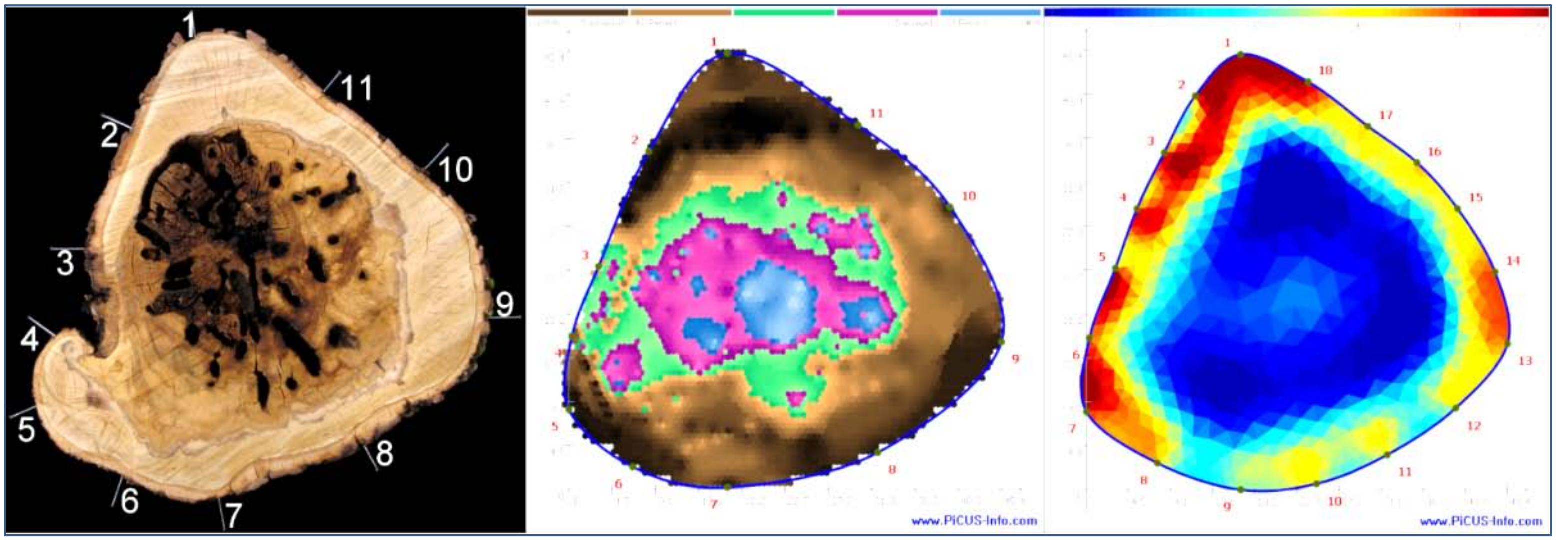
Assessing Internal Decay in Trees Nondestructively with Tomography



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Department of Plant Pathology & Ecology

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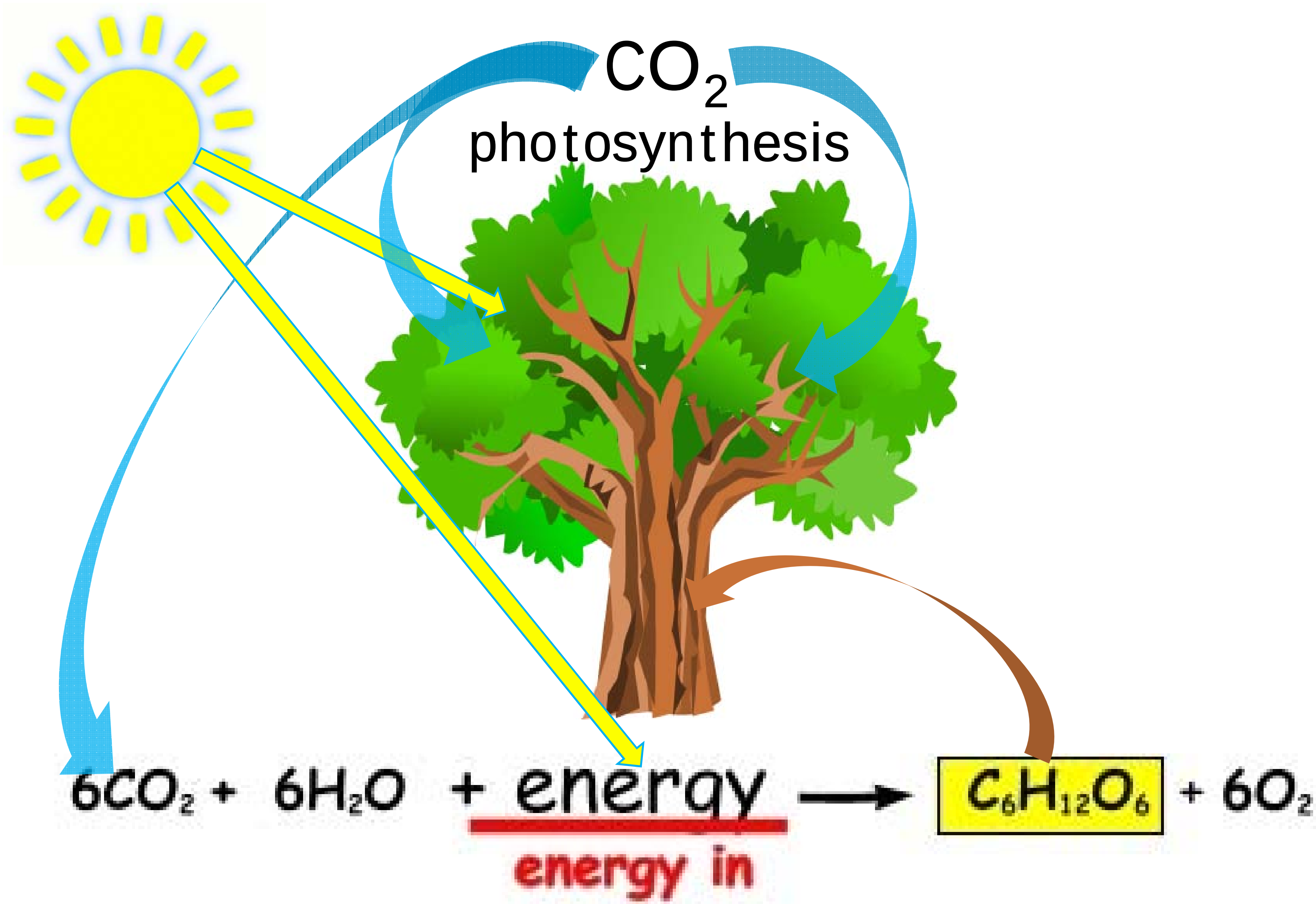
SPECIAL REPORT THE LIFE AND TIMES OF THE COLORADO RIVER
onearth
PUBLISHED BY THE NATURAL RESOURCES DEFENSE COUNCIL
BEHOLD, THE CARBON EATER
THE GLORY OF TREES
New science explains how forests could help save us from global warming
ALSO WHY ZOOS MATTER, TRANSYLVANIA'S SECRET WORLD, GREEN-COLLAR VETERANS, AND DEEP-SEA GOLD MINES
NRDC
Spring 2008

Atmospheric Carbon

- Fairly stable at 260-280 ppm for ~10,000 years.
- Began to increase at the dawn of the industrial revolution (~1750).
- Currently at >400 ppm;
  - ~30% higher than at *any* time in the last 650,000 years.

Carbon cycling in forests

- Nearly 90% of all biomass carbon on the planet is sequestered in forests.
- One acre of northeastern forest sequesters 60-100 metric tons of above-ground carbon.


CO_2
photosynthesis
$6CO_2 + 6H_2O + energy \longrightarrow C_6H_{12}O_6 + 6O_2$
energy in

