CONF-9307120--1

STRATEGIES FOR USING TREES TO MINIMIZE NET EMISSIONS OF CO_2 TO THE ATMOSPHERE

REMARKS BEFORE THE U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON ENERGY AND COMMERCE SUBCOMMITTEE ON ENERGY AND POWER

by
Gregg Marland
Environmental Sciences Division
Oak Ridge National Laboratory*
Oak Ridge, Tn 37831-6335

29 July, 1993

ABSTRACT

It is often assumed that trees grown to offset CO_2 emissions need then to be preserved in order to keep the CO_2 from returning to the atmosphere. My contention is that, in terms of atmospheric CO_2, a tree performs equivalently if it stores carbon or if its conversion to CO_2 displaces some other source of CO_2 that would otherwise be released. There is no difference in atmospheric CO_2 if we burn coal and save trees or if we burn trees and save coal. This manuscript compares the alternatives.

Through a simple model of carbon flows I compare net reductions of emissions of CO_2 to the atmosphere for various combinations of: 1.) the existing land use, 2.) the anticipated growth rate of trees, 3.) the fate of trees once they reach maturity, 4.) the efficiency with which trees are used once harvested, and 5.) time. The analysis focuses on the net carbon benefit and does not consider other factors that would enter into forest management decisions.

The model shows that when there is an existing forest and either low growth-rate potential or a large energy cost involved with harvest and use, the most carbon efficient solution is to protect the forest to store carbon. On the other extreme, where the land is not currently occupied with trees, when the potential growth rate is high and the harvest can be used efficiently, the most carbon efficient solution is to maintain a tree plantation and to use the harvest to displace fossil fuel emissions. This manuscript describes the intermediate cases, some of the nuances, and some semi-quantitative aspects of the model.

*Managed by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400 with the U.S. Department of Energy.

DISCLAIMER

It has been suggested that, since growing trees remove CO_2 from the atmosphere, tree planting could be used to offset the CO_2 which is released to the atmosphere when fossil fuels are burned. Consider a quick calculation. U.S. emissions of carbon dioxide from fossil fuel burning amounted to about 1.3 billion tons of carbon in 1990. If we divide this by the average annual rate at which forests in the contiguous 48 U.S. states take up carbon now, about 1.2 tons of carbon per hectare per year (286 million tons of carbon per year divided by 243 million hectares of forest and woodland, numbers from Turner et al., 1993), we find that it would take 1.1 billion hectares of forest to take up in trees and forest soils the carbon we discharge from burning fossil fuels. This is about 40% larger than the land area of the contiguous 48 states. The U.S. is not going to balance all of its CO_2 emissions by taking up carbon in forests resembling those we have now. We should also note that the uptake of 286 million tons of carbon per year in existing forests is possible only because of the continuous removal of carbon through harvests, and the re-creation of young, vigorously growing stands. To a first approximation, mature forests are no longer increasing in mass and hence are no longer taking up carbon.

Acknowledging that land available will limit how much carbon can be taken up in growing trees and that the growth cycle of trees will limit the length of time over which this uptake can be maintained, we have to ask how best to use the land which is available, and how much might be accomplished.

It is often assumed that trees grown to offset CO_2 emissions need then to be preserved in order to keep the CO_2 from returning to the atmosphere. My contention is that, in terms of atmospheric CO_2, a tree performs equivalently if it stores carbon or if its conversion to CO_2 displaces some other source of CO_2 that would otherwise be released. There is no difference in atmospheric CO_2 if we burn coal and save trees or if we burn trees and save coal. I will compare the alternatives.

Let me emphasize at this point that the rest of this discussion is focused primarily on carbon flows. I don't mean to imply that carbon management should be other than one of several criteria that influence land-use and forest-management strategies -- yet it is a new criterion, our concern here is with global climate change, and it is useful to isolate and examine the implications for net CO_2 emissions.

