Valuing Ecosystem Services
Forest Service seminar series
August 14, 2007

In Pursuit of Credit Trading: How Do We Count Forest Carbon?

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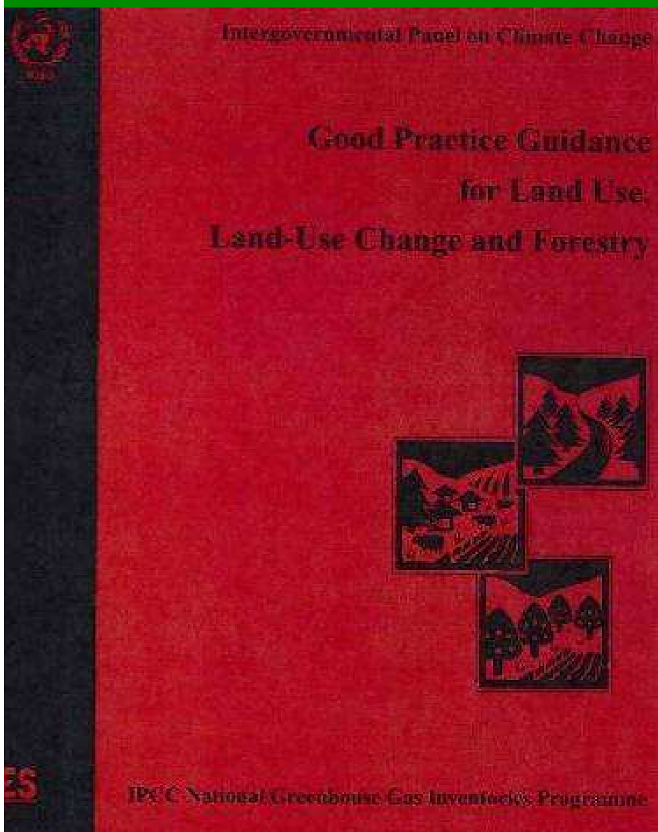
The ability to monitor carbon stocks of forests is not controversial anymore



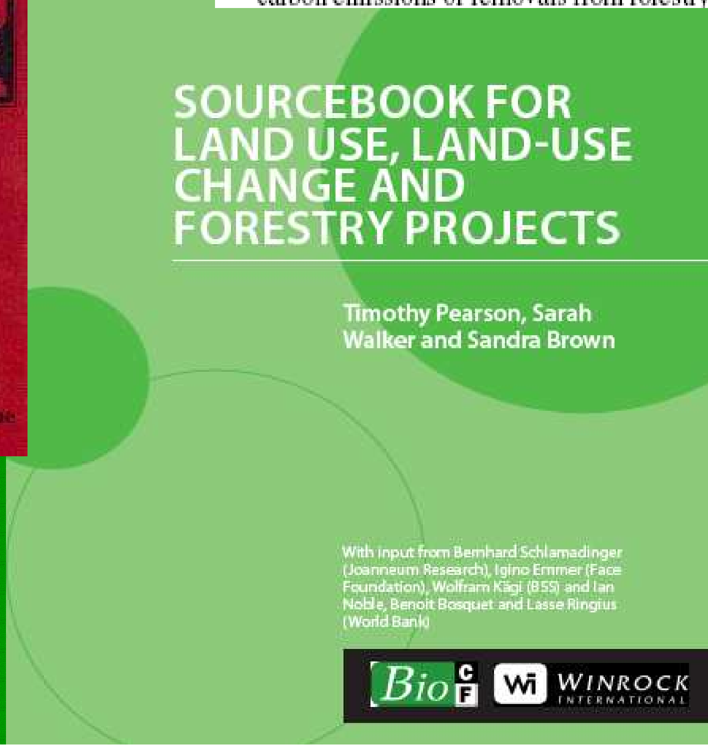
2005

Chapter 1, GHG Inventories: Part I

Appendix Section 3: Measurement Protocols for Forest Carbon Sequestration

3.1 Scope of Guidelines

The scope of this section is to provide guidance on protocols for measuring and monitoring carbon emissions or removals from forestry activities at both the entity and sub-entity scales. An



- Many resources available for both national and international activities
- Uses conventional methods

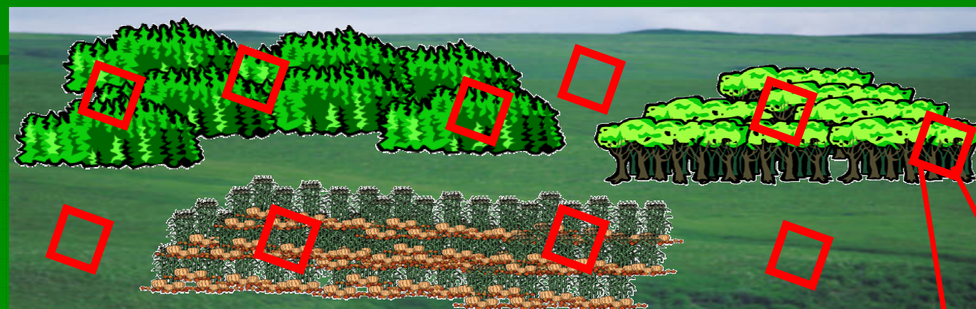
In a nutshell—terrestrial carbon stocks are measured and estimated by:

- Stratifying the project area
- Systematically put in plots
- Taking measurements of the live and dead mass and soil if needed
- Using allometric equations or factors to convert measurements to estimations of biomass/carbon
- Extrapolating to per hectare and again to entire project area
- Repeating over time

Key concept for measuring and estimating forest carbon stocks

- Not practical to measure everything so we sample

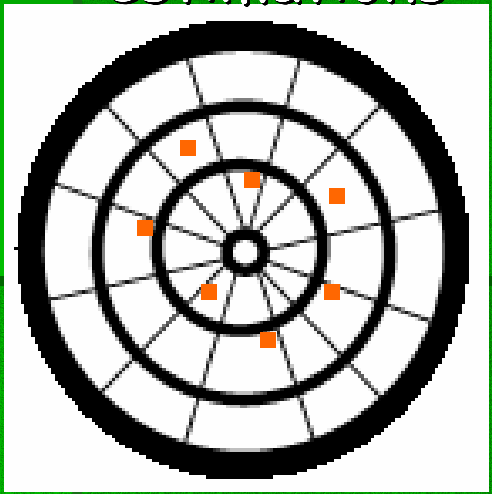
Carbon Sampling



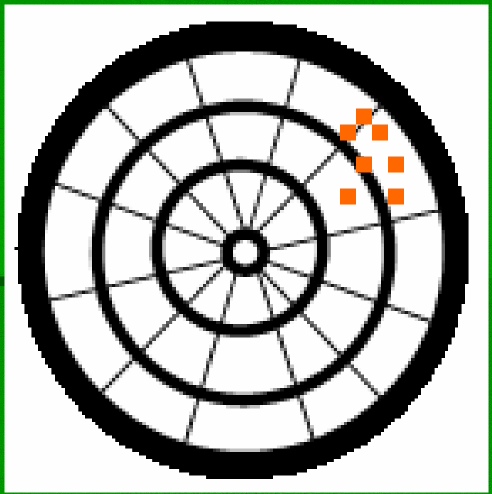
- Sample subset of land by taking relevant measurements of selected pool components in 'plots'
- Number of plots measured predetermined to ensure ***accuracy*** and ***precision***

Accuracy and precision

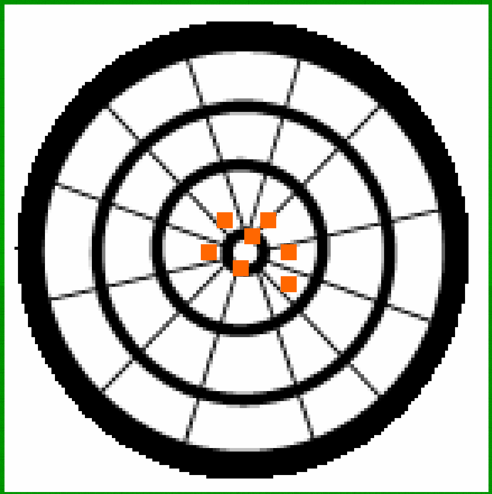
- Accuracy:
  - agreement between the true value and repeated measured observations or estimations
- Precision
  - illustrates the level of agreement among repeated measurements of the same quantity



