USDA
United States Department of Agriculture

Online Training Material: Remote Sensing for Forest Cover Change Detection

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Outline

- Course Motivation and Audience
- Landscape Changes
- Remote Sensing Technology for Assessing Landscape Change
- Course Overview: workflow review
- Next Steps
- Survey Request, your feedback helps inform our next steps and improve the materials

Training Development Goals

To build remote sensing capacity:

- Image processing theory and fundamental concepts
- Land cover mapping
- Accuracy assessment
- Detecting and monitoring landscape change

Our Objectives

Bridge the gap between training and project implementation:

- Develop a preliminary change detection workflow (project planning document)
- Remote sensing workflows instructions and project development strategies (hands on materials)
- Capstone Potential: study area is southern Thailand, but workflow can easily be implemented in any locale that is undergoing landscape change

Potential Applications

Greenhouse gas inventory reporting

- Context of the United Nations Framework Convention on Climate Change (UNFCCC)

Monitoring & Measurement, Reporting and Verification

- For REDD+ (Reducing Emissions from Deforestation and forest Degradation)

National Forest and Land Cover Inventories

- Inform national land management policies

Criteria for change detection workflow

Consistent and transparent methodology for generating activity data is important for informing policy decisions and measures.

1. IPCC Good Practice Guidance principles
   http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf
2. Methods and Guidance Document for forest monitoring in the context of REDD+, Global Forest Observation Initiative
   http://www.gfoi.org/methods-guidance/

Case Study: Forest Cover Change

- Focus is tracking changes in forest cover…
- But the methods presented applicable for assessing any land cover transition of interest, making it applicable for a wide range of users.

Suggested Skill Set

- Background in geographic information systems (GIS)
- General awareness of remote sensing technology and theory

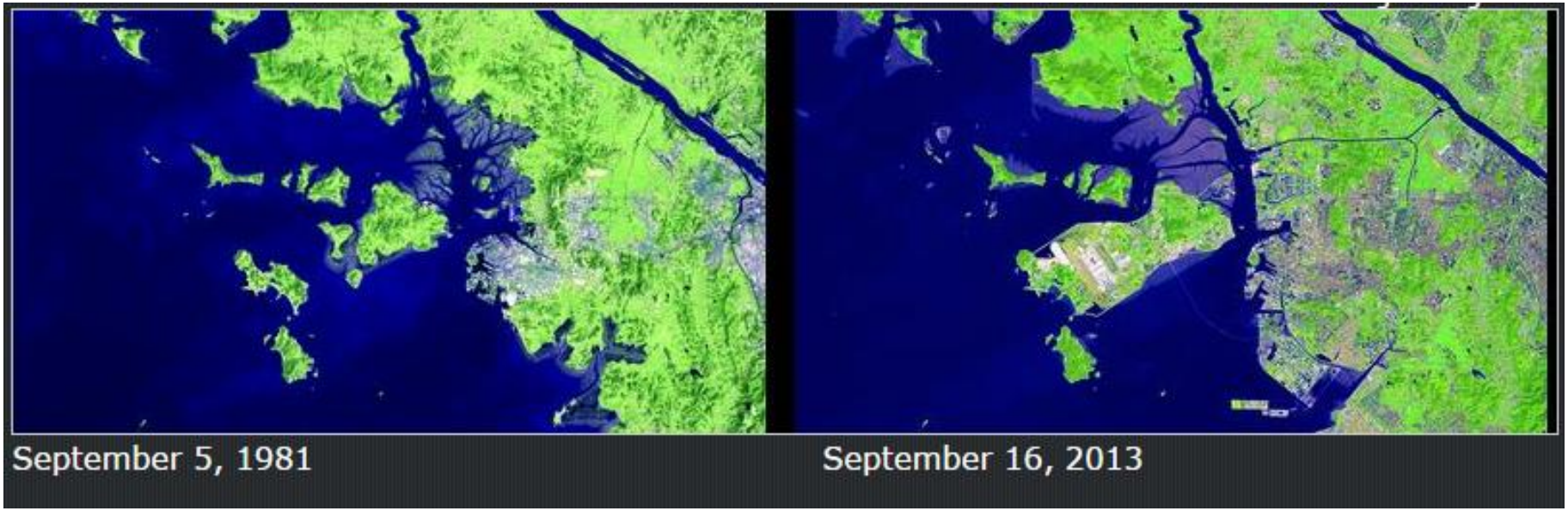
How will this help you?

- It will provide you with the **knowledge** and a set of associated **tools** to implement a processing **workflow**
- You will be able to… “Produce reliable, consistent and comparable reports on **change in forest cover and forest use** and associated anthropogenic greenhouse gas emissions or removals”

GFOI (2013) Integrating remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative: Pub: Group on Earth Observations, Geneva, Switzerland, 2014.

