1 of 1

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COSTS OF CREATING CARBON SINKS IN THE U.S.

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ABSTRACT

New models of the dynamic patterns of carbon uptake by forest ecosystems allow improvements in the estimation of the costs of carbon sequestration in the U.S. The preliminary results of an effort to update an earlier study indicate that conversion of environmentally sensitive and economically marginal cropland and pastureland in the U.S. could offset as much as 25% of current U.S. emissions at costs of $US 8-60 per short ton.

KEYWORDS

Carbon dioxide; sequestration; forestry; cost analysis; agriculture.

INTRODUCTION

In the last three years, several studies have been published that examine the costs and potential for conversion of marginal agricultural land to forest-stand carbon sinks. As a measure of the potential of forest-stands to remove carbon from the atmosphere, these studies have generally used the average carbon uptake rates of the forests over a pre-specified period of time. However, the "yield curves" of carbon for most types of forests show a great deal of variation over the life of the forest, with peak rates of uptake not being reached until 25 to 45 years after establishment. In a policy analysis that discounts future benefits, this delay in carbon uptake is important.

This study examines the importance of the biological characteristics of tree plantations to their feasibility as carbon sinks, derives cost curves describing the cost per ton of carbon captured as a function of the level of sequestering activity, and considers other aspects such as the sensitivity of the analysis to the elasticity of demand for cropland and pastureland and to the social discount rate.

The preliminary results indicate that conversion of environmentally sensitive and economically marginal cropland and pastureland in the U.S. could offset as much as 25% of current U.S. emissions at inframarginal costs of $US 8-60 per short ton. This is considerably lower than the costs estimated by several energy models that assume the primary policy instruments are emissions quotas and taxes.

DYNAMIC CONSIDERATIONS

An earlier study by Moulton and Richards (1990) developed marginal and total cost curves for the use of tree planting and modified forestry practices to capture atmospheric carbon on marginal agricultural land and forestland in the U.S. The analysis indicated that the costs per unit of carbon sequestered range widely as a function of land type (private cropland, pastureland and forestland) and as a function of the region of the country. That report was data-intensive, which made it possible to test for the effects of factors such as land availability, rental costs, and discount rates in ways not possible with previously available studies of carbon-sequestering costs.

This paper provides an interim report on the effort to update the 1990 report. The update takes advantage of new data and reflects some of the complexity and dynamics inherent in a large undertaking involving biological and economic components.

Carbon Yield Data

The original carbon yield data was expressed as an average annual sequestration rate. It has been replaced by yield curves that consider the dynamic nature of carbon uptake patterns. Figure 1 shows yield curves for three region/species combinations. Note the difference among the regions with respect to both the quantity and timing of carbon sequestering. In a world that discounts future flows of benefits, this is an important consideration.

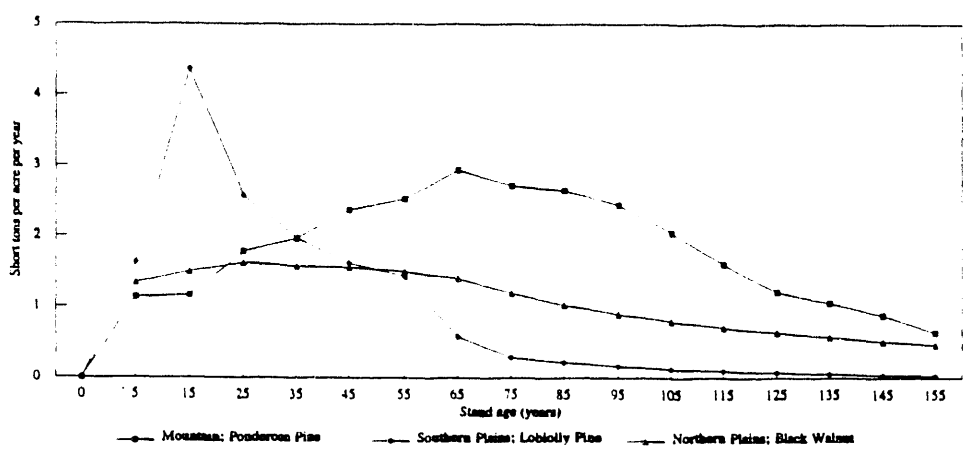

Fig. 1. Rate of annual carbon fixation as a function of forest-stand age for three region/species combinations

Historic Cost Data

The land cost, land inventory and establishment cost data have been replaced. The land costs are updated to reflect 1992 statistics on market transactions. They have also been adjusted to reflect the role of property taxes. The inventory of marginal land is updated from 1982 to 1987 figure, and is adjusted for land that has already been enrolled in the Conservation Reserve Program. The establishment costs now reflect both administrative overhead and failure rates of new stands.

