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Use of LiDAR in Forest Carbon Assessment for REDD*

TREEMAPS

Capacity building for REDD readiness

*** Reduced Emissions from Deforestation and Degradation**

Why Forest Carbon?

- Increasing concentrations of greenhouse gases due to human activities have been linked to the global climate change
- The Intergovernmental Panel on Climate Change (IPCC) estimates that 18% global greenhouse gas emissions are from deforestation
- Deforestation also leads to loss of biological diversity and ecosystem services
- The remaining biologically rich forest ecosystems are under further pressure because they are surrounded by world's poorest people who depend on forest resources
- Emerging carbon markets provide a new opportunity to break the cycle of poverty and forest degradation

Forest Carbon Opportunities

- In 2007, the UNFCCC proposed payments for reducing emissions from deforestation and forest degradation (REDD) in developing countries
- REDD provides opportunity to address climate change, ecosystem services and income for local communities
- To successfully market carbon following issues must be addressed
  - Additionality: REDD projects must make a real reduction in CO_2 emission
  - Leakage: emission reductions from REDD project must not result in unintentional loss of net carbon elsewhere
  - Permanence: emission reductions from REDD projects are not subsequently lost due to human activities or natural disturbance

Guidelines for Estimating Emissions

The IPCC guidelines provide three tiers for estimating emissions

- Tier 1 uses default emission factors (indirect estimation of the emissions based on canopy cover reduction) for forest activities ('activity data') that are collected nationally or globally
- Tier 2 applies emission factors and activity data from country-specific data
- Tier 3 uses methods, models and inventory measurement systems that are repeated over time, driven by high-resolution activity data and disaggregated sub-nationally at a finer scale.
- New technologies such as LiDAR are focusing at the Tier 3 level

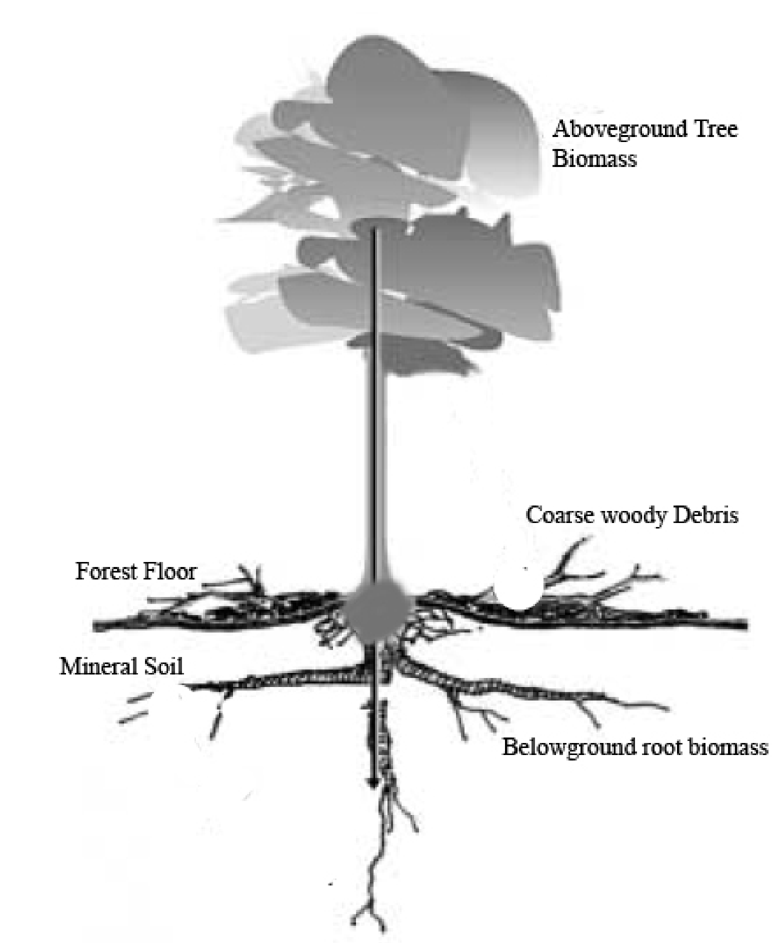
Forest Carbon Pools

- Above ground tree biomass
- Below ground root biomass
- Coarse woody debris biomass
- Soil organic carbon

BIOMASS is defined as the total amount of living organic matter in trees expressed as oven-dry tons per unit area

CARBON is calculated as ~ 48% of BIOMASS (Dry weight)

Above ground biomass accounts for 90% of forest biomass



REDD Process

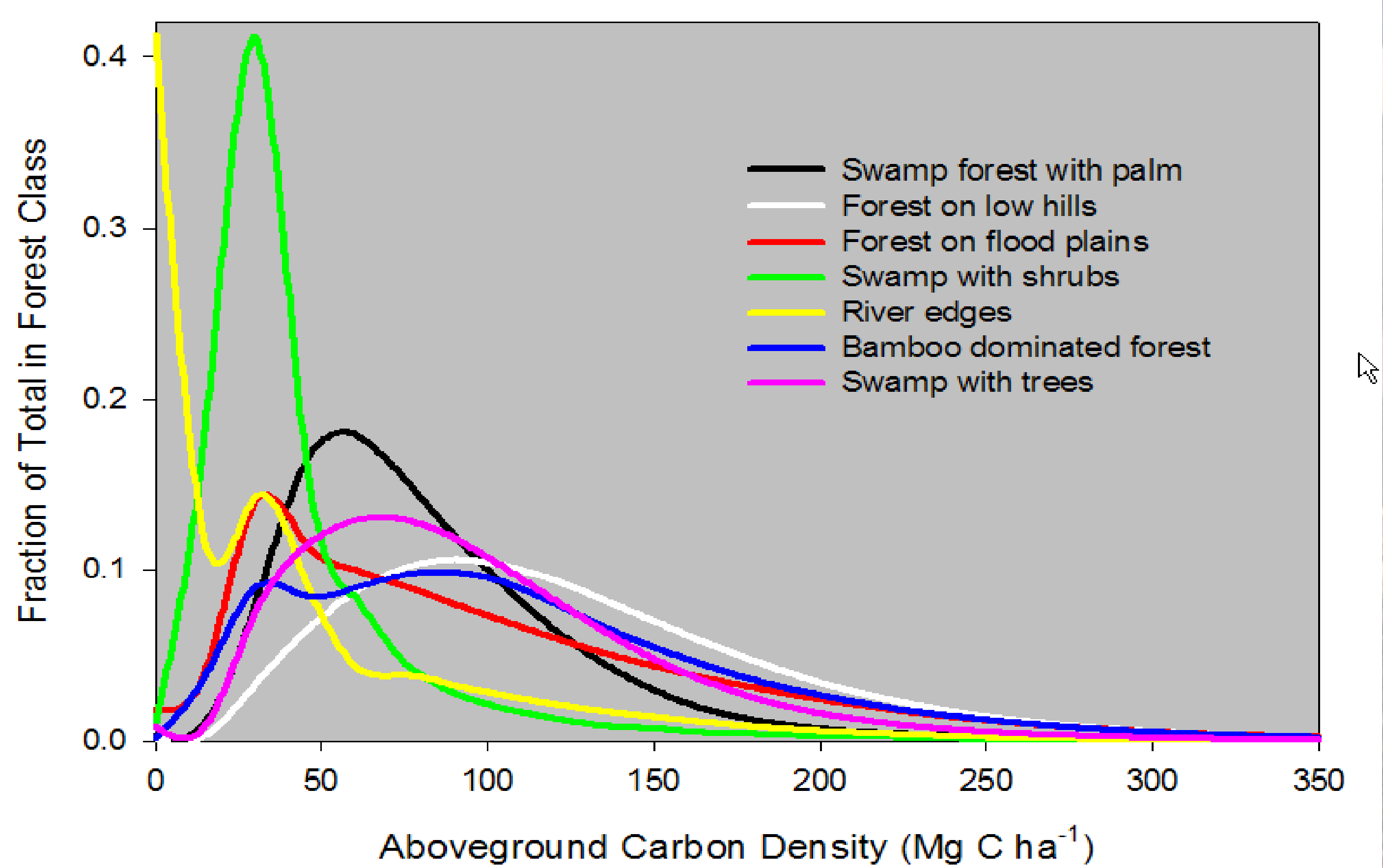
Measuring Reference Levels & Compliance

- How much carbon is stored in the forest?
- How much have the carbon stocks changed over the past 10 years? (Reference Emission Levels)
- How to monitor Additionality – difference between a ‘business as usual’ scenario and a “reduced emissions scenario”

TREEMAPS

How much carbon is **stored** in the forest?

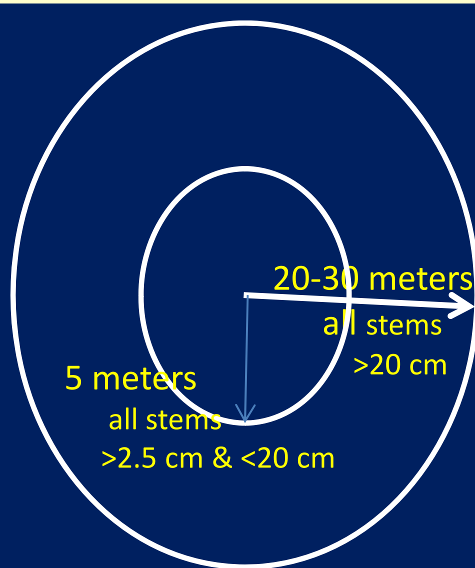
Carbon stored in different forest habitat types can be highly variable making it challenging to quantify carbon for REDD



MAPS

Quantifying carbon requires measuring vegetation in the field

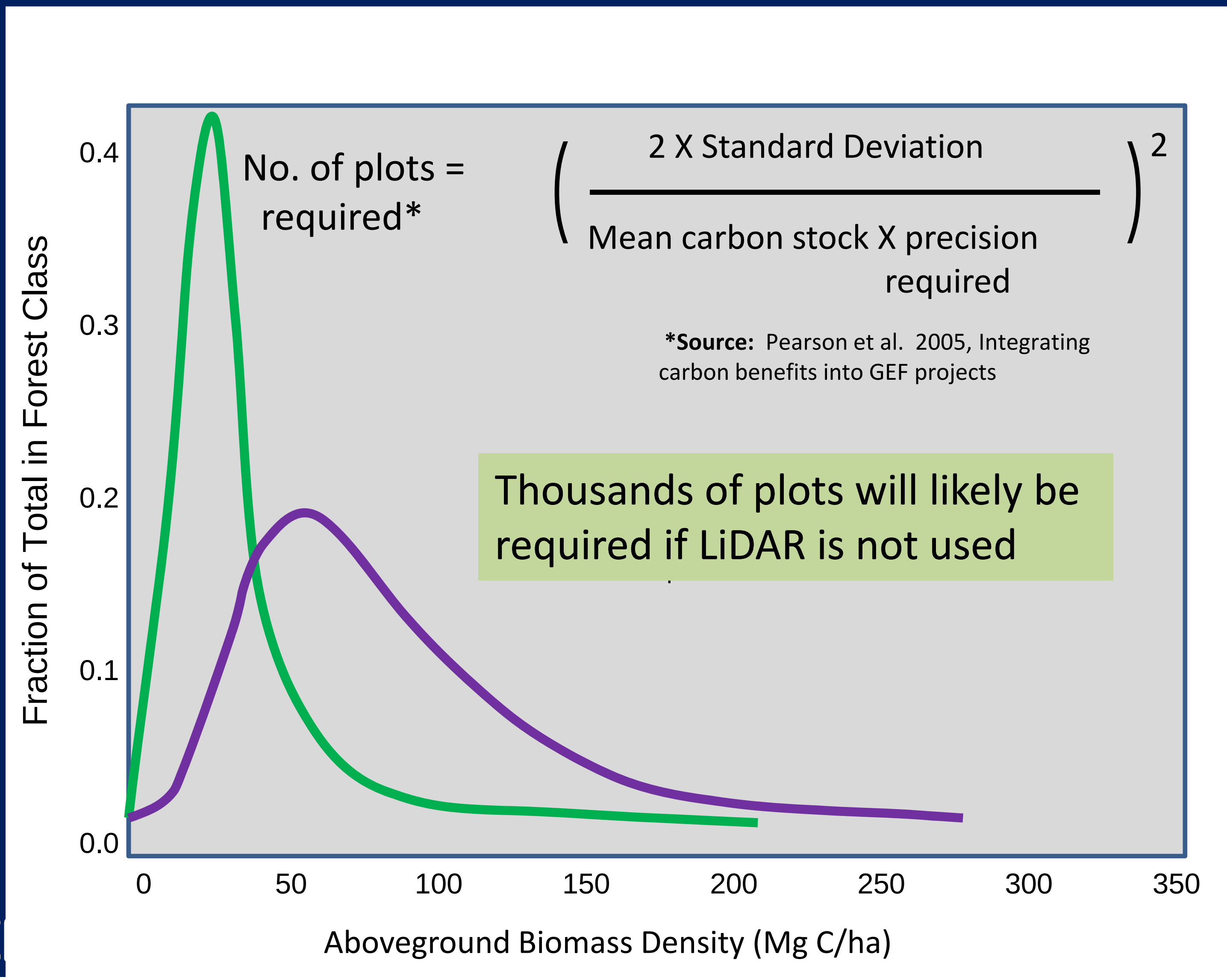
But how many are required?
How can LiDAR help?



Measure diameter (DBH) and height
Use allometric equations to calculate above ground biomass

How much carbon is stored in the forest?

