Improving Our Measures of Forest Carbon Sequestration and Impacts on Climate

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Information Needs for Climate Change Policy and Management

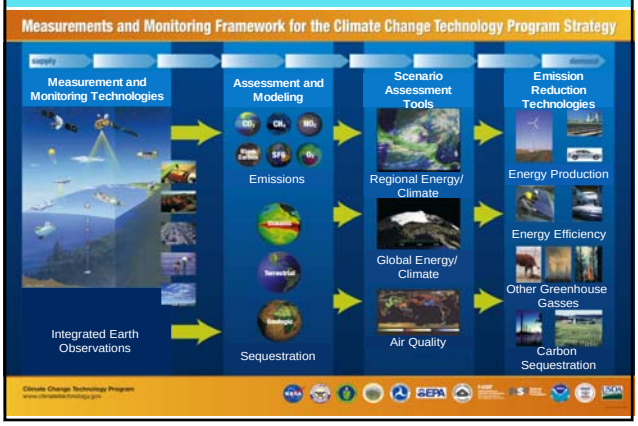
- "Good data" about past trends and current conditions (understand system status)
- Projections based on reasonable assumptions and models (guide policy)
- Monitoring system to track progress toward management goals (verification)

Improving our Measures of Forest Carbon Sequestration

OUTLINE

- What we need to know and why
- Monitoring design
- Information gaps
- Future technology and applications

Linking Monitoring with Decision Support

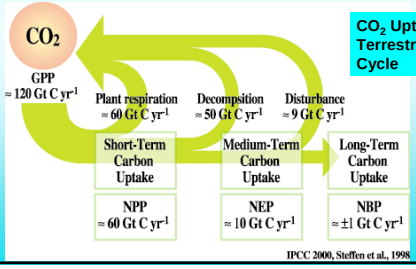


Indicators for Monitoring The Carbon Cycle

- CO_2 flux
- Net primary productivity
- Net ecosystem productivity
- Land use/land cover
- Vegetation structure and biomass
- Soil carbon
- Natural disturbance and management
- Harvested products
- Climate and meteorology

Monitoring Design: Temporal Considerations

- Need to separate interannual variability from longer-term trends (need long-term data sets)
- Ecosystem processes respond at different time intervals
- Reporting requirements (annual, periodic)

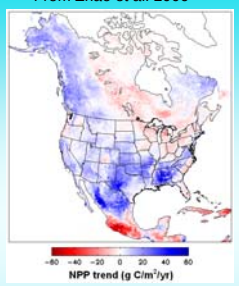


CO_2 Uptake by the Terrestrial Carbon Cycle

Monitoring Design: Spatial Considerations

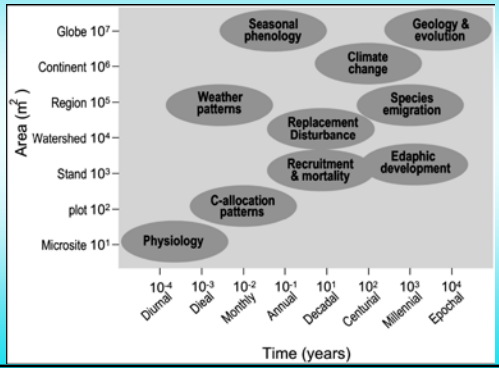
- Carbon policy: need a large enough spatial scale to detect impact – to factor out local causes such as land-use change
- Carbon management: need site-specific data to link with management actions
- Attribution: need high-quality, spatially-referenced observations of all likely causal variables (e.g., climate, N deposition, disturbance)

From Zhao et al. 2006



Temporal and spatial scales of major processes affecting forest ecosystems

(From Law et al. 2006)

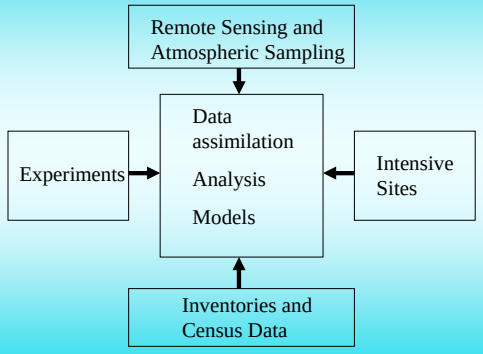


The Multi-tier Approach to Monitoring Links Extensive Observations with Intensive Ecosystem Process Studies

