Incorporatipon of Airborne Lidar-Derived Products into the Forest Planning and Monitoring Process.

---Project Level Applications---

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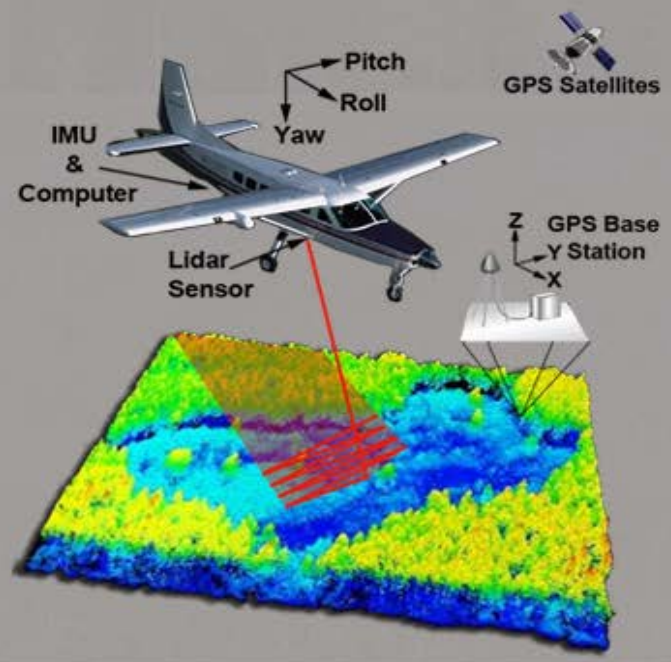
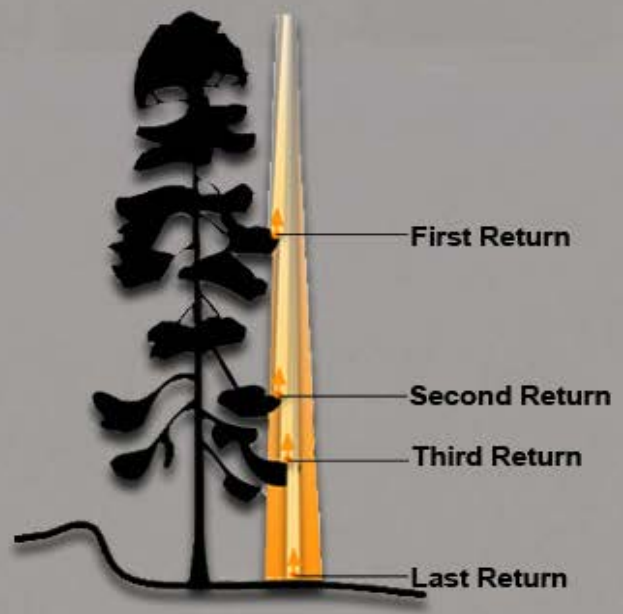
Airborne Lidar – How it Works

- Active Remote Sensing Technology
  - Directly Measures Locations Across the Landscape
- Types of Airborne Lidar Data
  - Discrete-Return
  - Full-Waveform
  - New Types Being Developed





Airborne Discrete-Return Lidar

- Small Footprint
- Accuracy

40121G2325

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	GPSTime	X	Y	Z	Intensity	ReturnNur	NumRetur	Class	ScanDirect	ScanAngle	GPSWeek	FlightLine	
2	508386.3	653013.1	4512603	1848.78	160	1	1	1	0	-10	1542	31	
3	508386.3	653013.1	4512604	1848.78	128	1	1	1	0	-10	1542	31	
4	508386.3	653013	4512604	1848.91	74	1	1	1	0	-10	1542	31	
5	508386.3	653013	4512605	1848.78	128	1	1	1	0	-10	1542	31	
6	508386.3	653012.9	4512605	1848.77	133	1	1	1	0	-10	1542	31	
7	508386.3	653012.9	4512605	1848.79	133	1	1	1	0	-10	1542	31	
8	508386.3	653012.8	4512606	1848.8	116	1	1	1	0	-10	1542	31	
9	508386.3	653012.8	4512606	1848.8	108	1	1	1	0	-10	1542	31	
10	508386.3	653012.7	4512606	1848.8	124	1	1	2	0	-10	1542	31	
11	508386.3	653012.7	4512607	1848.87	129	1	1	1	0	-10	1542	31	
12	508386.3	653012.7	4512607	1849.34	128	1	1	1	0	-10	1542	31	
13	508386.3	653012.7	4512607	1850.05	121	1	1	1	0	-10	1542	31	
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17	508386.3	653012.6	4512606	1848.83	114	1	1	1	1	-10	1542	31	
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19	508386.3	653012.7	4512605	1848.81	118	1	1	1	1	-10	1542	31	
20	508386.3	653012.8	4512605	1848.78	124	1	1	1	1	-10	1542	31	
21	508386.3	653012.8	4512604	1848.86	98	1	1	1	1	-10	1542	31	
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23	508386.3	653012.9	4512604	1848.87	150	1	1	1	1	-10	1542	31	
24	508386.3	653013	4512603	1848.88	163	1	1	1	1	-10	1542	31	
25	508386.3	653013	4512603	1848.88	169	1	1	1	1	-10	1542	31	
26	508386.3	653013.1	4512603	1848.84	158	1	1	1	1	-10	1542	31	
27	508386.3	653013.1	4512602	1848.63	116	1	1	2	1	-10	1542	31	
28	508386.3	653013.1	4512602	1848.63	146	1	1	1	1	-10	1542	31	

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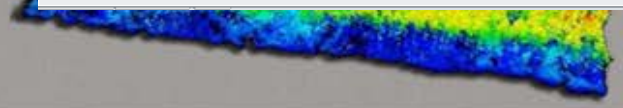
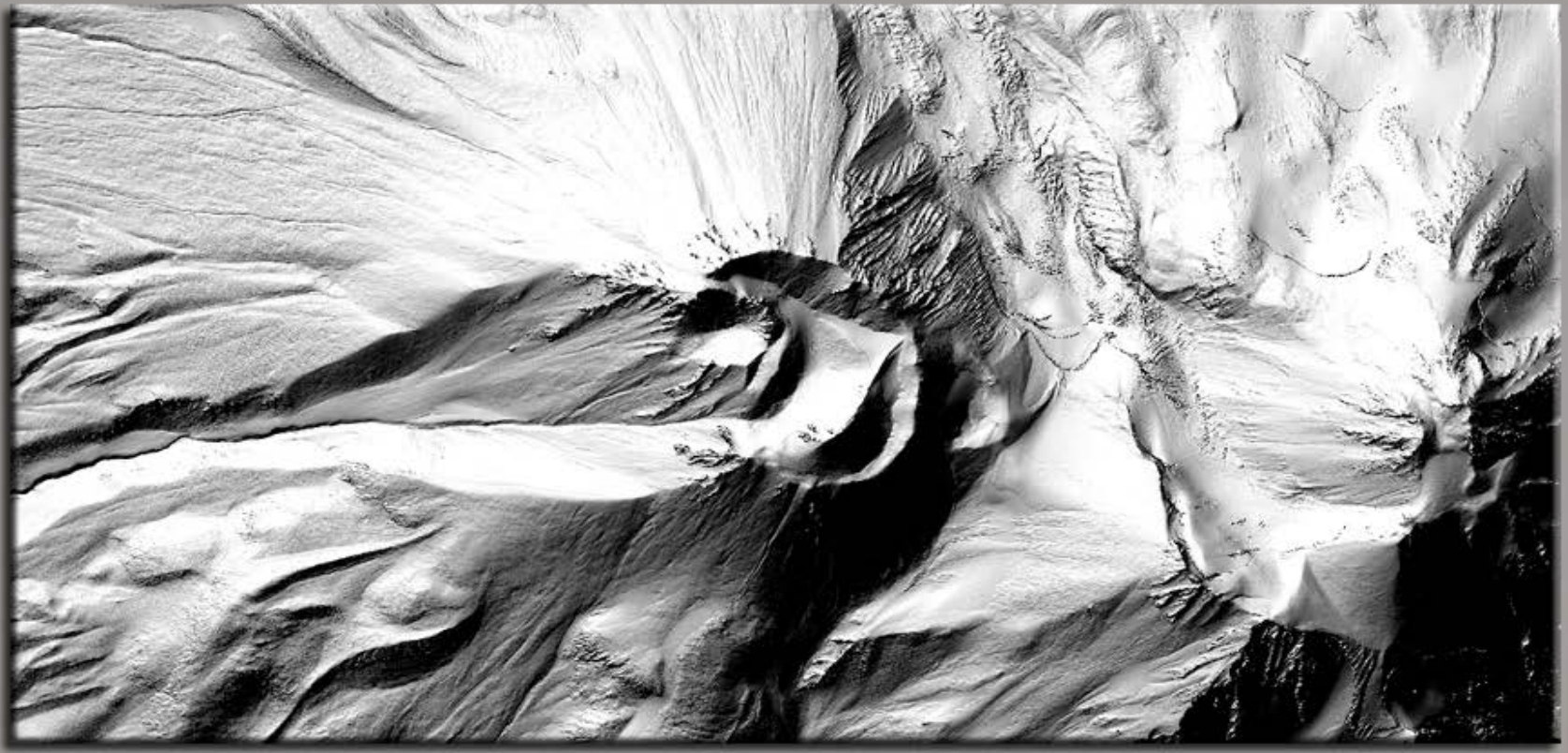


Lidar-Derived Products

- Bare Earth Digital Elevation Model (DEM)
  - ~1m Resolution



Lidar-Derived Products

- Bare Earth Digital Elevation Model (DEM)
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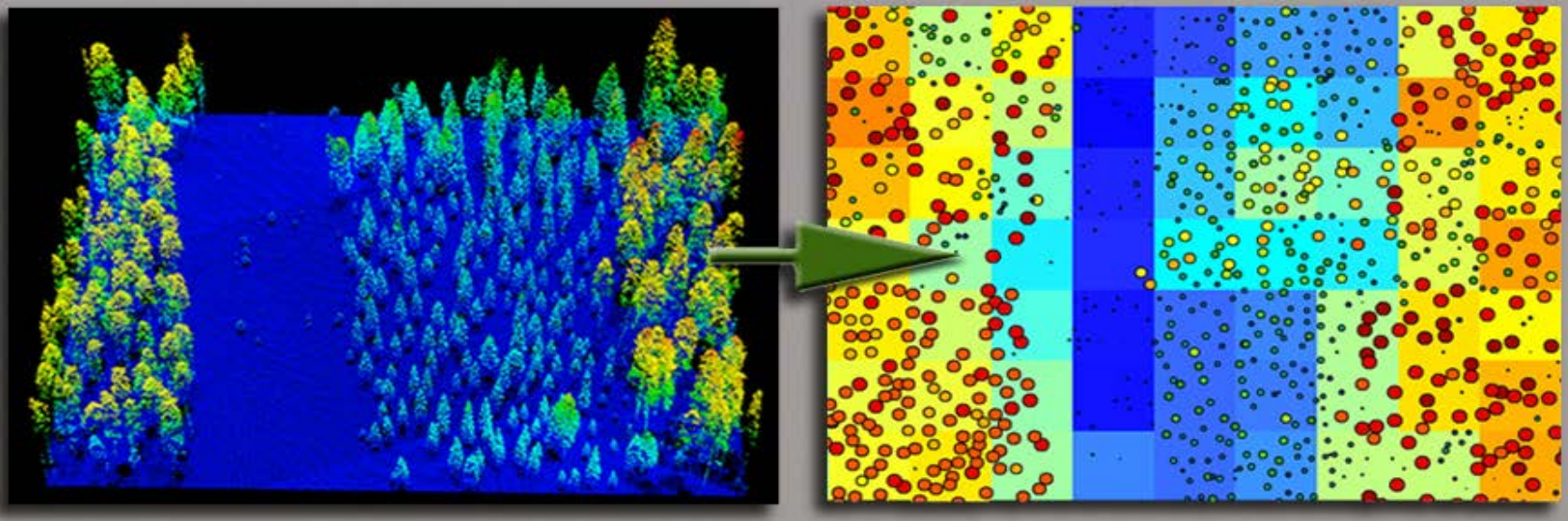
- Individual-Tree Based
  - Locate and Measure Individual Trees
- Area- or Plot-Based
  - Relate Field-Measured Metrics to Lidar Metrics



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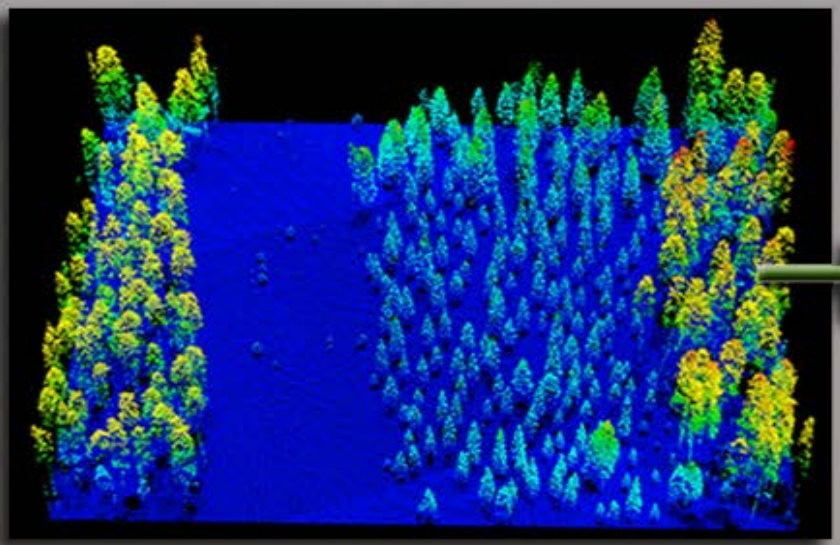
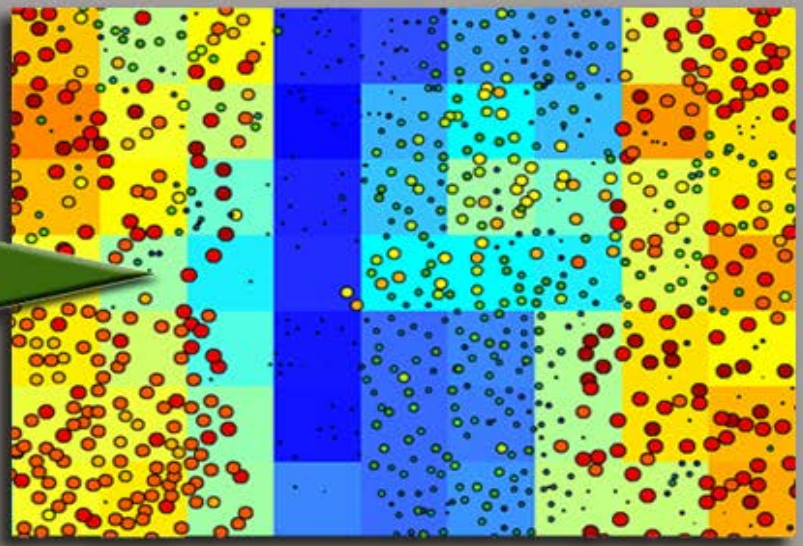
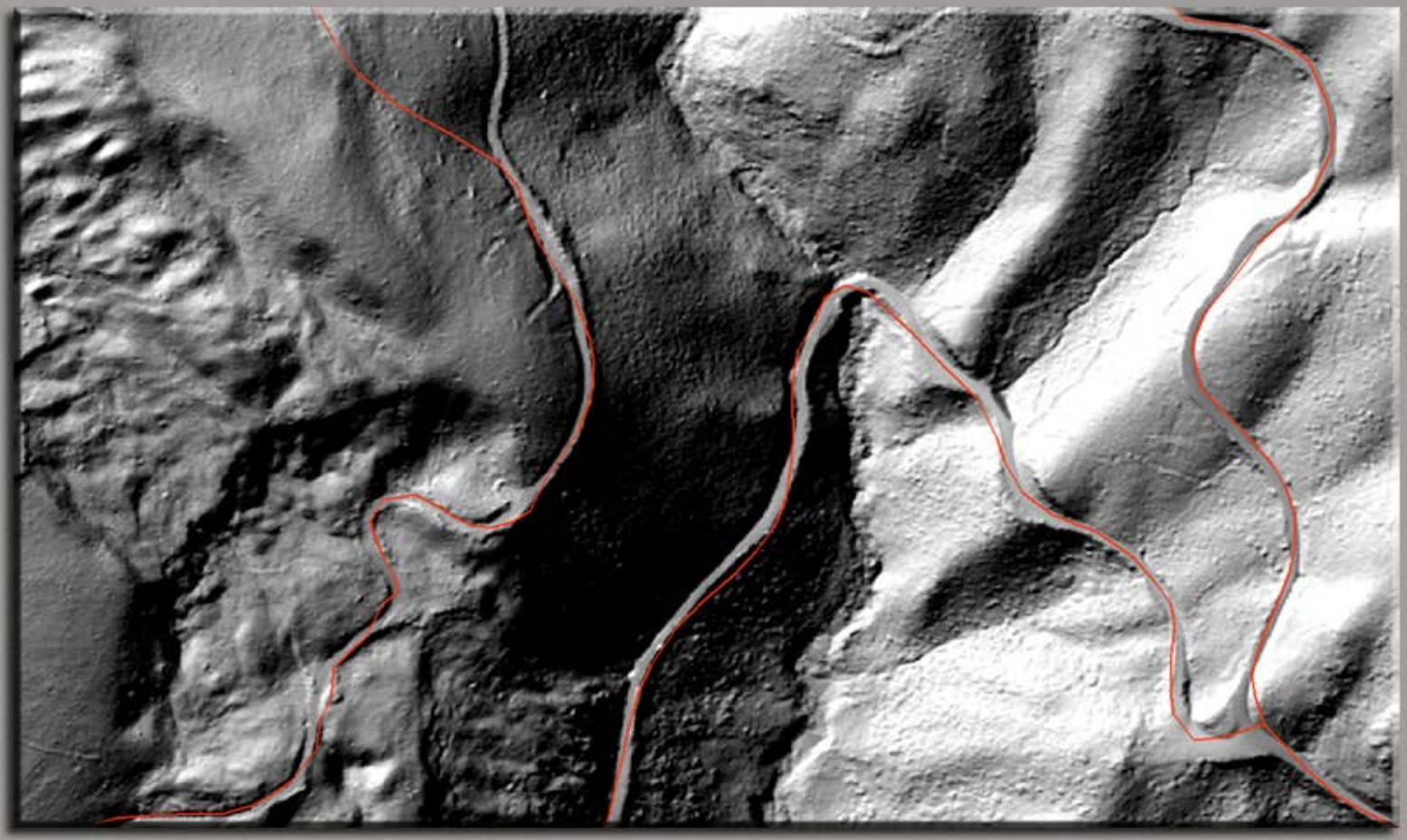




DEM Utilization – Roads



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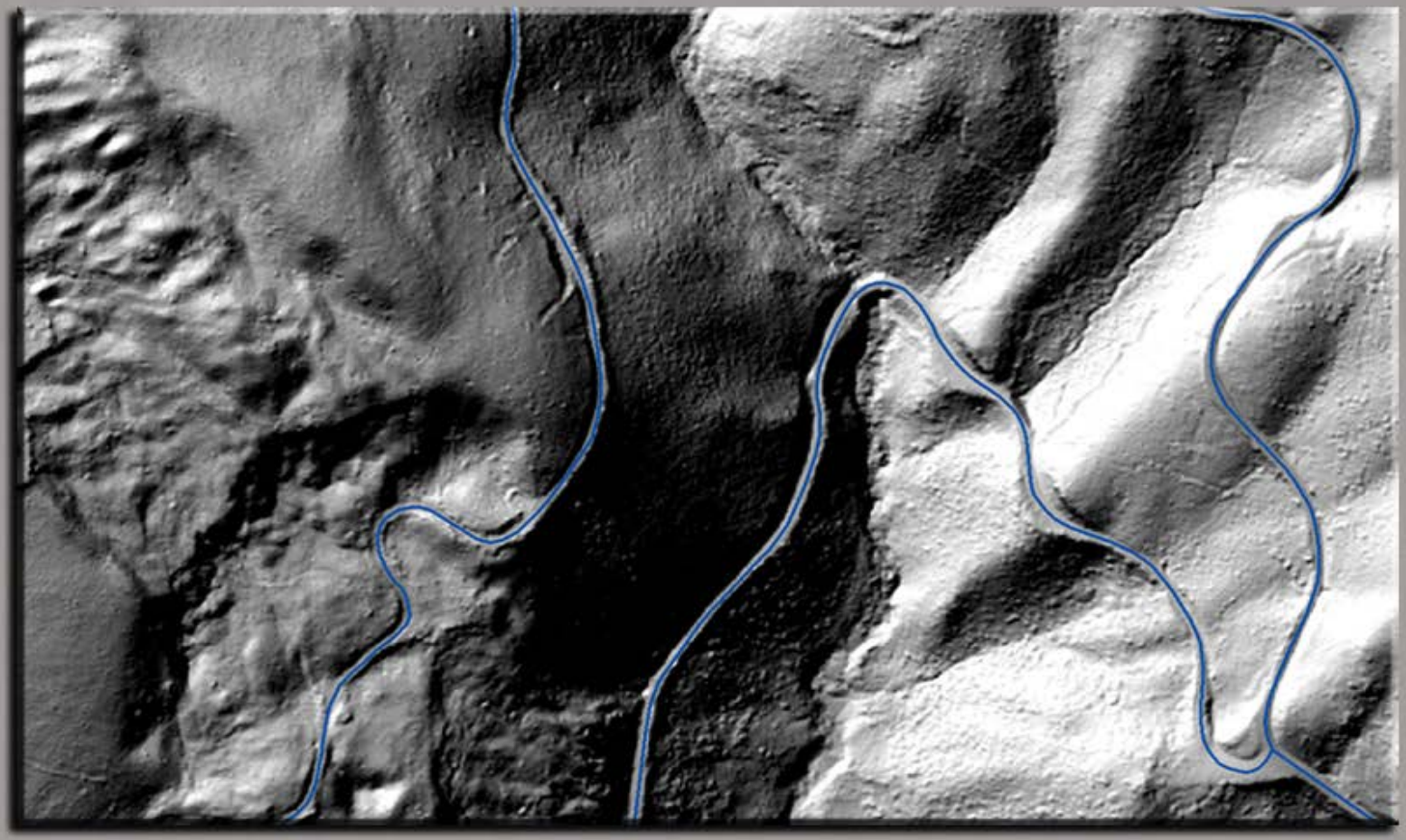
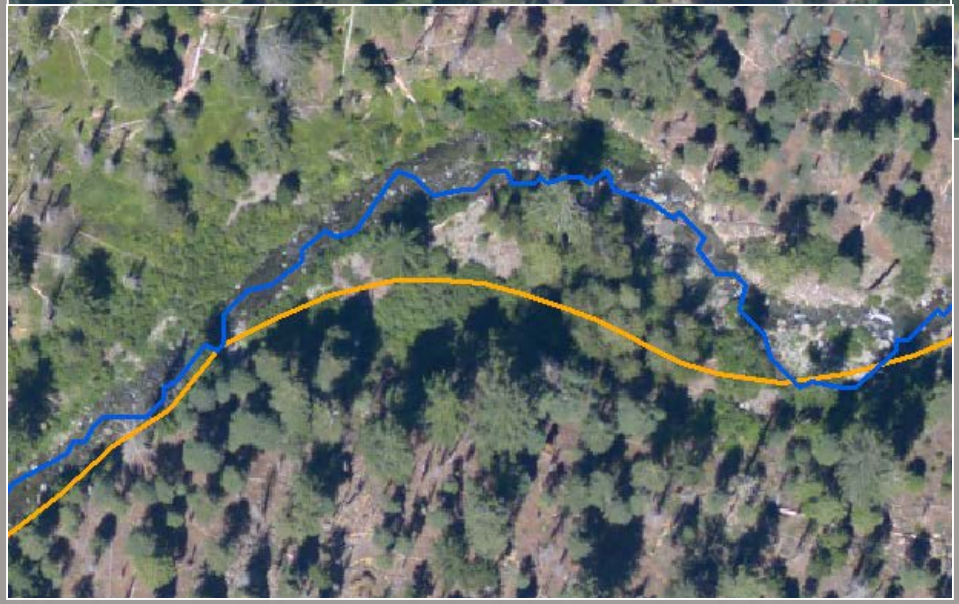