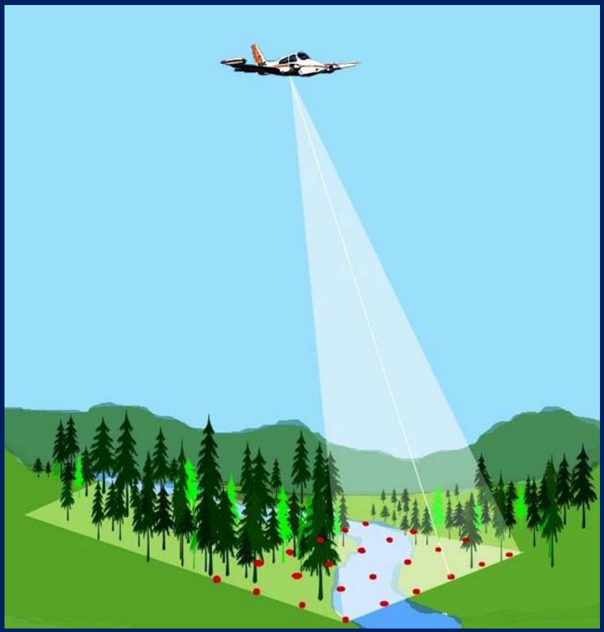
Many plots are necessary to accurately quantify carbon



How can LiDAR Help?

What is LiDAR?

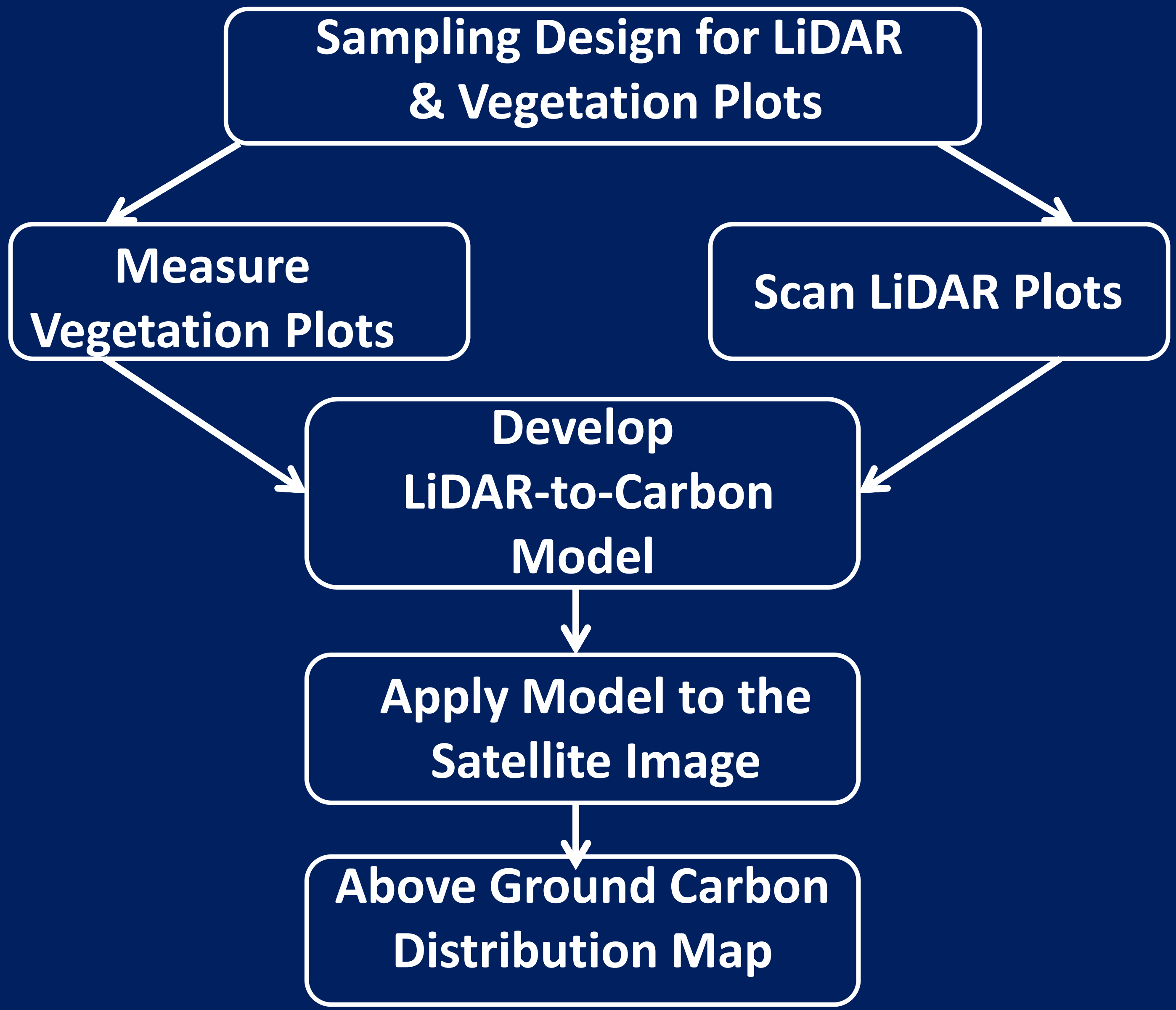
- LiDAR stands for Light Detection And Ranging
- Measures scattered light to find range on a distant target using light pulse
- The range to an object is determined by measuring the time delay between transmission of a pulse and detection of a reflected signal



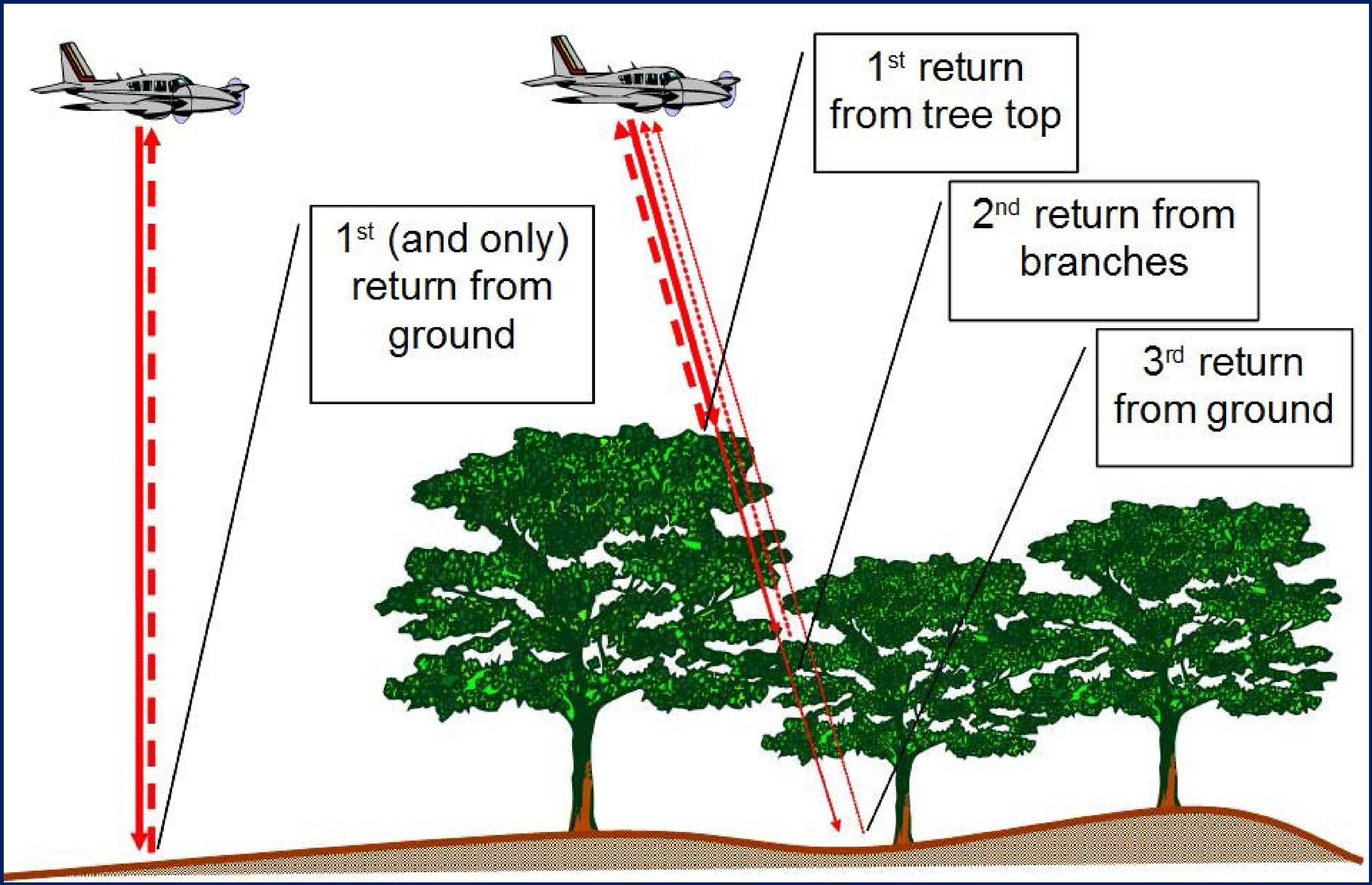
Use of LiDAR in Forestry

- A wide range of information can be directly obtained from LiDAR including
  - Digital elevation models
  - Tree heights and digital surface models
  - Crown cover
  - Forest structure
  - Crown canopy profile