Figure 1 illustrates in simplest terms two fundamental tree-growing strategies that might be considered: using growing trees to offset emissions from the energy sector, and using trees to displace emissions from the energy sector. I consider some variations on these strategies below. Figure 1 is strictly schematic and doesn't allow us to make quantitative comparisons, but it does suggest some of the factors we ought to evaluate in making quantitative comparisons. In particular, time is important. Looking at the figure as drawn, we would conclude that, over short time intervals, path B was to be preferred to path C, whereas when evaluated over longer times, path C appears to be the better choice. Also, paths C and D imply use of larger land areas than does path D because part of the energy contained in the harvested wood (or energy from fossil fuels) needs to be used when the trees are maintained, harvested, hauled to market, and prepared as fuel. The rate at which trees take up carbon, that is their growth rate or productivity, is also a very important factor.

We have built a mathematical model of carbon flows in a forest in order to compare different management strategies (see Marland and Marland, 1992). The model is very simple and the results should be taken as indicative rather than demonstrative, but it does allow us to contrast the alternatives. Consider four possibilities: 1.) trees are planted where trees did not previously exist and are left in place to sequester carbon, 2.) trees are planted where trees did not previously exist but are managed for rapid growth and are harvested regularly to be used as a fuel, 3.) standing forests are cut and replaced with plantations which are managed for rapid growth and are harvested regularly to be used as a fuel, and 4.) standing forests are preserved and managed to store carbon.

I should make clear that my reference to using wood as a fuel does not suggest fireplaces and wood stoves. To make a meaningful impact on atmospheric CO_2 emissions, wood (or biomass generally) has to be used with high efficiency to supply a modern energy carrier such as electricity or a liquid transportation fuel like ethanol.

If a tree takes up 1 kg of carbon, it has offset 1 kg of carbon discharged from, say, a coal-fired power plant. If we harvest that 1 kg of "tree carbon" and use it to supply energy, how much "coal carbon" or "oil carbon" can we leave in the ground, how much can we displace? Not much unless we are able to convert the "tree carbon" to useable energy with high efficiency. Our model considers how much carbon in the trees is lost during the harvest, how much fuel is needed to manage and harvest the trees and haul them to a power plant, and how efficiently wood can be converted into electricity. If we could convert wood to electricity with the same thermal efficiency as we do now for coal (such processes are being developed but for now the conversion is generally much less efficient, largely because of the high water content of wood), a kg of carbon in the forest could displace about .75 kg of carbon in coal. If we look at the energy losses encountered in converting wood to ethanol, it is more likely that a kg of "wood carbon" would displace only about half of this much "oil carbon" when used as a transportation fuel. The bottom line of this discussion is that carbon taken up in a tree to be left in the forest provides an essentially full offset of CO_2 emissions, but the rate of this offset will shrink as the tree matures. On the other hand, carbon taken up in a tree to be harvested for fuel provides only a partial (depending on the efficiency of conversion to useful energy) offset, but this offset can be continued indefinitely as long as we maintain the forest plantation.

The rate at which trees grow (i.e. take up carbon) is another important consideration. Harmon et al. (1990) examined the fate of the forest carbon when an old-growth forest was harvested. They showed that although some of the carbon ends up in long-lived products like construction lumber, the net amount of carbon stored in the living forest plus long-lived wood products did not recover for at least 250 years to the pre-harvest level, because of the slow growth of the forest toward its pre-harvest state. Although I would change their numbers a bit, because they did not give credit for the fossil fuel which was displaced by burning some of the forest products (Marland and Marland, 1992), the point is well made that it can take a very long time to get back to the starting point when the growth rate is slow.

Figure 2 shows some of the output from our model. Again, I would emphasize the qualitative conclusions of the model without belaboring the details of the input assumptions or the numeric output. The figure does make clear that there is not a single answer for managing forests to minimize net CO_2 emissions. The best choice for any given area depends on the characteristics of the area: whether it is already forested, what level of productivity can be expected, how much energy does it cost to manage the forest and convert the product into useful energy, how long a time perspective do we have. The figure is based on the average carbon saving per year when averaged over 50 years and both the carbon offset and the carbon displacement are counted. For areas not now occupied by forest, the maximum carbon benefit is achieved by simply planting trees and allowing them to stand and sequester carbon - when the expected productivity is less than about 4 tons carbon per hectare per year. For higher productivities, greater carbon benefit can be achieved by harvesting the trees and using them to displace fossil fuels, although very high productivity is required unless conversion from standing trees to useful energy is accomplished with high efficiency. If we were to average over longer times, the crossover point would move toward lower productivity because even the slow-growing trees would begin to mature and take up carbon less rapidly. for areas with pre-existing