Landscape change

- 32 years of shoreline changes in Incheon, South Korea



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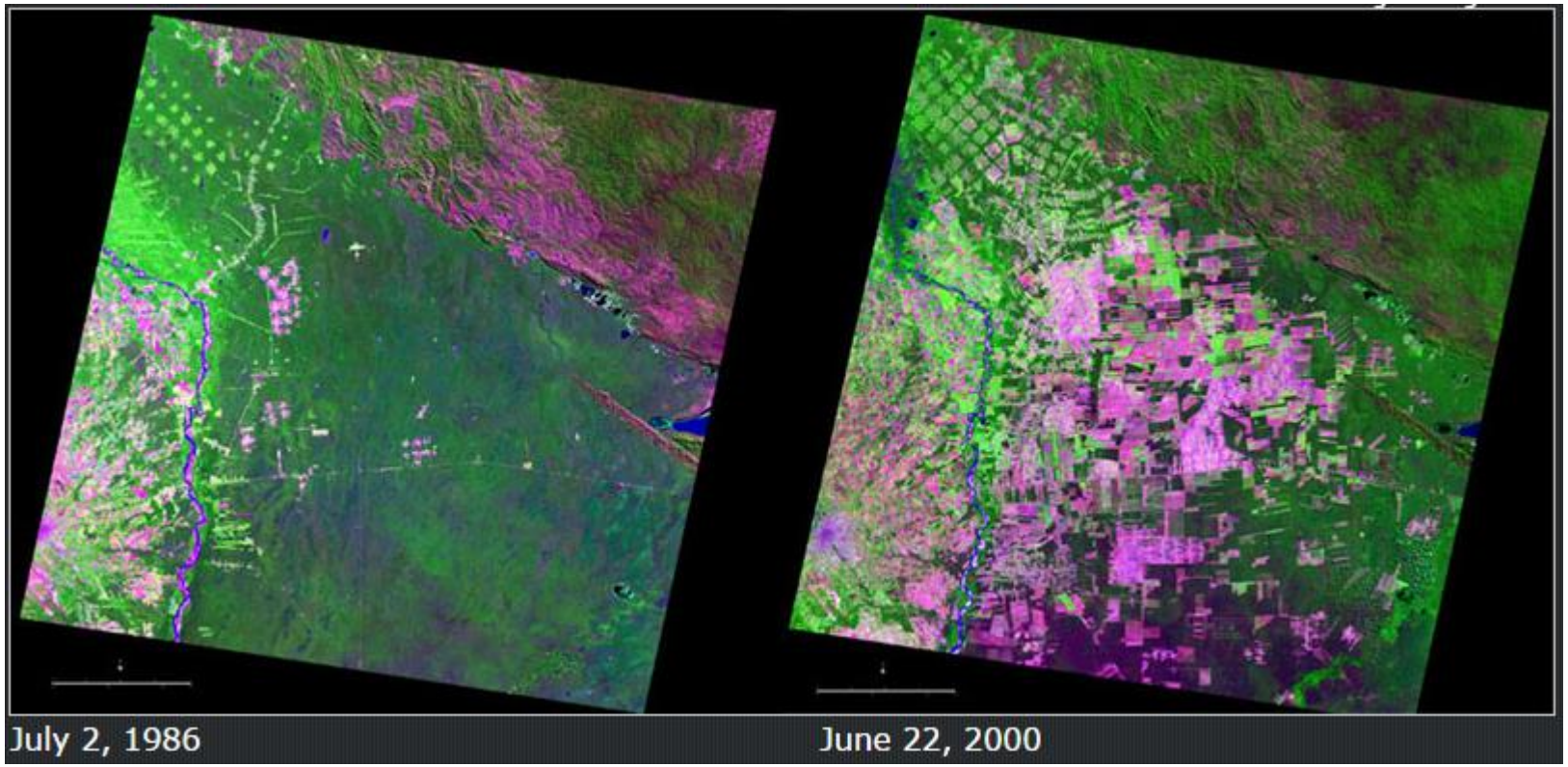
Landscape change

- 14 years of forest cover changes in Bolivia



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Characterizing landscape change

Cyclical land cover changes

- succession, agricultural practices and rotations, natural disturbances (fire, drought, etc.)

Semi-permanent land cover changes

- *Fast pace:* development, conversion to agriculture, sea level rise
- *Slow pace:* degradation, changes in community composition under changing climate

Change Agents

- Land use change: urban development, agricultural expansion, etc.
- Natural disturbances: wildfire, insect outbreaks, drought, storms, invasive species, etc.
- Growth cycle: regeneration, succession, etc.
- Forest management: harvest, thinning, planting, etc.

How do we map changes?

- Compare remotely sensed images from different times
- Assumption:

Landscape change -> Spectral change

Landscape after fire event

Landsat Images:

Pre-fire

Post-fire

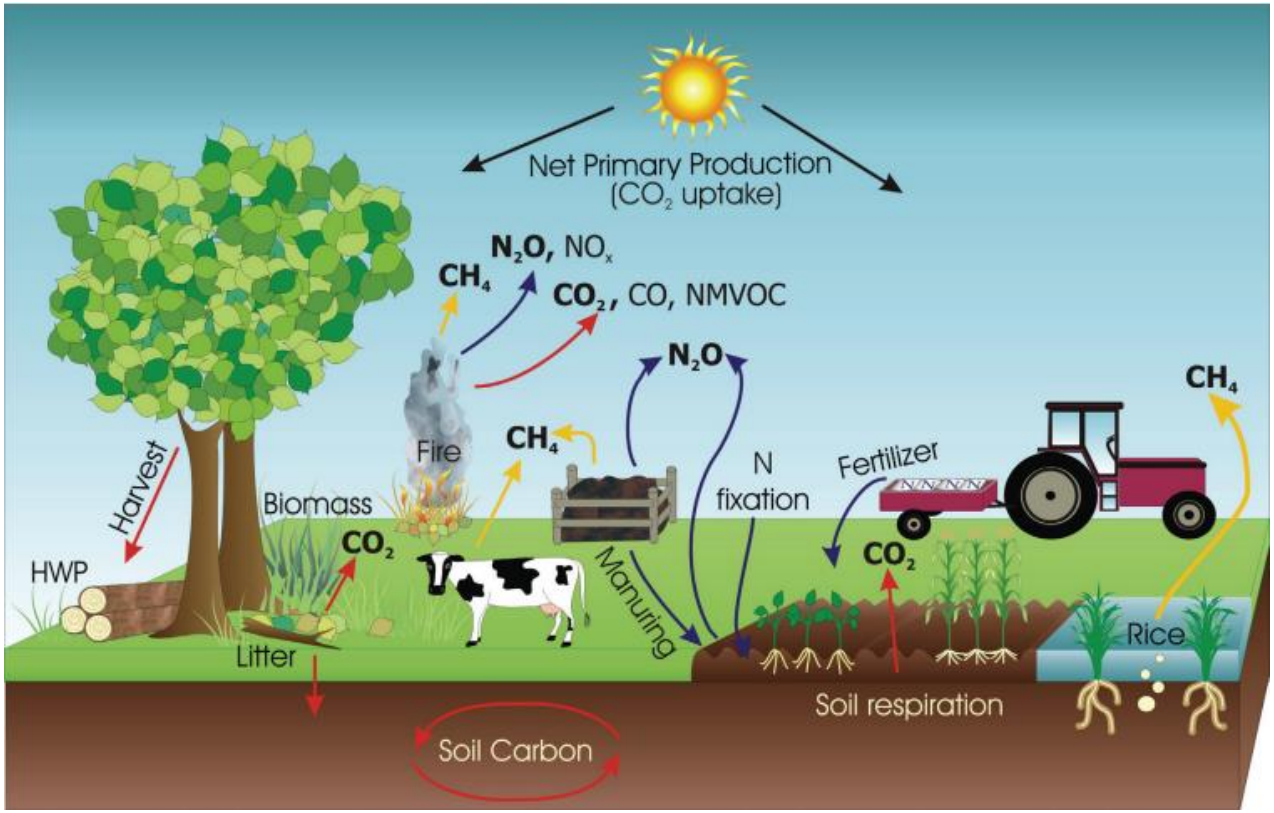
Relevance to Agency Goals

Remote Sensing provides information for four key resource management questions:

1. Inventory: how much is there?
2. Mapping: where is it?
3. Classification: what is it?
4. Monitoring: has it changed? If so, was there a gain or loss of (forest) cover?

Landscape Assessment Considerations

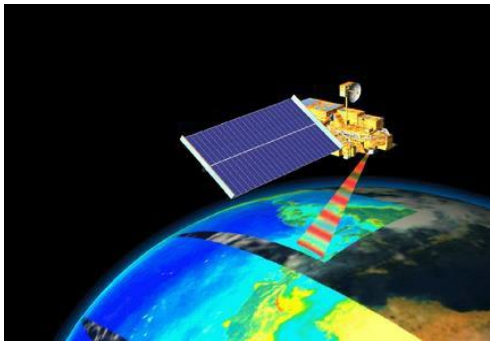
- Cost effective, save money
- Efficient, save time



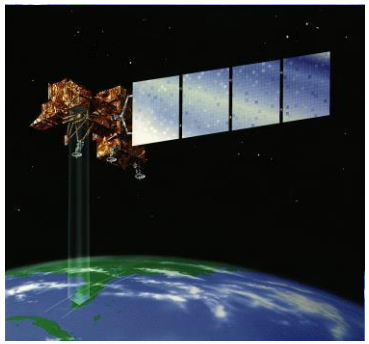
Complete wall to wall coverage, at no cost

- Satellite and aerial sensors provide:
  - Cover the globe
  - Consistent, repeatable measurements
  - Information on the full EM spectrum: human eye cannot see near infrared and shortwave infrared
  - Ever-growing archive of publically available imagery

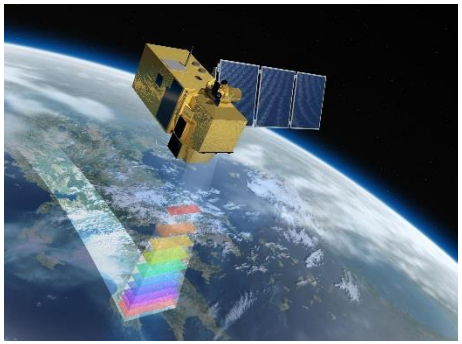
MODIS



Landsat

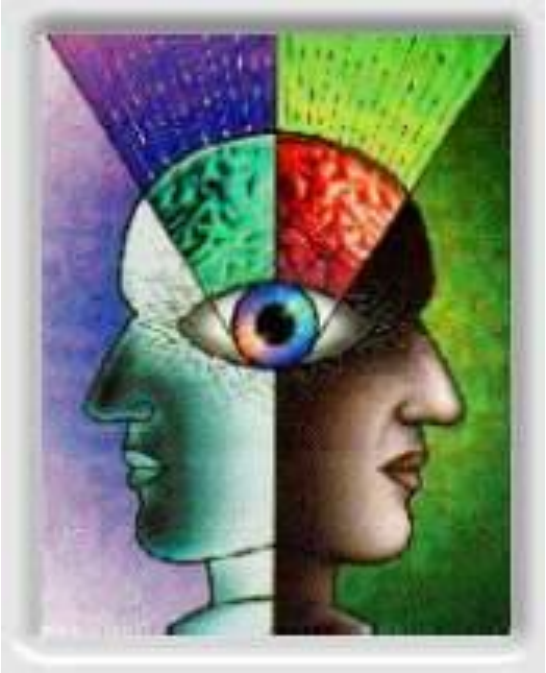


Sentinel



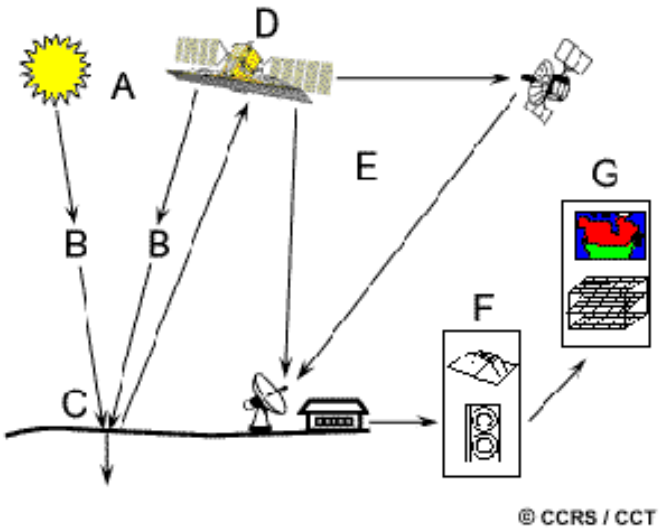
Assess images manually?