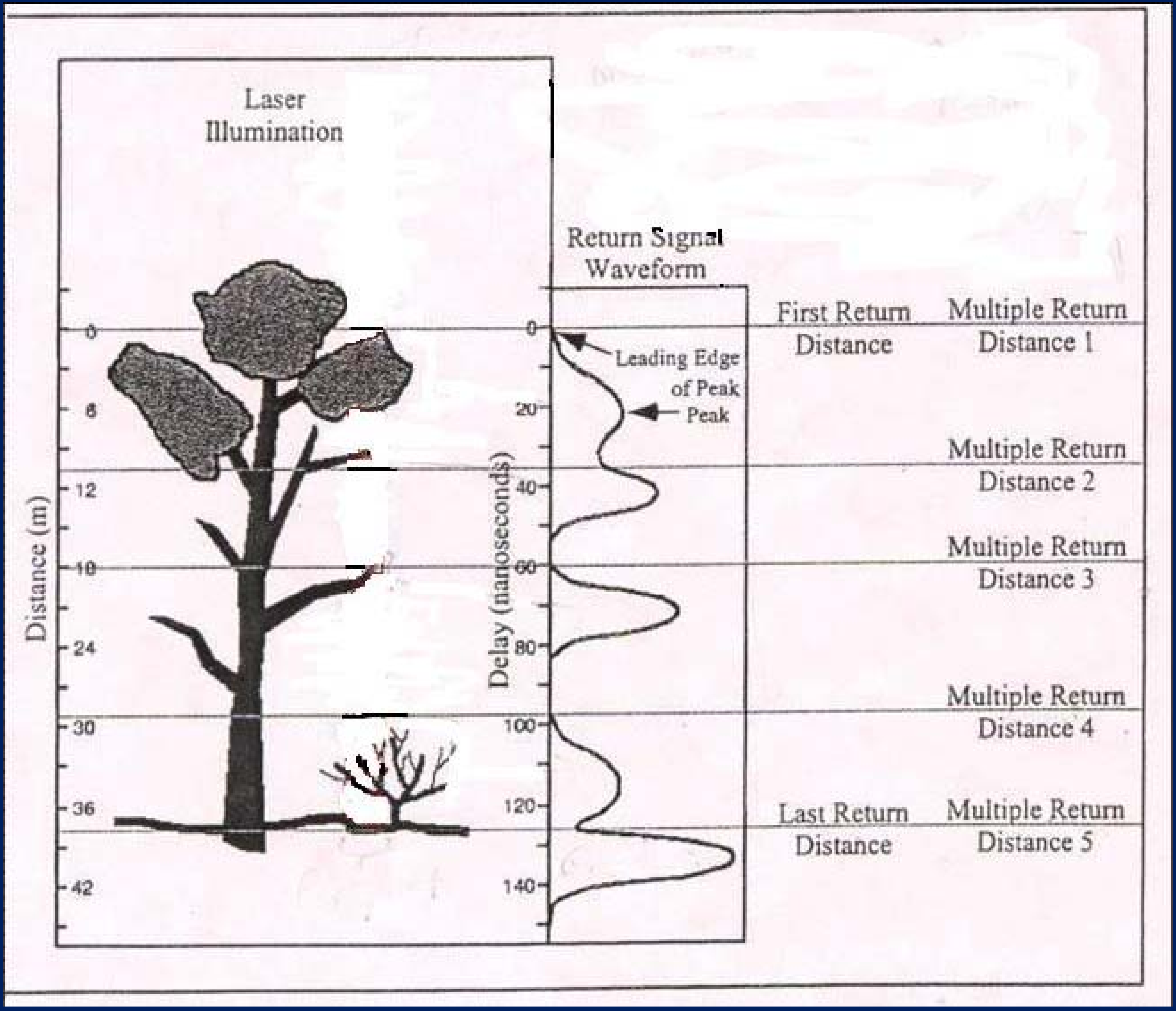
LiDAR Process to Derive Carbon



LiDAR Scanning

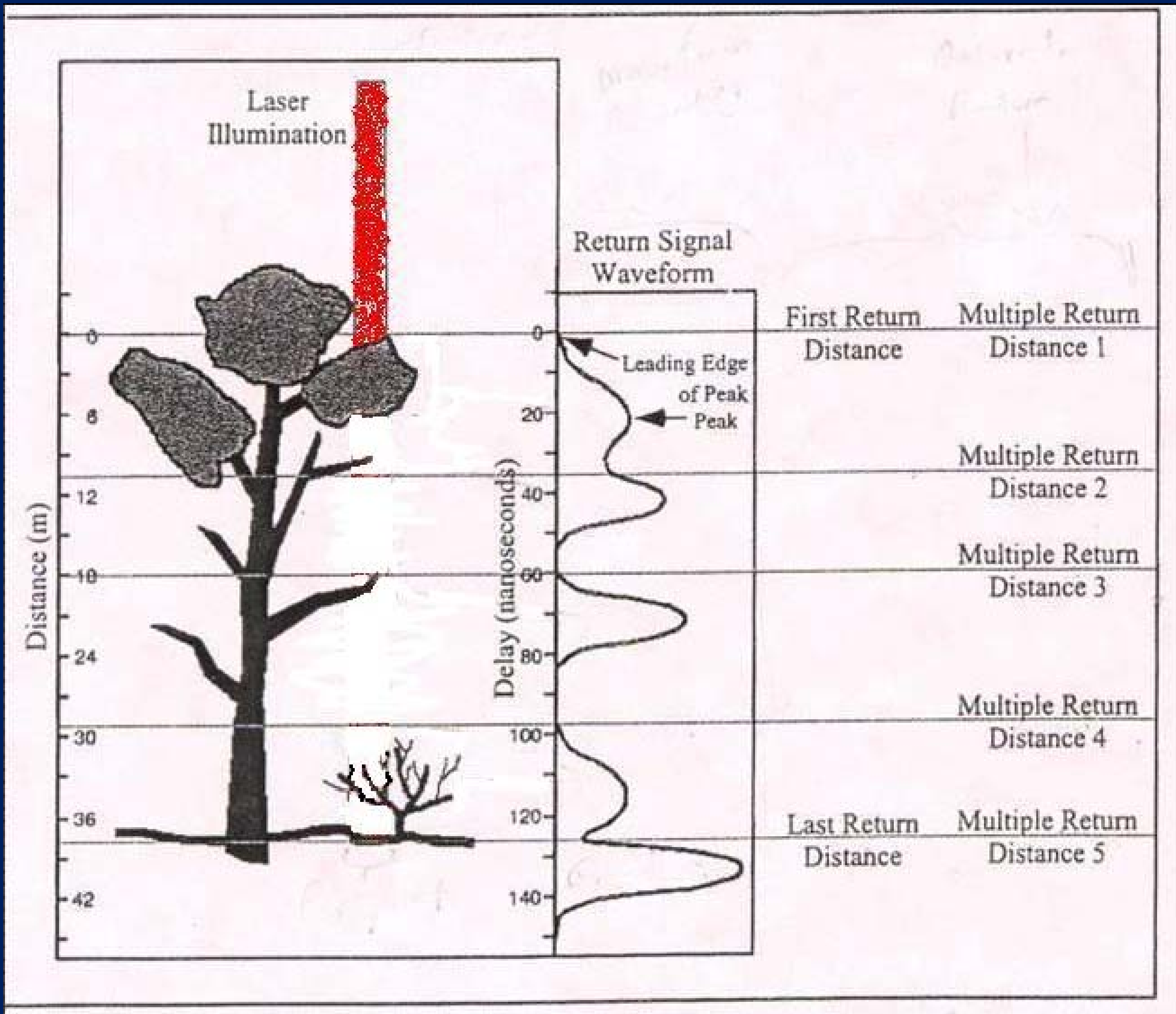


LiDAR (Single Pulse, Multiple Returns)



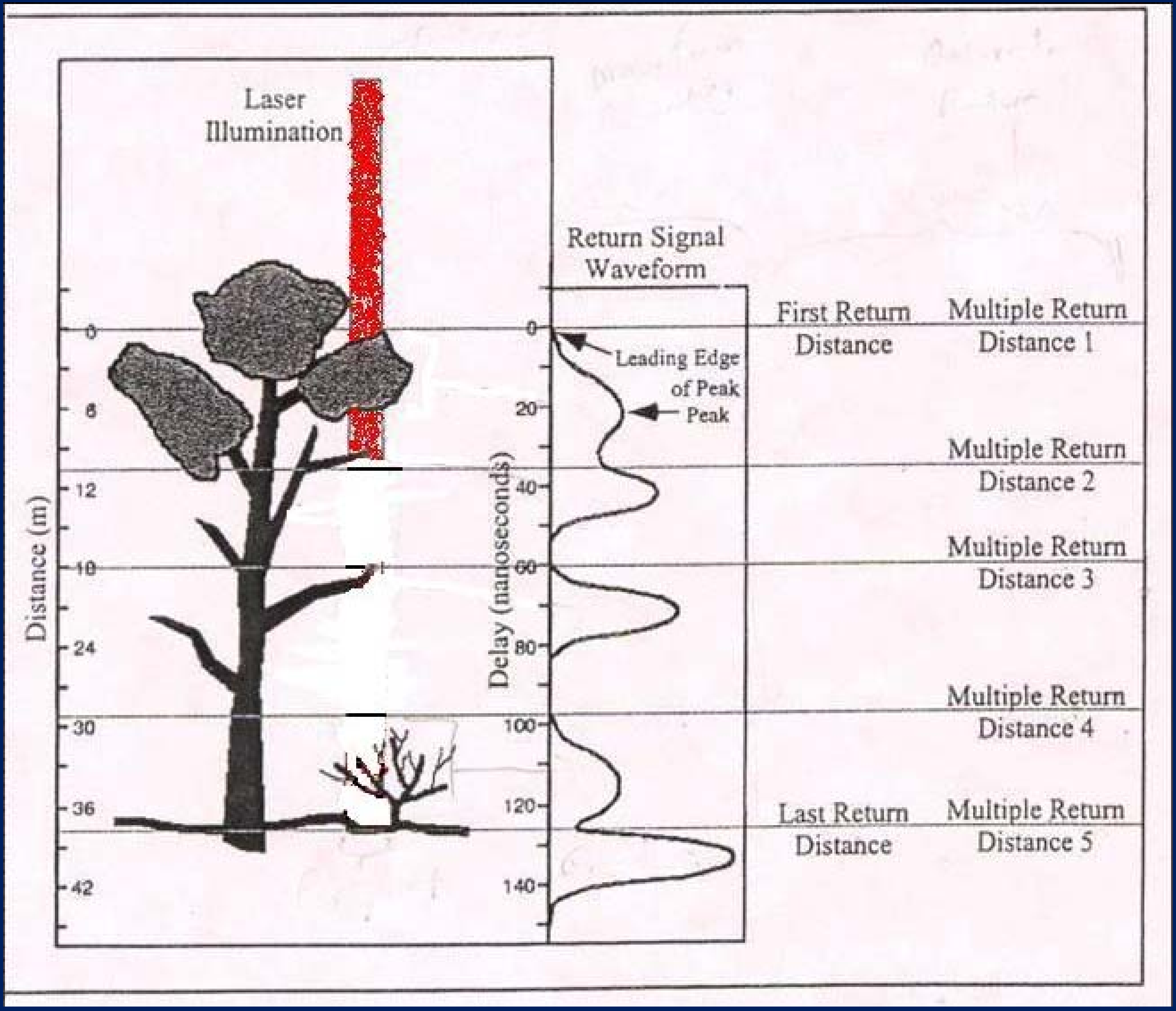
Source: Modified from Lefsky et al. 2002

LiDAR (Single Pulse, Multiple Returns)



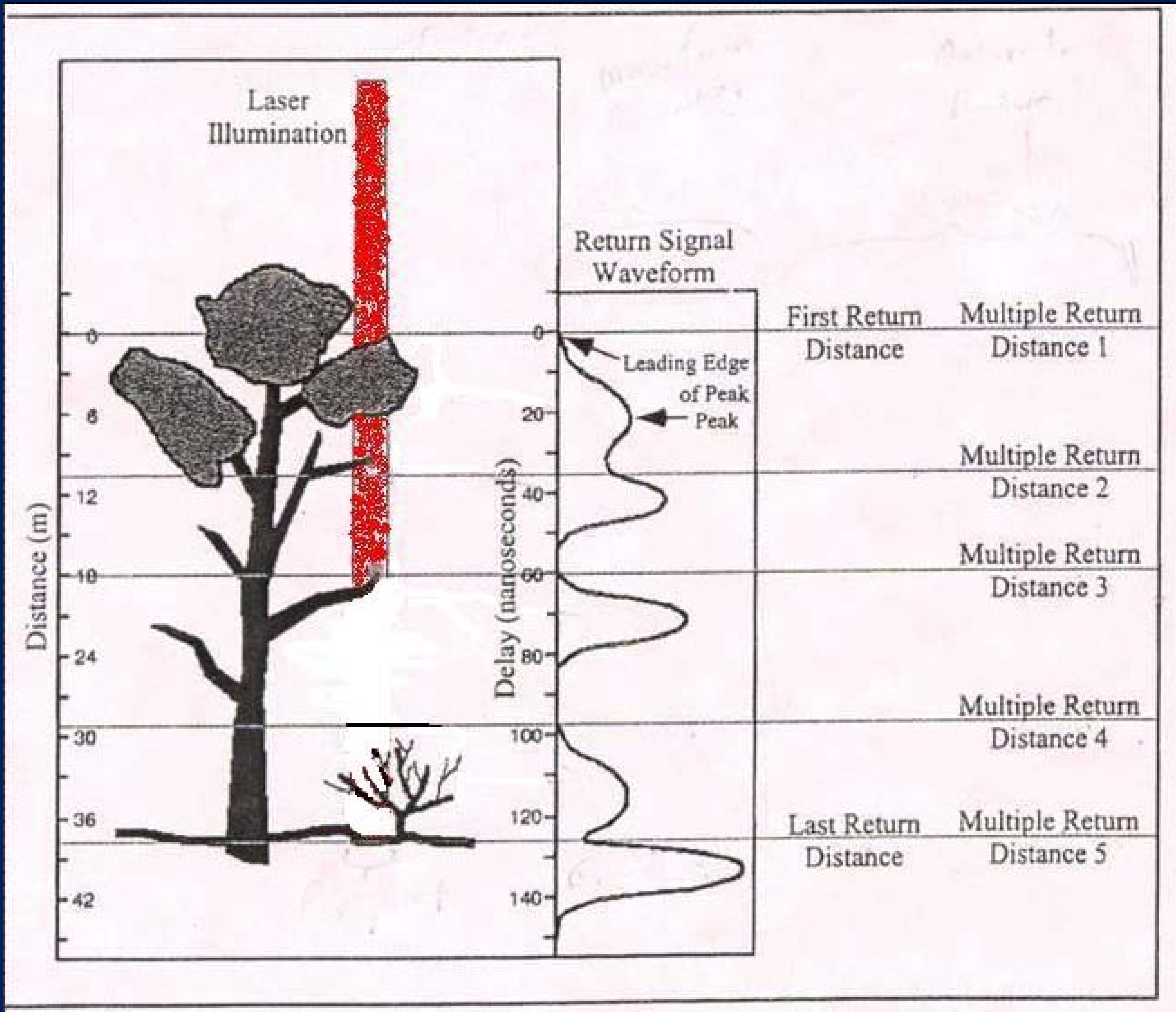
Source: Modified from Lefsky et al. 2002

LiDAR (Single Pulse, Multiple Returns)



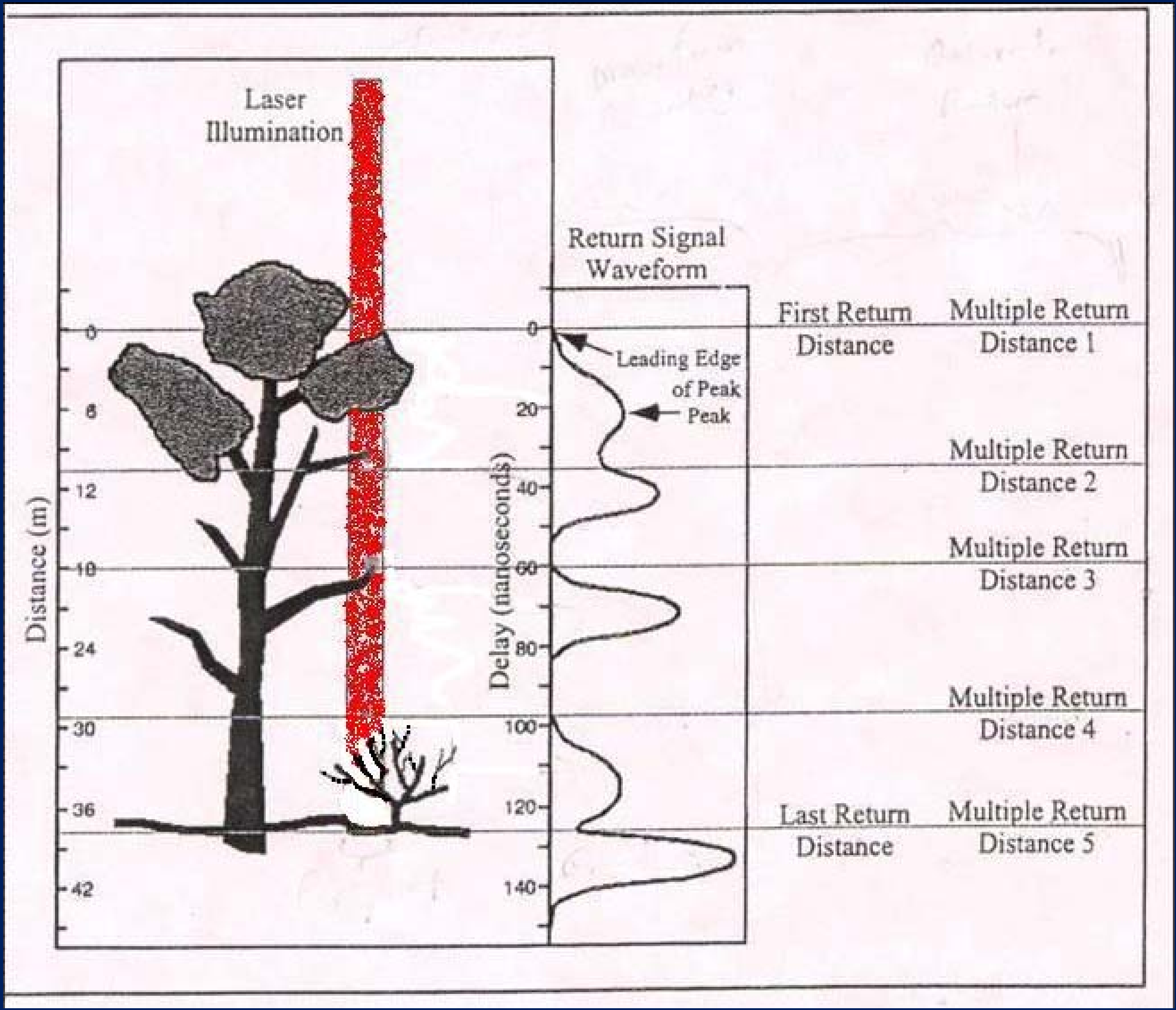
Source: Modified from Lefsky et al. 2002