Accurate
but not precise



Precise
but not accurate



Accurate and Precise

Principles of monitoring carbon

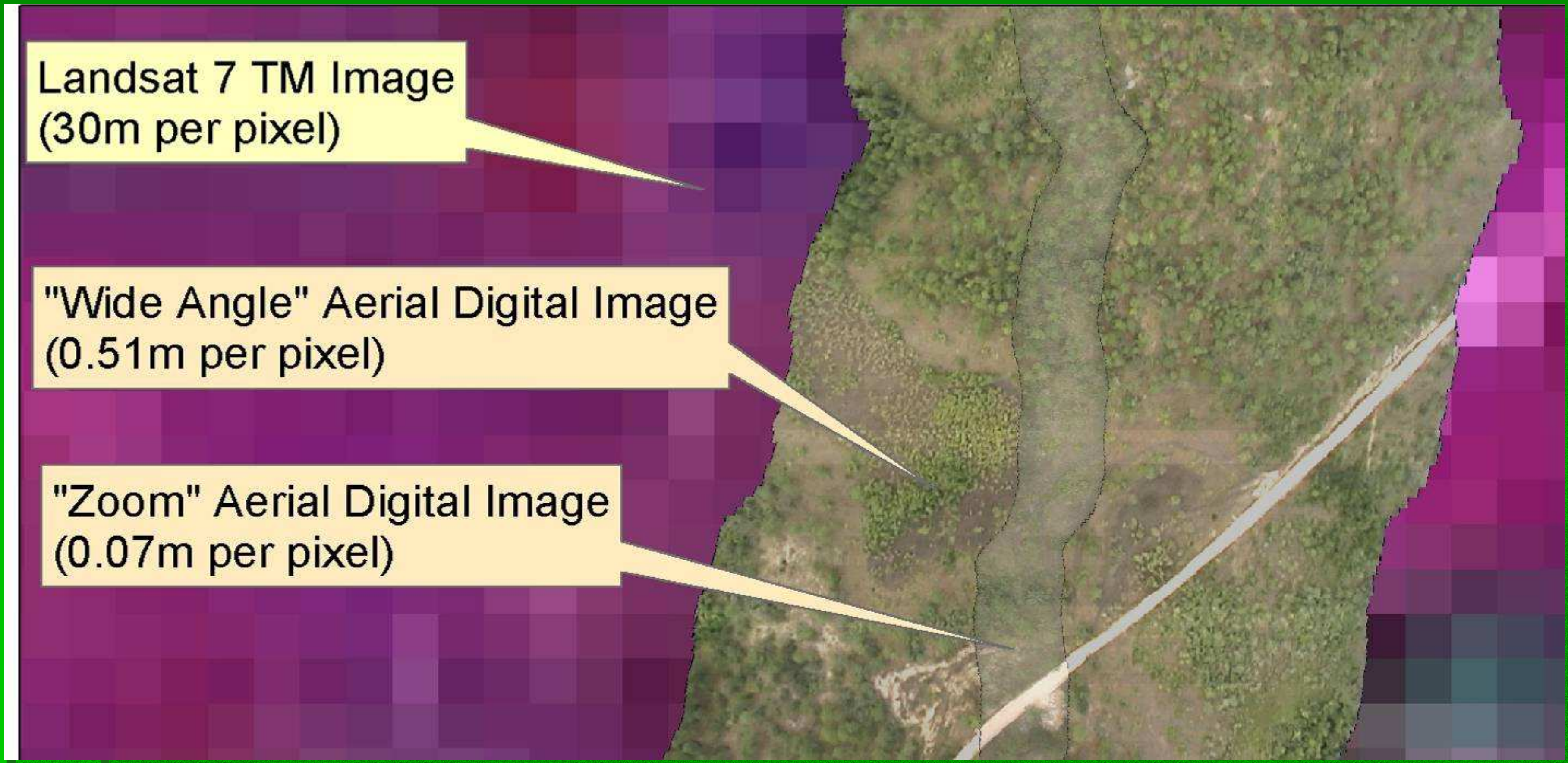
- There is a trade-off between the desired precision level of carbon-stock estimates and cost
- In general, costs will increase with:
  - Greater spatial variability of the C stocks
  - The number of pools that need to be monitored;
  - Precision level targeted;
  - Frequency of monitoring;
  - Complexity of monitoring methods.
- Stratification of the project lands into a number of relatively homogeneous units can reduce the number of plots needed.

Can remote sensing data be used to measure forest carbon stocks?

- Optical satellites in current use can differentiate forest from non forest

- But, cannot measure any proxy to give reasonable estimate of forest carbon stocks

Effect of scale of remote sensing data for biomass estimation



Effect of scale of remote sensing data

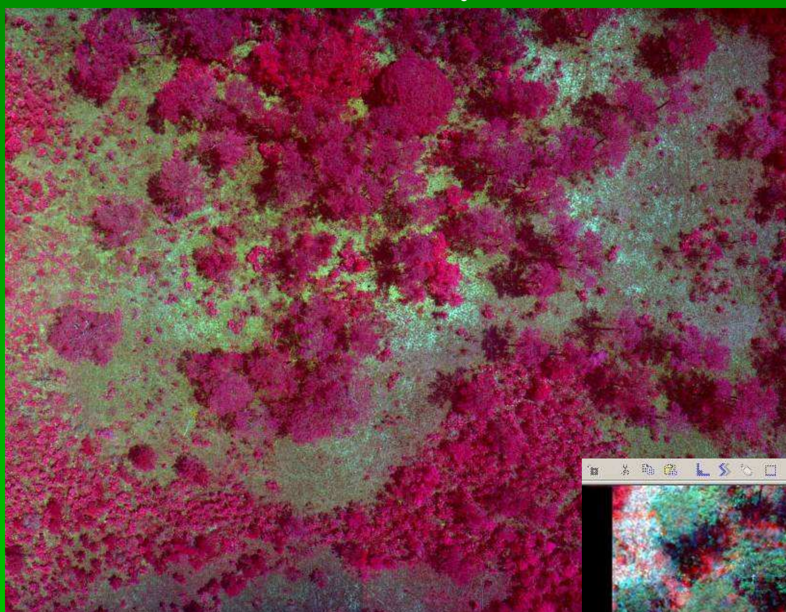
- 10-15 cm resolution imagery vs. 4-m Ikonos
- Ikonos not high enough resolution to identify individual crowns

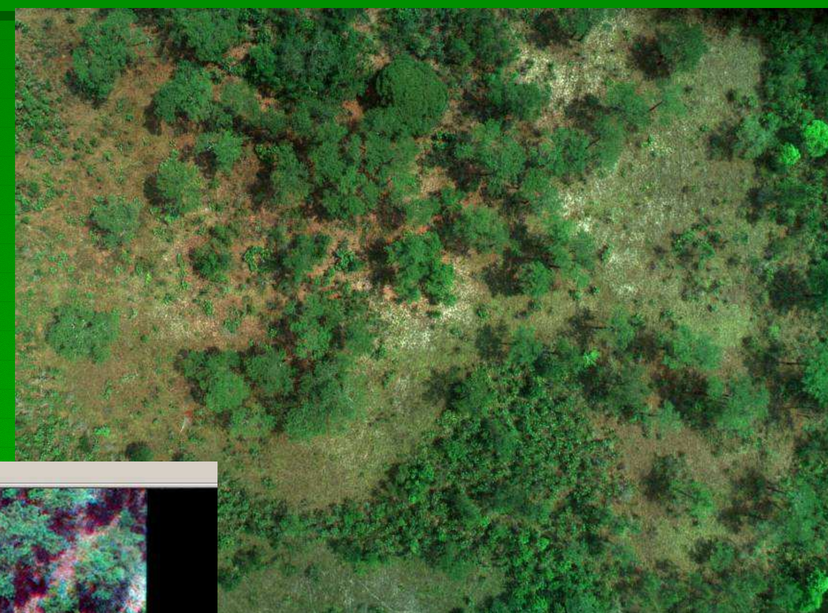
New monitoring techniques developing that are well suited to "project scale"

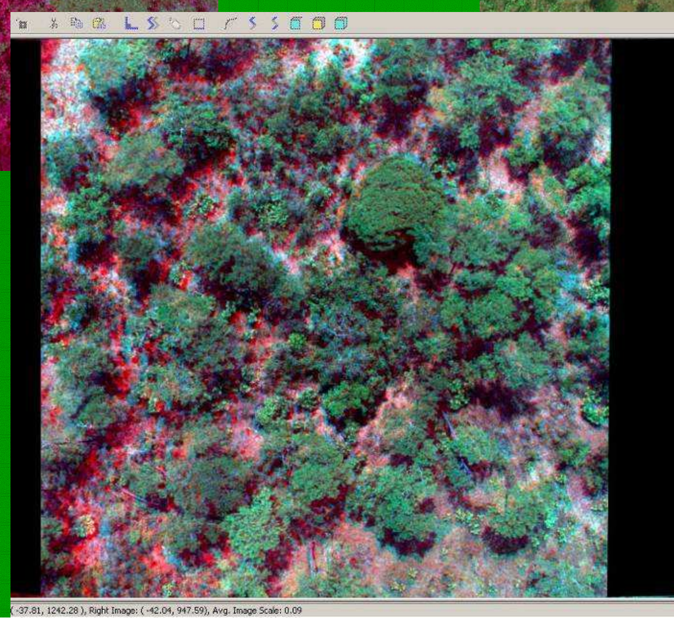
Individual trees are measured for height, crown area, and in some cases species—combine with equation of biomass of tree vs crown area x height or crown area alone

Can collect imagery …..

of resolution 10-50 cm, stereo pairs, multispectral





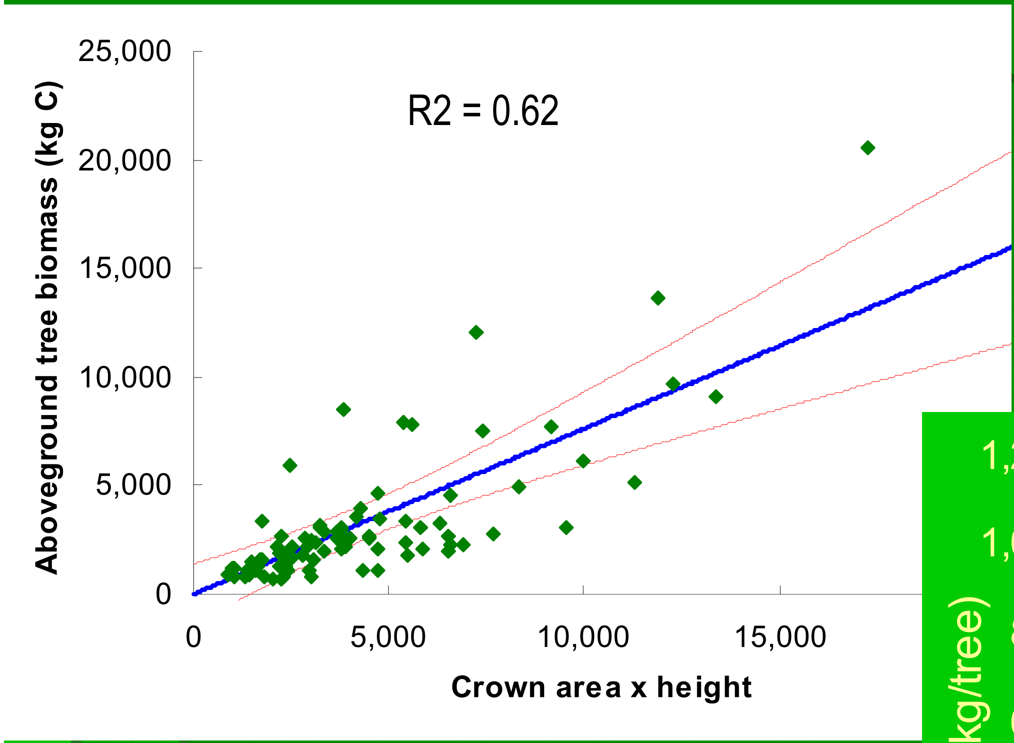


Imagery analysis-uses dual monitor setup – ERDAS Stereo Analyst on one side, ArcView on the other. Polaroid glasses and IR transmitter provide the stereo effect on the monitor

