The Science and Application of Forest Carbon Projects

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Key Words

Global warming, carbon sequestration, tree planting

This year—1999, now in its 7th month—is well on its way to becoming the hottest year in what has already been documented as the hottest decade on record both in the United States and worldwide. This makes a good setting for discussing global climate change, a much better setting than, say, the second week of a record-setting cold spell in February, 1999 when some climate change conferences were held, when one wondered if the locals might turn out at any moment carrying signs reading "Welcome Global Warming."

My comments focus on the planting of forest trees to sequester carbon dioxide, the primary greenhouse gas contributing to global climate change. This focus on tree planting is consistent with the Kyoto Protocol of December 1997, which gave emphasis to land-use changes—especially the extent and condition of forests—and to afforestation and reforestation, which are topics of particular interest to all of us concerned with nursery management.

I am addressing 2 concepts for your consideration. First, tree planting for climate change has the potential to become much larger than any prior tree planting program. Second, as nursery managers, you may have insights and data that could advance the understanding of the probable impacts of climate change on our forest resources.

Carbon is Okay

The carbon atom is the basic building block of life, as we know it on Earth. All living things contain carbon, so we can say that,

Life = f (carbon)

That is, life is a function of carbon.

Because carbon is a basic element, its amount in the universe is constant. The problem, then, is neither carbon nor its amount, but where and how it is found: there is simply too much carbon in the atmosphere in the form of carbon dioxide (CO_2).

Atmospheric Carbon is Clearly on the Increase

From 800 to 1,800, the concentration of CO_2 in the atmosphere stayed within the range of 275 to 285 parts per million on a volume basis (ppmv). This was known, but not given much attention, even as late as the 1960s. It was widely believed that world's carbon was in balance. This was sometimes described, in simple terms, as an equation with the green plants on one side and animals on the other. Green plants with their gift of photosynthesis take in CO_2 and emit oxygen (O_2), while the animals require O_2 and emit CO_2. Meanwhile, the oceans in their vast expanse, covering 70% of the Earth's surface, act as a buffer with a two-way exchange, either taking in or releasing CO_2 depending on the temperature of the surface waters and the relative concentration of CO_2 in the water and in the atmosphere.

Interestingly, green plants also require O_2 and emit CO_2 through respiration, as they draw upon their reserves of carbon-rich sugars and starches created during photosynthesis, for growth and other essential processes. Trees are net emitters of CO_2 whenever the rate of photosynthesis falls below the rate of respiration, as commonly occurs during seasonal dormancy, at night, and even during extended periods of overcast days during the growing season. Tree roots also require O_2 and release CO_2.

Fortunately, the O_2 requirement of healthy, growing trees is small compared to their production of oxygen and intake of CO_2, and the surplus carbon taken in is stored in the tree's roots, stem, branches, and foliage. Approximately one-fourth of the live (green) weight of wood and one-half of the dry weight of wood is solid carbon.

In 1956 meteorologists at Mauna Loa, Hawaii documented readings of atmospheric CO_2 that were consistently above the normal range. Actually, this had been going on for some time, and data from other stations in both the northern and southern hemispheres confirmed that CO_2 levels had been rising since the advent of the industrial age and the attendant increased consumption of fossil fuels. By the mid-1990s CO_2 levels were at 360 ppmv and still rising.

There is no serious debate among scientists about the increased concentration of atmospheric CO_2. What this means in terms of changes in the climate, however, is more contentious. Notwithstanding, the Intergovernmental Panel on Climate Change (IPCC) has cautioned that there is evidence of a discernable human influence on global climate. This, in turn, has led to the call for concerted international action with a major role assigned to forestry since at least 1989. (See "Forestry in United States Climate Change Action Plans: "From the Arch to Kyoto" in suggested readings section.)

Climate Change Impacts

The IPCC has estimated that the average global temperature has increased by 0.5 to 0.8 °C (about 1 to 1.5 °F) from the beginning of the industrial revolution in 1880 to the present and that temperature is likely to increase by another 3 °C with an error of plus or minus 1.5 °C (a range of 2.7 to 8.1 °F) sometime in the next century as the level of atmospheric CO_2 doubles over current readings. An increase in temperature of this magnitude has never been witnessed during the span of human existence, nor have scientists been able to reconstruct from historic evidence that a temperature increase of this magnitude has ever occurred. It is known, however, that the last Ice Age was caused by a drop in temperature of only 2 °C (3.6 °F).

