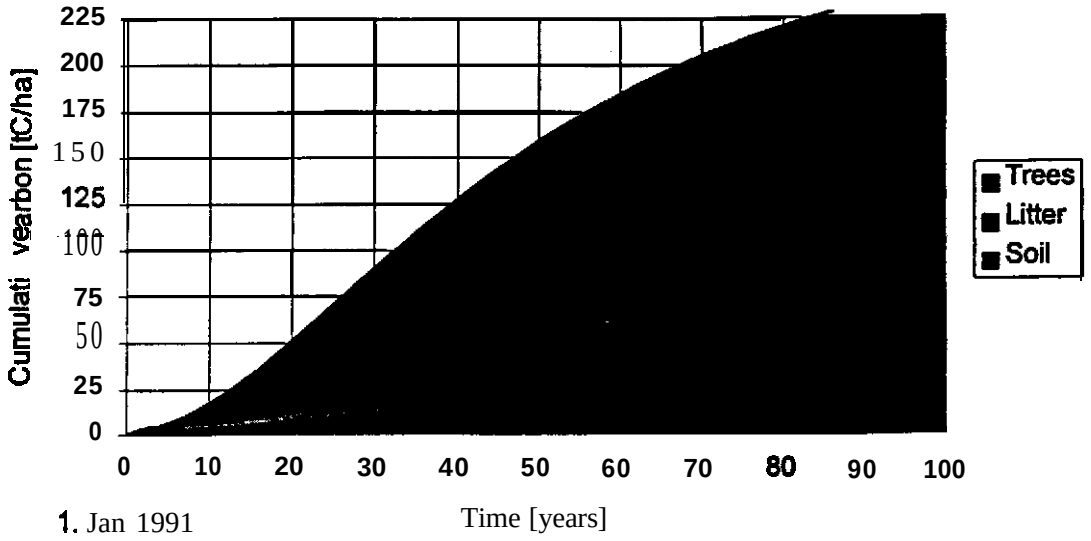


Figure I: Cumulative carbon-stock changes for an **afforestation** scenario.

