National Aeronautics and Space Administration

Advanced Webinar: Change Detection for Land Cover Mapping

Cindy Schmidt and Amber McCullum

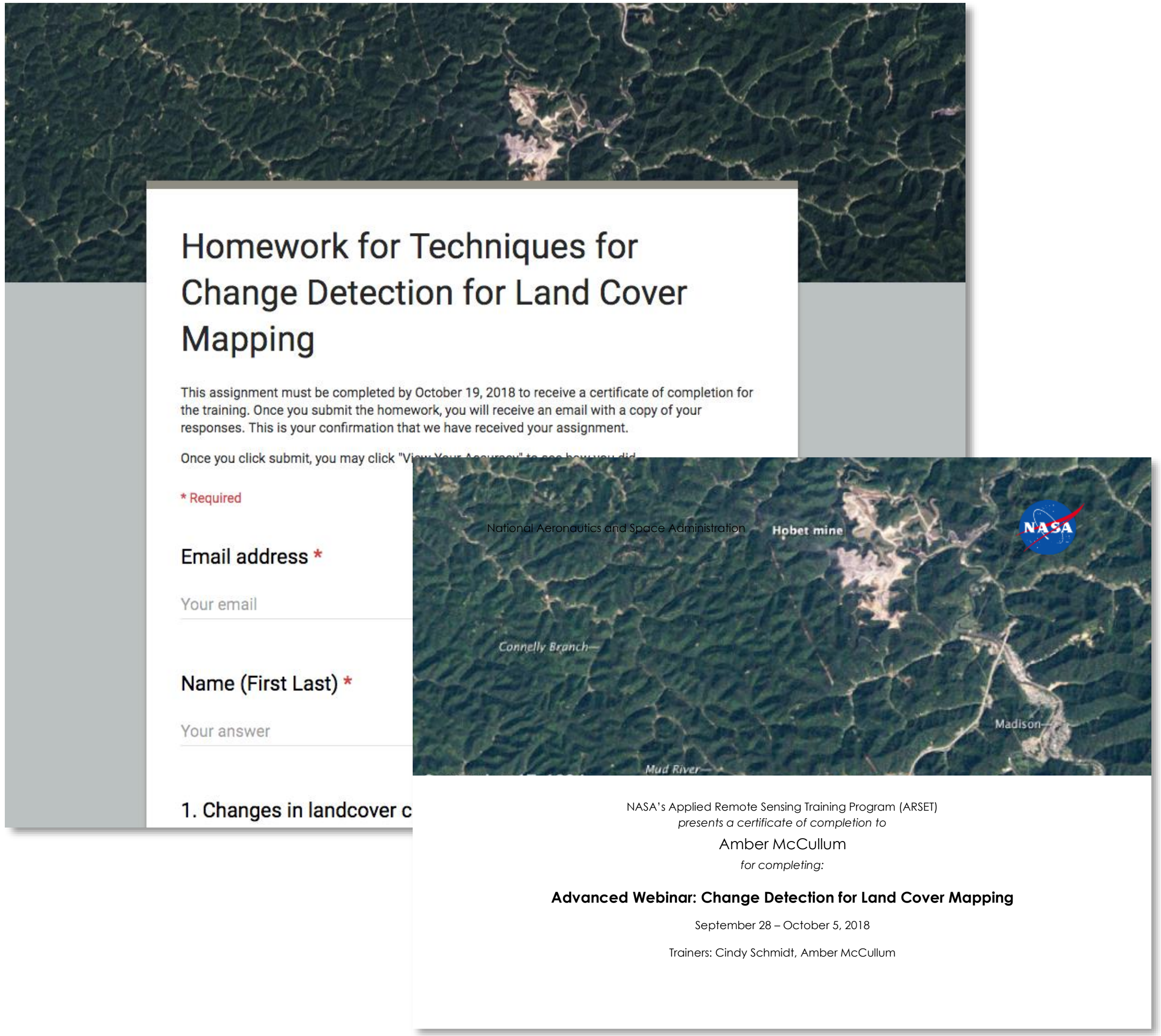
September 28, 2018

Course Structure

- Two, two-hour sessions on Friday, September 28, and Friday, October 5, 2018
- The same content will be presented at two different times each day:
  - Session A: 10:00-12:00 EDT (UTC-4)
  - Session B: 18:00-20:00 EDT (UTC-4)
  - **Please only sign up for and attend one session per week**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - https://arset.gsfc.nasa.gov/land/webinars/adv-change18
  - Q&A: Following each lecture and/or by email
    - cynthia.l.schmidt@nasa.gov, or
    - amberjean.mccullum@nasa.gov

Homework and Certificates

- Homework
  - One homework assignment
  - Answers must be submitted via Google Forms
- Certificate of Completion:
  - Attend both live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
    - HW Deadline: Oct 19^{th}
  - You will receive certificates approx. two months after the completion of the course from: marines.martins@ssaihq.com



Homework for Techniques for Change Detection for Land Cover Mapping

This assignment must be completed by October 19, 2018 to receive a certificate of completion for the training. Once you submit the homework, you will receive an email with a copy of your responses. This is your confirmation that we have received your assignment.

* Required

Email address *

Your email

Name (First Last) *

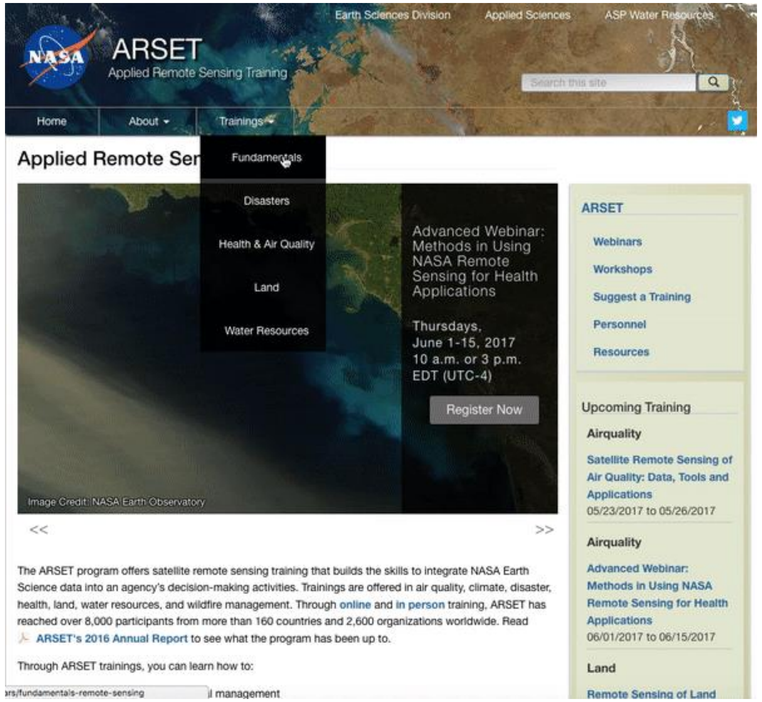
Your answer

1. Changes in landcover c

NASA's Applied Remote Sensing Training Program (ARSET)
presents a certificate of completion to
Amber McCullum
for completing:
Advanced Webinar: Change Detection for Land Cover Mapping
September 28 – October 5, 2018
Trainers: Cindy Schmidt, Amber McCullum

Prerequisites

- [Fundamentals of Remote Sensing]
  – Sessions 1 and 2A (Land)
  – On demand webinar, available anytime
- [Advanced Webinar: Land Cover Classification with Satellite Imagery]
- [Download and install QGIS] and all accompanying software Use this exercise for help: [Downloading and Installing QGIS]
- Download and install the R statistical program
- Download and install R Studio



Accessing Course Materials

https://arset.gsfc.nasa.gov/land/webinars/adv-change18

Earth Sciences Division | Applied Sciences | ASP Water Resources

NASA ARSET
Applied Remote Sensing Training

Search this site

Home | About | Trainings

Advanced Webinar: Change Detection for Land Cover Mapping

Dates: Friday, September 28, 2018 to Friday, October 5, 2018
Times: 10:00-12:00 and 18:00-20:00 EDT (UTC-4)
Registration Closes: Thursday, September 27, 2018

Land cover changes can impact many areas of life. These changes can affect deforestation, ecological communities, wildfire extent, and urban growth. This advanced series will focus on using satellite imagery to map changes in land cover. Attendees will learn change detection methods, including image subtraction and classification. They will also conduct their own change detection analysis. This training will use QGIS, the R statistical program, and the Random Forest algorithm. Both sessions will feature a lecture, time to complete a hands-on exercise, and time for questions.

Read more about the image above at NASA Earth Observatory.

Learning Objectives:

- Become familiar with Landsat bands and color combinations
- Understand how to visualize change in land cover using Landsat data
- Learn the basic steps for change detection by:
  - Conducting image subtraction between two dates using QGIS
  - Creating multi-date Landsat layer stacks
  - Conducting multi-date land cover classification using the Random Forest classification in R
  - Identifying and analyzing changes in land cover

Course Format:

- Two, two-hour sessions
- Sessions will be on Fridays, September 28 and October 5, with the same content being presented at 10:00 and 18:00 EDT (UTC-4)

Land Management

- Online Trainings
- In-Person Trainings

Upcoming Training

Disasters

Advanced Webinar: Radar Remote Sensing for Land, Water, & Disaster Applications; Capacitación en Línea Avanzada: La Teledetección por Radar y sus Aplicaciones para la Tierra, el Agua y Desastres
08/07/2018 to 08/16/2018

Airquality

High Temporal Resolution Air Quality Observations from Space
09/04/2018 to 09/25/2018

Water

Advanced Webinar: Processing Satellite Imagery for Monitoring Water Quality; Capacitación en Línea Avanzada: Procesamiento de Imágenes Satelitales para el Monitoreo de la Calidad del Agua
09/05/2018 to 09/19/2018

Course Format:

- Two, two-hour sessions
- Sessions will be on Fridays, September 28 and October 5, with the same content being presented at 10:00 and 18:00 EDT (UTC-4)
  - Convert to your local time »
- A certificate of completion will be provided to participants that attend all live webinars and complete the homework assignment. Note: Certificates of completion only indicate the attendee participated in all aspects of the training. They do not imply proficiency on the subject matter, nor should they be seen as a professional certification.

Prerequisites:

- Complete Sessions 1 & 2A of *Fundamentals of Remote Sensing*, or equivalent experience
- Download and install QGIS and all accompanying software.
  - Further instructions to come on which version of QGIS will be used during this training
  - This advanced training will use QGIS software, and although previous experience with this software is not required, some experience with geospatial software will be helpful. **We strongly recommend you open QGIS and ensure the software is working prior to starting the webinar.**
- Download and install the R statistical program – http://www.r-project.org/ - an open source statistical program that will be used for the classification algorithm called Random Forest, a type of decision tree classifier.
  - Download and install R studio – http://www.rstudio.com/ide/download/
  - Freely available graphical user interface which, although not required for the methodology, it will provide a more user-friendly interface for running the R statistical program, especially for users unfamiliar with R.

Audience:

Local, regional, state, federal, and international organizations interested in assessing vegetation conditions and analyzing land cover changes using satellite imagery. Professional organizations in the public and private sectors engaged in environmental management and monitoring will be given preference over organizations focused primarily on research.

Registration Information:

There is no cost for the webinar, but you must register to attend the sessions. Because we anticipate a high demand for this training, please only sign up for one session.

