WESTCARB Overview

Terrestrial Sequestration of CO_2: An Overview of the Science Drawing on Good Practice Guidance

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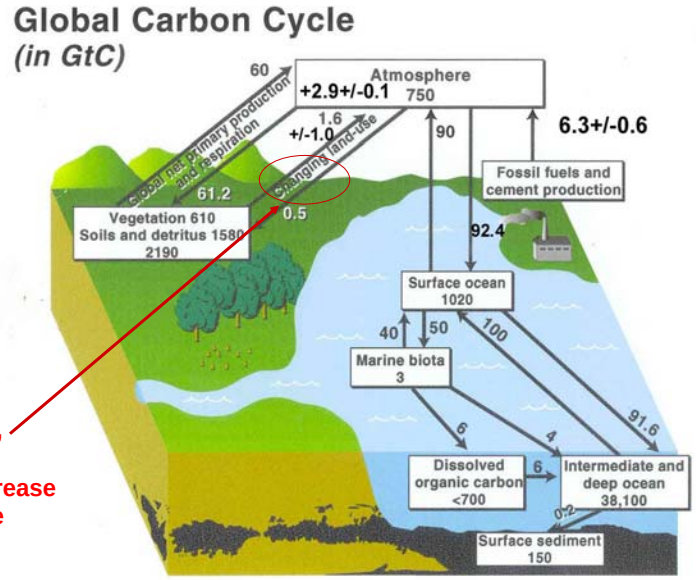
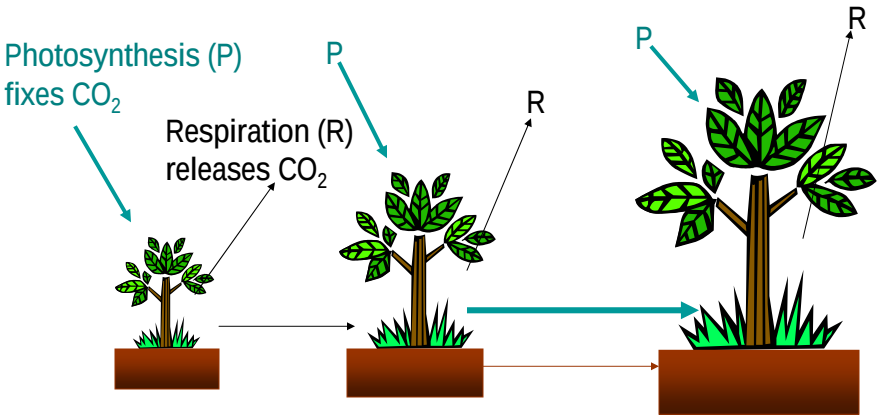
The Role of Terrestrial Ecosystems in the Global Carbon Cycle



Emissions from land-use change are about 25% of those from fossil fuel

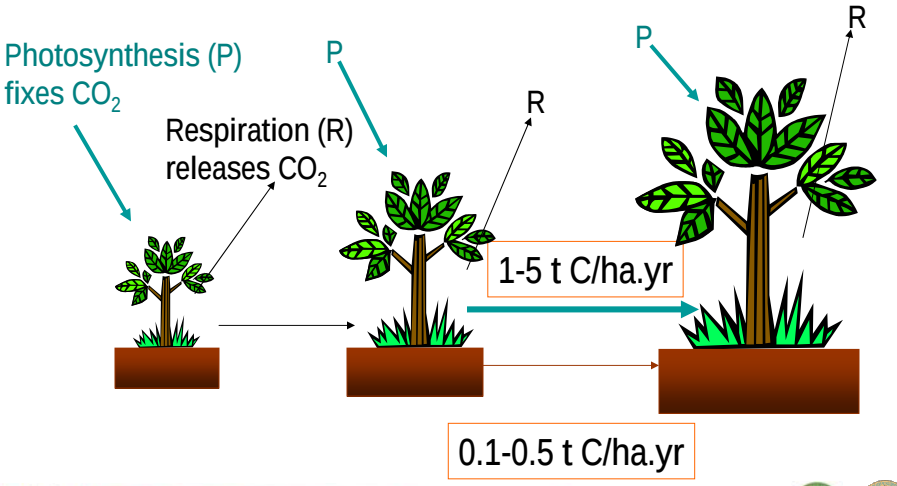
To mitigate carbon emissions, need to manage these flows to increase uptake and reduce emissions

How Do Ecosystems Sequester Carbon?