To conclude this discussion of the potential for reforestation or biomass energy crops in the U.S., it seems appropriate add a few words about the potential in the rest of the world. Discussion often focuses on the tropics because it is there that we are most conscious of current deforestation, and because in some tropical environments it is possible to get very high productivity. However, for all of the considerations of the land available and the potential for planting trees around the world, we recognize that the task is immense. In 1988 an independent power producer, Applied Energy Services, conceived a plan to offset CO_2 emissions from a U.S. power plant with a forestry project in Guatemala. Looking broadly at the project from 1992, Trexler et al. wrote, "There is also so much momentum built into the deforestation process in the form of population growth and rural settlement efforts that actually reversing current trends poses mammoth difficulties....(I)t would be a remarkable achievement...to bring the terrestrial biota into a CO_2 balance...It is even harder to conceive of an effort large enough to offset a significant portion of rapidly rising fossil fuel emissions of CO_2." This is not so much a statement of futility as a recognition that if deforestation is to be slowed, people must have a substitute for the goods and services sought from the forest. In the Guatemala project, 90% of the stemwood to be grown will be harvested for a variety of uses. The carbon benefit is achieved through substitution of sustainably produced wood for unsustainable harvest of the standing forest (Trexler et al., 1992). Unfortunately, "Guatemala's rural poverty, its 3-percent population growth rate, the on going migration of people from the countryside into the city, and the country's perennial political instability raise serious questions about the long-term robustness of the carbon-sequestering estimates" (Trexler et al., 1992). For the time being, the project addresses local self-interest, it provides some net-CO_2 benefit, it gives value to planting trees. It recognizes that the key is sustainable use.

To summarize, tree planting cannot provide a panacea for confronting increasing atmospheric CO_2. It can contribute, both through planting additional areas of forest or tree plantation and through protection of existing forest lands. In many instances it is appropriate to harvest trees from sustainable plantations to provide energy or other services because these tree products displace emissions from other sources and maintain a young, vigorously growing tree population.

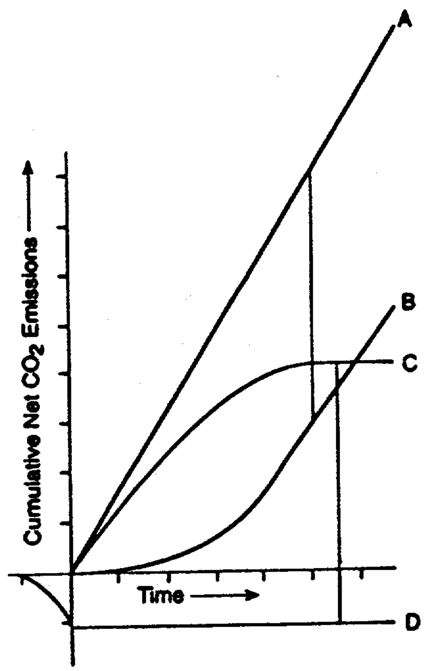


FIGURE 1: Schematic representation of cumulative net emissions of CO_2 as a function of time for various combinations of a coal-fired electric power plant and forest management strategy. Path A shows the uniform increase of cumulative emissions from the coal-fired power plant. If enough trees were planted so that CO_2 emissions from the power plant were exactly offset by the photosynthetic uptake of carbon in young, rapidly growing trees; the cumulative emissions for the sum of power plant and tree plantation would follow path B. The latter part of path B shows net emissions growing parallel to those of path A as the mature forest no longer has a net uptake of carbon. Path D represents the net emissions from a power plant which burns wood from a sustained-yield energy plantation established where trees did not previously exist. Path D envisions that a tree plantation is established some years prior to operation of the power plant so that the plantation can be partially harvested each year to fuel the power plant while new trees are planted to maintain the CO_2 balance. Path C also represents emissions from a power plant which burns wood from a sustained-yield plantation but in this case the plantation was planted after the harvest and burning of a pre-existing forest. The distance between paths C and D is related to the amount of carbon which was held in the pre-existing forest.