- Register for Session A, 10:00-12:00 EDT (UTC-4) »
- Register for Session B, 18:00-20:00 EDT (UTC-4) »

Course Agenda:

Agenda.pdf

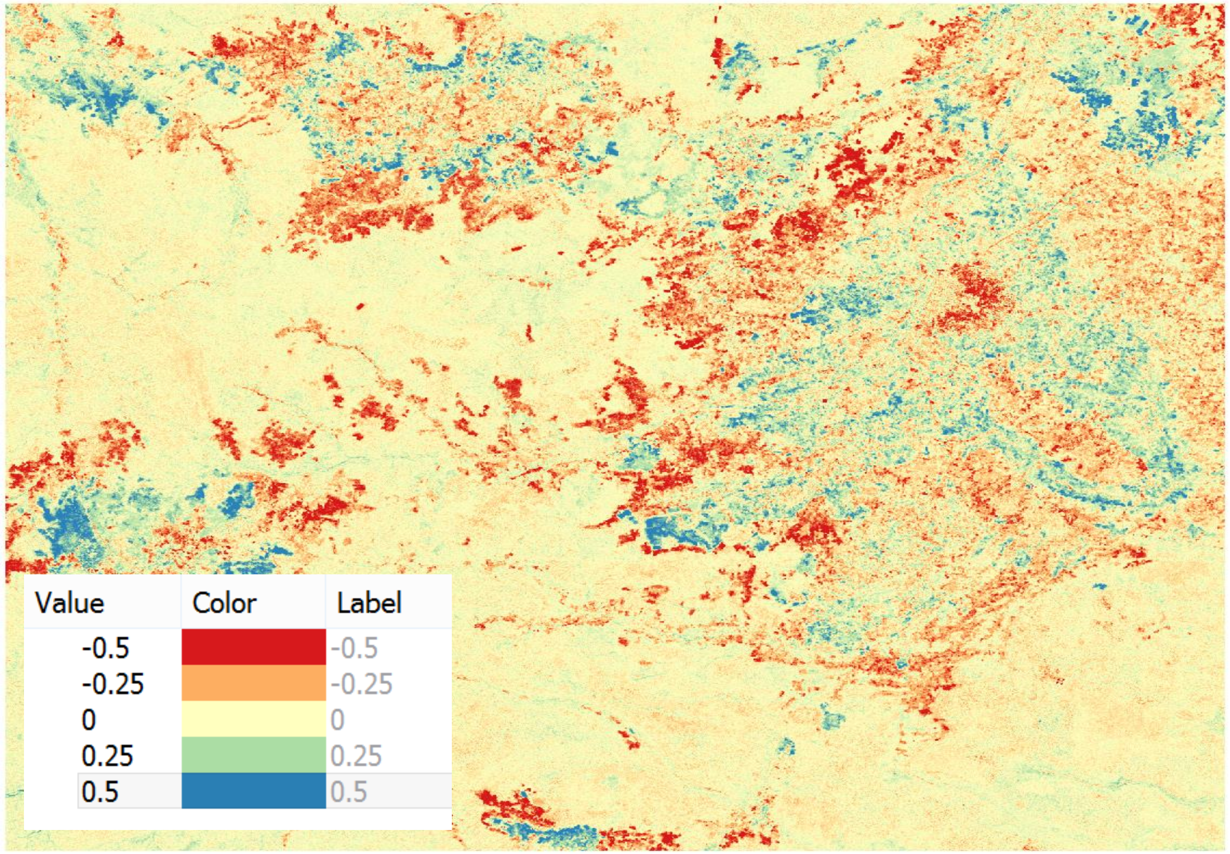
Session One: September 28

This session will focus on an introduction to change detection. Included will be an overview of change detection, how to visualize change, and how to analyze land cover change using the image subtraction method.

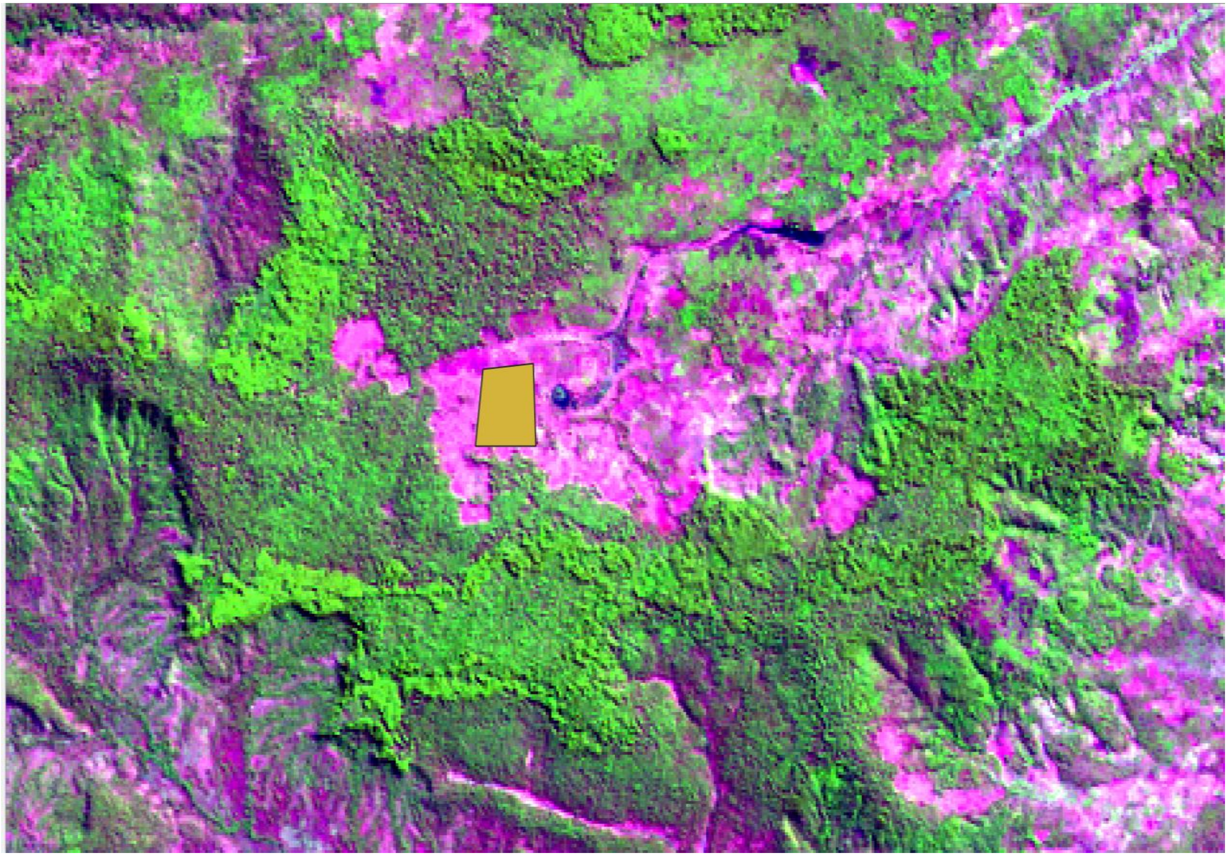
Session Two: October 5

This session will continue with conducting a change detection analysis and will include analyzing land cover change using different classification methods.

Course Outline



Session 1: Introduction to Change Detection



Session 2: Conducting Change Detection with QGIS & R

Session 1 Agenda

- Change Detection Overview
- Change Detection Methods
  - Visualizing change
  - Image subtraction
  - Image classification
- Exercise: Visualizing change using QGIS

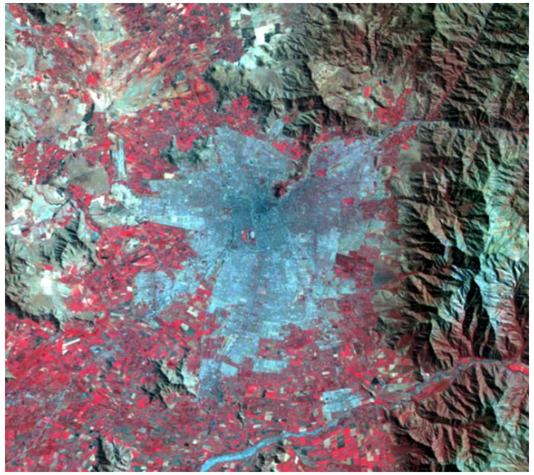
1984

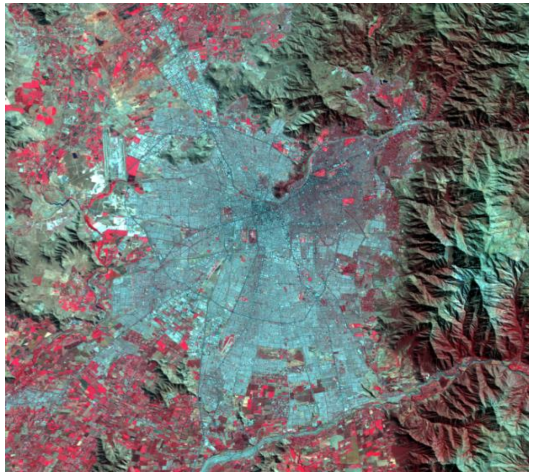
2015

Change Detection Overview

What is Change Detection?

- The conversion of the landscape from one dominant feature type to another
- Examples:
  - Changes in tree cover due to wildfire or land clearing
  - Urbanization
  - Land degradation due to over grazing
- Information that can be derived from satellites:
  - Where and when has change taken place?
  - How much and what kind of change has occurred?
  - What are the cycles and trends in the change?

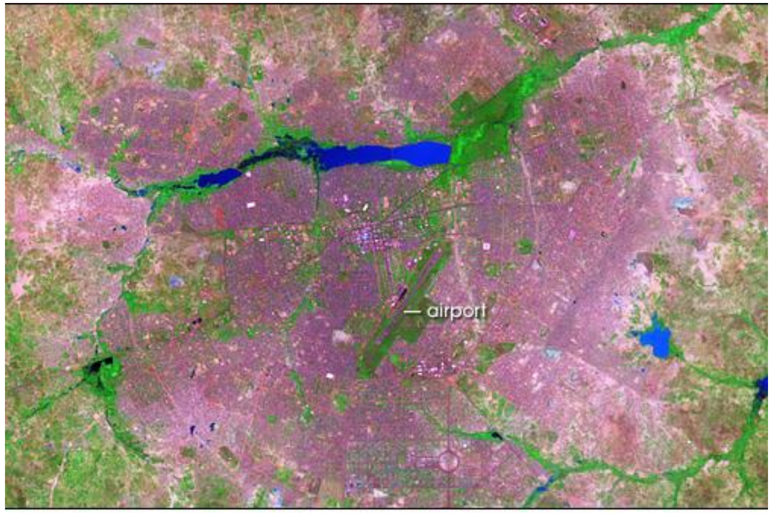




Images: Santiago, Chile urban growth from 1975 (top) to 2013 (bottom) from Landsat. Source: USGS

