Relating Small-Footprint Waveform Lidar Data to Woody Biomass for Improved Land Degradation Assessment

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Motivation

- **Limitations in current land degradation assessment approaches**: we lack detailed spatial information on vegetation composition, 3-D structure. The coarse resolution data limit our ability to unravel changes in the land surface at the scale at which processes occur (a few meters)

- **So what ?**

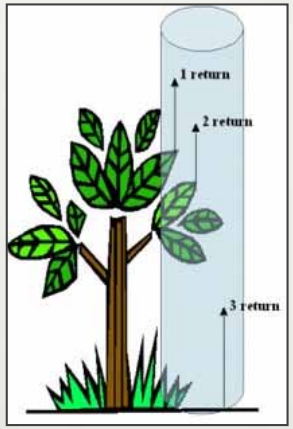
  It remains a challenge to assess many ecosystem process at the fine scale and effectively upscale to larger areas. We have traditionally focused on larger scale remote sensing, followed by fine scale inferences.

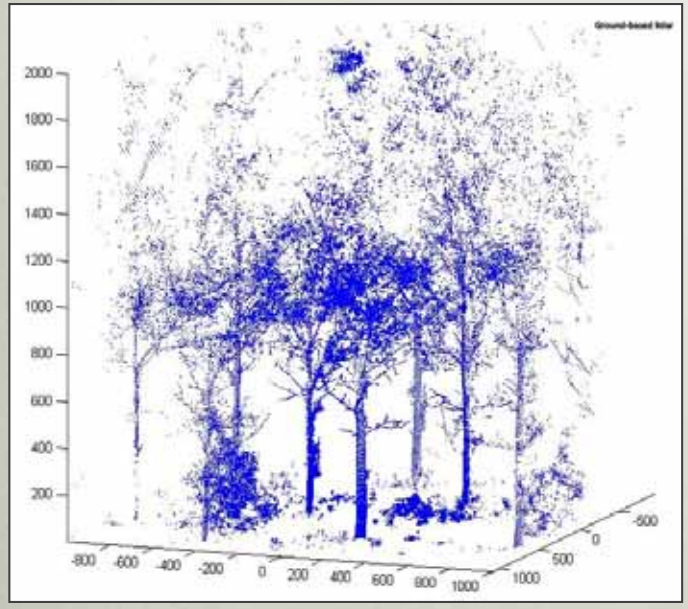
- **Potential Solution**

  LiDAR technology opens up a new potential to improve our ability to quantify land cover change and terrestrial productivity in fine scale.

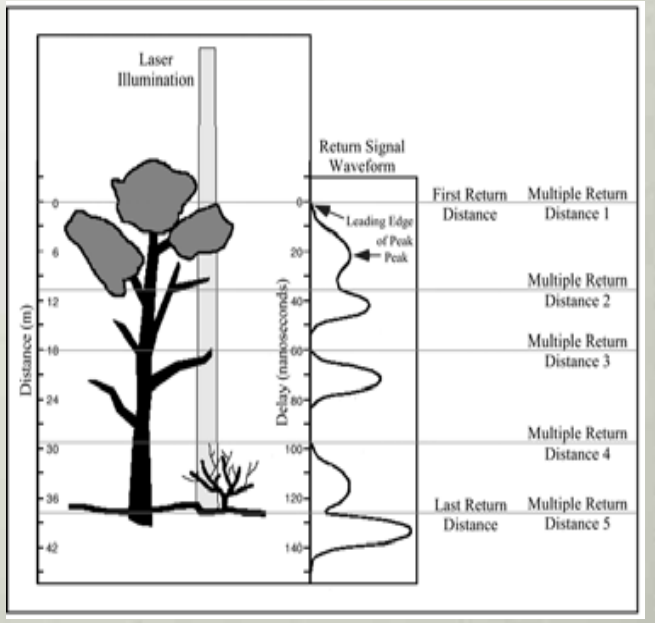
Lidar Technology

- **Types of LiDAR**





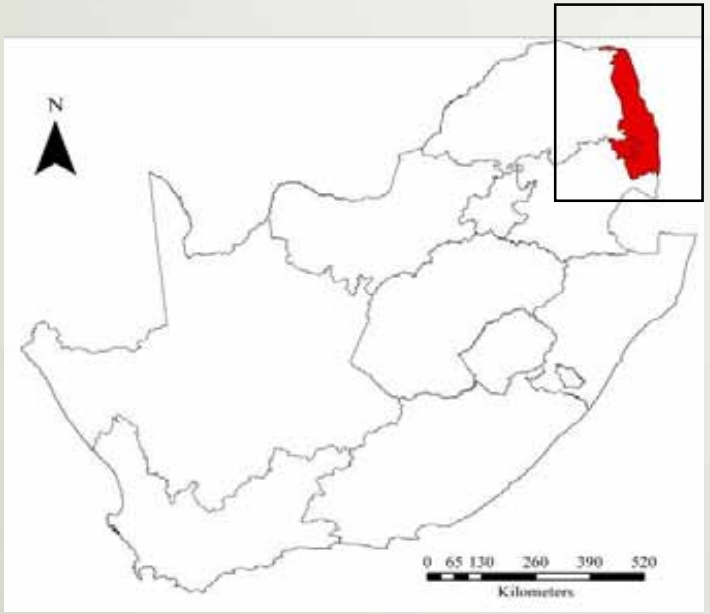
Ground-based discrete returns (point clouds)