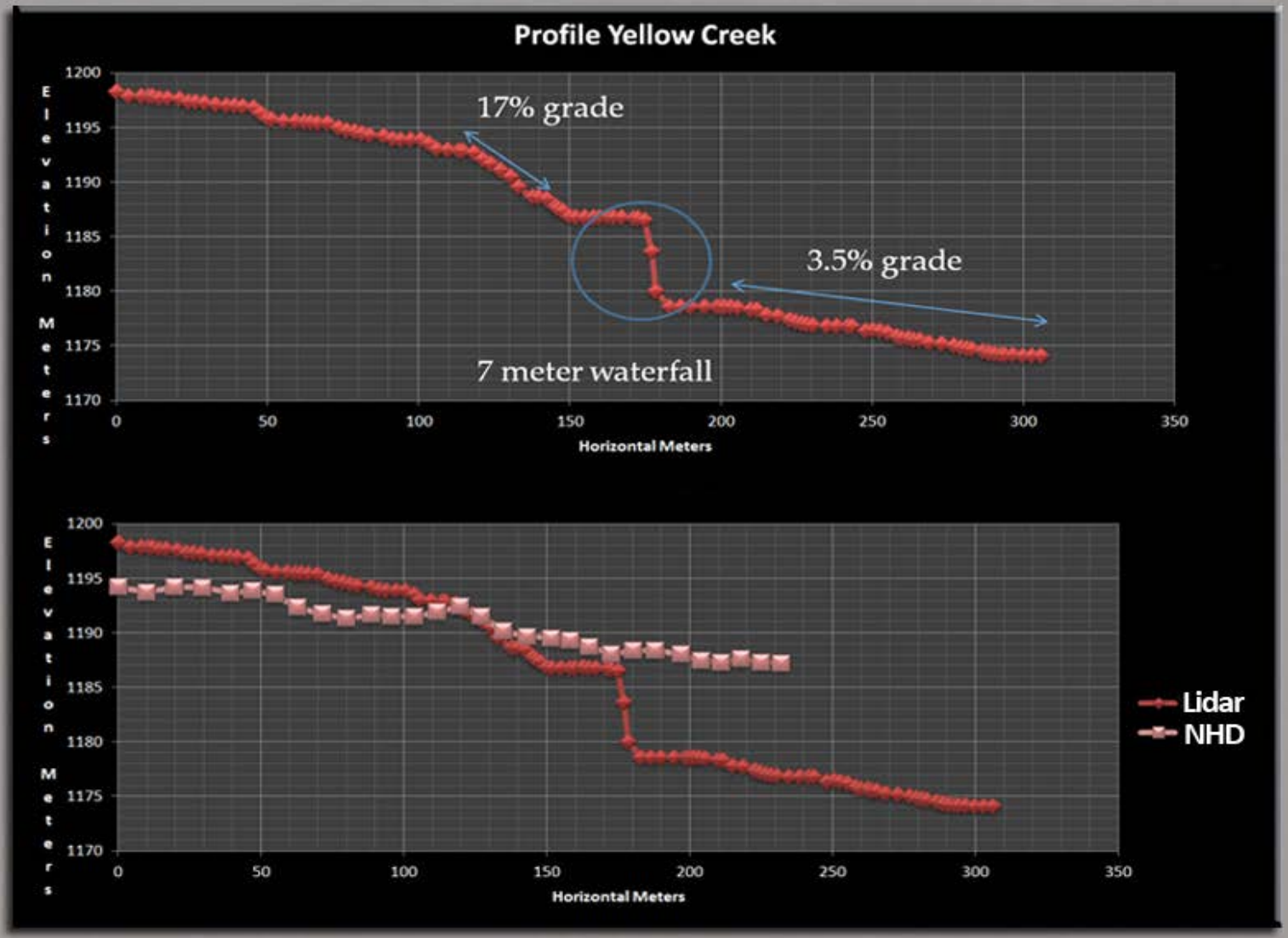
DEM Utilization – Stream Classification



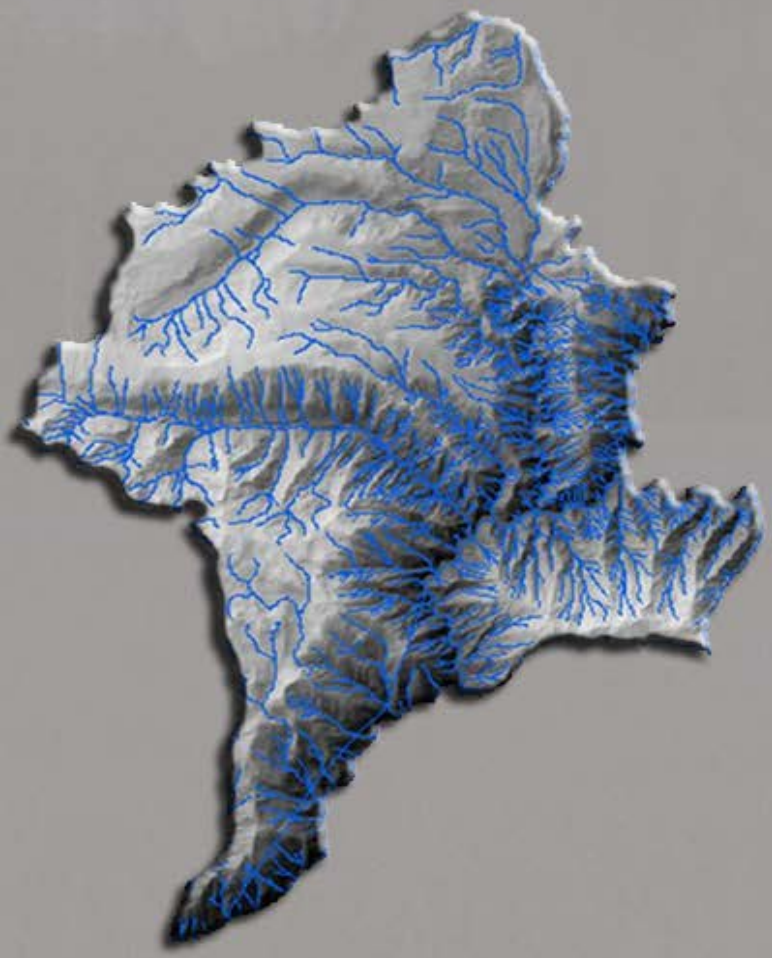
Blue: Lidar-derived

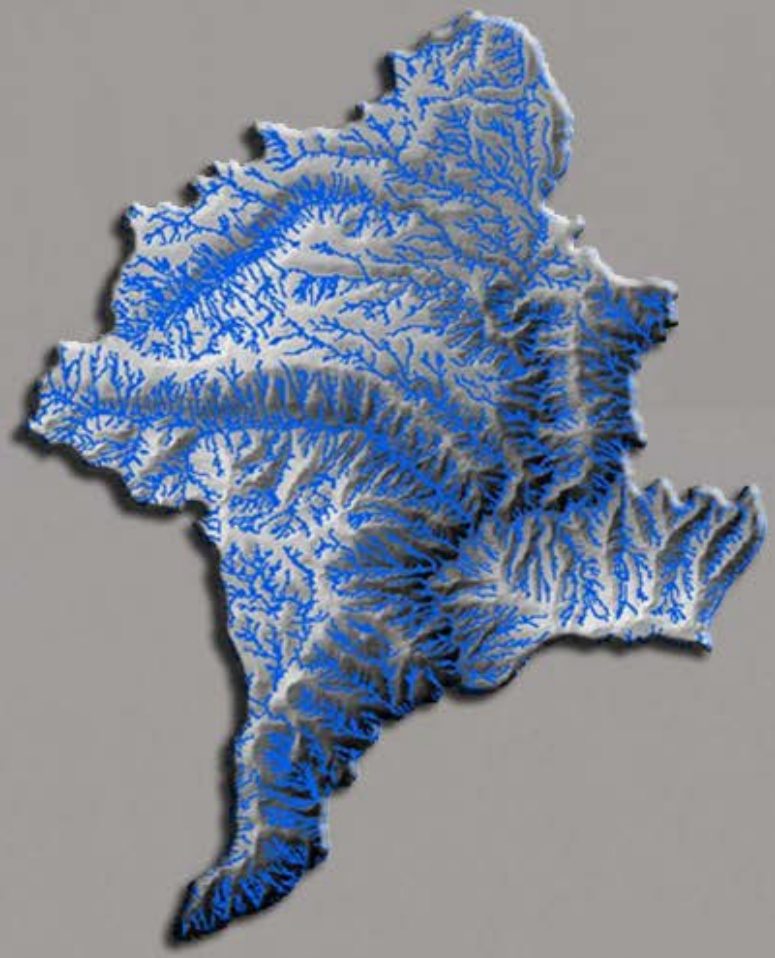
Orange: National Hydrography Dataset (NHD)

DEM Utilization – Stream Profiles



DEM Utilization – Hydrology





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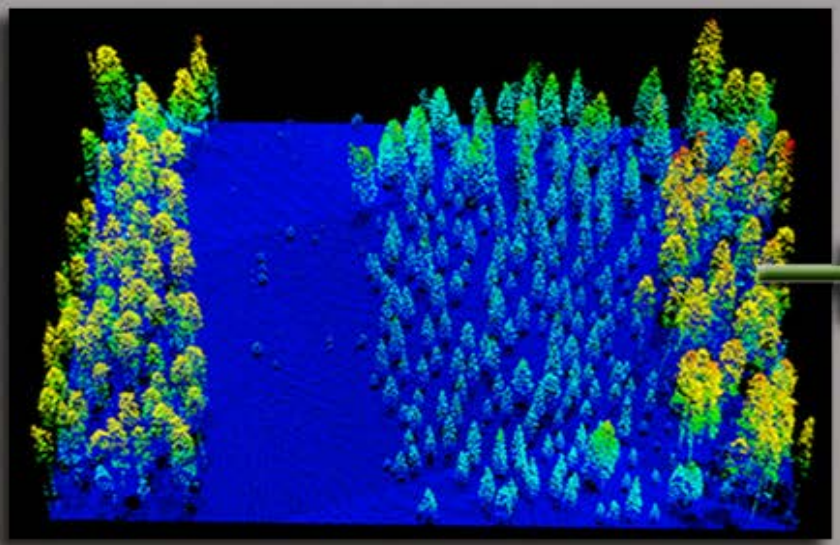
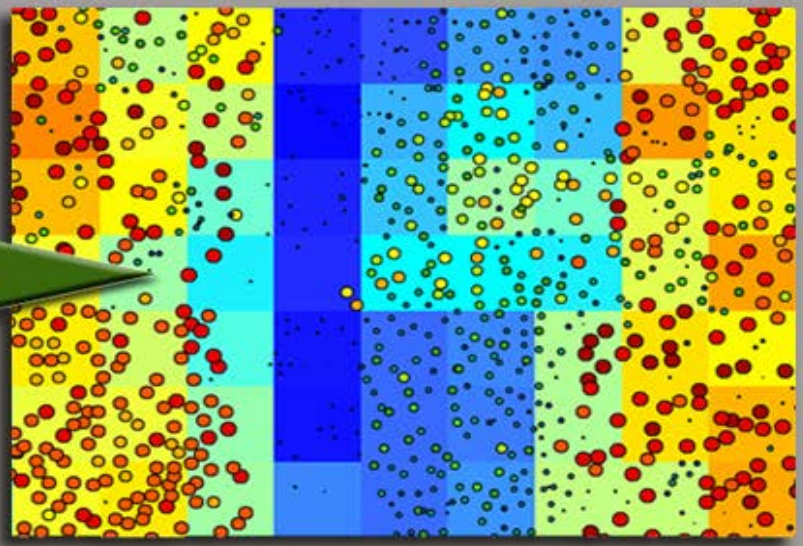
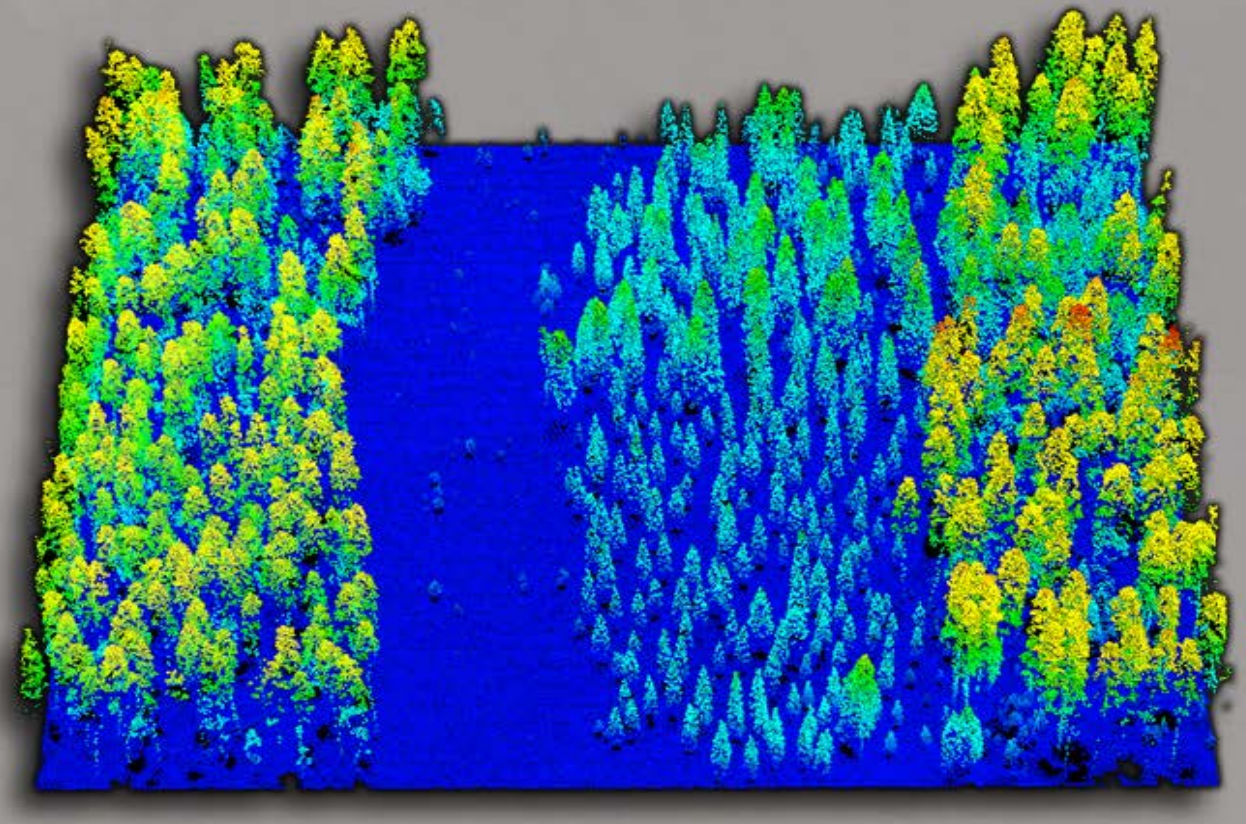




Individual-Tree Product Creation



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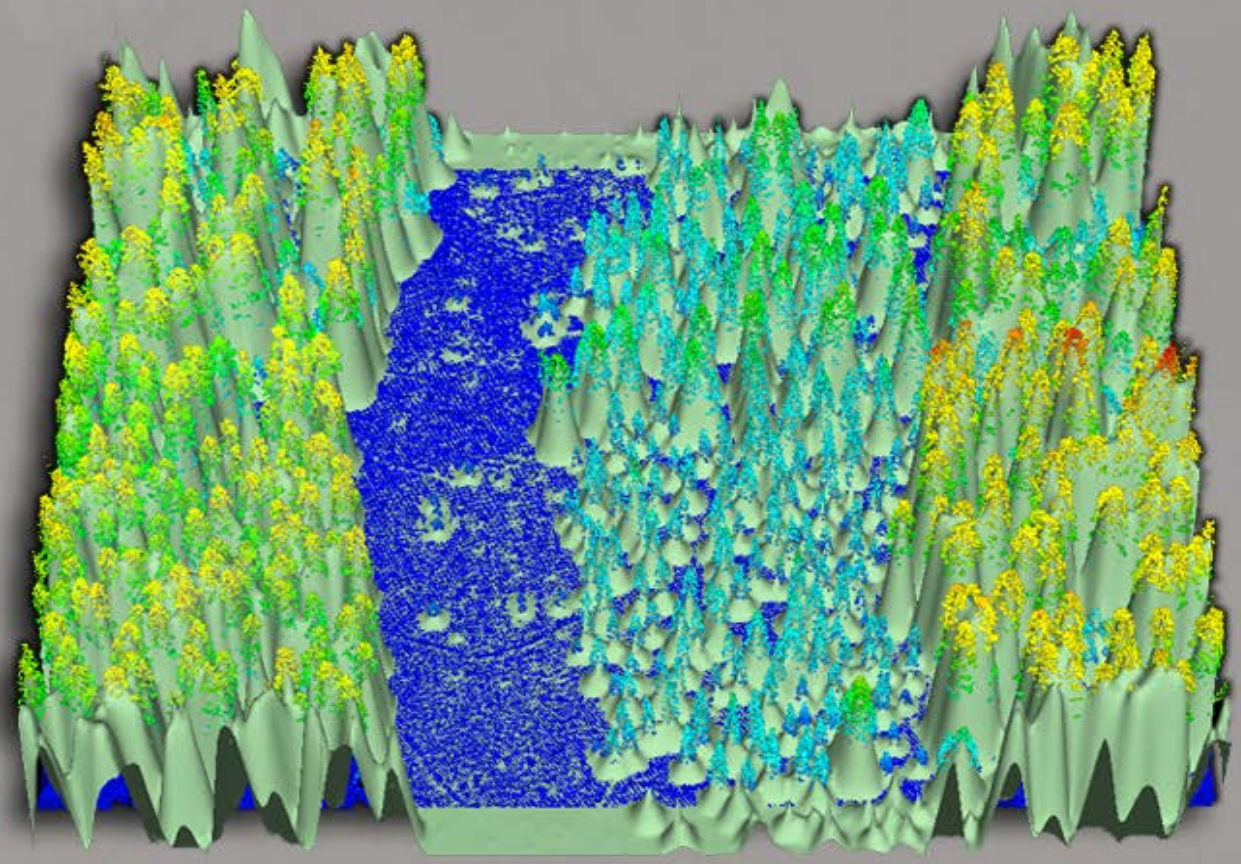

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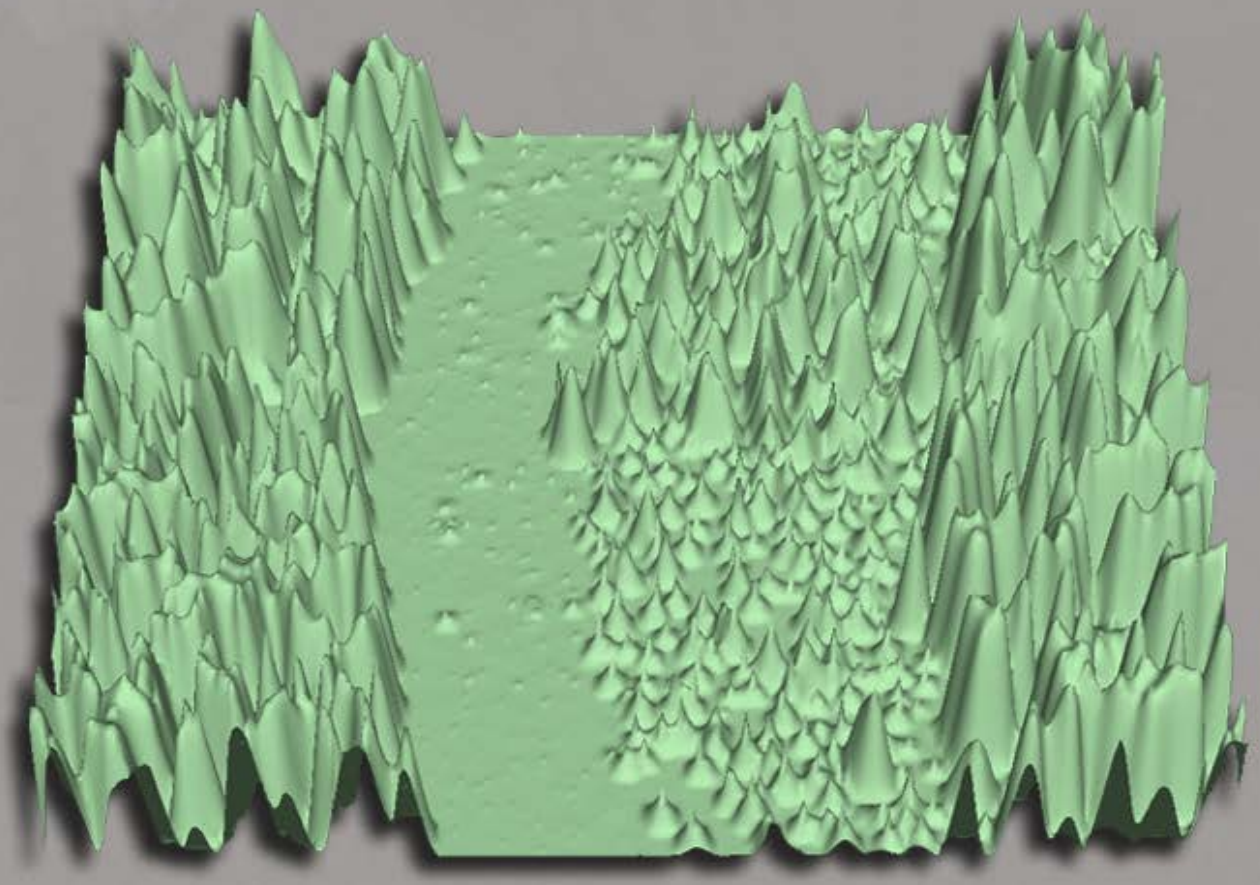
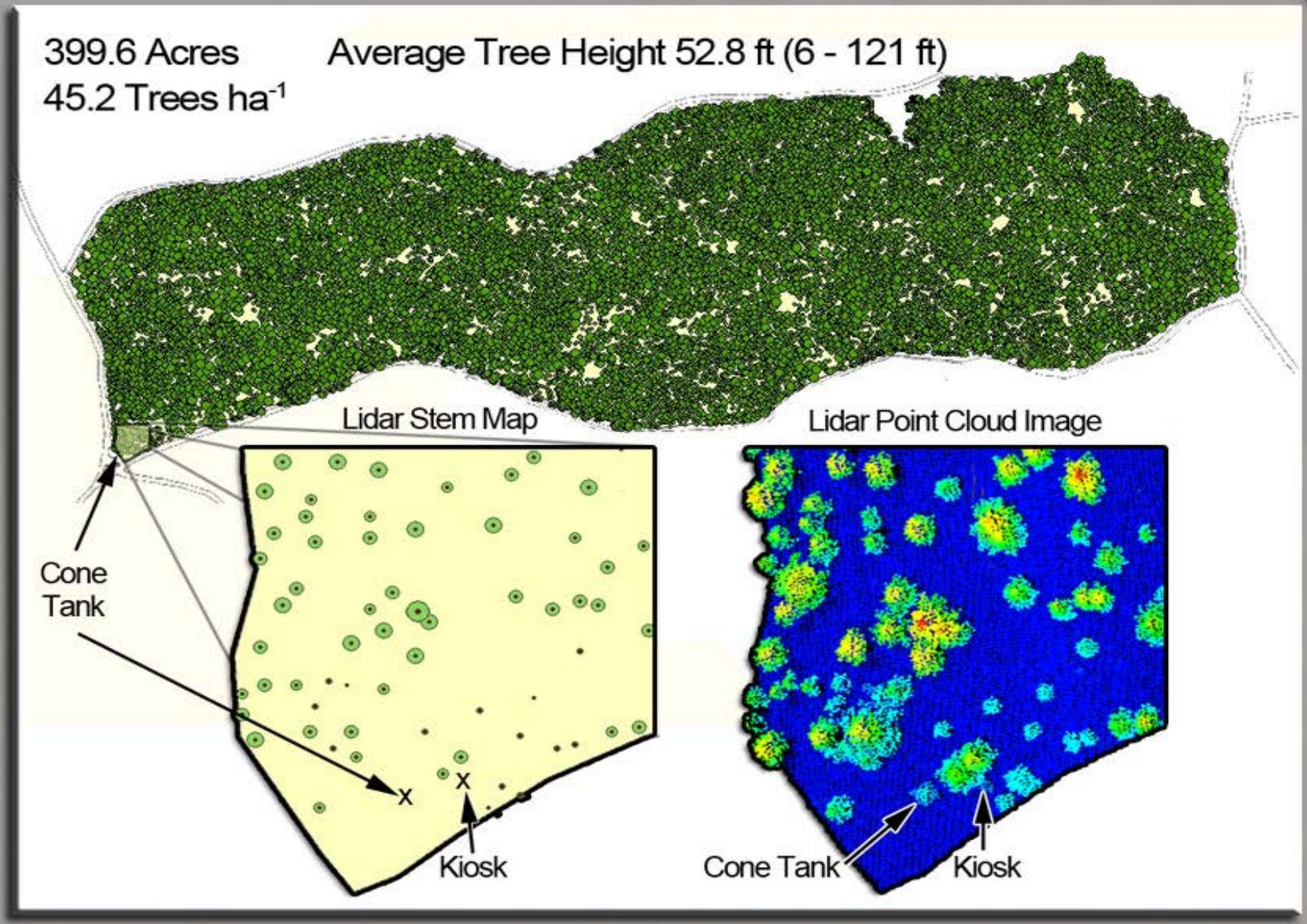