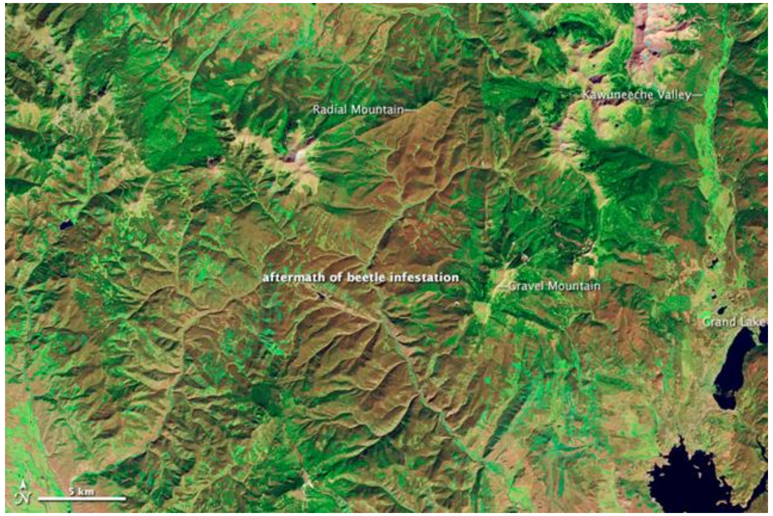
Broad Categories of Change

- Change in shape or size of patches of land cover types (urbanization)
- Slow changes in cover type or species composition (succession) vs. abrupt land cover transitions (wildfire, deforestation)



Urbanization in Burkina Faso, 2006

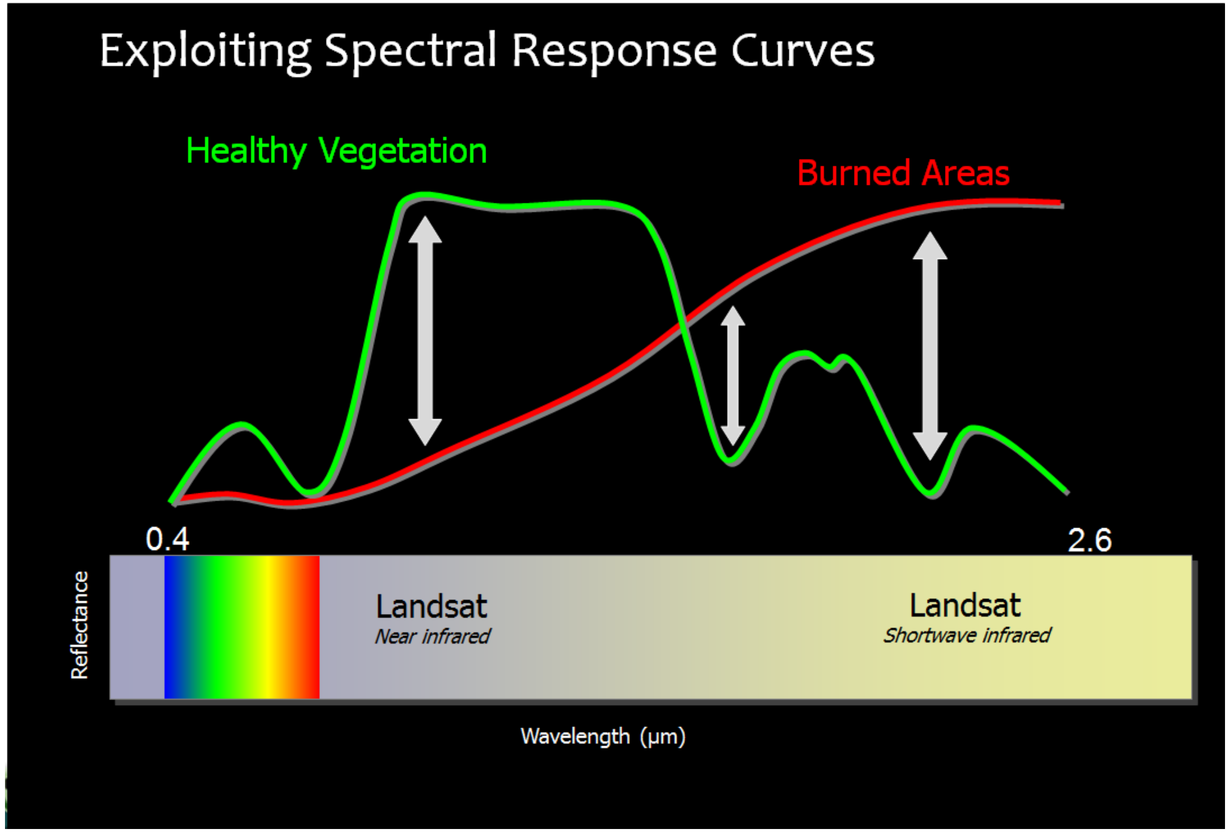
- Slow changes in condition of a single cover type (forest degradation due to insect or disease)
- Changes in timing of extent of seasonal processes (drought monitoring)



Bark Beetle Infestation: Colorado, 2011

Change Detection Using Remote Sensing

- Changes on the landscape can be detected as changes in the spectral value of pixels
- Example pre and post burn:
  - Healthy vegetation has high reflectance in the G and NIR but low in the SWIR
  - Burned areas have low reflectance in the G and NIR but high in the SWIR



Change Detection Goals

- Identification of the geographical location and types of changes
- Quantification of changes
- Assessment of the accuracy of the change detection results

Identifying the location of and quantifying change is easy.

Identifying the cause of change is not.

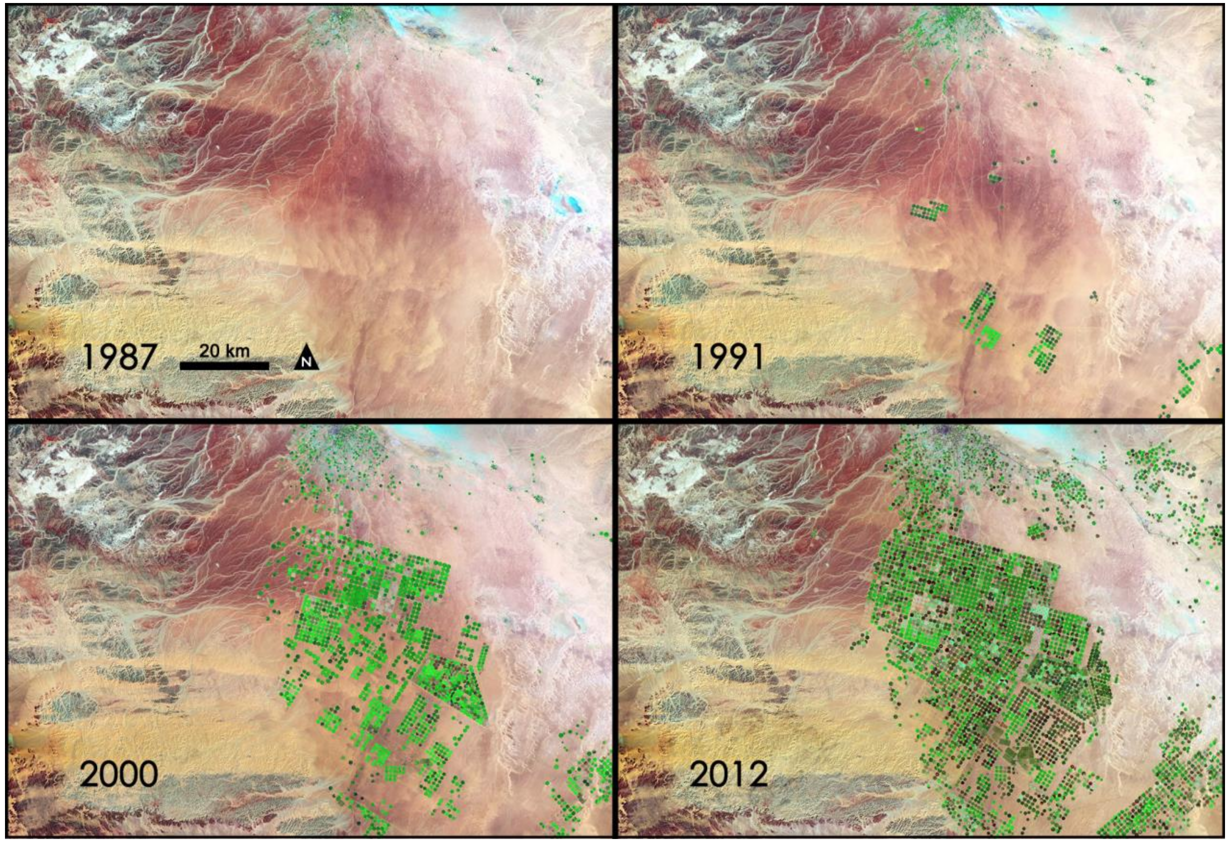
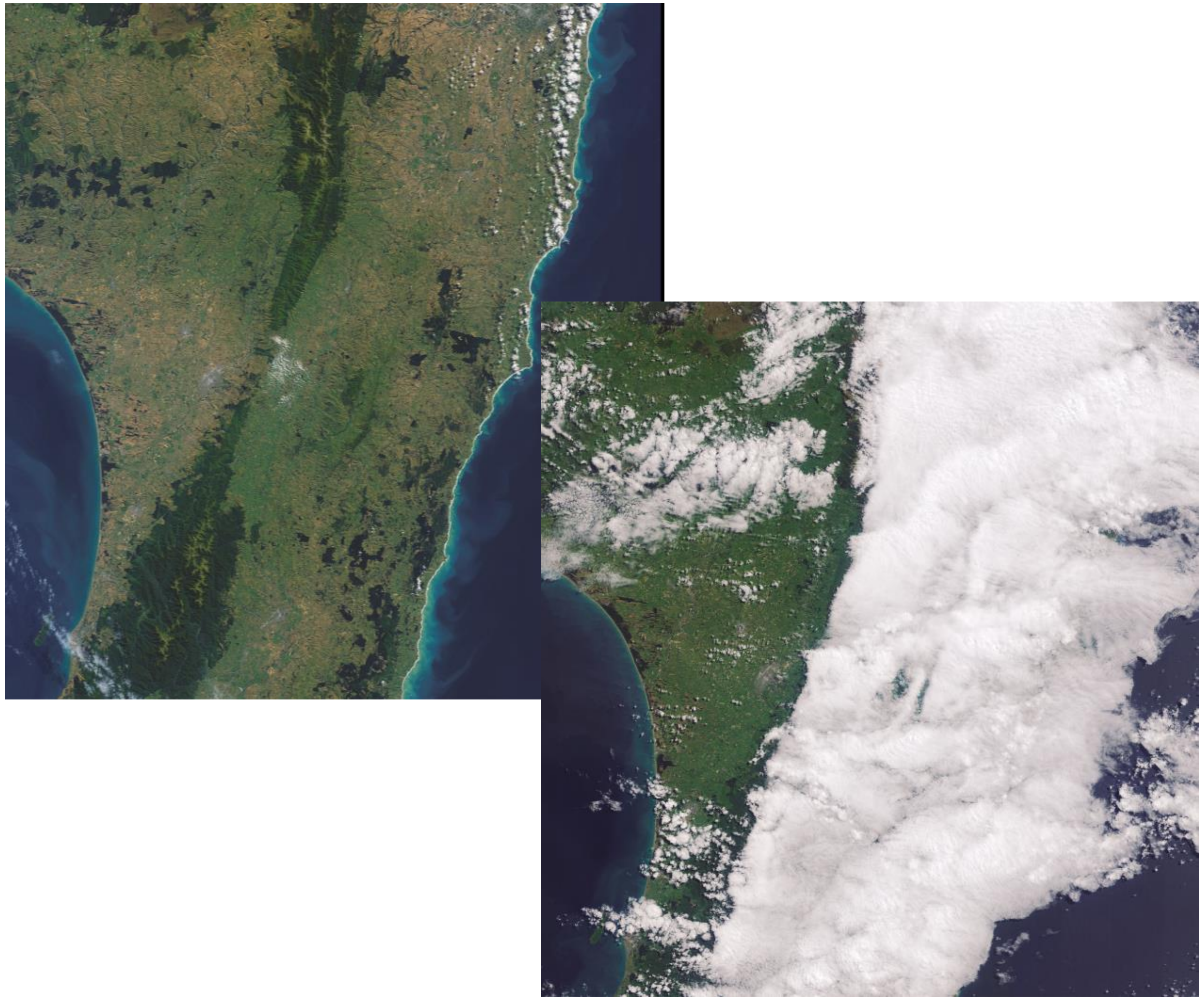


Image: Landsat images of Saudi Arabia's agricultural growth. Credit: NASA

What are the criteria for image selection?

