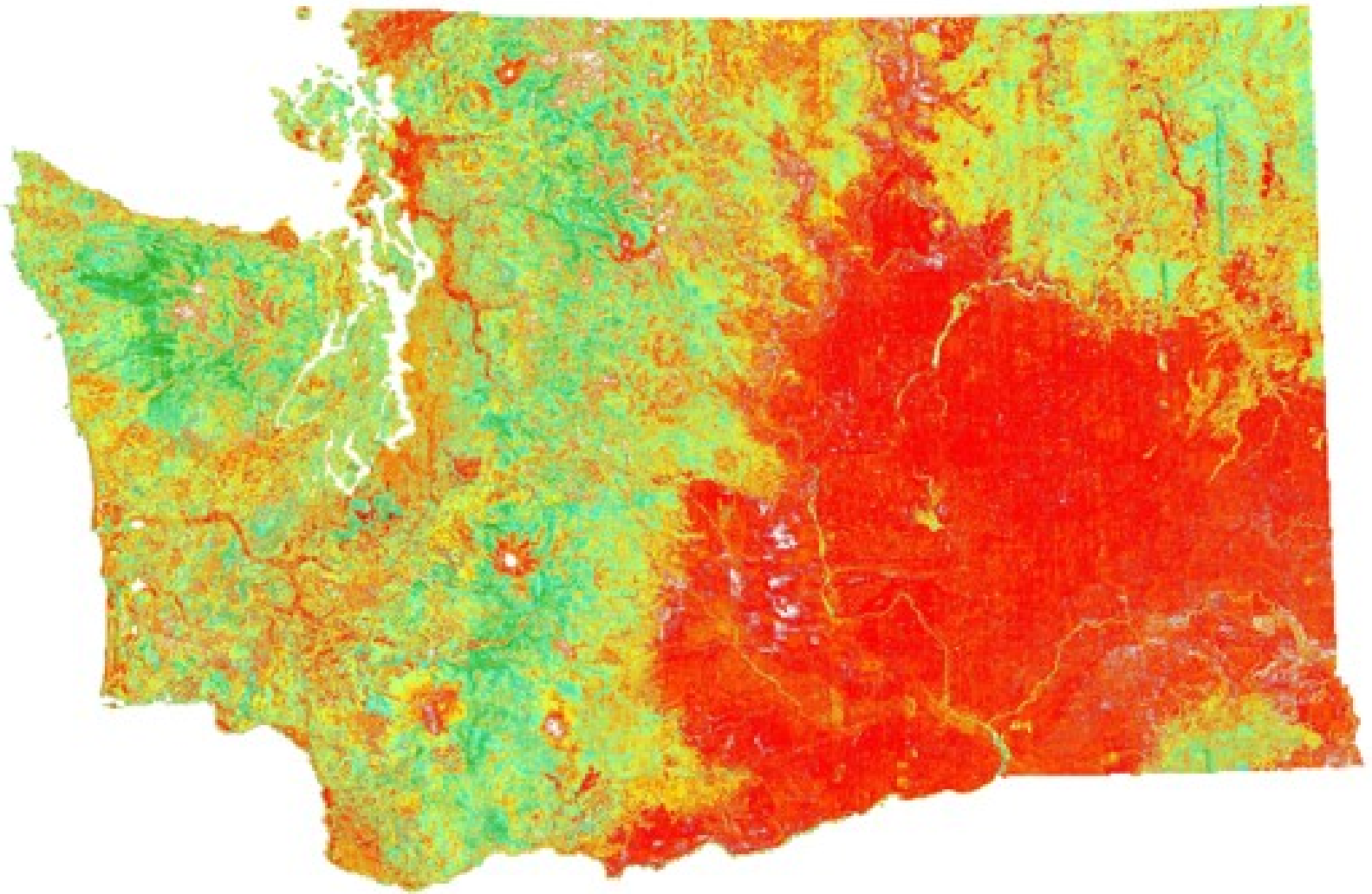
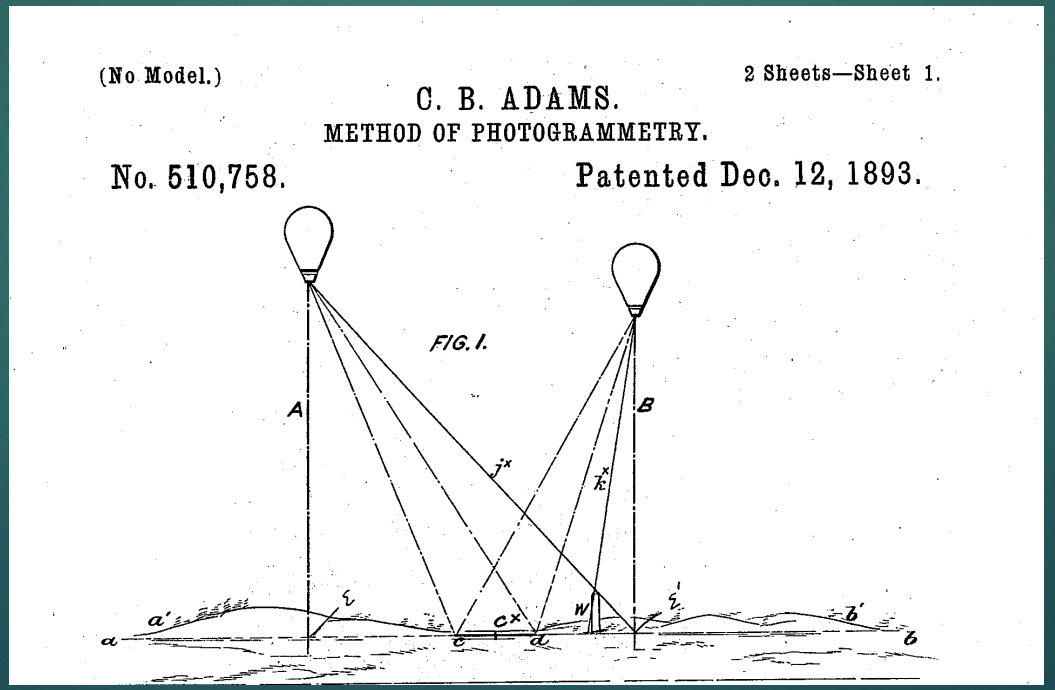
Forest Inventory with NAIP Photogrammetric Point Clouds



IFC Meeting
3/23/2021
Jacob Strunk

- Photogrammetry is "the art, science, and technology of obtaining reliable information about physical objects and the environment, through processes of recording, measuring, and interpreting imagery and digital representations of energy patterns derived from noncontact sensor systems" (Colwell, 1997:3).


(No Model.) 2 Sheets—Sheet 1.

C. B. ADAMS.

METHOD OF PHOTOGRAMMETRY.

No. 510,758. Patented Dec. 12, 1893.

FIG. 1.

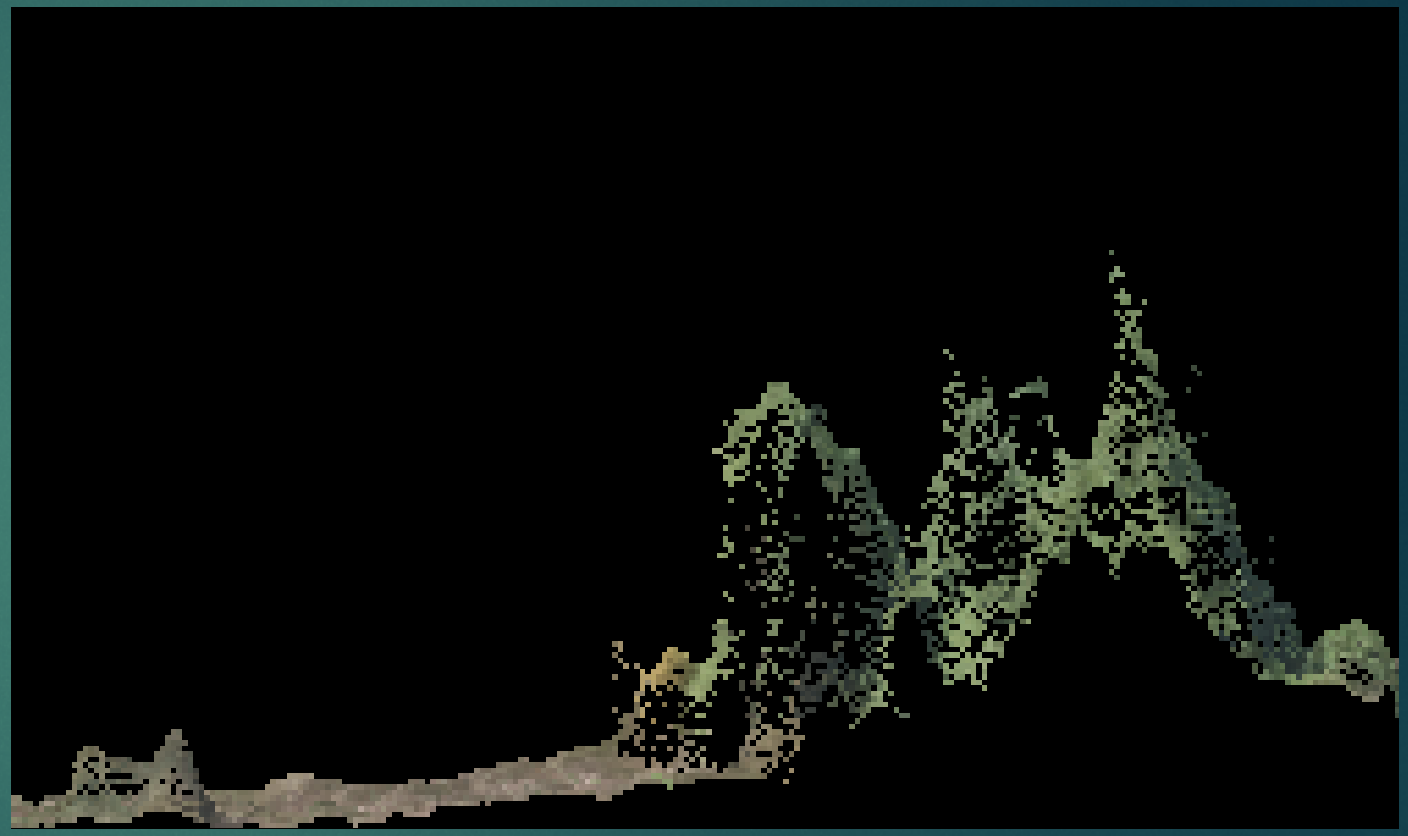
Terminology

- Digital Aerial Photogrammetry **(DAP)**

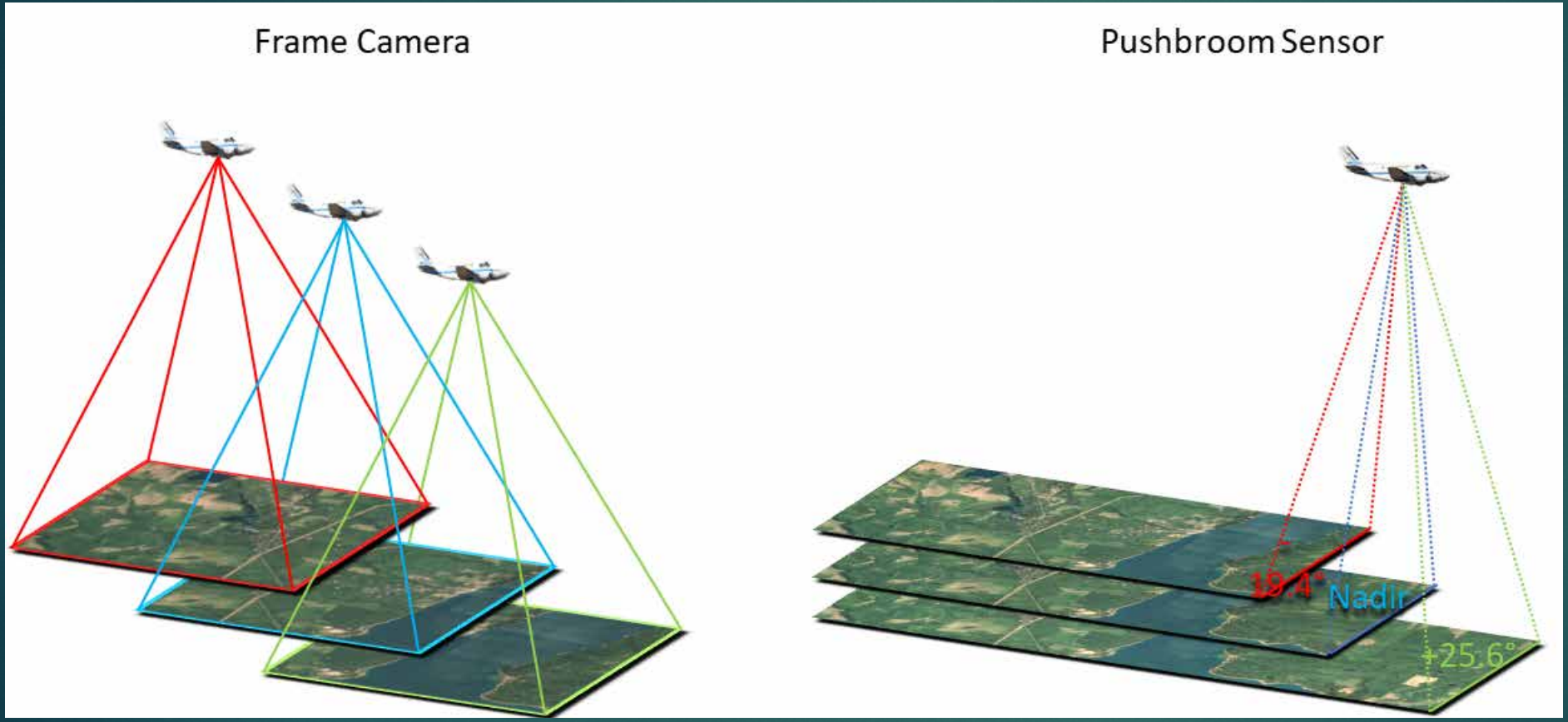
- Dense Image Matching (DIM)
- Photo-derived Digital Surface Model
- Photogrammetric point cloud
- "Phodar"
- …

And related

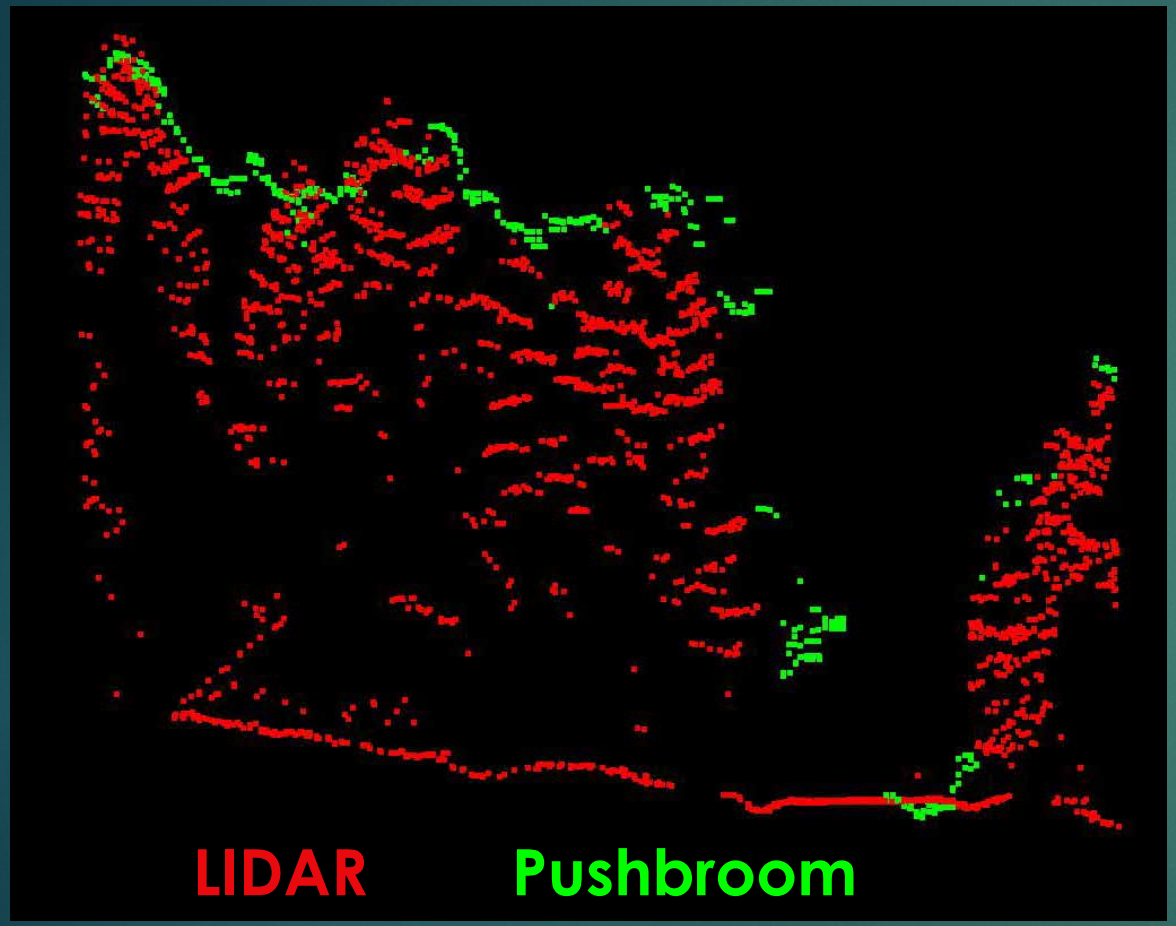
- Structure From Motion (SFM)



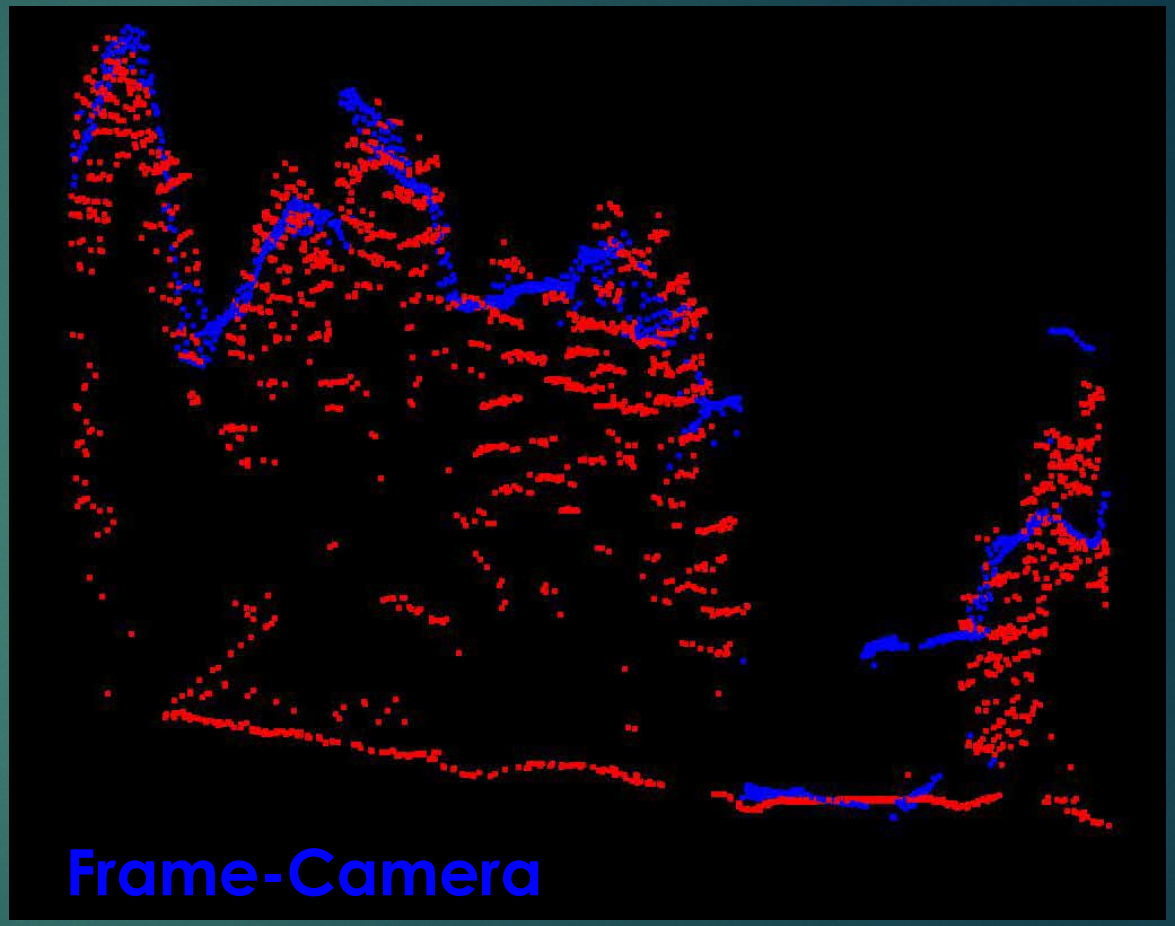
Pushbroom Sensor Derived Stereo



- Multiple look angles
- Stereo comes from forwardlap (only)
- Sidelap is minimal (5-10%), not used