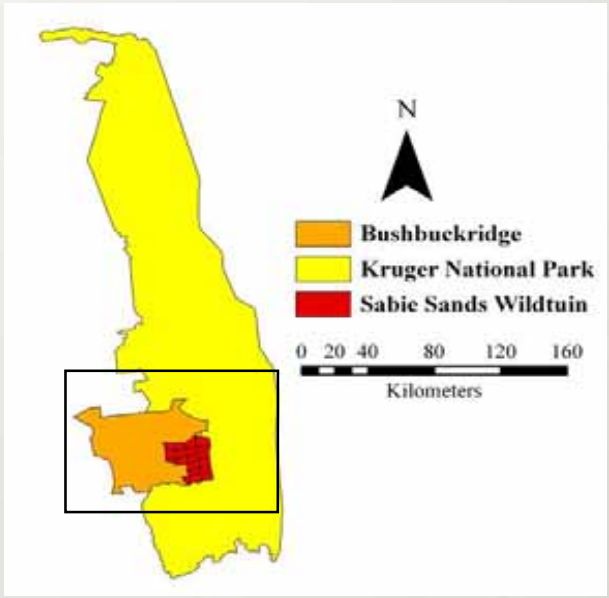


Full-waveform (our research focus here)

Methods

- **Study area**





The study area is bounded by (22°8'00" S; 30°34'52"E) and (25°32'48"s; 32°2'50"E). in South Africa, which consists of :

- **Bushbuckridge region (communal range lands)**
- **Sabie Sands Wildtuin (private conservation area)**
- **Kruger National Park (state-owned conservation area)**

Methods

- **Field and remote sensing data**

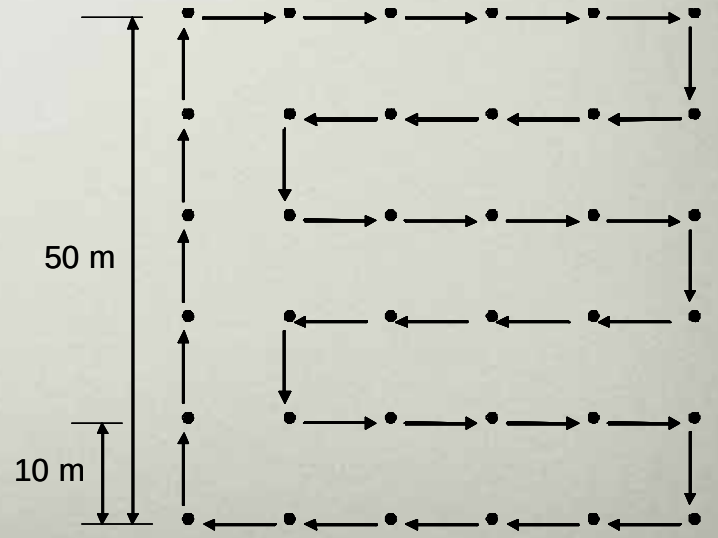
Remote sensing data:

1. Lidar Waveform data across land-use gradient (pixel size: 0.56m, vertical resolution: 0.5ns / 0.15m)
2. Discrete Lidar data (point clouds, DEM)

Field data:

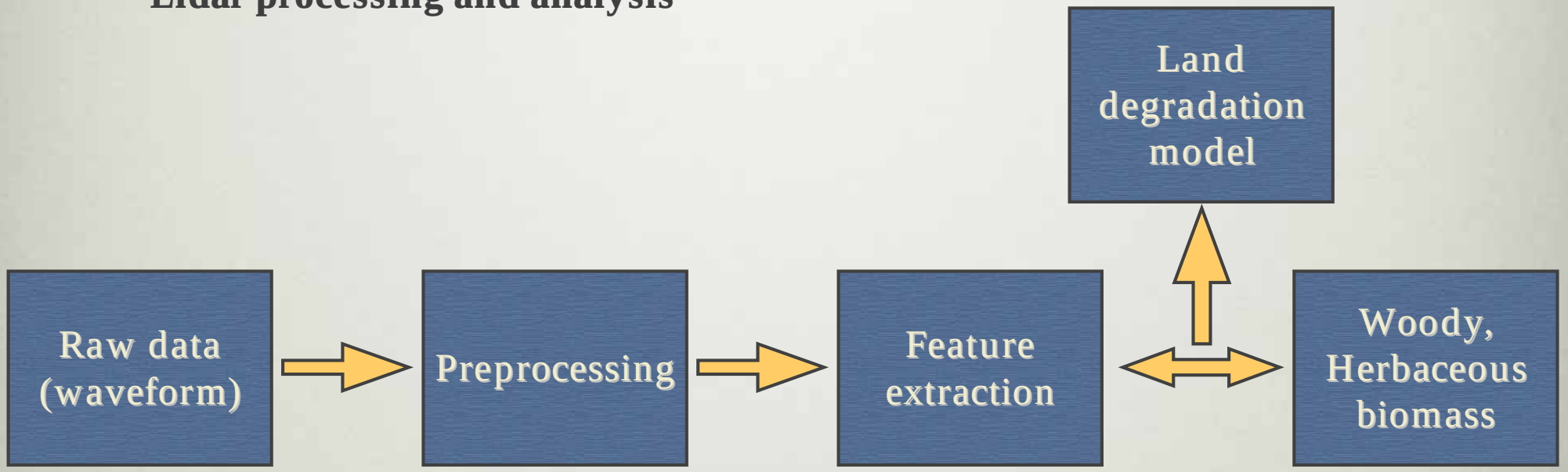
Field data for the research were collected from 36 sites, each 50 x 50 m in size. A total of 36 plots (2-5 meter variable radius) were laid out within each site on a 10 m spacing to result in a grid-like pattern.

