COMPLEX FOREST DYNAMICS INDICATE POTENTIAL FOR SLOWING CARBON ACCUMULATION IN THE SOUTHEASTERN UNITED STATES

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Aims & Scope

- Develop an carbon accounting approach that:
  1. Unambiguously separates land use change from net sequestration
  2. Separates net sequestration by disturbance
     - Natural: effects of fire, weather, insects & diseases
     - Anthropogenic: effects of forest management (primarily cutting)
  3. Provides a mechanism for short term forecasts.
- Understand the relative contribution of land use change and disturbance on net forest sequestration (sequestration – emission)

Some Carbon Accounting Background

- This analysis follow IPCC carbon (C) accounting principles.
- C accounting principles ≠ C cycle science
- Net C stock change = sequestration - emission + afforestation-deforestation
- Land Use ≠ Land Cover

IPCC Guidance

Some key excerpts from IPCC Good Practice Guidance for LULUCF

- "…capable of representing carbon stock changes and greenhouse gas **emissions** and **removals** and the relations between these and **land use** and **land-use changes**
- …capable of representing **management** and **land-use change** consistently over time, **without being unduly affected** either by **artificial discontinuities in time series data** or by effects due to interference of sampling data with **rotational or cyclical patterns of land use** (**e.g., the harvest-regrowth cycle in forestry**, or managed cycles of tillage intensity in cropland).
- **Forest land** includes systems with **vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category**."

The Issue

- Combining land use change, sequestration, emission is confusing
  - UN Expert review panel suggested separation
  - Domestically C based land use policy is hard to develop because of ambiguity.
- State Department CO_2 reduction negotiators need risk articulated.
- Risk
  - Forest aging
  - Natural disturbance
  - Land use competition
- Risk from natural disturbance can be ‘mitigated’ using Kyoto Protocols for attribution of natural disturbance.

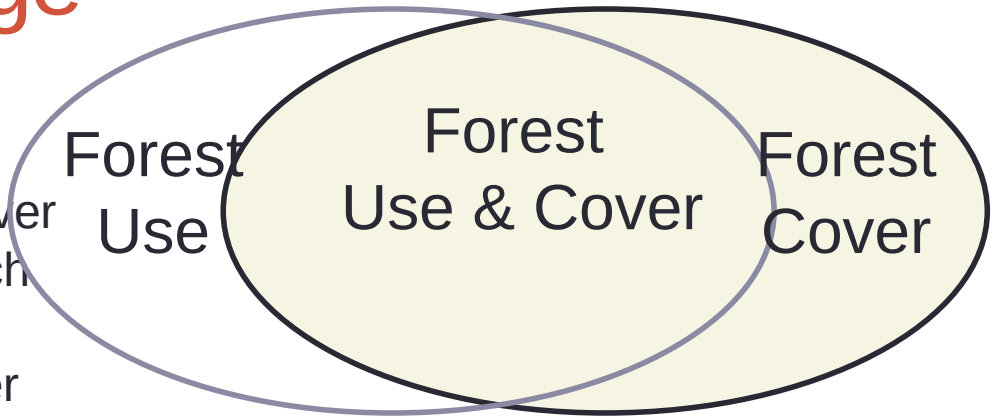
First some requisites:

- What is a forest land use
  - ‘Use’ is a socioecominic choice.
  - It is the purpose for which the land is managed
- This differs substantially (particularly in the South) from forest cover
- Both are important but….

Forest Use and Forest Cover: definitions and drivers of change

- FIA Example forest land use definition: Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds *in situ*. It does not include land that is predominately under agricultural or urban land use.

- NLCD Example forest land cover definition: Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover



Drivers of change

- Conversion to developed
- Natural conversion from agriculture to forest
- Tree planting
- Harvesting
- Severe fire and insect outbreaks
- Some thinning operations