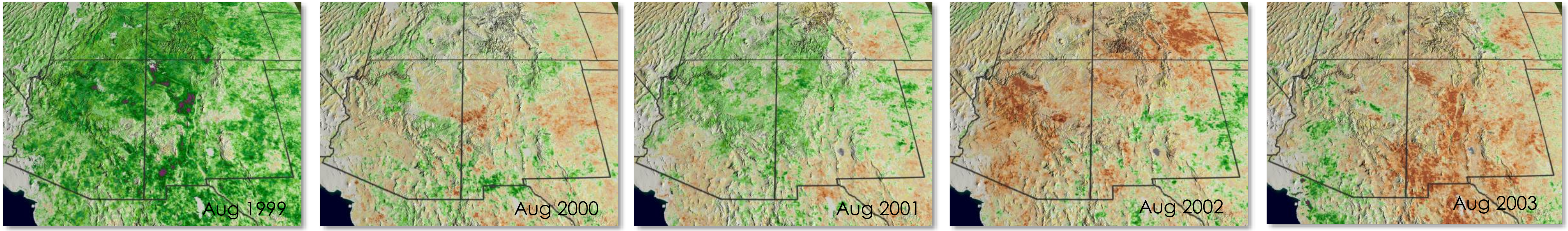
- The challenge is to separate real change from spectral change. Choose images that are:
  - Collected at a similar time of day
  - Collected during the same season
  - Nearly cloud free
  - Co-registered with one another
  - Radiometrically and Atmospherically corrected



Clouds over New Zealand with Landsat data: NASA Earth Observatory images by Joshua Stevens: https://www.giss.nasa.gov/research/features/201612_clouds/

Collection Time and Dates

- Images need to be collected at about the same time of day to reduce differences in sun angle
- Ideally, images from different years should be within the same month to avoid seasonal and phenological differences
  - Differences in vegetation greenness
- Be aware of different annual precipitation amounts
  - Drought years vs. non-drought years



NDVI Anomalies in the southwestern United States. Image Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio.

Satellite Data Pre-Processing

Landsat Surface Reflectance Products

- Surface Reflectance products generated from the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS)
  – Originally developed by NASA
- Available from EarthExplorer:
  – http://earthexplorer.usgs.gov

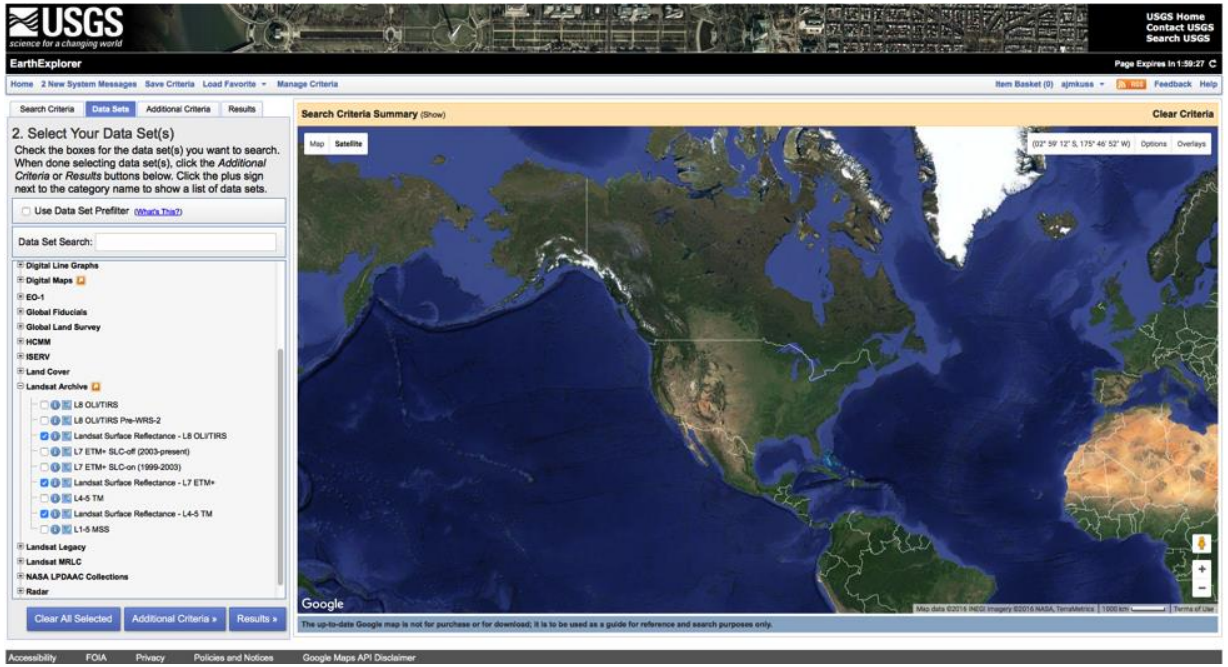
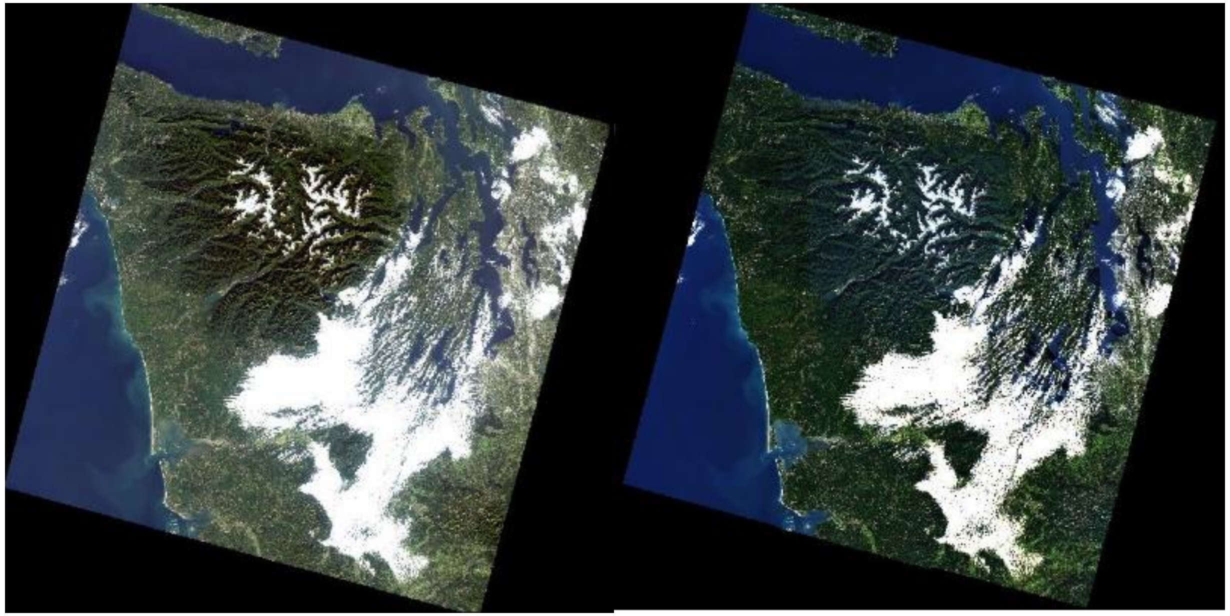


Image: Landsat 4-7 and 8 Surface Reflectance Products Available from EarthExplorer

Satellite Data Pre-Processing

Landsat Surface Reflectance Product Caveats

- Landsat 7 images are not gap-filled
- The usefulness of surface reflectance products is reduced in:
  - Hyper-arid or snow-covered regions
  - Low sun angle conditions
  - Coastal regions
  - Areas with extensive clouds
- Panchromatic band (ETM+ Band 8) is not available in the product
- The products for Landsat 4, 5, 7 are only available for specific dates



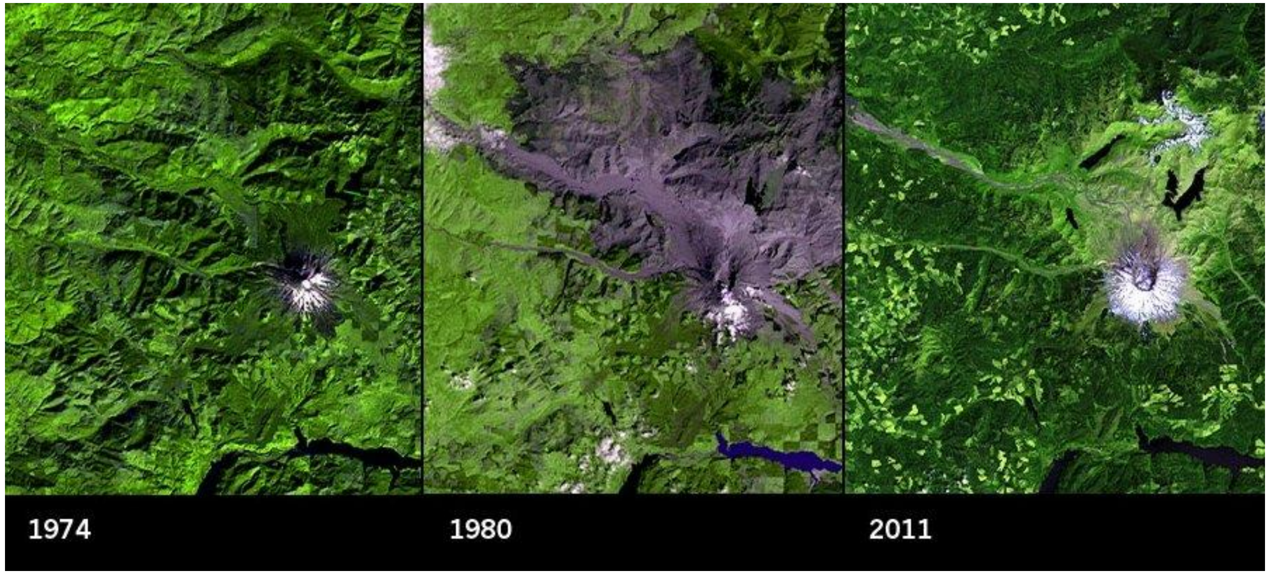
Example of the unprocessed Landsat image (left) and the LEDAPS processed Landsat image (right)

