How to Design and Implement Carbon Measuring and Monitoring Activities for LUCF Projects

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Project design issues

- Baselines and additionality
- Leakage
- Permanence
- **Measuring and monitoring**
- Issues vary with projects in developed versus developing countries

Leakage

- Leakage is the unanticipated loss or gain in carbon benefits <u>outside</u> of the project's boundary as a result of the project activities-divide into two types:
  – Primary leakage or activity shifting outside project area
  – Secondary leakage or market effects due to change in supply and demand

Primary leakage

- Likely of little concern in developed country activities
- Activity shifting of greater concern in developing countries

Secondary Leakage

- Of concern in developed country projects related to changing forest management practices, protection of forests, or establishing commercial plantations because of impact on timber supply
- Of minimal concern for restoring native forests
- However,
  - companies doing "good" things for climate mitigation should be rewarded
  - could be a minor issue as leakage should be picked up in national GHG accounting

Project duration concerns:

•A unique feature of LUCF projects is the possibility of a reversal of carbon benefits from natural or human activities regimes
•Good knowledge of disturbance regimes for most forests of e.g. N. America
•Build potential disturbance into accounting system
•Postpone emissions for several decades to buy time to develop and implement policies and measures requiring longer lead times

Measuring and monitoring carbon by Winrock

- Developed methods manual for monitoring carbon storage in forests and agroforests (McDicken 1997) -being revised
- Developed software package for data analysis and modeling
- Tested methods in U.S., Guatemala, Belize, Bolivia, Brazil, Indonesia, and the Philippines
- Examples of current projects
  - The Nature Conservancy -- Bolivia, 634,000 ha of forest protection
  - US electric utilities -- Midwest, USA, 20,000 ha of reforestation (uplands and bottomlands) and prairie restoration
  - The Climate Trust– US, 1000 ha of forest restoration/protection,
  - The Nature Conservancy -- Belize, 14,000 ha of forest protection
  - The Nature Conservancy -- Brazil, 7,000 ha of forest restoration/protection

Measuring and monitoring

- Techniques and methods for measuring individual carbon pools in LUCF projects exist, and are based on peer reviewed principles of forest inventory, soil sampling, and ecological surveys .
- Long history of measuring forests for commercial reasons—methods can be adapted for carbon
- Methods for measuring non-CO_2 GHG fluxes are less well developed and are often based on changes in carbon pools (e.g. CH_4, CO, N_2O from biomass burning).

Carbon measuring and monitoring

- Land-use change and forestry projects are generally easier to quantify and monitor than national inventories:
  - they have clearly defined boundaries,
  - easier to stratify,
  - efficient sampling, and
  - a choice of which pools to measure.

Getting started

- Use maps, aerial photos, satellite images, etc. to define area
- Stratify project area
  - Grouping similar subgroups of vegetation
  - Reduce variability of the entire population
  - Guides all monitoring activities during lifetime of the project
  - Requires vegetation maps, other spatial data layers, remote sensing products, and the like

Getting started (cont:)

- Establish preliminary plots to estimate carbon pools per hectare and variation in each stratum
- Use Sample Size Calculator to estimate number of plots needed per strata to achieve target level of precision and cost per plot
  - recommend about +/-7-8% of mean with 95%
- Install permanent measuring and monitoring plots

Which carbon pools to measure and monitor?

- Selection of pools depends on:
  - Type and size of project
  - Magnitude of pool
  - Rate of change of pools
  - Expected direction of change
    - must measure if change is negative
  - Cost to measure
  - Attainable accuracy and precision

Identification of carbon pools for inventorying and monitoring

Project type	Carbon pools						
	Live biomass			Dead biomass			Wood
	Trees	Understory	Roots	Fine	Coarse	Soil	products
Avoid emissions							
•Stop logging and protect	Y	M	R	M	Y	N	Y
•Improved forest management	Y	M	R	M	Y	N	Y
Sequester carbon							
•Restore native forests	Y	M	R	R	Y	R	N
•Plantations	Y	N	R	M	M	R	Y
•Agroforestry	Y	Y	R	N	N	R	M
•Soil carbon management	N	N	M	M	N	Y	N
•Short-rotation plantations	Y	N	M	N	N	Y	*

