Carbon sequestration in a 25-year-old tree-based intercropping system in Southwestern Ontario
• Exponentially growing populations
• Rising atmospheric CO2 levels
• Degrading land and soil quality
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Carbon sequestration in a 25-year-old tree-based intercropping system in Southwestern Ontario
Tree-Based Intercropping (TBI)

Proven to have many ecological and economical benefits.
TBI in southwestern Ontario...

- Agricultural crops grown between widely spaced tree rows
- Variety of tree species and agricultural crops
Proven to have many ecological and economical benefits
Tree biomass takes in carbon from the atmosphere to act as a carbon sink

$\text{[sequestration]} = \text{[photosynthesis]} \times \text{[respiration]}$

TBI to mitigate climate change
Tree biomass takes in carbon from the atmosphere to act as a carbon sink

\[ C[\text{sequestration}] = C[\text{photosynthesis}] - C[\text{respiration}] \]
Trees provide litterfall that act as a natural source of C and N to reduce need of fertilizer and chemicals and thus GHGs!
C and N improve longevity of soil to reduce the need of clearing more land for agriculture.

Can also be planted on remedial/degraded land to improve soil conditions for agriculture later.
Gaps in Research

• Lack of empirical data for TBI systems
• Doesn't always consider belowground C pools
• What do these systems look like after 25 years?
My research topic

• Can TBI systems sequester more carbon than conventional agricultural systems in southwestern Ontario?
Research Objectives

- Quantify above- and belowground C pools in tree biomass and soil organic carbon (SOC)
- Measure quantity and quality of carbon fluxes
- Model C sequestration potential of a 25 year old TBI system compared to conventional agricultural systems
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Research in Guelph, Ontario

Guelph Agroforestry Research Station
30 ha site, established 1987
Soil: sandy loam; calcareous parent material
Density: 111 trees/ha; RCBD
Research in Guelph, Ontario

Guelph Agroforestry Research Station
- 30 ha site, established 1987
- Soil: sandy loam; calcareous parent material
- Density: 111 trees/ha; RCBD
Poplar hybrid
*Populus sp.*

Red oak
*Quercus rubra*

Black Walnut
*Juglans nigra*

Norway spruce
*Picea abies*

White cedar
*Thuja occidentalis*

Maize
*Zea mays*

Soybean
*Glycine max*

Winter Wheat
*Triticum aestivum*

Barley
*Hordeum vulgare*
Above- and belowground C

Soil Significance
- Importance of understanding soil properties for ecosystem health
- SOC changes indicate the soil and climate conditions
- Soil structure affects water holding capacity and nutrient availability

SOC Results
- Average C concentration (%) vs. SOC stock (g/m²)
- Higher SOC concentration:
  - East direction (predominantly wind)
  - Close to the tree (0.5 m)
  - At shallower surfaces (0.6 m)
- Lower SOC stock:
  - East direction, predominantly wind
  - Close to the tree (0.5 m)
  - At deeper surfaces (2.0 m)

Tree Biomass Significance
- Faster growing tree species sequester more carbon in less time
- Allometric equations can act as growth models and predict C sequestration potential
  - \( y = ax \)
  - \( y \): biomass
  - \( x \): measurable variable (e.g., DBH, height)
  - \( a, b \): species-specific coefficients

Soil Organic Carbon
- Key factors contributing to SOC:
  - Tree species
  - Soil type
  - Management practices
- Long-term management strategies
  - Incorporate SOC into soil management plans
  - Monitor and adjust SOC levels over time
Above-ground:
- Destructive sampling of 3 trees per species
- Measure DBH, height, and mass of woody components
- Subsamples for C analysis

Below-ground:
- 2m² root excavation
- Weighed total root biomass
- Subsamples for C analysis
Tree Biomass Results

To determine C Content

- Determine above and belowground tree biomass
- Account for moisture content
- Calculating C content from subsamples (predicting to be ~50% C)
Carbon content (kg) for five species from a 27 year old TBI system