- Herbaceous biomass (and species)
- Woody biomass (and species)
- Herbaceous water content
- Bare soil fraction
- Litter quantity
- Trees measurement(diameter-at-breast-height, height)
- Differential GPS location



Methods

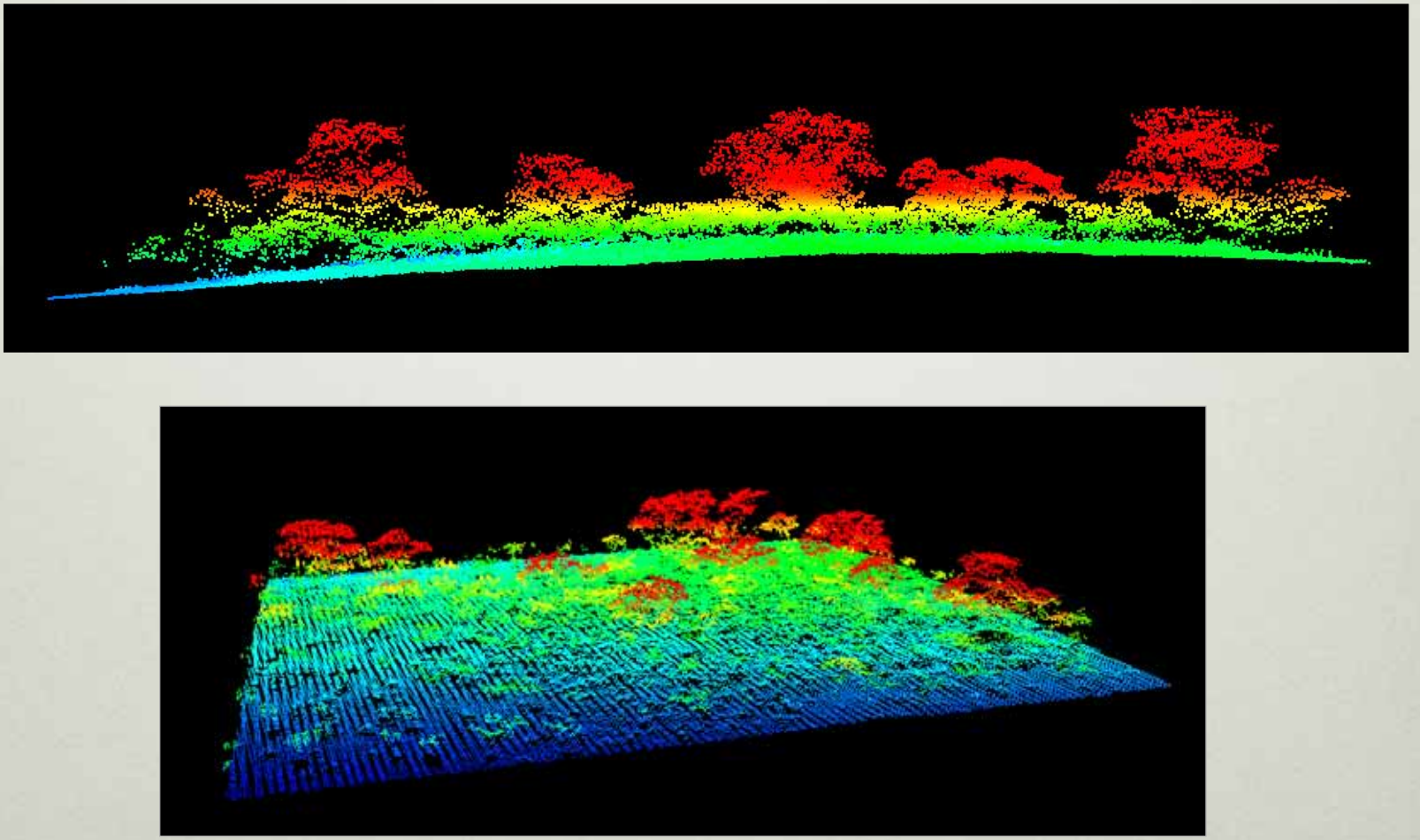
- **Lidar processing and analysis**



1.Noise filtering
2.Receiver Impulse response estimation
3.Advanced Signal deconvolution
4. Waveform decomposition.
5.Multi-angular based waveform reconstruction
….