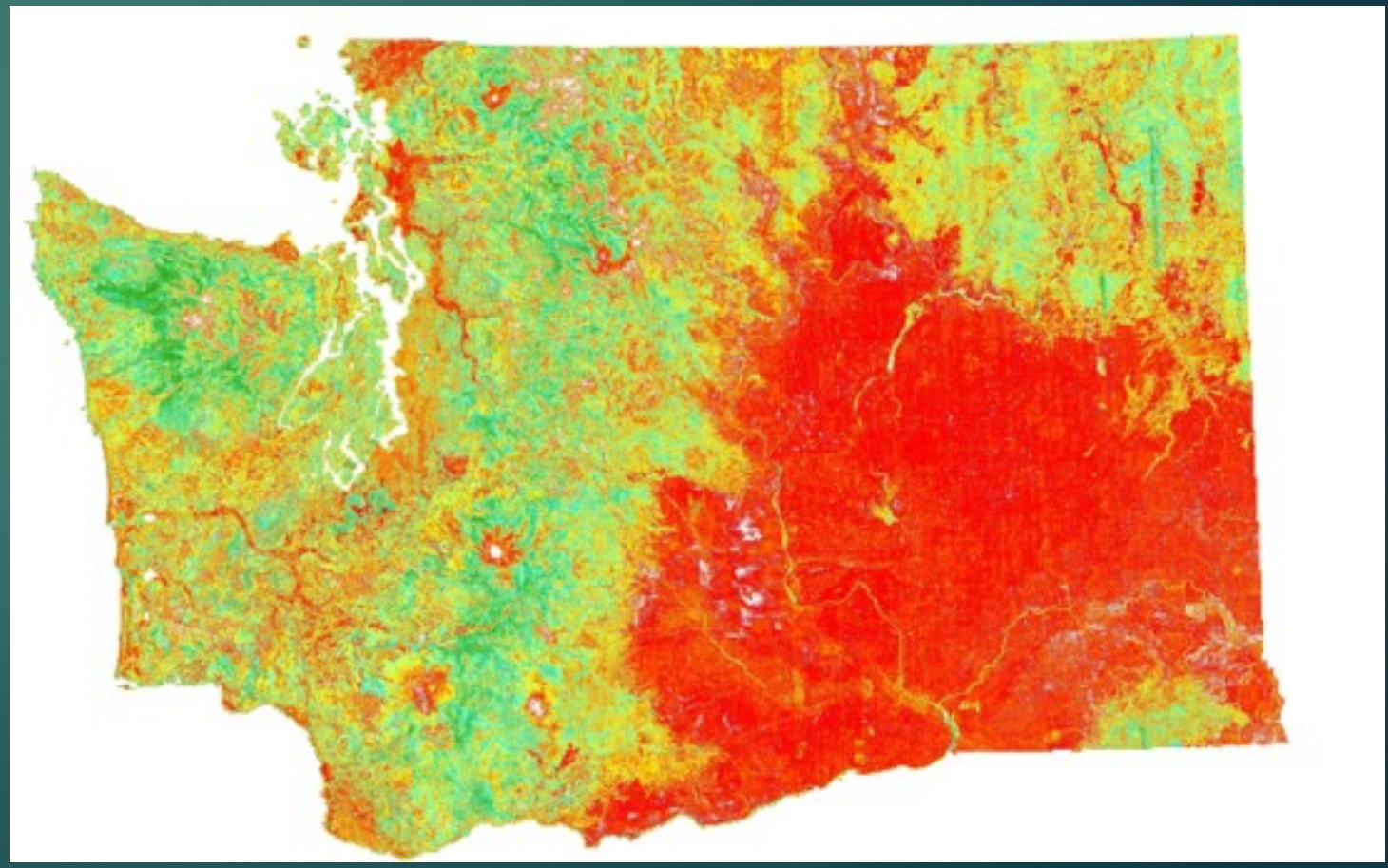
WA State, 40cm pushbroom, Socet



WA State, 30cm frame, Trimble Inpho

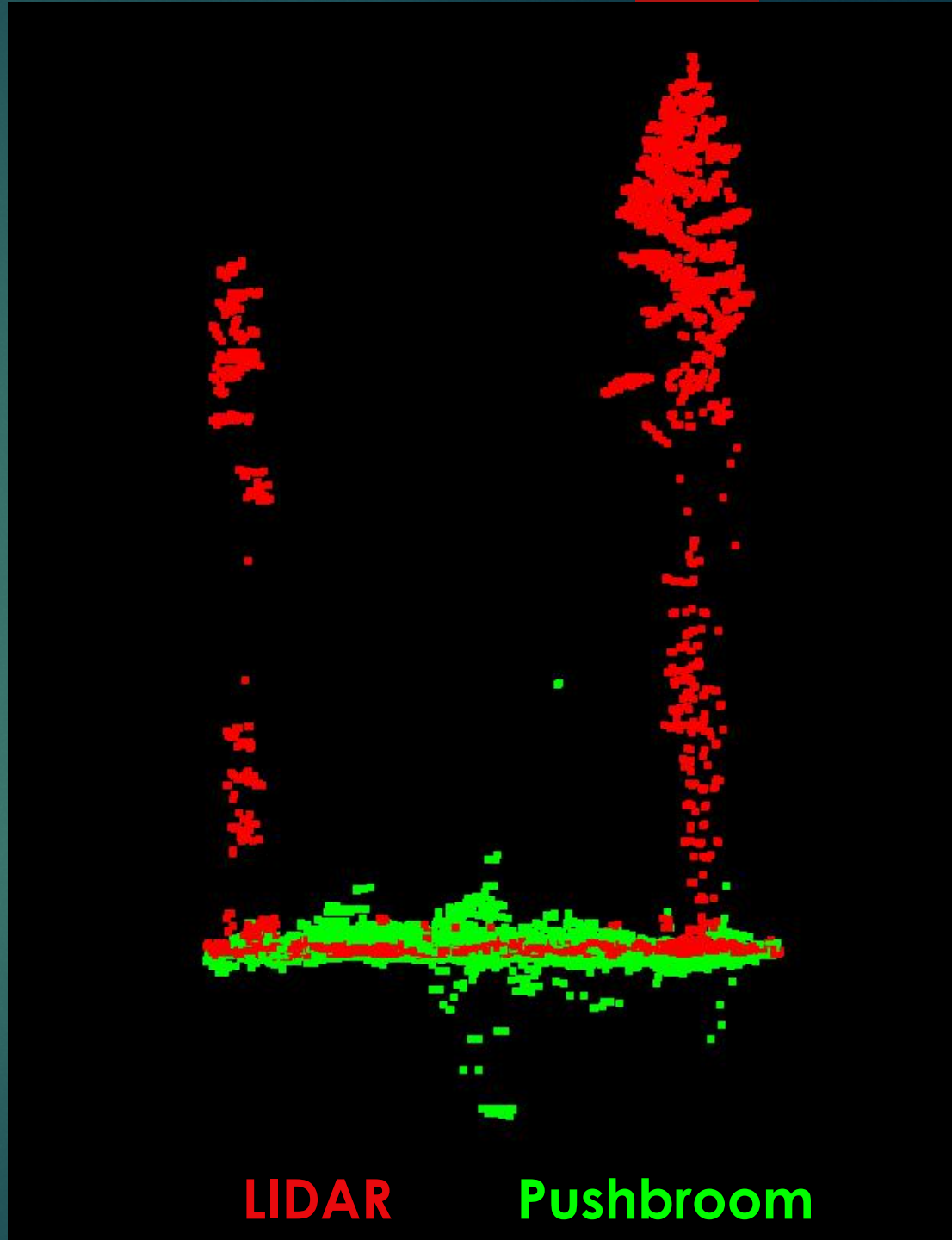
"NAIP" DAP

- National Agricultural Imagery Program (NAIP)
- ***Pushbroom sensor***
- *Canopy surface model (lidar~ish)*
- Data quality: DAP < lidar
- Low cost point cloud
  - $0.27 - $1.0 / square mile
  - 0.04¢ / acre, 6 - 24 acres for 1¢
- Consistent, huge areas (states)
- Frequent (2 years)
- 30cm – 60cm GSD (~ 3 – 11 ppm)
- 4-band

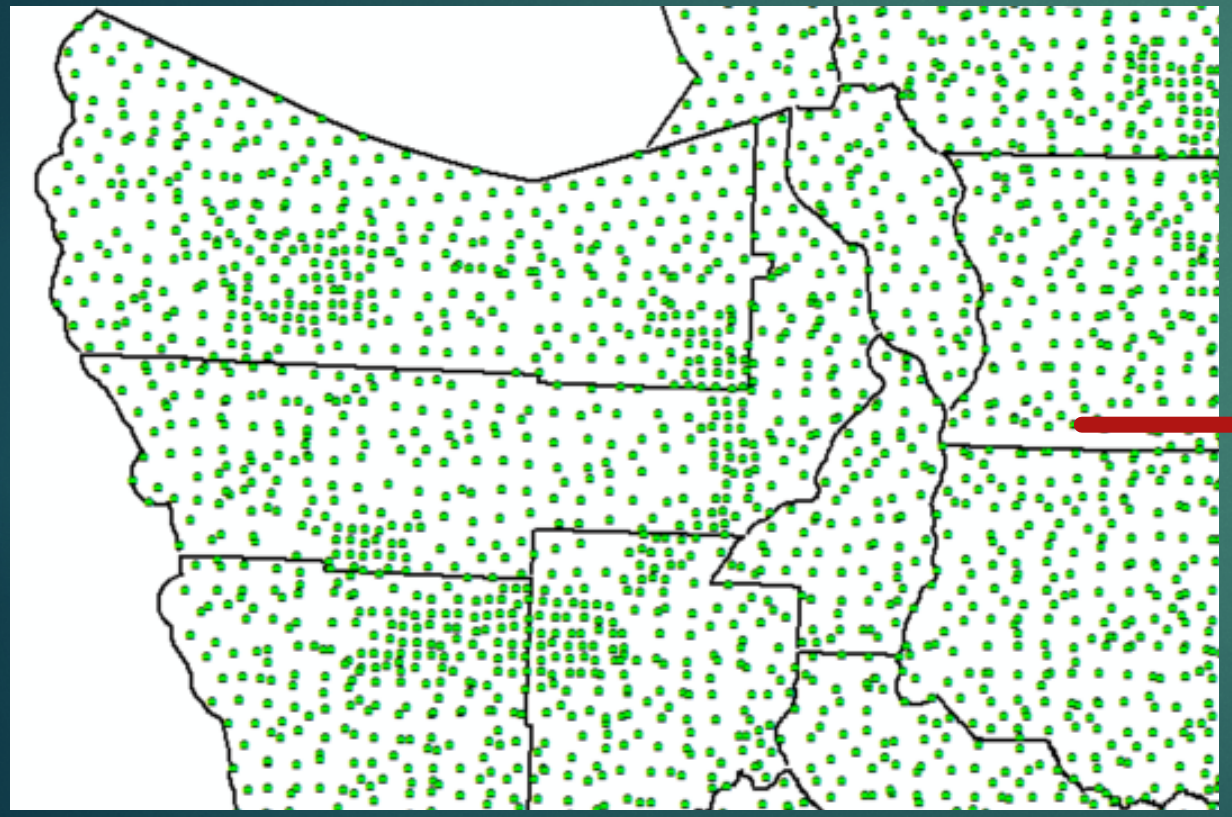


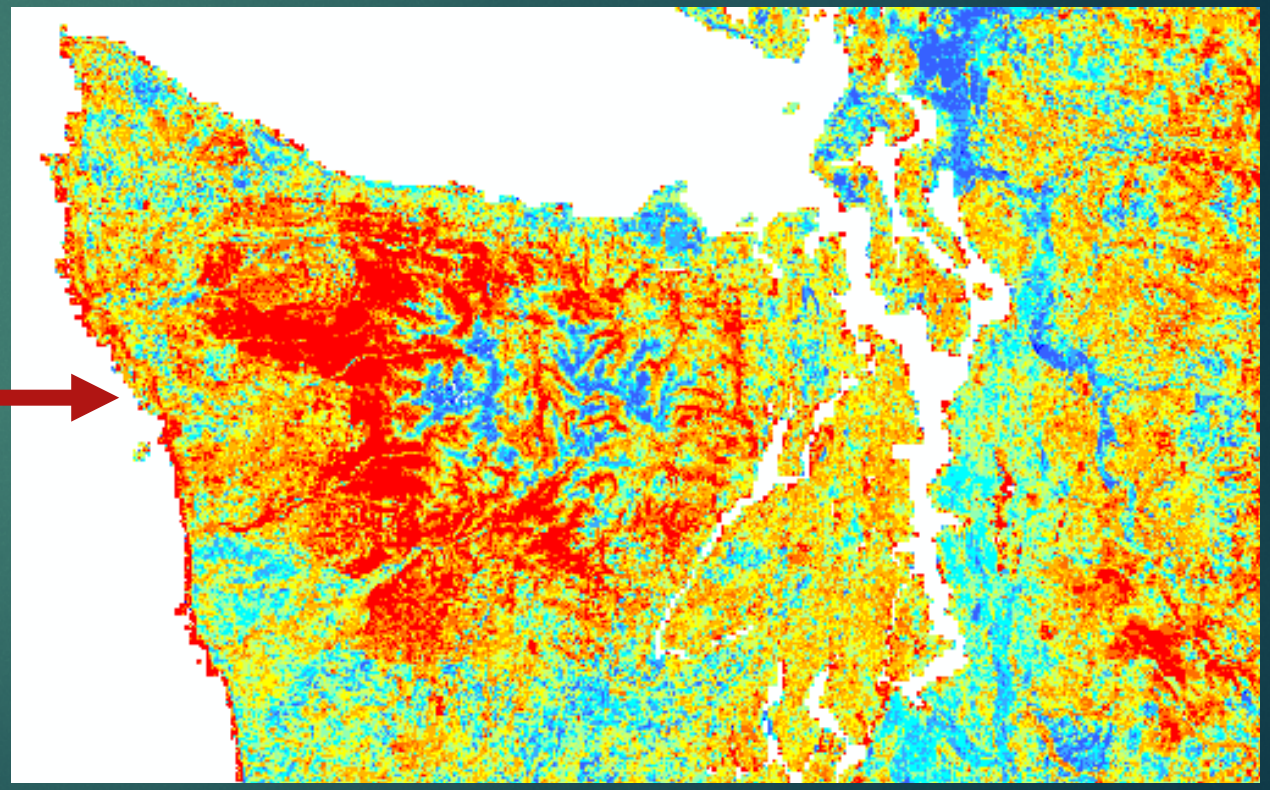
Disadvantages of "NAIP" DAP

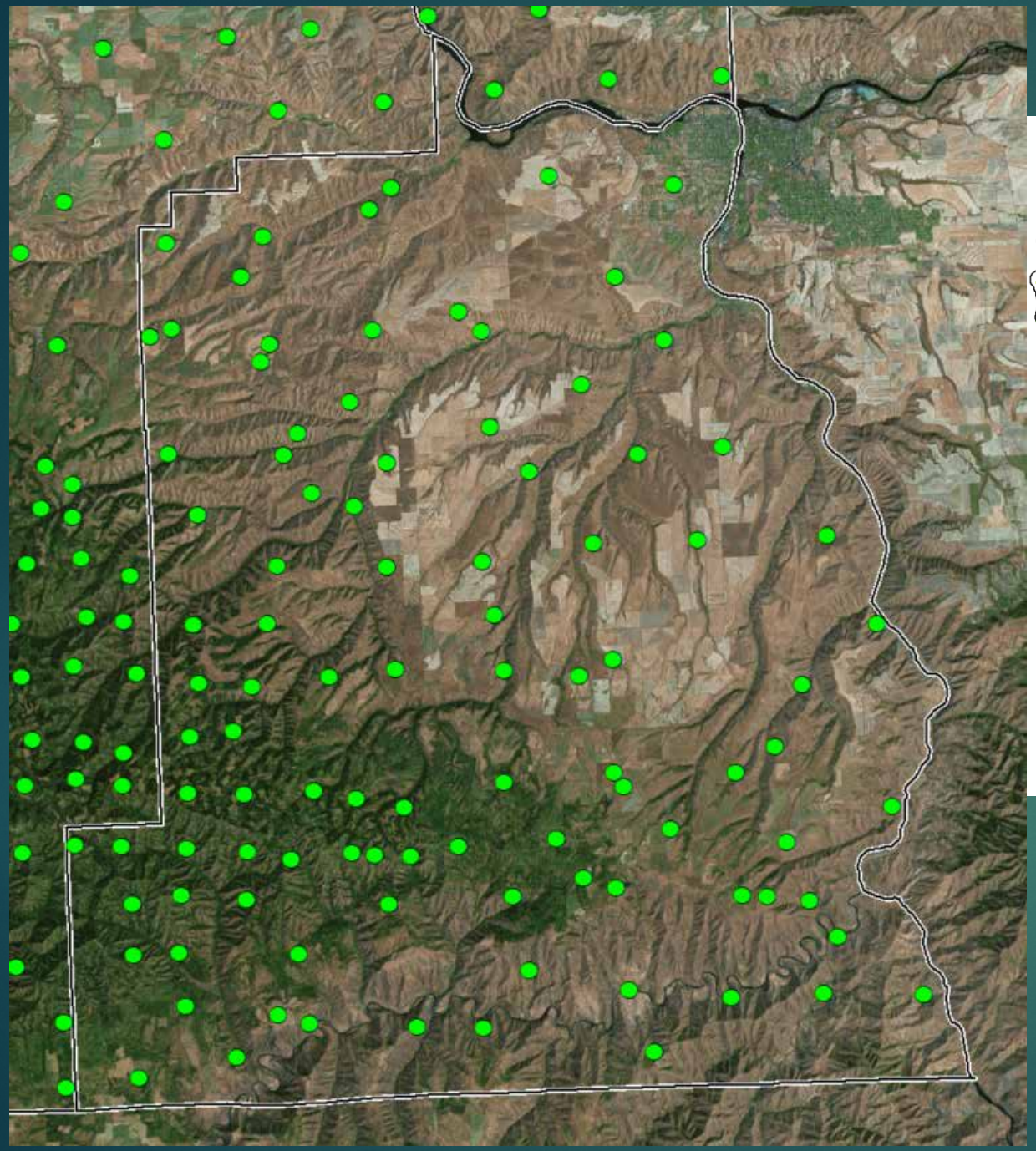
- Misses trees in openings
- Sharp edges lost
- Canopy gaps missing

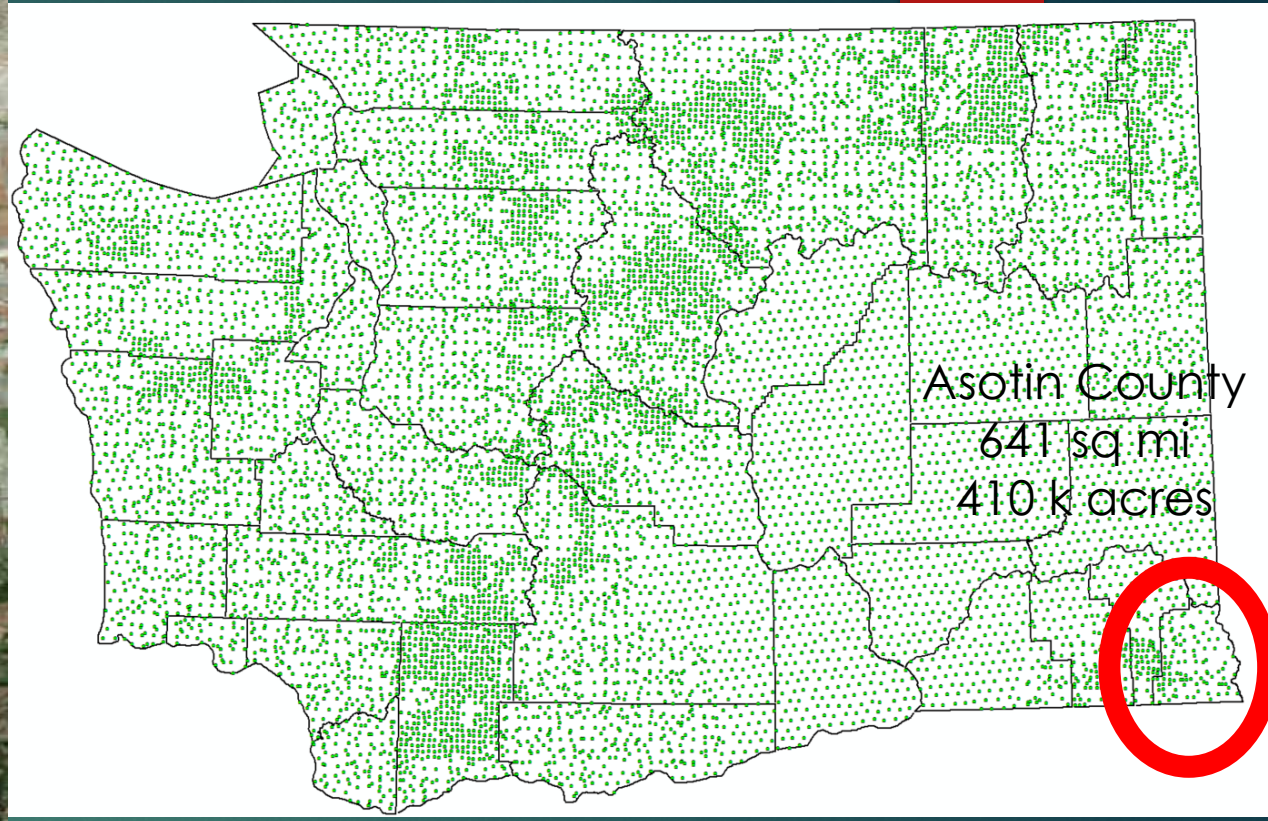


Objectives:
Increase Efficiency + Enable Maps









A powerful, consistent dataset
County level: finest resolution*
Limited ability to make fine scale inference*

** without auxiliary information*

Some Options

- Airborne lidar (expensive, incomplete)
- Various airborne & spaceborne passive sensors
- LCMS (satellite trajectory)
- …

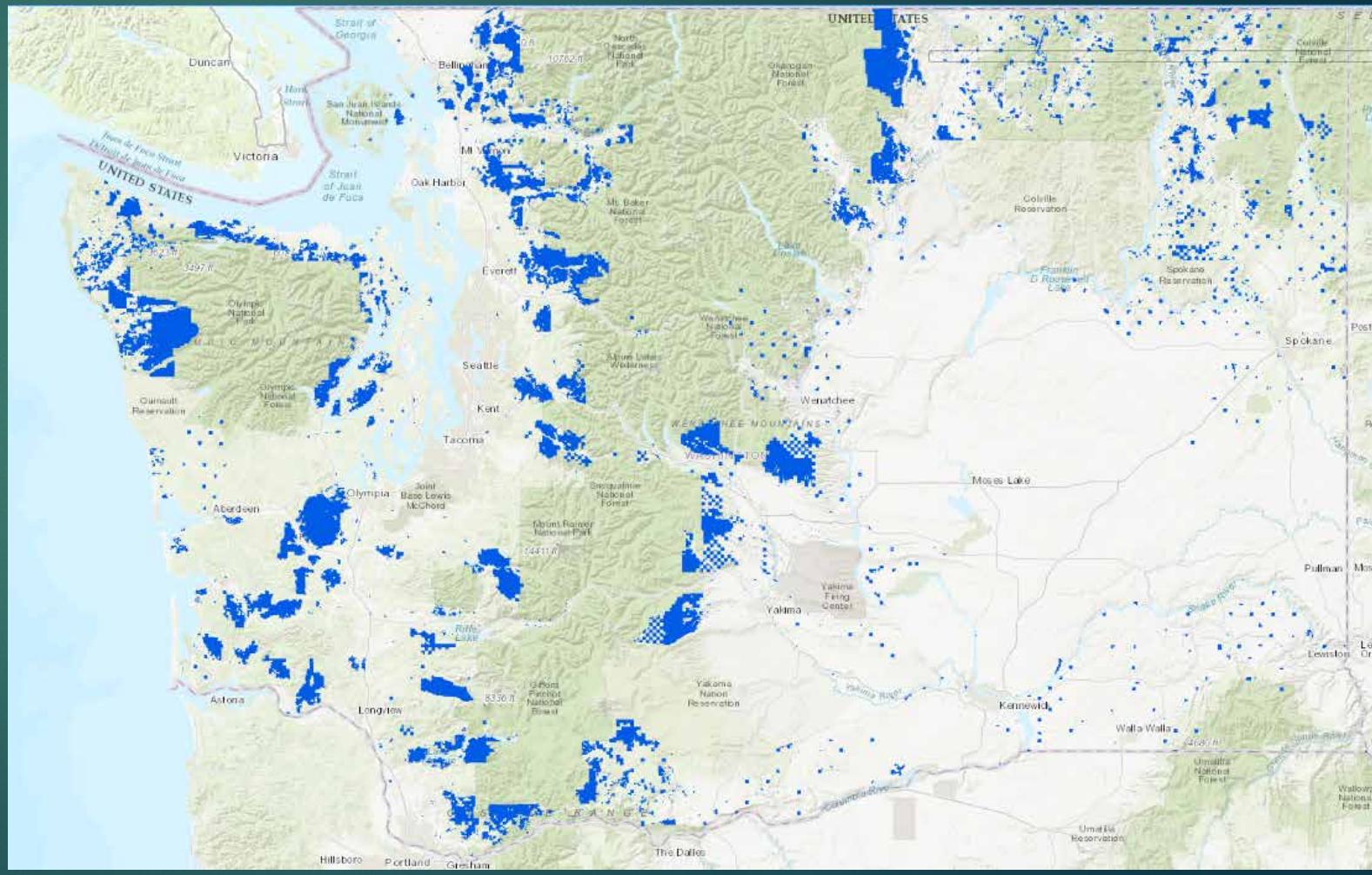
- Or (and?)

- NAIP Digital Aerial Photogrammetry (DAP)

How is DAP Used?

But First: Some Background

- Washington State DNR operational with DAP for forest inventory in 2015*
- Several DAP Updates (RSFRIS 3.0)
- https://data-wadnr.opendata.arcgis.com/datasets/rs-fris-polygon-data

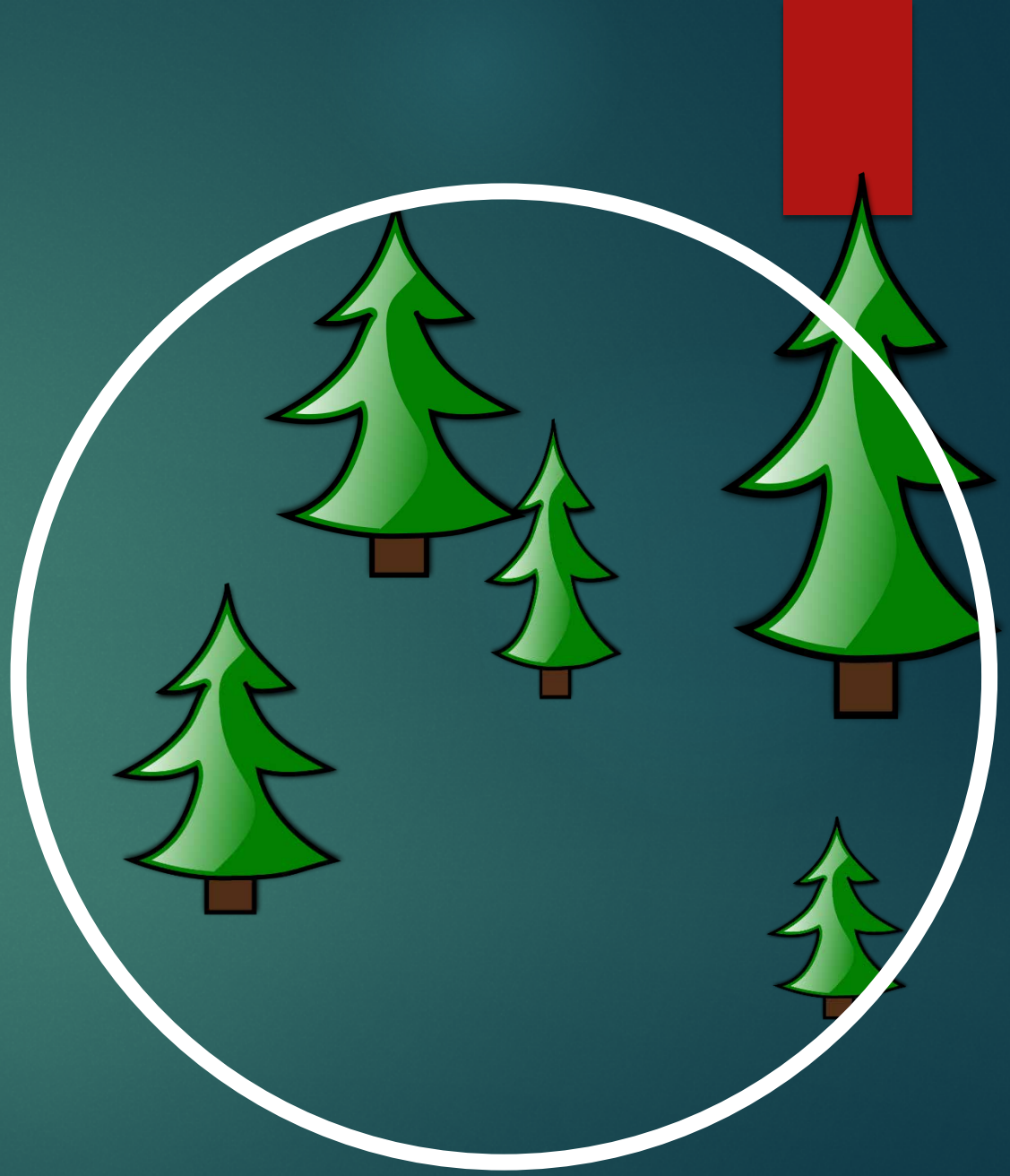


*Caleb Maki, Peter Gould

How is DAP Used?