What information do we need to use the 3D imagery approach

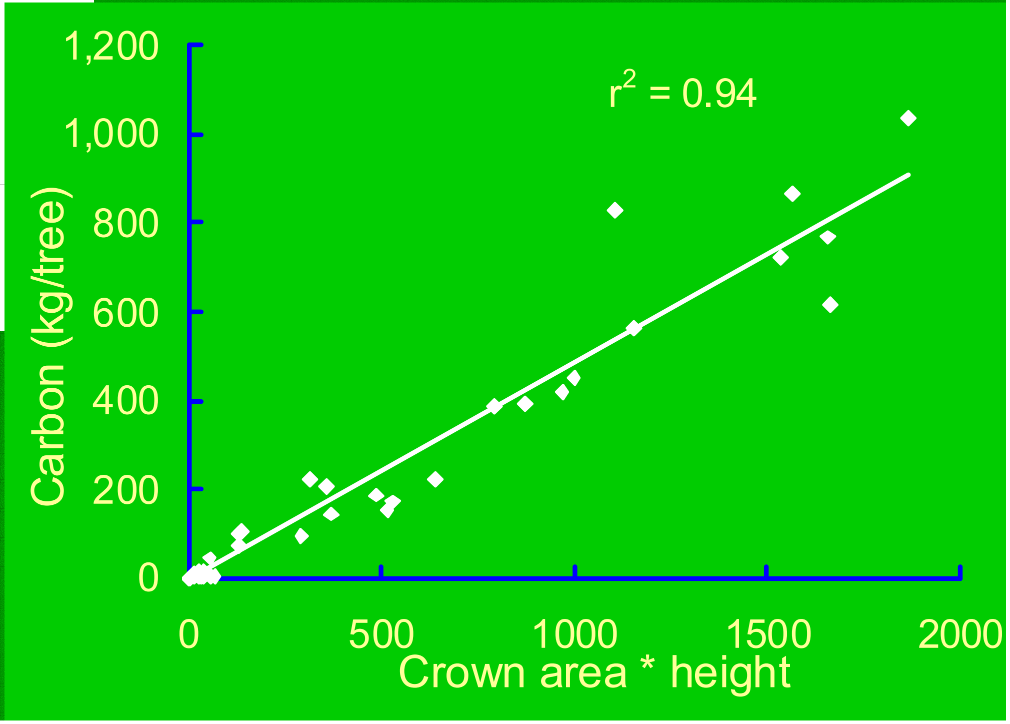
- Biomass typically determined through measurements at DBH or from volume
- Neither measurement is possible from aerial imagery
- Instead new relationships are required for crown area and/or tree height - both measurable from overhead

Develop new allometric equations based on crown area & height

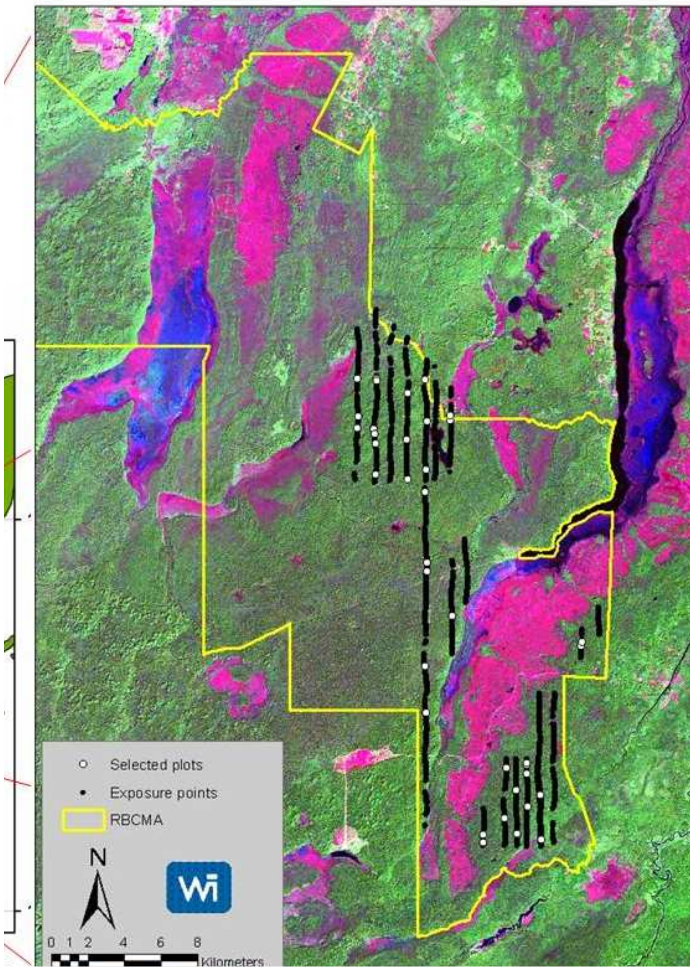


Broadleaf

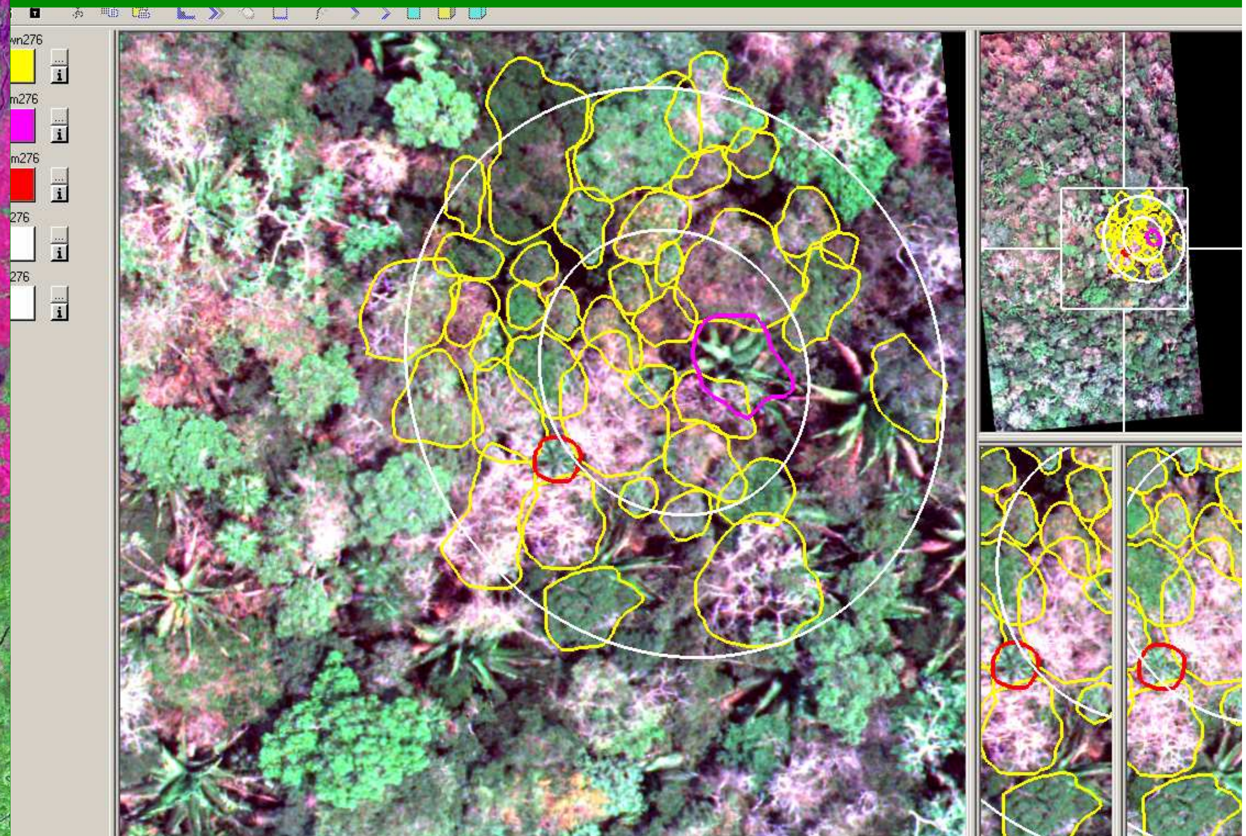
Tropical pine



Application of approach to a tropical closed canopy forest (Belize)