- Hybrid Poplar
- Black Walnut
- Red Oak
- Norway Spruce
- White Cedar

Legend:
- Blue: Belowground
- Red: Aboveground
Tree Biomass Significance

- Faster growing tree species sequester more carbon in less time.
- Allometric equations can act as growth models and predict C sequestration potential.
  - $y = ab^x$
  - $y$: biomass
  - $x$: measurable variable (i.e. DBH, height)
  - $a, b$: species-specific coefficients
Soil Organic Carbon

Soil samples collected:
- Depths: 0-10cm, 10-20cm, 20-40cm
- Distances: 0.5m, 1.0, 1.5m, 2.0m
- Directions: east and west
- = 72 samples per tree

Fumigated soil with 12 M HCl for 7 days to remove inorganic carbon

Analyzed for SOC with LECO CR-12 Carbon Analyzer
SOC Results

Average OC concentration (%) vs. SOC stock (g/cm²)

Higher OC Concentration:
- East direction (predominant wind)
- Closer to the tree row (0.5 m)
- At shallower surfaces (0-10 cm)

Higher SOC stock:
- East direction (predominant wind)
- Closer to the tree row (0.5 m)
- At deeper surfaces (20-40 cm)
Higher OC Concentration:

- East direction (predominant wind)
- Closer to the tree row (0.5 m)
- At shallower surfaces (0-10 cm)
Higher SOC stock:

- East direction (predominant wind)
- Closer to the tree row (0.5 m)
- At deeper surfaces (20-40 cm)
Soil Significance

- Importance of establishing TBI systems in the predominant wind direction

- SOC closest to the tree row can compensate for tree shading
- SOC within the top 40 cm of soil is beneficial for crop roots and nutrient uptake

- Improves long term soil conditions, crop yields, and long term stability of SOC in TBI systems
Soil Significance

• Importance of establishing TBI systems in the predominant wind direction

• SOC closest to the tree row can compensate for tree shading

• SOC within the top 40 cm of soil is beneficial for crop roots and nutrient uptake

• Improves long term soil conditions, crop yields, and long term stability of SOC in TBI systems
Above- and belowground C

- Detailed sampling of 3 trees per species
- 5 traits: DBH, height, and other woody parameters
- Subsamples for C analysis

Tree Biomass Significance

- Faster growing tree species sequester more carbon in less time
- Allometric equations can aid in growth models and predict C sequestration potential
  - $y = m b^x$
  - $y$: biomass
  - $x$: measurable variable (e.g., DBH, height)

SOC Results

- Average OC concentration (%) vs SOC stock (g/m²)

Soil Organic Carbon

- Sampled in October
- 3 replicates: 3, 5, 10
- Statistical tests performed
- 65 samples, 3 replicates
- Analysed for SOC in April 2023
- Kept in airtight container

Tree Biomass Significance

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- Allometric equations can aid in growth models and predict C sequestration potential
  - $y = m b^x$
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Next Steps...
Litter Decomposition
Modeling

- Combine above- and belowground C pools and fluxes to model C sequestration potential of TBI system over 25 years
25 years

Diagram showing the carbon cycle including:
- Atmosphere
- Assimilation by Trees
- Assimilation by Crops
- Soil Respiration
- C removal from crop harvest
- Harvest/Storage in Wood Products
- Long term SOC accumulation
- Leaching Carbon

Key components:
- Aboveground Tree C
- Belowground Tree C
- C in crops above-ground
- C in crops below-ground
- Litterfall
- 15m
- 20 cm

Diagram illustrates the flow of carbon through different components of the ecosystem.
Expected Results

• Higher C sequestration vs. conventional agriculture
• Newly formed allometric equations to predict growth and sequestration
• Higher carbon inputs
• Higher concentrations of SOC
Who Cares?

Future Generations
- Land management and amelioration
- Sustainable agricultural practices
- Food security

Government
- Meet climate change goals through C sequestration and reduction of GHG
- Provide tax incentives and C credits to land owners

Policy Makers
- Develop models to improve human estimates
- Improve accuracy of our predictions

Land Owners
- Benefits of Till
- Application of modeling systems for C credits
Land Owners

- Benefits of TBI
- Application of modeling systems for C credits
Policy Makers

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Future Generations

- Land management and amelioration
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- Food security
Thank you!