- The human eye and brain = a very effective and complex remote sensing sensor
- Humans instantaneously derive information using the following image attributes
  - Size
  - Shape
  - Tone/color
  - Texture
  - Shadow
  - Association
  - Pattern



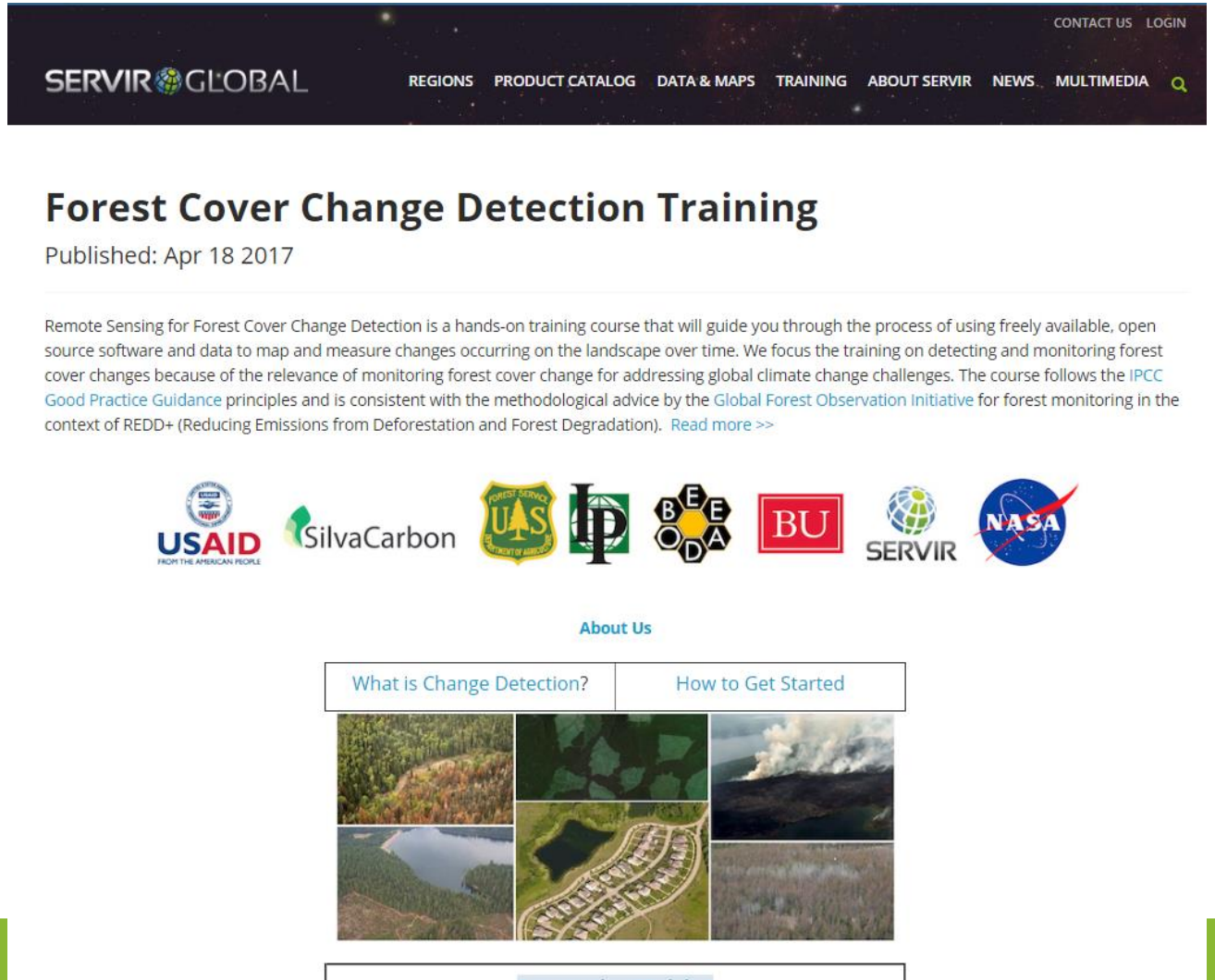
Why RS when human eye is effective?

- Remote Sensing technology attempts to duplicate the human (brain-eye) process
- Advantages of remote sensing technology:
  - Fast processing with automated machine learning algorithms
  - Computer advancements: processing power and virtually unlimited storage capacity



Introduce Online Training Course

https://www.servirglobal.net/Global/Articles/Article/2549/forest-cover-change-detection-training



Training Materials

Provide an overview of the change detection workflow:

Module 1: Project Planning and Documentation

Module 2: Acquiring Data with Google Earth Engine

Module 3: Mapping Land Cover (time 1)

Module 4: Mapping and Classifying Areas of Change (time 1 vs. 2)

Remember complete details are found in the module presentations and exercises online.

Free and open source software

The following software is used in the training:

- Image processing and data download:
  - Google Earth Engine
- Image analysis, creating land cover maps:
  - QGIS
- Reference data collection:
  - Google Earth
  - Collect Earth desktop (online version coming soon!)





Workflow

Module 1: Project Planning and Documentation

- Articulate project goals
- Plan your remote sensing approach
- Document methods

Module 2: Acquiring Data with Google Earth Engine

Module 3: Land Cover Mapping (time 1)

Module 4: Mapping and Classifying Areas of Change (time 2)

Analysis Prerequisites

- Clearly define project scope and objectives
- Identify the information needs:
  - Change phenomena of interest (e.g., forest harvest, fire, forest degradation)
  - Define study area
  - Determine frequency for change analysis (e.g., seasonal, annual, biennial)
  - Consider limitations

These considerations determine appropriate methods and whether or not change can even be detected

Methodology Resources

Consistent and transparent methodology for generating activity data is important for informing policy decisions and measures.

