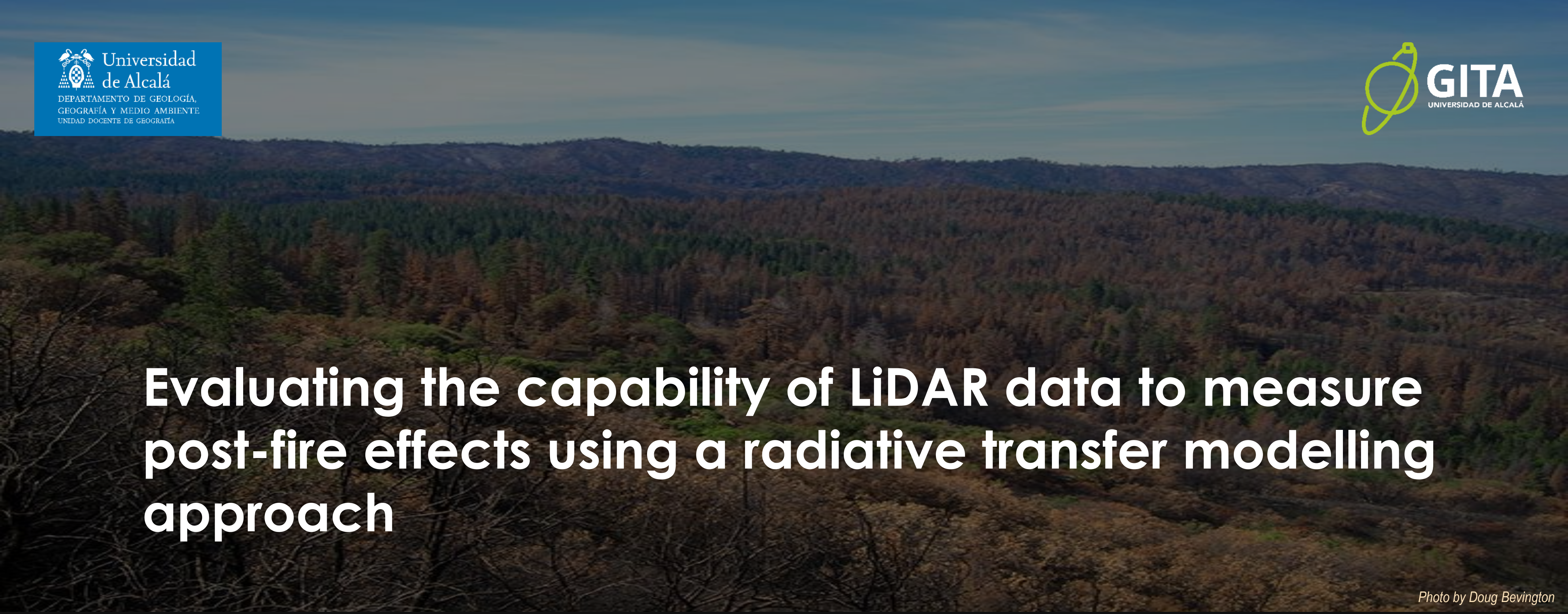

Evaluating the capability of LiDAR data to measure post-fire effects using a radiative transfer modelling approach

Photo by Doug Bevington

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Presentation Outline

- Introduction
- Research questions
- Methodology
- Results
- Conclusions and future works

Introduction

- Providing accurate information on fire effects is critical to understanding post-fire ecological processes and design appropriate land management strategies
- Effects on: vegetation pattern distribution, GHGs emissions; habitat quality, soil nutrients, carbon and hydrological cycles (Bond et al., 2004; van der Werf et al., 2010; Casas et al., 2015; Yue et al., 2015).
- Socio-economic implications including health issues related to air quality, property damage or even human casualties (Chuvieco 2010).

