Enhancing Soil Carbon Sequestration in Hybrid Poplar Plantations Through Plant Genetics

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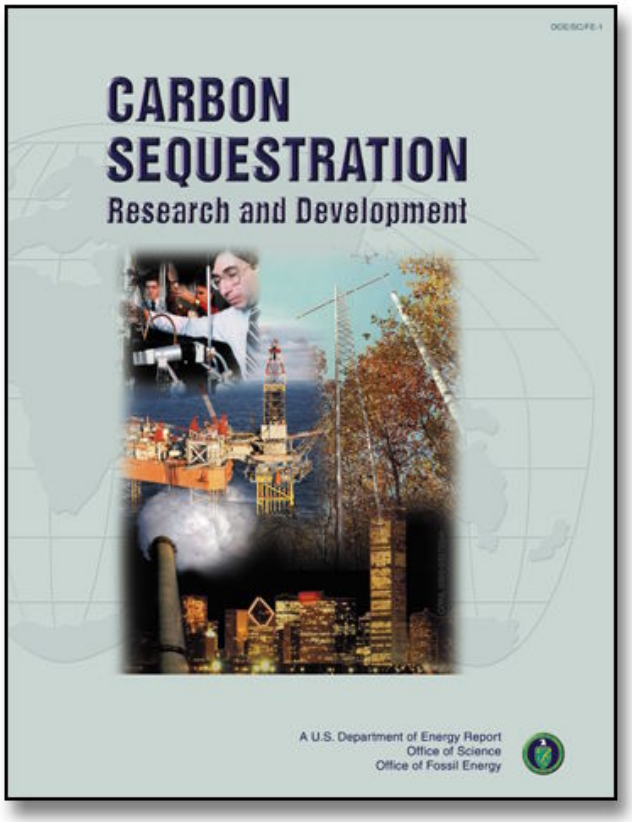
Sequestration is a Major Carbon Management Strategy

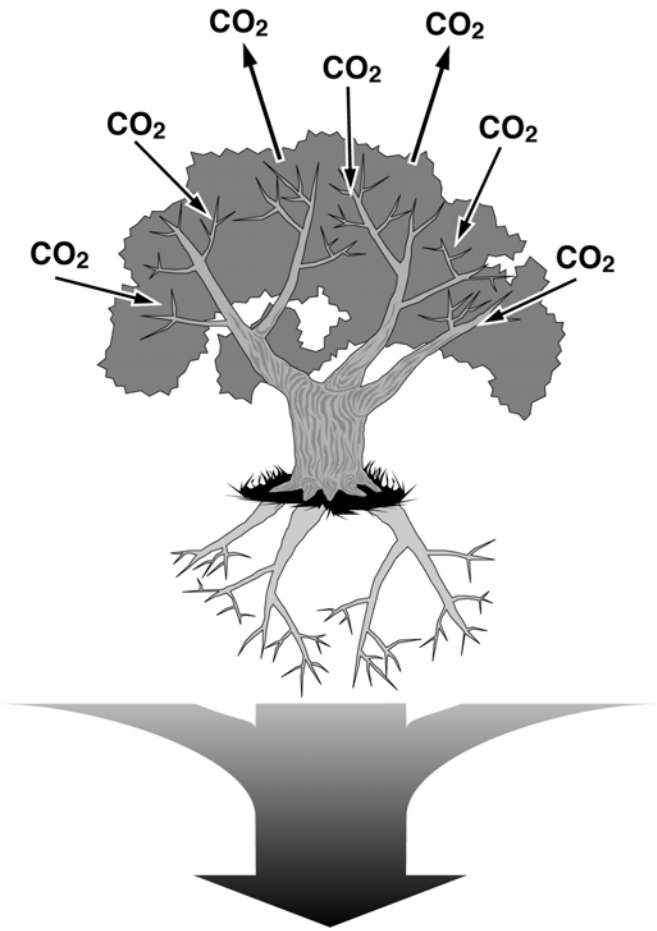
- **Possible Options**
  - **Separation and capture**
  - **Ocean sequestration**
  - **Geologic formations**
  - **Advanced biological**
  - **Advanced chemical**
  - **Terrestrial biosphere**



Above Ground
Leaves
Branches
Stem

Biomass Distribution

Below Ground
Tap Root
Structural Roots
Fine Roots



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Above Ground
Lignin
Cellulose
Secondary Metabolites

Tissue Chemistry

Below Ground
Lignin
Cellulose
Secondary Metabolites

Carbon Sequestration

Overarching Goal

Understand the fundamental genetic control of plant-based processes that are important for carbon sequestration and use that information in models to assess the potential to enhance carbon storage in managed ecosystems.