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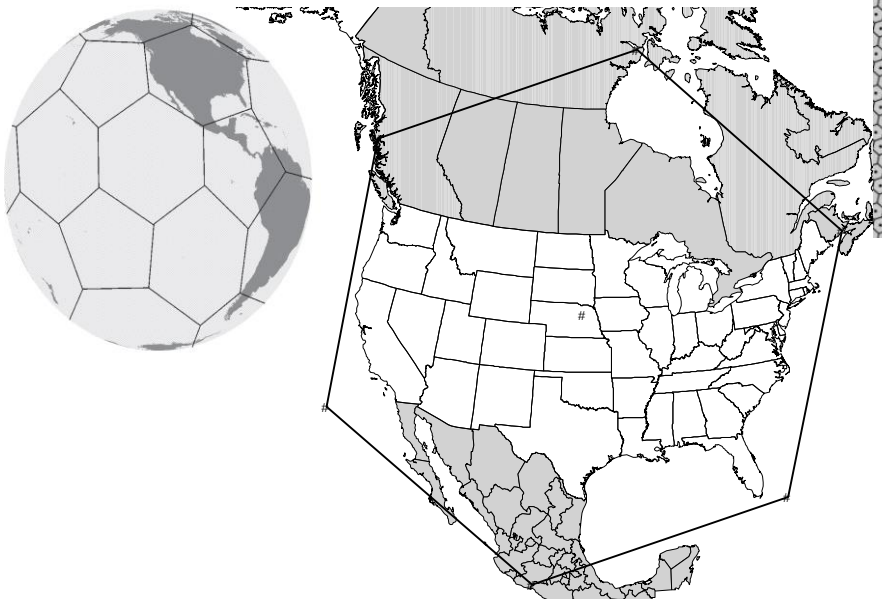
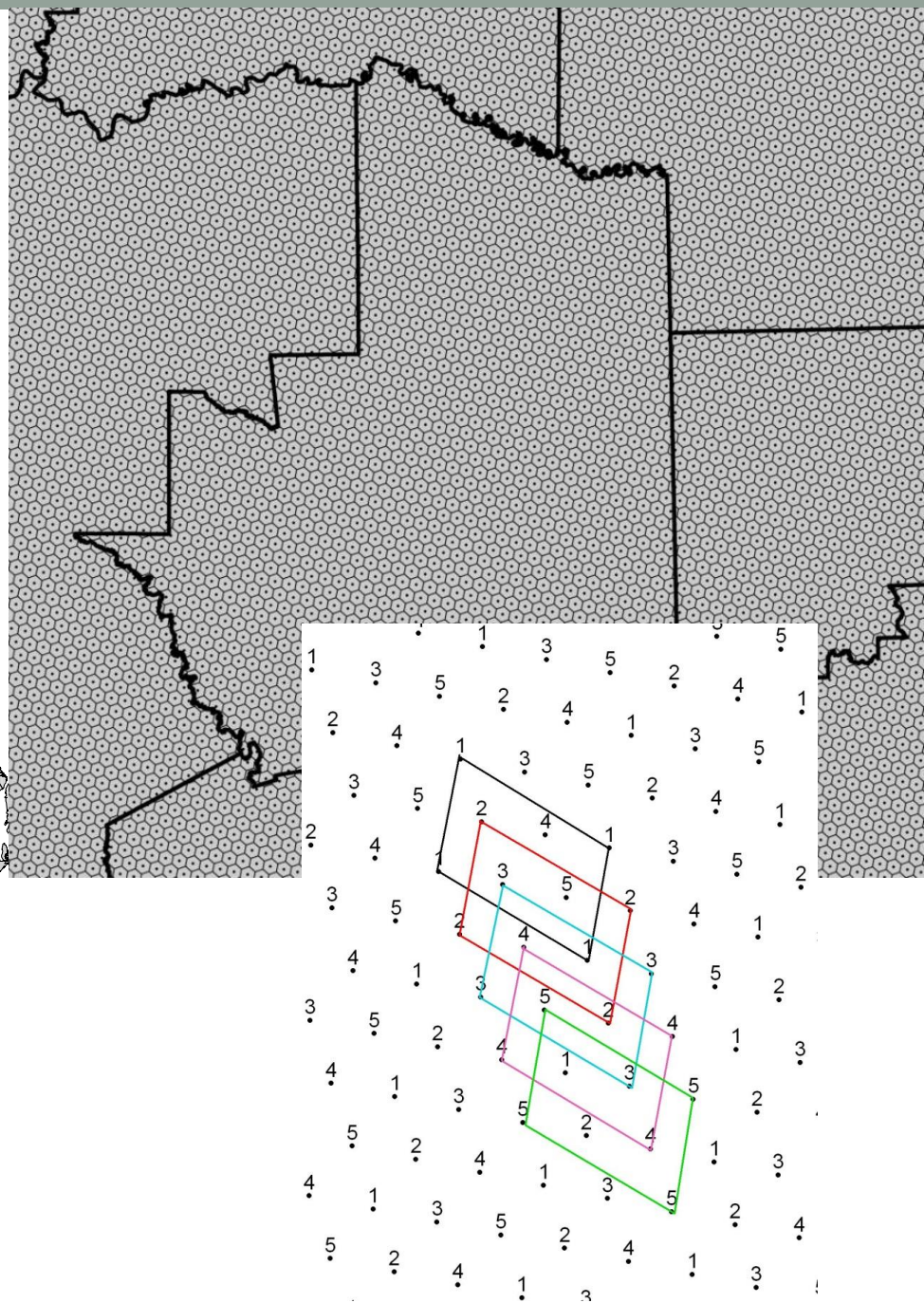
Data Used

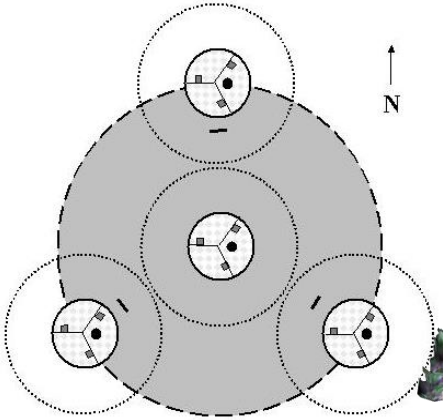
- We used data from the USFS Forest Inventory and Analysis program
- FIA is a longitudinal study over space and time across all land uses and covers.
- Plot locations are permanent arising from a global design.

