

## ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

 @NASAARSET

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# Remote Sensing of Land Indicators of Sustainable Development Goal (SDG) 15

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Instructors: Cindy Schmidt and Amber McCullum

Session 2: June 21, 2017

# Course Structure

- Three sessions: Tuesday, June 20; Wednesday, June 21; Thursday, June 22
  - Each session will be given twice:
    - Session A: 1:00 – 2:00 p.m. EDT (UTC-4)
    - Session B: 10:00 – 11:00 p.m. EDT (UTC-4)
  - Please only sign up for and attend the same session each week
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - <http://arset.gsfc.nasa.gov/land/webinars/sdg15>
  - Q&A: Following each lecture and/or by email
    - [cynthia.l.schmidt@nasa.gov](mailto:cynthia.l.schmidt@nasa.gov), or
    - [amberjean.mccullum@nasa.gov](mailto:amberjean.mccullum@nasa.gov)

# Homework and Certificates

- Homework
  - Answers must be submitted via Google Form
- Certificate of Completion:
  - Attend all 3 webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
    - **HW Deadline: July 6<sup>th</sup>**
  - You will receive certificates approx. two months after the completion of the course from: [marines.martins@ssaihq.com](mailto:marines.martins@ssaihq.com)

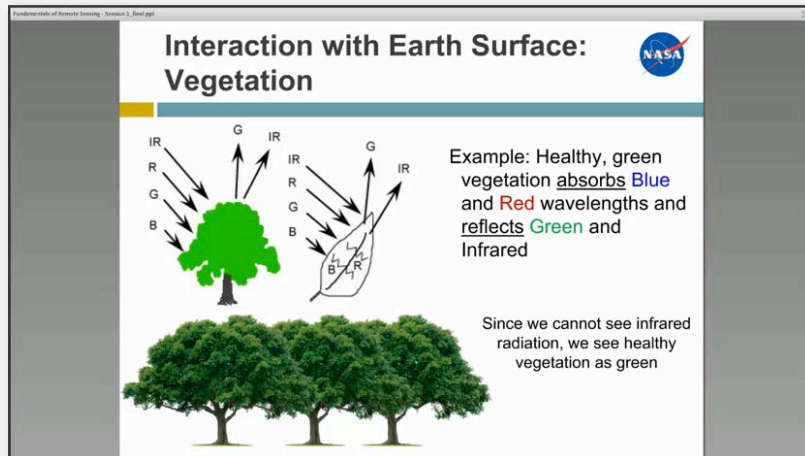
The image shows two overlapping documents. The top document is a Google Form titled "Carbon Monitoring Homework 1". It includes instructions to complete questions and submit by June 23rd, 2016. It has fields for "Name" and "Email", both marked as required. Below these are three questions with multiple-choice options:

1. Which of these data portals do NOT provide Landsat data? \*
  - A. GloVis
  - B. Earth Explorer
  - C. MRTWeb
  - D. WELD
2. What is the formula for NDVI? \*
  - A.  $(\text{Red} - \text{Near Infrared}) / (\text{Blue} - \text{Near Infrared})$
  - B.  $(\text{Near Infrared} - \text{Red}) / (\text{Near Infrared} + \text{Red})$
  - C.  $(\text{Green} - \text{Blue}) / (\text{Green} + \text{Blue})$
  - D.  $(\text{Red} - \text{Green}) / (\text{Near Infrared} - \text{Green})$
3. Chlorophyll in plants absorbs green waveler

The bottom document is a Certificate of Completion from ARSET (Applied Remote Sensing Training). It is presented by Land Management to Amber McCullum for completing advanced training in "Remote sensing of forest cover and change assessment for carbon monitoring". The certificate is dated June 9 - July 7, 2016. It features the NASA logo and the text "National Aeronautics and Space Administration".

# Prerequisite

- Fundamentals of Remote Sensing
  - Sessions 1 and 2A (Land)
  - On demand webinar, available anytime
  - <http://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing>



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Applied Remote Sensing Training

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Health & Air Quality

Land

Water Resources

Advanced Webinar: Methods in Using NASA Remote Sensing for Health Applications

Thursdays, June 1-15, 2017  
10 a.m. or 3 p.m. EDT (UTC-4)

Register Now

Image Credit: NASA Earth Observatory

ARSET

Webinars

Workshops

Suggest a Training

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Resources

Upcoming Training

Airquality

Satellite Remote Sensing of Air Quality: Data, Tools and Applications  
05/23/2017 to 05/26/2017

Airquality

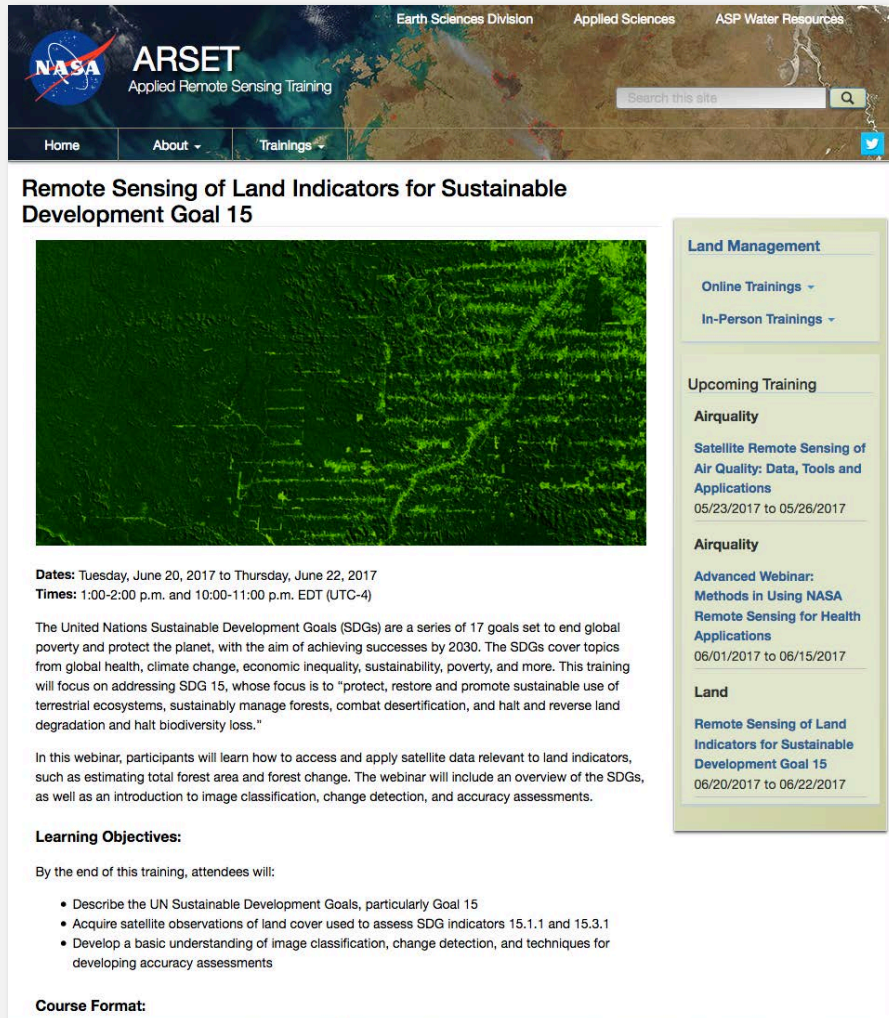
Advanced Webinar: Methods in Using NASA Remote Sensing for Health Applications  
06/01/2017 to 06/15/2017

Land

Remote Sensing of Land

# Accessing Course Materials

<http://arset.gsfc.nasa.gov/land/webinars/sdg15/>



The screenshot shows the ARSET website header with the NASA logo and 'Applied Remote Sensing Training' text. The main content area features a satellite image of a forest. The page title is 'Remote Sensing of Land Indicators for Sustainable Development Goal 15'. Below the image, there are sections for 'Dates', 'Times', a description of the course, 'Learning Objectives', and 'Course Format'. A sidebar on the right contains navigation links for 'Land Management', 'Upcoming Training', and 'Land'.

**Remote Sensing of Land Indicators for Sustainable Development Goal 15**

**Dates:** Tuesday, June 20, 2017 to Thursday, June 22, 2017  
**Times:** 1:00-2:00 p.m. and 10:00-11:00 p.m. EDT (UTC-4)

The United Nations Sustainable Development Goals (SDGs) are a series of 17 goals set to end global poverty and protect the planet, with the aim of achieving successes by 2030. The SDGs cover topics from global health, climate change, economic inequality, sustainability, poverty, and more. This training will focus on addressing SDG 15, whose focus is to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."

In this webinar, participants will learn how to access and apply satellite data relevant to land indicators, such as estimating total forest area and forest change. The webinar will include an overview of the SDGs, as well as an introduction to image classification, change detection, and accuracy assessments.

**Learning Objectives:**

By the end of this training, attendees will:

- Describe the UN Sustainable Development Goals, particularly Goal 15
- Acquire satellite observations of land cover used to assess SDG indicators 15.1.1 and 15.3.1
- Develop a basic understanding of image classification, change detection, and techniques for developing accuracy assessments

**Course Format:**

## Audience:

Regional, state, federal, and international organizations interested in addressing monitoring requirements for the SDGs through the use of remote sensing. 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. Space is limited, and preference will be given to organizations listed above over organizations focused primarily on research. You will be notified by email if your registration has been approved on or before June 16, 2017. Please register for **only one session**.

- [Register for Session A, 1:00 - 2:00 p.m. EDT \(UTC-4\)](#) »
- [Register for Session B, 10:00 - 11:00 p.m. EDT \(UTC-4\)](#) »

## Course Agenda:

[Agenda.pdf](#)

### Session One: Overview of SDG 15

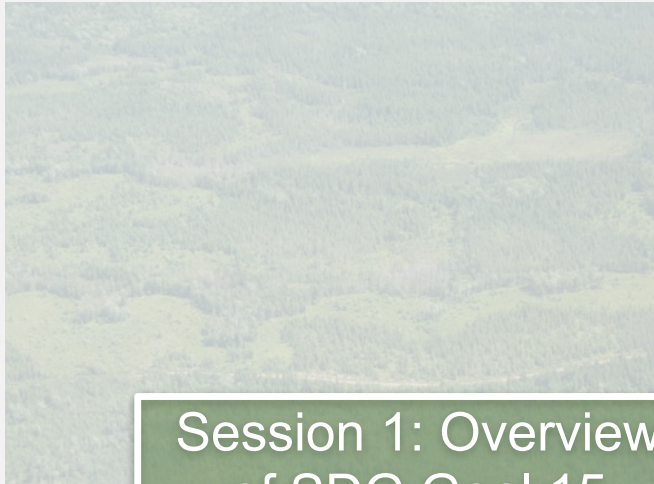
June 20, 2017

- [Presentation Slides \(English\)](#) »
- [Presentation Slides \(Spanish\)](#) »
- [View the recording](#) »

- Introduction to the Sustainable Goals Framework
  - Overview of SDG 15
  - International Institute for Sustainable Development's (IISD's) SDG Knowledge Hub
  - Group on Earth Observations (GEO) and the SDGs
- State of the World's Forests
- Introduction to the role of land-based remote sensing for targets and indicators
- Remote sensing data sources for assessment of land cover
  - Landsat
  - MODIS
  - VIIRS
  - Sentinel

Course materials are provided here and will be active after each week

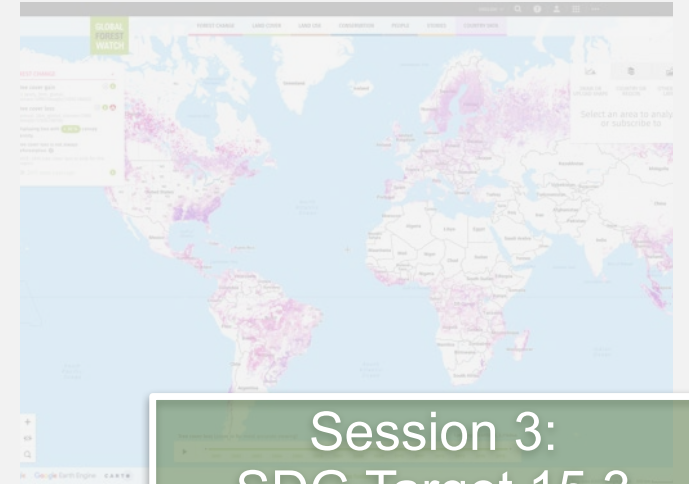
# Course Outline



Session 1: Overview  
of SDG Goal 15



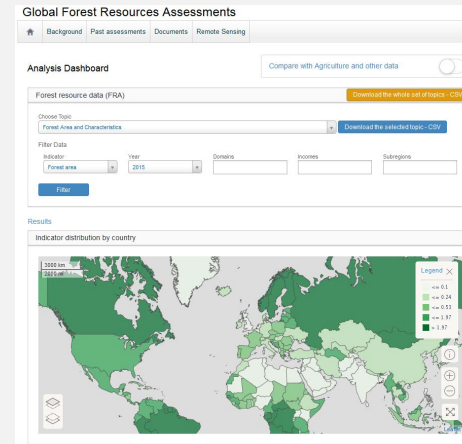
Session 2:  
SDG Target 15.1



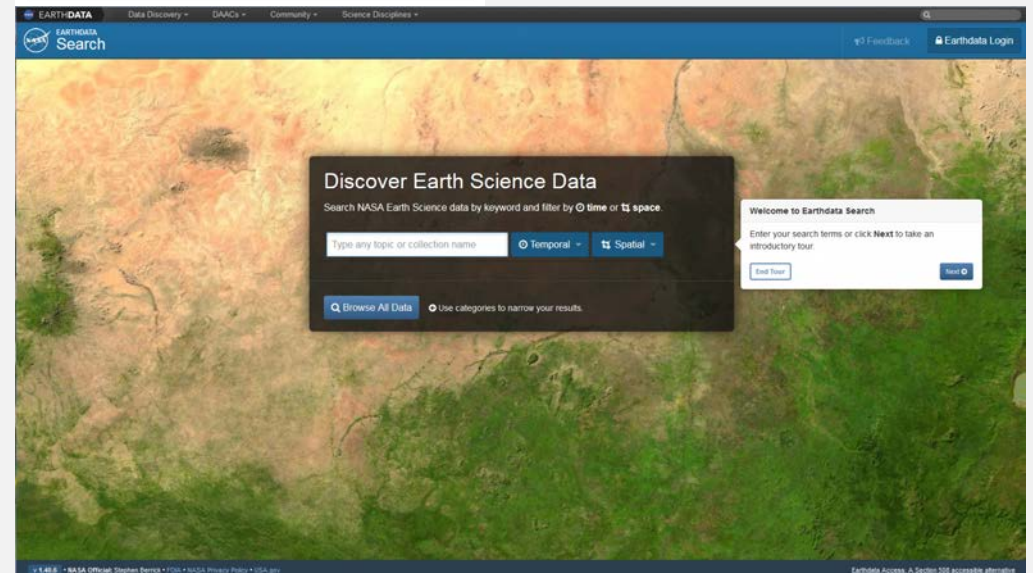
Session 3:  
SDG Target 15.3

# Session 2 Agenda

- SDG Target 15.1 and Indicator 15.1.1
- Land cover visualization and data access tools
- Land cover classification from satellite imagery
- Demo: MODIS Land Cover and Global Forest Watch