1. Slope, width of waveform
2. Energy distribution
3. Principal components
4. Frequency patterns
….

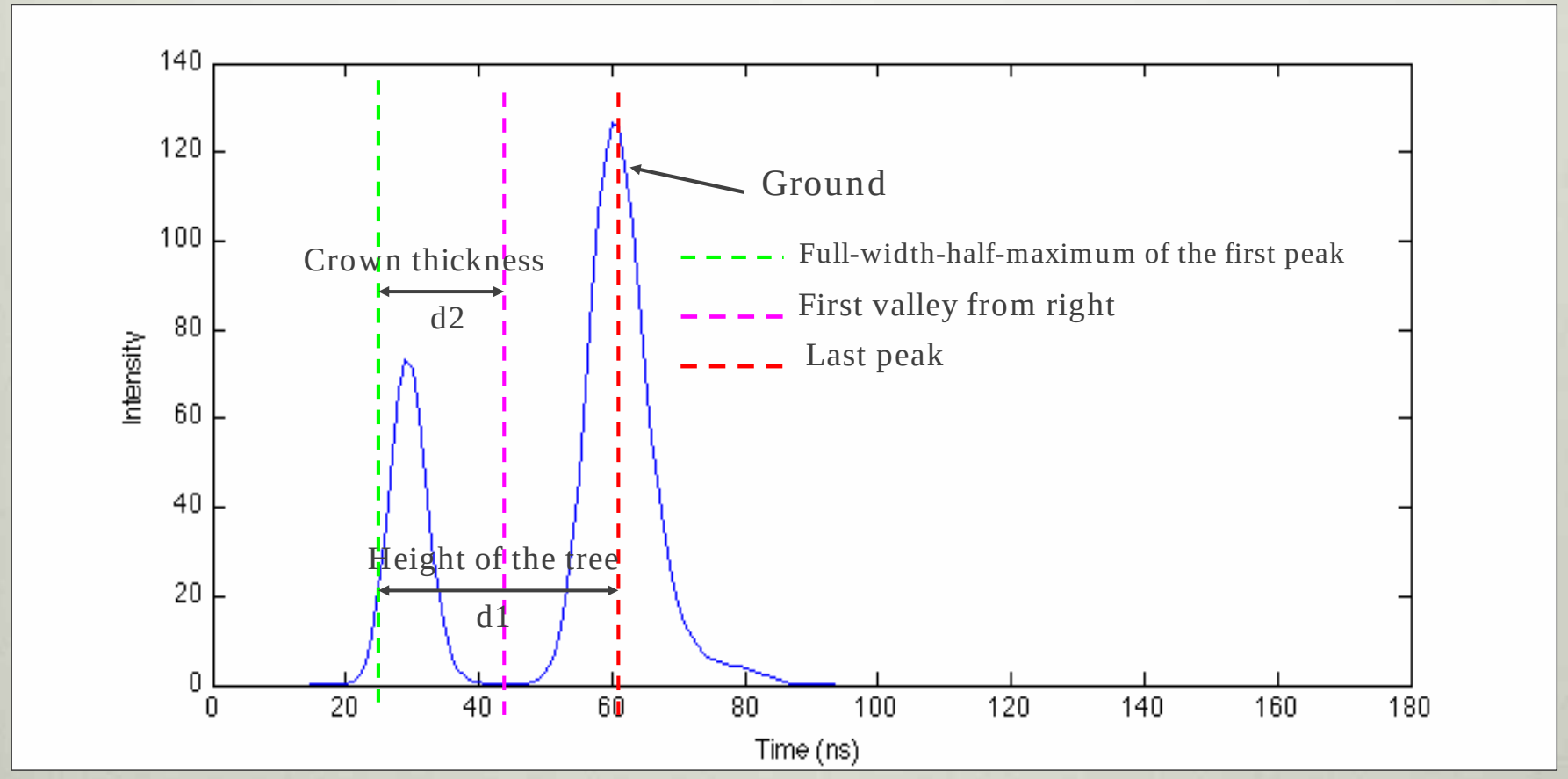
Initial results – discrete return



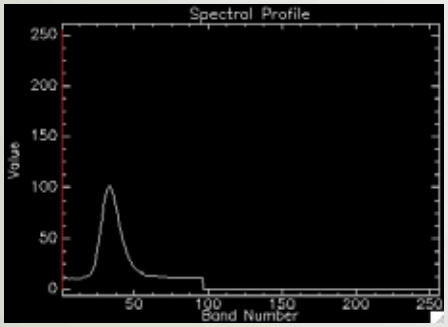
Discrete returns (point clouds)