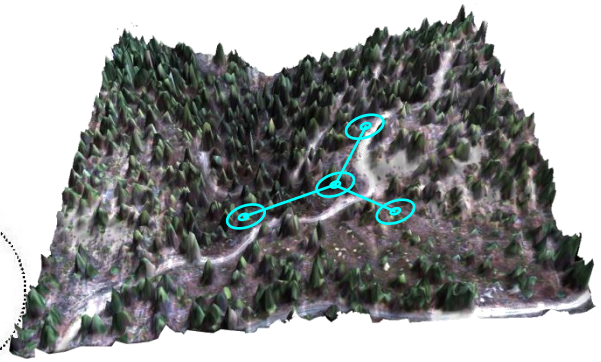


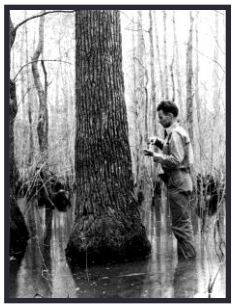


Data Used

- Plot information
  - Land Use (all plots regardless of whether area is forested)
  - stand age
  - Disturbance
    - Cutting
    - Fire
    - Insect & disease
    - Weather
  - Carbon stock
    - SOC
    - Live above ground
    - Live below ground
    - Dead wood
    - Litter
- Time 1 and time 2 data available



