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Semi-Arid Ecosystem Plant Functional Type and LAI from Small Footprint Waveform Lidar

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INTRODUCTION

- In this study we use variables derived from full waveform lidar to demonstrate their capacity to differentiate key plant functional types (PFTs) including aspen (AS), Douglas fir (DF), juniper (JP), bitterbrush (BT), sagebrush (SG), bare ground (GD); and leaf area index (LAI) in a heterogeneous tree-shrub, co-dominant, semi-arid ecosystem.
- Our results provide a solution to difficulties in deriving shrub and LAI estimates from discrete return lidar in semi-arid ecosystems, in which returns are often too low to characterize the vegetation.
- By imputing our results, we can assess landscape-wide ecosystem structure, state, habitat suitability as well constrain uncertainties in vegetation dynamic models.

FULL WAVEFORM LIDAR

Full waveform lidar emits an amplified laser beam and digitizes the backscattered energy as a near continuous waveform with a high vertical resolution (~1 ns = 15 cm). The resultant 3D wave contains properties of both the emitted wave and the target (Fig. 1). These waveform properties can be used to infer biophysical properties of vegetation.

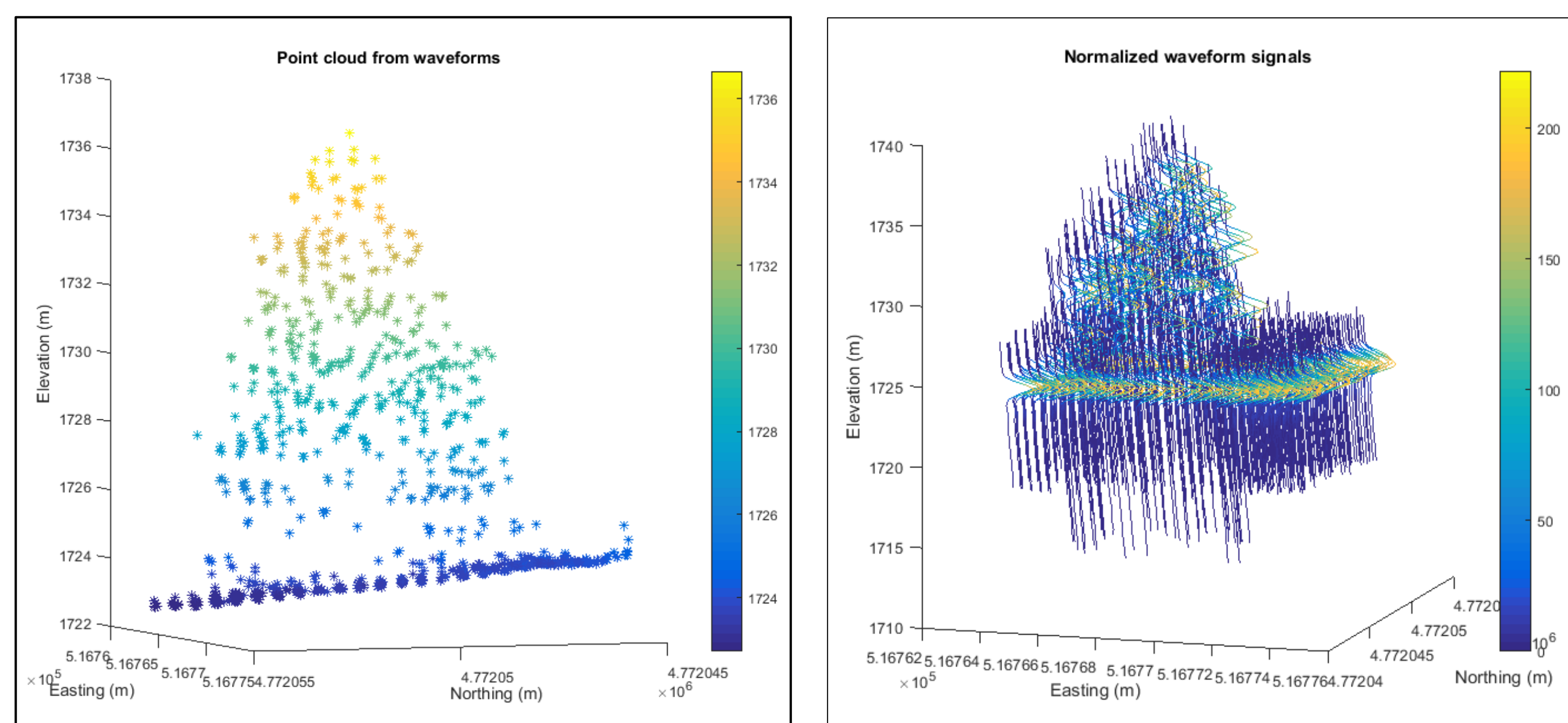


Figure 1. Discrete return lidar point cloud from a juniper tree (left). Full waveform lidar representation of the same juniper tree (right).

METHODS

Vegetation was classified into PFTs and the LAI was derived by first geolocating the waveforms and then approximating the backscattered full waveform signals. We implemented a sum of Gaussian approximation and frequency domain deconvolution techniques to extract the variables from waveform signals (Fig. 2). An ensemble random forest algorithm was applied to the derived variables at 1 m and 10 m spatial scales to differentiate the dominant PFTs in the study site (Fig. 3).