- Similar to lidar (ABA)

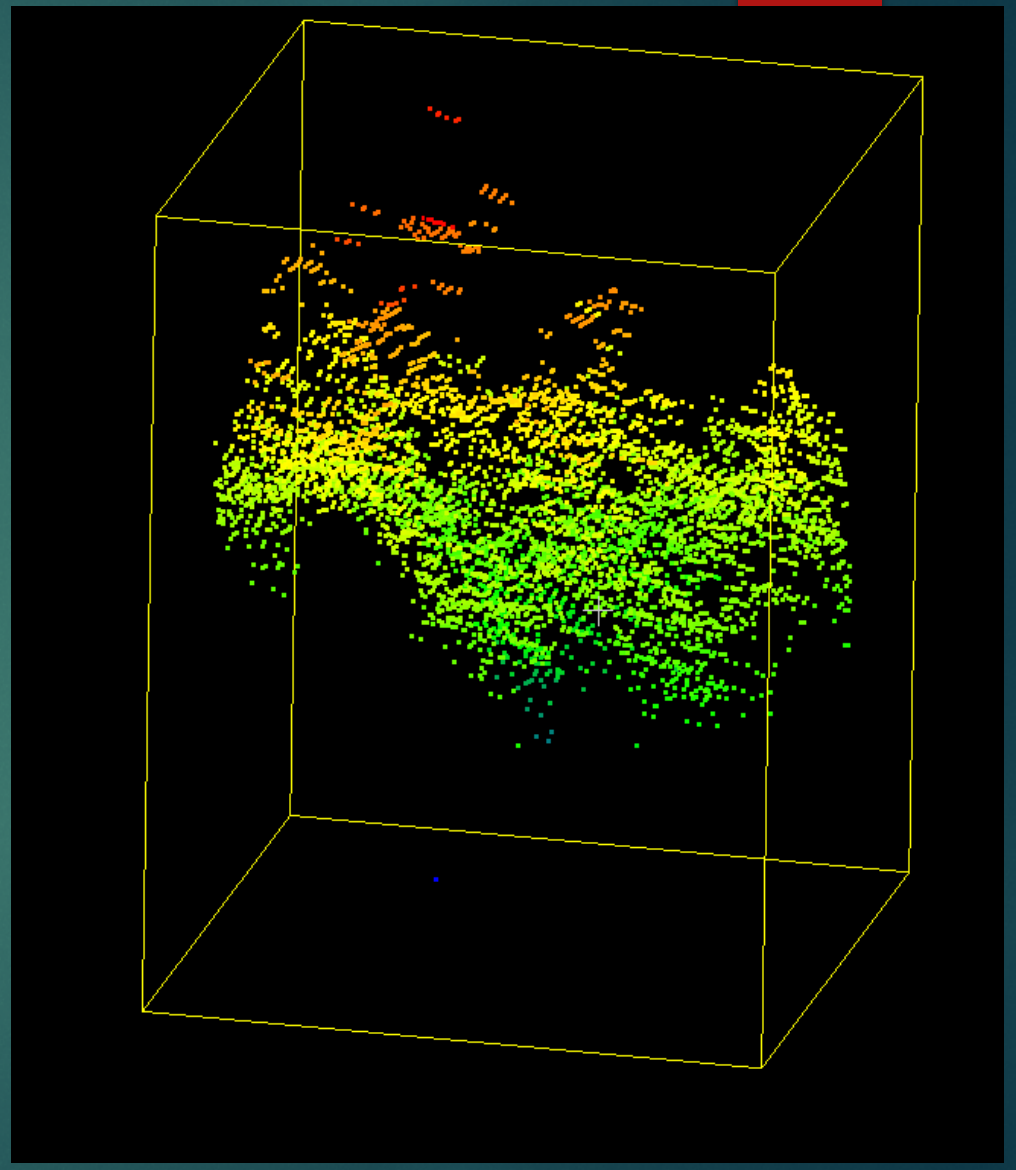
- 1) Measure field plots in the field
  - High Precision GNSS (GPS) !!!!
  - Garmin not ok!
  - HRMSE -> 1 m
  - Need survey grade



https://fsapps.nwcg.gov/gtac/CourseDownloads/Training/Remote_Sensing/Lidar_Point Cloud_Processing/Exercises/

How is DAP Used?

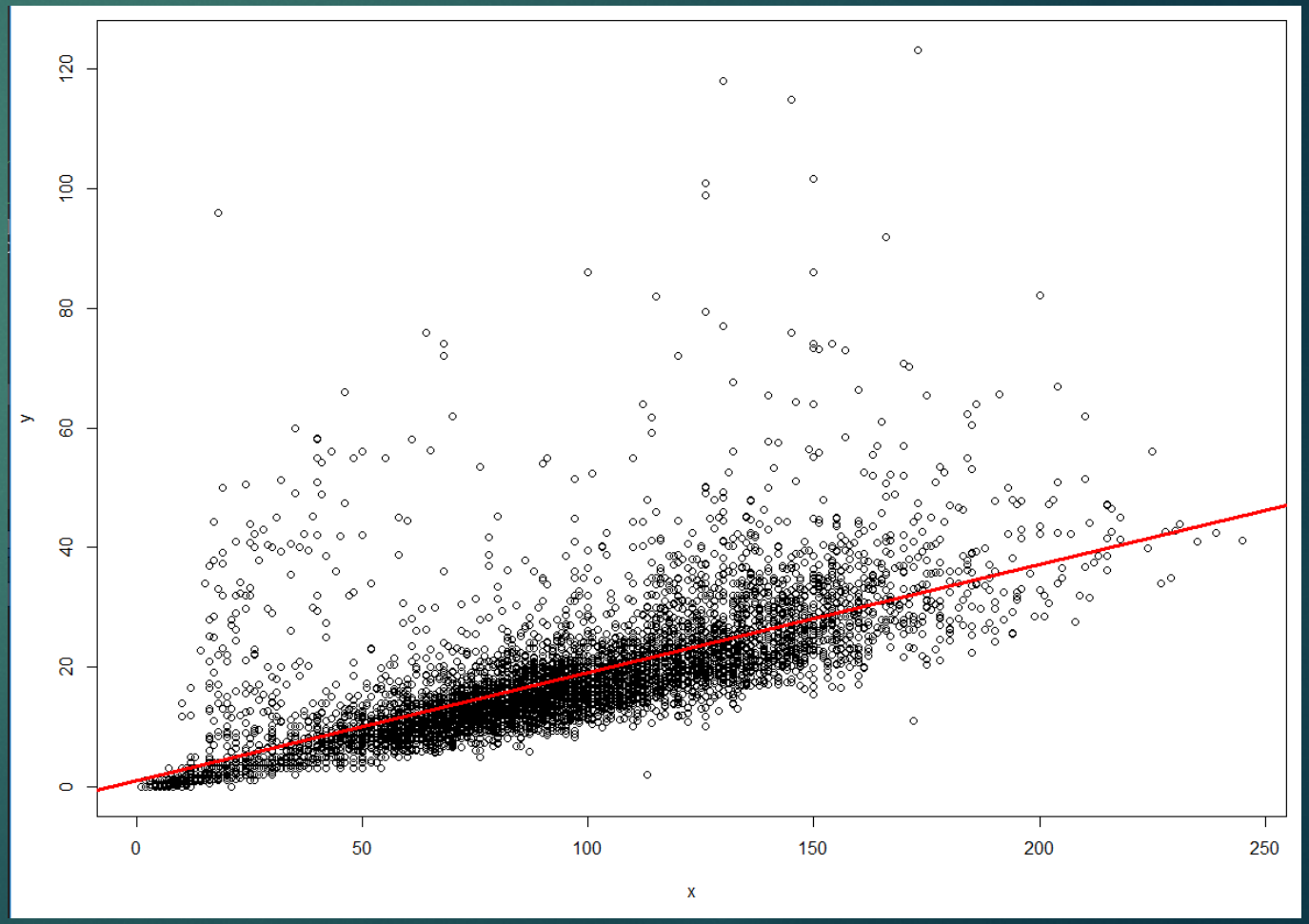
- Similar to lidar
  - 2) Measure field plot with remote sensing



How is DAP Used?

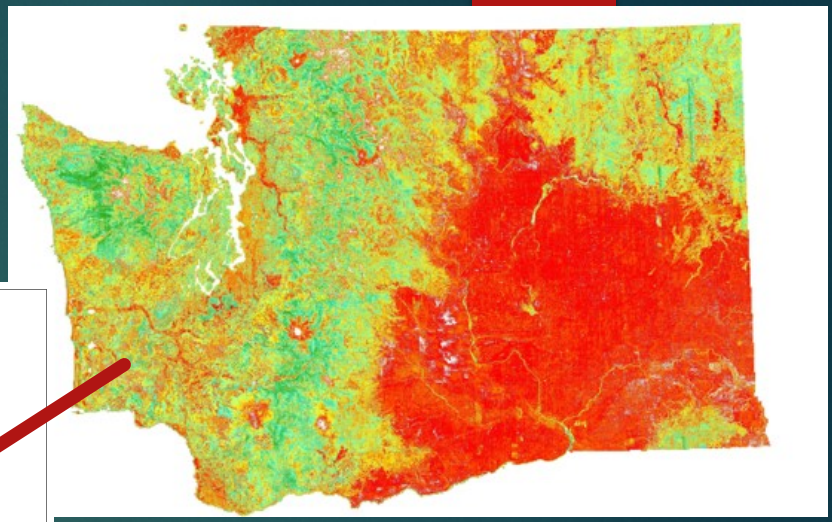
- Similar to lidar
  - 3) Fit a model

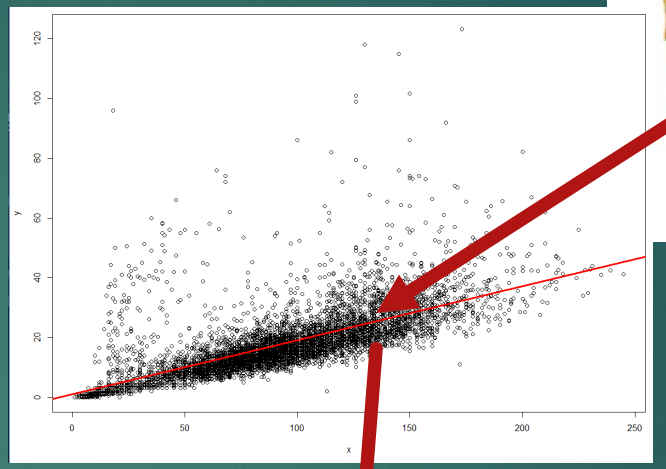
y= f(x) + error

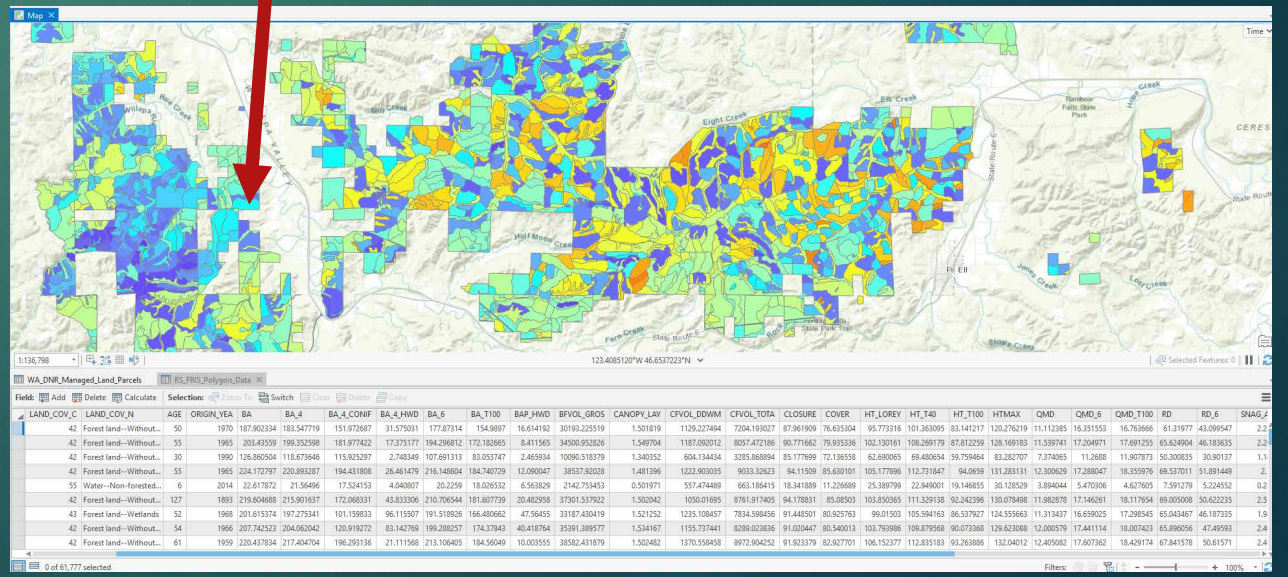


How is DAP Used?

- Similar to lidar
  - 3) Predict / estimate



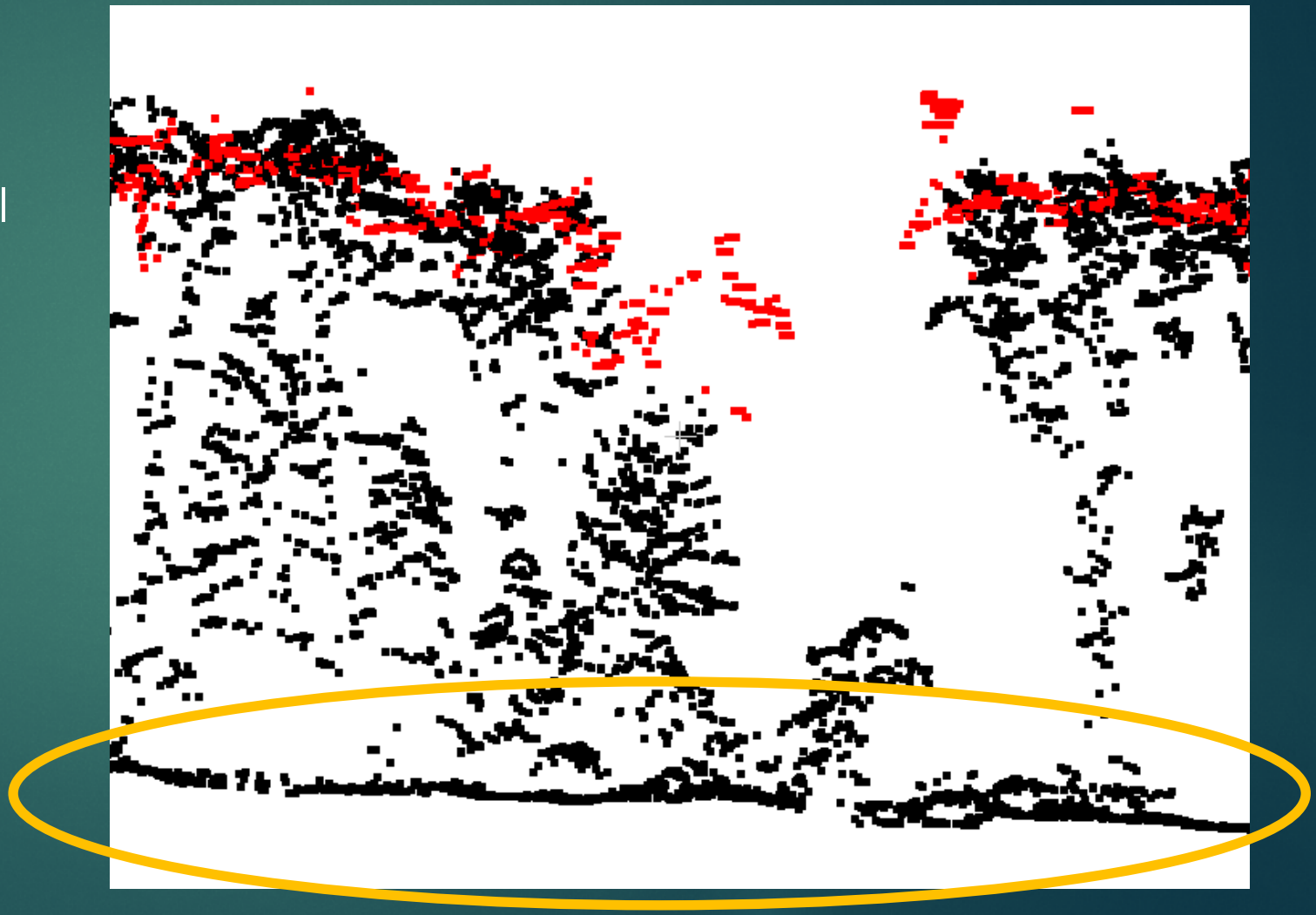




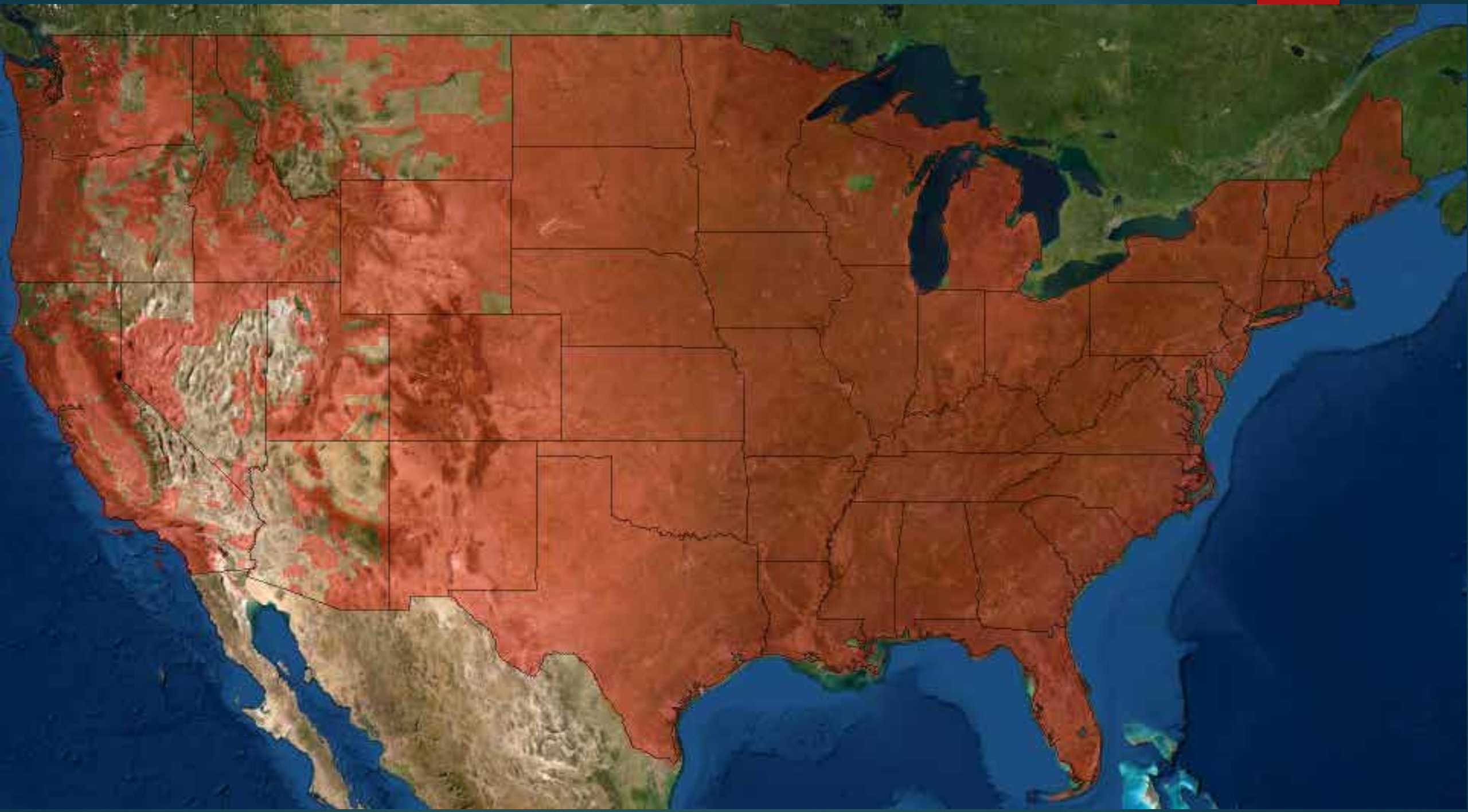
https://data-wadnr.opendata.arcgis.com/datasets/rs-fris-polygon-data

A key difference (lidar vs DAP)

- Lidar Measures ground
- DAP needs a ground model
  - Lidar is best
  - USGS is ok (NED?*)