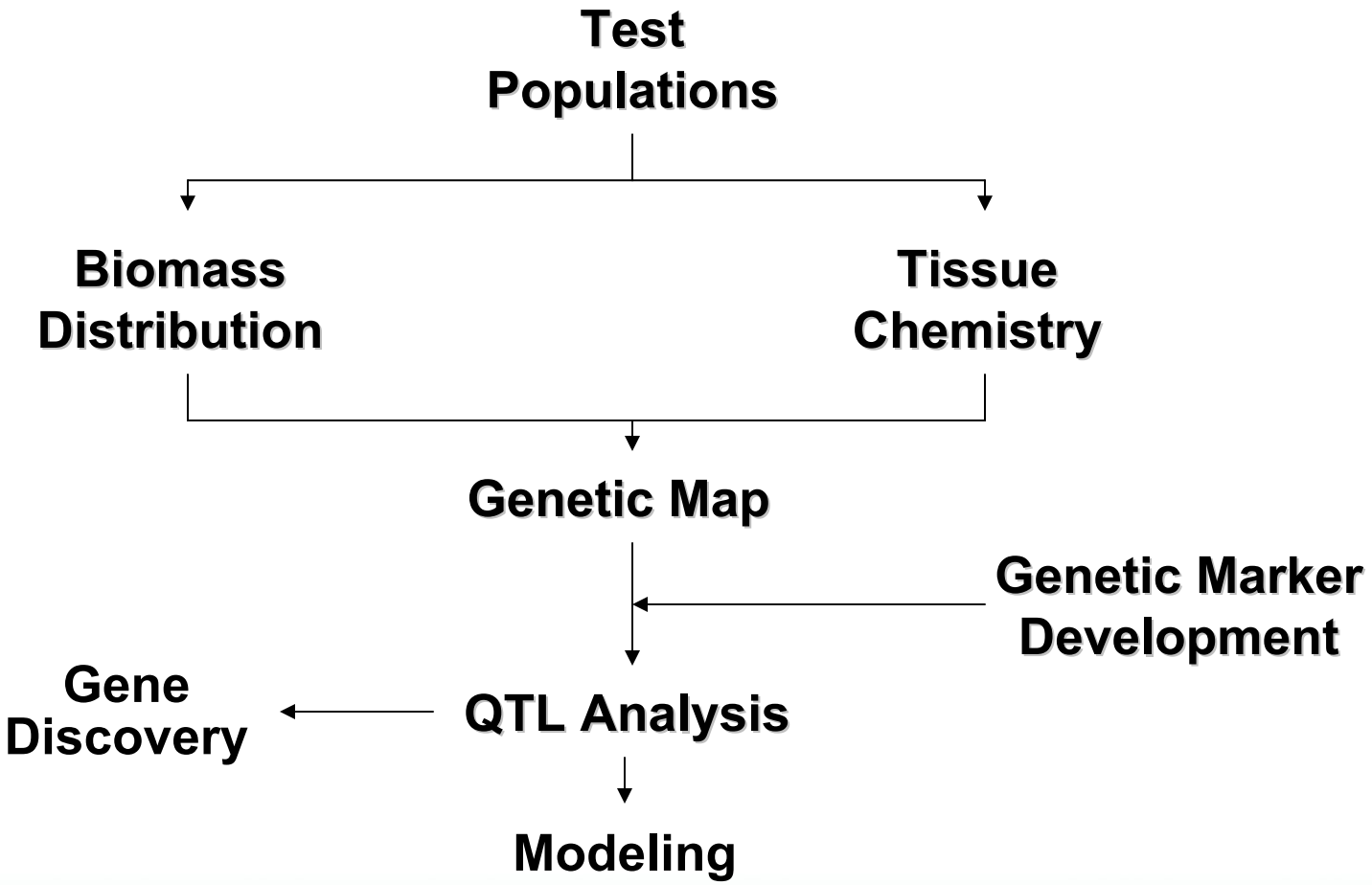
Primarily focus on

Quantity and quality of leaf and fine-root litter inputs

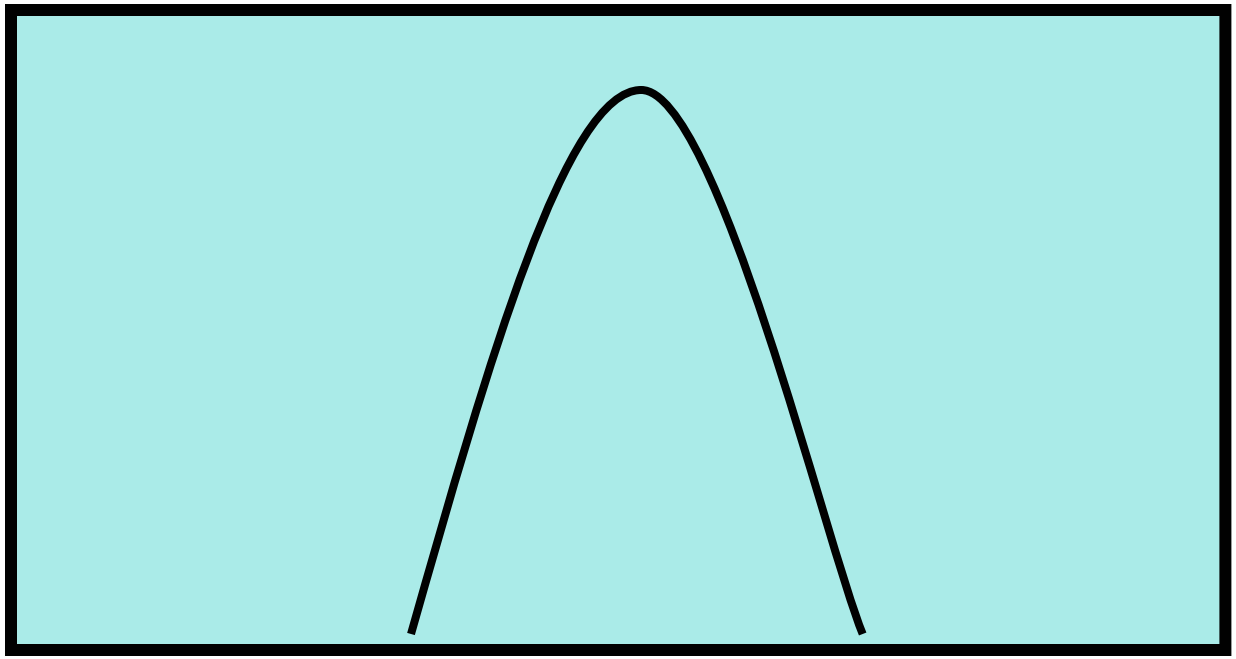
Project Objectives

- *Determine intra-specific variation in biomass distribution and litter chemistry for hybrid poplar,*
- *Evaluate the genetic control of these traits, and*
- *Incorporate this information into models to assess carbon sequestration potential in managed plantations.*

