Net Ecosystem Carbon & Nitrogen

Robert Scheller
Professor of Landscape Ecology

February 2021

NC STATE UNIVERSITY

NECN Philosophy

- Why NECN?
  - Total Ecosystem Carbon
    - Aboveground
    - Belowground soil C accounting
    - smoke emissions: flaming vs. smoldering
    - Net Ecosystem Exchange ~ flux towers
    - Net Biome Production: incorporating disturbance effects

NECN Philosophy

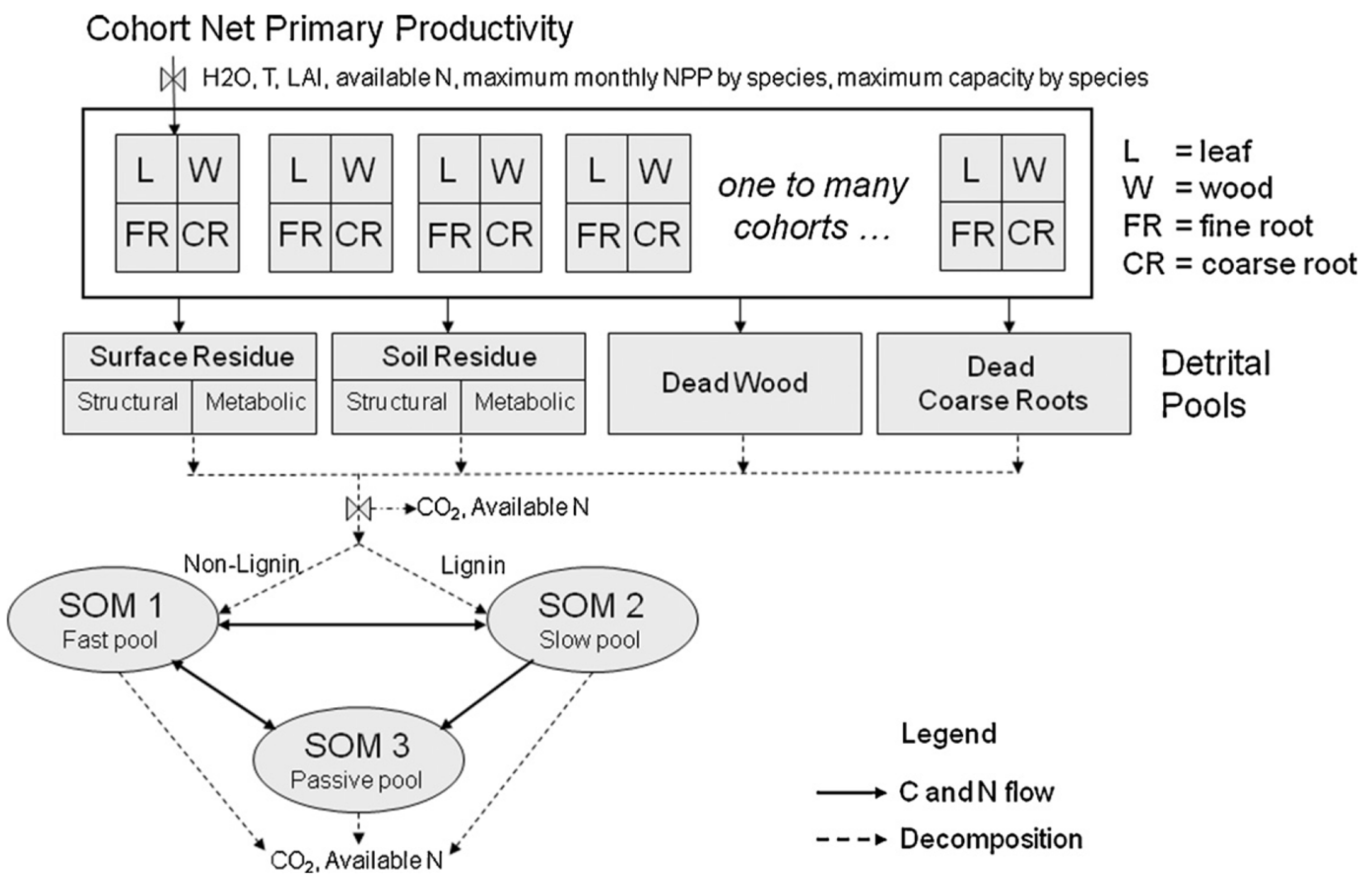
- Why NECN?
  - Total Ecosystem Nitrogen
    - Nitrogen is very often the primary limit to growth
    - Different tree/shrub species have varying N requirements
    - N allocation: roots, bole, foliage
    - N allocation: seasonal resorption

