Industrial forest mapping: a Landsat Spatial and Temporal Approach

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Mastura Mahmud (Universiti Kebangsaan, Malaysia)

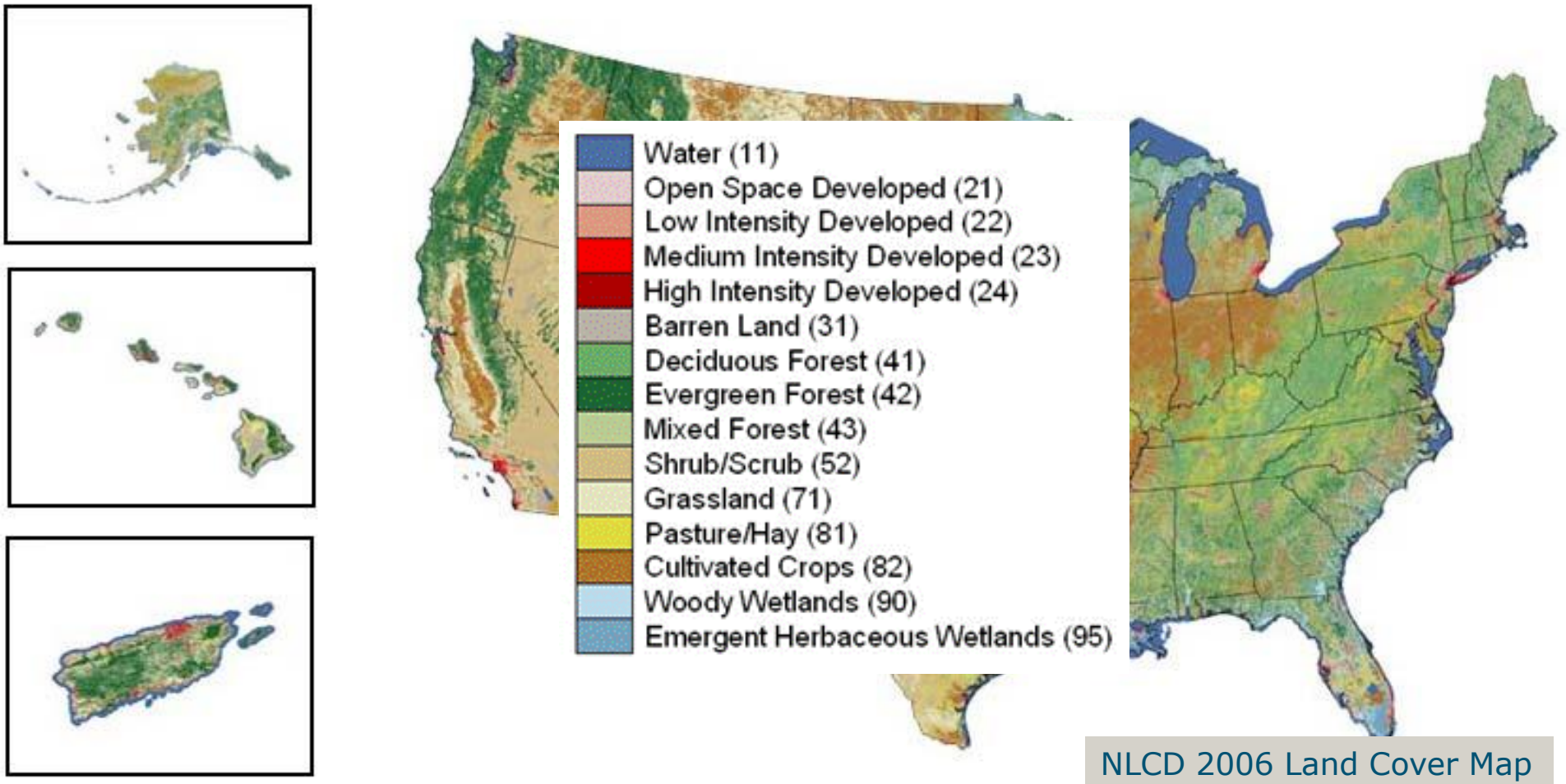
Nicola Clerici (Universidad del Rosario, Colombia)

University of Idaho College of Natural Resources

Objective of the project

- Prototype a method for monitoring and mapping globally industrial forests, using Landsat data
- Industrial forest = forest with productive use:
  - Plantations
  - Semi-natural forests
- Study Area:
  - Wall-to-wall CONUS
  - test sites in tropics
- Tests of combined used of Landsat and LIDAR

Large RS heritage on forest



NLCD 2006 Land Cover Map

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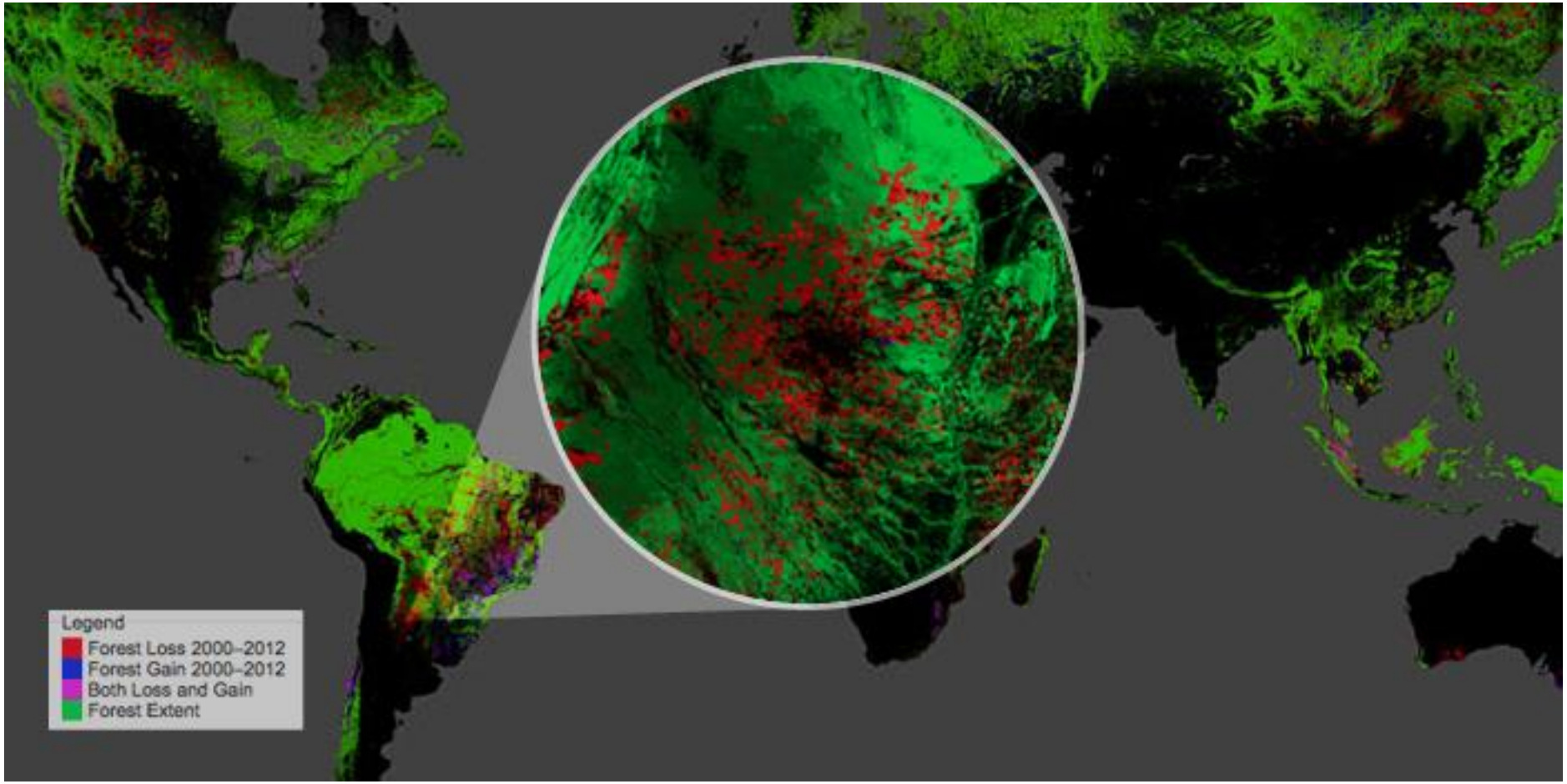
Large RS heritage on forest monitoring



Hansen et al 2014

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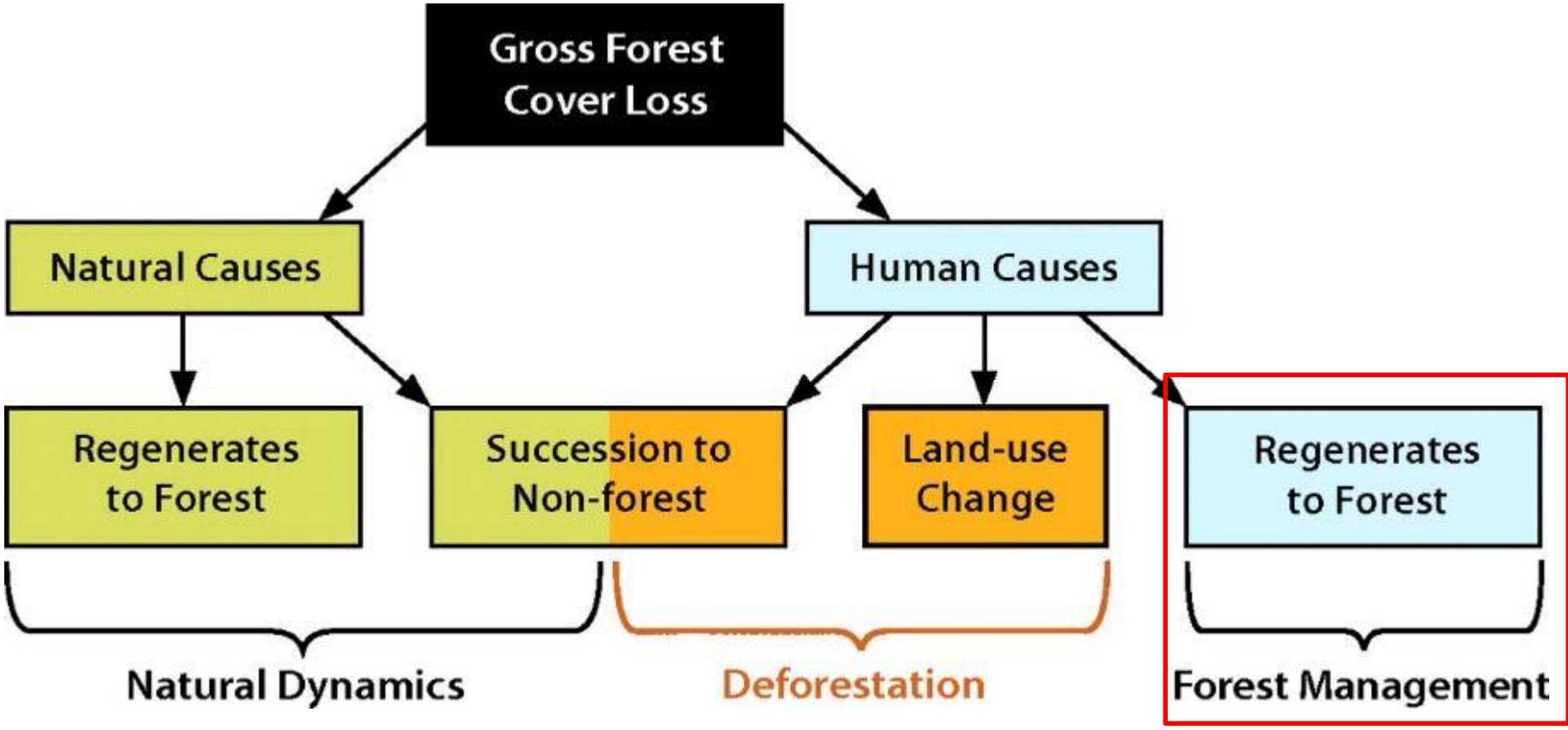
Gross Forest Cover Loss ≠ Deforestation



Kurtz, 2010

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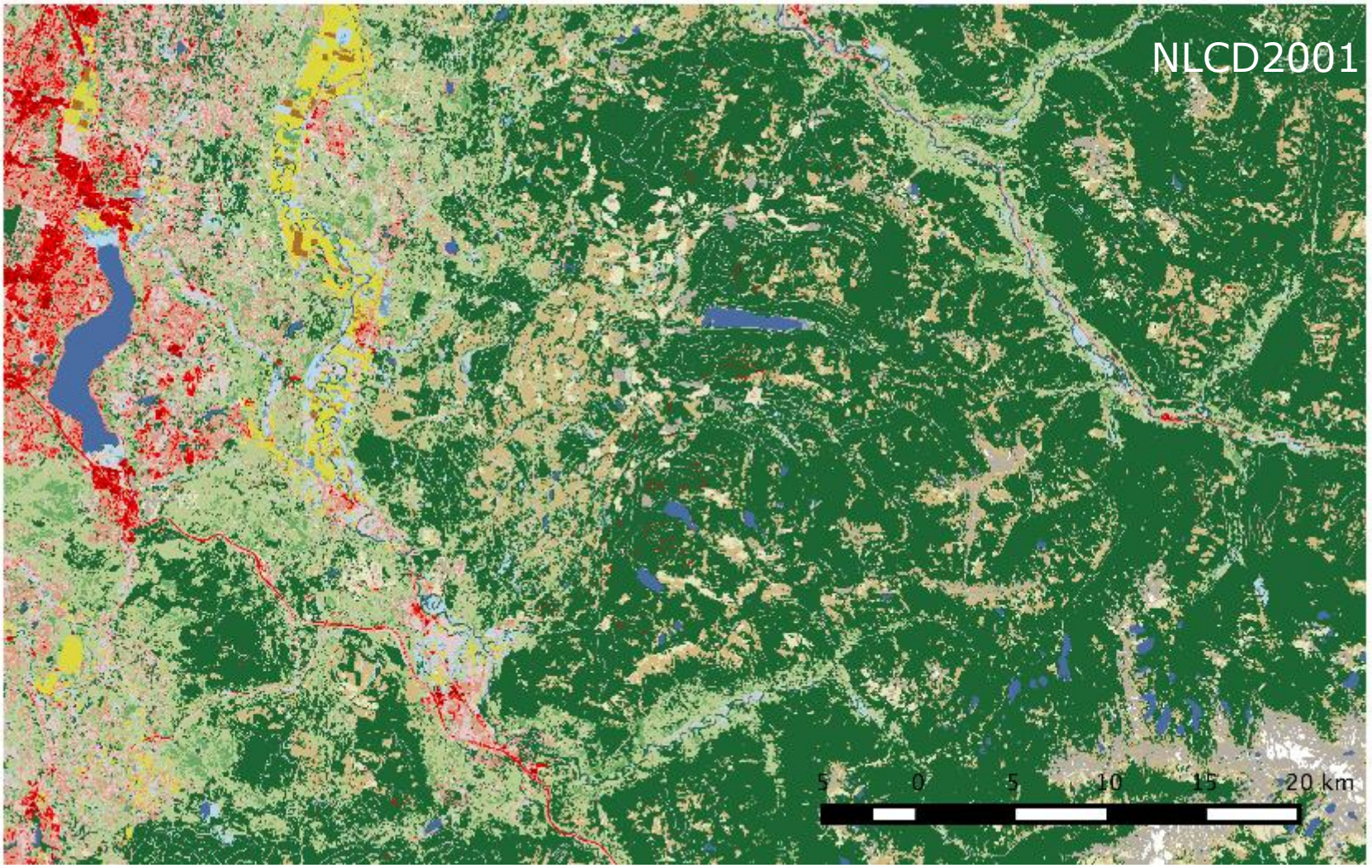
Mapping Forest Land Cover ≠ Land Use



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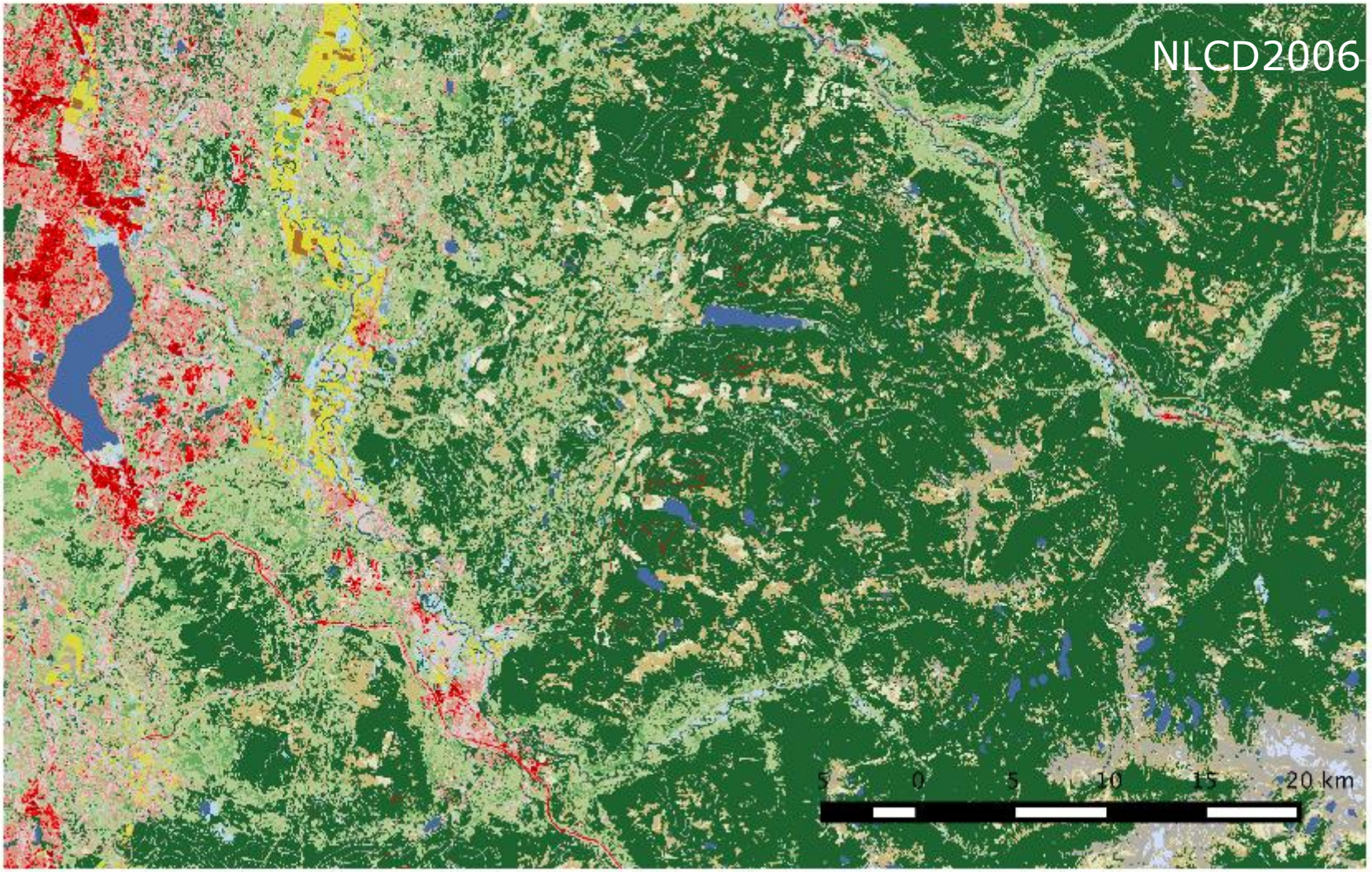