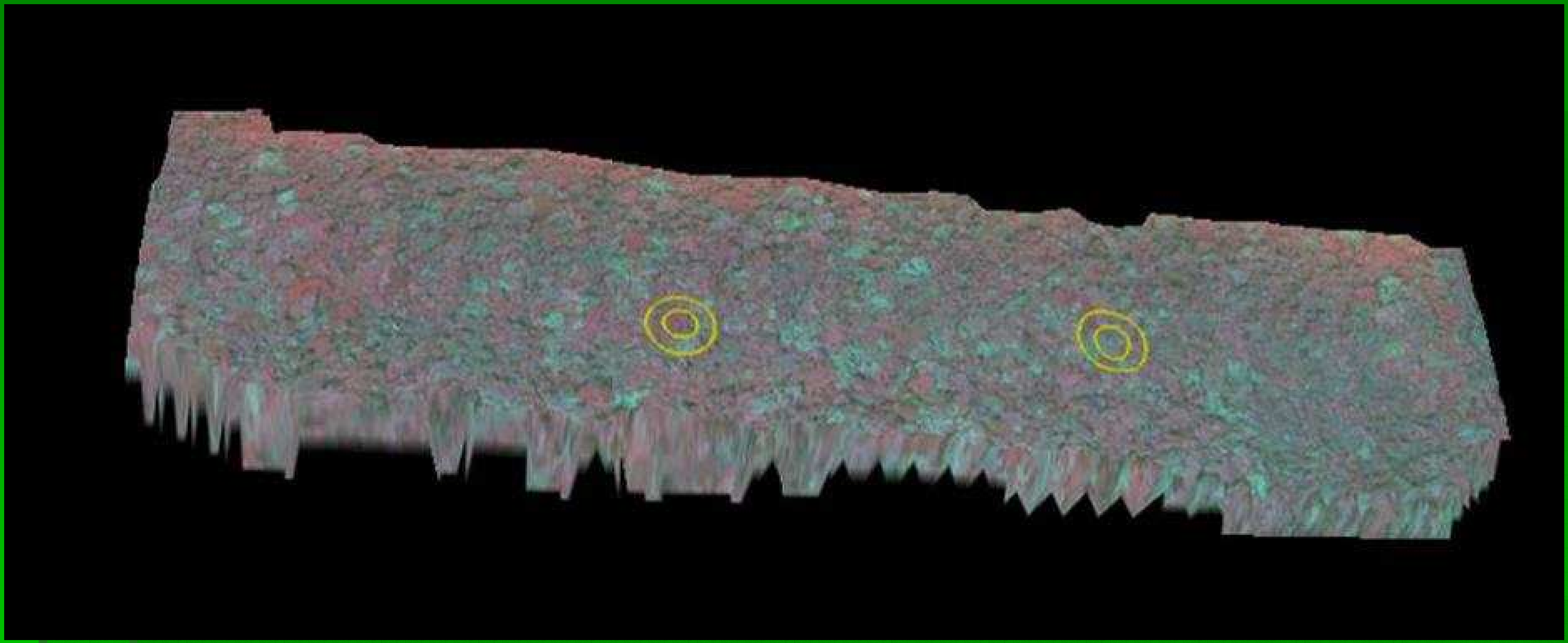


Fly parallel transects and systematically select images



Establish plots and measure tree crown area and height

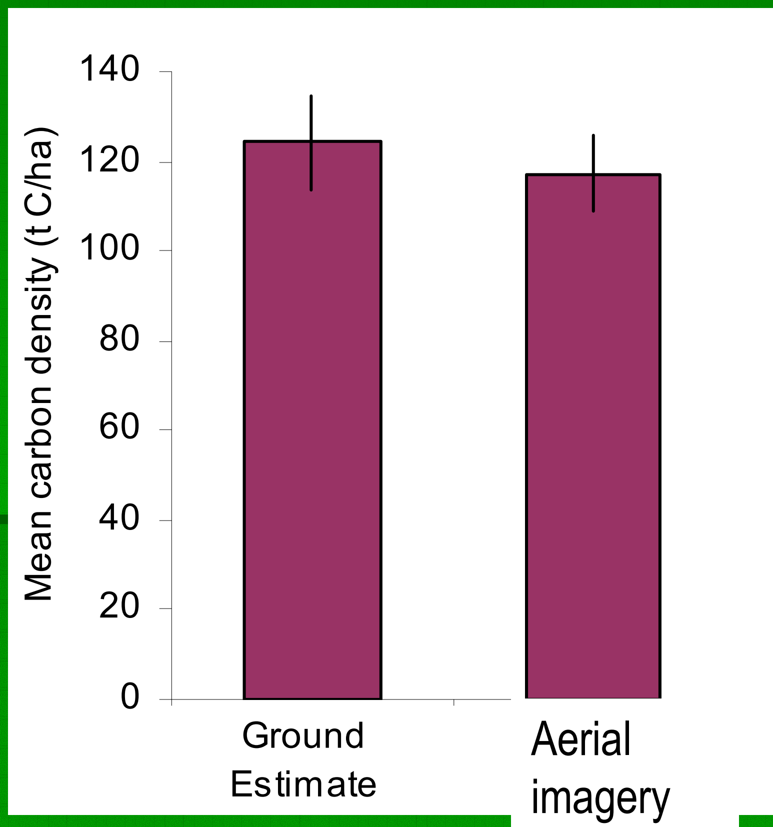
Aerial measurements



- 117 km of transects were flown
- 39 aerial plots installed (= 1.45 % of flown area)

Comparable results

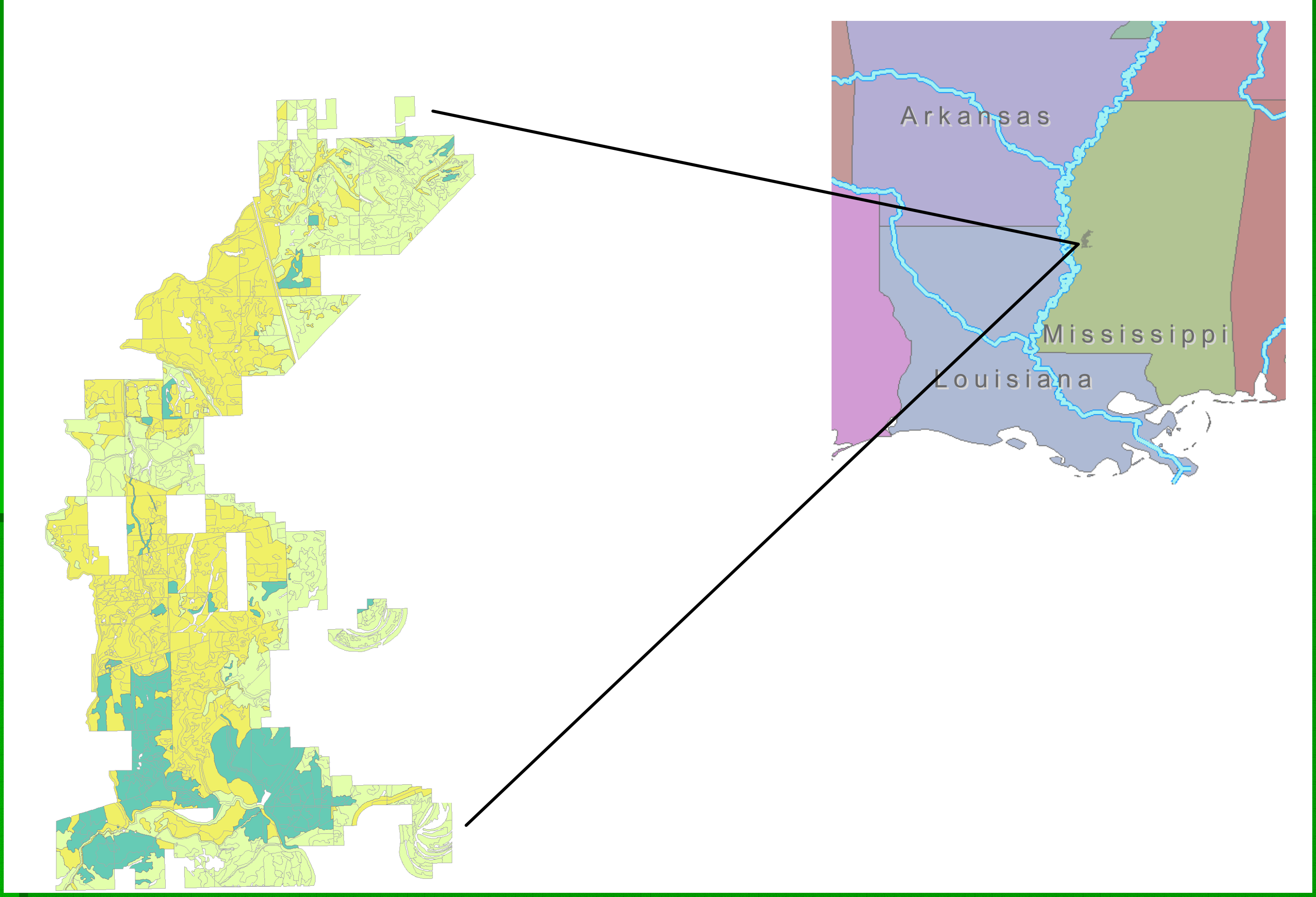
but fewer plots needed for aerial method



Number of plots required to estimate biomass to within 8 % of mean with 95 % confidence

