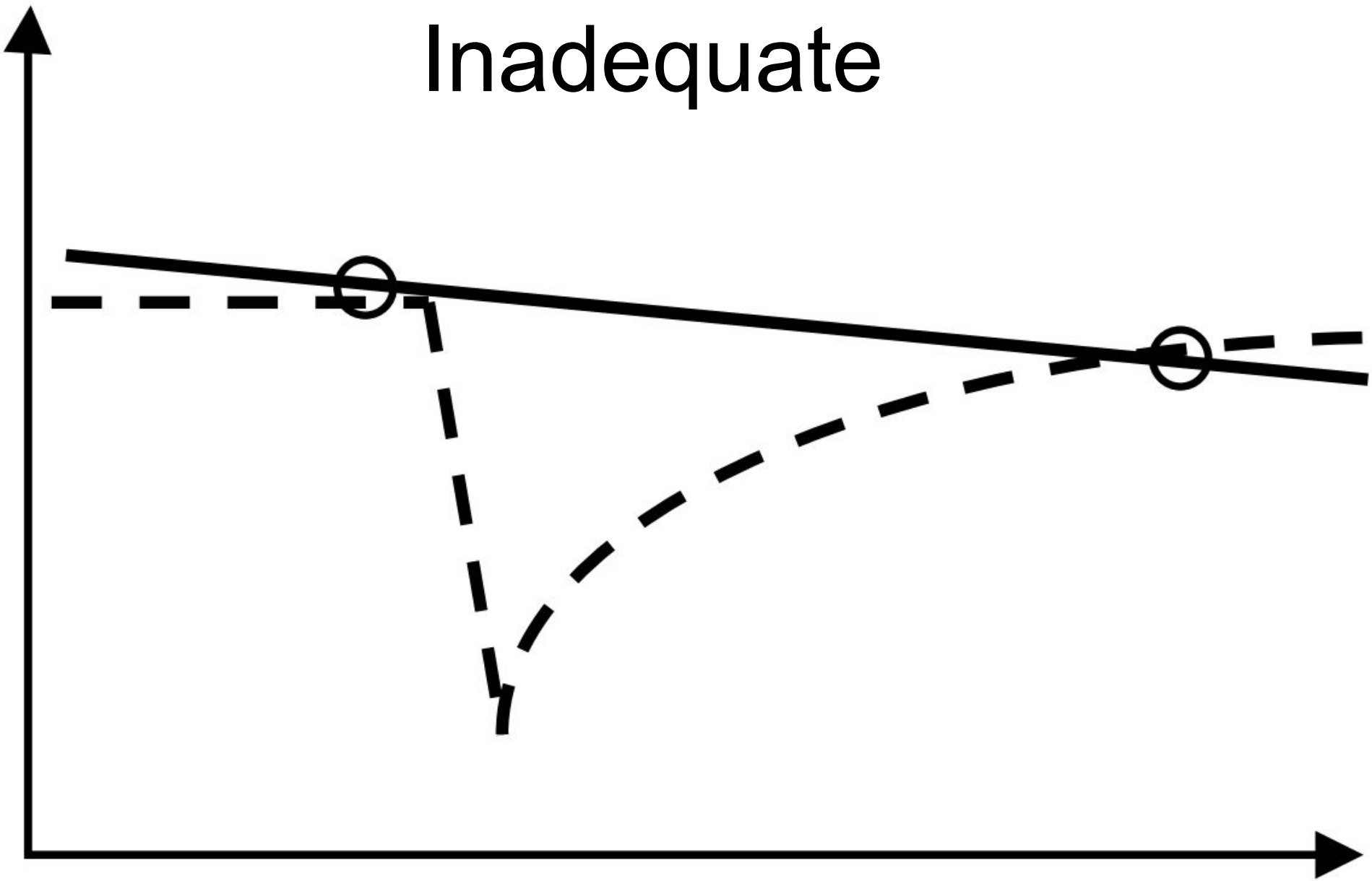
Monitoring tropical forest changes using satellite time series

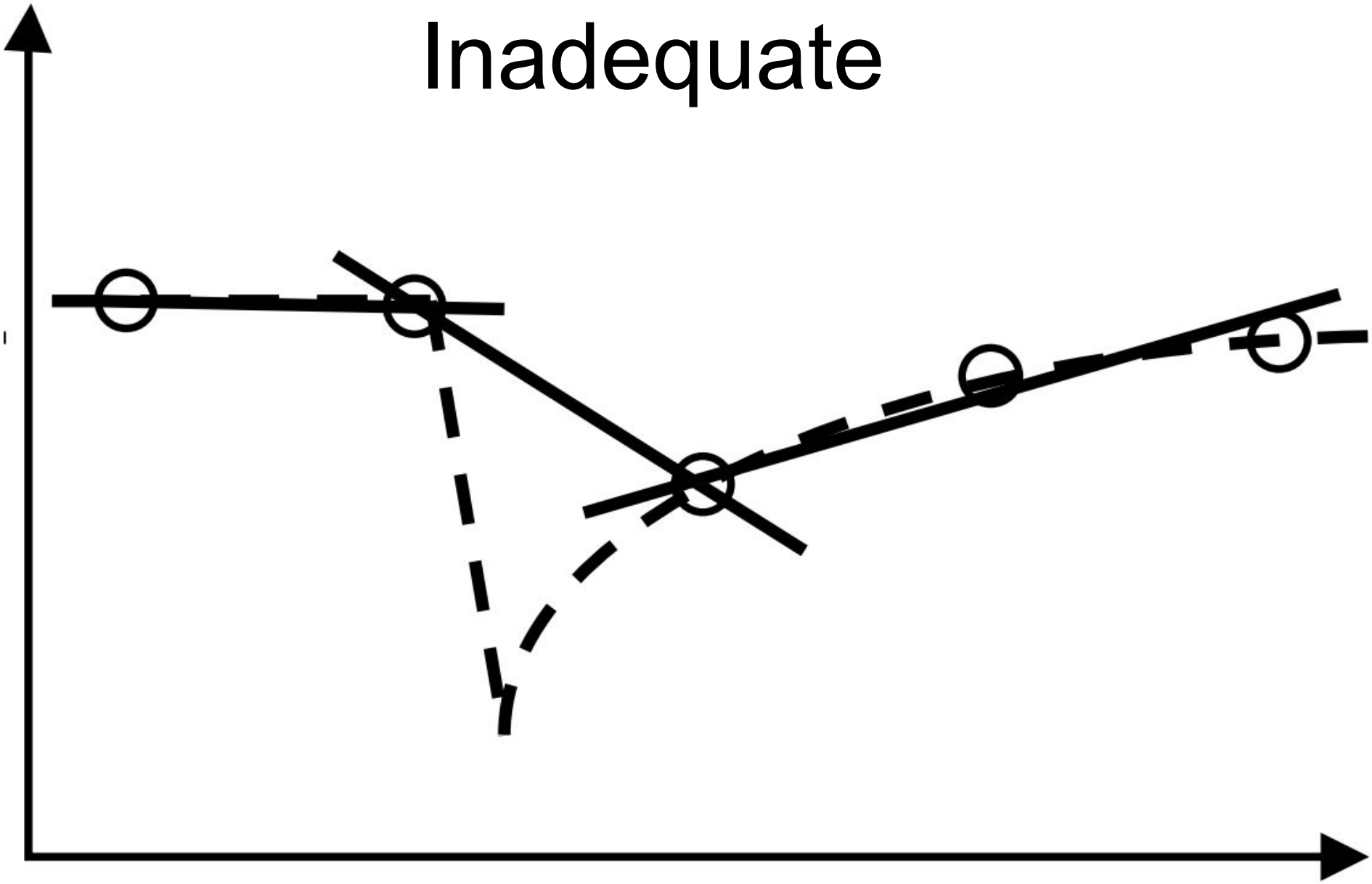
Martin Herold, Pontus Olofsson, Jan Verbesselt, Erik Lindquist,

WAGENINGEN UR
For quality of life

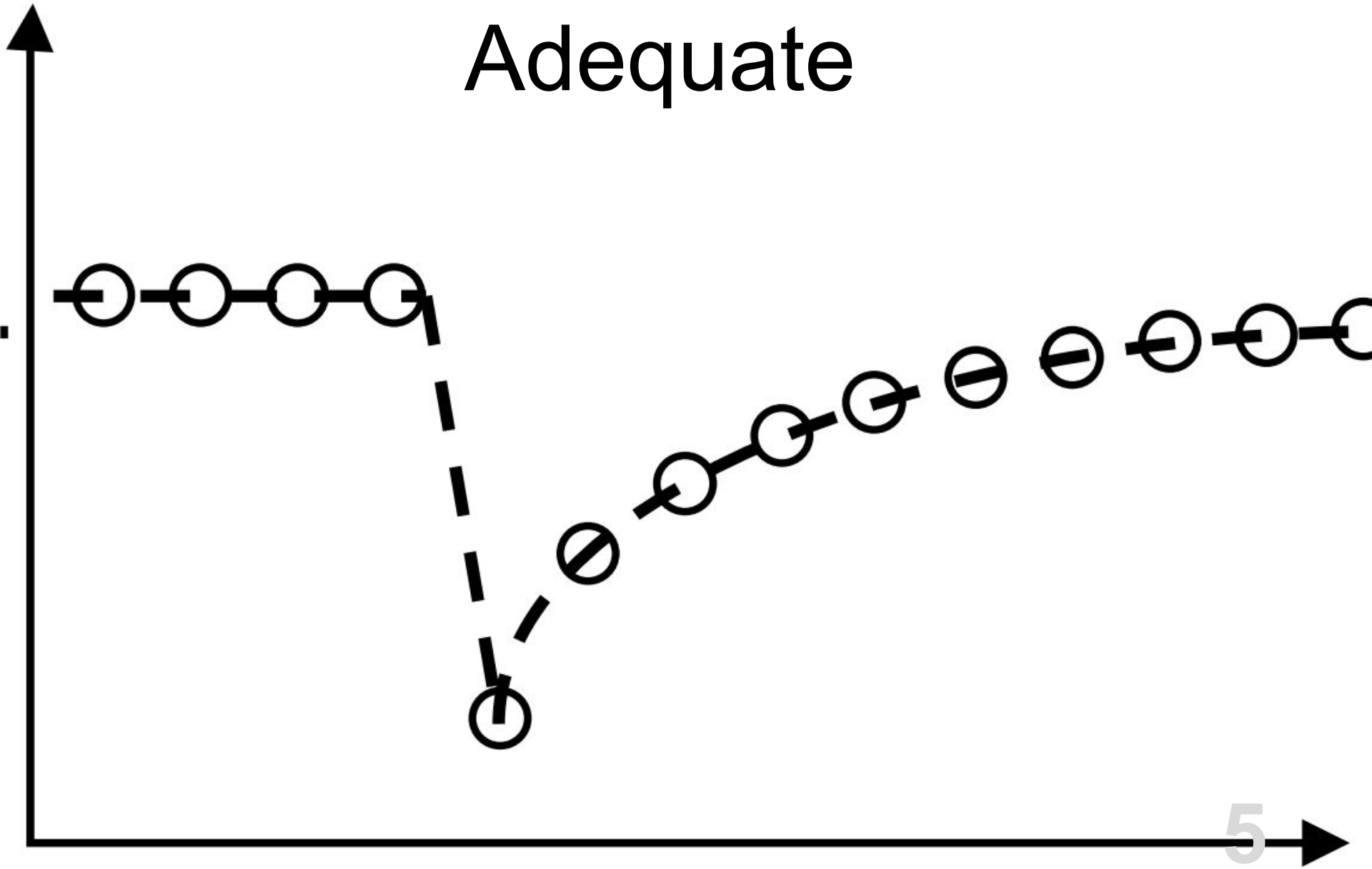
Inadequate

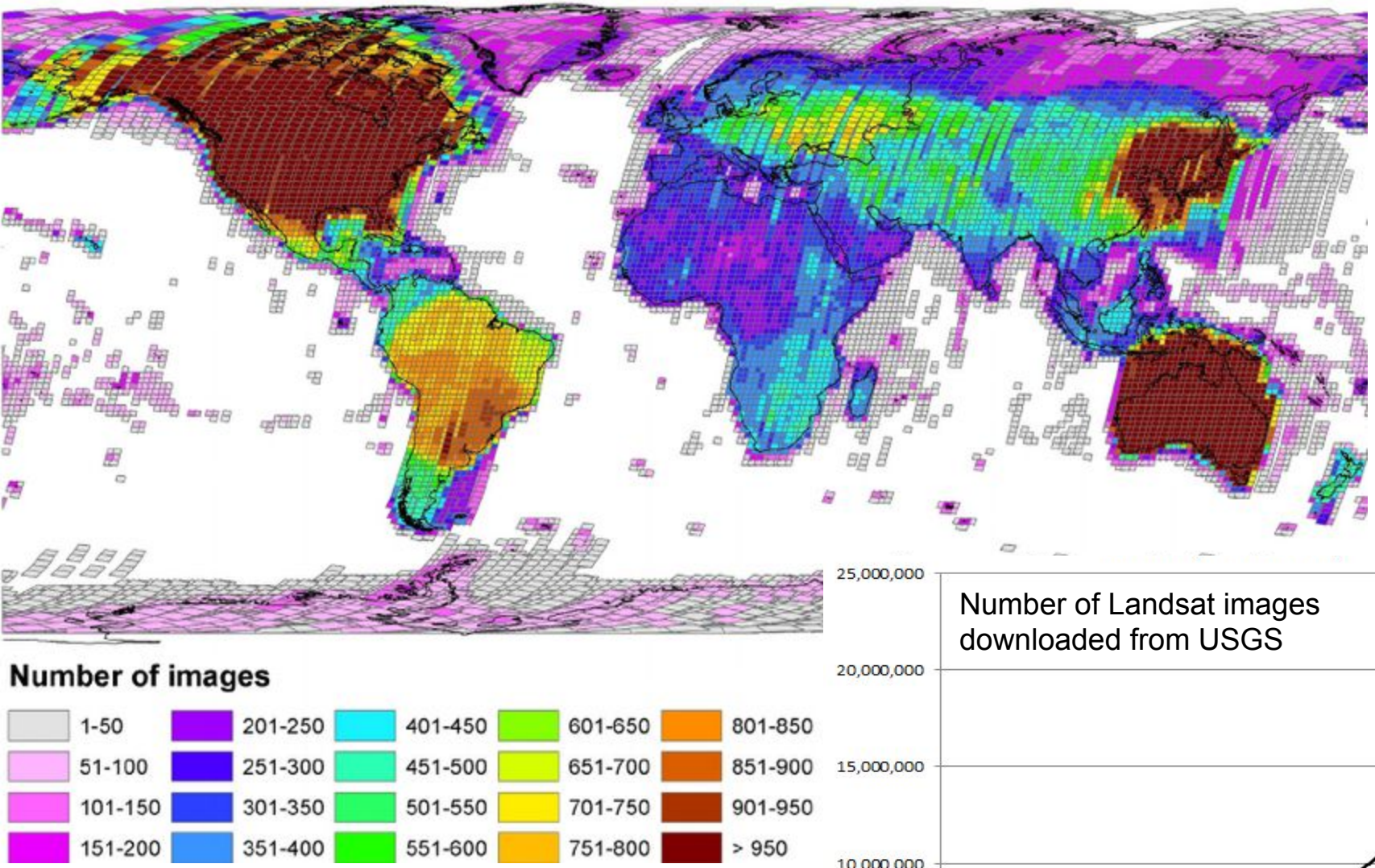


Inadequate

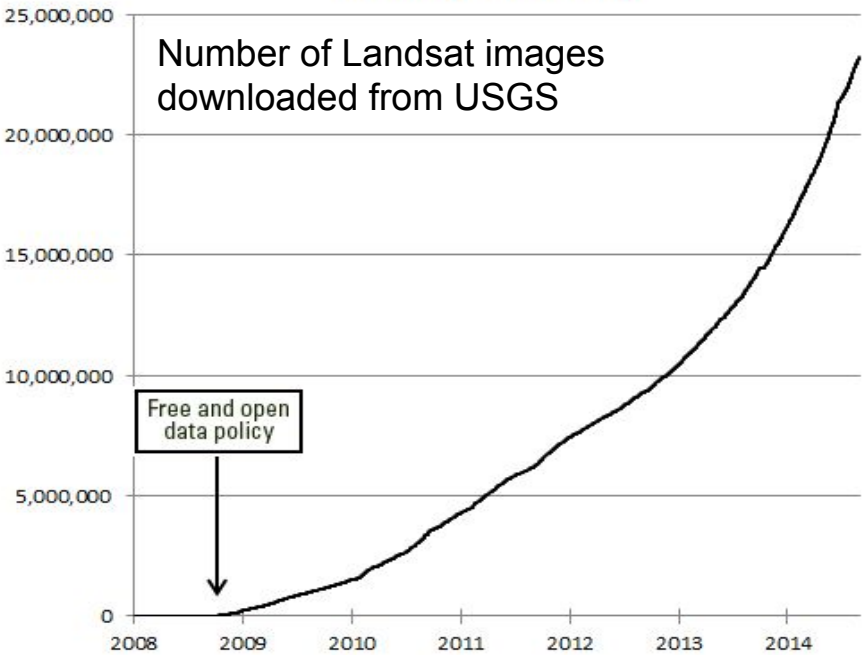


Adequate





From Wulder et al. (2015)



How to achieve this analysis?

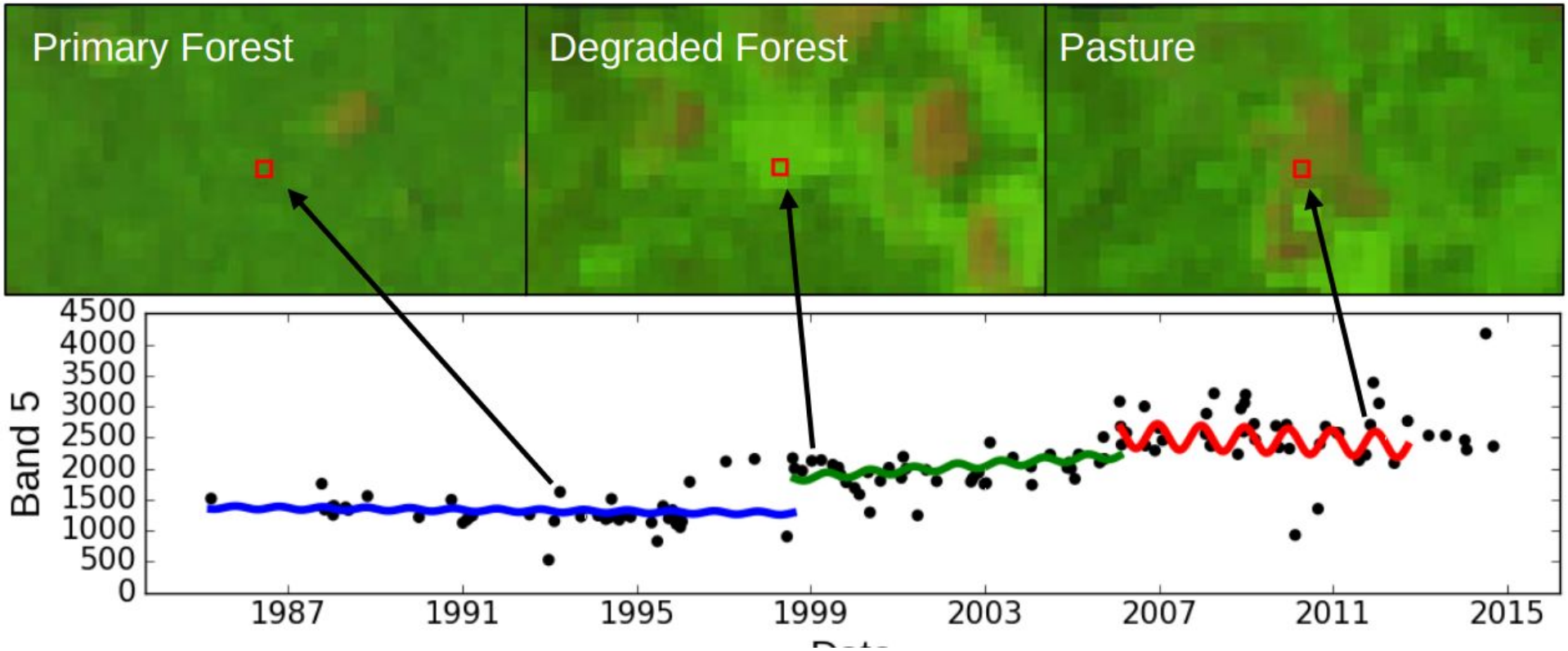
Three main approaches:

- *"Best images"* -- selects best image at fixed intervals -- global forest cover change every 5 years (GLS)
- *Compositing* -- selects best pixels in time series according to some criteria -- global forest cover change every year (GLAD, LandTrendr, VCT)
- *"All images"* -- ingests *all* observations -- allow for monitoring of land conversion and timing of activities (CCDC, BFAST)