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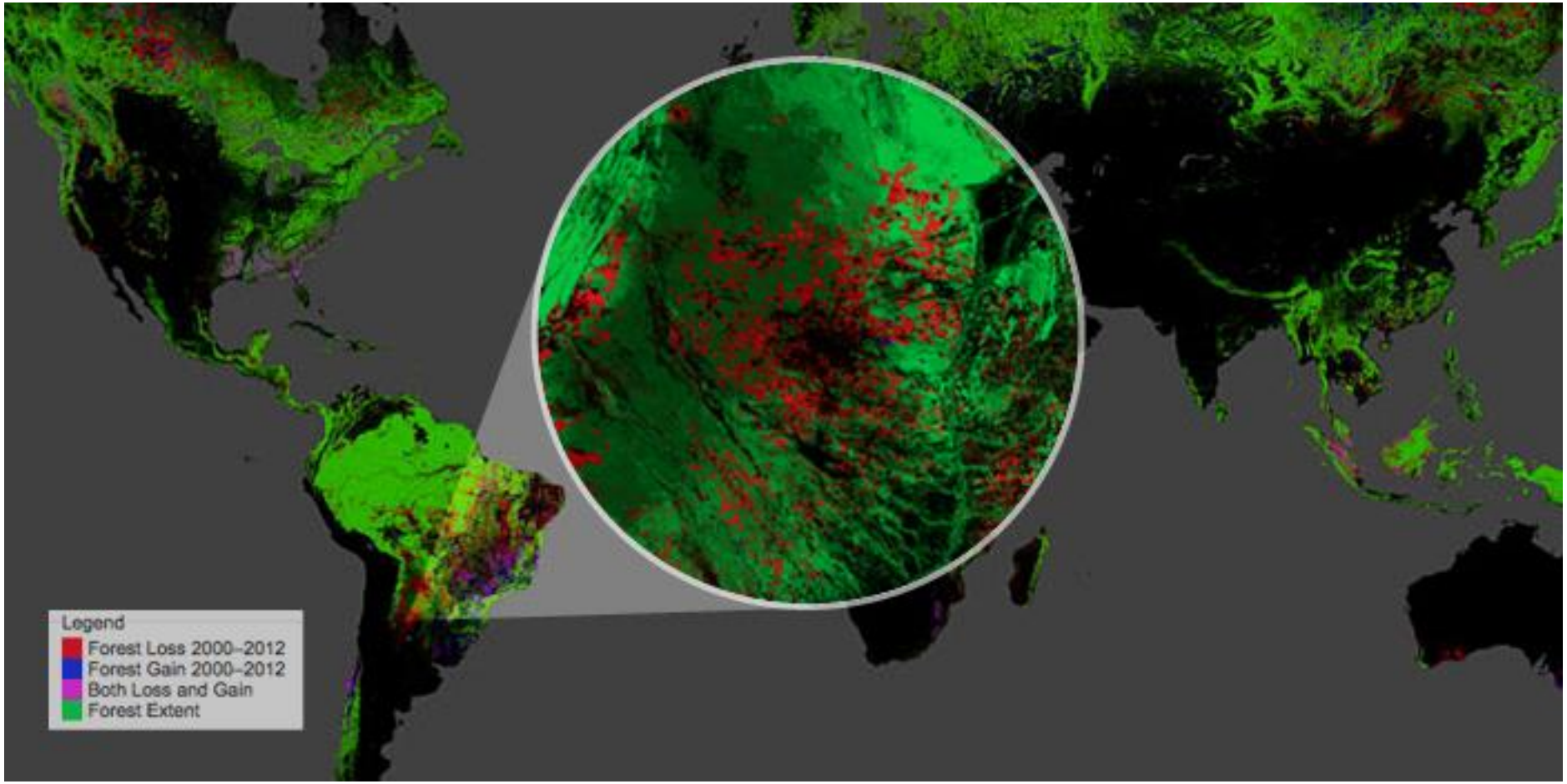
Current project activities

1. Detecting Landsat-era forest management activity: 2003-2011 forest clearcuts in the CONUS

2. Detecting pre-Landsat forest management activities combining Lidar and Landsat data: test cases in the Pacific Northwest

Large RS heritage on forest monitoring



Hansen et al 2014

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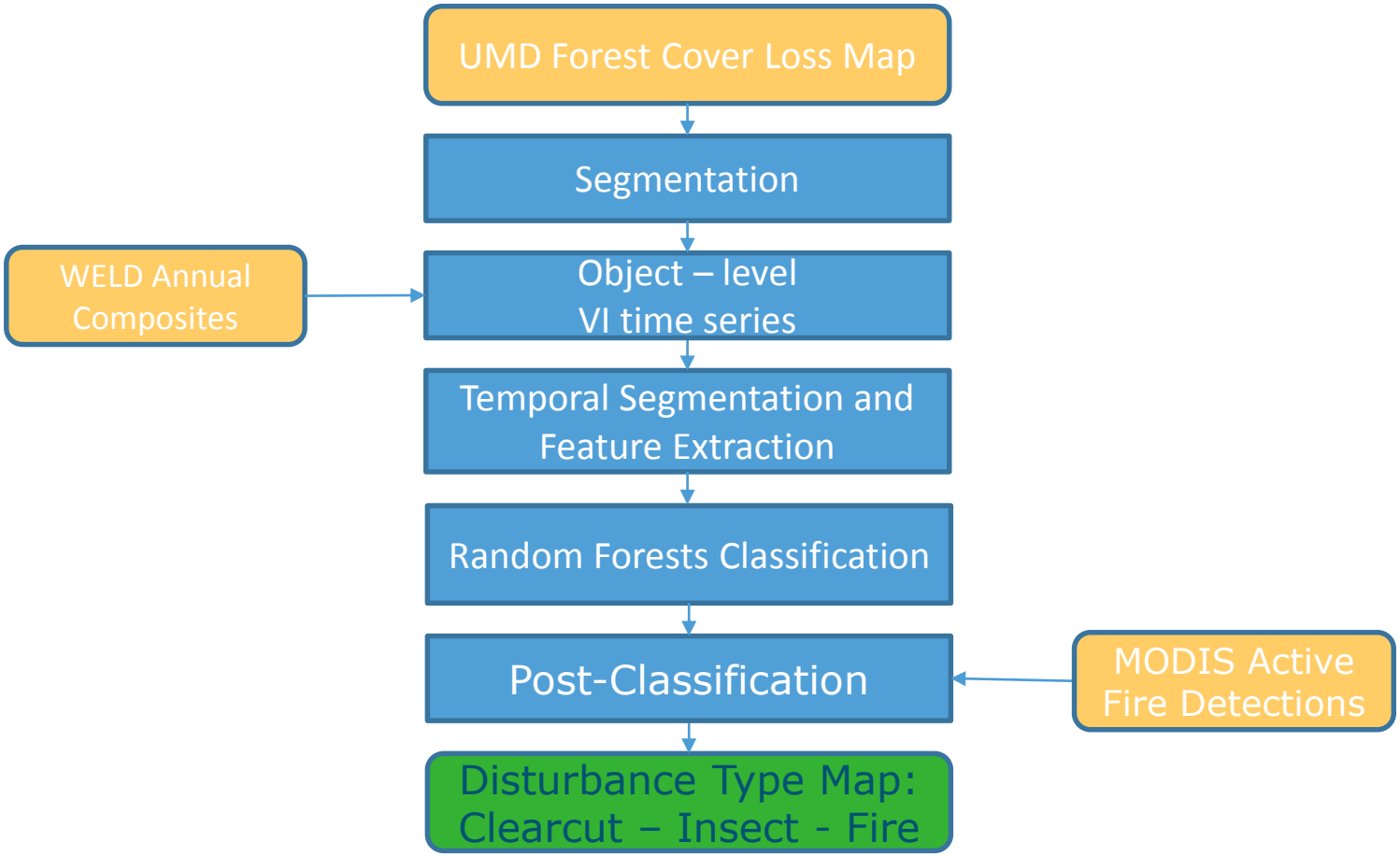
Disturbance type characterization in the CONUS



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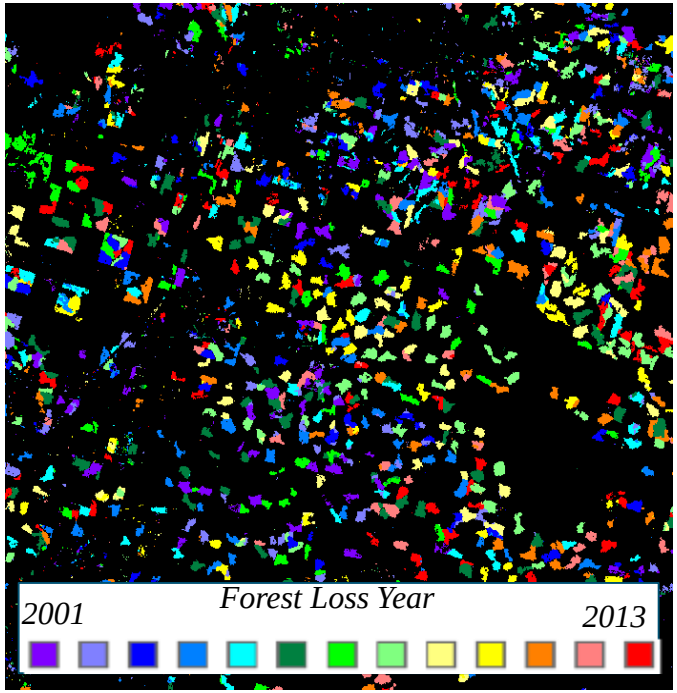
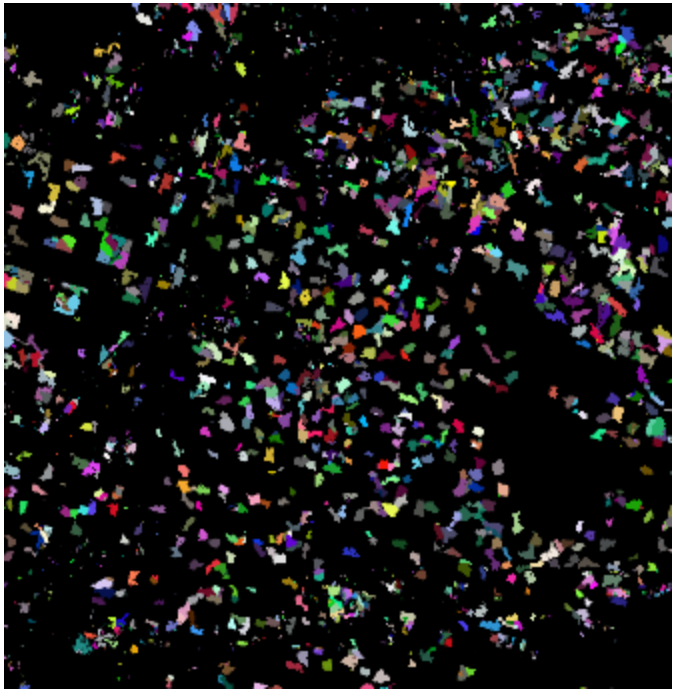
1 – Segmentation



Forest cover loss map

Forest cover loss *objects*:
8-neighbourhood connectivity
Same forest cover loss year

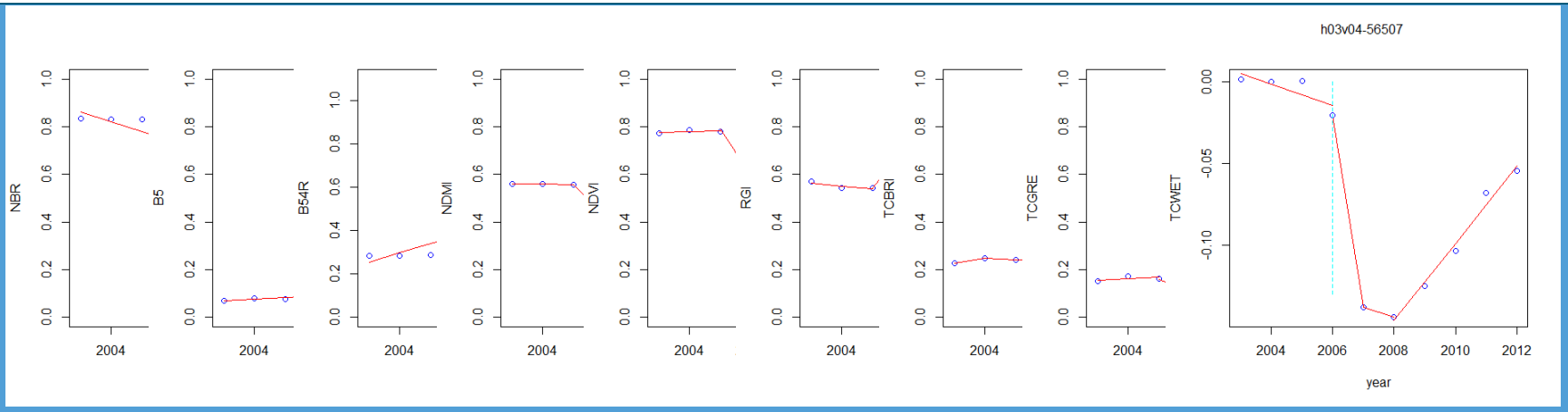


Temporal analysis

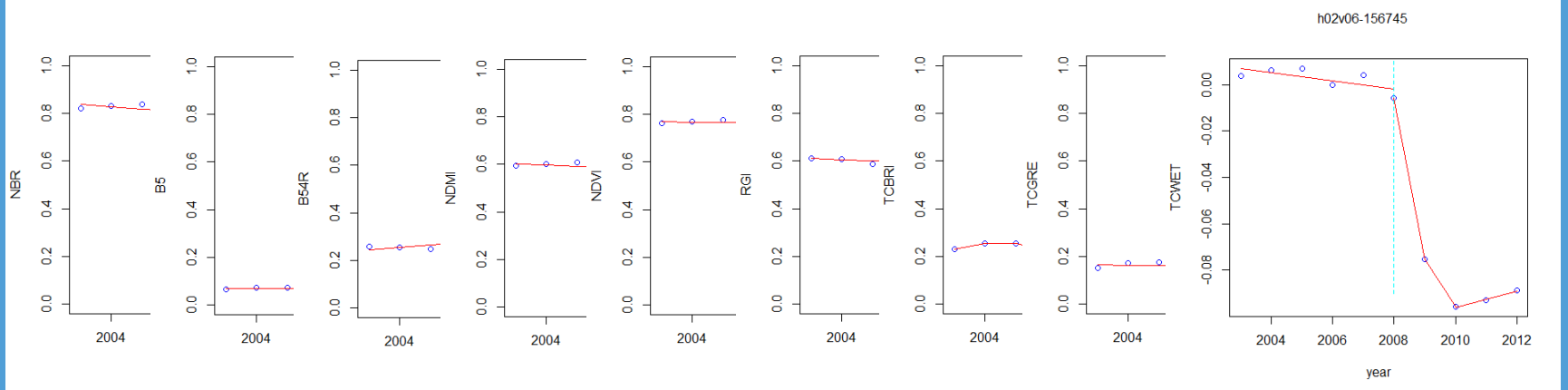
Object-oriented version of the LandTrendr Algorithm (Kennedy et al, 2010)

- Time series of spectral indices for each object, extracted from the WELD annual composites
  - RGI, NDVI, NDMI, B54R, NBR, ρ_{B5}, TC_{BRI}, TC_{GRE}, TC_{WET}
- Temporal segmentation of the trajectory
- Classification based on the trajectory characteristics

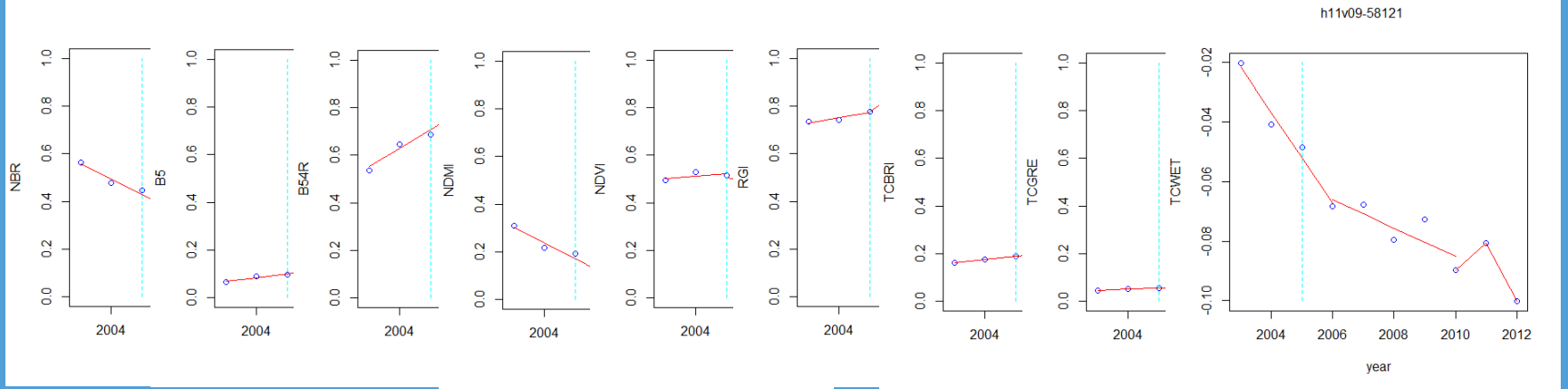
CLEARCUT



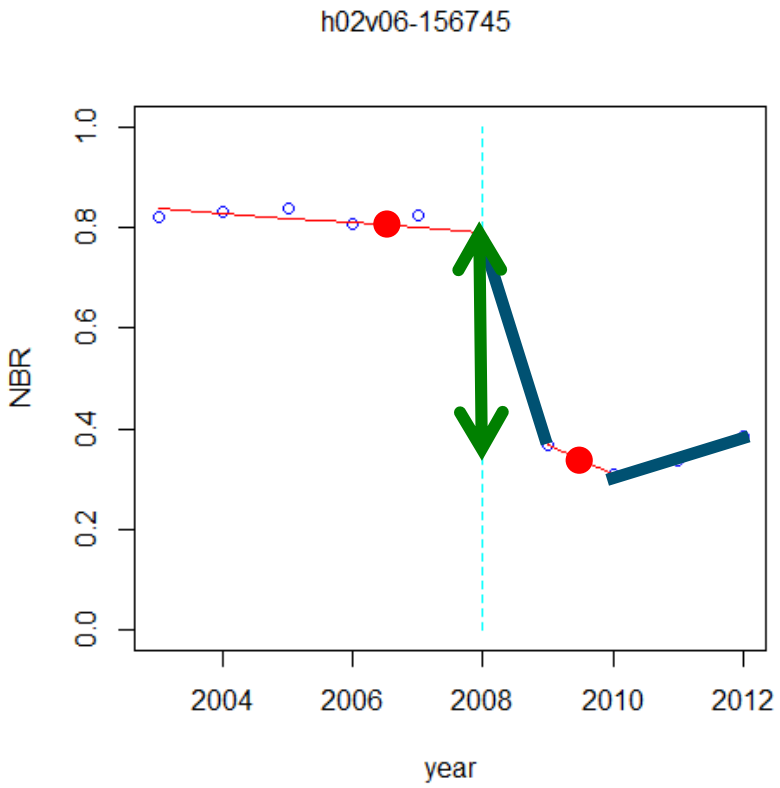
FIRE



INSECT OUTBREAK



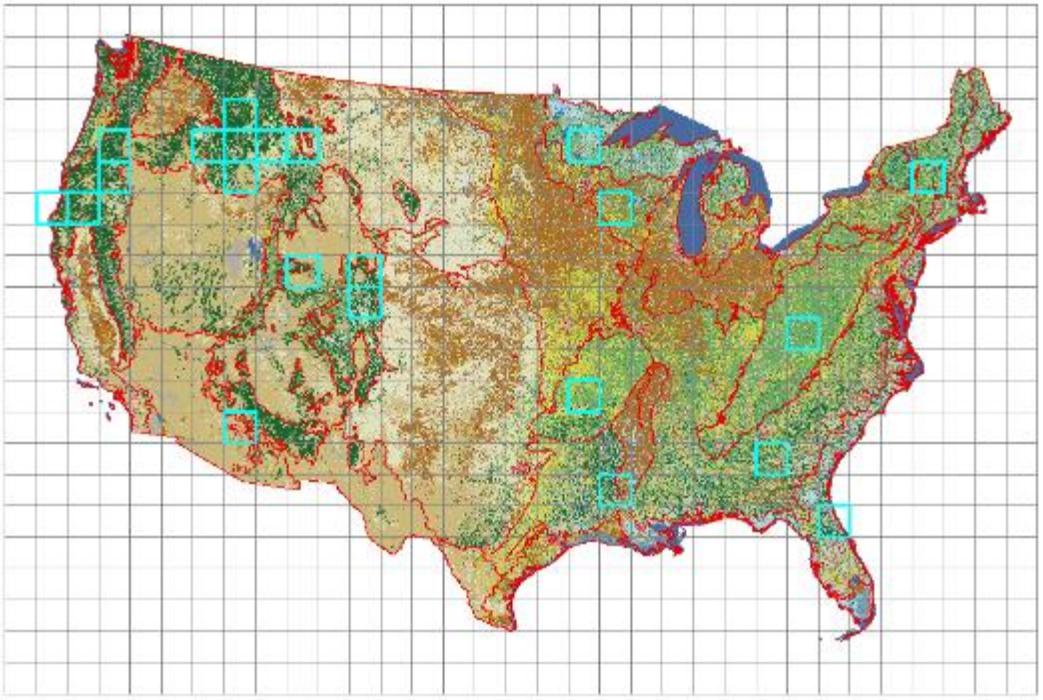
Temporal Trajectory Segmentation



Representative parameters:

- Minimum and maximum slope
- Average value in the 2 years before and 2 years after the disturbance
- Magnitude of the change between the two average values

Random forest classification: training data



Training set of ~ 2000 forest cover loss objects of known disturbance types

Visual interpretation of:

- WELD composites
- USDA NAIP aerial photos
- high resolution satellites imagery
- ancillary datasets (MTBS perimeters and USFS insect outbreak locations)