Individual-Tree Product Applications



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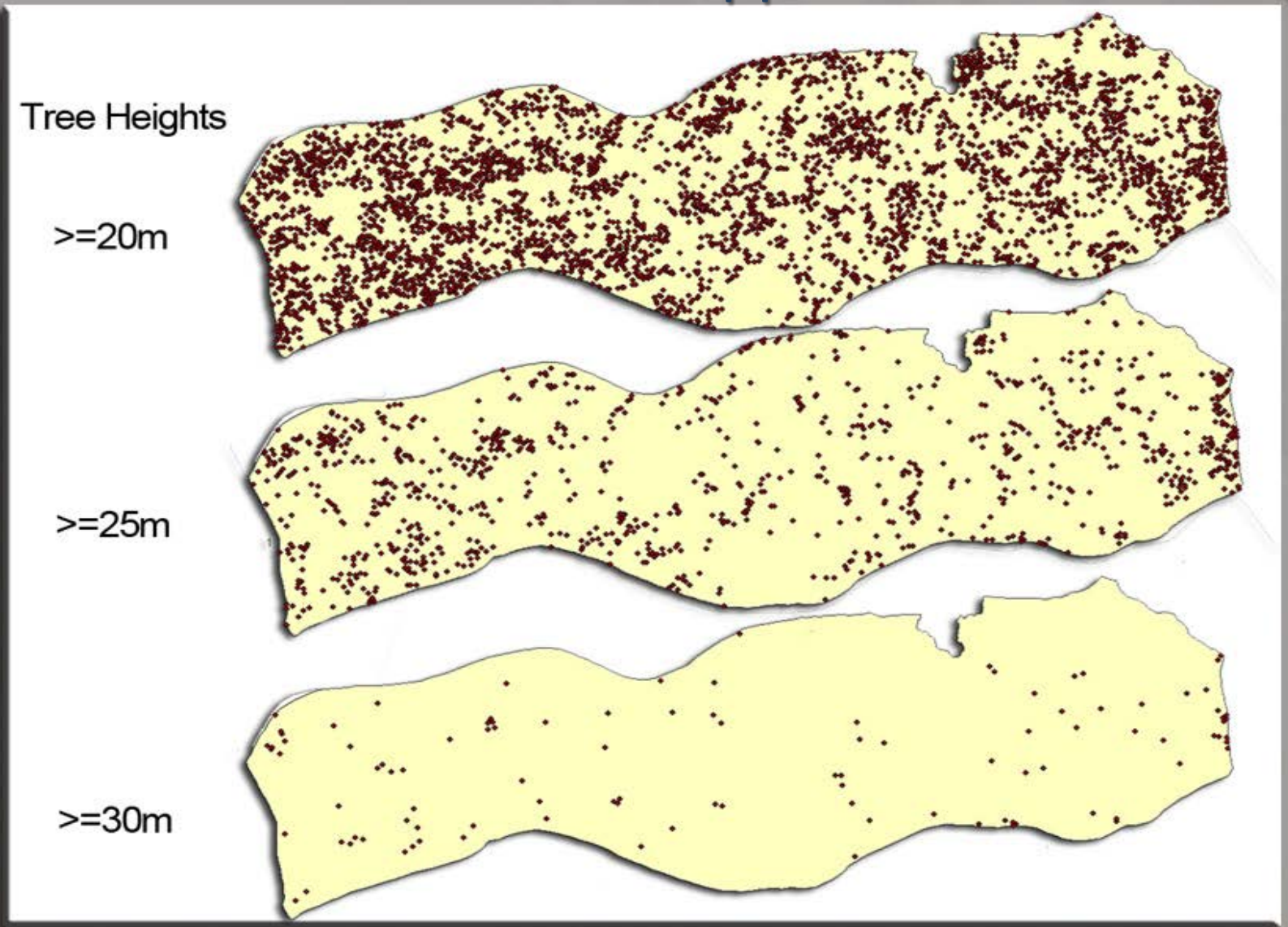
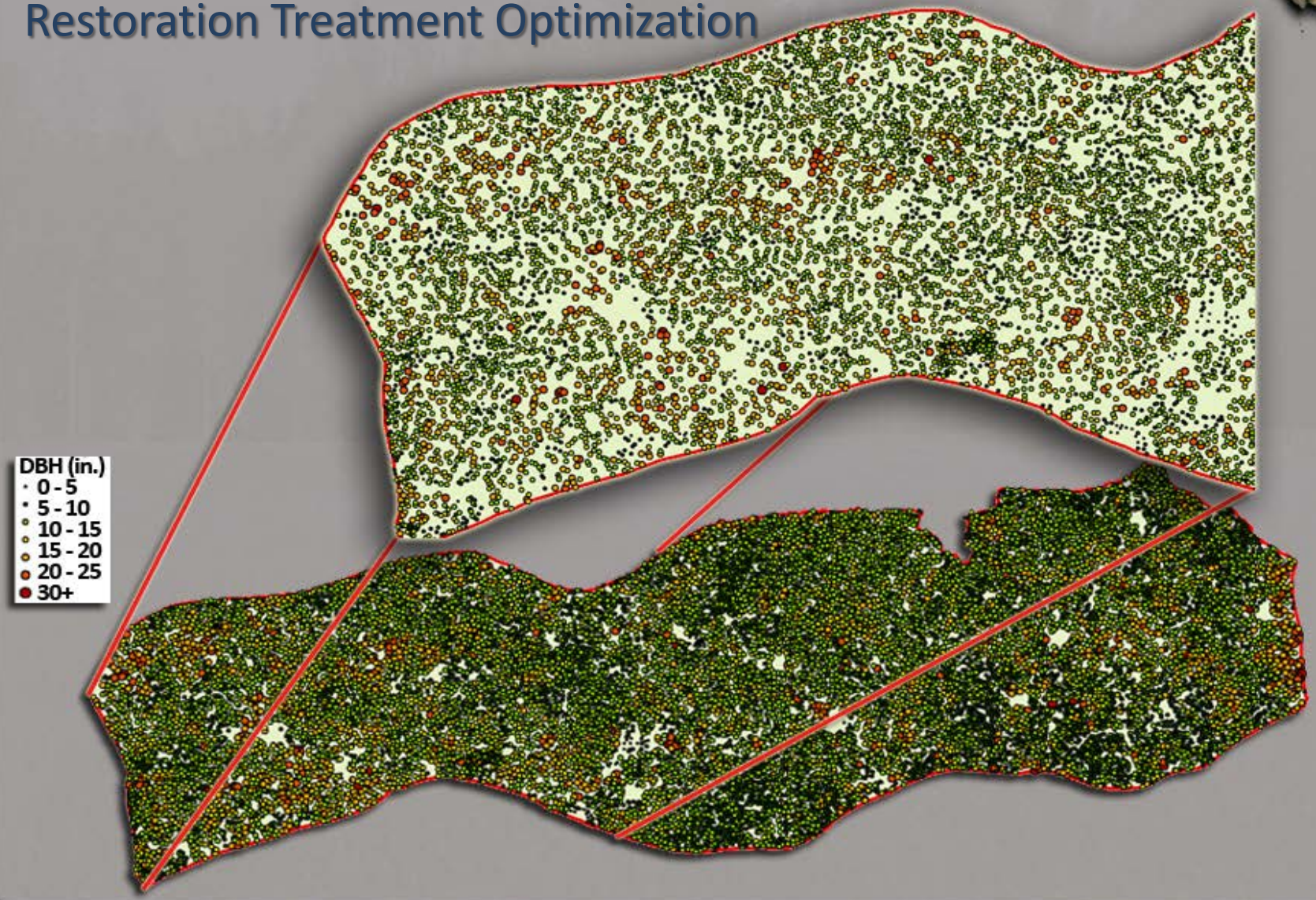


Individual-Tree Product Applications

Restoration Treatment Optimization



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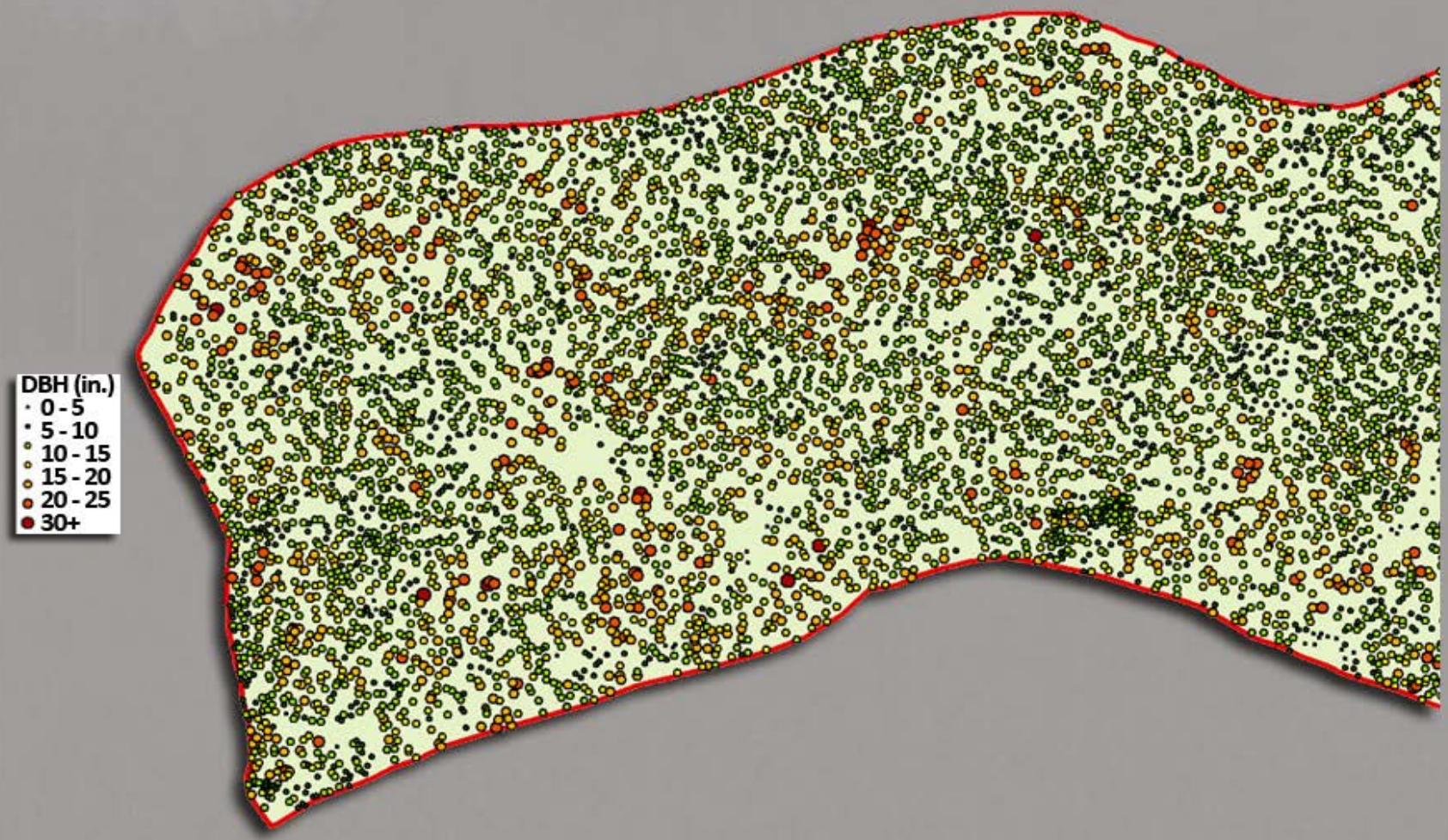

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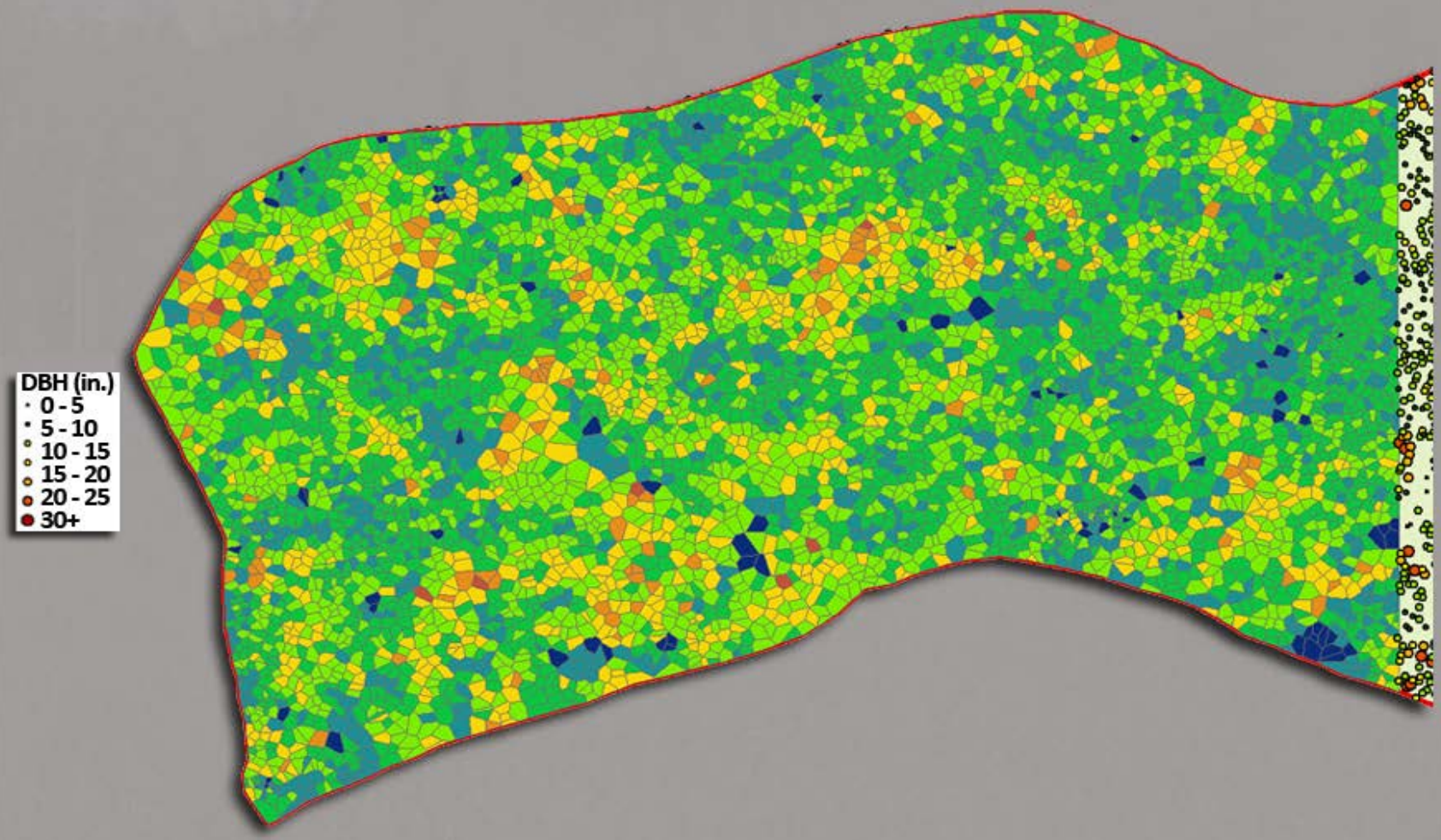
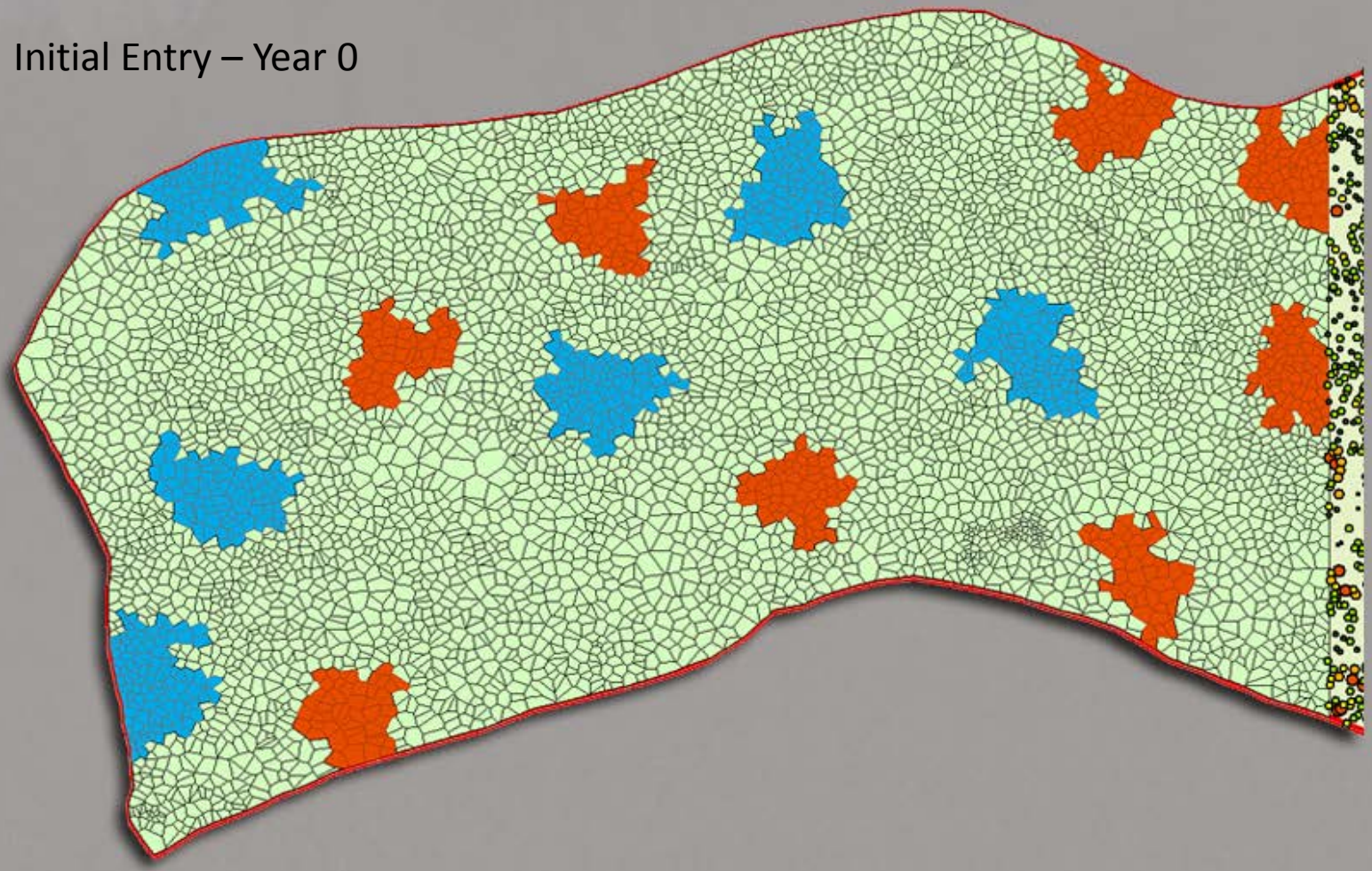