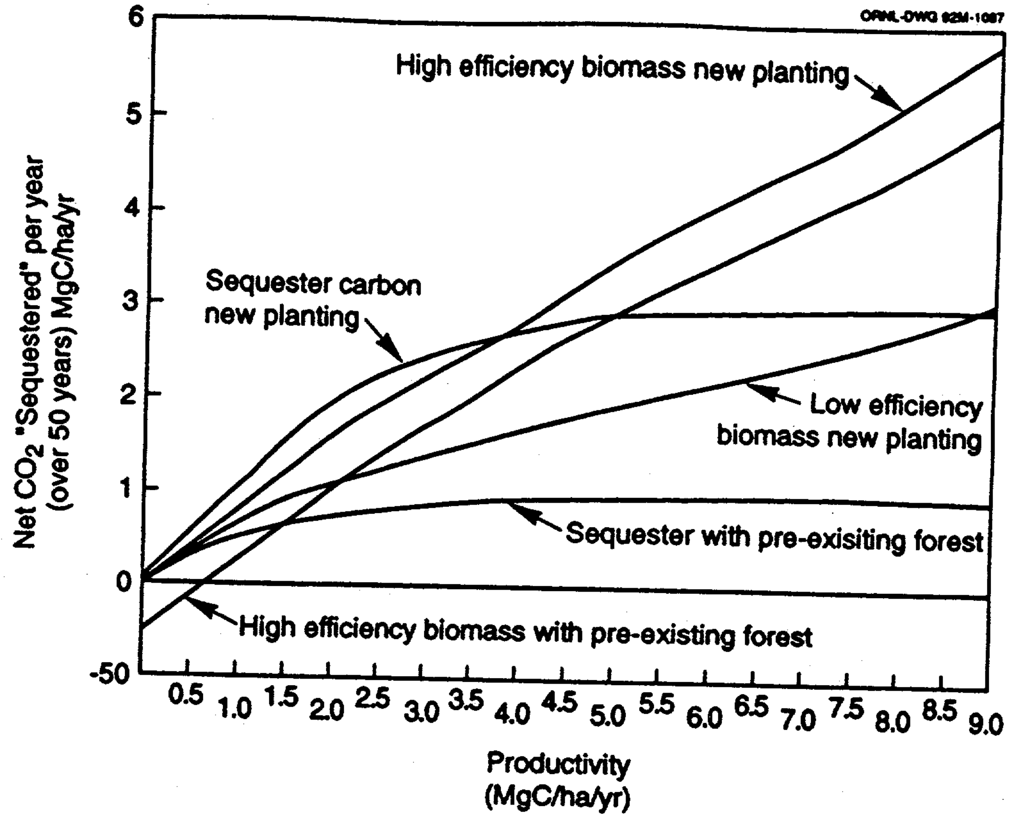
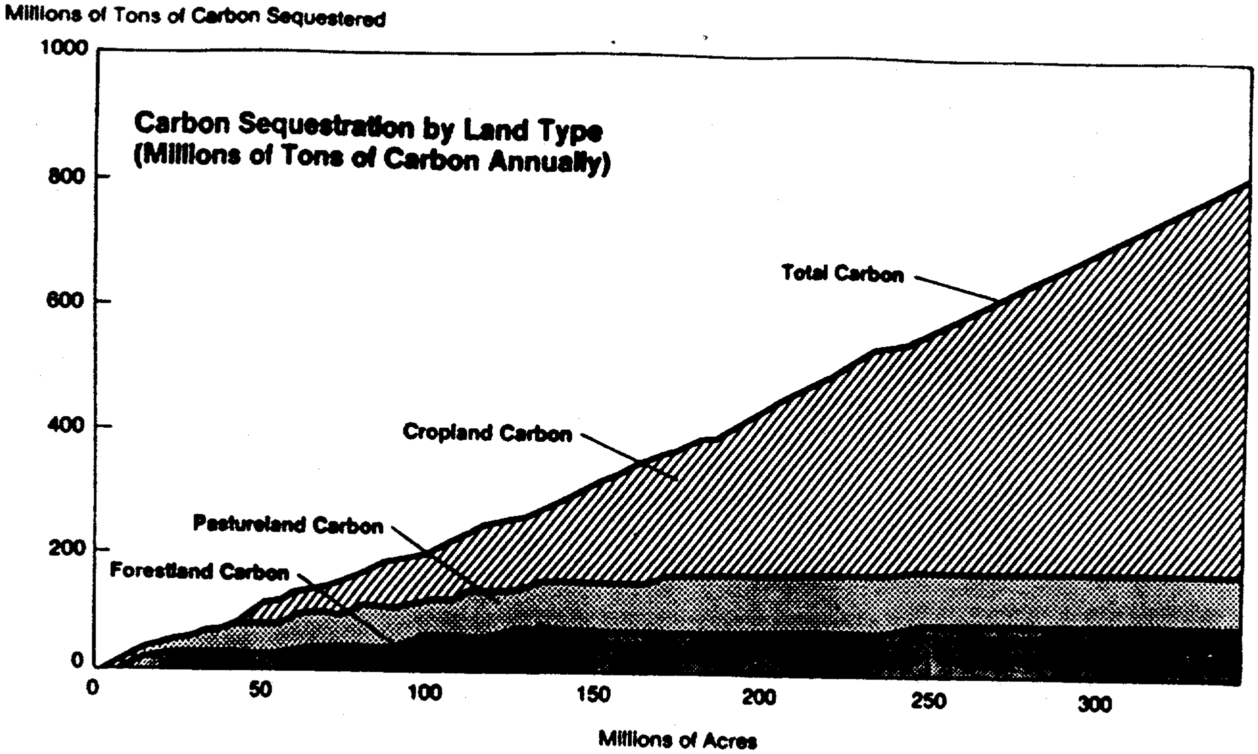