(Left) Global Forest Resource Assessment, Credit: Food and Agriculture Organization .  
(Below) Earthdata Search



# Target 15.1 and Land Cover Tools

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## SDG: Target 15.1

- By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements
  - Indicator: 15.1.1: Forest area as a proportion of total land area

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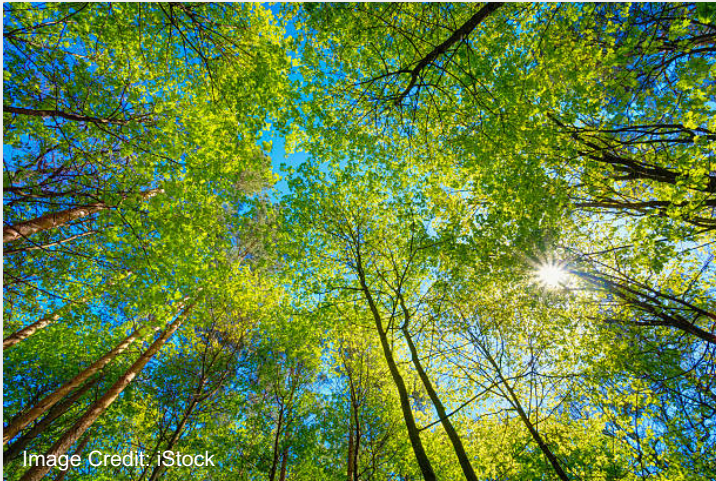
May be used as a rough proxy for the extent to which the forests in a country are being conserved or restored, but it is only partly a measure for the extent to which they are sustainably managed

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# Indicator 15.1.1

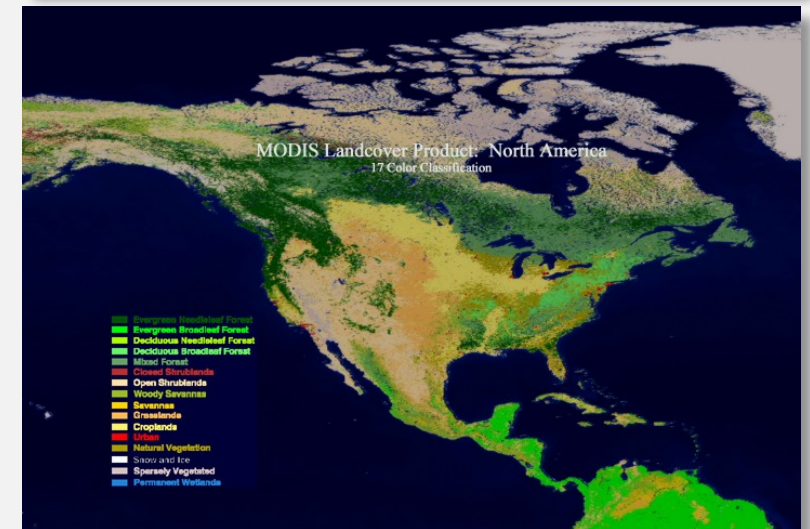
## Definitions

- **Forest:** “land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use” (Food and Agriculture Organization (FAO))
- **Total Land Area:** “total surface area of a country less the area covered by inland waters, like major rivers and lakes” (BIP)



# Global Forest and Land Cover Data

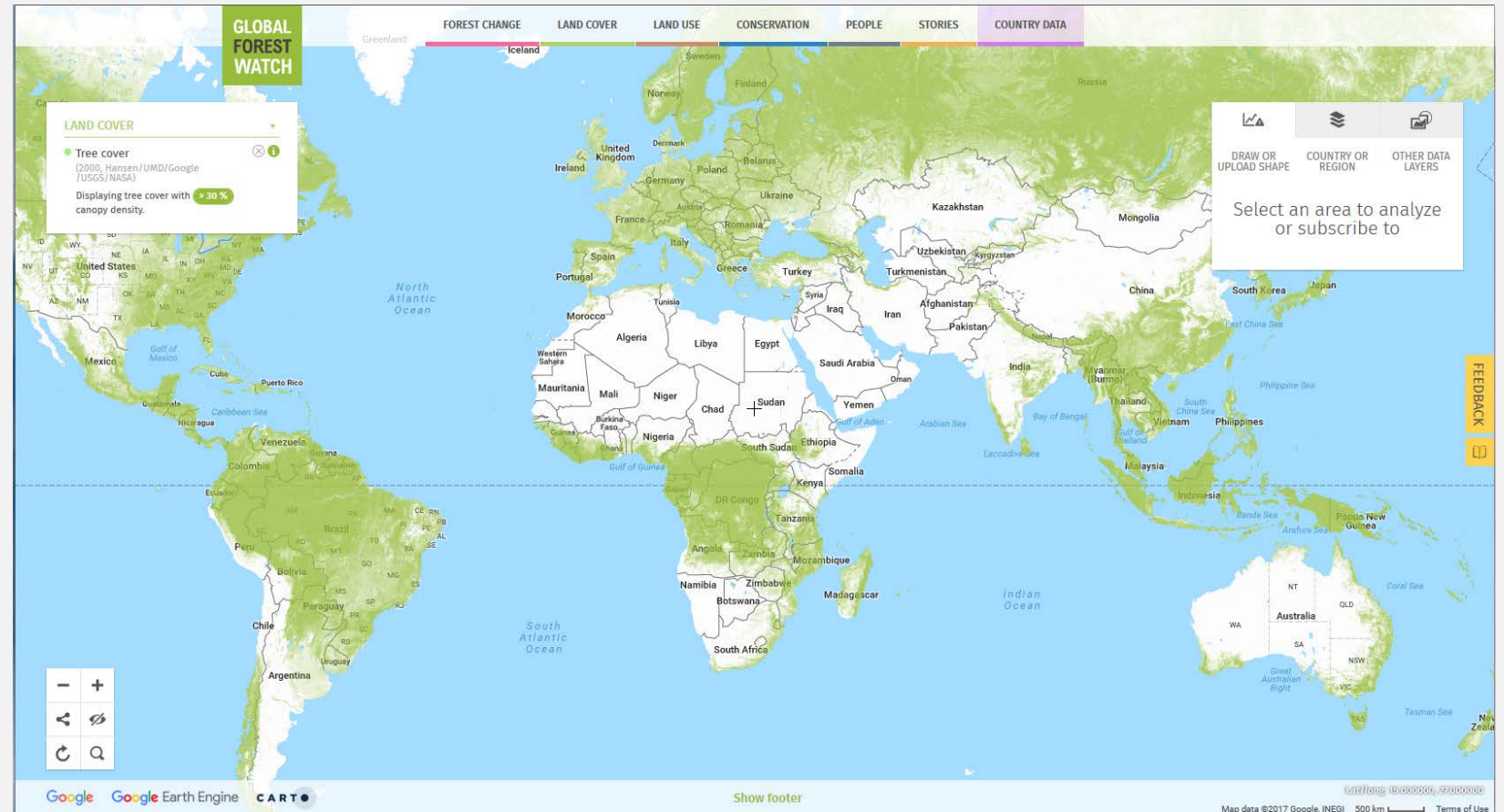
- Global Forest Watch (Hansen, et al. 2013)
- FAO Global Forest Resource Assessments and the Forest Land Use Data Explorer
- FAO Global Land Cover SHARE (GLC-SHARE)
- European Space Agency Climate Change Initiative Land Cover
- GlobeLand30 (China)
- MODIS Land Cover



# Global Forest Watch

[www.globalforestwatch.org](http://www.globalforestwatch.org)

- Area of tree cover with varying canopy densities
- Spatial resolution: 30 meters
- Date of Data: 2000
- Definition: All vegetation taller than 5 meters in height



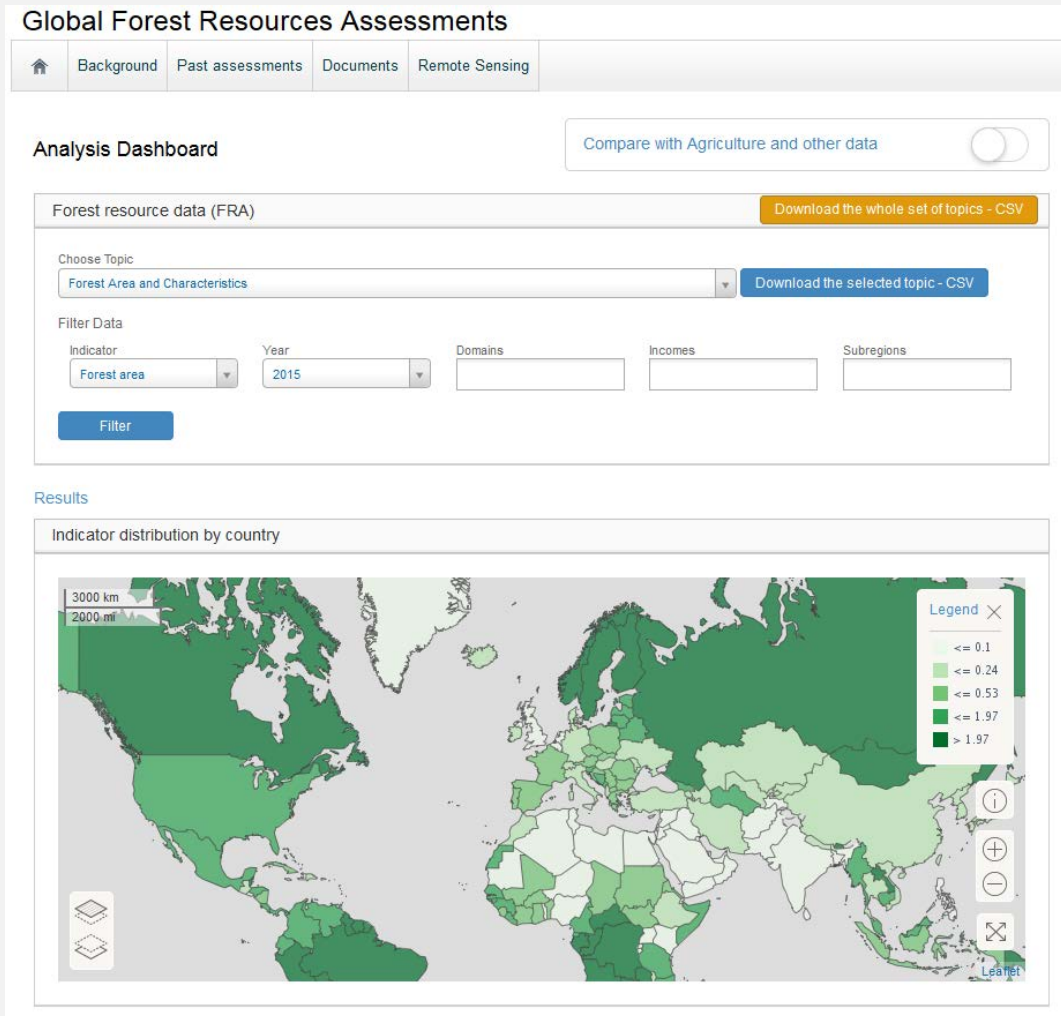
Source: Hansen et al. 2013

# FAO Global Forest Resource Assessments

<http://www.fao.org/forest-resources-assessment/en/>

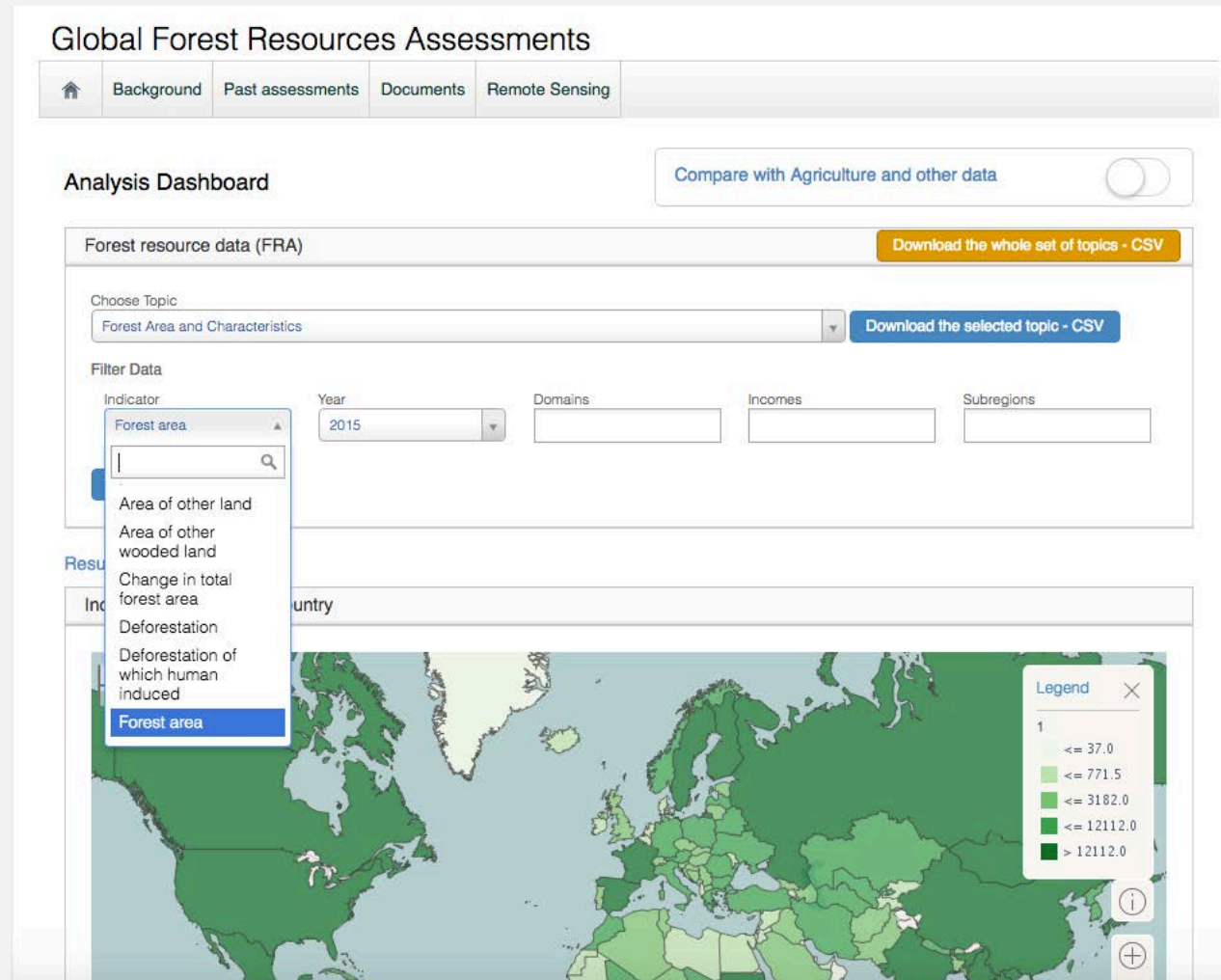
- Produced every five years
- Based on two primary sources of data:
  - country reports prepared by national correspondents
  - remote sensing conducted by FAO and national and regional partners
- Key Outputs:
  - synthesis document: “How are the World’s Forests Changing?”
  - country reports
  - maps (downloadable images)
  - Forest Land Use Data Explorer (FLUDE) – online visualization platform