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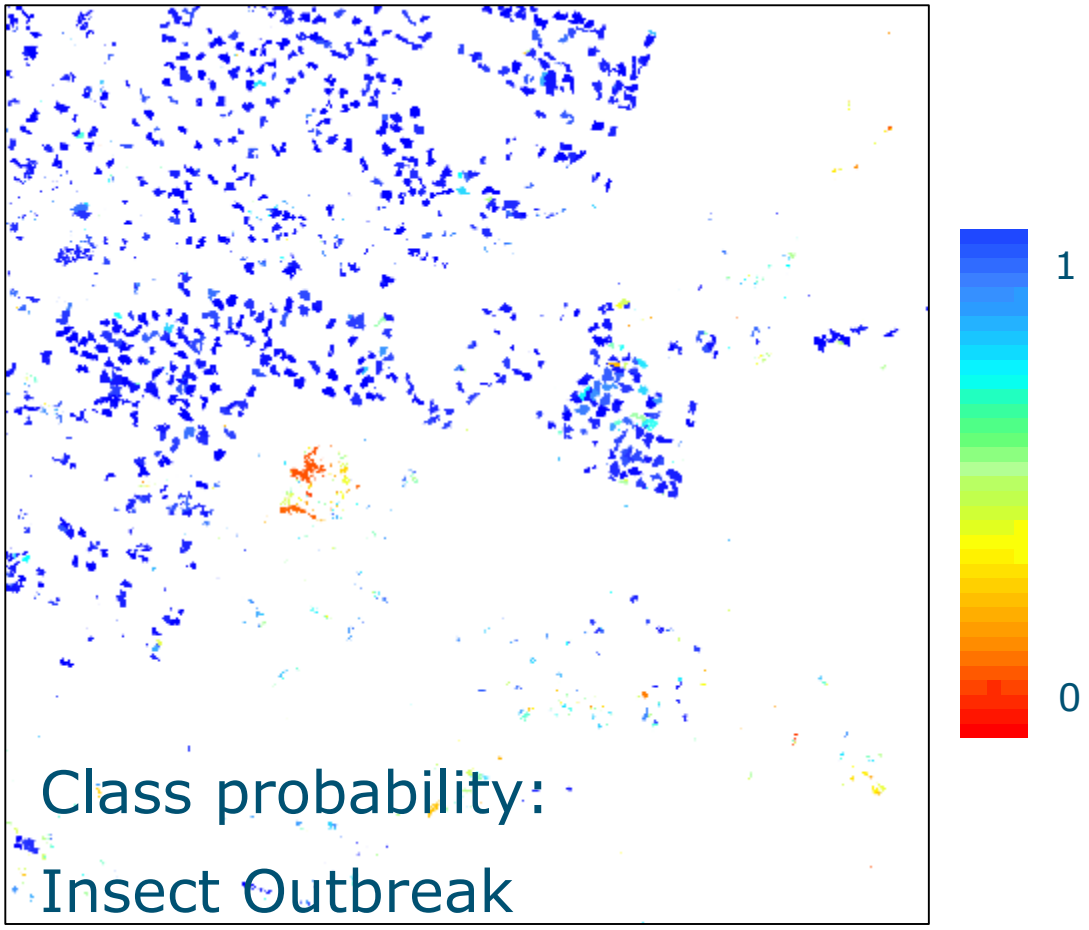
Random forest classification output



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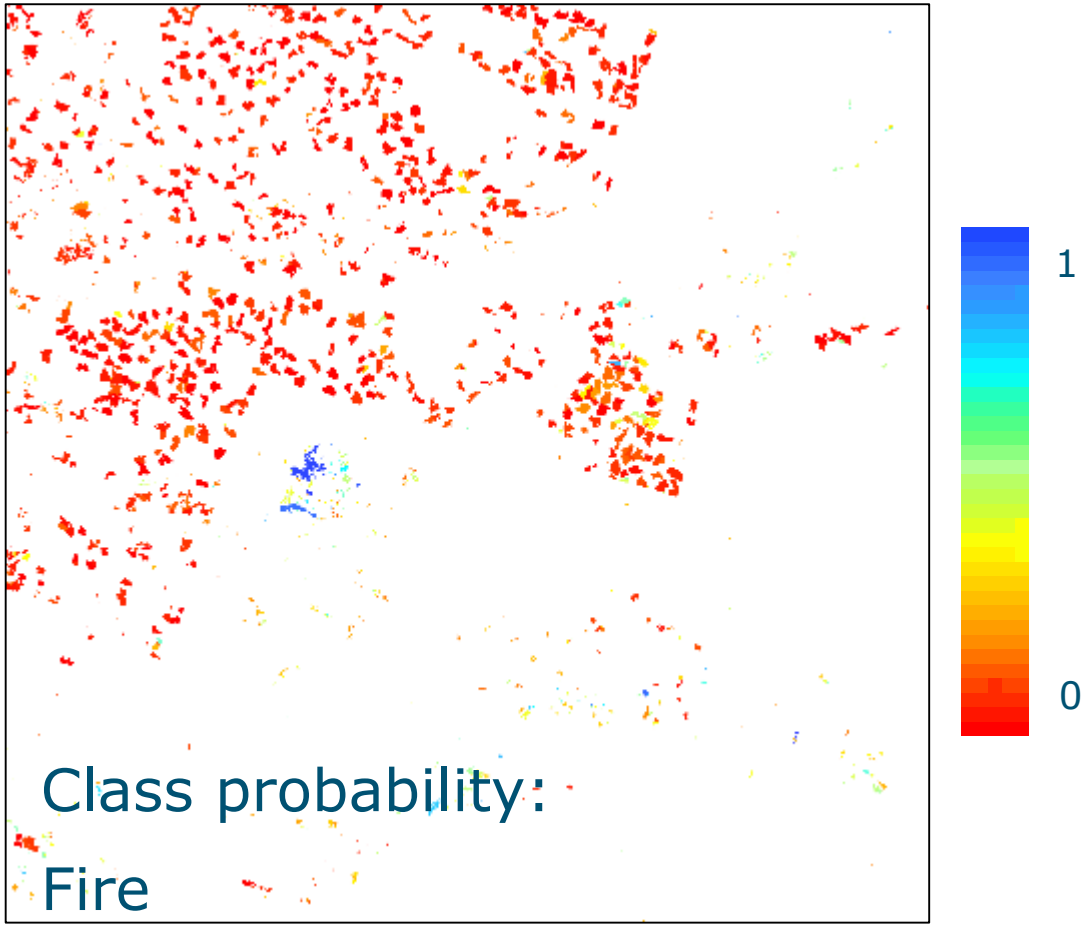

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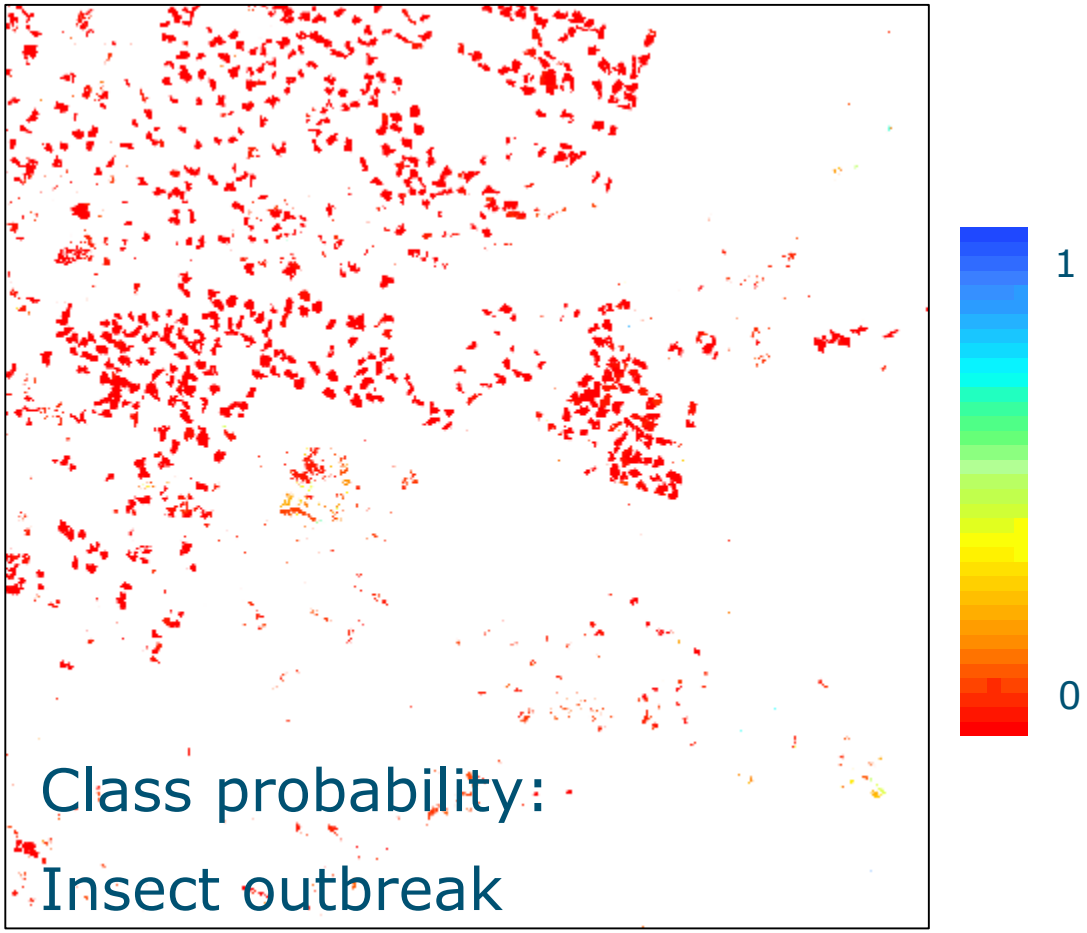

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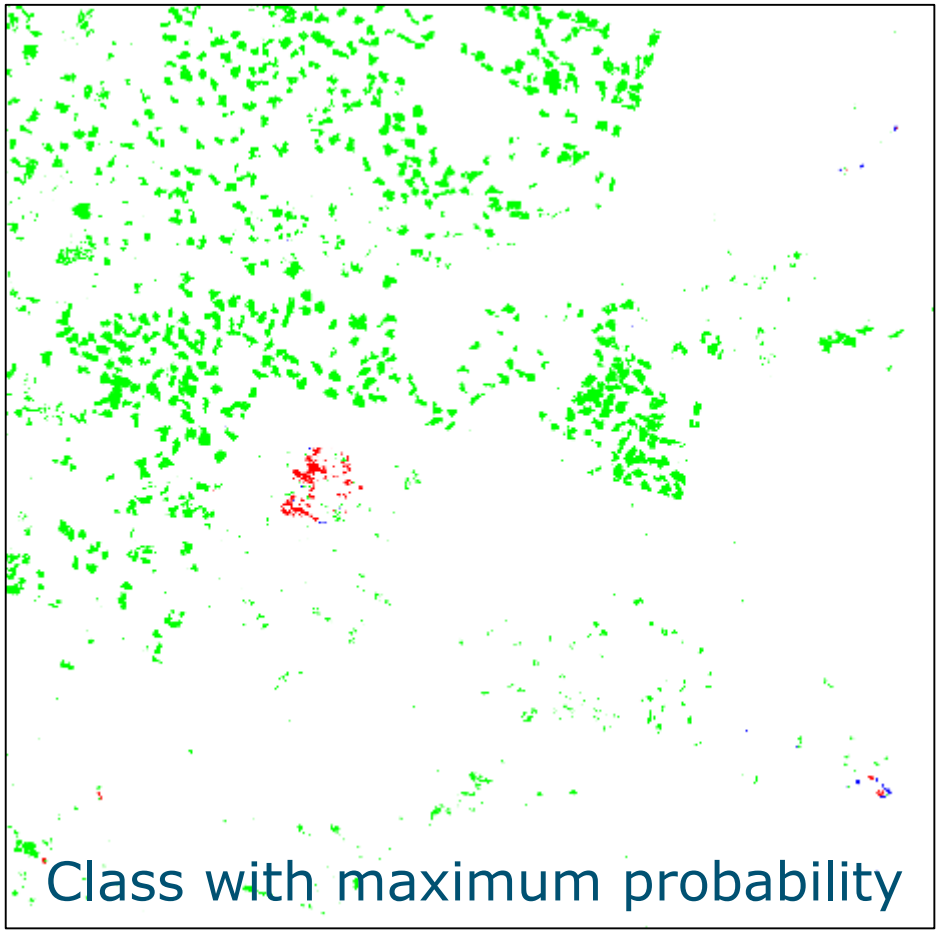

Clearcuts

Fires

Insect outbreaks

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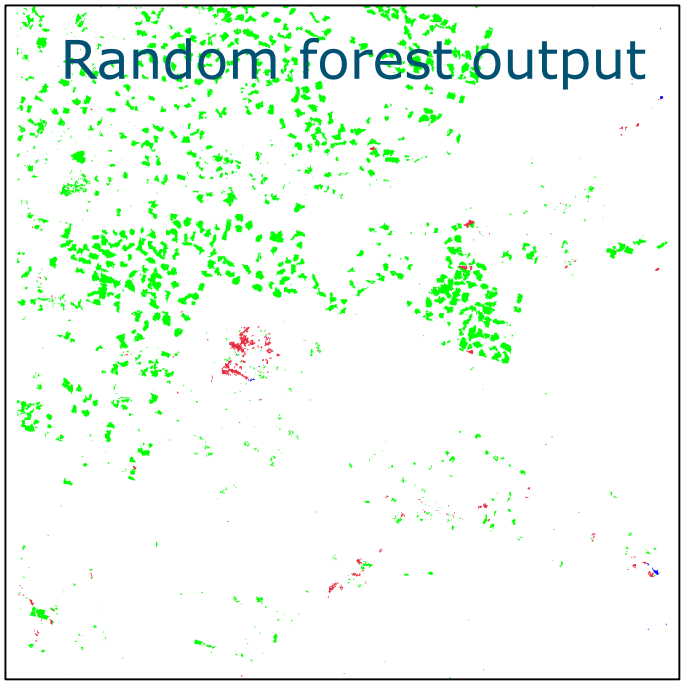
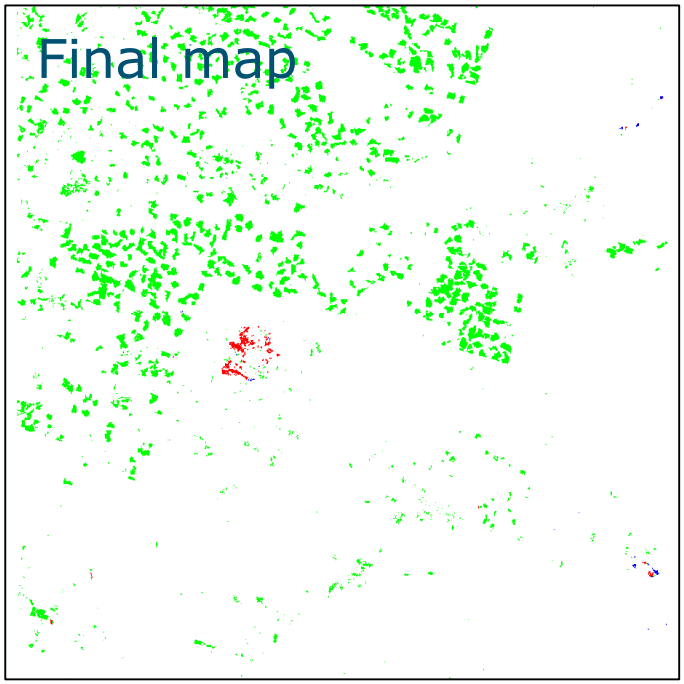
Post classification with MODIS active fires





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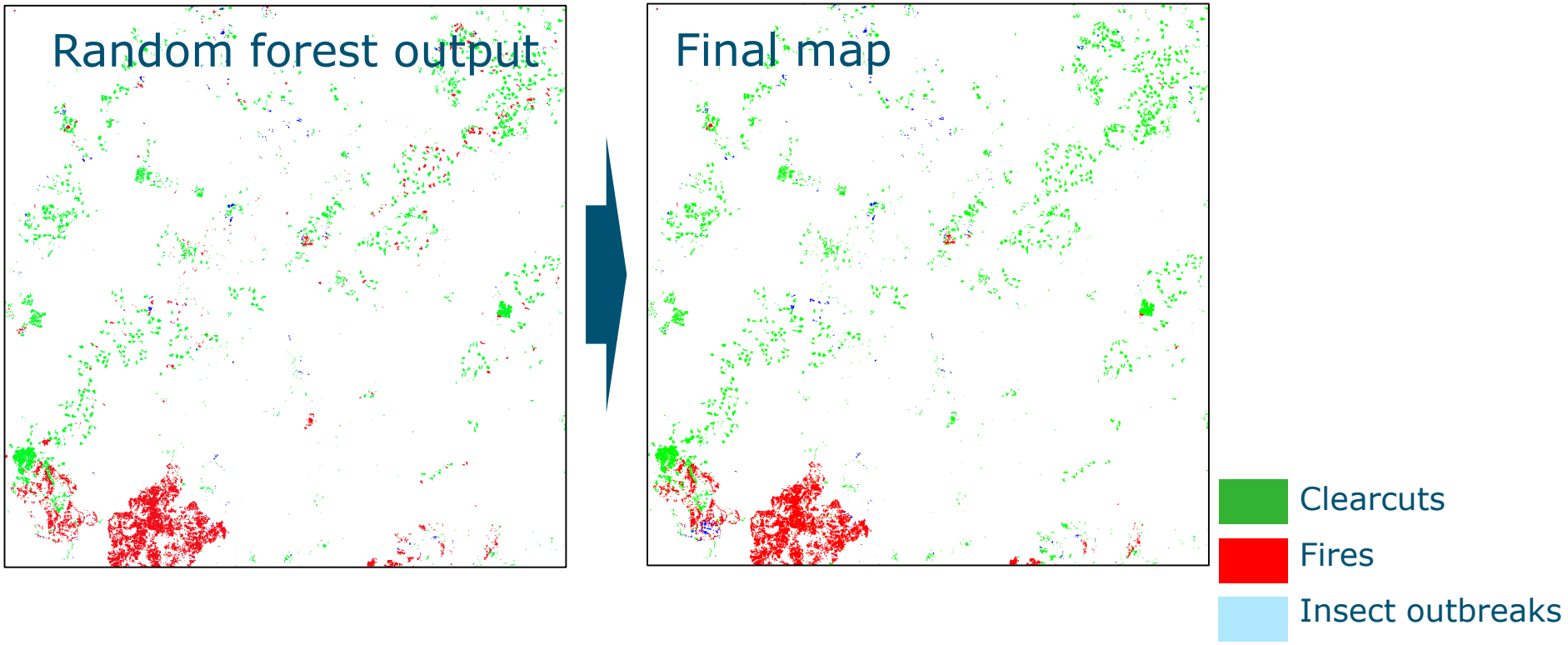