FIGURE 2: Output from a simple model of carbon balance in a forest system (see Marland and Marland, 1992) shows that biomass fuel plantations can, under some circumstances, result in more net "sequestering" of carbon than would simple storage of carbon in standing trees. The advantage of the biomass plantation increases with plantation productivity and with the efficiency with which the biomass is produced and used, and depends on how the site was occupied prior to establishment of the plantation. This model run assumes that the maximum standing biomass which can be supported on the site is 150 Mg C/ha (1 Mg = 10^6 g = 1 metric ton) and that forest productivity is initially at the rate described on the abscissa but approaches 150 Mg C/ha asymptotically. Carbon "sequestered" includes both the increase in standing mass in the forest and the displacement of CO_2 emissions when biomass is substituted for fossil fuels. "High efficiency" means state-of-the-art efficiency for plantation management and substitution for caol at a coal-fired electric generating plant. "Low efficiency" is fuel substitution at half of this net system efficiency and is near what might be envisioned for a system producing liquid transportation fuel from cellulose. Values for carbon sequestering are the average over the first 50 years. Consideration of longer time intervals would increasingly favor biomass fuels.



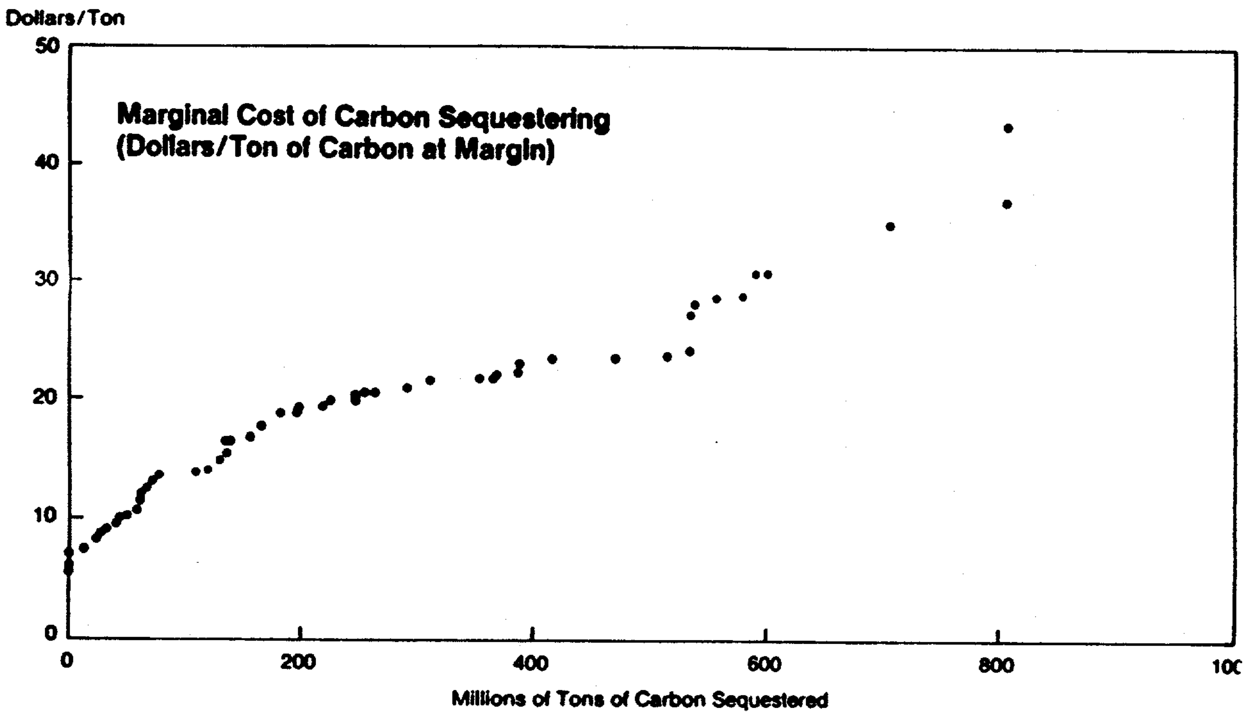


FIGURE 3: Estimates by Moulton and Richards (1990) of the land available for reforestation in the U.S. and the cumulative amount of carbon which would be sequestered annually (above) and of the amount of carbon which can be sequestered and the cost per ton of the carbon sequestered (below). The text above suggests that the numbers on these figures are optimistic but that the shapes of the respective curves are revealing, as is the relative portions of the 3 types of land in the upper plot.
(Tons here are short tons whereas through the rest of this paper metric tons are used (1 short ton = .9 metric ton).