Demand for Agricultural Land

The land costs are also adjusted to account for the non-marginal nature of the land requirements. When large quantities of an essentially fixed supply of land are withdrawn from the economy, the market price and social value of the remaining land can be expected to rise. This is now reflected in the model. .

Carbon Components

By breaking the carbon sequestration patterns down into the four major components - tree, soil, litter and understory - it is now possible to address questions of uncertainty regarding the underlying data.

At the same time, the analysis follows a similar model to that of Moulton and Richards (1990). The yield data for the appropriate species is aggregated for each of 10 regions of the contiguous 48 states. These aggregates are then combined with land area, land cost and establishment cost figures to develop estimates of regional carbon sequestration potential and unit costs in dollars per short ton. The regional figures are combined and sorted in ascending order according to cost, thereby deriving cost curves that show the marginal and total costs of carbon as a function of the amount of carbon being fixed.

A future report will include consideration of how the choice of forest-stand rotation length for various regions of the U.S. affects the cost of carbon sequestration. It will track the path of carbon returning to the atmosphere for those regions that are harvested for wood products and replanted for subsequent rotations. It will also further refine the carbon yield curves to reflect recent biological studies.

RESULTS

The marginal and total cost curves are shown in Figures 2 and 3, respectively. The marginal cost of carbon sequestration ranges from $US 8 to $US 60 per short ton, in nominal dollars, i.e. in the dollars of the year in which the carbon is sequestered. Because the sequestration is spread out over 160 years, the present value of those costs is considerably less than the sum of the nominal dollars. The total cost curve is denominated in present (1992) dollars and shows that the present cost of a program to sequester 54 billion tons of carbon over 160 years approaches $US 250 billion.

Figure 4 shows how the carbon accumulates over time and by component. Clearly, the most important of the four ecosystem components is the tree carbon, which comprises approximately 80% of the total carbon at the end of 160 years. The soil carbon is the next most significant of the ecosystem components and contains approximately 15% of the total carbon. Carbon in the litter component contains most of the balance of the total carbon, with relatively little being contributed by the understory component.

The observations regarding relative component contribution are significant for several reasons. First, while there is significant uncertainty regarding the soil, litter and understory component carbon levels, the yield figures for wood volume are relatively well documented, as are carbon density and above-ground to below-ground tree mass ratios. The fact that the component that makes the largest contribution to the carbon sequestering is the one about which the most is known reduces the overall uncertainty of the model results. Second, many

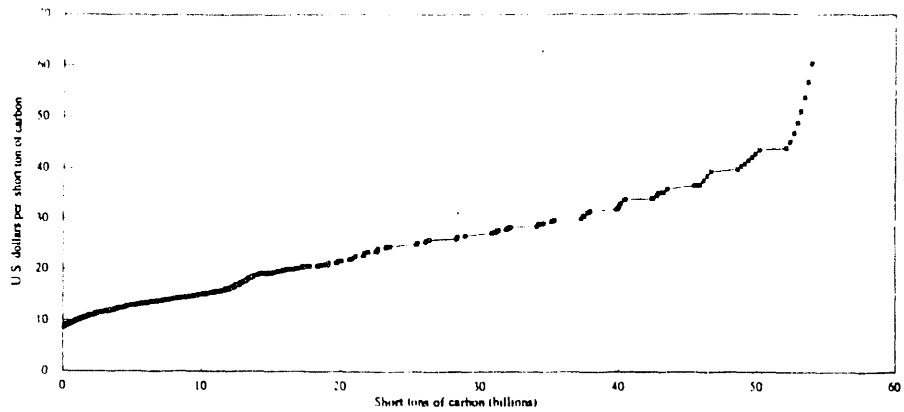

Fig. 2. Marginal cost curve for carbon sequestration under a 160-year program. expressed in nominal dollars.

