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BioSCape **RadSCape**: radiative transfer simulation and validation of the dynamic structural and spectral properties of the vegetation of the Cape

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High Level Project Overview

Objectives

- Investigate the ***spectral and spatial dependencies*** in this complex ecosystem, using simulation, validated with real AVIRIS | LVIS data
- Evaluate our ability to ***assess post-fire biodiversity recovery*** using real data and simulated approaches
- Identify ***next-gen systems*** for assessment of such low-stature, biodiverse systems

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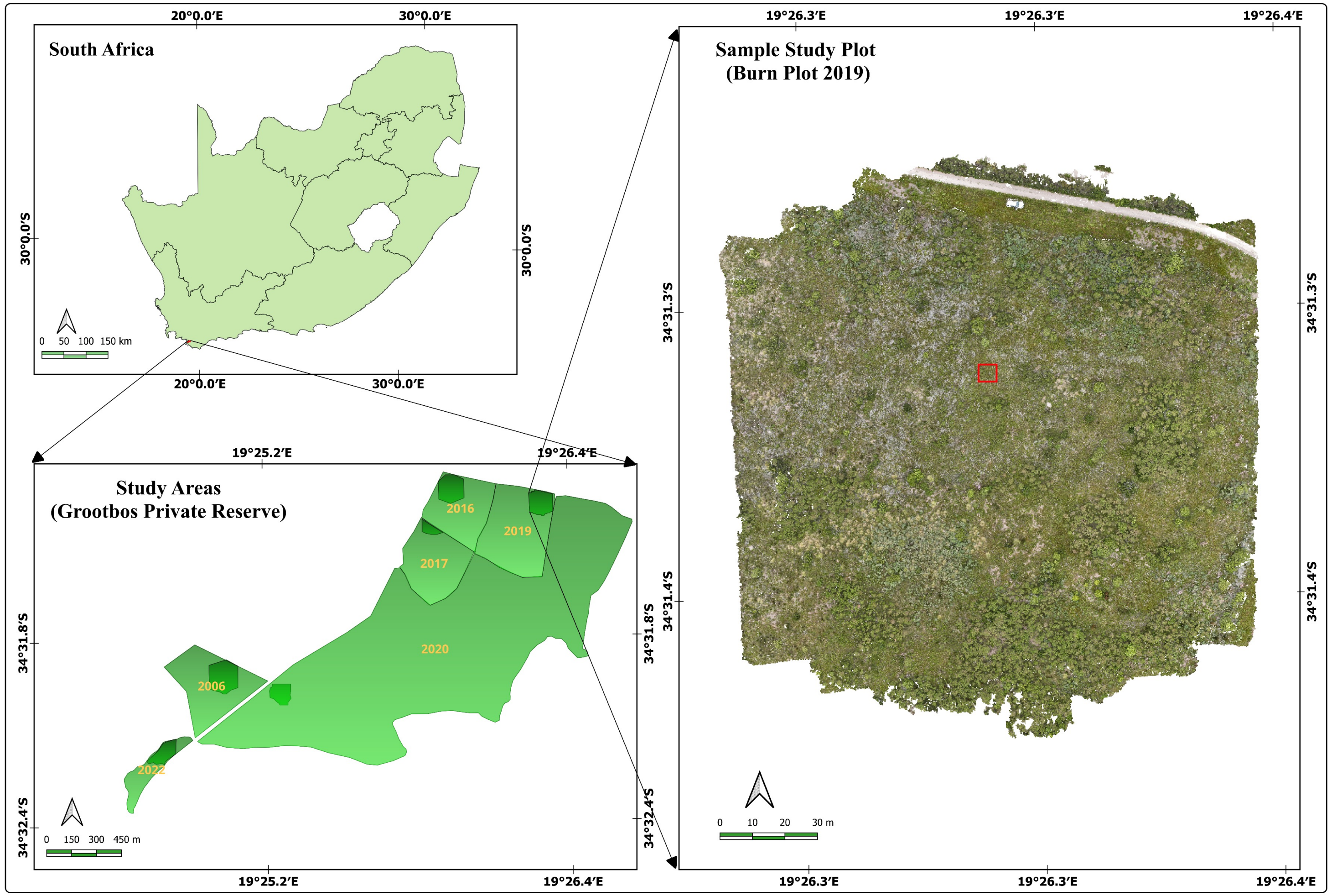
Study area



(***left***) Grootbos Private Reserve, South Africa; (***right***) one of six study sites (burn-year = 2019). The red square in the figure shows the location of reference plot (5m x 5m)

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Our approach – i) drone data (4-band & SfM)

Initially used high-res (2.5cm) 4-band drone data to ***assess spectral & structural differences between burn years***