# Forest Land Use Data Explorer

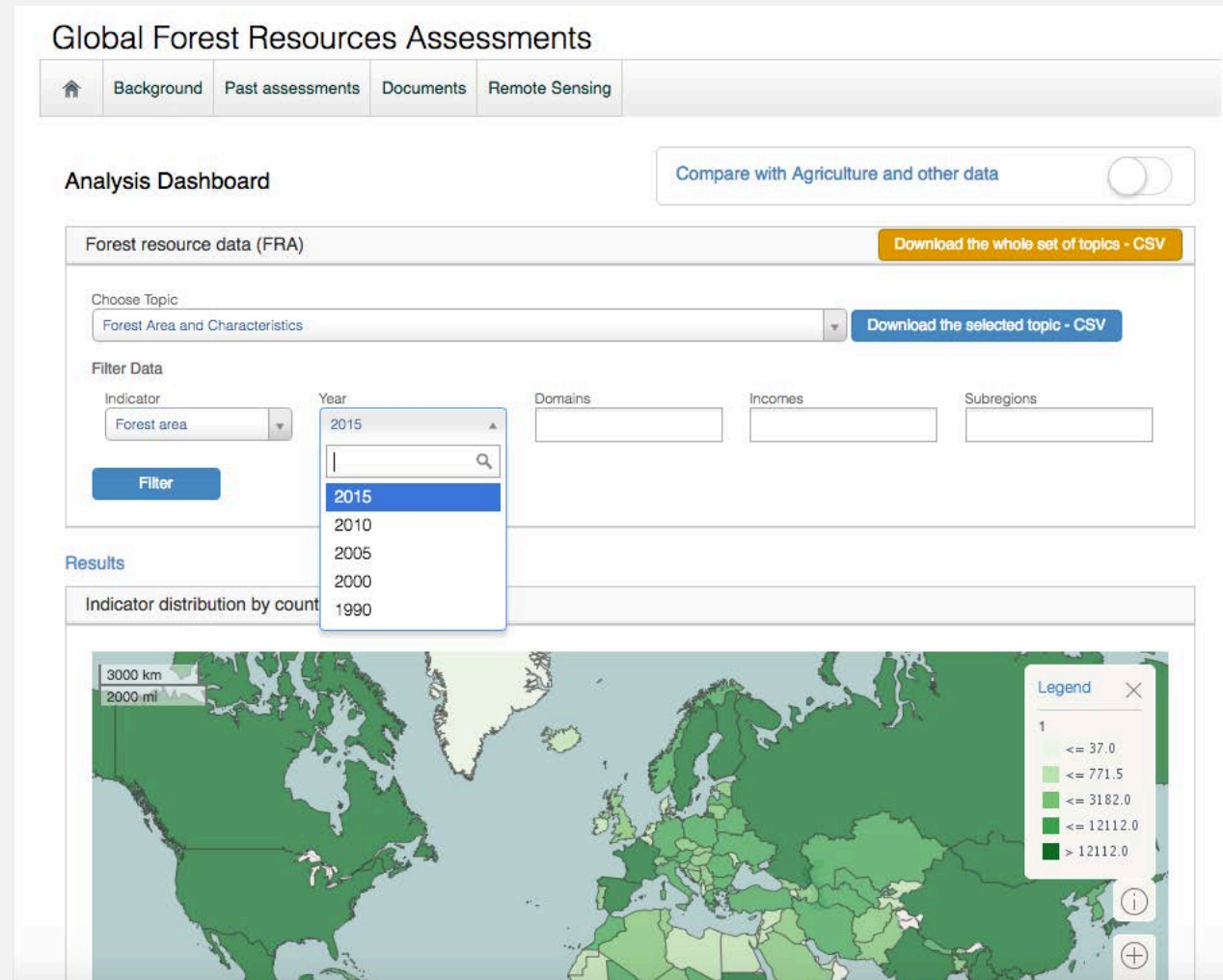


- Most data from the Global Forest Resources Assessment from 2015
- Provides access to datasets that relate to forests, including:
  - agriculture
  - rangelands
  - demographics
  - market prices
  - land use classifications and maps
- You can download data or assemble and analyze data