Carbon cycling in trees

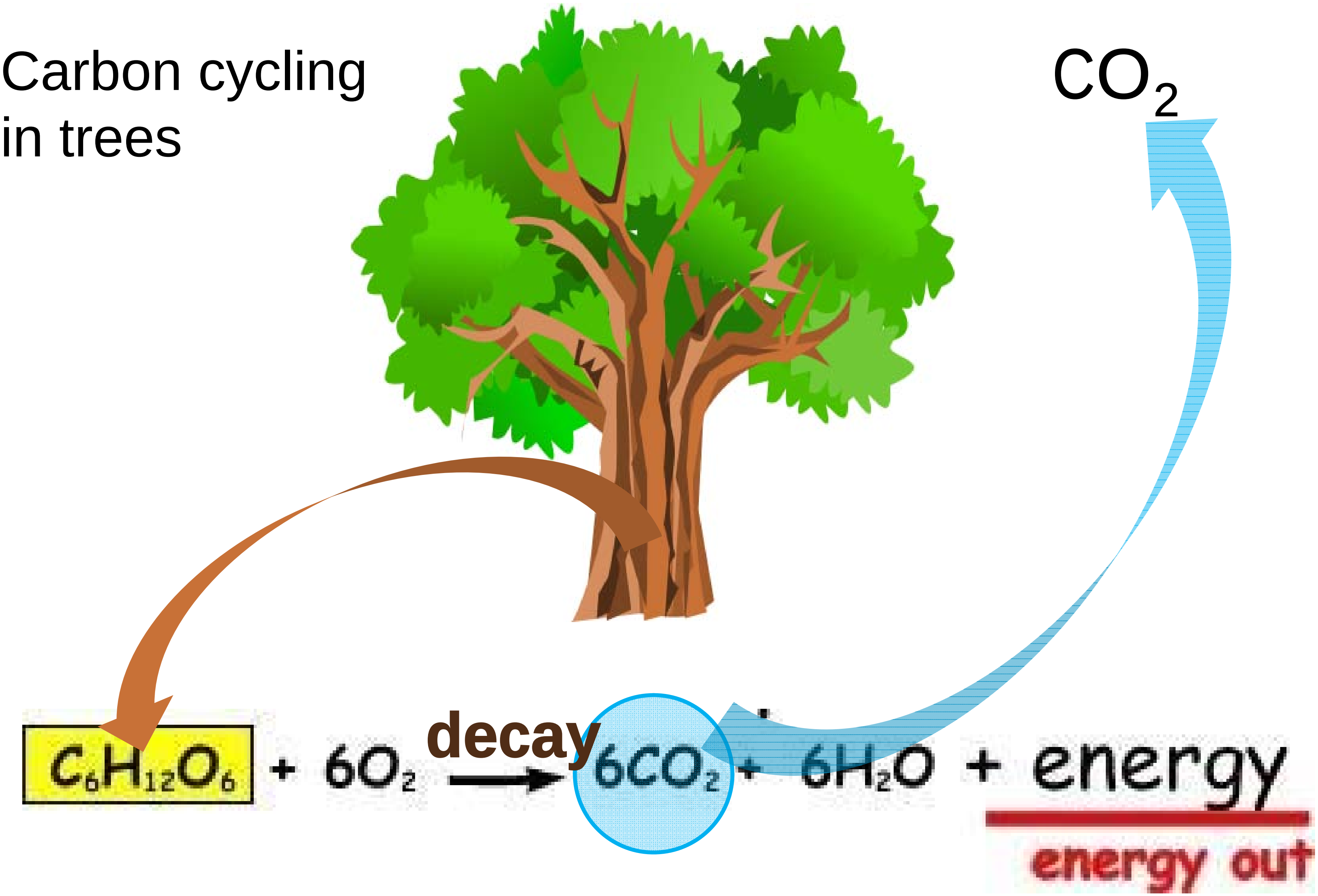
- Photosynthesis:

  CO_2 from atmosphere → wood

- Internal decay bacteria and fungi:
  - present inside trees for decades, slowly degrading wood.

- As decay organisms metabolize wood, CO_2 released back into the atmosphere.

Carbon cycling in trees



Internal decay in living trees

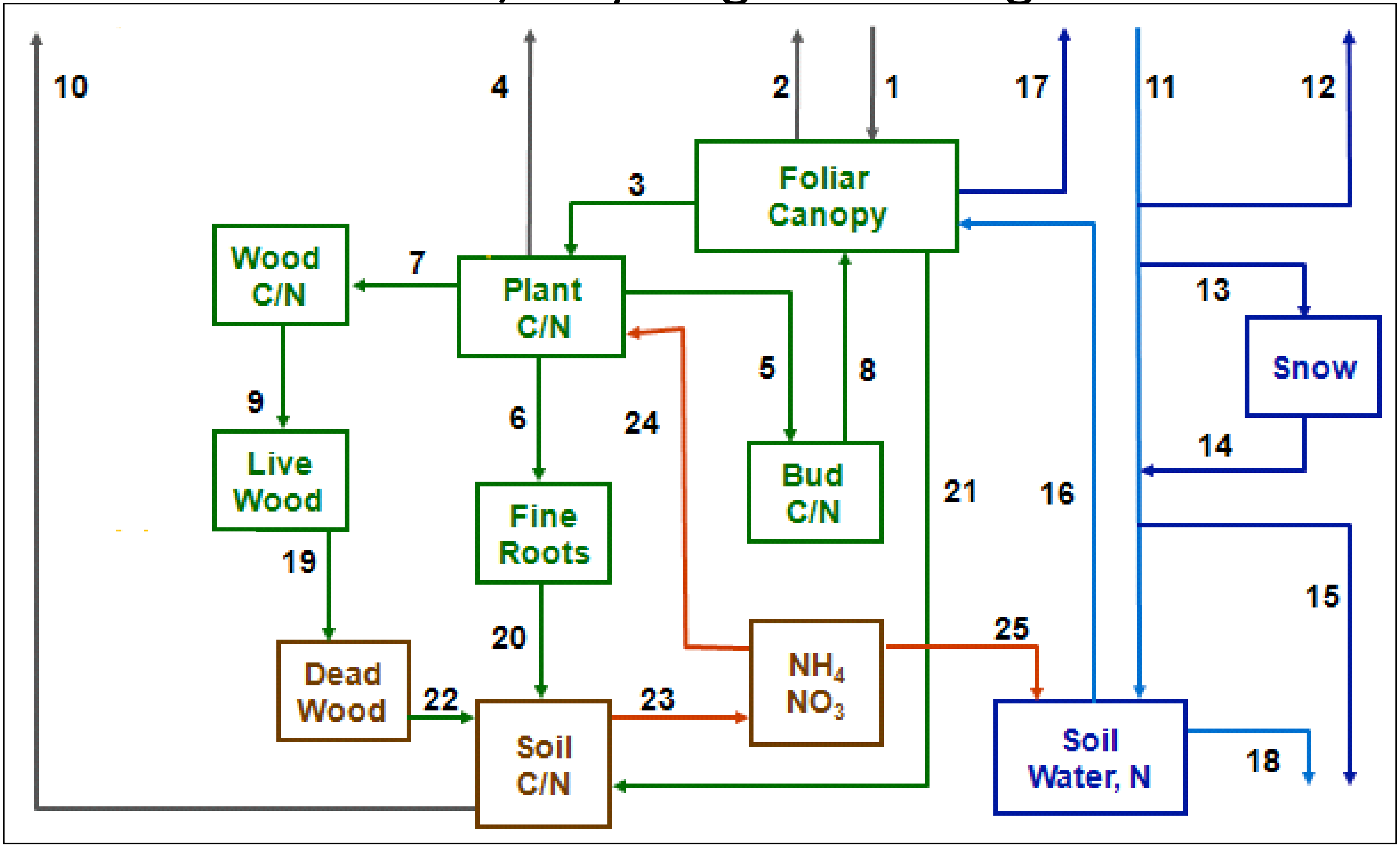
- Nearly ubiquitous;
- Releases (returns) CO_2 to atmosphere;
- Acts as a countervailing force to photosynthesis;
- Reduces net rate of carbon sequestration in forests.

Internal decay in living trees

- Plays an important role in the forest carbon cycle;

- Unaccounted for in forest carbon-cycle models…

Forest C/N cycling and storage



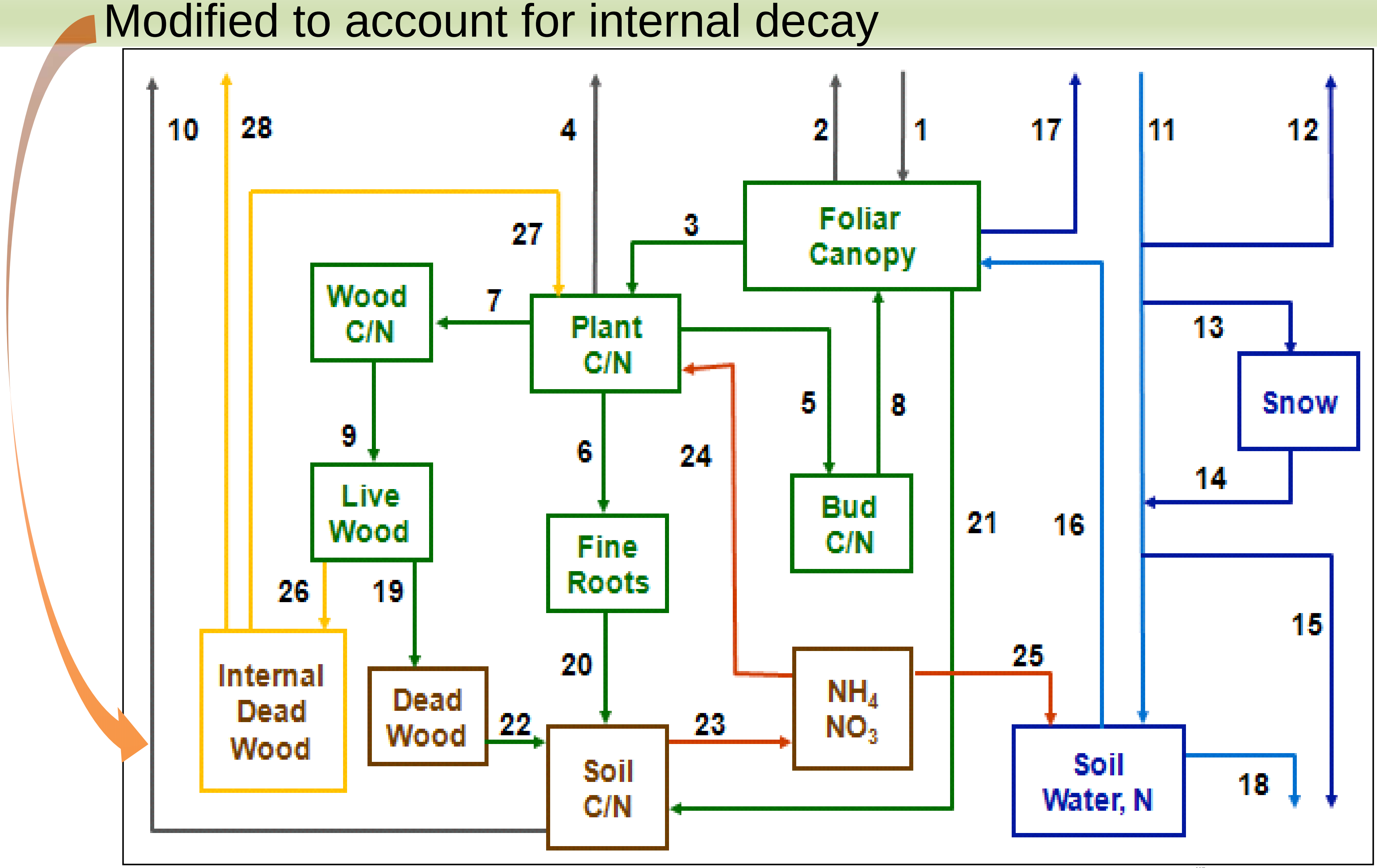
Internal decay in living trees

- Unaccounted for in forest carbon-cycle models…

No quantitative data!