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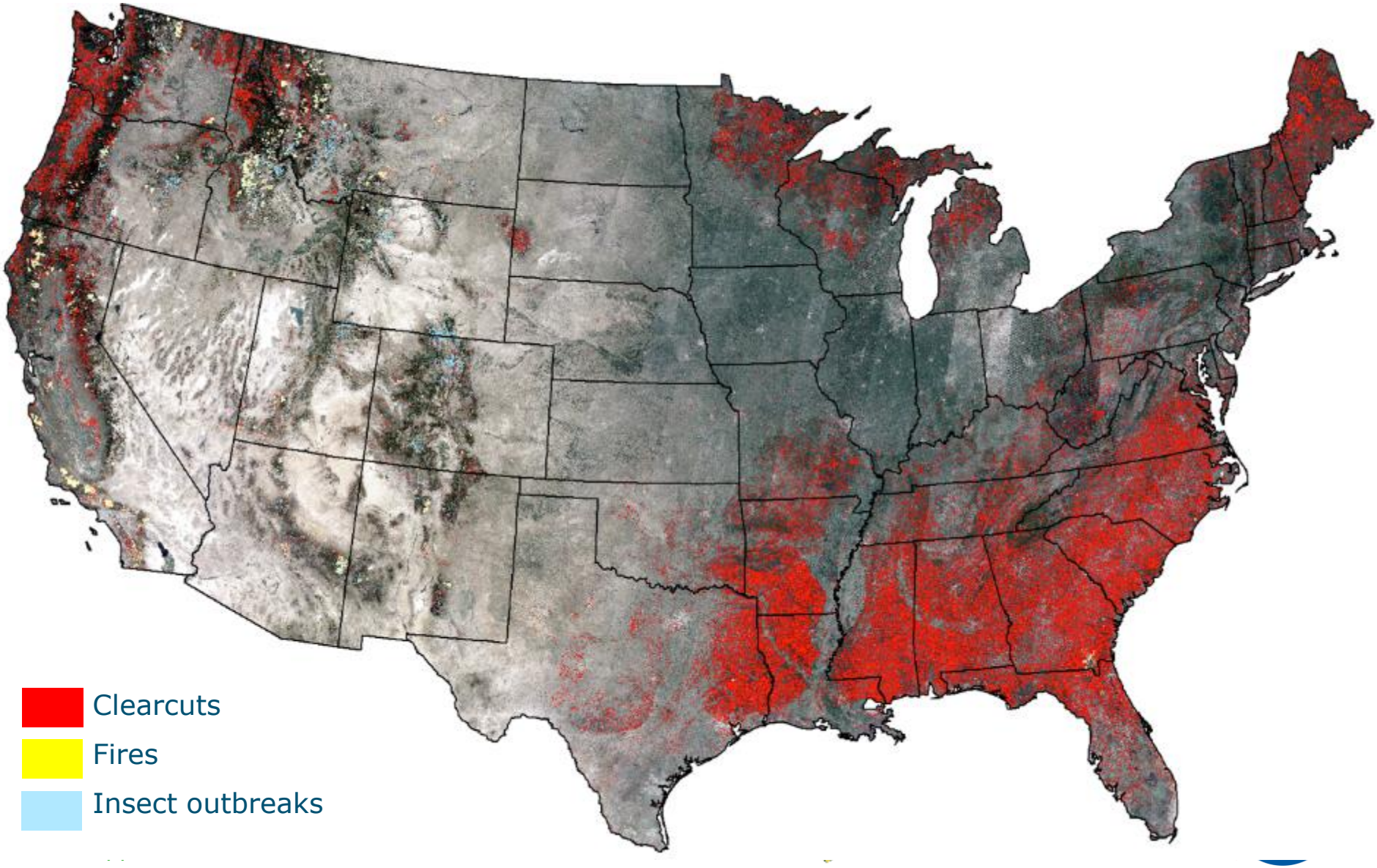
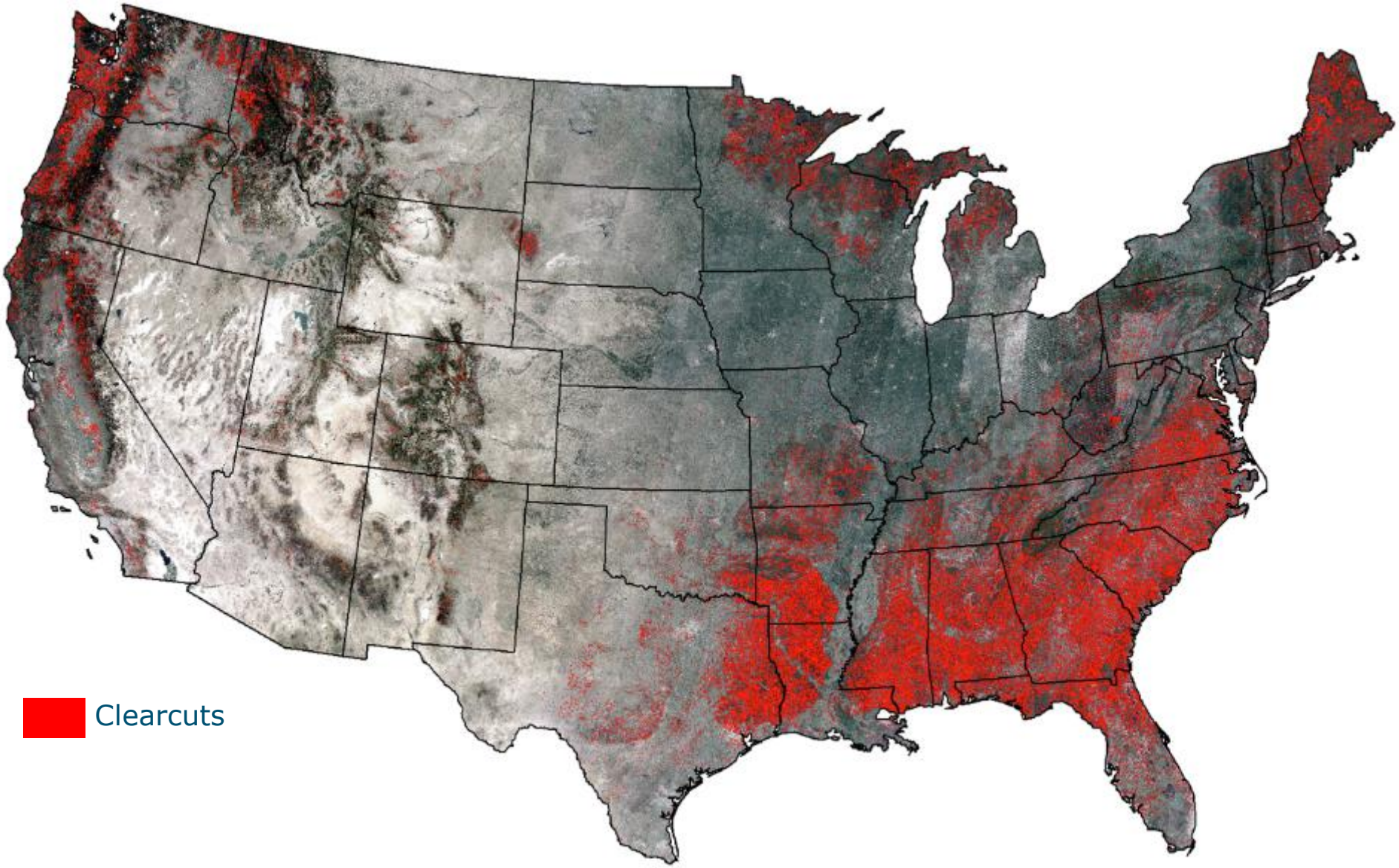
2004-2011 forest disturbances

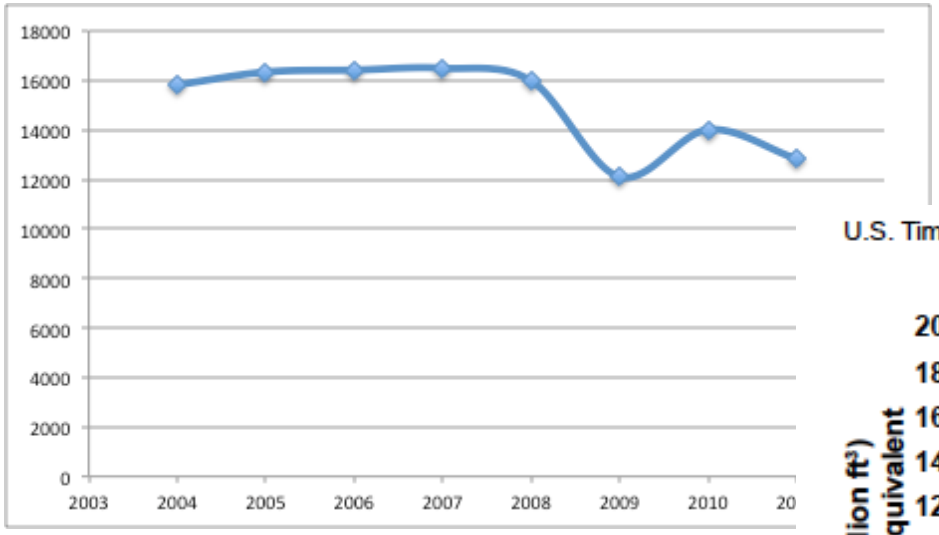


2004-2011 Clearcuts

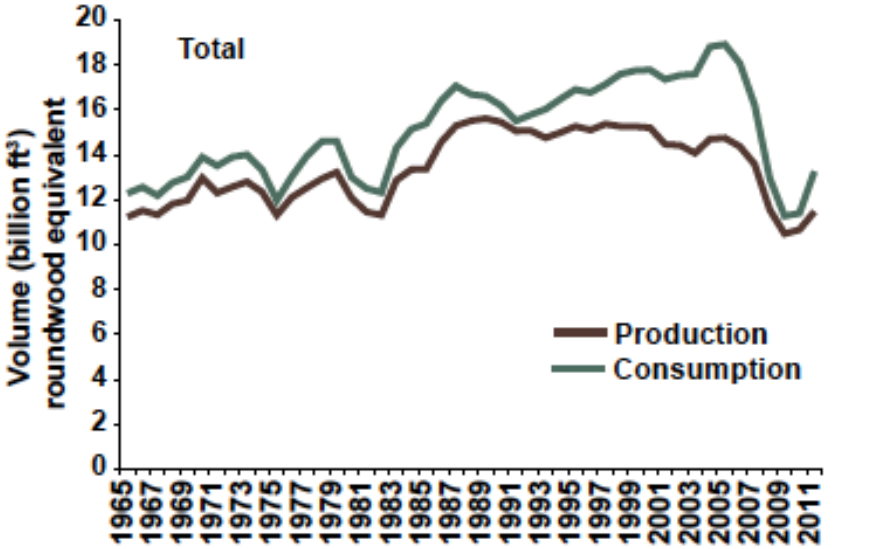


Clearcut trends

CONUS clearcuts



U.S. Timber Production, Trade, Consumption and Price Statistics 1965–2011



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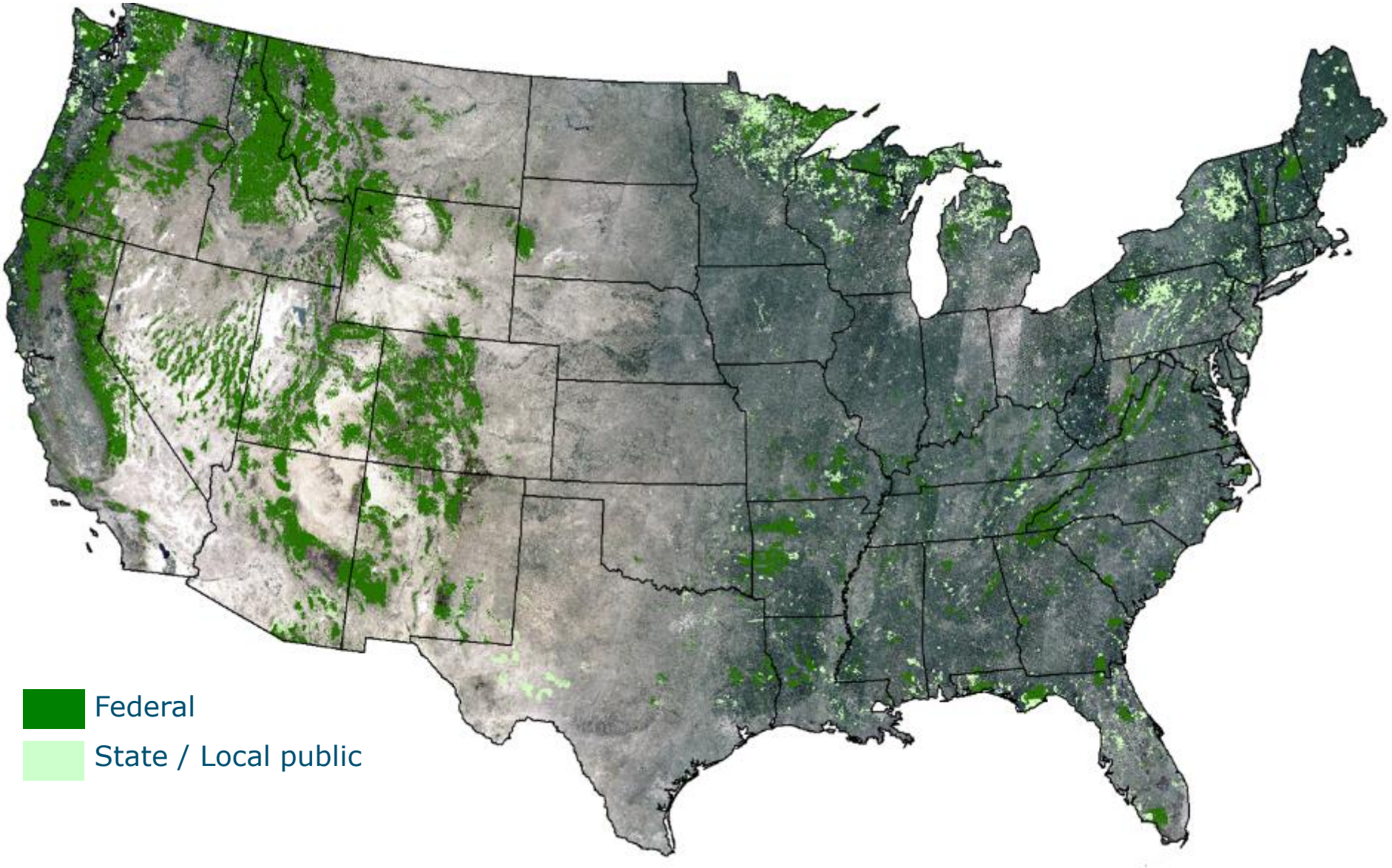
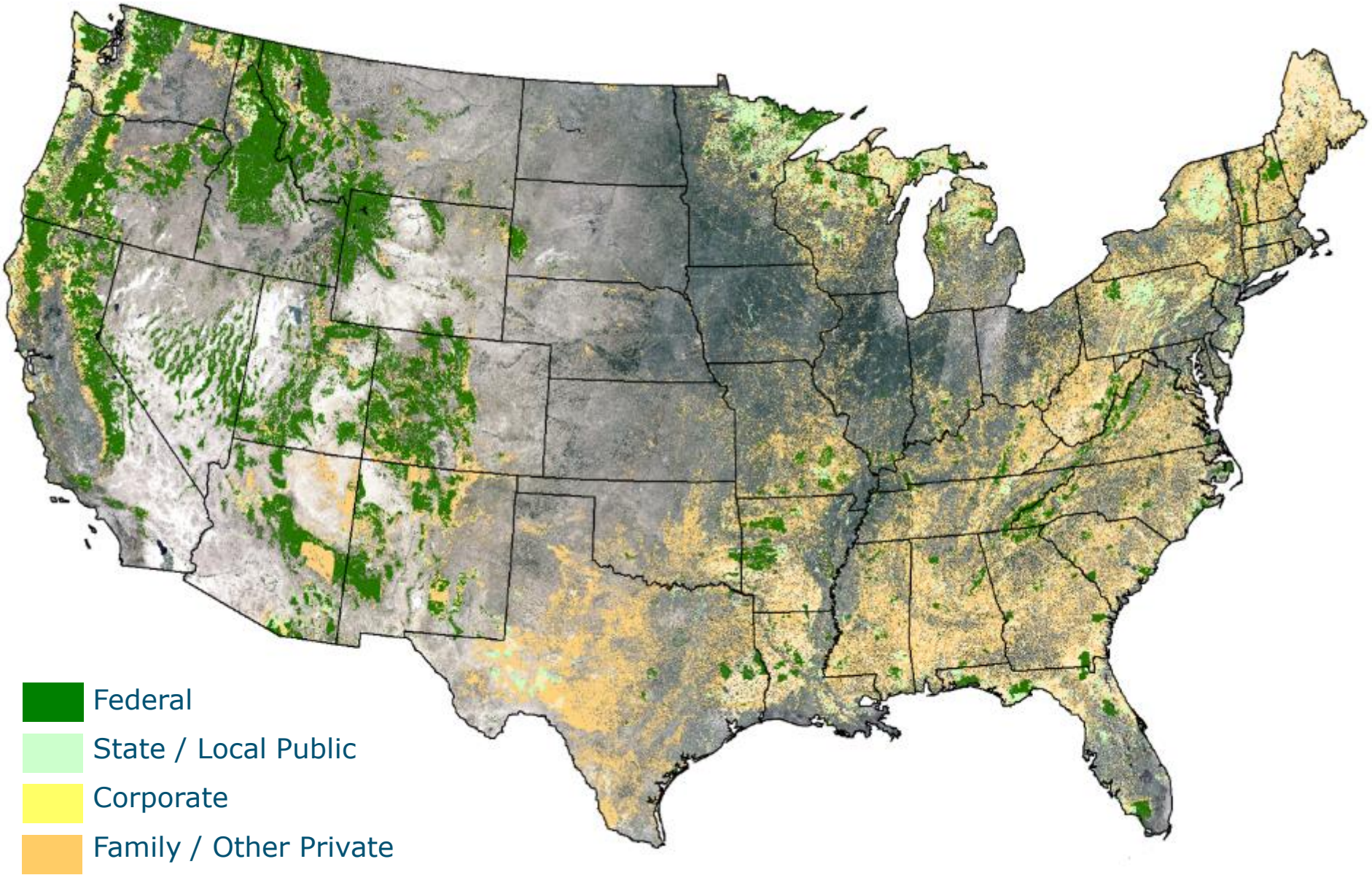
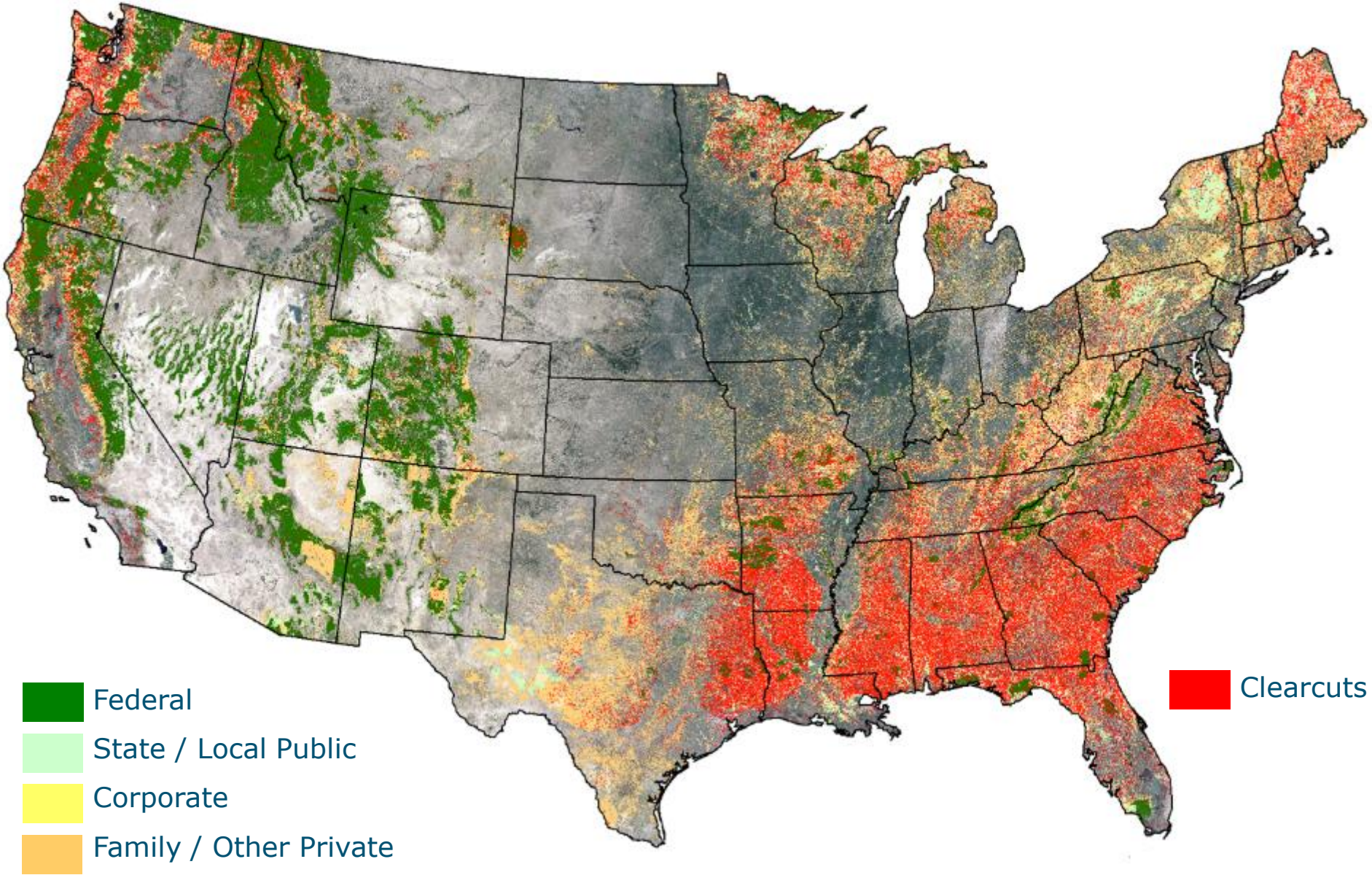
Forest Ownership: Public