1. IPCC Good Practice Guidance principles
   http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf
2. Methods and Guidance Document for forest monitoring in the context of REDD+, Global Forest Observation Initiative
   http://www.gfoi.org/methods-guidance/

Workflow

Module 1: Project Planning and Documentation

Module 2: Acquiring Data with Google Earth Engine

- Learn JavaScript
- Access Landsat (or Sentinel, MODIS) archive
- Mask clouds and shadows
- Export a cloud free composite

Module 3: Land Cover Mapping (time 1)

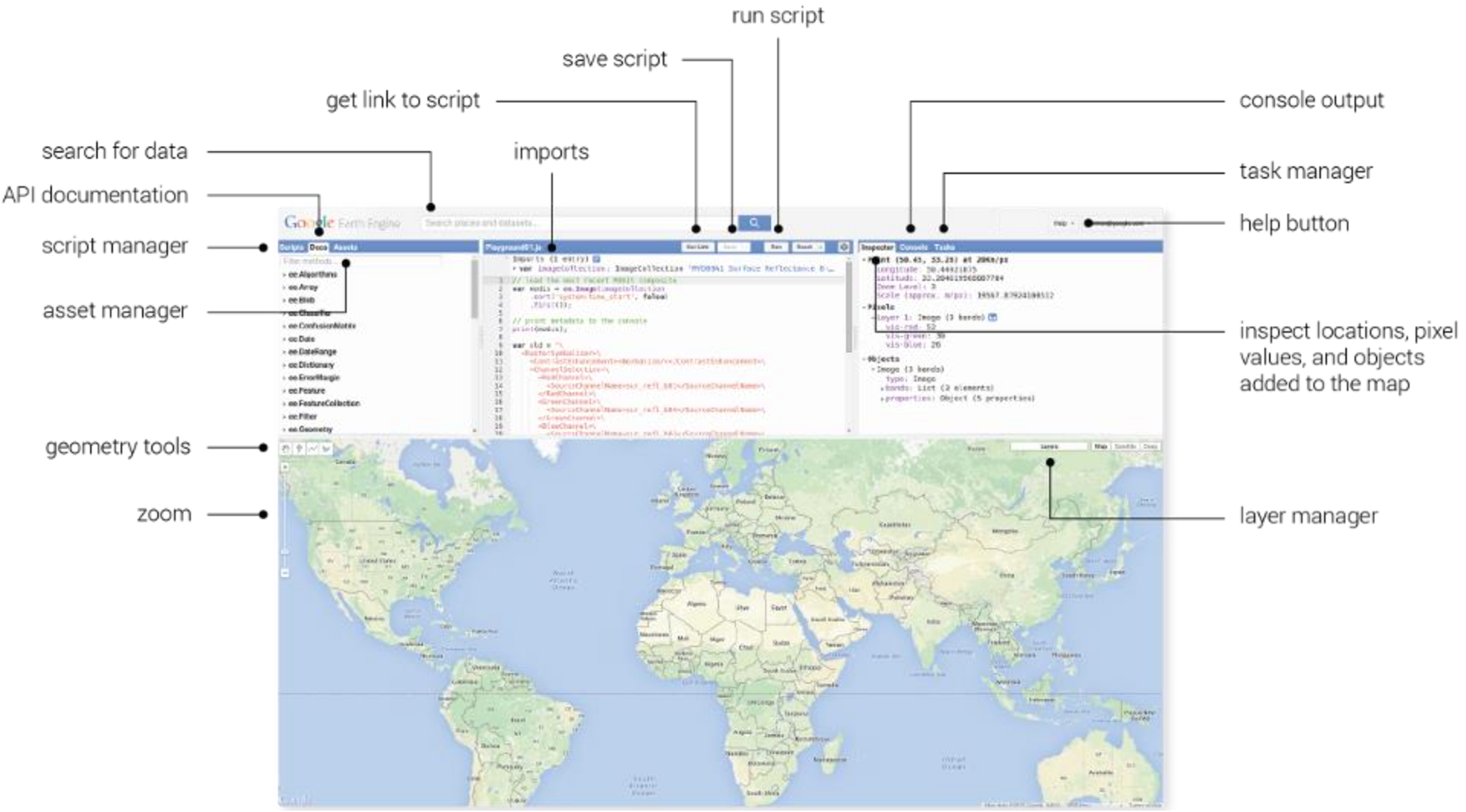
Module 4: Mapping and Classifying Areas of Change (time 2)

Create a cloud free image composite

Landsat composite, before cloud mask:

Landsat composite, after cloud mask:

Google Earth Engine Code Editor



Google Earth Engine

1. Data catalog: access to publicly available data

> 200 public datasets
> 4000 new images every day
> 5 million images
> 5 petabytes of data

Image: Dave Thau

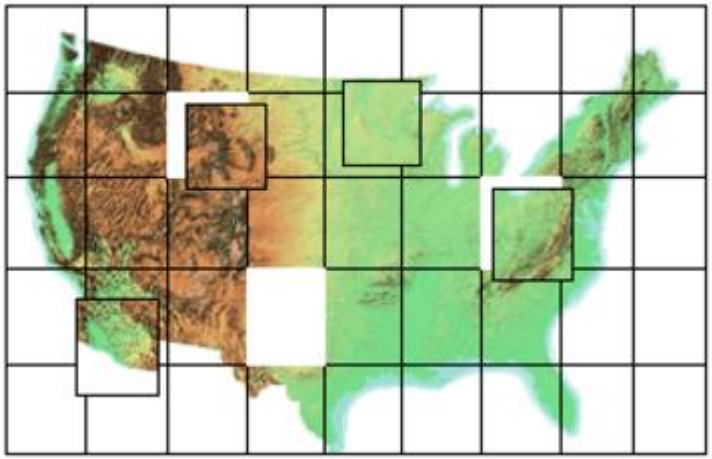
Google Earth Engine 2016 User Summit presentation

