# AN OVERVIEW OF THE SIERRA ANCHA EXPERIMENTAL FOREST'S ROLE IN THE FREE-AIR CO¬2 ENRICHMENT LARGE WOOD DECOMPOSITION EXPERIMENT

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## INTRODUCTION

### Background: Duke University Free-Air CO2 Enrichment (FACE) Study

The Duke University FACE facility is located near Chapel Hill, in Orange County, North Carolina on the eastern edge of the North Carolina piedmont. The initial prototype plot was established in June, 1994 and eleven additional treatment plots were activated in August 1996 and operated until October, 2010 (http://face.env.duke.edu/main.cfm). To date, 263 publications have reported on results from the experiment. $CO_2$ enrichment was discontinued in October 2010 and the final harvest began. Trees for the decomposition study were harvested in early 2011. Later that year, the logs of three diameter classes representing different positions of the bole were sent to cooperators in the Southern Research Station, Northern Research Station, Rocky Mountain Research Station, Pacific Southwest Research Station, and the Pacific Northwest Research Station to be incubated on site for the Face Wood Decomposition Experiment.

Findings from the Duke FACE study showed that increased tree growth and changing soil chemistry and provided data to model of how forests will react to elevated $CO_2$. Water use efficiency and photosynthesis increased in trees grown under elevated $CO_2$, while total water use remained unchanged. The increase in water use efficiency was achieved through increased photosynthesis, not through decreased stomatal conductance (Ellsworth et al. 1995). Enhanced photosynthesis was observed for 10 years and the effect is more pronounced in current year needles than in older needles (Ellsworth el al. 2012). Nitrogen use efficiency increased as leaves acclimated to the increased $CO_2$ and one year-old needles allocated less nitrogen (N) to Rubisco, a major user of plant N (Crouse et al. 2008). Net primary productivity, growth rate, litter production and fine root production were all increased in elevated $CO_2$ conditions (DeLucia el al. 1999). Though growth and photosynthesis were increased overall, wintertime photosynthetic activity decreased compared to trees grown in ambient conditions, indicating increased overwintering stress for trees grown in the elevated $CO_2$ environment (Hymus et al. 1999).Trees grown in elevated $CO_2$ also reached reproductive maturity at a younger age and produced more seeds and cones than their ambient counterparts (LaDeau and Clark 2001).

Allen el al. (2000) observed that elevated $CO_2$ increased carbon input into the soil, but also increased belowground respiration thereby accelerating carbon losses. Similarly, it was found that increased allocation of carbon (C) underground enhanced microorganism activity and accelerated decomposition and tree N uptake, thus creating a positive feedback. On the ecosystem-level, tree mass was the main C sink while soil was not a significant C sink (Drake et al. 2011). Hofmockel et al. (2011) observed that in elevated $CO_2$ plots tree N sources shifted to the increased N mineralization in the organic and 0-15 cm soil horizon and to deeper rooting to maintain the increased growth.

Throughfall volume decreased as did the deposition of ammonium nitrogen, nitrate nitrogen, and hydrogen ion. Deposition of dissolved organic C and potassium increased (Lichter et al. 2000). At a depth of 200-cm soil solution cation concentration increased 271%, alkalinity increased 162%, and silicon concentration increased 25%. The flux of dissolved inorganic C to ground water increased 33% (Andrews and Schlesinger 2001). Microarthropod abundances deceased in the litter of elevated $CO_2$ plots, through this decrease was only significant in the oribatid mites. Though populations were smaller, the increased volume of litterfall increases microarthropod habitat and decreases habitat desiccation which should help mite populations rebound (Hansen et al. 2001).