Forest Carbon-cycle Model:

Modified to account for internal decay



Internal decay in forests

➢ ***No quantitative data!***

Unknowns:

- Rate of C loss (decay) in trees;
- Extent and magnitude of internal decay in forests.

Role of internal decay in carbon dynamics of forest ecosystems

Phase I (funded and near completion):

Develop and validate experimental approach

Phase II (pending funding):

Use methodology to measure extent, magnitude and rate of internal decay in northern hardwood forests

Collaborators:
Dr. Nicholas Brazee, University of Massachusetts, Amherst
Dr. Shawn Fraver, University of Maine

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Methods for Nondestructively Assessing Internal Decay

- Visual Assessments
- Wooden mallet
- Tomography

Assessing Internal Decay with Tomography

- ***Sonic Tomography (SoT)***
  - Velocity of sound is directly proportional to wood density;
    - Fastest through non-decayed (dense) wood;
    - Slower through decaying (less dense) wood;
    - Slowest through cavities.

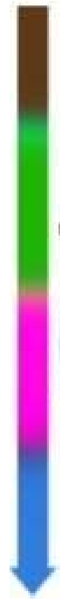
Assessing Internal Decay with Tomography

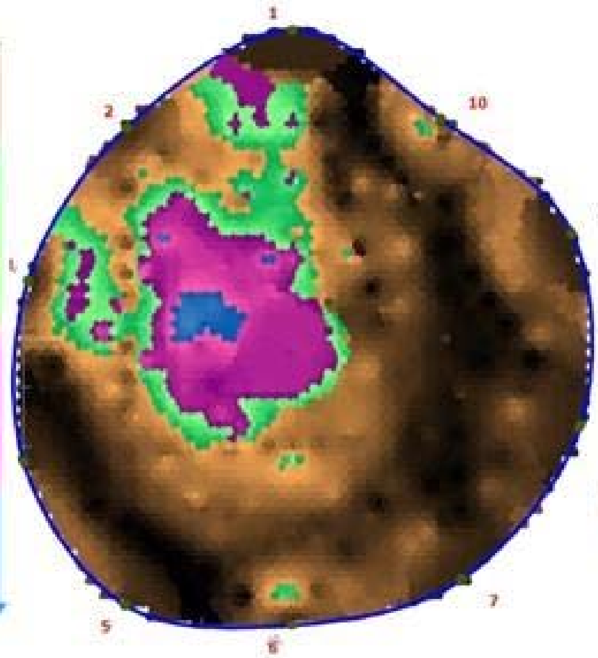
- ***Electrical Resistance Tomography (ERT)***
  - Electrical current varies with anything that alters the electrical field; e.g. water, ions.
  - Wet wood (e.g., wood undergoing decay) carries current faster than dry (non-decayed) wood.

Sonic Tomography

Fast = dense
= no decay

Slow = less dense
= decaying
or decayed (cavity)

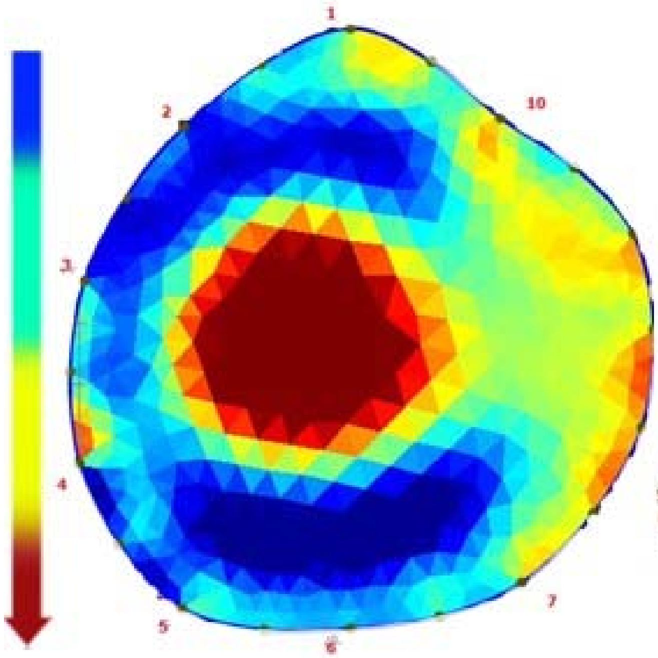




Electrical Resistance Tomography

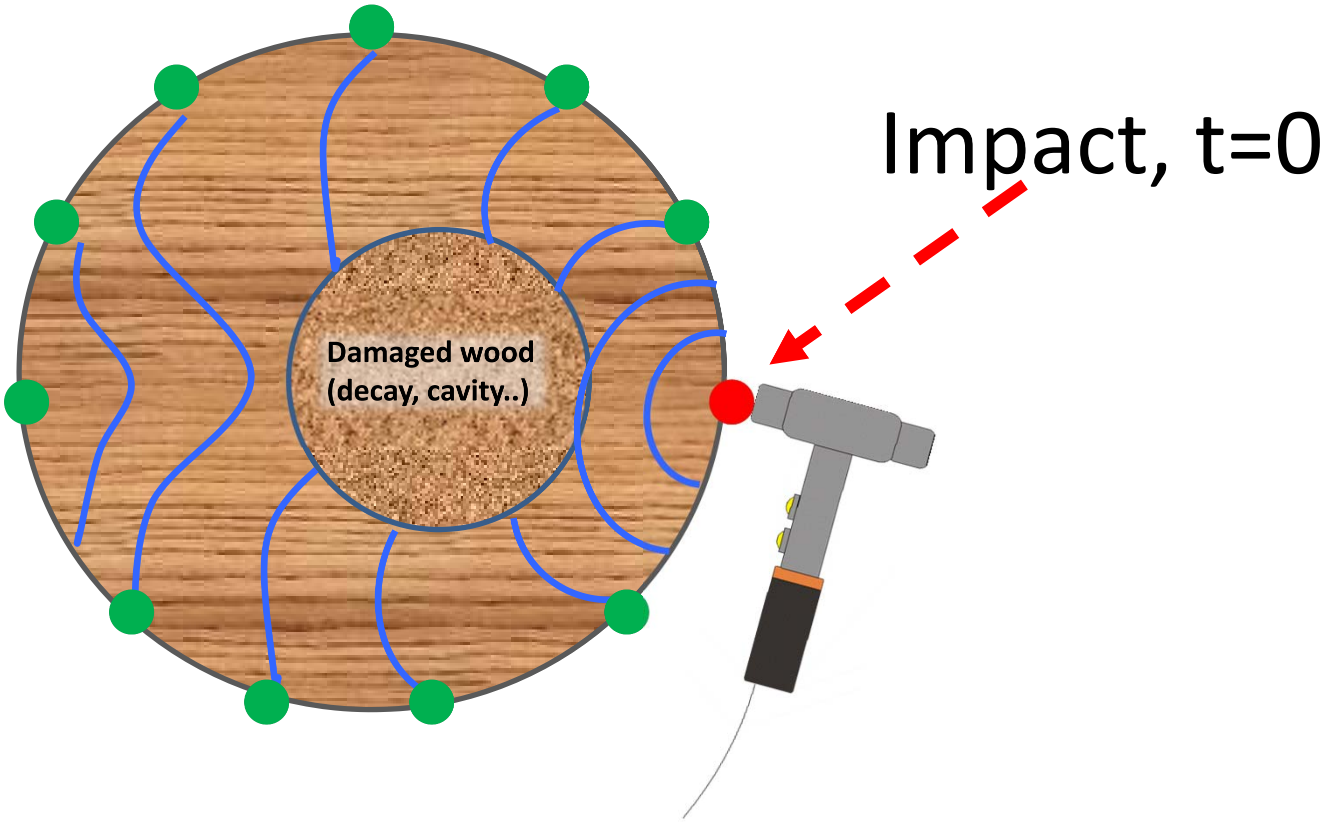
Low = high water content
= incipient decay