Results - spectral feature selection & ML

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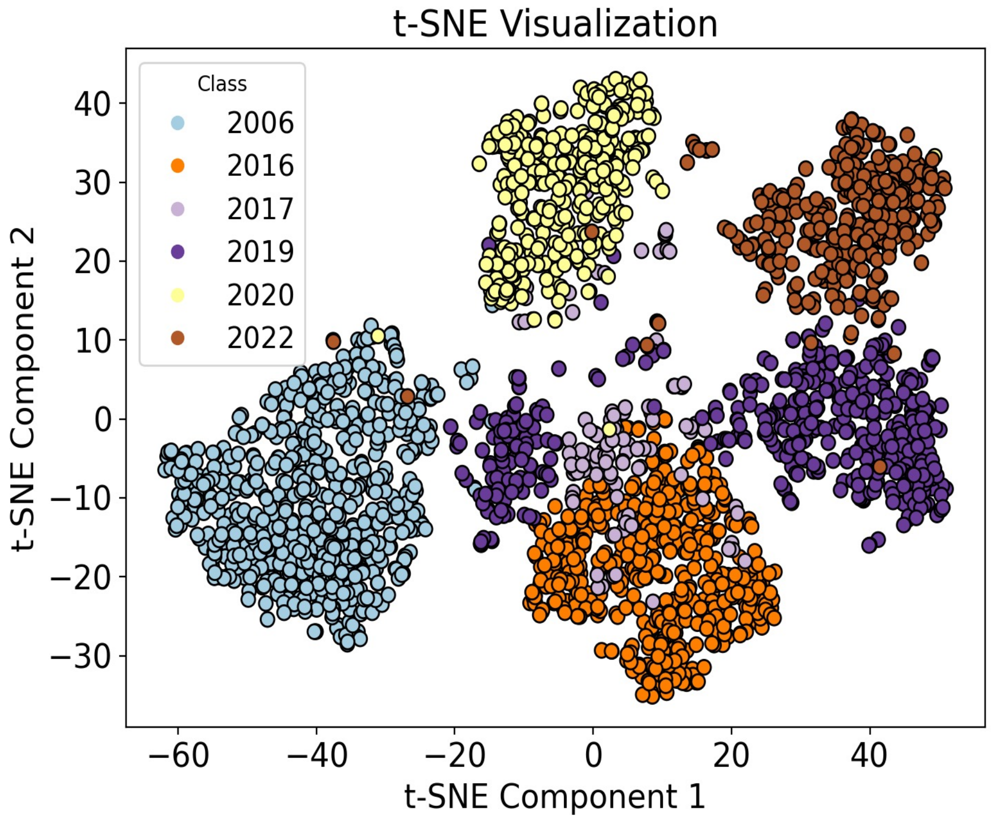
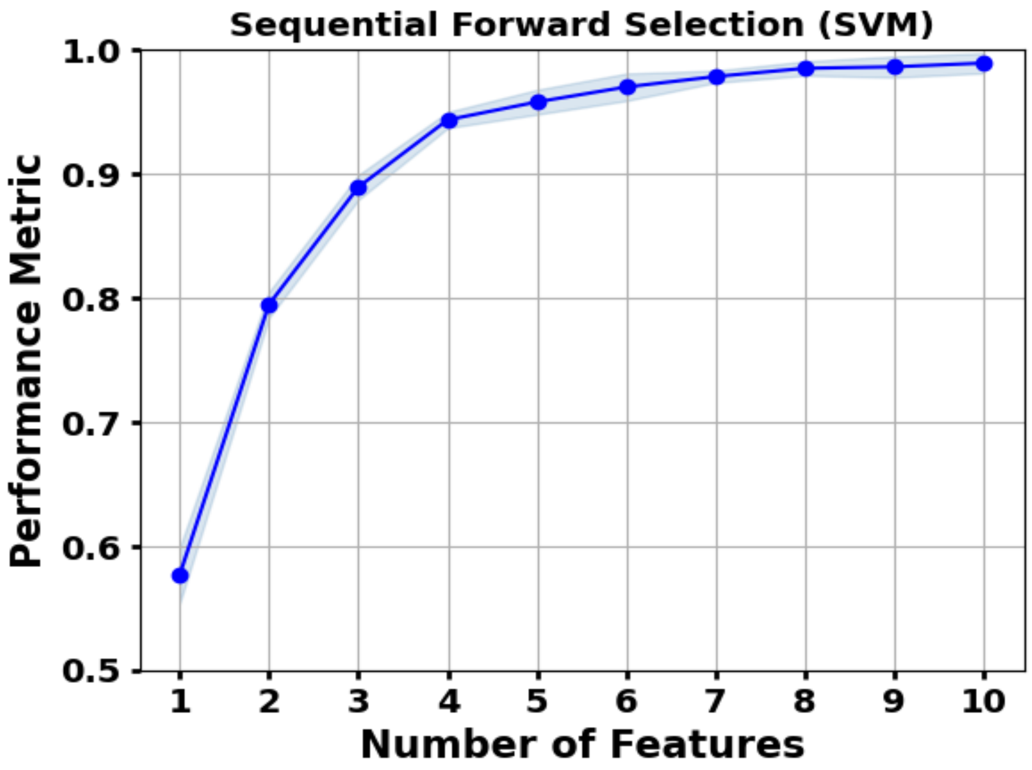


t-SNE plot used to visualize high-dimensional features of fynbos images by reducing it to a low-dimensional feature space to see different burned area clusters



- ***Spectral***: Mean of NIR, CV-of-RE, mean-of-CVI, CV-of-LCI, CV-of-Ratio1
- ***Texture***: Mean of dissimilarity Red band, mean of homogeneity NIR band

Results – spectral alpha-diversity mapping

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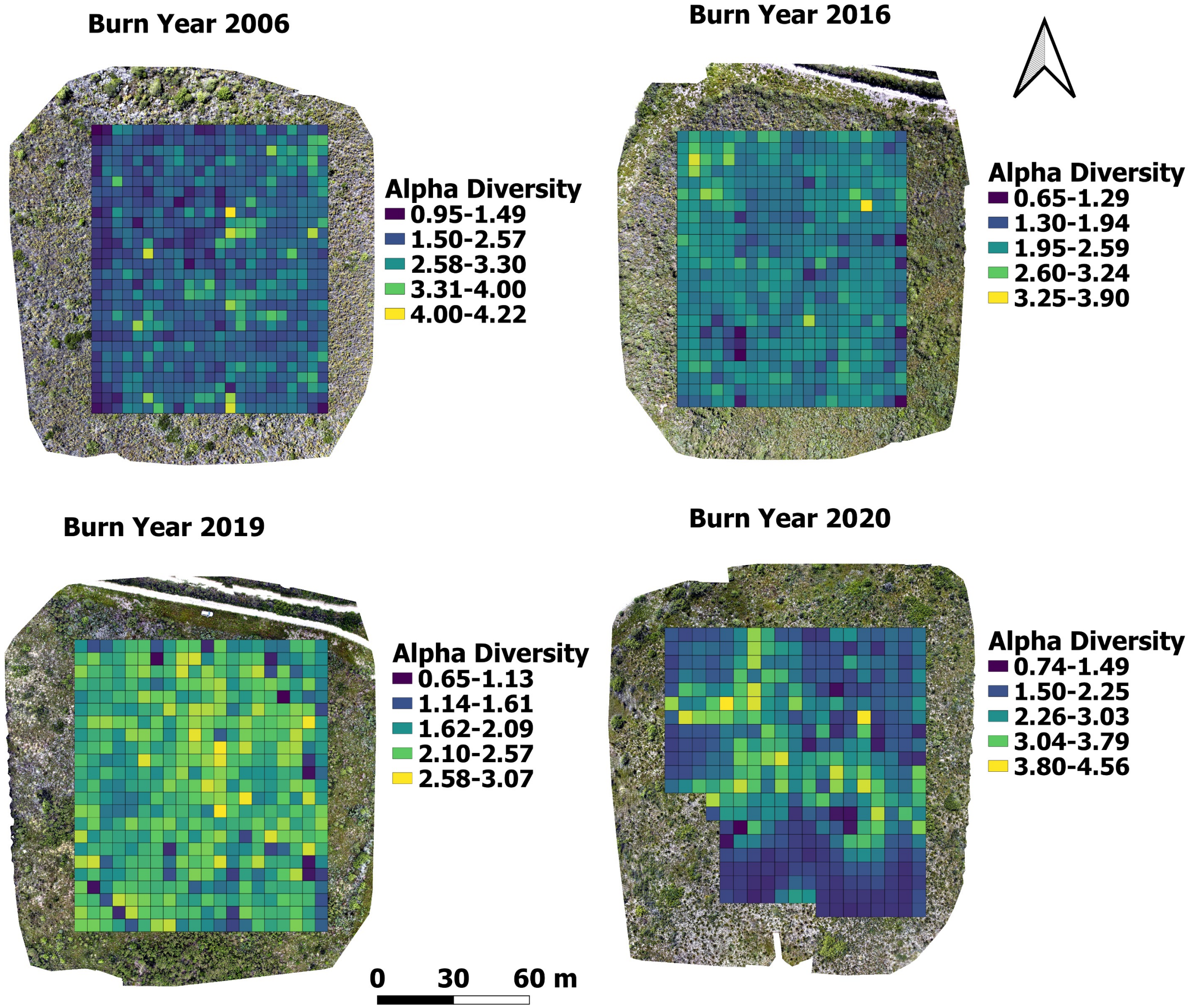