NECN Philosophy

- Why NECN?
  - C & N tracked across many pools:
    - Cohorts
    - Dead wood and roots
    - Dead foliage and humus
    - Three soil pools (following CENTURY model): Fast, slow, passive
    - Mineral N

NECN Philosophy

- Why NECN?
  - C & N tracked across many pools:



NECN Philosophy

- Why NECN?
  - Built from principles of ecosystem ecology
  - Primary drivers:
    - Mass balance
    - Water budgets (AET, PET, CWD, etc.)
    - Leaf Area Index (LAI)
    - Weather and climate change (monthly)
    - Heterotrophic respiration
  - Cohorts compete for light, water, N

NECN Philosophy

- Why NECN?
  - Functional Response of Species to Climate
    - Regeneration and Growth
    - Temperature
    - Soil Moisture
  - Other Key Species Traits
    - N fixer?
    - Leaf longevity
    - Epicormic resprouting

NECN Philosophy

- Why NECN?
  - Next generation design:
    - No ecoregions!
    - Maps as inputs
    - Soil water balance and regeneration at cell-scale
    - CSV inputs
    - Tight links with disturbances
    - Tight link with climate projections
    - No cohort spin-up

Common Applications

- Carbon and Climate Change
- Nitrogen limits and N deposition
- Smoke emissions

NC STATE
UNIVERSITY

Discussion Break

- Everyone give an example of goals / scenarios where you think NECN might be useful

Input Walkthrough

- A brief tour

- From the example:

- https://github.com/LANDIS-II-Foundation/Extension-NECN-Succession/blob/master/testing/Core7-NECN6.6/NECN_LTB_landscape.txt

Common Data Sources and Challenges

- Species Inputs
- LAI and light table
- Input maps
- Functional group properties
- Disturbance effects

Species Inputs

- Example on screen

LAI and Light Table

- NECN determines shade class of a cell using modeled LAI of the cell
- Probability of suitable light is determined by the shade class of the cell and the shade tolerance of the species
- Species shade tolerance defined by user in the species table, other factors are provided by the LAI table and light establishment table.

Leaf Area Index Determines Shade

```
MaximumLAI

>> Shade      Max LAI
>> Class
>> ----------  --------------------
       1        2
       2        4
       3        6
       4        8
       5        10
```

MaximumLAI table determines the shade class for each cell based on LAI. The left column is the minimum value of LAI for assignment to that shade class

- e.g. with the example table, a cell with modeled LAI of 7 would be assigned a shade class of 3

```
LightEstablishmentTable
>> Spp Shade    Probability
>> Class          by Actual Shade
>> ----------  -------------------
>>              0            1            2            3            4            5
       1        0.71513961   0.14296328   0.05597292   0.02831985   0.01643340   0.04117
       2        0.48200635   0.21131895   0.10263309   0.05849241   0.03674448   0.10880
       3        0.17888790   0.31529263   0.20247909   0.11672447   0.06797111   0.11864
       4        0.02749268   0.19276773   0.23992545   0.18649094   0.12543924   0.22788
       5        0.001568513  0.051464001  0.149236027  0.188126608  0.170169509  0.43943
```

LightEstablishmentTable determines the probability that a cell has a suitable light for regeneration

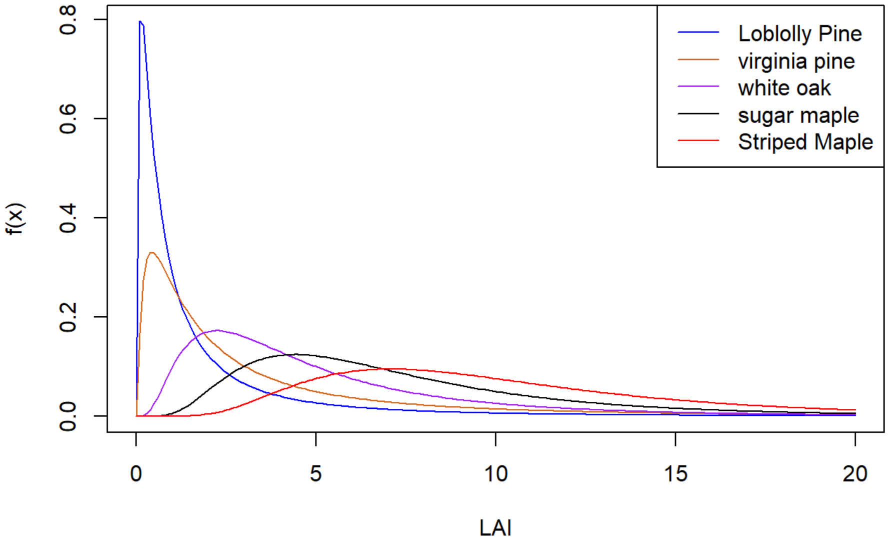
- e.g. the probability that a cell with shade class 3 would be a suitable light environment for a species with shade tolerance class 4 is **0.186**