LiDAR (Single Pulse, Multiple Returns)



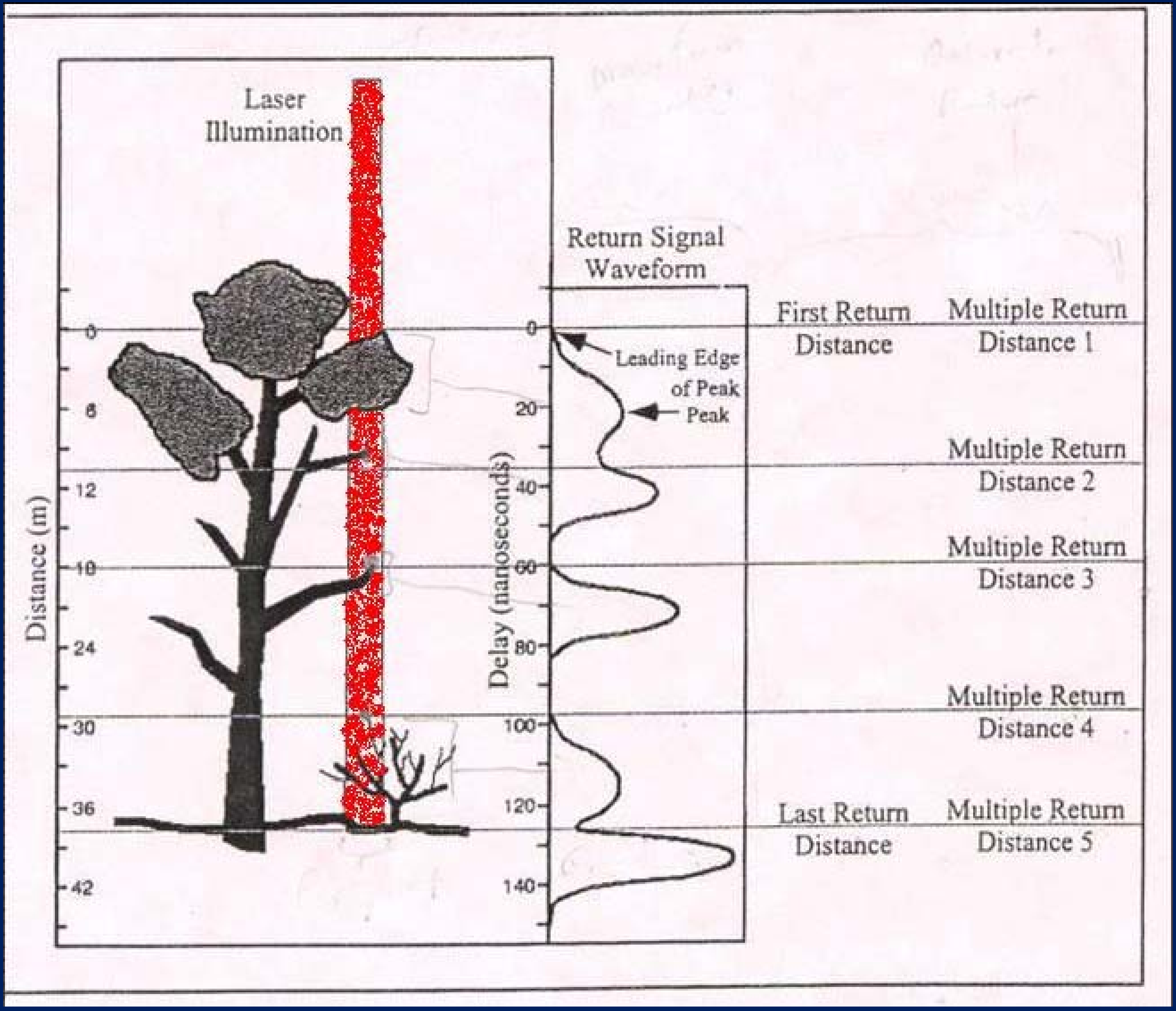
Source: Modified from Lefsky et al. 2002

LiDAR (Single Pulse, Multiple Returns)



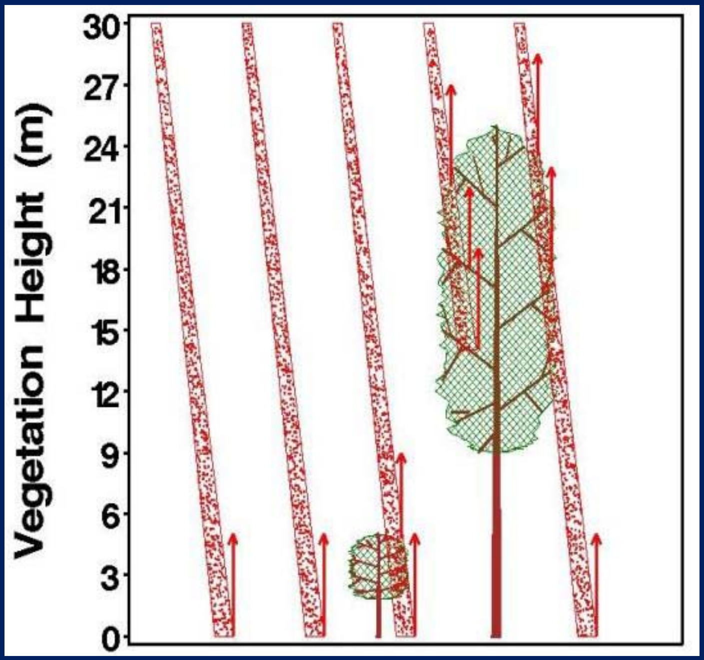
Source: Modified from Lefsky et al. 2002

LiDAR (Single Pulse, Multiple Returns)



Source: Modified from Lefsky et al. 2002

Multiple Returns



Raw Deliverable Data

Pulse	Easting (X)	Northing (Y)	Elevation (Z)	Intensity	Return
1	548099.93	4981996.19	110.36	64.5	1
1	548276.81	4981998.93	106.82	192.3	2
1	548332.65	4981997.5	106.21	141.4	3
2	548304.22	4981997.11	108.14	38.9	1
3	548172.52	4981994.87	110.06	141.1	1
3	547963.93	4981991.26	111.8	125.5	2
4	548248.6	4981994.46	108.14	6.53	1
5	548325.1	4981995.57	106.93	2.69	1
6	548315.38	4981993.11	107.2	1.67	1
6	548275.6	4981992.42	106.78	116.3	2
6	548172.16	4981989.92	119.86	107.9	3
7	548184.86	4981989.56	110.57	57.3	1
7	548091.08	4981984.67	119.27	167.1	2
8	548333.64	4981987.11	106.44	191.8	1
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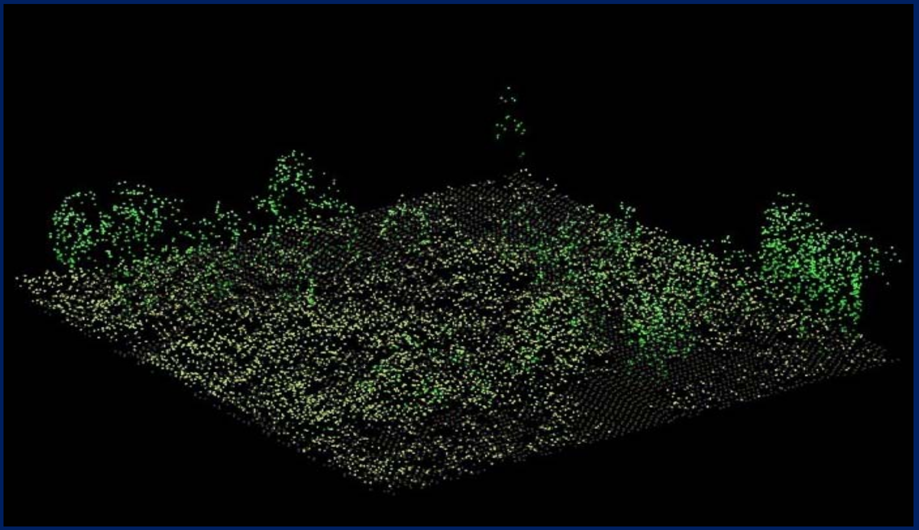
.	.	.	.	.	.

3D XYZ Point-Cloud

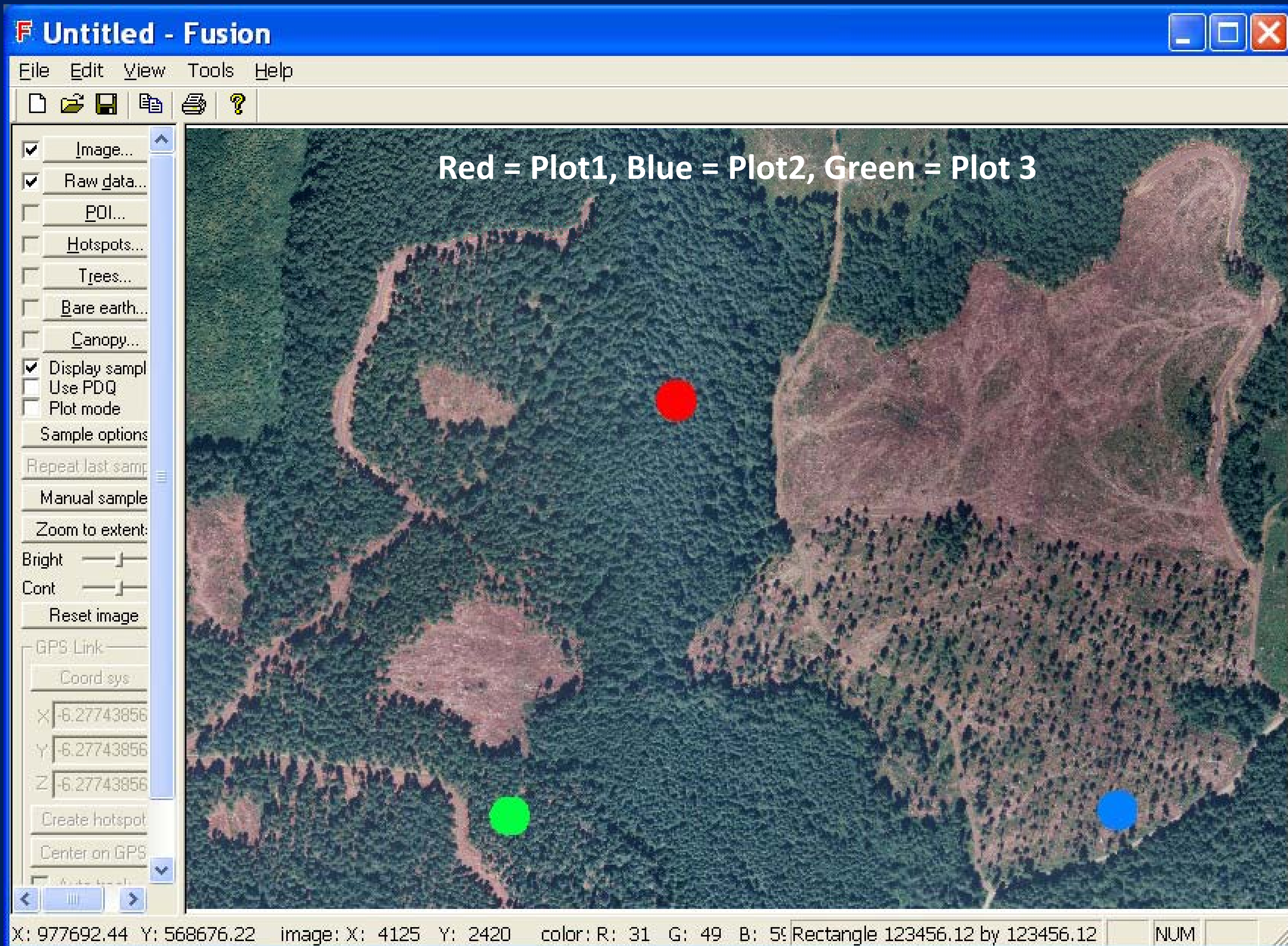


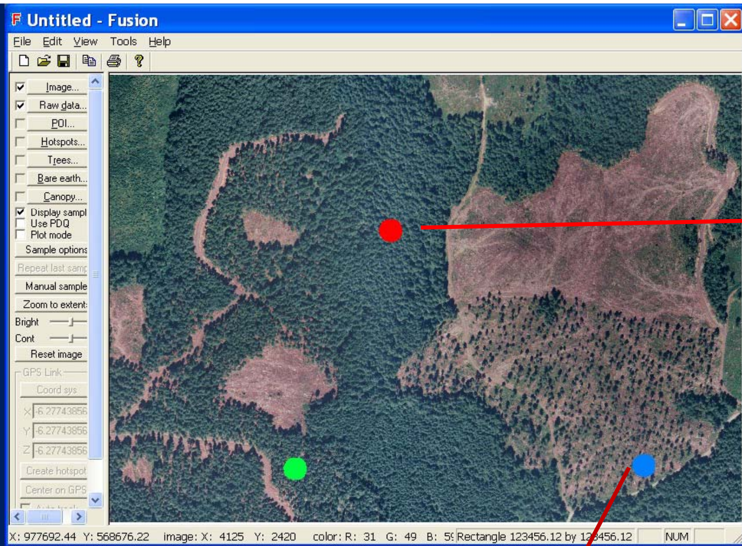
Classification Value Description for LiDAR returns