# Forest Land Use Data Explorer

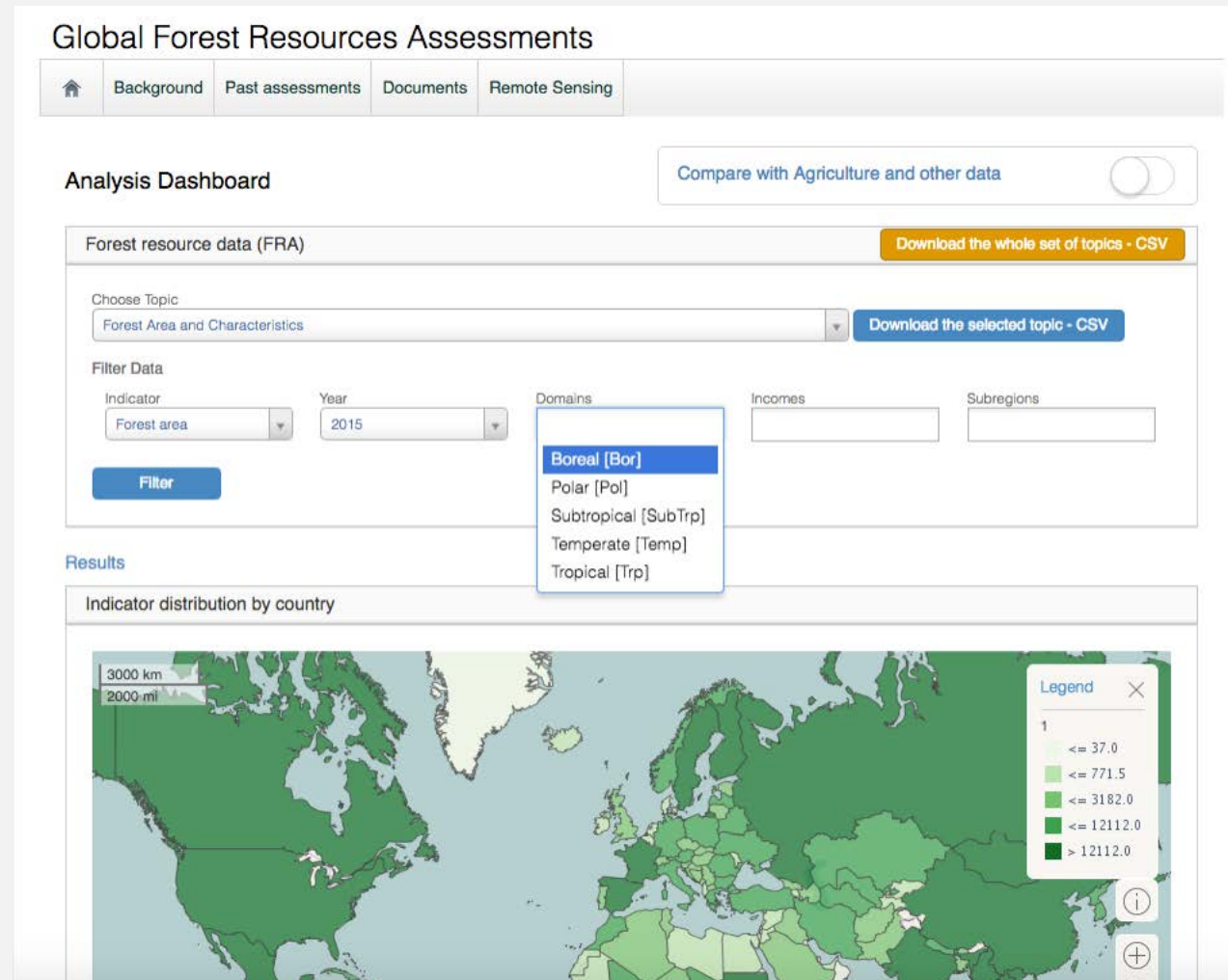


# Forest Land Use Data Explorer

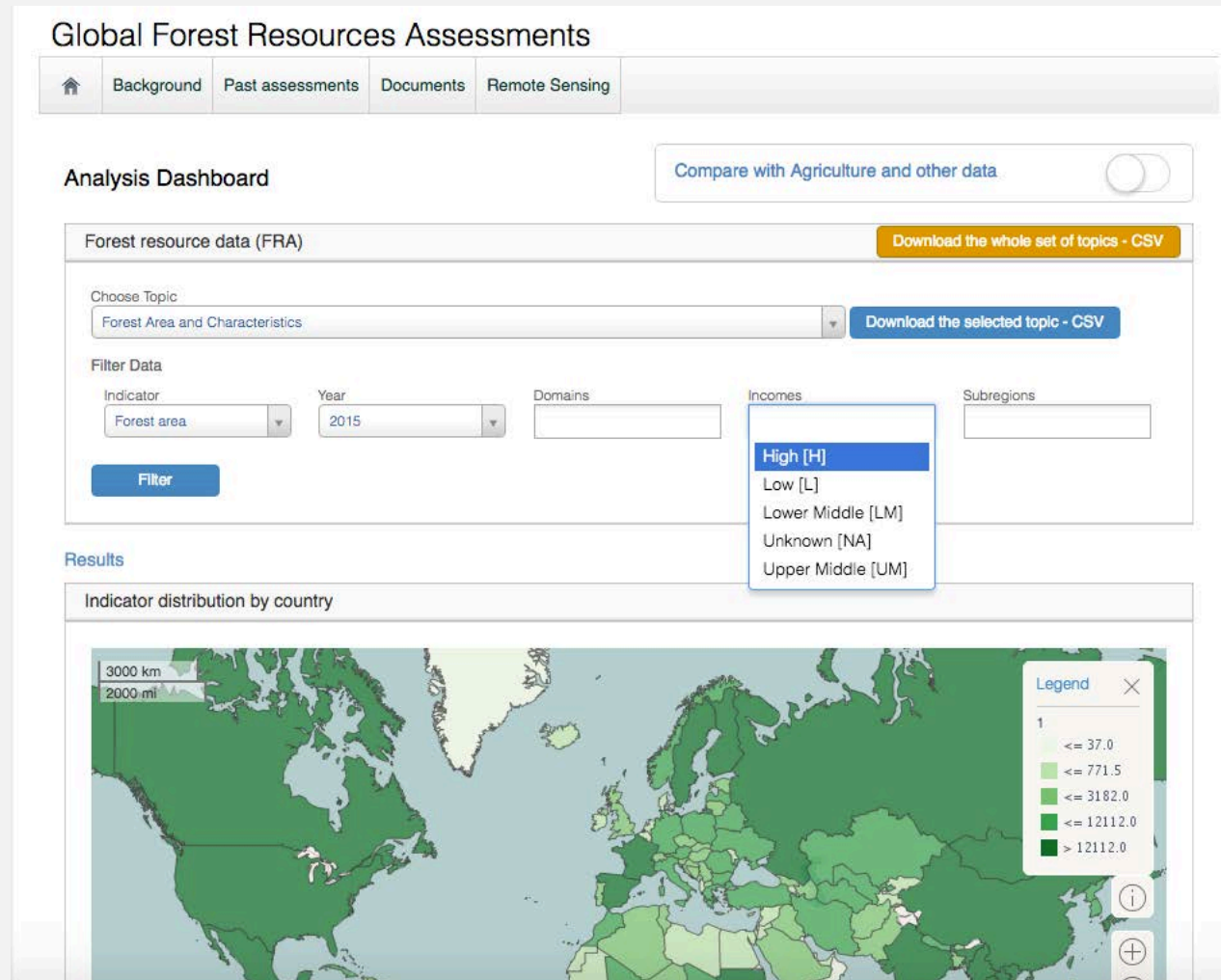




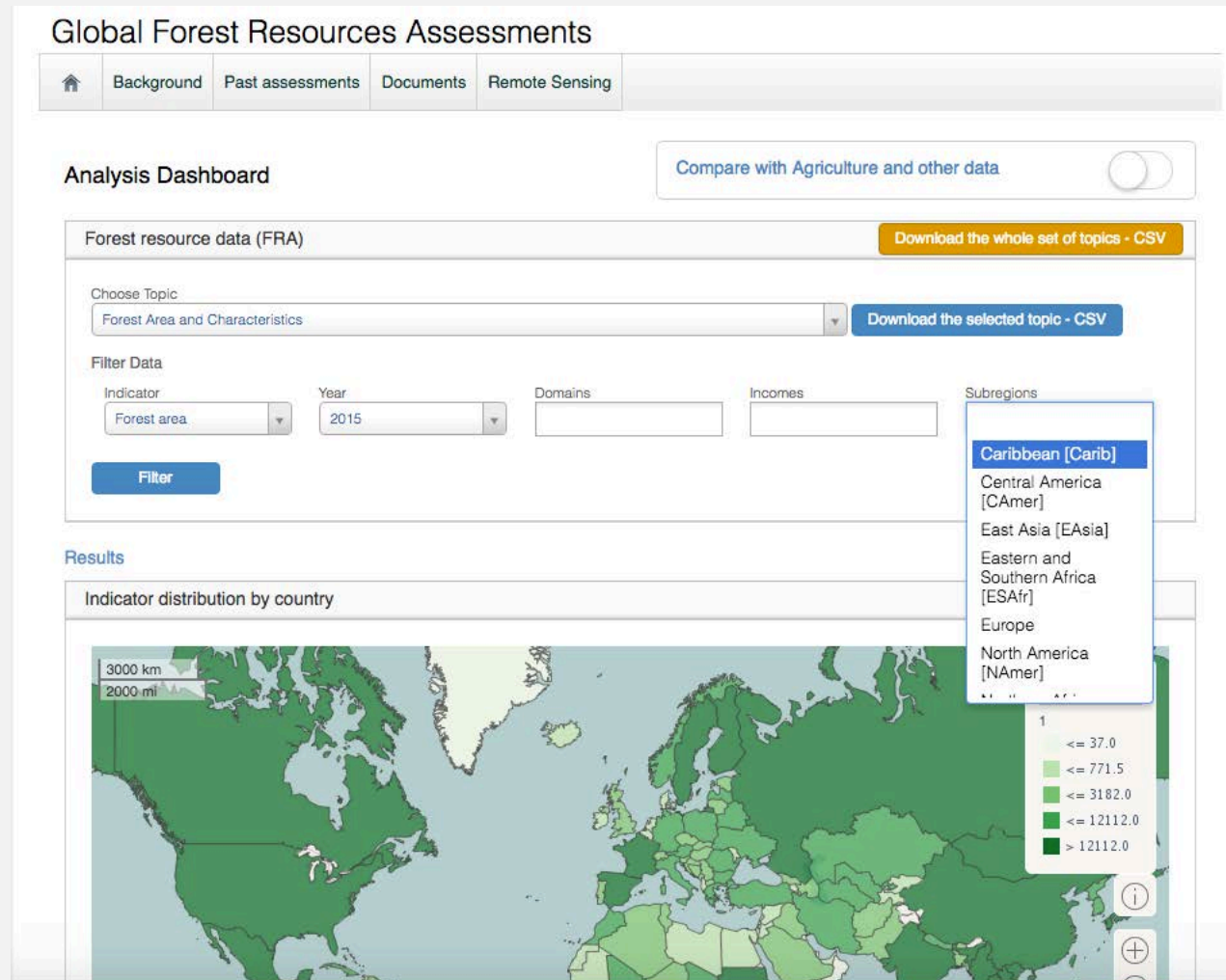
# Forest Land Use Data Explorer



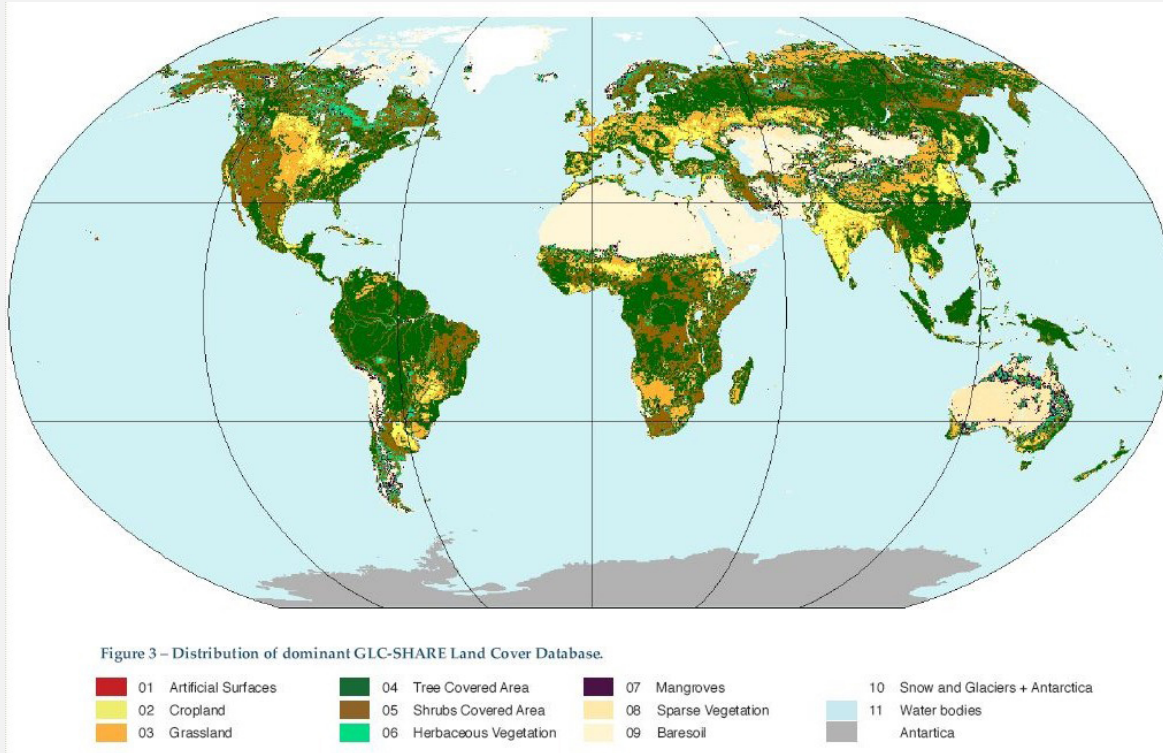
# Forest Land Use Data Explorer



# Forest Land Use Data Explorer



# FAO Global Land Cover-SHARE



- Available for 2014
- Includes 11 land cover classes
- Available for download through FAO GeoNetwork portal:  
<http://www.fao.org/geonetwork/srv/en/main.home>
- FAO also has national and regional land cover datasets for many countries in Africa and the Himalayas:  
[http://www.glcnet.org/dat\\_1\\_en.jsp](http://www.glcnet.org/dat_1_en.jsp)

# ESA Climate Change Initiative Land Cover

<http://www.esa-landcover-cci.org>

- Annual global land cover time series from 1992-2015
- Spatial Resolution: 300 meters
- Remote Sensing Sources:
  - NOAA AVHRR, SPOT, ENVISAT, PROBA-V
- 22 land cover classes based on the UN Land Cover Classification System
- Visualization and download:
  - CCI Land Cover viewer: <http://maps.elie.ucl.ac.be/CCI/viewer/>

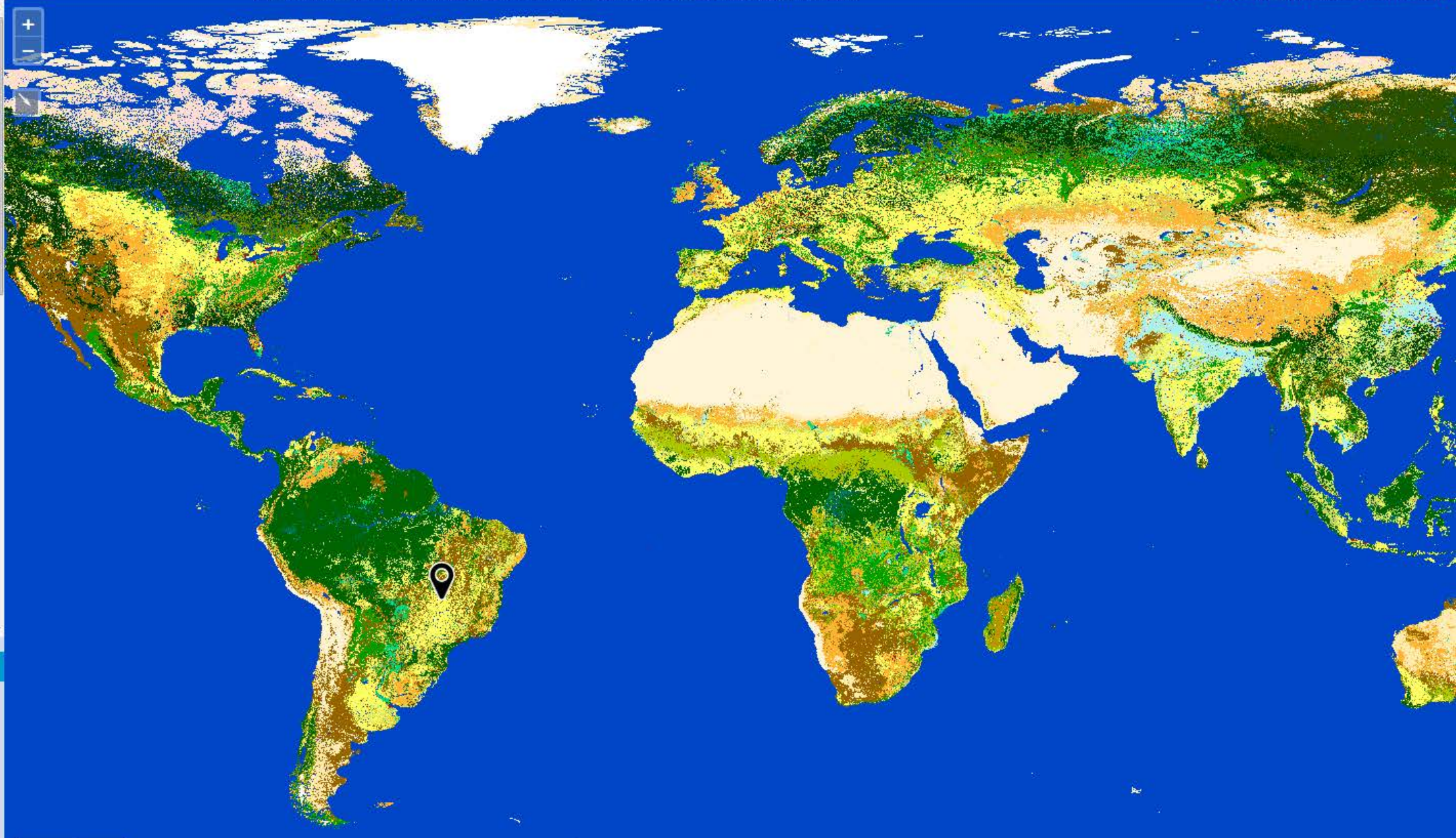




- ### Land cover legend
- view global (level 1)
- Cropland, rainfed
  - Herbaceous cover
  - Tree or shrub cover
  - Cropland irrigated or post-flooding
  - Mosaic cropland (>50%) / natural vegetation (Tree, shrub, herbaceous cover) (<50%)
  - Mosaic natural vegetation (Tree, shrub, herbaceous cover) (>50%) / cropland (<50%)
  - Tree cover, broadleaved, evergreen, closed to open (>15%)
  - Tree cover, broadleaved, deciduous, closed to open (>15%)
  - Tree cover, broadleaved, deciduous, closed (>40%)
  - Tree cover, broadleaved, deciduous, open (15-40%)
  - Tree cover, needleleaved, evergreen, closed to open (>15%)
  - Tree cover, needleleaved, evergreen, closed (>40%)
  - Tree cover, needleleaved, evergreen, open (15-40%)
  - Tree cover, needleleaved, deciduous, closed to open (>15%)
  - Tree cover, needleleaved, deciduous, closed (>40%)
  - Tree cover, needleleaved, deciduous, open (15-40%)

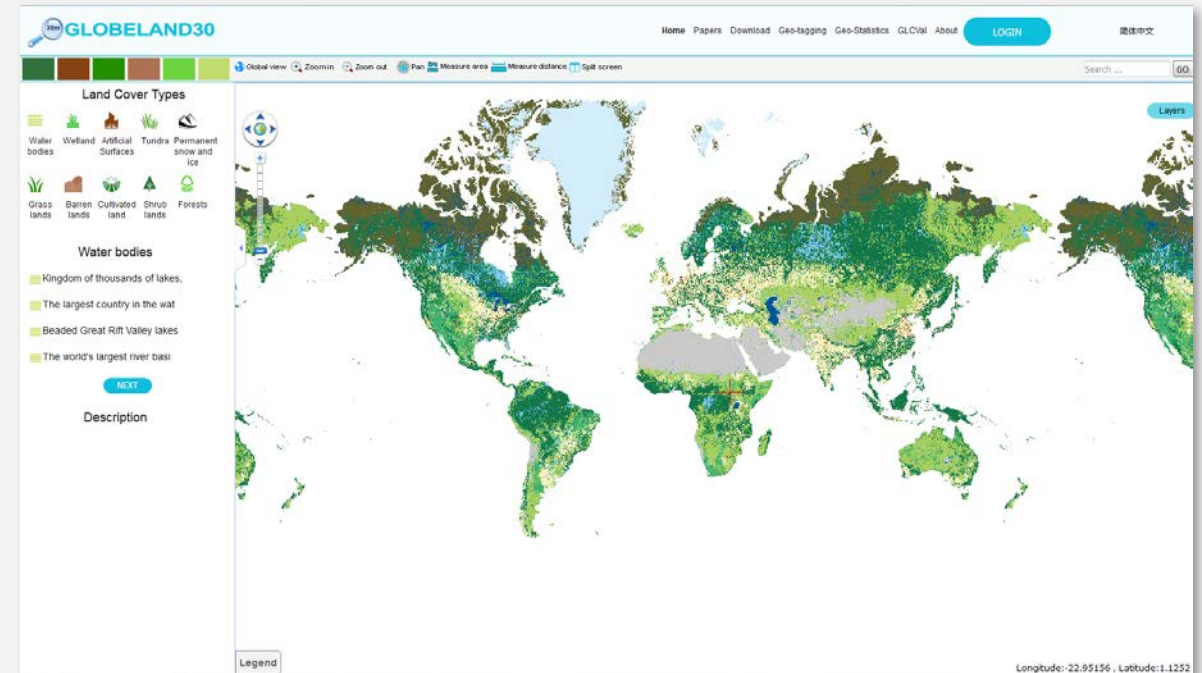
### Documentation

- [Product User Guide v2](#)
- [Quick User Guide for Maps v2.0.7](#)
- [Quick user guide Land Surface Seasonality products](#)
- [Legend for LC Map v2.0.7](#)
- [Preview LC Map v2.0.7 for Year 2015](#)
- [Preview MERIS SR Composite](#)