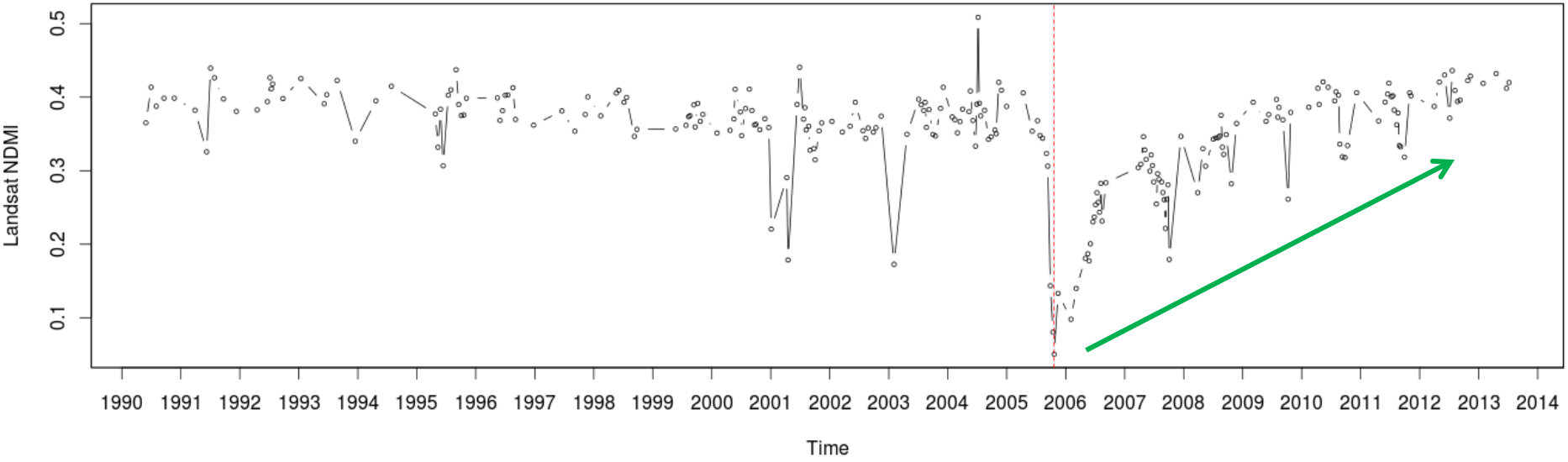
Name	Where	Inputs	Outputs
GLAD	University of Maryland	Yearly 'best' composite images	Deforestation map
LandTrendr	Oregon State University / US Forest Service	Yearly 'best' composite images	Change maps
bFast/ bFastMonitor	Wageningen University (Netherlands)	All available images, forest mask	Change map
Continuous Change Detection and Classification (CCDC/YATSM)	Boston University / United States Geological Survey	All available imagery, training data	Change maps, land cover classifications

Complexity

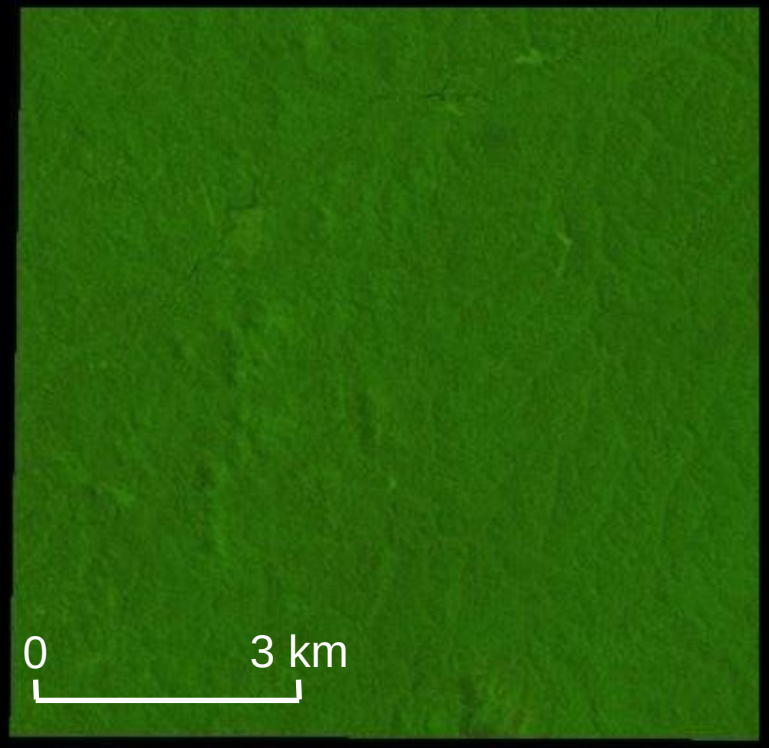
Example, CCDC/YATSM, Colombia



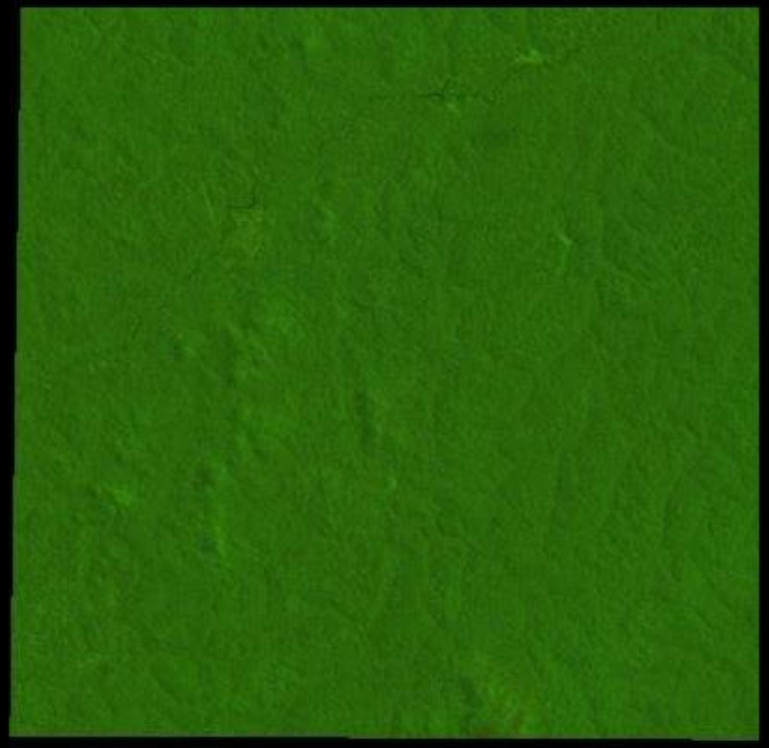
Forest monitoring using dense Landsat time series



2000 - 249



Observed

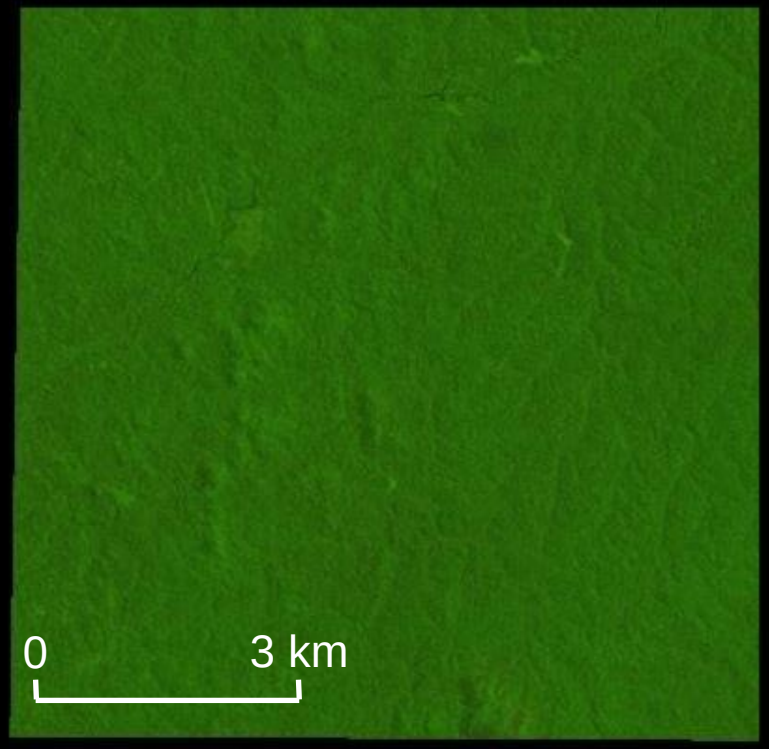


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 249



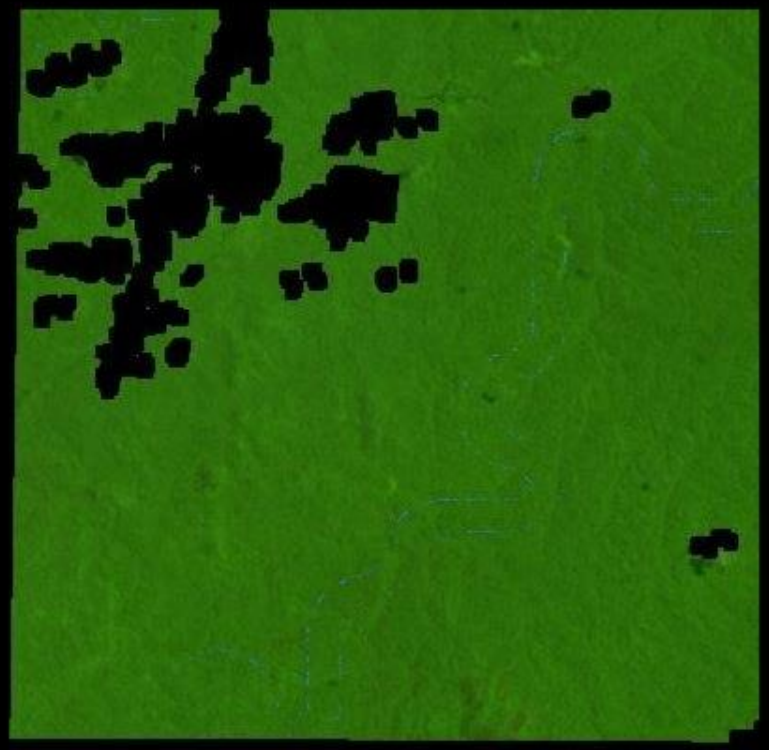
Observed

Predicted

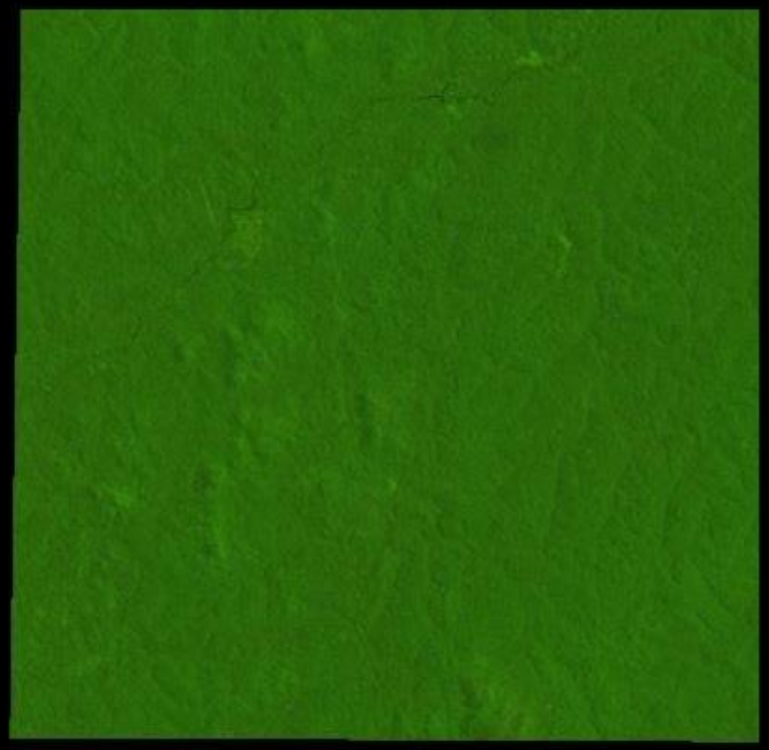
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 257



Observed

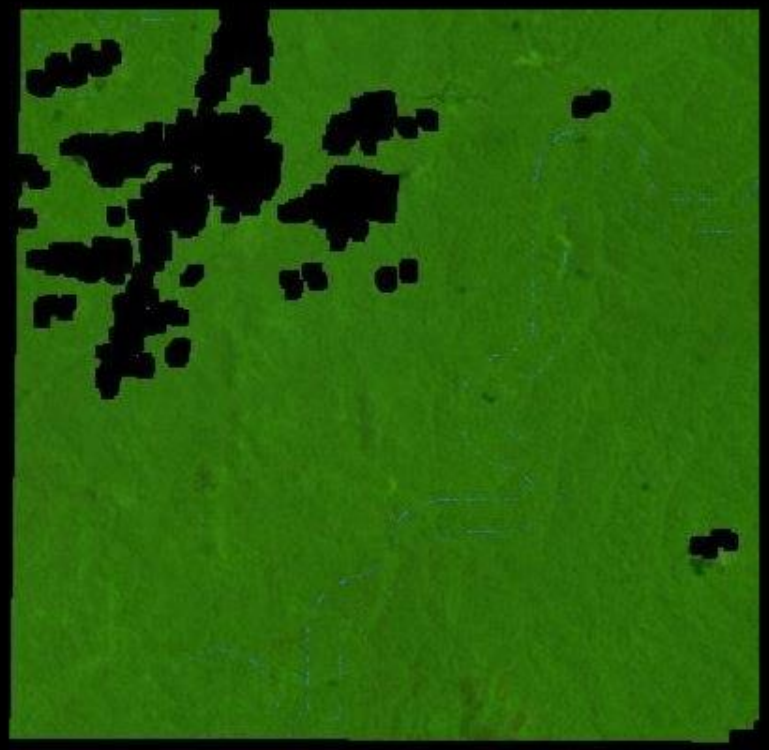


Predicted

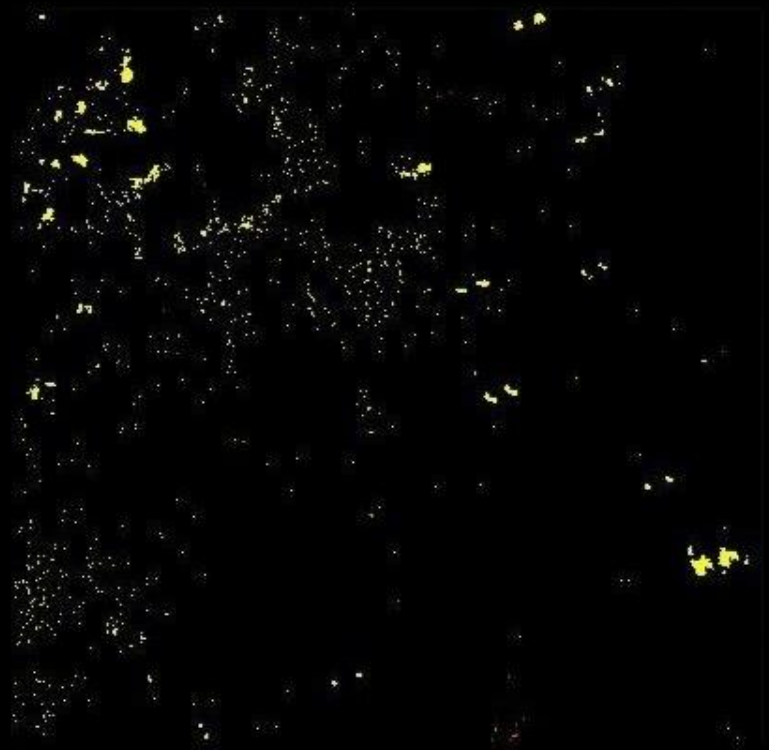
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 257



Observed

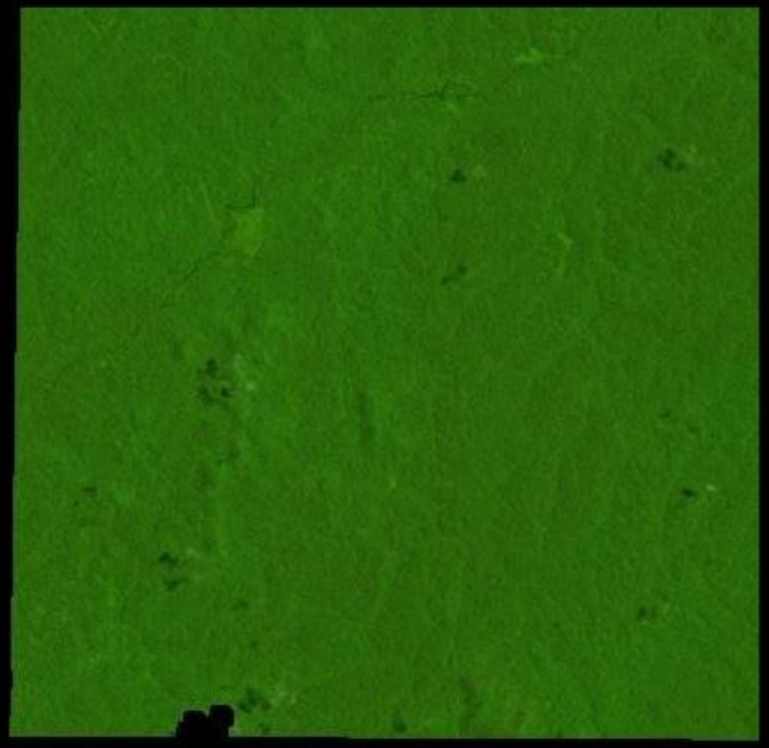


Predicted

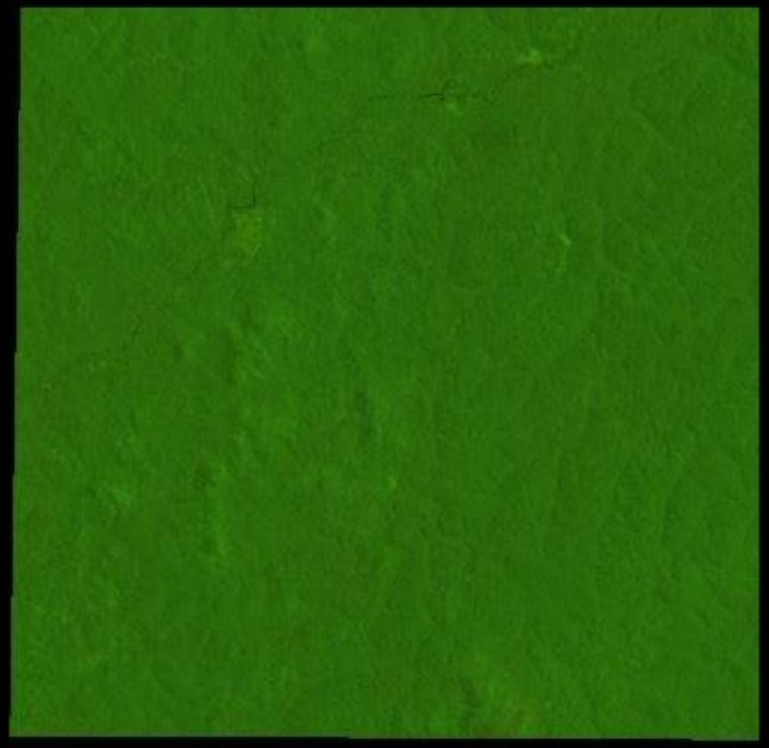
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 265