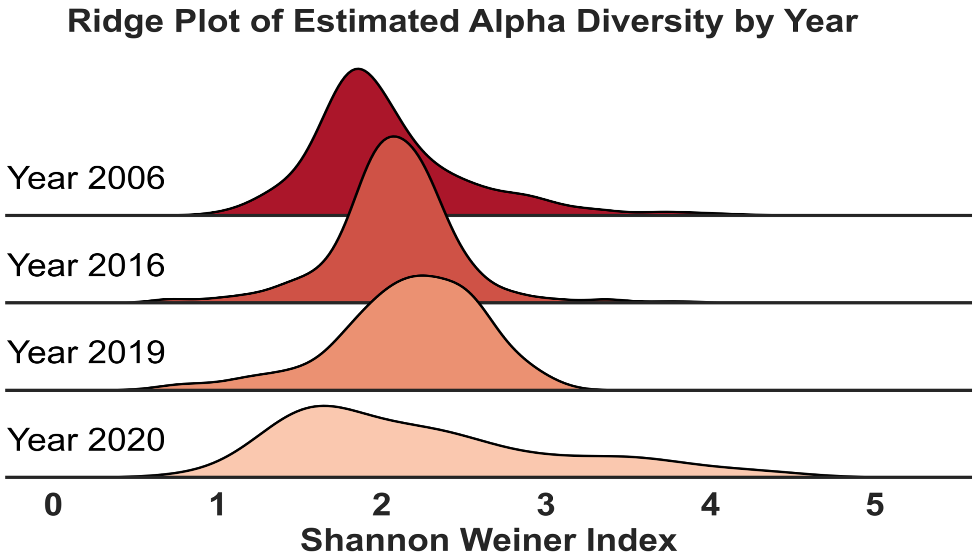

- Alpha-diversity tends to decrease in old Fynbos (2006, 2016) vs. young fynbos sites (2019,2020)
- Post-fire succession is characterized by a gradual reduction in species richness, indicating a decline in biodiversity as the ecosystem ages

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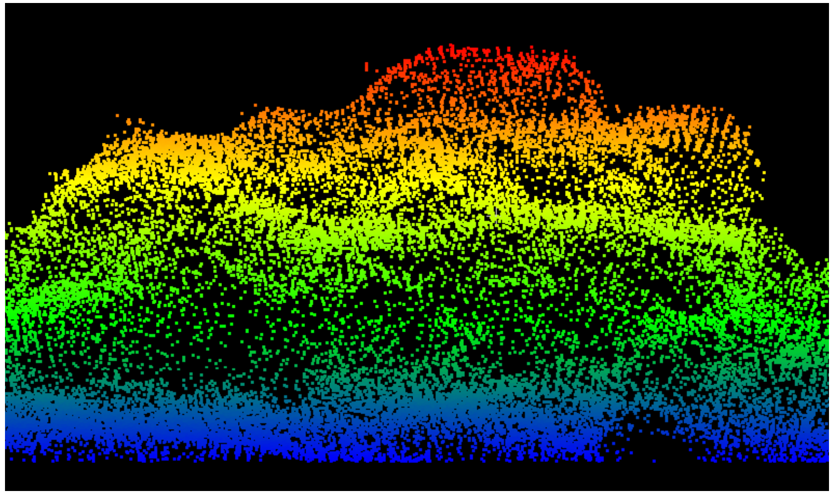
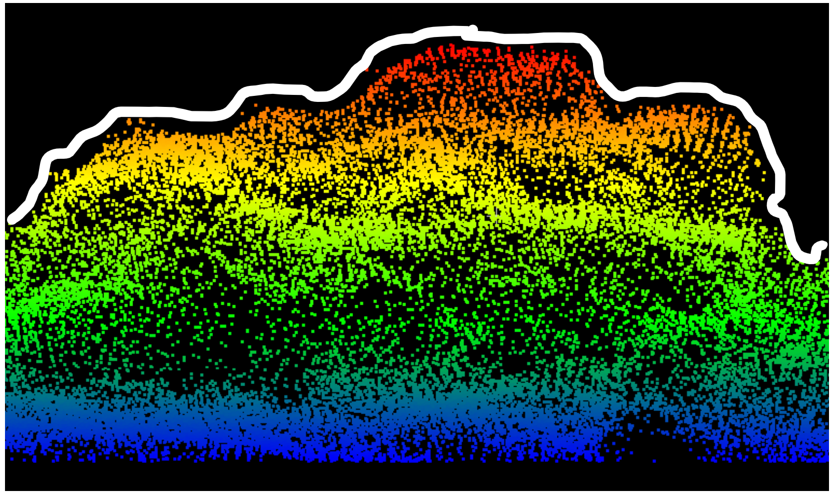
Results – structural features