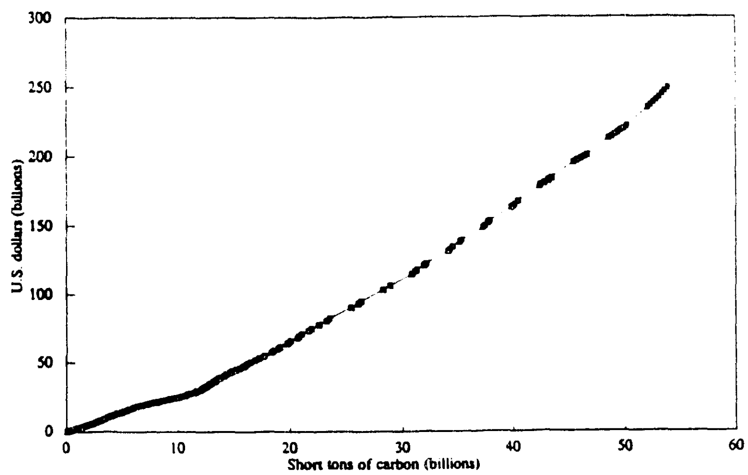

Fig. 3. Total cost curve for carbon sequestration under a 160-year program, expressed in present (1992) dollars.

studies have included only the tree carbon in their "sequestration accounting." The observation regarding the relatively small contribution of the other components de-emphasizes this omission. Third, the fact that most of the carbon is in the tree component suggests that the contribution of continued storage of carbon in the wood products that are made from the harvested timber may be a significant factor.

Figure 5 shows the annual carbon increment, broken down by component, over 160 years. The understory component is not included because of its relatively insignificant contribution and the fact that it is actually negative at some points. As could be derived from the slopes of the curves in Figure 4, the total annual increments during the second through fifth decades are quite high, approximately 520 to 640 million short tons, but drop off relatively rapidly thereafter. The timing of the decrease is related to the fact that the growth of softwoods in the southern parts of the country declines very rapidly after 40 to 60 years. Even with the decline of the southern pines, the total program is still capturing carbon at a rate of over 150 million tons per year at 160 years, over 10% of the current U.S. carbon emissions rate.

One of the features of this study is that it considers the dynamic nature of the carbon sequestration pattern. Whereas other studies, and the earlier version of this study, have

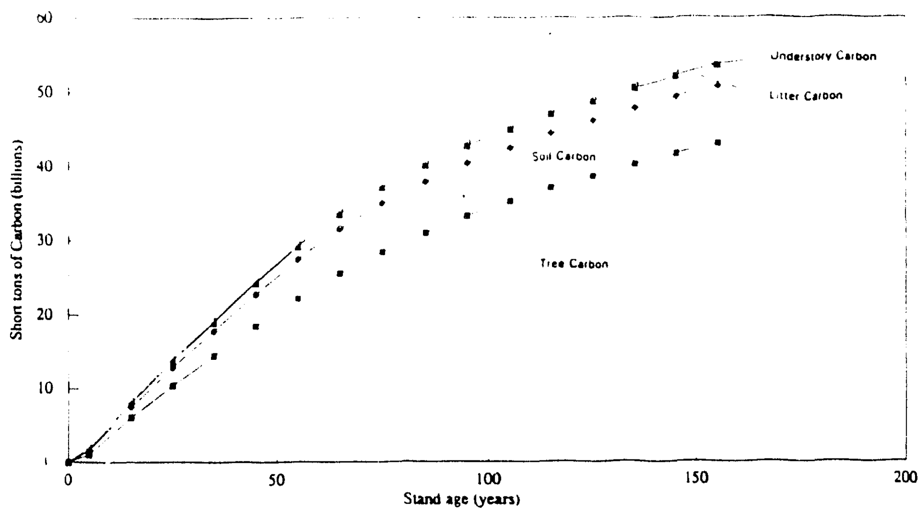

Fig. 4. Accumulation of carbon, by component, under a 54-billion-short-ton, 160-year program.