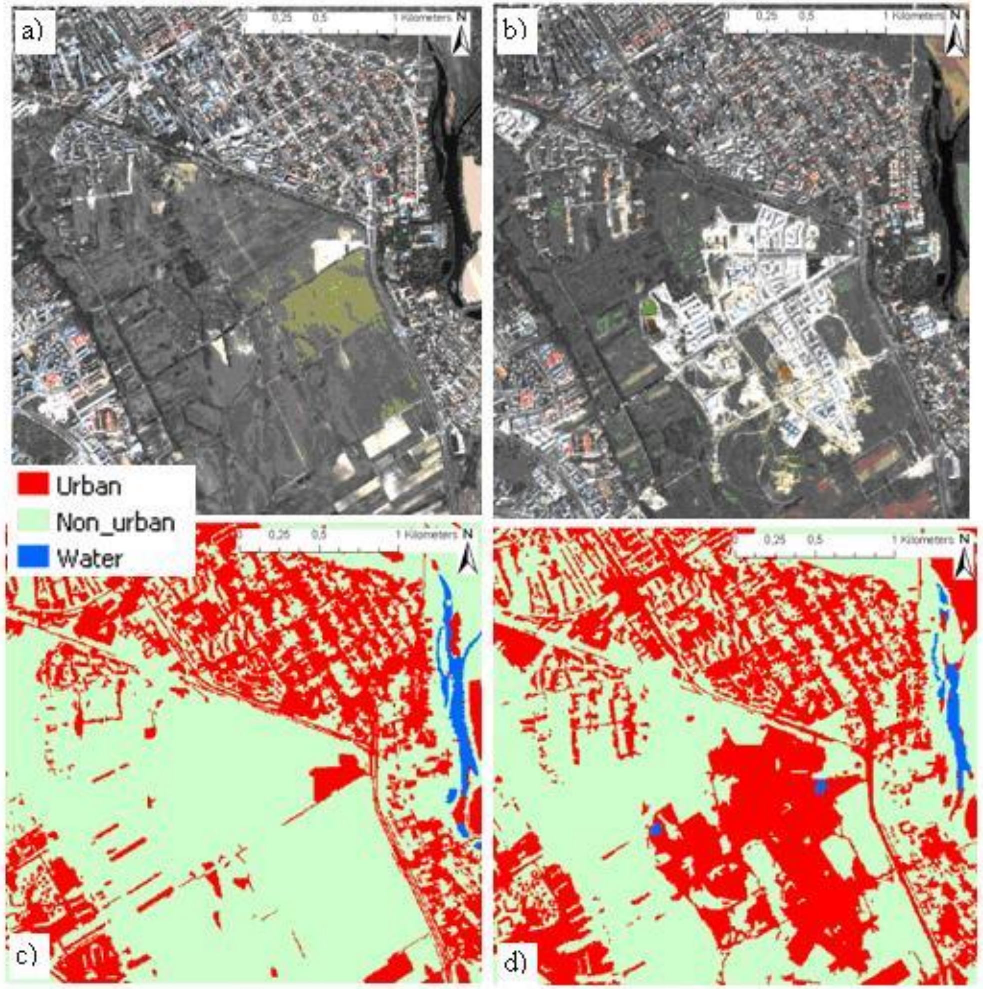
Image Credit; USGS

Change Detection Methods

Change Detection Methods

- Visual Analysis
- Classification Approaches
- Image Differencing
- Temporal Trajectories

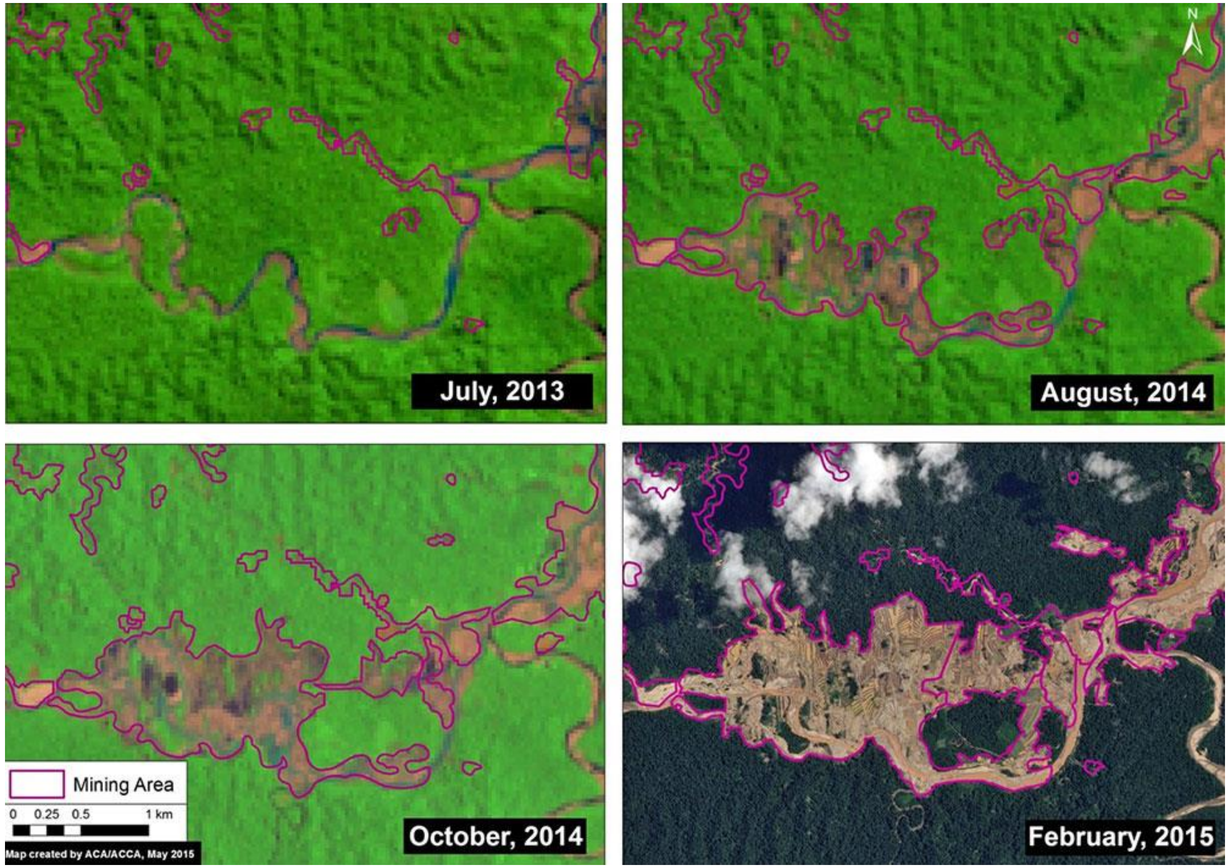




- Left: Mount Saint Helens eruption, 1980. Image Credit: [Pantaleo, 2013](), Right: Analyzing urban growth using multi-temporal high resolution Ikonos imagery from 2002 (a) and 2008 (b) in Warsaw, Poland; (c) Object-oriented classification result for 2002; (d) Object-oriented classification result for 2008. Image Credit: [Taubenbock and Esch, 2011]()

Visual Inspection

- Visual interpretation involves the delineation of change on a computer screen (rather than a paper map)
- This allows production of results that are automatically in digital form
- Good for large changes like shape or size of large patches
- Not as good for subtle changes like land degradation
- Does not take advantage of spectral response



- Deforestation along the Upper Malinowski in Peru due to mining from Landsat and SPOT 7. Credit: Amazon Conservation Association

Classification Approaches

Post-Classification Comparison

- Land cover classification of two dates separately
- Subtract one image from another to identify change
- Not recommended because:
  - Errors from each classified map will be multiplied in the change map
  - Tends to ignore subtle changes within a class

Classification of Multi-Date Imagery

- Stack two dates of imagery into one file.
- Can include image transforms that highlight desired change
- Classify the two-date image
- Change classes will be unique
- Recommended because:
  - It uses the raw pixels values to identify change
  - Can detect subtle changes

Image Differencing

- Subtract image date 1 from image date 2
- 0 means no change; positive or negative values indicate change
- Image dates can be individual bands or image transformations (NDVI, NBR, etc.)
- Advantages
  - Can be used to detect subtle changes
  - Easy to compute
- Disadvantage: Can be difficult to interpret

Image Differencing

8	10	8	11
240	11	10	22
205	210	205	54
220	98	88	46

Image Date 1

5	9	7	10
97	9	8	22
98	100	205	222
103	98	254	210

Image Date 2

3	1	1	1
143	2	2	0
107	110	0	-168
117	0	-166	-164

Difference Image = Image 1 - Image 2

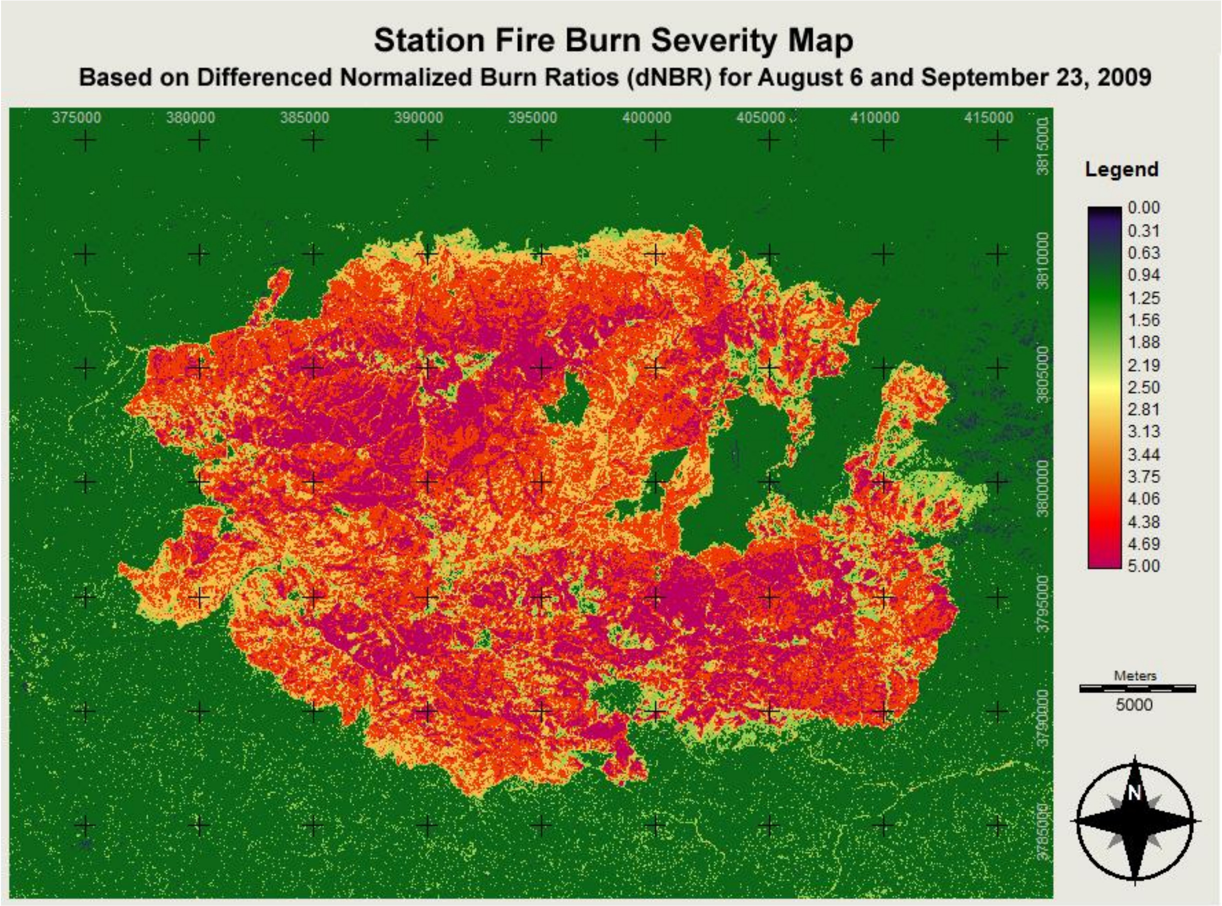
Example: Vegetation Image Differencing

- Wildfire burn extent and severity with the Normalized Burn Ratio (NBR)

$$NBR = \frac{(NIR - SWIR)}{NIR + SWIR}$$

- Compare pre- and post-burn images to identify burn extent and severity with a differenced map

$$dNBR = NBR_{prefire} - NBR_{postfire}$$



Example of dNBR from the Station fire in Angeles National Forest from August-September 2009. Image Credit: [Irene Nester]

Temporal Trajectories and Time Series

- Can take advantage of the entire satellite image archive (i.e. Landsat: 1985-current) by using an annual time series to examine changes and trends
- Example: Landtrendr (Kennedy et al., 2010) products include:
  – Magnitude of change: 1-100 percent tree cover loss
  – Duration: 1-25 years
  – Year of onset of disturbance
- Look for an advanced webinar in 2019!!