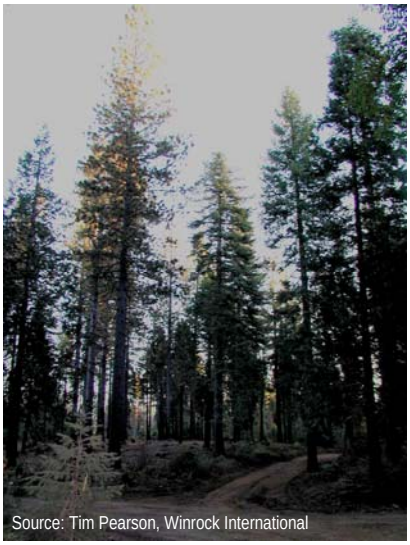
Photosynthesis exceeds respiration, resulting in storage of carbon in plants, dead organic matter, and soil

At What Rate Does Carbon Accumulate?



Afforestation

- Convert agricultural or grazing land back to forest
  - Return to native forest
  - Convert to forest land for timber production



Source: Tim Pearson, Winrock International

Mixed conifers

Source: Jon Johnson, Washington State University

Afforestation

- Convert to forest land with fast-growing species
- 10 dry t/acre-yr at 6–8 year rotations

Hybrid Poplar
28 years old
110 feet tall
32 inches diameter

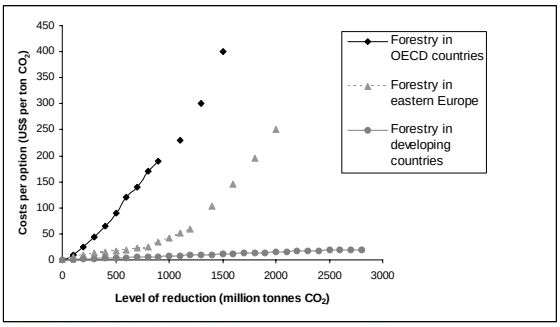
Conserve Forests

Source: Tim Pearson, Winrock International

- Stop forest conversion to non-forest
- Longleaf pine in SE (120 year old forest)
  - 174 t C/ha
- Redwood (150 year old forest)
  - 478 t C/ha

Can Activities in Terrestrial Ecosystems Make a Difference?

- IPCC 2nd and 3rd assessment reports suggest an aggressive program could sequester and avoid carbon emissions equivalent to about 12–15% of business-as-usual fossil fuel emissions over a 50-year period
- Developing countries offer the greatest opportunity at low cost



IPCC 2001

International Actions on Terrestrial Carbon Sequestration—Kyoto Protocol

- Allows for emission-allowance trading for carbon sequestration from changes in management of forest lands, crop lands, and grazing lands (Joint Implementation) between developed countries under a cap
- Allows for emission-offset trading between developed (capped countries) and developing countries (non-capped) for afforestation and reforestation project activities only (Clean Development Mechanism)

Domestic Actions on Terrestrial Carbon Sequestration

- Voluntary program of DOE 1605(b); currently under revision
  - The Nature Conservancy/Electric Utility partnerships developed several pilot projects under US Activities Implemented Jointly program—mostly conservation in developing countries
    - e.g., Noel Kempff, Bolivia; Rio Bravo, Belize; Itaqui, Brazil
  - Utilitree, Powertree, and other individual utilities restoring bottomland forests along the Mississippi Valley

- CA Climate Action Registry
- The Climate Trust of Oregon
- Northeastern states (RGGI)—in development

What Is a Terrestrial Carbon Sequestration Project?

- Planned set of eligible activities within a specific geographic location over a specified time frame
- Projects include activities that do something different from business as usual and with the purpose of sequestering carbon
- The carbon benefits are the difference between the business-as-usual activity and the "with-project" activity

Types of Domestic Project Activities

- 1605 (b) essentially does not limit project activity type
- Chicago Climate Exchange permits:
  - Afforestation, forest management, forest conservation, conservation tillage, and conversion of agricultural land to grass
  - Afforestation projects should afforest land that was not forest or was degraded as of December 31, 1999
- CCAR permits only:
  - Conservation-based forest management
  - Afforestation and reforestation
  - Conservation
- NE States (RGGI) considering only afforestation
- The Climate Trust includes afforestation mostly and some conservation