Observed

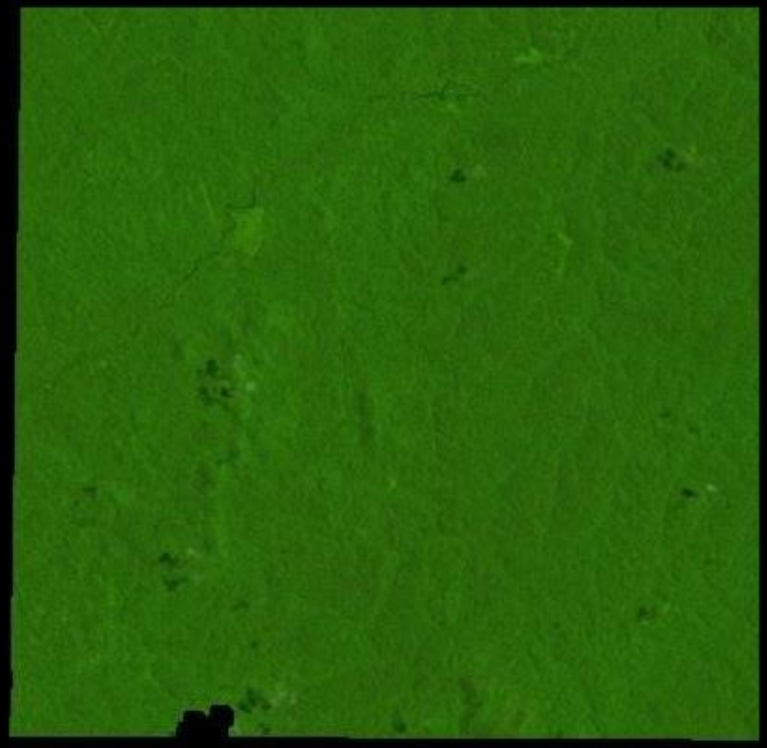


Predicted

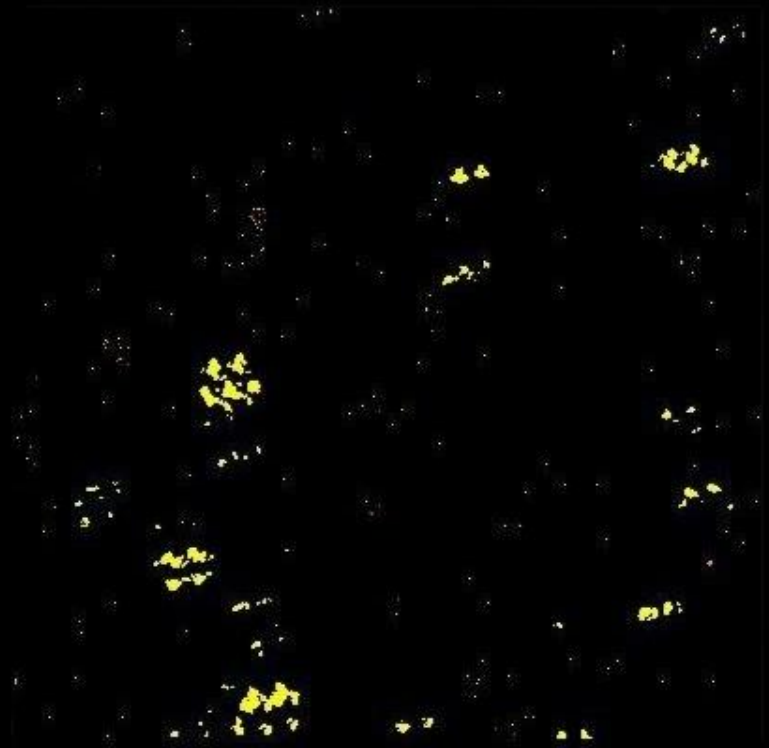
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 265



Observed

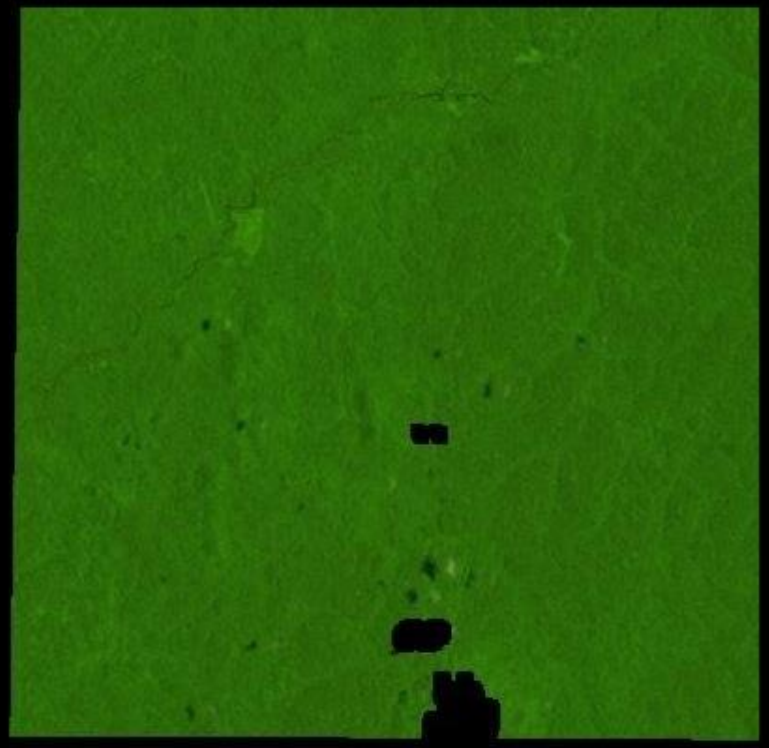


Predicted

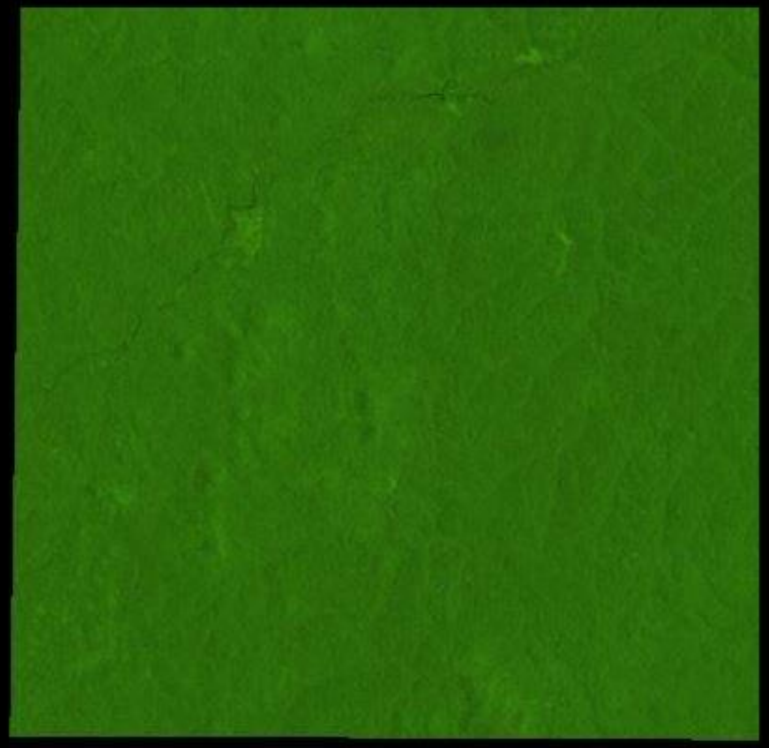
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 281



Observed

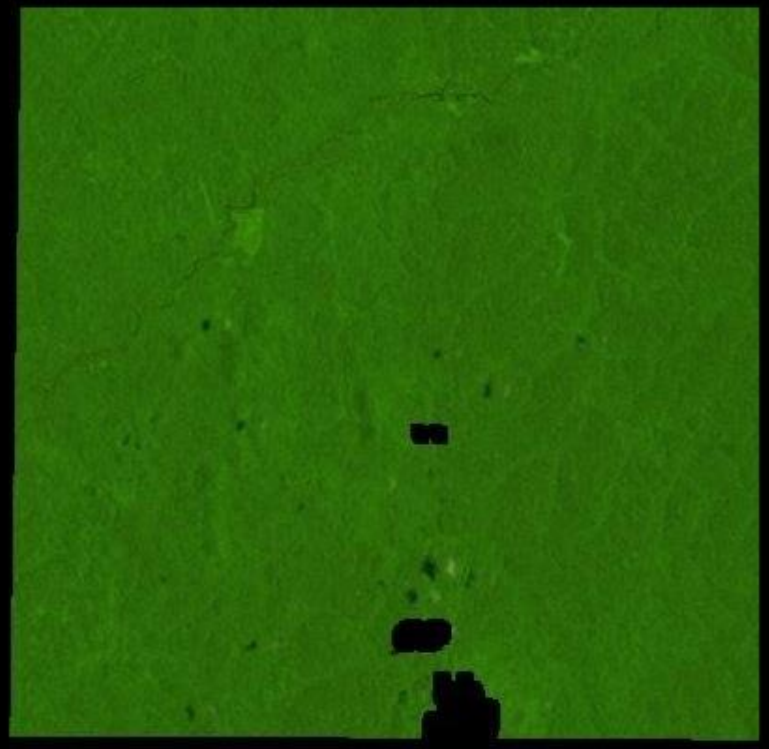


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 281



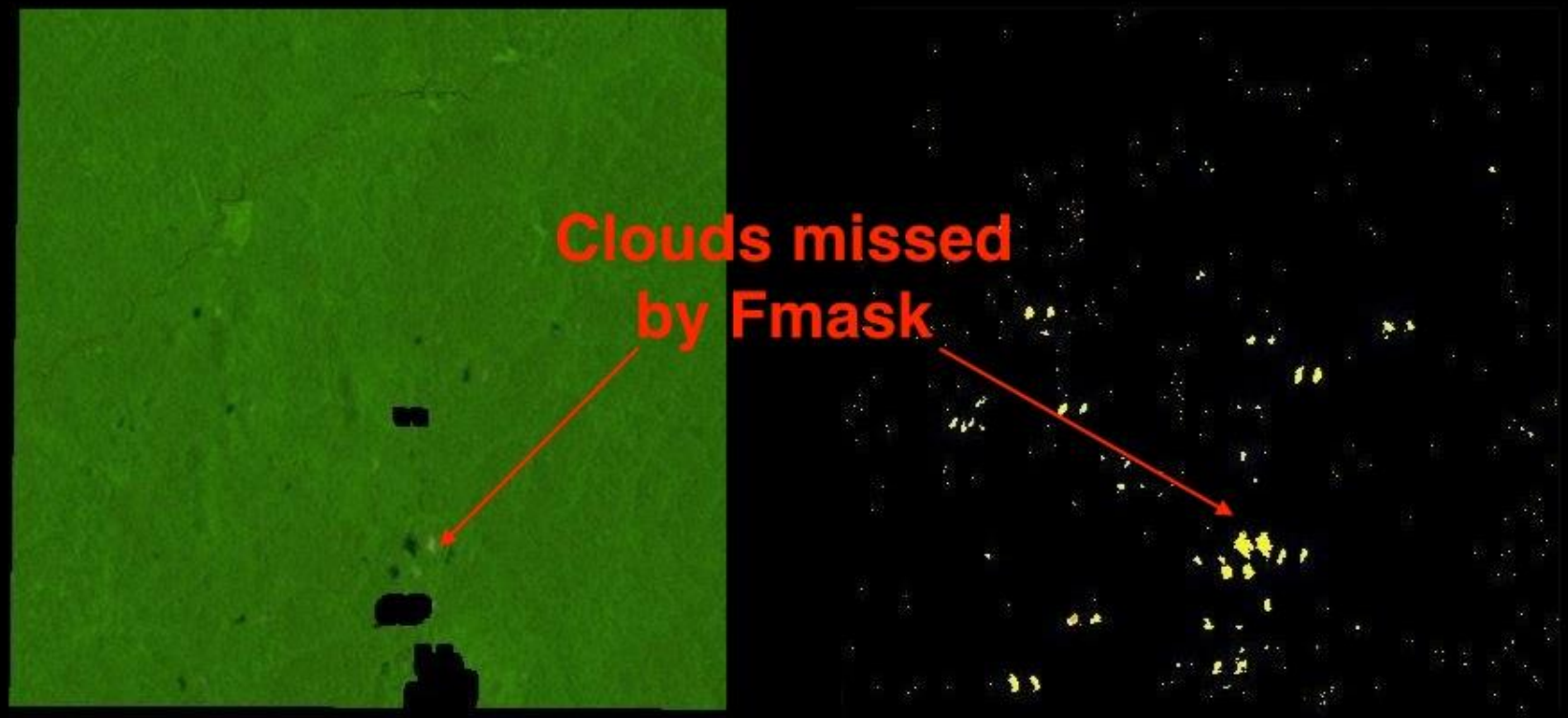
Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 281



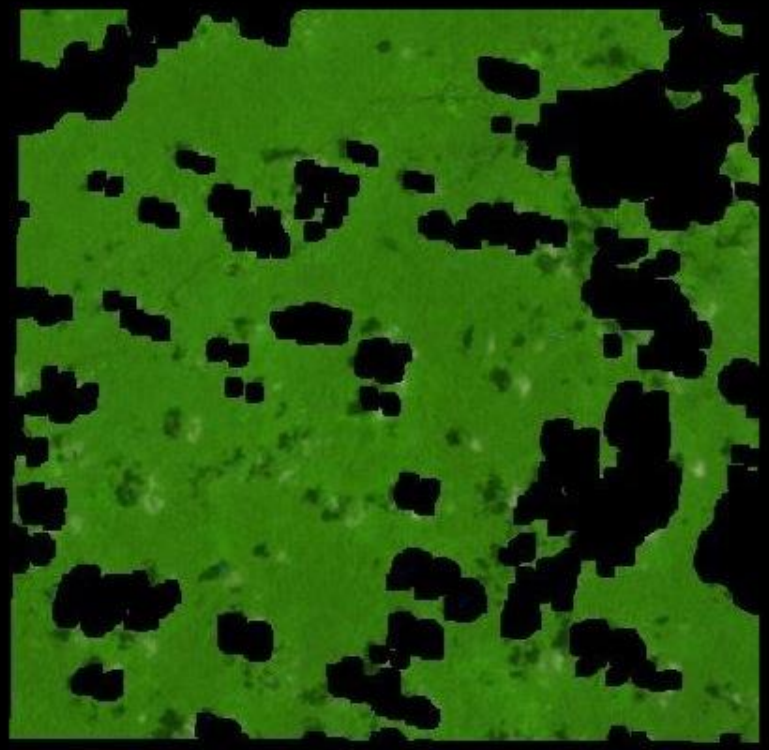
Observed

Predicted

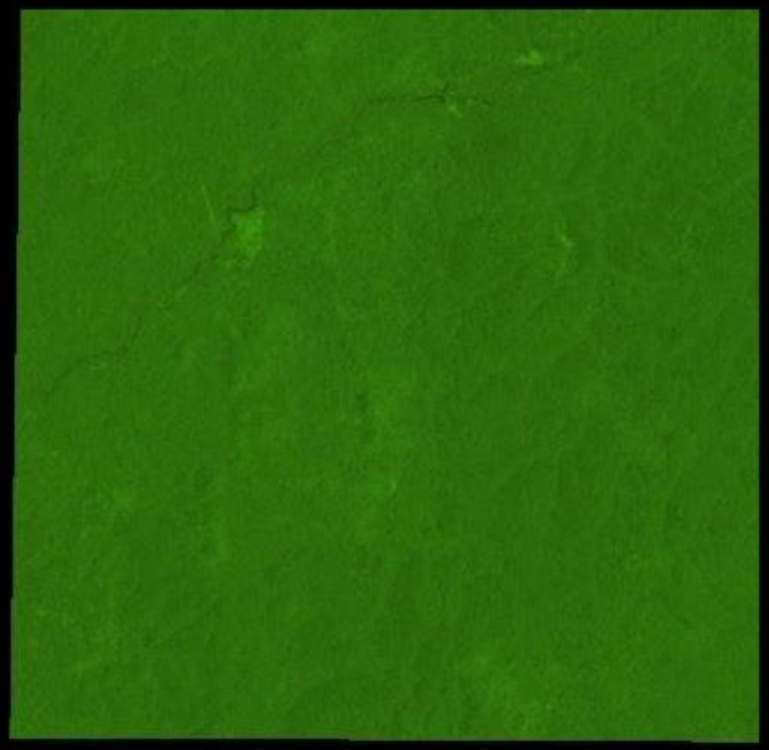
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 305



Observed

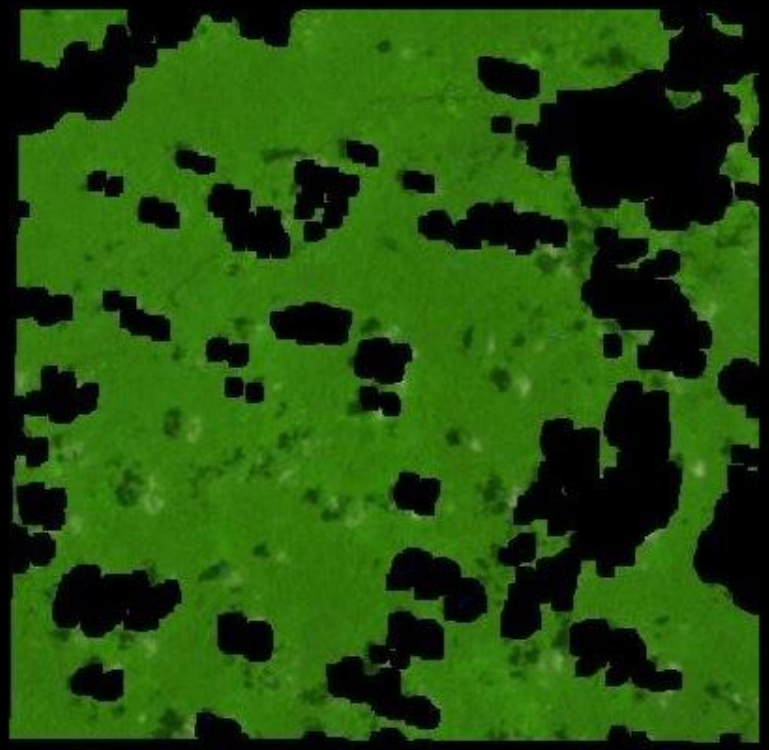


Predicted

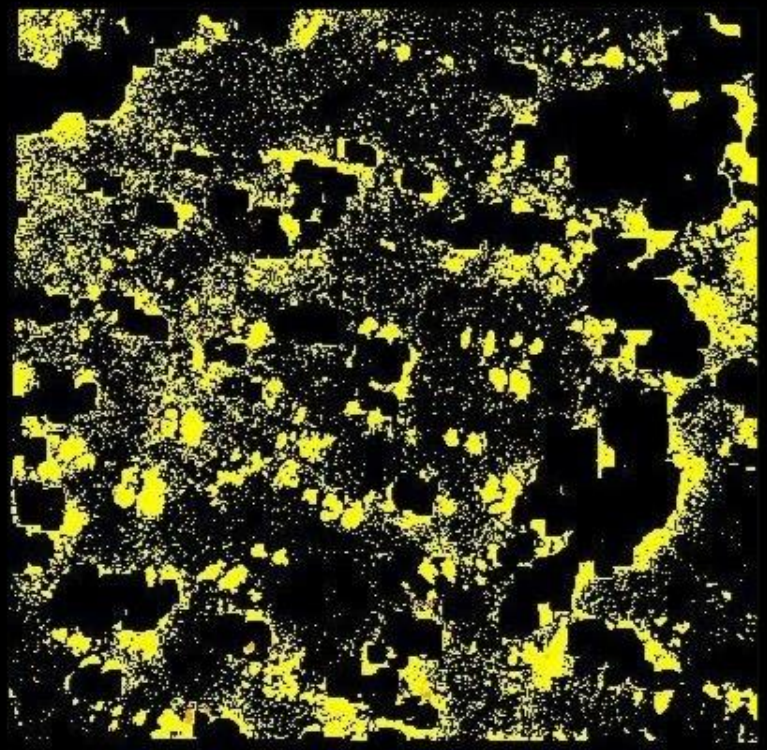
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 305



Observed

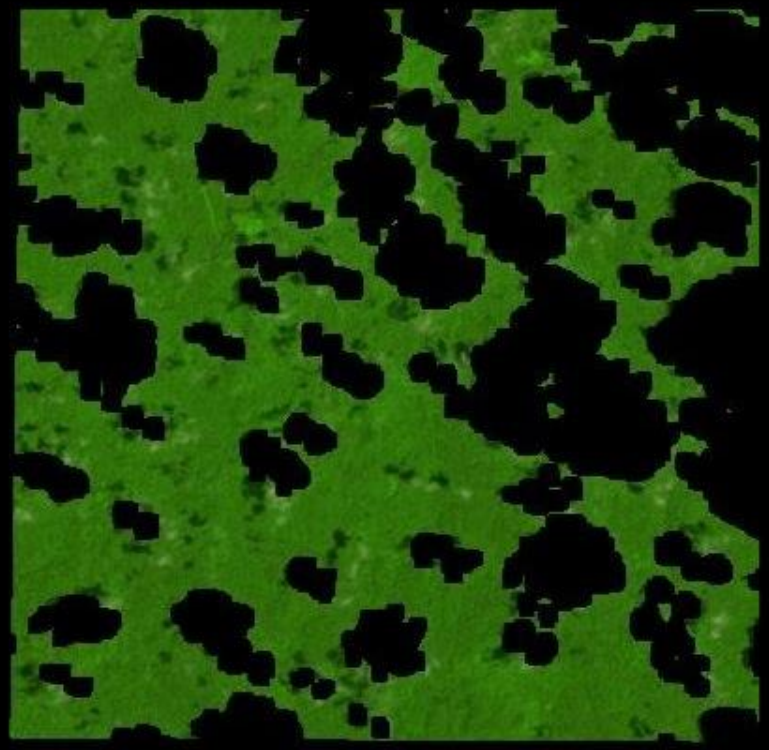


Predicted

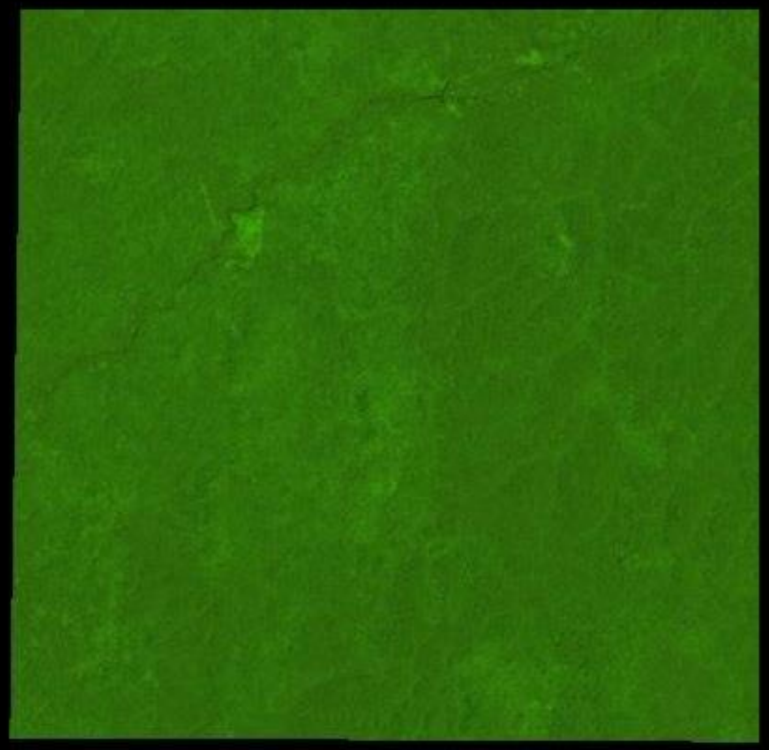
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 329