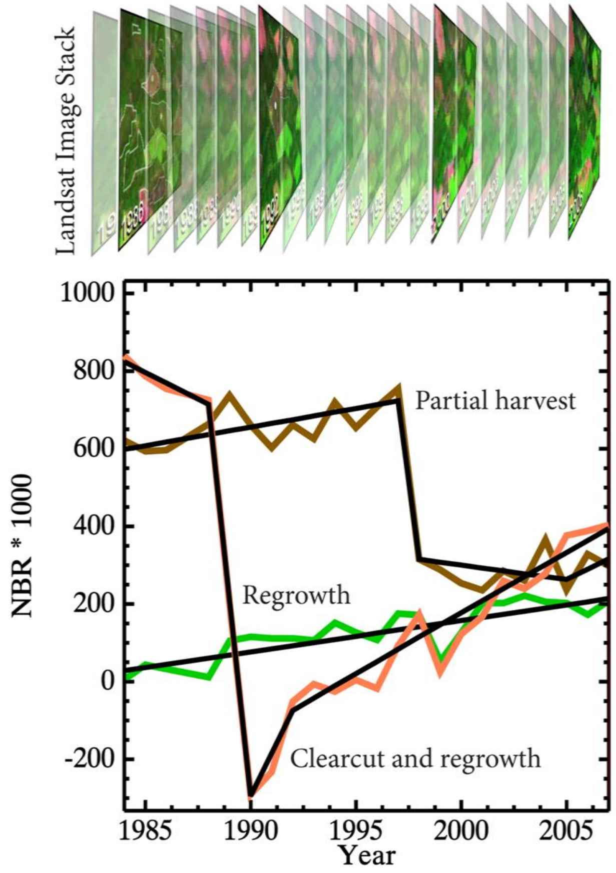


Figure 1. Temporal segmentation in the LandTrendr algorithm. a) A stack of yearly Landsat Thematic Mapper (TM) images is aligned, cleaned, and normalized. b) Statistical algorithms fit straightline representations (black lines) of cleaned pixel values (colored traces).

Image Credit: [Oregon State University]

Change Detection Case Study Examples

Mining in West Virginia: Visual Investigation

- https://earthobservatory.nasa.gov/WorldOfChange/Hobet
- Identification of mountaintop mining expansion from 1984 to 2015
- Active mining: appears white in image
  – Operation expansion evident
- Rock debris piles with impacts to braches of the nearby Mud River

Rubber Plantation Growth: Vegetation Image Differencing

- Fan et al., 2015, Phenology-Based Vegetation Index Differencing for Mapping of Rubber Plantations Using Landsat OLI Data
- Vegetation index differencing (NDVI and others) used
- Two-distinct phenological changes of rubber plants: nearly complete defoliation (leaf-off) and full foliation (leaf flushing)
- These phases are used to delineate rubber plantations within fragmented, tropical, and mountainous landscapes

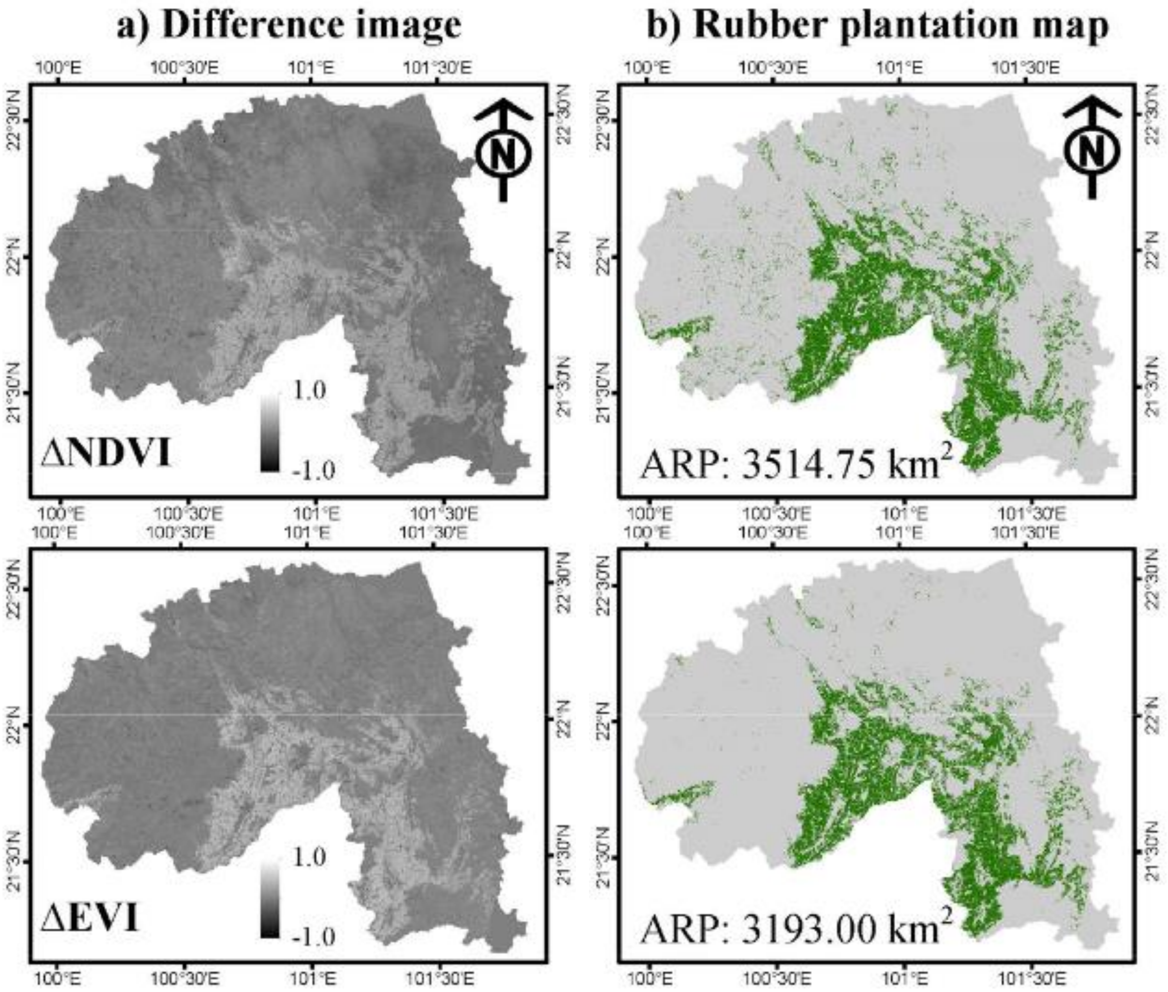


Image Credit: Phenology-Based Vegetation Index Differencing for Mapping of Rubber Plantations Using Landsat OLI Data. Source

Land Cover and Lake Management: Classification-Based Approach

- Zhao et al., 2012, Examining Land-Use/Land-Cover Change in the Lake Dianchi Watershed of the Yunnan-Guizhou Plateau of Southwest China with Remote Sensing and GIS Techniques: 1974–2008
- Land cover types classified
- Indentifies increases in agricultural regions and urban development in the watershed

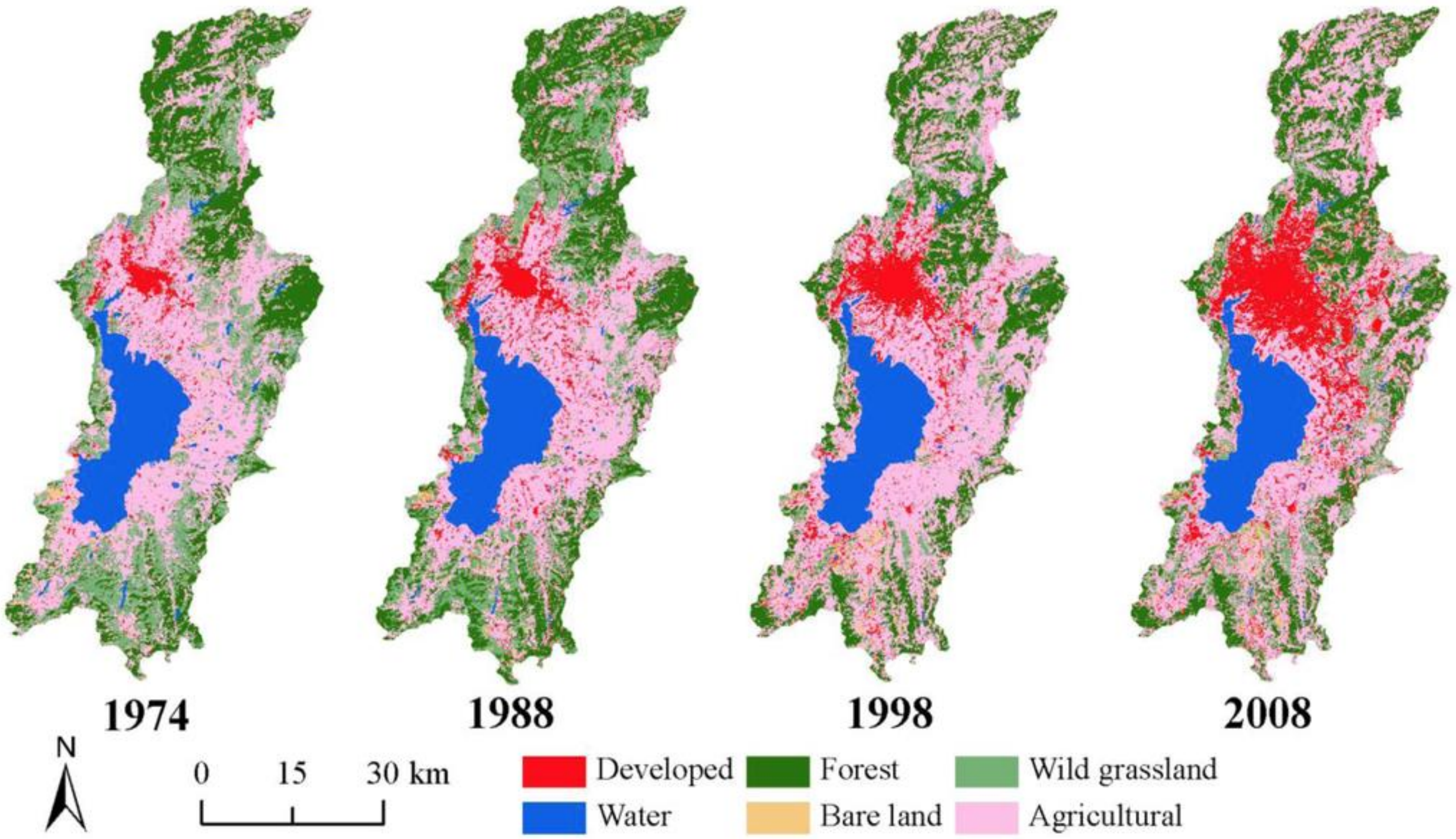
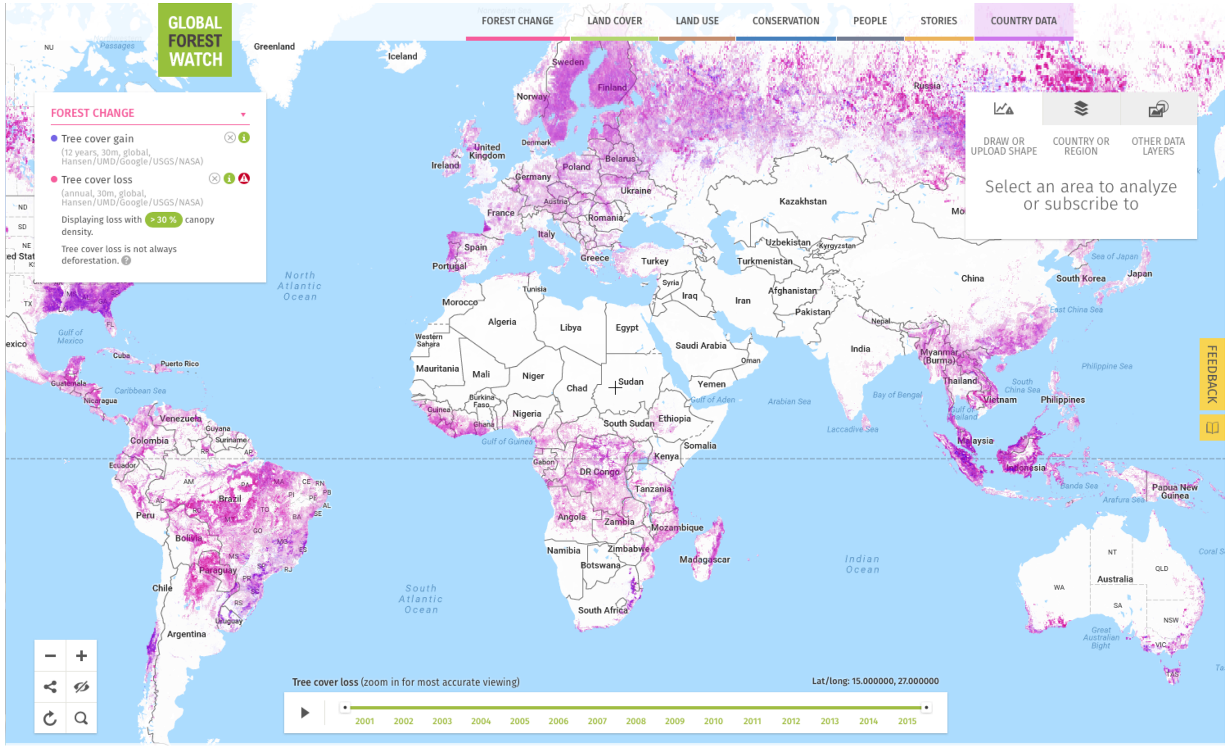