High = low water content
= sound wood
OR cavity

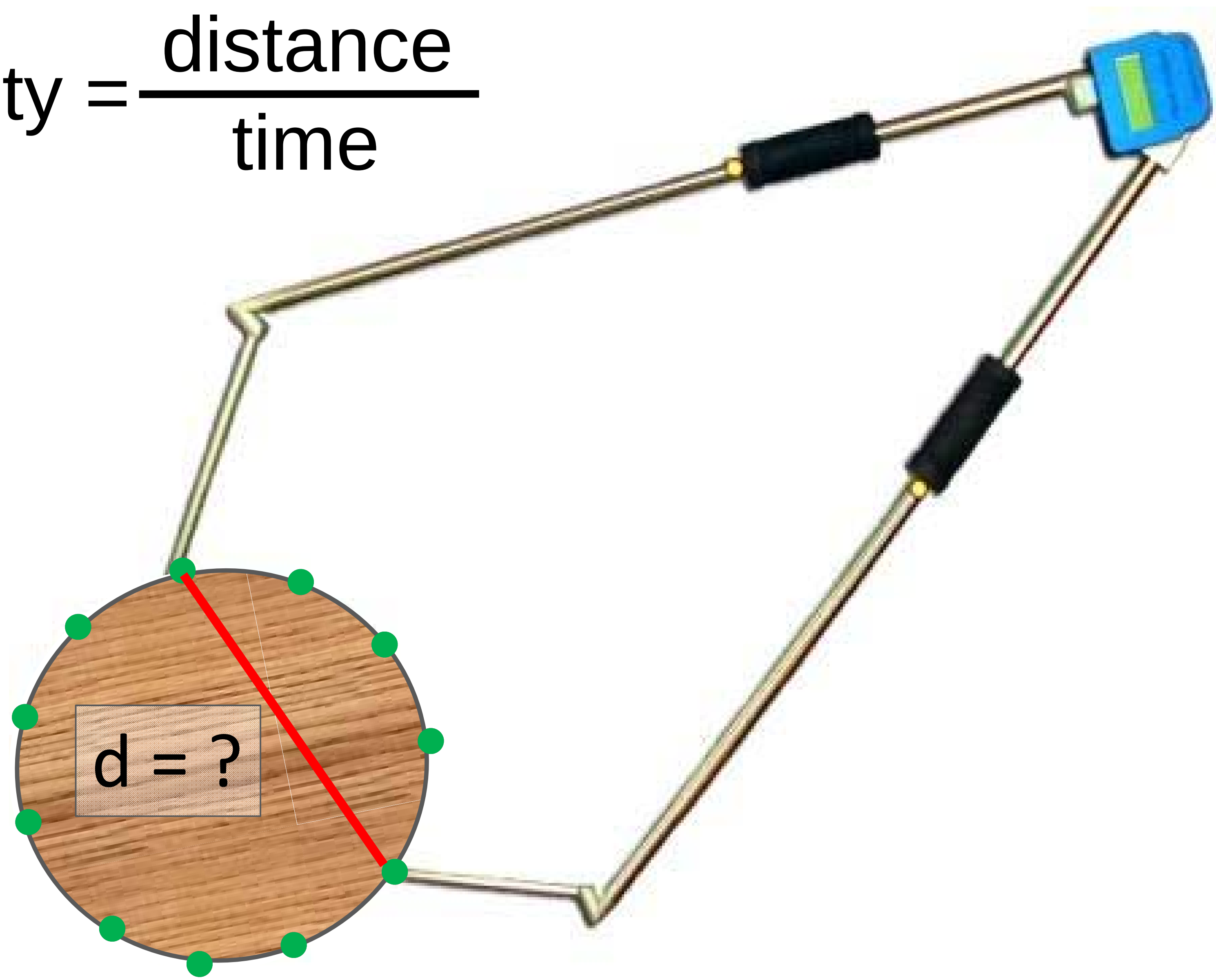


Sonic Tomography

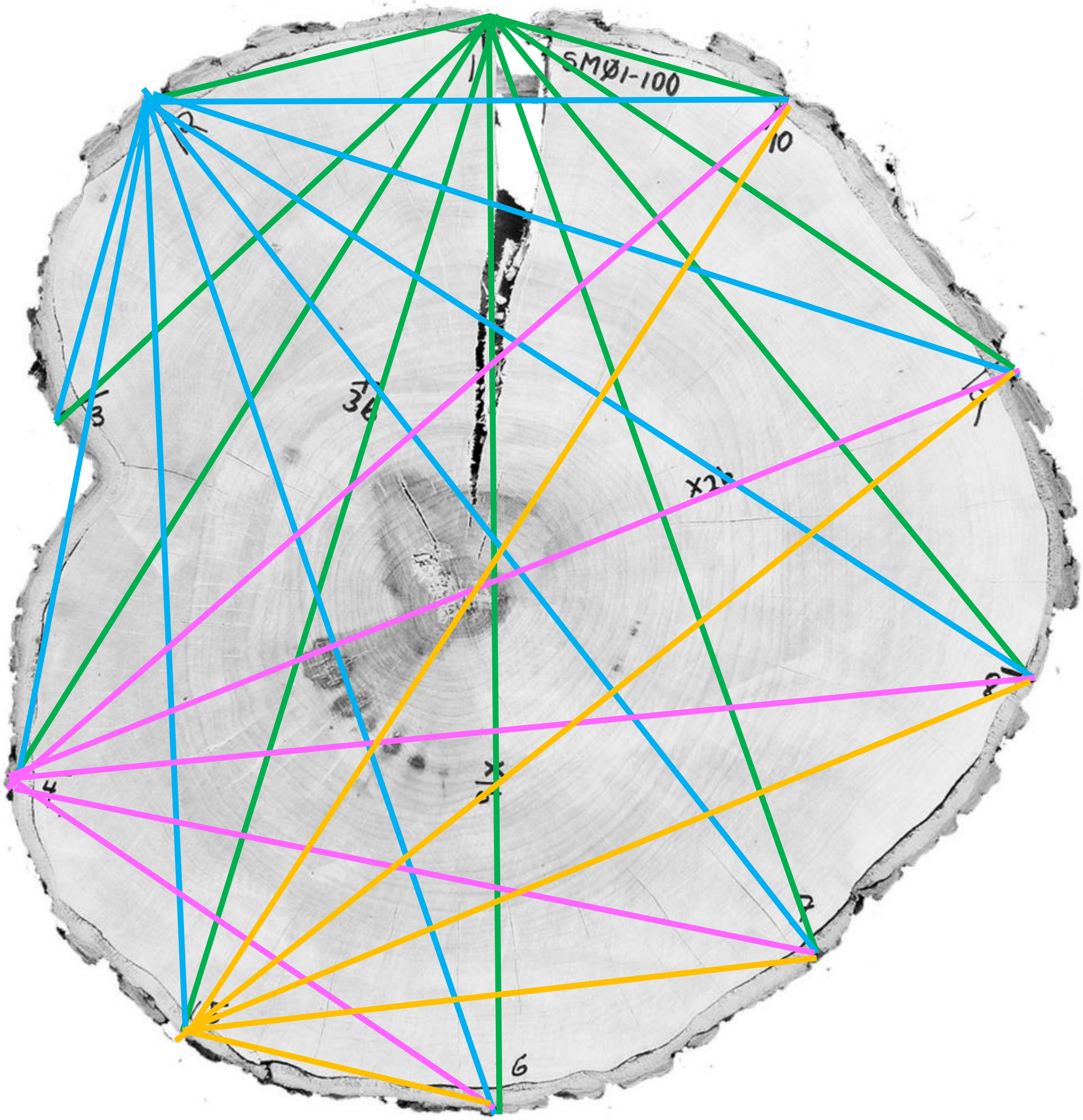
Where do sound waves travel ***SLOW*** (decay) relative to where they travel ***FASTEST*** (no decay)?