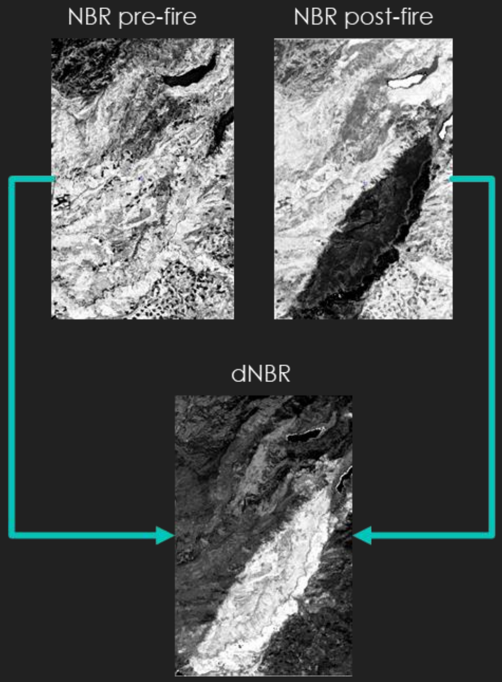






Introduction

- The impact of a fire is generally described in terms of its severity, which represents the ecological change caused by fire (Lentile et al., 2006).
- Spatial and temporal heterogeneity of fire effects → remote sensing techniques.
- Spectral indices: NBR, dNBR, RdNBR (Miller and Thode 2007; Miller et al. 2009)
- Radiative transfer approach (Chuvieco et al., 2006; 2007; de Santis et al., 2010)
- Validation using CBI (0-3) or GeoCBI (de Santis and Chuvieco, 2009).
- Inability to accurately capture damage on under- and mid-story vegetation in low and moderate severity areas, especially under high canopy cover (Miller and Quayle, 2015).



- Only structural changes on canopy are considered
  - Snag detection using intensity data (Wing et al., 2015; Casas et al., 2016).

Research questions

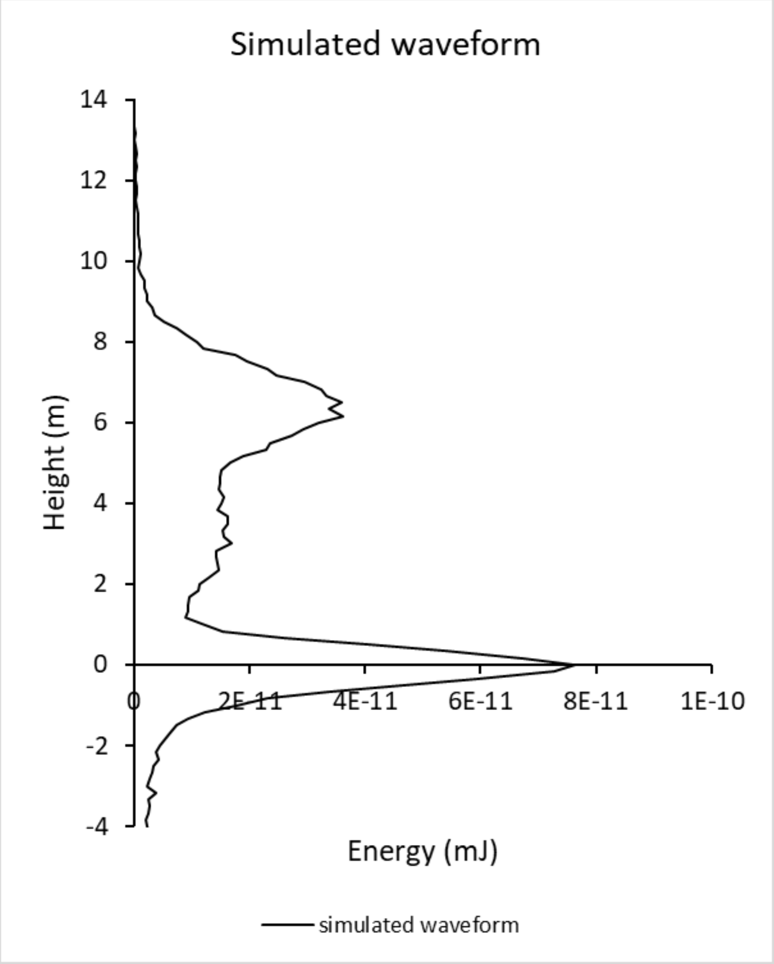
- What the potential of full waveform LiDAR data for providing a comprehensive characterization of post-fire effects?
- What is the sensitivity of LiDAR metrics to different severity degrees as measured by CBI?
- Can we develop a new LiDAR metric to better capture severity?