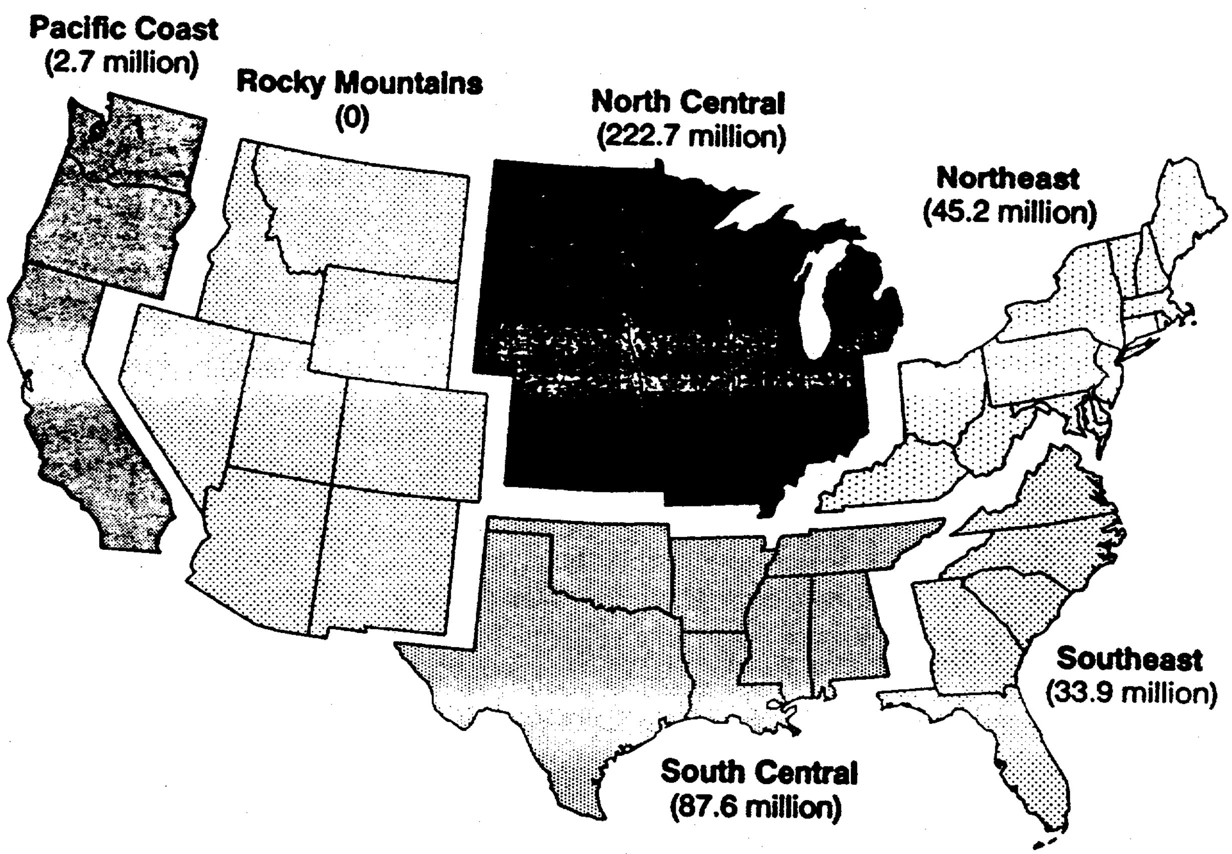


FIGURE 4: Land areas of the United States, by region, which are considered capable of supporting production of wood energy crops without irrigation. (Areas are in acres where 2.47 acres = 1 hectare. The total is about 392 million acres or 160 million hectares.) The portion of this that will support a productivity of at least 2.5 tons C/ha/yr is estimated to be 52 million hectares (128 million acres) in the north central region, 19 million hectares (46 million acres) in the south central, 10 million hectares (25 million acres) in the northeast, 10 million hectares (24 million acres) in the southeast, and 1 million hectares (2 million acres) in the Pacific coast region. From Wright et al. (1992).

Harmon, M.E., W.K.Ferrell, and J.F. Franklin, 1990, "Effects on Carbon Storage of Conversion of Old-Growth Forests to Young Forests". Science 247:699-701.

Marland, G., and S. Marland, 1992, "Should We Store Carbon in Trees?" Water, Air, and Soil Pollution 64:181-195.

Moulton, R.J., and K.R. Richards, 1990, "Costs of Sequestering Carbon Through Tree Planting and Forest Management in the United States". General Technical Report WO-58, U.S. Department of Agriculture Forest Service.

