Change in biomass accumulation over thirty-seven years in a nutrient-limited, upland temperate forest

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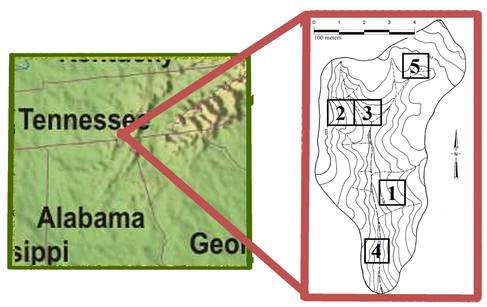
INTRODUCTION:

- Second-growth forests recovering from major logging disturbances are predicted to reach a steady-state condition in which aboveground biomass is maintained at a site-specific threshold. It may take as long as 170 years to achieve this steady-state condition.[1]
- Maximum biomass and rate of accumulation are influenced by factors such as stand age, climate, and edaphic factors.[2]
- Recent studies conclude that the maximum productivity threshold of many forests will be substantially increased in response to elevated CO_2 levels.
- However, model predictions suggest that the positive effects of increased CO_2 and changing climate on biomass accumulation may not be manifest in forests that are strongly nutrient-limited.[3]
- Therefore, long-term studies are critical to assess the patterns of biomass accumulation in forests where productivity is controlled by soil properties.

SITE DESCRIPTION:

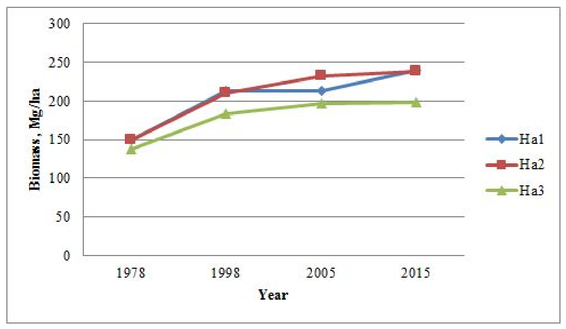
- Sampling took place in Cross Creek watershed in Franklin State Forest, located on the southern Cumberland Plateau in Tennessee.
- Watershed experienced heavy logging around 1900.
- Our study site was formerly part of a Tennessee Valley Authority (TVA) watershed ecosystem study conducted in the 1970s.[4]
  - Watershed exhibited a mean net loss of base cations, but a net accumulation of available nitrogen.



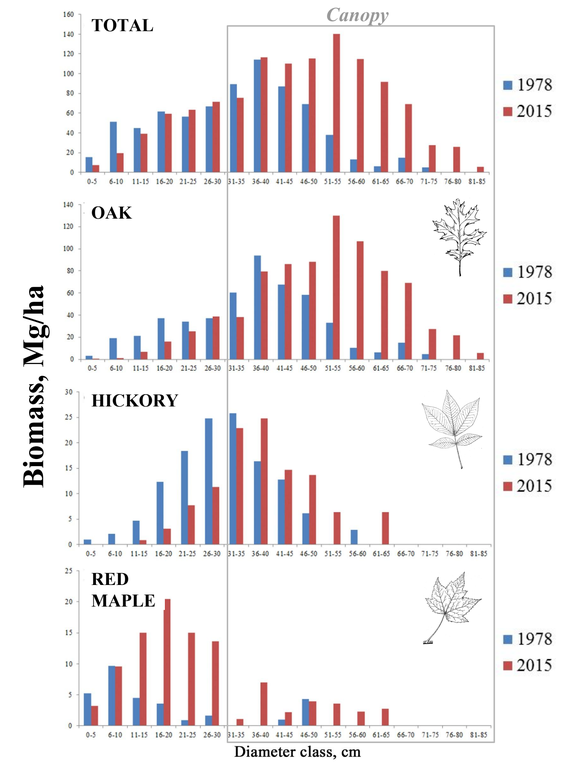
OBJECTIVES:

- To assess change in total aboveground woody biomass over time and determine trends in aggradation following long-term recovery from logging disturbance.
- To examine species-specific changes in biomass distribution among forest size classes.