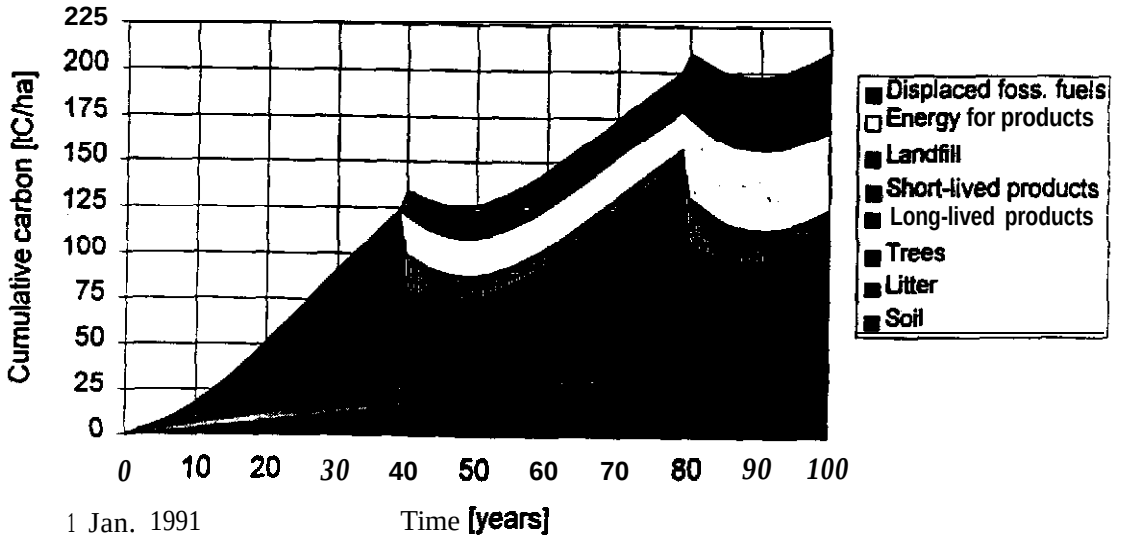
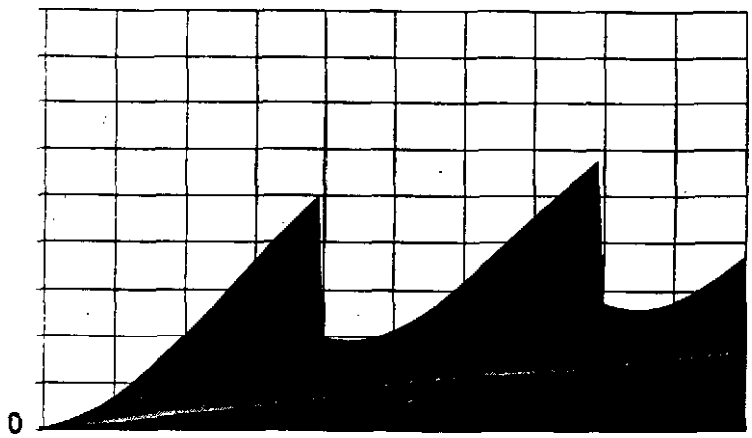
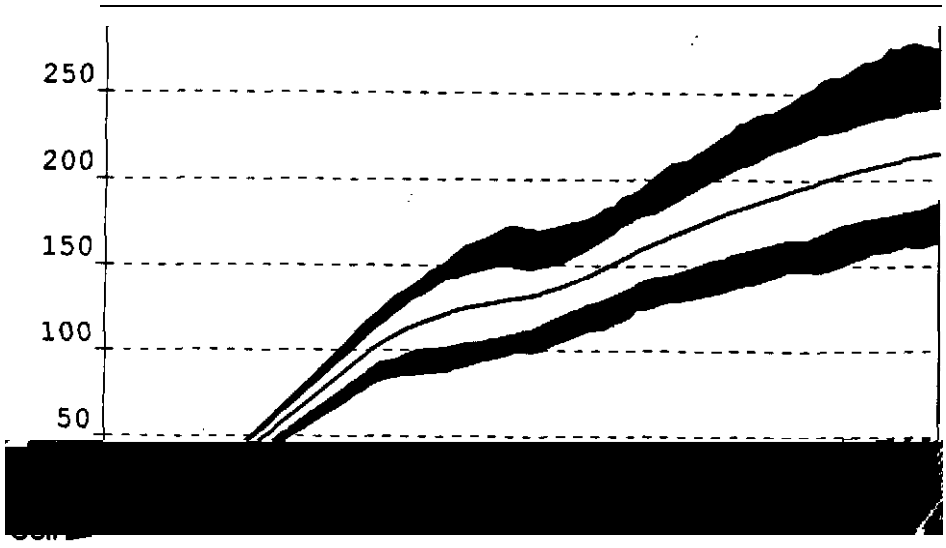


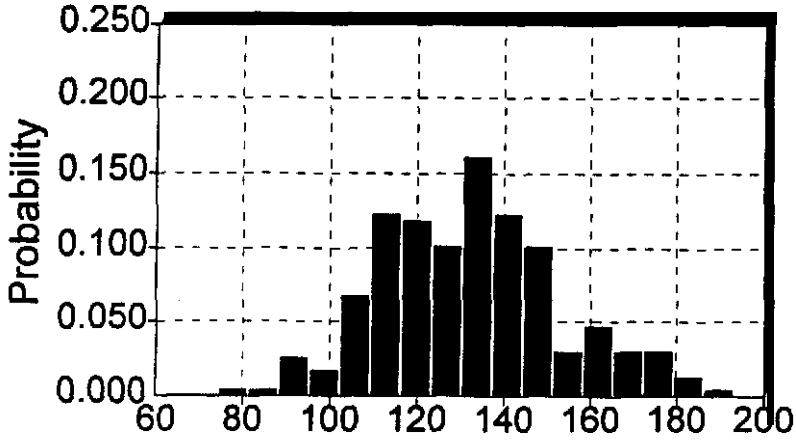
Figure 2: Cumulative carbon-stock changes for a scenario involving afforestatand harvest. These are net changes in that, for example, the diagram

Another challenge of the Kyoto Protocol has to do with the way in which carbon credits accrue. The Protocol, and subsequent decisions of the Congress of Parties to the Framework Convention, establish that emissions or sinks in the biosphere will be measured as tbe changes in carbon stocks-exactly as illustrated in the GORCAM diagrams above. Given this dictate, the change in carbon stocks for the landowner who is

