Christmas Tree Carbon Science, Part I: What It Is It And Why Should You Be Interested?

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Carbon. What is it, and why should you, a Christmas tree grower, be concerned about it? Simply put, carbon is an atom, and is one of the building blocks of all living things. In the media, however, the term "carbon" is used when really what is meant is "carbon dioxide". Carbon dioxide (CO_2) is an odorless, colorless gas molecule. It is produced when cells and animals respire (breathe), and also when organic matter, such as wood or petroleum products, is burned. No matter what its source, all forms of CO_2 are the same; there is no such thing as "good" CO_2 or "bad" CO_2.

Carbon dioxide makes up only a tiny fraction of the earth's atmosphere, but it has an important job of absorbing and trapping heat in the atmosphere. While atmospheric CO_2 absorbs a small amount of the heat coming from the sun, it is especially good at trapping heat that radiates from the earth. As a result, CO_2 and certain other gases (like methane and nitrous oxide) help to warm the earth's atmosphere and surface. This is often referred to as the "greenhouse effect," because these gases act like a greenhouse over the earth's surface, trapping heat.

During the last 400,000 years, CO_2 levels in the earth's atmosphere have ranged between 175-300 parts per million (ppm). Since the end of the last ice age about 10,000 years ago, CO_2 levels in the atmosphere have been relatively constant between 260-280 ppm until the end of the 19th century (Petit et al. 1999). However, starting in the late 1800s (the Industrial Era, when large-scale factories started operating in Europe and the U.S.), atmospheric levels of CO_2 have risen steadily from 280 ppm to the current level of about 385 ppm (Figure 1)

Geological evidences suggest that current levels of atmospheric CO_2 are the greatest in earth's history since the appearance of plants about 400+ million years ago. This change in atmospheric CO_2 is important because scientists have shown direct links between the earth's surface temperatures and atmospheric CO_2 levels (see IPCC 2007). As you may recall from earlier in this article, this occurs because CO_2 absorbs heat (remember the greenhouse effect?). Normally, this is a good thing, because otherwise this heat would escape into outer space and the earth would be much cooler than its current day average of about 60° F. However, increasing levels of CO_2 in recent decades may be causing changes in temperatures, precipitation patterns, and consequently vegetation distributions (where plants can grow). Much recent research has shown that the world's average surface temperature has increased about 1.1° F in the past century, and is predicted to increase another 4-9° F in the next century (IPCC 2007). This increase in the earth's surface temperature is the "global warming" we hear about so much these days. What does this global warming mean for Christmas tree growers in North Carolina? We'll address this question in Part II of this article in the next edition of *Limbs & Needles*.

The good news for Christmas tree farmers is that planting trees fights global warming! This is because all plants photosynthesize. This is the process by which plant leaves absorb CO_2 from the atmosphere, combine it with sunlight energy and water, and make food (the sugar, sucrose) for themselves. This is often represented by the following equation:

$$6CO_2 + 6H_2O + \text{sun energy} \rightarrow C_6H_{12}O_6 + 6O_2.$$

Thus, it takes 6 molecules of CO_2 to make 1 molecule of sucrose sugar. (As a side note, this process occurs with about 33% efficiency, slightly greater than the 25-30% efficiency of modern automobile engines.) Previous research has shown that a black spruce tree farm in Canada can "sequester", or absorb from the atmosphere, between 0.2-1.2 tons of C/acre per year for Christmas tree-sized trees (1-7 ft tall and less than 20 years in the field; Gaboury et al. 2009). However, this research was conducted in Canada, with cooler temperatures and a shorter growing season than many Christmas tree farms in the U.S. There are no published results yet for