*Stores carbon in unburned fossil fuels

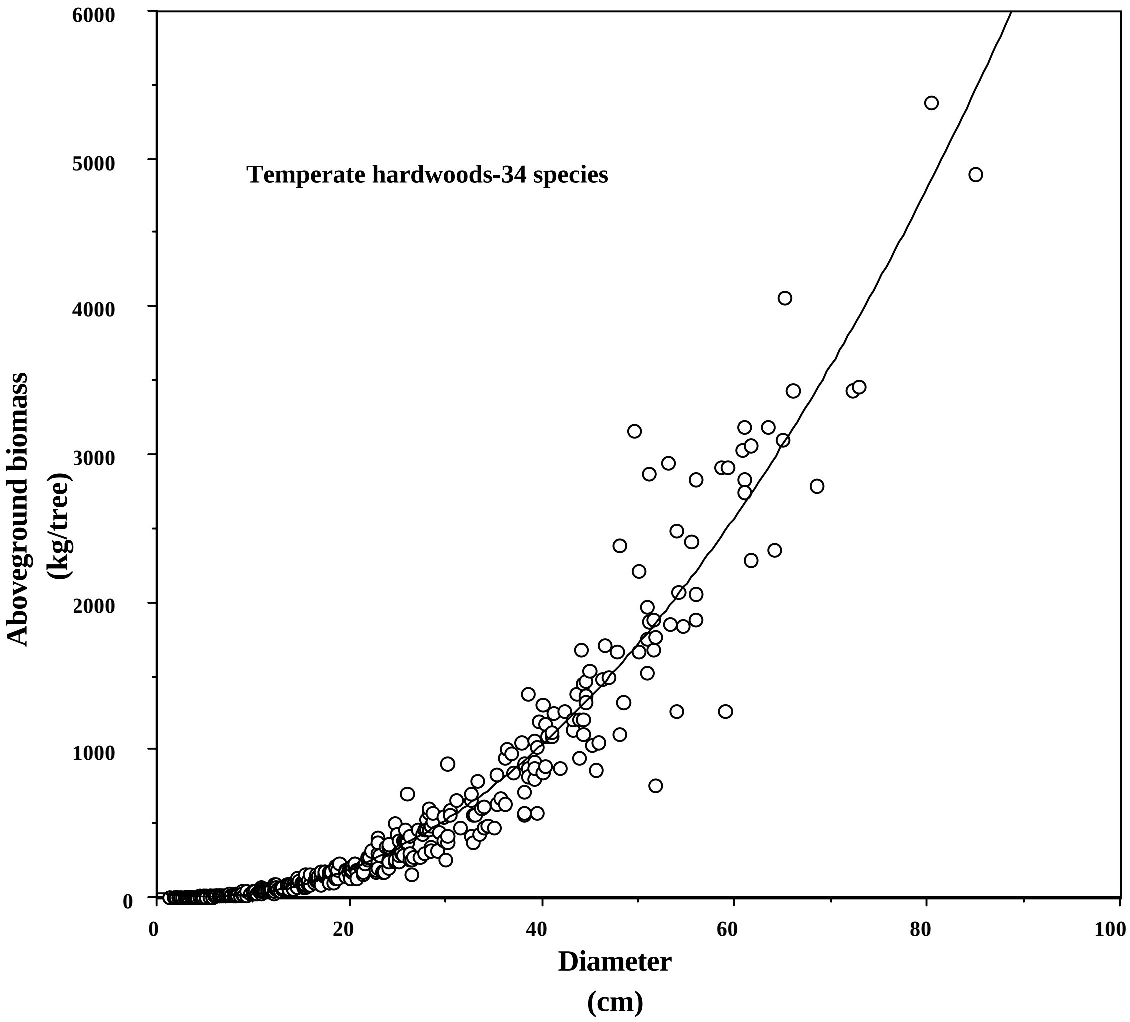
Y=yes, R=recommended, M=maybe, N=not recommended

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

Measure Aboveground Biomass

Measuring diameter at breast height of all trees within the boundaries of the permanent plot—biomass carbon estimated from regression equations

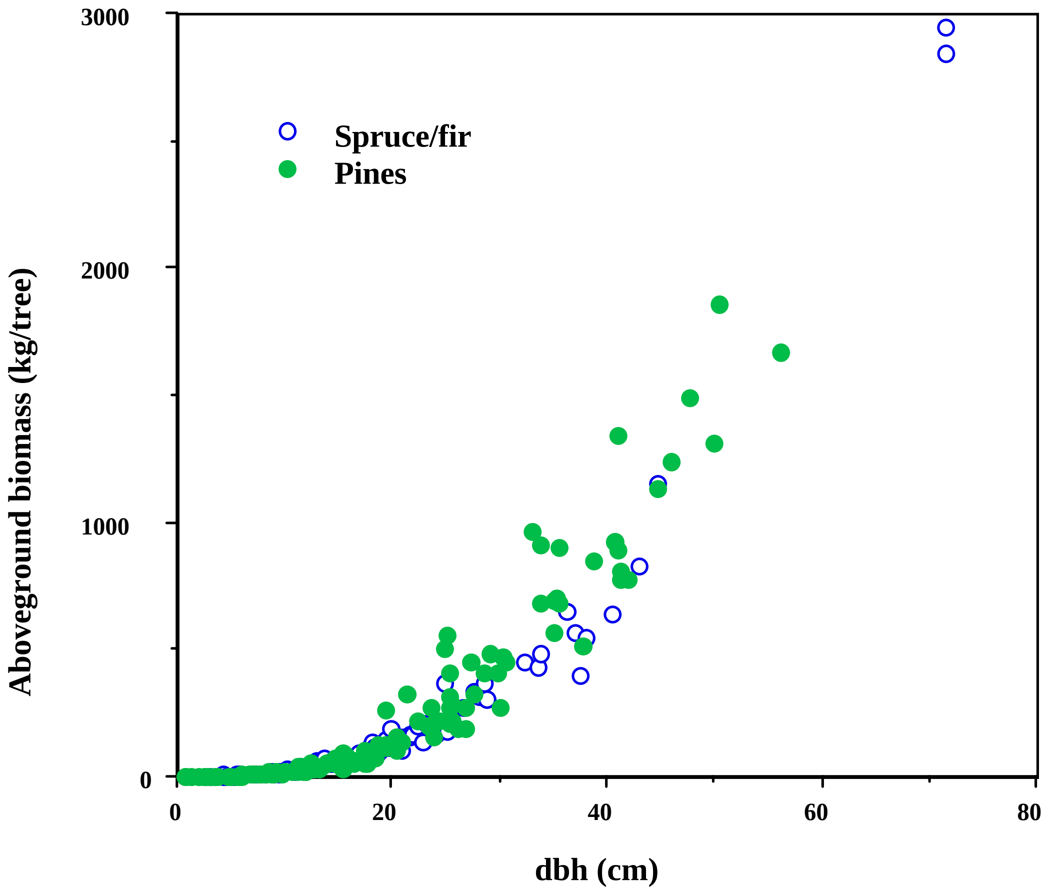
Allometric relationship-hardwoods



Mixed hardwoods:
$r^2 = 0.99$
N = 454
Range dbh = 1.3-85 cm

(Schroeder et al. 1997)