Individual-Tree Product Applications

Restoration Treatment Optimization

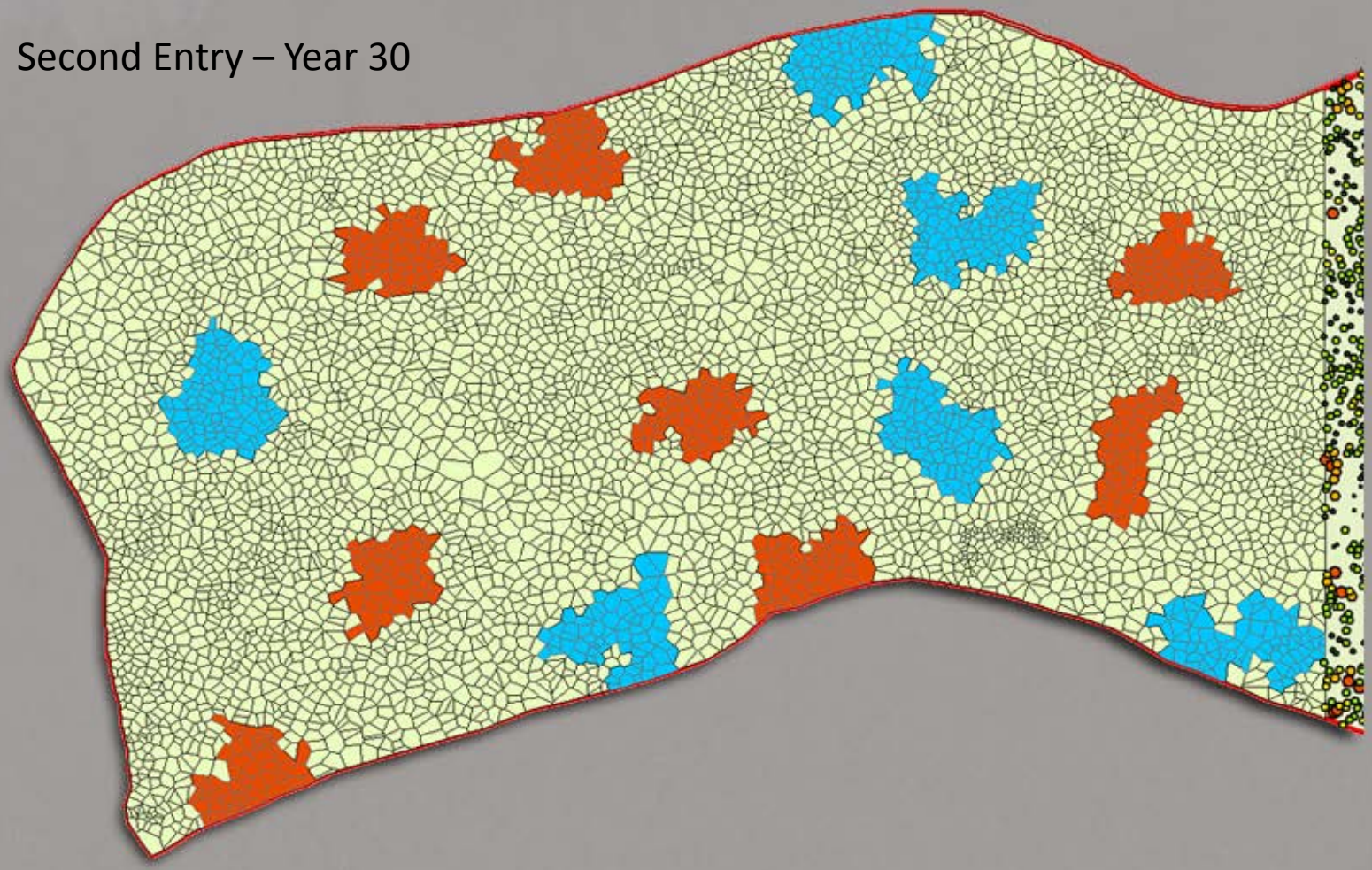
Initial Entry – Year 0



Individual-Tree Product Applications

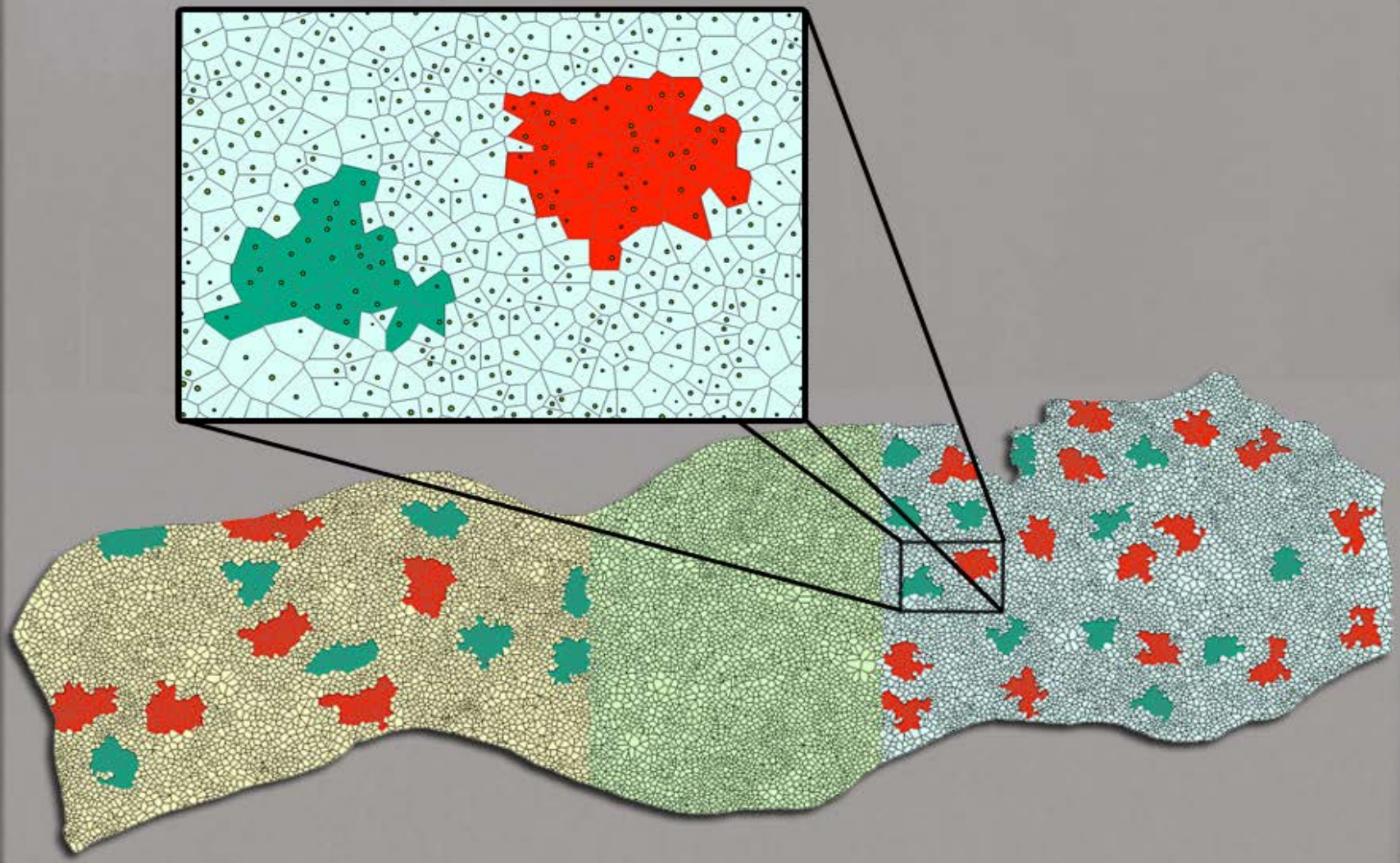
Restoration Treatment Optimization

Second Entry – Year 30



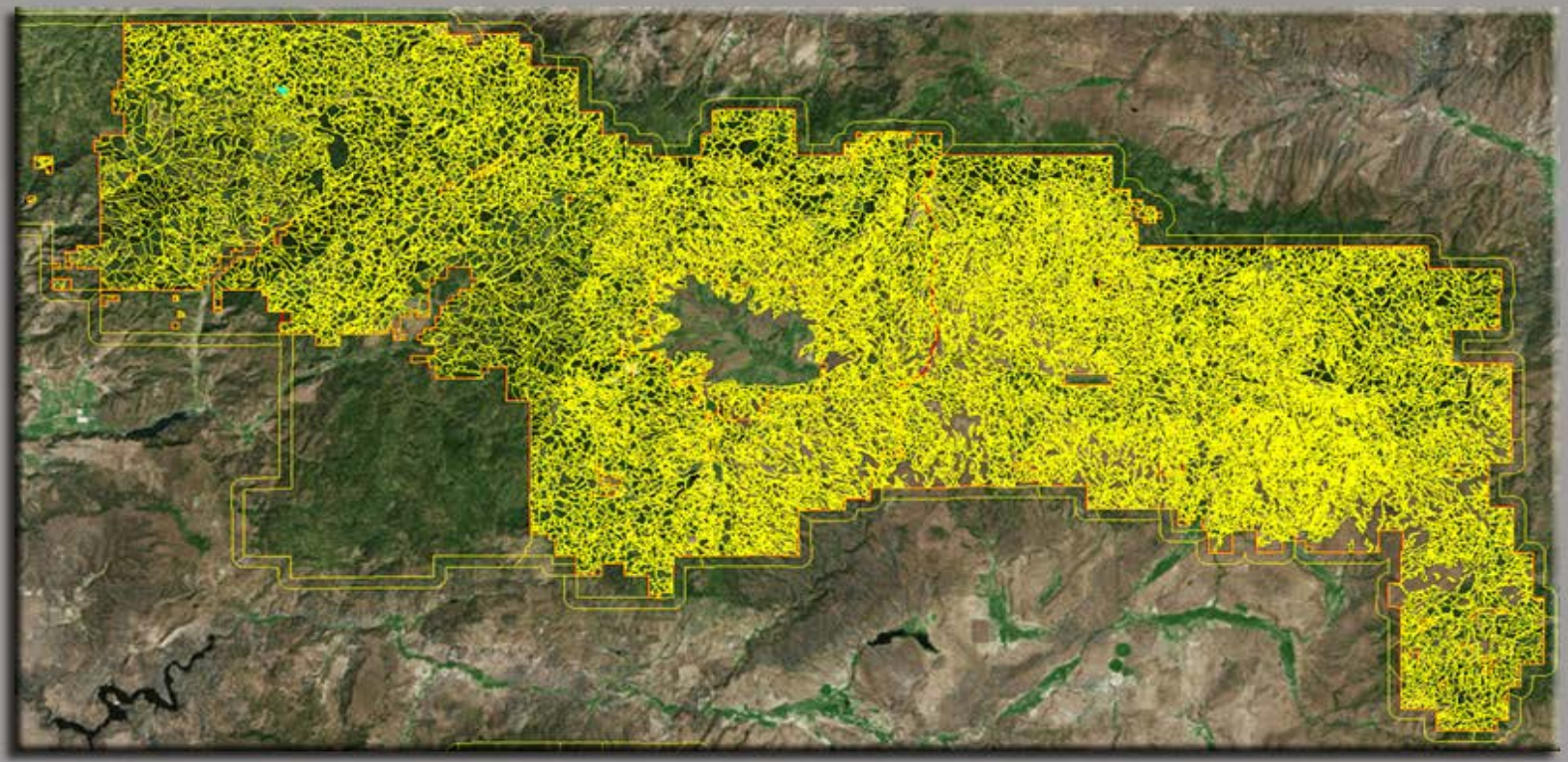
Individual-Tree Product Applications

Restoration Treatment Optimization



Individual-Tree Product Applications

FVS Tree List Generation



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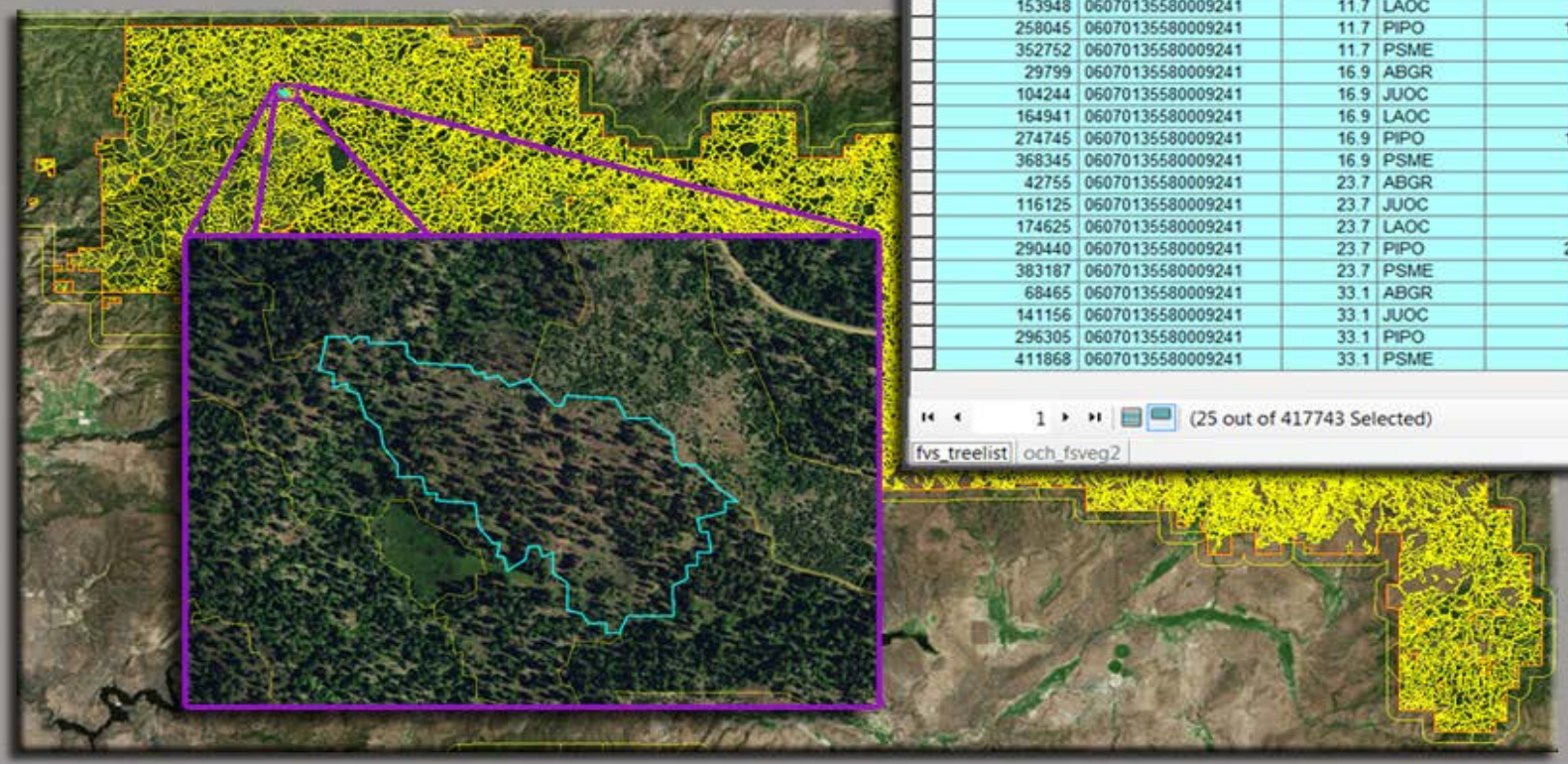

Table

fvs_treelist

OBJECTID *	SETTING_ID	DBH	Species	TPA
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126528	06070135580009241	6.9	JUOC	2.6
182352	06070135580009241	6.9	LAOC	0.6
222420	06070135580009241	6.9	PICO	1.2
294676	06070135580009241	6.9	PIPO	25
396062	06070135580009241	6.9	PSME	4.9
15403	06070135580009241	11.7	ABGR	5.4
90350	06070135580009241	11.7	JUOC	0.3
153948	06070135580009241	11.7	LAOC	0.9
258045	06070135580009241	11.7	PIPO	13.7
352752	06070135580009241	11.7	PSME	1.7
29799	06070135580009241	16.9	ABGR	5.1
104244	06070135580009241	16.9	JUOC	1.2
164941	06070135580009241	16.9	LAOC	0.6
274745	06070135580009241	16.9	PIPO	11.3
368345	06070135580009241	16.9	PSME	2.2
42755	06070135580009241	23.7	ABGR	2.5
116125	06070135580009241	23.7	JUOC	0.6
174625	06070135580009241	23.7	LAOC	0.4
290440	06070135580009241	23.7	PIPO	22.4
383187	06070135580009241	23.7	PSME	2.2
68465	06070135580009241	33.1	ABGR	1.6
141156	06070135580009241	33.1	JUOC	0.3
296305	06070135580009241	33.1	PIPO	5.6
411868	06070135580009241	33.1	PSME	0.9

1 (25 out of 417743 Selected)

fvs_treelist och_fsveg2

Individual Snag Detection

Contents lists available at ScienceDirect

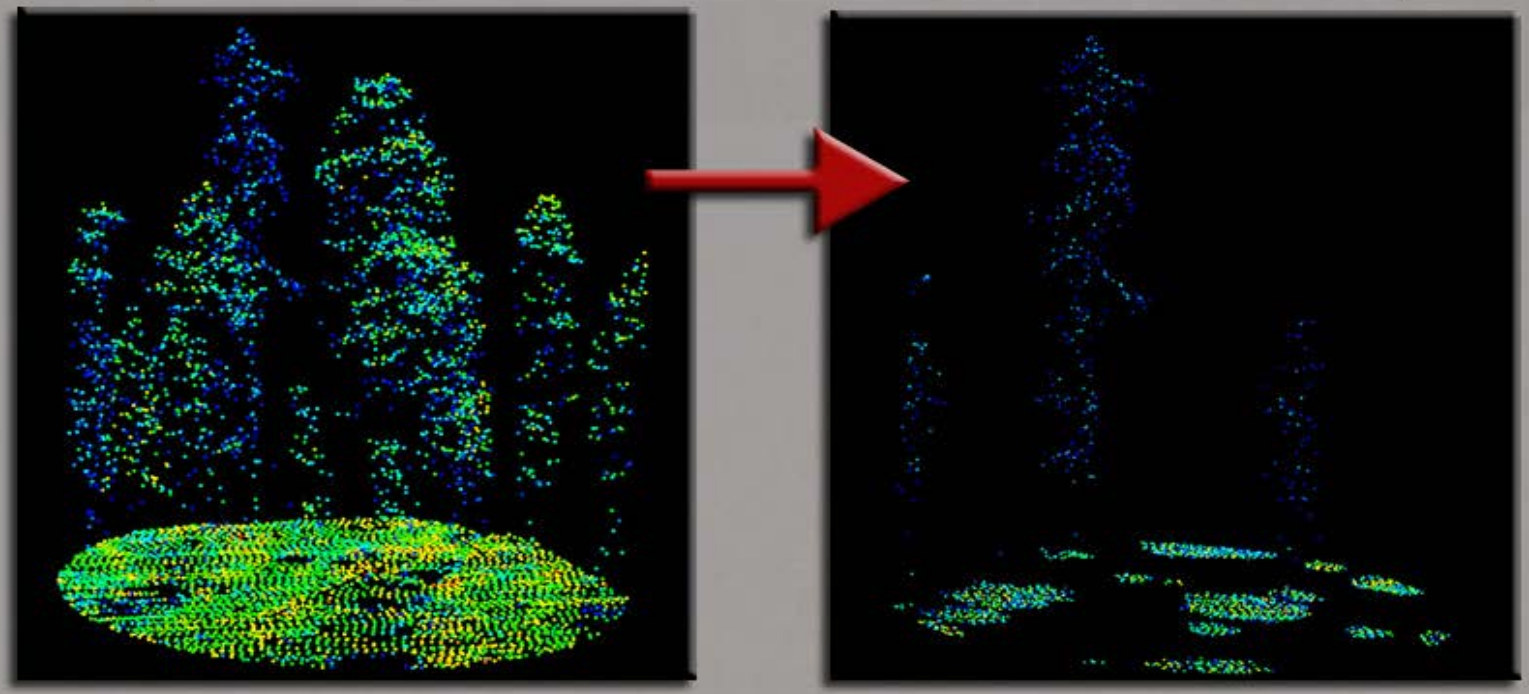
Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

Individual snag detection using neighborhood attribute filtered airborne lidar data

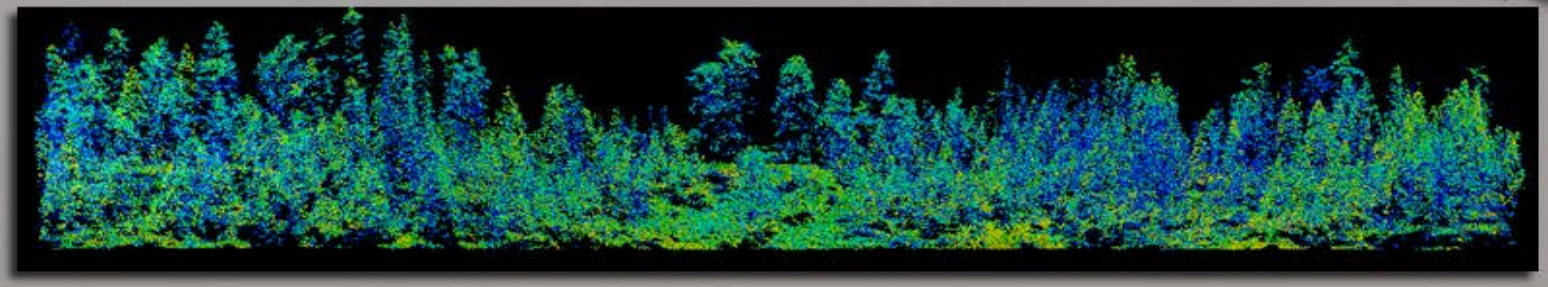
Brian M. Wing [a,*], Martin W. Ritchie [a], Kevin Boston [b], Warren B. Cohen [c], Michael J. Olsen [d]

[a] U.S.D.A. Forest Service, Pacific Southwest Research Station, 3644 Avtech Parkway, Redding, CA 96002, United States
[b] Department of Forest Engineering, Resources, & Management, Oregon State University, 204 Peavy Hall, Corvallis, OR 97331, United States
[c] U.S.D.A. Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97731, United States
[d] School of Civil and Construction Engineering, Oregon State University, 101 Kearney Hall, Corvallis, OR 97331, United States



Individual Snag Detection

Pre-Fire



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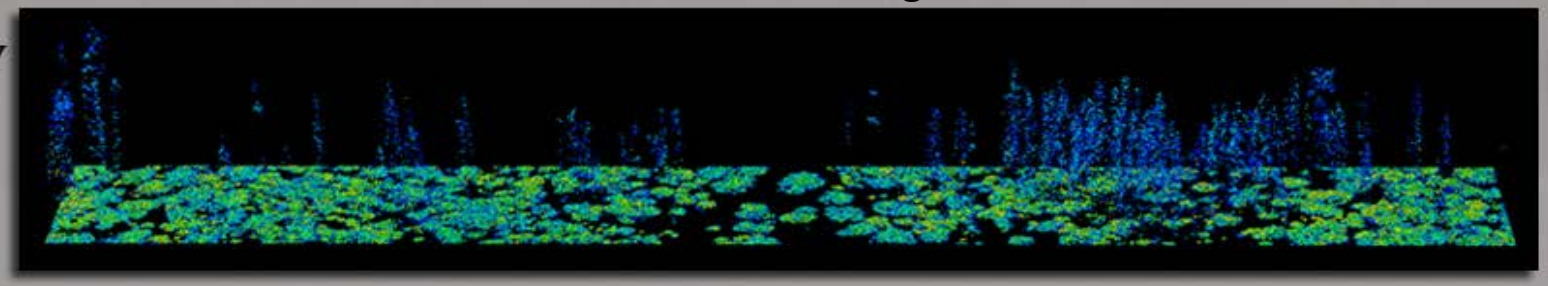
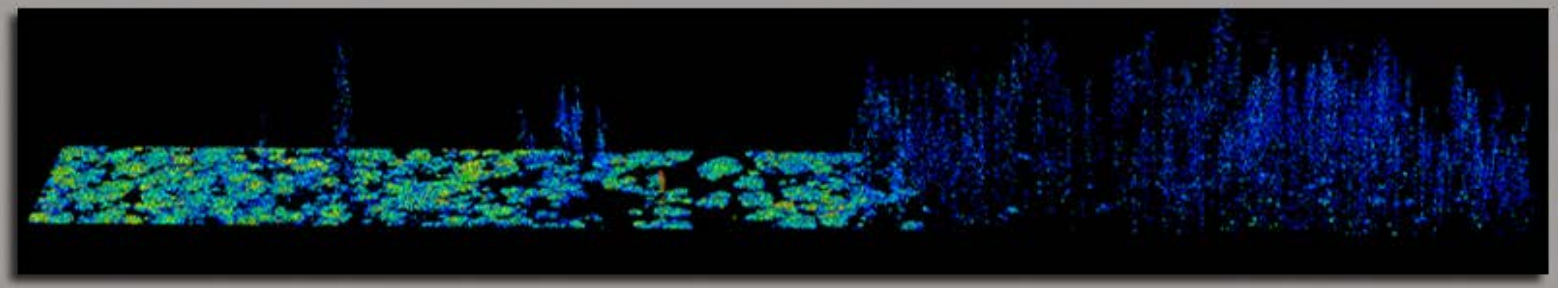
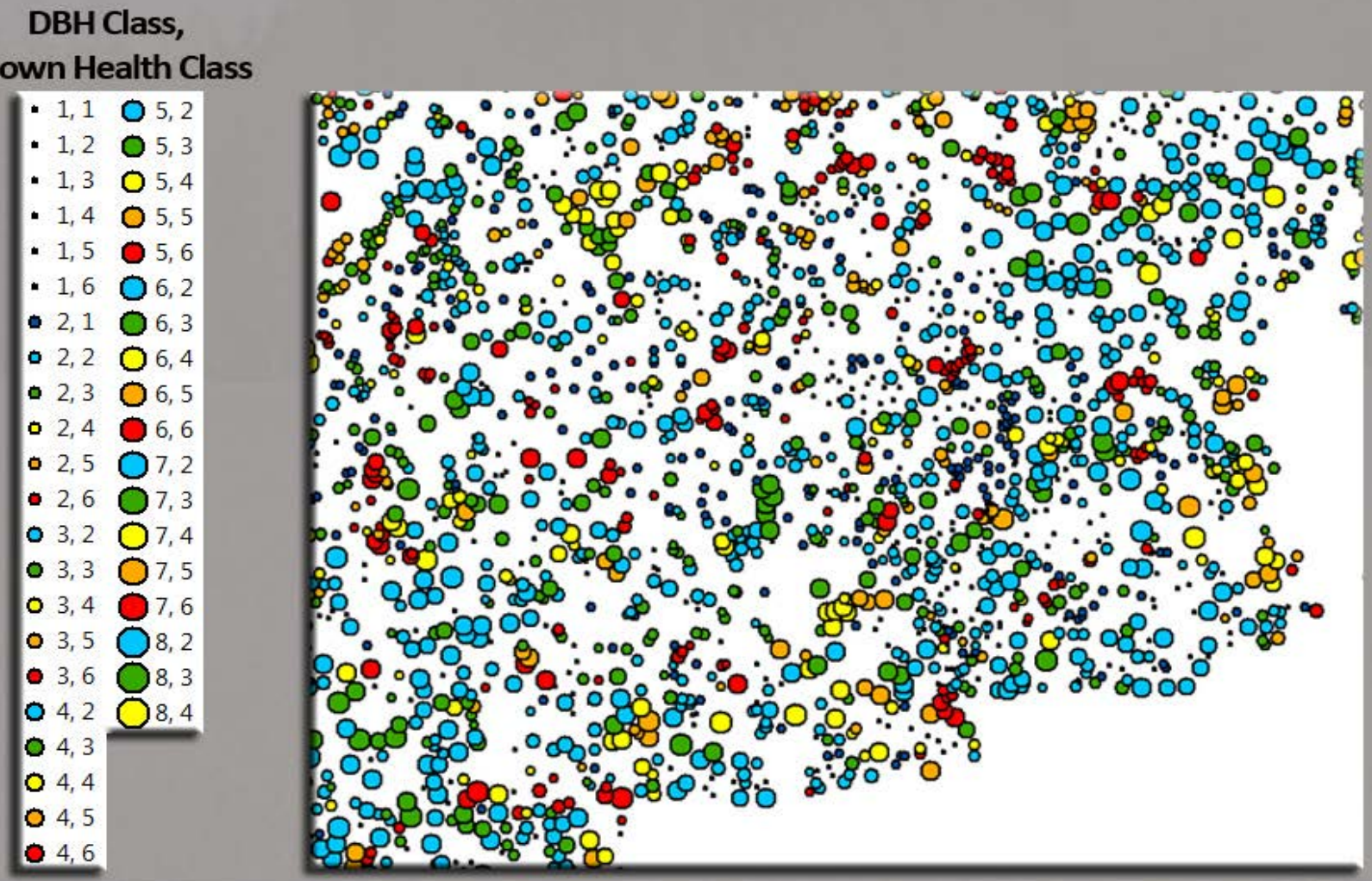


Post-Fire Snags



Individual Tree Crown Health



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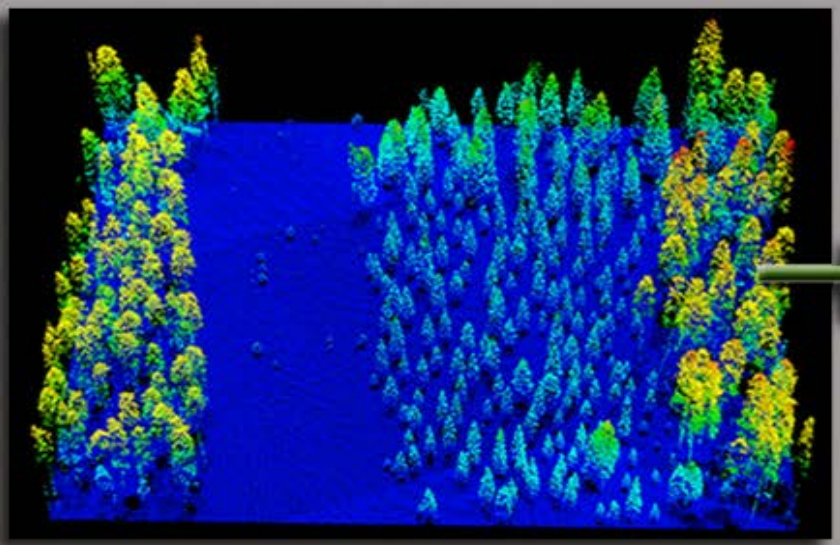
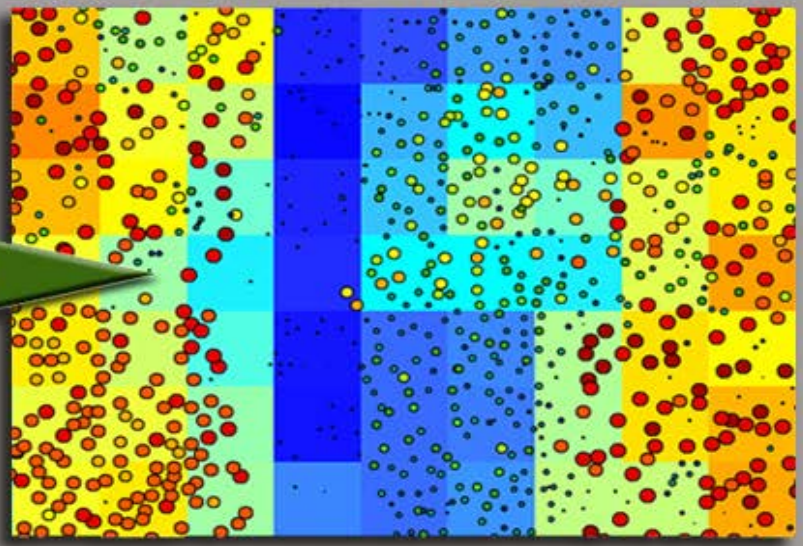
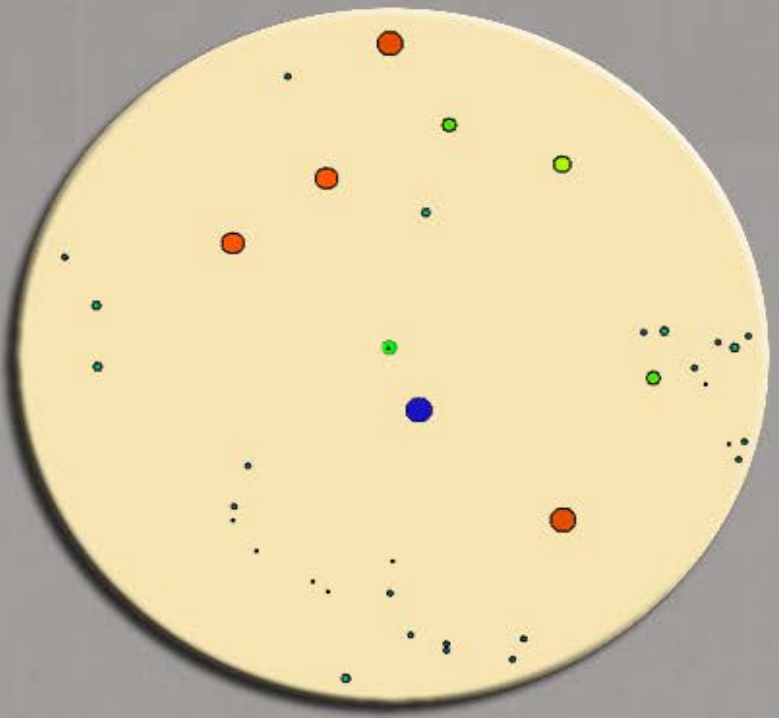
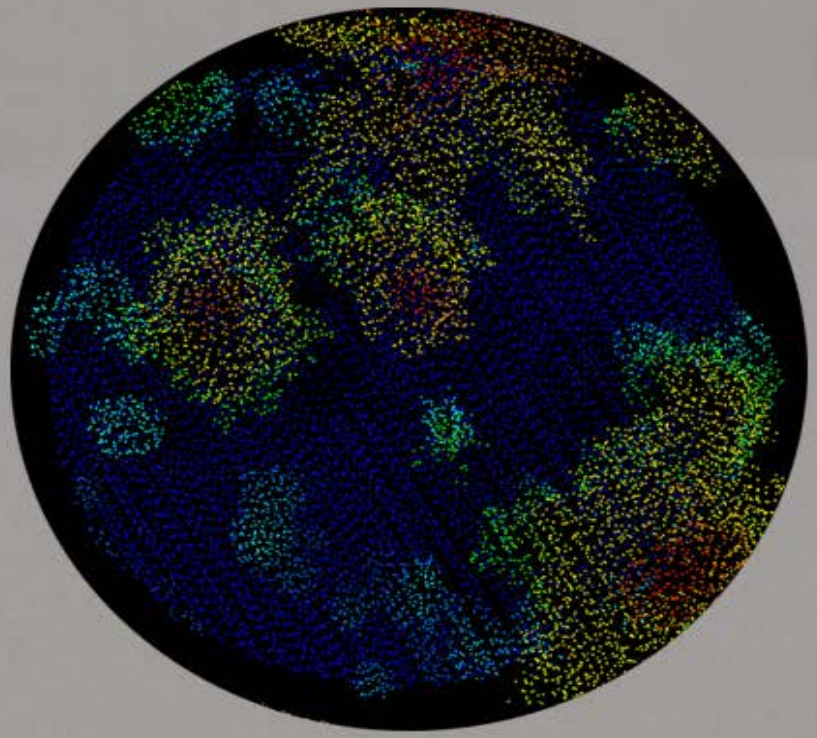