Forest Ownership: Public and Private



Disturbances and Land Ownership



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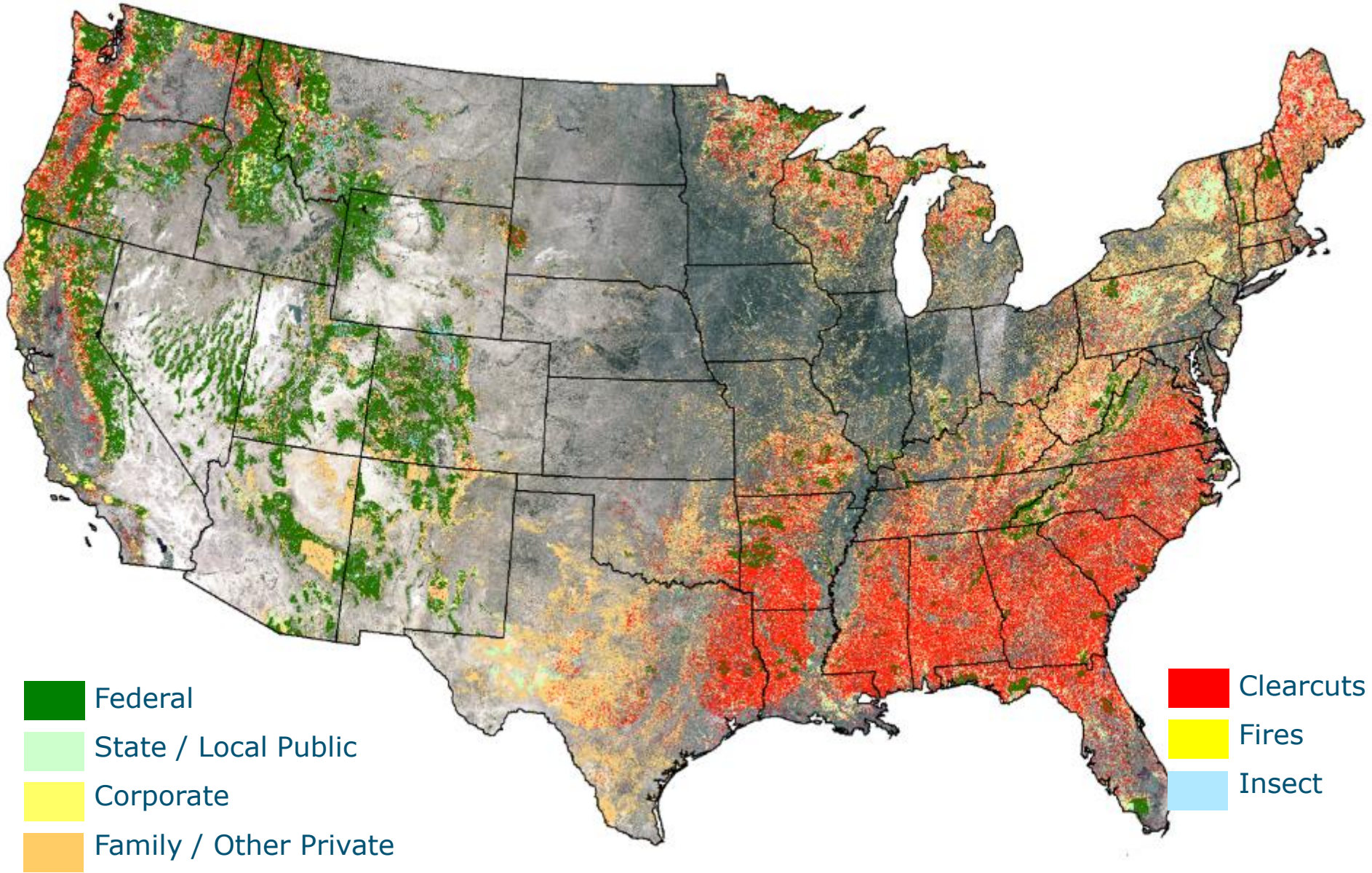

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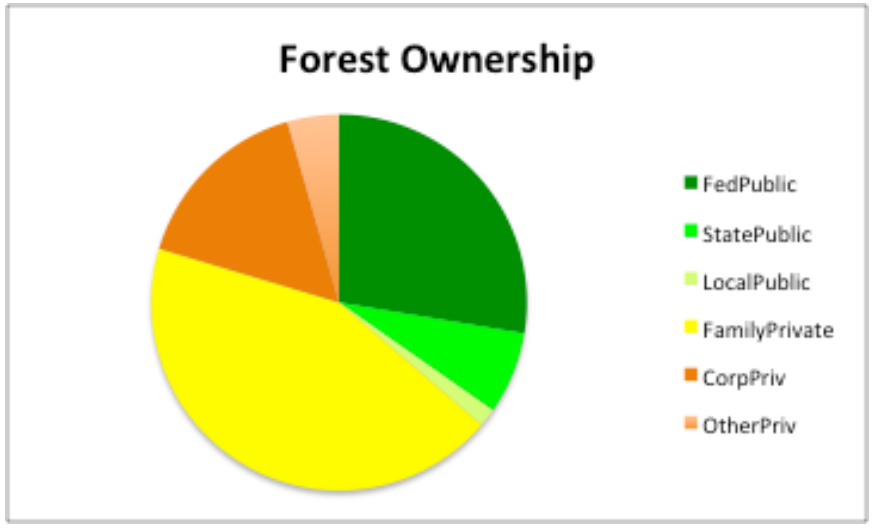

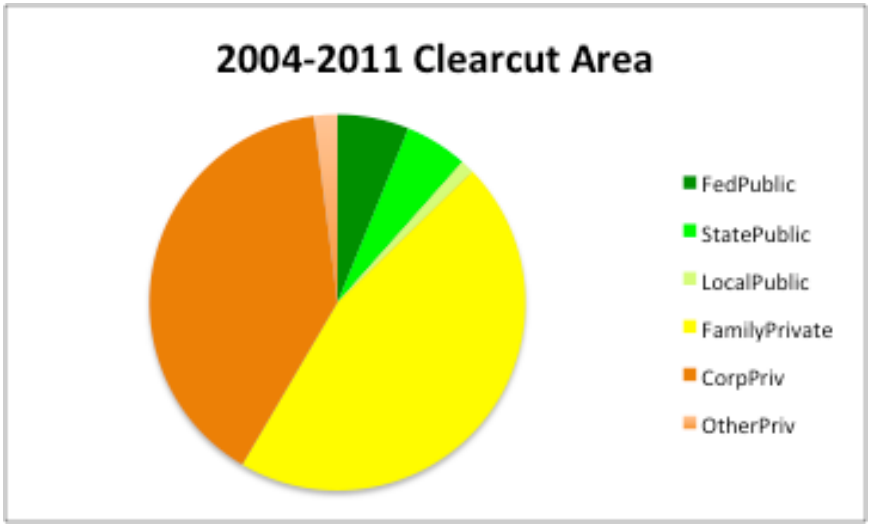

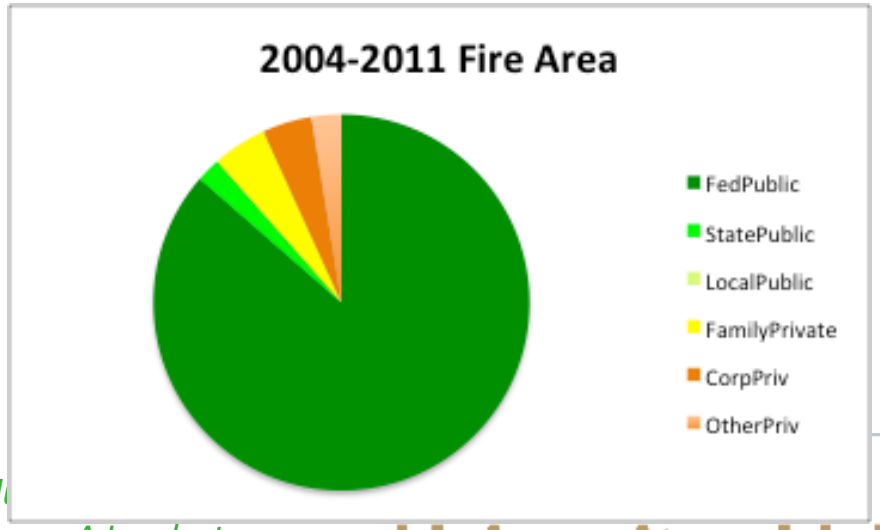

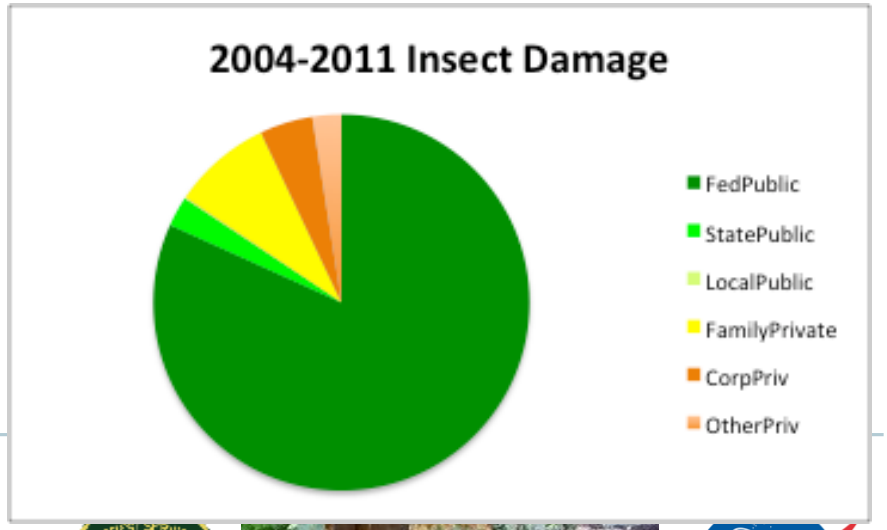

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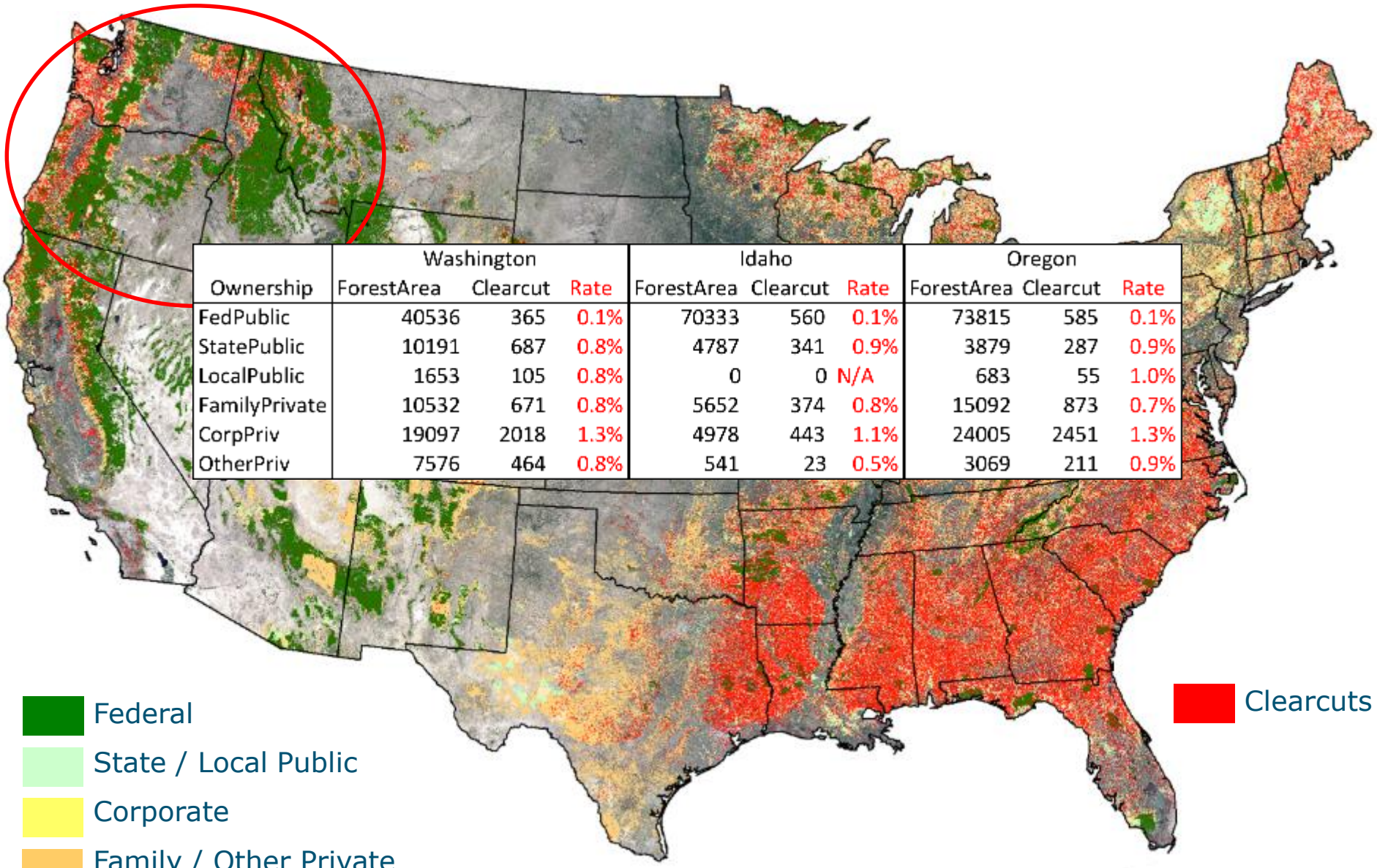


	Washington			Idaho			Oregon		
Ownership	ForestArea	Clearcut	Rate	ForestArea	Clearcut	Rate	ForestArea	Clearcut	Rate
FedPublic	40536	365	0.1%	70333	560	0.1%	73815	585	0.1%
StatePublic	10191	687	0.8%	4787	341	0.9%	3879	287	0.9%
LocalPublic	1653	105	0.8%	0	0	N/A	683	55	1.0%
FamilyPrivate	10532	671	0.8%	5652	374	0.8%	15092	873	0.7%
CorpPriv	19097	2018	1.3%	4978	443	1.1%	24005	2451	1.3%
OtherPriv	7576	464	0.8%	541	23	0.5%	3069	211	0.9%

Federal

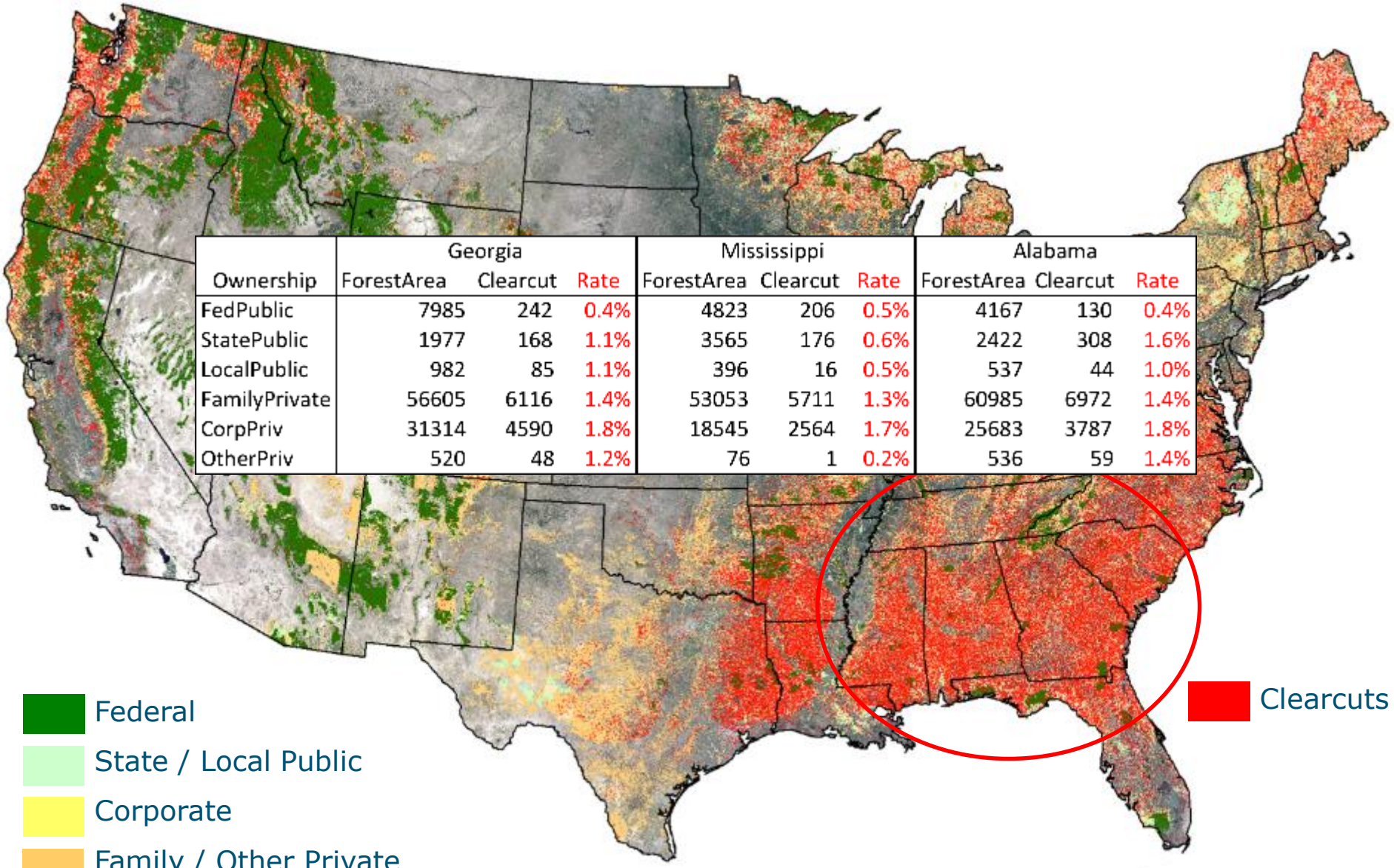
State / Local Public

Corporate

Family / Other Private

Clearcuts

Disturbances and Land Ownership



Ownership	Georgia			Mississippi			Alabama		
	ForestArea	Clearcut	Rate	ForestArea	Clearcut	Rate	ForestArea	Clearcut	Rate
FedPublic	7985	242	0.4%	4823	206	0.5%	4167	130	0.4%
StatePublic	1977	168	1.1%	3565	176	0.6%	2422	308	1.6%
LocalPublic	982	85	1.1%	396	16	0.5%	537	44	1.0%
FamilyPrivate	56605	6116	1.4%	53053	5711	1.3%	60985	6972	1.4%
CorpPriv	31314	4590	1.8%	18545	2564	1.7%	25683	3787	1.8%
OtherPriv	520	48	1.2%	76	1	0.2%	536	59	1.4%

Federal

State / Local Public

Corporate

Family / Other Private

Clearcuts

What is the logging rate? Is it sustainable?

