Sustainability 101: Just What is Carbon Sequestration?

Mary Owen
UMass, Amherst, Extension Turf Program
Carbon Sequestration......

• Capture and storage of carbon
  – ocean, soil, biomass
  – injection of CO$_2$ from power plant emissions into geologic formations (e.g. oil and gas reservoirs and unmineable coal seams) (DOE)
  – fixation of carbon through the process of photosynthesis
Sequestered C
C fixation in turfgrasses
Photosynthesis is the process by which chlorophyll containing plants combine carbon dioxide and water, in the presence of light energy (sunlight), into simple sugars and carbohydrates.

$$6\text{CO}_2 + 12\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$$
Photosynthesis

$6\text{CO}_2 + 12\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$

(chlorophyll)
Carbohydrates in turfgrasses
Non-structural CHO

Energy (sink priority)
Storage (CHO reserves)
Structural CHO

Large molecules provide architecture of the plant.
Respiration is the process by which energy is released from carbohydrates for plant growth & development

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Respiration

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(chlorophyll)

Respiration

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 12\text{H}_2\text{O} \]
Respiration

- Provides energy for metabolism, cell maintenance, growth, and nutrient uptake and transport

- $C_3$ and $C_4$ use the same pathway

- Happens in all living plant parts
Cool season, C₃ turfgrasses

**Bluegrasses,**  
*Poa spp.*  
Kentucky  
annual

**Bentgrasses,**  
*Agrostis spp.*  
creeping  
velvet  
colonial

**Fine fescues,**  
*Festuca spp.*  
creeping red  
Chewings  
hard

**Tall fescue,**  
*Festuca arundinacea or Schedonorus pheonix*

**Rye grasses,**  
*Lolium spp.*  
perennial  
annual  
intermediate
Warm season, $C_4$ turfgrasses

Bermudagrass,  
*Cynodon* spp.

Buffalograss  
*Bouteloua dactyloides*

Kikuyugrass  
*Pennisetum clandestinum*

Seashore paspalum  
*Paspalum vaginatum*

Zoysiagrass  
*Zoysia* spp.

St. Augustine grass  
*Stenotaphrum secundatum*
C₃ leaf structure

- CO₂
- Light
- mesophyll cells
- stoma
- chloroplast
- H₂O
- epidermis

Adapted from Fry & Huang, 2004
Photosynthesis

Growth
CHO storage

Respiration
Maintenance
CHO loss
Tissue loss

Light compensation point

Adapted from Fry & Huang, 2004
Factors Affecting PHS

- Light
- Temperature
- Water
- Nutrient Availability
- Leaf Characteristics
Light

• **Light Saturation Point** – level at which PHS reaches maximum

• **Light Compensation Point** – level at which PHS and RESP reach equilibrium
  – zero net carbon gain
  – no plant growth will occur

• Both LSP and LCP are higher in $C_4$ than in $C_3$
Net photosynthesis

Light level

Light saturation point

C₃

C₄

Adapted from Fry & Huang, 2004
Photosynthesis

Growth
CHO storage

Respiration

Maintenance
CHO loss
Tissue loss

Light compensation point
Photorespiration

• In C$_3$ grasses, seldom in C$_4$
  – O$_2$ is consumed
  – CO$_2$ is released

• Can result in a net reduction in photosynthesis especially during high temperatures
Temperature

Net photosynthesis

C₃

C₄

Adapted from Fry & Huang, 2004
Temperature

Optimum temperature for photosynthesis

$C_3$: 68-77°F (20-25°C)

$C_4$: 86-95°F (30-35°C)

When exposed to full sunlight and high temperatures $C_4$ grasses can produce 2X the dry matter that $C_3$ can produce.
Seasonal growth patterns: $C_3$ and $C_4$ Grasses

Adapted from J.S. Ebdon
Some other $C_4$ plants........