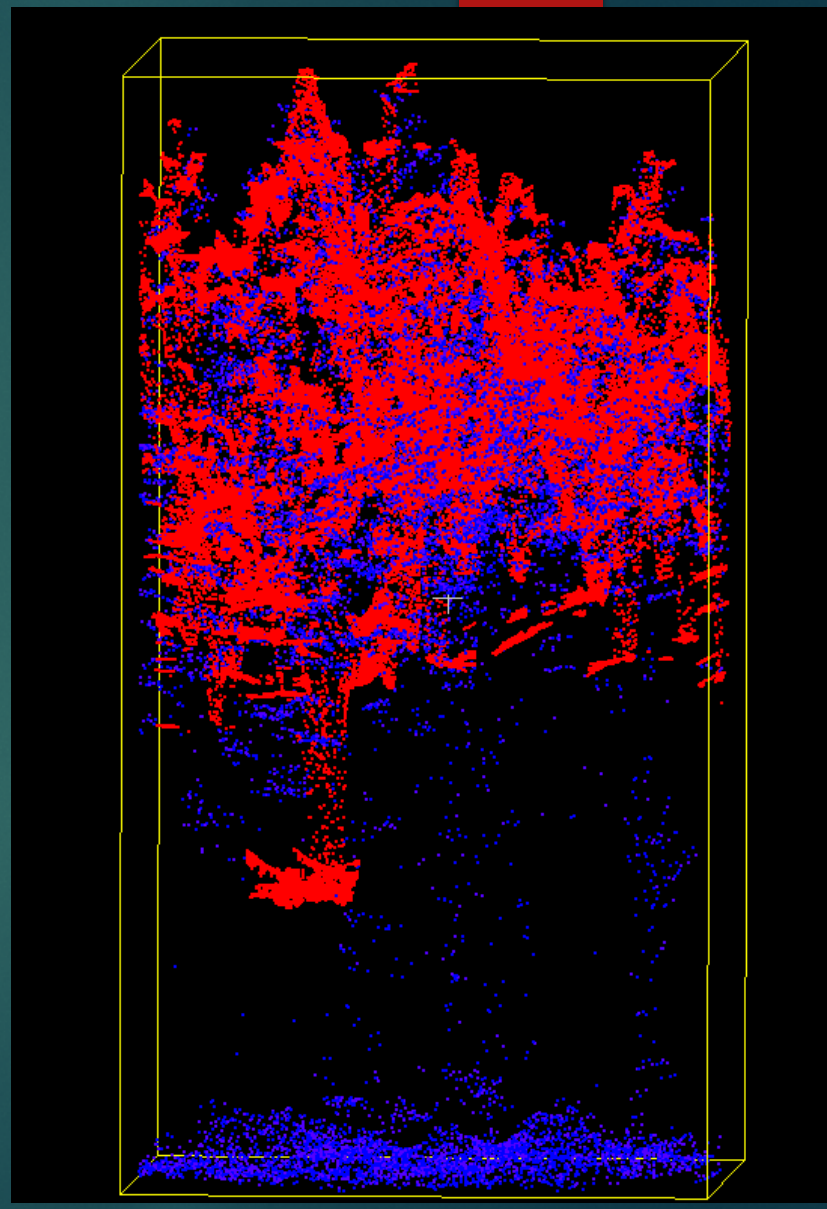


*National Elevation Dataset



Recent DAP Projects

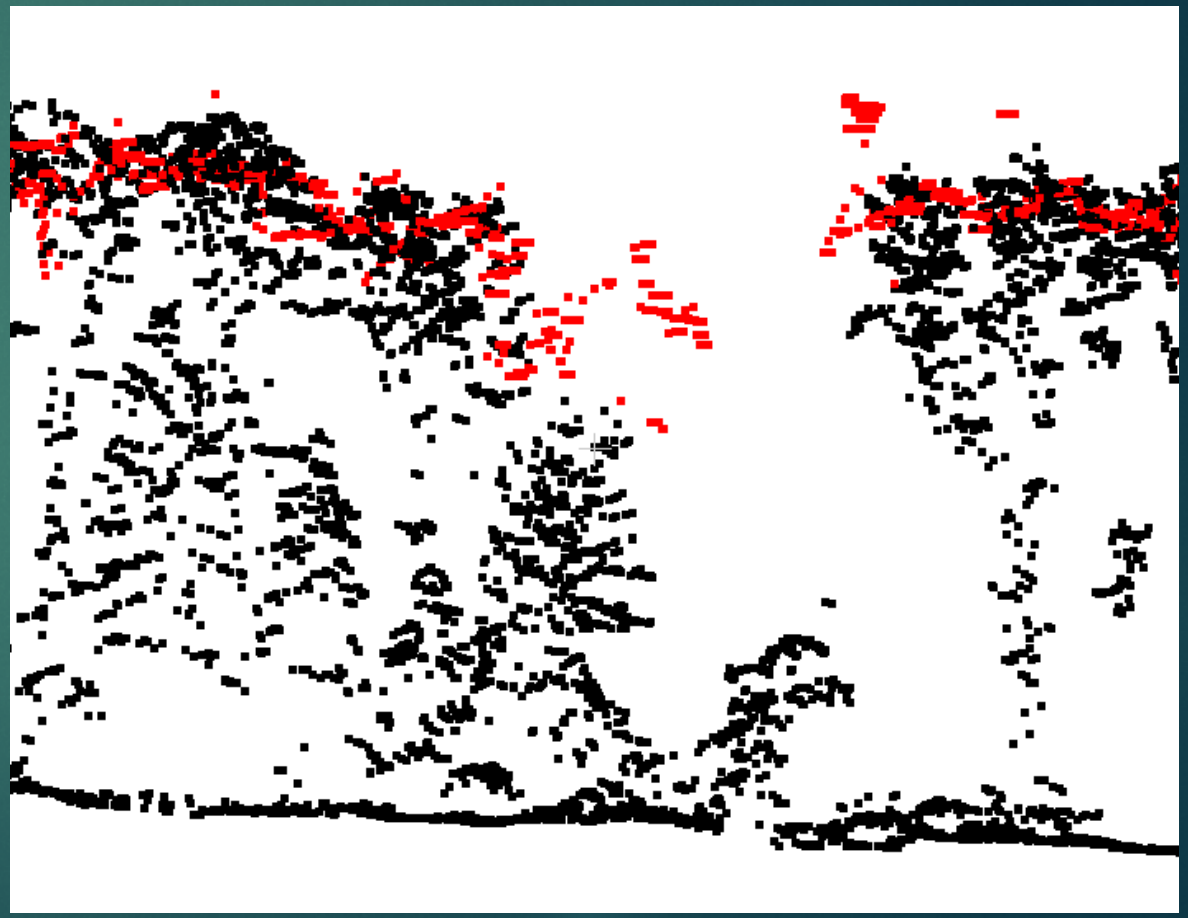
1. Pushbroom DAP evaluation protocol (**NH,CT**, TN, WV)
2. WA Modeling with DAP, Landsat, Env. Gradients
3. Lidar vs Pushbroom DAP (14") vs Frame Camera DAP (3", 6", 12")
4. OR DAP (2017/2018) – starting



Summary of Pushbroom DAP Results

- Clear visual defects in DAP (relative to lidar)
- Metrics strongly agree with lidar (pixel, plot level)
- DAP metrics have high correlation with wide range of Forest attributes
- 3-4 fold relative efficiency (versus HT Simple Random Sample)
- Advantages of using DAP + Env. gradients + Landsat

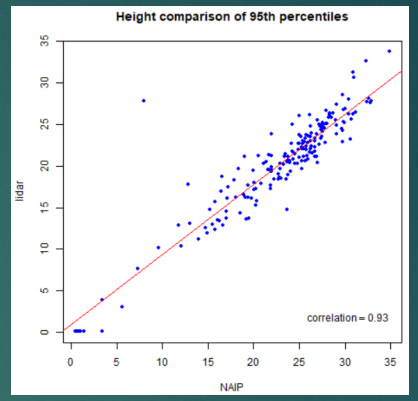
Pushbroom Sensor
Lidar

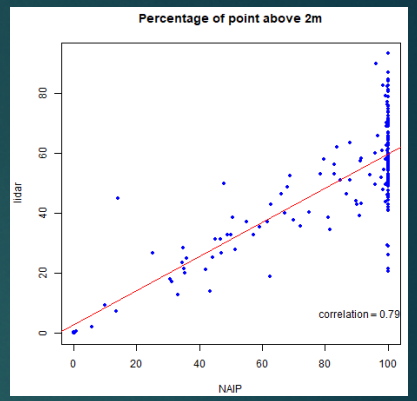


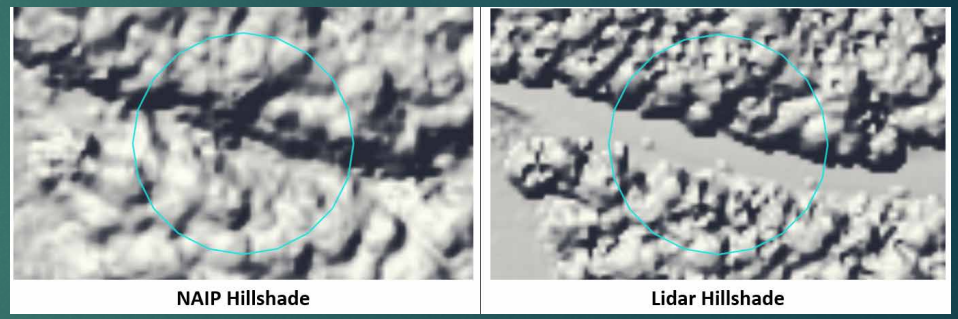
Point Cloud Comparison Results Vary

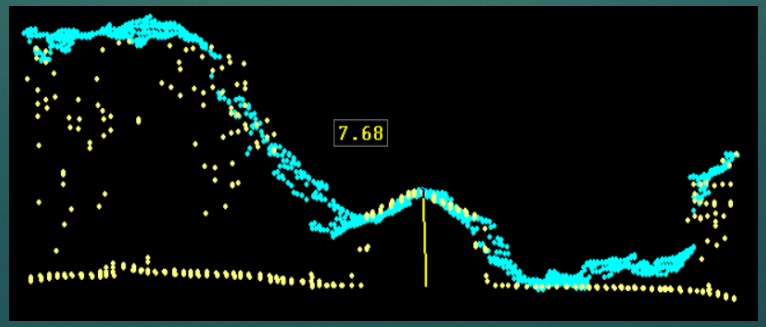
Jeremy Webb 2020 CT Report
QSI, 40 cm, Leica XPro

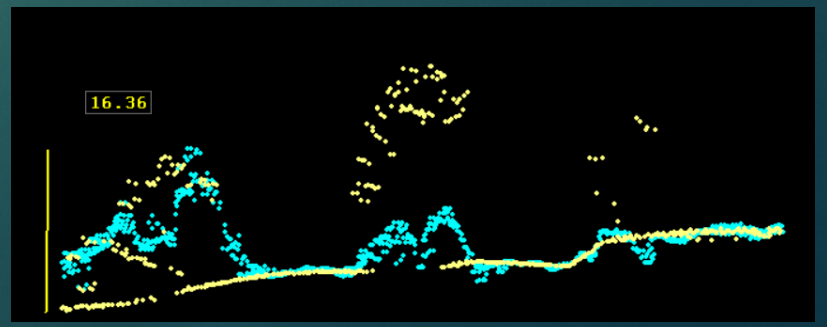
- Scale (tree vs plot vs stand etc.)
- Approach (visual, statistical)
- Attribute (P05 vs P90)
- Software (socet, xpro)
- Vendor, imagery, analyst, location …
- ***[MUST PROCESS USING ORIGINAL IMAGES]***
- ***[SOFTWARE SPECIFIC PYRAMIDS]***



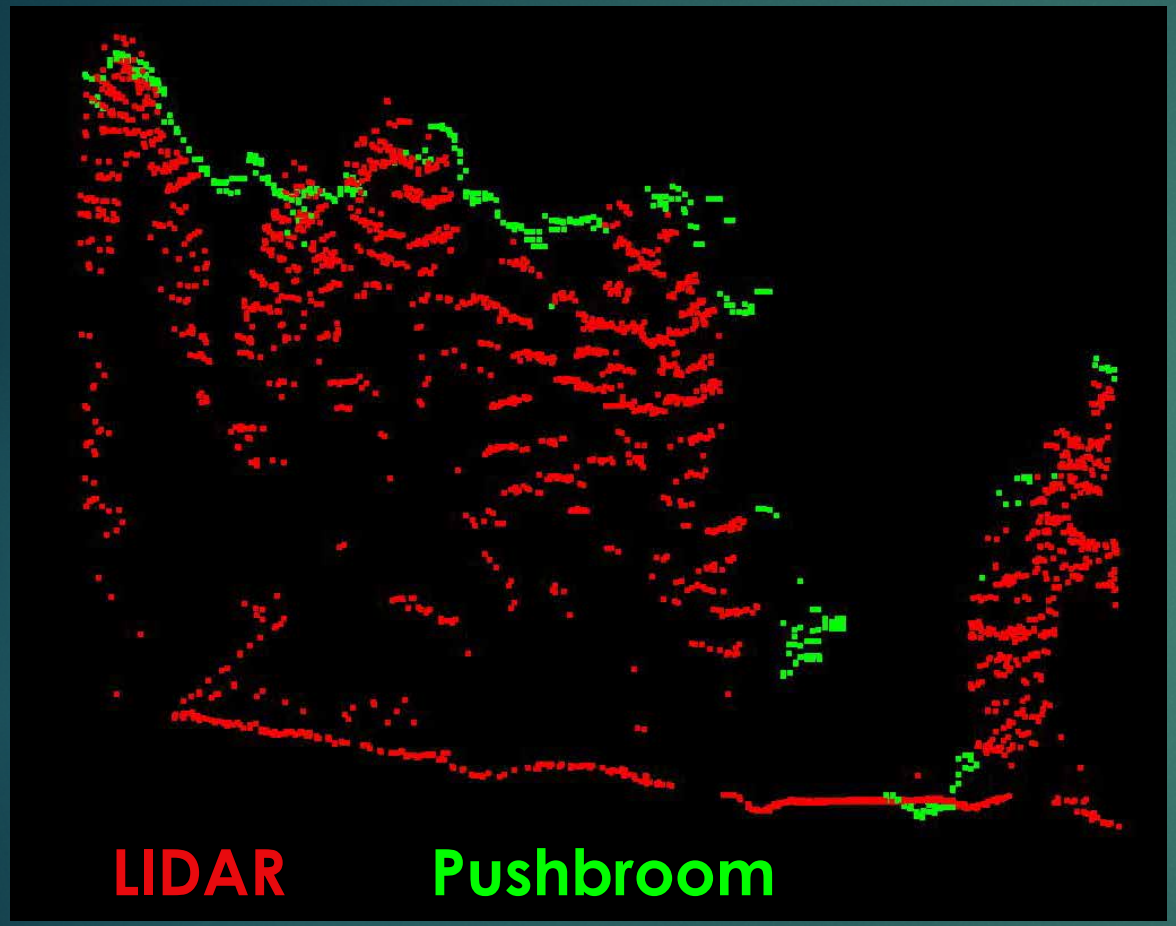




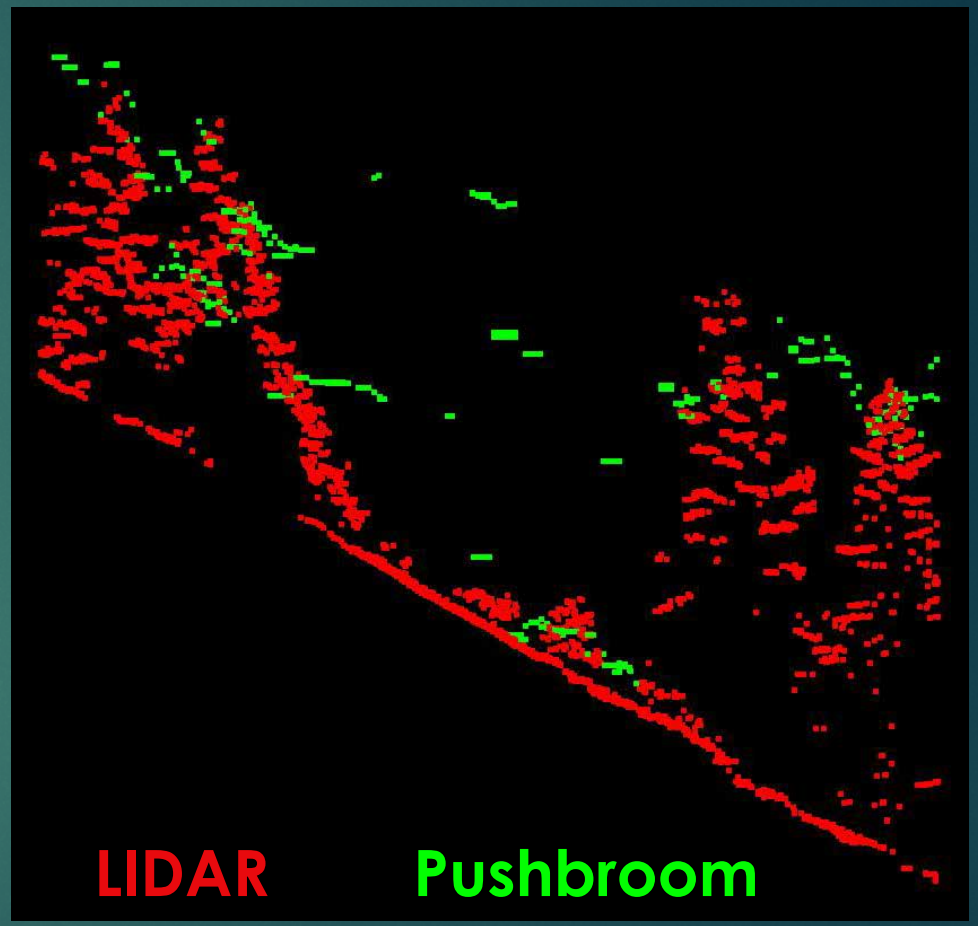




“Good” Site

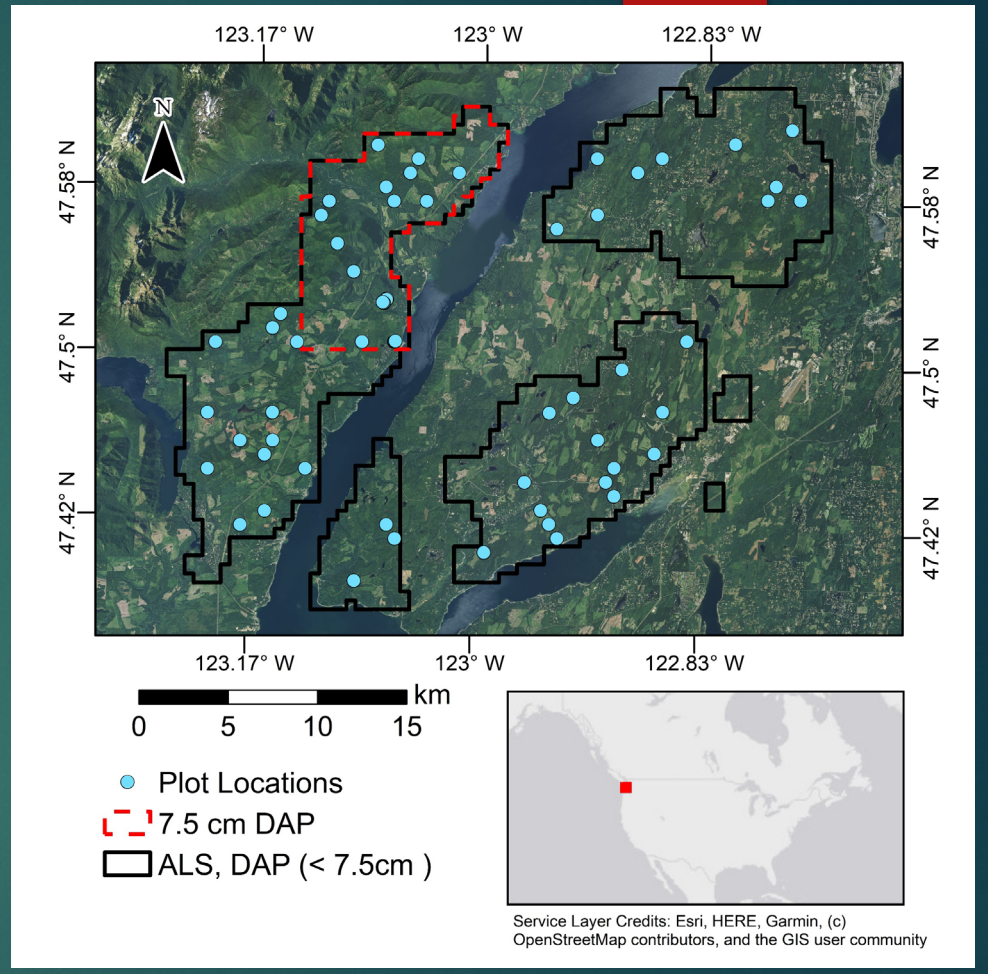


“Bad” Site



Modeling Analysis #1

		ba		volume		Lorey's ht		trees/ha	
dataset	n	R^2	RMSE	R^2	RMSE	R^2	RMSE	R^2	RMSE
7.5 cm[a]	20	79	22	88	20	90	10	57	30
15 cm	57	71	38	83	32	91	13	55	42
30 cm	57	75	35	82	32	91	13	58	40
40 cm PB	57	67	40	78	35	89	15	50	44
lidar	57	73	37	85	30	91	13	70	34

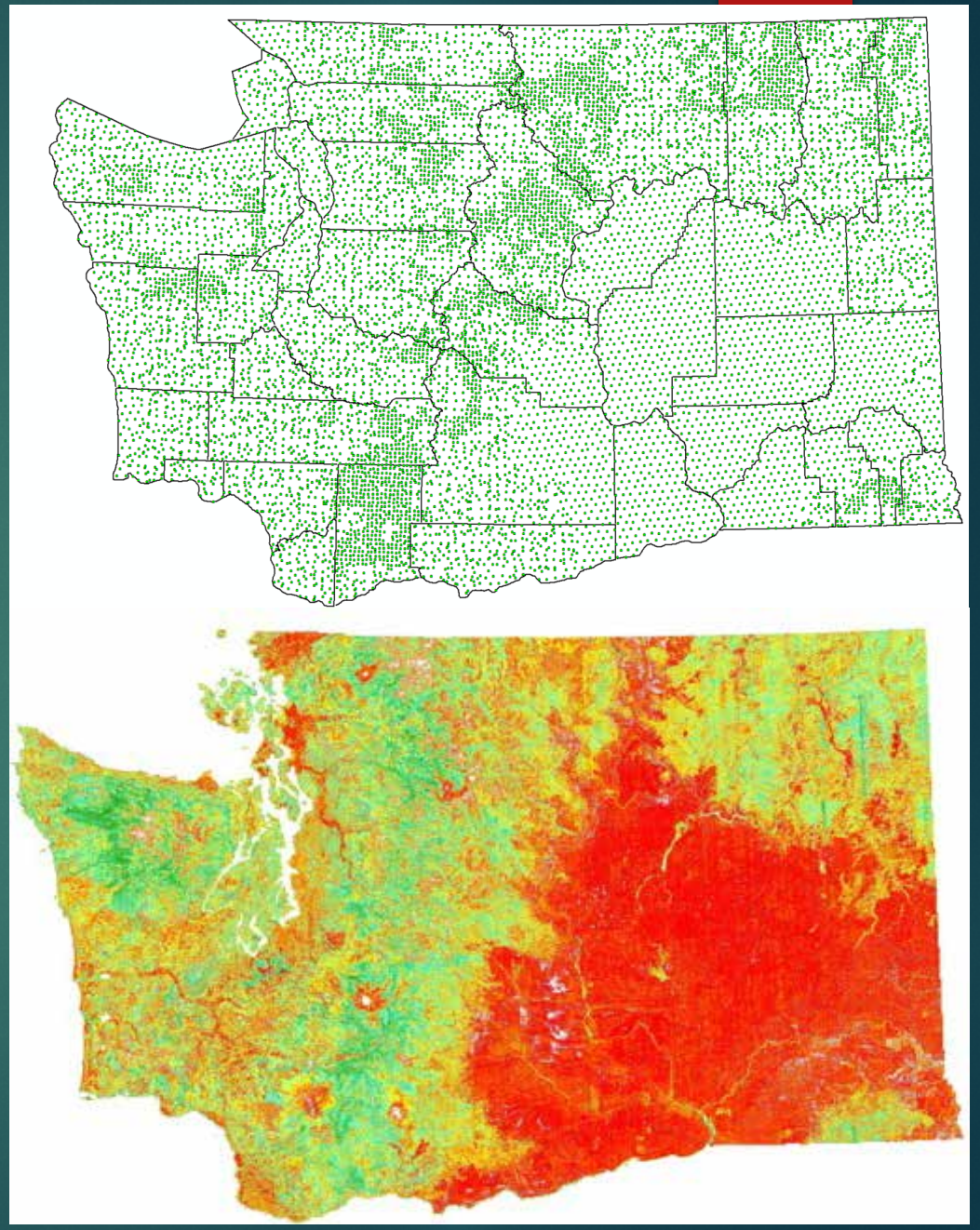


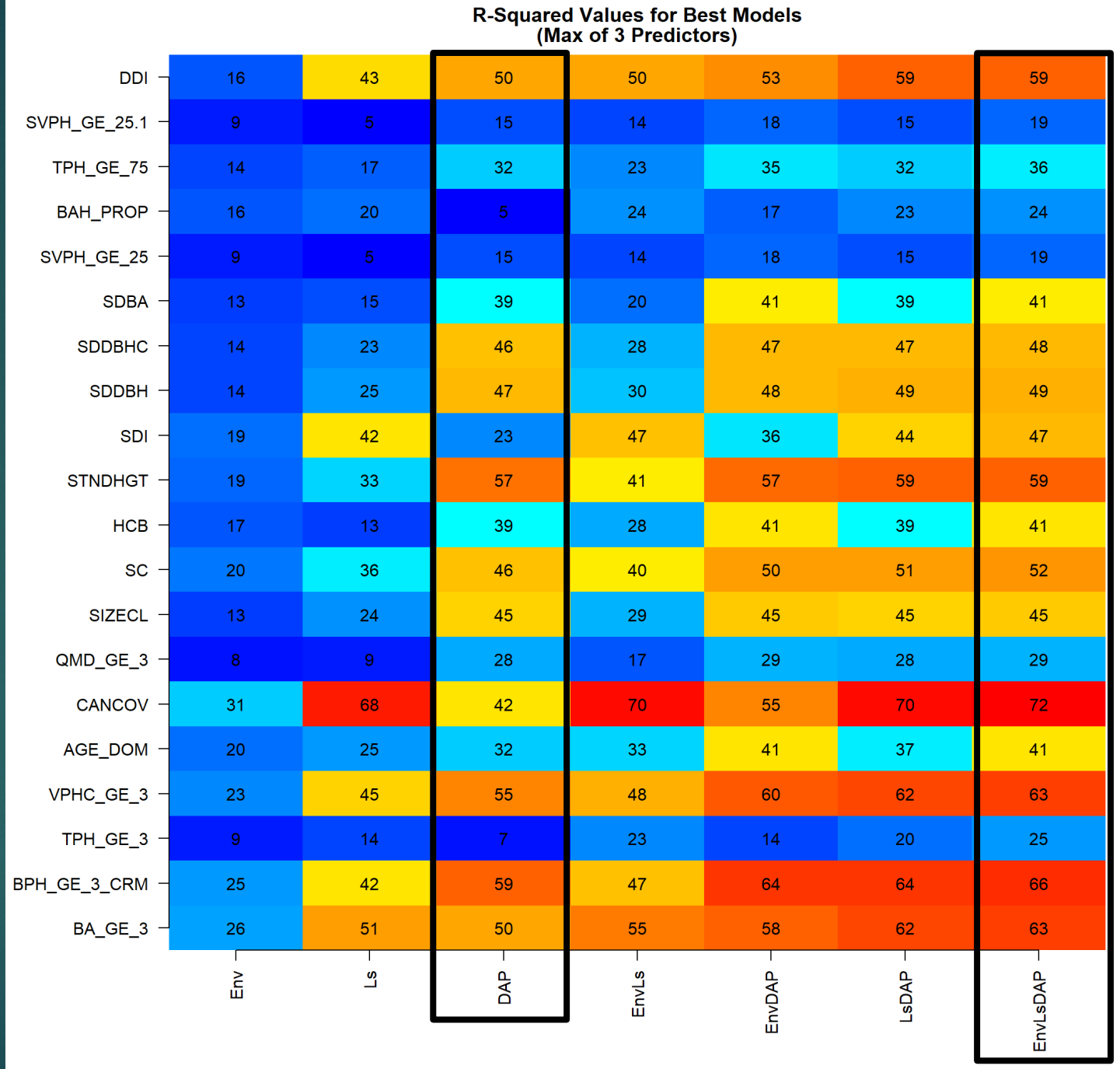
Strunk, J.L.; Gould, P.J.; Packalen, P.; Gatziolis, D.; Greblowska, D.; Maki, C.; McGaughey, R.J. Evaluation of pushbroom DAP relative to frame camera DAP and lidar for forest modeling. *Remote Sensing of Environment* **2020**, *237*, 111535, doi:10.1016/j.rse.2019.111535.