$$\text{Velocity} = \frac{\text{distance}}{\text{time}}$$




8
9
10
8
9
10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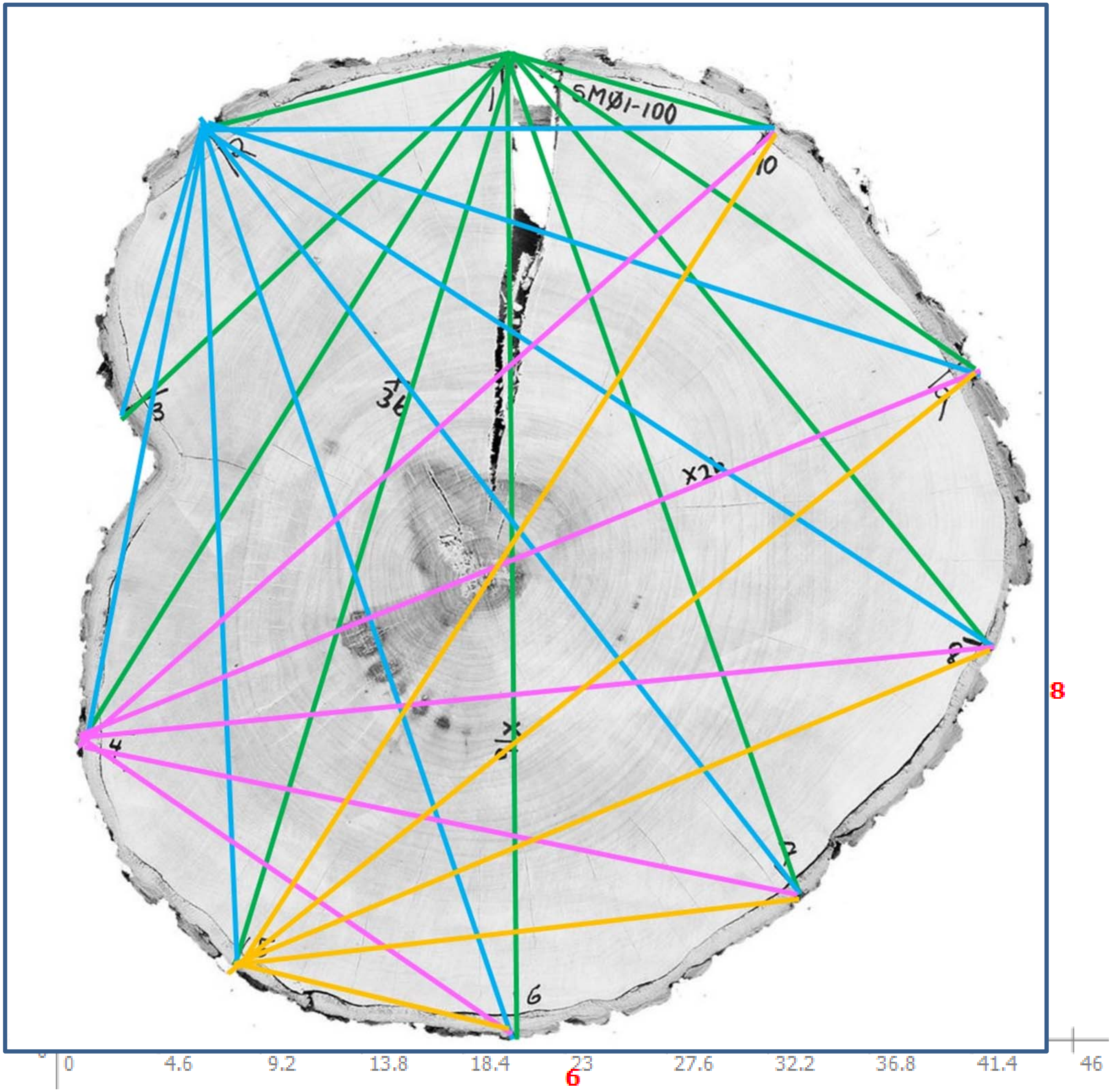
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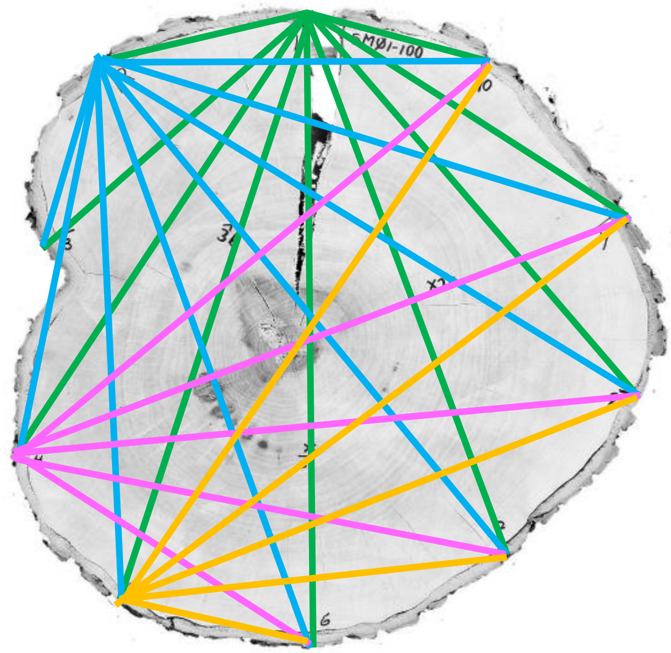

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PiCUS³ Sonic Tomograph
TreeTronic³


5
4

Phase I:
Develop and validate experimental approach

- Great Mountain Forest, Norfolk, CT; Summer 2014
- Three principle northern hardwood species:
  - Sugar maple, yellow birch, American beech
- 18 trees of each species (3 healthy)
  - 3 tomographic cross-sections per tree
  - Fell trees; cut "cookies" at each cross-section
    - Validate/calibrate tomography
    - Estimate C loss due to decay
    - Estimate age of tree; lifetime rate of decay

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GREAT
MOUNTAIN
FOREST
NORFOLK, CONN.

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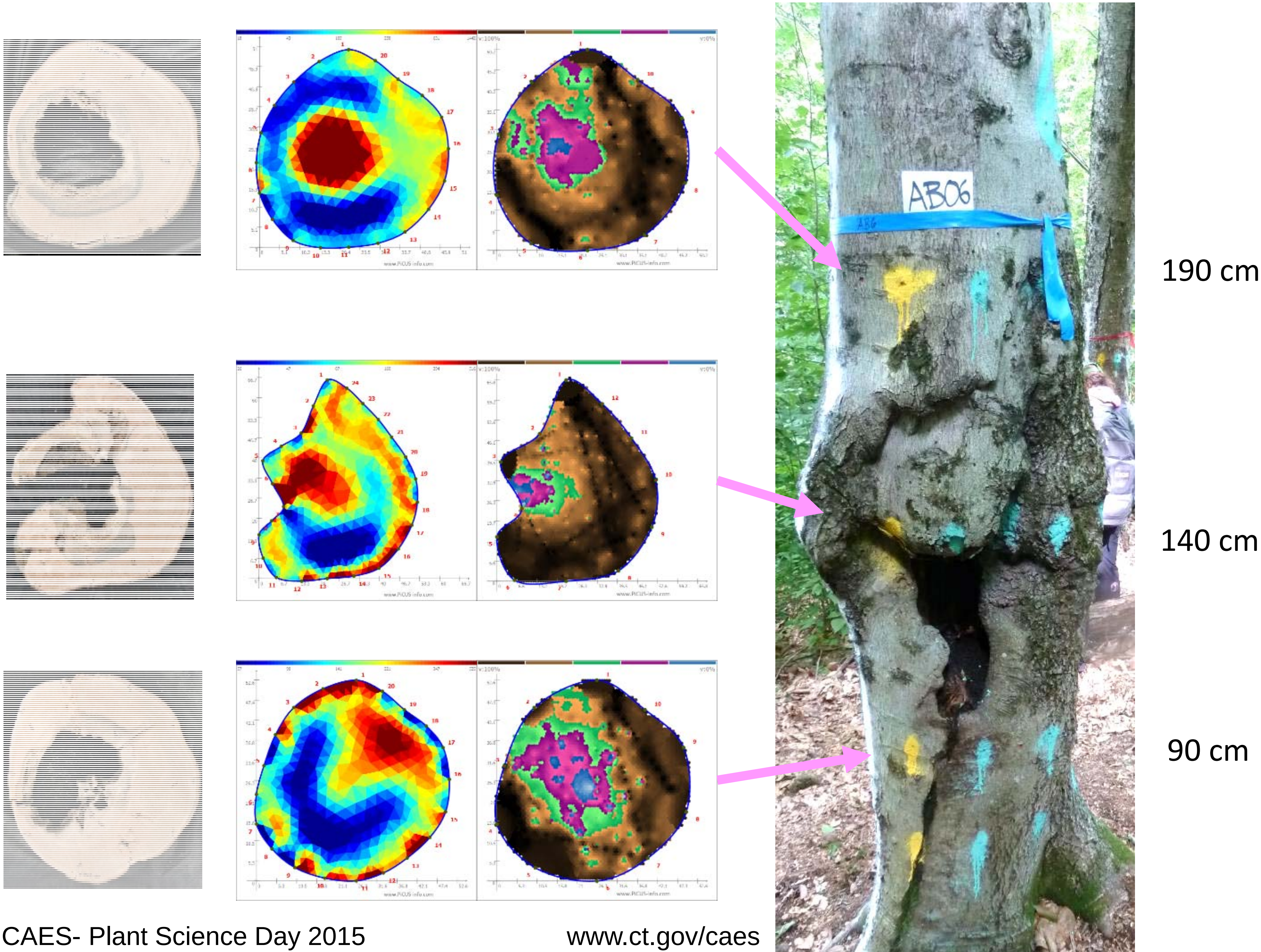
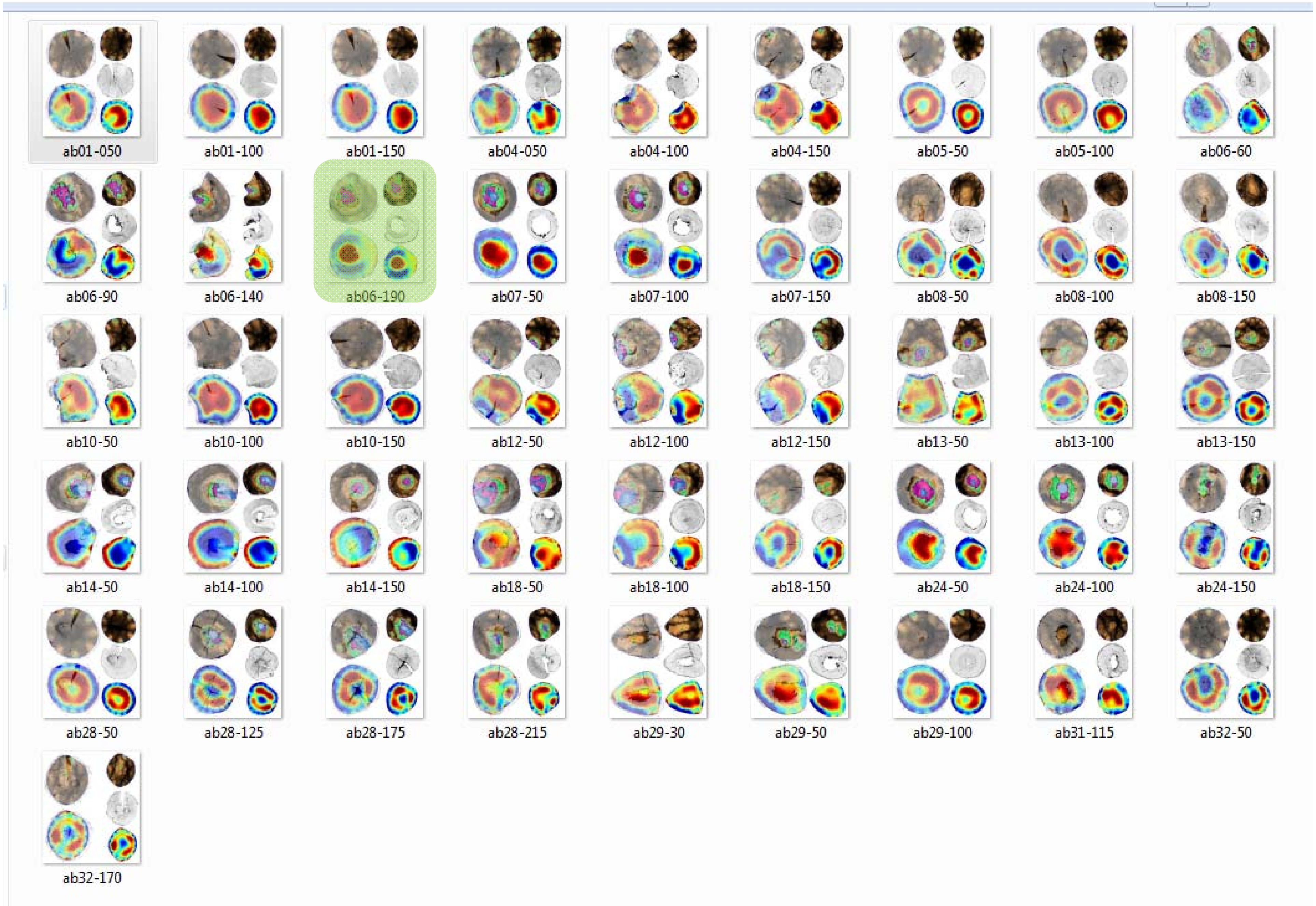
Phase I:
Develop and validate experimental approach