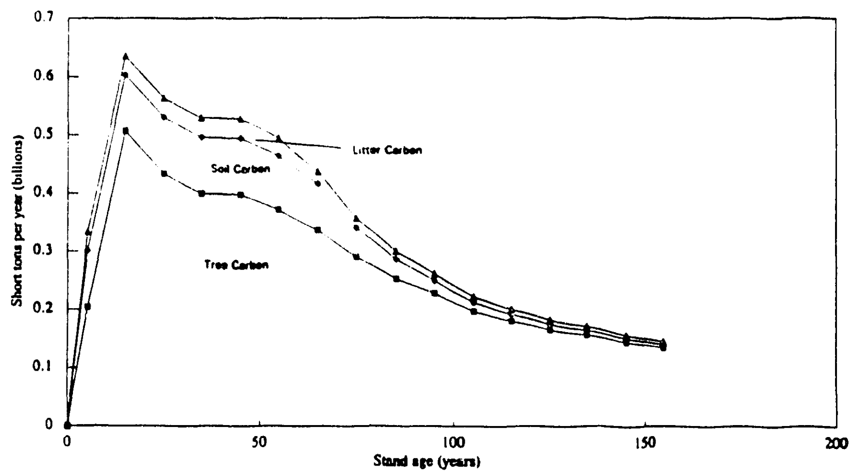

Fig. 5. Annual carbon increment, by component, under a 54-billion-short-ton, 160-year program.

expressed yields in long-run average tons per year, this study considers the actual pattern of carbon capture and accounts for that in the cost calculation. However, this different approach has made it difficult to compare the results of this study to the results of other studies, particularly in terms of the estimated potential amount of atmospheric carbon reductions. It would require 160 years to capture the 54 billion short tons that could be captured if 100% of the land were used. That averages to about 340 million short tons per year. However, if the yields are averaged over only 100 years, the capture rate goes up to 440 million short tons per year. Over the first 50 years, it is 540 million short tons per year. The latter figure is approximately 40% of recent U.S. carbon emissions rates.

SENSITIVITY ANALYSIS

The results of the base case were tested for sensitivity to assumptions regarding discount rates, elasticity of demand for agricultural land and the amount of agricultural land that can be converted to forest-stands.

Discount Rate

The discount rate plays a critical role in the calculation of the unit cost of carbon sequestration. Because the initial capital payments are matched to the irregular flow of carbon by discounting the relative value of the carbon to a "net present ton equivalent" (NPTE), a lower discount rate has the effect of increasing the number of NPTEs in a given flow of carbon. This decreases the unit cost of carbon. The inverse is true of an increased discount rate.

The importance of the choice of discount rate was tested by running sensitivity analyses for discount rates of 3%, 5% and 7%. The results, shown in Figure 6, indicate that the range of nominal unit costs jumps substantially as the discount rate rises - from a range of $US 6 to $US 39 per short ton in the case of a 3% discount rate to $US 12 to $US 84 in the case of a 7% discount rate. In general, the lower discount rate makes the northern regions with species that have peak growth rates during the fourth and fifth decades relatively more attractive, while the higher discount rates favor regions that peak during the second and third decades.