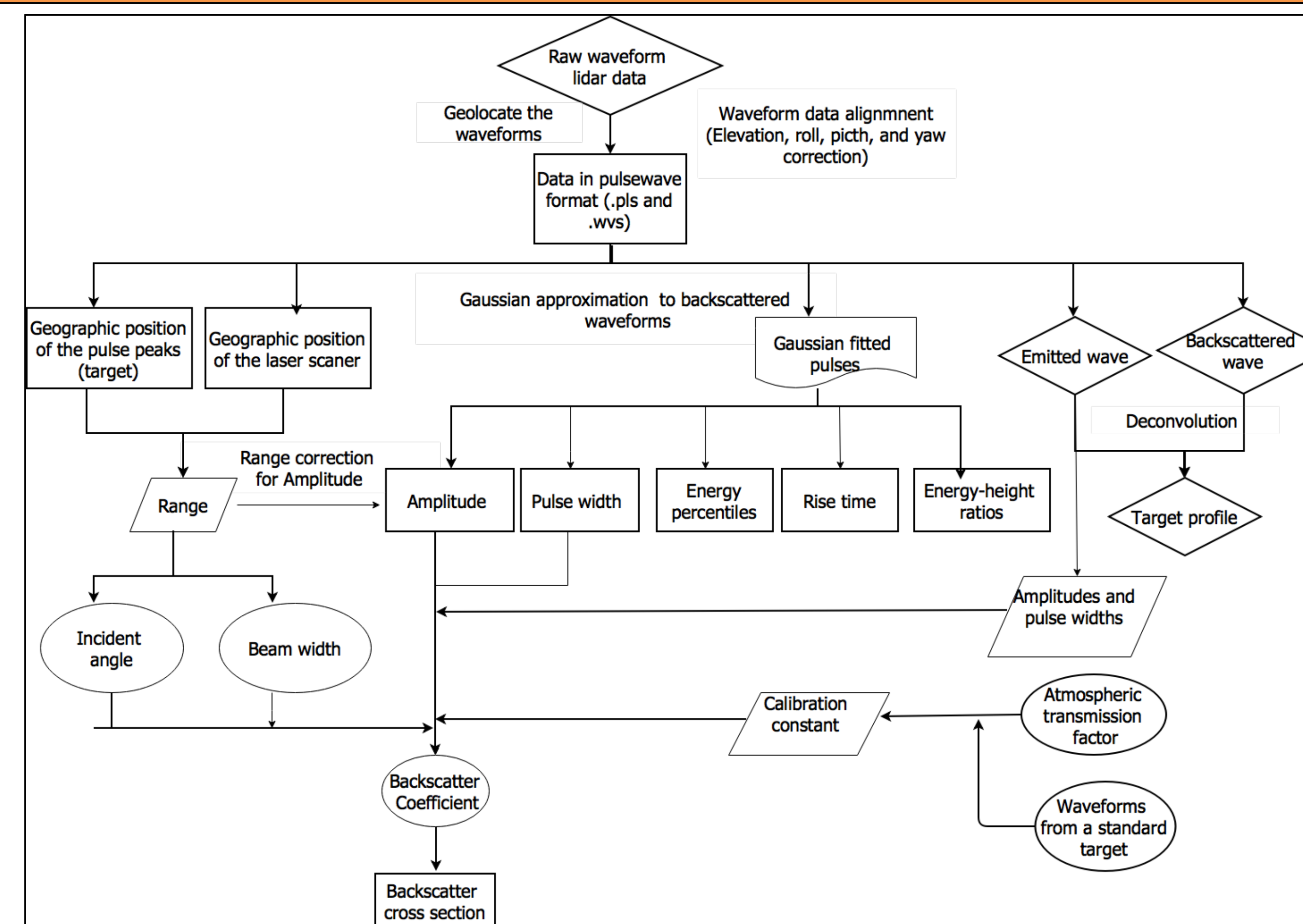


Figure 2. Variable derivation from the lidar waveforms.