Google Earth Engine

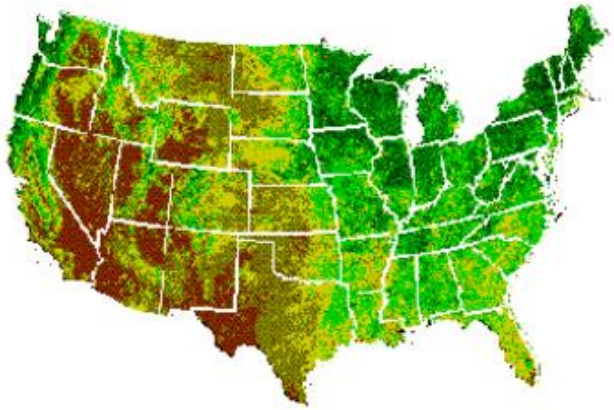
1. Public data catalog
2. Processing power
   - Cloud processing on Google's computer clusters
   - Distributed, just in time computation

Computation Engine

Divides data in independent grids



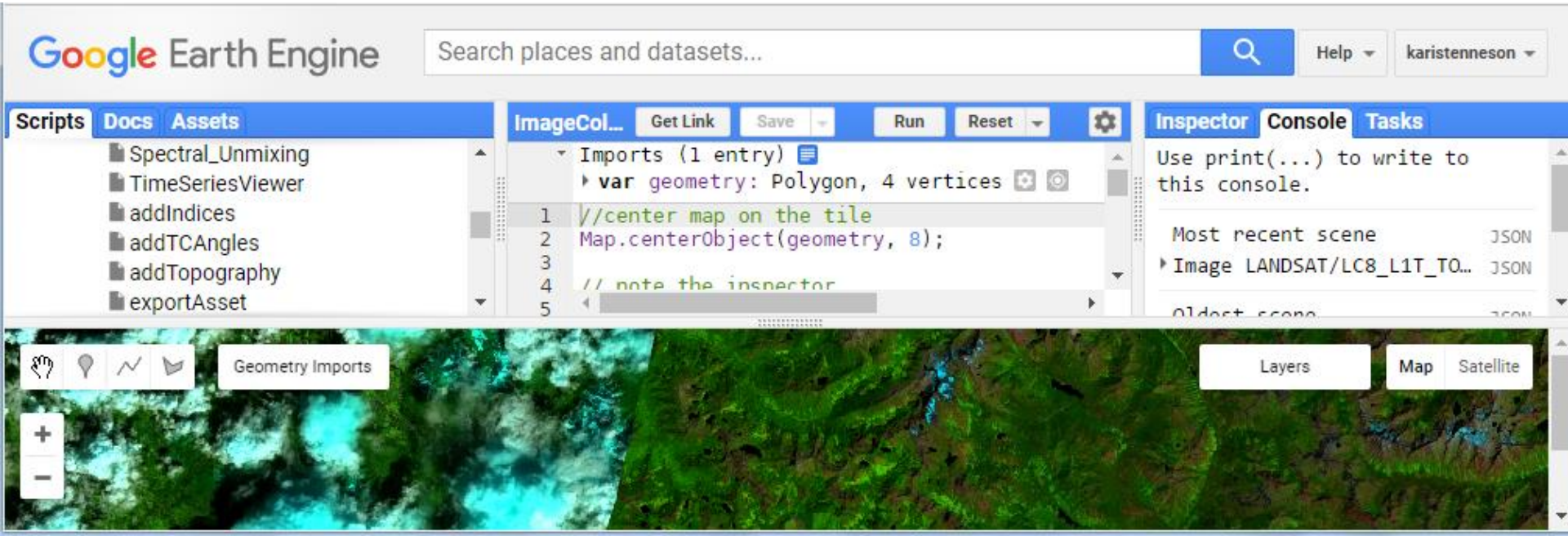
Storage Clusters (petabytes of data)
Computing clusters (1,000's of CPUs)



Merges all grid calculations

Google Earth Engine

3. Interactive development platform
   - Mapping, plotting, printing interface
   - Comprehensive toolset to analyze data
     - scientific algorithms ready for use
     - building blocks to create your own workflow



Google Earth Engine

1. Public data catalog
2. Processing power
3. Interactive development platform
4. Save and share work routines
   - Example scripts
   - Developer's forum
   - Share your own repository