Methods

- Full waveform simulation
  - FLIGHT 3D radiative transfer (North, 2010)
    - Monte Carlo evaluation of photon transport within a 3D representation of vegetation.
    - Energy binned into m bins according to path length.
    - Sensor parameters equivalent to Land, Vegetation and Ice Sensor (LVIS).
    - Vegetation is modeled using geometric primitives.
      - Turbid medium described by leaf area density, leaf-angle distribution; and the optical properties of leaves, branch, shoot and ground components.
    - Forest plots represented using field information (García et al., 2010)

Param	alue
$X_0, Y_0,$	, 10000
q_0, f_0	0, 0
b	1
b_{FOV}	1.9
w	7
E_t	5
D_t	1

Plot	Ve					and nsity s/ha)
1	O					24
2						60
3						20
4						96
5	Pi					16
6						08
7	Pi					08
8	Pi					04
9						88
10	Oak; Pine	0.91 (0.48)	1.5	5.85 (0.75)	3.74	192



Methods

- Simulation of post-fire scenarios
  - Severity levels based on CBI. Simplifications (Chuvieco et al., 2006)
    - 5 strata (A- substrate; B- herbs, low shrubs and trees < 1 m; C- shrubs and trees up to 5 m; D) suppressed and intermediate trees; E) dominant and co-dominant trees.
    - Variables assessed:
      - Change in soil color
      - Char cover in substrate (%).
      - Litter consumed (%).
      - Change in cover (%).
      - Living and resprouting species (%)
      - Canopy mortality (%).
      - Char height (m).
    - Each stratum is scored individually and averaged to provide a plot CBI value.

  - Severity levels based on CBI.
    - 3 strata (A- substrate; B&C- Understory; D&E- Overstory)
    - Variables assessed:
      - Change in soil color (proportion of ash and charcoal).
      - Change in cover (LAI reduction).
      - % of foliage altered (change in leaf color).
    - Each stratum is scored individually and averaged to provide a plot CBI value
    - Optical properties:
      - Reflectance: measured (ASD FieldSpec® 3 / GER-2600 spectroradiometer)
      - Transmittance: estimated (Prospect 5-D / LIBERTY)
    - 1348 simulations for each plot after removing unrealistic scenarios

Variable change and associated CBI

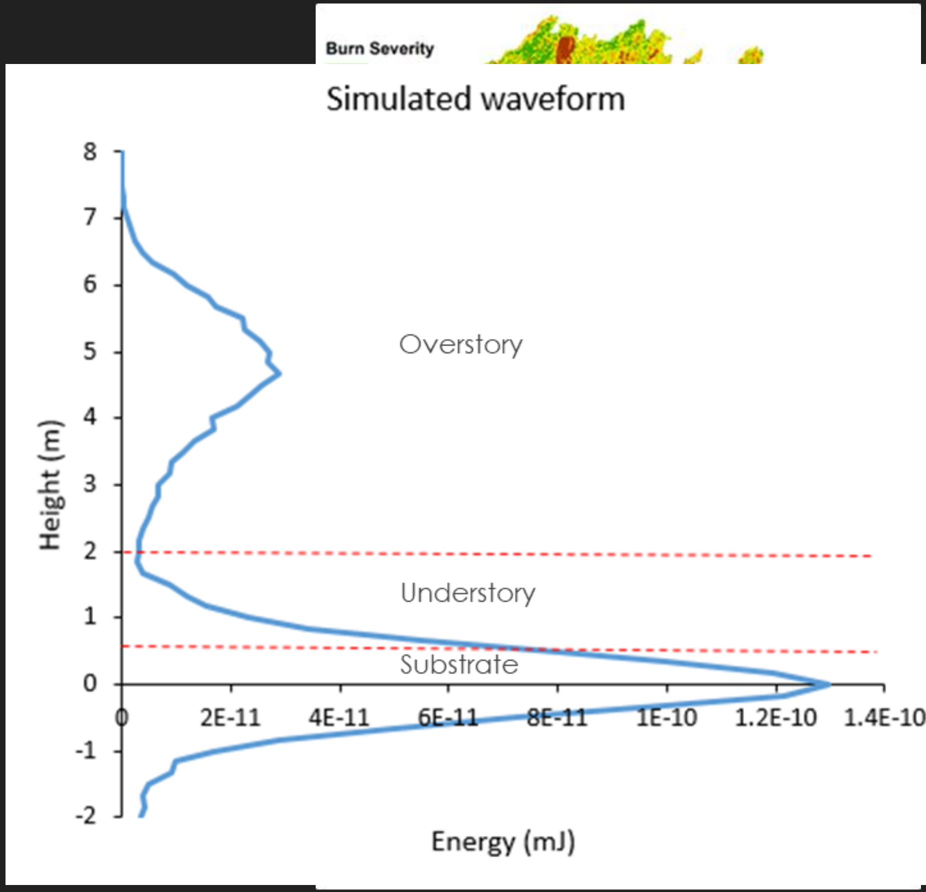
Susbtrate		Understory and Overstory	
CBI	% change in color	PFA (% of scorched / brown leaves)	PCC(% LAI reduction)
0	0	0	0
0.5	5	12.5	7.5
1	10	25	15
1.5	25	52.5	42.5
2	40	80	70
2.5	60	95	85
3	80	100	100