Initial results

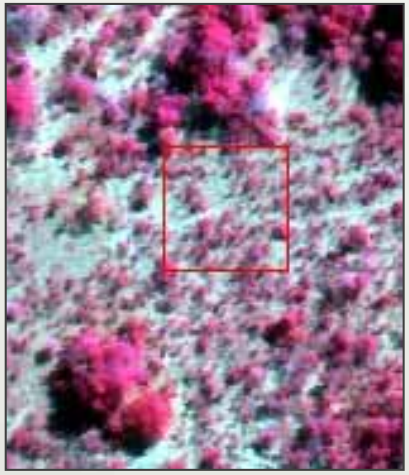
Metrics extraction from waveform

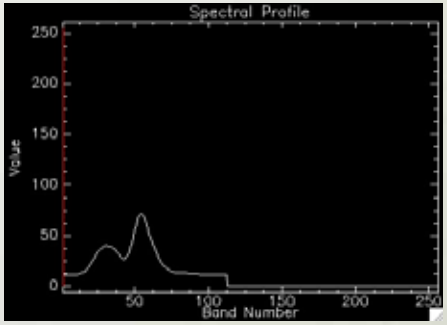


Initial results

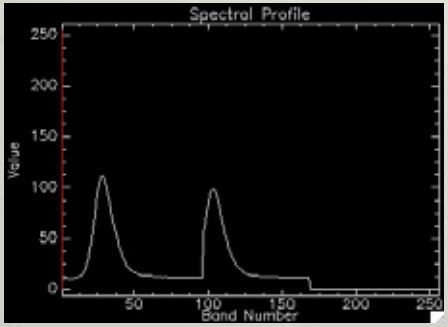


Ground





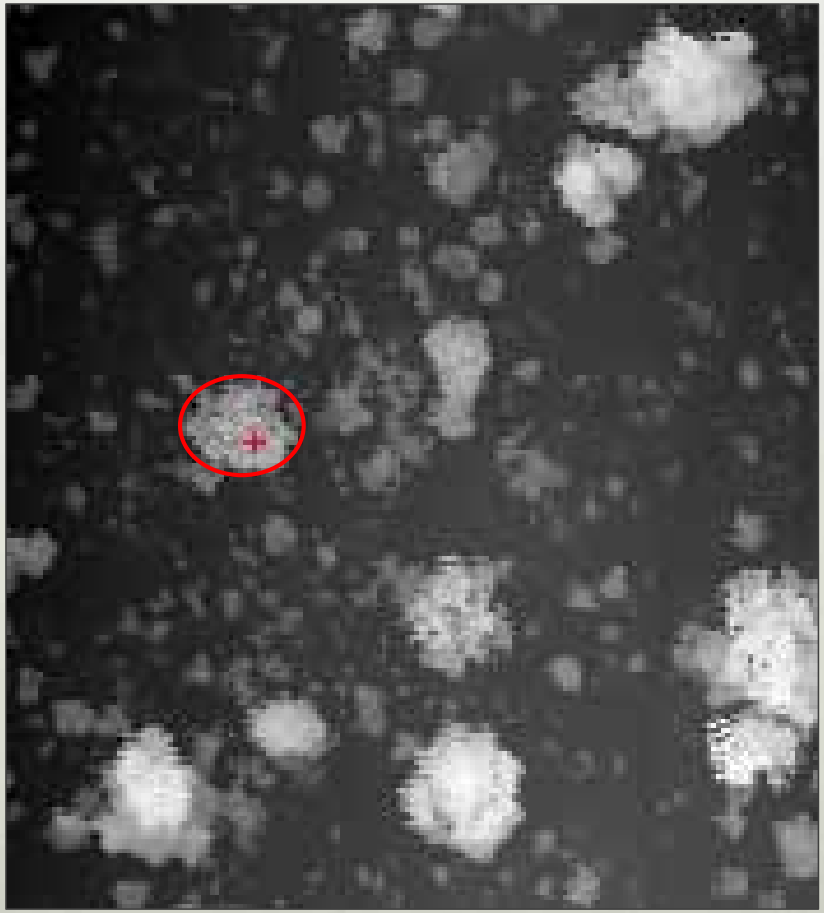
Shrub Ground



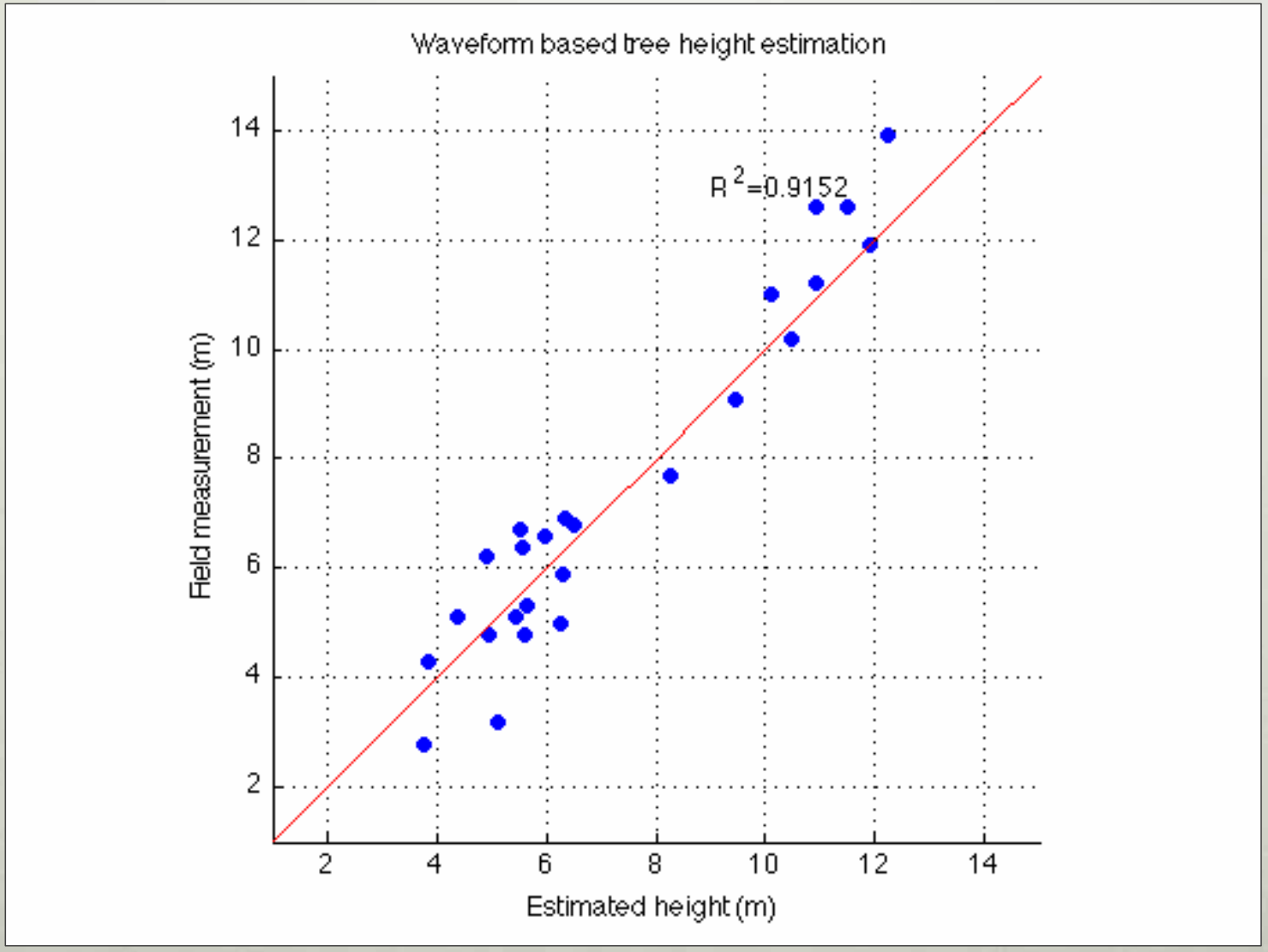
Branch + Ground

Initial results - visualisation

Individual tree level biomass estimation



Initial results