- Great Mountain Forest, Norfolk, CT; Summer 2014
- Three principle northern hardwood species:
  - Sugar maple, yellow birch, American beech
- 18 trees of each species (3 healthy)
  - 2-4 cross-sections per tree
  - Fell trees; cut “cookies” at each cross-section
    - Validate/calibrate tomography
    - Estimate C loss due to decay
    - Estimate age of tree; lifetime rate of decay



AB06
190 cm
140 cm
90 cm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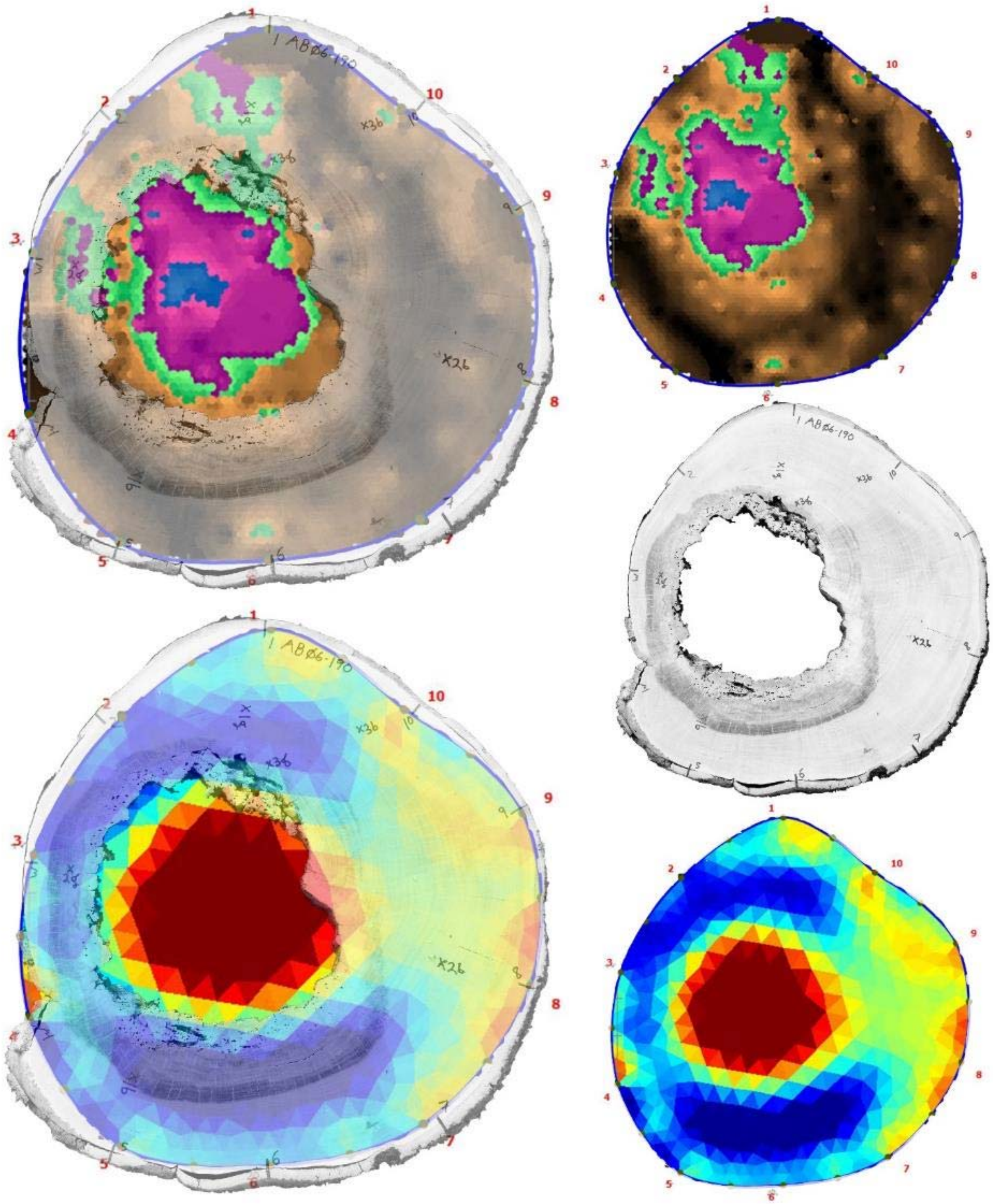

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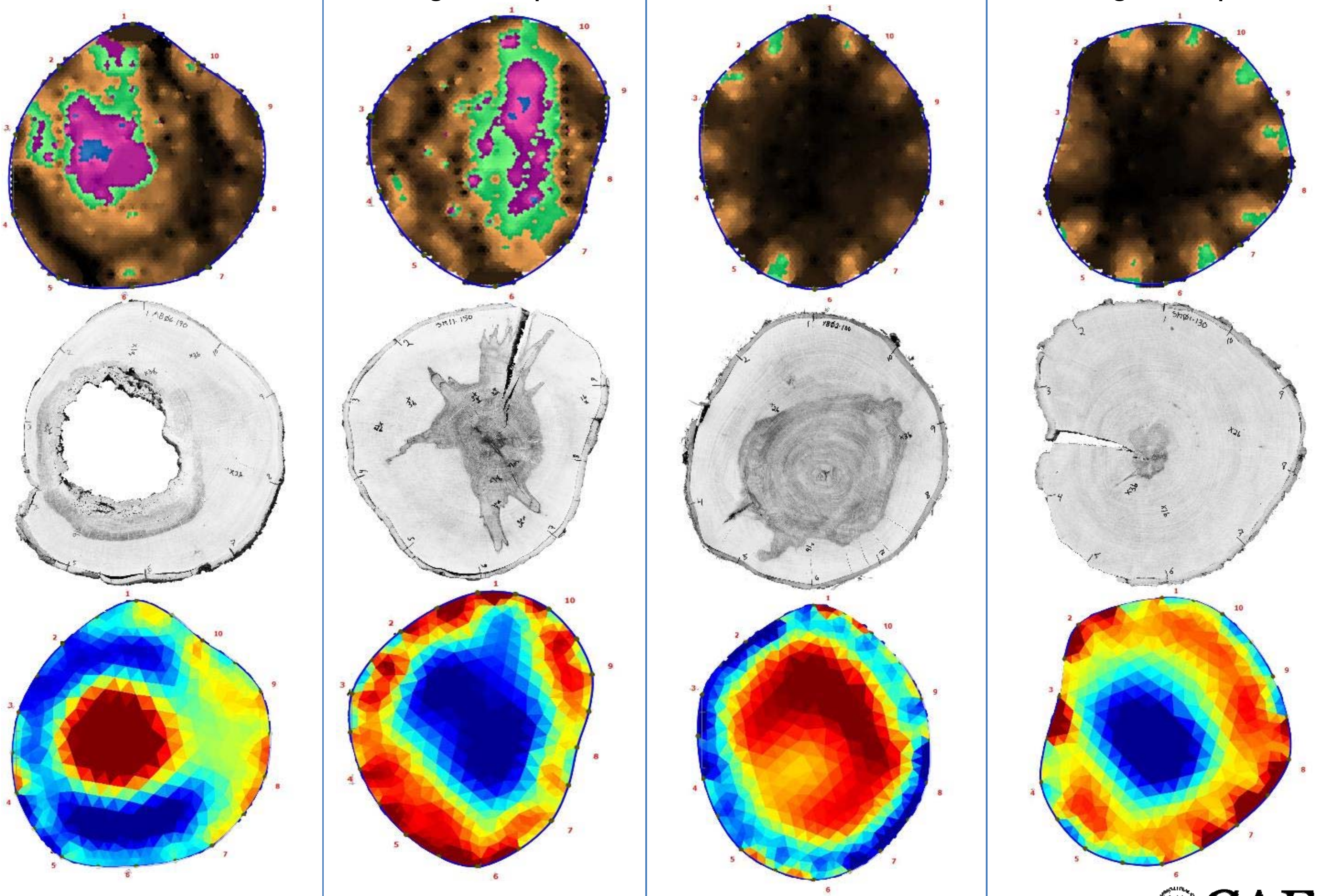
American Beech | Sugar Maple | Yellow Birch | Sugar Maple