PFA and PCC combination

CBI-Percentage of Cover Change	CBI-Percentage of Foliage Altered						
	0	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
0	0	0.25	0.5	0.75	1	1.25	1.5
0.5	0.25	0.5	0.75	1	1.25	1.5	1.75
1	0.5	0.75	1	1.25	1.5	1.75	2
1.5	0.75	1	1.25	1.5	1.75	2	2.25
2	1	1.25	1.5	1.75	2	2.25	2.5
2.5	1.25	1.5	1.75	2	2.25	2.5	2.75
3	1.5	1.75	2	2.25	2.5	2.75	3

Methods

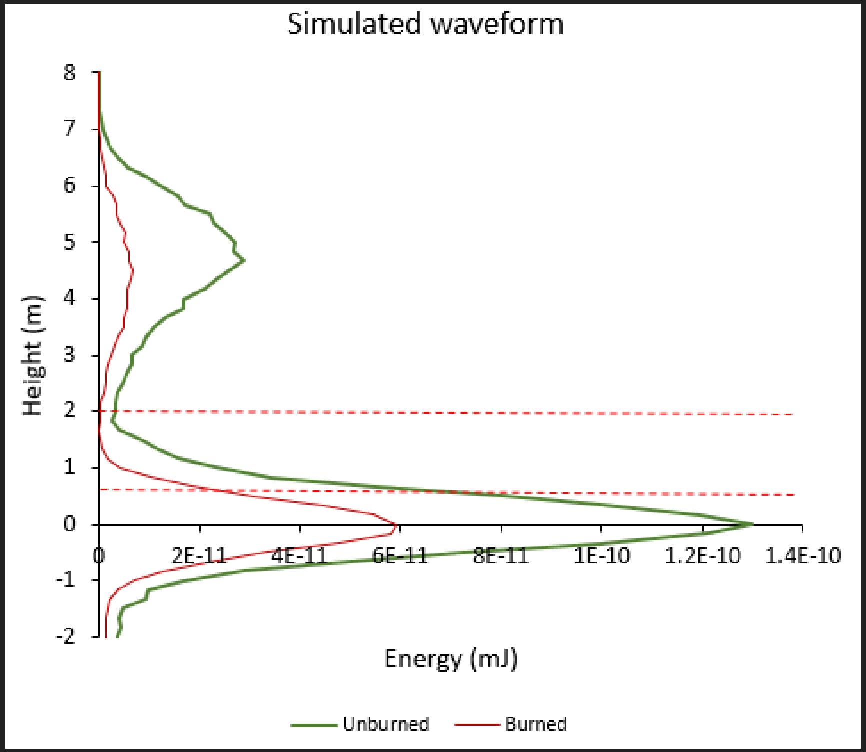
- LiDAR metrics
  - Common structural metrics:
    - 1st to 9th deciles of the energy relative to the ground elevation; 25th and 75th percentile; quadratic mean canopy height; mean canopy height; coefficient of variation of the canopy height profile.
    - **Area under the waveform**
      - Waveform divided in 3 strata:
        - Subtrate (ground signal).
        - Understory (2 m).
        - Overtory (> 2m).
    - Modeling burn severity
      - $$Rel\_Chg_{LM} = \frac{|LM_{post-fire} - LM_{pre-fire}|}{LM_{pre-fire}},$$