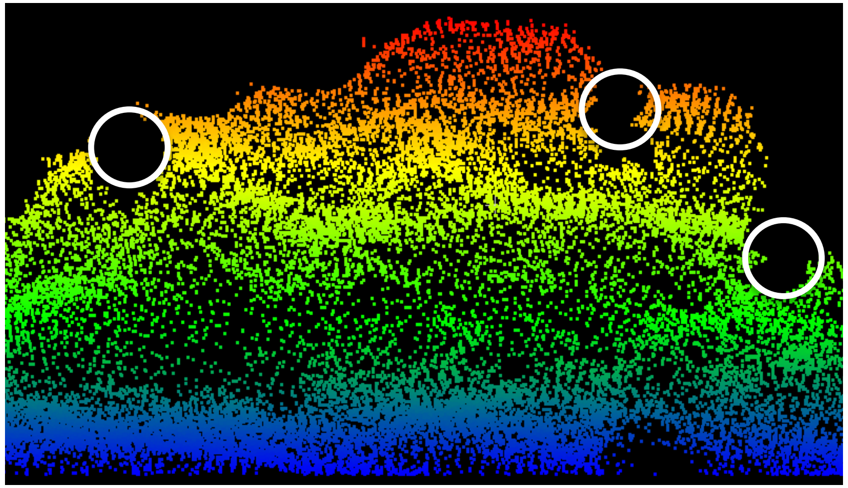
Mean Height



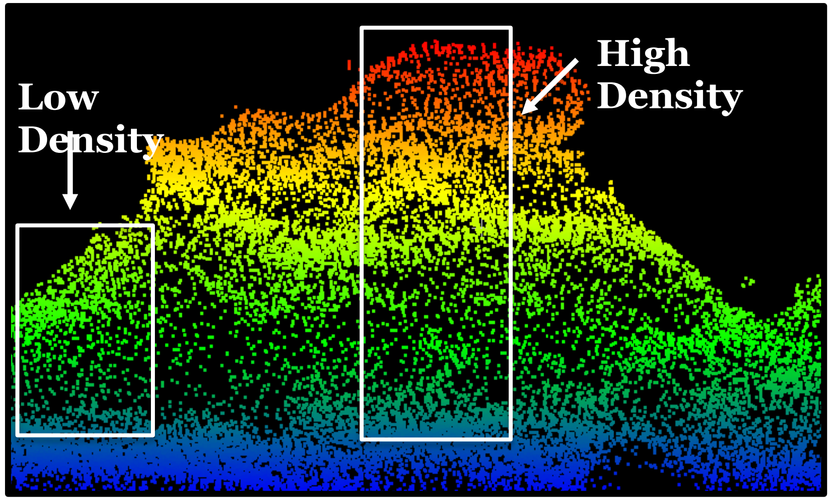
Canopy Height



Top Rugosity

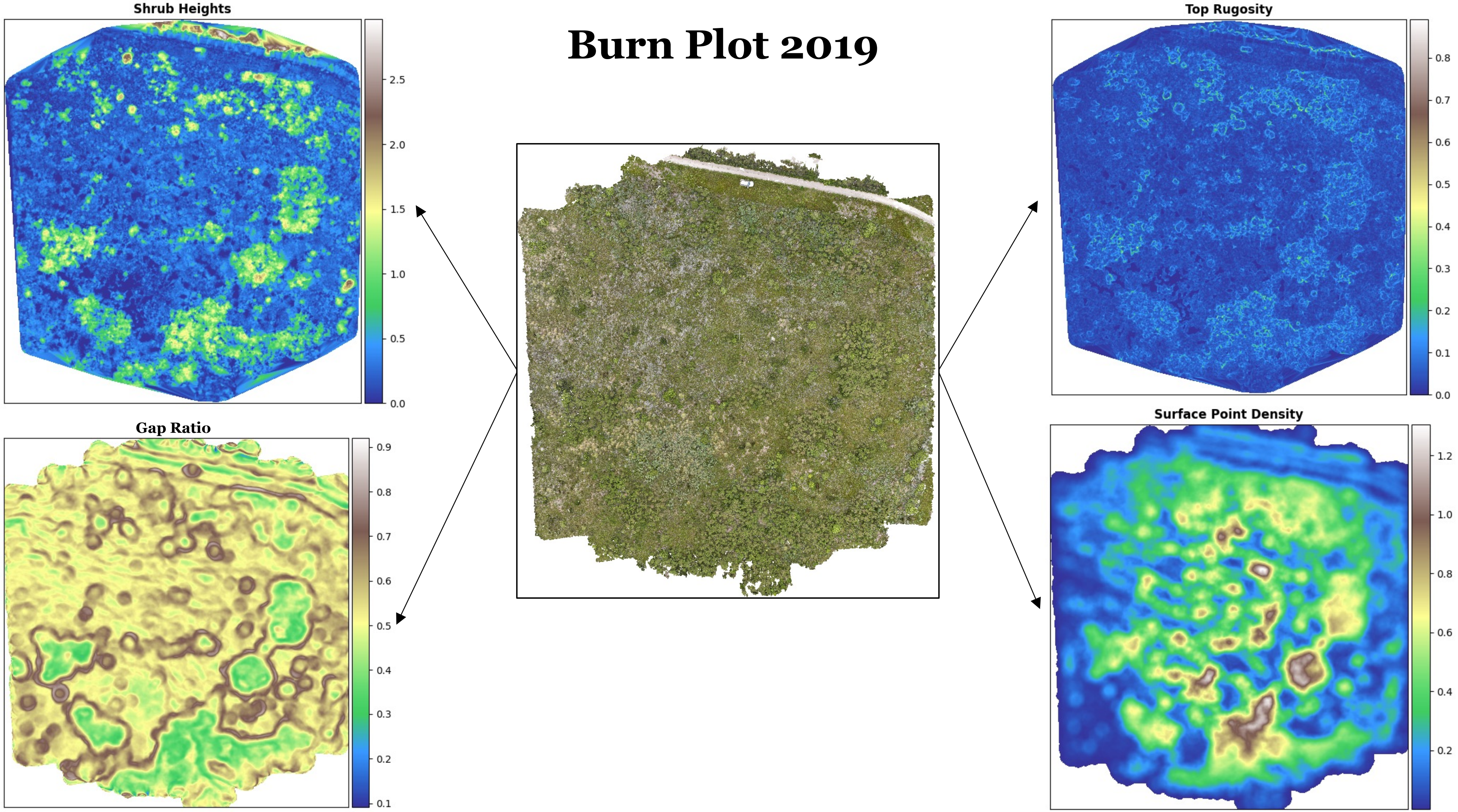


Surface Gaps



Surface Point Density

Results – structural features



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Results – structural features