116 25

Example of an application to bottomland forests in the Delta National Forest, MS

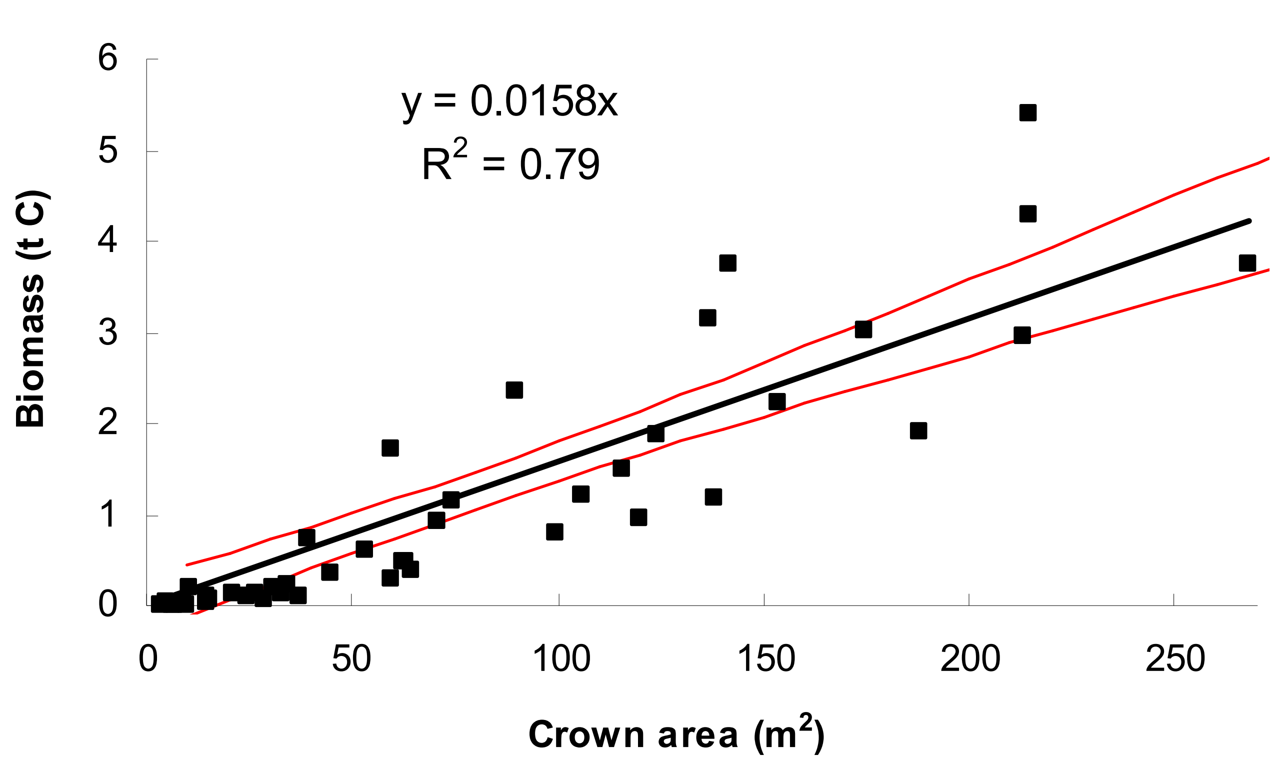


Ground measurement

23 ground plots recorded in mature forest in Delta NF

Allometric relationship for broadleaf bottomland species

44 trees measured to determine relationships between biomass, and crown area and tree height

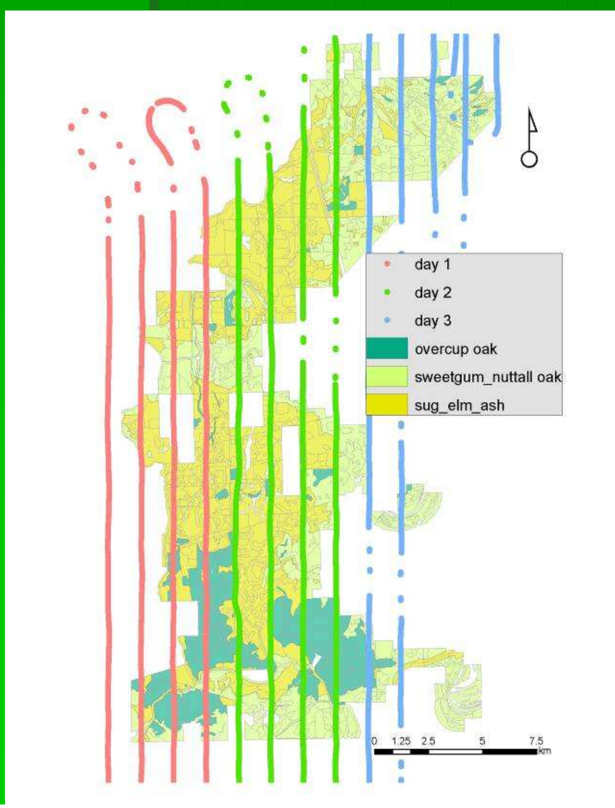


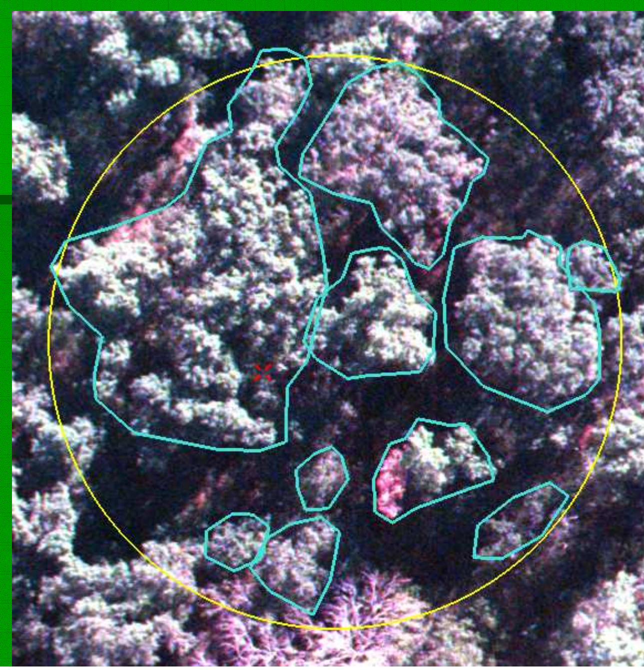
Relationship passes through origin to remove problem of not being able to distinguish between separate tree crowns

Aerial measurements

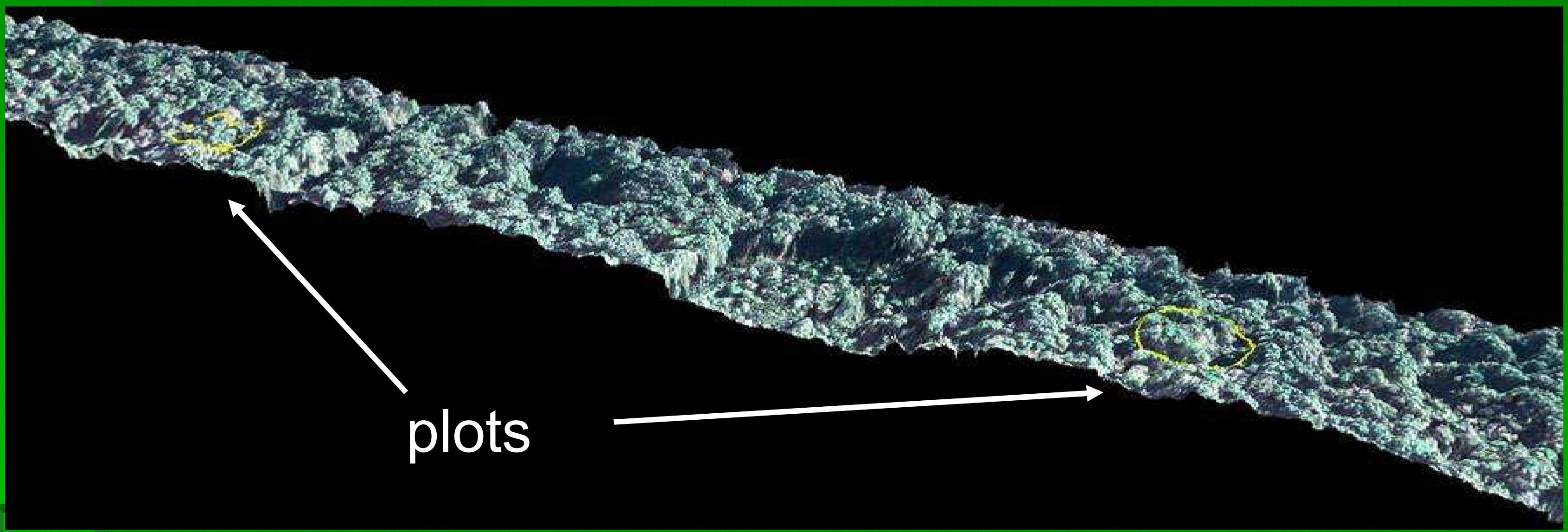
335 km of transects were flown over Delta National Forest (archived)

Determined optimal plot size
Measured 30 plots





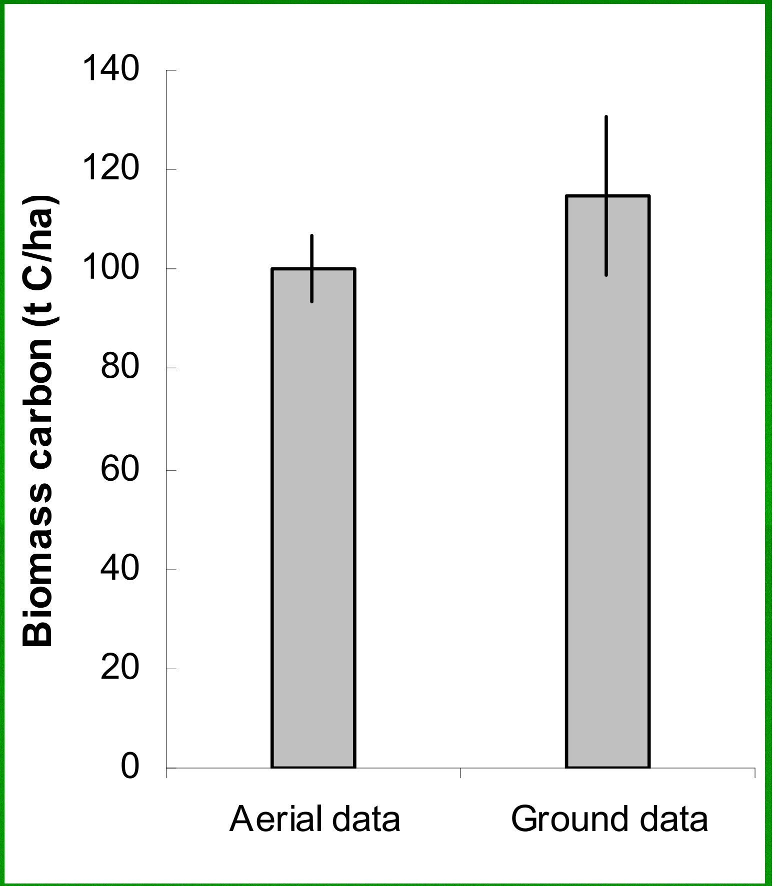
Transect over the Delta National Forest



Transects draped over a DEM

Advantages of imagery approach in bottomlands

- 30 image plots measured biomass to a precision of 6.7% of the mean at 95 % confidence
- 23 ground plots measured biomass to precision of 13.8 %
- Navigating swamps and sloughs in the bottomland forests is time consuming and dangerous



Total person-hours to achieve same precision

	Pine Savanna	Closed Forest	Bottom-land Forest
Field (prep)*	1,266 (73)	374 (24)	254 (19)
Aerial Imagery (prep)*	403 (89)	107 (74)	102 (82)

Prep=person-hours for first two steps

Total person-hours to establish and collect data per plot

	Pine Savanna	Closed Forest	Bottom-land Forest
Field	3.4	2.7	3.6
Aerial imagery	0.71	1.12	0.82
#plots needed Field/imagery	327/327	116/25	63/20
Breakeven # of plots	29	38	26

Know how to measure
How do we account?