García et al., (2017). http://dx.doi.org/10.1002/2015JG003315

Results

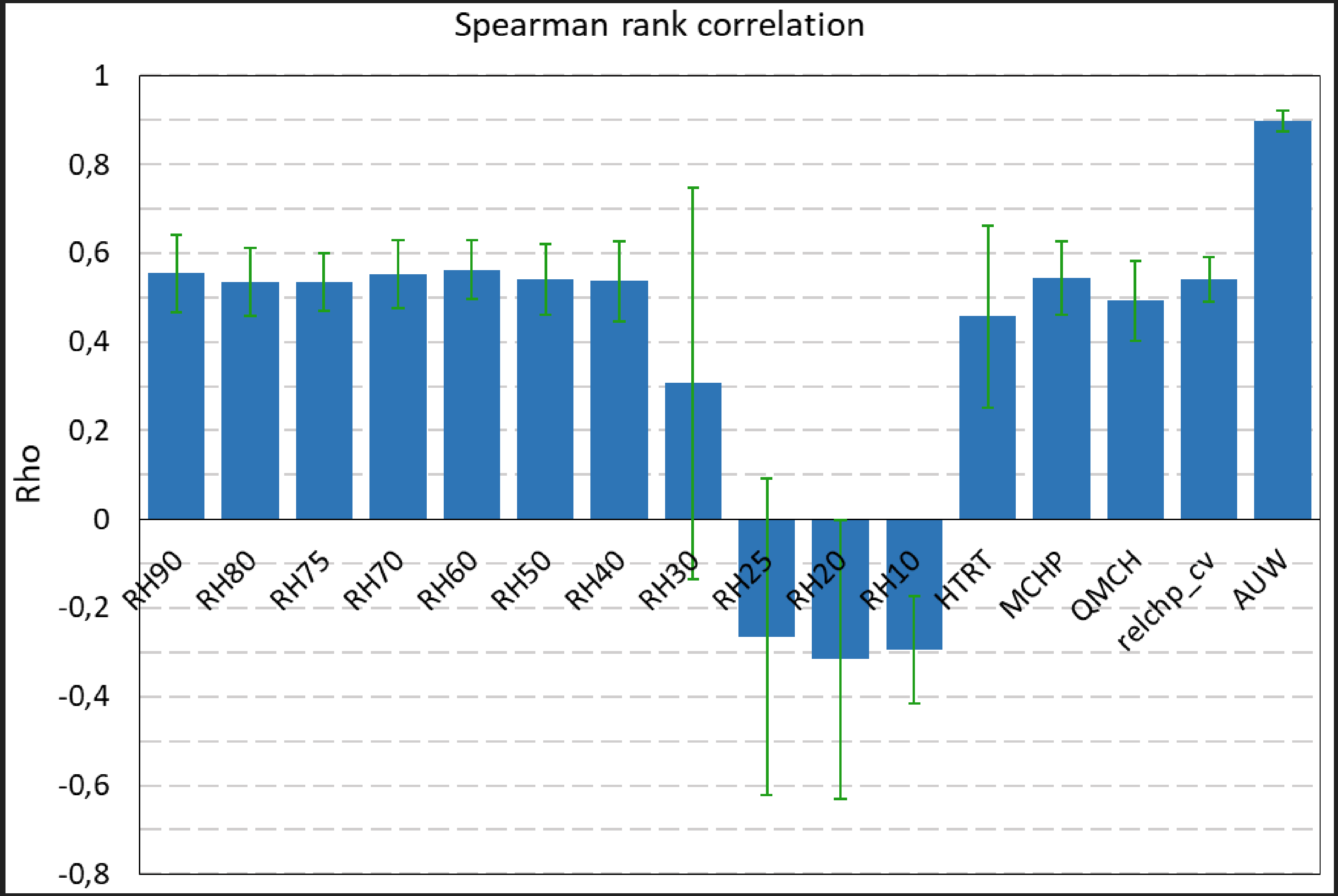
- Sensitivity of LiDAR to severity levels