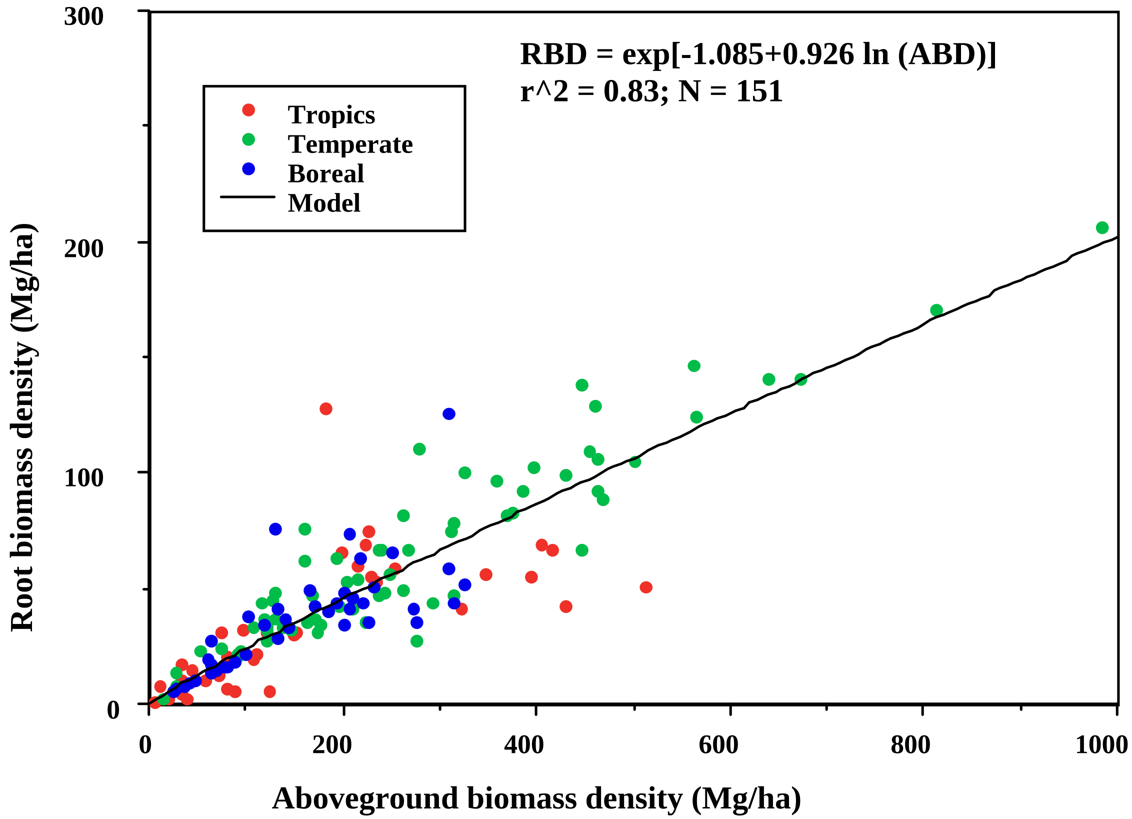
Allometric relationships-softwoods



Spruce/fir (3 species):
r^2=0.98
N=103
range dbh=2.9-71.6 cm
Pines (5 species):
r^2=0.98
N=137
Range dbh=1-56 cm

(Brown and Schroeder 1999)

Regression equation for estimating root biomass



(Cairns et al. 1997)

Measurements of coarse dead wood

- Dead wood a significant component of forests (up to 10-20% of aboveground biomass)
- Important in forest management activities that produce slash
- Techniques for measuring volume are well established (e.g Harmon and Sexton 1996) and no more time consuming than for live trees

Measuring Dead Wood

- For standing dead trees estimate biomass using regression equations or volume from detailed measurements
- Use line intersect method for lying dead wood volume
- Sample dead wood to obtain density estimates by density classes

Measuring Understory and Fine Litter

- Use four clip plots (0.25 m2) to sample understory vegetation and litter within the permanent plot
- Collect total fresh weight and dry a sub-sample to calculate dry biomass

How to ensure quality control in monitoring

- Develop Standard Operating Procedures (SOPs) for all aspects of field and laboratory activities
- Develop formal procedures to verify methods used to collect field data and ensure same procedures are used during the project life
- Develop techniques to enter and analyze data
- Develop formal procedures for achiving data

Sources of error in measuring carbon pools

- Three main sources are:
  - Sampling error—number and selection of plots to represent the population of interest
  - Measurement error —e.g. errors in field measurements of tree diameters, laboratory analysis of soil samples
  - Regression error — e.g. based on use of regression equations to convert diameters to biomass
- All these sources can be quantified and "added"