RESULTS:



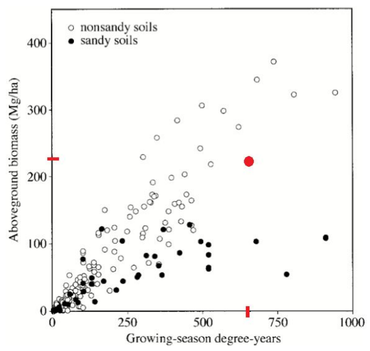
- Biomass significantly increased across all plots from 1978 to 2015 (repeated measures ANOVA p=0.0021).
- However, the rate of total biomass aggradation slowed substantially from 1998 to 2015, suggesting a plateau in aggradation (repeated measures ANOVA p=0.2528).
- The results for Ha1 show a drop in biomass followed by recovery, reflecting a multiple tree fall gap that occurred in 2005.



There was a significant shift in biomass distribution among size classes in the forest. Oak-hickory biomass in the subcanopy has decreased while red maple has increased over the thirty-seven year period. Two-sample two-sided Kolmogorov-Smirnov bootstrapped tests comparing diameter distributions in 1978 and 2015 find significant differences in all cases (p<0.0001).

DISCUSSION:

- The thirty-seven year time span covered in this study captures the end of a one-hundred year recovery following logging. Biomass is **no longer significantly increasing,** having reached an average value of **225.1 Mg ha^{-1}.**
- **Total aboveground biomass is higher than expected** based on other, similar studies of post-disturbance secondary forests.[2]
- Elevated CO_2 levels, cation depletion, and nitrogen accumulation may play site-specific roles in determining patterns of biomass aggradation in nutrient-limited forests.



Summary comparison of aboveground biomass accumulation in broadleaf stands from global secondary forests growing on sandy and non-sandy soils. GSDY = stand age x growing-season length x growing-season temperature. Cross Creek data represented in red. (Figure adapted from Johnson et al. 2000)

- Shifts in species composition can also affect nutrient dynamics and biomass aggradation of a forest.[5]
- Our study represents one of the few long-term assessments of biomass accumulation in southeastern, nutrient-limited forests and contributes new data to our understanding of regional patterns in carbon sequestration.

METHODS:

- In the five 1-hectare plots, all woody stems >3cm DBH and >1.5m in height were identified and measured. Canopy stems were defined as those being >30cm DBH.
- Plots were censused four times over a thirty-seven year period: 1978, 1998, 2005, and 2015.
- Biomass estimates were calculated using the national-scale allometric equations developed by Jenkins *et al*.[6]

ACKNOWLEDGEMENTS:

- We acknowledge the contributions of J. Leighton Reid, George Ramseur, Callie Oldfield, Chris Morris, Ed Haubenreiser, Zack Loehle, Emily Riedlinger, and many other undergraduate researchers who assisted with data collection over the years.

LITERATURE CITED:

1. Bormann, F.H., and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, 253 p.
2. Johnson, C.M., D.J. Zarin, A.H. Johnson. 2000. Post-disturbance aboveground biomass accumulation in global secondary forests. Ecology. 81(5): 1395-1401.
3. Comins, H., and R. McMurtrie. 1993. Long-Term Response of Nutrient-Limited Forests to CO2 Enrichment; Equilibrium Behavior of Plant-Soil Models. Ecological Applications. 3(4): 666-681.
4. Kelly, J.M. 1988. Annual Elemental Input/Output Estimates for Two Forested Watersheds in Eastern Tennessee. Journal of Environmental Quality 17(3):463-468.
5. Eisen, K., and A.E. Plotkin. 2015. Forty years of forest measurements support steadily increasing aboveground biomass in a maturing, Quercus-dominant northeastern forest. Journal of Torrey Botanical Society 142(2):97-112.
6. Jenkins, J.C., D.C. Chojnacky, L.S. Heath, and R.A. Birdsey. 2003. National-Scale Biomass Estimators for United States Tree Species. Forest Science 49(1):12-35.