Project Activities Depend on Definition of Forest

- International requirements need to define
  - Canopy coverage (10–30% canopy closure)
  - Minimum tree height (1–5 meters)
  - Minimum area (0.05 and 1.0 hectare or 0.12–2.47 acres)
  - Once chosen must remain fixed
- Definition chosen has implications for kinds of activities could engage in
- For large countries like the U.S. could be problematic

Markets for Buying and Selling Carbon Credits Are Developing

- European Union's Emission Trading Scheme (EU ETS) (~EU20-30/t CO_2)
  - Operates within the European Union; its entities are allocated European Emissions Allowances (EUAs; their "cap") by EU member governments
  - No allowances for trading carbon sequestration credits
- Chicago Climate Exchange (~$2-3/t CO_2)
- Retail Market
  - Comprises companies and individuals without significant emissions but who wish to be climate-neutral to demonstrate their social responsibility
- World Bank's Carbon Finance Includes Eight Funds
  - One dedicated to carbon sequestration—BioCarbon Fund in developing countries

Why are Carbon Sequestration Activities Limited?

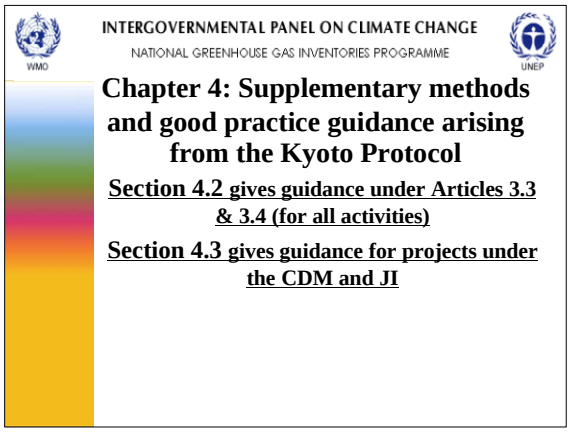
- Technical issues to overcome
  - ✓ Quantification and monitoring of carbon benefits
  - ✓ Baseline
  - – Leakage
  - – Reversibility or non-permanence
  - – Project duration

Quantification and Monitoring

- What is standard for the carbon quantity?
  - – Precision level
    - Common standard tending towards a confidence interval of +/- 10% of mean with 95% confidence
- Projects under Kyoto uses “conservative” estimate
- CCAR deducts a percentage if outside of +/-10% of mean; zero credit if >+/-30% of mean
- How costly is it to monitor to acceptable standards?

Measuring and Monitoring

- Collection and archiving of all relevant data for estimating the net anthropogenic GHG removals by sinks during the crediting period
- Procedures well established and based on peer reviewed methods
- Guidelines for wood products still being debated



Cost of Monitoring—Depends on Area and Variability of Stocks

Costs for afforestation project in the USA—aboveground and belowground biomass pools

Project size (ha)	Coefficient of Variation (%) 10		20		30		40	
	Sample size	Cost $/ha	Sample size	Cost $/ha	Sample size	Cost $/ha	Sample size	Cost $/ha
10	3	327.18	7	328.78	8	329.18	9	329.58
100	4	32.76	14	43.88	26	55.07	39	66.31
1,000	4	3.28	16	4.40	34	5.54	58	7.78
10,000	4	0.33	16	0.44	35	0.55	62	0.89