Noel Kempff: Carbon inventory results based on 625 permanent plots

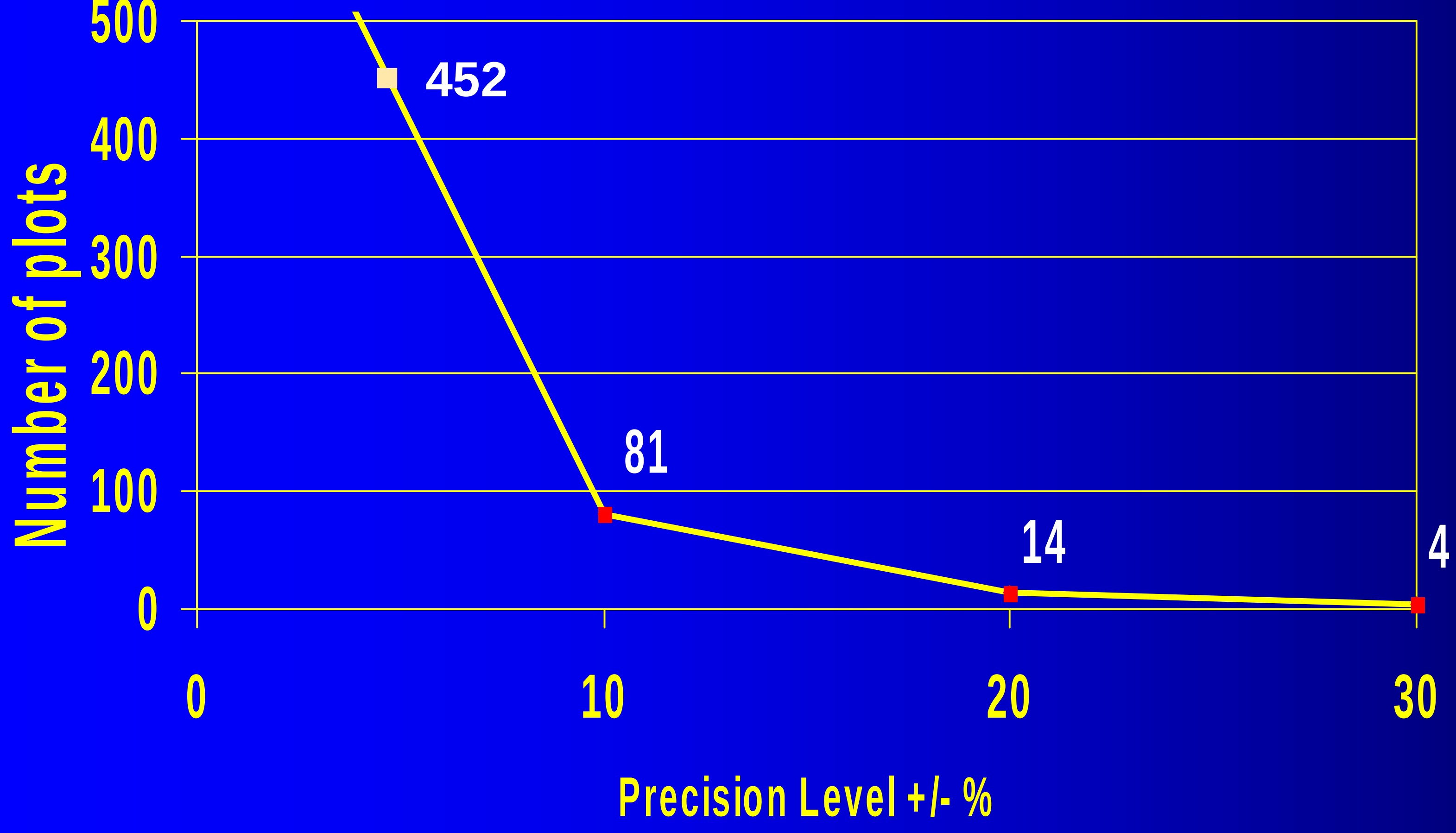
Strata	Area (ha)	Above-ground woody biomass	Palm biomass	Standing dead biomass	Lying dead biomass	Understory	Litter	Below-ground biomass	Soils	Mean
		t C/ha								
Tall (6T1)	226,827	129.1	0.5	4.1	11.0	2.0	3.6	25.8	26.9	203
Liana (6L2)	95,564	55.5	0.5	2.3	4.7	3.8	4.0	11.1	39.9	122
Flood T. (6H4)	99,316	131.8	1.1	3.2	11.3	1.9	3.1	26.4	44.8	224
Flood S. (6F3)	49,625	111.7	0.2	3.0	9.6	2.1	2.9	22.3	55.5	207
Mixed L. (6M5)	159,471	89.6	1.5	4.4	7.7	2.6	4.3	17.9	24.4	152
Burned (6Q6)	3,483	56.9	0.2	1.6	4.9	0.9	4.2	11.4	36.0	116
Weighted mean		**106.7**	**0.8**	**3.6**	**9.1**	**2.4**	**3.7**	**21.3**	**33.3**	**181**