Initial results – tree-level woody and foliar biomass

Estimation of mean & standard deviation for crown thickness and crown volume

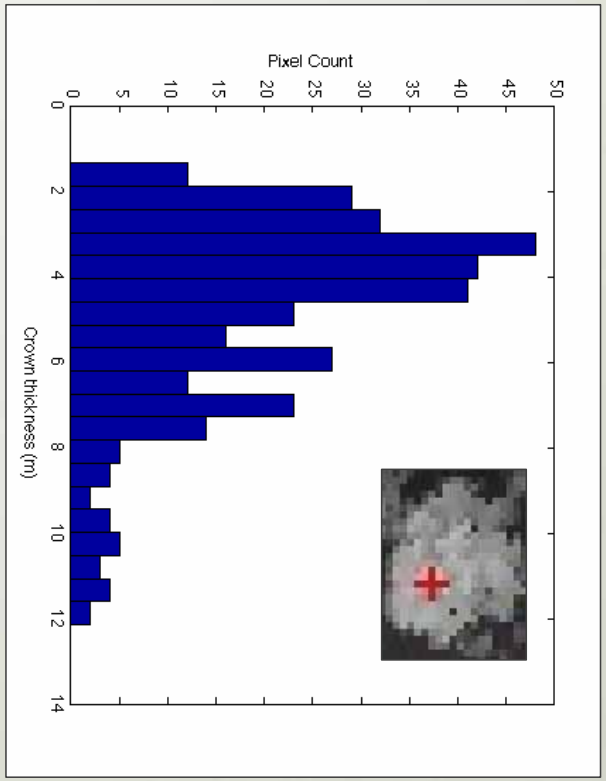
Graph shows the histogram of crown thickness (***d2***) in pixel level for a tree.

Mean: $\bar{d}_2 = \sum_N d_{2,i}$

Std: $d_{2,std} = \sqrt{\frac{\sum_N (d_{2,i} - \bar{d}_2)^2}{N}}$

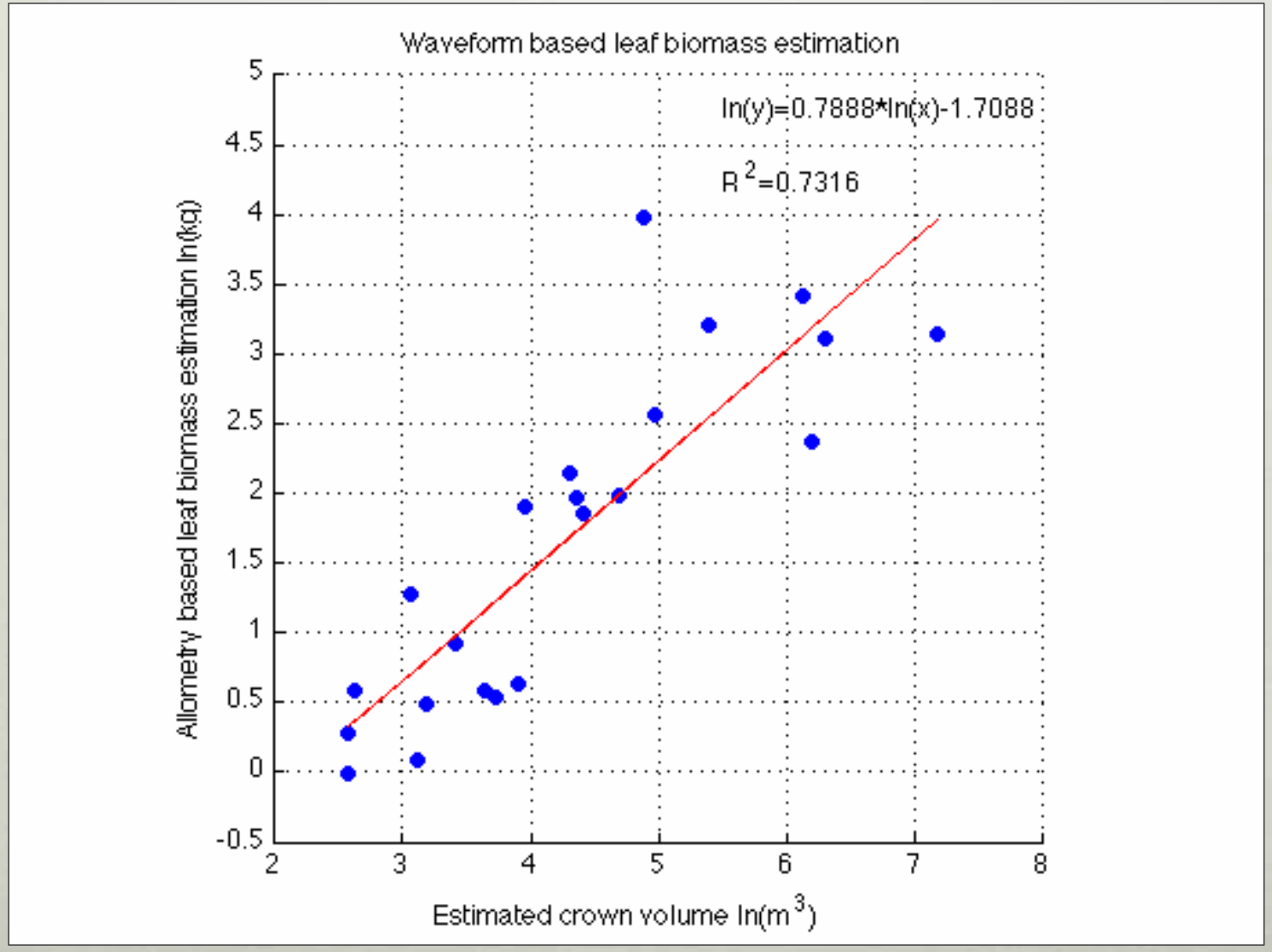
The crown volume is approximated by…. $S\sum_N d_{2,i}$