Burn year prediction results

Classifiers	Burn Year Prediction on Test Data (429 samples) [F1-Scores]						Overall Accuracy
	2006	2016	2017	2019	2020	2022	
Random Forest	1.00	0.85	0.60	0.78	0.78	0.83	85%
1D CNN	1.00	0.82	0.54	0.74	0.75	0.81	83%
SVM	1.00	0.80	0.56	0.76	0.80	0.80	83%
KNN	1.00	0.80	0.56	0.78	0.77	0.74	82%
Naïve Bayes	1.00	0.76	0.50	0.72	0.79	0.78	81%
Des-Tree	1.00	0.75	0.44	0.72	0.73	0.72	80%

Easiest to predict

Difficult to predict

- We **predicted the burn year** of unseen subplots by training few classifiers, using "*burn year*" as label and four structural metrics as features
- **SMOTE** *(Synthetic Minority Oversampling Technique)* was used to generate samples for the minority class during training
- Most of the **confusion in classification** was found between burn **year 2016 vs. 2017** and **year 2019 vs. 2020**

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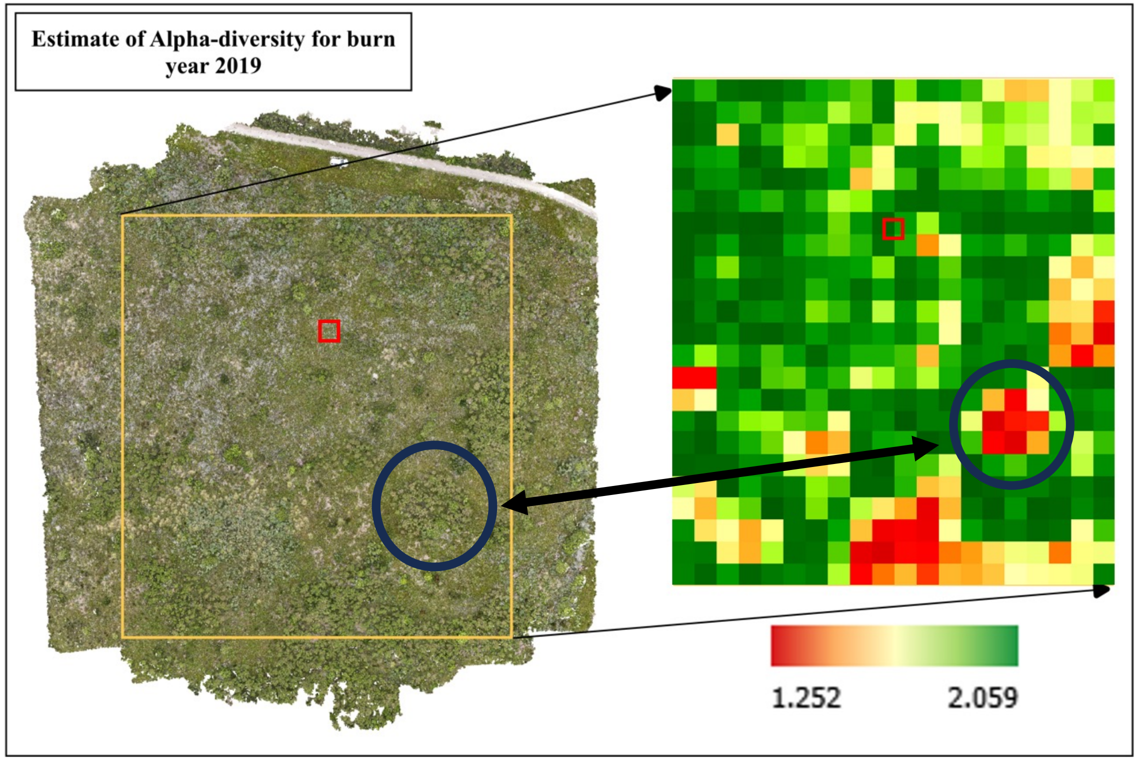
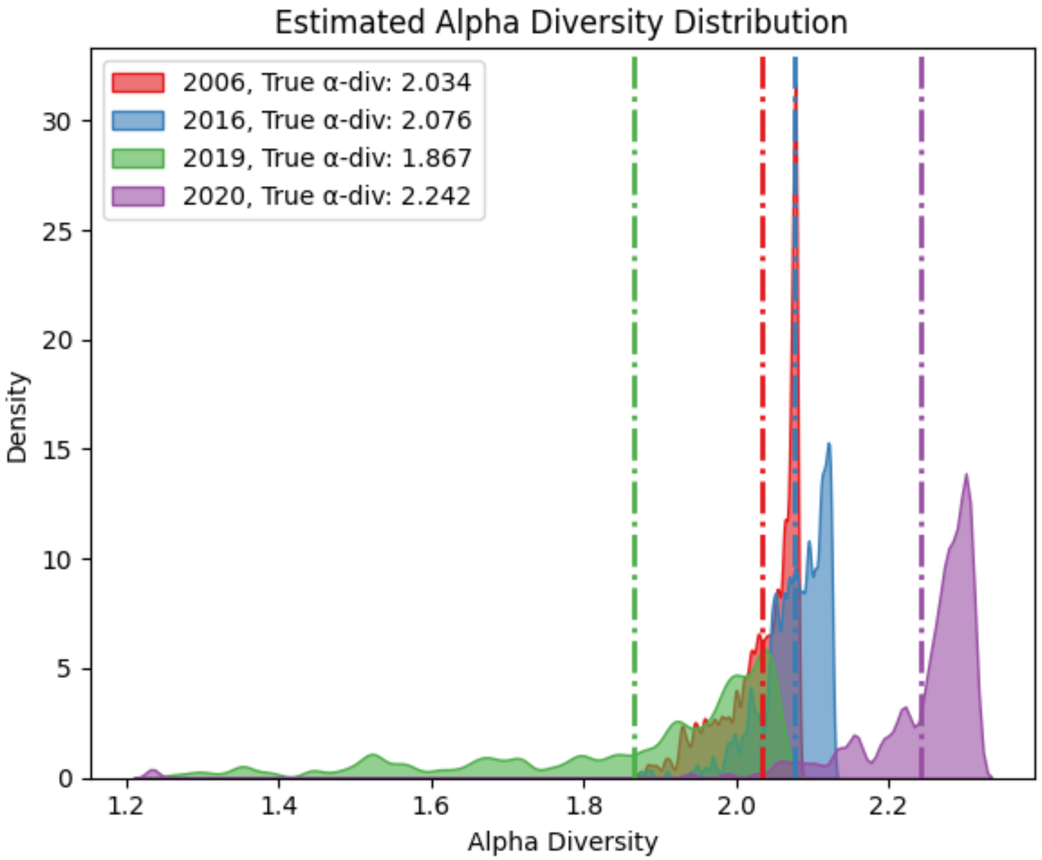
Results – structural features