Observed

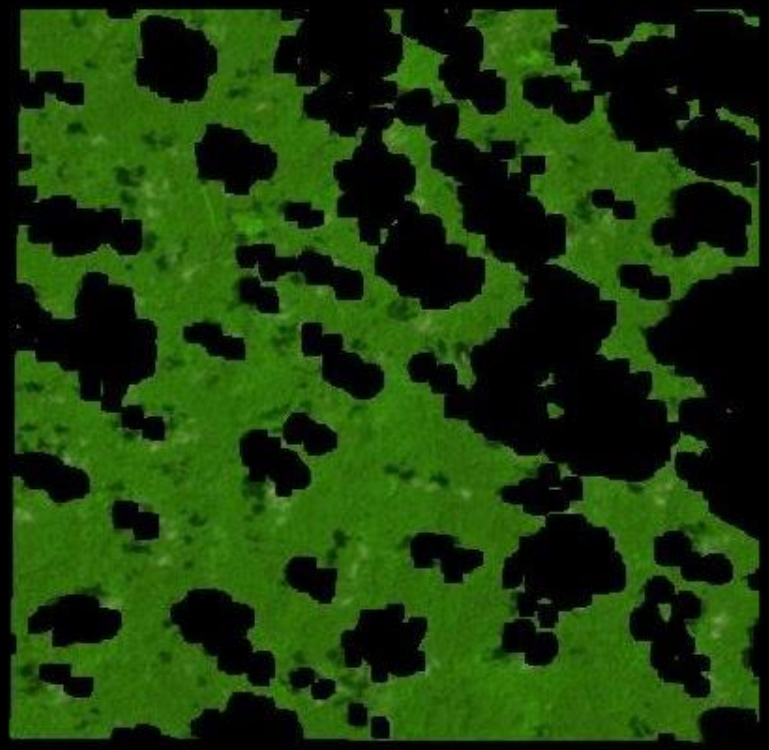


Predicted

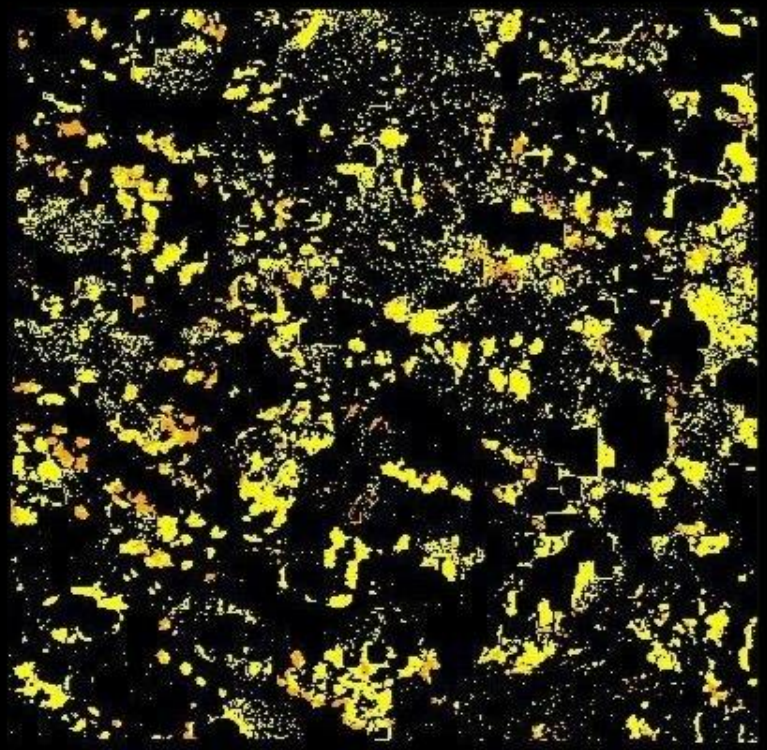
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2000 - 329



Observed

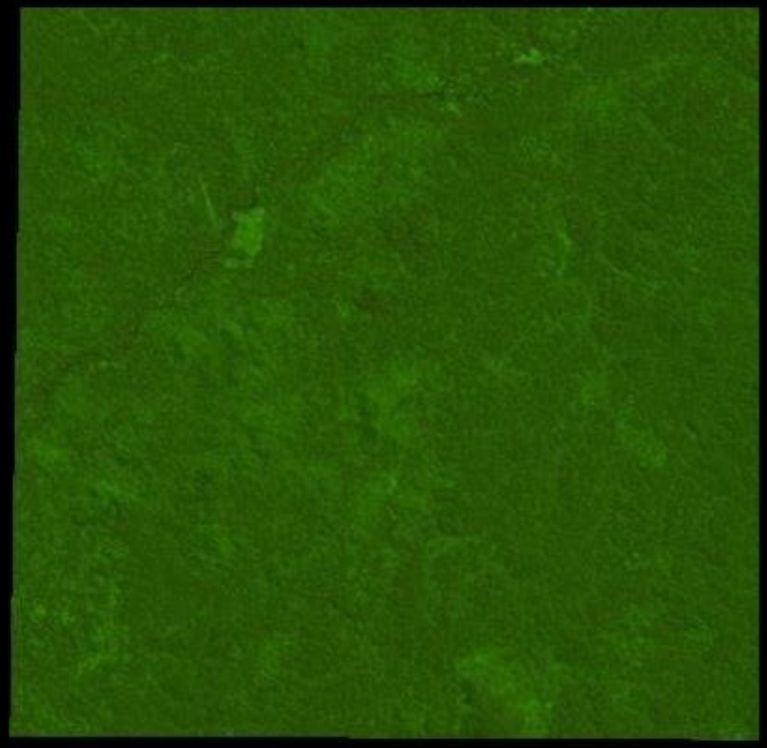


Predicted

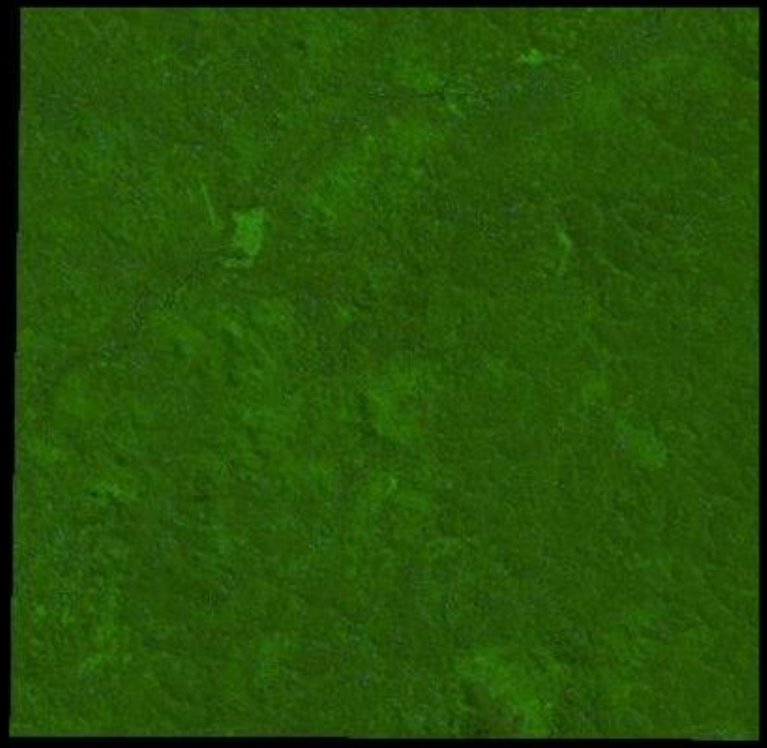
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 115



Observed

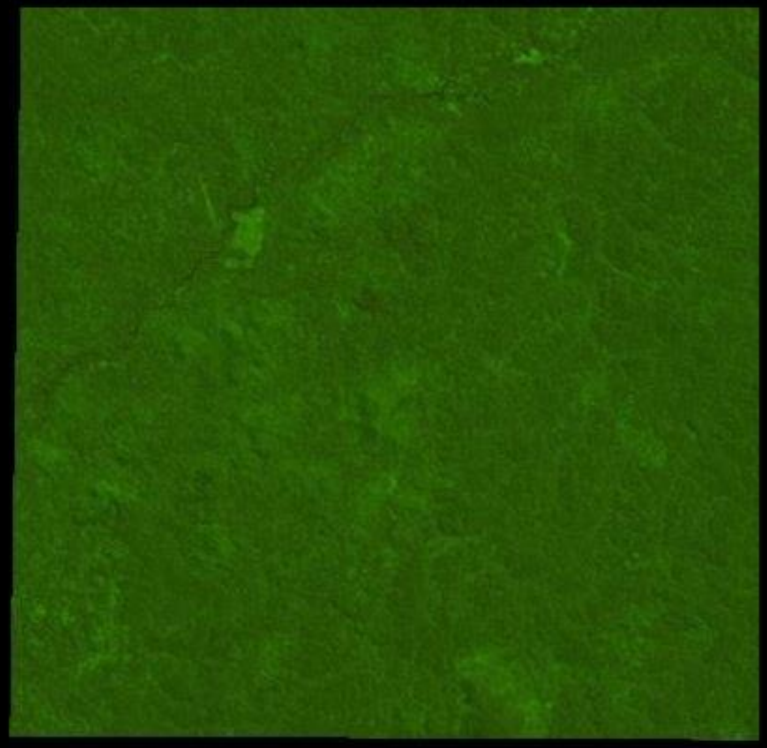


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 115



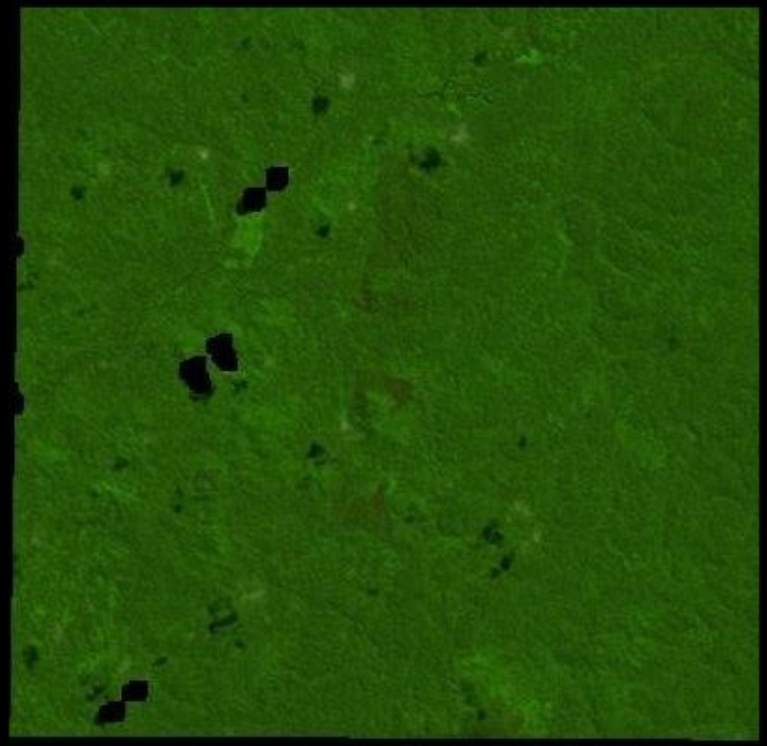
Observed

Predicted

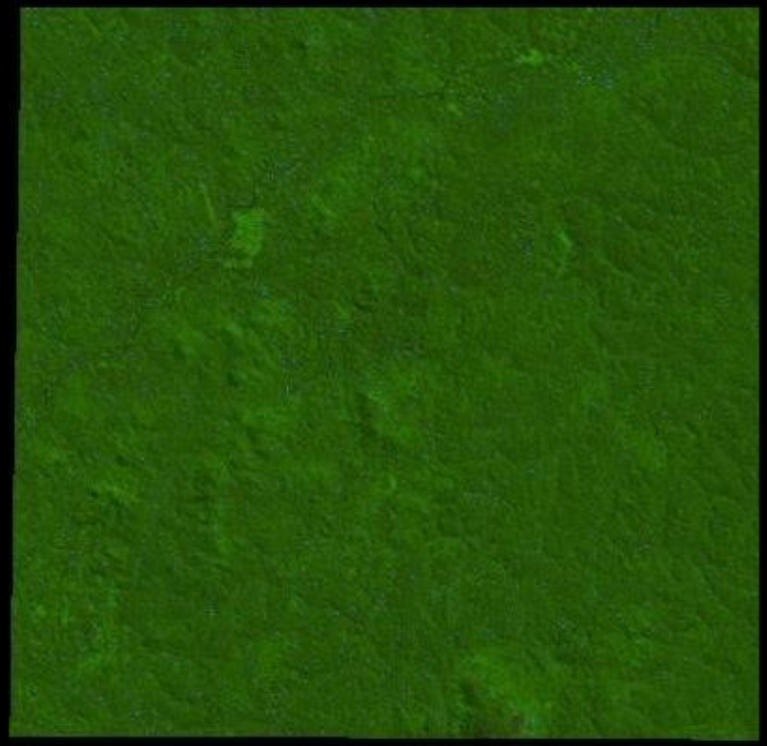
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 139



Observed

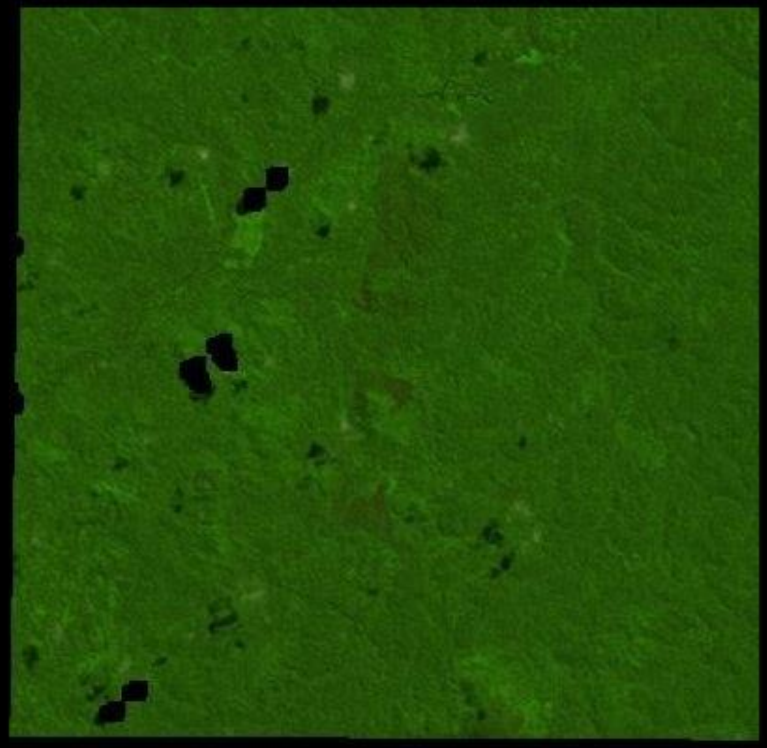


Predicted

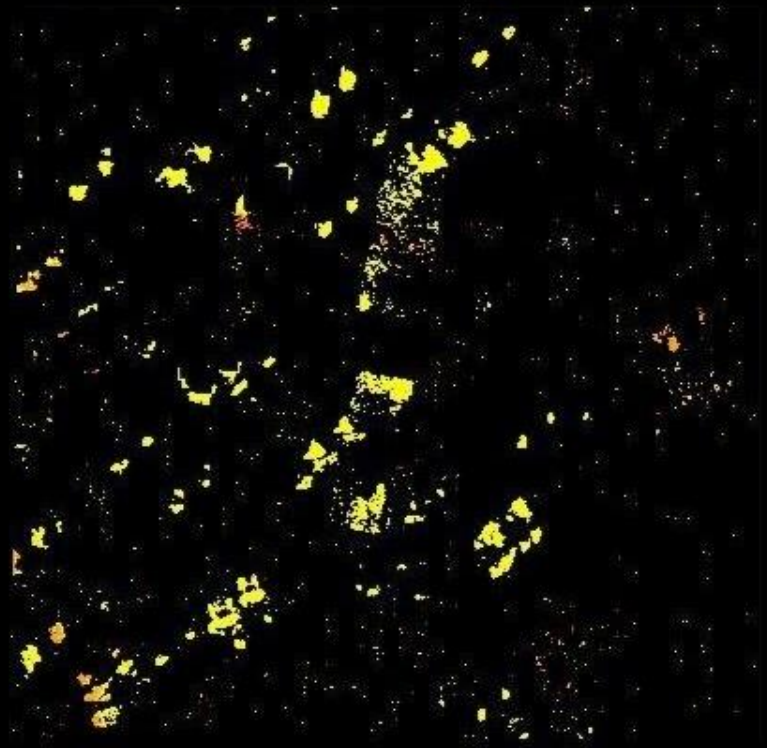
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 139



Observed

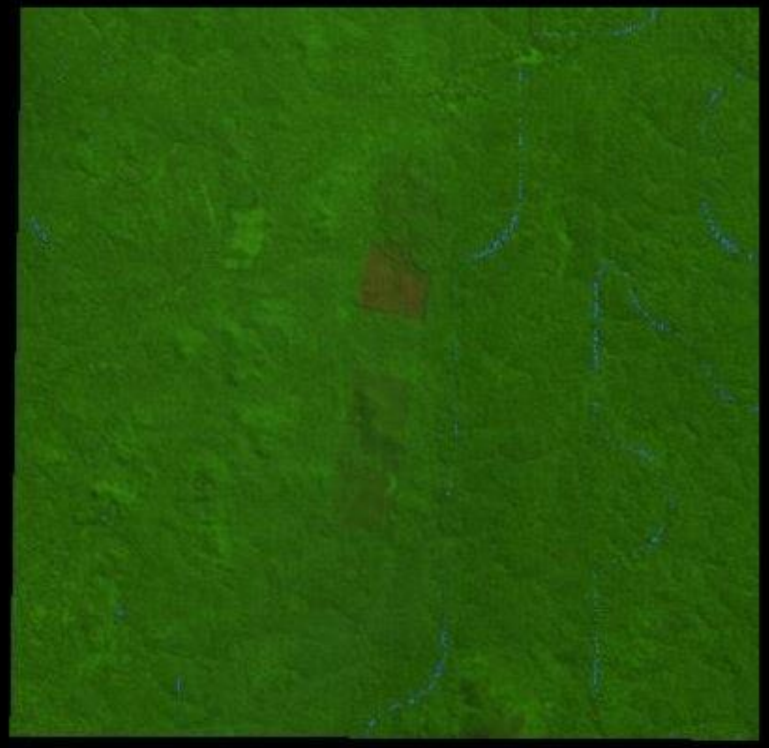


Predicted

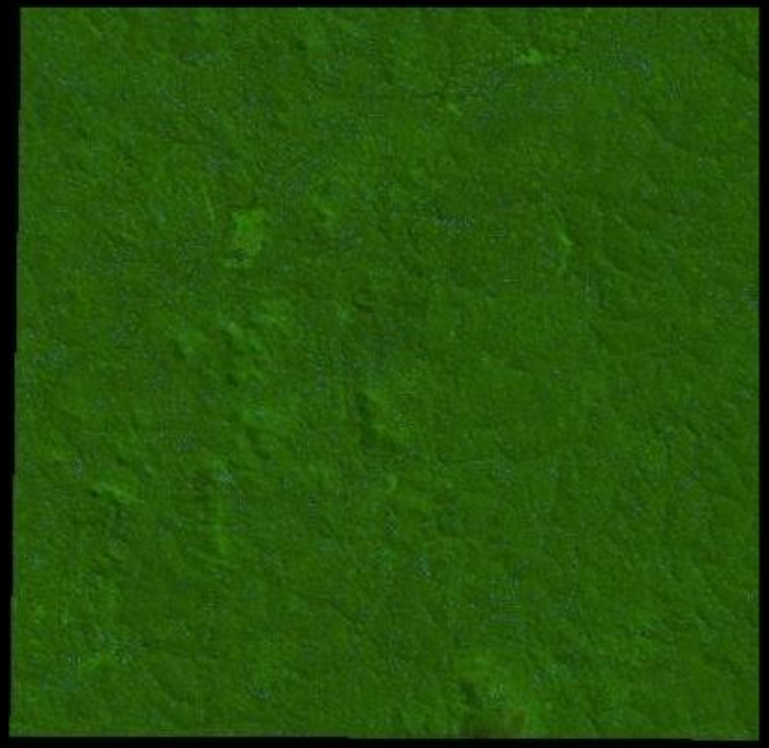
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 163