Early speculation that the Earth is on a doomsday path with the oceans rising hundreds of feet and the occurrence of other catastrophic events have moderated, and, in fact, there may even be some benefits associated with climate change. The general consensus today is that temperatures near the equator will change little, but temperatures will rise in the temperate and boreal zones. Mean sea level may increase by 15 cm to 95 cm (6 to 37 in), due mainly to thermal expansion of sea water, and there will be an increase in floods, droughts, wildfire, and infectious diseases.

At greatest risk are people in the poorest nations and natural ecosystems. Much of the world's human population and associated infrastructure is located in low-lying coastal areas. Coping with coastal flooding and other climate-induced events would be costly but possible in the United States and other wealthy nations, but nearly impossible in many of the poor nations.

Natural ecosystems at greatest risk are those already under stress and those with limited mobility and few suitable alternative locations. Coral reefs, coastal wetlands, and maritime forests could be extensively damaged, as could alpine and subalpine forests.

Recent studies suggest that Great Lakes shipping could benefit from an extended ice-free shipping season due to warming in the United States and Canada. Production may also be increased in agriculture and forestry in these countries, due to a longer growing season and increased rates of crop and tree growth in a CO_2 enhanced environment. The Corn Belt could move northward toward Canada, and over time tree species would also shift to the north.

One positive effect of the concern over climate change has been the great expansion of research in the physical sciences. Exciting work is being done at an accelerated pace on weather systems, ocean currents, carbon in agricultural soils, and forestry to name but a few areas of study. Climate change research is in its infancy, and much is yet to be learned. It is in this context that I invite members of the tree improvement and nursery profession to consider how their special knowledge could contribute to a greater understanding of how different climate change scenarios could impact our forests.

Current forest research on the adaptation of forest communities to climate change has focused largely on how changes in CO_2, temperature, and moisture affect the growth and vigor of existing trees in various age classes. This is important and critical work, but I would like to see the experts in tree improvement and nursery science move ahead to the next phase and look at the immediate and long-term effects of these climate variables on the life cycle of trees during highly critical periods, such as flower and fruit setting and germination. Here are 2 examples:

"We know that many forest trees do not produce good crops of seeds every year; instead, a good seed crop tends to occur every other year, or perhaps, only once in every 3 to 5 years, and that the best seed years are associated with alternating crisp cool nights and warm sunny days. But a likely consequence of climate change will be warmer nights, due to an increase in low clouds, and fewer cloudless days.

Certain species of trees have chill requirements for fruit setting and seed germination. What would be the consequences of warmer and shorter winter seasons?"

Climate change models cannot yet give forecasts of weather conditions for specific regions or local areas. But likely scenarios can be developed to reflect a range of different conditions. With specific knowledge and records (for example, annual seed production in orchards), it should be possible to determine some of the probable consequences of climate change on natural stands and on seed orchards. Would it become prudent to relocate or expand the size of seed orchards and to gather and store more seeds during good seed years? Nurseries use refrigeration to stratify seeds, and in this respect, are not dependent upon nature, but might there be other problems? Alternatively, it may be found that forests are highly resilient and few significant problems are likely to occur. If so, this would be an important finding to document.

The Dual Role of Forests

The United States Geological Survey estimates that on a worldwide basis the destruction of forests through deforestation—mainly in the form of land clearing for agriculture in the tropical countries—annually releases about 30% as much CO_2 as, and is second only to, the burning of fossil fuels.

In contrast to the world situation, the forests in the United States are relatively young, following the occurrence of extensive logging at the turn of the last century and continued logging since then and, on the whole, have been increasing in wood volume and other biomass and, hence, in the amount of carbon stored. Birdsey and Heath of the Northeastern Forest Experiment Station estimate that, for the period 1950 to 1990, United States forests added an average of 309 million tons of carbon per year, enough to offset 25% of our CO_2 emissions from the burning of fossil fuels. They estimate, further, that for the 1991 to 2040 period, United States forests will offset 202 million tons of carbon per year, or 15% of projected US fossil fuel emissions.

Tree Planting to Sequester Carbon

More than a dozen forestry related options to reduce CO_2 emissions and to increase the storage of carbon in forests (sinks) have been proposed (Table 1). Several of these actions are already being implemented and others may become commonplace, simply because reducing United States emissions to a level 7% below 1990 levels—as currently called for in the Kyoto Protocol—through the reduction in fossil fuel emissions alone, is unrealistic. Transportation, electric power generation, manufacturing, farming, our homes, and our very life styles are based on the use of fossil fuels, and this cannot be rapidly nor radically changed without causing major disruptions.