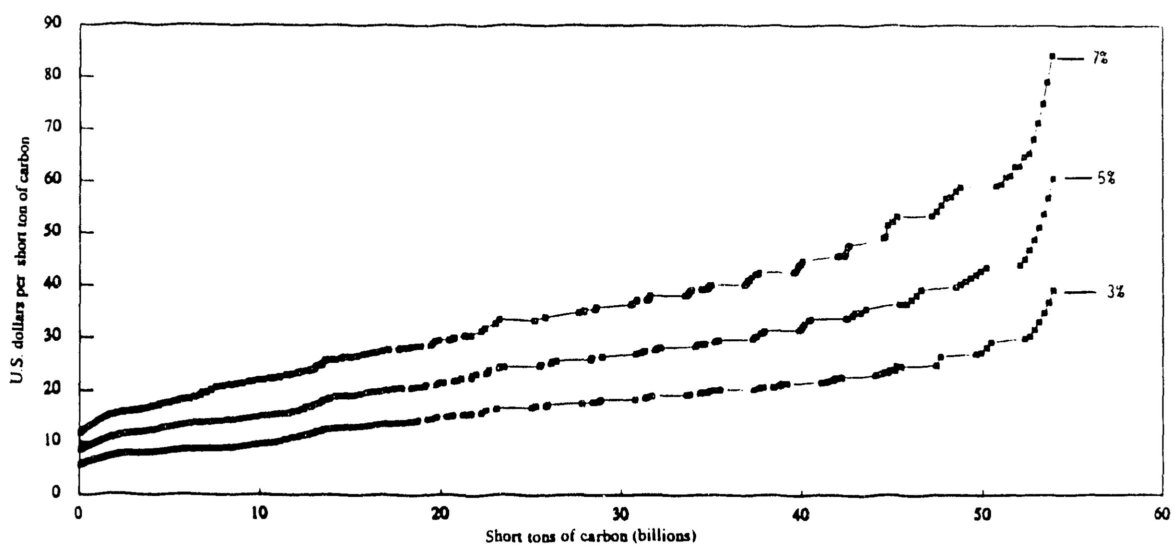

Fig. 6. Effect of discount rate on the nominal costs of carbon sequestration.

The choice of discount rate has no effect on the actual tons of carbon sequestered. Only the nominal cost (the cost expressed in the dollars of the year in which the sequestration takes place) is expected to rise with an increase in the discount rate. The total cost, expressed in present dollars, should not change because the value of capital outlays are the same regardless of the choice of a discount rate. The only exception to this is the valuation of the tax flow associated with the land. The capital cost of the land is calculated as if it includes a "buy-out" of future tax obligations; that is, it includes the present value of all future tax obligations. Because this flow of obligations has a lower value if the discount rate is higher, the effect of lowering the discount rate is to decrease the total cost of the project expressed in present dollars. In this case, the present value of total costs for sequestering 54 billion tons over 160 years is $US 269 billion in the case of a 3% discount rate and $US 239 billion for a 7% discount rate.

Elasticity of Demand for Agricultural Land

The elasticity of demand for agricultural land is a measure of how the demand for cropland and pastureland changes as a function of the price. When the supply of cropland is perfectly inelastic (absolutely fixed), the elasticity of demand can be used to estimate the path of prices as increasing amounts of land are withdrawn from agricultural production.

However, this variable is at best a very rough estimate of the actual price response to a decrease in the supply of land. The elasticity should ideally be both region- and crop-specific, but data for that level of disaggregation is not available. Further, the assumption that the supply of agricultural land is perfectly inelastic, while common in agricultural economics modeling, is not completely realistic. Finally, the elasticity used in this model, -0.584, may be a valid aggregate estimate given today's supplies of agricultural land, but may change dramatically at infra-marginal supplies of land.

A sensitivity analysis was conducted to address the uncertainty related to the choice of the elasticity of demand. As expected, the unit cost of carbon capture was essentially unchanged at lower rates of sequestration. As shown in Figure 7, the y-intercepts for the three levels tested are all approximately $US 9 per short ton of carbon. However, the marginal unit cost for the extreme case of 54 billion short tons shows a dramatic increase in response to a higher elasticity - rising from $US 60 per short ton in the case of an elasticity of -0.584 to $US 116 for an elasticity of -1.54, and $US 268 when the elasticity is -2.5. At the same time, the total costs, expressed in present dollars, for a 54 billion ton program rise from $US 248 billion for the lower elasticity to $US 360 billion and $US 567 billion for the higher two elasticities. Note, however, that for a program designed for 50% of the total potential, 27 billion tons of a possible 54 billion tons, the total cost differential is much smaller - approximately $US 100 billion in the case of an elasticity of -0.584, $US 110 billion for an elasticity of -1.5 and $US 124 billion with an elasticity of -2.5.