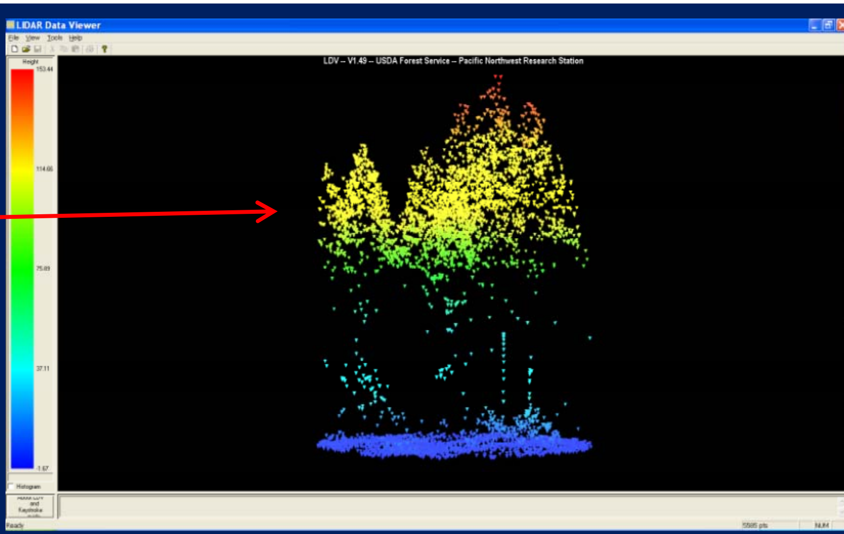
0	Created (never classified)
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key Point (mass point)
9	Water

Viewing Raw LiDAR data

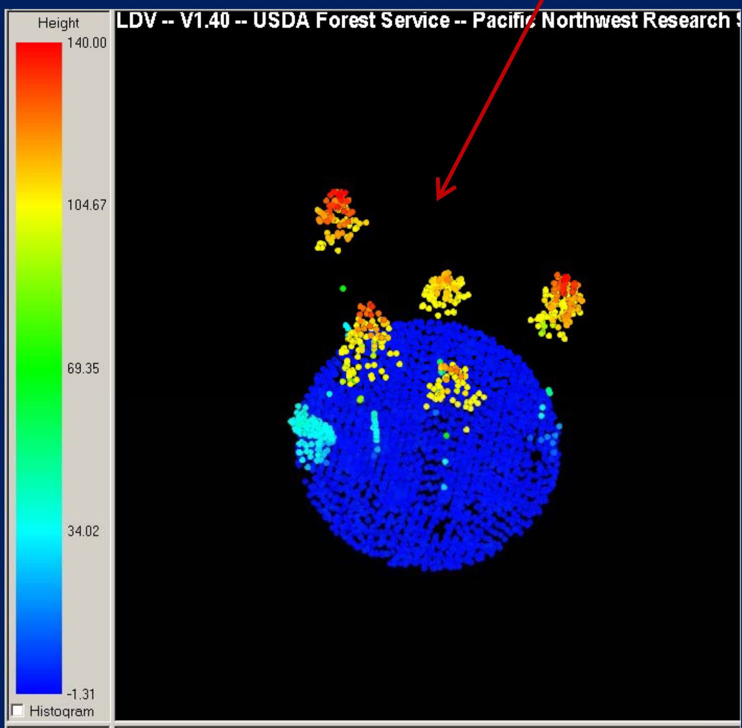
- Several Open Source and Proprietary software available to view LiDAR data
- Use Fussion Software from USDA to view raw LiDAR data (Point cloud) - Free
- LAStools – Free and License
- LP360 – add-on to ARC GIS - License

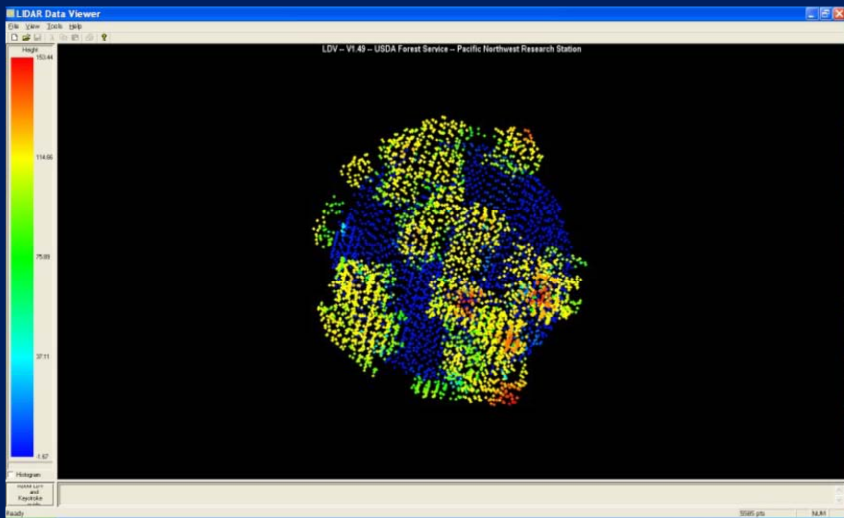

Untitled - Fusion
File Edit View Tools Help
Image...
Raw data...
POI...
Hotspots...
Trees...
Bare earth...
Canopy...
Display sampl
Use PDQ
Plot mode
Sample options
Repeat last samp
Manual sample
Zoom to extent
Bright
Cont
Reset image
GPS Link
Coord sys
X -6.27743856
Y -6.27743856
Z -6.27743856
Create hotspot
Center on GPS
Red = Plot1, Blue = Plot2, Green = Plot 3
X: 977692.44 Y: 568676.22 image: X: 4125 Y: 2420 color: R: 31 G: 49 B: 5! Rectangle 123456.12 by 123456.12 NUM



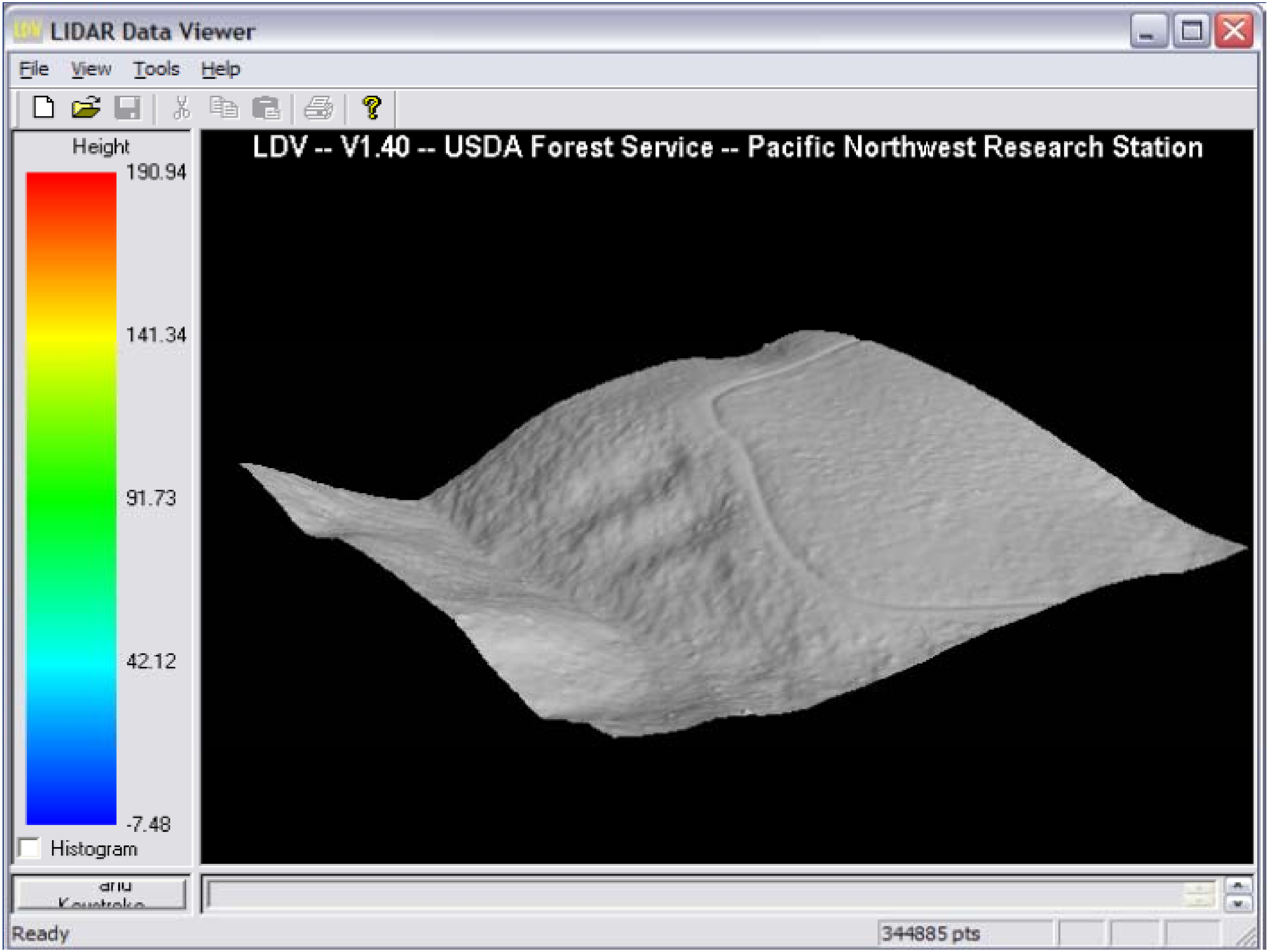


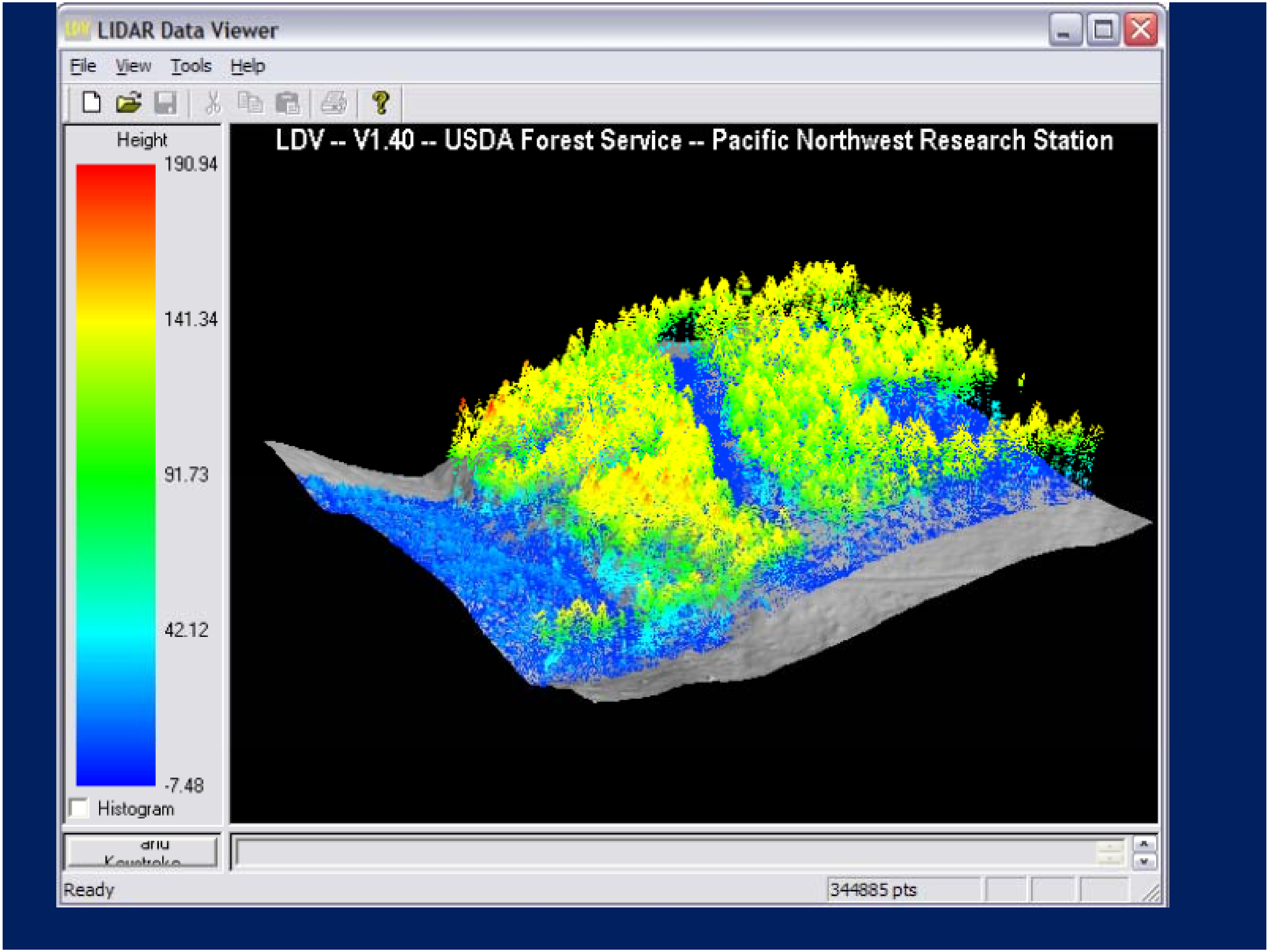
Profile of LiDAR point cloud, based on a plot center and radii