Image Credit: Examining Land-Use/Land-Cover Change in the Lake Dianchi Watershed of the Yunnan-Guizhou Plateau of Southwest China. [Source]

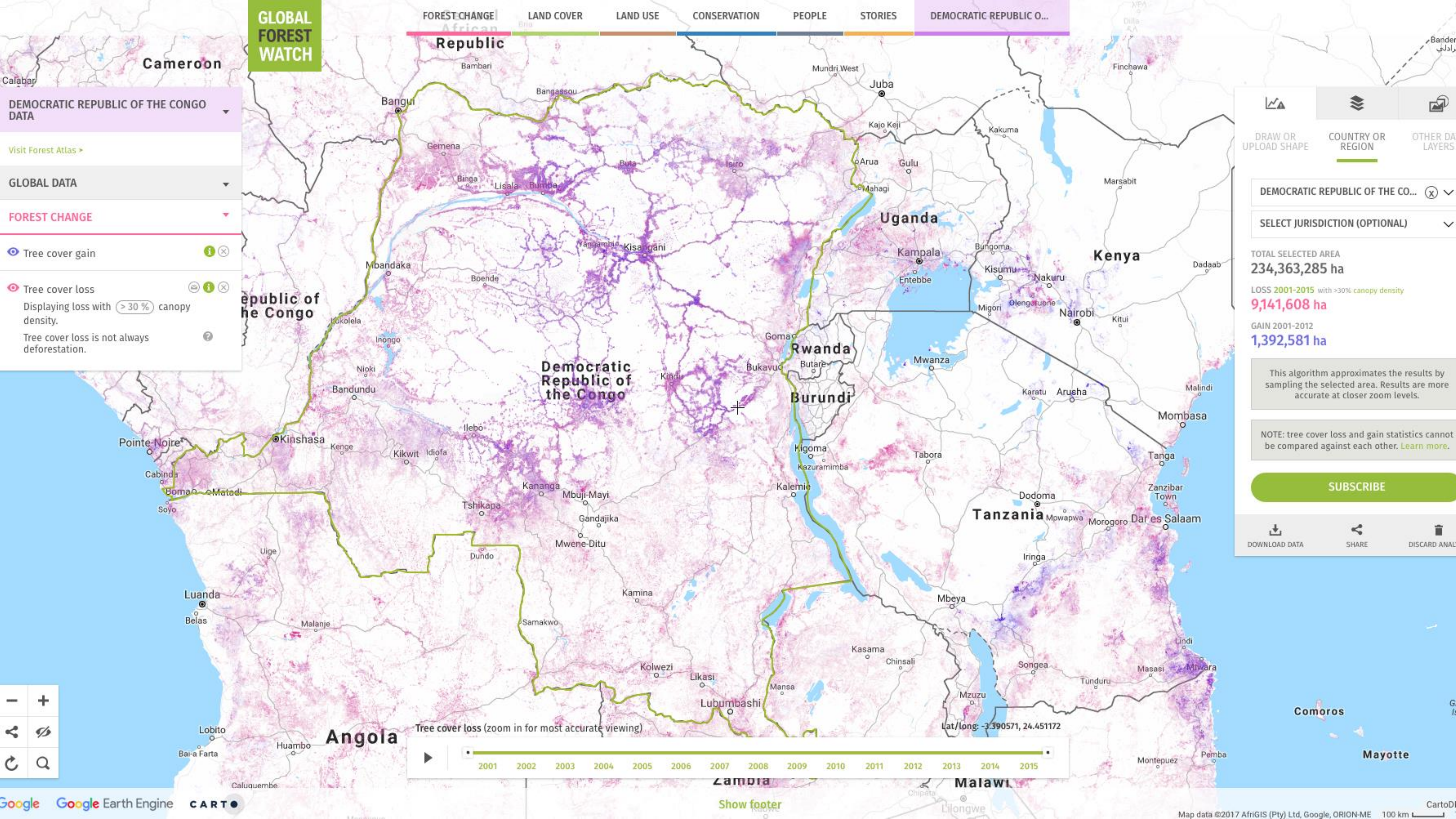
Webtools for Change Detection & Analysis

Forest Disturbance: Global Forest Watch

- https://www.globalforestwatch.org
- Identifies areas of tree cover loss from 2001-2017
- 30 m spatial resolution
- Includes location and amount of disturbance but not cause



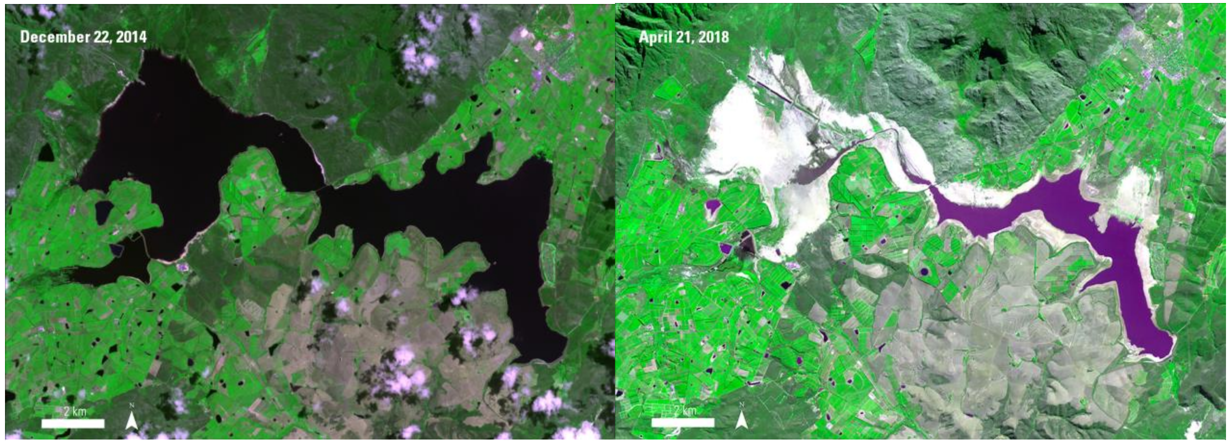
Source:Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53.

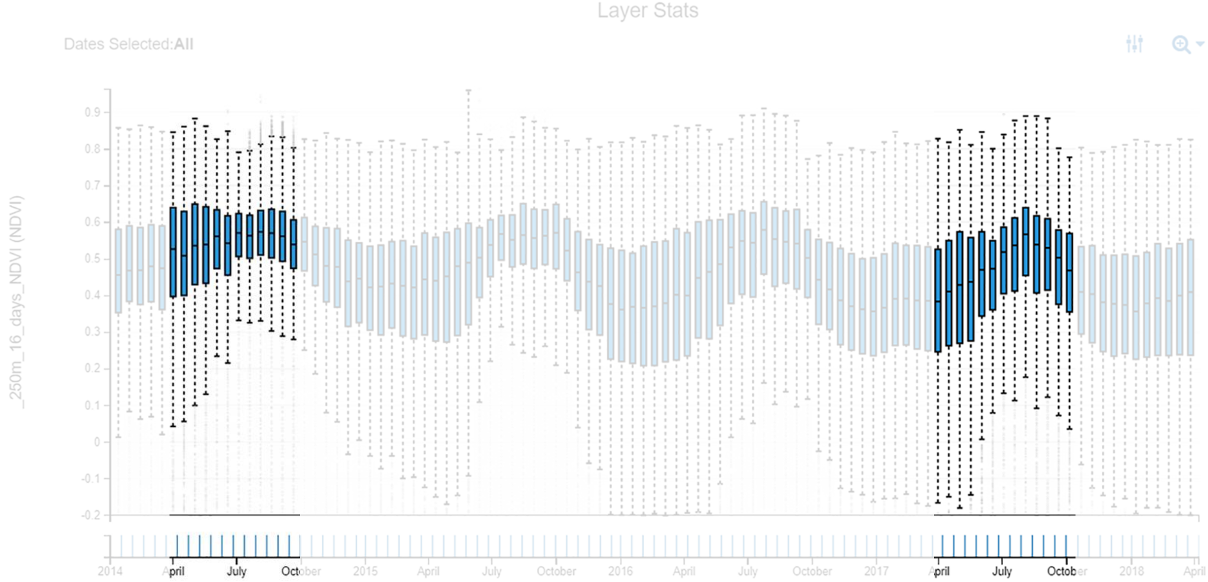

GLOBAL FOREST WATCH
FOREST CHANGE
LAND COVER
LAND USE
CONSERVATION
PEOPLE
STORIES
DEMOCRATIC REPUBLIC O...
DEMOCRATIC REPUBLIC OF THE CONGO DATA
Visit Forest Atlas >
GLOBAL DATA
FOREST CHANGE
Tree cover gain
Tree cover loss
Displaying loss with > 30 % canopy density.
Tree cover loss is not always deforestation.
DRAW OR UPLOAD SHAPE
COUNTRY OR REGION
DEMOCRATIC REPUBLIC OF THE CO...
SELECT JURISDICTION (OPTIONAL)
TOTAL SELECTED AREA
234,363,285 ha
LOSS 2001-2015 with >30% canopy density
9,141,608 ha
GAIN 2001-2012
1,392,581 ha
This algorithm approximates the results by sampling the selected area. Results are more accurate at closer zoom levels.
NOTE: tree cover loss and gain statistics cannot be compared against each other. Learn more.
SUBSCRIBE
DOWNLOAD DATA
SHARE
Cameroon
Republic
Democratic Republic of the Congo
Uganda
Kenya
Rwanda
Burundi
Tanzania
Angola
Malawi
Comoros
Mayotte
Bangui
Kisangani
Mbandaka
Kinshasa
Pointe-Noire
Luanda
Kananga
Mbuji-Mayi
Lubumbashi
Kolwezi
Goma
Bukavu
Kampala
Nairobi
Mombasa
Dar es Salaam
Dodoma
Juba
Tree cover loss (zoom in for most accurate viewing)
Lat/long: -3.390571, 24.451172
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Google Earth Engine
CARTO
Show footer
Map data ©2017 AfriGIS (Pty) Ltd, Google, ORION-ME
100 km