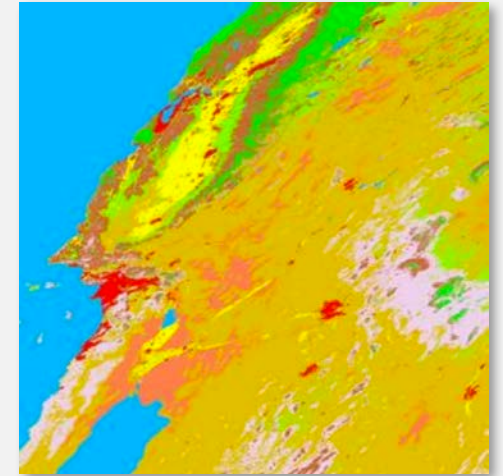
# GlobeLand30 (China)

- Launched in 2010
- Spatial resolution 30 meters
- 10 land cover classes
- For years 2000 and 2010
- <http://www.globallandcover.com/GLC30Download/index.aspx>

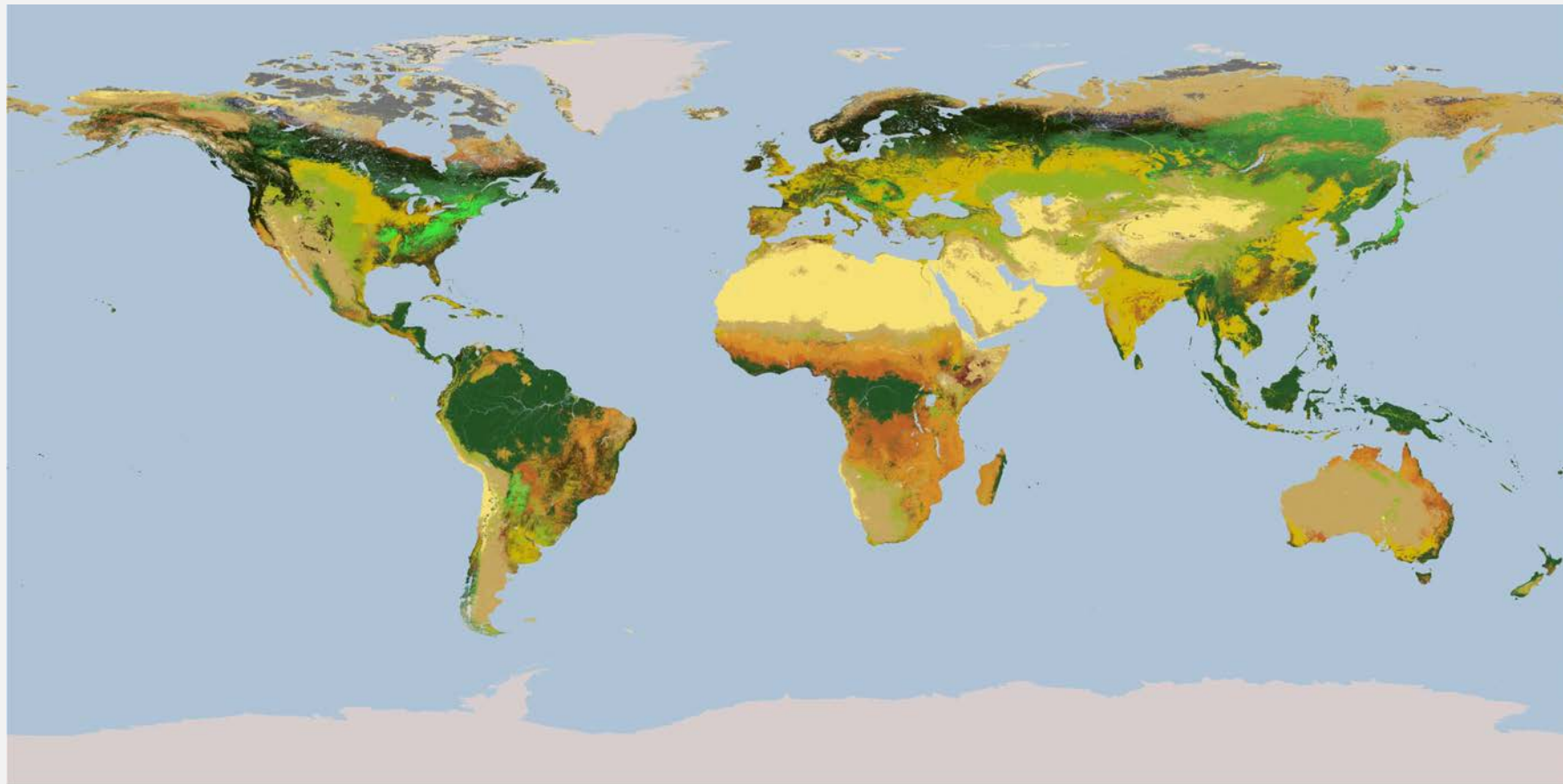


## MODIS Land Cover (MCD12Q1)

- Contains five classification schemes
  - Identifies 17 land cover classes identified by the International Geosphere Biosphere Programme, which includes 11 natural vegetation classes, 3 developed and mosaicked land classes, and 3 non-vegetated land classes
- Spatial Resolution: 500 meters
- Temporal Coverage: 2001-2013 annually
- *Note:* MODIS Version 5 processing has ended so years after 2013 will not be processed. The new suite of Version 6 land cover products are *expected* to be complete by end of 2017.
- Download data from NASA's Earthdata: <http://search.earthdata.nasa.gov>







- |   |   |   |
|---|---|---|
|  0 Water                        |  6 Closed Shrublands    |  12 Croplands                     |
|  1 Evergreen Needleleaf Forest |  7 Open Shrublands     |  13 Urban and Built-Up           |
|  2 Evergreen Broadleaf Forest  |  8 Woody Savannas      |  14 Cropland/Natural Veg. Mosaic |
|  3 Deciduous Needleleaf Forest |  9 Savannas            |  15 Snow and Ice                 |
|  4 Deciduous Broadleaf Forest  |  10 Grasslands         |  16 Barren or Sparsely Vegetated |
|  5 Mixed Forests               |  11 Permanent Wetlands |  17 Tundra                       |

**EARTHDATA Search**

**Browse Collections**

Features

- Map Imagery
- Near Real Time
- Subsetting Services

Keywords

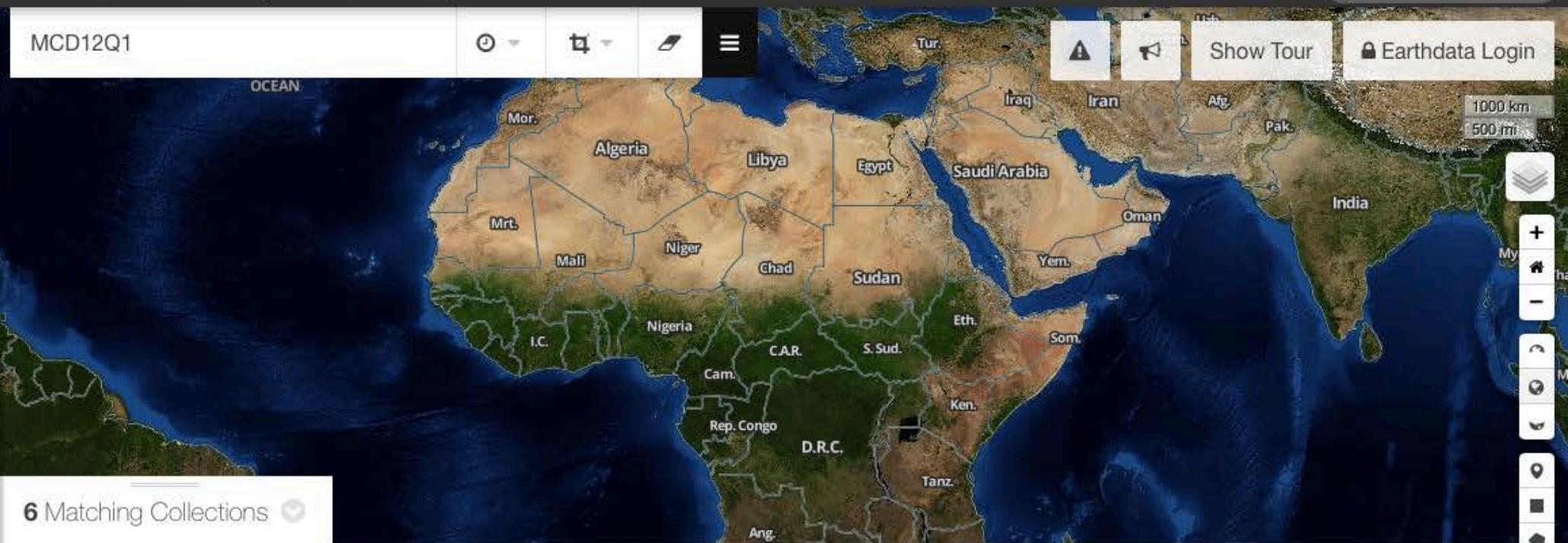
Platforms

Instruments

Organizations

Projects

Processing levels



6 Matching Collections

Only include collections with granules  Include non-EOSDIS collections

Tip: Add + collections to your project to compare and download their data. [Learn More](#)

Report a metadata problem

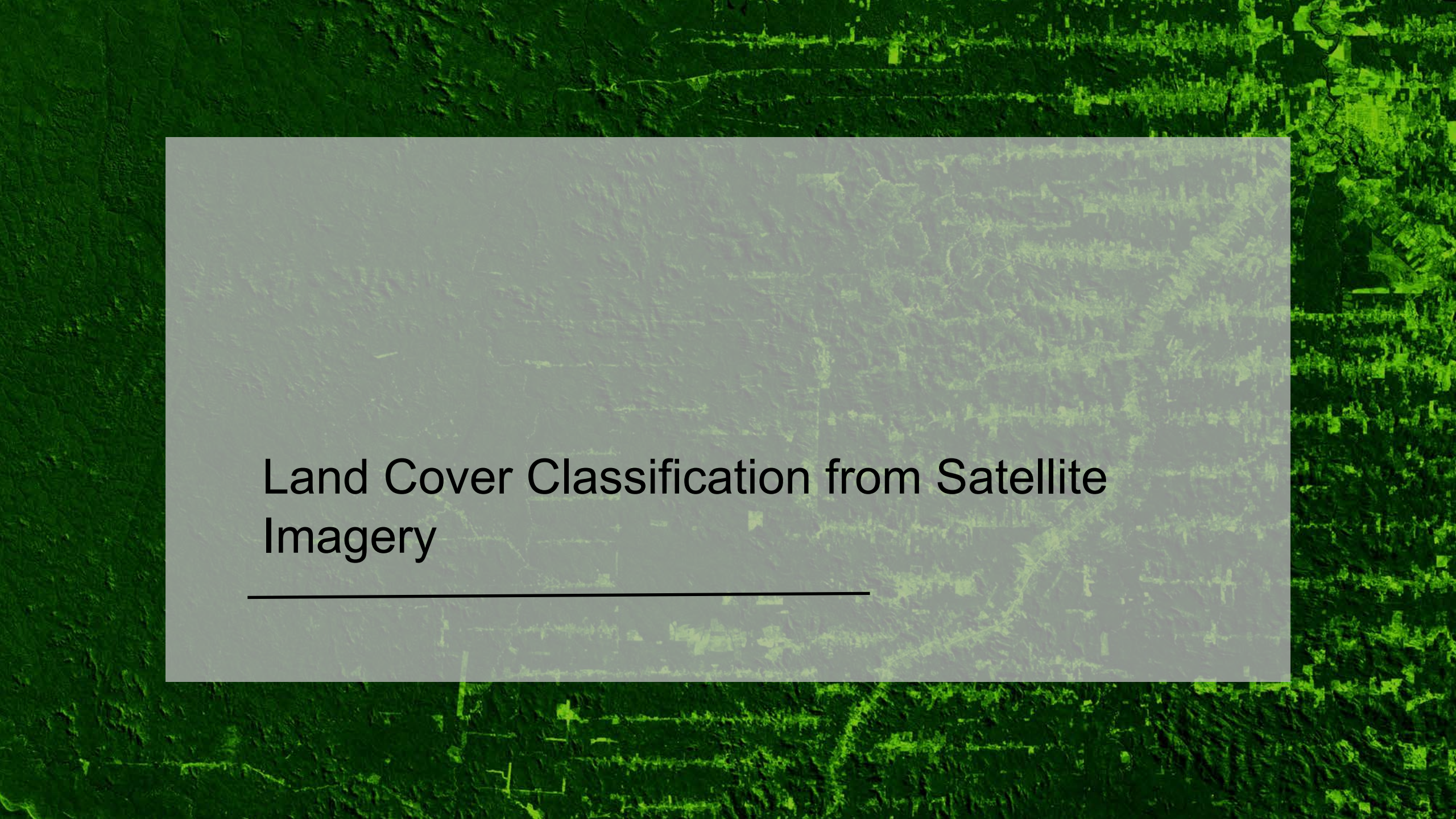
- MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V051**

4121 Granules • 2001-01-01 ongoing • The MODIS Land Cover Type product contains five classification schemes, which describe land cover properties derived from observations spanning a year's input of Terra- and Aqua-MODIS data. The primary land cover scheme identifies 17 land cover classes defined by the Internation...

SUBSETTING MCD12Q1 v051 - LP DAAC
- GLDAS Noah Land Surface Model L4 3 hourly 0.25 x 0.25 degree V2.0 (GLDAS\_NOAH025\_3H) at GES DISC**

184087 Granules • 1948-01-01 to 2010-12-31 • Global Land Data Assimilation System Version 2 (hereafter, GLDAS-2) has two components: one forced entirely with the Princeton meteorological forcing data (hereafter, GLDAS-2.0), and the other forced with a combination of model and observation based forcing data sets (hereafter, ...