The planting of forest trees to increase the extent of forests and growth of biomass on poorly stocked existing forest land was recognized in the Kyoto Protocol developed by the international community in Japan in 1997. If this protocol is ratified by the United States Senate, it will attain treaty status and become a legally mandated, national commitment.

Tree planting is a well-established technology. Currently, about 2.5 million acres are planted annually using over 1.6 billion trees. Most tree planting (almost 90%) occurs on private sector lands: companies in the forest industry and nonindustrial private landowners each planted over 1 million acres in 1997. Forest carbon projects can be undertaken on all ownerships, but

Table 1. Forestry Options to Reduce Emissions or Enhance Sinks

1. Reduce conversions of forests to other land uses (deforestation)
2. Increase afforestation
3. Increase reforestation
4. Reduce timber harvesting
5. Improve logging techniques to avoid damage and losses to residual growing stock
6. Reduce wildfire losses
7. Reduce energy use in growing, harvesting, and processing
8. Increase recycling of wood and wood products
9. Replace fossil fuels with biomass for energy (short rotation woody crops, residues)
10. Extend the life of forest products (improved design, better preservative treatments)
11. Substitute wood for more energy-intensive products, like steel and concrete
12. Increase agro-forestry
13. Increase the planting and care of urban trees

Source: Moulton 1998

nonindustrial private owners almost certainly will be in the forefront, as they own the agricultural land suitable for afforestation and, by far, the greatest share of forest lands in need of reforestation.

As shown in Figure 1, tree planting in the United States has increased from less than one-half million acres in 1950 to 2.5 million acres annually in recent years. Two peak periods of planting have occurred during this period. The first is the Soil Bank Program (1956 to 61), during which 2.2 million acres were planted, and the Conservation Reserve Program, which added another 2.2 million acres during 1986 through 1989 and a total of 2.8 million acres to date. These programs, as well as tree planting on private lands through the Forestry Incentives Program (FIP) and the Stewardship Incentive Program (SIP), have given us experience in delivering federal tree planting programs on private ownership. We know what incentives are required to attract private landowners to participate and have proven the effectiveness of delivering Federal forestry programs through the State Forestry agencies, and we have a solid infrastructure of public and private nurseries, tree planting vendors, and consulting foresters available to get the job done.

Curbing emissions and sequestering enough CO_2 to bring our emissions down to 7% below 1990 levels will be an immense undertaking, requiring tree planting on a scale far exceeding the programs of the past: doubling annual tree planting to 5 million acres over a 5 year period and keeping it there for at least 10 years to add 20 million acres of additional planting may be required. Whether this ever occurs, and the actual extent of a forest carbon program, depends on many factors, including whether there are any major breakthroughs in the science of climate change, whether international agreement can be reached on carbon trading between nations, and how zcarbon stocks are to be measured in existing forests and in any new projects.

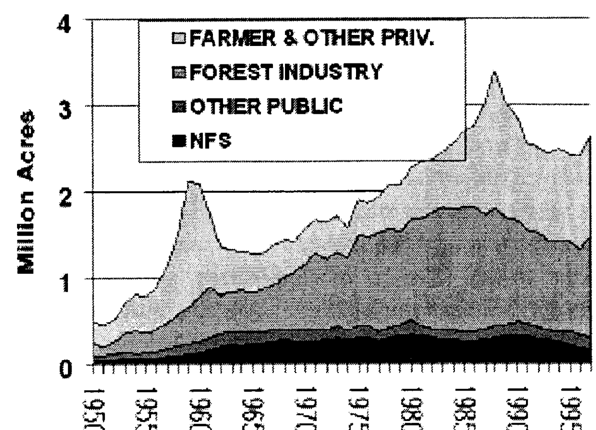

Figure 1. Tree planting in the United States from 1950 to 1997.

Concluding Comments

Tree planting for global climate change has the potential to be large—indeed, very large. And members of nursery associations will be in the midst of it all, trying as always to forecast tree stock needs 1 to 4 years into the future.

I also encourage you to consider, as mentioned earlier, how changes in climate may affect our forest trees during critical life stages, such as during seed formation and during germination. The variability associated with climate changes should be used to update current thoughts on tree planting and nursery management.

SUGGESTED ONLINE READINGS

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