	Northwest	Northeast	Midwest	Southeast
Forest type	Dry and moist conifer	Spruce	Northern & central hardwoods	Southern pine
Rotation - Sawlogs	50-60 yr	60-80 yr	80-100 yr	25 yr
Rotation -Pulp	20 yr	20 yr	-	12-15 yr
General silvicultural practices	Thin at age 12-14, possible thin 10 yrs before harvest	Thin at age 12-14, possible thin 10 - 15 yrs before harvest	Multiple thinnings, first at age 20-25	Row crop plantation; intensive fertilization and thinning
Final harvest regeneration system	Clearcut	Partial harvest	Clearcut	Clearcut
Maximum clearcut size – State law	California: 8.1 ha Oregon: 48.6 ha Washington: 97.1 ha Idaho: 40.5 ha on state lands; otherwise, no limit	Maine: 97.1 ha with restrictions; New Hampshire, Vermont, New York: No limit	No limit	No limit

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What's next

- Refinement of the methodology
- Validation and uncertainty assessment (spatial and temporal)
- Is forest harvest in CONUS sustainable?
    - Clearcut rate by region and forest type
    - Comparison with rotation times

Current project activities

1. Detecting Landsat-era forest management activity: 2003-2011 forest clearcuts in the CONUS

2. Detecting pre-Landsat forest management activities combining Lidar and Landsat data: test cases in the Pacific Northwest

Mapping the extent of the industrial forest

- Well defined for plantations, where it can be solved as a classic RS problem (tree specie mapping)
- Weakly defined for semi-natural plantations, where the vegetation composition is the same as natural vegetation. Remote sensing alone is not sufficient:
  - Ownership and protection status
  - Logging history shapes forest characteristics
  - Shape of homogeneous plots
  - Stand age

Tropical Plantations

- Brazil: eucalyptus

Tropical Plantations

- Malaysia: Oil Palm and Rubber

Industrial Forest in CONUS: semi-natural forest

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Characteristics of industrial clearcuts

- Logging practices are dictated by forest type, forest productivity, economic considerations, constraints due to regulations

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Distinctive Patterns: California

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Distinctive Patterns: Maine

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Distinctive Patterns: Oregon

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From Landsat…

Clearwater NF
(Idaho)

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From Landsat…

Clearwater NF
(Idaho)

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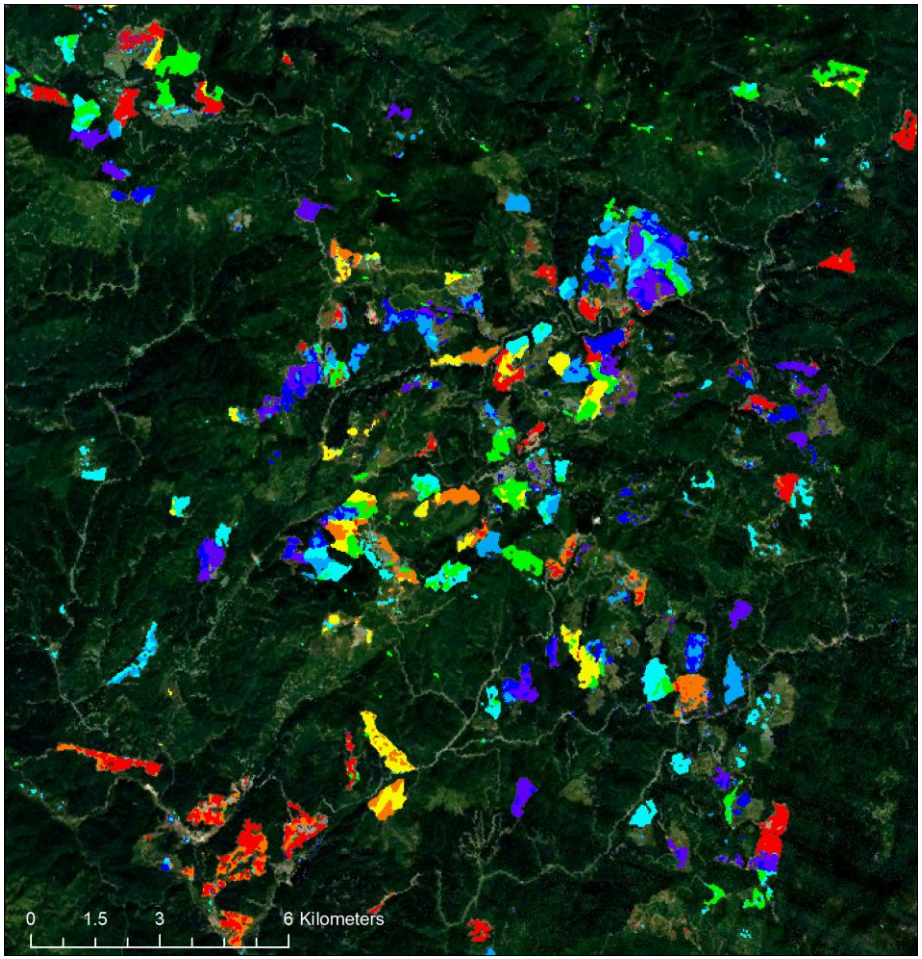
From Landsat…



Year
2004
2005
2006
2007
2008
2009
2010
2011

Clearwater NF (Idaho)

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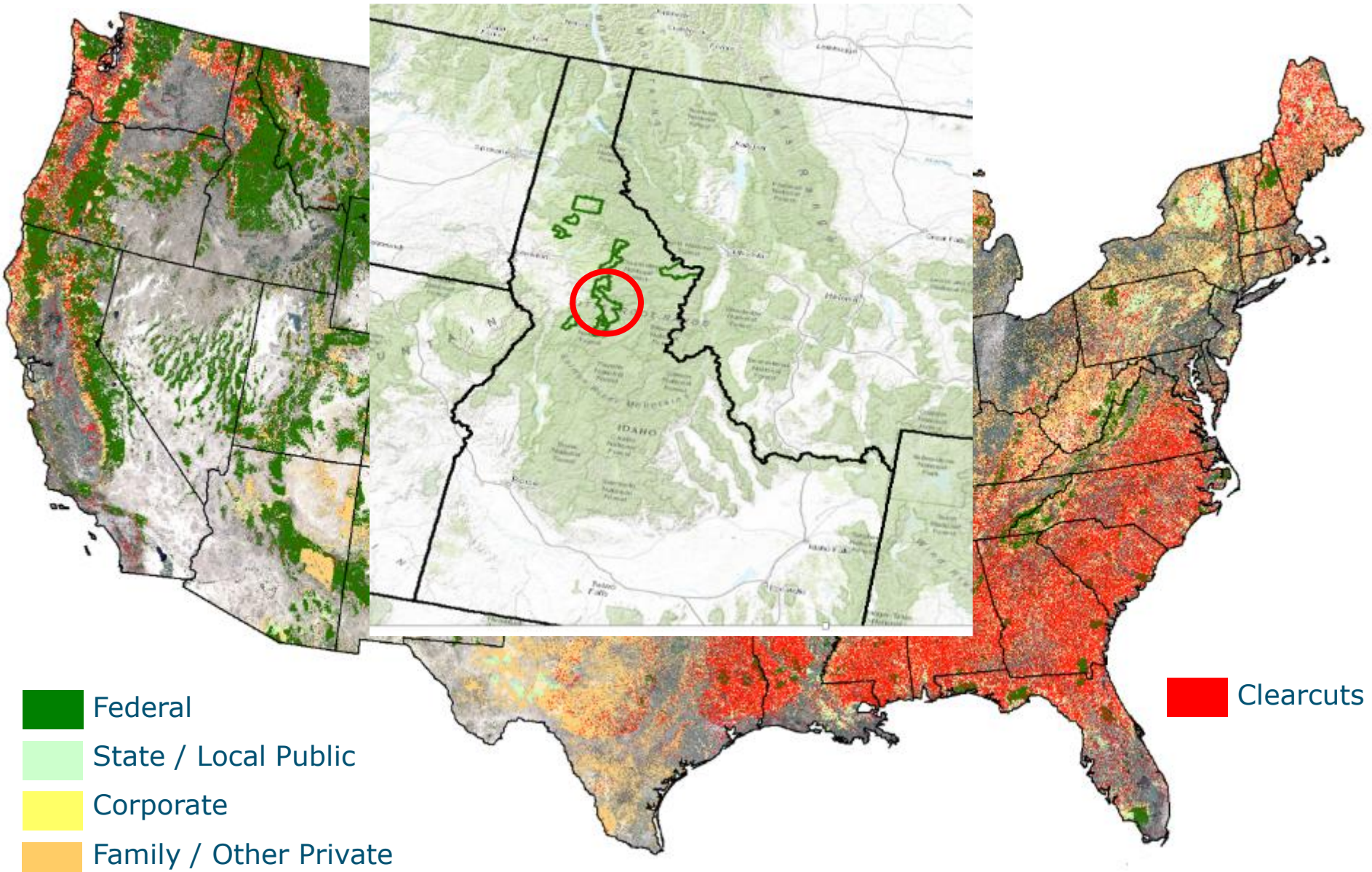
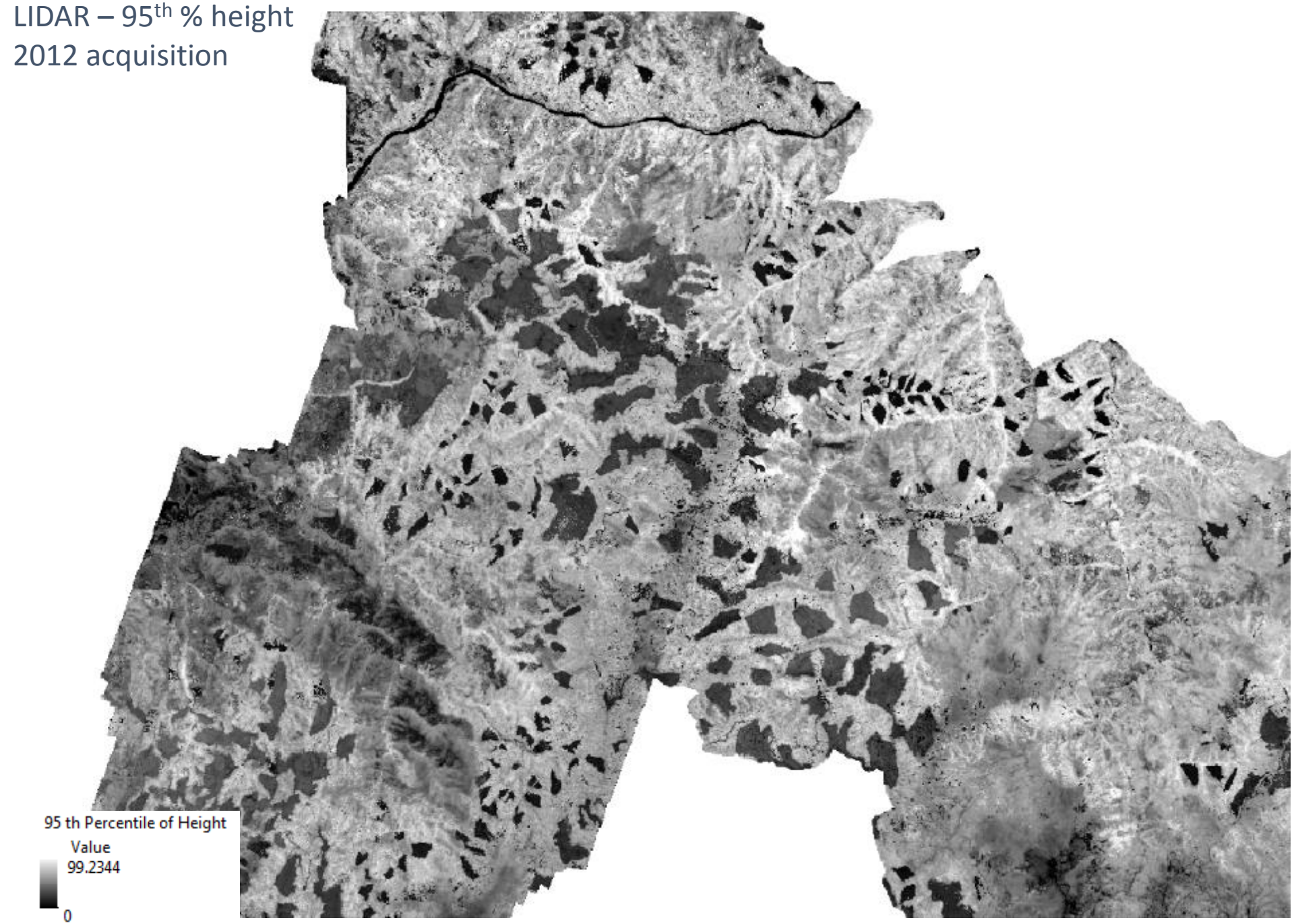
Deforestation or forest management?Object-oriented classification

- Use of ancillary information about forestry practices
- Classification based on
  - Size
  - Shape (compactness, linear or curvilinear edges)
  - Contextual information
  - Presence or absence of logging in previous years
- LIDAR – Landsat data fusion

Detecting past clearcuts: LIDAR–L8 fusion

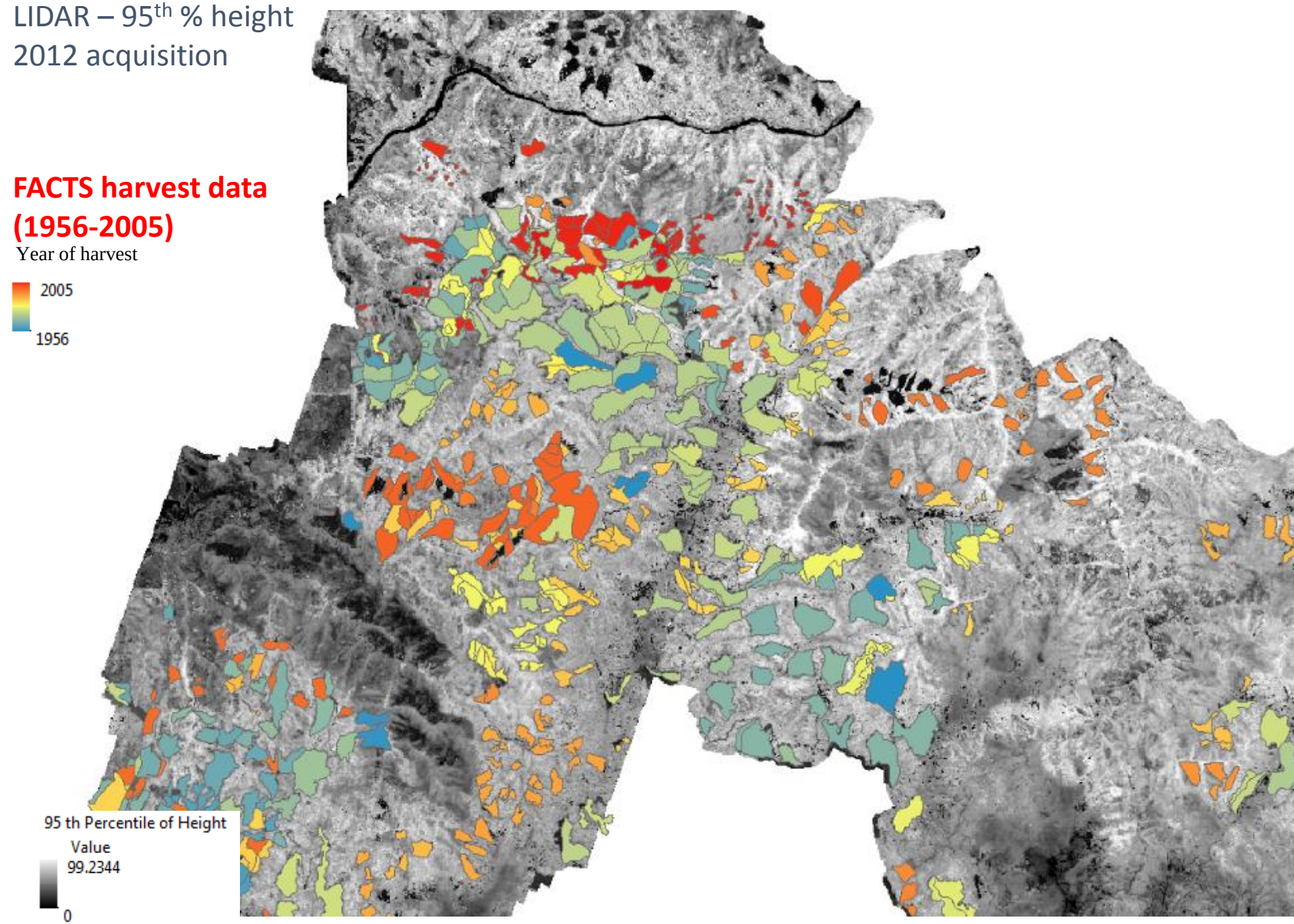


LIDAR – 95th % height 2012 acquisition



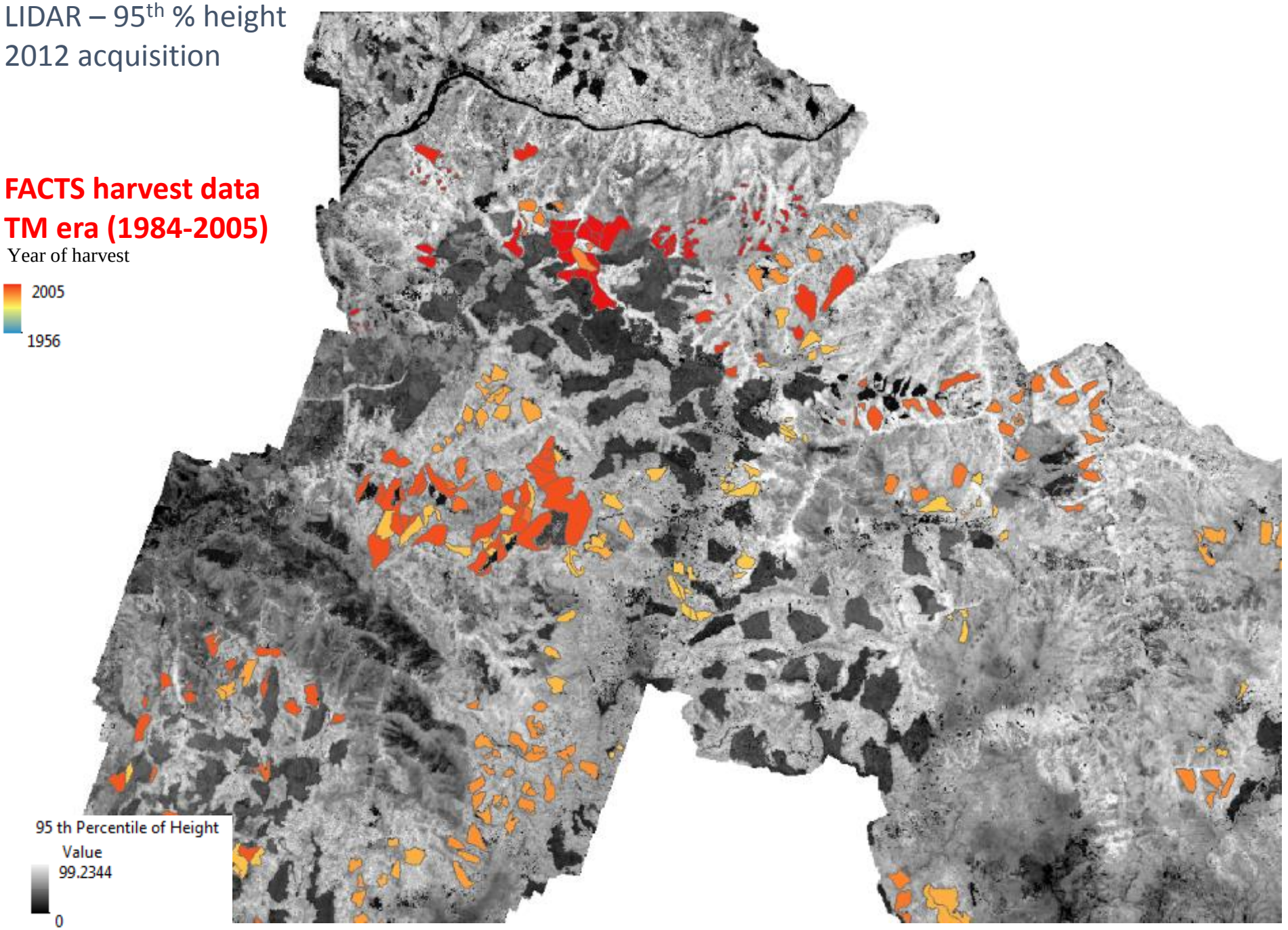
LIDAR – 95th % height
2012 acquisition

FACTS harvest data (1956-2005)



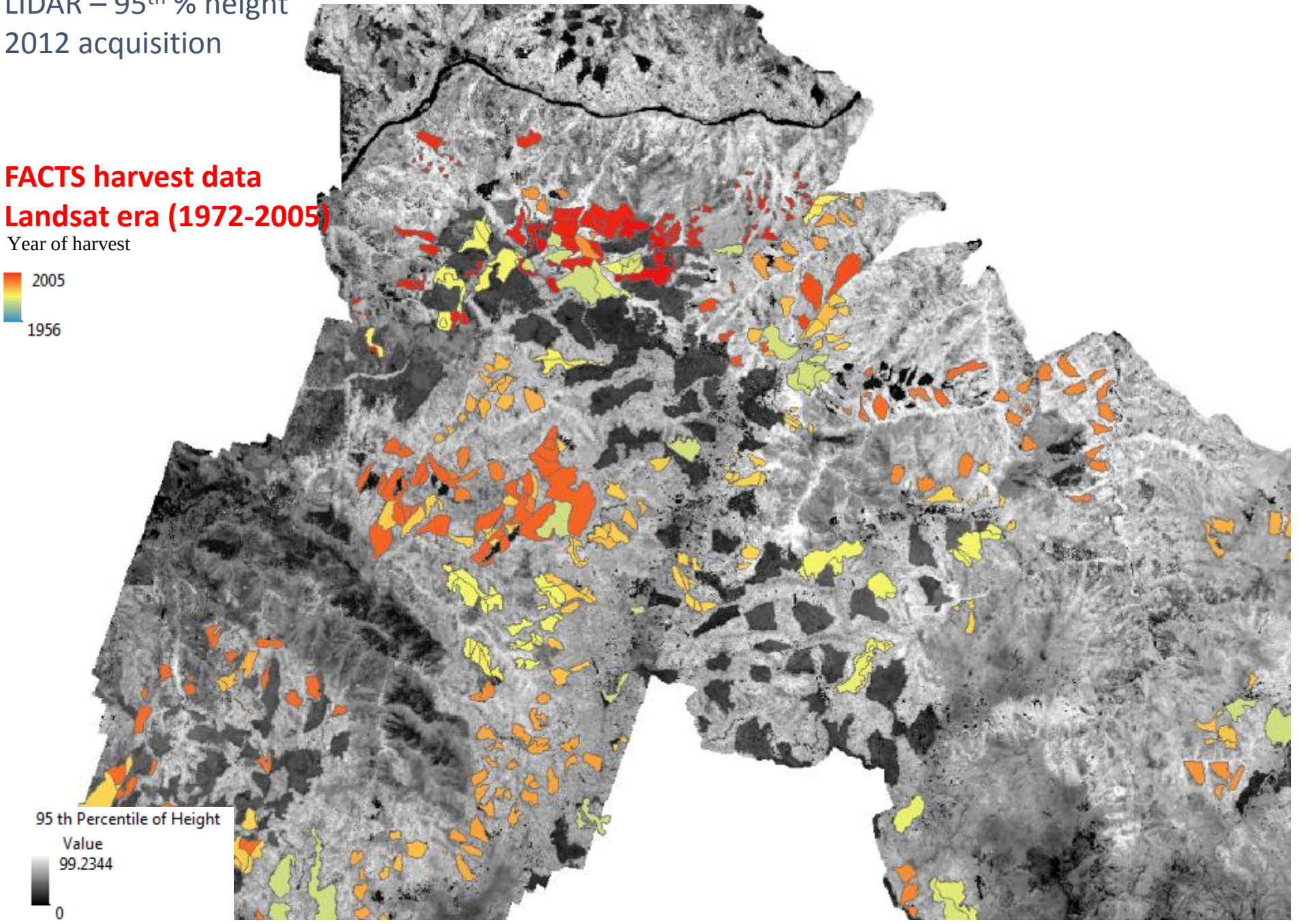
LIDAR – 95th % height
2012 acquisition

FACTS harvest data
TM era (1984-2005)