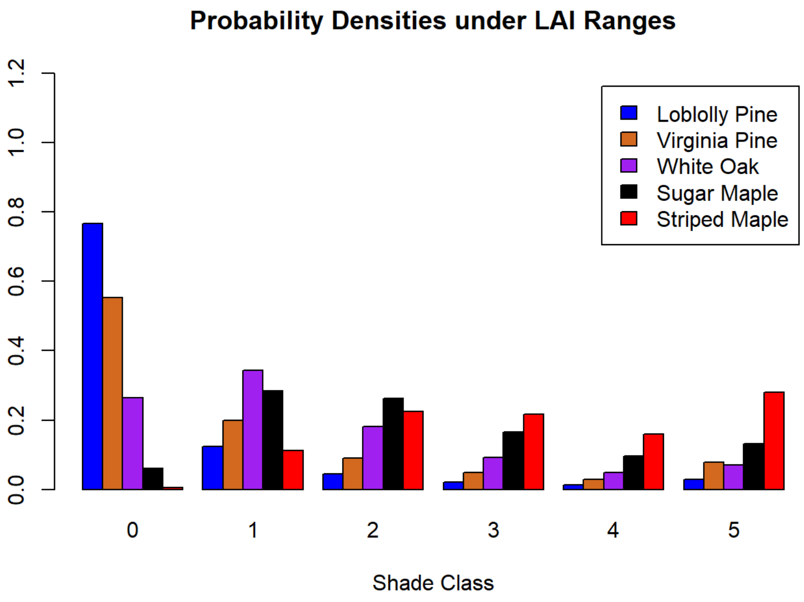
Leaf Area Index Determines Shade

- How to estimate probability of suitable light?
- Old school: Expert opinion
- Cool kids: Data
- Specifically plot data that includes regeneration (< 1" dbh)

Leaf Area Index Determines Shade

- Christopher Gerstle: ctgerstl@ncsu.edu
- FIA Data





Input Soil Maps

- You will need a good source of soils data
- Most difficult is the initial SOC, SON pools
  - First, approximately allocate C: NEED RULE OF THUMB
  - C:N ratios across pools need to be fixed in parallel so as not to fix one layer by stealing from another layer.
  - If you start N too high or low, they will be squirrelly
  - A good starting ratio is ~35C:1N (SOM3 > SOM2 > SOM1)

Functional Group Properties

- Groups of trees that share common physiological traits, e.g., Northern hardwoods.

- Shape of soil temperatures effect on growth.
- LAI ~ Biomass Relationship
- Response of growth to moisture.
- Monthly wood mortality and decay
- Turn over of leaves and roots