GLDAS\_NOAH025\_3H V2.0 - NASA/GSFC/SED/ESD/GCDC/GESDISC

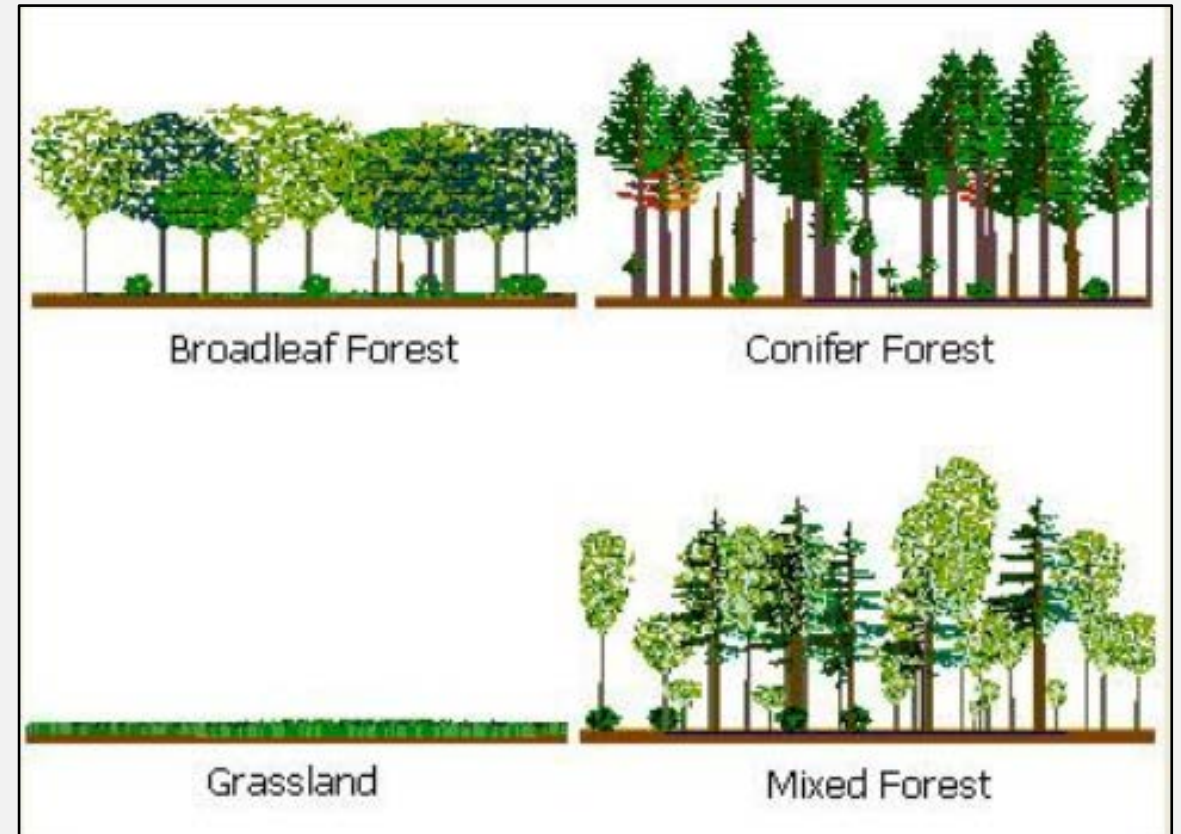
The background of the slide is a high-resolution aerial satellite image of a forested area. The terrain is rugged, with numerous ridges and valleys. The vegetation is dense and appears in various shades of green and brown, indicating different types of forest cover. A semi-transparent white rectangular box is centered on the image, containing the title text. Below the title, a thin black horizontal line is drawn across the width of the text area.

# Land Cover Classification from Satellite Imagery

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# Classification Scheme

- The schema is used to categorize and label land cover
- A well designed classification scheme is critical to deriving useful information
- Rules:
  - Must be exhaustive: all land cover in image must be included
  - Must be mutually exclusive: no overlap between classes
  - Must be based on what can be interpreted in the imagery



# Classification Scheme

## More Considerations

- Schemes should be:
  - Hierarchical
    - Forest
      - Hardwood
      - Softwood
  - Based on measurable land cover characteristics
    - Size class, percent canopy cover, etc.
- Avoid subjective, interpretive classes, such as “old growth”

## Classification Scheme: Example

- Water
- Non-Vegetated: <20% vegetated
- Rangeland: <10% tree crown closure
- Forest: >10% tree crown closure (CC)
  - Hardwood: 65% hardwood trees
    - sparse (10% to <30% CC)
    - medium density (30% to <66% CC)
    - dense (66% CC)
  - Softwood: 65% softwood trees
    - sparse (10% to <30% CC)
    - medium density (30% to <66% CC)
    - dense (66% CC)
- Other

# Classification Schemes

Classification Schemes	Purpose	Description	Minimum Mapping Unit	Temporal Product Frequency
Forest/Non-Forest	Trend analysis, basis for other products	Extent of all forest types	< 0.5 ha	Annual
Forest Stratification	Provide consistency in biomass density with a stratum for more accurate estimates	Suggested primary stratification: primary forest, modified natural forest, planted forest	< 0.5 ha	Annual
All Land Use Categories	National baseline mapping	For example, the UN-FAO Land Cover Classification System	< 0.5 ha	Annual

# Turning Data Into Information

## Spectral vs. Informational Classes

### Spectral Classes

- Groups of pixels that are uniform with respect to their pixel values in several spectral bands

### Informational Classes

- Categories of interest to users of the data (e.g. water, forest, urban, agriculture, etc.)

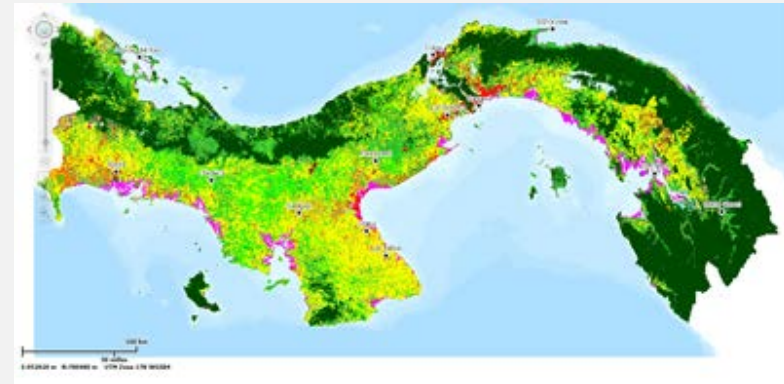
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Image classification is the process of grouping spectral classes and assigning them informational class names

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Satellite image of Panama

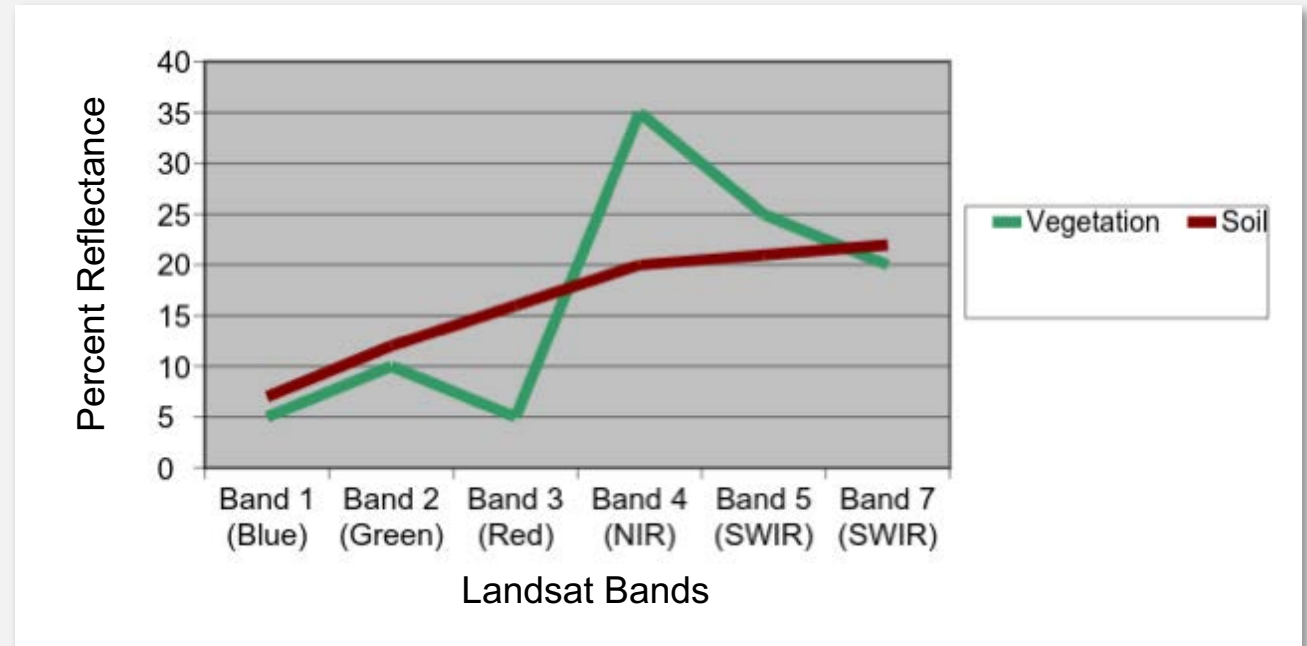


Land cover map of Panama



# Land Cover Mapping Basics

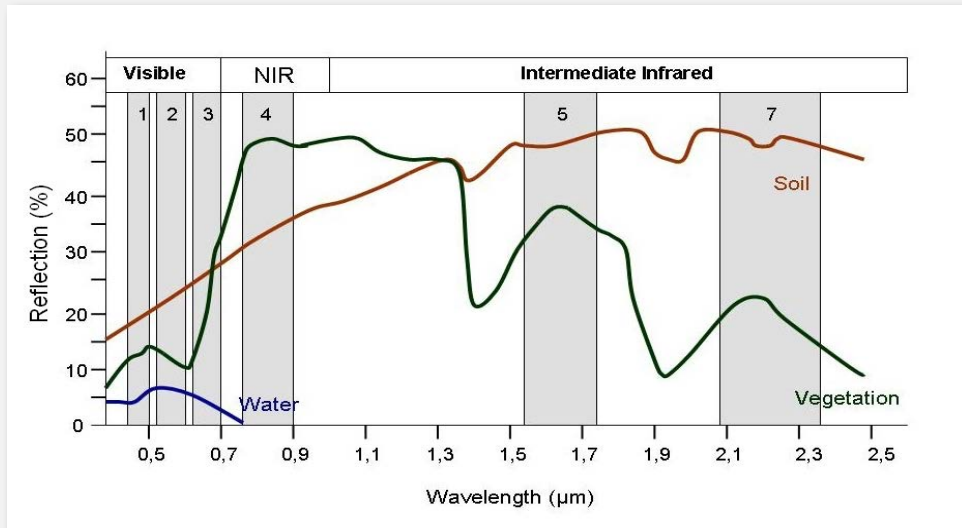
- Remember that objects on the ground reflect electromagnetic radiation differently in different wavelengths
- That is called the object's **spectral signature**
- Example: **Green** vegetation absorbs **Red** wavelengths but reflects NIR wavelengths



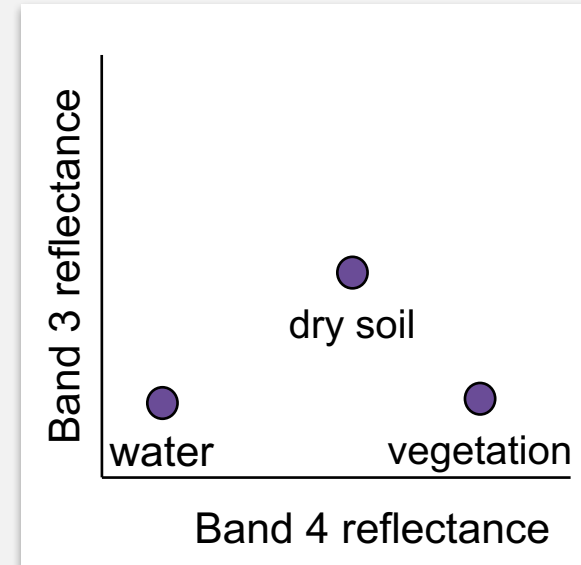
# Land Cover Mapping Basics

## Spectral Plots

- Look at spectral signatures by plotting Band 3 (Red) vs. Band 4 (NIR) reflectance values

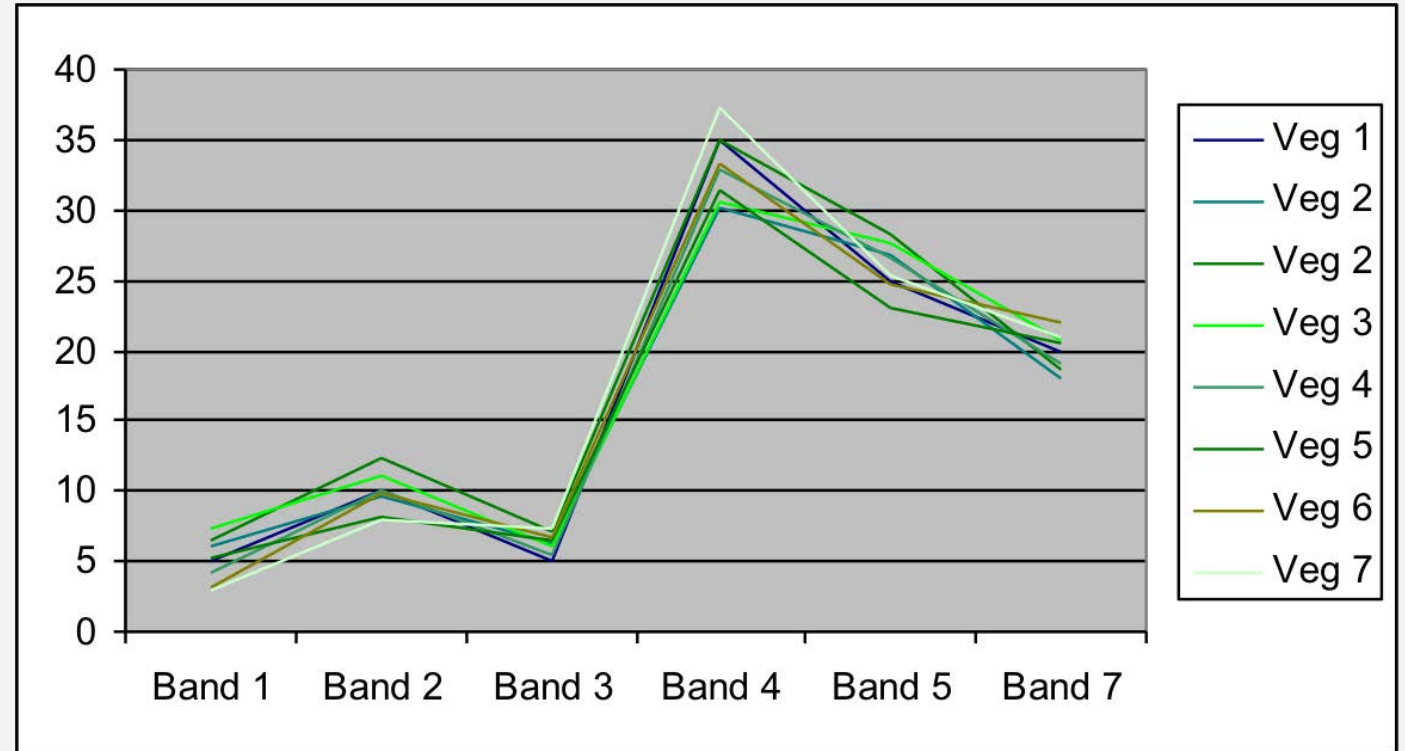


- Objects (soil, water, and vegetation) fall in different places in the plot
- The software uses this to distinguish between different land cover types