USFS approach to forest health monitoring

NASA MODIS with field validation – "bigfoot"

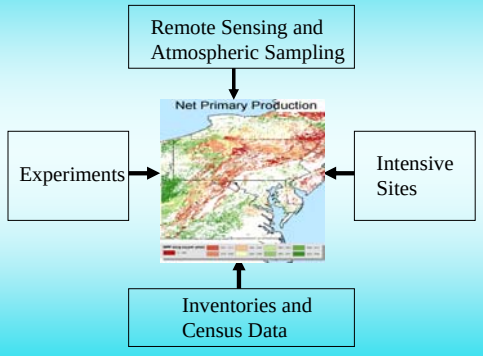
Analysis: Integration of Measurements



Analysis

- Need to separate causes of observed effects (e.g., "human-induced" from "natural")
- Combining observed data with models – the variable of interest may not be observed directly, but may be closely linked with another variable that can be observed
- A complementary controlled experiment may be required to firmly establish cause and effect relationship
- Interested In past trends, current conditions, projections

Analysis: Integration of Measurements



Pan et al. 2001

Example: Relative Influence of Factors on the 20th Century Carbon Budget of U.S. Forests

- Land use and management = strong influence
  - Forest regrowth on abandoned farm land
  - Fire suppression
  - Plantation forestry
- Environmental changes = weak influence
  - CO_2 fertilization
  - N deposition/acid deposition
  - Tropospheric ozone
  - Climate change

21st Century:
↑ Climate change
↑ CO_2 fertilization
↑ Wildfire
↓ Fire Suppression
↓ Forest Regrowth

Casperson et al. 2000; Goodale et al. 2002; Birdsey et al. 2006

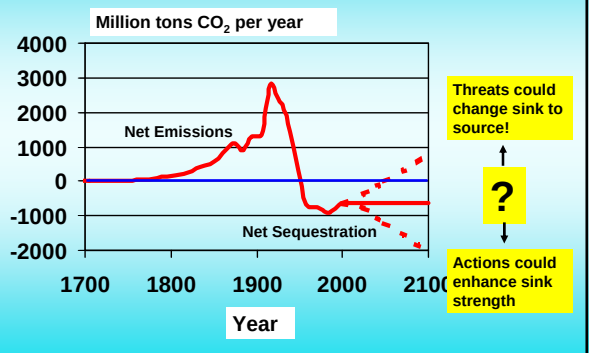
Example: U.S. Greenhouse Gas Registry - Filled in 1605(b) Form

Change in carbon stock for forestry activities, first reporting year, New Jersey Pinelands (in metric tons of carbon)

Activity	Area (ha)	C stock in base period	C stock in year prior to reporting year	C stock in reporting year	Change in C stock in reporting year	Estimation method	Rating
Forest management	266,000	38,000,000	38,000,000	38,226,100	226,100	Model (COLE)	B

Change in carbon stock = 226,100 t/yr

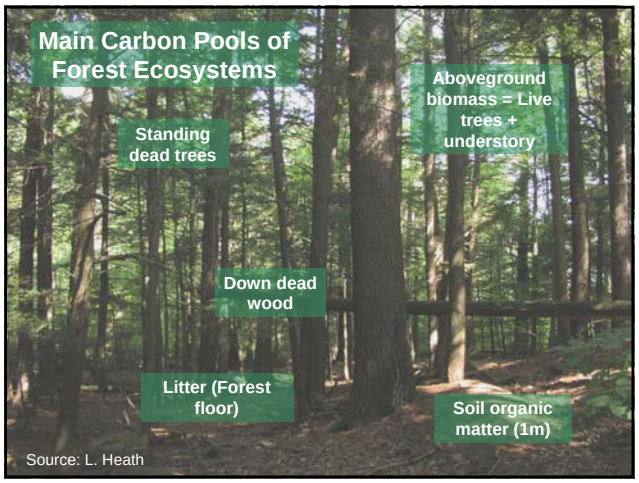
Example: The Carbon Budget of the U.S. Forest Sector (Forest Ecosystems and Wood Products)