Functional Group Properties

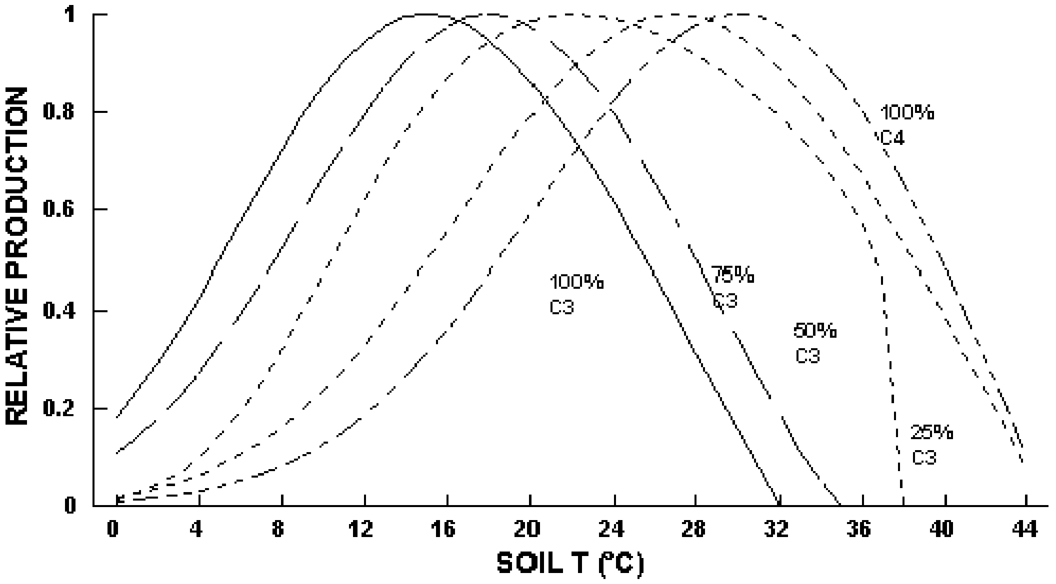
- Growth Response to soil temperature

Four parameters determine the relationship between soil moisture and relative production (ANPP).

$$k = \frac{a_3 - T_s}{a_3 - a_2}$$

$$L_t = k^{a_4} e^{\frac{a_4(1-k^{a_5})}{a_5}}$$

Ts: Soil temperature



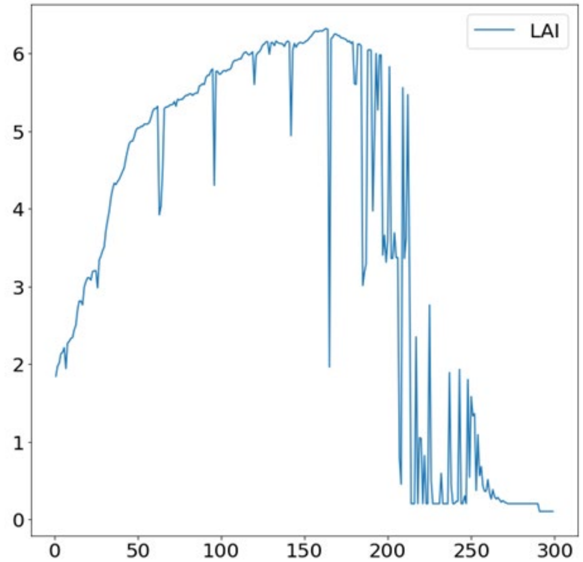
Functional Group Properties

- LAI ~ Biomass Relationship
- Captures
  - Effect of total AGB
  - Seasonal changes in LAI
  - No seasonal changes for conifers
- LAI Determines
  - Growth and competition for light
- Calibrated against plot data of similar forest types