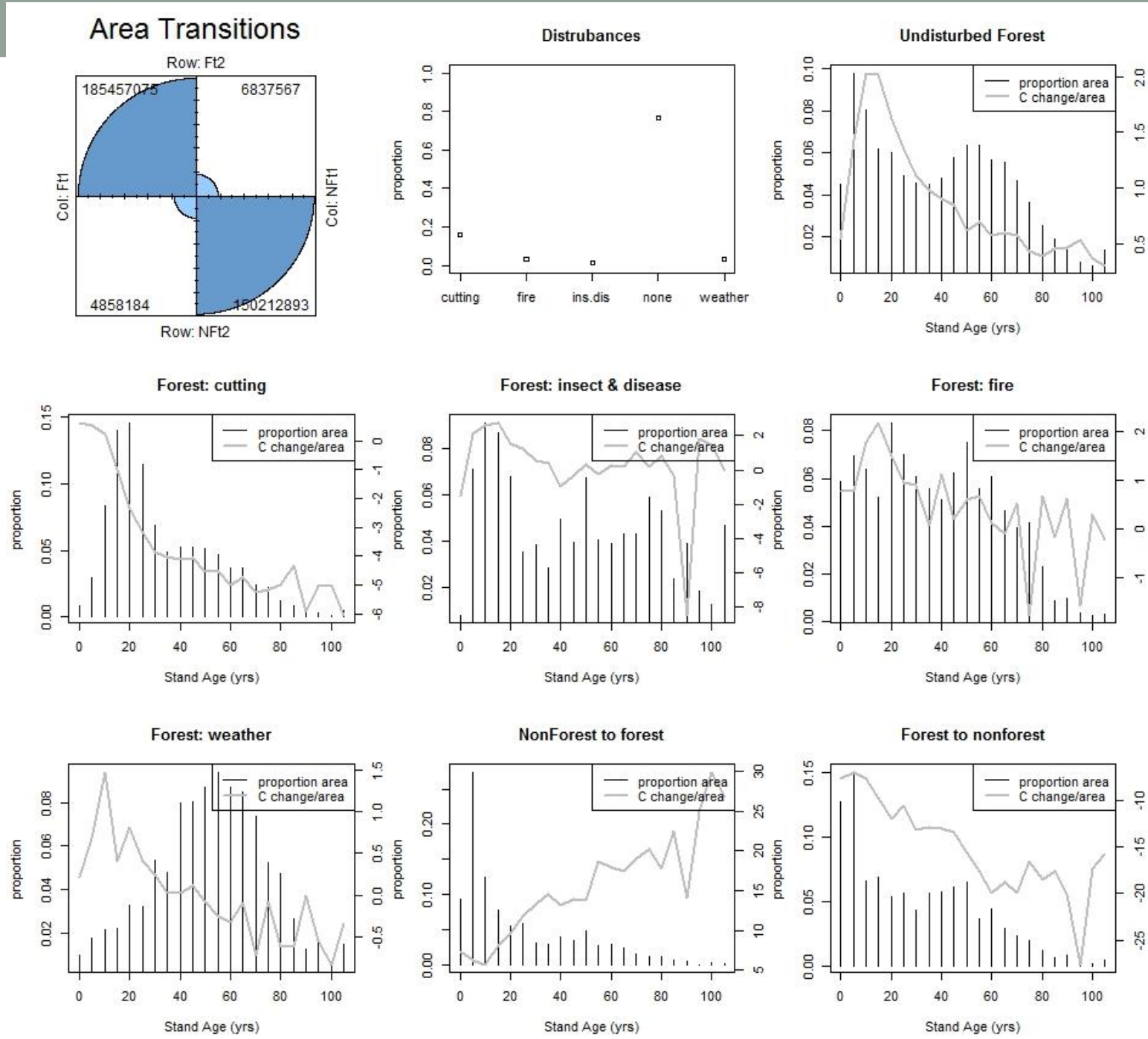




Data Used

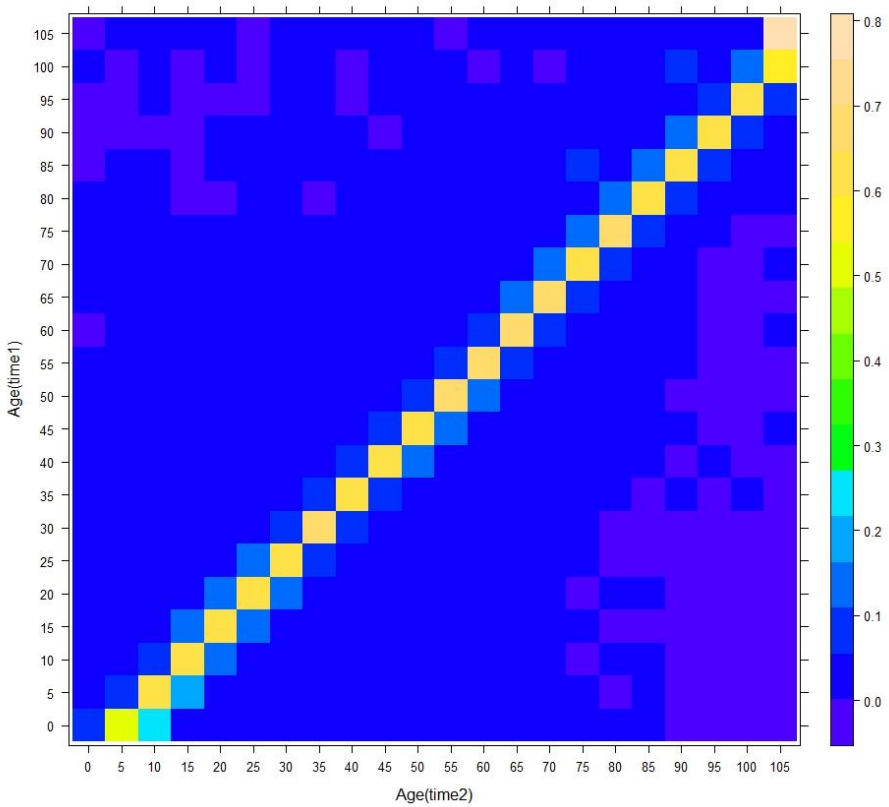
- Carbon information (**δC**)
  - Carbon stock change (t_2-t_1) per unit area for undisturbed forest by age class.
  - Carbon stock change per unit area for disturbed forest (e.g. cutting, weather, etc.) by age class
  - Carbon stock transfer rates per unit area for deforestation (agriculture, developed, water, other) by age class
  - Carbon stock transfer rates per unit area for afforestation (agriculture, developed, water, other) by age class
- Age information (**λ**)
  - Age transitions probabilities between t_1 and t_2 for undisturbed forest
  - Age transitions probabilities between t_1 and t_2 for disturbed forest (cutting, weather, fire, insects & diseases)
- Area information (**A**)
  - Areal extent of all land uses and land use transitions by age class
  - Areal extent of disturbances by age class

Example

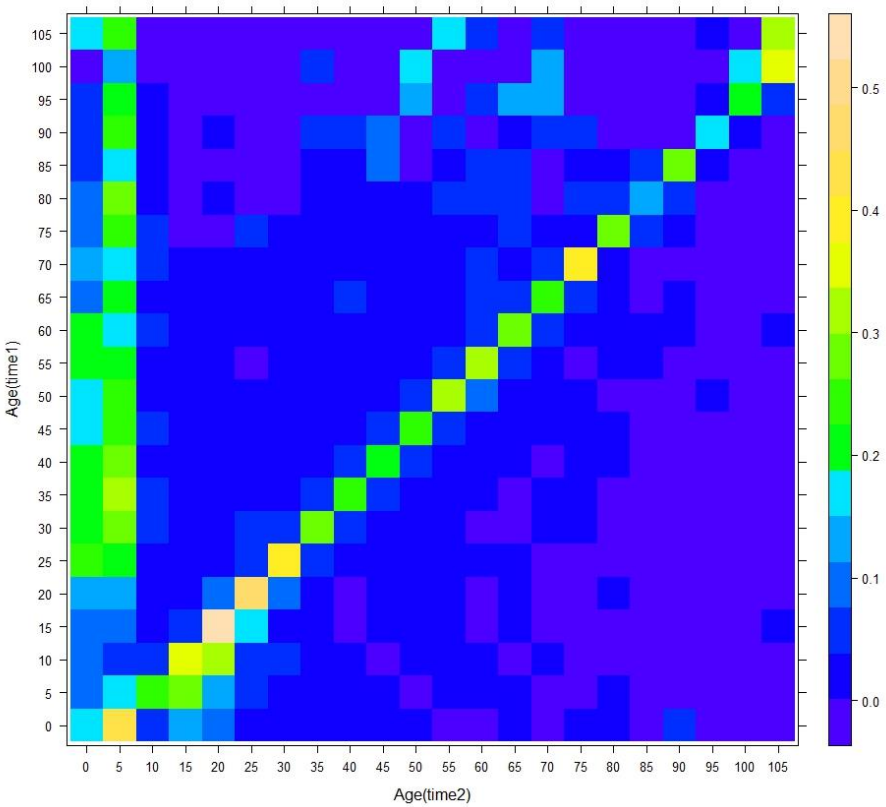

Area Transitions
Row: Ft2
185457075
6837567
Col: Ft1
Col: NFt1
4858184
150212893
Row: NFt2
Distrubances
proportion
cutting
fire
ins.dis
none
weather
Undisturbed Forest
proportion area
C change/area
Stand Age (yrs)
Forest: cutting
Forest: insect & disease
Forest: fire
Forest: weather
NonForest to forest
Forest to nonforest

Example: Age transitions

λ undisturbed forest



λ forest with cutting



Estimation and Forecasting

Estimation

$\Delta C_{d(t)} = \mathbf{A}_{d(t)} \boldsymbol{\delta} \mathbf{C}_d$

- Carbon stock change at time *t* in domain *d*.
- *d* in
  - undisturbed forest
  - fire disturbed forest
  - weather disturbed forest
  - insect& disease disturbed
  - cutting disturbed
  - Forest to agriculture
  - Agriculture to forest
  - Likewise for other land use transfers