Alpha-Diversity for burn plot 2019



Distribution Of Estimates

Question: "To what extent do the subplots differ structurally from the reference subplot?"

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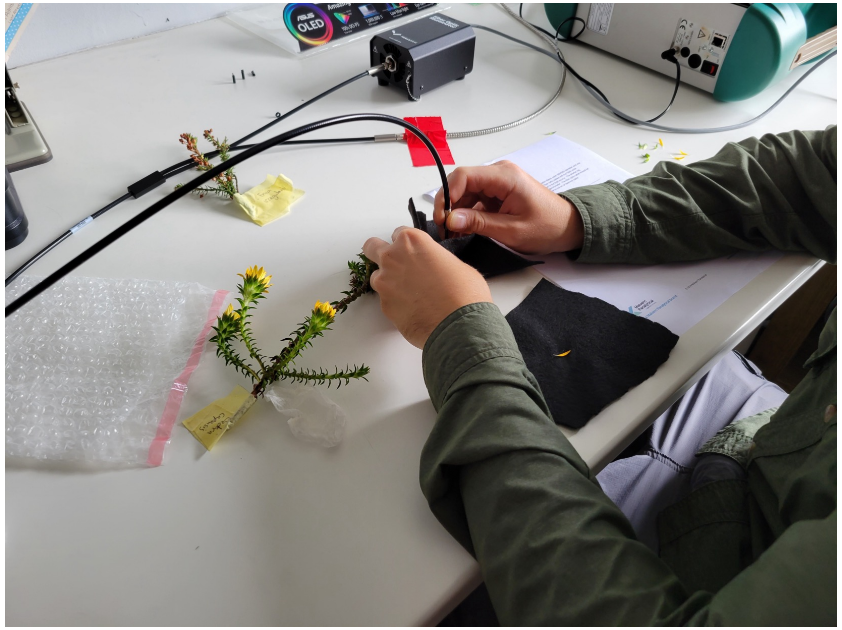
Fynbos DIRSIG Scene Update - 3D Modeled Species

(created by 3D artist)

Spectral Property Attribution

- Field measurements of each species used to fit *PROSPECT* parameters
- *PROSPECT* output includes spectral reflectance and transmittance
- Each species has multiple data files (random instance selection)



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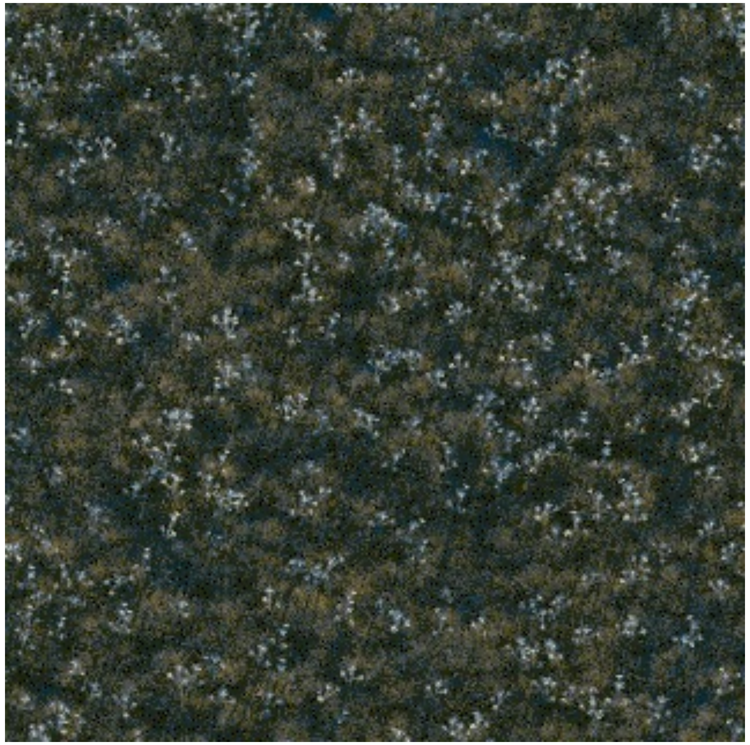
Fynbos DIRSIG Scene Update – scene instantiation