- Various protocols exist for monitoring carbon stocks –including detailed methods
  - CA Climate Action Registry (CCAR-offsets)
  - US DOE 1605b (entity or sub-entity)
  - RGGI model rule (RGGI-offsets)
  - Chicago Climate Exchange (CCX-offsets)
- How do they compare?

Carbon pools for forests

Project type	Carbon pools						
	Live biomass			Dead biomass			Wood
	Trees	Understory	Roots	Litter	Wood	Soil	products
•Forest protection	**Y**	M	R	M	**Y**	N	**Y**
•Change management	**Y**	M	R	M	**Y**	N	**Y**
•Restore native forests	**Y**	M	R	R	**Y**	R	N
•Industrial plantations	**Y**	N	R	M	M	R	**Y**

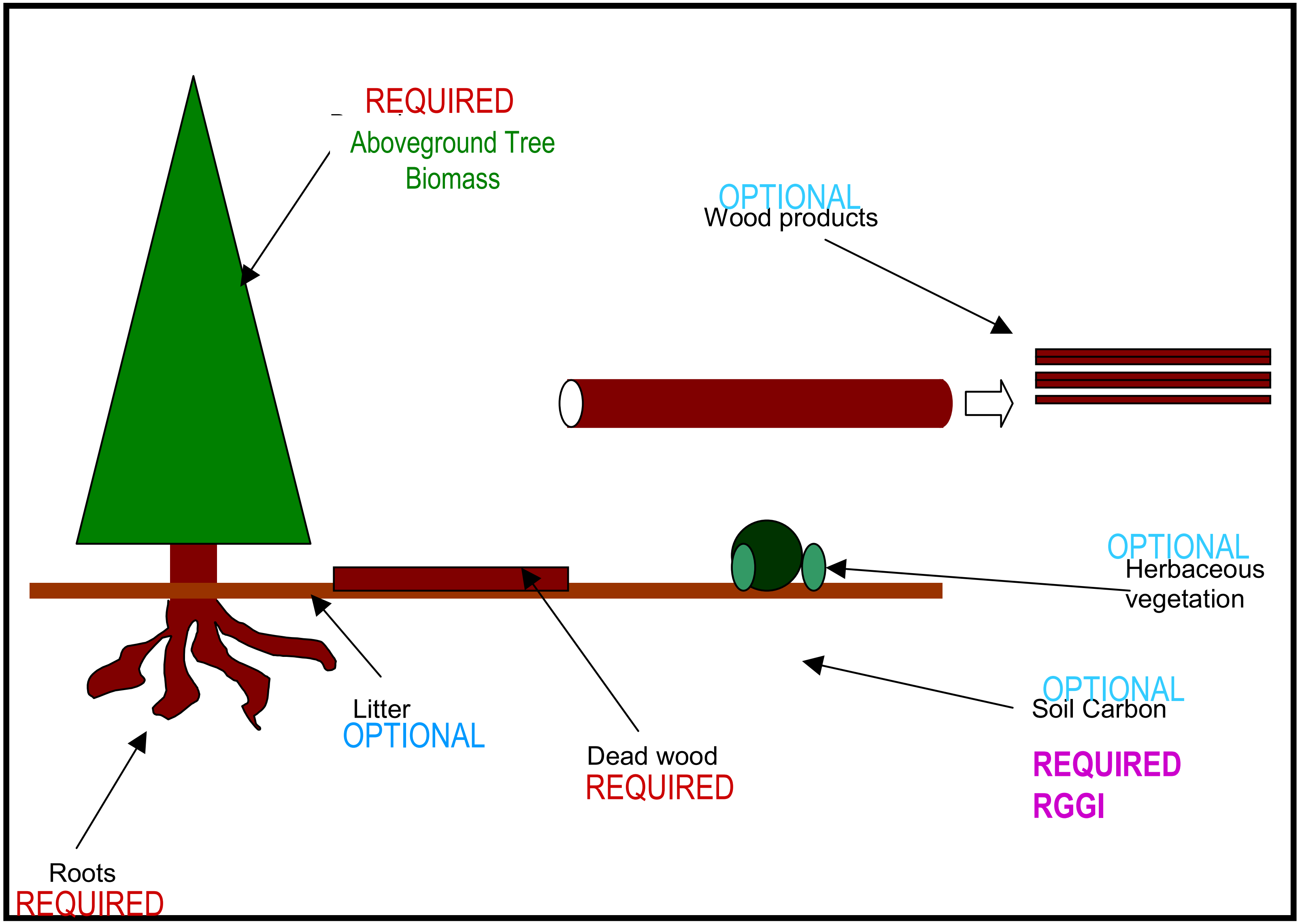
Y=yes, R=recommended, M=maybe, N=not recommended

-Selection of pools varies by project type
-Different measuring and monitoring designs are needed for different types of projects

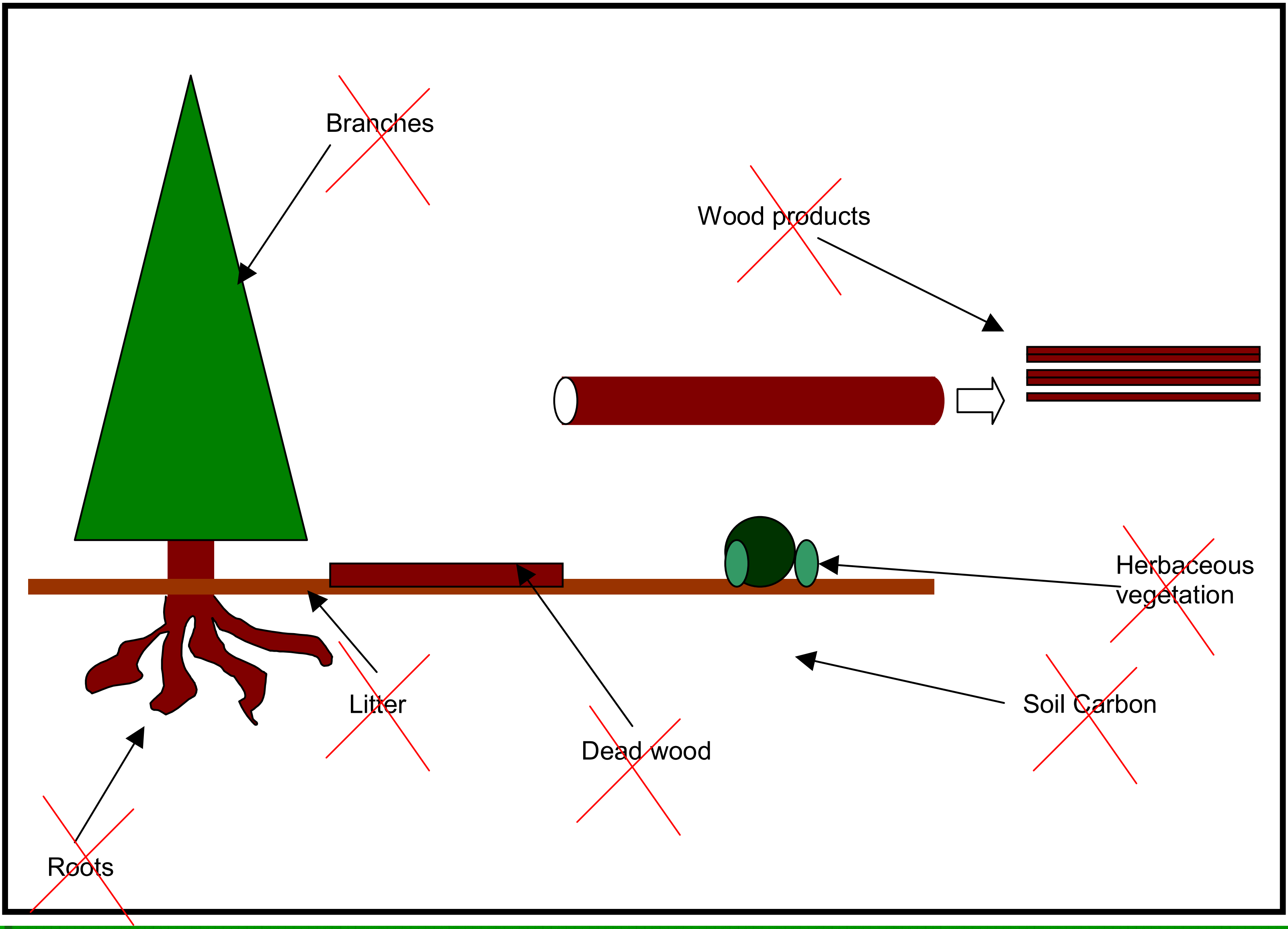
Different protocols require different measurement pools