Change Detection and Analysis: AppEEARS

Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)

- Cloud-based computing using MODIS and other imagery (not Landsat yet)
- Time series analysis of user-specified points or areas
- Outputs include time series data in csv format for easy analysis
- Example: Monitoring changing reservoir levels in Cape Town, South Africa





NDVI time series shows that the range of values between Apr-Oct. 2014 (non-drought) were narrowly distributed and higher compared to April-Oct. 2017 (drought)

System for Earth Observations, Data Access, Processing, and Analysis for Land Monitoring (SEPAL)

- Developed by UN Food and Agriculture Organization (FAO), with funding from Norway, to help countries develop National Forest Monitoring Systems
- Cloud-based computing platform for data access and processing
- Includes two-date change detection and time series analysis
- https://sepal.io

Credit: https://www.youtube.com/watch?v=9MgO8uqfhhA

Exercise: Change Detection Visualization and Image Differencing Using QGIS

2-Date Image Visualization

- Objective: Easily visualize change
- What you can't do with this approach:
  - Quantify change
  - Determine cause of change
- Approach:
  - In multi-band band rendering (QGIS), put
    - NIR band, Date 1 in the Red band
    - NIR band Date 2 in the Green band
    - NIR band Date 1 in the Blue band
  - Results in increased vegetation as green, decreased vegetation as purple and no change as grey

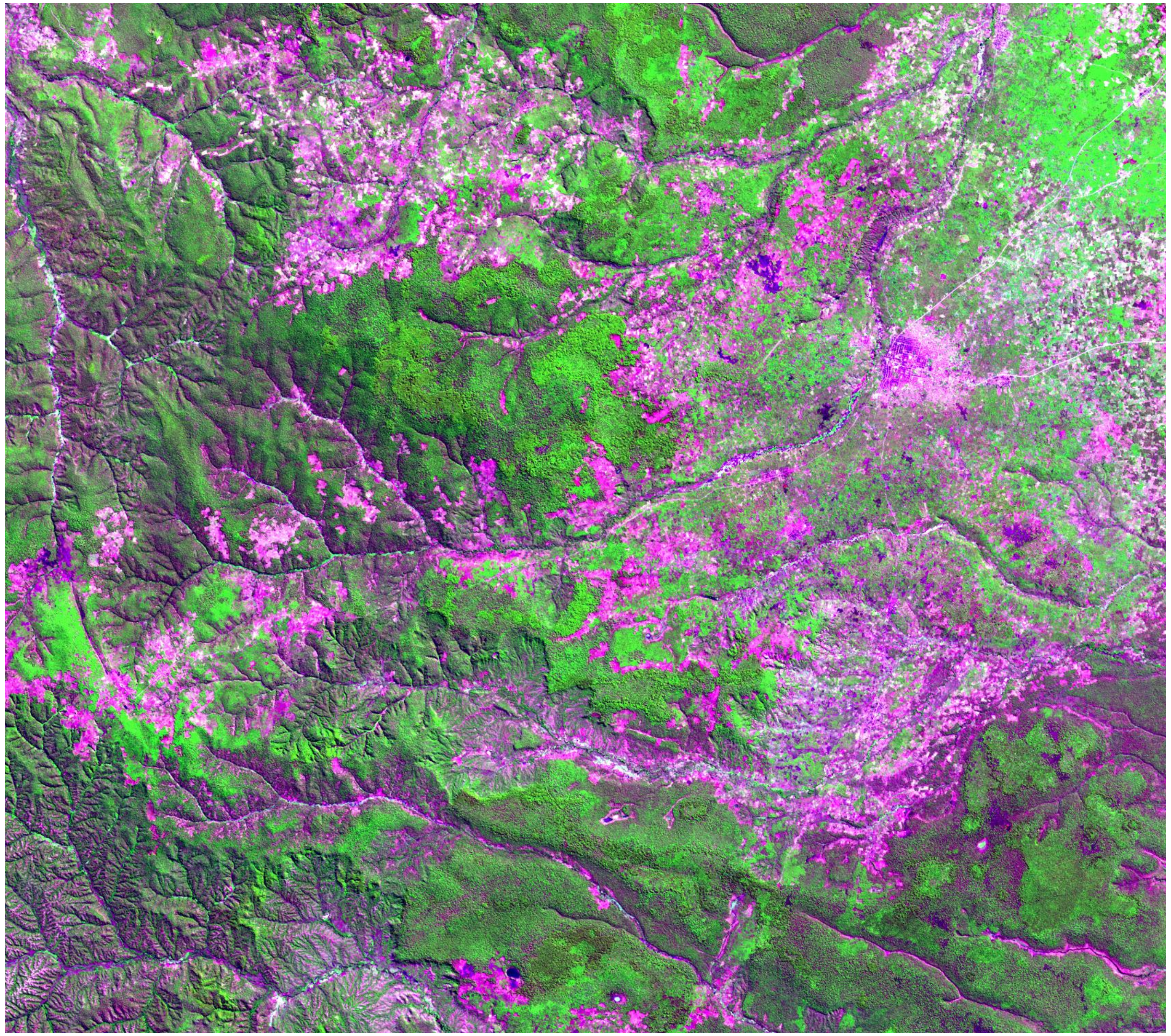
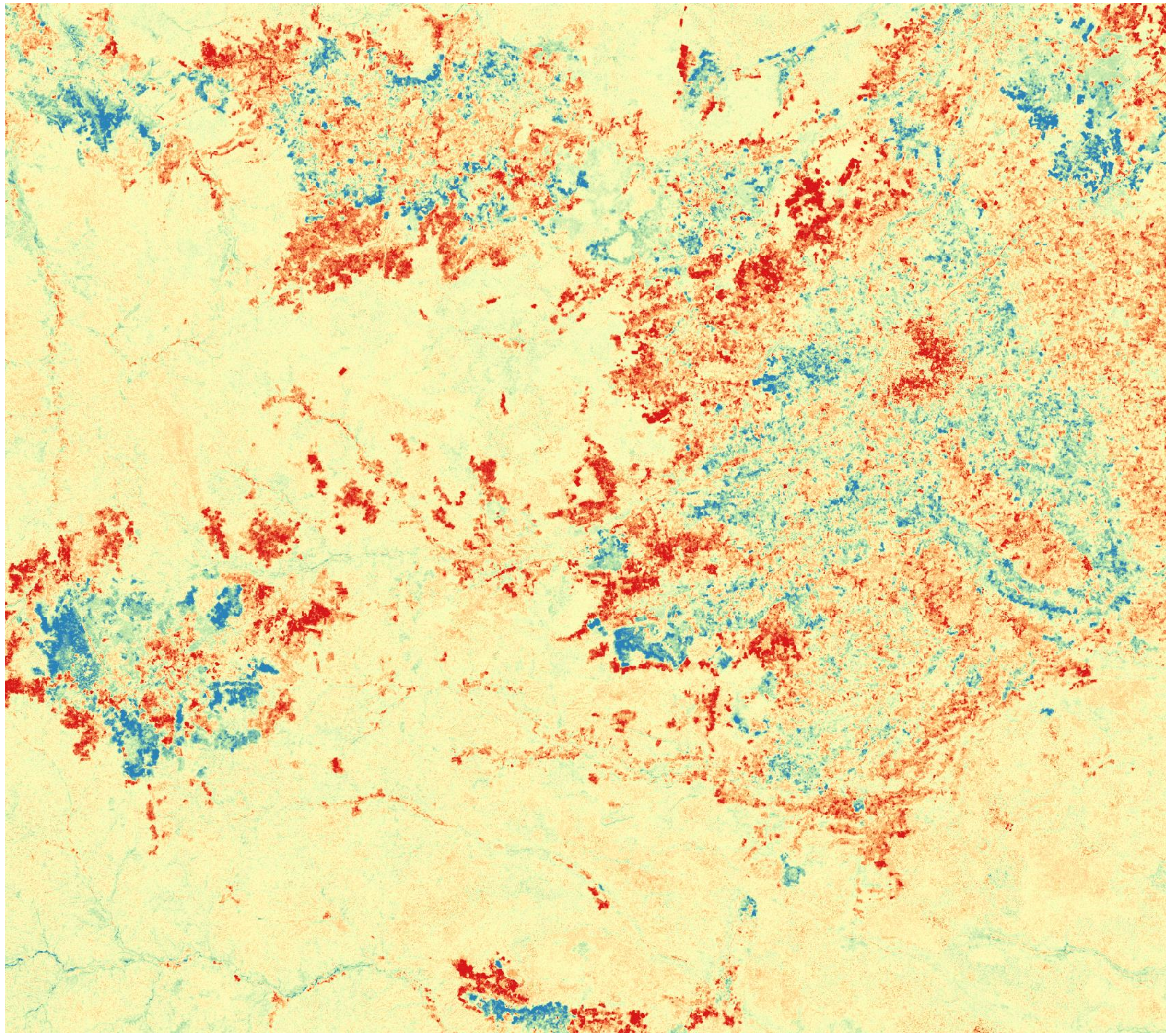


Image Transform and Differencing

- Objective: Easily visualize and quantify change
- You can only identify cause of change using expert interpreters
- Result can be used in image classification approach (next week)
- Approach:
  - Conduct image transform (NBR) on each image
  - Subtract one image from the other



Contacts

- ARSET Land Management & Wildfire Contacts
  - Cynthia Schmidt: Cynthia.L.Schmidt@nasa.gov
  - Amber McCullum: AmberJean.Mccullum@nasa.gov
- General ARSET Inquiries
  - Ana Prados: aprados@umbc.edu
- ARSET Website:
  - http://arset.gsfc.nasa.gov

Thank You

Next Session: Conducting Change Detection with QGIS and R

Friday October 5th

Question and Answer Session

Please type your questions in the Question Box

Additionally, you can type your name, location, organization, and email address to connect with your fellow land remote sensing professionals