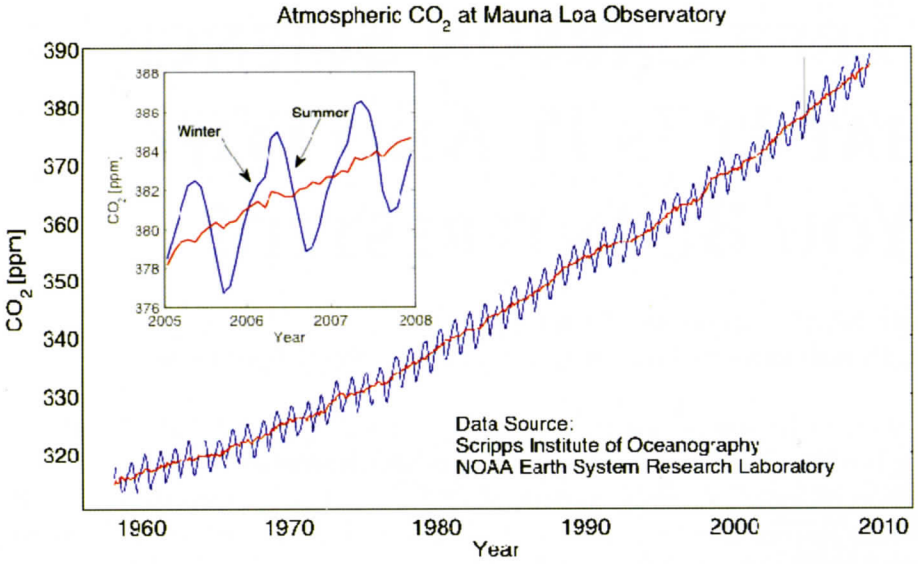

Figure 1. *Atmospheric CO_2 concentrations at the Mauna Loa Observatory in Hawaii from 1958 until 2008. The elevation of the sampling site and the isolation of the Hawaiian Islands result in measurements that are representative of the entire northern hemisphere. Monthly measurements are shown in blue, and a running average is shown in red. Concentrations decrease during the summer and increase during the winter because of differences in photosynthetic activity between the seasons (inset). The average concentration of CO_2 is increasing through time because more CO_2 enters the atmosphere each year than is removed.*

CO_2 sequestration rates of Fraser fir, although preliminary research by Dr. Ryan Emanuel at Appalachian State University suggests that Christmas tree farms in North Carolina could potentially sequester about 1.0 ton of C/acre per year. For comparison, the average American car emits about 1.5 tons of C into the atmosphere per year (http://www.greencarcongress.com/2009/04/epa-ghg-20090415.html).

While trees sequester, or remove, CO_2 from the atmosphere, they also release a little CO_2 back into the air due to respiration. Just like animals, the metabolic processes in plant cells "burn" sugars and oxygen to release energy, and release CO_2 as a by-product, which is then released from the cell to the plant leaf to the atmosphere. In addition to cellular respiration in plant tissues, respiration also occurs in the cells of organisms in the soil (e.g., bacteria, fungi, insects, etc.). In fact, the amount of CO_2 emitted by soil and plant respiration in a tree plantation may actually be greater than the amount of CO_2 captured during photosynthesis, especially in younger tree farms (Huang et al. 2007, Gaboury et al. 2009). Thus, any factors that slow down soil respiration, such as lower soil temperatures, decrease the amount of CO_2 released back to the atmosphere. Therefore, farming practices that increase photosynthesis and CO_2 capture from the atmosphere (such as optimal fertilization and soil moisture) and decrease CO_2 release back to atmosphere (such as maintaining beneficial cover crops to keep soil temperatures low) ultimately favors the "CO_2 budget" of a farm (see Figure 2). This is directly analogous to your own financial budget—you earn more profit by maximizing income while minimizing expenses. The good news for us is that many of the IPM and BMP practices you already use act to tip the CO_2 budget of our farms in the right direction (taking CO_2 out of the atmosphere and not releasing back)!

Let's look at this term "CO_2 budget" more closely. Often you will see this referred to as a "carbon budget". Either way, both terms attempt to summarize the carbon-sequestering ("carbon-negative") and carbon-releasing ("carbon-positive") activities of an operation. This concept is important in today's economy because environmentally responsible products ideally are either carbon-negative or carbon-neutral after one considers *all* the activities associated with creating and getting this product to the homes of consumers. A total carbon budget for a farm then is not just the CO_2 absorbed from the trees minus the CO_2 released from respiration processes. In fact, all activities that absorb or release carbon must be included in a CO_2 budget. Realistically, almost all of these activities release carbon back into the atmosphere—mowing, tractor operation, delivery of supplies to farms by motor vehicles, and shipping trees. Activities such as application of pesticides, herbicides, and fertilizers further impact the carbon budget of a farm because one has to operate cars or gas-powered machinery to purchase and apply these substances.