Modeling Analysis #2

- WA-wide study with FIA plots
- Alternatives (to NAIP DAP) large-area data sources
  - LandTrendr fitted tasseled cap vertices and NBR
  - Topographic indices
  - Climatic Indices
  - Soil indices

} Environmental Gradients

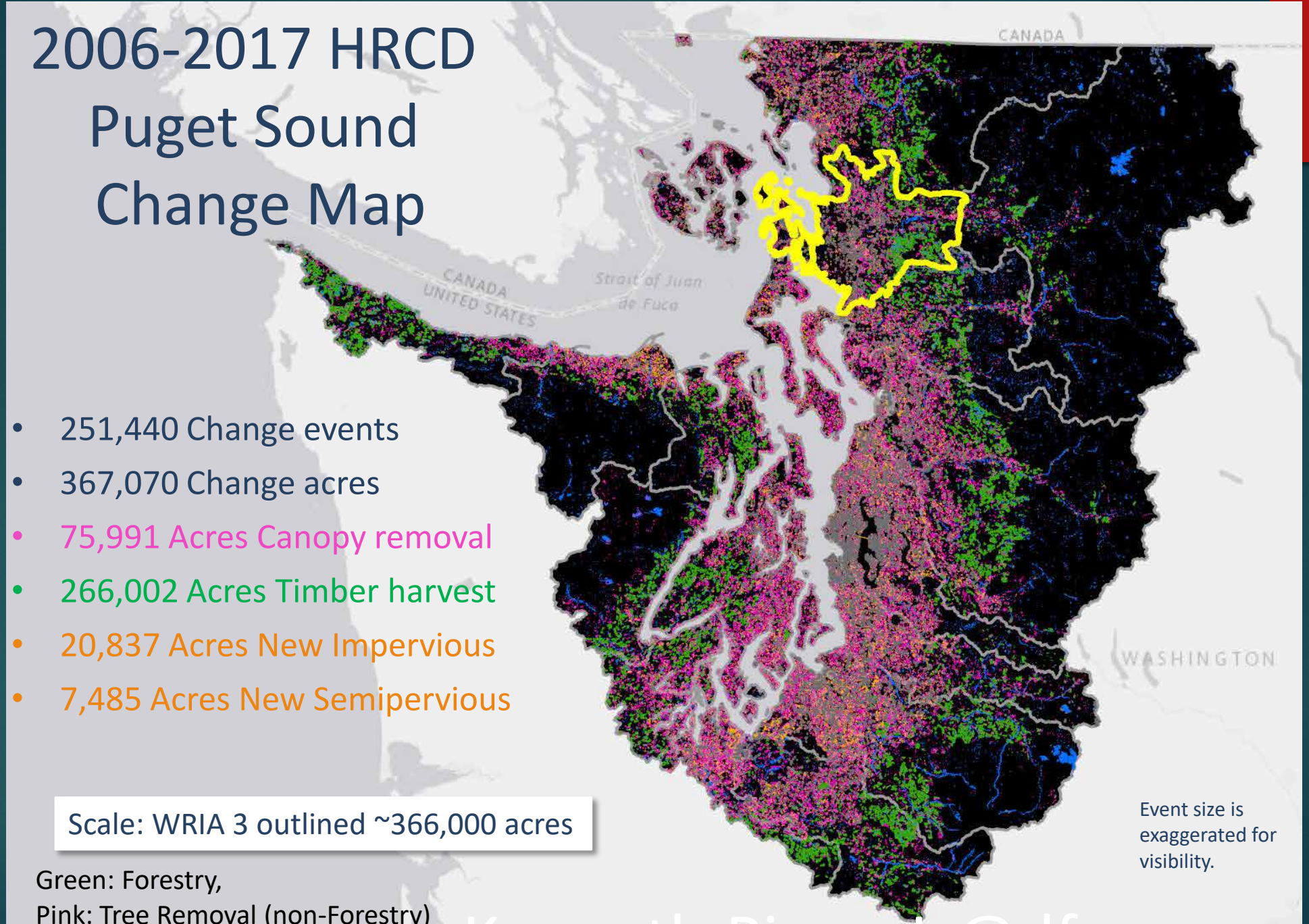



R-Squared Values for Best Models
(Max of 3 Predictors)
DDI 16 43 50 50 53 59 59
SVPH_GE_25.1 9 5 15 14 18 15 19
TPH_GE_75 14 17 32 23 35 32 36
BAH_PROP 16 20 5 24 17 23 24
SVPH_GE_25 9 5 15 14 18 15 19
SDBA 13 15 39 20 41 39 41
SDDBHC 14 23 46 28 47 47 48
SDDBH 14 25 47 30 48 49 49
SDI 19 42 23 47 36 44 47
STNDHGT 19 33 57 41 57 59 59
HCB 17 13 39 28 41 39 41
SC 20 36 46 40 50 51 52
SIZECL 13 24 45 29 45 45 45
QMD_GE_3 8 9 28 17 29 28 29
CANCOV 31 68 42 70 55 70 72
AGE_DOM 20 25 32 33 41 37 41
VPHC_GE_3 23 45 55 48 60 62 63
TPH_GE_3 9 14 7 23 14 20 25
BPH_GE_3_CRM 25 42 59 47 64 64 66
BA_GE_3 26 51 50 55 58 62 63
Env
Ls
DAP
EnvLs
EnvDAP
LsDAP
EnvLsDAP

2017 Tree Cover

Kenneth.PierceJr@dfw.wa.gov

2006-2017 HRCD Puget Sound Change Map



- 251,440 Change events
- 367,070 Change acres
- 75,991 Acres Canopy removal
- 266,002 Acres Timber harvest
- 20,837 Acres New Impervious
- 7,485 Acres New Semipervious

Scale: WRIA 3 outlined ~366,000 acres

Event size is exaggerated for visibility.

Green: Forestry,
Pink: Tree Removal (non-Forestry)
Orange: Development

Kenneth.PierceJr@dfw.wa.gov

Conclusions

- DAP can be used for large area forest mapping
- Tree scale results lacking (visual inspection, individual trees, gaps)
- Results vary
- Improvements when paired with LS, Env

- NAIP DAP has good Value!
- High resolution (1-2 feet)
- Frequent and inexpensive
- $100,000 vs $30,000,000 (lidar) for Oregon

Conterminous USA = 3,119,885 sq miles

Some remaining research questions:

- Satellite DAP
- Forest / non-forest, forest area
- Canopy fuels
- Disturbance
- Growth
- Individual Tree Detection

End

- Questions?

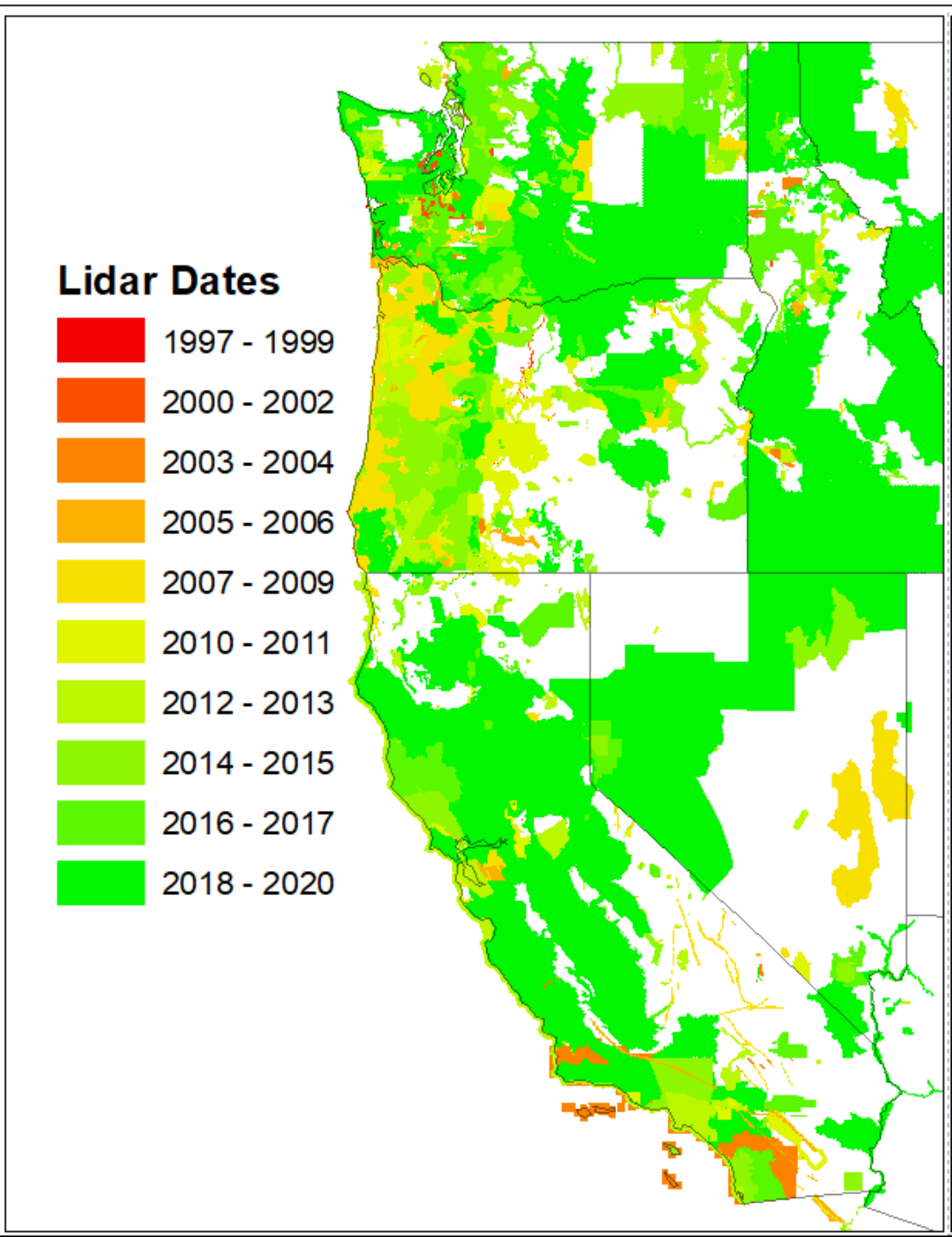
Some Options

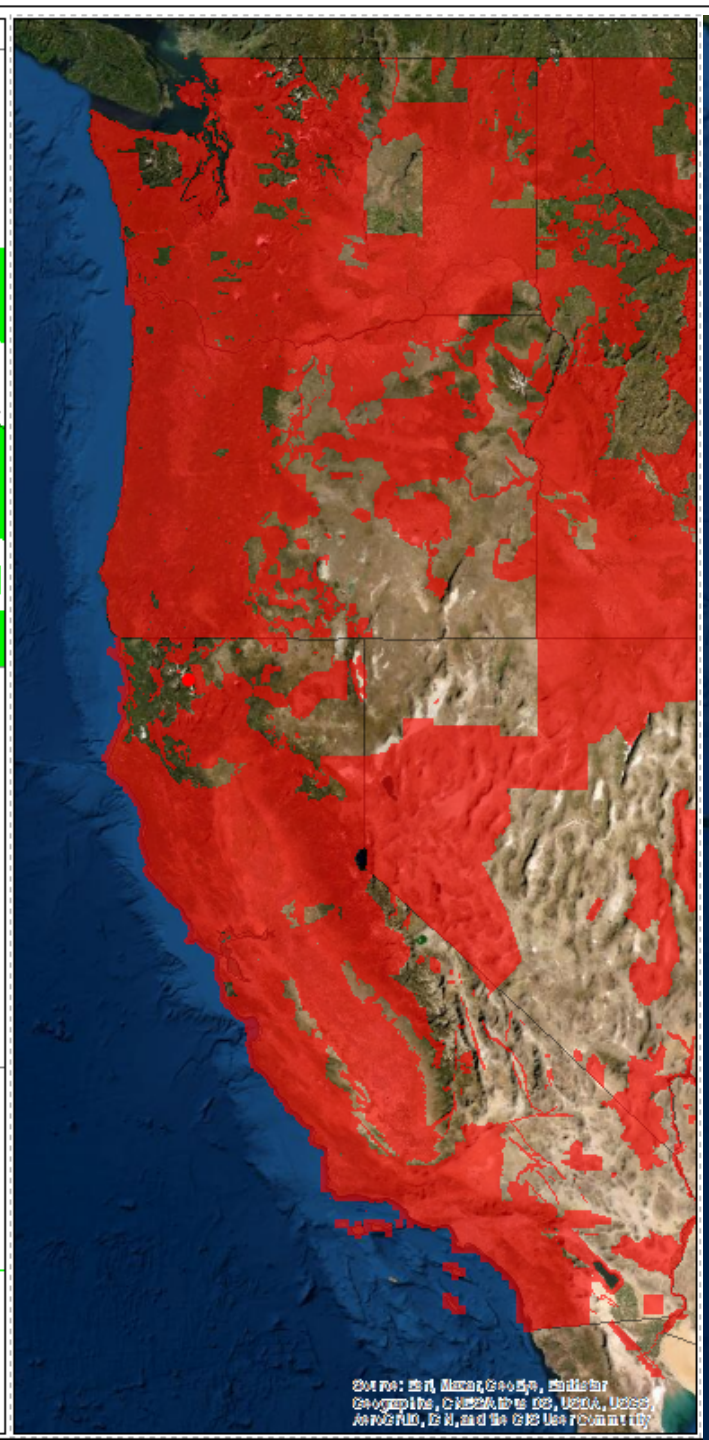
- Airborne lidar (expensive, incomplete)
- Various airborne & spaceborne passive sensors
- LCMS (satellite trajectory)
- …

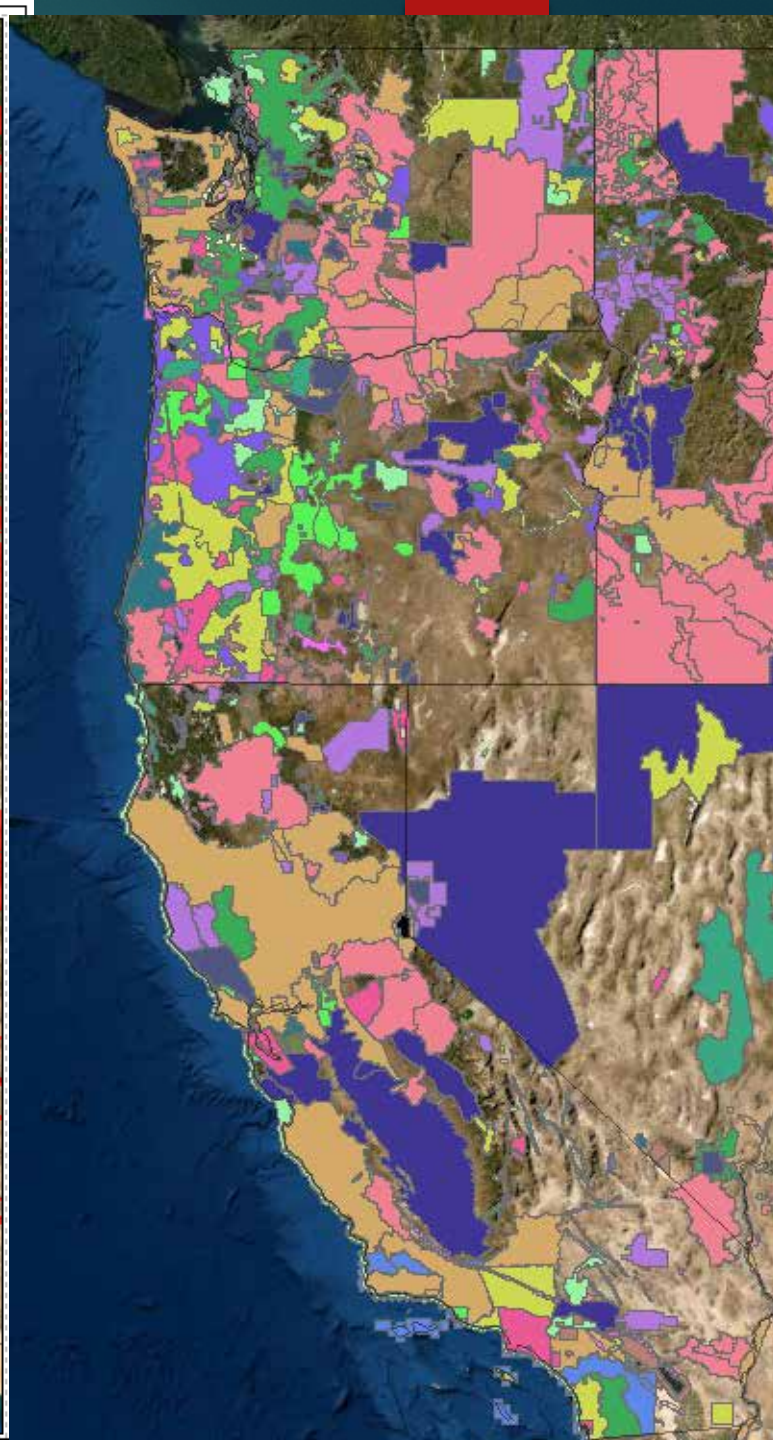
- Or (and?)

- NAIP Digital Aerial Photogrammetry (DAP)

Landsat


Lidar Dates
1997 - 1999
2000 - 2002
2003 - 2004
2005 - 2006
2007 - 2009
2010 - 2011
2012 - 2013
2014 - 2015
2016 - 2017
2018 - 2020

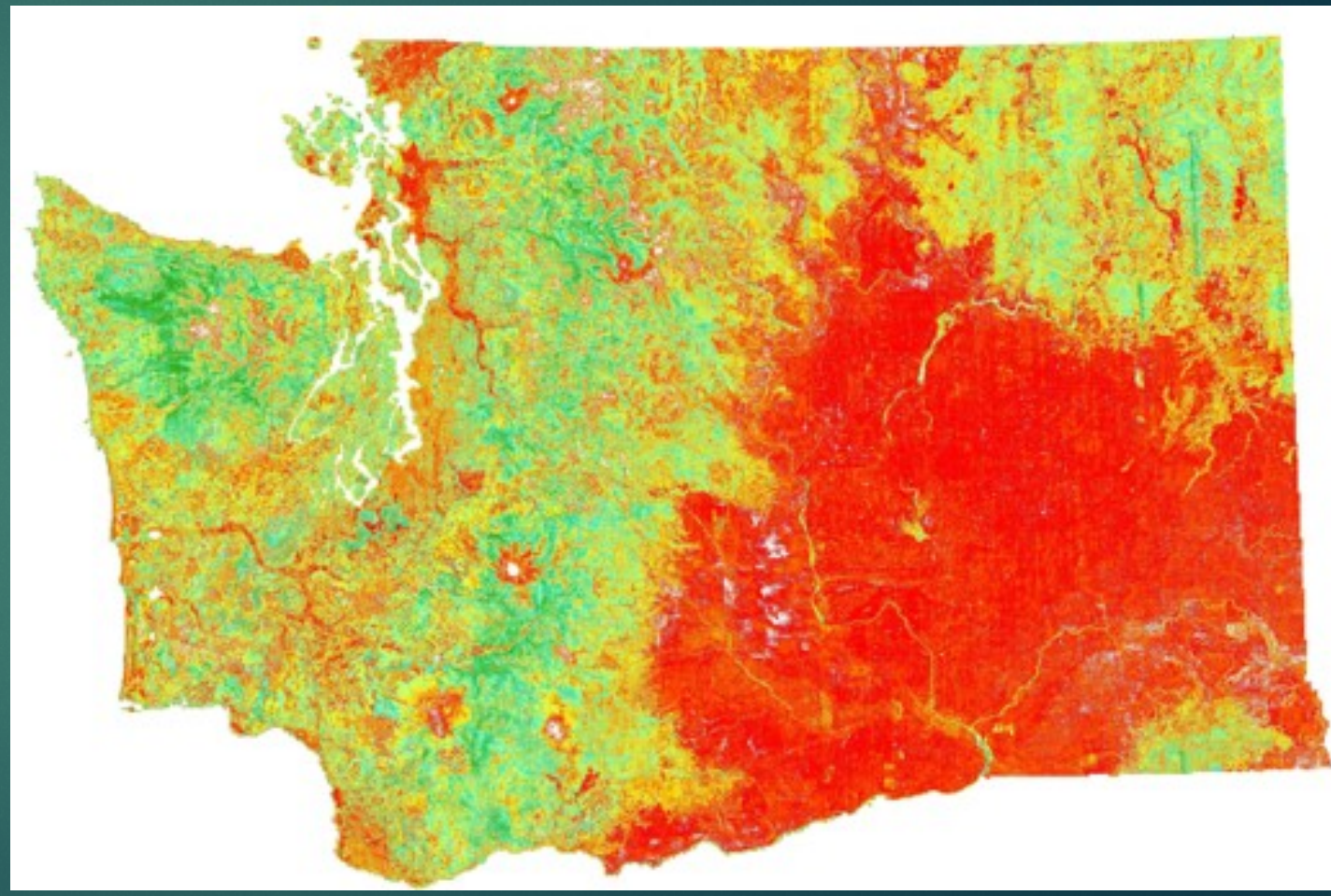




Advantages of "NAIP" DAP

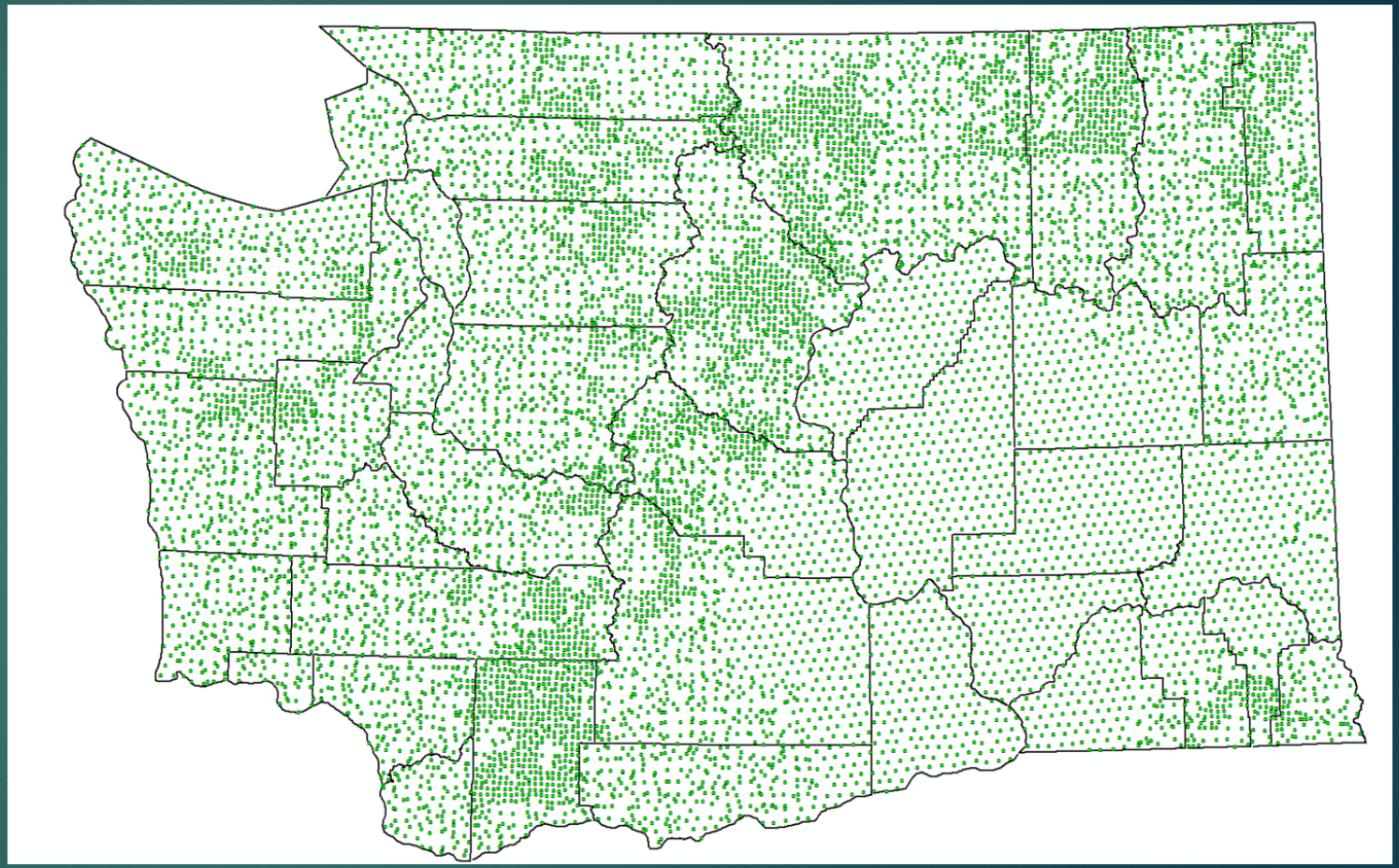
- Consistent state-wide forest structure
- Frequent (2- years)
- Wall-to-wall Height, 1-2 foot GSD
- Affordable
  - $100k for OR for 2020*