Total 634,286 ha

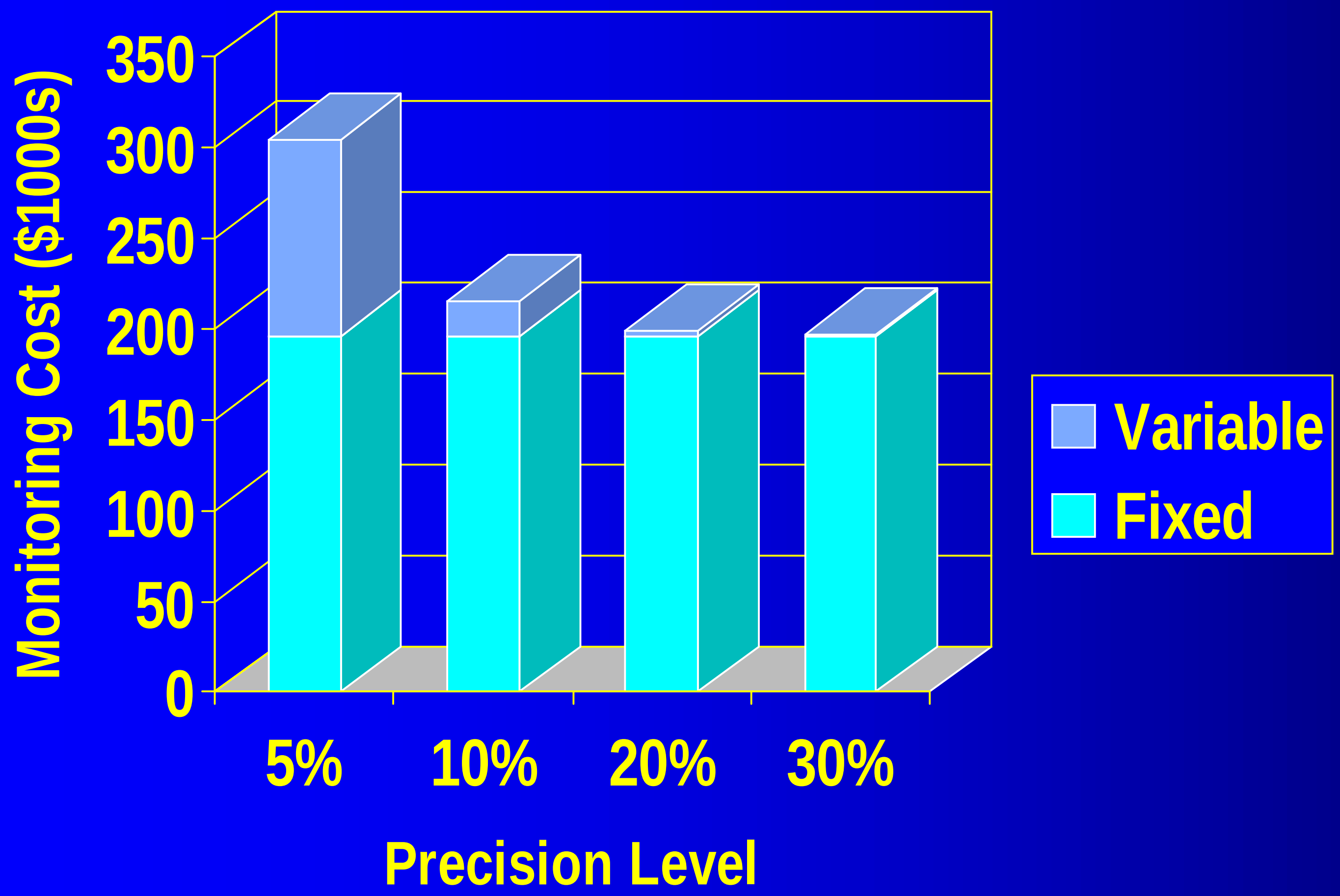
95% confidence limit (% of mean): 4.2

Project Total Carbon Content	114,852,218
Confidence interval (minimum)	110,074,406
Confidence interval (maximum)	119,630,030

Achieving Precision – Noel Kempff



Cost of Precision – Noel Kempff



Cost of Measuring and monitoring

- Site-specific and depends on type of project and desired precision
- Field experience on large tracts suggests initial inventory costs can be kept reasonable-- <$0.10/t C
- Always seeking new methods to reduce costs