Workflow

Module 1: Project Planning and Documentation

Module 2: Acquiring Data with Google Earth Engine

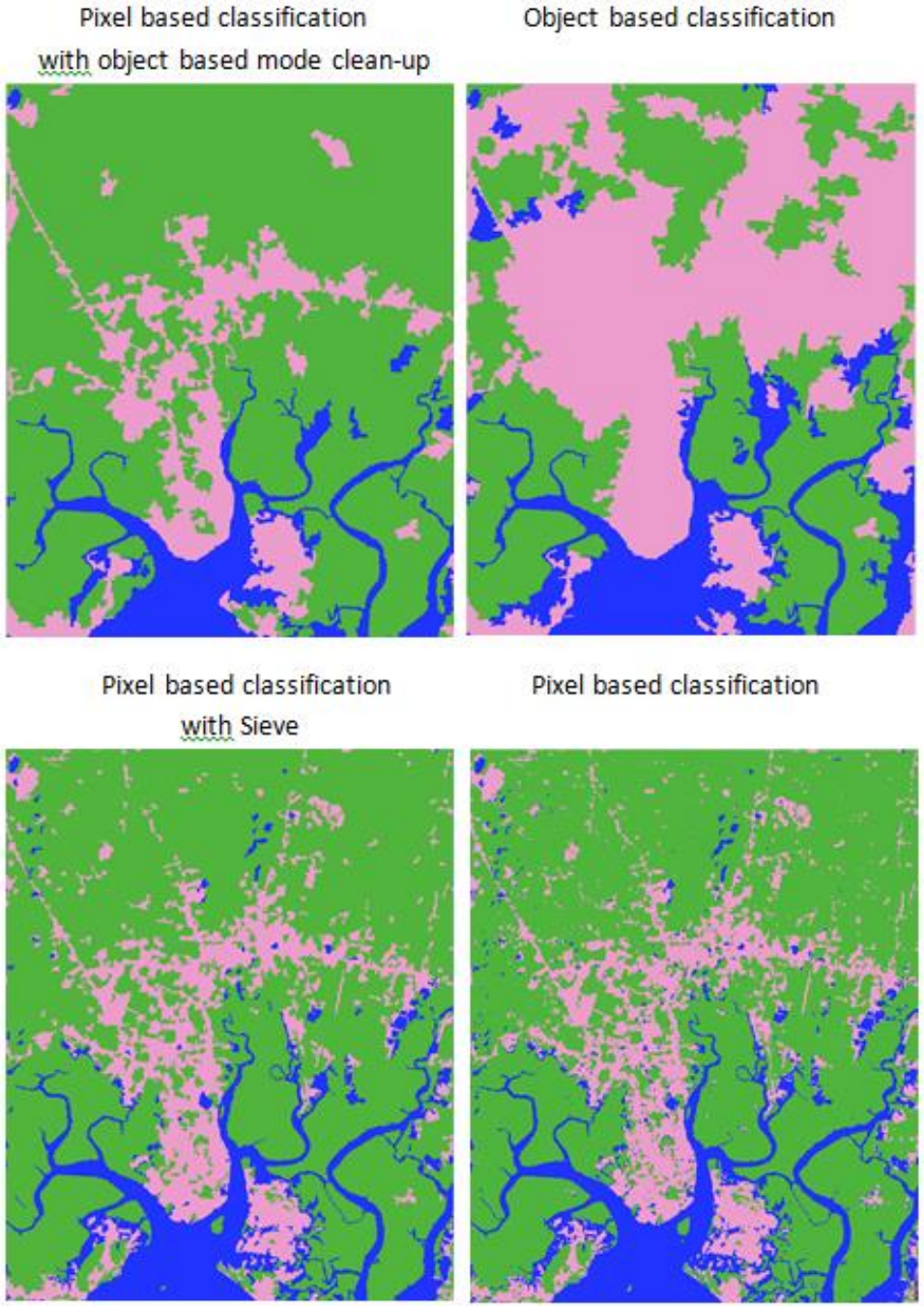
Module 3: Create a Land Cover Map

- Calculate image transforms, e.g. vegetation index
- Collect reference data
- Train machine learning algorithm
- Classify imagery to create a land cover map
- Assess map accuracy

Module 4: Mapping and Classifying Areas of Change (time 2)

Map Land Cover

- Learn 4 different methods
- Study area is located in southern Thailand, an area undergoing forest loss and regrowth