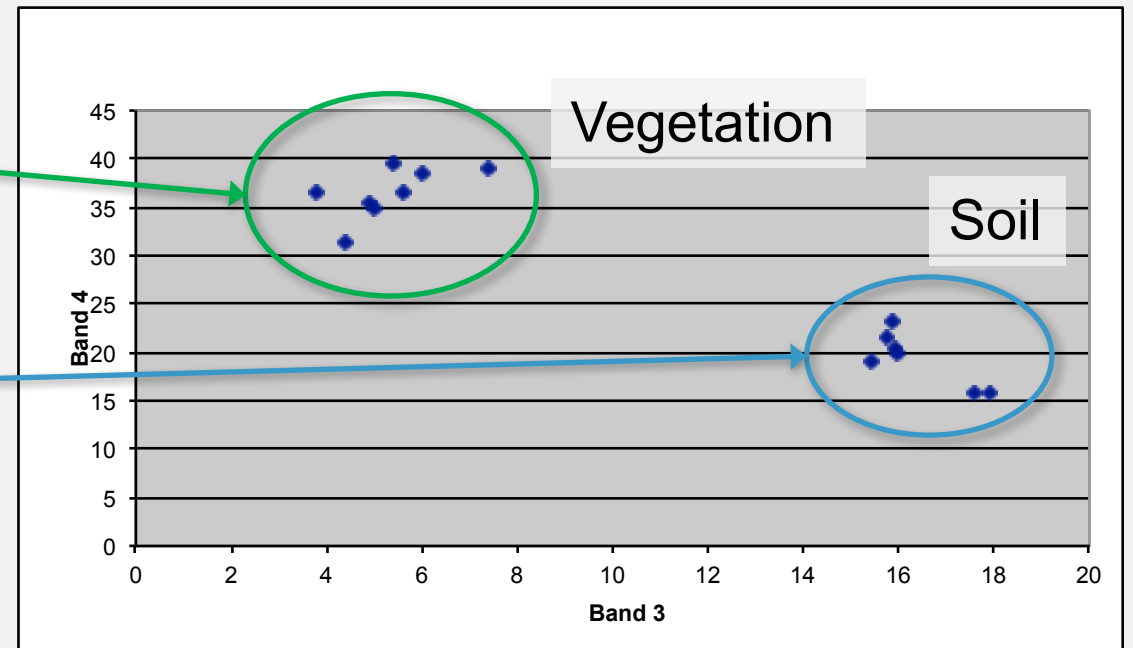
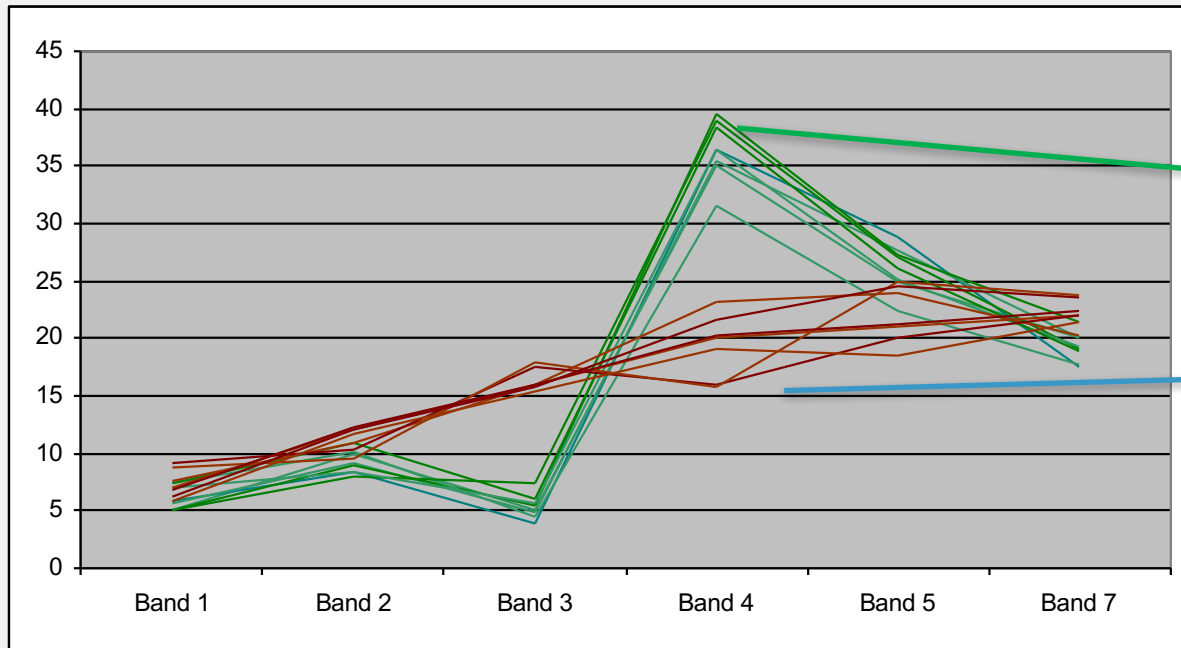
# Spectral Signatures

- There is some variation in reflectance values at different wavelengths
- Depending on the land cover classes you want, the trick is to identify this variability



# Spectral Variation

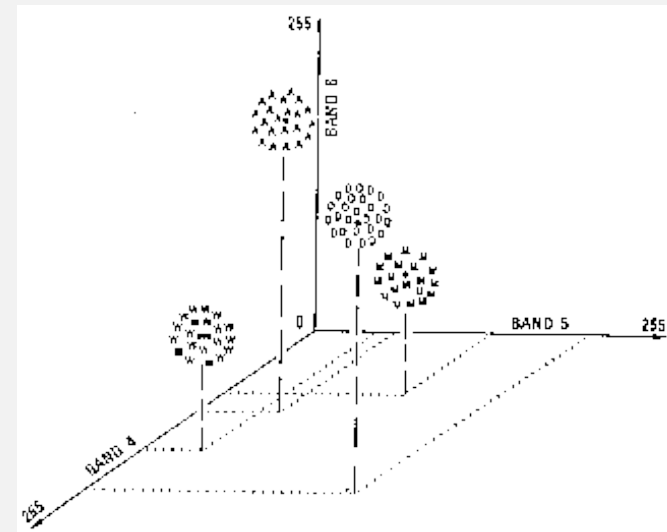
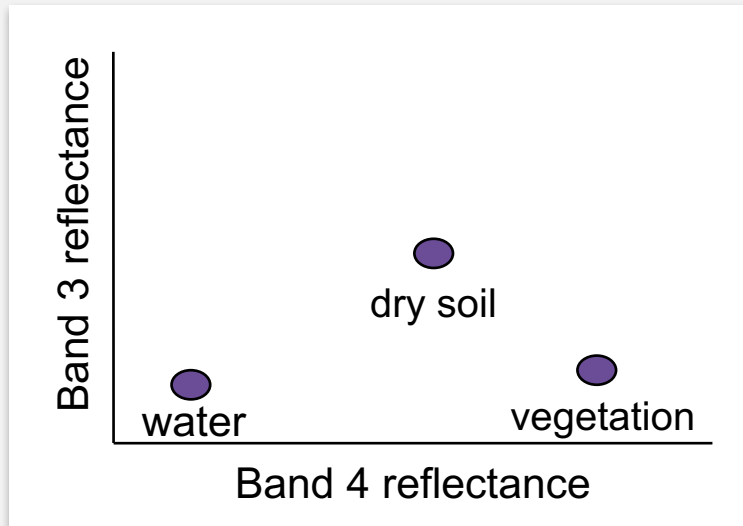
- Easier: distinguishing between broad classes (e.g. vegetation and soil)
- Harder: distinguishing *within* broad classes (e.g. vegetation types)
- Variation within and between type (broad classes) is below



# Multi-Dimensional Spectral Plots

To make things even more confusing...

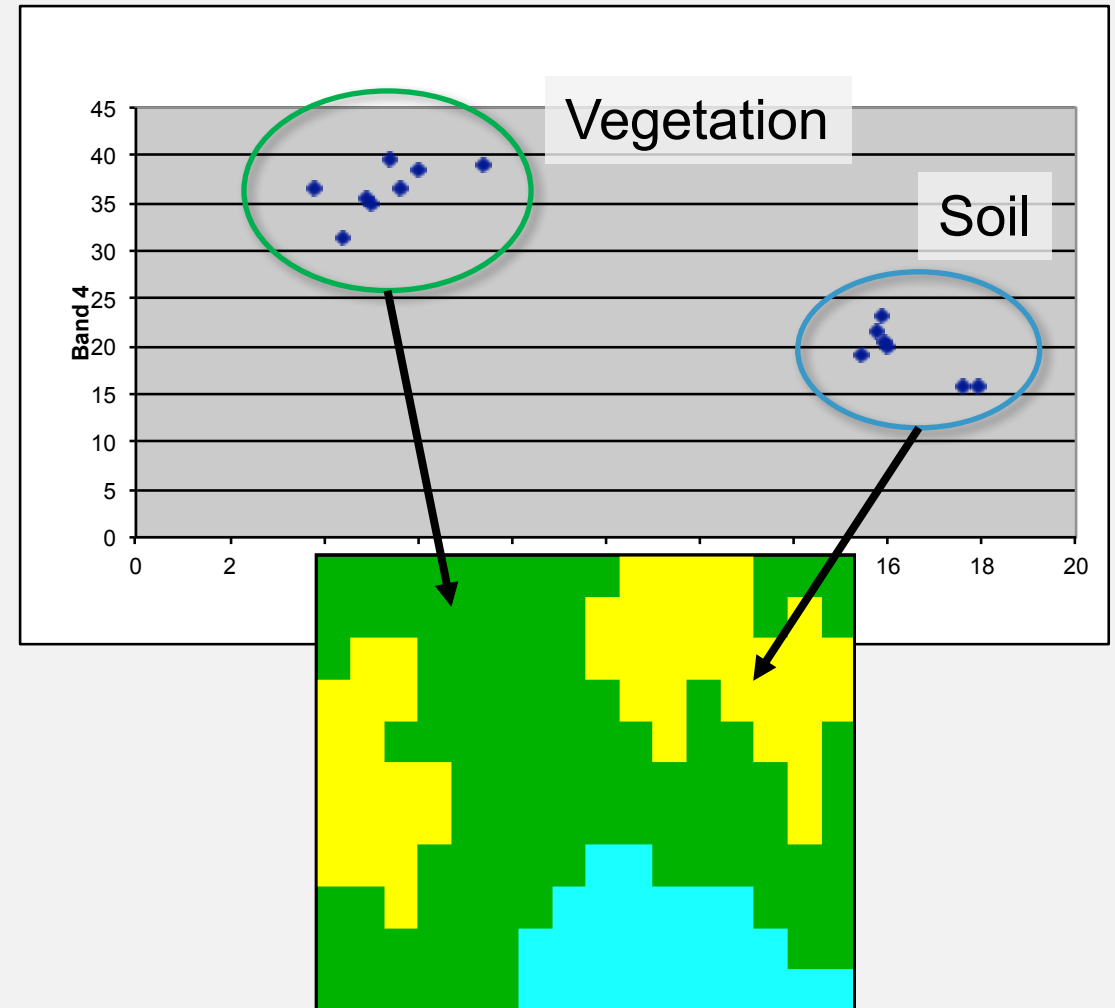
- When looking at spectral plots, each band represents a different dimension
- This is a 2 dimensional plot:
- In a spectral plot, pixels are plotted in n-dimensional space (where n represents the number of bands)
- This a 3 dimensional spectral plot:



Sabins, F. F. (1987). Remote Sensing: Principles and Interpretation (2nd ed.). W.H. Freeman and Company.

# Image Classification

- Requires delineating boundaries of classes in n-dimensional space using class statistics
- Each group of pixels is characterized by:
  - min.
  - max.
  - mean
  - standard deviation
- All the pixels in the image that fall within those statistics are given those labels

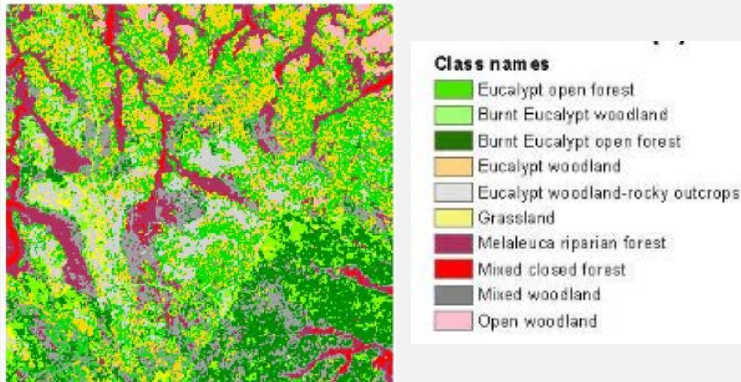


# Image Classification

## Approaches

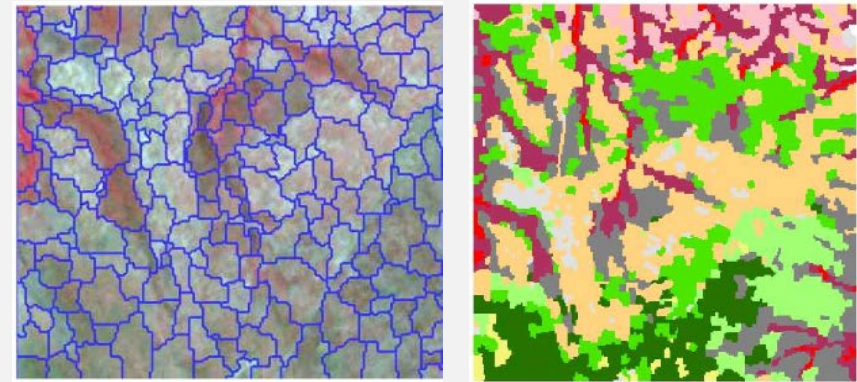
### Pixel-Based

- Each pixel is grouped in a class
- Useful for multiple changes in land use within a short period of time
- Best for complete data coverage and a need for methods to ensure time series consistency at the pixel level



### Object-Based

- Pixels with common spectral characteristics are first grouped together (segmentation)
- Useful for:
  - reducing speckle noise in radar images
  - high resolution imagery



Whiteside, T., & Ahmad, W. (2005, September). A comparison of object-oriented and pixel-based classification methods for mapping land cover in northern Australia. *Proceedings of SSC2005 Spatial intelligence, innovation and praxis: The national biennial Conference of the Spatial Sciences Institute*.