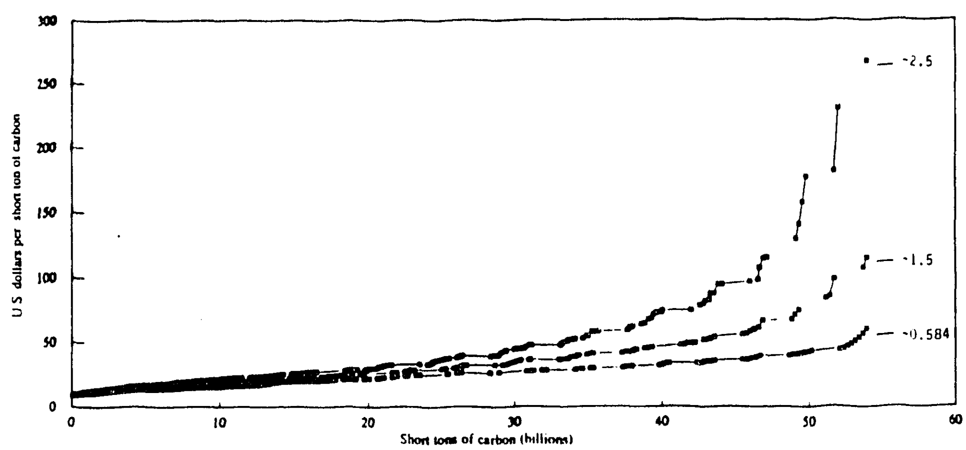

Fig. 7. Effect of elasticity of demand for agricultural land on the nominal costs of carbon sequestration.

Land Availability

One of the difficulties in conducting an engineering or "least cost" type of analysis is that it assumes that 100% of the marginal agricultural land is available for conversion to tree plantations. In fact, that level of participation by agricultural land owners is not likely in the absence of the exercise of eminent domain or public taking powers. This tendency of some land owners to hang on to their land longer or more stubbornly than others can be addressed in three ways.

First, this study is based on an inventory of environmentally sensitive and economically marginal agricultural land. The inventory includes 187 million acres of cropland and 57 million acres of pastureland, out of a total of 422 million acres of cropland and 129 million acres of pastureland in the U.S., or 44% in each case. At the same time, the land costs used apply to average cropland and pastureland. It is quite possible that if there is not enough lower quality agricultural land made available for carbon sequestering activities, the government may offer payment to owners of land in the better land class categories. The secondary benefits of soil erosion controls would not accrue, but those benefits have not been included in this cost analysis in any case.

Second, the use of the elasticity of demand for farmland will also account for non-marginal valuation by land owners. The fact that land owners may demand significantly more than current market prices is built into that calculation.

Finally, constraints can be introduced to limit the amount of marginally agricultural land that can be converted. Figure 8 shows the marginal curves for a program that uses only 50% of the total available marginal land of both types in each region. While the total amount of carbon sequestered over 160 years is only 27 billion tons - exactly one-half that possible when all marginal land is used - the total cost is $US 110 billion or approximately 30% of the cost when all land is used. This result is not surprising given the increasing marginal cost of expanding the sink within a given region.

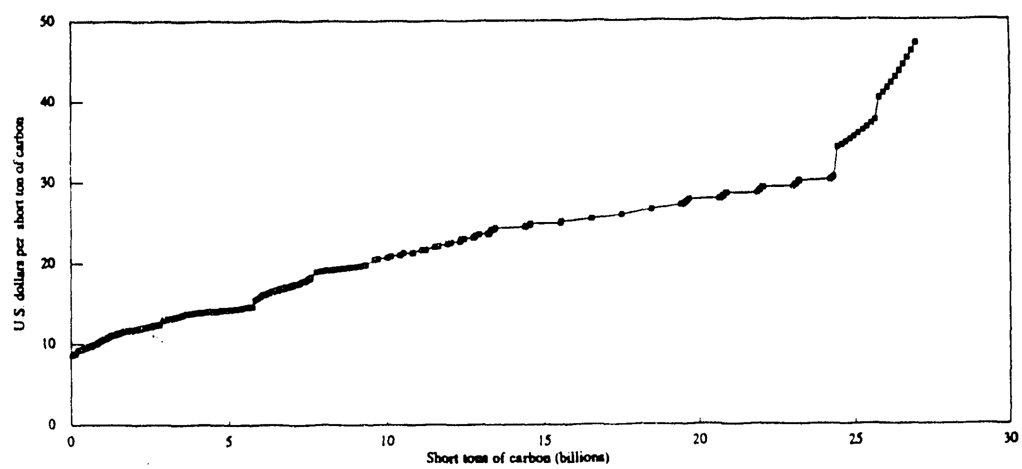

Fig. 8. Effect of constraining agricultural land supply in inventory by 50%.

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