*Prices can vary dramatically



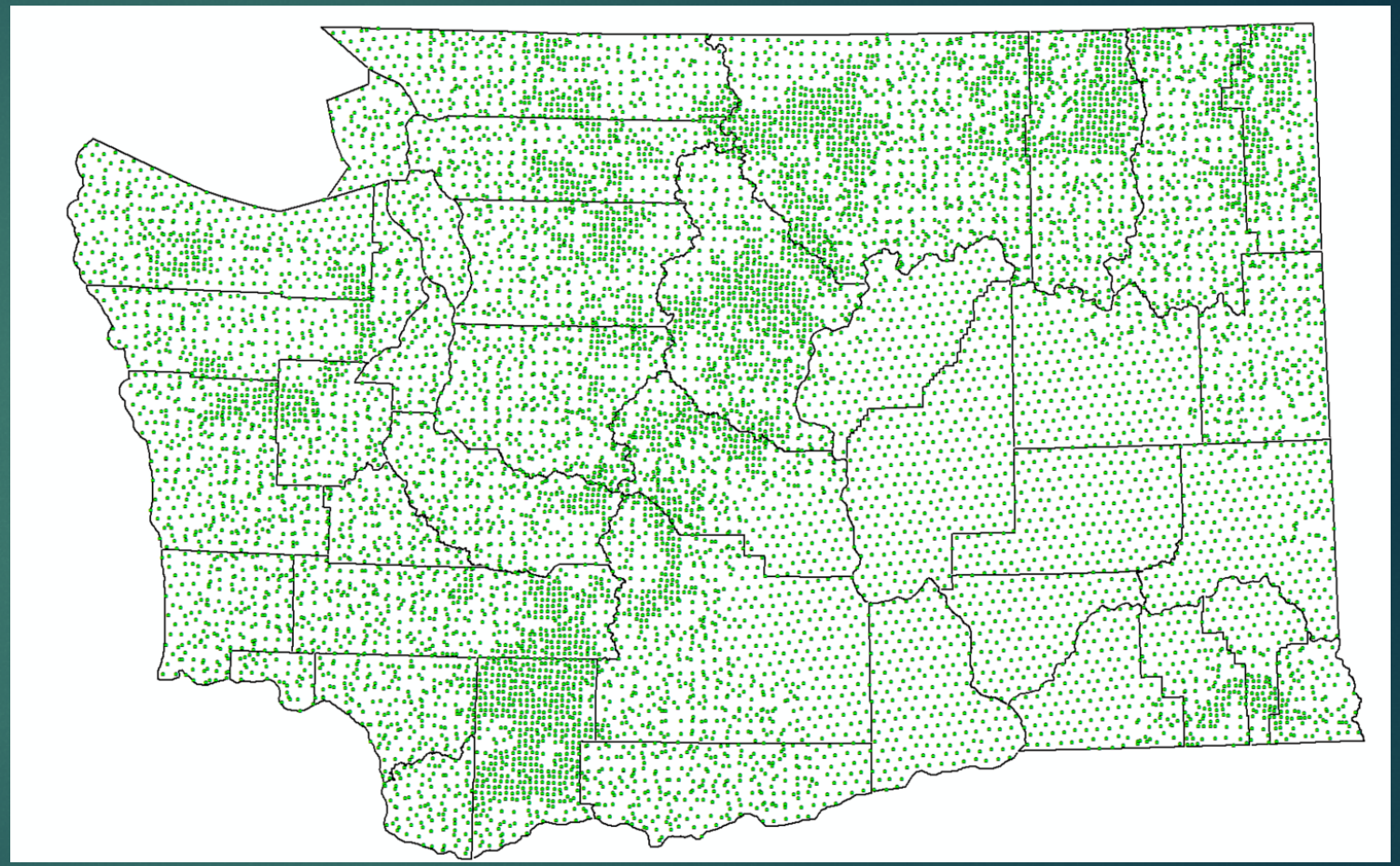
FIA Plot Grid

- A powerful, consistent dataset



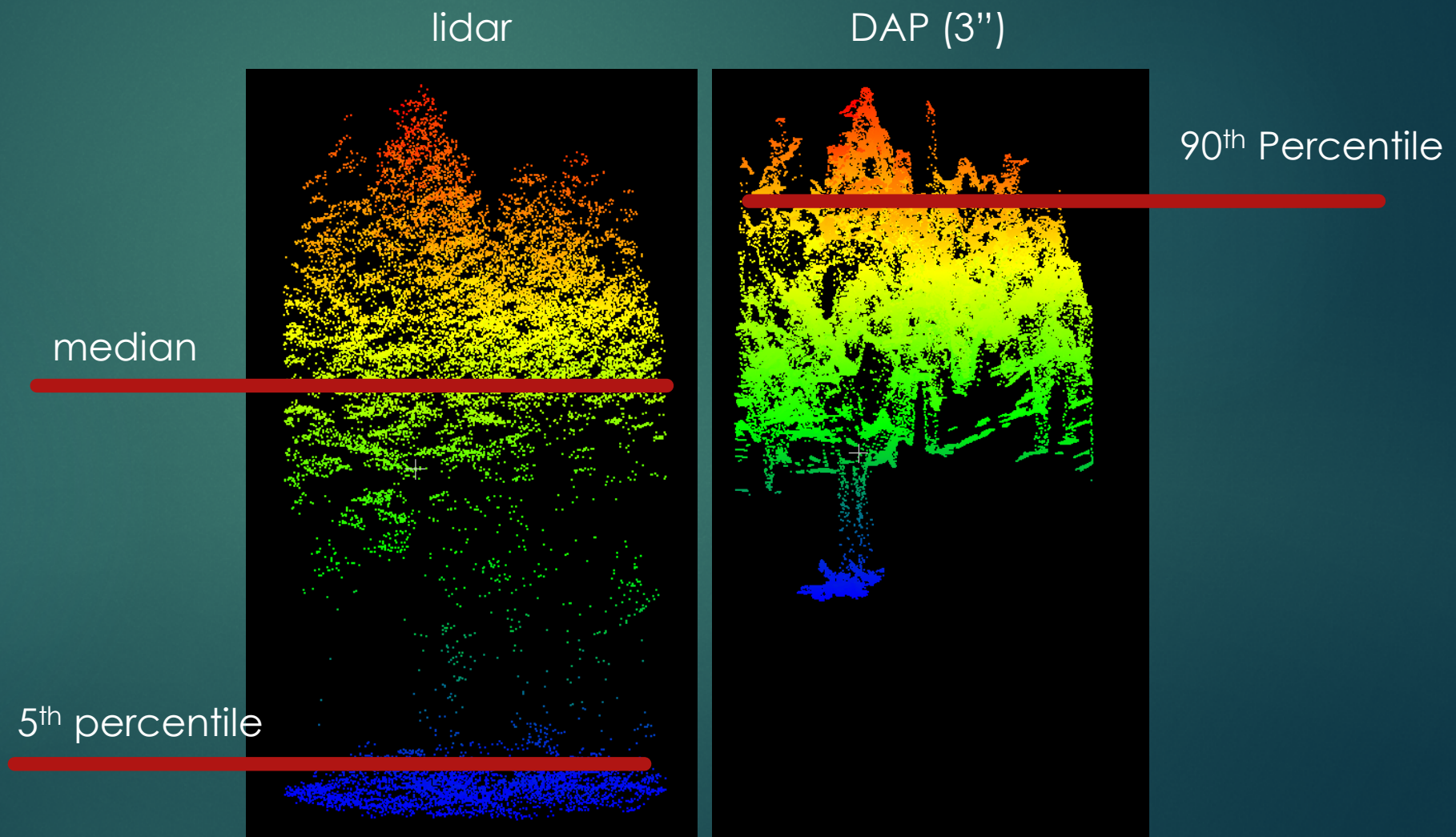
FIA Plot Grid

- A powerful, consistent dataset
- County level: finest resolution*
- Limited ability to make fine scale inference*

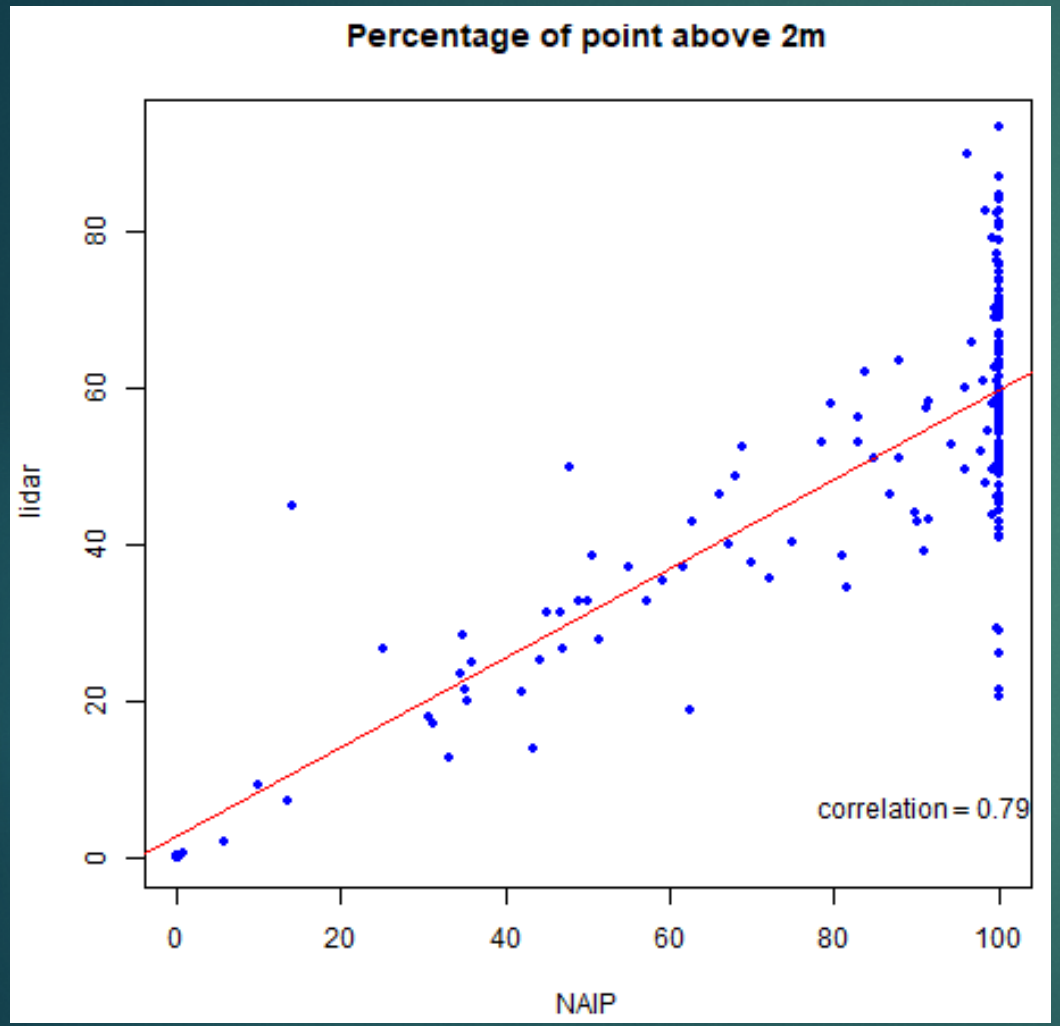


** without auxiliary information*

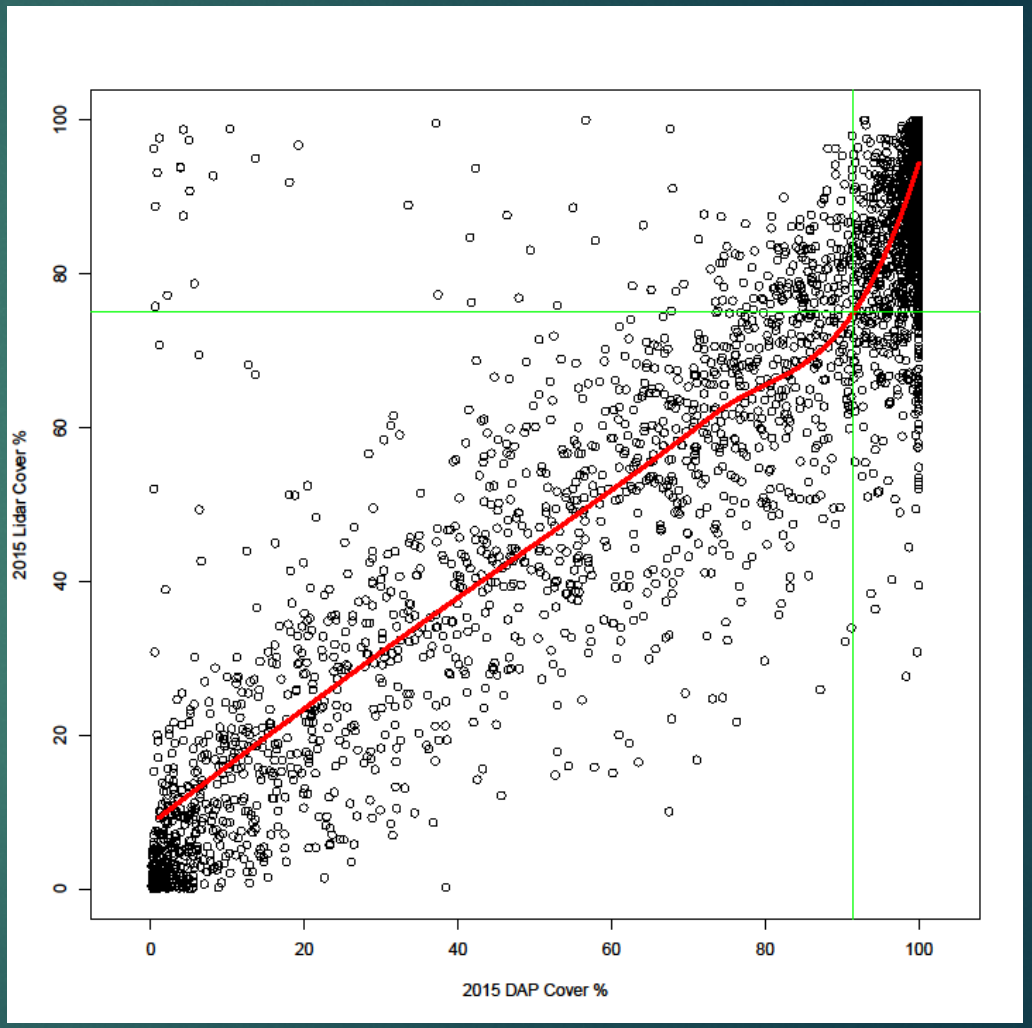
DAP (Point Cloud) Evaluation Protocol



2018 CT, QSI, 40 cm, Leica Xpro
DAP saturates at 60% lidar cover



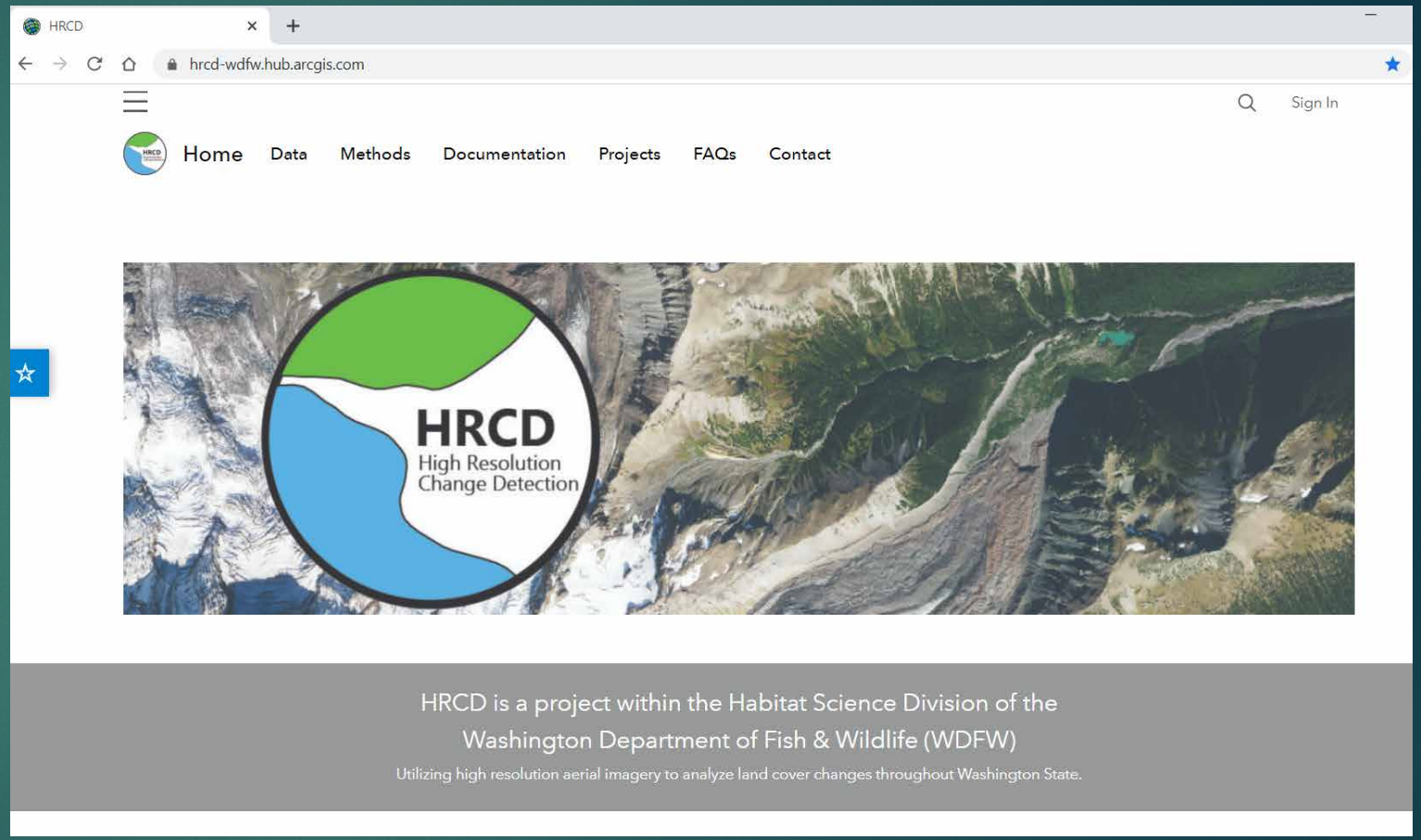
2015, WA, WA DNR, 40 cm, Socet
DAP saturates at 75% lidar cover



Strunk, J.L. et. al. Evaluation of pushbroom DAP relative to frame camera DAP and lidar for forest modeling. *Remote Sensing of Environment* **2020**, *237*, 111535

Other People's Work

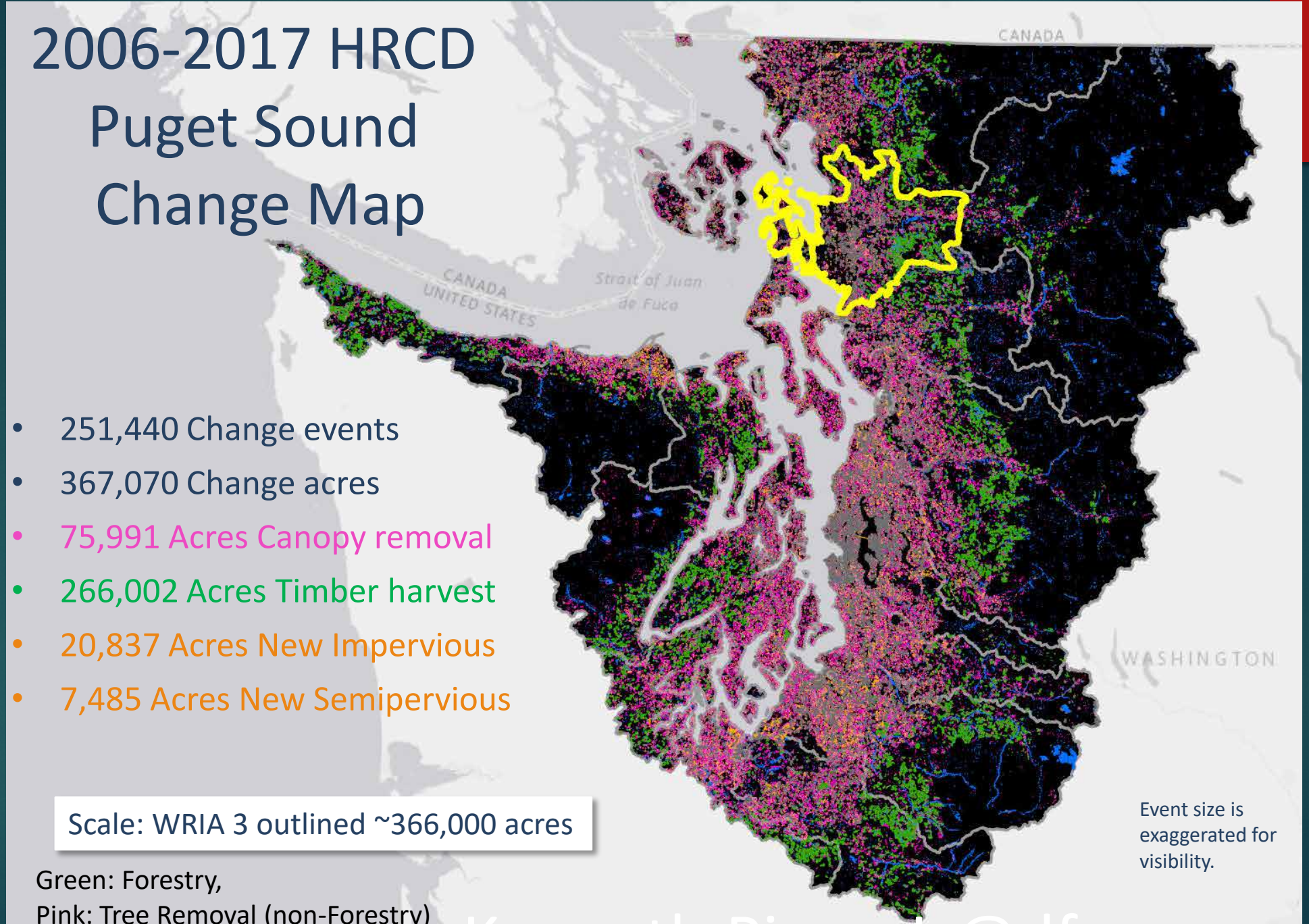
- Change Detection
- Forest Mask
- Streams



hrcd-wdfw.hub.arcgis.com

Kenneth.PierceJr@dfw.wa.gov

2006-2017 HRCD Puget Sound Change Map



- 251,440 Change events
- 367,070 Change acres
- 75,991 Acres Canopy removal
- 266,002 Acres Timber harvest
- 20,837 Acres New Impervious
- 7,485 Acres New Semipervious