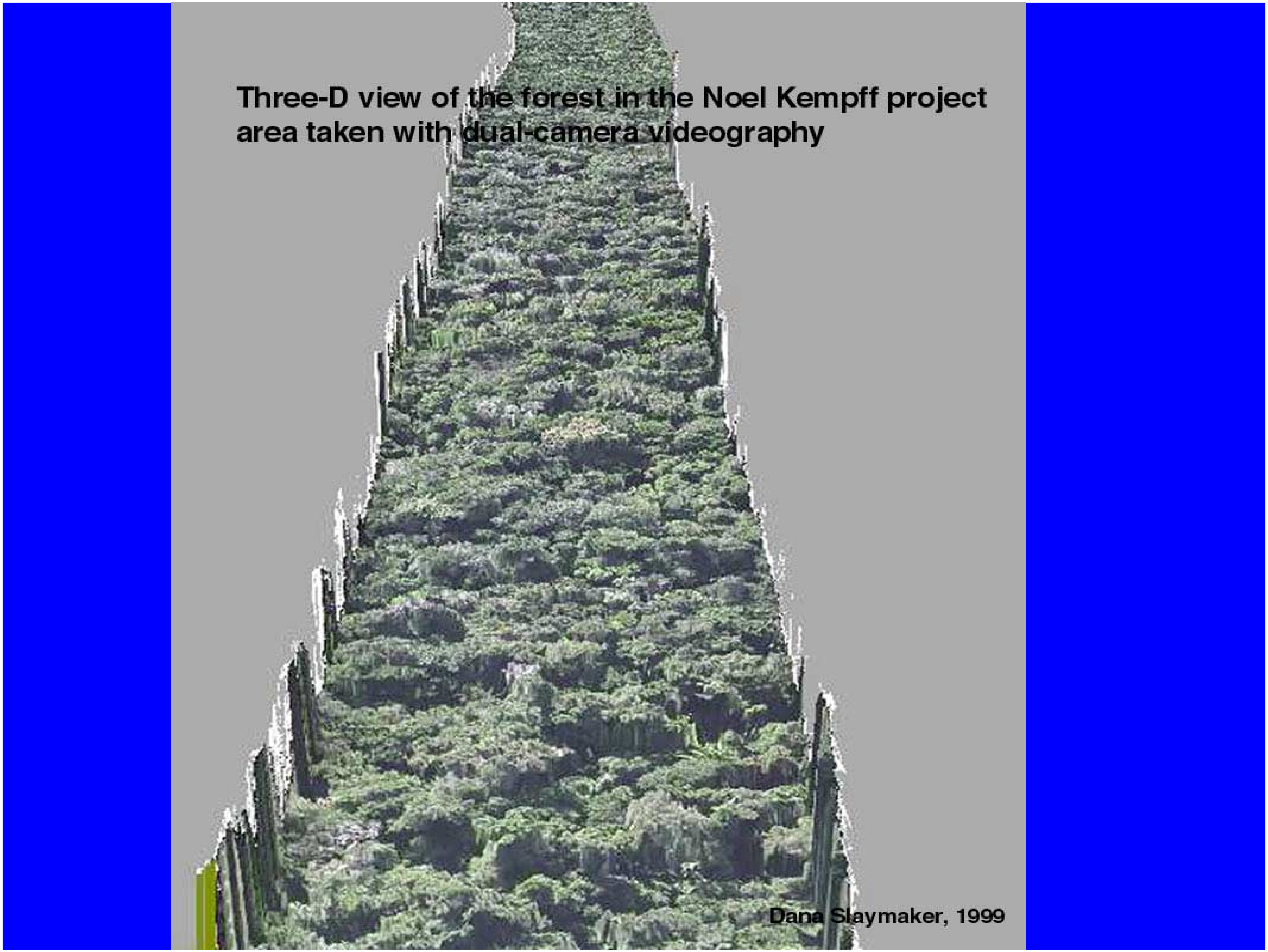
Technological advances in monitoring: dual camera videography

- Goal: to develop cost-efficient, remote sensing methods for measuring and monitoring carbon in forest vegetation

The dual camera videography includes a digital gyroscope and pulse laser along with dual videos, fly video transects and construct georeferenced mosaics. The system fits out the side of any aircraft.