High $ ↓ Low $

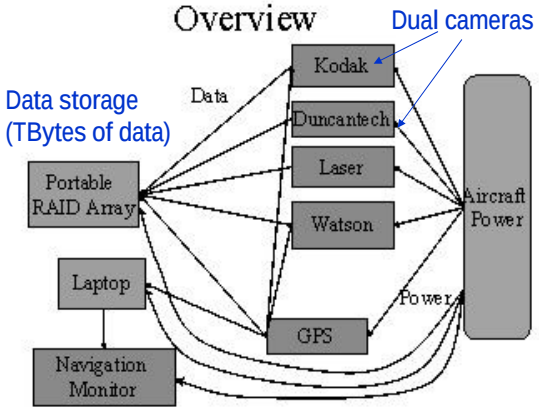
→

Future Directions in Monitoring Carbon Sequestration

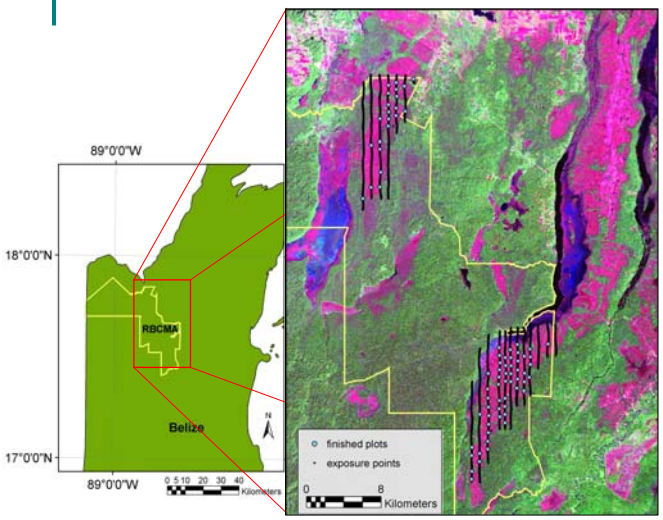
- Need ***cost-effective*, transparent, accurate, and precise monitoring methods**
- Field techniques well-developed and commonly used, but…
  - Can be time-consuming and relatively costly, especially over highly heterogeneous systems
  - Problems with accessibility, particularly over large areas that increases cost
- Need remote methods that can monitor carbon precisely and accurately

Multispectral 3D Digital Aerial Imagery System (M3DADI)

Uses "off-the-shelf" equipment to collect high-resolution imagery



Collect Imagery

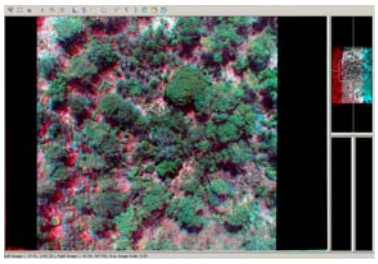


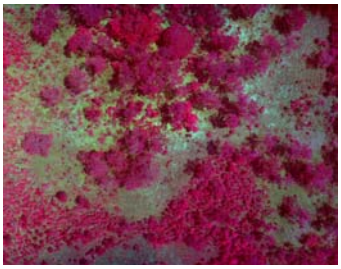
- Fly sampling transects (200 m wide)
- Stratify area
- Systematically or randomly select images for plot installation

Digital Imagery Collects:

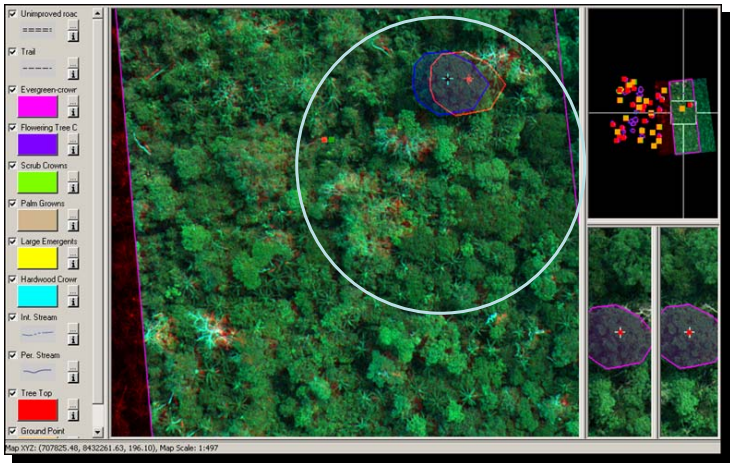
- 10 cm resolution, stereo pairs, multispectral