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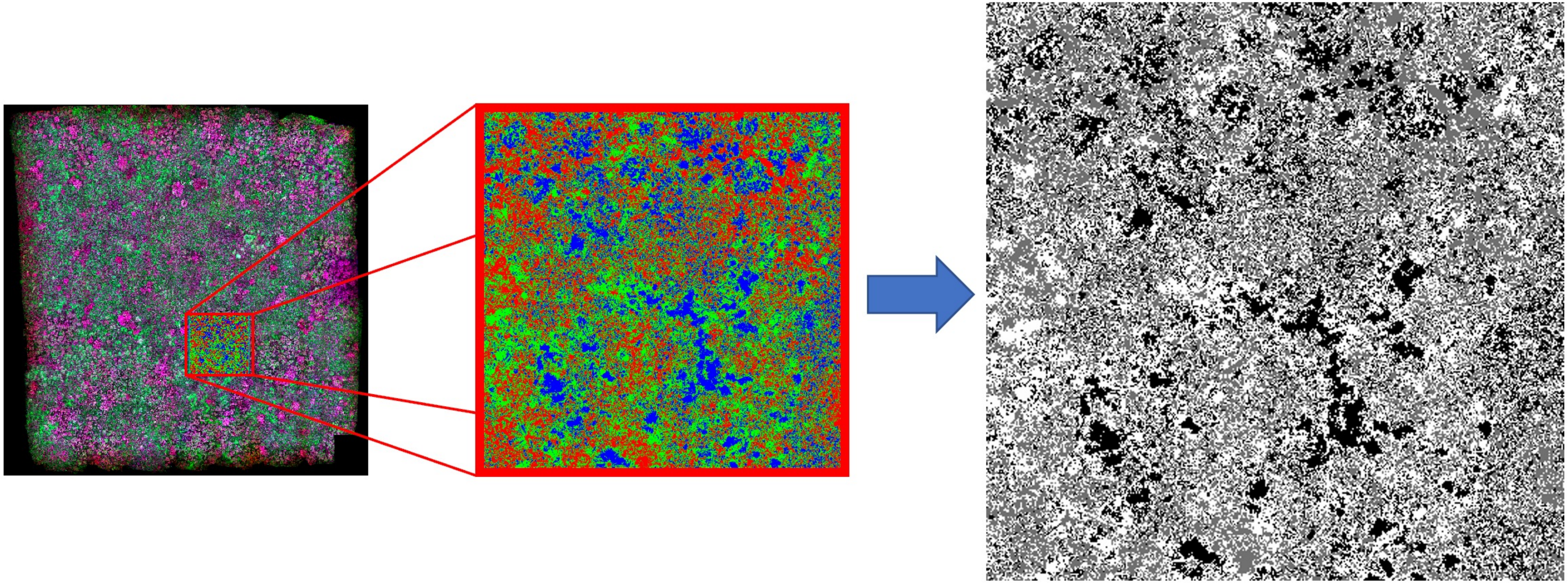
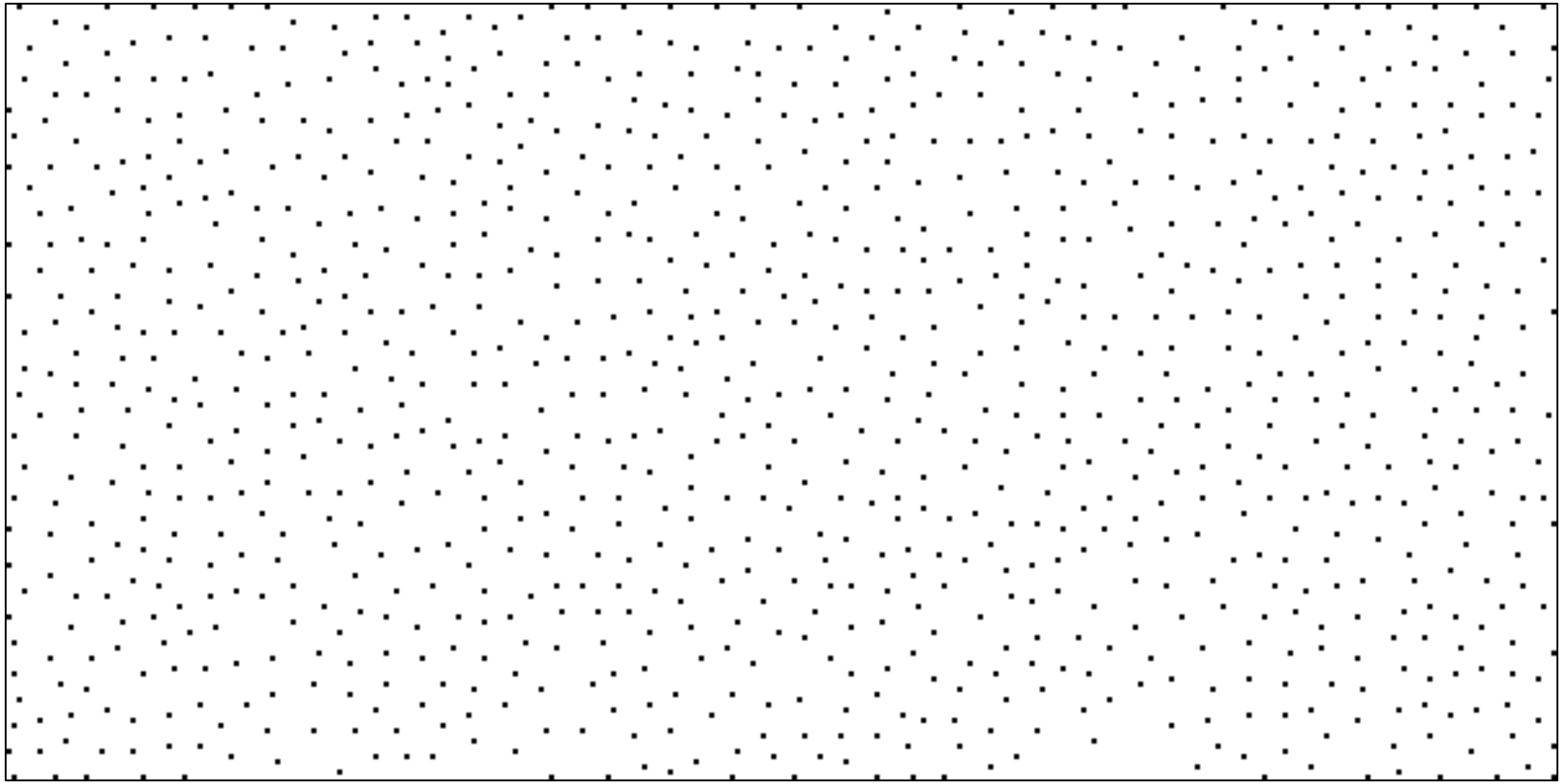
Spatial Patterns from Drone Imagery

- Classification algorithm used to extract general spatial patterns of plant species
- Grayscale image used as a density map



Blue Noise

- Poisson Disc Sampling algorithm used to generate blue noise
- Used to generate natural spatial patterns