Scenario	CBI Substrate	CBI Understory	CBI Overstory	CBI Plot
13	0.5 (5% color change)	2 (52.5% color | 85% LAI)	0 (0% color | 0% LAI)	0.83 (Low)
870	2 (40% color change)	2.25 (100% LAI)	1.25 (52.5% color | 15% LAI)	1.83 (Moderate)
1247	3 (80% color change)	2.25 (100% LAI change)	2 (52.5% color | 85% LAI)	2.42 (High)

Results

- LiDAR metrics evaluation



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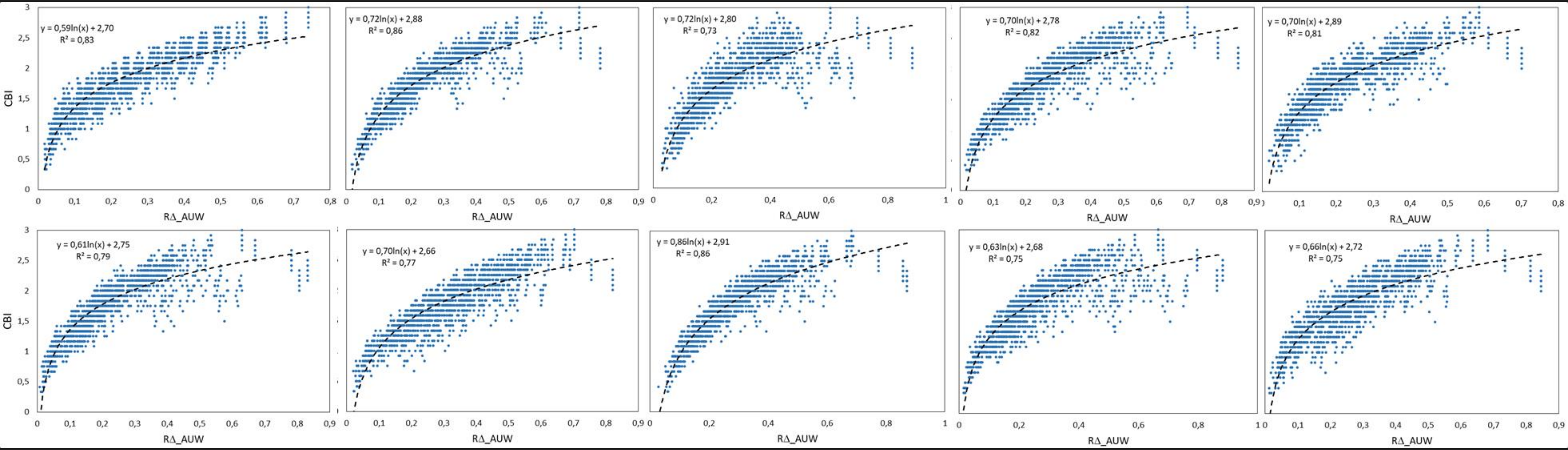
Results

- Severity modeling



Conclusions and future works

- Full waveform LiDAR shows sensitivity to different severity degrees.
- LiDAR capture fire caused damage beyond structural changes
- Traditional LiDAR metrics offered less capability to estimate severity
- A new metric (RΔ_AUW) has been proposed showing higher sensitivity to severity as measured by CBI.
- *Evaluation of RΔ_AUW in different ecosystems*
- *Application to discrete return data*
- *Application to satellite LiDAR missions (GEDI)*

Thank you!!!

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