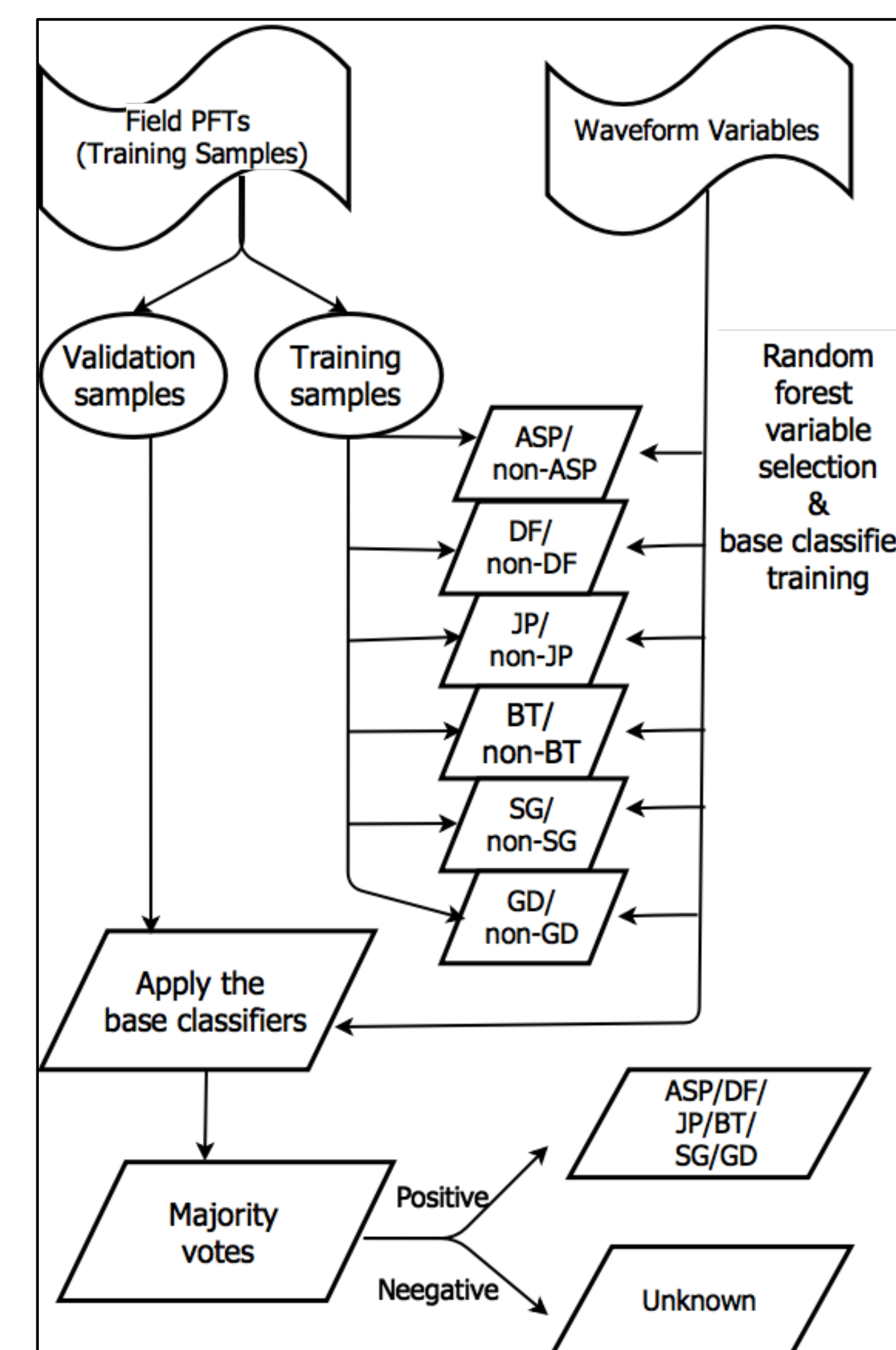


Figure 3. Ensemble random forest for PFT classification.