Overhead view of the sample LiDAR point cloud subset


LIDAR Data Viewer
File
View
Tools
Help
Height
190.94
141.34
91.73
42.12
-7.48
Histogram
LDV -- V1.40 -- USDA Forest Service -- Pacific Northwest Research Station
Ready
344885 pts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Height
190.94
141.34
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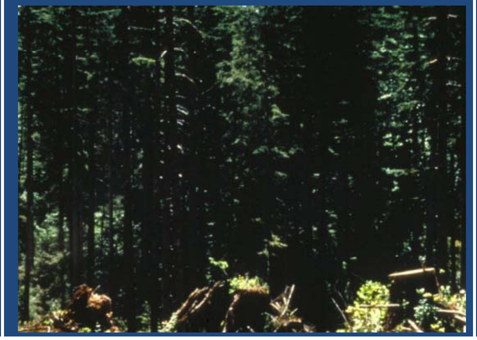
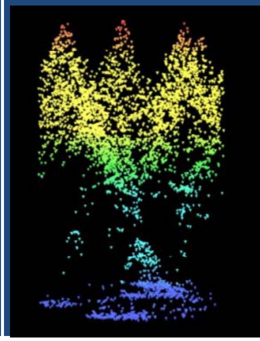
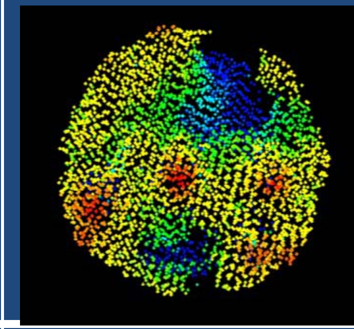
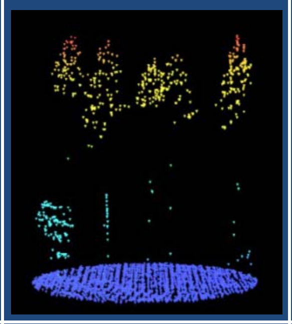
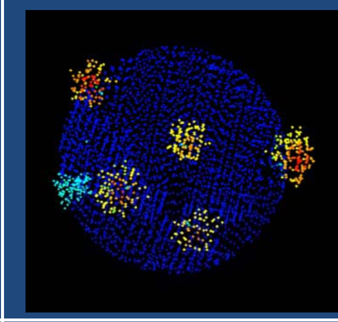
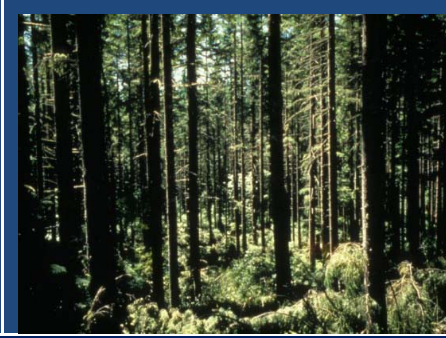
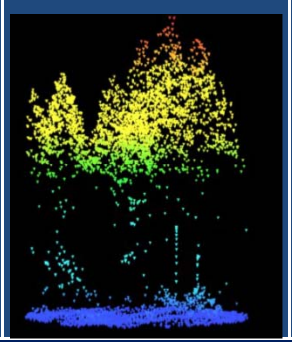
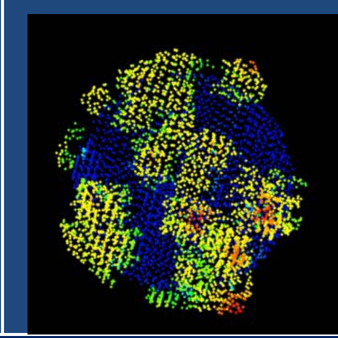
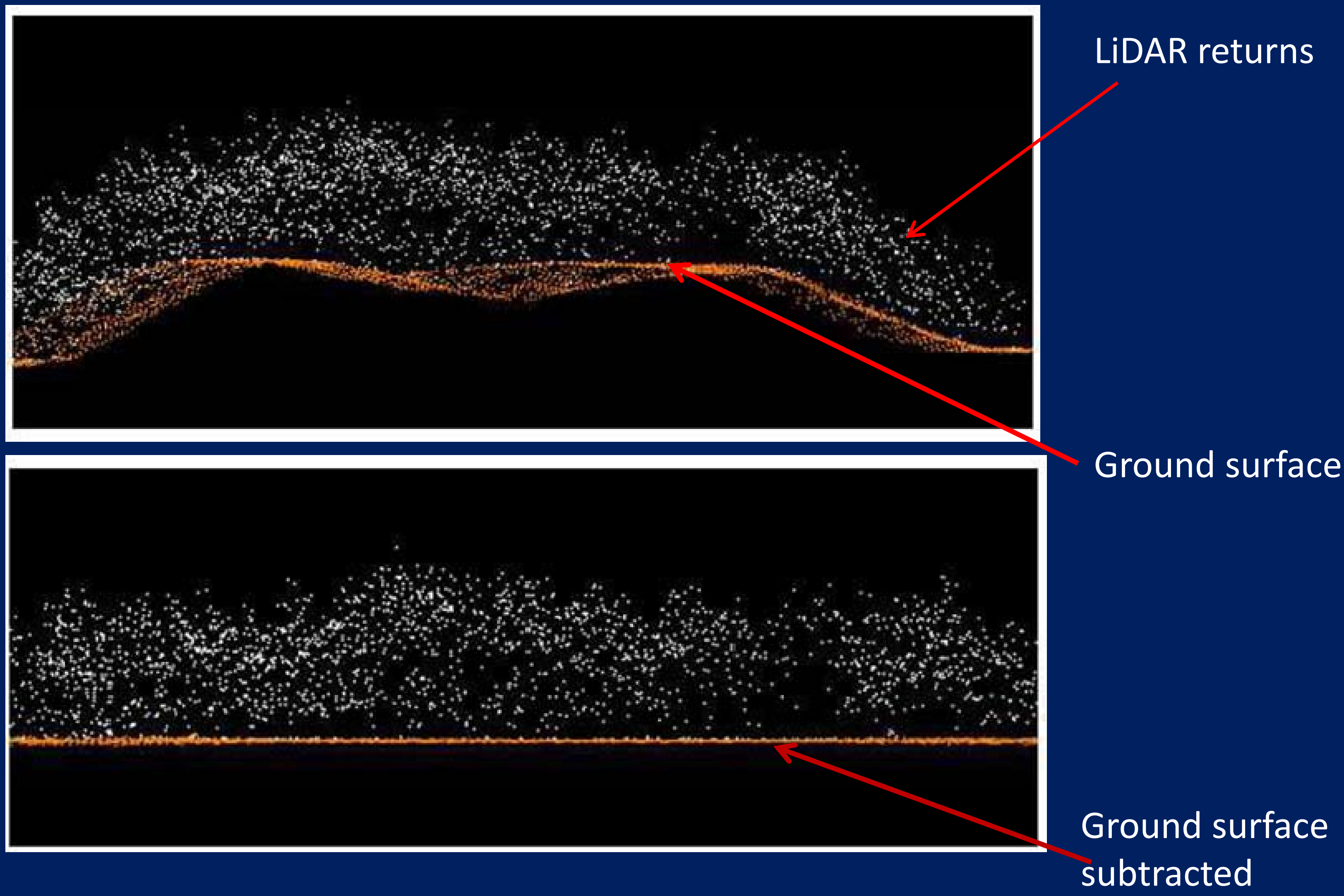
Ready
344885 pts

Plot 1 "Oldgrowth" Control Stand	Site Photo 	Plot 1 Profile 	Plot 1 Overhead View 	Plot 1 Cloud Metrics %Cover = 90 Elev Min = 3 Elev Max = 180 Elev Mean = 115 Elev StdDev = 33
Plot 2 "Heavy Thinning" Stand Treatment	Site Photo 	Plot 2 Profile 	Plot 2 Overhead View 	Plot 2 Cloud Metrics %Cover = 15 Elev Min = 6 Elev Max = 140 Elev Mean = 94 Elev StdDev = 36
Plot 3 "Light Thinning" Stand Treatment	Site Photo 	Plot 3 Profile 	Plot 3 Overhead View 	Plot 3 Cloud Metrics %Cover = 64 Elev Min = 3 Elev Max = 153 Elev Mean = 108 Elev StdDev = 31

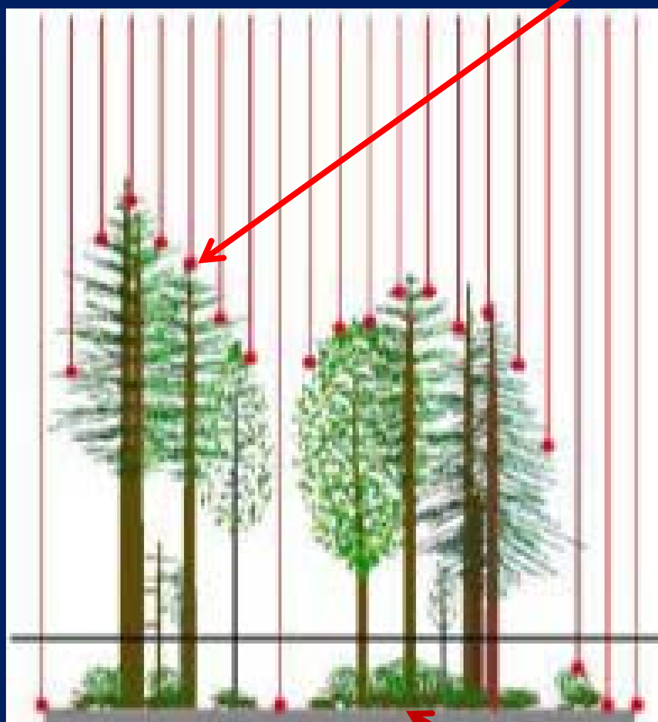
How do we predict Above Ground Biomass (AGB) from LiDAR?