Observed

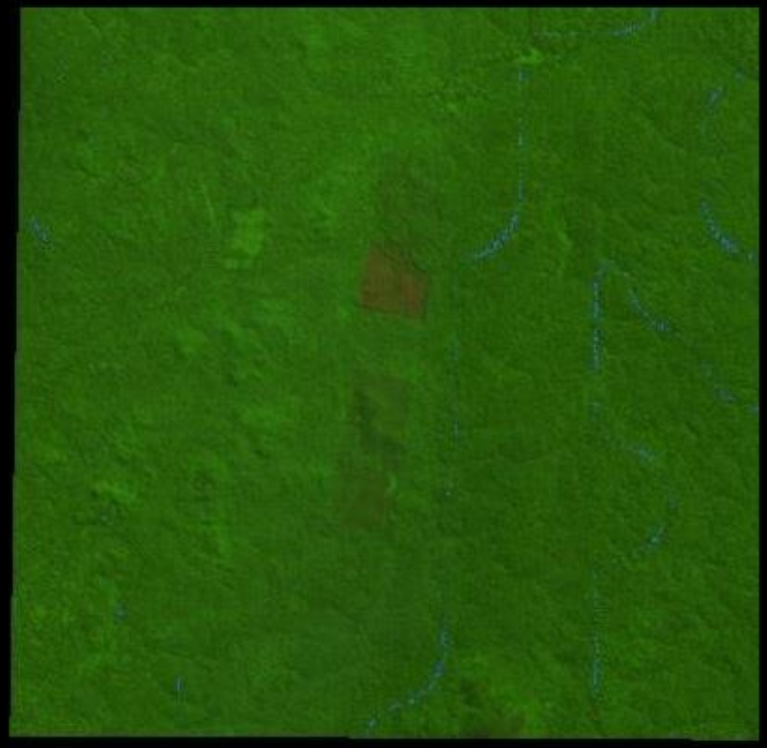


Predicted

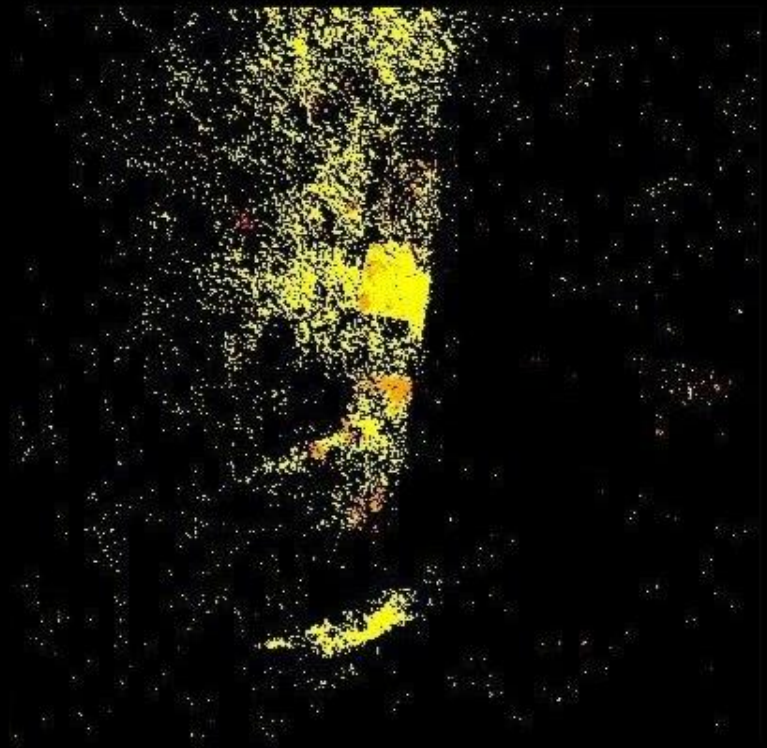
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 163



Observed

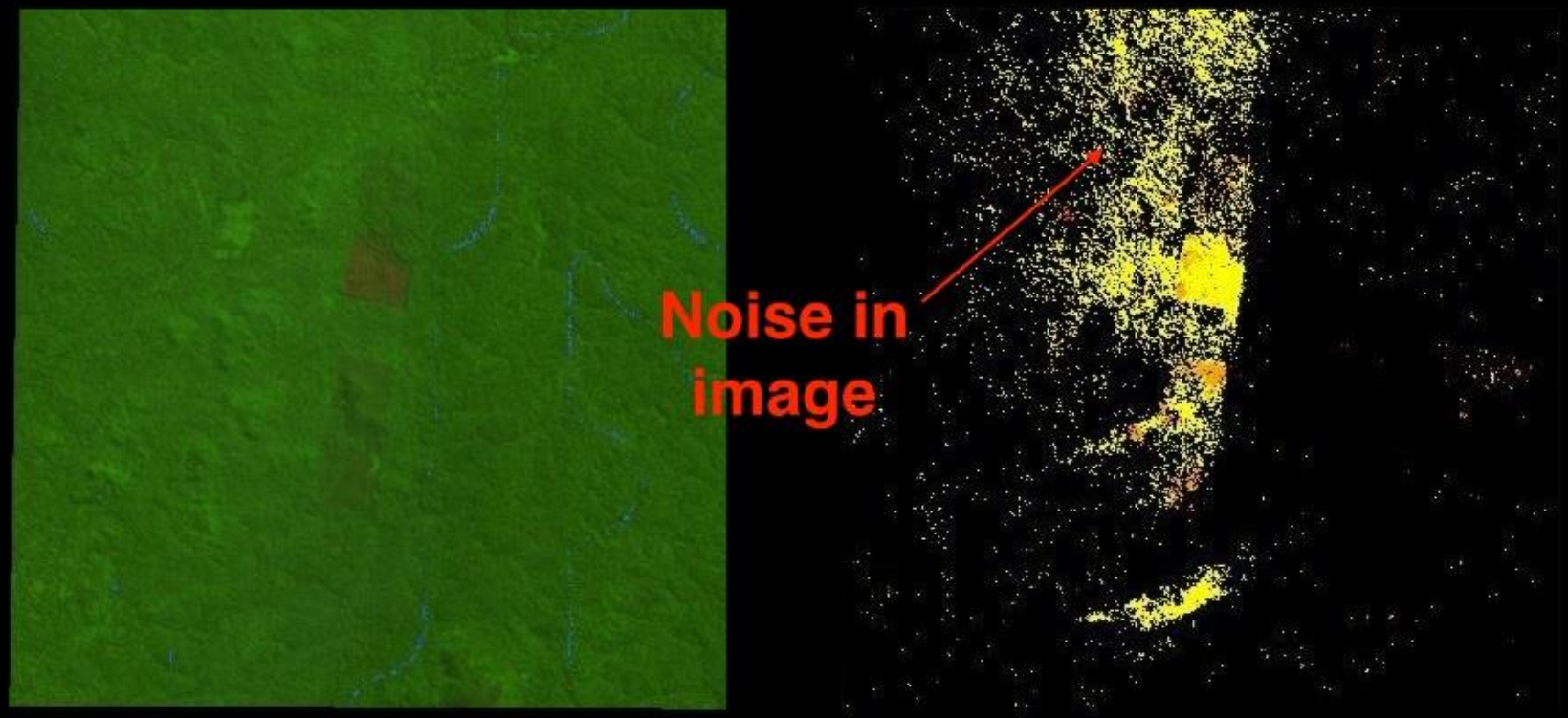


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 163



Observed

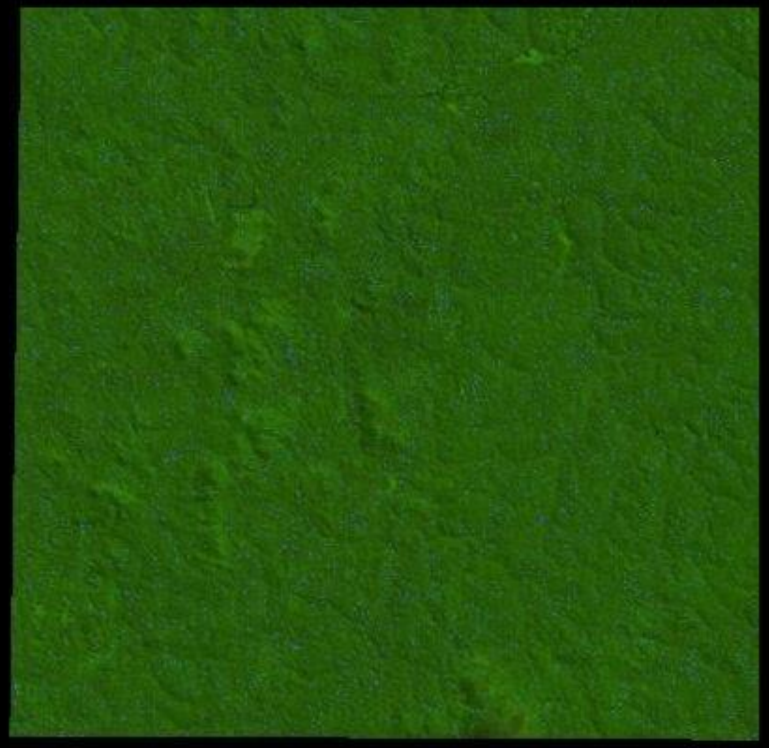
Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 179

Observed



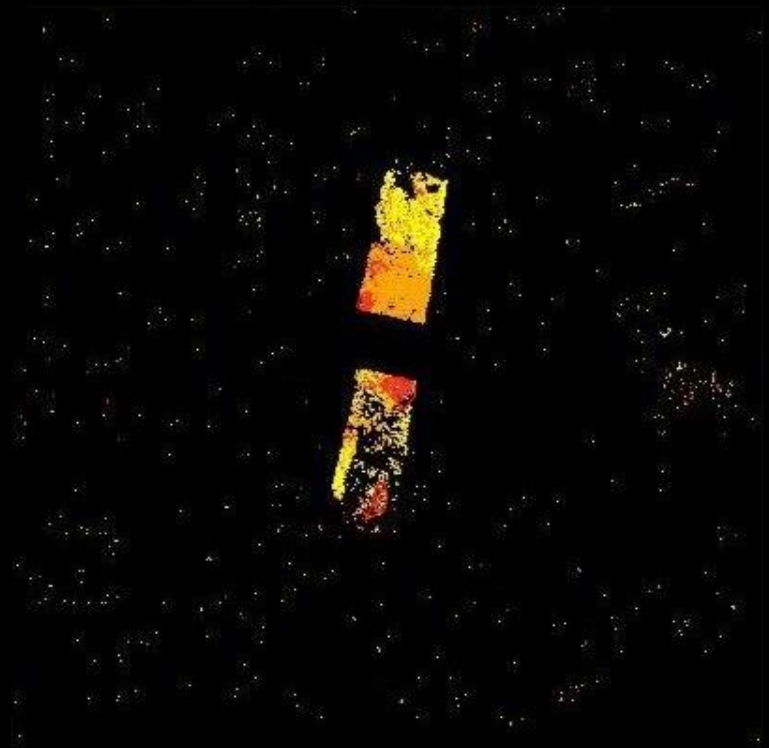
Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 179

Observed



Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 195

Observed

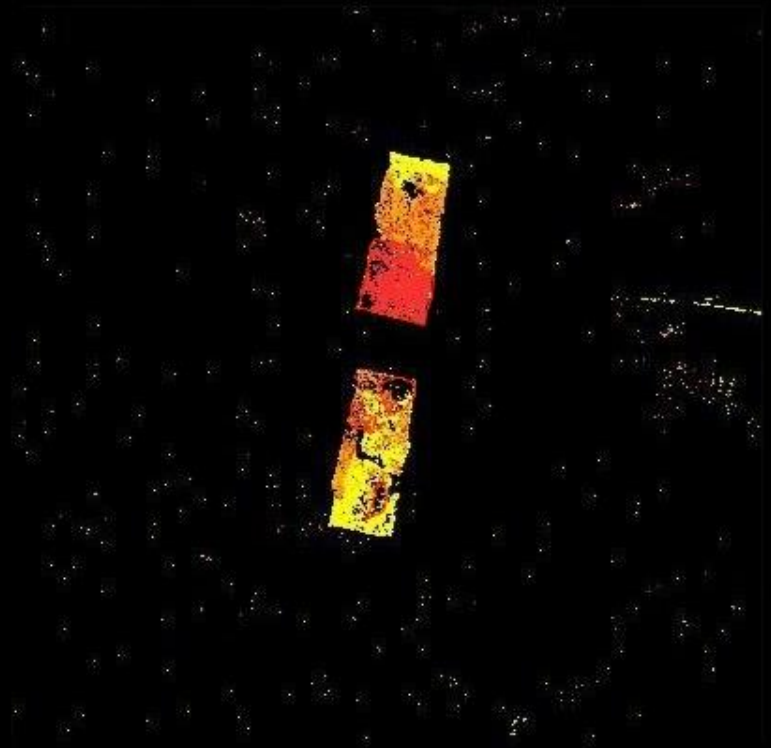
Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 195

Observed

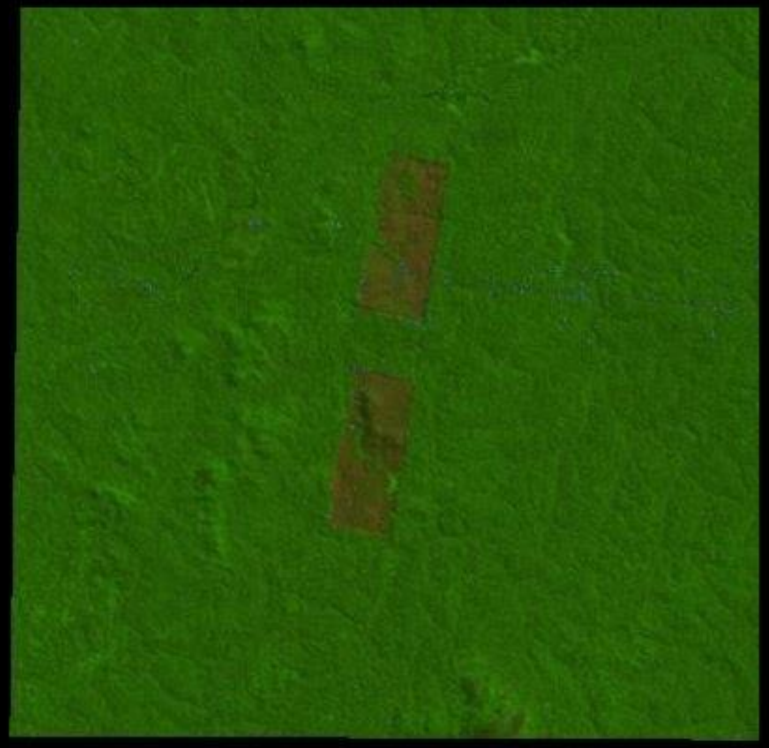


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 211



Observed

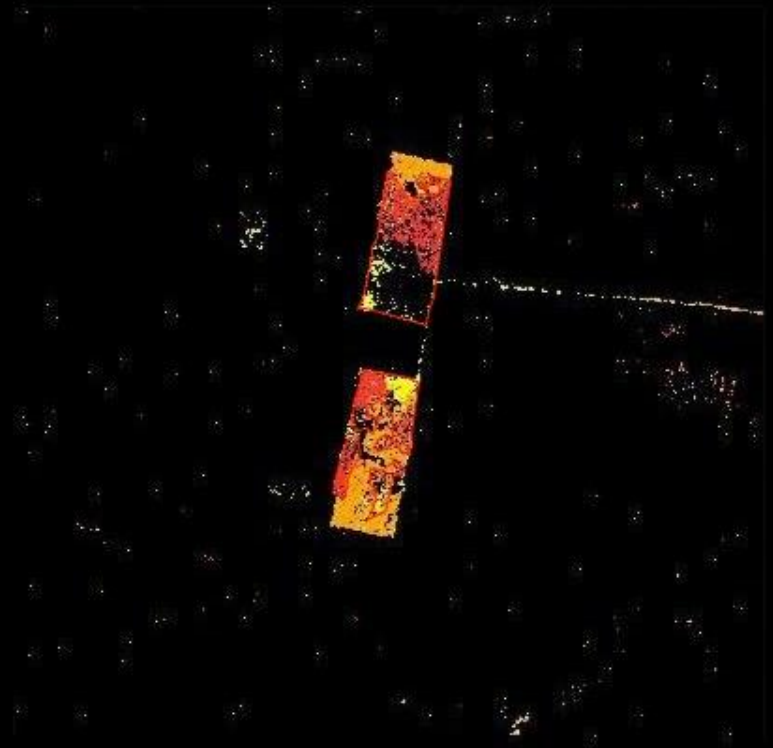
Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 211

Observed

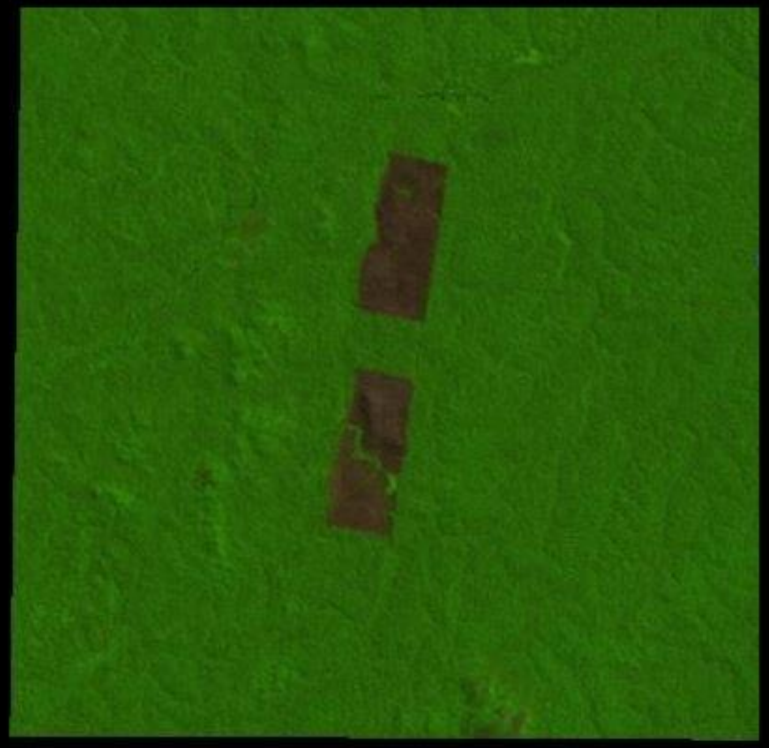


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 227



Observed

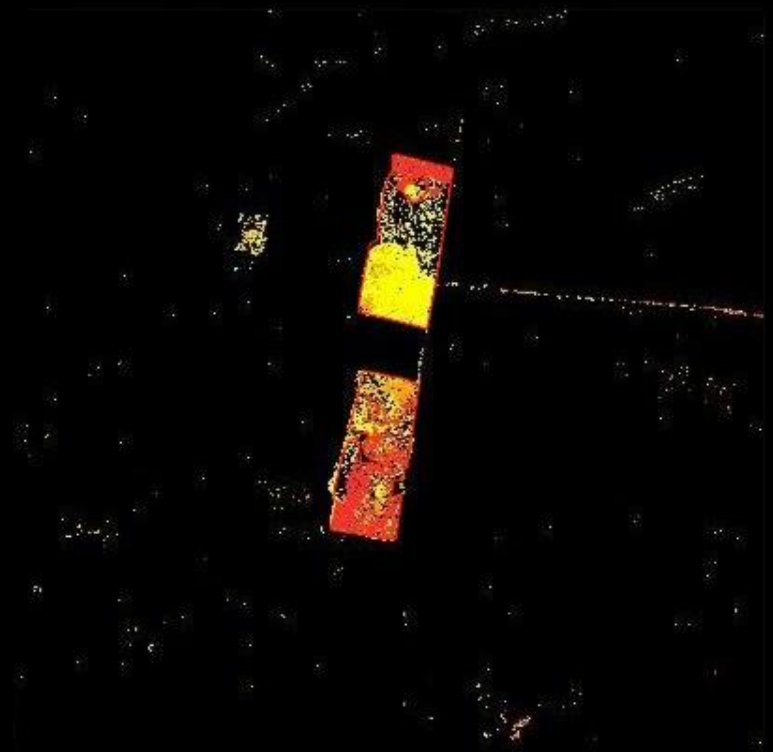
Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 227