- crabgrass
- yellow nutsedge
- nimblewill
Water

• Necessary for PHS

• Affects open/close of stomates
  – too little or too much can lead to stomatal closure (reduced CO₂)

• Water deficit → synthesis of abscisic acid in roots → stomatal closure

• C₄ grasses are more efficient at water use
Leaf Characteristics

- Greater leaf area = more PHS
- As leaf angle increases, canopy shade increases and PHS is reduced
- Pubescent leaves reflect more light and are less efficient at PHS
# Role of Nutrients in PHS

<table>
<thead>
<tr>
<th>Nutrient(s)</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>N &amp; Mg</td>
<td>Essential parts of chlorophyll</td>
</tr>
<tr>
<td>Fe</td>
<td>Activates enzymes involved in chlorophyll production</td>
</tr>
<tr>
<td>S</td>
<td>Involved in electron transport in PHS (chemical movement of energy)</td>
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<tr>
<td>Fe, S, Mn, and Cu</td>
<td>Parts of several proteins involved in PHS</td>
</tr>
<tr>
<td>Cl</td>
<td>Needed for evolution of $O_2$ through PHS</td>
</tr>
<tr>
<td>K</td>
<td>Promotes maintenance of cell turgor and stomatal opening</td>
</tr>
</tbody>
</table>

Lack of adequate nutrition can result in stomatal closure, leading to reduced PHS.
Factors Affecting Respiration

- CHO availability
- $O_2$ availability
- Temperature
- Water
- Nutrient availability
- Plant physiological condition and age
Not all turf areas can fix CO$_2$ effectively
All that’s green does not photosynthesize
Seasonal growth patterns: $C_3$ and $C_4$ Grasses

$C_3$ grasses

$C_4$ grasses

Adapted from J.S. Ebdon
• Carbon stored in plant tissue eventually ends up in the soil as soil organic carbon (SOC) in the soil organic matter (SOM).
Soil profile with horizons

- **O** organic residue
- **A** topsoil
- **B** subsoil
- **C** substratum
- **D** bedrock (if present)
Humates are a form of sequestered C
Soil organic matter can be depleted by:

- extensive cultivation
  - introduction of high levels of \( \text{O}_2 \) and increase in microorganism activity
- high N fertilizer use
Cover crops, No-till
Manures, Green manures
Turf is a perennial crop.....

...highly trafficked turf poses a challenge
CO$_2$ and Turf studies:


• Milesi et al., 2005. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. Env. Mgt.

CO$_2$ and Turf studies:


Turf and CO$_2$ studies summary

- Soil organic matter accumulates from root, shoot and litter turnover, especially as turf matures
- Total C sequestered continues to increase as turf matures
- Different grasses may vary in the amount of C they sequester
Turf and CO$_2$ studies summary

- Well watered, well fertilized turf is a significant carbon sink
- Turf maintained under high and low fertility is a significant sink for both C and N when clippings are returned
- Nutrient needs of some types of turf (e.g. lawns, undisturbed parkland, etc) allowed to mature for a long period of time may have a reduced need for additional nutrient input.
• Low fertilization and clipping removal on young stands can result in rapid decline of biomass (SOC).

• Reducing N inputs and returning clippings as a turf stand ages can lead to minimal long term nutrient leaching potential.

• Use of PGRs in combination with N fertility may increase C sequestration.
Management strategies to promote carbon sequestration
Select grasses and cultivars best suited to site and use, with emphasis on stress, traffic and pest tolerance.
Maintain turf cover. Provide adequate and balanced nutrition.
Use excellent establishment practices.

Irrigate to ensure functional quality, with conservation as a priority.
Build roots

Be careful with build-up of organic matter in sand based systems.
Return clippings, either straight away or compost and use as topdressing.
Manage traffic
Consider energy and resource efficiency whenever possible.

- manufacture, transport and application of turf management materials
- water distribution
- equipment operation and maintenance
Consider converting peripheral lawns into *managed* meadows.
Thank you!