When trying to market natural Christmas trees as a "green", more environmentally responsible product compared to artificial Christmas trees, one has to consider more than just CO_2. Additionally, consumers wanting an environmentally responsible product are concerned with human health issues, environmental quality impacts, and the costs associated with obtaining resources for a product (i.e., mining, forestry operations). Much like the idea of a carbon budget, there are also terms for product "budgets" that weigh all these issues. Popular terms for such a product budget are "Cradle to the Grave" studies or "Life Cycle Analysis" (LCA). LCAs summarize *all* the positives and negatives of *all* activities associated developing a product and delivering it to the consumer.

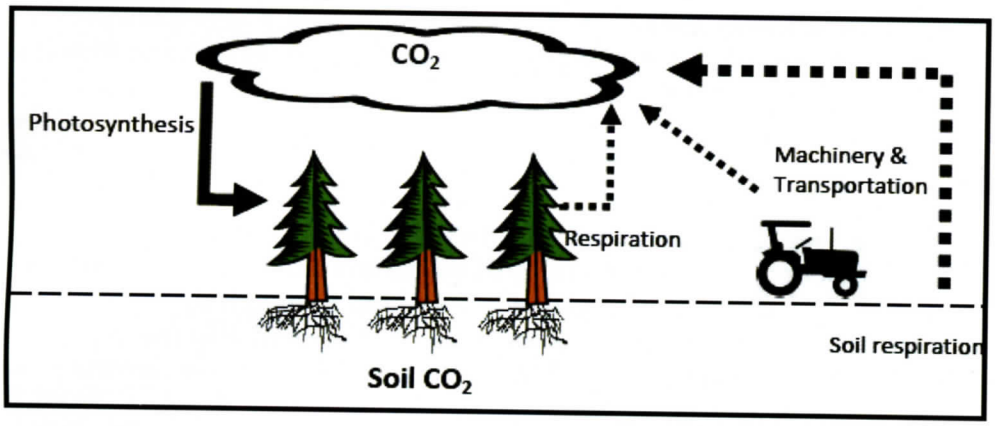

Figure 2. Conceptual diagram of CO_2 fluxes into and out of a Christmas tree farm. Black arrow represents CO_2 that is absorbed from the atmosphere, while the dotted arrows represent CO_2 that is released from the tree farm into the atmosphere.

To put this in our perspective, a recent report by a Canadian environmental consulting firm, Ellipsos, performed a study that compared the LCAs of natural vs. artificial Christmas trees (Couillard et al. 2009; read the full document at http://www.ellipsos.ca/site_files/File/LCA%20Christmas%20Tree-ellipsos.pdf). While limited in scope (they used just one Christmas tree field for their study), they found that the carbon balance for an individual natural Christmas tree was about +24 kg CO_2 over its entire life in the field (six years in this study). The "+" indicates that the overall process of growing a tree is carbon positive (actually releases more CO_2 than absorbs), after one considers all the labor, machinery, and transportation associated with growing that tree. However, the carbon balance of an artificial was estimated to be about +48 kg CO_2, most of which was associated with the manufacturing process and the initial transportation from China to North America. Therefore, while the net carbon budget for a natural tree in the field for six years still released some CO_2 back into the atmosphere, it was about half that of an artificial tree. Because the authors of this report calculated carbon budgets for natural trees based on burning of wood chips for energy at the end of their life cycle (vs. local mulching which is the common practice in North Carolina), the CO_2 budget for our farms may be closer to zero. (You *do* remind your customers to mulch, don't you?) Combining the climate change impacts with the

Ashe & Alleghany News

The Ashe and Alleghany County Christmas Tree Associations would like to invite you to participate in the 2009 Farm Expo in Laurel Springs, NC. This event is being co-sponsored by Ashe/Alleghany Christmas Tree Associations, North Carolina Cooperative Extension, Ashe and Alleghany Counties, Ashe/Alleghany Cattlemen's Associations and the Upper Mountain Research Station. The 2009 Farm Expo will target all agricultural commodity groups including Christmas trees, livestock, row crops, and small fruits and berries. Farmers from the entire High Country Region of NC and VA are encouraged to attend this broad based Farm Expo.