National Academy of Sciences, 1992, "Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base". Panel on Policy Implications of Greenhouse Warming; Committee on Science, Engineering, and Public Policy; National Academy of Sciences, National Academy of Engineering, Institute of Medicine; National Academy Press, Washington D.C., 918 pp.

Parks, P.J., 1992, "Converting Marginal Crop and Pasture Land to Trees and Forests". pp. 97-121 *in* R.N. Sampson and D. Hair (eds.), Forests and Global Change, Volume One: Opportunities for Increasing Forest Cover, American Forests, Washington D.C.

Trexler, M.C., L.A. Loewen, C.A. Haugen, 1992, "Global Warming Mitigation through Forestry Options in the Tropics". pp. 73-96 *in* R.N. Sampson and D. Hair (eds.), Forests and Global Change, Volume One: Opportunities for Increasing Forest Cover, American Forests, Washington D.C.

Turner, D.P., J.J. Lee, G.J. Koerper, J.R. Barker, 1993, "The Forest Sector Carbon Budget of the United States: Carbon Pools and Flux Under Alternative Policy Options". EPA/600/3-93/093, U.S. Environmental Protection Agency, 202 pp.

Wright, L.L., R.L. Graham, A.F. Turhollow, and B.C. English, 1992, "Growing Short-Rotation Woody Crops for Energy Production". pp. 123-156 *in* R.N. Sampson and D. Hair (eds.), Forests and Global Change, Volume One: Opportunities for Increasing Forest Cover, American Forests, Washington D.C.