Can view in 3-D

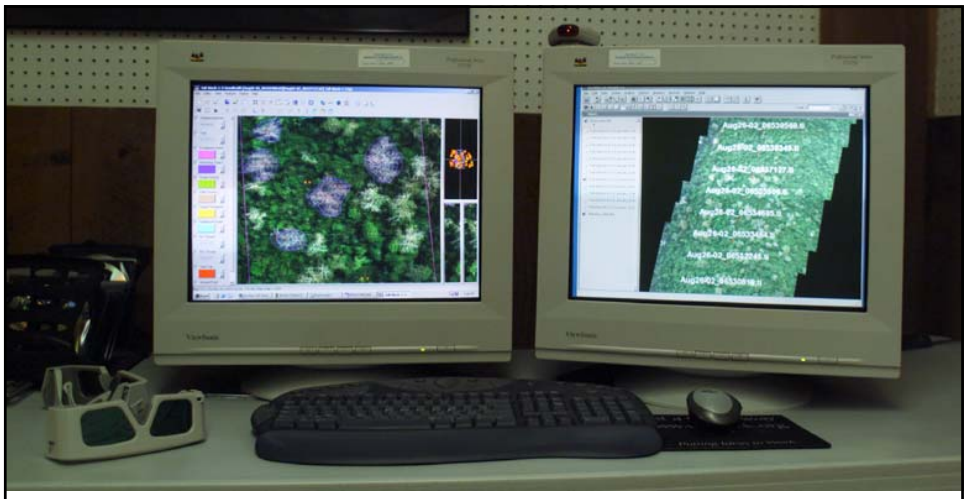




Collecting Measurements for Carbon Estimation

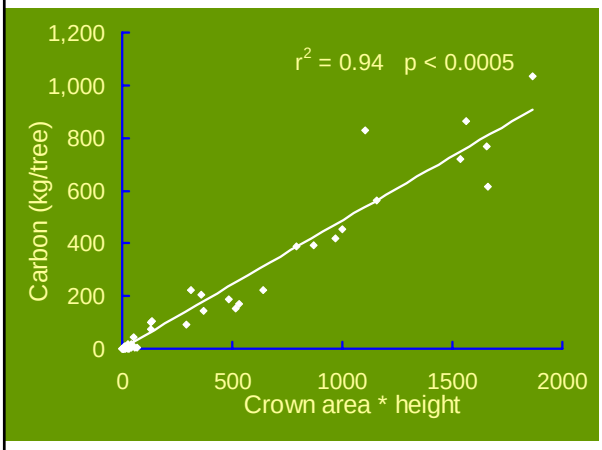


Install “image plots”, measure individual trees for height, crown area, and in some cases species—combine with equation of biomass of tree or volume of tree vs. crown area and height

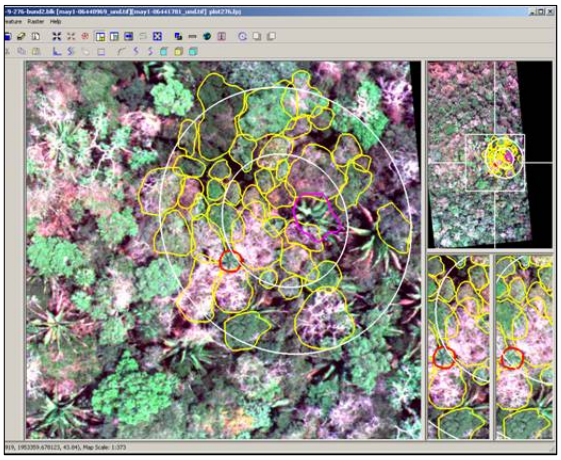


Imagery analyzed using dual monitor setup—ERDAS Stereo Analyst on one side, ArcView on the other. Polaroid glasses and IR transmitter provide the stereo effect on the monitor.

New Biomass Models Are Needed to Use with Imagery Data—e.g., Pine Trees

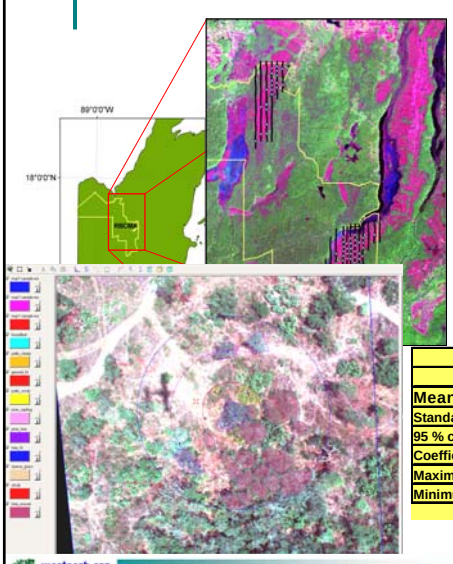


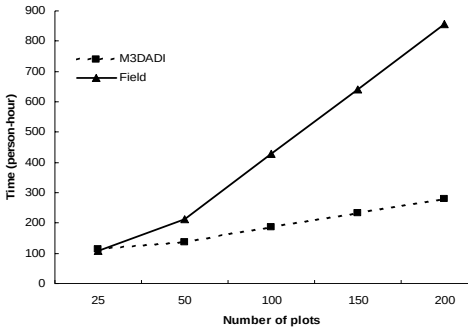
Works Well in Complex Closed Forests…



- 39 imagery plots: mean carbon stock in trees = 117.3 ± 8.7 t C/ha
- 101 field plots: mean carbon stock in trees = 124.4 ±10.6 t C/ha
- Essentially the two methods give same results
- **Cost in person-hours:**
  - 107 for imagery method
  - 374 for conventional field method