S is the pixel size (56mX0.56m)

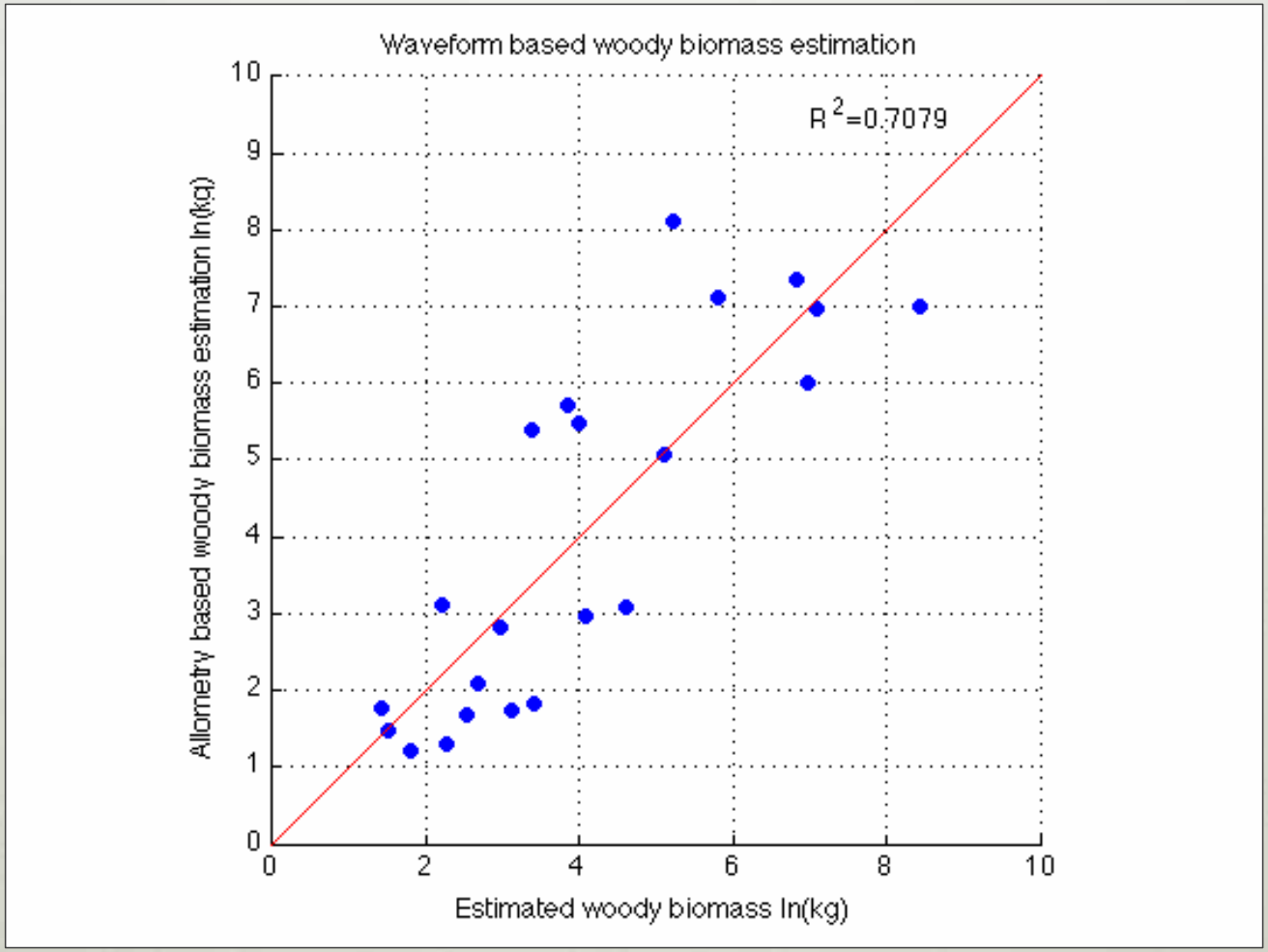


I.e., the graph represents the crown thickness estimate for each pixel within the crown footprint = many "thinner crown pixels on the periphery…