Find new ways to diversify your farm, learn about the newest tools of the trade, and enjoy tours of the beautiful Upper Mountain Research Station. Specialists from North Carolina State University, Appalachian State University, and North Carolina A & T University will be on-site to demonstrate the newest and best research on many different Agricultural commodities. Vendors from all areas of Agriculture will also be on-site and will be able to demonstrate new equipment and techniques.

The event will be begin at ***1:00 pm, Saturday, August 29, 2009 at the Upper Mountain Research Station,*** 8004 NC Hwy 88 East, Laurel Springs, NC 28644; located on NC Hwy. 88 East, two miles west of the Laurel Springs Post Office. Participants will pay a minimal entry fee which covers all of the educational programs as well as a farm fresh dinner prepared by the ***Ashe/Alleghany Cattlemen's Association.***

Please RSVP to the Ashe or Alleghany County Extension Office by August 17 in order to receive your dinner ticket!

A free junk swap will be held from 1:00 pm until dark if you have any used equipment that you are looking for or a home for some you no longer need.

If you are interested in participating in the junk swap, being a vendor or if you have any questions, please call the North Carolina Cooperative Extension, Ashe County Center (336) 846-5850 OR Alleghany County Center at (336) 372-5597. We look forward to seeing you at this event!

environmental and public health impacts, natural trees appear to be an even better choice to responsible consumers. According to this LCA study, consumers would need to display an artificial Christmas tree for more than 20 years in order for its benefits to rival that of natural Christmas trees!

In conclusion, Christmas tree growers need to understand the basics of carbon science not only to understand how their crop impacts global climate change, but also to know how this can improve the marketability of their trees. Because Christmas trees have the ability to absorb CO_2 from the atmosphere, Christmas tree farms have the potential to mitigate the increases in atmospheric CO_2, thereby slowing global warming. The total carbon budget of a Christmas tree plantation is determined not just by natural flows of CO_2 (photosynthesis, respiration), but also by all farm activities involved with growing trees and then getting them to people's houses. Furthermore, Life Cycle Analysis studies weigh not just carbon budgets, but also the impacts of a product on the environment and public health. A recent LCA found that natural Christmas trees are the more environmentally responsible choice, unless a customer uses an artificial tree for more than 20 years. Because the number of studies investigating carbon budgets in tree plantation is quite limited, much more research is needed in this area. In the next issue of *Limbs & Needles*, part II of this article will highlight current research on carbon in Christmas trees in North Carolina as well as the U.S.

Acknowledgments

The NCSU Christmas Tree Genetics program is grateful for ongoing financial support that promotes our cutting edge research of Christmas tree breeding, genetics, and physiology. Appalachian State University funded Dr. Emanuel's Christmas tree farm monitoring program.

Literature Cited

1. *Couillard S, Bage G, Trudel J-S. 2009. Comparative life cycle assessment (LCA) of artificial vs natural Christmas tree. Ellipsos report 1043-RF3-09.*
2. *Gaboury S, Boucher J-F, Villeneuve C, Lord D, Gagnon R. 2009. Estimating the net carbon balance of boreal open woodland afforestation: A case-study in Quebec's closed-crown boreal forest. Forest Ecology and Management 257:483-494.*
3. *Huang M et al. 2007. The ecosystem carbon accumulation after conversion of grasslands to pine plantations in subtropical red soil of South China. Tellus 59B:439-448.*
4. *IPCC. 2007. Climate Change 2007: The Physical Science Basis. Summary for Policymakers. IPCC, Geneva, Switzerland.*
5. *Petit JR et al. 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature 399:429-436.*