Plot-Based Product Creation Steps

1. **Collect LiDAR-Oriented Field Data**
2. Extract Normalized LiDAR Plot Point Clouds
3. Derive Plot-Level LiDAR Metrics
4. Develop Regression Models (LiDAR Metrics vs. Field Data)
5. Apply Models to Entire LiDAR Acquisition (Rasters)





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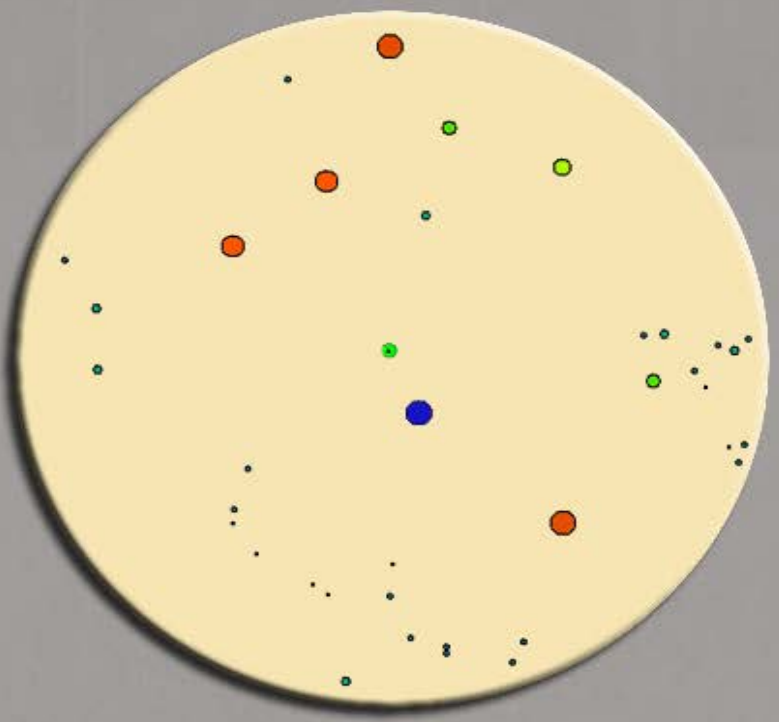

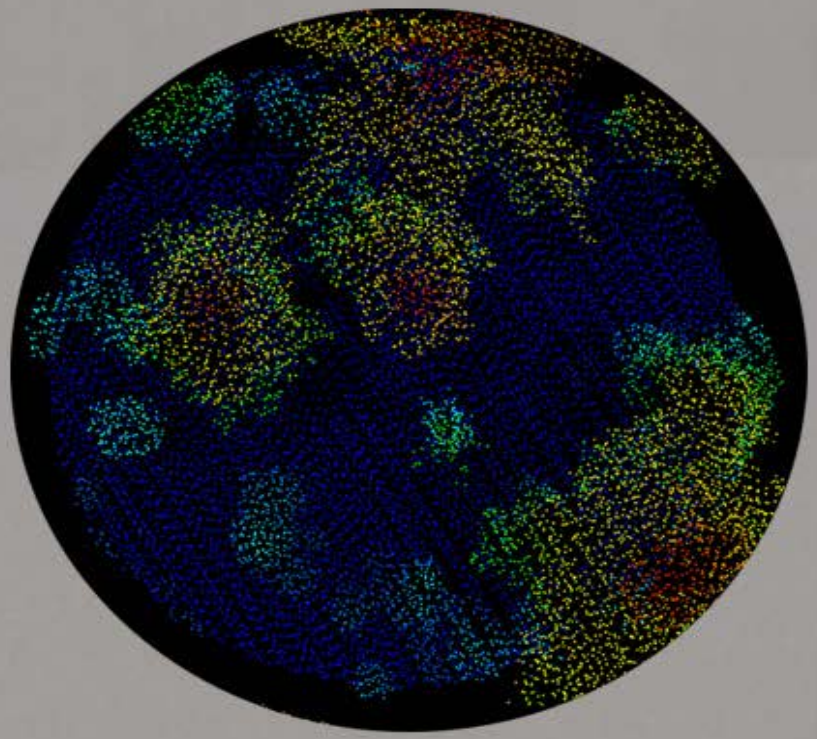

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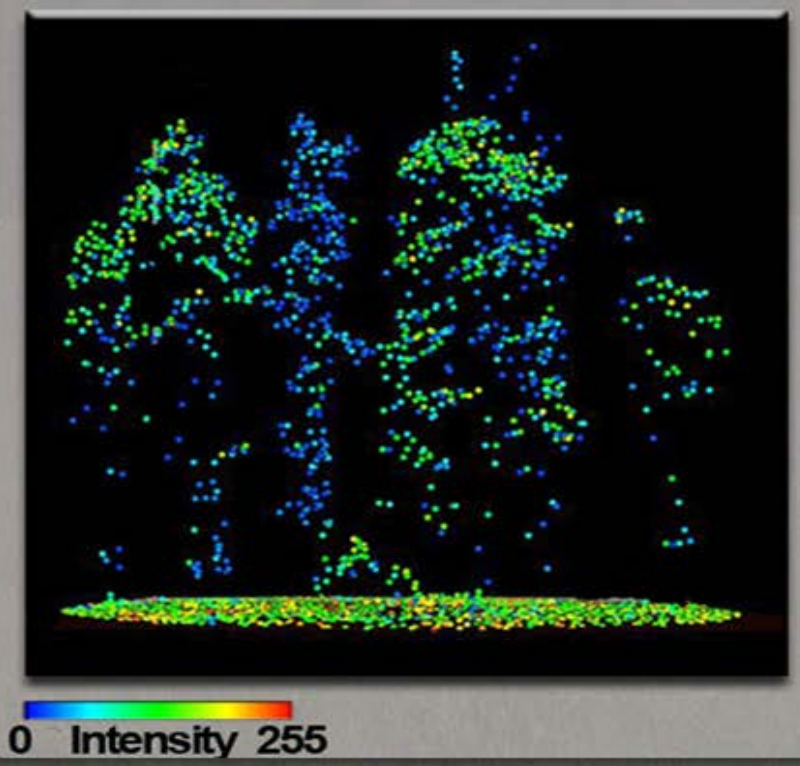
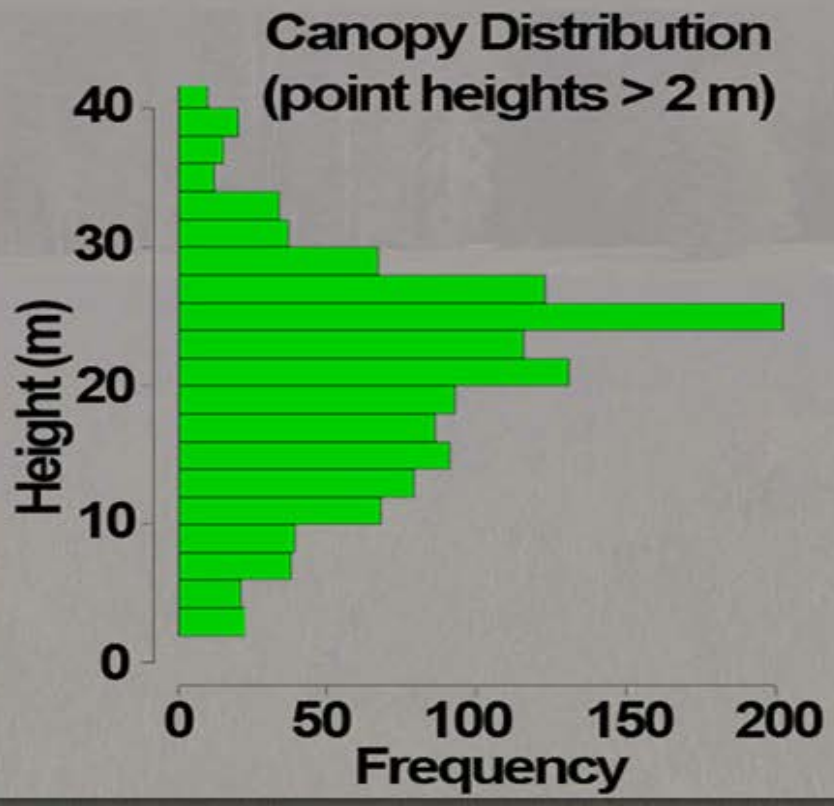
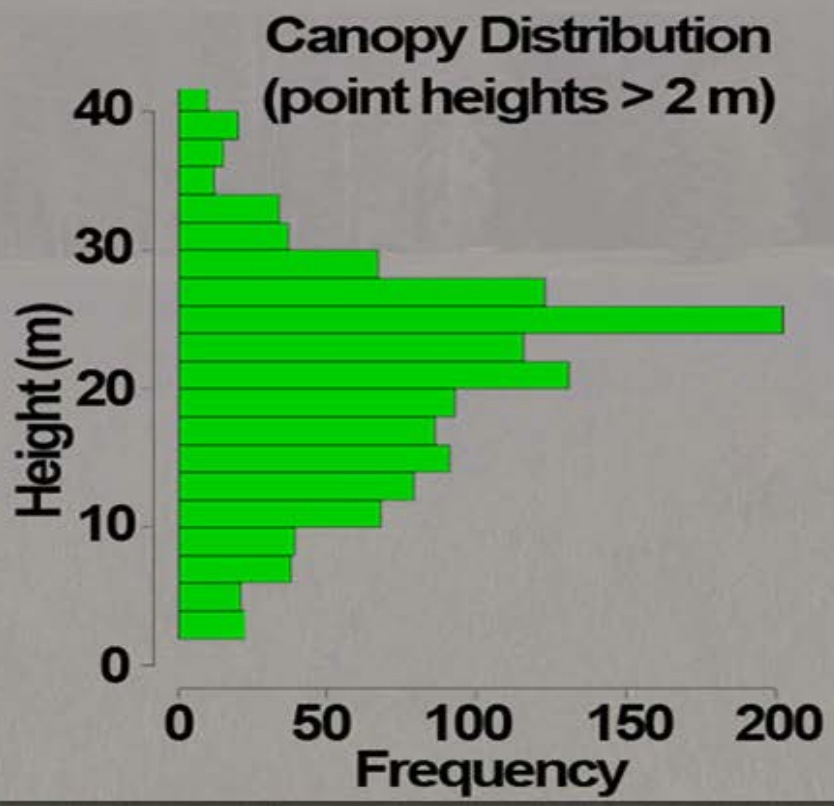




Plot-Based Product Creation Steps

1. Collect LiDAR-Oriented Field Data
2. Extract Normalized LiDAR Plot Point Clouds
3. **Derive Plot-Level LiDAR Metrics**
4. Develop Regression Models (LiDAR Metrics vs. Field Data)
5. Apply Models to Entire LiDAR Acquisition (Rasters)

Variables	Description
$P01_h$	1st percentile height (m)
$P05_h$	5th percentile height (m)
$P10_h$	10th percentile height (m)
$P20_h$	20th percentile height (m)
$P25_h$	25th percentile height (m)
$P30_h$	30th percentile height (m)
...	...
$P99_h$	99th percentile height (m)
Min_h	minimum height (m)
Max_h	maximum height (m)
$Mean_h$	mean height (m)
$Mode_h$	mode height (m)
SD_h	standard deviation of heights (m)
CV_h	coefficient of variation of heights (m)
$D5_h$	proportion of points above 5 m (%)
$D10_h$	proportion of points above 10 m (%)
$D15_h$	proportion of points above 15 m (%)
$D20_h$	proportion of points above 20 m (%)
DM_h	proportion of points above the mean height (%)
DMd_h	proportion of points above the mode height m (%)
CC_h	proportion of points above 2 m (%)
VolCov	lidar canopy density (CC_h x $Mean_h$)



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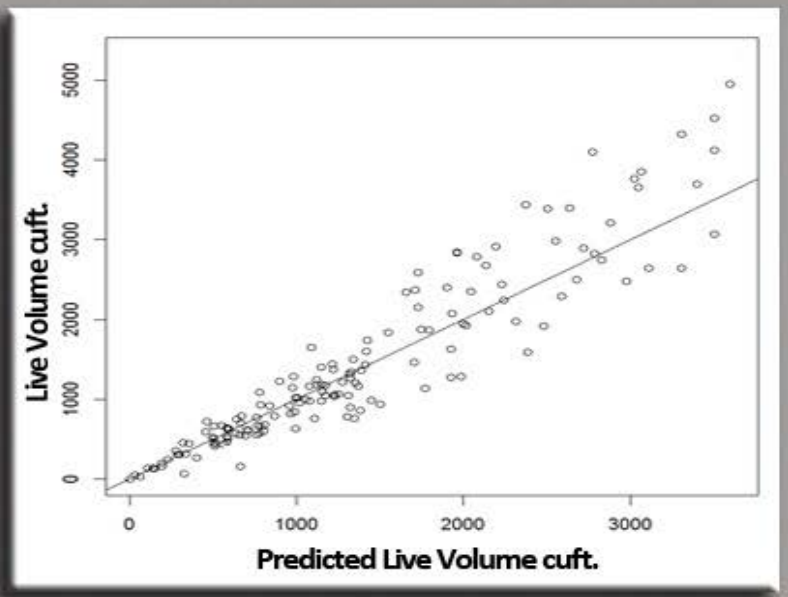

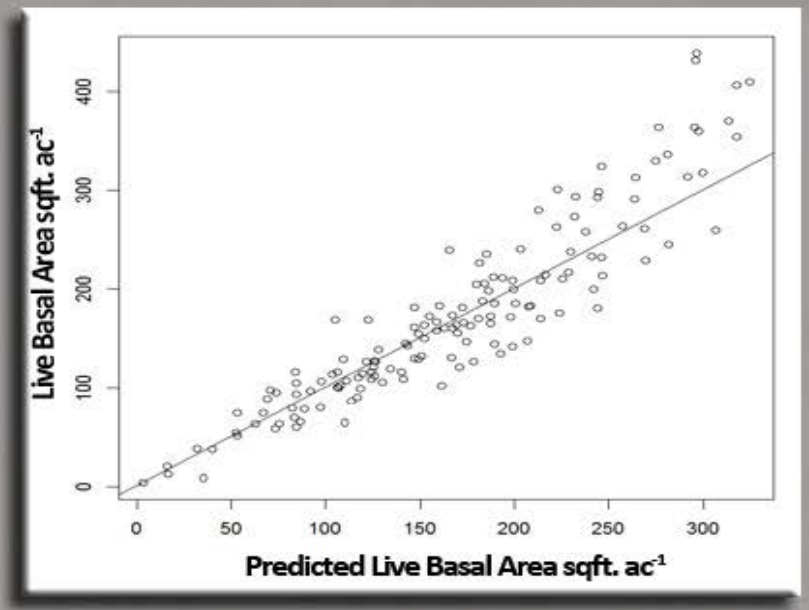

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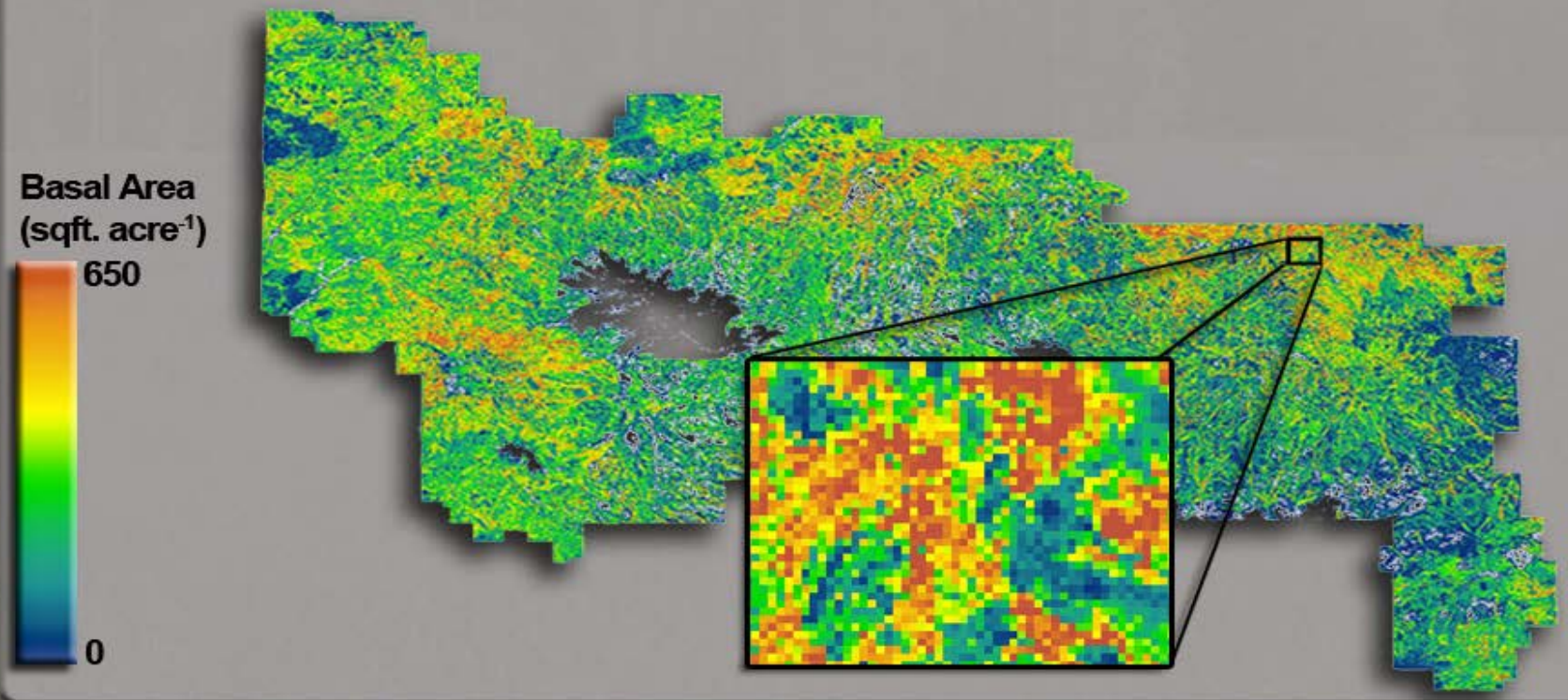
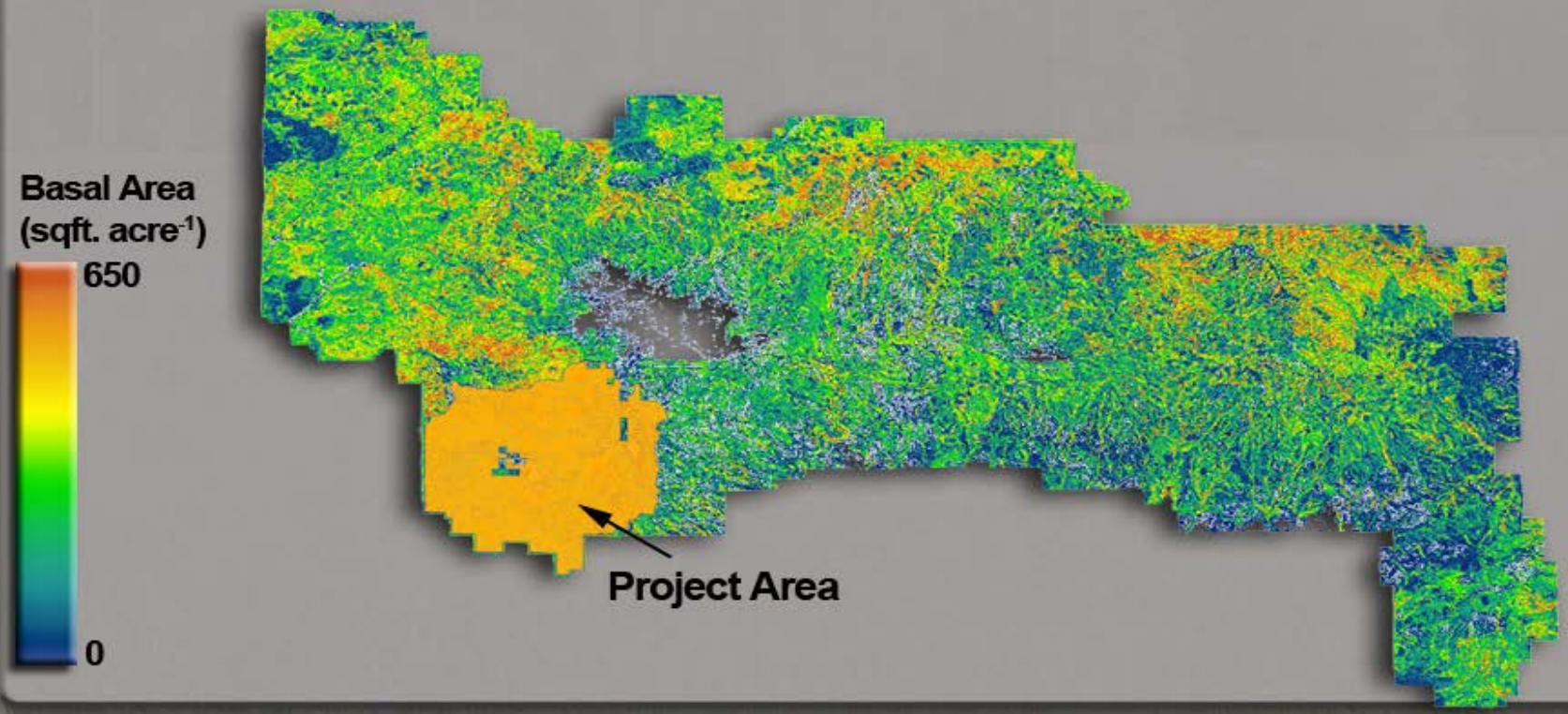
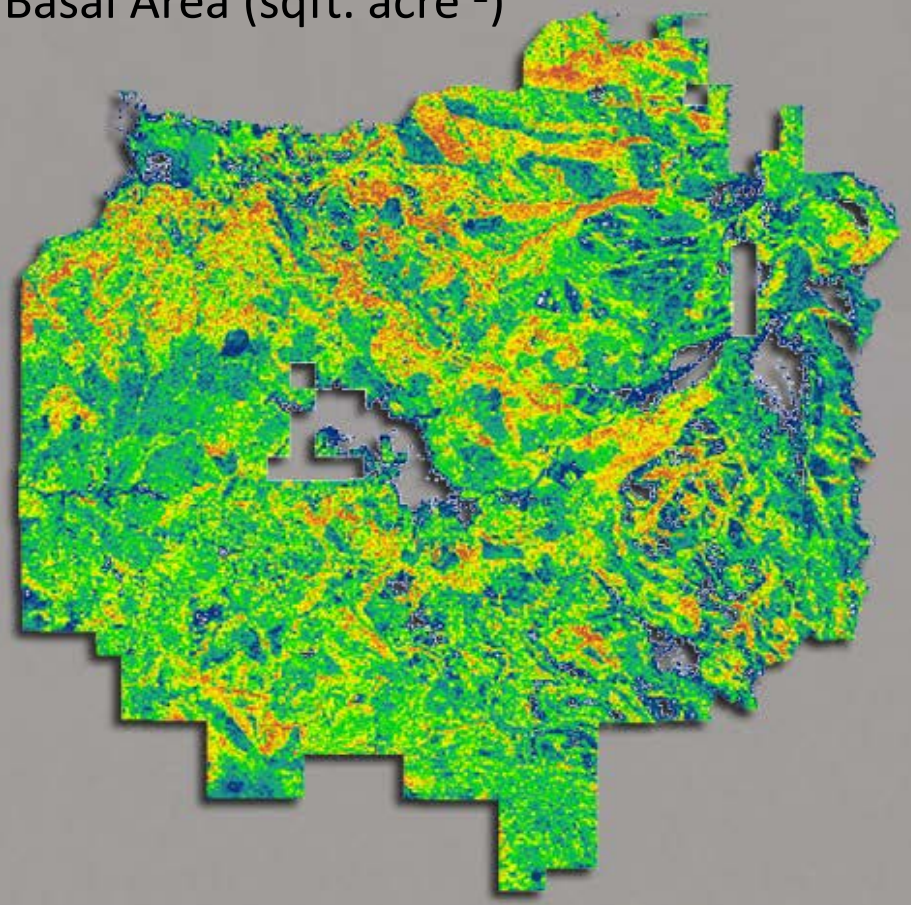