Forecasting

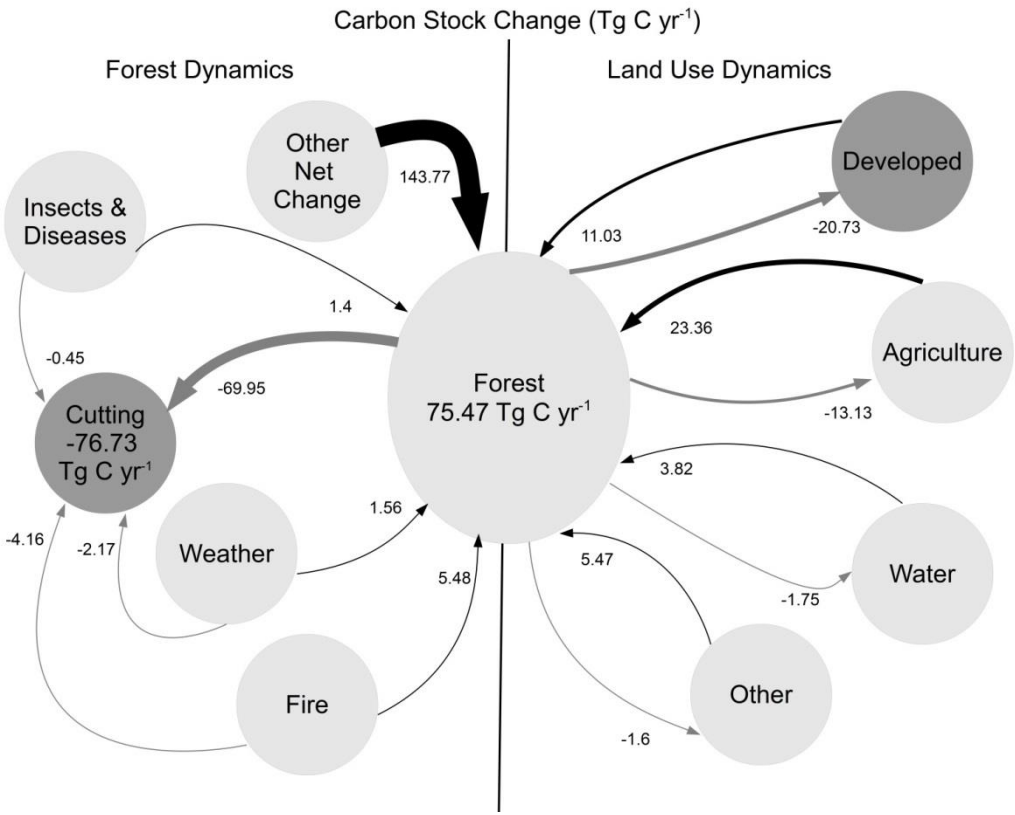
$\Delta C_{d(t+1)} = \boldsymbol{\lambda}_d \mathbf{A}_{d(t)} \boldsymbol{\delta} \mathbf{C}_d$

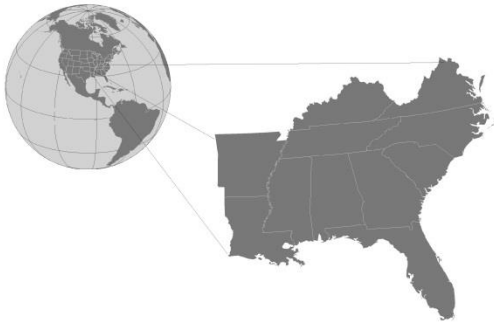
- $\boldsymbol{\lambda}_d$ is identity matrix for land use transfers
- This model assumes only forest aging and no change to disturbance rates/severity or land use transition.
- But….
  - $\mathbf{A}_{d(t+1)} = \boldsymbol{\lambda}_d \mathbf{A}_{d(t)}$
  - $A = \sum \sum \mathbf{A}_d$ (i.e. total area is fixed)
  - The $\mathbf{A}_d$ vectors can be manipulated in any fashion under the constraint that A is fixed.
  - Changes in land use transitions and disturbance can be evoked in that way
- Changes in disturbance severity and atmospheric enrichment effects can be incorporated by modifying $\boldsymbol{\delta} \mathbf{C}_d$

C dynamics

Land transfers from land use change are can move large amounts of Carbon into and out of the Forest,

- Forest loss to development remains a key land use transitions which shifts about 13% of the C sequester out of forests
- Forest gains from agriculture offset this loss.
- The gross carbon transfer from land use change was 14x larger than the net change demonstrating the importance of land use transfers in the South.