Figure 4. Distribution of rise time and standard deviation of cumulative lidar energy at 90th percentile of PFTs.

2. Lidar variables that relate to the target structure (pulse width, energy distribution, and rise time) dominate the variables that relate to radiometric properties (backscatter cross section) (Fig. 4, 5a, and 5b).

RESULTS

1. Associations of waveform derived percent energy, rise time, pulse width, backscatter cross section and deconvolved target profiles separate PFTs of trees and shrubs from each other and from bare ground (Fig. 4).

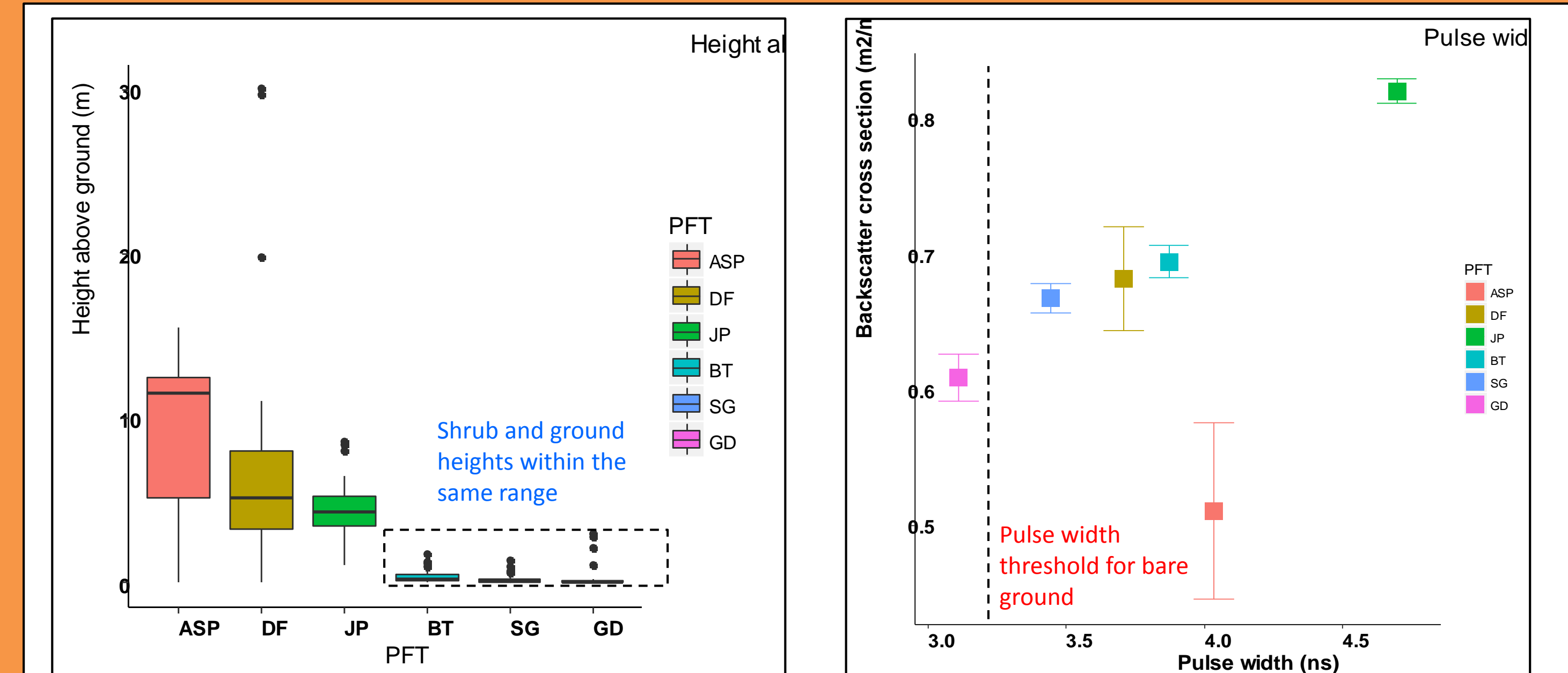
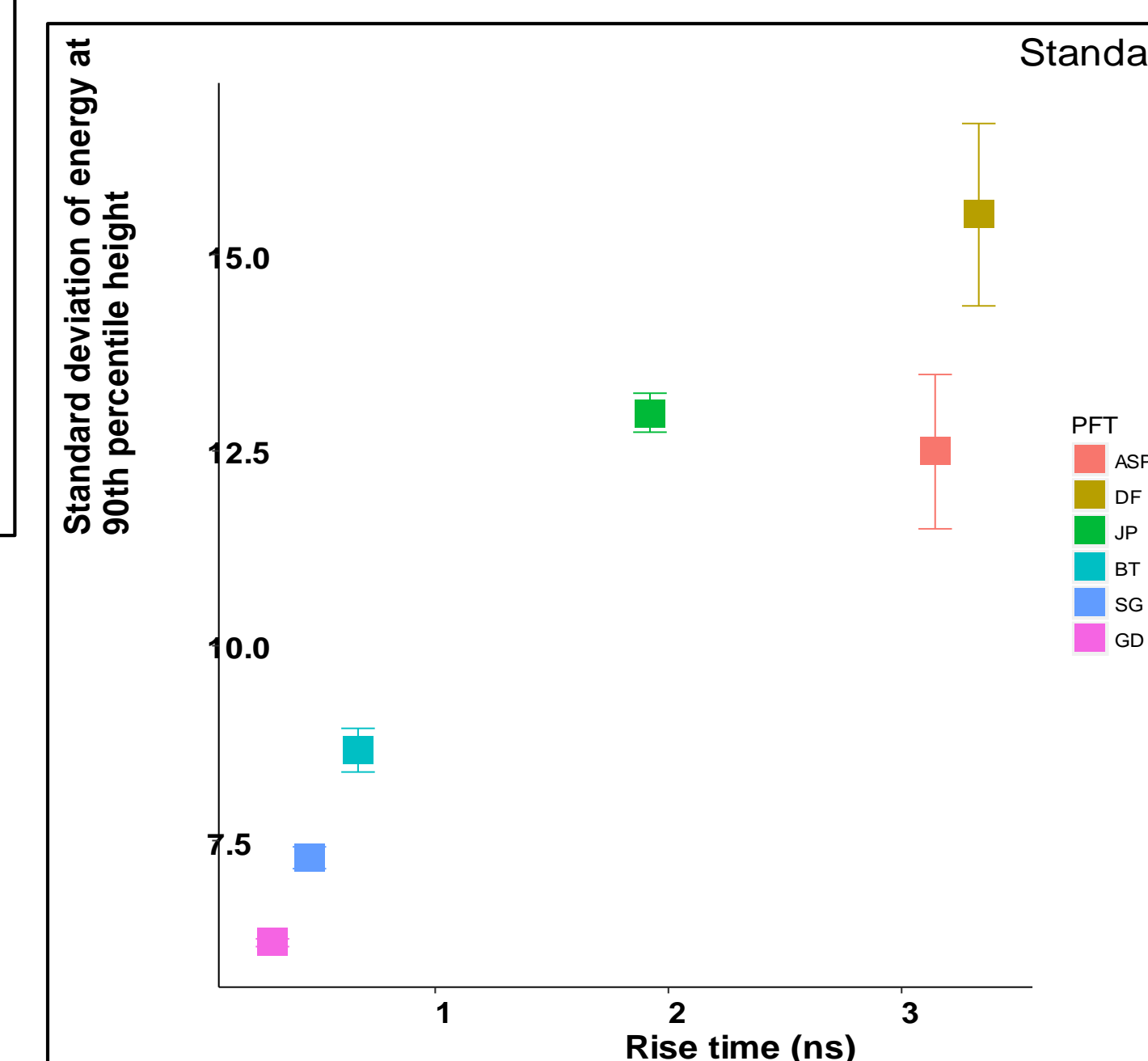
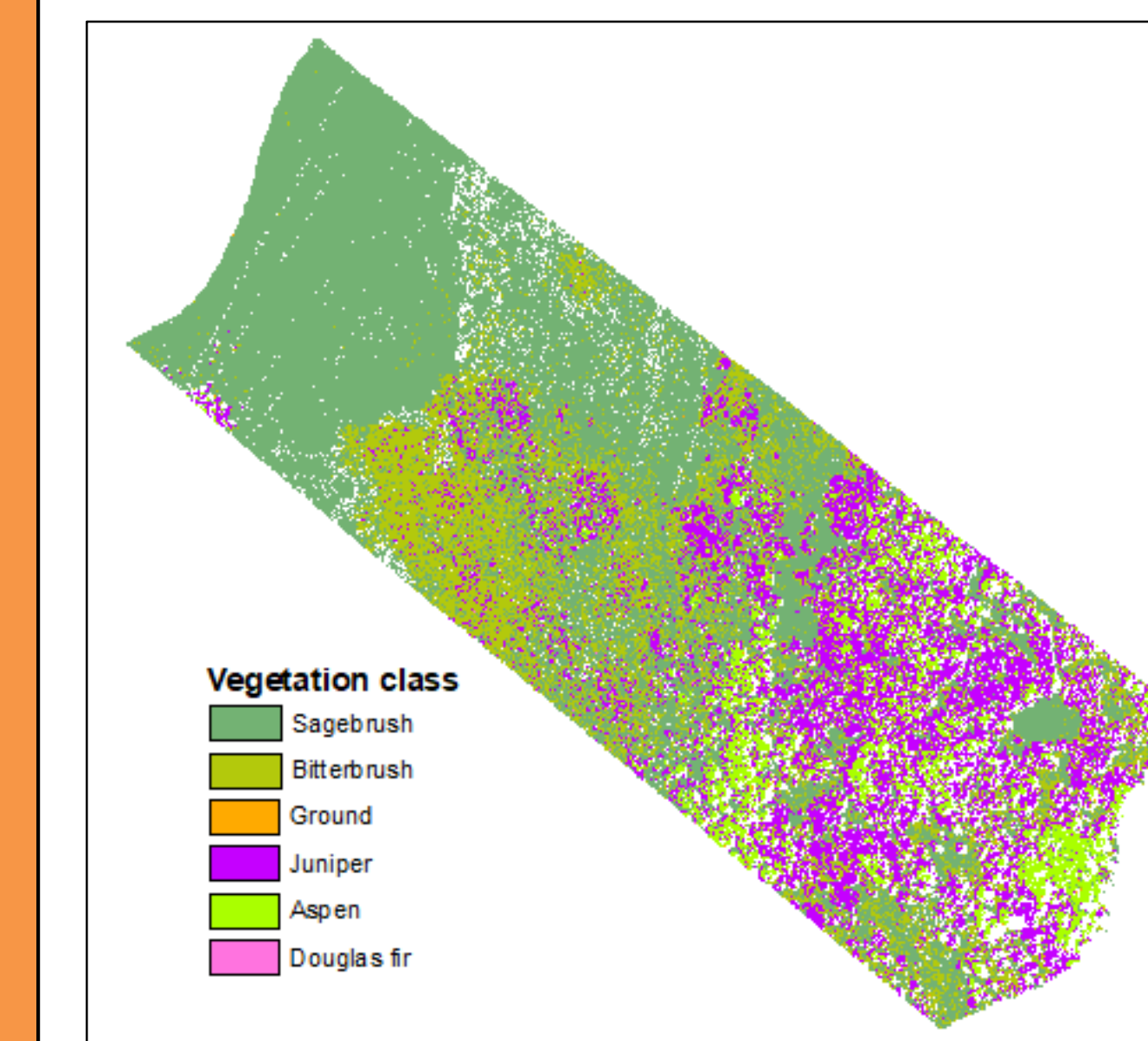