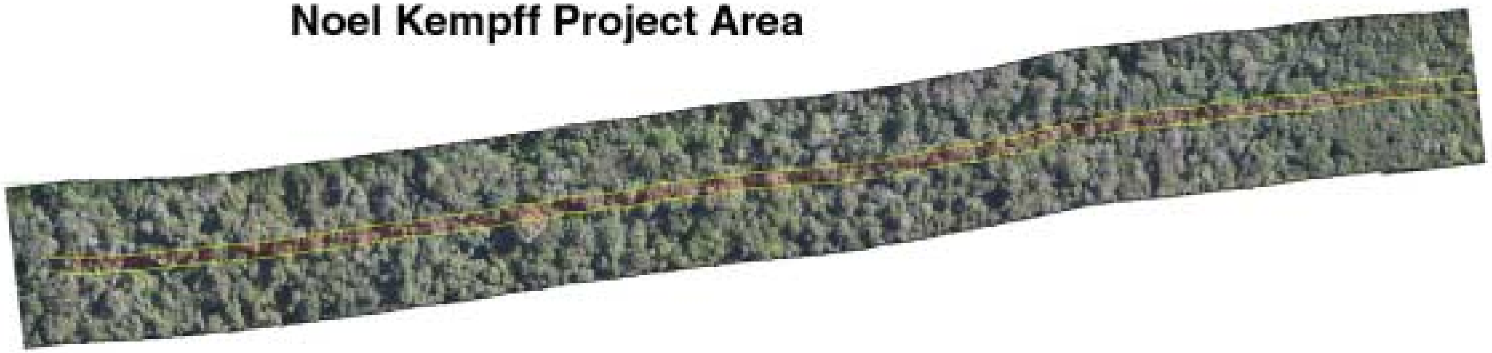
New Monitoring Methods

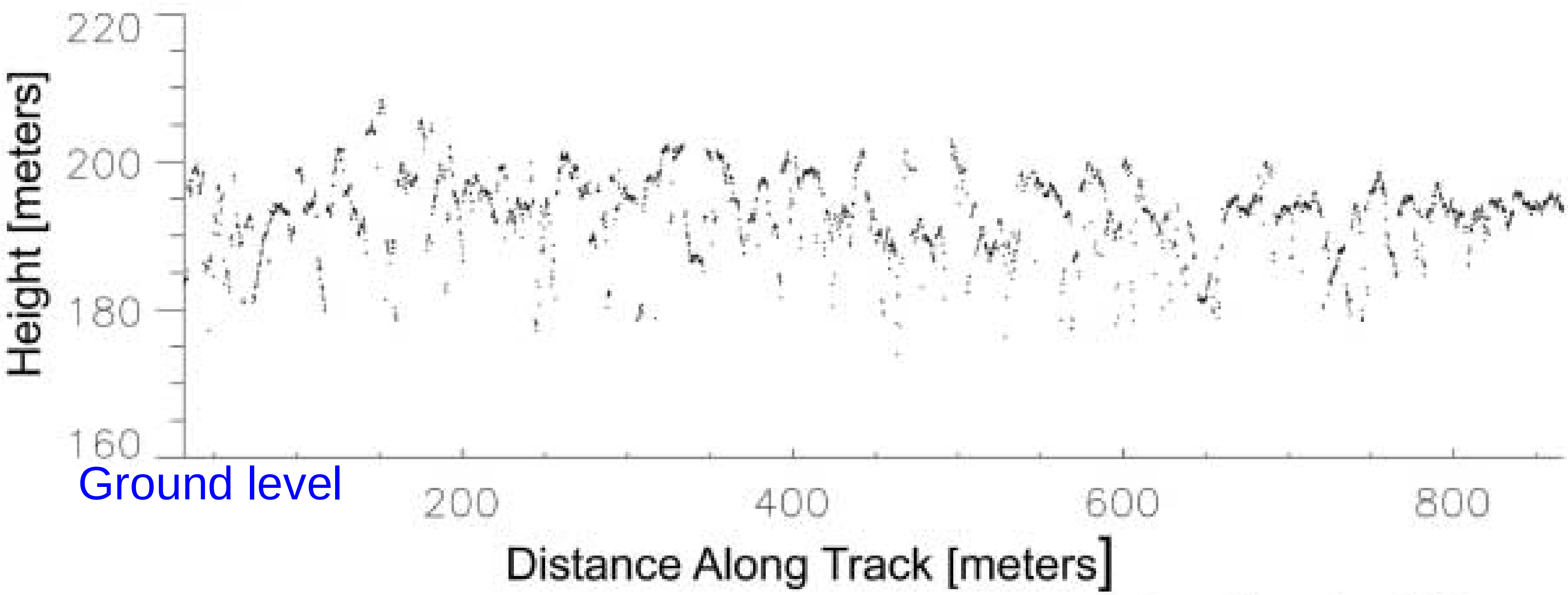
- Fly aerial transects, GPS located and digitally recorded
- Aerial photography or videography
- Generate georeferenced 2D mosaics or 3D terrains


Three-D view of the forest in the Noel Kempff project area taken with dual-camera videography
Dana Slaymaker, 1999