## DECOMPOSITION

Large woody debris is an important component of forest biomass and plays many critical roles including preventing erosion, providing habitat for small mammals and birds, and providing a food source for arthropods and microorganisms. Despite having many important ecosystem functions, and being a major pool of detrital biomass and C sink, there is an inadequate understanding of factors influencing decomposition of large woody debris and no mechanistic models to represent decay across the United States. There are many factors affecting

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Table 1 FWDE sites; all of the sites are part of the Forest Service's Experimental Forest network except the Duke Forest (Trettin et al. 2011)

| Experimental Forest | State | Physiographic Setting | Ecoregion | MAP (mm) | MAT (C) | Elevation (m) | Station |
|---|---|---|---|---|---|---|---|
| Santee | SC | Coastal Plain | Warm temperate moist forest | 1350 | 18 | 0-10 | SRS |
| Duke Forest | NC | Piedmont | Warm temperate moist forest | 1200 | 15 | 200 | Duke University |
| Coweeta | NC | Mountain | Warm temperate wet montane forest | 1650 | 11 | 806 | SRS |
| Marcell | MN | Glacial Plain | Warm continental | 780 | 3.3 | 250 | NRS |
| Sierra Ancha | AZ | Mountain | Tropical/subtropical steppe mountain | 410-850 | 7 | 1460-1830 | RMRS |
| Tenderfoot Creek | MT | Mountain | Temperate steppe mountains | 810 | 5 | 1800-2400 | RMRS |
| Fraser | CO | Mountain | Cold temperate subalpine wet forest | 584 | .5 | 2680 | RMRS |
| San Dimas | CA | Mountain | Mediterranean mountain | 200 | 9.9 | 5100-8415 | PSW |
| Andrews | OR | Mountain | Marine Mountain | 2500 | 1.8 | 1350-5300 | PNW |

Figure 1. Vertically mounted logs

Figure 2. Horizontal log with soil gas probe

wood decomposition including: leaching, fragmentation, seasoning - a process of drying and shrinking in arid environments, respiration, and biological transformation. The FWDE provides the unique opportunity to examine all these processes with a common substrate across a wide range of climatic conditions.

The addition of the Sierra Ancha Experimental Forest to the FWDE provides several benefits to the study. It is one of the dryer sites with average annual precipitation of 834 mm (Gottfried and Neary 2001). It also has 10 years of climate data. It is estimated in the forests of Arizona that there are between 0 and 20 Mg/ha of large woody debris (Woodall and Monleon 2008). Understanding the processes influencing of the decay of this material is important for forest managers, especially in the face of climate change as rates of decomposition will likely be changing as well as inputs of new material.

## METHODS

The study uses nine different field sites across the United States in order to represent a wide range of climatic conditions (table 1).

There are a total of 48 Pinus taeda logs at each study site; twenty four logs grown in ambient $CO_2$ and 24 grown in elevated $CO_2$. The logs in each treatment are from trees cut into six sections. Since the log size and position in the bole are known to influence decomposition, there are three bole positions represented; upper, middle and lower. Half of the logs in each size class are mounted vertically to decompose like standing dead trees (figure 1), and half are placed on the ground to decompose as downed trees (figure 2). In addition, soil gas and soil water are sampled under 6 vertical and 6 horizontal logs. Soil temperature is measured in one location. Volumetric water content is measured in 6 logs, and temperature is monitored in 4 logs. Volumetric water content is measured with a CS616 and temperature is measured with a CS 107 (Trettin et al 2011).

## RESULTS AND DISCUSSION

There are few results to report in the first year of monitoring of this long term study. Based on personal observations the vertical logs are beginning to dry and shrink, the collars fitted to hold them up have needed to be tightened. The bark on the vertical and horizontal logs is beginning to slough off. And the horizontal logs are beginning to incorporate into the soil. So far none of the logs are showing significant insect damage.

The vertical and horizontal logs decompose at different rates because they are exposed to different microenvironments. The vertical logs are more exposed to wind and sun, and may experience greater daily temperature fluctuations. The horizontal logs are moister because they are adjacent to the litter and soil.

## CONCLUSION

Long term research such as the FWDE is essential to gaining a full understanding not only of how biogeochemical factors affect decay, but also how climate change will affect forest ecosystems and nutrient cycling. The Forest Service's experimental forest network is a great asset for long term research projects. In addition to the variables being monitored on the FWDE site at the Sierra Ancha Experimental Forest there is another long term study located two hundred meters away which is monitoring weather and canopy conditions. The information it provides will be able to complement the data collected on the FWDE. In order to answer questions about phenomena such as decomposition or climate a commitment to long-term research is required. Not only does long-term research answer long-term questions, it also can provide an anchor for other research. When certain infrastructure is in place such as weather monitoring stations, other short term research projects are easier to establish and provide can provide answers.

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