The pools that are permissible and/or required under each of the protocols has implications for the quantity of carbon that can be reported and for the full accounting of the changes in carbon stocks as a result of the project

CCAR/RGGI

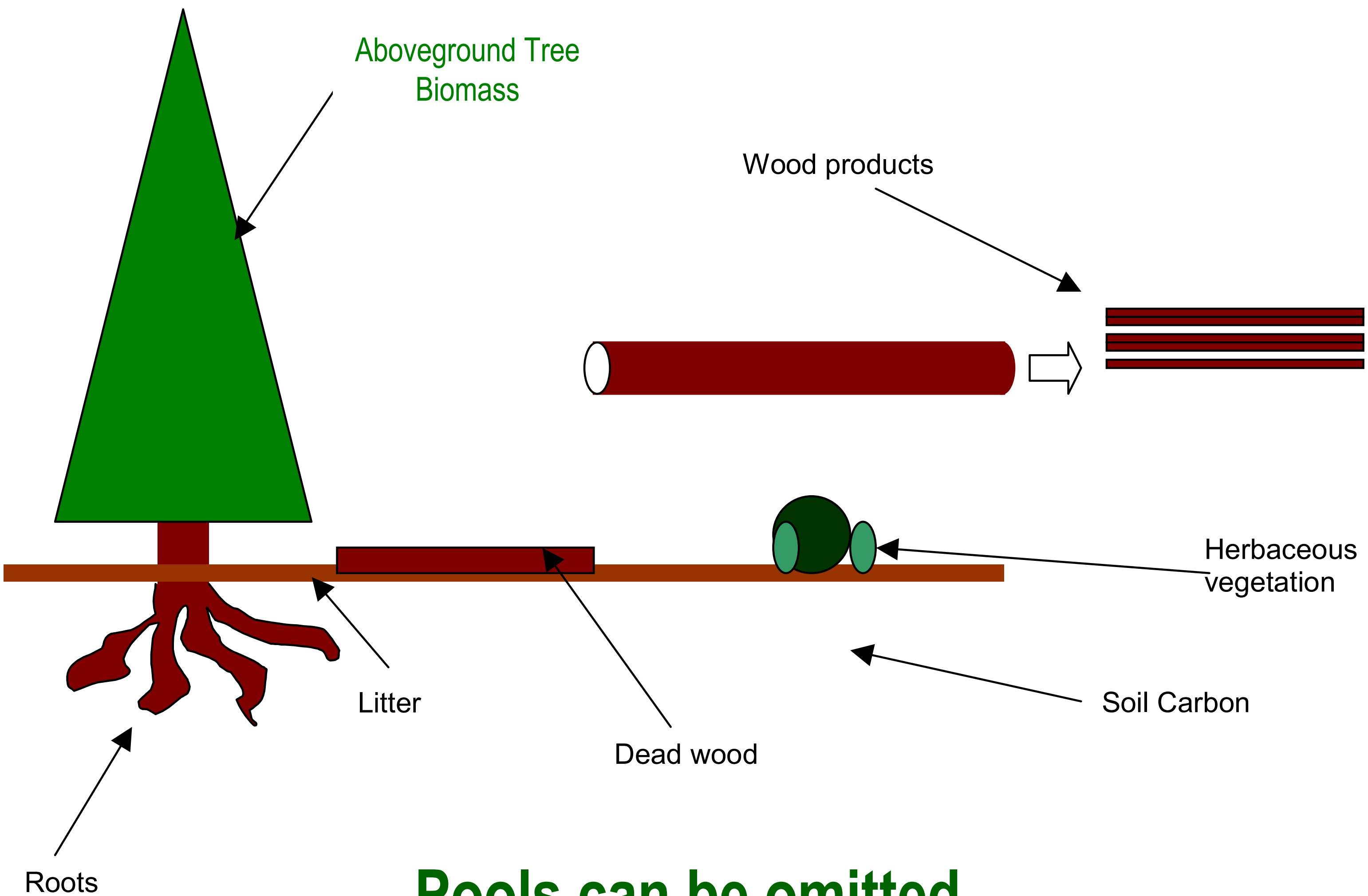

REQUIRED
Aboveground Tree
Biomass
OPTIONAL
Wood products
OPTIONAL
Herbaceous
vegetation
OPTIONAL
Soil Carbon
REQUIRED
RGGI
Litter
OPTIONAL
Dead wood
REQUIRED
Roots
REQUIRED

CCX



Only stem is eligible

1605 (b)



Pools can be omitted

Protocol comparison

	CCX	CCAR	RGGI	1605(b)
Admissible Activities	Unlimited for reporting on own lands. Limited to reforestation and conservation (in Brazil) on "offset" lands	>Forest-management >Reforestation >Conservation	>Afforestation	Unlimited, except for activities that require a baseline to show benefit, such as conservation of mature forest
Measurement Pools	**Required:** Wood in the main stem of the tree up to the terminal bud **For offset activities** – aboveground tree biomass with option of other pools subsequent to approval by CCX committee	**Required:** Live aboveground and belowground tree biomass Standing dead wood Down dead wood **Optional:** Soil carbon Dead organic matter, forest floor Live aboveground non-tree biomass	**Required:** Live aboveground tree biomass and belowground tree biomass Soil Carbon Dead organic matter, coarse woody debris (optional if baseline measurement is at or near zero) **Optional:** Live aboveground non-tree biomass Dead organic matter, forest floor	All pools included. Pools can be omitted as long as they don't lead to greater than *de minimis*[1] emissions

Protocol comparison (cont.)

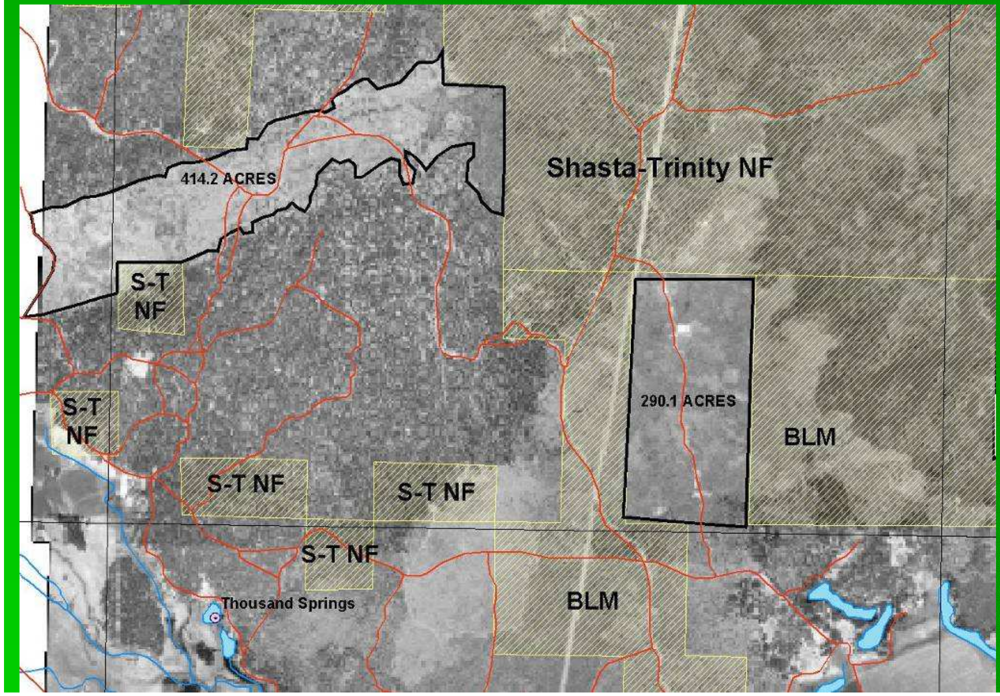
	CCX	CCAR	RGGI	1605(b)
Measurement Requirements	Measurement required. Permanent plots allowed	Permanent plots required	Measurement required but permanent plots effectively excluded	Measurement not required for registration
Baseline	Cap and Trade Baseline for "offset" conservation activities	Required (qualitative and quantitative)	Required	1 to 4 base years
Non-CO_2 gases	Non-CO_2 gases are not included	Optional	Not discussed in model rule	Required if are more than *de minimis*

Protocols comparison (cont.)

	CCX	CCAR	RGGI	1605(b)
Leakage	All forest land inside and outside the project must be managed sustainably but this does not preclude leakage	Assessment of activity shifting is required, but quantification only required if on-site Assessment of market effects, upstream and downstream effects only encouraged	Not discussed in model rule	Must certify activities do not lead to increased emissions elsewhere in entity, but no requirements for outside entity boundaries
Permanence	Indefinite reporting required on own lands. Project activities require "legal protection status"	Legal Easement Required	Legal Easement Required	No proof needed
Additionality[3]	No requirement for financial additionality	No requirement for financial additionality	No requirement for financial additionality	No requirement for financial additionality
Third Party Certification	Required	Required	Required	Not Required