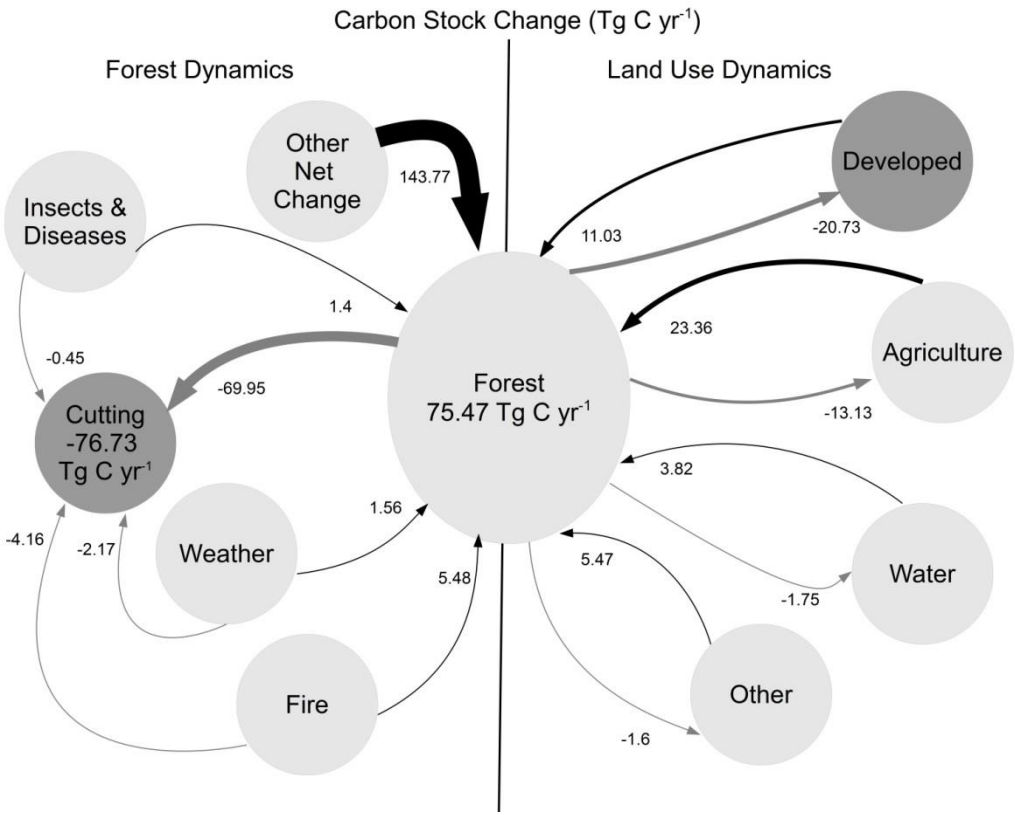
C dynamics

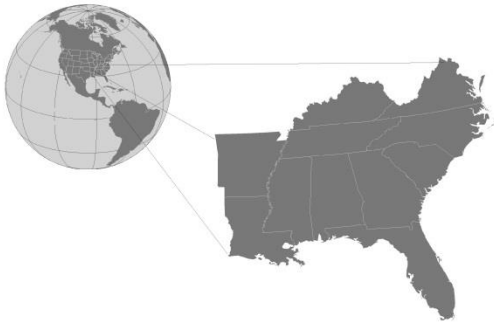
Natural forest disturbances did not cause net emissions

- Losses due to insects and diseases, weather, and fire were compensated by subsequent regrowth, storage of dead material on site, and the stability of the soil carbon pool.

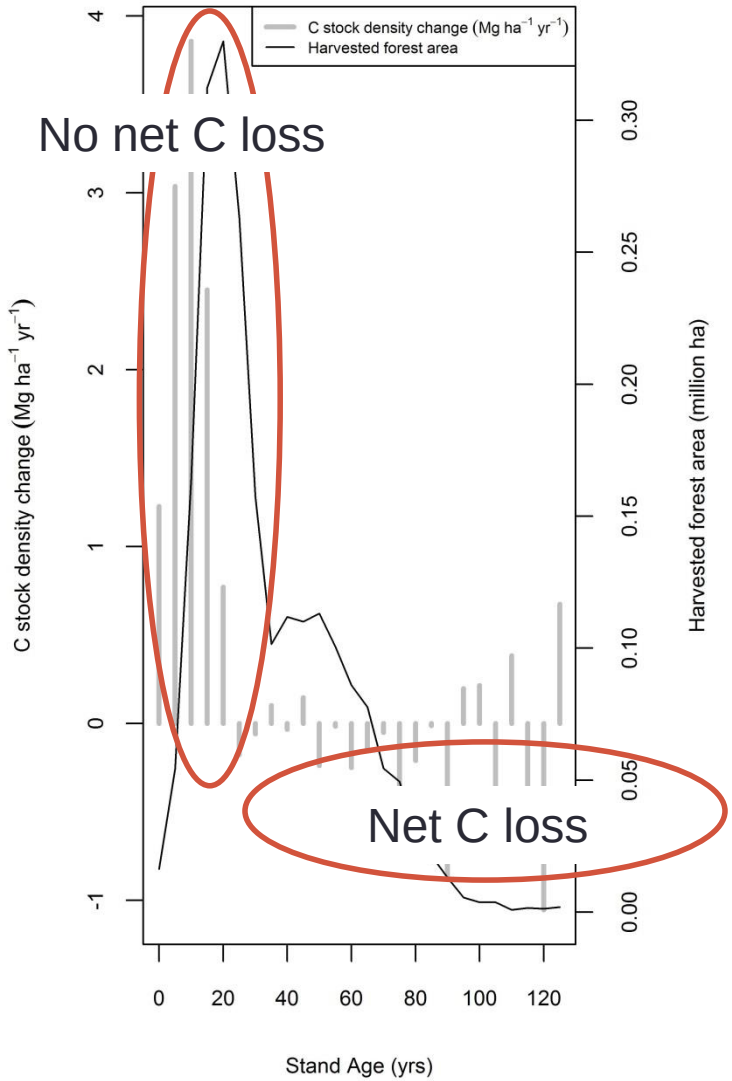
Forest cutting was the largest component of decreases