Plot-Based Product Incorporation



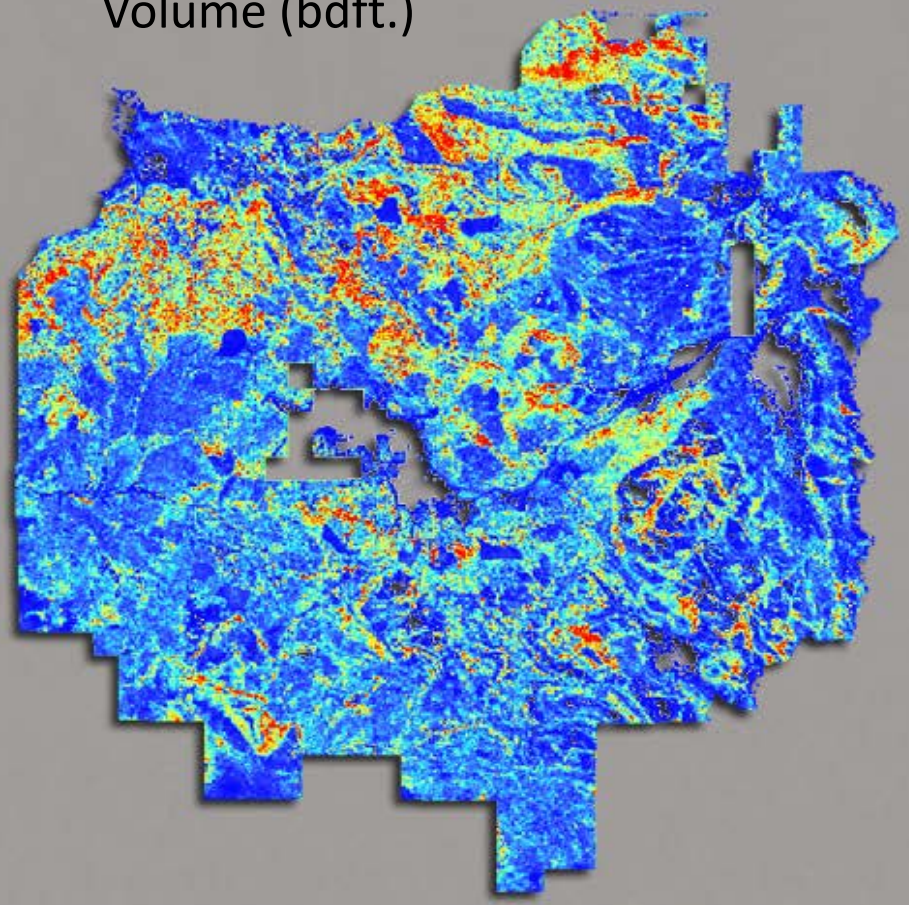
Plot-Based Product Incorporation

Basal Area (sqft. acre^{-1})



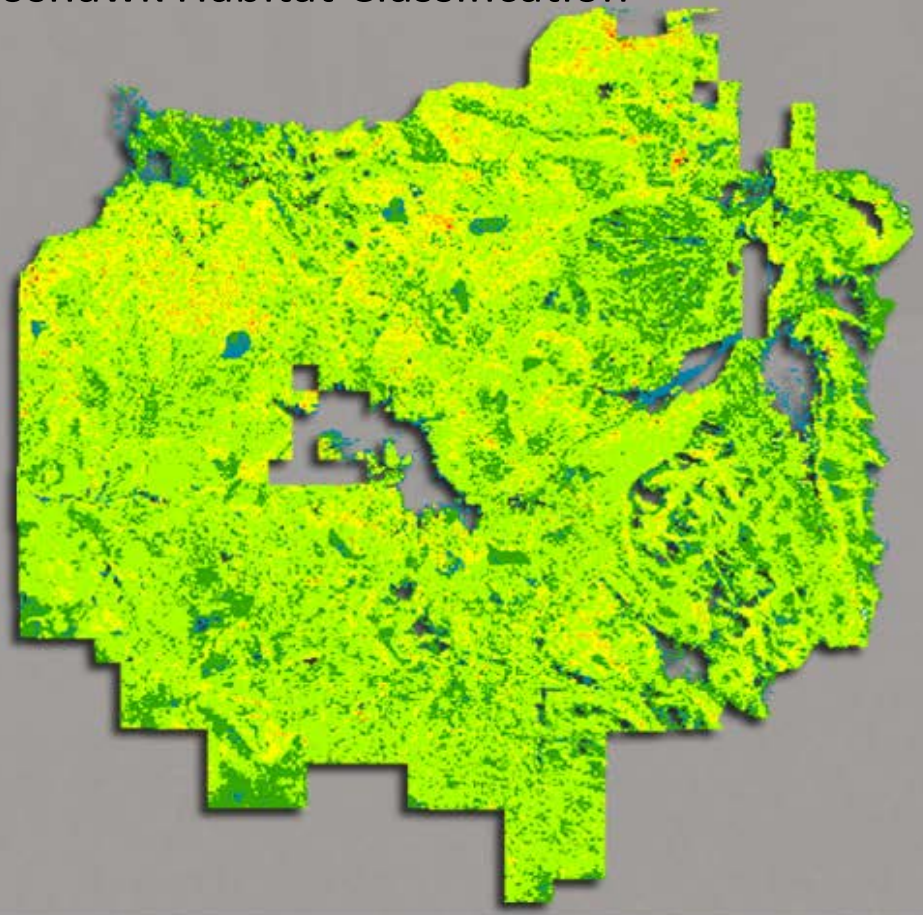
Plot-Based Product Incorporation

Volume (bdft.)



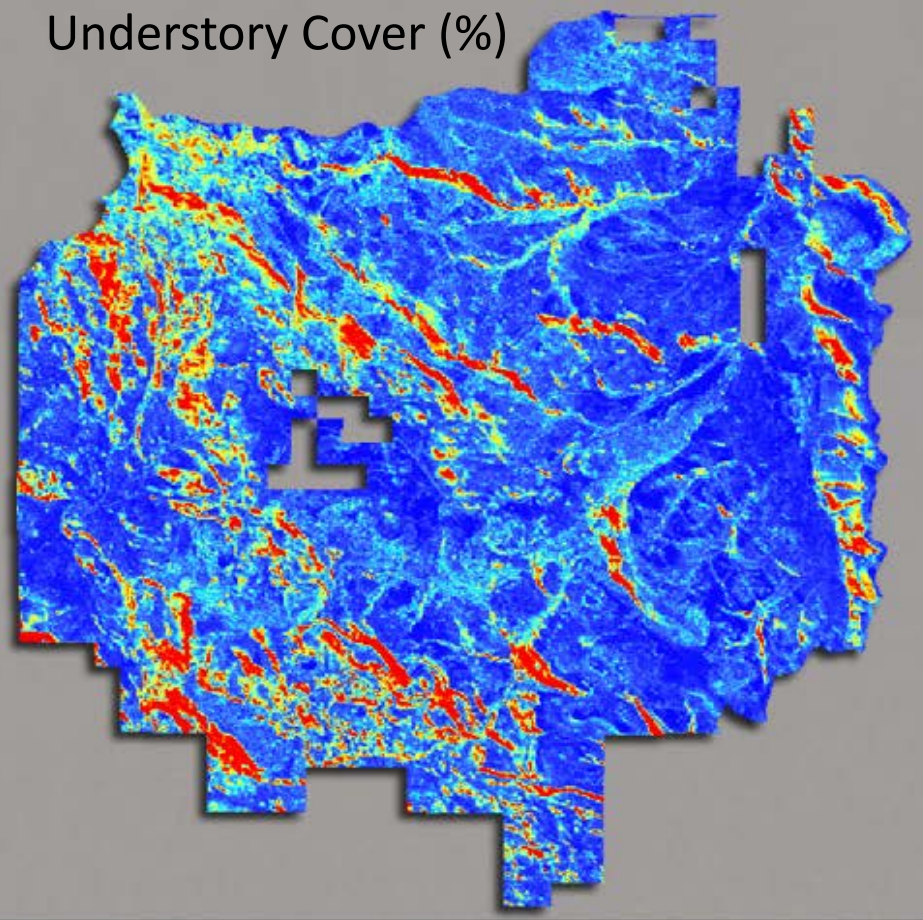
Plot-Based Product Incorporation

Goshawk Habitat Classification



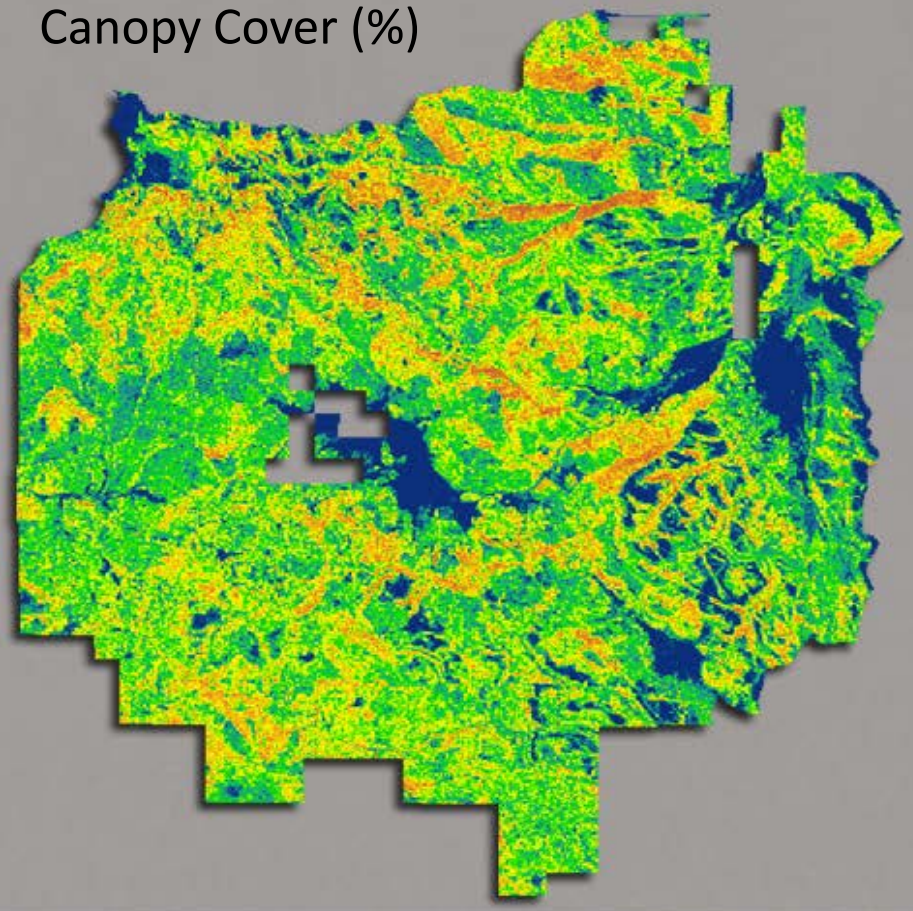
Plot-Based Product Incorporation

Understory Cover (%)

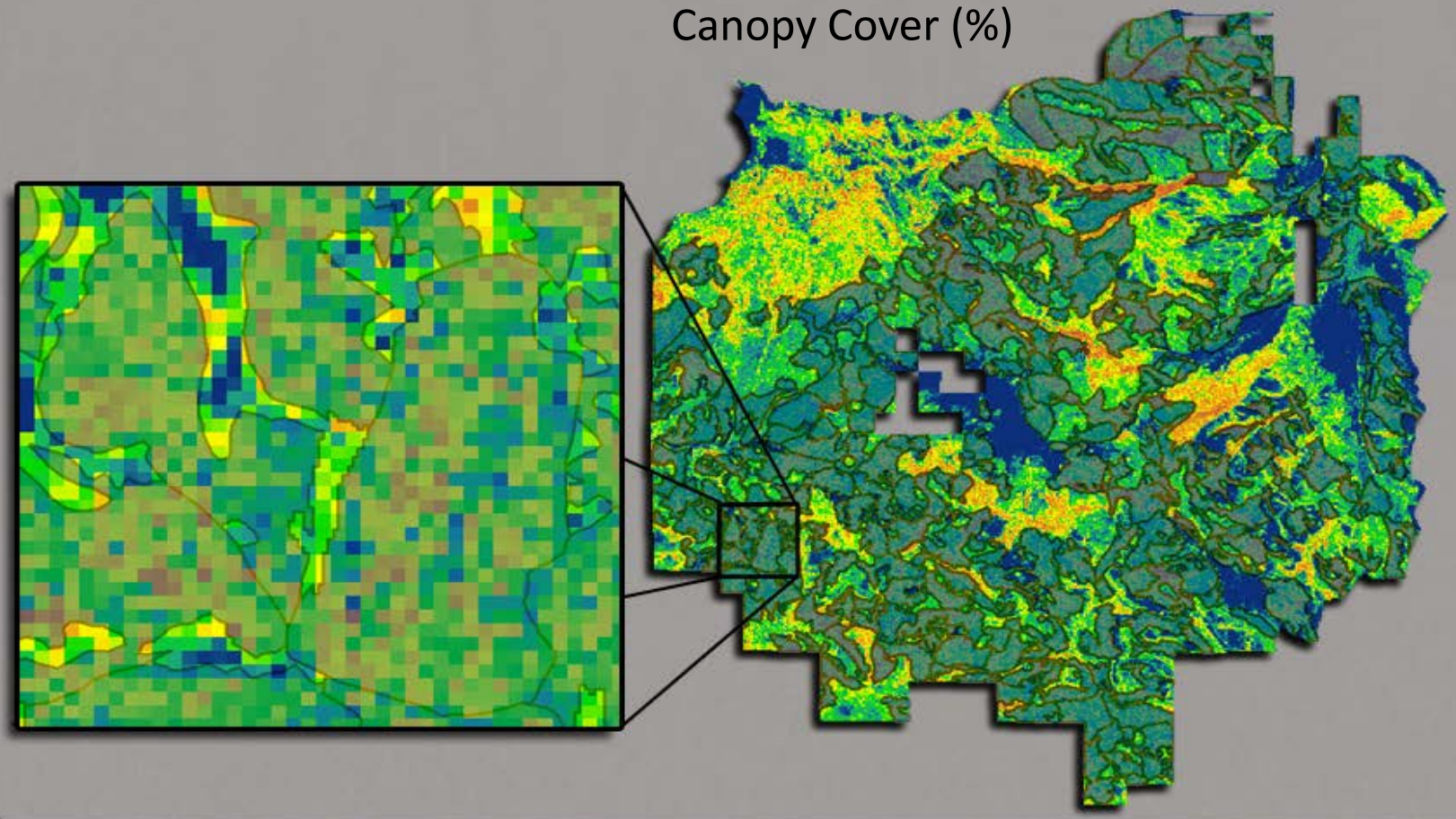


Plot-Based Product Incorporation

Canopy Cover (%)



Plot-Based Product Incorporation



Plot-Based Product Incorporation

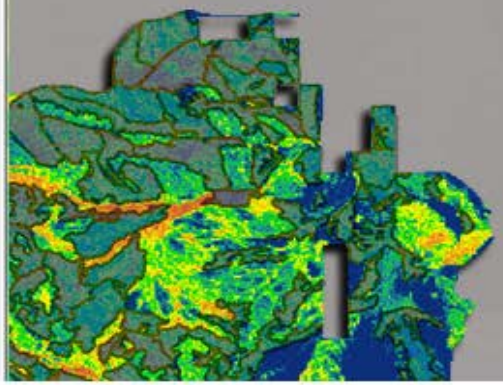
Table

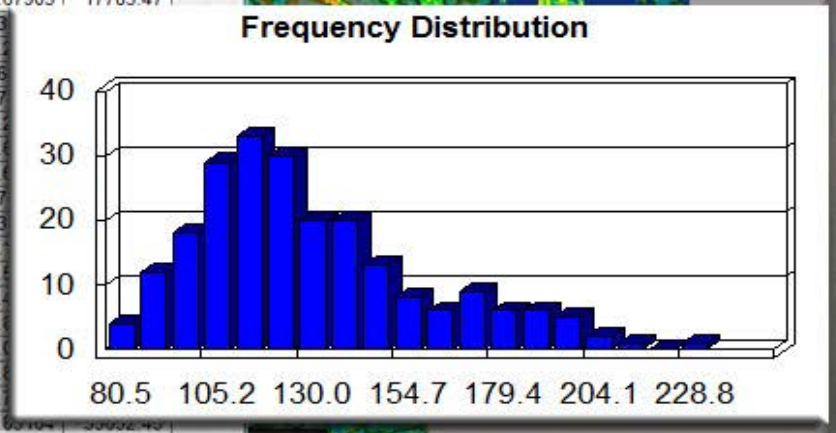
och13gapbasft

Rowid	ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
1	1	356	320392.2	6.074832	288.5256	282.4508	94.05083	43.5272	33482.1
2	2	171	153896.3	30.02881	213.382	183.3532	113.3906	34.33805	19389.8
3	3	49	44098.93	38.7999	267.7914	228.9915	124.7711	45.95424	6113.782
4	4	297	267293.5	0	292.3801	292.3801	112.2274	55.89684	33331.53
5	6	63	56698.62	0.259328	192.0348	191.7755	96.27222	51.80174	6065.15
6	8	54	48598.82	58.71654	211.9633	153.2468	136.1914	32.31278	7354.336
7	9	70	62998.47	21.46358	174.9944	153.5308	91.70319	35.20583	6419.224
8	10	32	28799.3	0.06629	267.8236	267.7574	120.7923	71.99537	3865.352
9	11	300	269993.4	5.515758	315.259	309.7433	144.4578	49.64857	43337.33
10	12	570	512987.5	2.7551	344.8956	342.1405	165.6627	66.9043	94427.73
11	13	680	611985.1	4.086895	365.085	360.9981	153.5051	57.6926	104383.4
12	14	763	686683.3	15.44728	427.0968	411.6495	214.3733	55.52118	163566.8
13	15	112	100797.5	16.08062	255.8523	239.7717	82.82555	44.54845	9276.462
14	16	755	679483.5	11.41423	362.0833	350.6691	175.3689	66.28735	132403.5
15	17	499	449089.1	5.890503	313.2702	307.3797	133.4727	51.15485	66602.86
16	18	231	207894.9	32.44246	364.7548	332.3123	190.3596	60.82699	43973.08
17	19	200	179995.6	0.025369	208.7766	208.7512	88.91737	35.67905	17783.47
18	20	571	513887.5	10.11995	302.0763	291.9563	153.3772	53	
19	21	755	679483.5	4.198511	263.665	259.4665	115.7431	42	
20	22	672	604785.3	0.849456	337.1523	336.3028	202.0214	66	
21	23	545	490488.1	4.855392	354.8767	350.0213	177.8158	57	
22	24	275	247494	18.4625	273.0983	254.6358	164.4992	45	
23	25	734	660583.9	15.90906	347.0692	331.1601	147.7971	54	
24	26	418	376190.8	3.671534	332.9043	329.2328	119.2942	59	
25	27	853	767681.3	16.82279	335.9013	319.0785	183.7905	57	
26	28	218	196195.2	2.436334	310.4358	307.9994	137.953	63	
27	31	202	181795.6	70.77827	330.5561	259.7779	236.7432	44	
28	32	314	282593.1	4.089305	301.11	297.0207	124.0025	53	
29	33	211	189895.4	13.4757	244.8969	231.4212	107.5242	42	
30	34	310	278993.2	9.974507	256.2588	246.2843	98.66915	44	
31	35	271	243894.1	11.7607	247.6788	235.9181	101.9585	42	
32	36	453	407690.1	5.167605	235.7099	230.5423	110.5368	39	
33	37	711	639884.4	0.992174	327.5485	326.5563	122.3258	55	
34	38	245	220494.6	8.195614	278.3932	270.1976	145.5202	52	

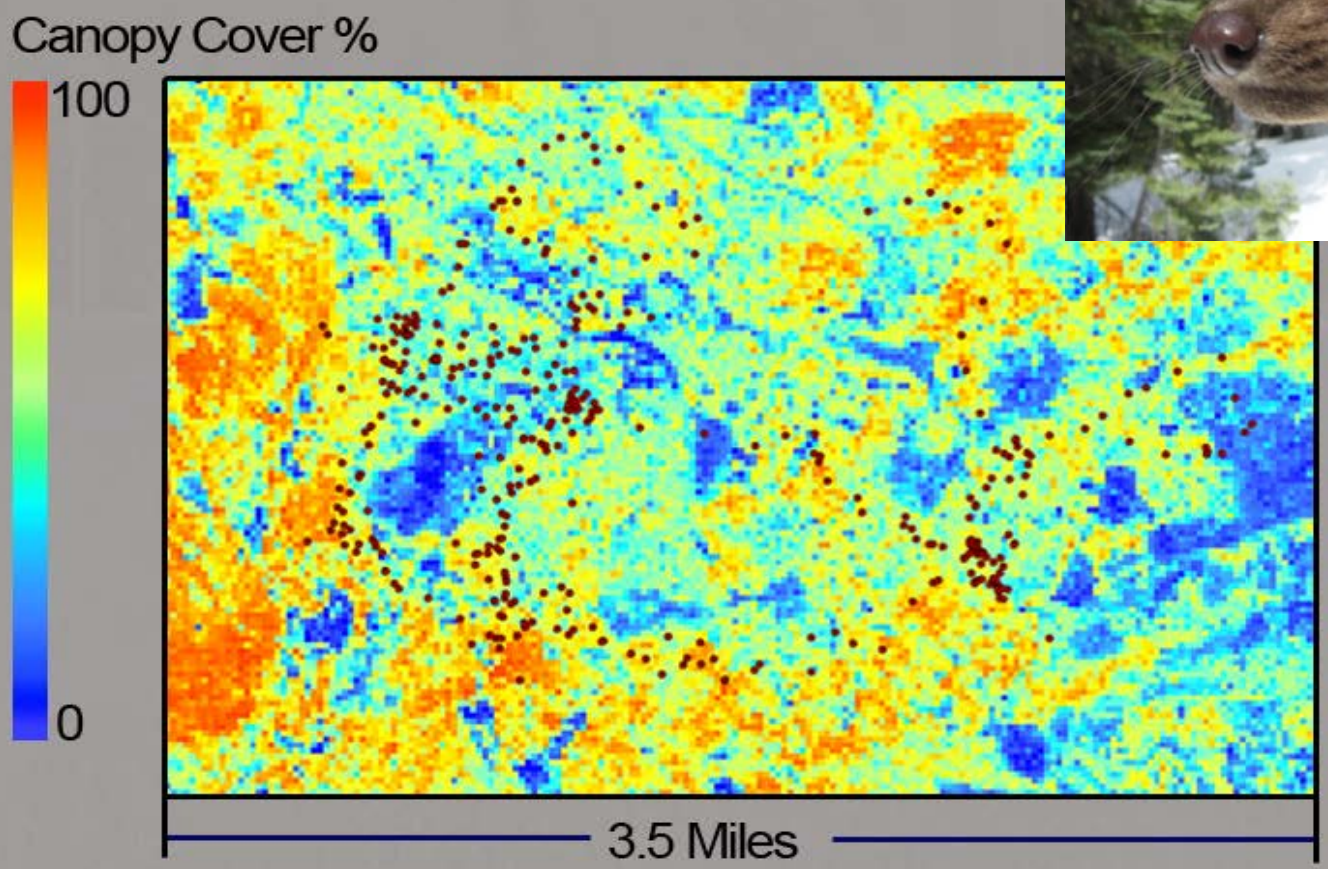
0 (0 out of 223 Selected)