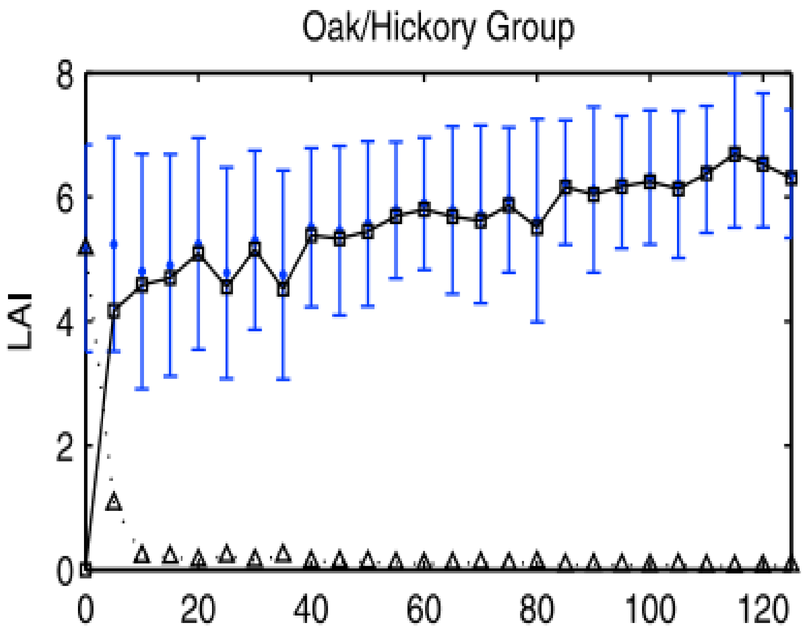
Functional Group Properties

- LAI ~ Biomass Relationship: Example

LANDIS-II LAI



Published records



Northern Mesic Hardwoods:*Quercus montana*

NC STATE
UNIVERSITY

Functional Group Properties

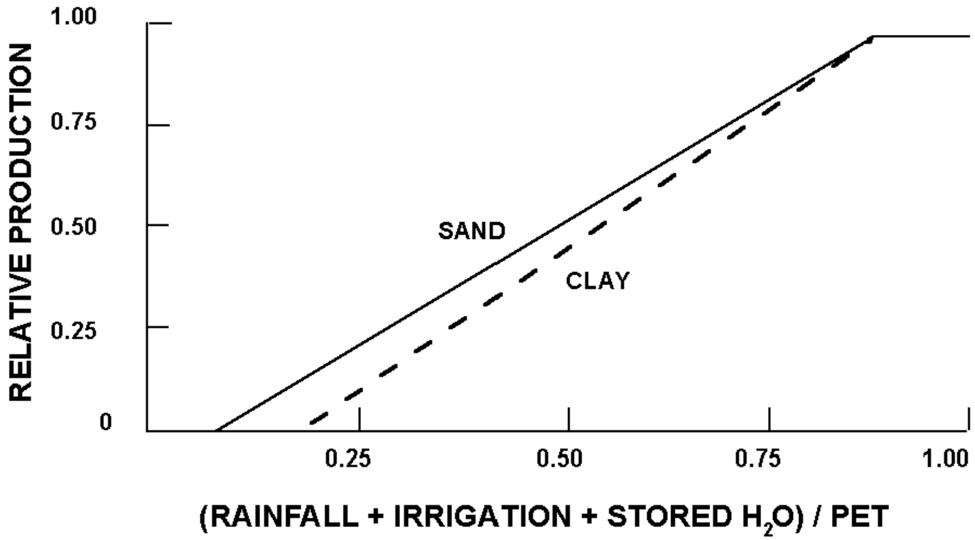
- Response of Growth To Soil Moisture

Control the relationship between water content, the ratio of P~ET and growth. As water is limited growth.

This creates a multiplier that controls max ANPP.

- $$L_w = 1 + \frac{1}{M_1 - (M_1 * WC)} + (r - M_2)$$

r: ratio of P/ PET
WC: Stored water



NC STATE
UNIVERSITY

Disturbance Effects

- If not listed, assume all dead material on the ground
- Otherwise, need to find reasonable values for FIRE and HARVESTING
- Quick review

Output Checklists

Climate-future-log: in approximate order

- Graph temperature and precipitation
  - Look at the units and the over long-term behavior
  - If either is far off, then likely using the wrong unit selection in the climate-generator input file

Output Checklists

NECN-succession-log: in approximate order

- Mineral N: should vary ~2-10
  - Consider adjusting atmospheric inputs
  - Consider adjusting DenitrificationRate
- Soil Carbon: Stable without disturbance?
  - Which pool is least stable?
  - Is the CN ratio stable? If not, N input maps may be off
  - If CN stable, adjust decay rates

Output Checklists

NECN-succession-log: in approximate order

- AGB
  - Appropriate change for landscape age?
  - Young should be increasing
  - Older should be stable or maybe even declining a bit
  - Is Mineral N too limiting or not limiting enough?

Output Checklists

NECN-prob-establish-log: in approximate order

- What are the limiting factor for each species?
  - Are there species with Pest always 0.0?
  - Are there species with Pest always 1.0?
  - Others as expected?

Output Checklists

SINGLE CELL with Calibrate turned on

Calibrate-log: in approximate order

- What is limiting the growth of your cohorts?
- Is temperature appropriately limiting for each month? (e.g., cold winters should be ~0.0)
- Is N too limiting or not limiting enough?

Primary Literature

- Parton, W.J., Scurlock, J.M.O., Ojima, D.S., Gilmanov, T.G., Scholes, R.J., Schimel, D.S., Kirchner, T., Menaut, J.C., Seastedt, T., Garcia Moya, E., Kamnalrut, A., Kinyamario, J.I., 1993. Observations and modeling of biomass and soil organic matter dynamics for the grassland biome worldwide. Global Biogeochemical Cycles 7, 785–809.
- Scheller, R.M., D. Hua, P.V. Bolstad, R. Birdsey, D.J.Mladenoff. 2011. The effects of forest harvest intensity in combination with wind disturbance on carbon dynamics in a Lake States mesic landscape. Ecological Modelling 222: 144-153.
- Lucash M.S., R.M. Scheller, A.M. Kretchun, K. Clark and J. Hom. 2014. Impacts of climate change and fire on long-term nitrogen cycling and forest productivity in the New Jersey Pine Barrens. Canadian Journal of Forest Research 44: 402-412.

Thank You!

- rschell@ncsu.edu