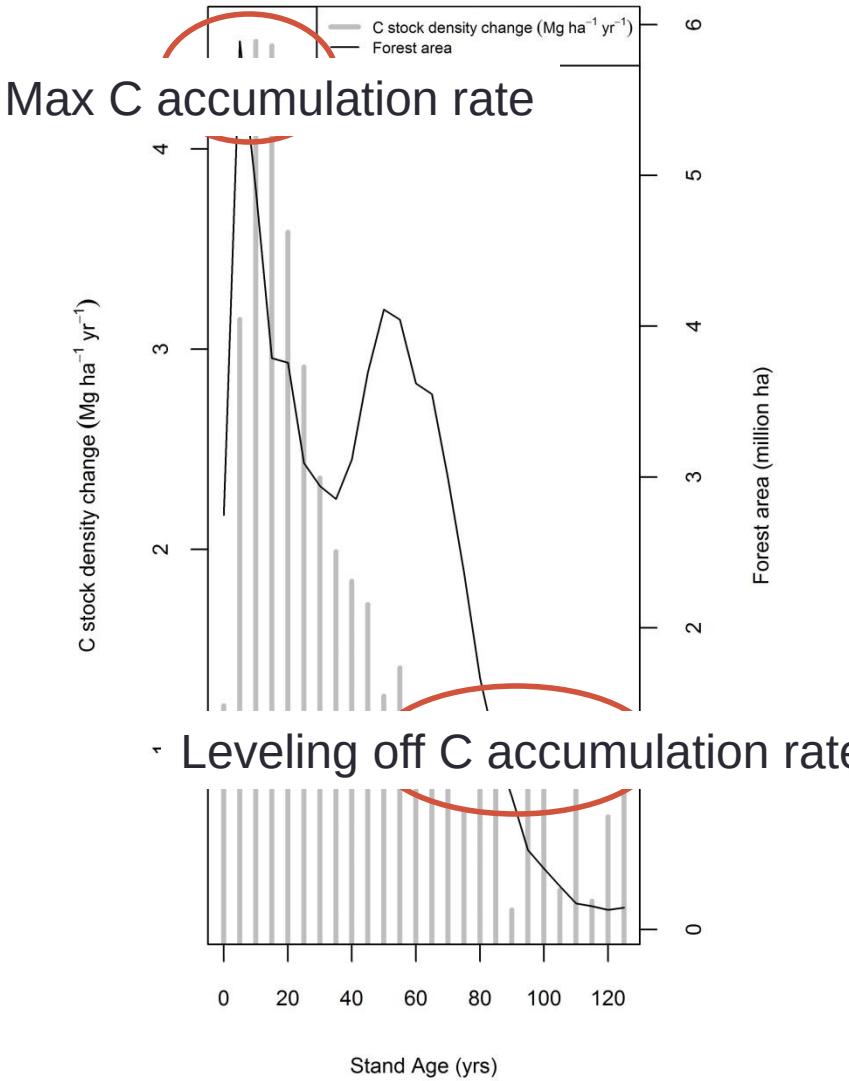
- About half of the sequestration of forests was removed by forest cutting (144 vs 77), 20% which would be stored in harvested wood products
- Many of the naturally disturbed areas were salvaged cut.
- Growth more than compensates for cutting losses. While forest cutting removes a proportion of the above ground carbon on a site it also reverts forest land back to a more productive period which influences the aging process (along with natural disturbance).