och13gapbasft | och13gapvolcf | och13gapuncvclc | och13gapcc25ft

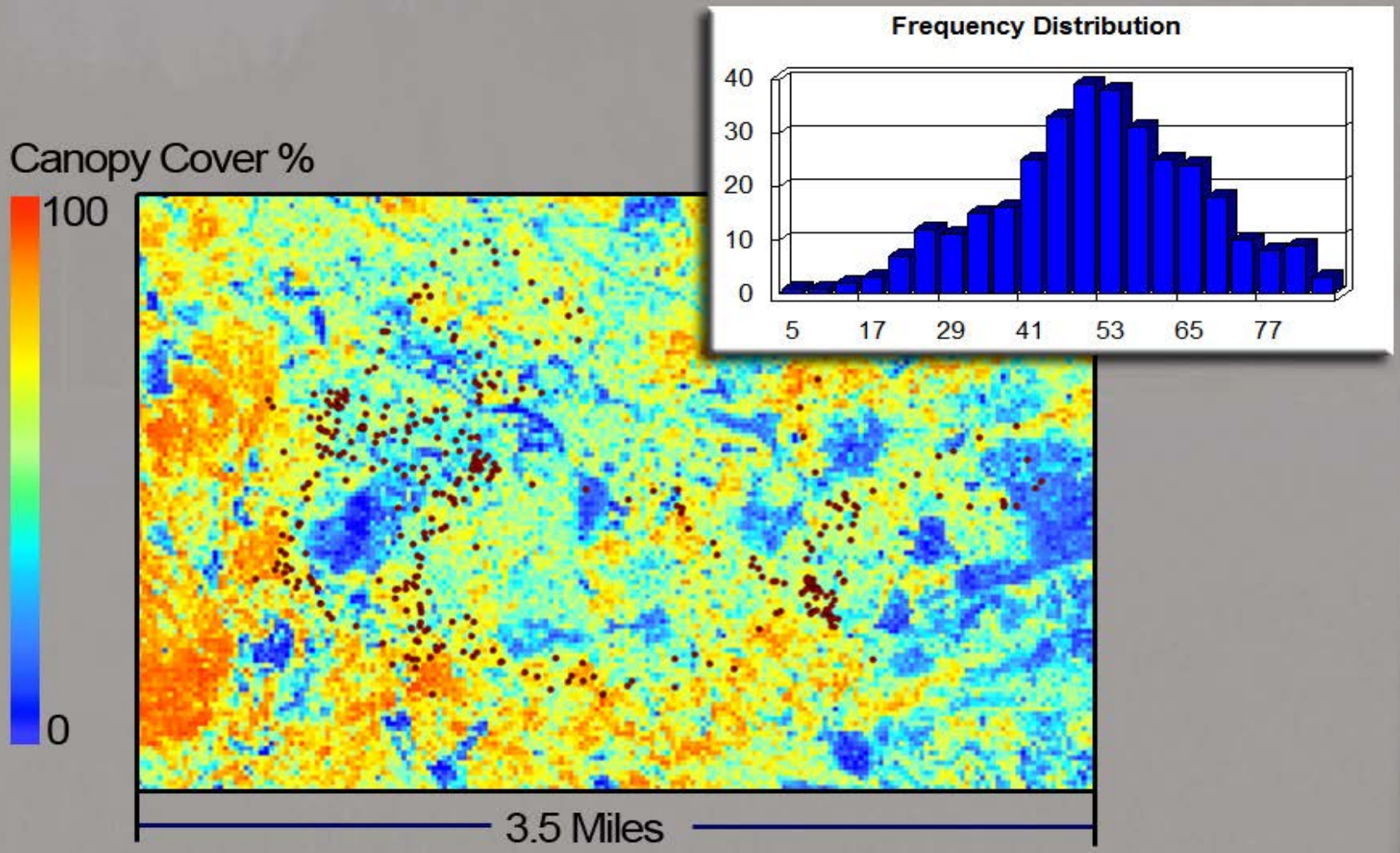




Plot-Based Products - Wildlife



Plot-Based Products - Wildlife



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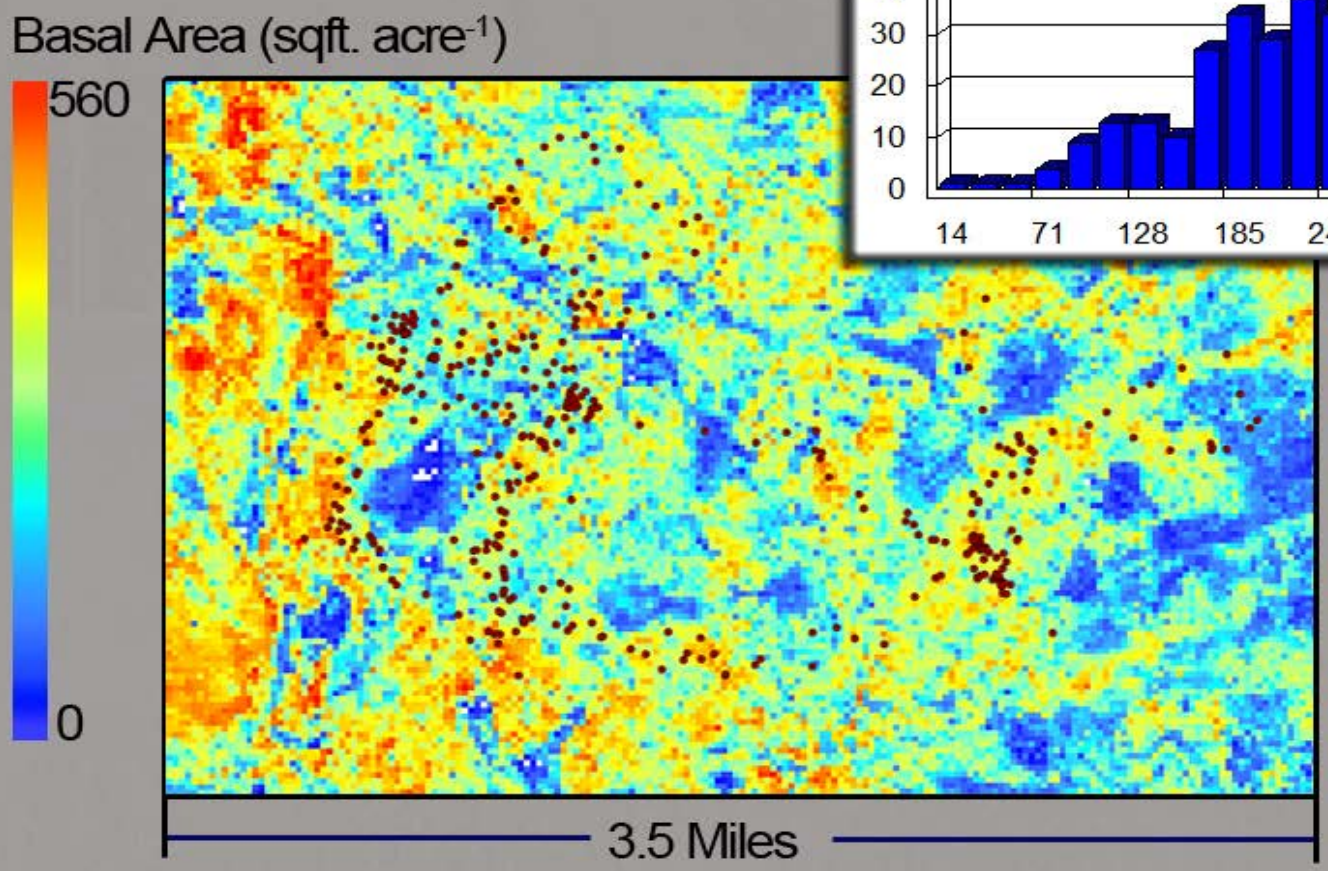

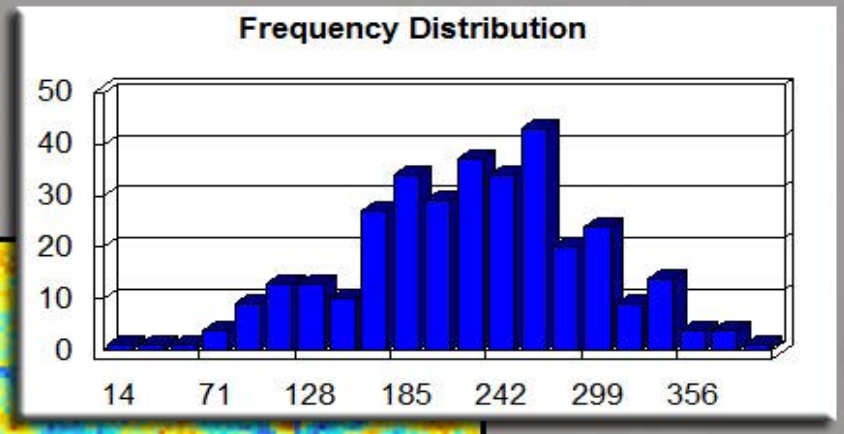

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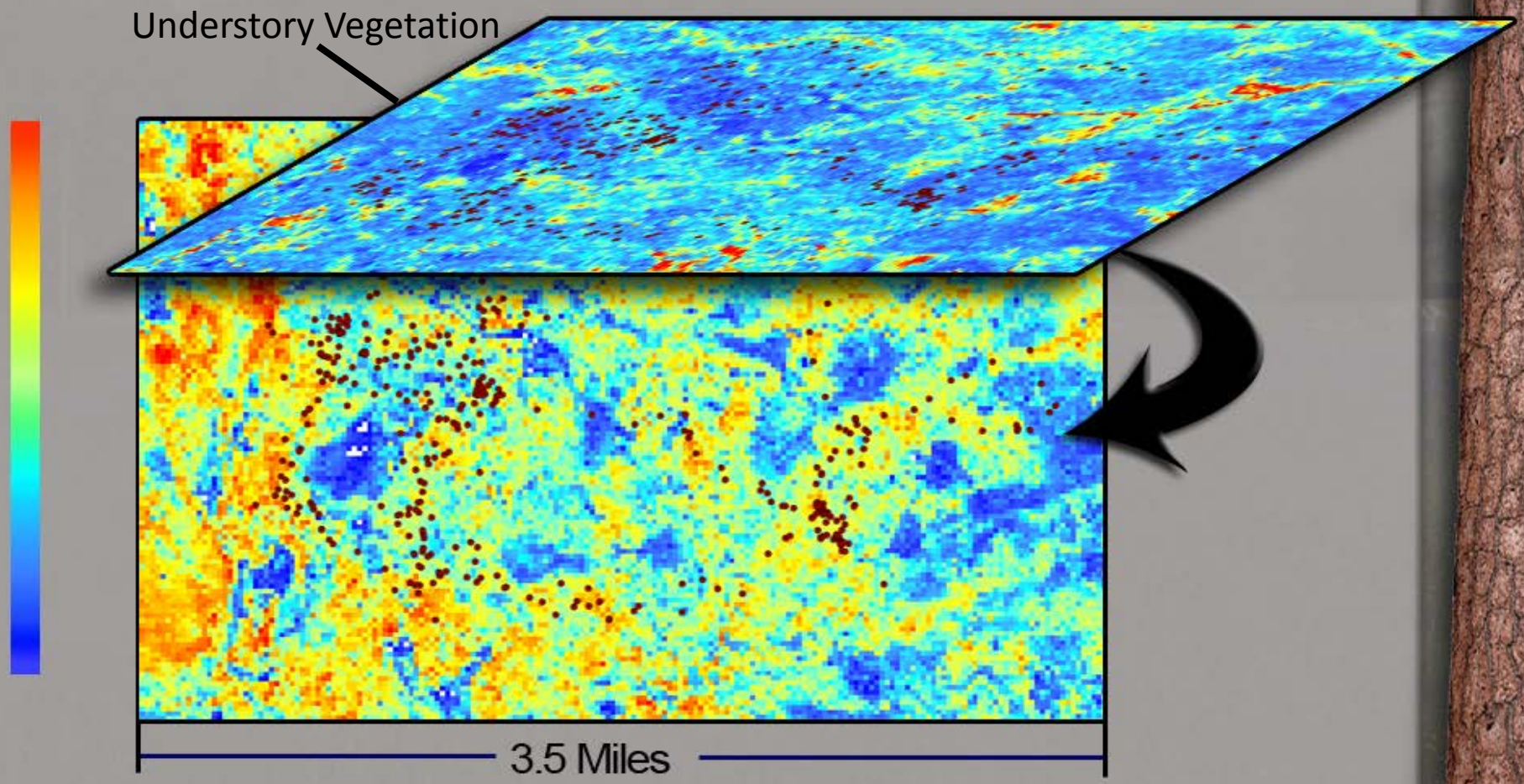

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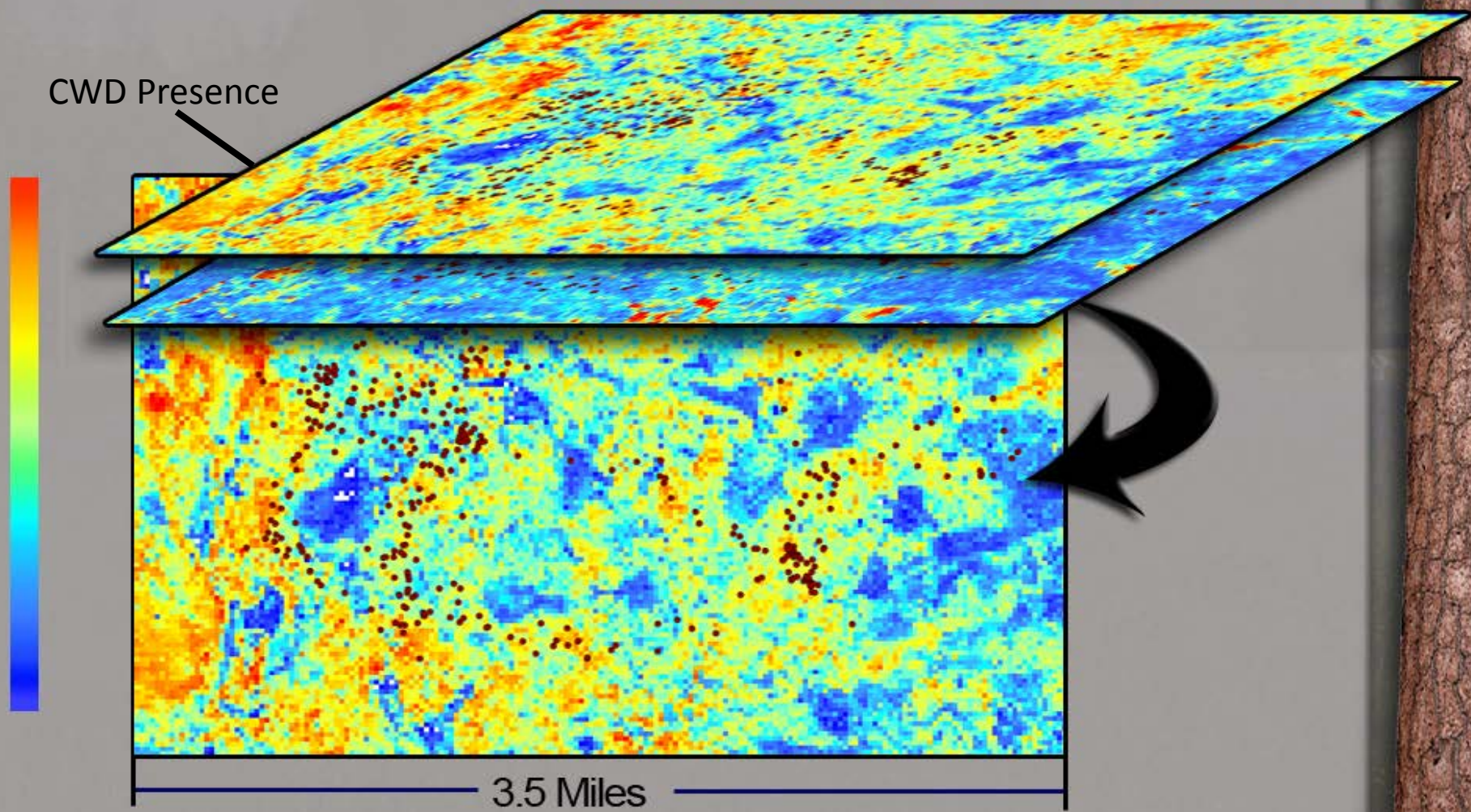
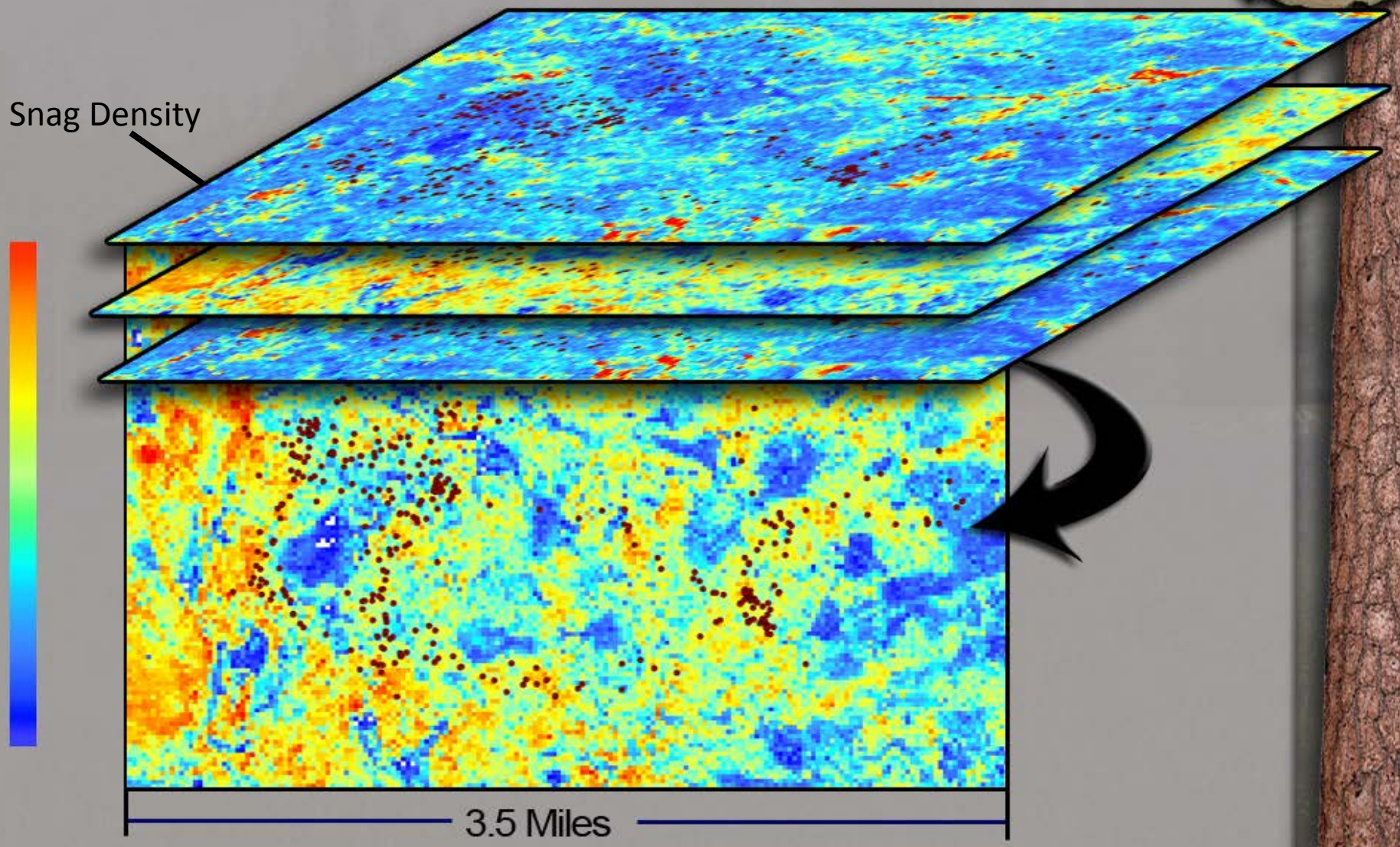
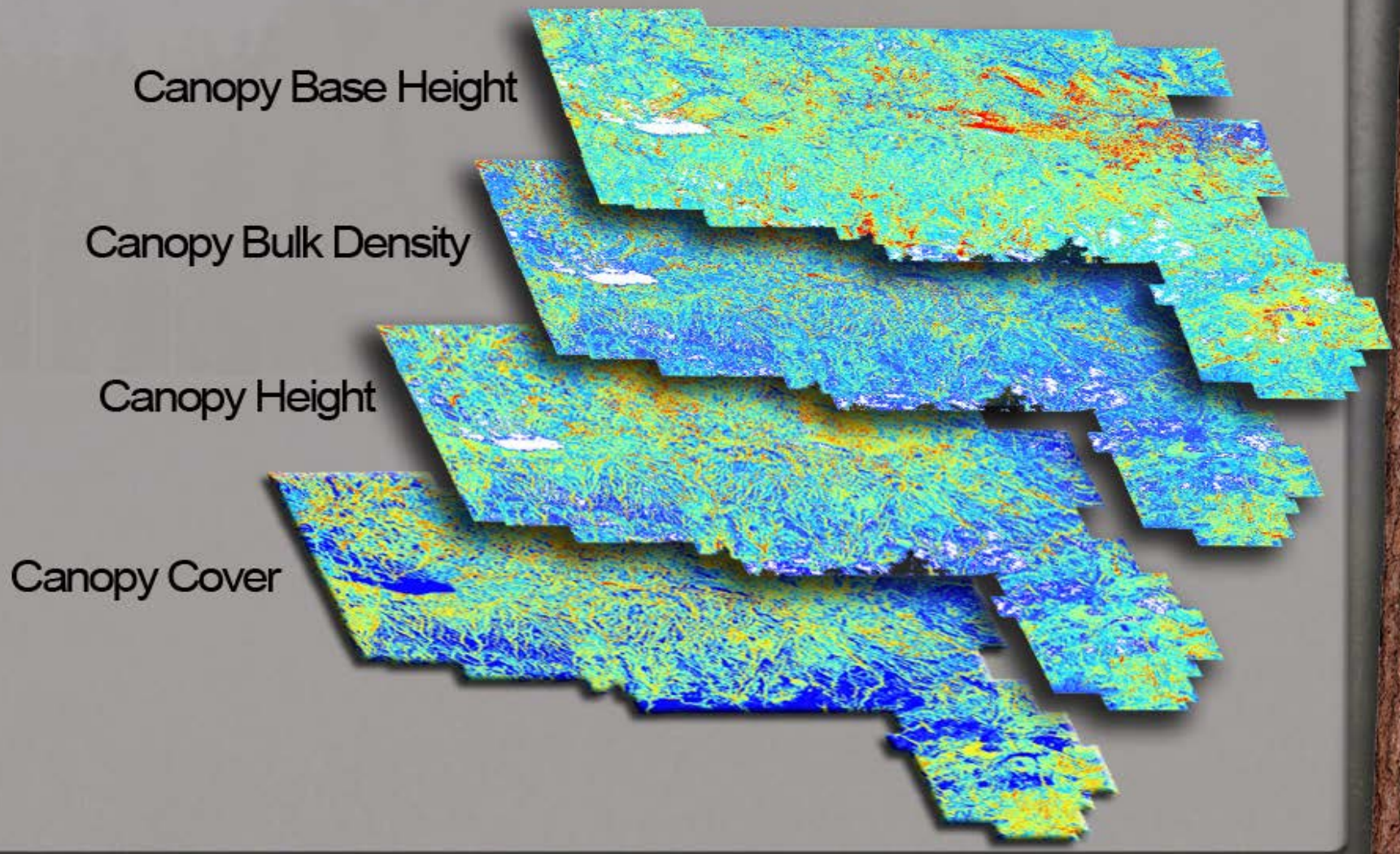