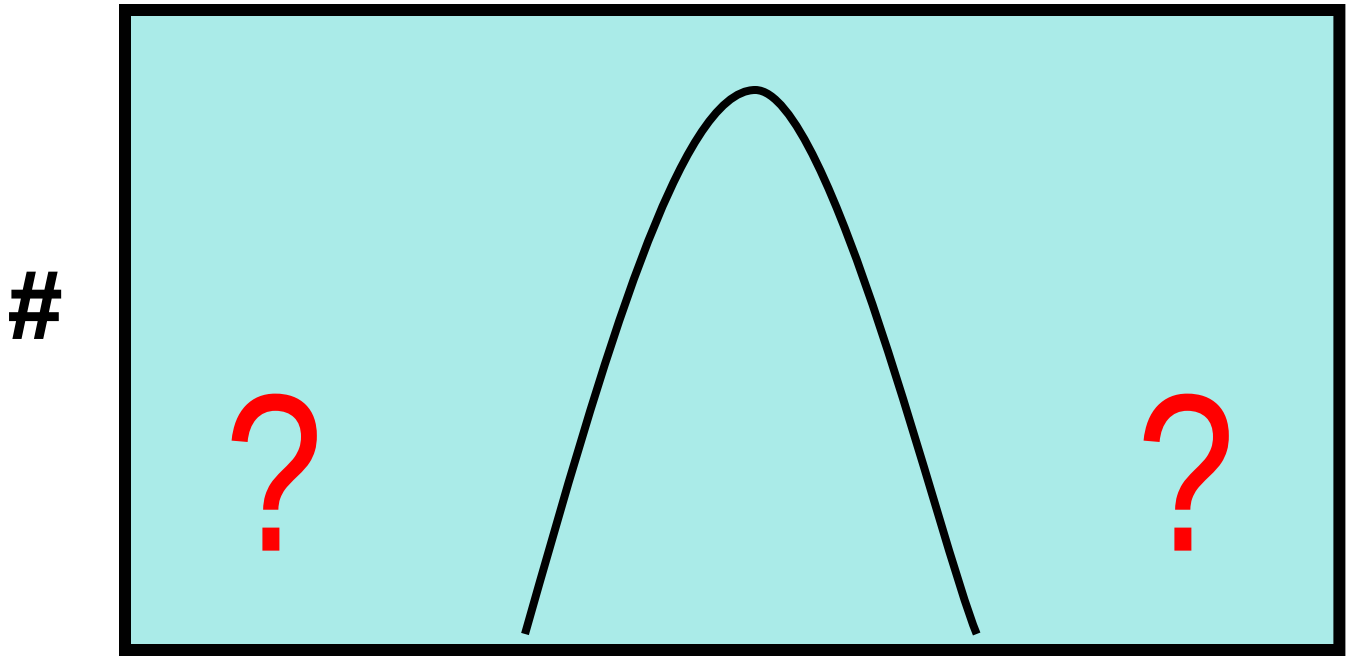
Technical Approach

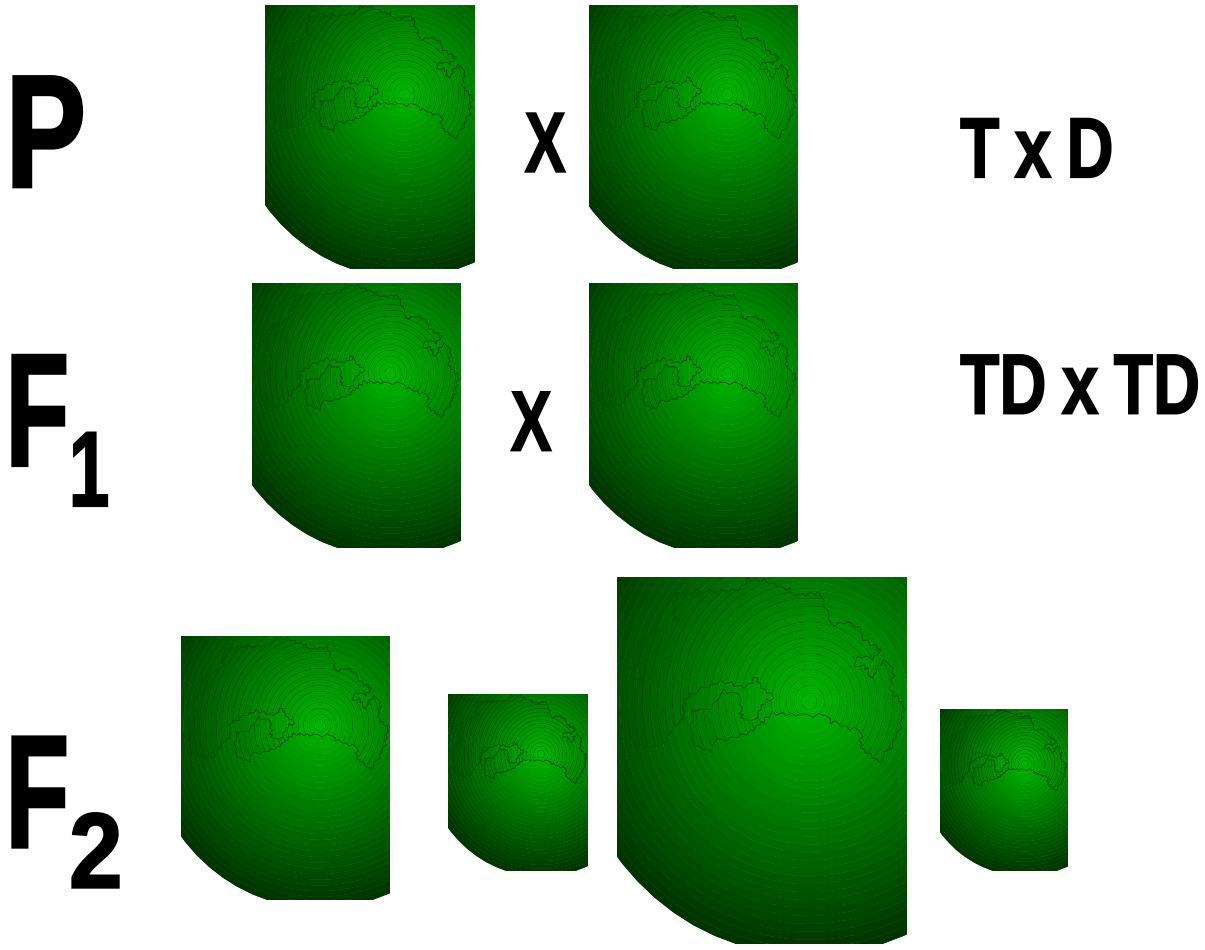


Observed Variation in a Process or Trait

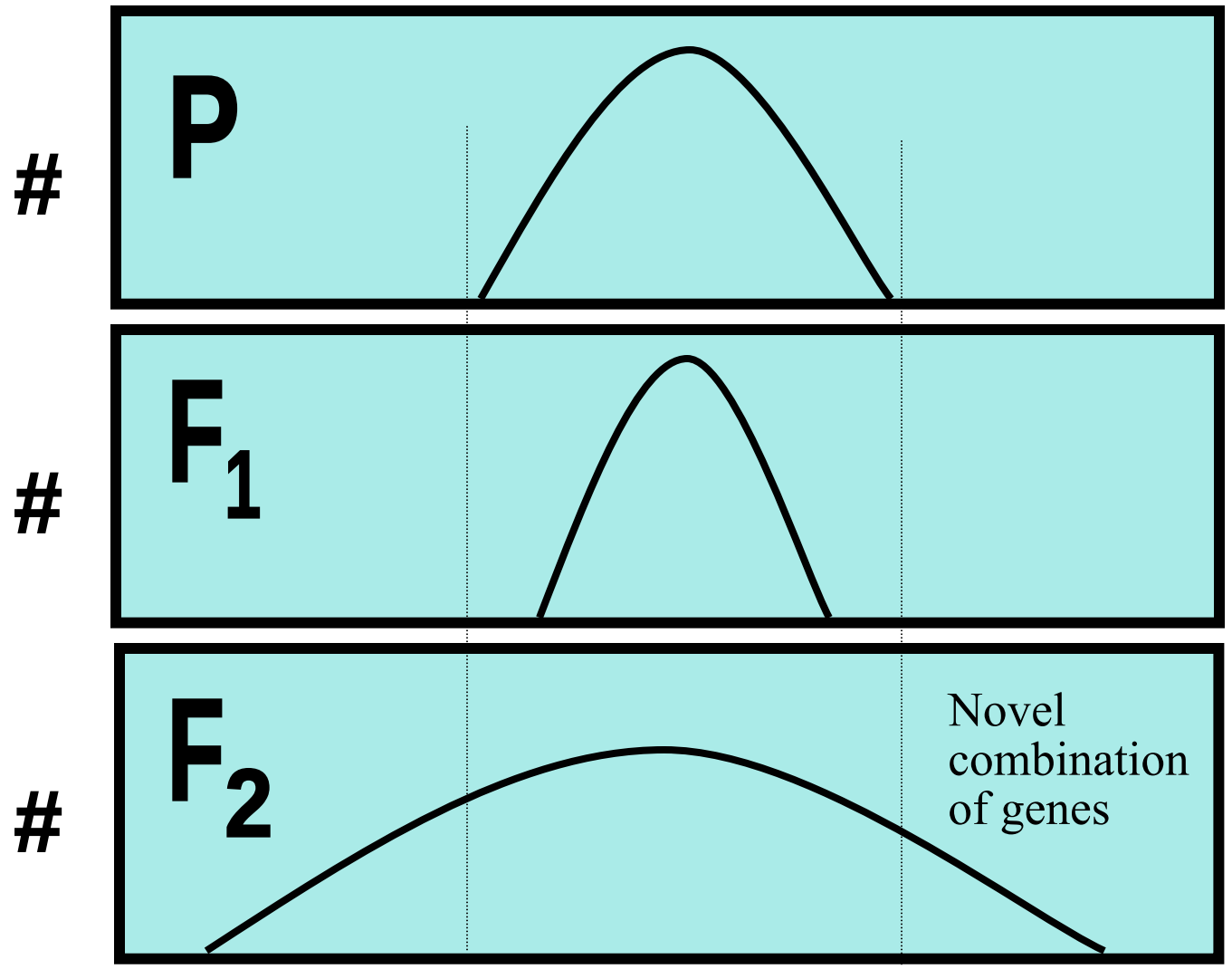


Examine Process or Trait Outside "Normal" Expectations