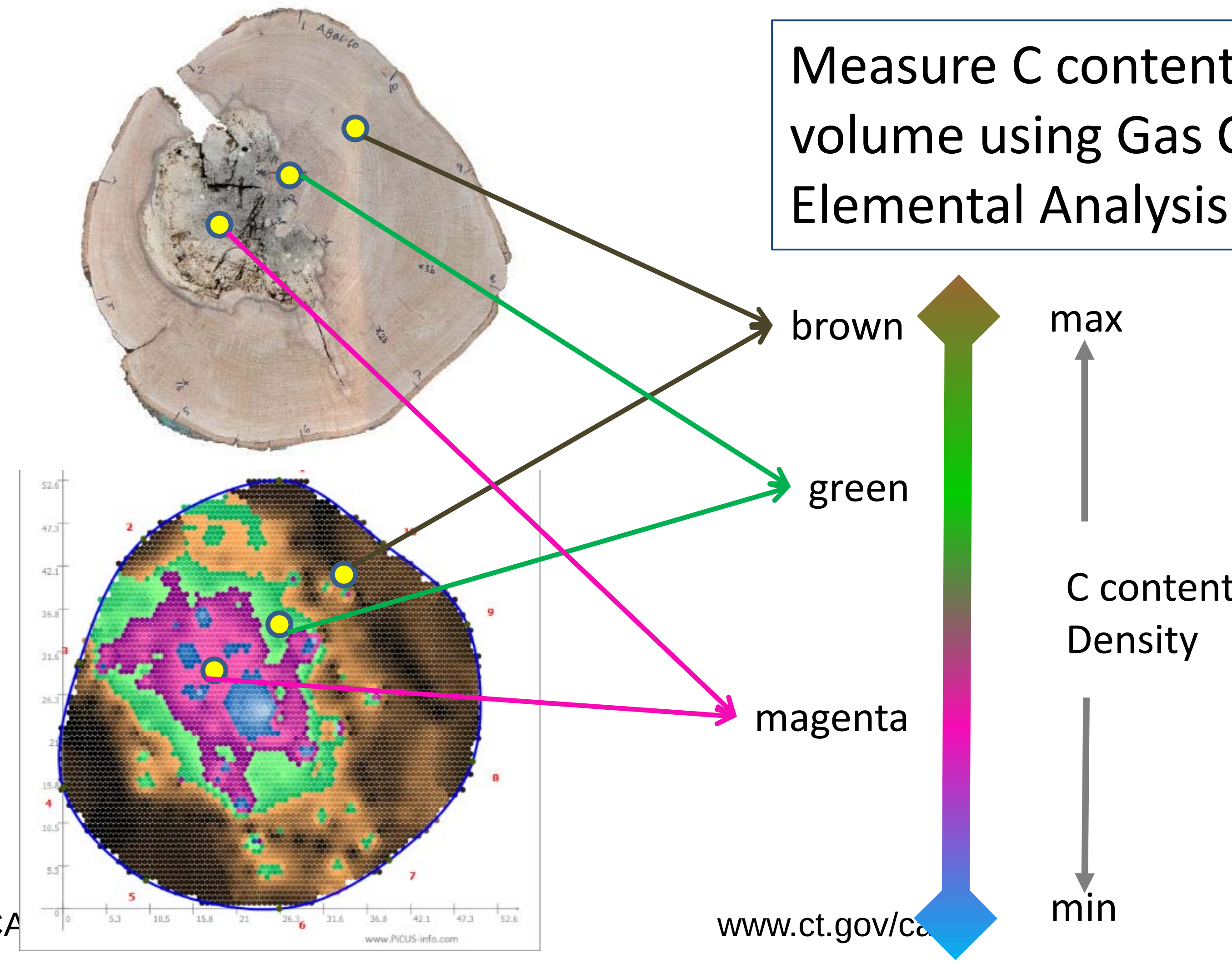


Internal Decay Metrics

- Three parameters:
  - Volume of decay:
    - ***Tomography***
  - C loss relative to non-decayed wood:
    - ***Gas Chromatography***
  - Age of tree:
    - ***Dendrochronology***
- Lifetime Rate of Decay:
  - Total amount of C lost in lower bole (2 m) over the life of the tree.

Calibrating tomography and carbon concentration

Measure C content as a function of volume using Gas Chromatographic Elemental Analysis (GCEA)



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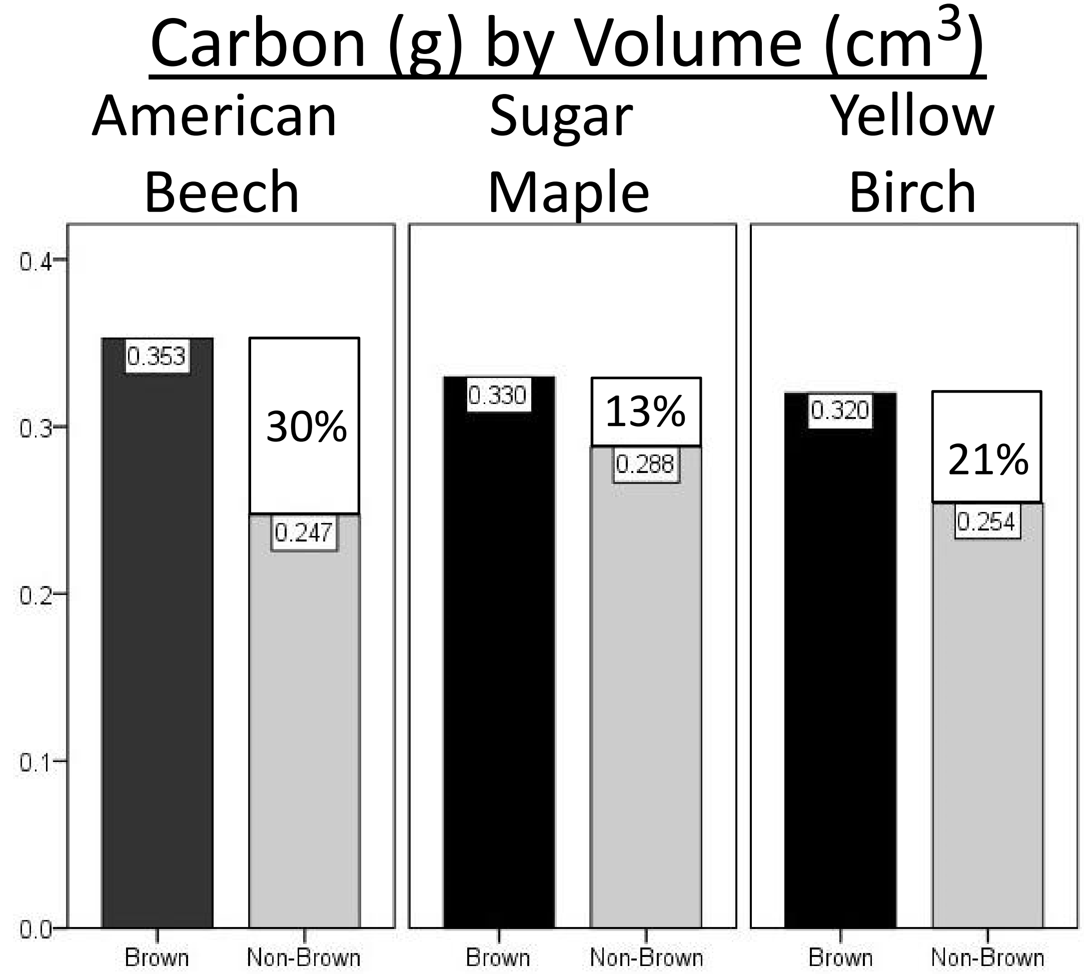
DEWALT
Strongarm5.com
18V
AB12-100

Calibrating tomography with carbon concentration

>500 wood samples (brown, green, magenta)