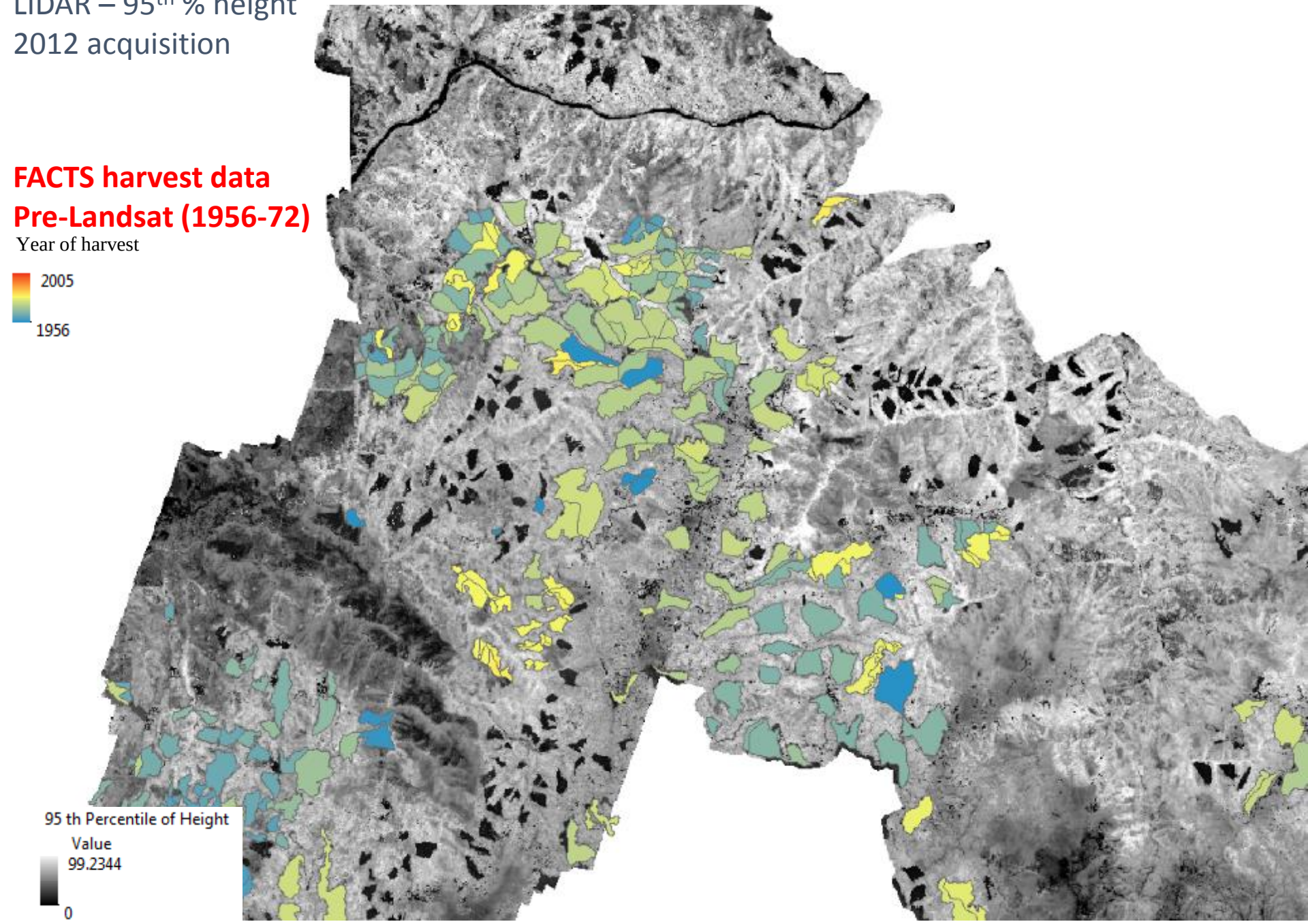
LIDAR – 95th % height
2012 acquisition

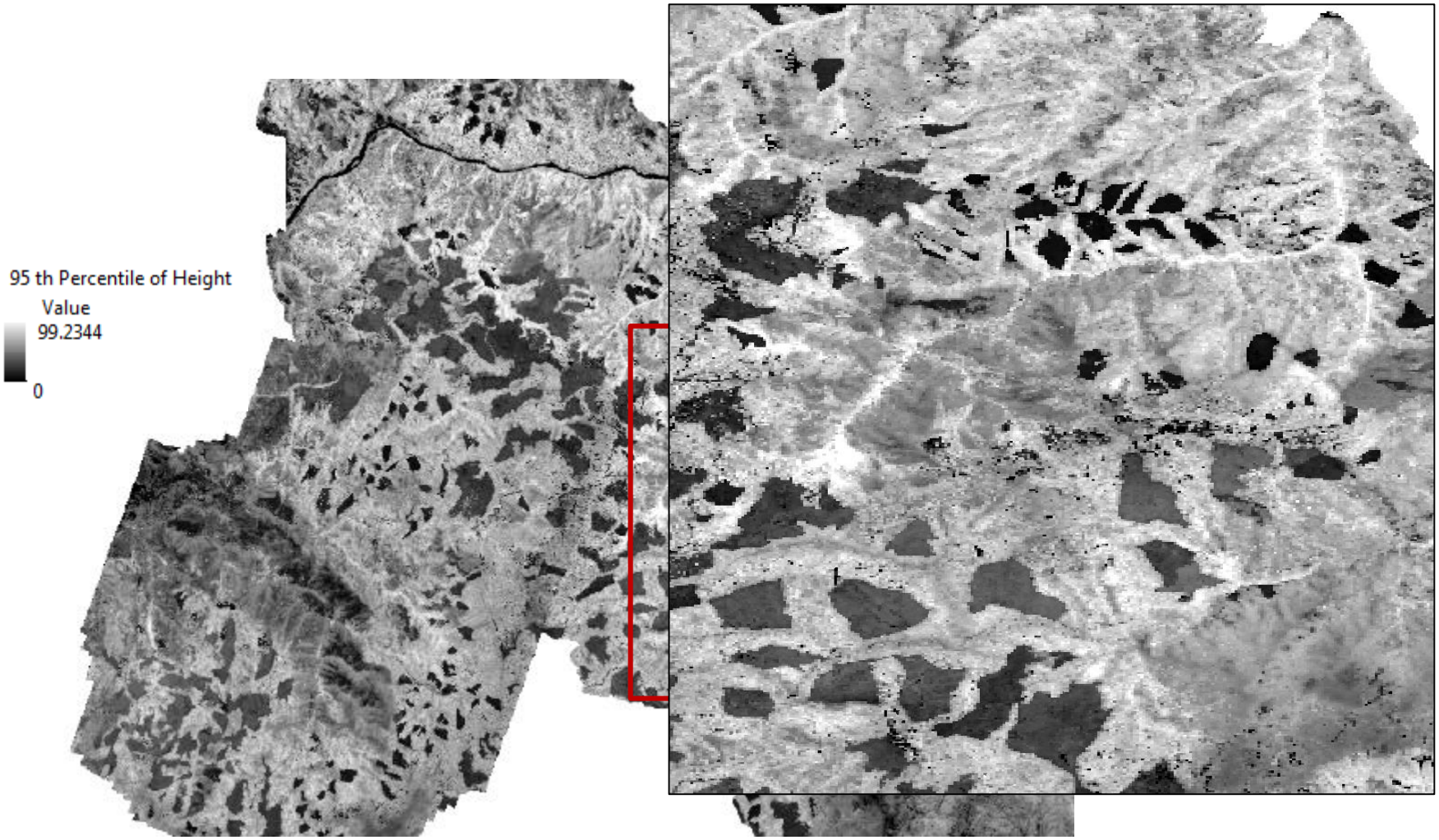
FACTS harvest data
Landsat era (1972-2005)



LIDAR – 95th % height
2012 acquisition

FACTS harvest data
Pre-Landsat (1956-72)





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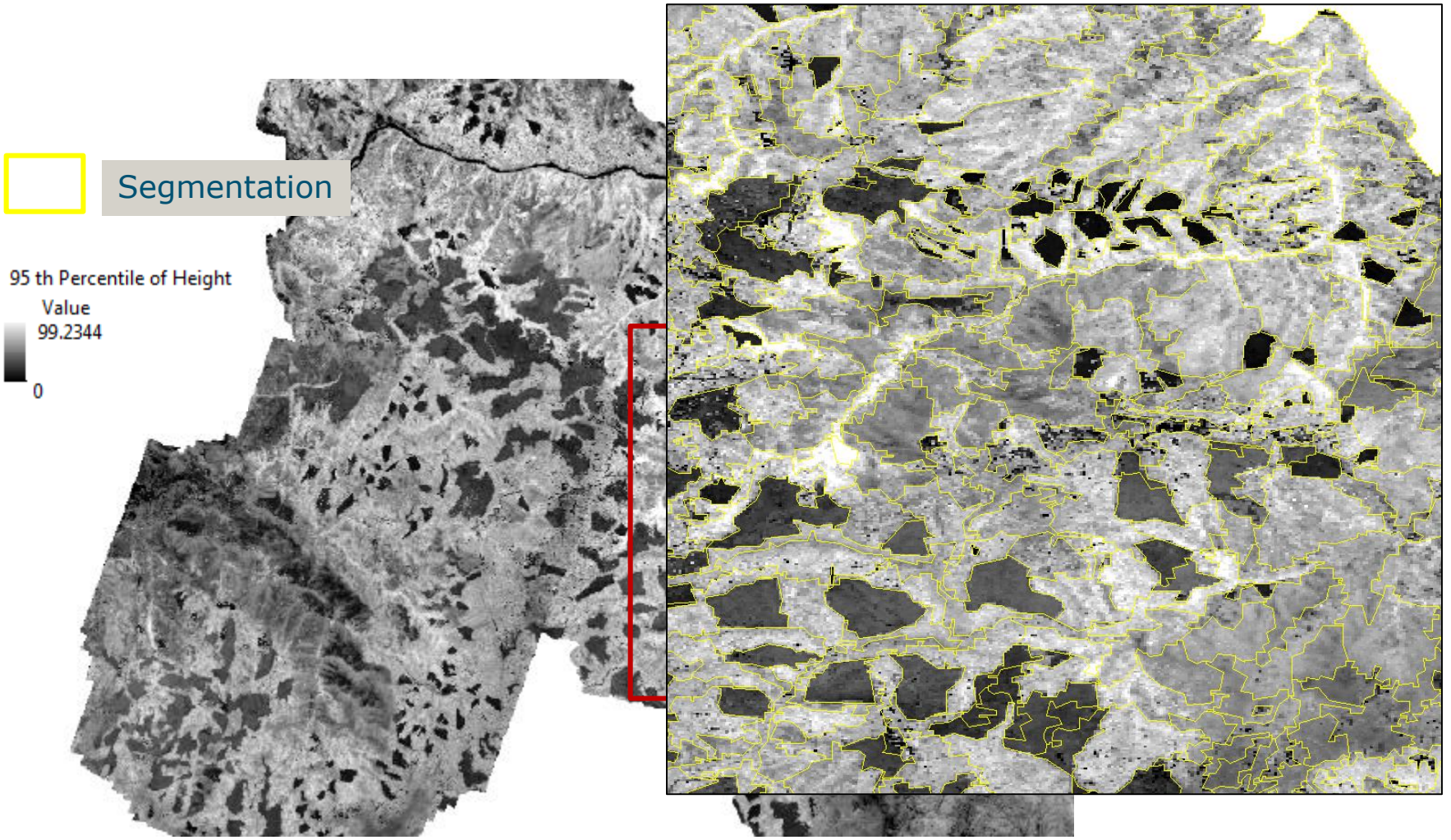

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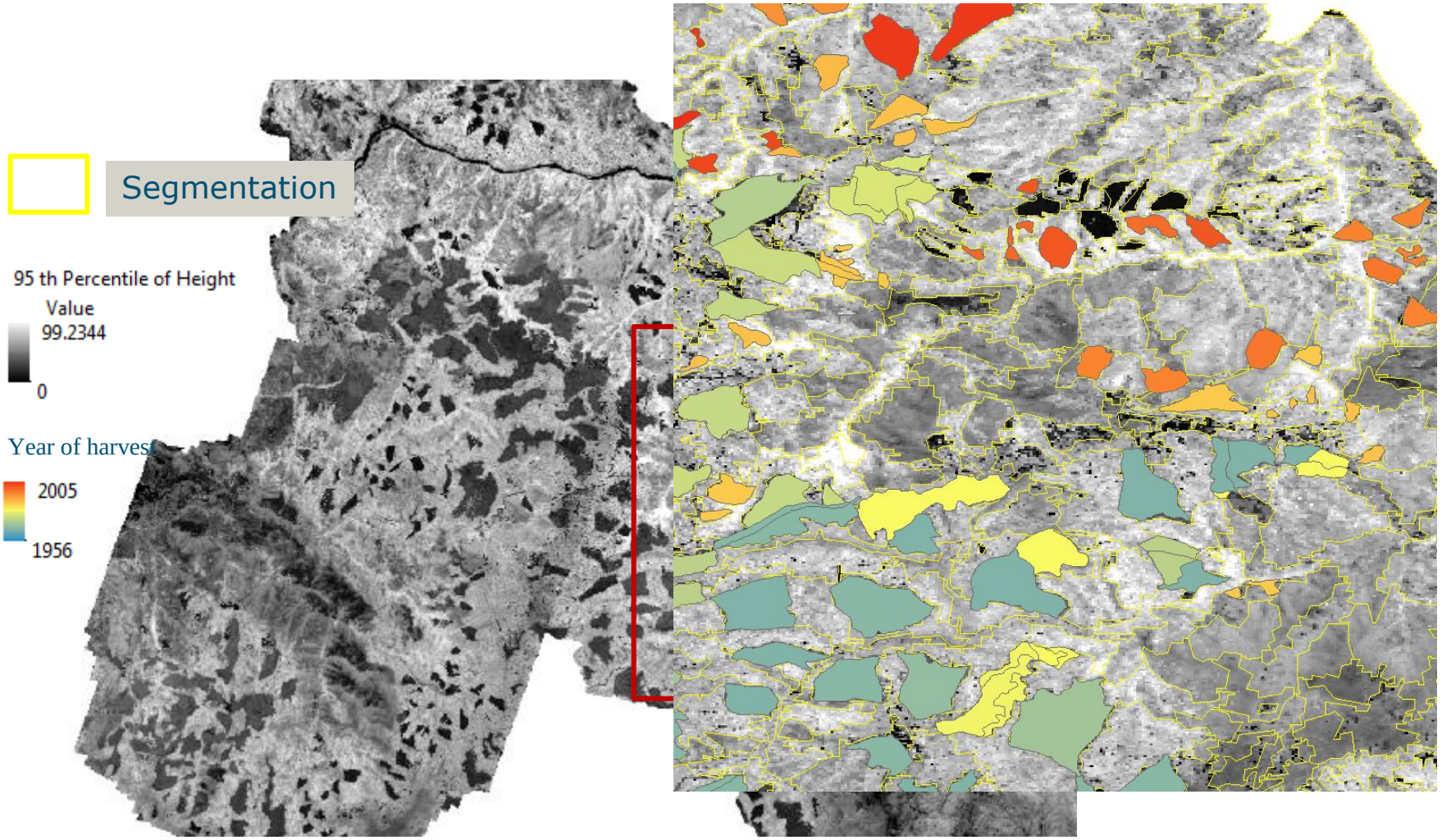

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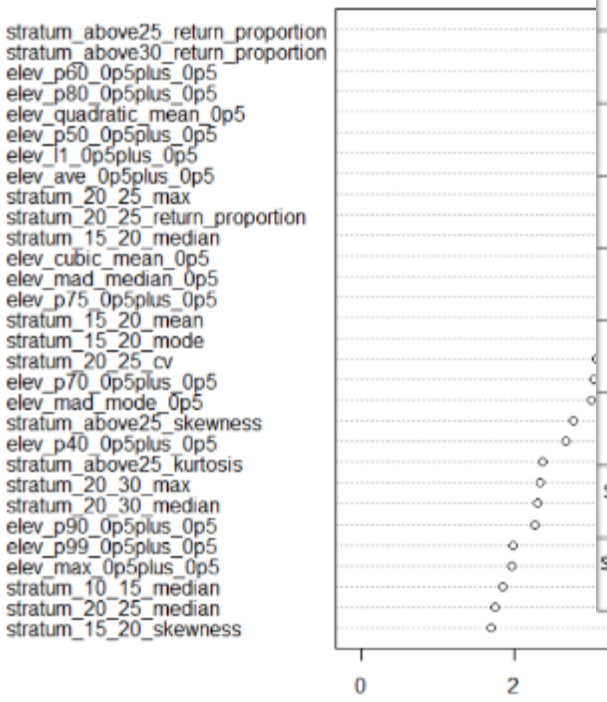
LiDAR classification: Disturbed/indisturbed

```
        OOB estimate of
Confusion matrix:
          change No chang
change       302        1
No change     10       11
```



Metrics	Estimate	Std..Error	z.value	p-value	AIC	accuracy(training)	accuracy(testing)
stratum_above25_return_proportion	20.76967	2.287706	9.078819	1.10E-19	174.3443	0.891	0.909
elev_p80	0.281691	0.030303	9.295961	1.46E-20	176.0561	0.885	0.900
elev_p75	0.303031	0.03278	9.244525	2.36E-20	170.719	0.894	0.891
elev_ave	0.474609	0.052788	8.990879	2.45E-19	157.388	0.903	0.882
elev_p70	0.328164	0.035747	9.180101	4.31E-20	164.7914	0.903	0.882
elev_p90	0.262199	0.028969	9.051018	1.42E-19	180.3216	0.873	0.882
elev_p60	0.355331	0.038407	9.251617	2.21E-20	166.9559	0.903	0.873
elev_p90	0.257348	0.028422	9.054401	1.37E-19	184.6507	0.870	0.873
elev_p95	0.243657	0.02756	8.840953	9.49E-19	190.3655	0.864	0.873
stratum_above30_return_proportion	16.97659	1.886525	8.998869	2.28E-19	144.6348	0.906	0.873
stratum_15_20_median	6.749445	0.959271	7.036015	1.98E-12	190.1267	0.882	0.873

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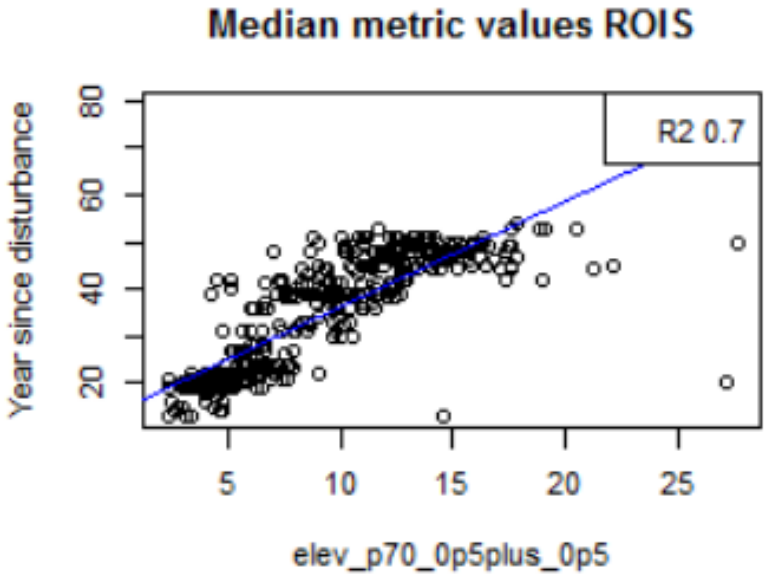
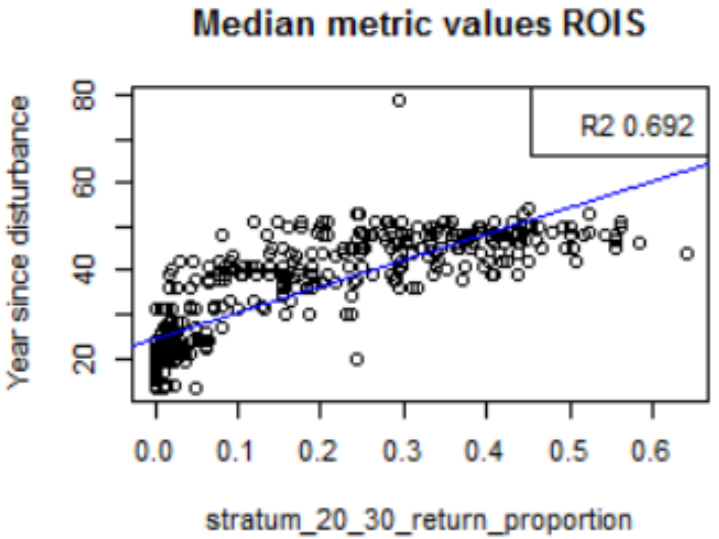
LiDAR analysis: time since disturbance