Observed

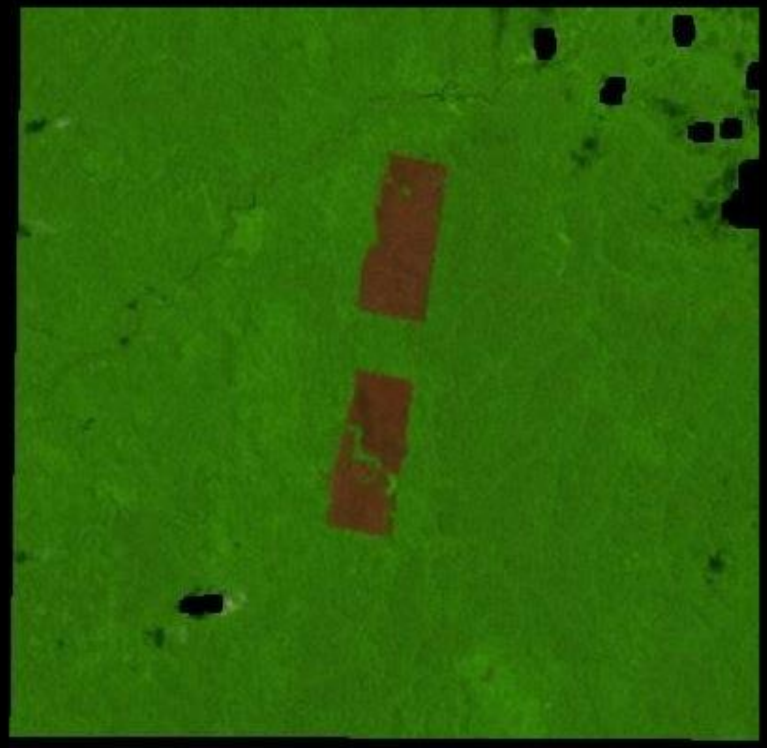


Predicted

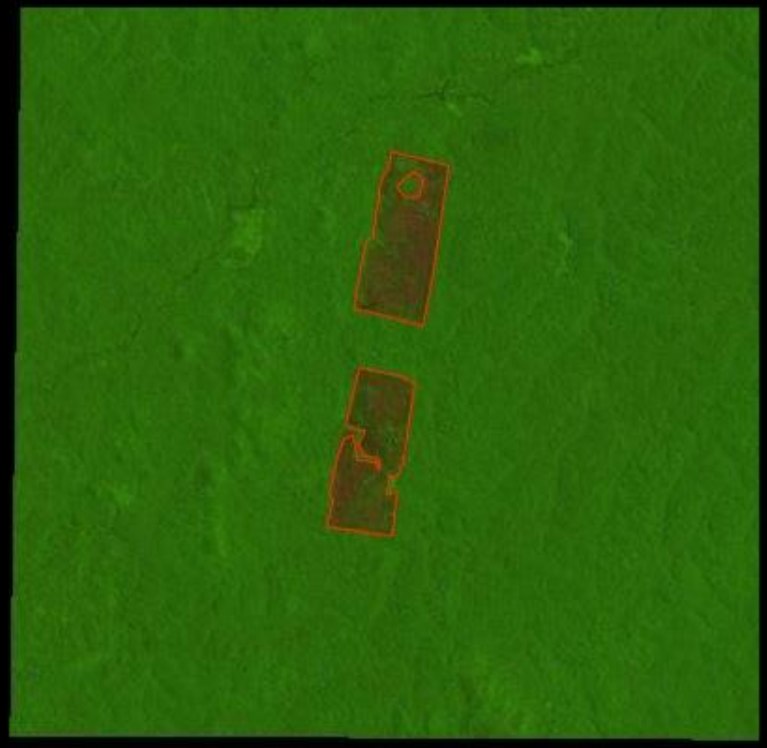
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 275



Observed

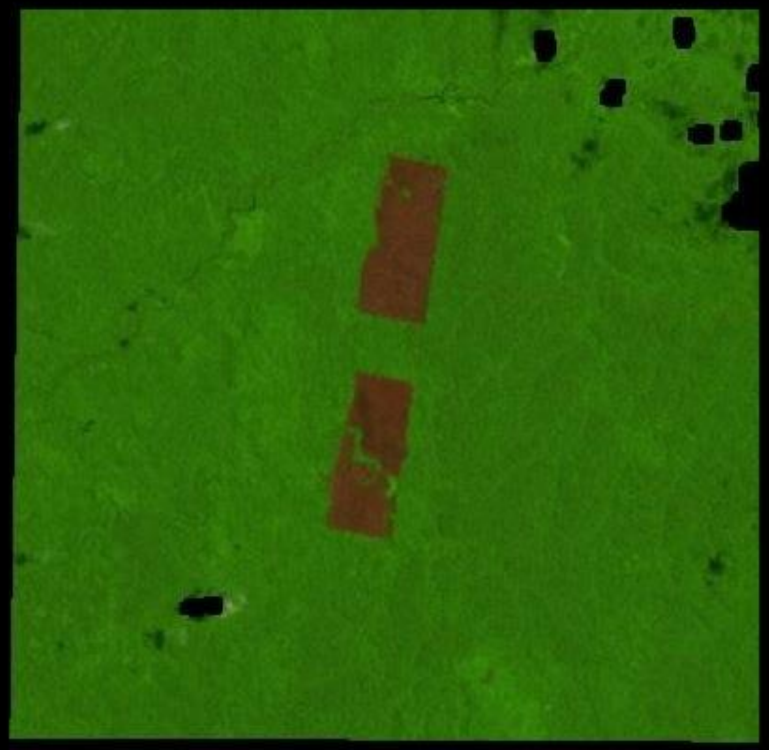


Predicted

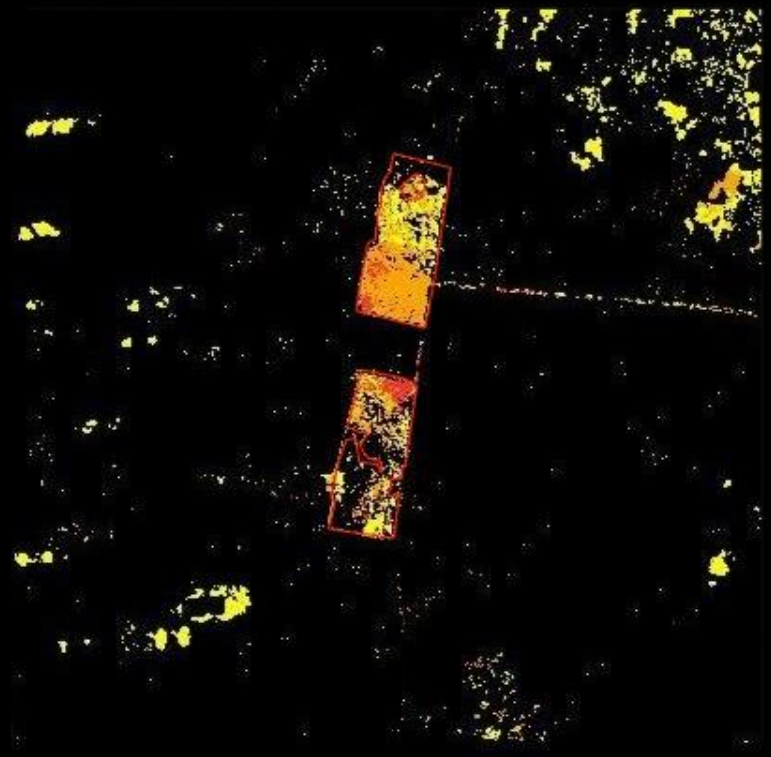
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 275



Observed

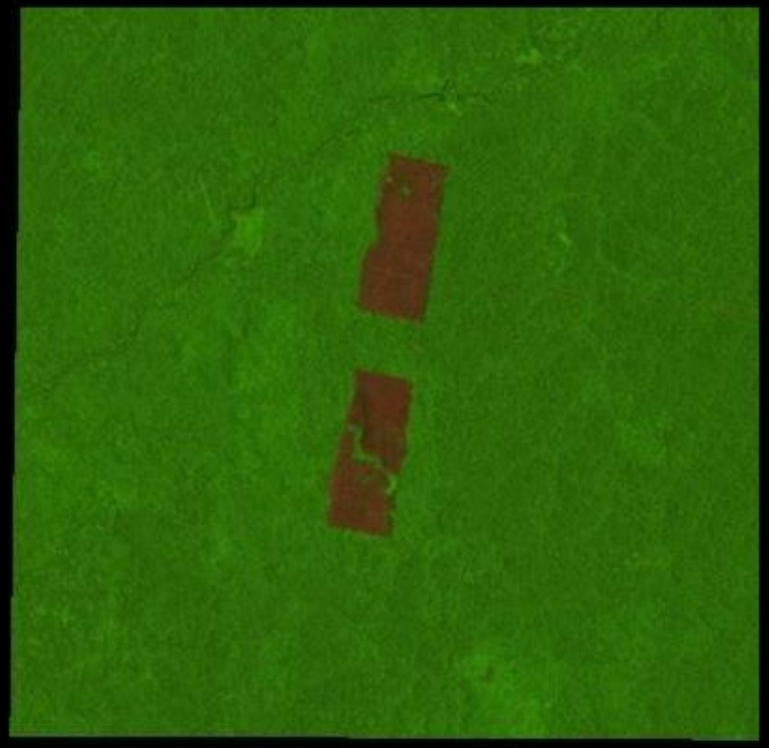


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 283



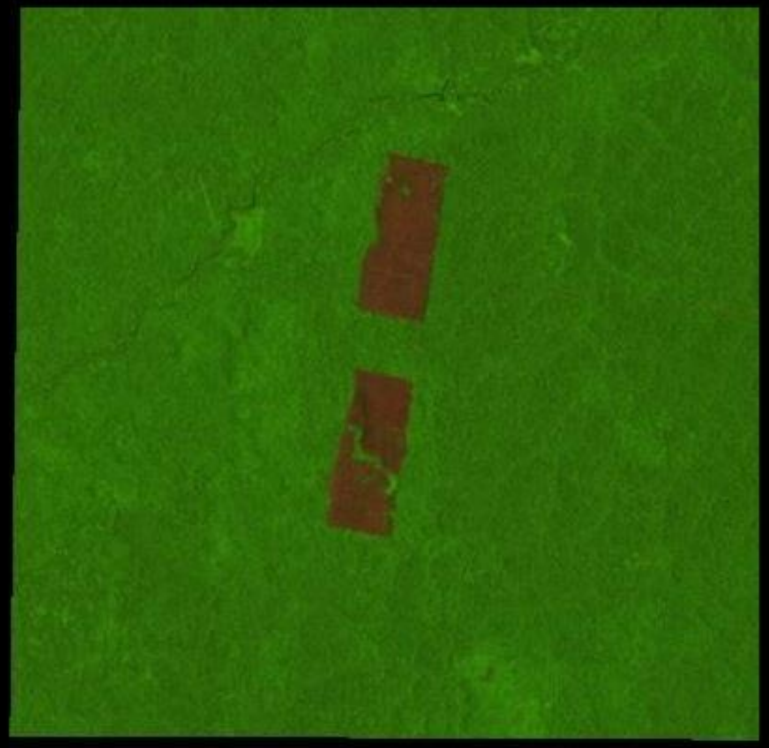
Observed

Predicted

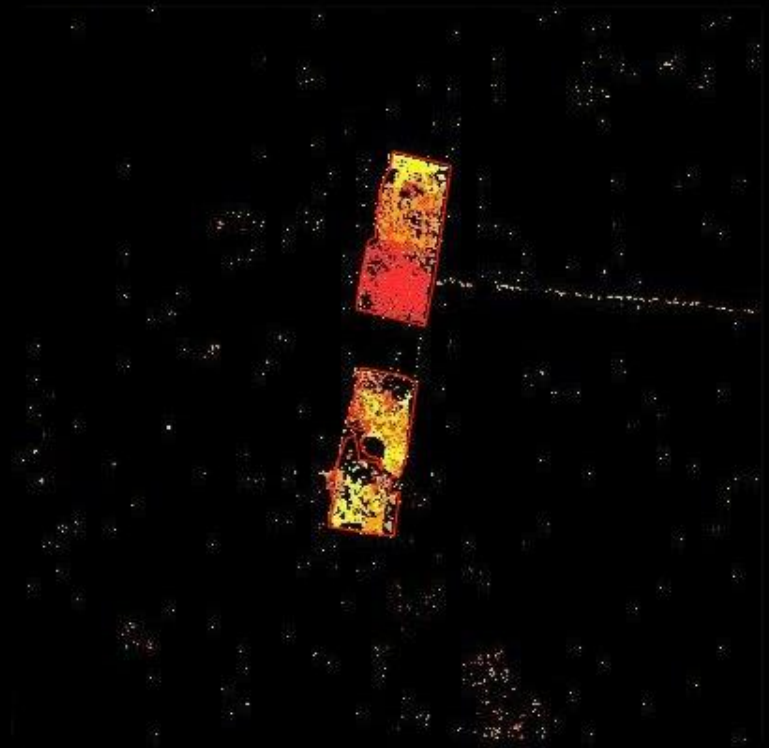
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 283



Observed

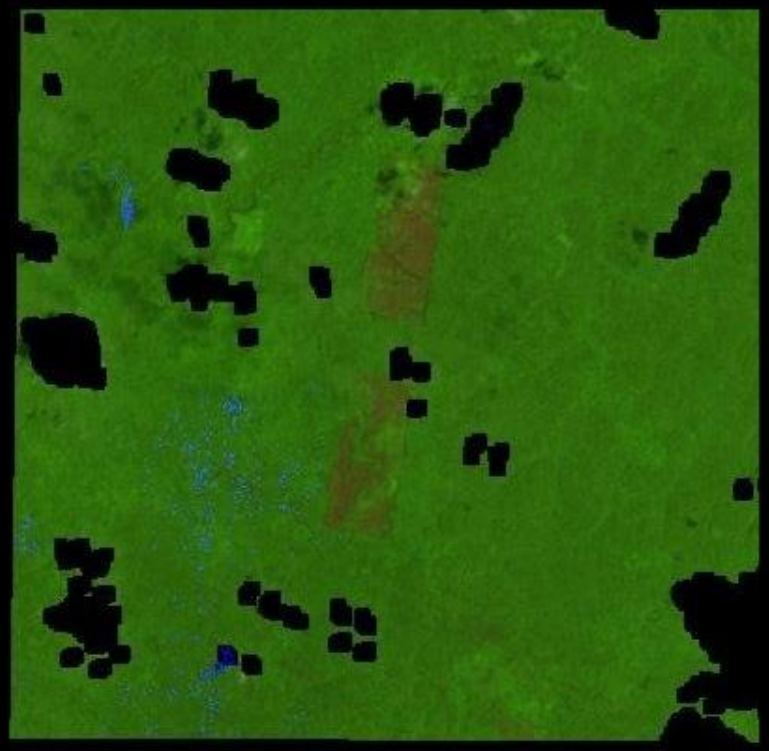


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 315



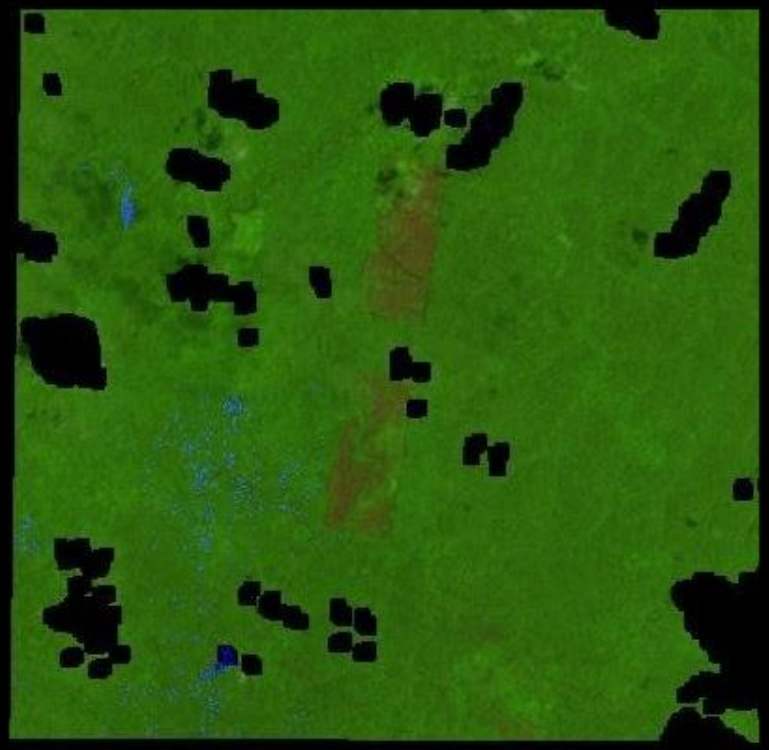
Observed

Predicted

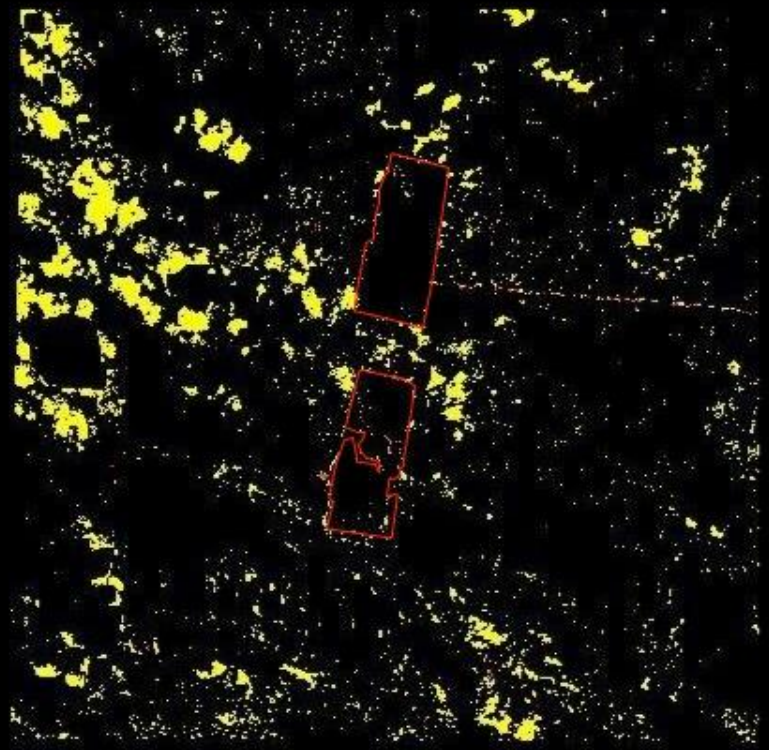
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2001 - 315