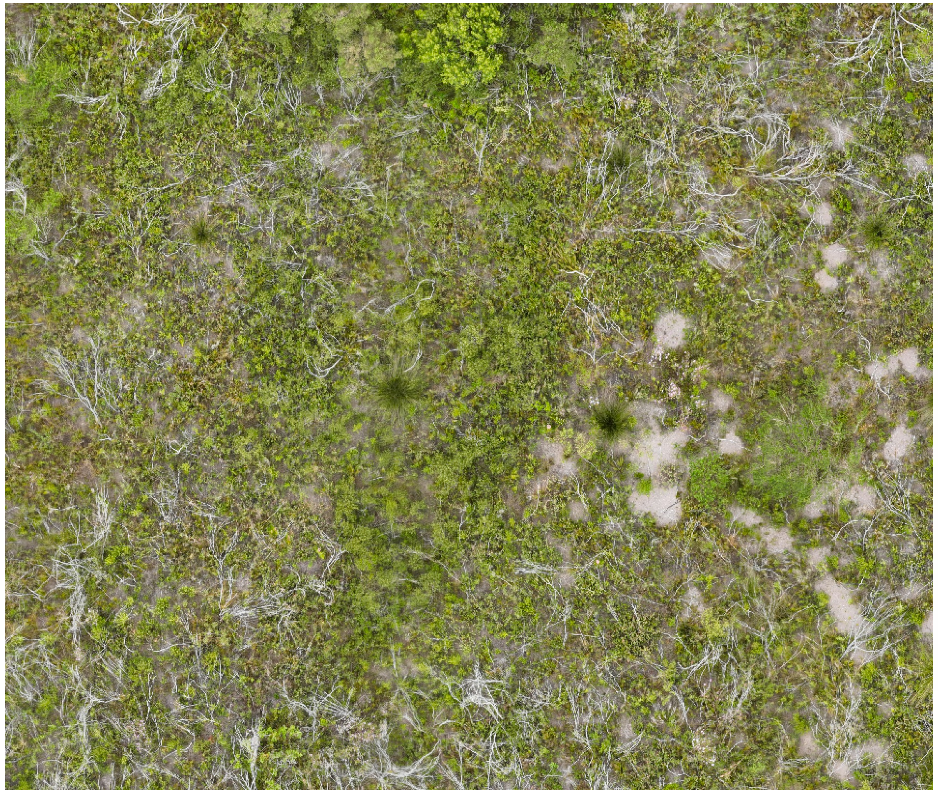


https://a5huynh.github.io/posts/2019/poisson-disk-sampling/

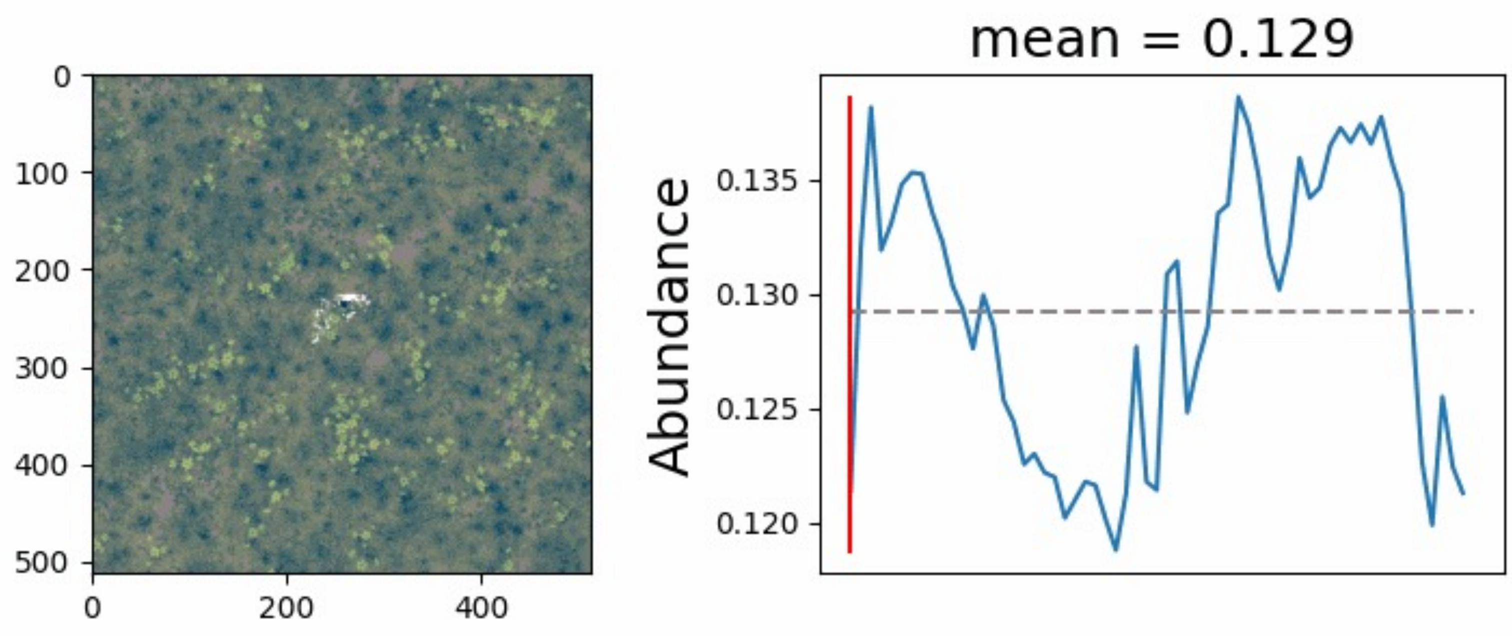
Additional Field Data

- **Data collected in each burn plot was used when instancing each species**
  - Mean diameter
  - Percent cover
- **Unique instances**
  - Random rotations
  - Random scaling
- **Script can generate unique scenes**
  - Any size (computational limitations)
  - “Inspired by” each burn plot

DIRSIG Scene: Ground Abundance Comparison



Drone Image



Ground Abundance
(pixel ratio)

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DIRSIG Scene: Varying Extent

Examples of varying scene extent for 2019 burn plot

10m x 10m

20m x 20m

30m x 30m

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Next steps

- Validation with real AVIRIS & LVIS data
- Evaluation of spectral-structural dependencies
- Assessing that "ideal" sensing system for such highly diverse, complex systems

BIOSCAPE
Biodiversity Survey of the Cape