Laser Altimeter Profile

Noel Kempff Project Area

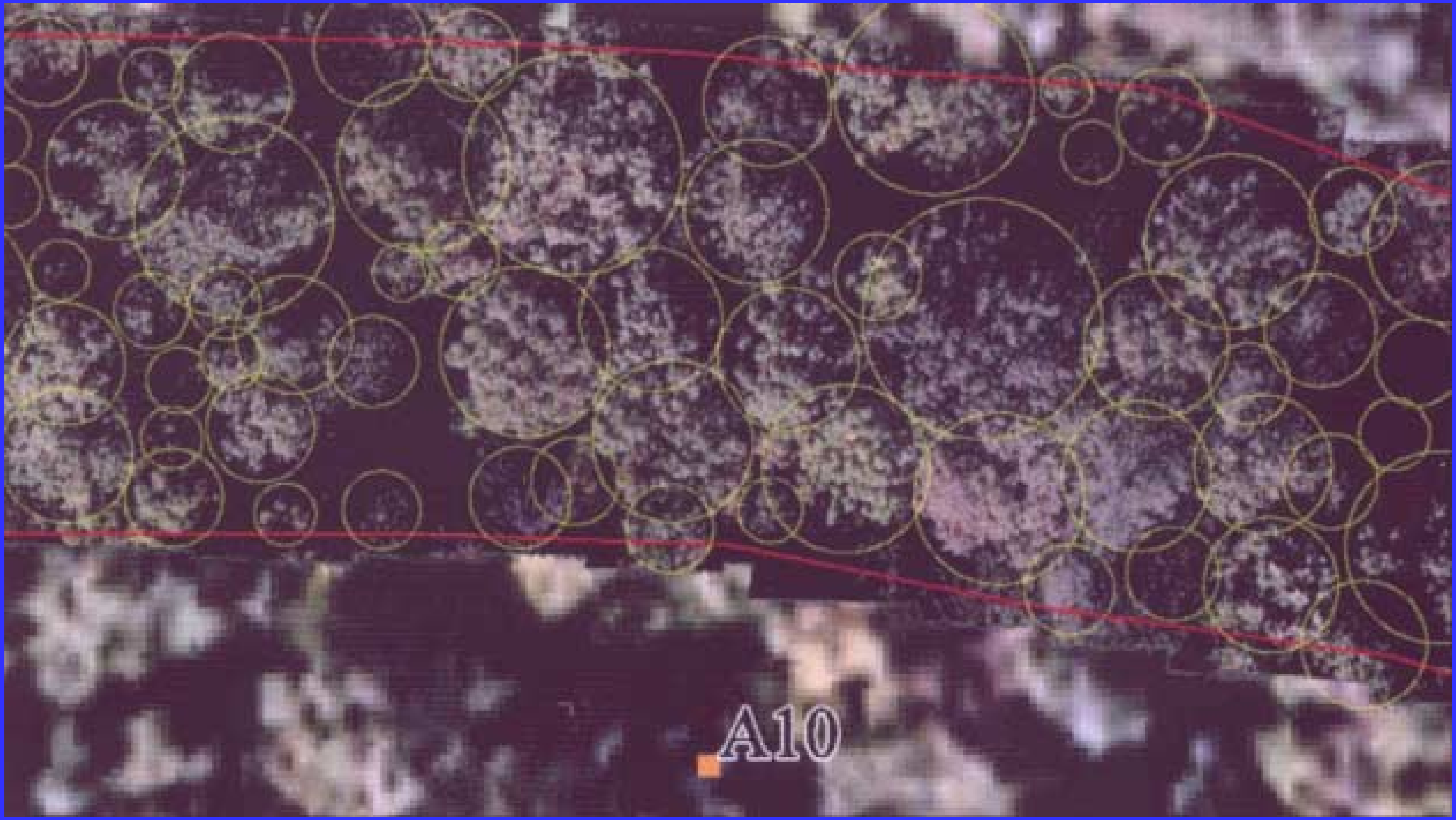


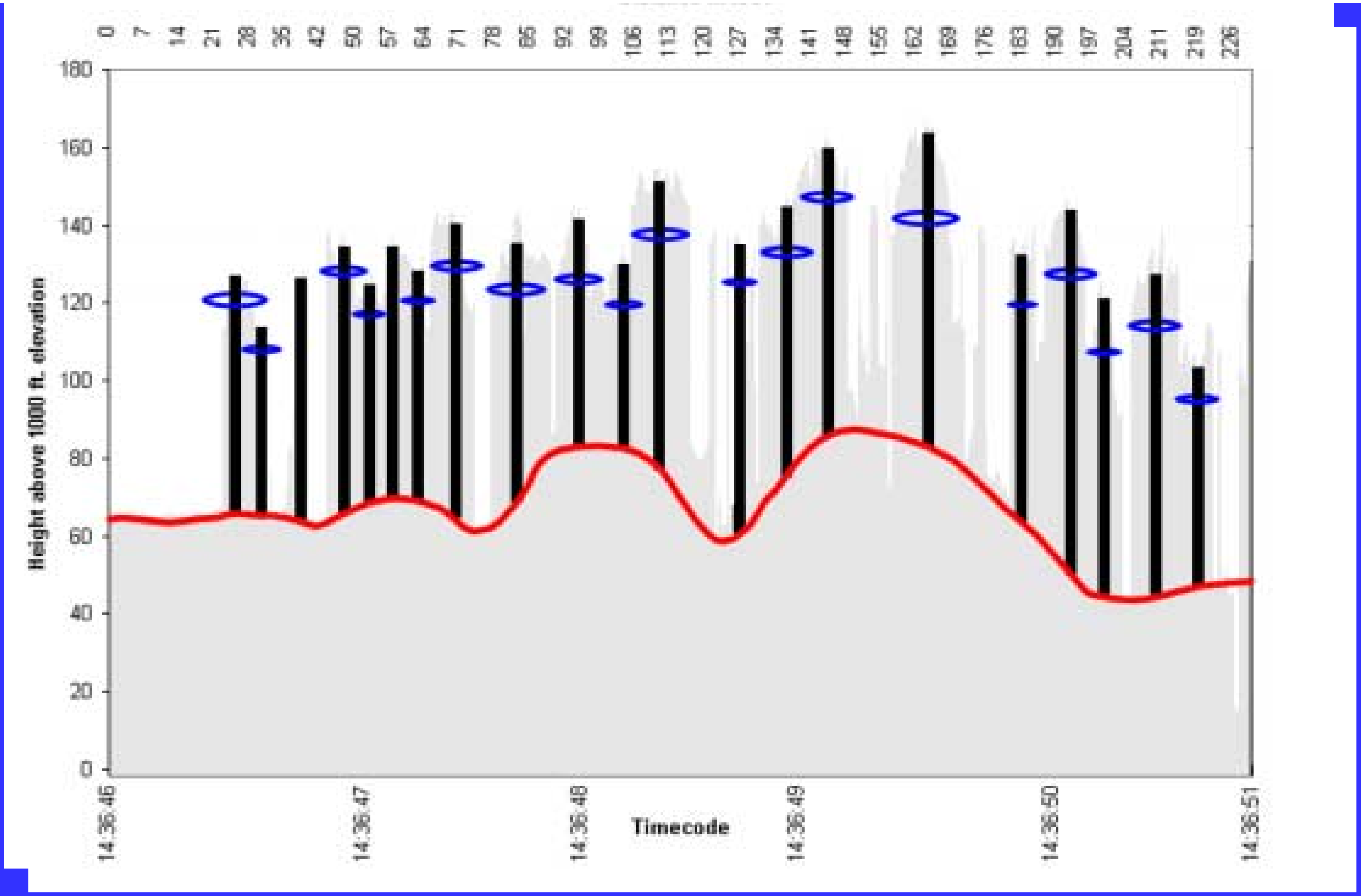


Dana Slaymaker, 1999

Dual Camera Videography

Identify crowns and measure their diameter and area





Data are used from the 3D reconstruction and the laser profiles to create a simple forest model of number, height, and crown diameter of trees that can be used with allometric regression equations to estimate biomass of the forest.

Preliminary results of carbon measurements from videography

- For the mixed liana forest strata in the Noel Kempff project:
  - from ground plots—carbon in trees is 89.6 t/ha, 95% confidence interval of 8.7% of the mean
  - from videography plots—carbon in trees is 87.7 t/ha, 95% confidence interval of 7.3% of the mean