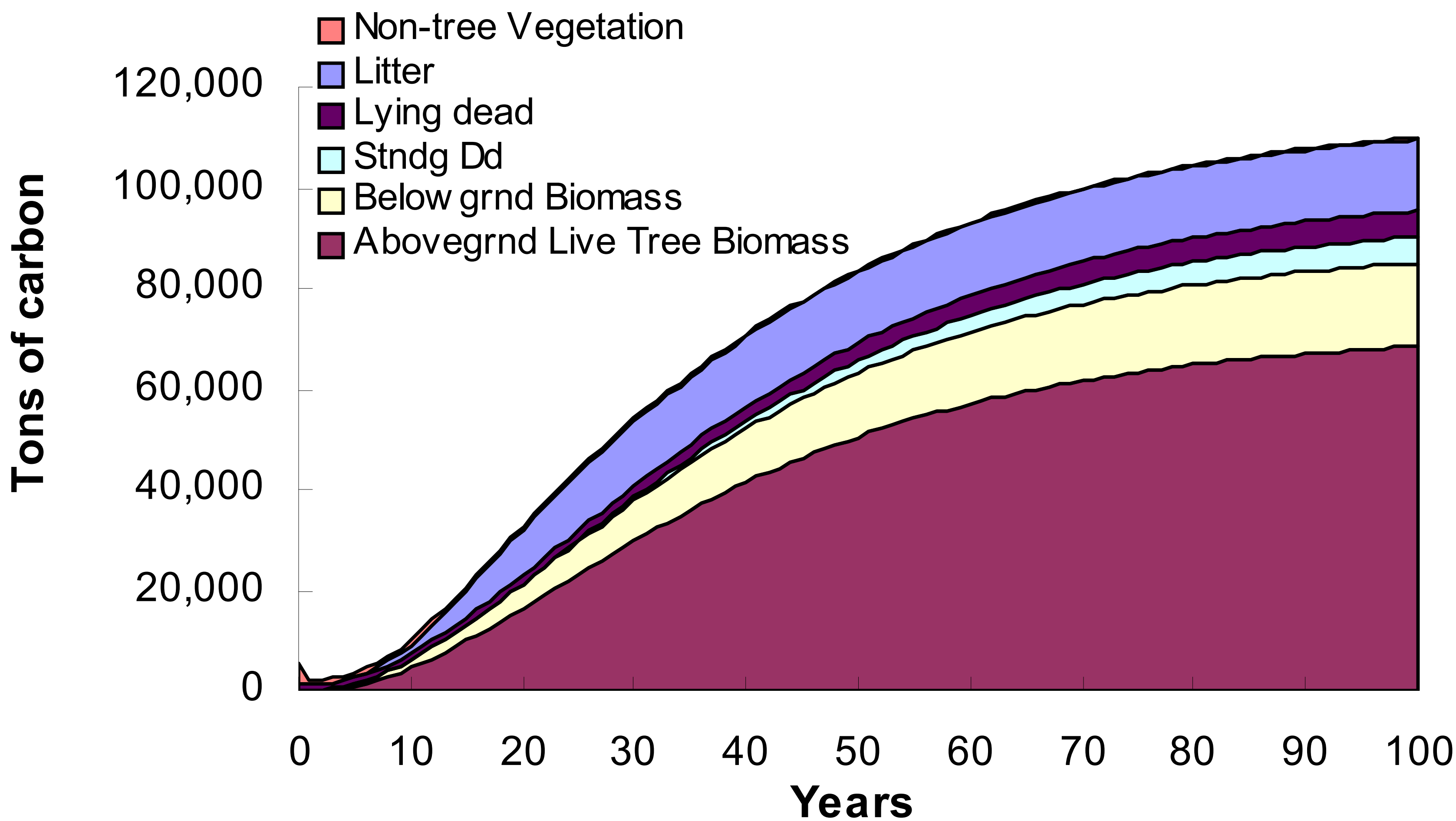
Application to an afforestation project

- 704 acre site in Shasta County California
- Surrounded by private forest lands, BLM lands and Shasta-Trinity National Forest
- Land is currently grazed rangeland with sparse tree/shrub cover



Target is to produce a forest like this

Carbon accumulation in afforestation activity



Based on data for Sierran mixed conifers in California

Effect of protocols differences on reportable credits for the same afforestation activity—t CO_2 eq

	CCAR	1605(b)	RGGI	CCX
Baseline	0	15,675	51,015 (due to soil C pool)	0
Net Carbon Gain (after 60 years)	259,254	303,828	260,983	118,044
Excluded Pools	Non-tree vegetation, forest floor, soil organic matter	Soil organic matter	Non-tree vegetation, coarse woody debris, forest floor	Branches, roots, non-tree vegetation, forest floor, soil organic matter

Addressing uncertainty in CCAR

The defined deductions for uncertainty under CCAR

Sampling error no greater than X % on either side of mean at 90% confidence level	Deductions to required pools derived from field sampling
0 to 5 %	0 %
5.1 to 10 %	10 %
10.1 to 15 %	20 %
15.1 to 20 %	30 %
> 20 %	100 %

For example a carbon stock of 8000 t C ± 800 (10 % of the mean) would permit a claim for credit of only 7200 t C *(8000 – 800)*

Uncertainty in CCX and RGGI

- The CCX guidelines state that:

"the calculations of increases in Carbon Stocks shall be 'discounted' conservatively to account for the statistical variance associated with the measurement and calculation methods used"

  - It is probable that confidence intervals will be used but it is unclear whether 90% or 95% will be the choice

- For RGGI details are not yet clear

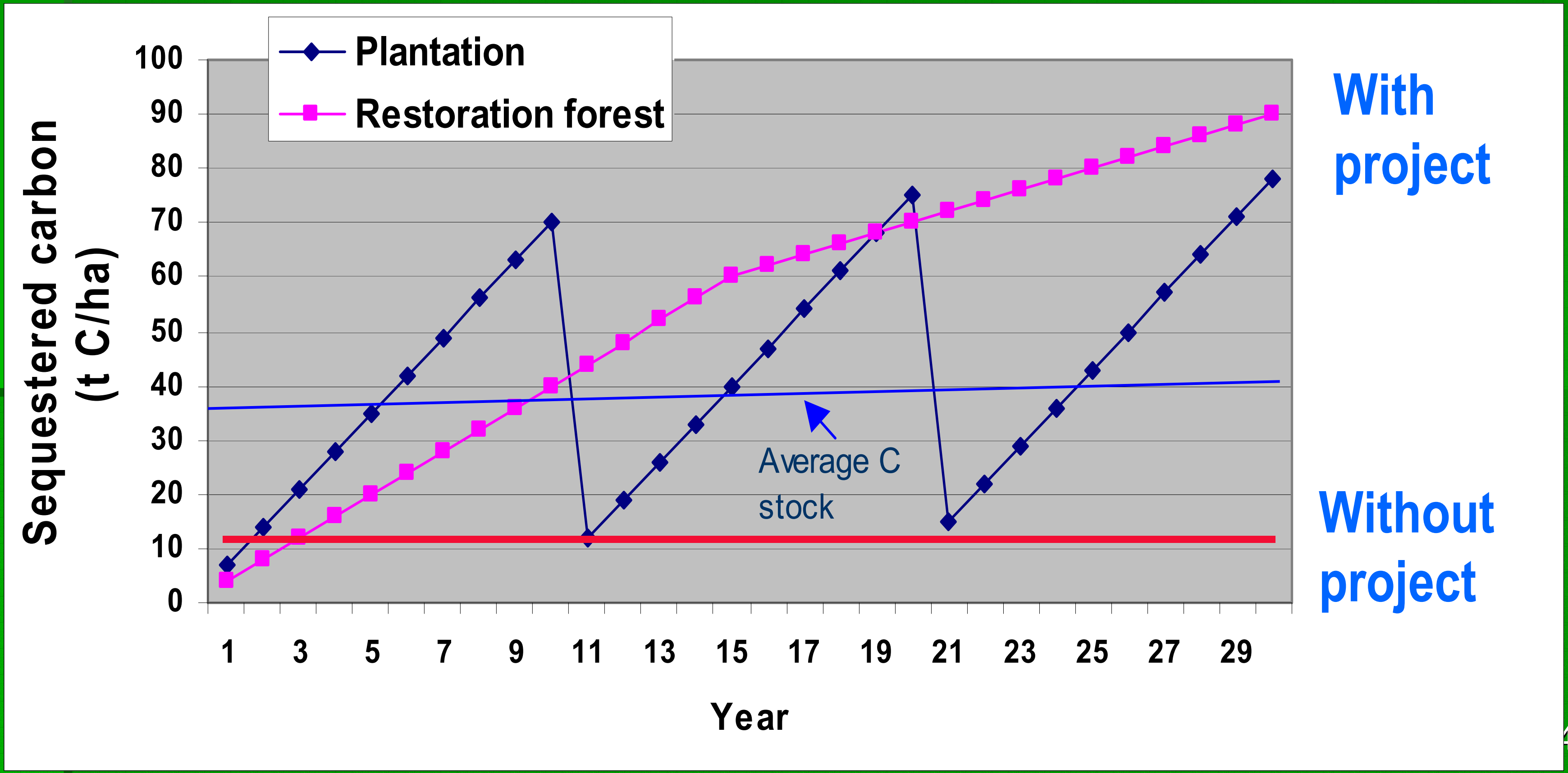
Rating system for 1605b –requires a B grade

Forest Ecosystem Carbon Pools	Harvested Wood Products Pool	Rating
Estimates from look-up tables that match specific site conditions and management practices, as documented using independent data or information. Use of the USFS COLE model or an approved[1] model, validated with data specific to the site conditions and management practices. Sampling with quantified accuracy	Use of an approved[1] model validated with data specific to the product mix of the entity	A
Estimates in look-up tables adapted to specific site conditions and management practices. Use of an approved[1] model that is parameterized specifically for site conditions and management practices. Use of the Forest Service COLE model	Use of specific data on harvest and product mix and default decay factors provided in section 4 of the Appendix	B
Typical application of regional look-up tables that generally match the site conditions and management practices. Use of an approved[1] model that generally matches site conditions and management practices.	Use of aggregate data on harvest and default decay factors provided in section 4 of the Appendix	C
Use of look-up tables for site conditions and management practices that are not represented by the tables.		D

How does afforestation “project activity” affect carbon stocks?

Carbon stocks in short rotation plantations vs restoration of native forests

Credits from a project are: with project –without project measured as changes in C stocks



Conclusions

- Many resources available to design and implement a first class M&M plan to achieve desired accuracy and precision for carbon trading purposes
- Need to develop a protocol that gives the same estimate of carbon credits no matter where applied in the US and for which market
- Current satellite remote sensing data unsuited for estimating forest carbon stocks
- Technologies available for remotely measuring key forest indices that can be converted to carbon stock estimates for project scale activities cost -effectively

For more information, contact Sandra Brown

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