Observed

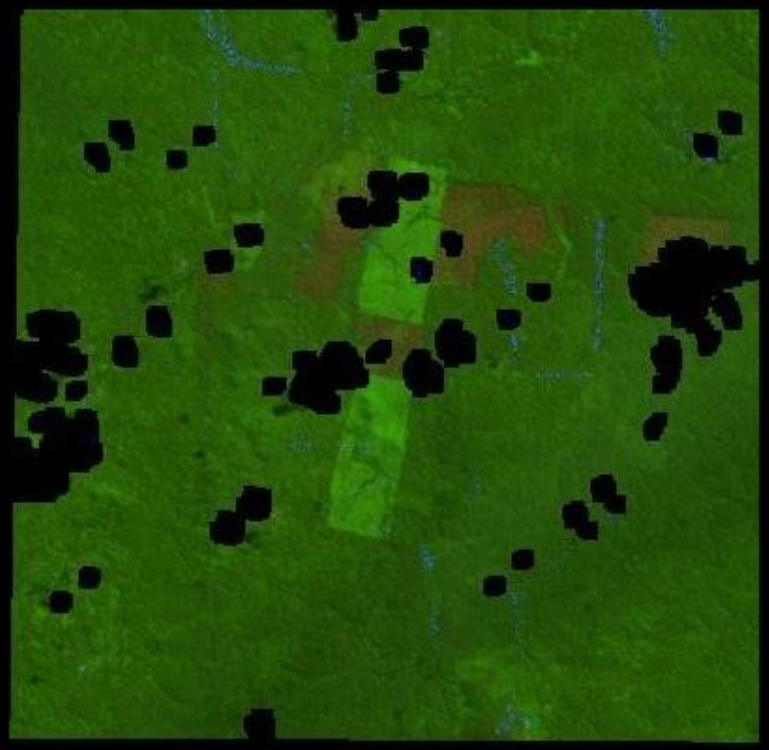


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 134



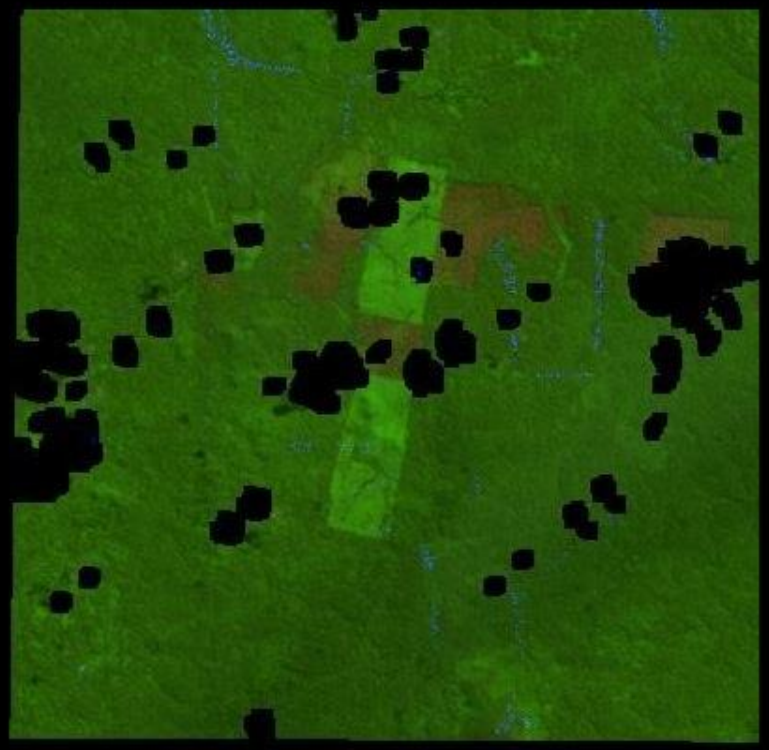
Observed

Predicted

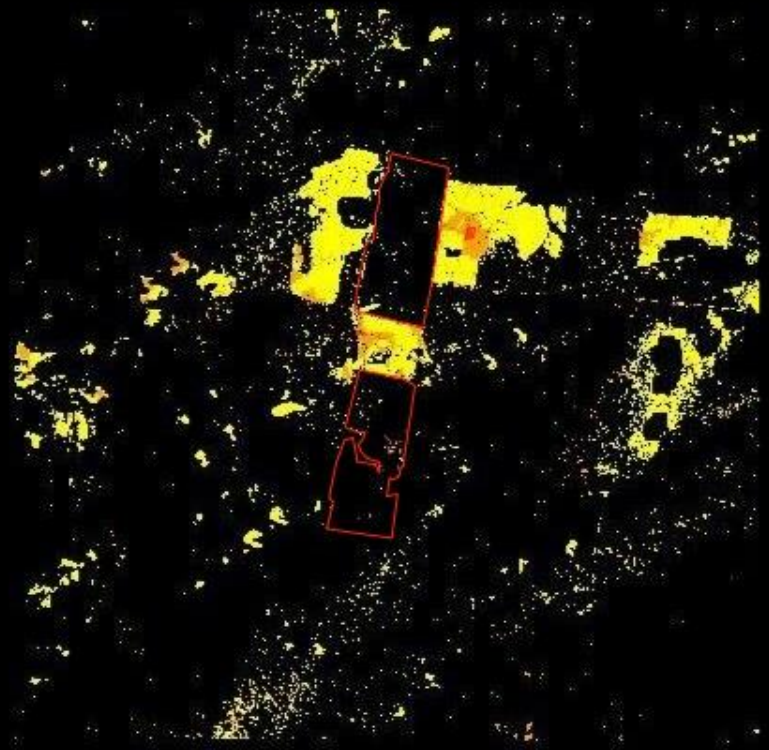
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 134



Observed



Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 150

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 150

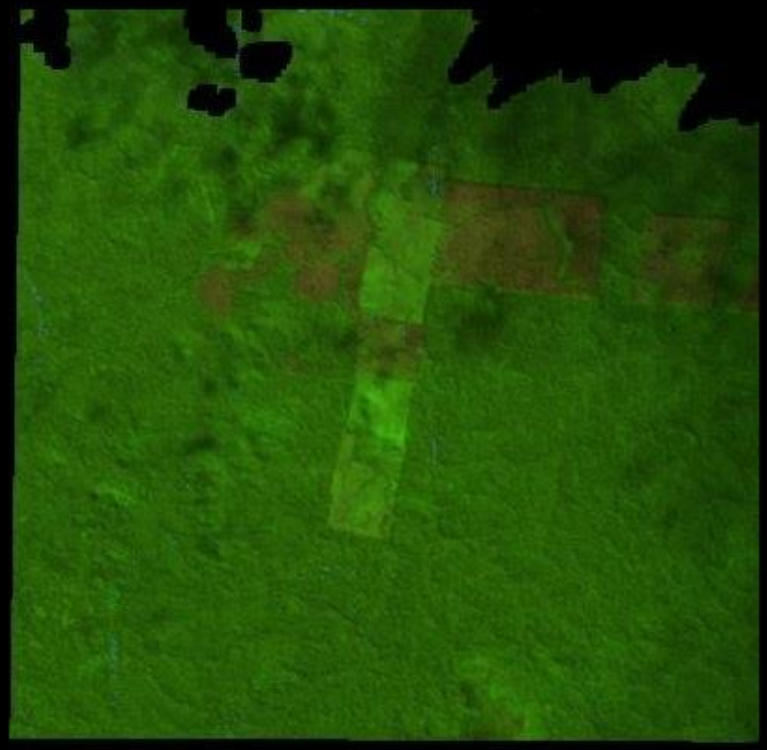
Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 166



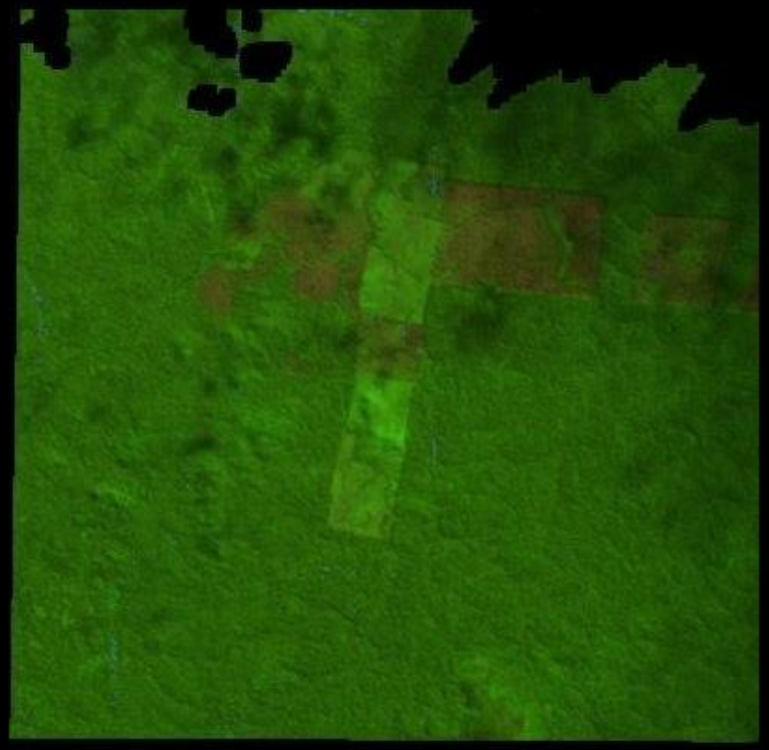
Observed

Predicted

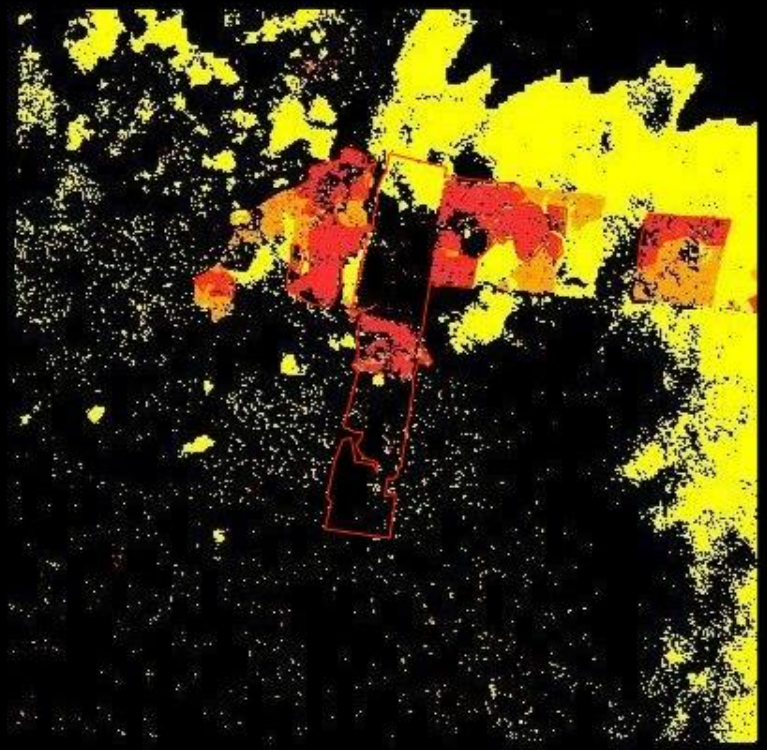
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 166



Observed

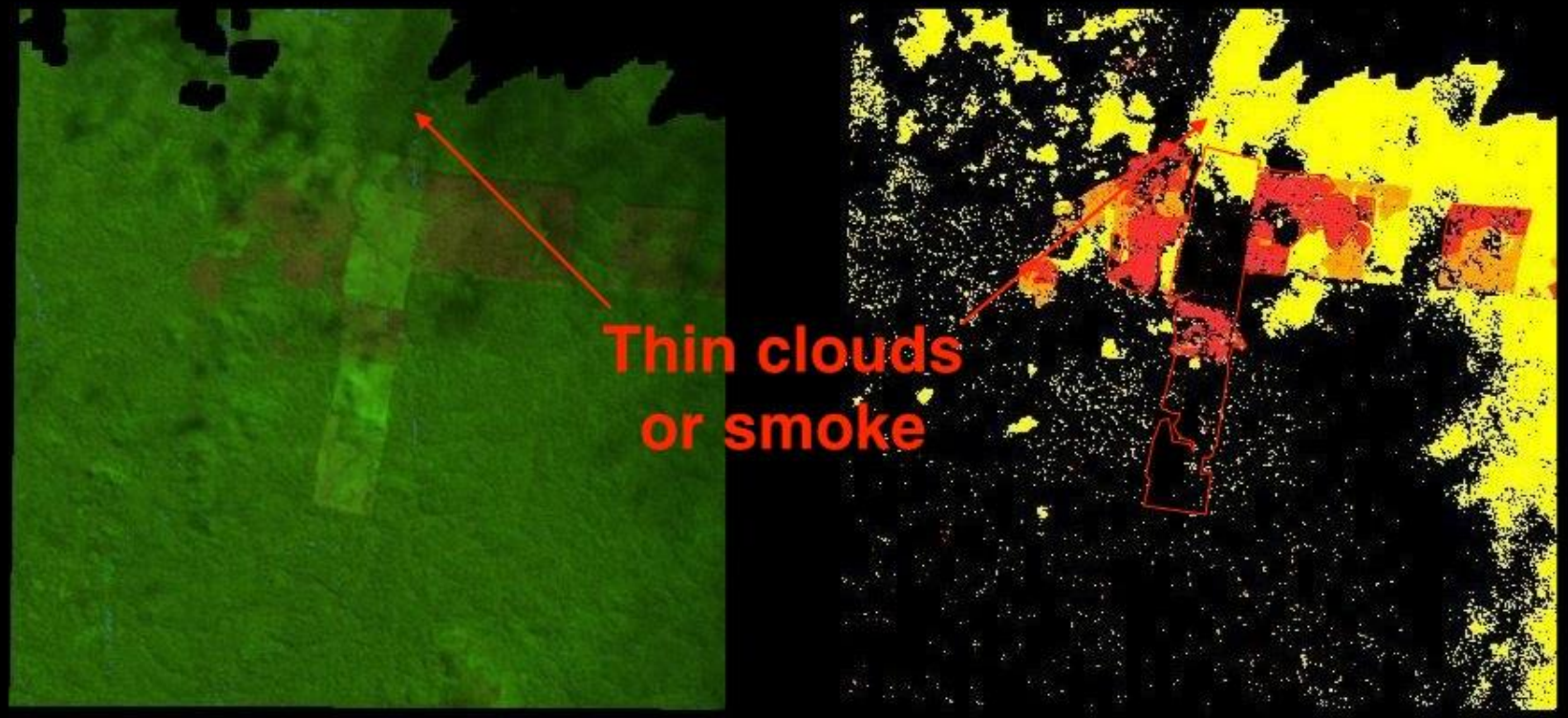


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 166



Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 182

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 182

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 214

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 214

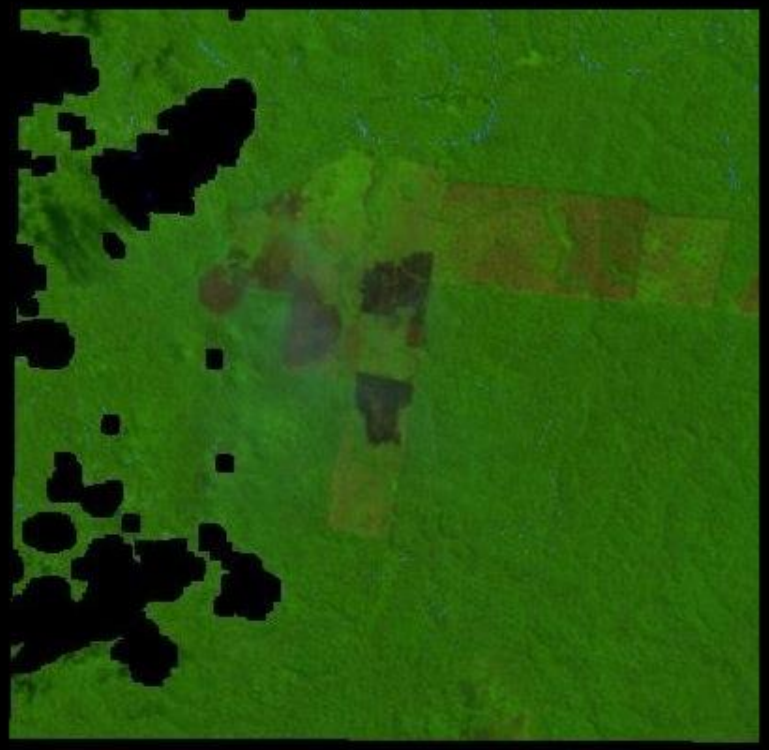
Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 230



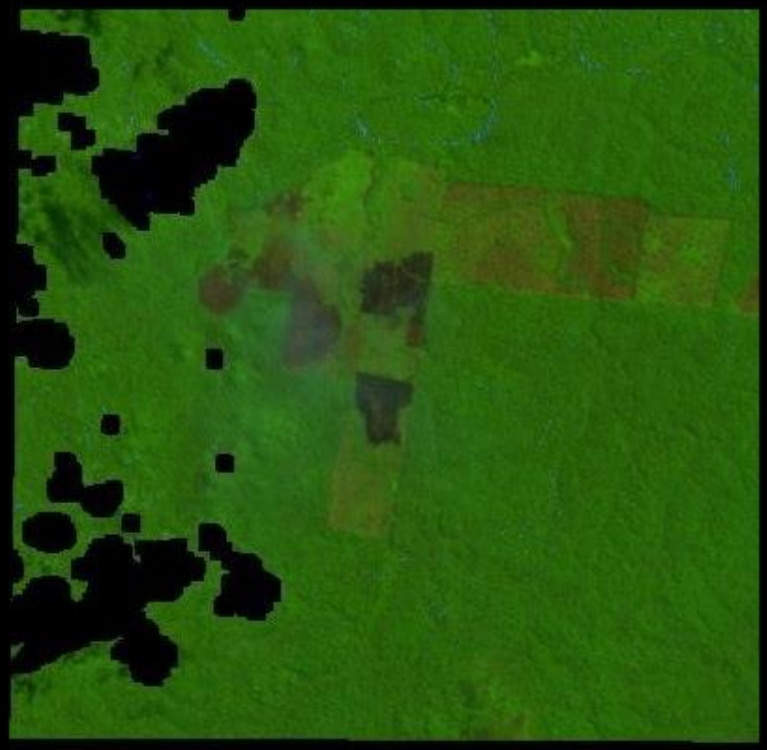
Observed

Predicted

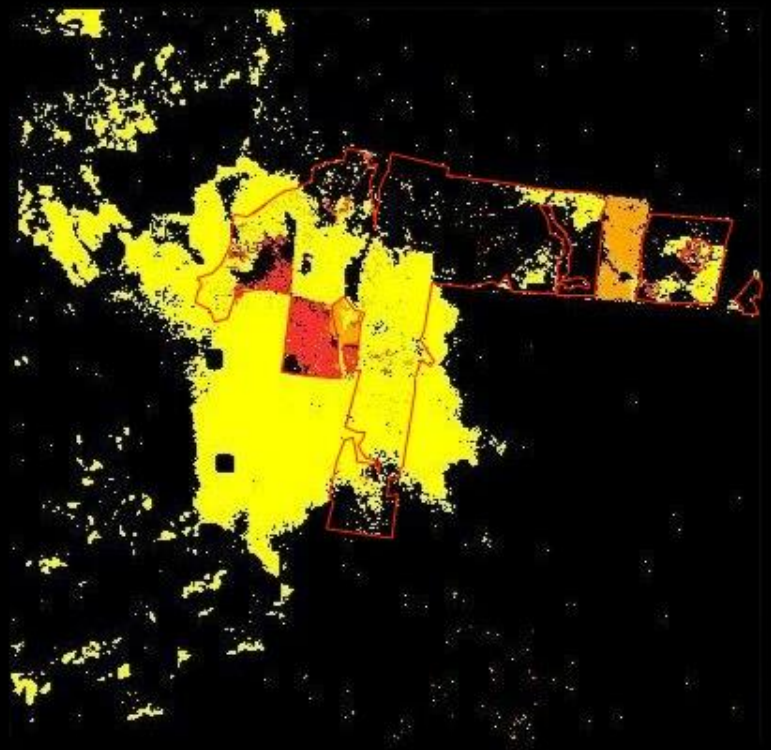
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 230



Observed



Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 246

Observed

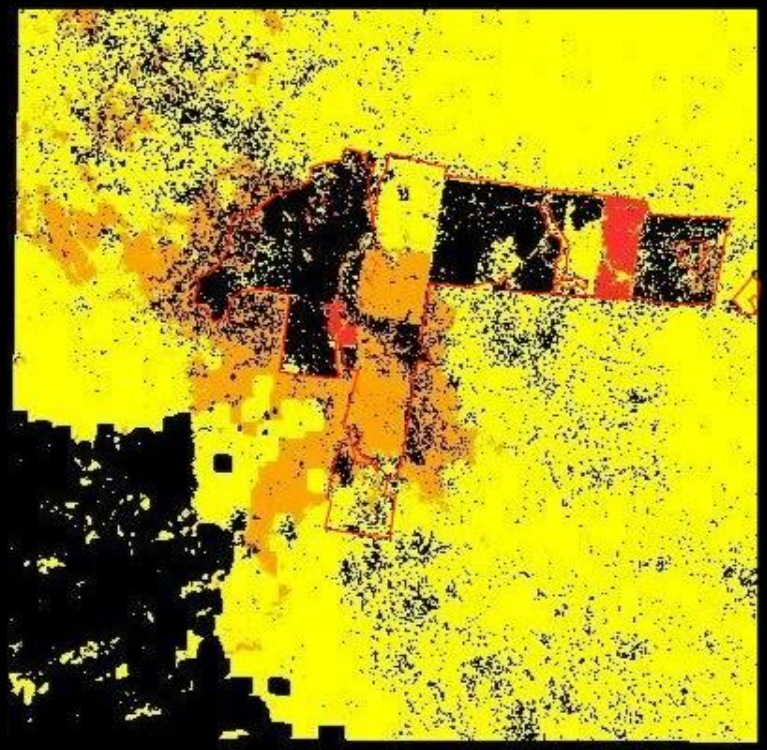
Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 246