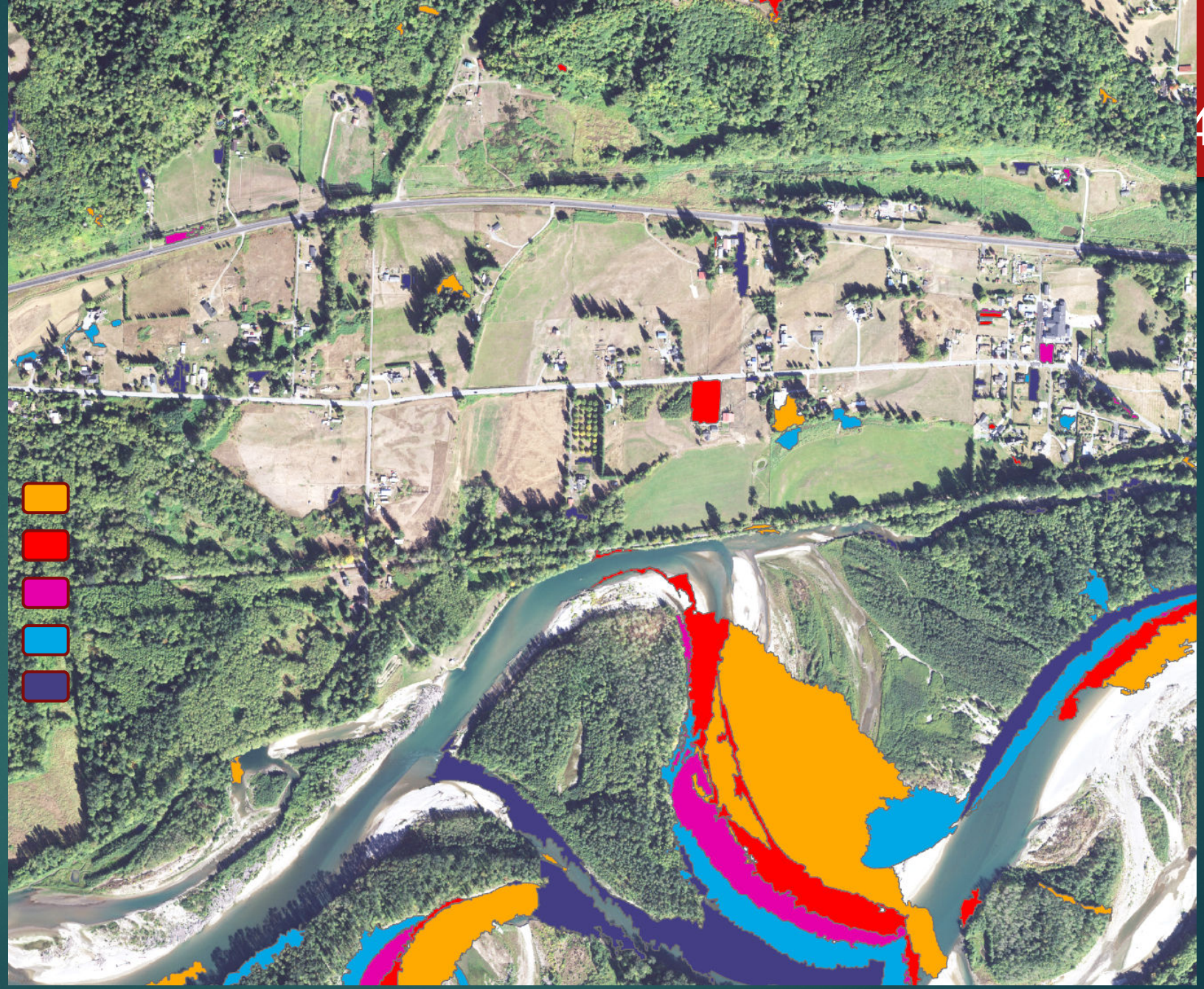
Scale: WRIA 3 outlined ~366,000 acres

Event size is exaggerated for visibility.

Green: Forestry,
Pink: Tree Removal (non-Forestry)
Orange: Development

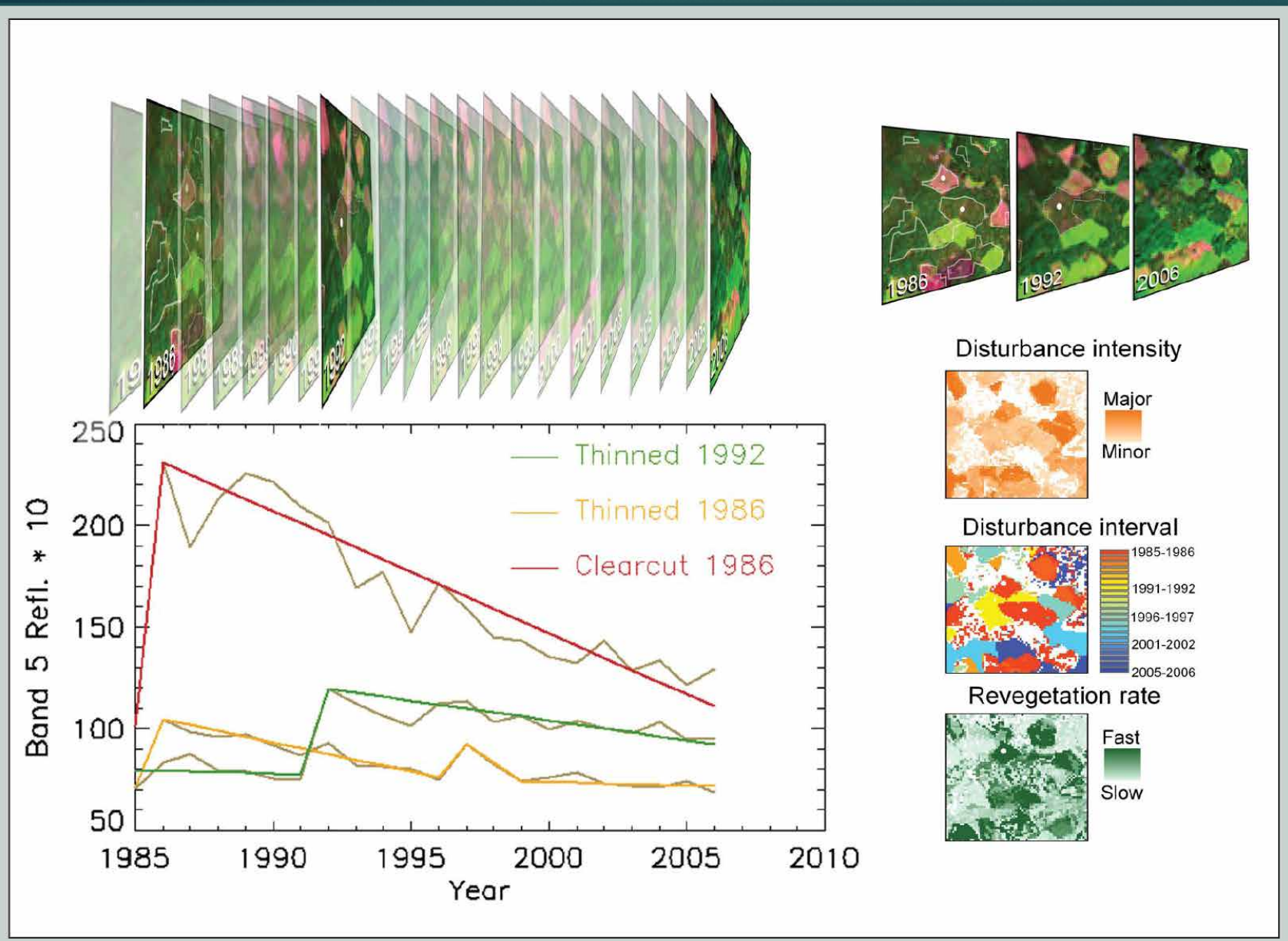
Kenneth.PierceJr@dfw.wa.gov

2006-2017 Change Locations



Kenneth.PierceJr@dfw.wa.gov

Landsat (LandTrendr)



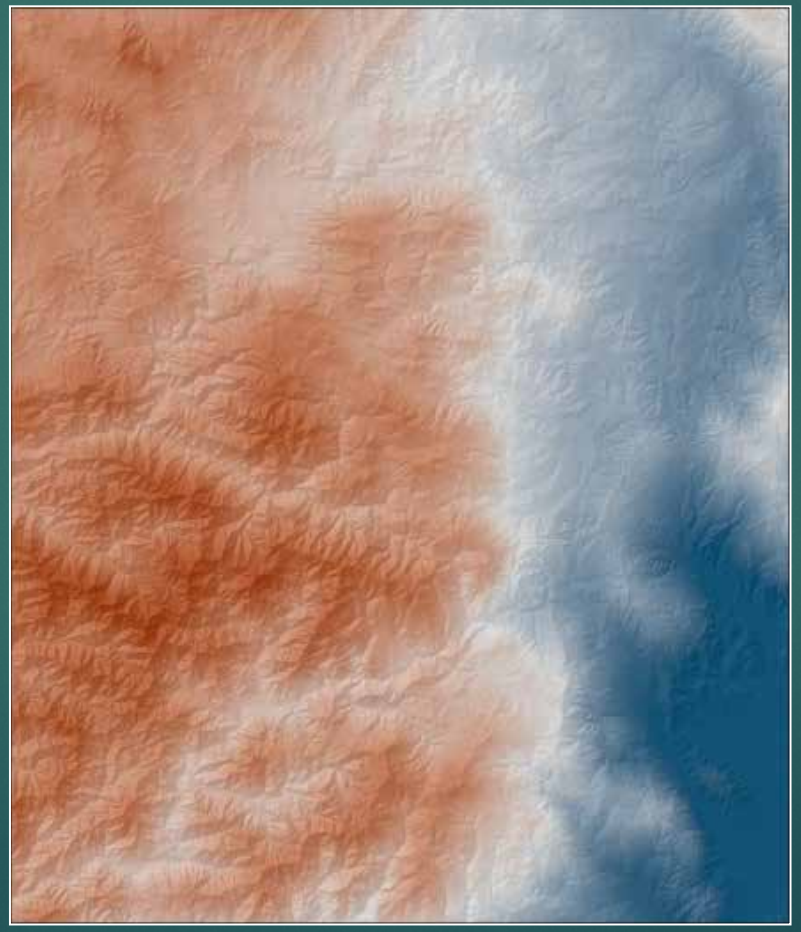
- Temporal normalization and segmentation at pixel level
- Minimizes noise from sun angle, phenology
- Segments describe sequences of disturbance, regrowth
- Yearly time-step
- Detects gradual and subtle changes
- Normalized imagery for multiple years for GNN modeling

*Kennedy et al. (2010), Rem. Sens. Env.

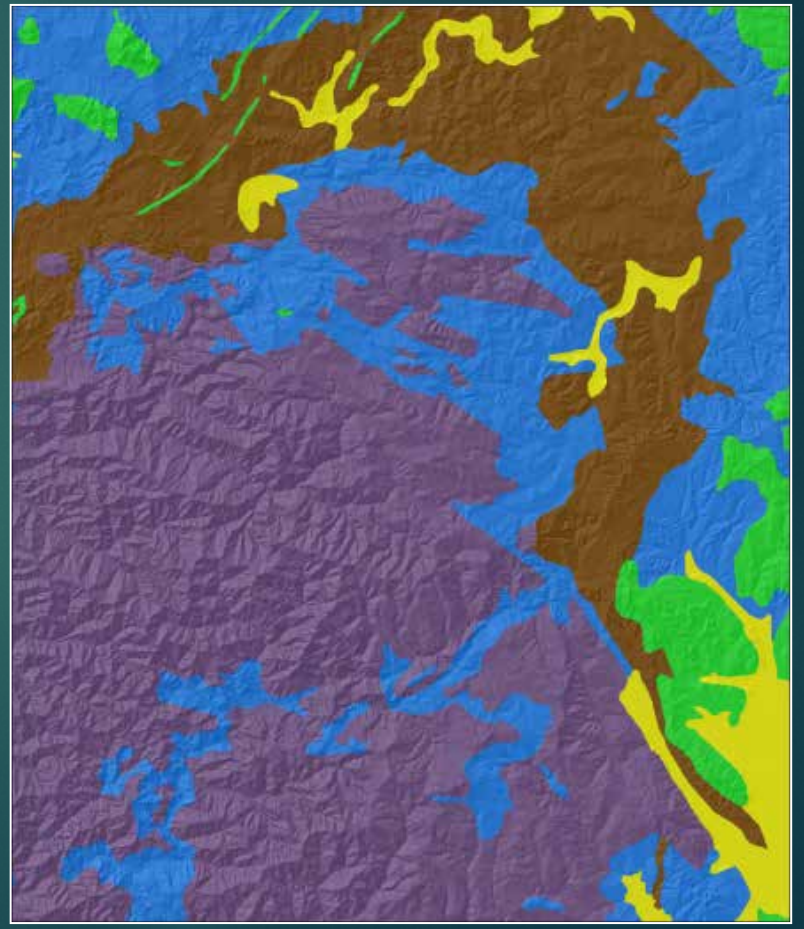
Environmental Gradients

Elevation

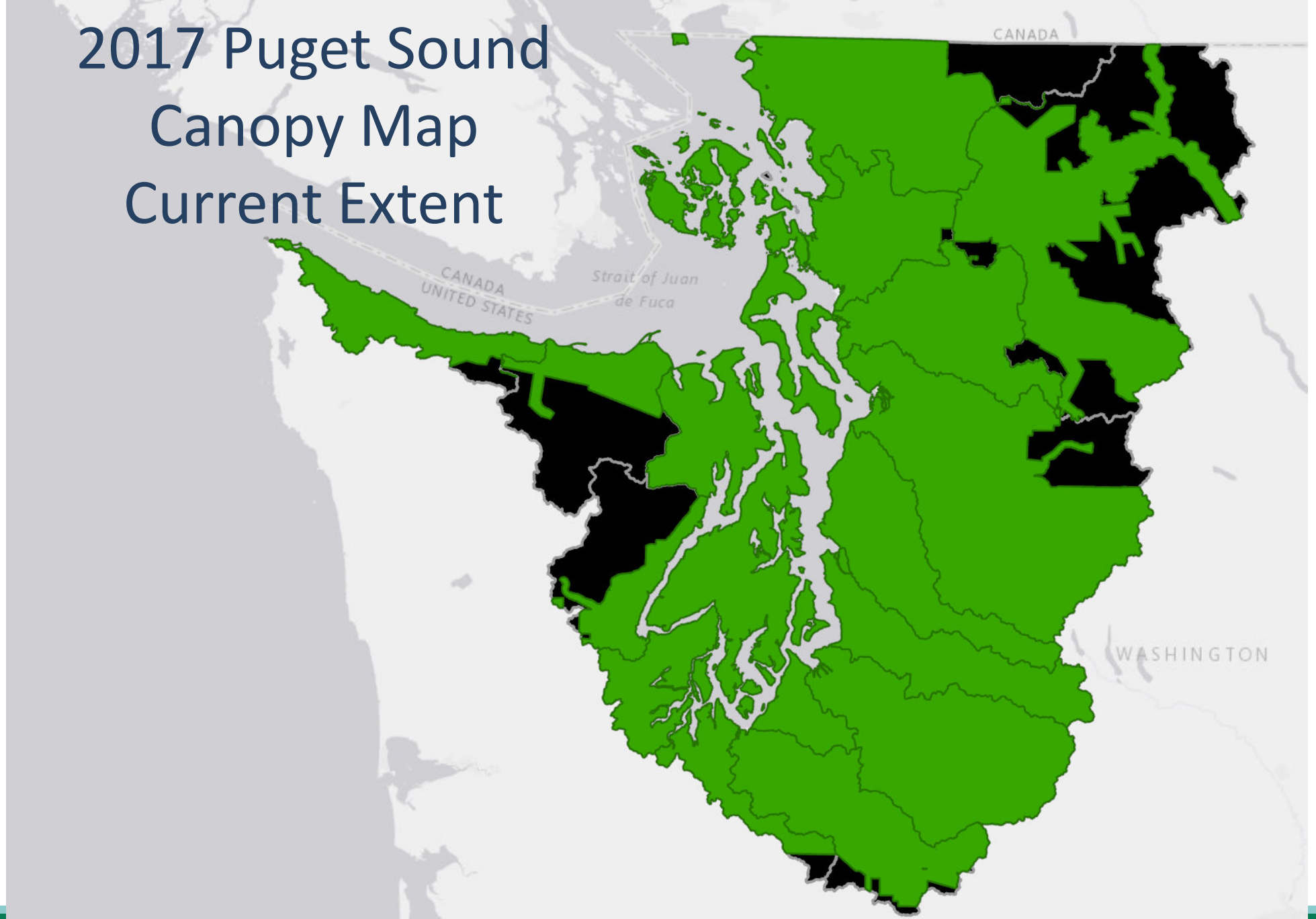
Climate



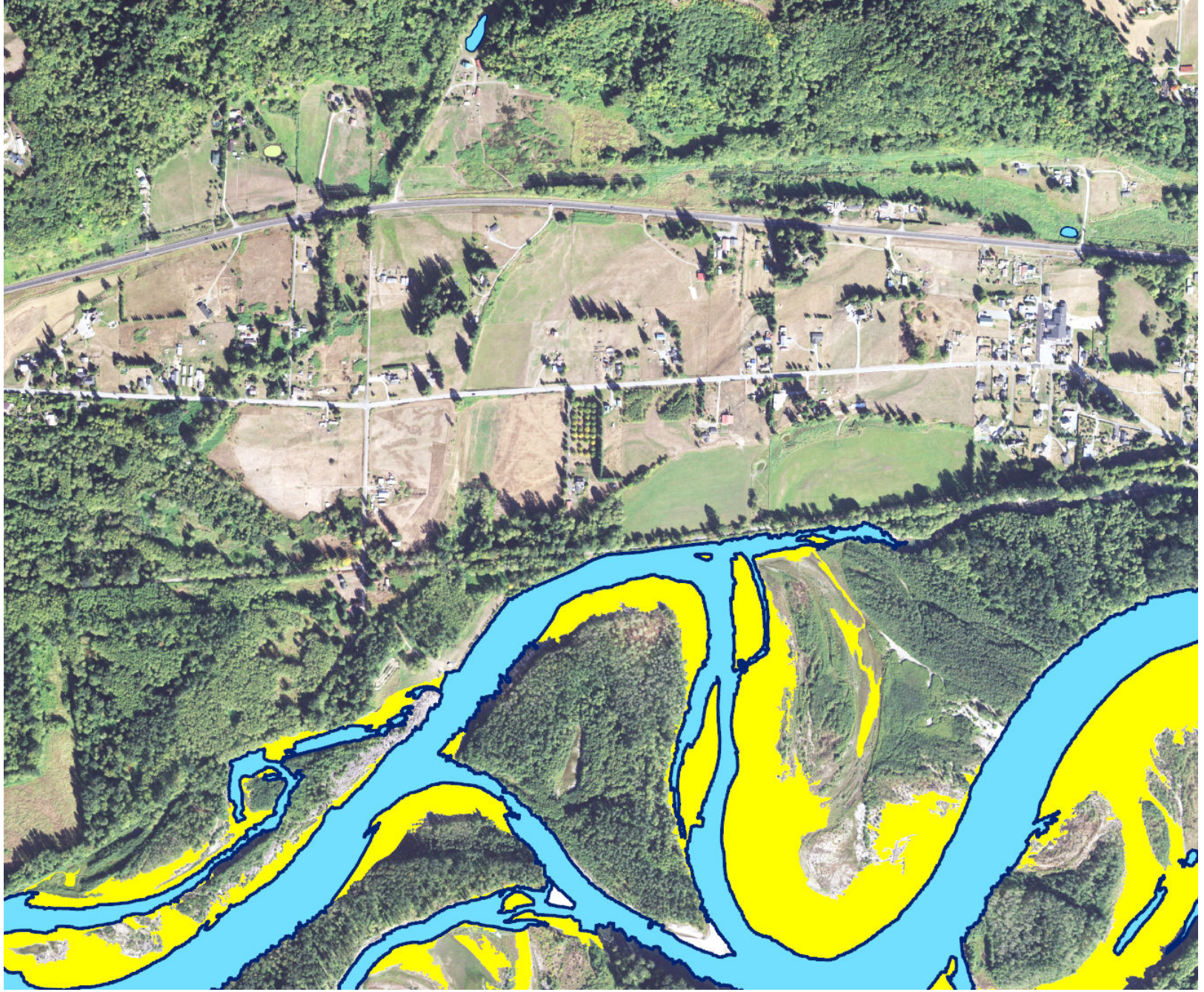
Soils / Geology



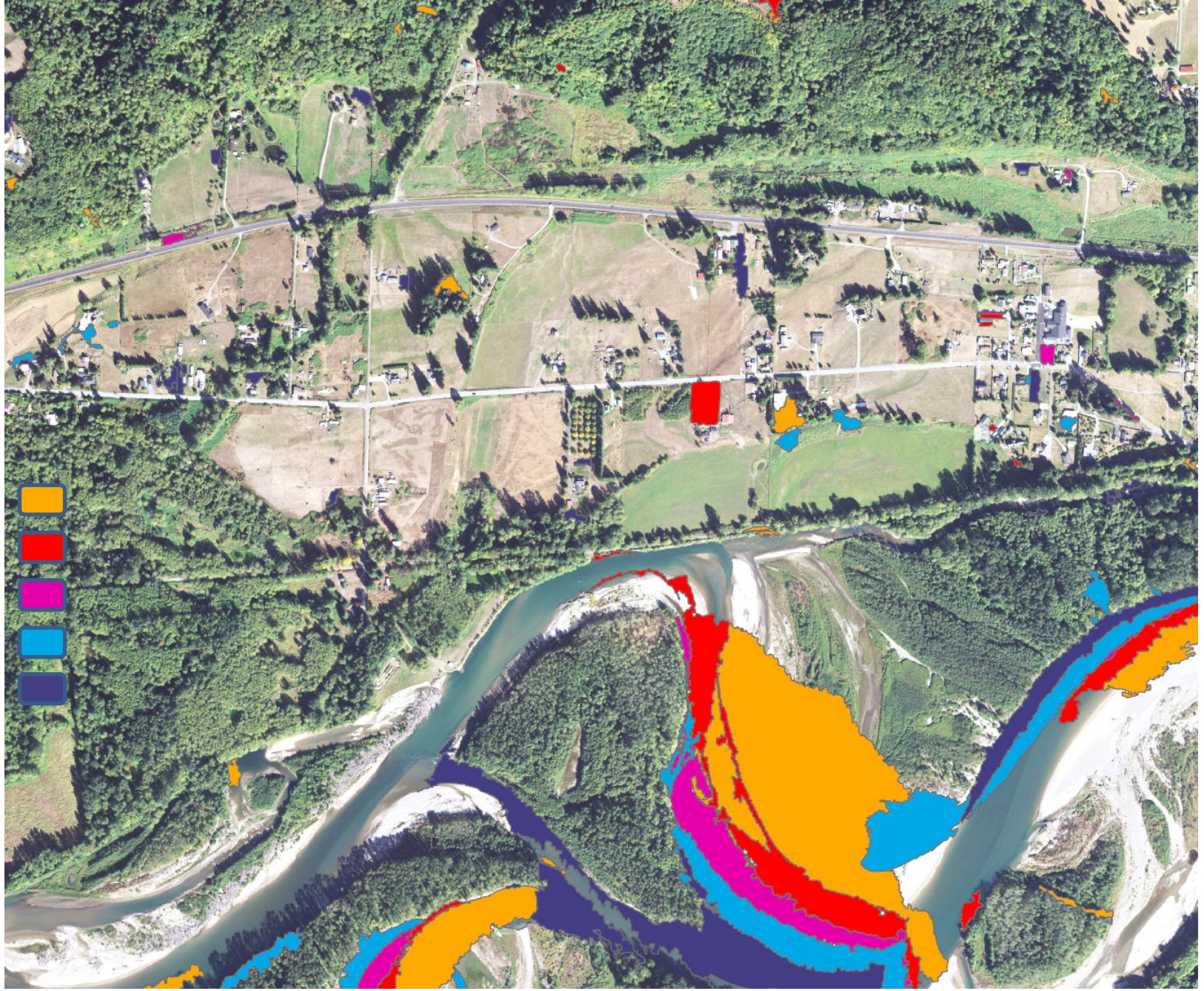
2017 Puget Sound Canopy Map Current Extent