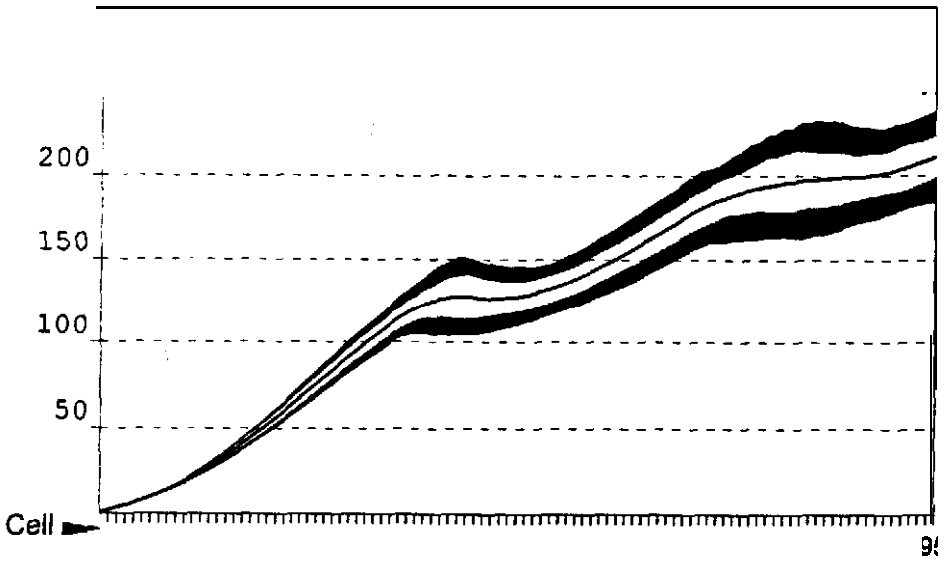


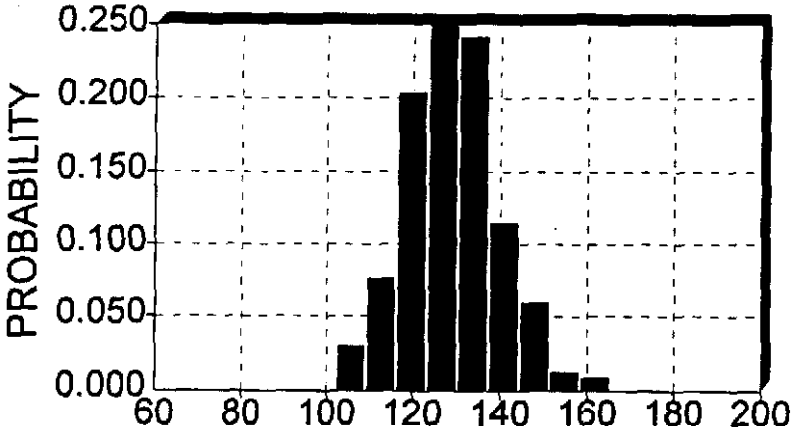
95% percentile values in Figure 5 arc at 99. 132, and 171 tC/ha after 50 years. In other words, in order to achieve the carbon benefits predicted in Figure 2 (128 tC) with a certainty of 95%, and witb the probability distributions assumed For various input parameters, the project area would have to be increased from 1 ha to 1.29 ha (128 divided by 99). Conversely, the project envisioned in Figure 2 would generate 128 tC/ha credit if all of the values were perfectly known but only 99 tC/ha with the uncertain&s assumed here and





Figures 6 and 7 are exactly as in Figures 4 and 5 except that the deviations from the mean for the various input parameters are only half as large, i.e. the uncertainties of the input parameters are smaller. It can be





A crediting scheme that discounted credits in proportion to their uncertainty would require careful balancing between the need for accurate measurement of carbon sinks and the cost of providing tbe required measurements. There appear to be two ways for projects to increase carbon credits for a project with uncertain outcome. One could either increase the project area or increase tbe accuracy with which key parameters are predicted and measured.

In summary, the Kyoto Protocol establishes the principle that removing carbon dioxide from the atmosphere is to be valued in tbe same way as is reducing emissions to the atmosphere. At the same time it creates many challenges on how these credits are to be measured and credited. We have yet to