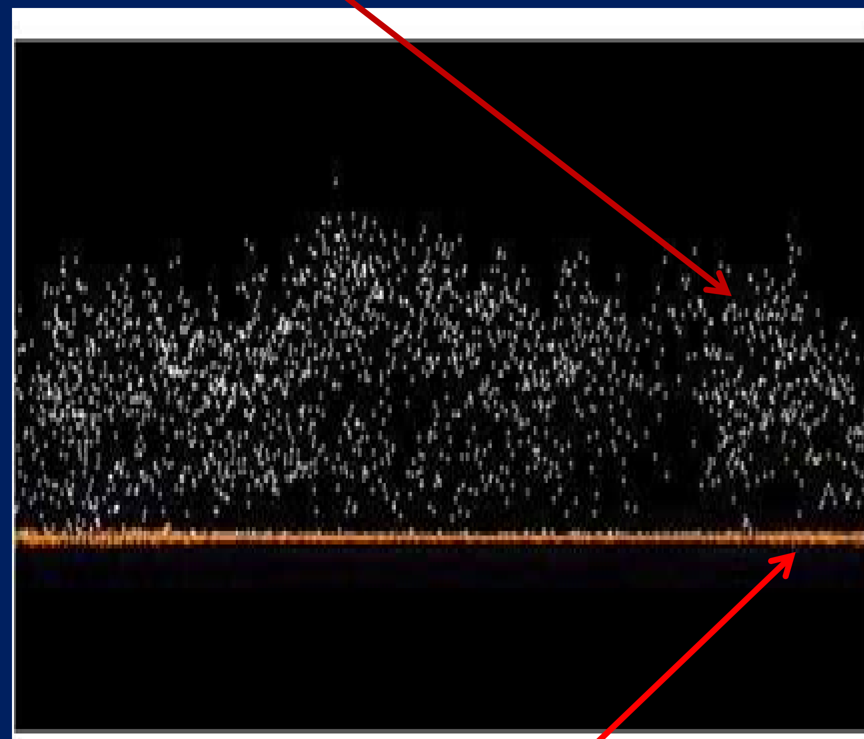
LiDAR Point Cloud



LiDAR Point Cloud

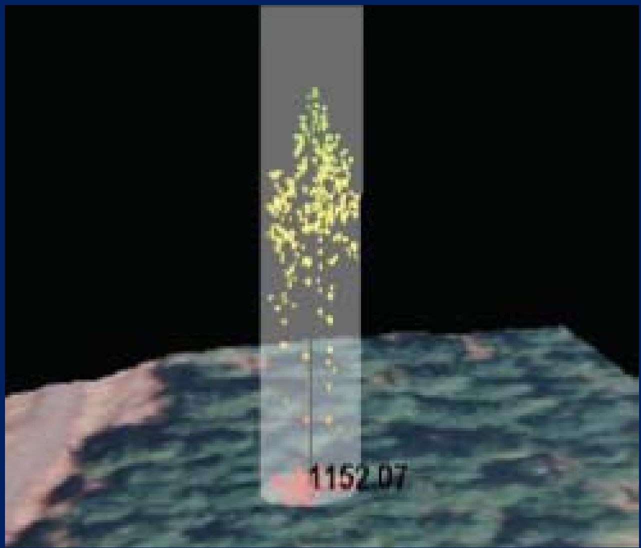
LiDAR returns



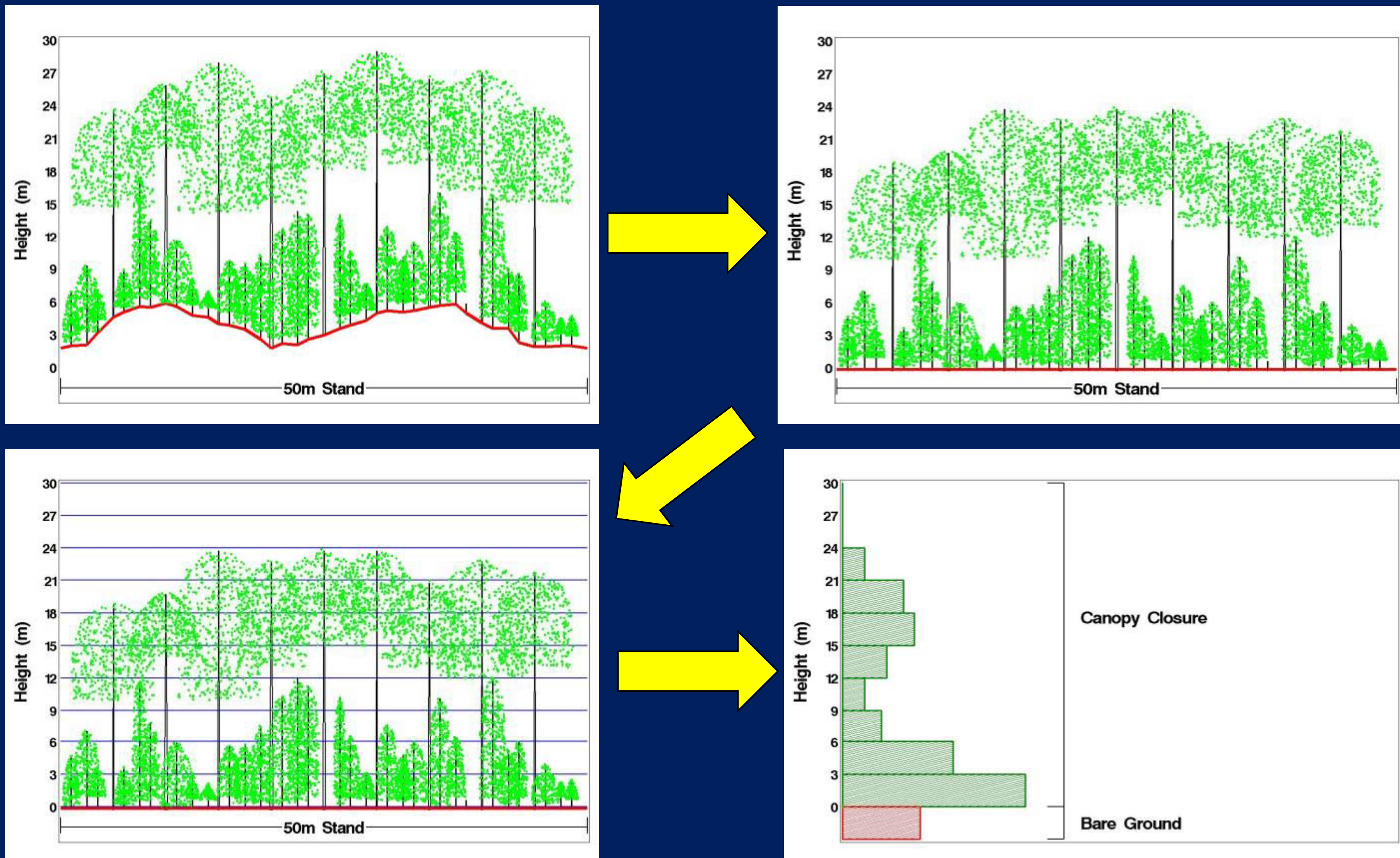


Ground surface

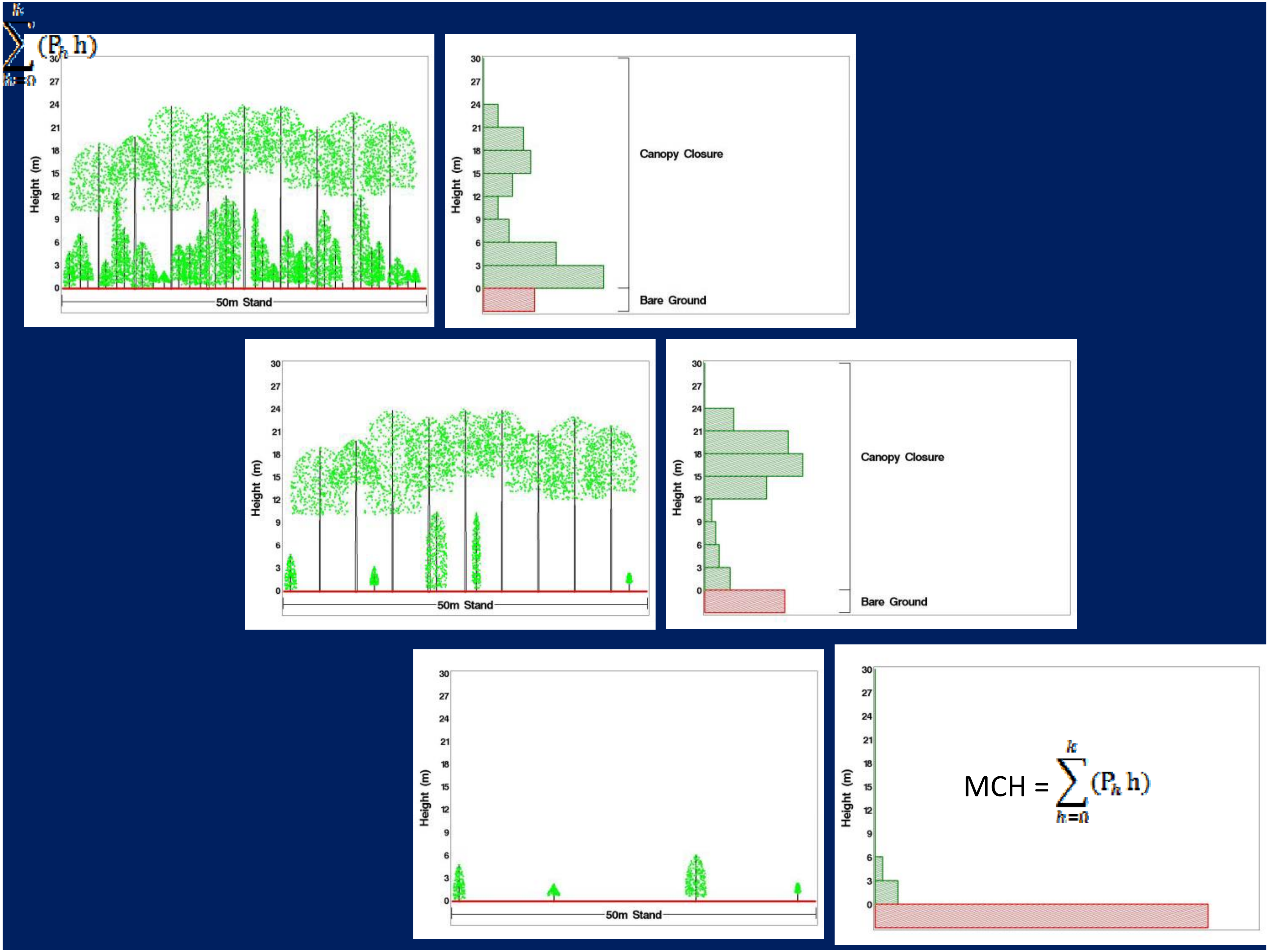
Developing LiDAR-to-Carbon Metrics



- Binning of point cloud
- Bin size = at least 5 times number of pulse returned per m^2
- If there is 1 pulse return per m^2
- Bin size = 5 X 5 m horizontal
- Vertical bin size = 1 m
- Data from bins can be used to model
  - Vertical height profile
  - Canopy crown cover
  - Forest structure
  - Crown canopy profile



Height (m)
30
27
24
21
18
15
12
9
6
3
0
50m Stand
Height (m)
50m Stand
Height (m)
50m Stand
Height (m)
Canopy Closure
Bare Ground



Height (m)
50m Stand
Canopy Closure
Bare Ground
Height (m)
50m Stand
Canopy Closure
Bare Ground
Height (m)
50m Stand
Height (m)
$MCH = \sum_{h=0}^{k} (P_h h)$

LiDAR Data Calibration

- Calibration of LiDAR data with field data is necessary for predicting AGB
- Regression models are used to establish relationship between LiDAR variables and field measured data
- Mean canopy profile height & crown canopy profile are commonly used explanatory variables for modeling AGB
- Above ground Carbon Density (ACD) = AGB x 0.48
- Usually several models are tested for each forest type & a best fit model is selected

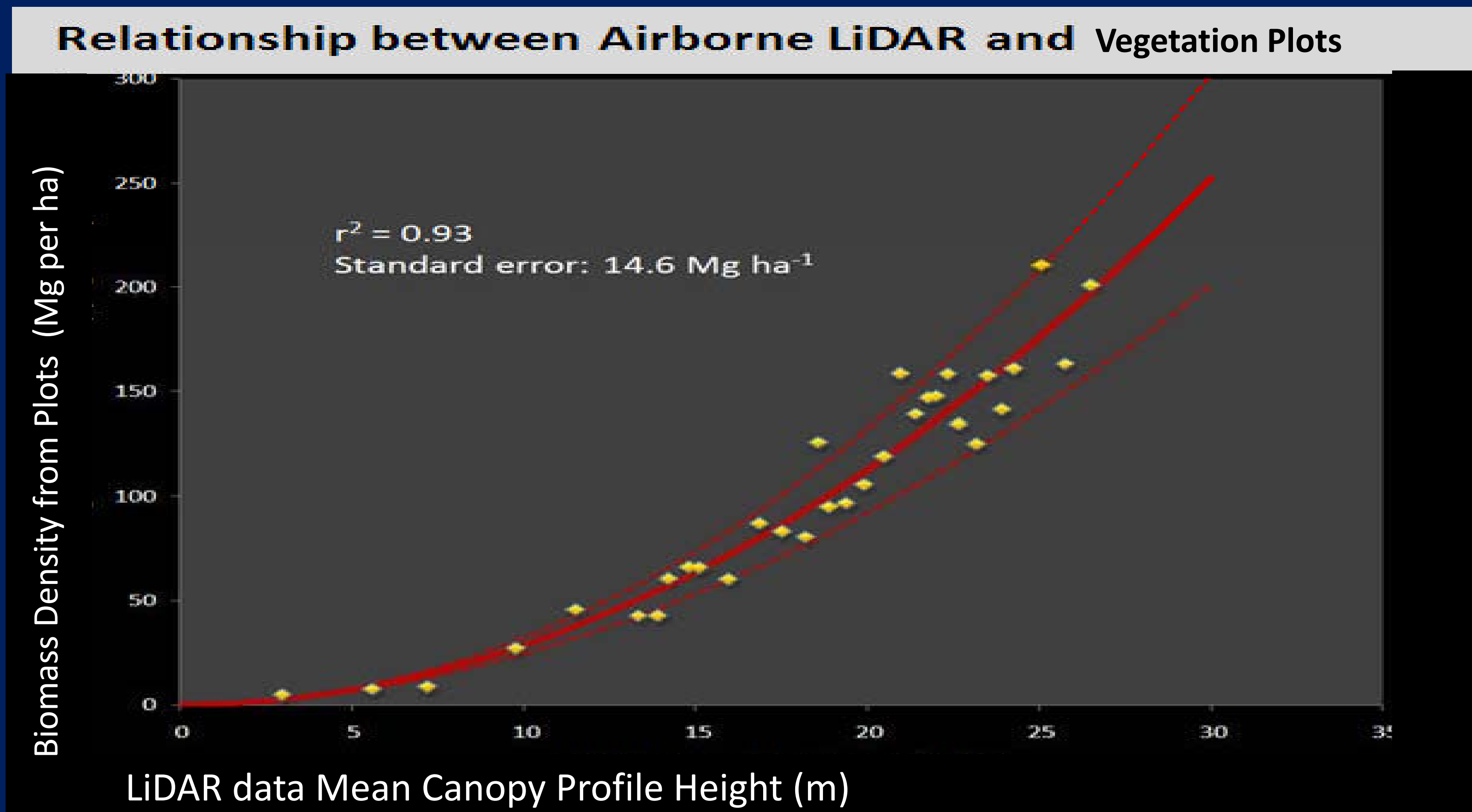
LiDAR to Carbon Model

- Lefsky (2002), Asner (2009) found Mean Canopy profile Height (MCH) to best explain AGB
  - Asner (2009) developed a non-linear regression model