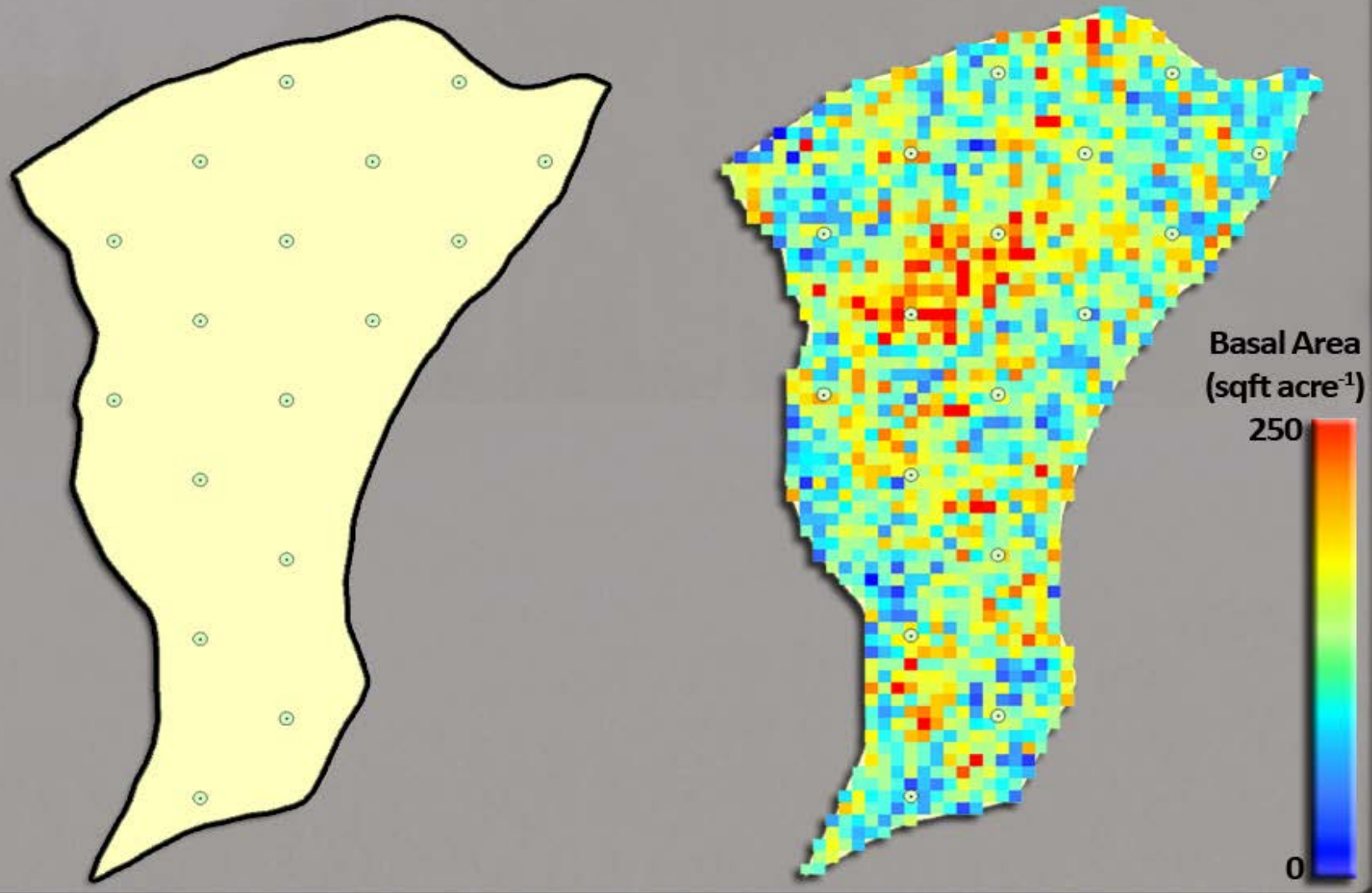
Plot-Based Products - Wildlife



Plot-Based Products – Fire & Fuels



Old vs. New



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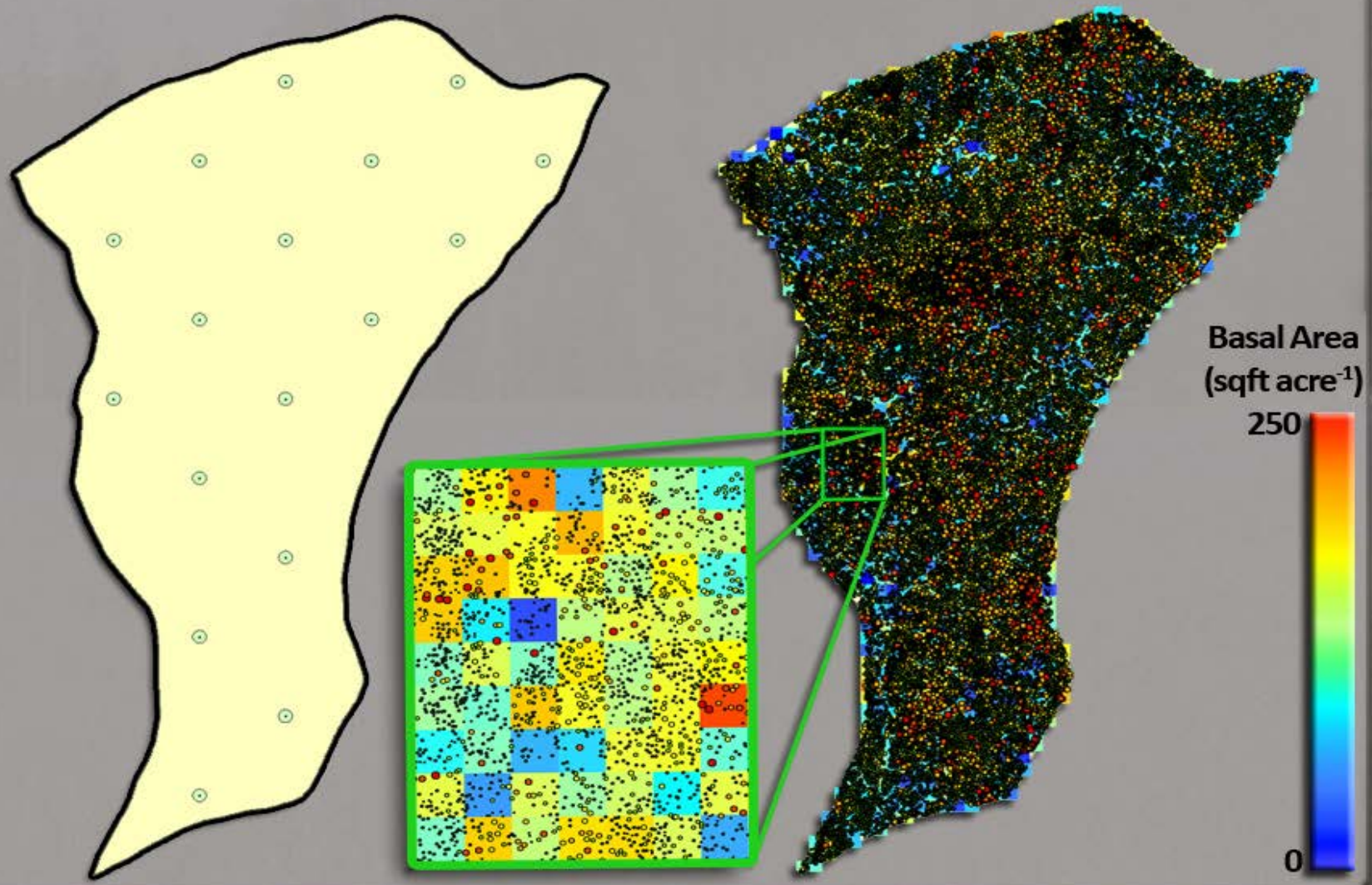
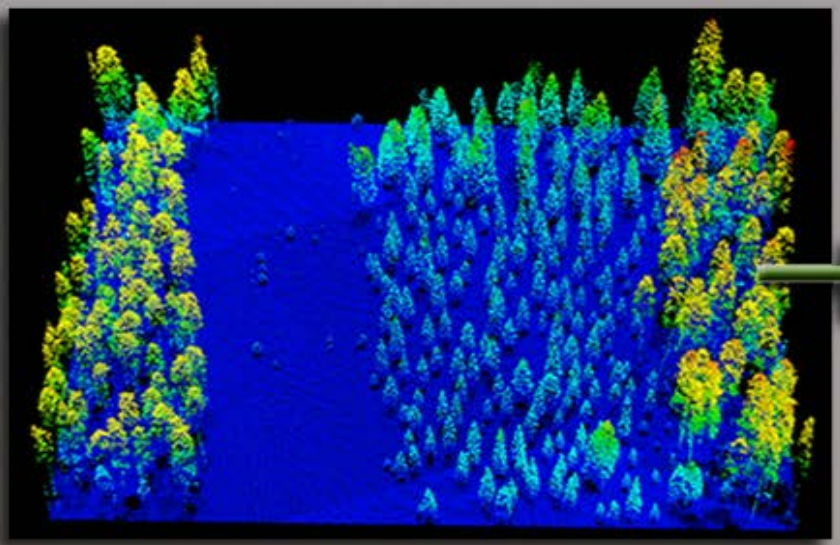
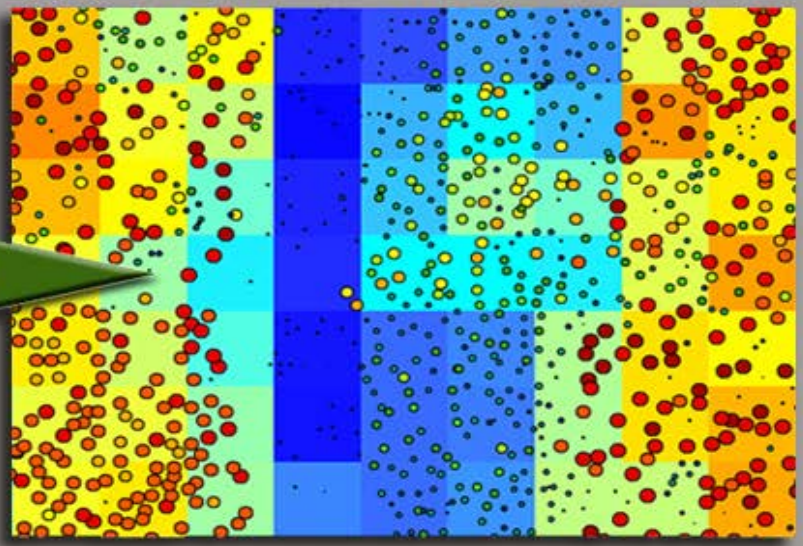


Lidar-Derived Products for Eastside Forests

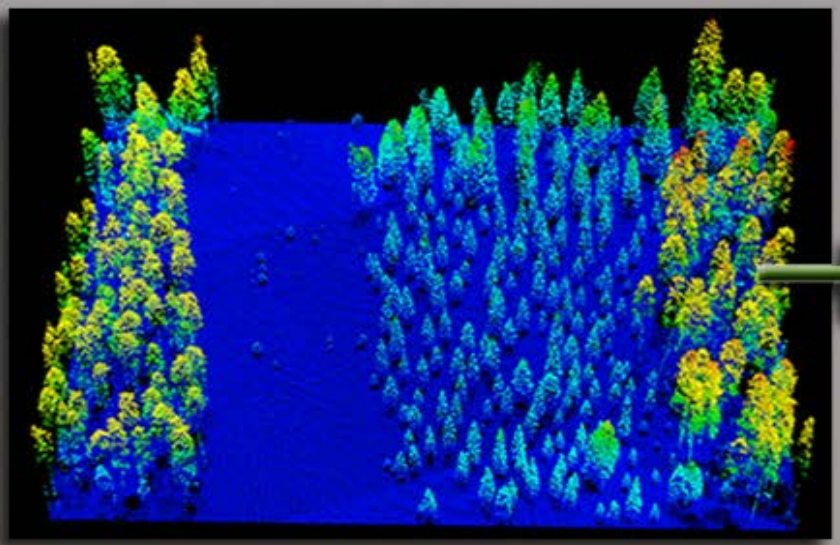
- Currently Available:
  - Canopy Cover
  - Maximum Height & DBH
  - Basal Area
  - Individual Tree Layers (Updating)
  - TPA by Size Class (by species) (Updating)
  - Canopy Cover by Height Strata
  - Understory Cover

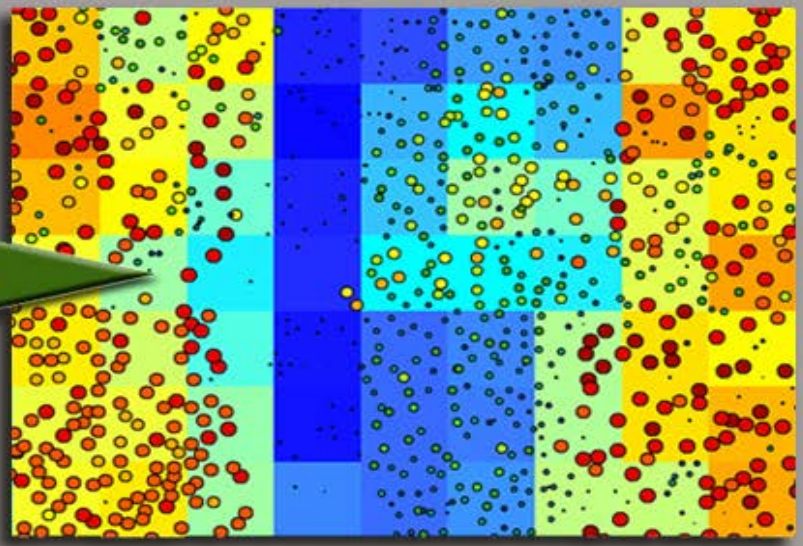




Lidar-Derived Products for Eastside Forests

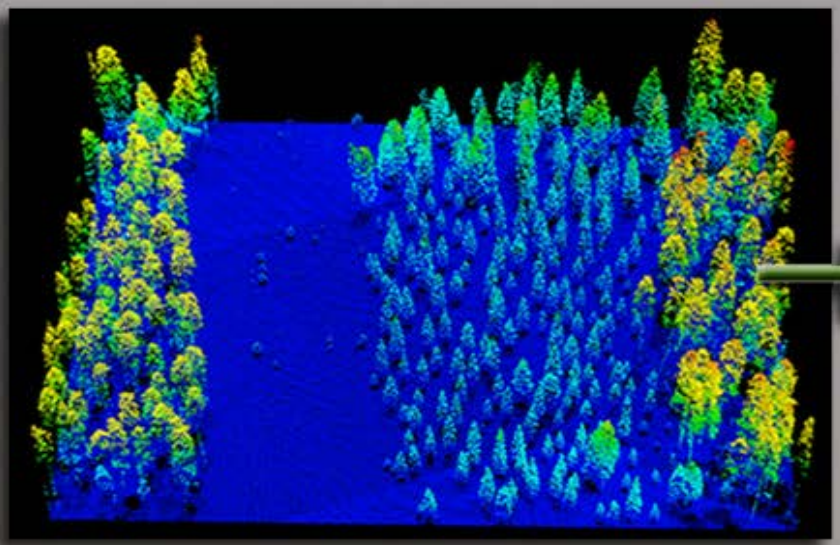
- Currently Available (cont.):
  - Goshawk Habitat (VSS Classes - Ochoco)
  - Biomass
  - Volume (cuft. & bdft.)
  - Canopy Base Height
  - Crown Bulk Density
  - Canopy Height

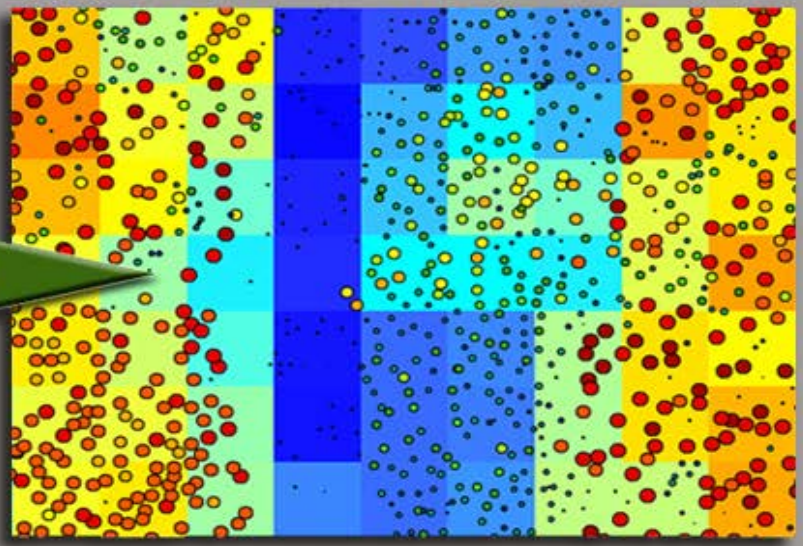




Lidar-Derived Products for Eastside Forests

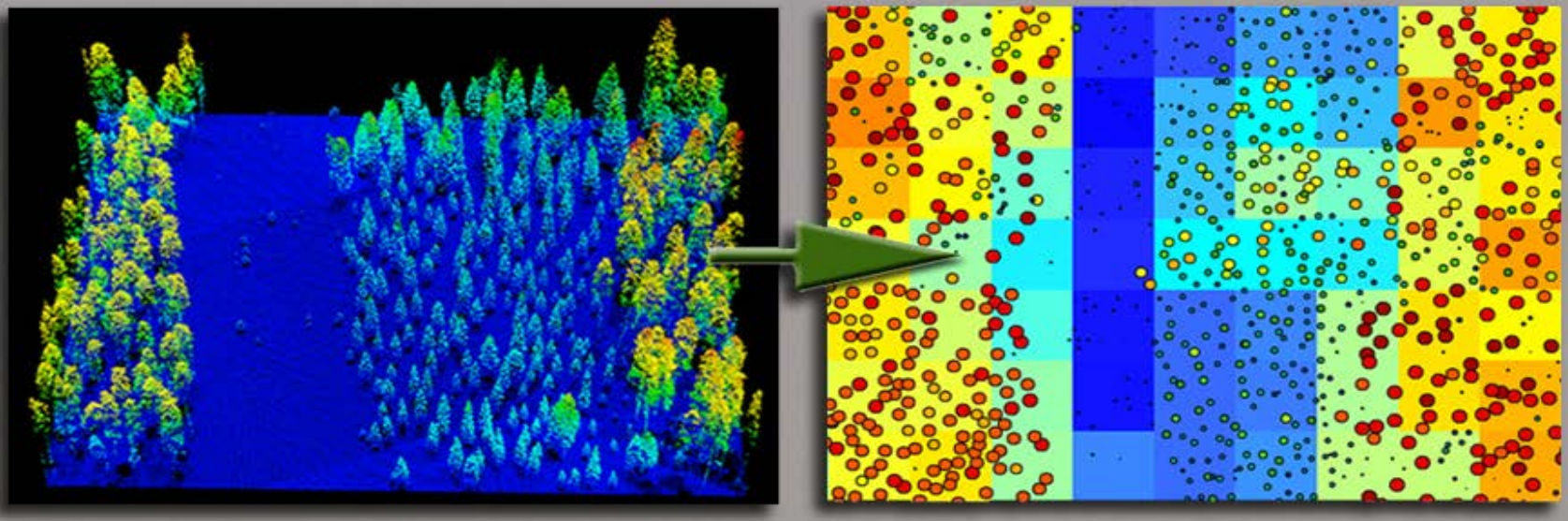
- In Future:
  - FVS Tree Lists (soon – completed for Ochoco)
  - Snags (soon)
    - Stem Map & Density
  - Live vs. Dead Tree Attributes (soon)
  - Eastside Screens Structure Classes (soon)
  - Late Seral ID and Potential Late-Seral ID





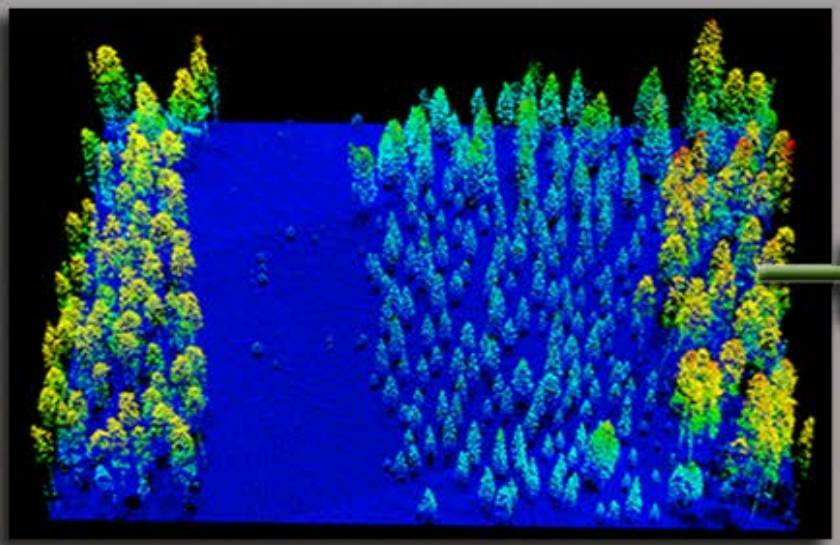
Lidar-Derived Products for Eastside Forests

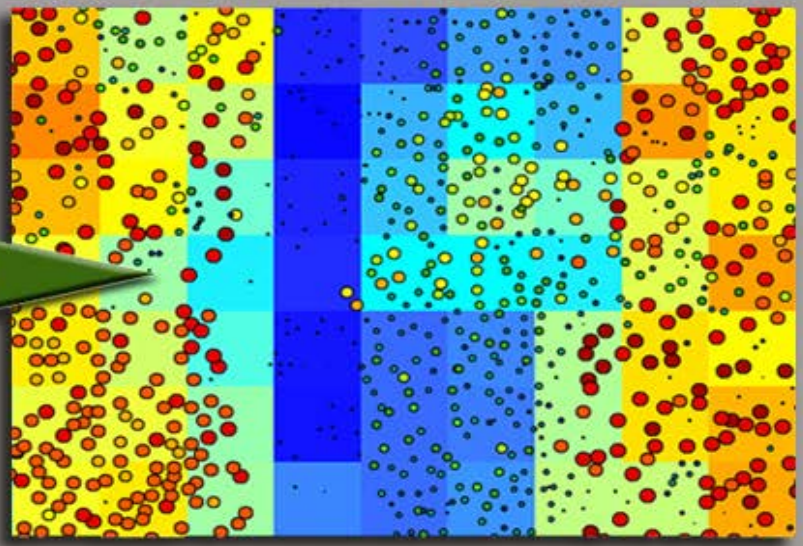
- In Future (cont.):
  - Viable Classes and Wildlife Habitat
    - Structure Stages, Density, Seral Composition
  - Coarse Woody Debris Presence / Absence
  - Understory Vegetation Cover and Hiding Cover
  - Riparian CWD Presence
  - Many more…



Applications

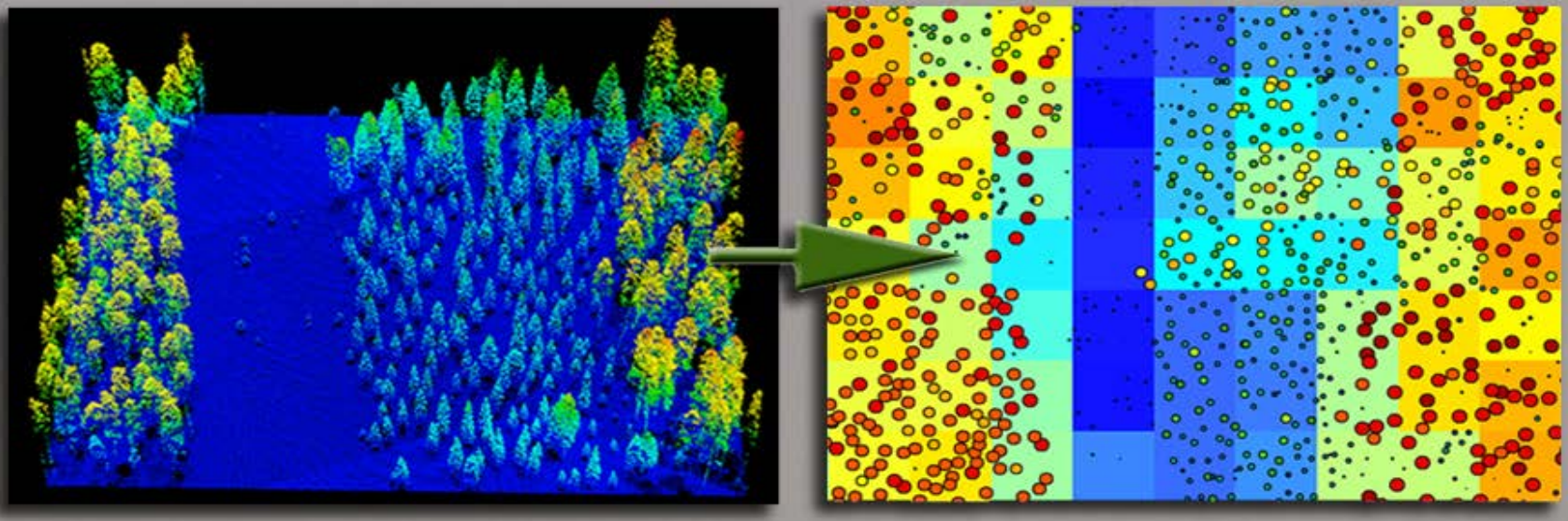
- Increase Field Work & Planning Efficiency
- Identify Areas of Interest
  - Risk of High Severity Fire
  - Wildlife Habitat
  - Late Seral & Potential
  - Tree Size and Forest Structure
  - Many more…





Applications

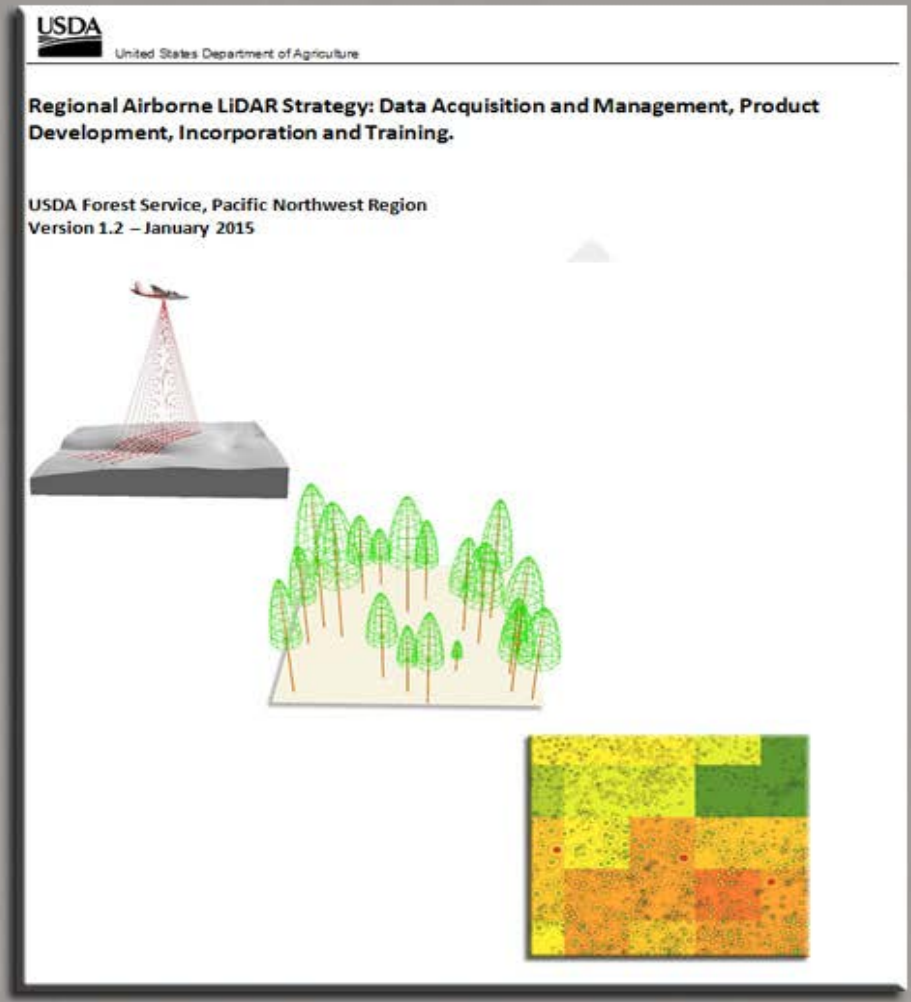
- Individual Stand to Landscape Level Assessments
  - Interactions and Trade-offs
- Optimize Restoration Planning & Treatments
- Assess & Monitor Restoration Treatments
- Just getting started…



Regional Lidar Strategy

Identifies Challenges

Outlines Solution Strategies



USDA
United States Department of Agriculture

Regional Airborne LiDAR Strategy: Data Acquisition and Management, Product Development, Incorporation and Training.

USDA Forest Service, Pacific Northwest Region
Version 1.2 – January 2015

Regional Lidar Strategy

Component Goals

Acquisition

Strategically optimized and efficient collection of quality airborne lidar data for the region.

Field Data Collection

Efficient collection and delivery of the lidar-friendly field data required to generate the defined lidar-derived products.

Modeling & Analysis

Efficiently create and generate robust models for the prediction of the defined lidar products.

Product Creation & Management

Efficiently create and manage final lidar-derived products and incorporate them into the product delivery frameowrk.

Incorporation of Products & End-User Training

Incorporate products into the forest planning and monitoring process at all levels.

Provide practical training for end-users to facilitate efficient and robust incorporation of products.