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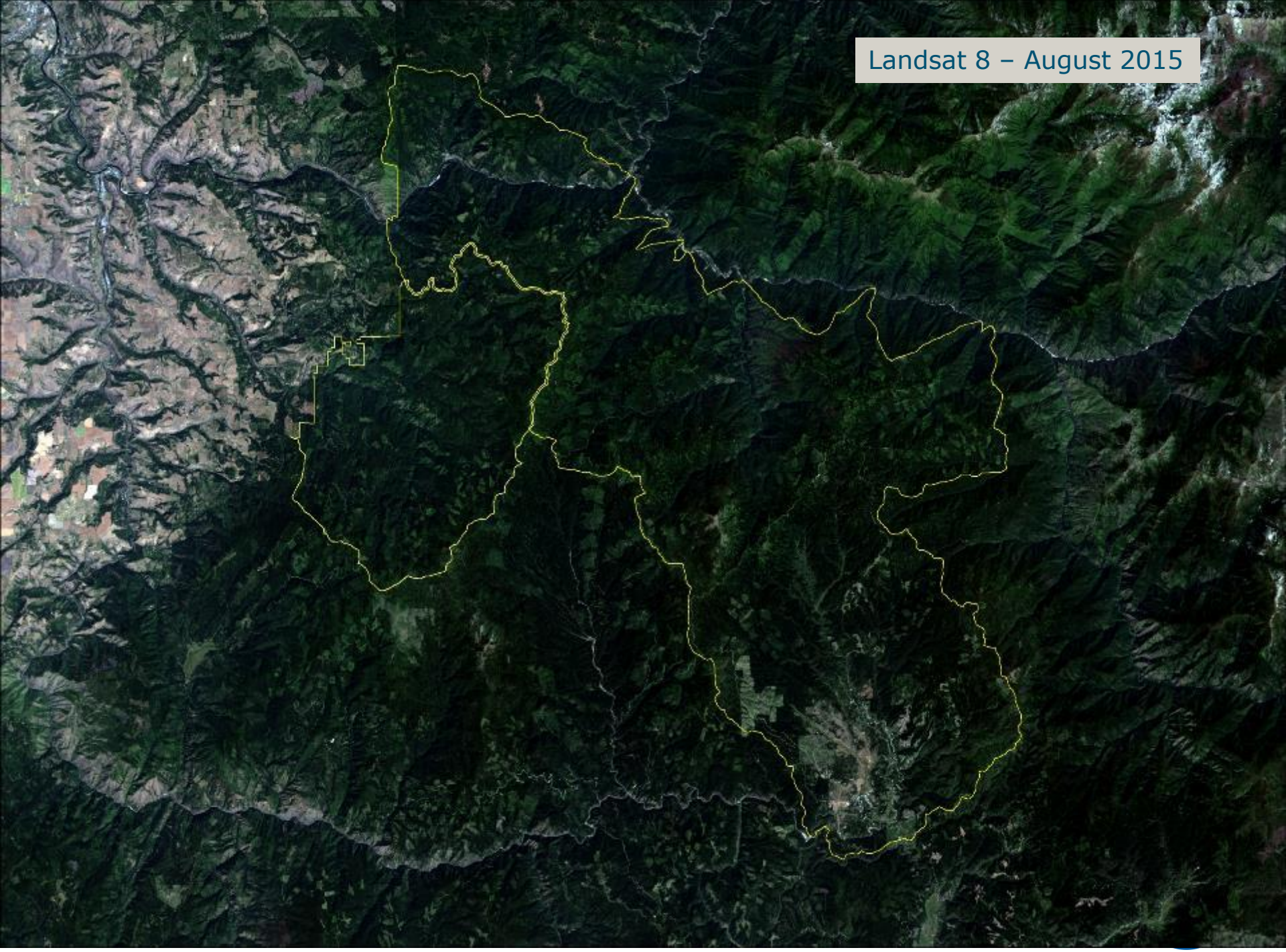
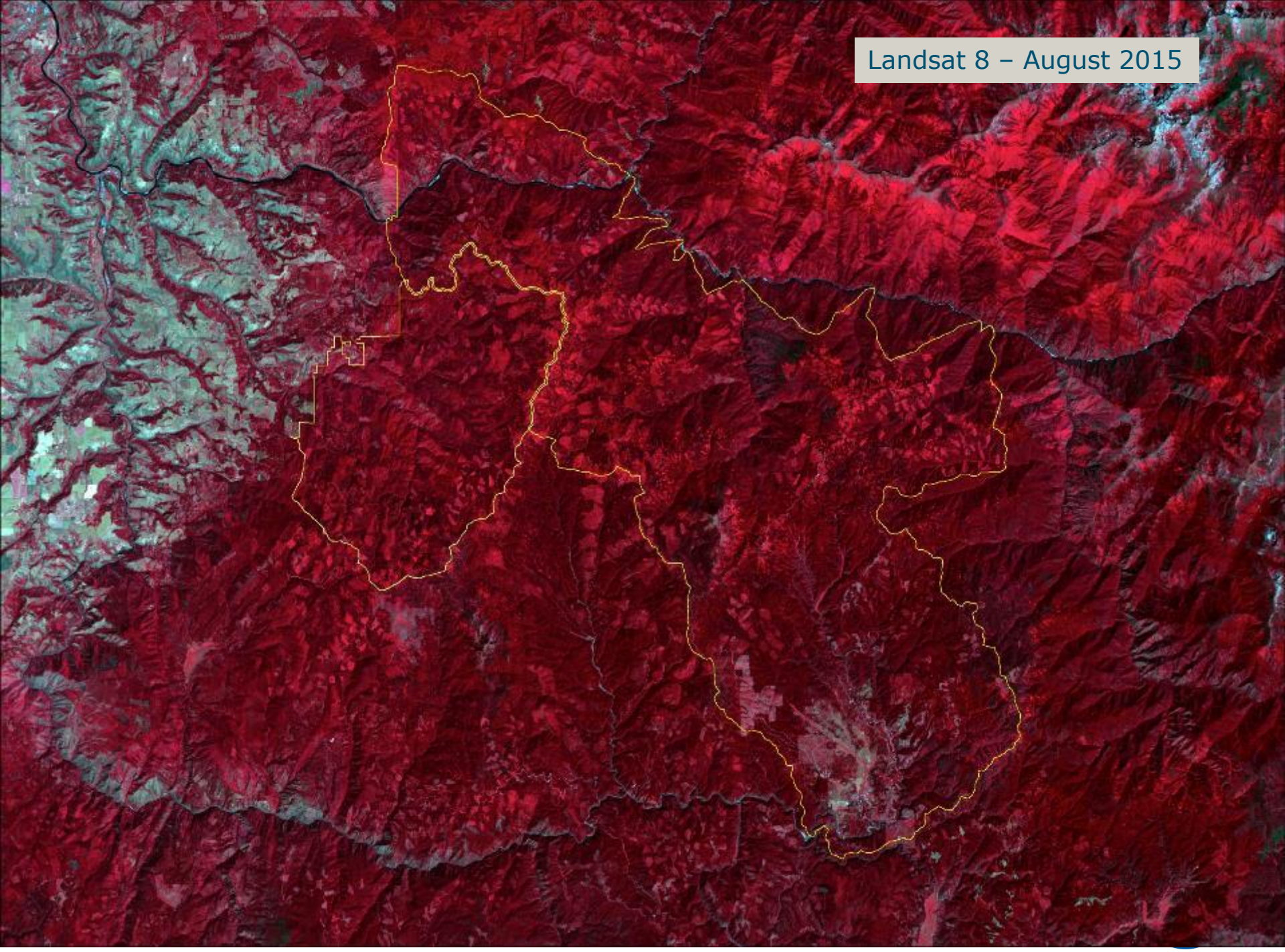
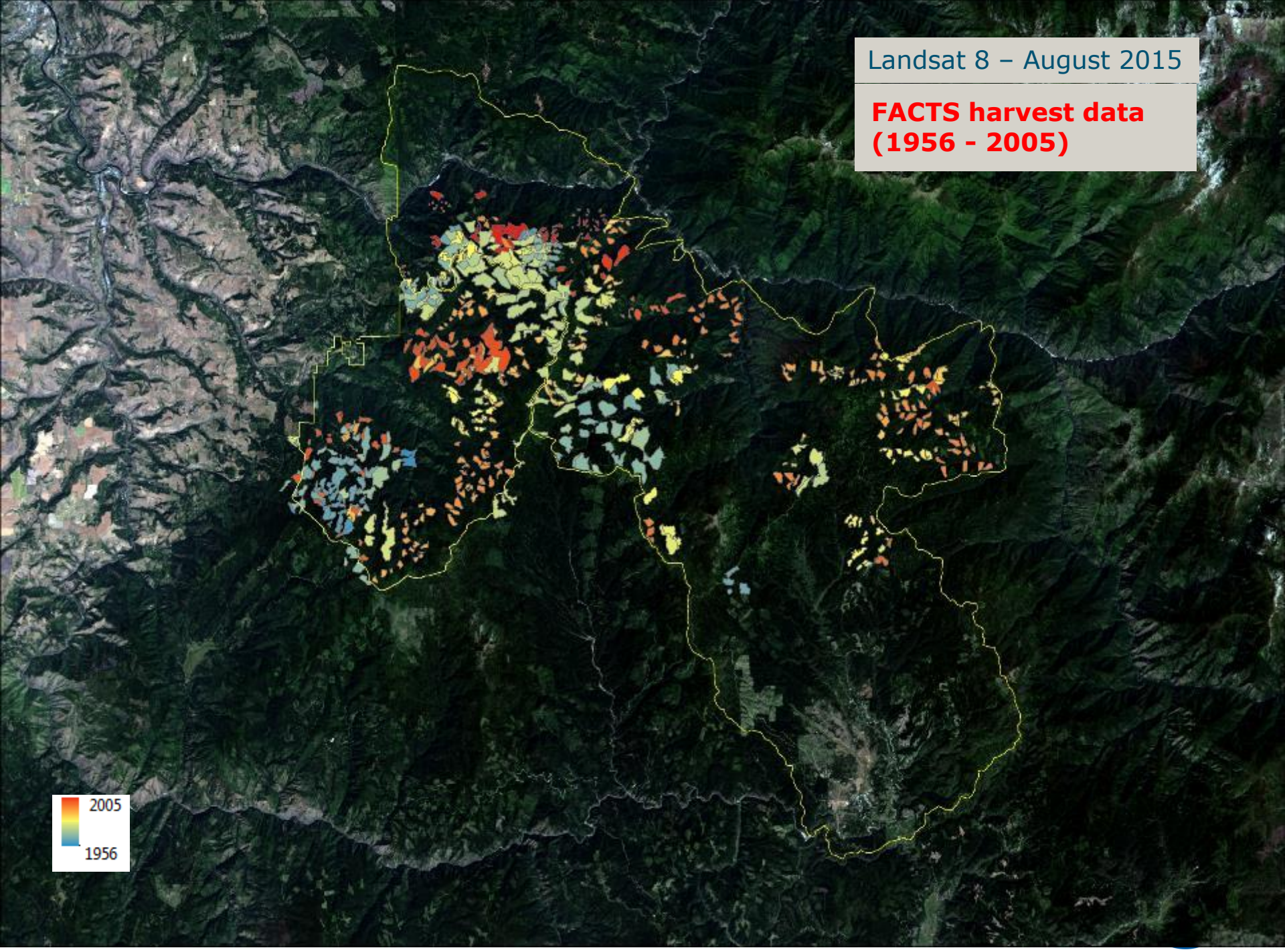
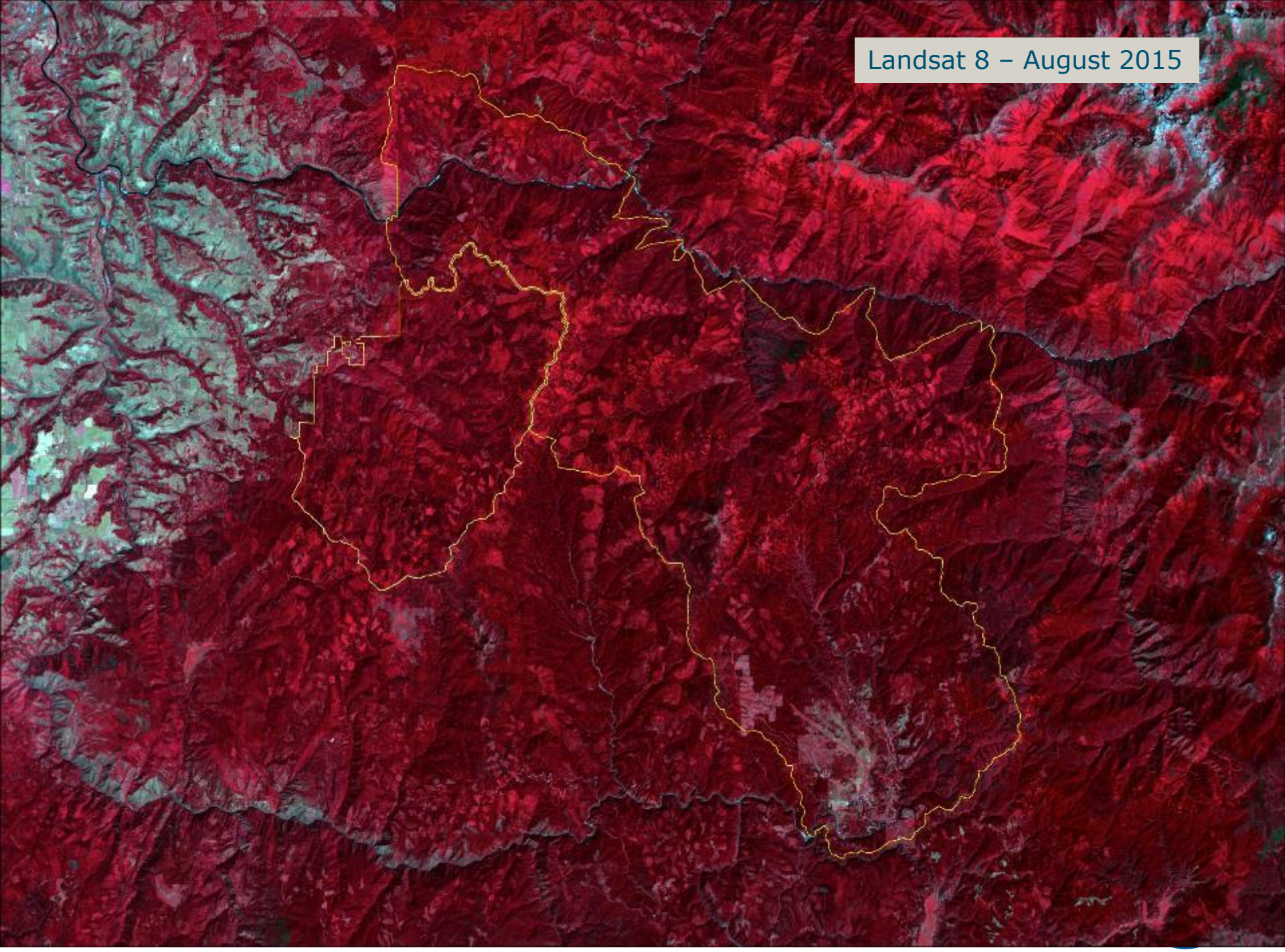

Landsat 8 – August 2015


Landsat 8 – August 2015


Landsat 8 – August 2015
FACTS harvest data
(1956 - 2005)
2005
1956


Landsat 8 – August 2015

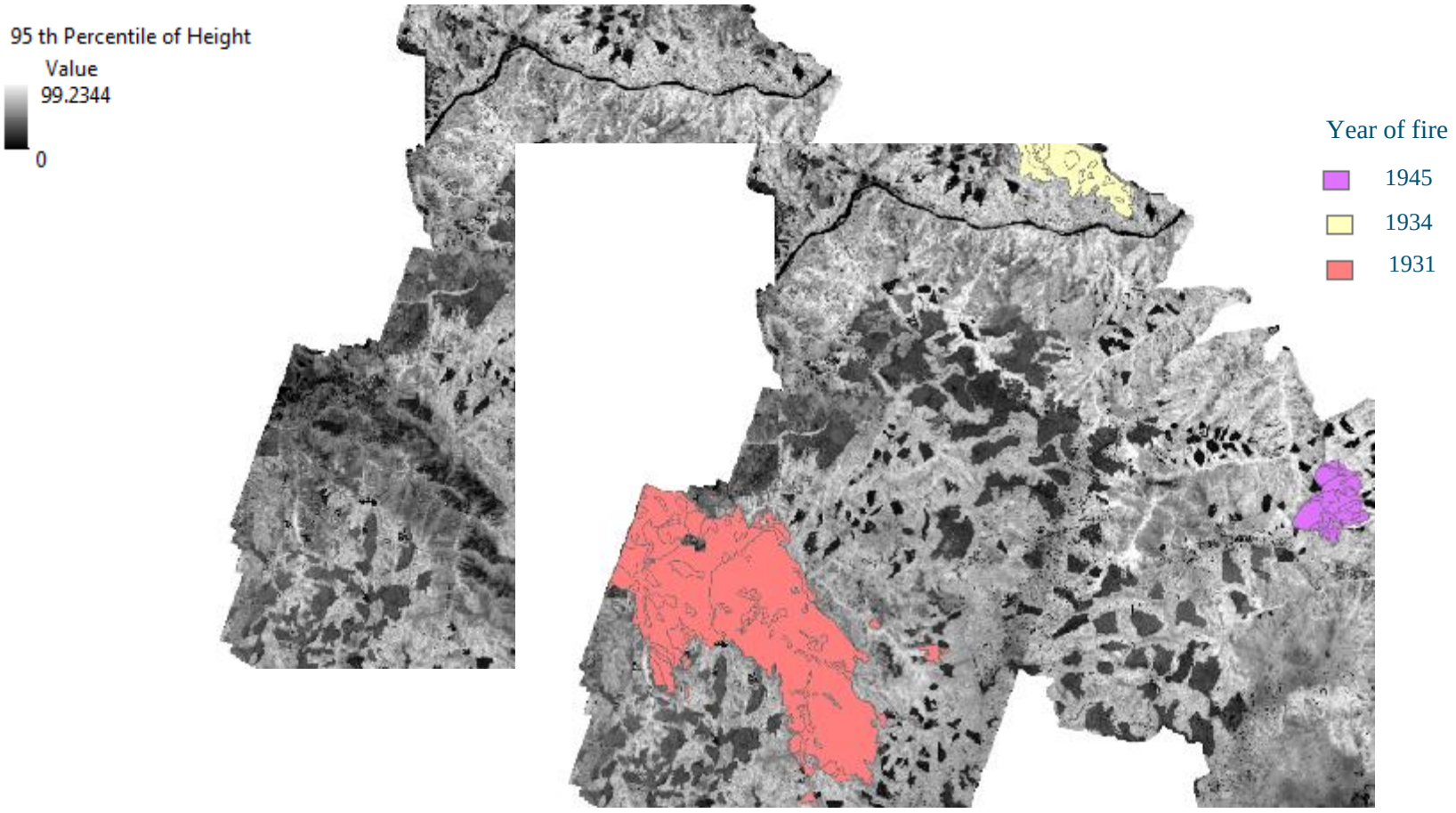
Landsat 8 – August 2015
FACTS harvest data
(1956 - 1972)
2005
1956

What's next?

- LiDAR analysis:
  - Other disturbacnes (fire)
  - Data collection
  - Additional sites
- LiDAR – Landsat data fusion
  - Analysis of shapes and patterns from the 2004-2011 clearcuts
  - Potential for object oriented classification combining LiDAR metrics and vegetation indices
  - Waiting for L8 WELD

Comments, suggestions and criticism are extremely welcome!

Bonus slide: fire



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