Observed

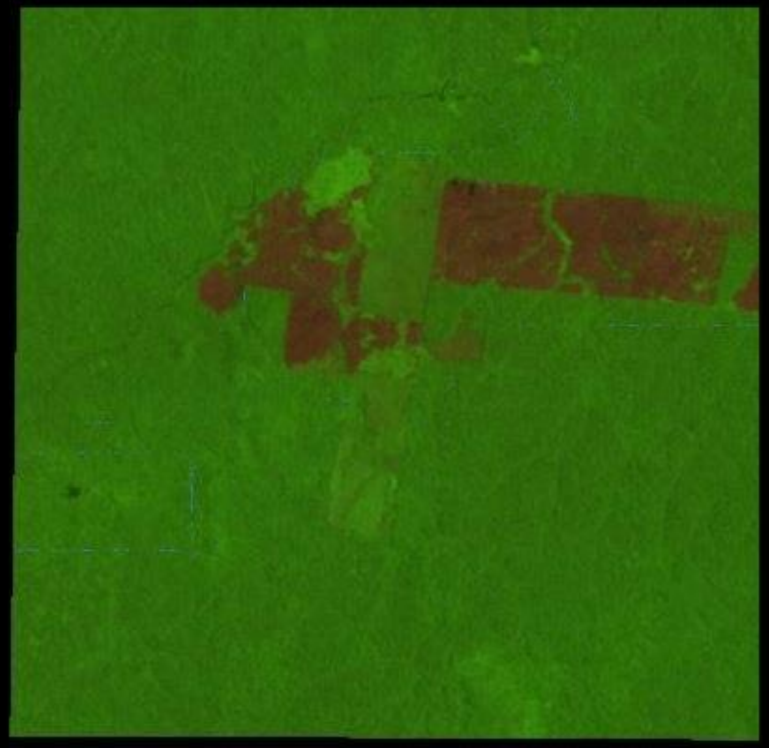


Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 262



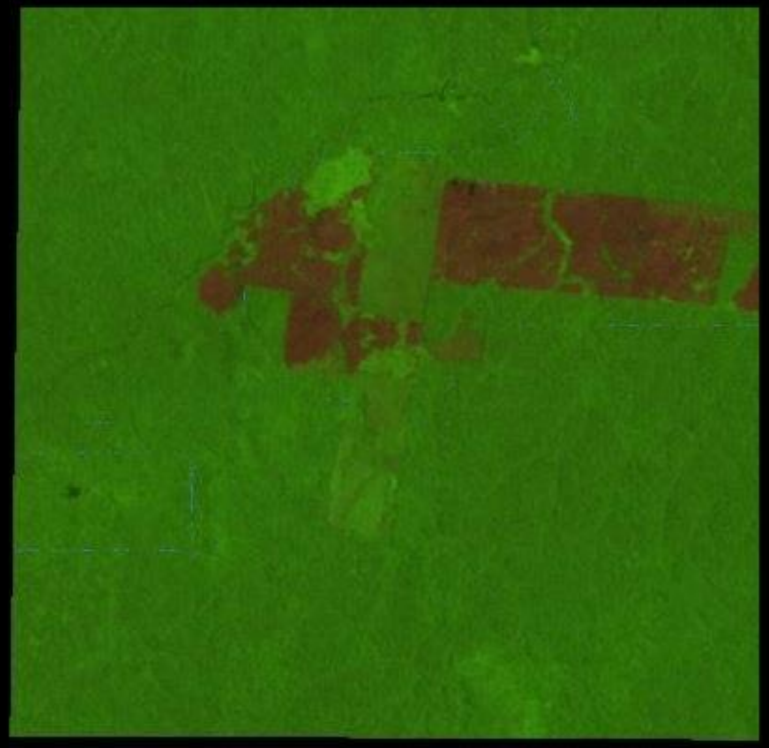
Observed

Predicted

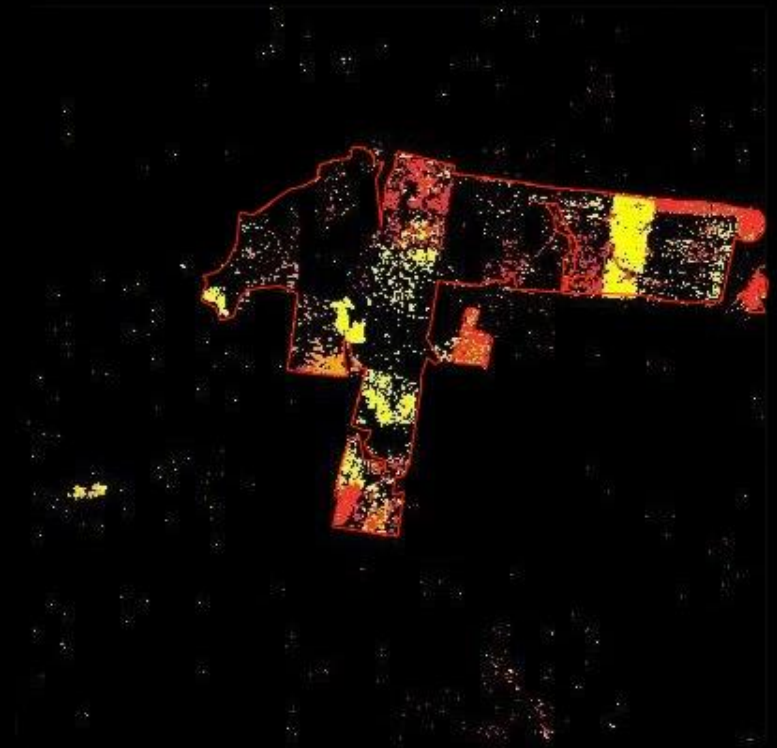
Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2002 - 278



Observed



Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2003 - 137

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2003 - 137

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2003 - 193

Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

2003 - 193

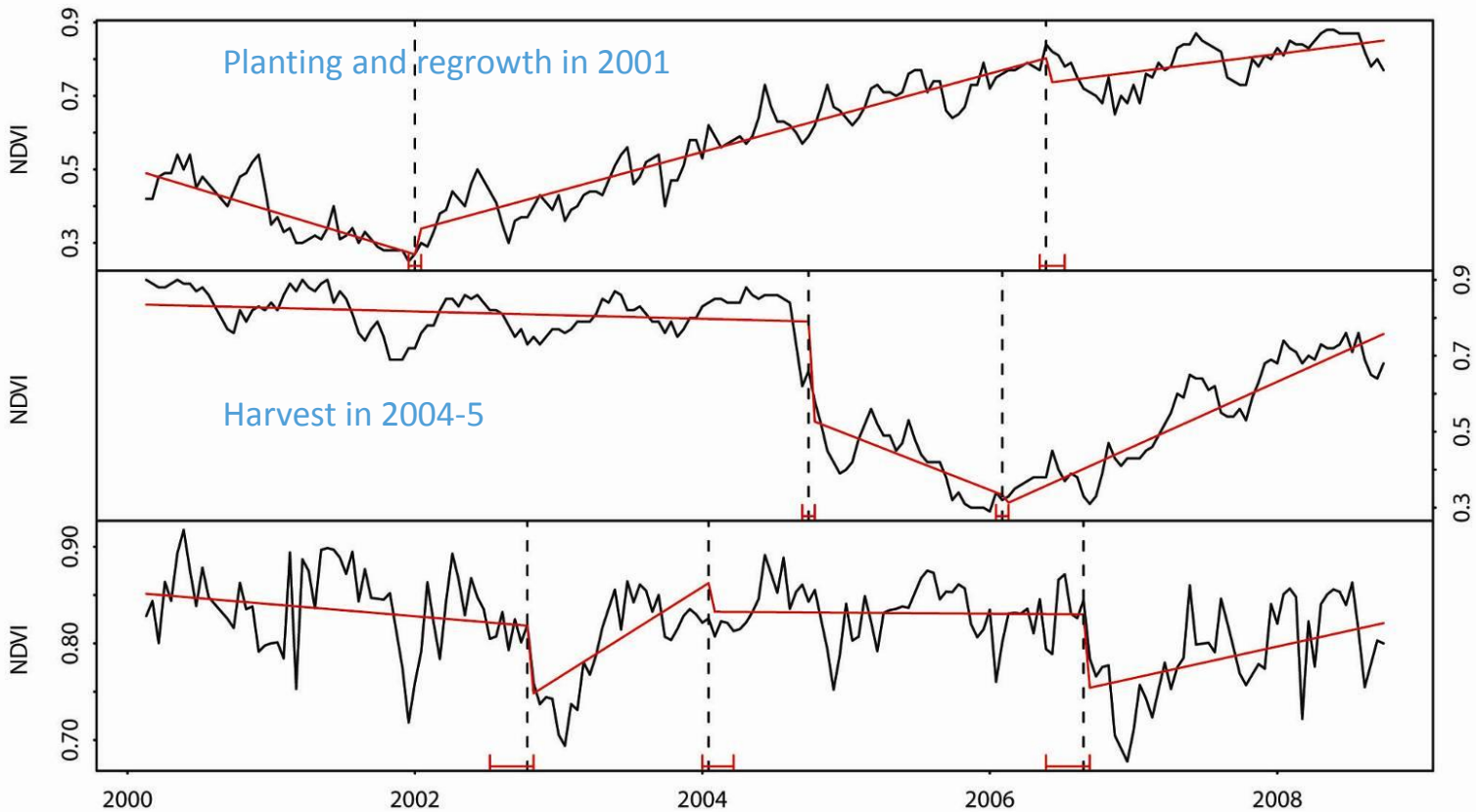
Observed

Predicted

Threshold:

- 1 Day
- 2 Day
- 3 Day (Change)
- Detected Change Area

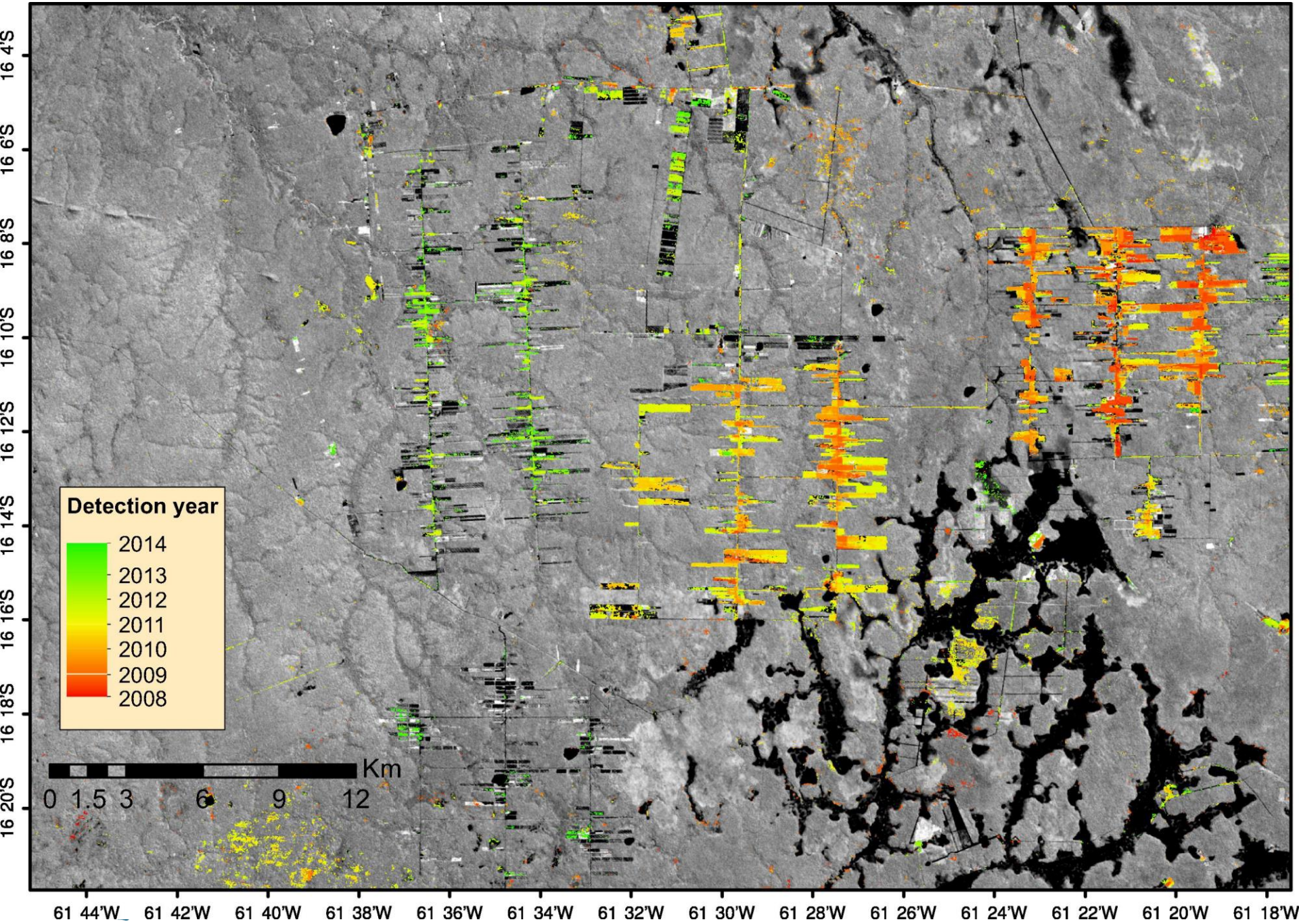
BFAST method



Drought stress in 2003 and tree Mortality in 2007

WAGENINGEN UR
For quality of life

Verbesselt, J., Hyndman, R., Newnham, G., & Culvenor, D. (2010). Detecting trend and seasonal changes in satellite image time series. RSE.


Detection year
2014
2013
2012
2011
2010
2009
2008
Km
0 1.5 3 6 9 12
16 4'S
16 6'S
16 8'S
16 10'S
16 12'S
16 14'S
16 16'S
16 18'S
16 20'S
61 44'W
61 42'W
61 40'W
61 38'W
61 36'W
61 34'W
61 32'W
61 30'W
61 28'W
61 26'W
61 24'W
61 22'W
61 20'W
61 18'W

Free R toolkit: BFASTspatial

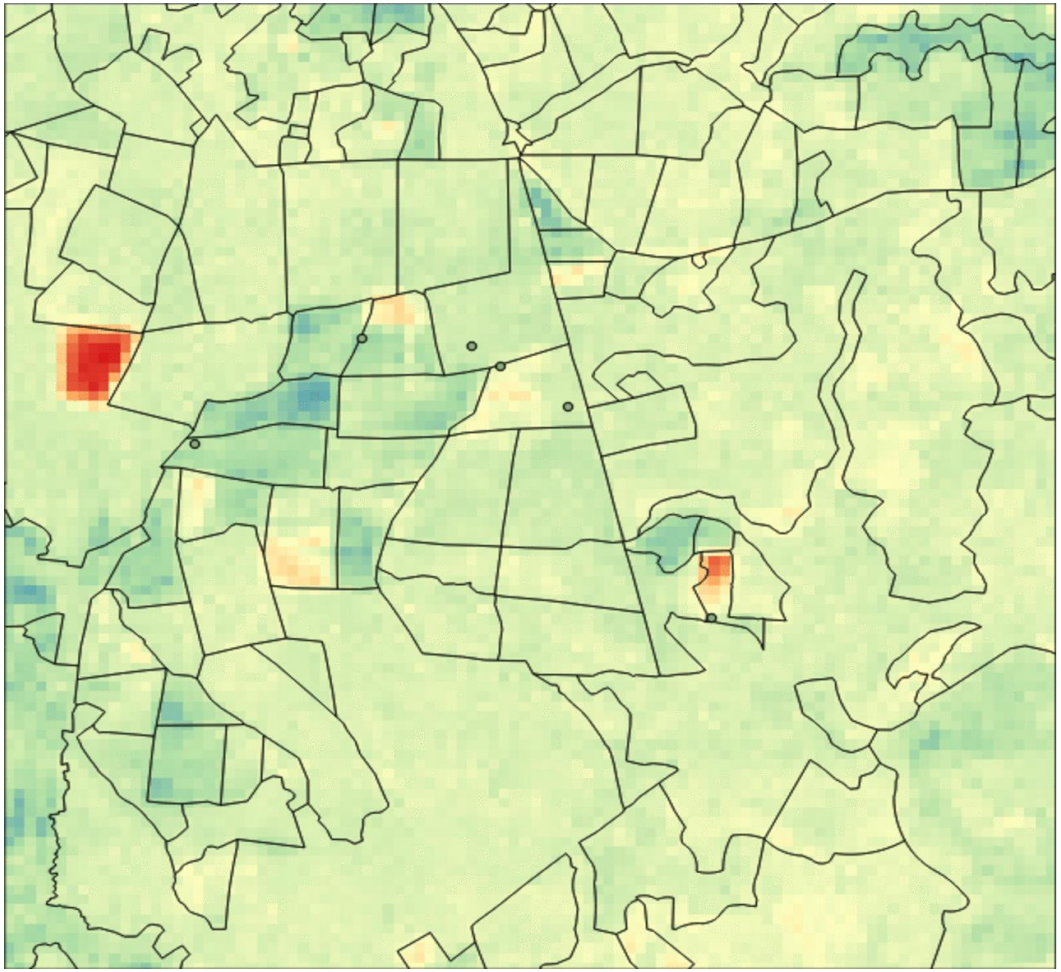
- Change detection using Landsat and MODIS data
  - Loïc Dutrieux, Ben DeVries, Jan Verbesselt

- http://github.com/dutri001/bfastSpatial
- Fully documented with tutorial and presentation

Tutorial session

- bfastSpatial
  - Intro:
    - http://dutri001.github.io/bfastSpatial/quickStart#/
  - Tutorial:
    - https://dutri001.github.io/bfastSpatial/
- Interactive application of change monitoring:
  - https://loicdutrieux.shinyapps.io/bfmApp/
- Community based monitoring
  - www.cbm.wur.nl

BFAST Monitor Time Series Analysis
2008 – 2015 implemented in FAO OpenForis and SEPAL



Strong Negative Change

-3787.000000
-2093.250000
-399.500000
1294.250000
2988.000000

Strong Positive Change

Atopixco, Mexico, 10 x 10 km site

Community timber management

460 Landsat acquisitions analyzed

Linked with timber harvest and planting records including thinning

WAGENINGEN UR
For quality of life

BEEODA: a suite of open-source software and educational materials for processing Earth Observation data

Email: olofsson@bu.edu
bullocke@bu.edu

Web: http://beeoda.org

GitHub: http://github.com/beeoda

BEEODA

BEEODA

beeoda.org/

Search

Home | About | Services | Modules | Contact | BEEODA Team

Open Source Modules

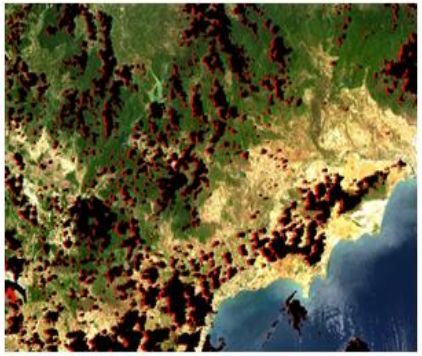
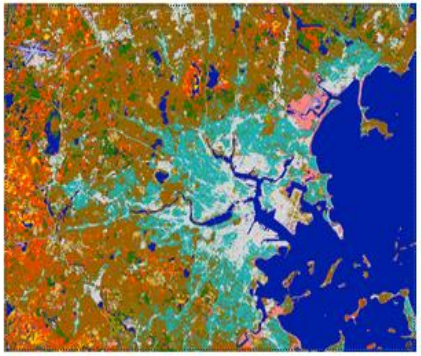
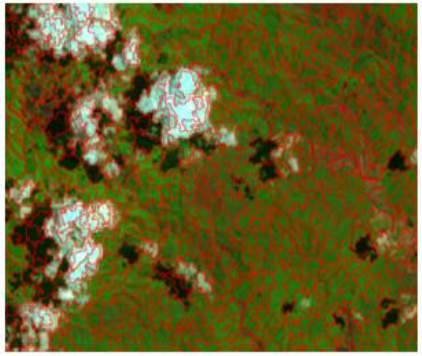


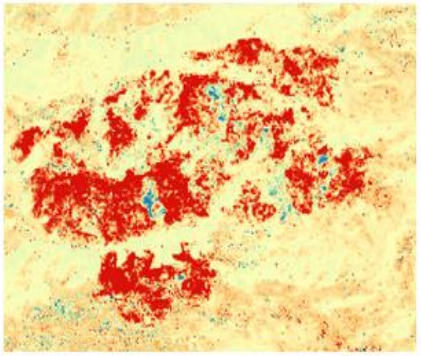
Image Pre-Processing
Downloading, atmospheric correction, etc



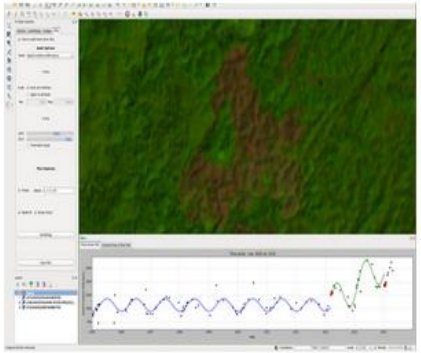
Classification
Random forest, etc



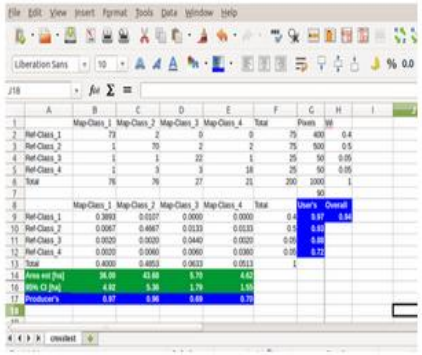
Object-Based Analysis
Segmentation and Classification



Change Detection
Direct Classification, PCA, MAD, etc



Time Series Analysis
CCDC, YATSM, etc



Area and Accuracy Estimation
Statistical inference

BOSTON UNIVERSITY