Non-brown:
green + magenta

Non-brown = cavity
100% C lost to decay



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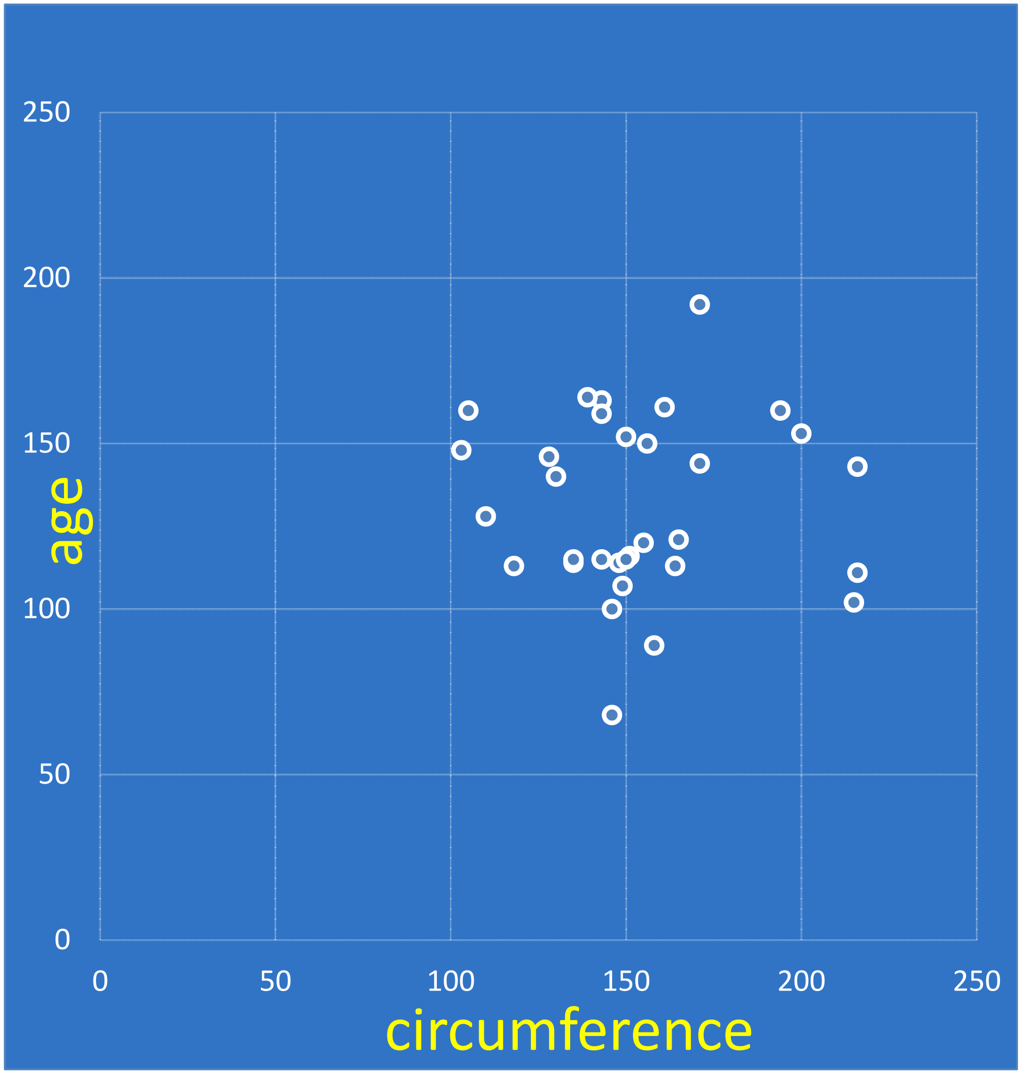
Dendrochronology

Tree ages:

65-192 years old

Circumference not predictive of age



Calculating Carbon Lost to Decay

C_{total} [C content assuming no decay]

$= V_{total} \times 0.353 \text{ g/cm}^3$

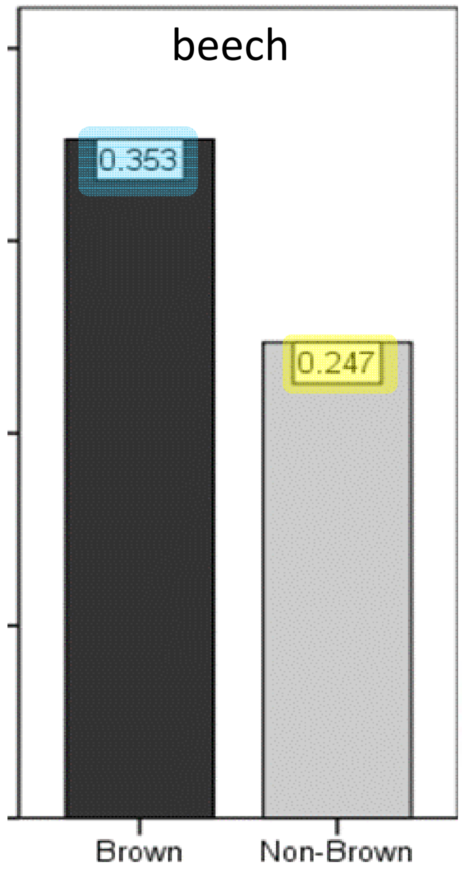
$C_{br} = V_{br} \times 0.353 \text{ g/cm}^3$

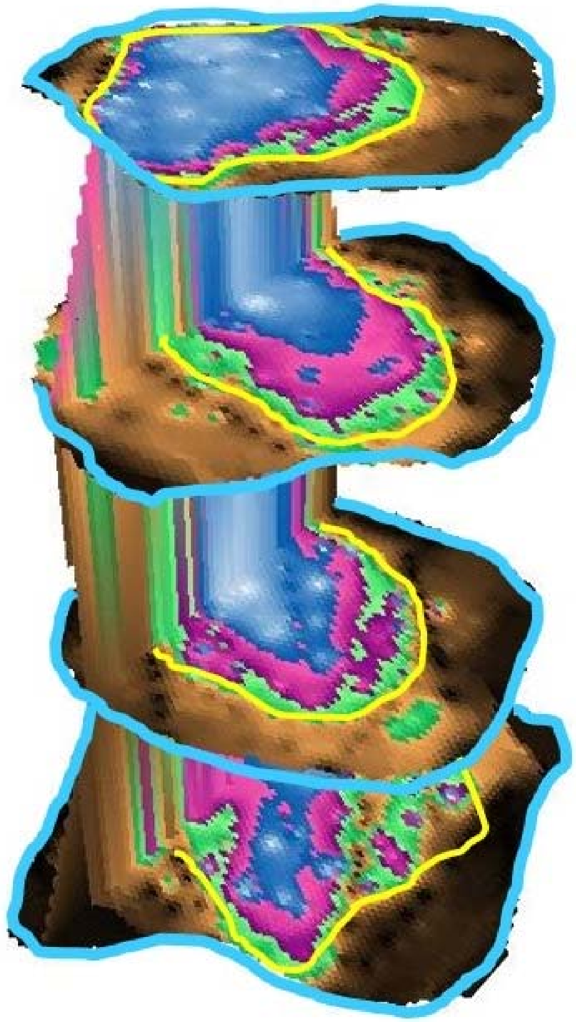
$C_{nbr} = V_{nbr} \times 0.247 \text{ g/cm}^3$

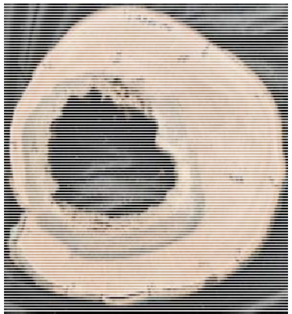
$C_{cav} = V_{cav} \times 0 \text{ g/cm}^3$

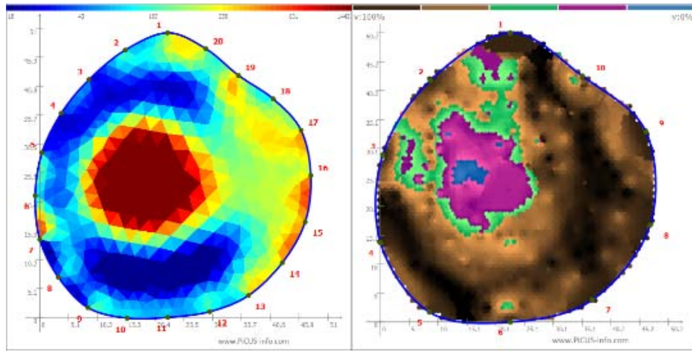
C lost to decay =

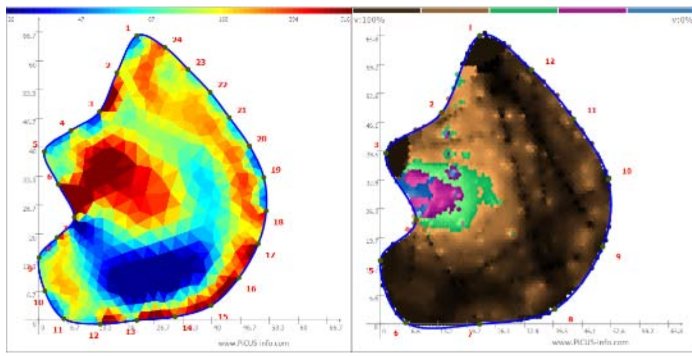
$C_{total} - (C_{br} + C_{nbr} + C_{cav})$

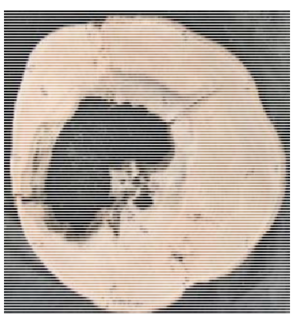


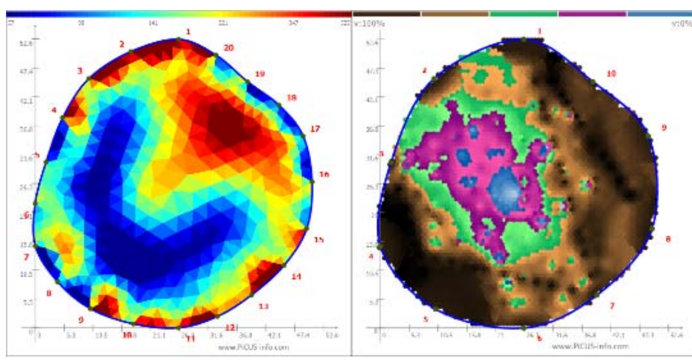












190 cm

140 cm

90 cm

American Beech, AB24
Age: 148 years old

Potential C = 53,073 g
C lost to decay = 11,496 g
(21.6%)

Lifetime Rate of C Loss:
78 g per year

190 cm

140 cm

90 cm

Role of internal decay in carbon dynamics of forest ecosystems

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Phase II:

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Acknowledgments

- ***National Science Foundation***
- ***Co-PI's***
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