Figure 5. a) Distribution of height above ground of selected PFTs. b) Distribution of pulse width and backscatter cross section of PFTs.

3. Inclusion of height above ground improves tree PFT separation, however shrub PFTs and ground were confused (Fig. 5a). Shrub-ground confusion can be eliminated using percent energy (Fig. 4), pulse width and backscatter cross section (Fig. 5 b)



4. Resulted in a high overall PFT accuracy (@1 m, 80%; @10m, 89% accuracy) (Fig. 6).

Figure 6. PFT classification map of a lidar flight line

5. Gap fraction derived from the waveform backscatter cross section shows a strong negative correlation with plot scale shrub LAI (Fig. 7).

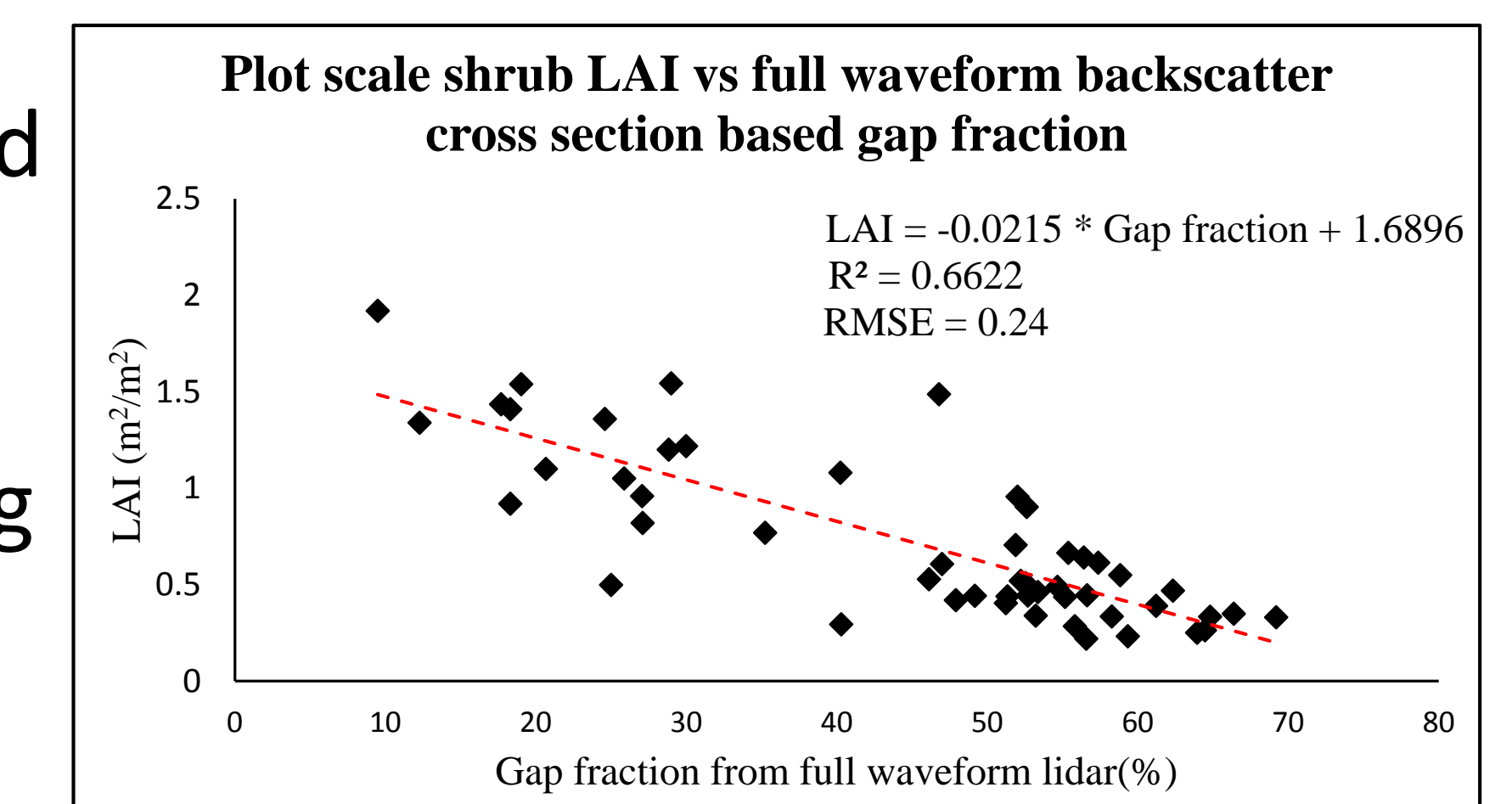


Figure 7. Correlation of waveform derived plot scale gap fraction and field observed LAI

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