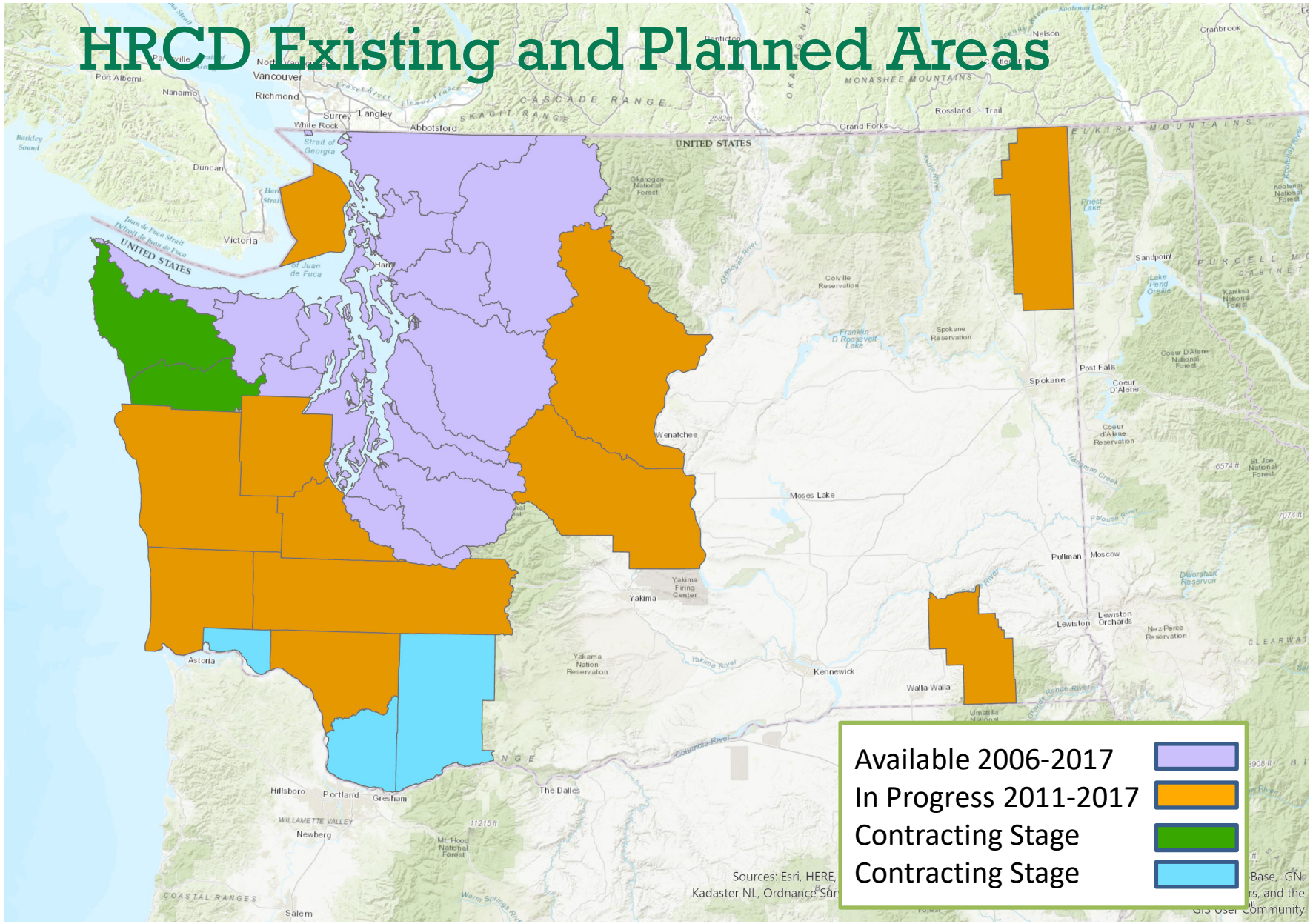
2017 Mapped Surface Water and Gravel

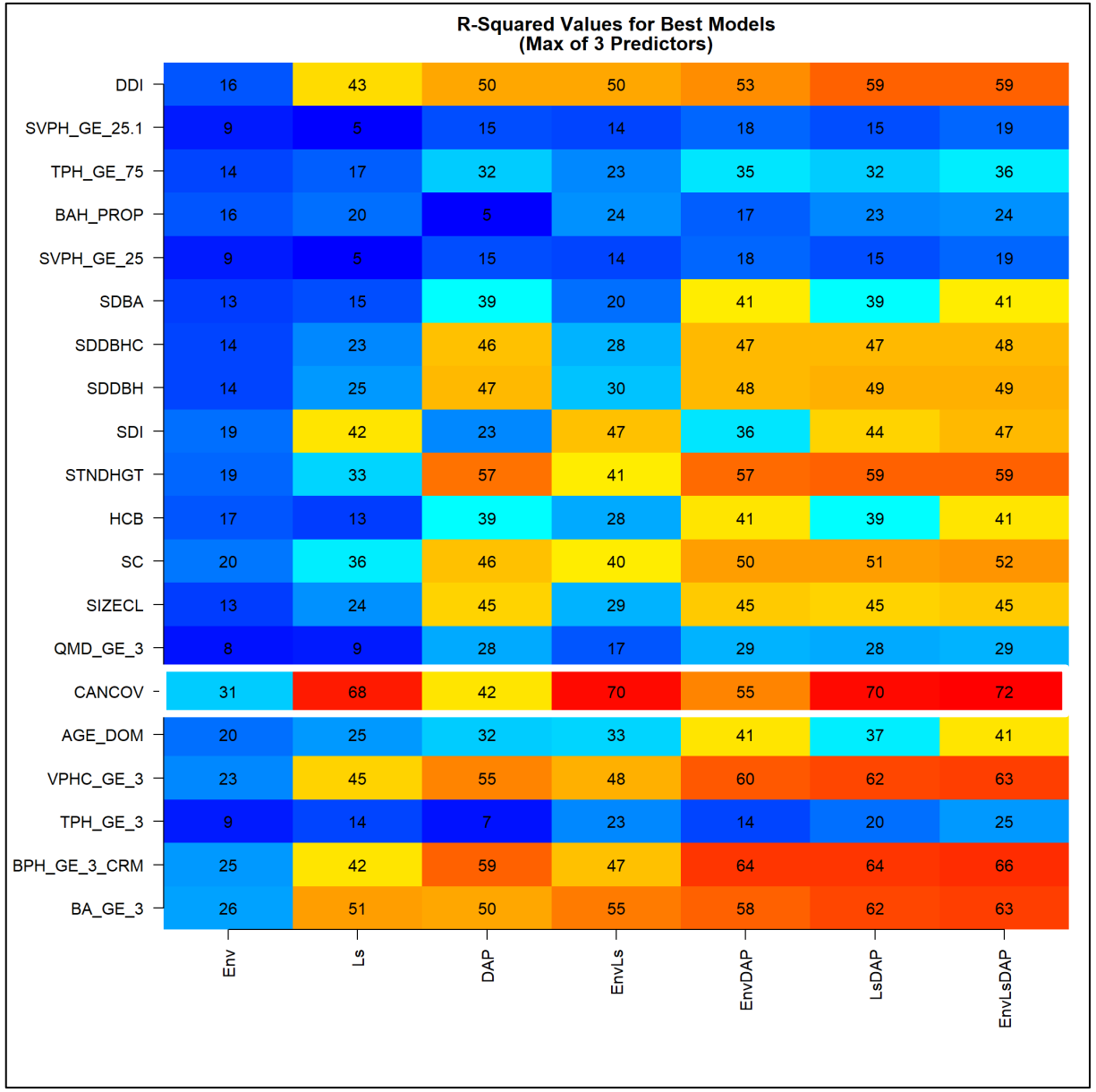


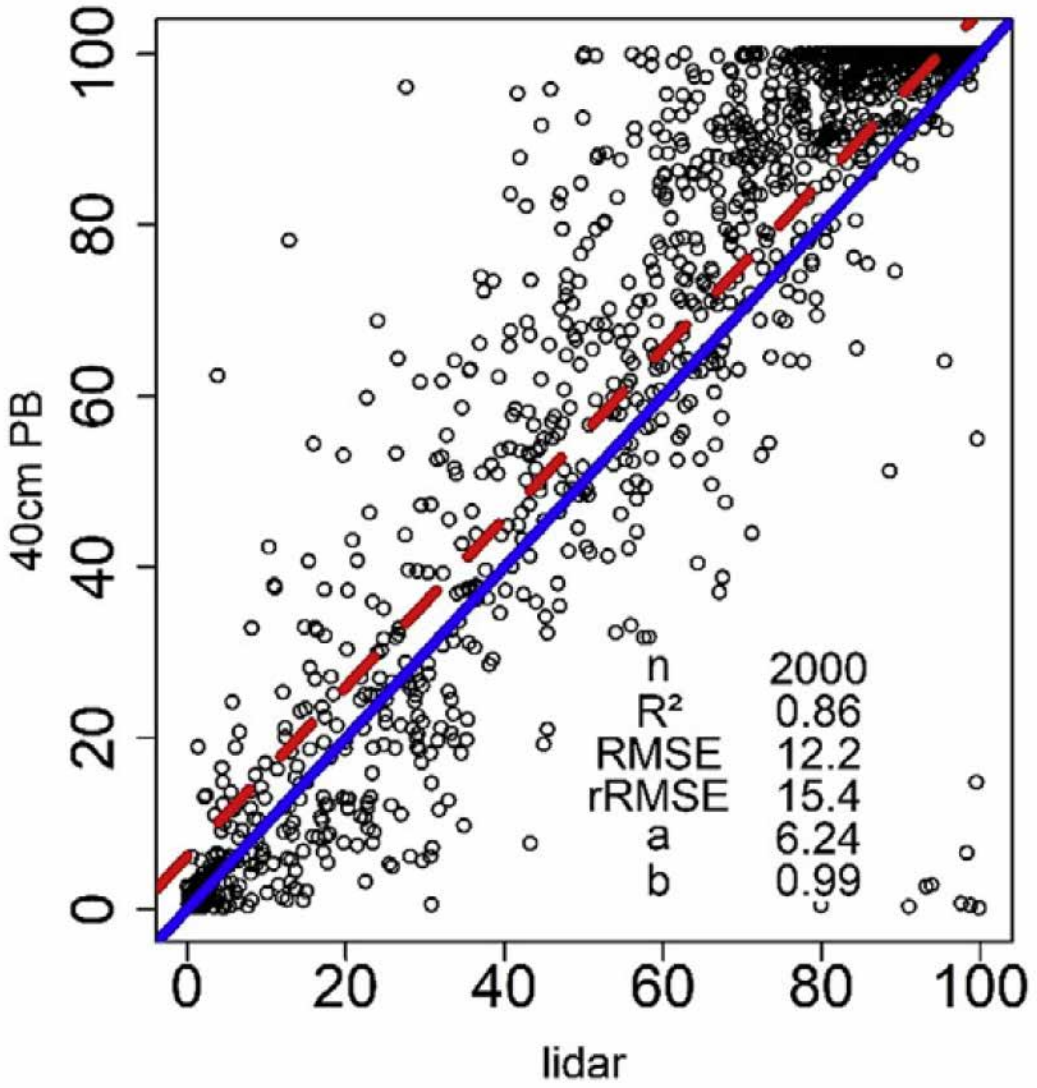
2006-2017
Change
Locations



HRCD Existing and Planned Areas

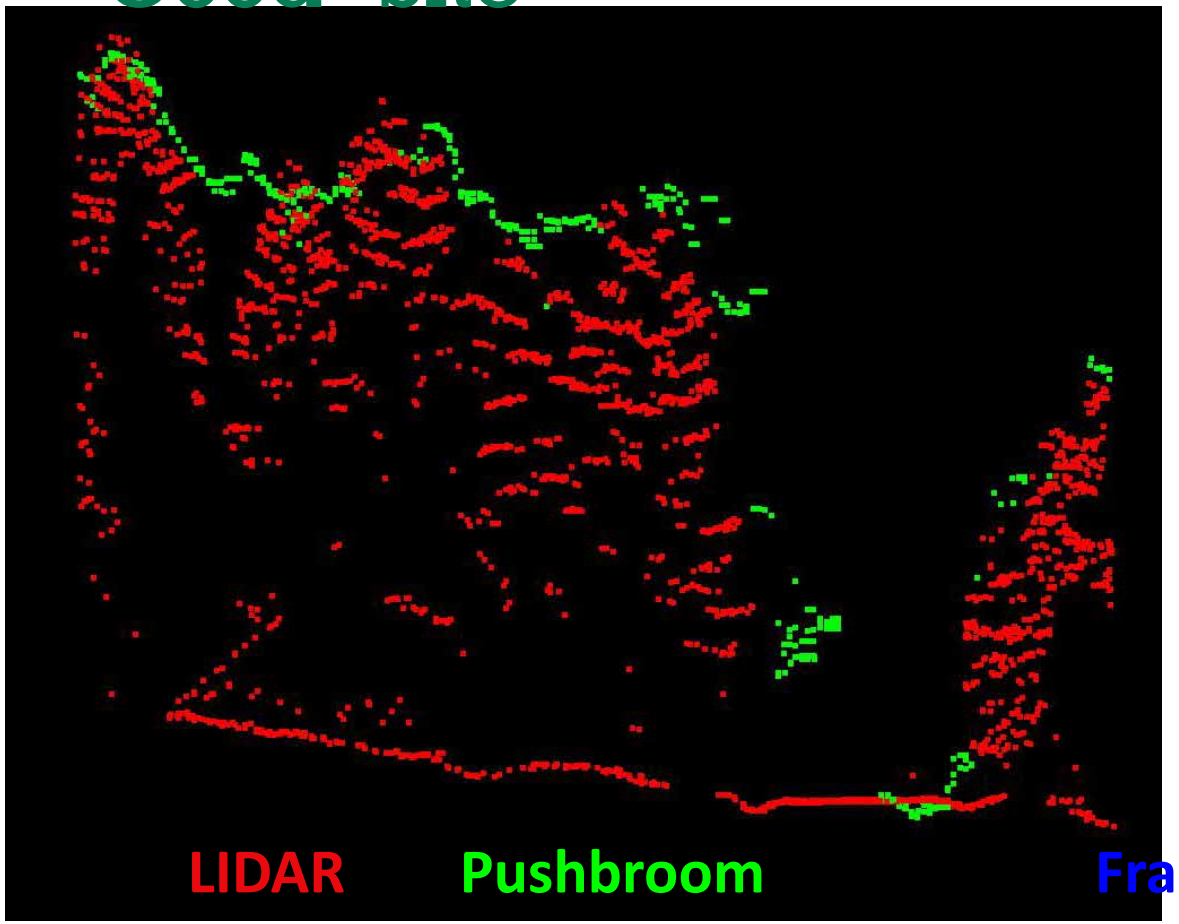


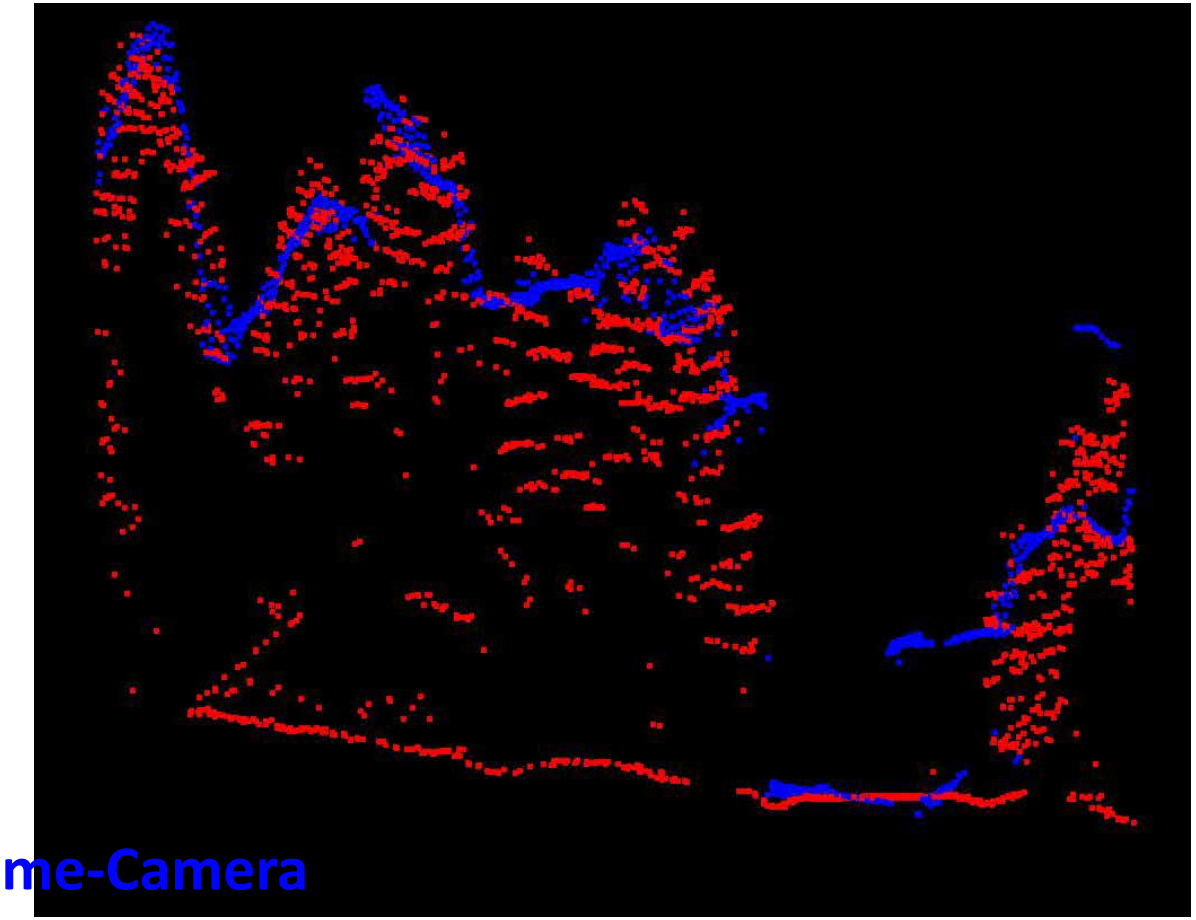




*FIA doesn't "measure" cover or closure, it is an allometric prediction

“Good” Site

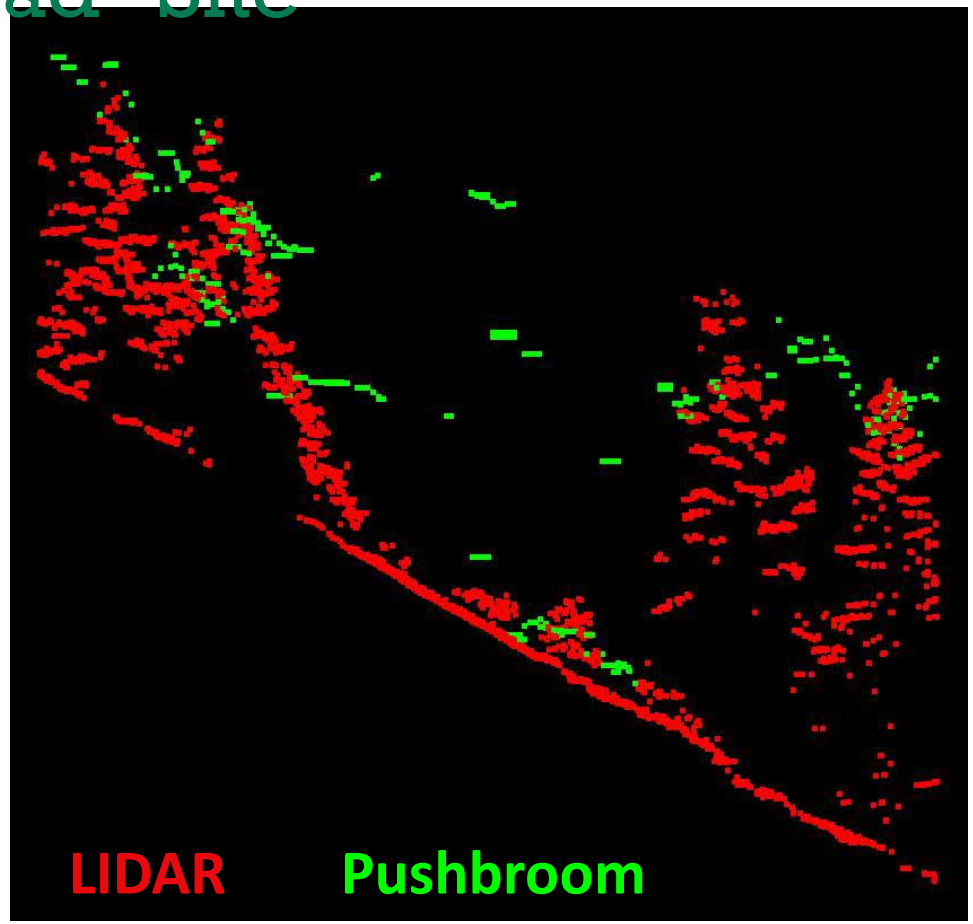


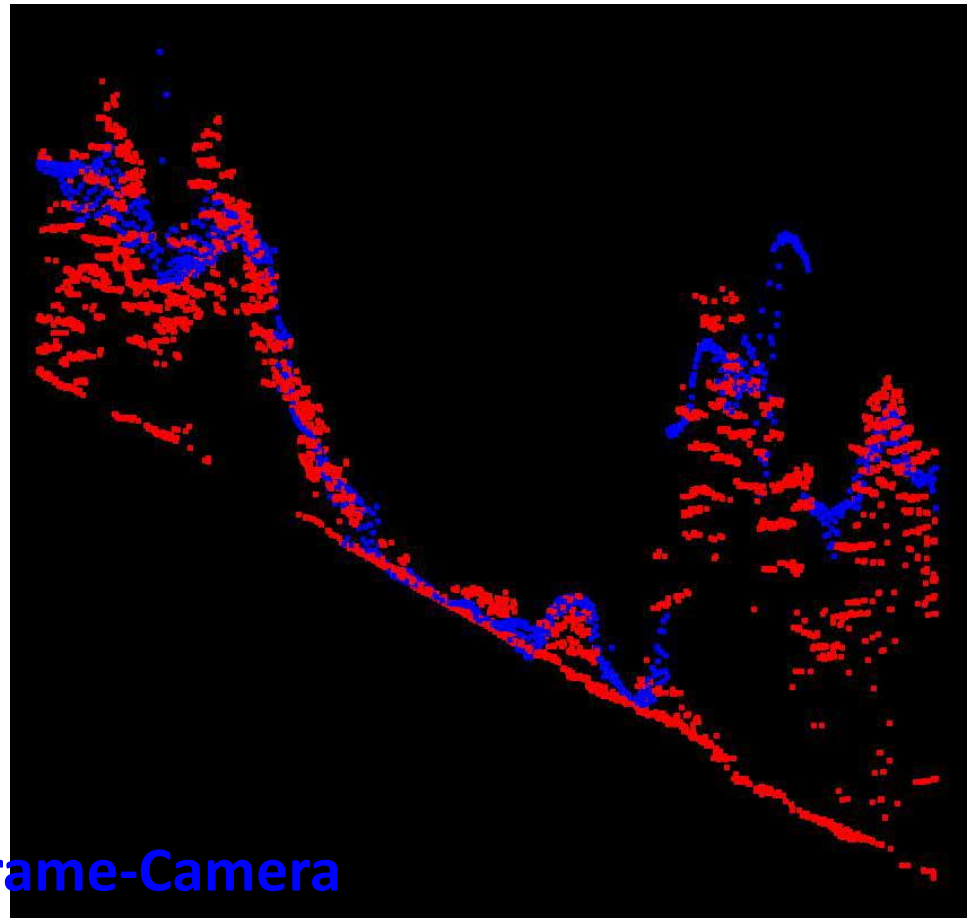


WA State, 40cm pushbroom, Socet

WA State, 30cm frame, Trimble Inpho

“Bad” Site





WA State, 40cm pushbroom, Socet

WA State, 30cm frame, Trimble Inpho