Initial results



Initial results



ln(Woody biomass) = 1.39*ln[crown volume] + 0.36*ln[crown(std)] - 1.94

Brief conclusions

- Waveform lidar technology / data show great promise for estimating woody and foliar biomass at fine scales
- We are just scratching the surface – waveforms offer a richness of physics-based metrics that relate to “biological” woody and herbaceous biomass parameters
- Much pre-processing is required to properly assign and construct a per-pixel, volumetric waveform
- Detailed, accurate, and precise ground-truth is needed – we cannot compare a high-structural resolution waveform to relatively crude allometric estimations (…like killing a fly with a canon ball)

Future Research

- Using photogrammetry-based approaches to improve the field data accuracy – generating 3-D tree models (e.g., volume of the tree).
- Waveform radiative modeling (the influence of the surface geometry and radiometry on waveform shape (DIRSIG lidar simulation environment)
- Waveform unmixing into structural components
- Data fusion (hyperspectral and lidar waveform)

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Visibility and cover influence lion hunting behavior

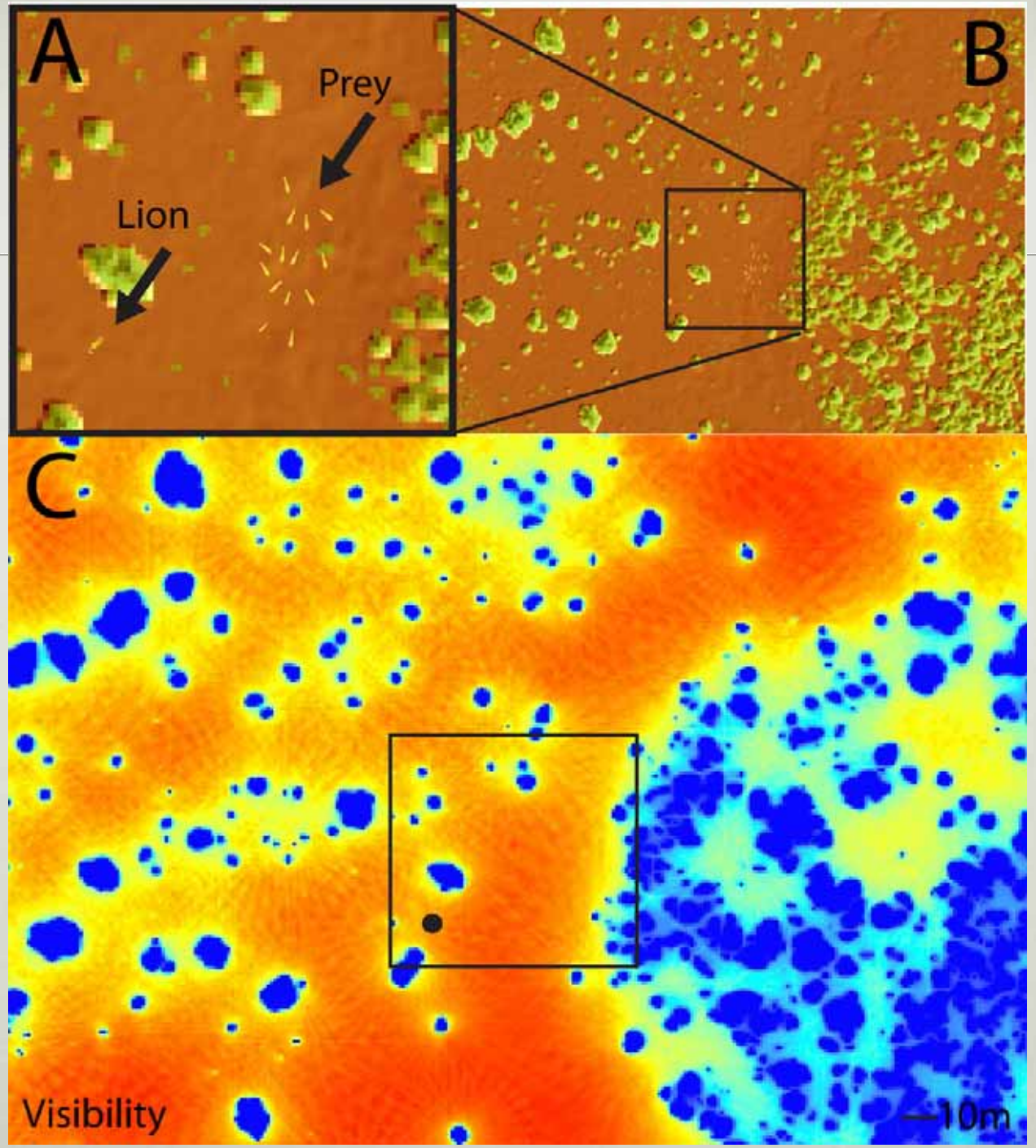
How does vegetation structure, specifically the visibility, influence lion hunting patterns?

1. Identify the location of lion kills from telemetry data and field observations.

2. Calculate visibility from CAO Lidar data.

3. Compare the location of lion kills across sexes and prey types with visibility and other vegetation structure indices.

Craig Tambling removing a lion collar in 2005



(A-B) Cartoon of lion and prey locations atop CAO data.
(C) Visibility modeled from CAO data.

http://cao.ciw.edu