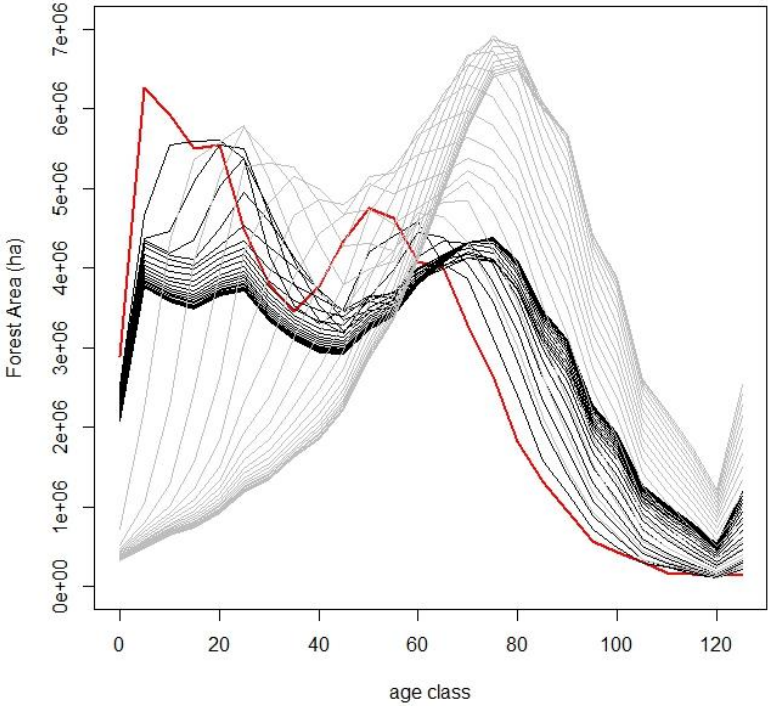
Forest Cutting

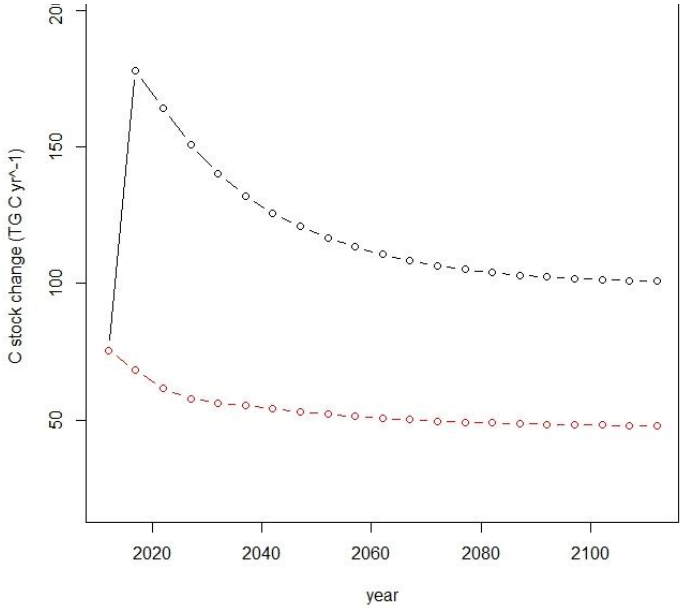




Forest Aging

- We can force the forest to age
- Must account for disturbance effects when estimating age transition probabilities
- Can also turn off disturbances to examine impacts on aging



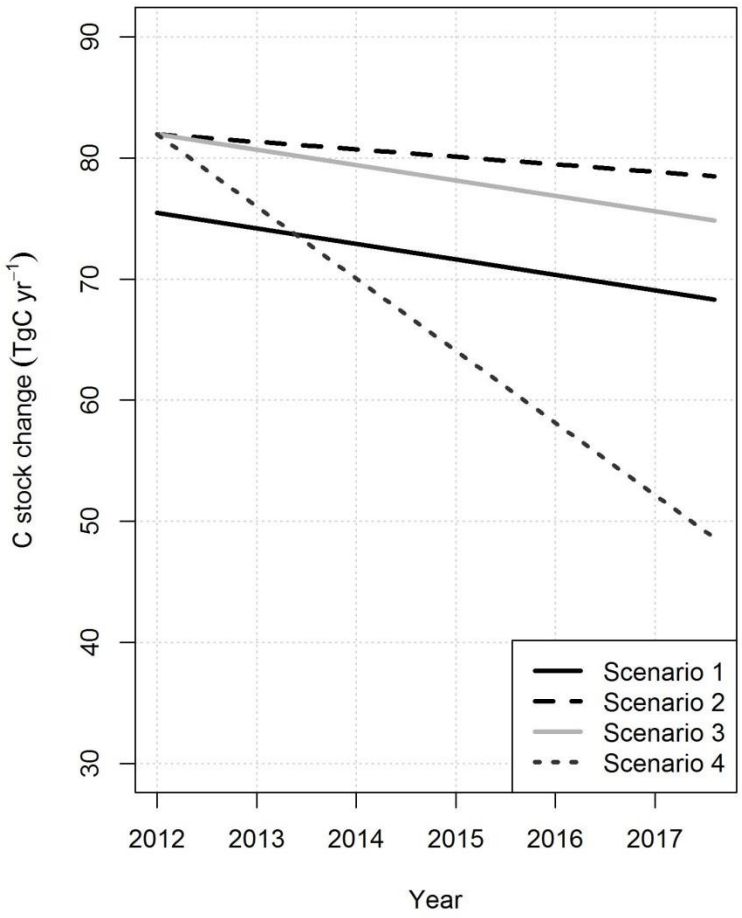


Projections

- Model appropriate for short-term projections 5-10 years
- Approach incorporates biological process (aging, natural disturbance)
- Also incorporates human impacts (forest management, land use change)
- Mid to long-term projections should more fully integrate economic projections
- Projection scenarios can be developed by modifying biological processes and human impacts.

Scenarios

- Scenario 1: forest remaining as forest from 2007-2012 projected to 2017.
- Scenario 2: Forest remaining as forest from 2012-2017 plus additions to forest land from other land uses. Land use transitions to forest were assumed to occur at the 2007-2012 rates.
- Scenario 3: Forest remaining as forest from 2012-2017 plus additions to forest land from other land uses. The 2007-2012 land use transition rates for agriculture to forest were decreased by 10% and the transitions from forest to developed were increased by 10%. All other rates remained at observed levels.
- Scenario 4: Forest remaining as forest from 2012-2017 plus additions to forest land from other land uses. The 2007-2012 land use transition rates for agriculture to forest were reversed.



Key Points

- Land use change is important
  - Need to include C dynamics for all land uses to understand full implications
- Forest cutting is the primary disturbance driver
  - Some harvested wood C is stored in long term products
- Forest aging is the primary biological driver
  - Forest management can be a useful tool to offset aging dynamic
  - Forest management approaches need to be developed while keeping other ecosystem services in mind
- Current efforts include
  - Extending analysis to whole US
  - Incorporating land use policy options as scenarios
  - Examining impacts of potential atmospheric enrichment on sequestration
  - Implementing model in both a forecasting and backcasting mode.

Thanks

Questions?

Source:

http://www.nature.com/srep/2015/150123/srep08002/full/srep08002.html