Segregating Population


#
P
#
F1
#
F2
Novel
combination
of genes
Process/Trait of Interest

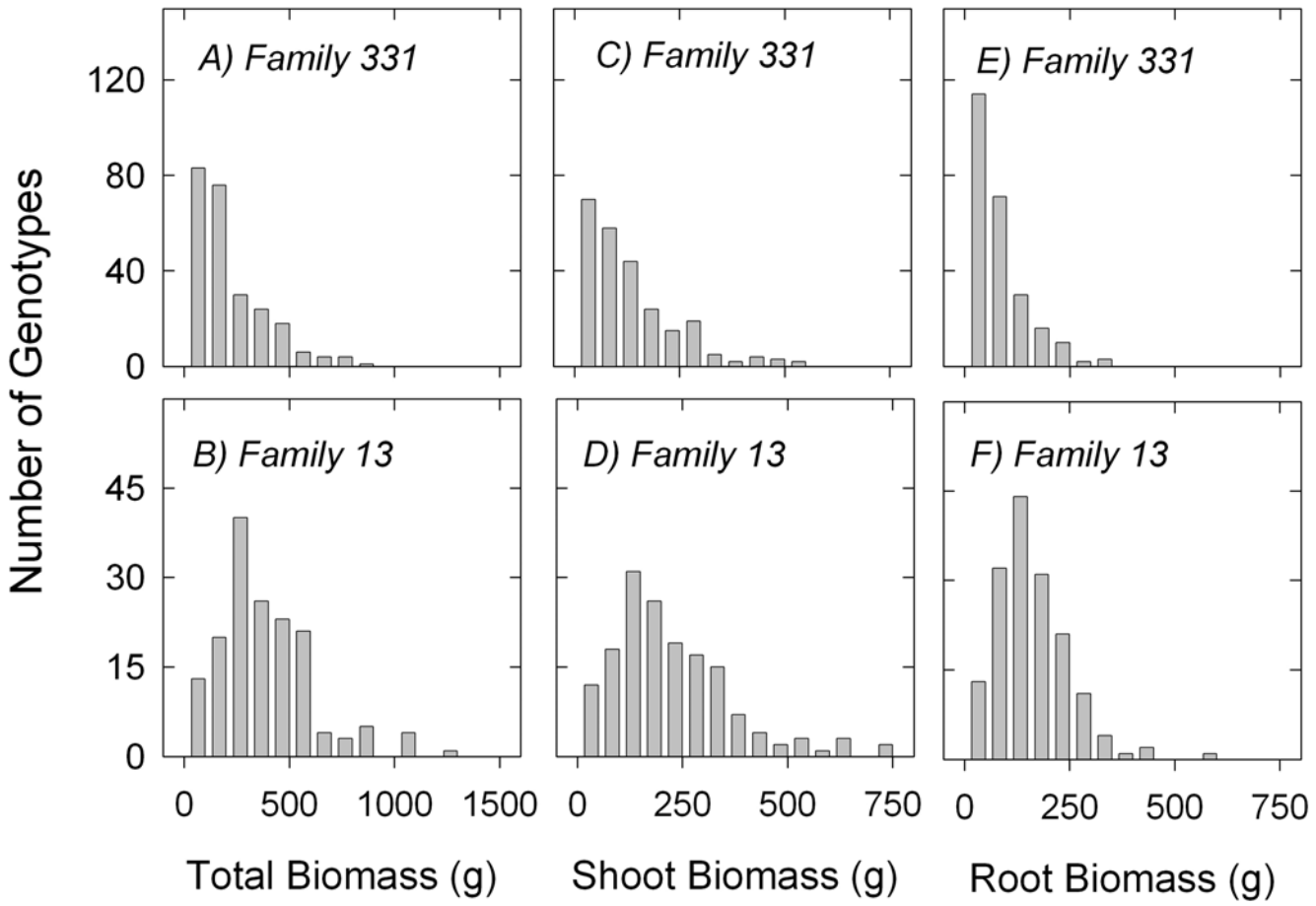

Boise Cascade
Fiber Farm
Administrative Office
No Smoking On Boise Cascade Property