$$AGB = a * MCH^{b}$$

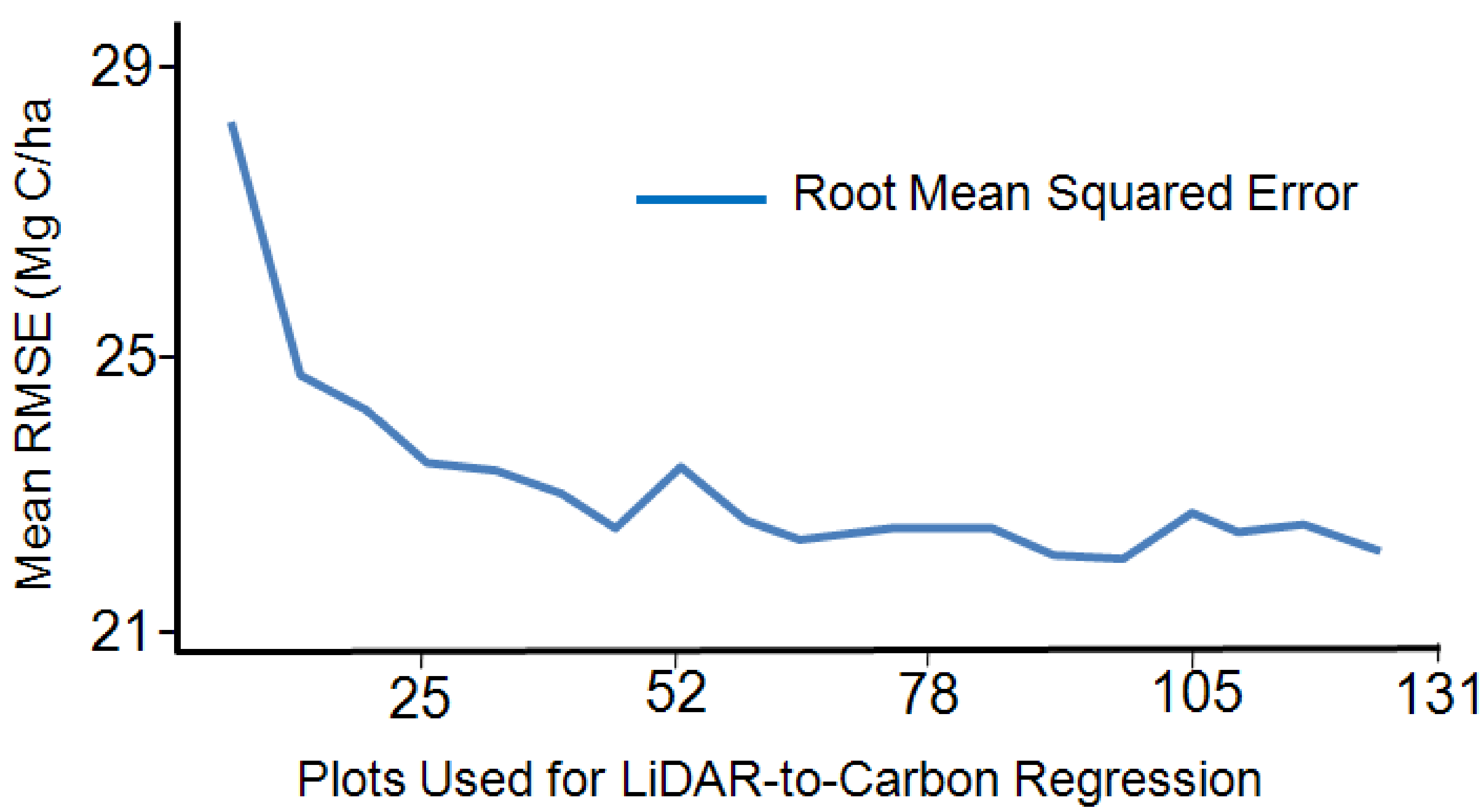
    - MCH = Mean canopy height profile, a & b are coefficients
- Once the best fit model has been chosen and tested, it is good until significant change in vegetation composition occurs
- LiDAR scanning is <u>needed only once</u> to built models
- These models can be used for time series analysis to establish reference levels both historical & future

The close correlation between LiDAR and carbon stocks measured in vegetation plots increases accuracy and allows for a major reduction of the number of plots collected



How many plots are necessary to accurately quantify carbon?

Fewer than 100 plots may need to be collected when LiDAR as used compared with many thousands of plots being required when LiDAR is not used



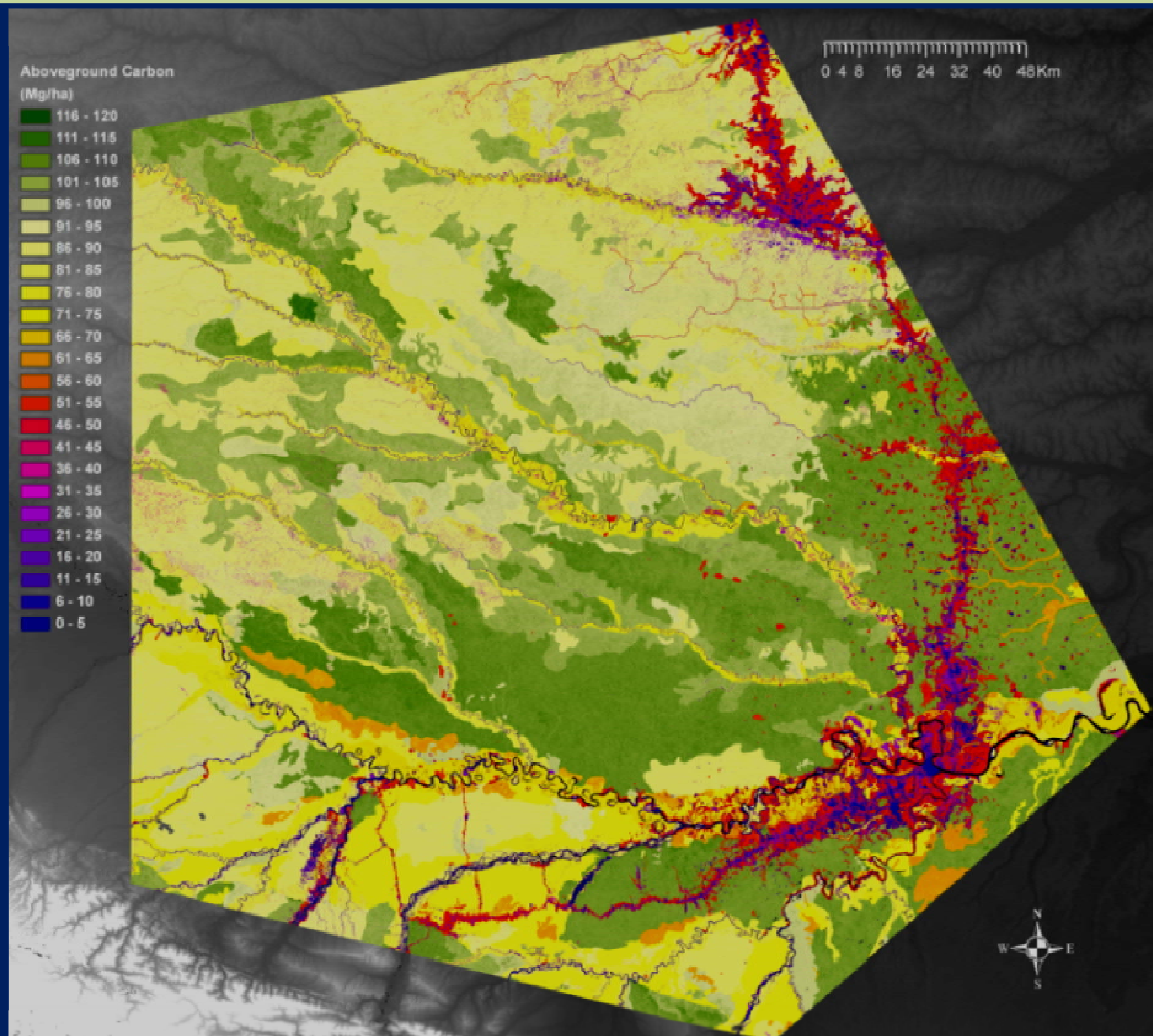
Sensitivity of the LiDAR-to-C regression to the number of field plots

Scaling ACD to Landscape

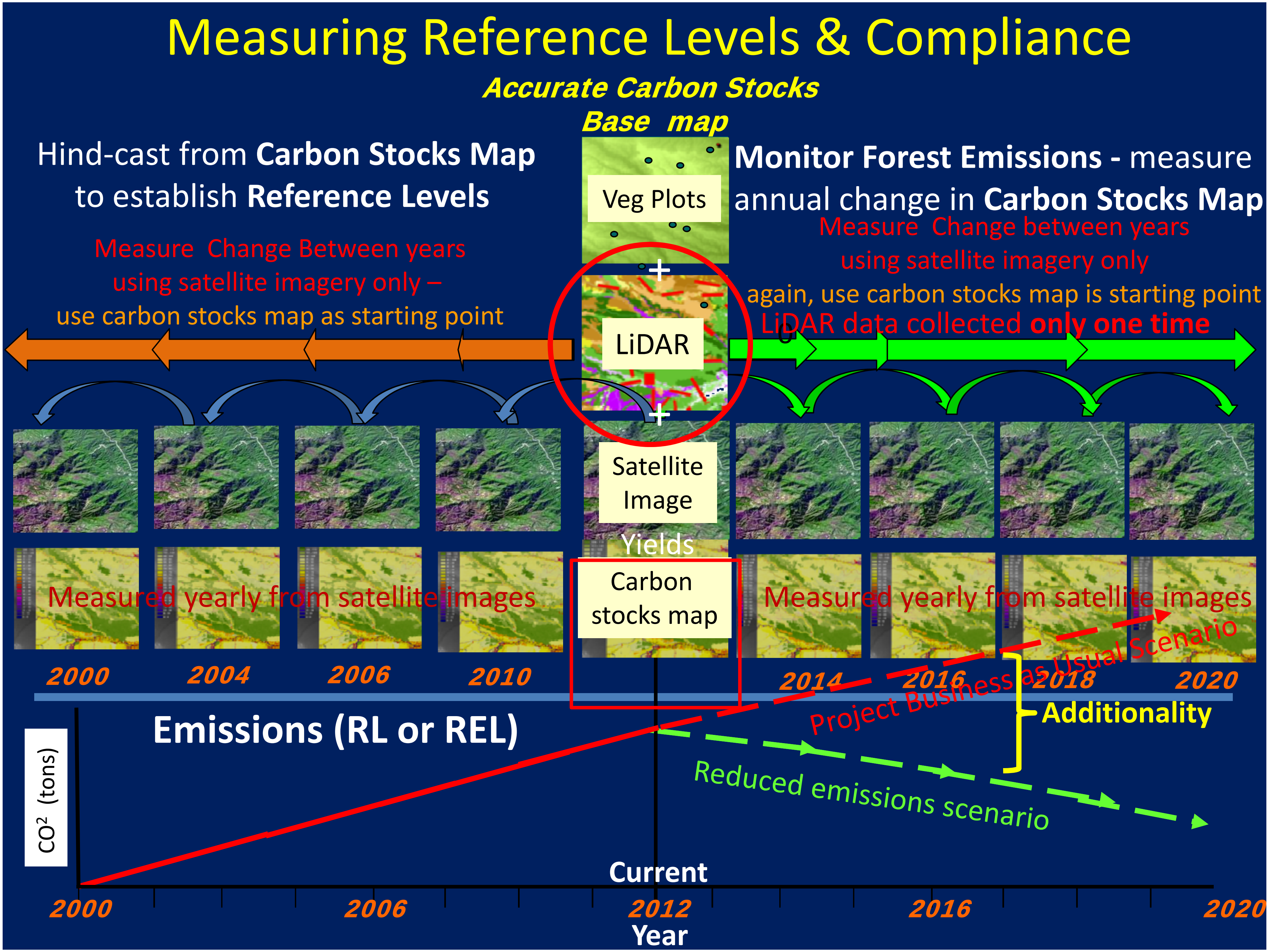
- How can we scale ACD prediction from LiDAR sampling areas to the landscape?
- By applying LiDAR-Carbon model to satellite data
- Different satellite systems & methods are available for vegetation classification
  - LANDSAT, MODIS, SPOT, ASTER
  - Rapid Eye

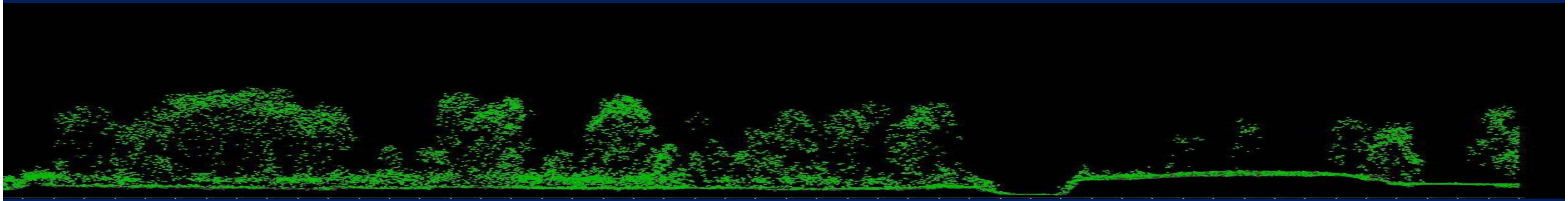
Forest Aboveground Carbon Storage in 4,300,500 ha at 0.1 ha Resolution

With an accurate carbon stocks base map it is possible to create **Reference Levels** and Monitor (MRV) emissions using satellite imagery



TREEMAPS


Measuring Reference Levels & Compliance
Accurate Carbon Stocks
Base map
Hind-cast from Carbon Stocks Map to establish Reference Levels
Measure Change Between years using satellite imagery only –
use carbon stocks map as starting point
Veg Plots
LiDAR
Satellite Image
Yields
Carbon stocks map
Monitor Forest Emissions - measure annual change in Carbon Stocks Map
Measure Change between years using satellite imagery only
again, use carbon stocks map is starting point
LiDAR data collected only one time
Measured yearly from satellite images
Measured yearly from satellite images
2000
2004
2006
2010
2014
2016
2018
2020
Emissions (RL or REL)
CO² (tons)
Project Business as Usual Scenario
Additionality
Reduced emissions scenario
Current
2000
2006
2012
2016
2020
Year



Thank You