From Birdsey 2006

Summary of Requirements for Greenhouse Gas Registries and Inventories

- For greenhouse gas registries…
  - ☑Measurement plus model
  - ☑Independent verification
  - ☑Precision = plus or minus 10% @ 95% conf.
  - ☑Accounts for natural disturbance
- For greenhouse gas inventories…
  - ☑Follows IPCC "Good Practice Guidance"
  - ☑"Stock-change" approach with independent verification by flux tower data and models



Carbon Pools of Harvested Wood Products

- Wood and paper in use (A-)
- Wood and paper in landfills (B-)
- Wood burned for energy (B)
- Wood product emissions (B)

Data quality:
A = good
B = Fair
C = Poor

What We Monitor and Report: Carbon Pools in Forest Ecosystems

Data quality:
A = good
B = Fair
C = Poor

Detailed measurement and estimation	*Summarized estimates for default tables*	*Summarized estimates for reporting*
Live trees: above-ground (A)	Live trees (A-)	Ecosystem carbon (B)
Live trees: below-ground (B)		
Tree seedlings (A)	Understory vegetation (C+)	
Shrubs, herbs, forbs, grasses (C)		
Standing dead trees: above-ground (A)	Standing dead trees (A-)	
Standing dead trees: below-ground (B)		
Down dead wood (B)	Down dead wood (B-)	
Stumps and dead roots (C)		
Fine woody debris (B)	Forest floor (C+)	
Litter (C)		
Humus (C)		
Soil carbon (C)	Soil carbon (C)	

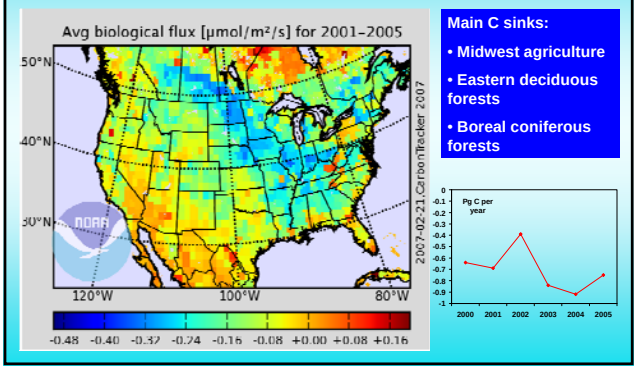
Biggest challenge: Soil C

- Spatially variable
  - at all scales!
- Sampling and analysis are resource intensive
- Soil C cycling is poorly understood
- Existing process models mostly ag based, extremely difficult to parameterize

Special Problem of Land-Use Change

- Land use change has major carbon consequences (in both directions)
- Timely, consistent, and accurate land use change data are currently a challenge to obtain
  - Issue of scale and resolution
- Quality data at a fairly fine scale would improve estimates, enable analysis of leakage, and permit “potential analyses”

Need for Improved Temporal and Spatial Resolution: Biological Carbon Sources and Sinks (from CarbonTracker web site)



Main C sinks:

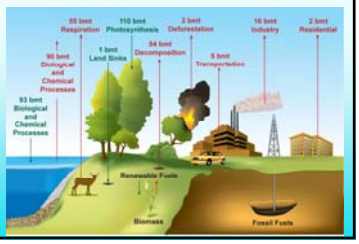
- **Midwest agriculture**
- **Eastern deciduous forests**
- **Boreal coniferous forests**

Some Current and Planned Observation Systems - Climate and Carbon

- Land inventories (USDA and others)
- AmeriFlux (DOE and other Agencies)
- Long Term Ecological Research network (National Science Foundation)
- Experimental site networks (USDA, Universities)
- Satellite observation systems (NASA, NOAA)
- National hydrologic monitoring (USGS)
- National Ecological Observation Network (NEON)
- Global Terrestrial Observing System (GTOS)

Expanding the Accounting to More Accurately Reflect Feedbacks to the Climate System

- **We currently focus on carbon – either in organic form or as carbon dioxide**
- **Other GHGs that are a factor in forests:**
  - **Methane**
  - **Nitrous oxide**
- **Albedo**
- **Evapotranspiration**



Conclusions

- Objective, science-based monitoring and analysis is needed for policy and management
- We need to do a better job monitoring carbon in soils and from land-use change
- We need more spatially and temporally explicit information about forest carbon changes
- We need an expanded effort to include all greenhouse gases and effects on climate