Planting and Harvest

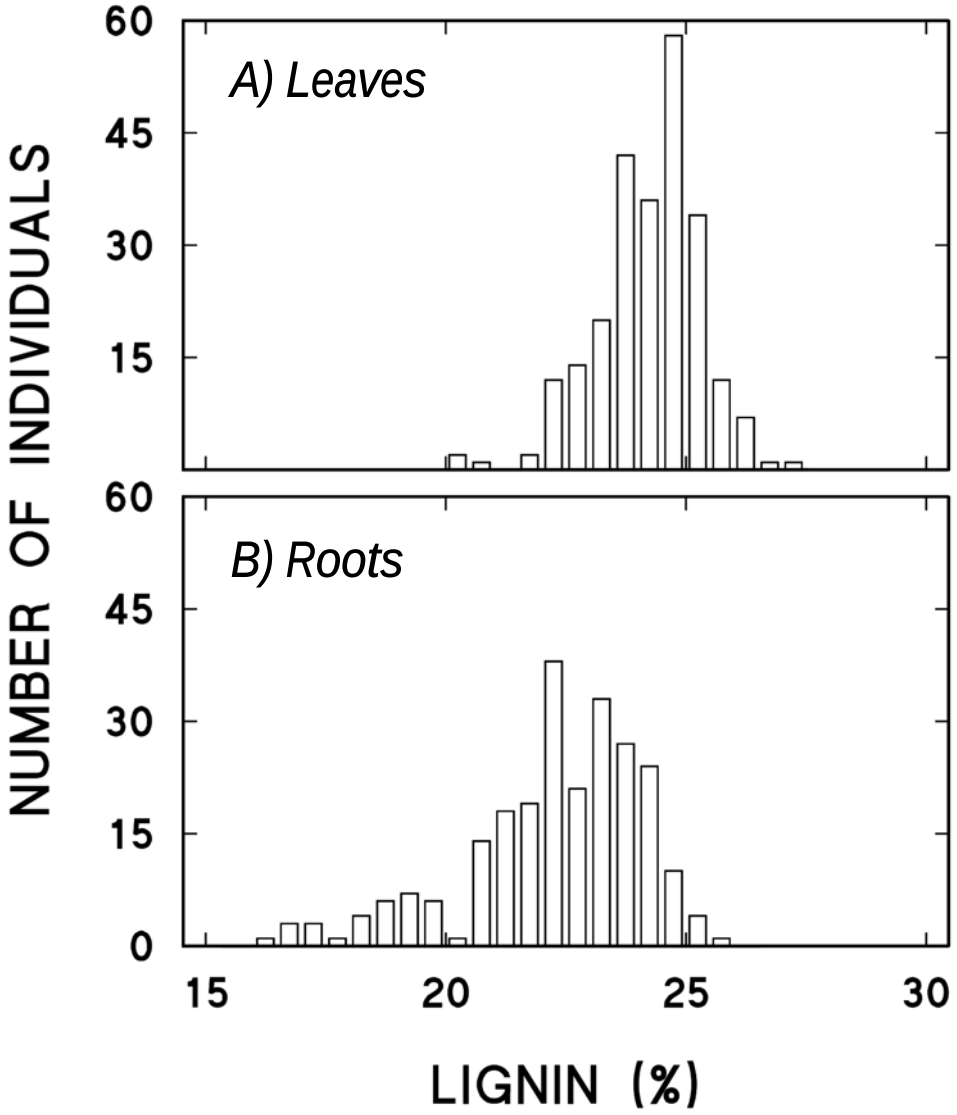
Family 331

Family 13

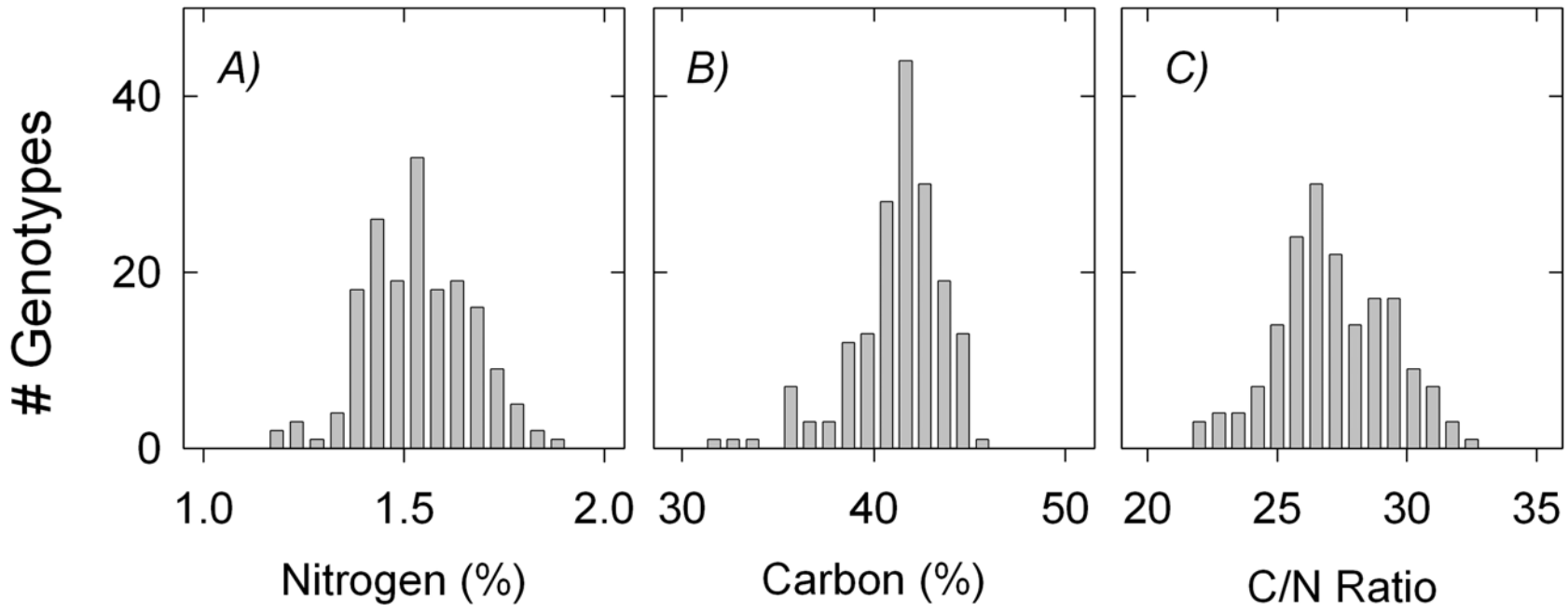