Ecological Applications, 15(3), 2005, pp. 1083–1095
CREATING A VIRTUAL TROPICAL FOREST FROM THREE-DIMENSIONAL AERIAL IMAGERY TO ESTIMATE CARBON STOCKS Brown et. al.,





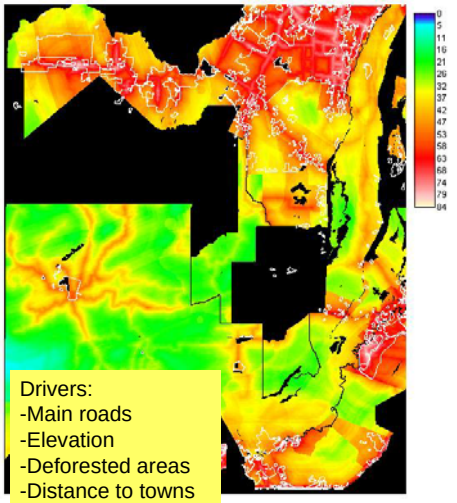
	Biomass t C/ha				
	Trees	Palmettos	Shrubs	Grass	Total
Mean	6.8	2.8	0.5	3.1	**13.1**
Standard deviation	8.0	4.5	1.6	1.0	**9.5**
95 % confidence interval	1.8	1.0	0.4	0.2	**2.2**
Coefficient of variation (%)	117	163	303	31	**72**
Maximum	40.9	23.2	12.6	4.5	**46.3**
Minimum	0.0	0.0	0.0	0.0	**2.4**

Baselines

- A projection of the changes in land use and the carbon stocks in the project area in the absence of the project
- Project specific and prepared in a transparent and conservative manner
- Baselines can be problematic for changes in forest management or forest conservation
  - For changes in harvesting practice, how to deal with harvested wood products
  - How to project a deforestation trend or show a deforestation threat?

Deforestation Baselines—Example for Belize

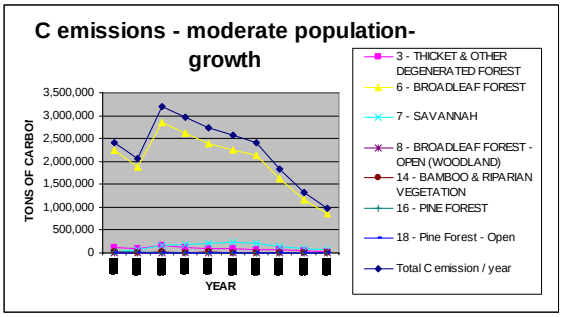
- Analysis of rate of land-use change from satellite imagery
- Analysis of spatial pattern of land-use change and key drivers to produce a map of vulnerability for further deforestation
- Simulation of rate and pattern of land-use change into the future
- Calculation of projected spatially-specific carbon emissions or removals



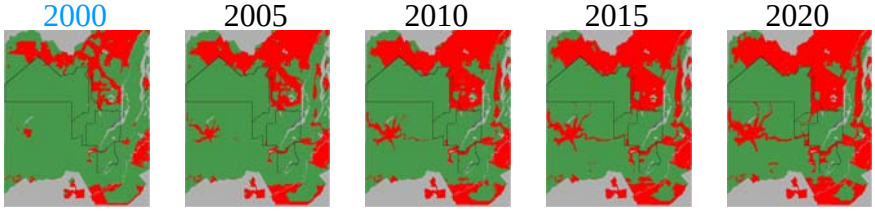
Drivers:
-Main roads
-Elevation
-Deforested areas
-Distance to towns

Projected Deforestation for Northern Belize

1999—Reality



2000 2005 2010 2015 2020



Summary

- Many opportunities exist for terrestrial carbon sequestration that can significantly mitigate GHG emissions
- Domestically, there is a lot of activity by private sector and by States
- Internationally, terrestrial carbon sequestration activities are limited
- Conventional, cost-effective methods are well established for quantifying and monitoring carbon sequestration on the land
- New potentially more cost-effective methods for monitoring are developing
- Scientific challenges exist for developing baselines for certain project types, especially for forest conservation, changes in forest management, and harvested wood products