# Image Classification

## Methods

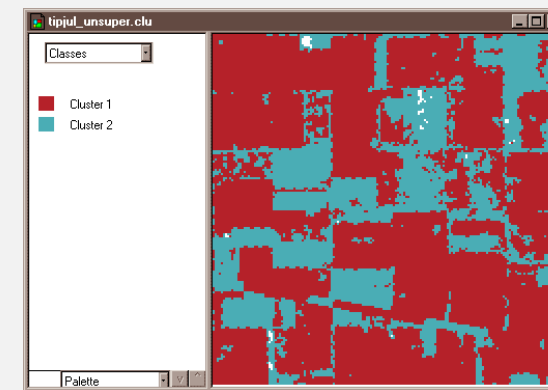
### Supervised

- Uses expert-defined areas of known vegetation types (training areas) to tune parameters of classification algorithms
- Algorithm then automatically identifies and labels areas similar to the training data



### Unsupervised

- Uses classification algorithms to assign pixels into one of a number of user-specified class groupings
- Interpreters assign each of the groupings of pixels a value corresponding to a land cover class



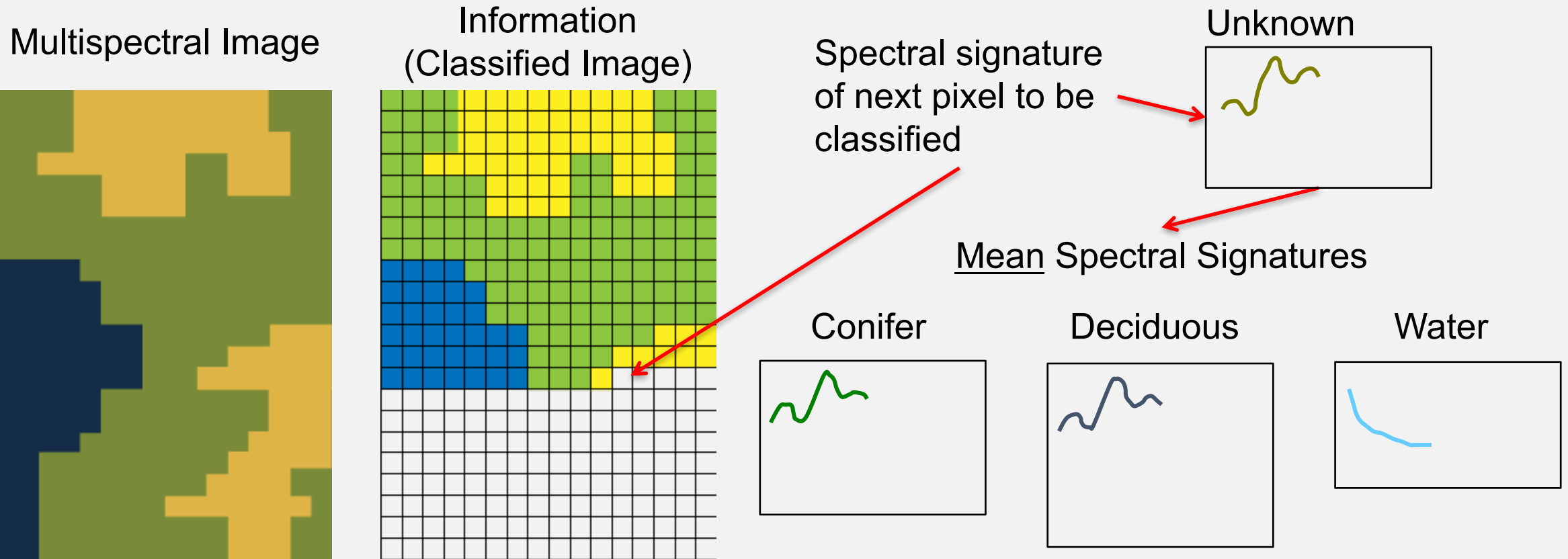
Credit: David DiBiase, Penn State Department of Geography



# Image Classification

## Supervised Method

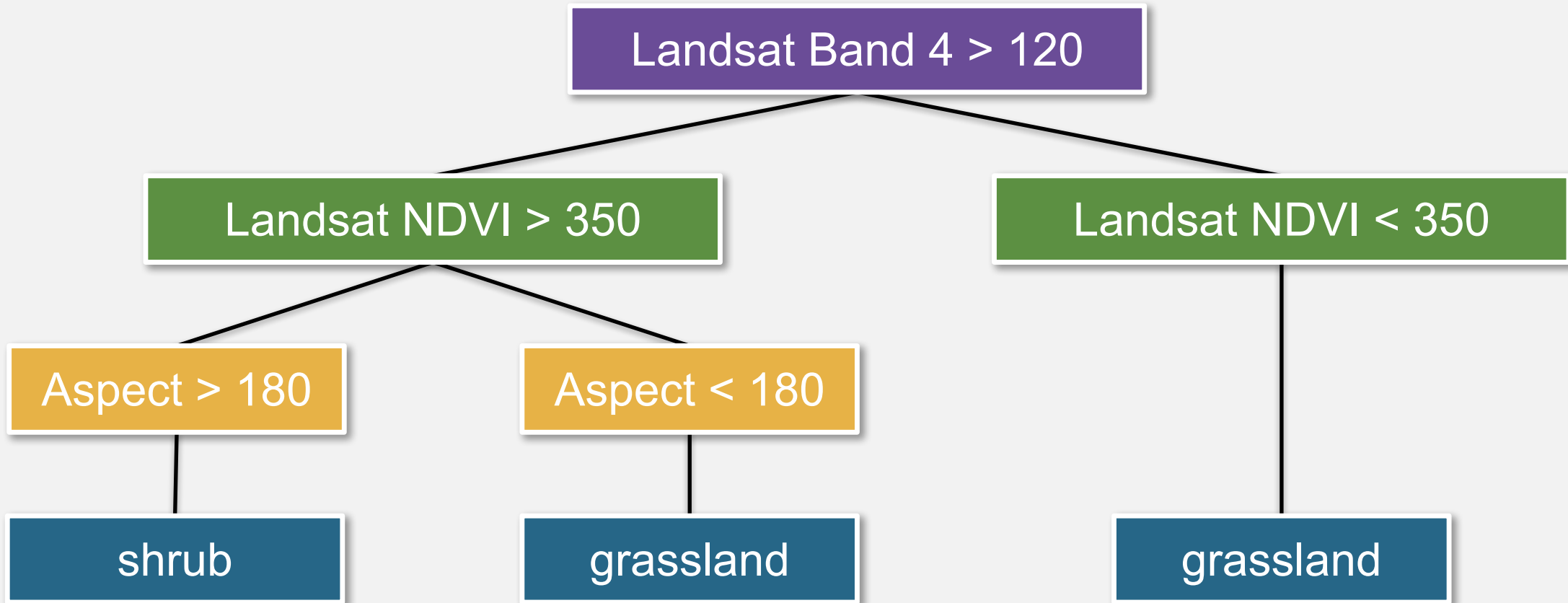
The spectral signature of each pixel in the image gets matched with the training signatures and the image is classified accordingly



# Classification Methods

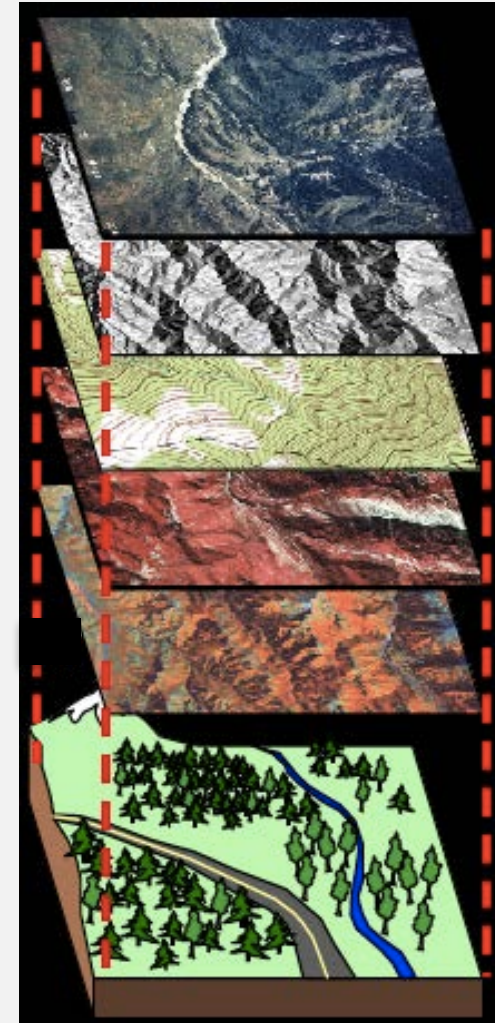
- **Classification Algorithms:** classifies the whole image by comparing the spectral characteristics of each pixel to the spectral characteristics of the training sites
  - Example: QGIS, Semi-Automated Classification Plugin has three: minimum distance, maximum likelihood, and spectral angle mapping
- **Decision Tree** (Classification and Regression Tree or CART): uses training data to develop a tree-like set of rules to determine the class for certain combinations of input data
  - Then every pixel is labeled with a class utilizing the decision rules of the classification tree
- **Random Forest:** Creates many decision trees based on predictor variables

# Decision Tree Using Landsat bands, NDVI and Digital Elevation Model Data



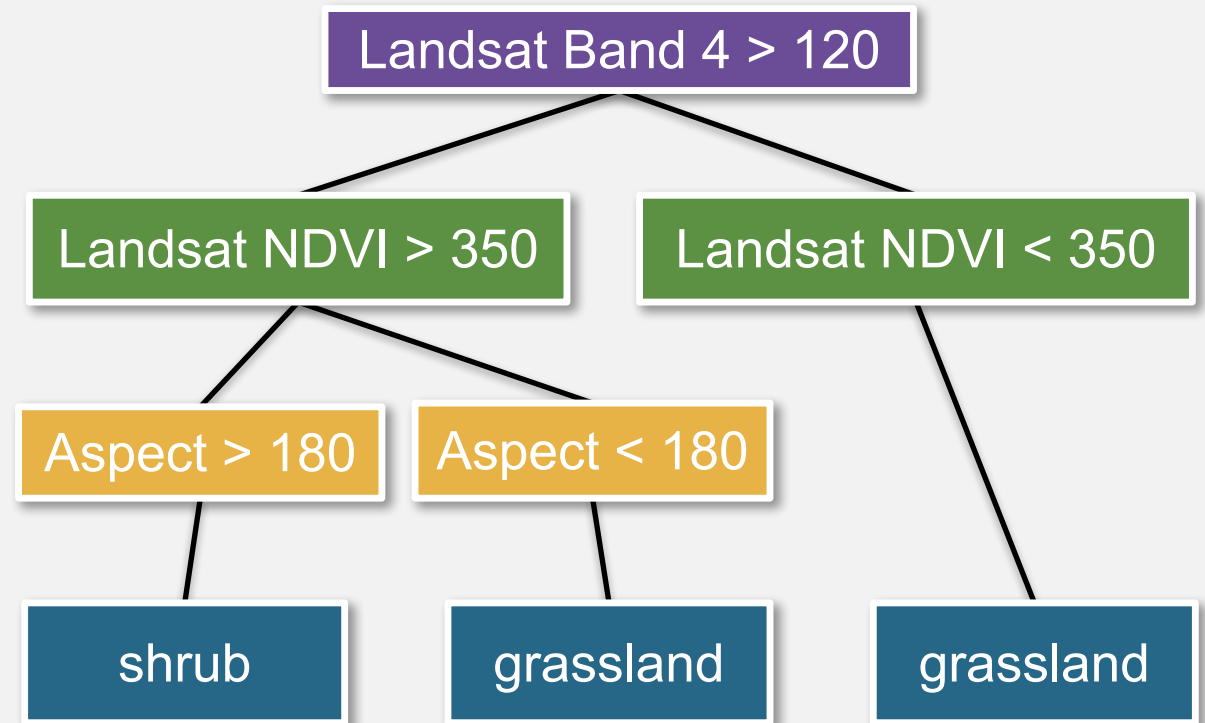
# Random Forest Inputs

- Training or reference data for each class
- Predictor variables such as:
  - Multispectral image bands
  - Topographic variables: slope, elevation, aspect
  - Bioclimatic variables: temperature, precipitation, etc.
- Derived predictor variables such as:
  - NDVI
  - Other transformations (tasseled cap, etc.)



# Random Forest Classification

- Random input variables are selected and used on the training data to make trees
- The image on the right is an example of one decision tree. Hundreds are created randomly using the training and reference data and built for your various classes.
- The decision trees, or random forest model, are used to classify the whole image



# Summary

- Indicator 15.1.1: Forest area as a proportion of total land area
- Satellite imagery can be used to derive forest area in several ways
  - Existing forest maps (e.g. Global Forest Watch)
  - Existing land cover maps (e.g. ESA Climate Change Initiative Land Cover)
  - Create your own land cover map

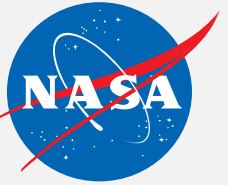
# MODIS and GFW Demo

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# Contacts

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- ARSET Website:
  - <http://arset.gsfc.nasa.gov>





## ARSET

Applied Remote Sensing Training

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# Thank You

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Next Session (tomorrow):

*SDG Target 15.3*