>1000 trees have been harvested



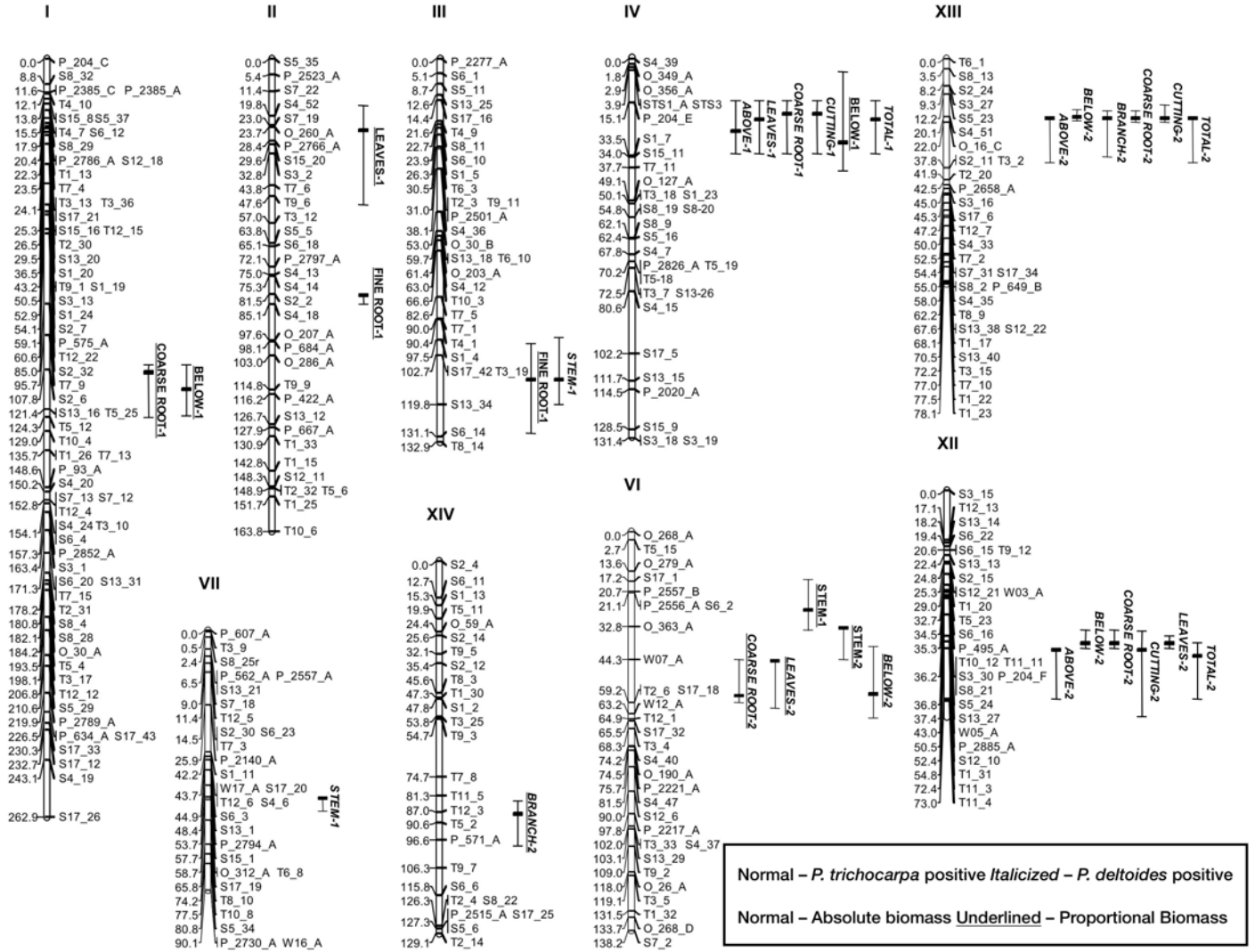
Distribution of above- and below-ground biomass varies widely among individuals.

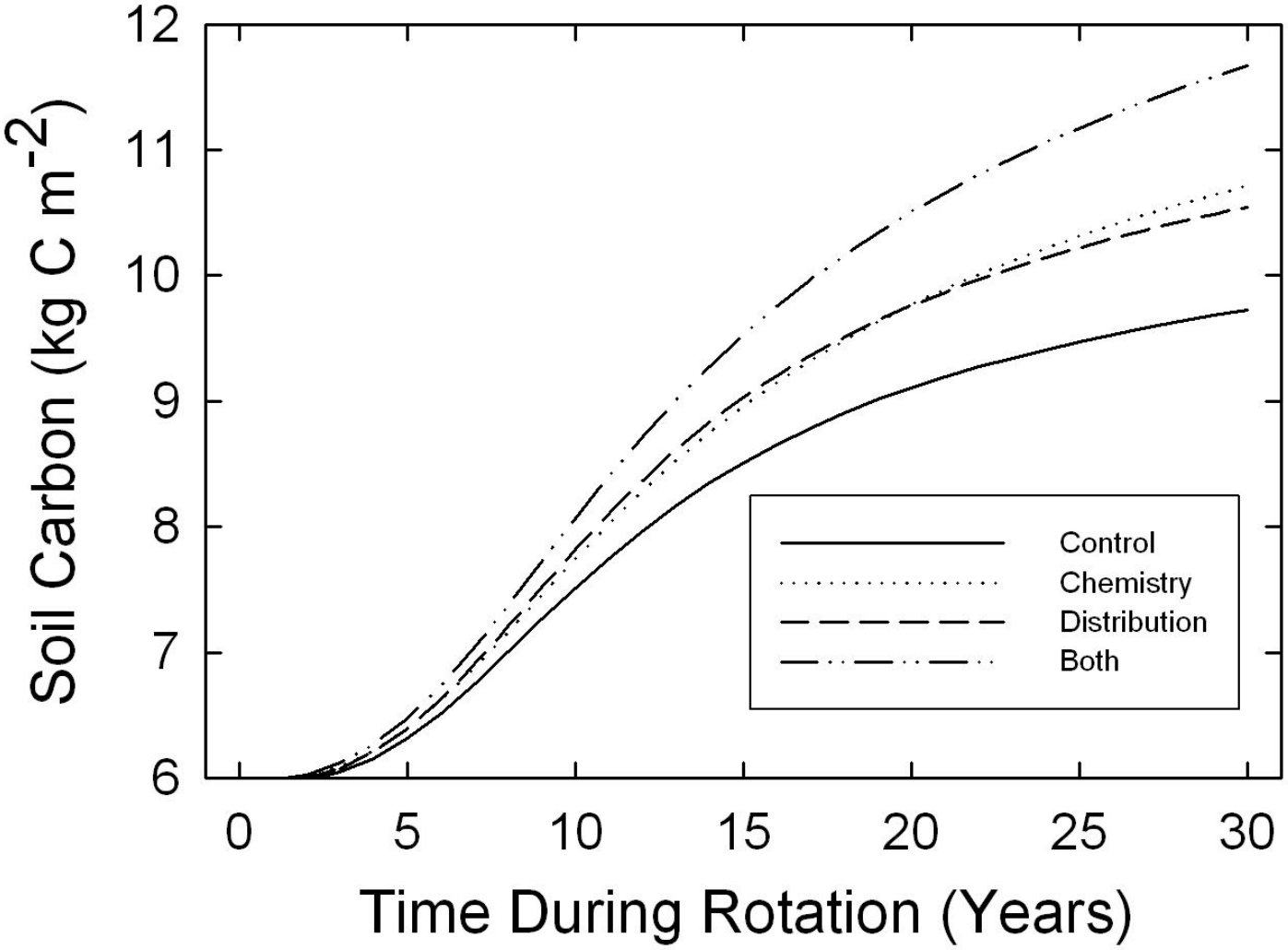


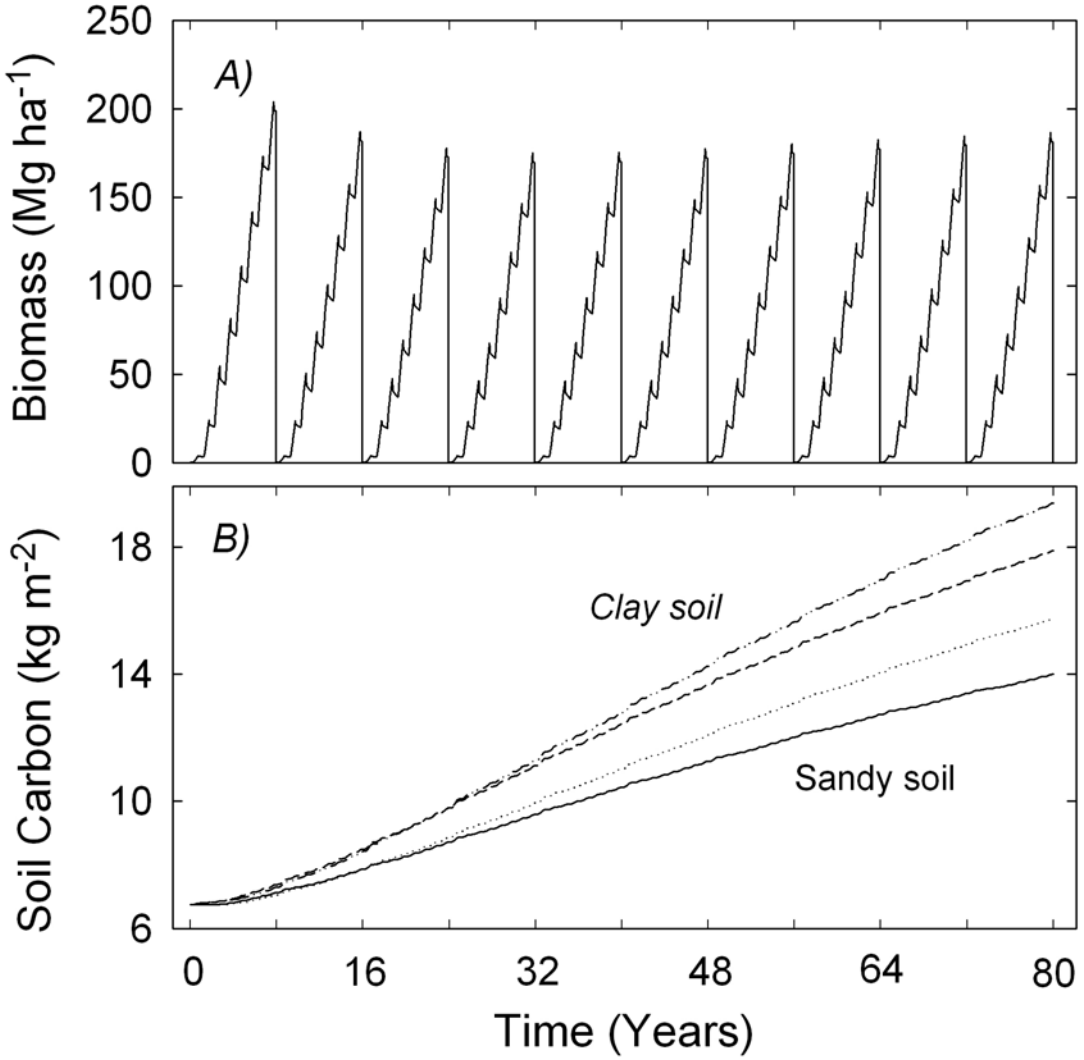
Leaf and fine-root lignin also varied widely among hybrid poplar genotypes.



In addition to lignin, other chemical constituents also varied among individuals.


I
II
III
IV
XIII
VII
XIV
VI
XII
Normal – P. trichocarpa positive Italicized – P. deltoides positive
Normal – Absolute biomass Underlined – Proportional Biomass


Soil Carbon (kg C m-2)
12
11
10
9
8
7
6
0
5
10
15
20
25
30
Time During Rotation (Years)
Control
Chemistry
Distribution
Both


A)
B)
Biomass (Mg ha-1)
Soil Carbon (kg m-2)
Clay soil
Sandy soil
Time (Years)
250
200
150
100
50
0
18
14
10
6
0
16
32
48
64
80

Extrapolations

- *Assume that 222 x 10^6 ha are available globally for managed forest plantations*
- *Accept that genetics could enhance rates of soil sequestration by 0.25 to 0.67 Mg C ha^{-1} $year^{-1}$*
- *Then calculations show that the global magnitude of this effect could approach 0.16 Gt C $year^{-1}$*

Conclusions

- *Considerable genetic variation exists for traits of interest to carbon sequestration,*
- *Models suggest that changes in litter quantity and quality through breeding will enhance carbon sequestration, and*
- *Global magnitude of this enhancement could approach 0.16 Gt C year^{-1} or ca. 2% global carbon emissions.*

Genetic Analysis in *Populus* Reveals Potential to Enhance Soil Carbon Sequestration

ENVIRONMENTAL SCIENCES

In a paper published in the Canadian Journal of Forest Research, ORNL scientists provide insights into genetic mechanisms that control rates and magnitudes of carbon transfer and turnover in plants and soils. They suggest harnessing the genome to enhance the natural capacity of plants and soils to sequester carbon and thus mitigate rising atmospheric CO_2 concentrations. Incorporating information derived from this study into a computer model shows that increasing biomass distribution to roots and altering tissue chemistry to favor long-term pools of soil organic matter could increase global carbon sequestration by 0.35Gt carbon/year—about 4% of global carbon emissions.

The scientists reached that conclusion by assembling an extensive above-and below-ground carbon inventory for more than 1000 hybrid poplar (*Populus*) trees. Field data collected over 3 years were combined with a newly-developed genetic map to identify regions of the genome responsible for distributing dry mass to stems, branches, leaves, and roots. Results indicate that traits associated with distribution of dry mass are controlled by a relatively few genes. Thus fundamental knowledge gained through the basic biological sciences can address questions related to managing carbon terrestrial ecosystems.

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