Software: QGIS, Google Earth

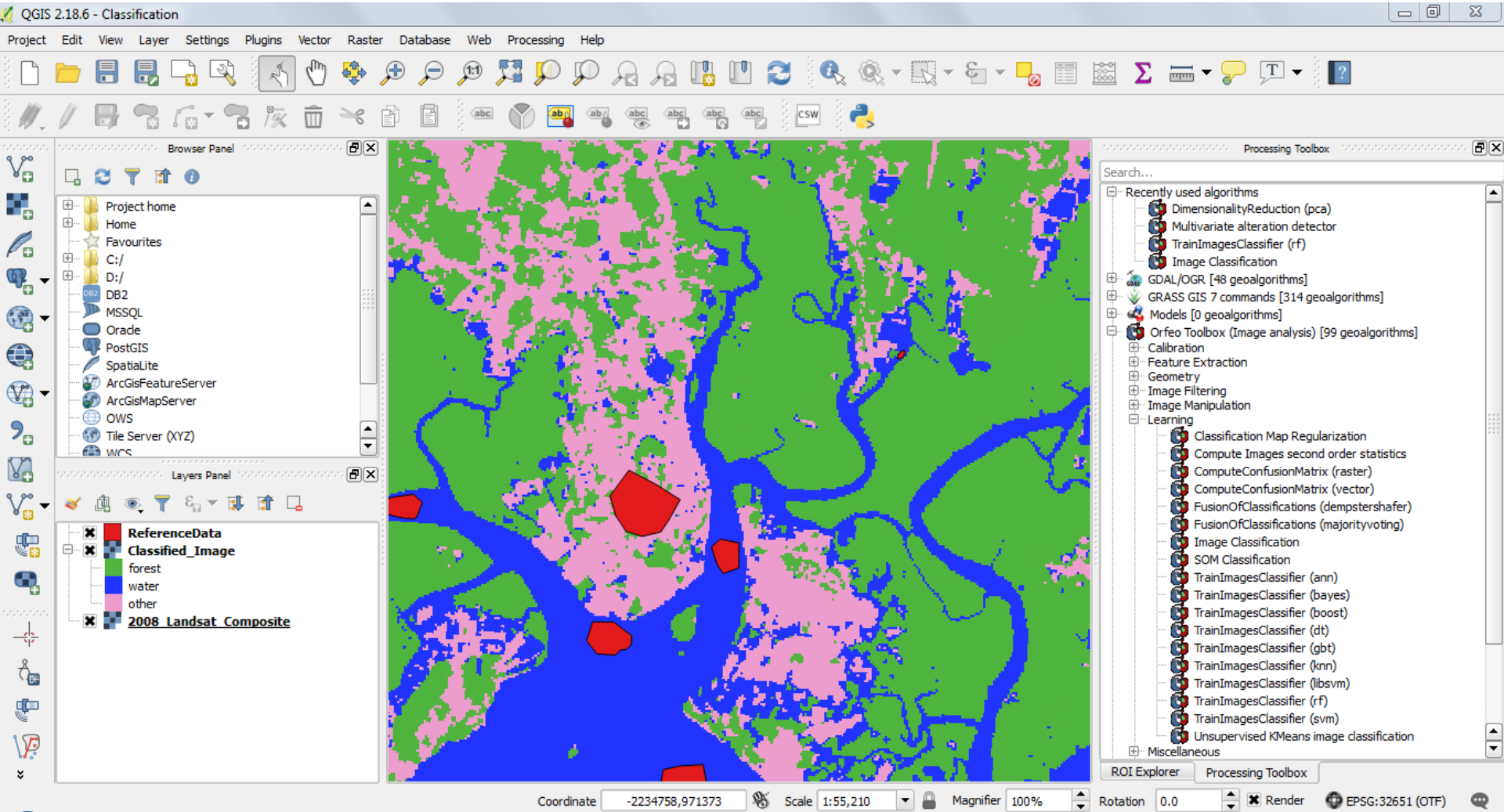
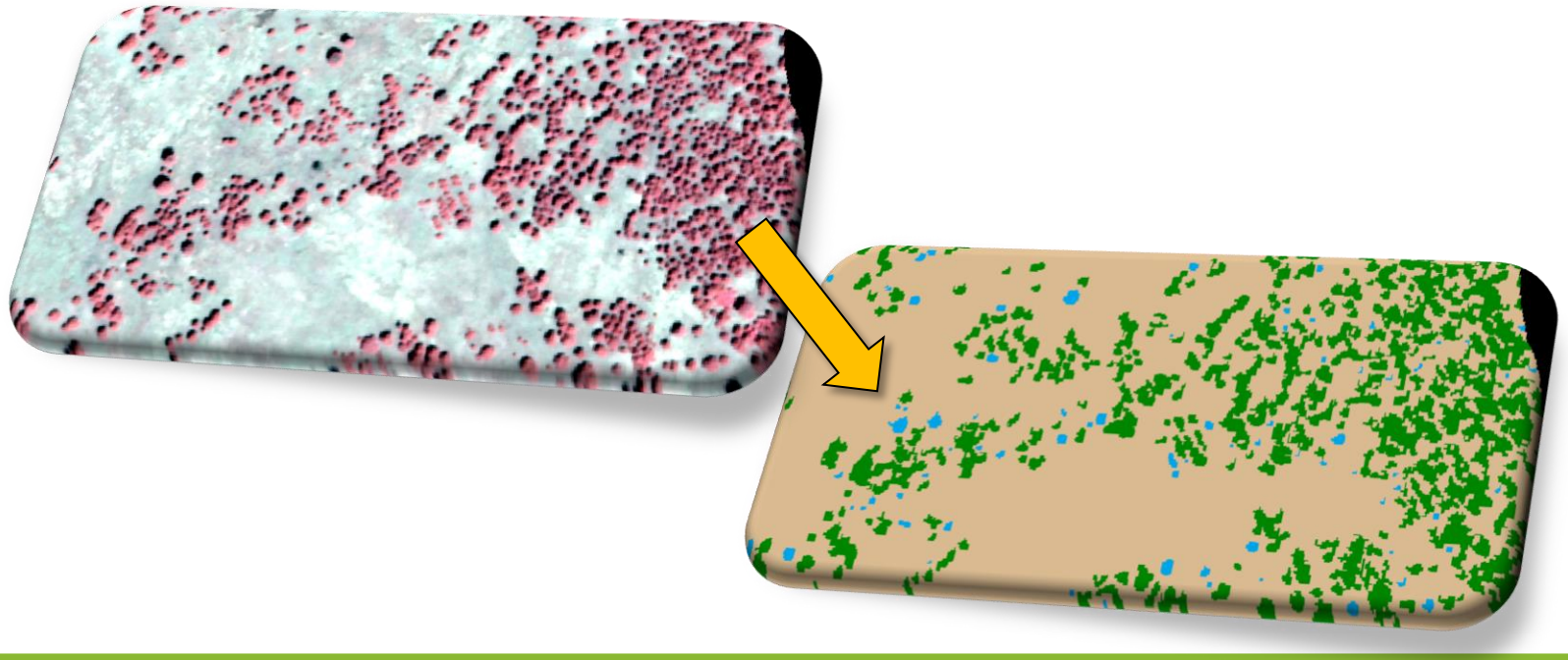


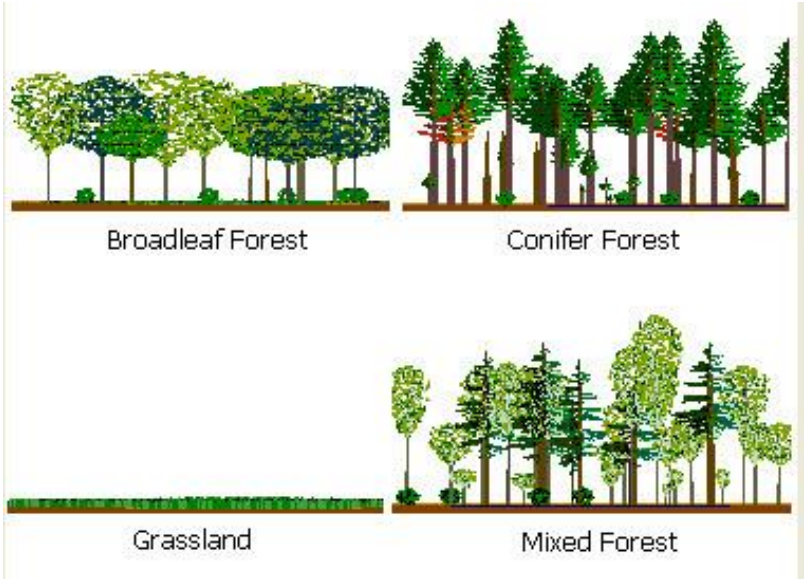
Image Classification

The automated process of categorizing pixels or image objects into a thematic classes (e.g., conifer, deciduous, herbaceous)



Classification Scheme

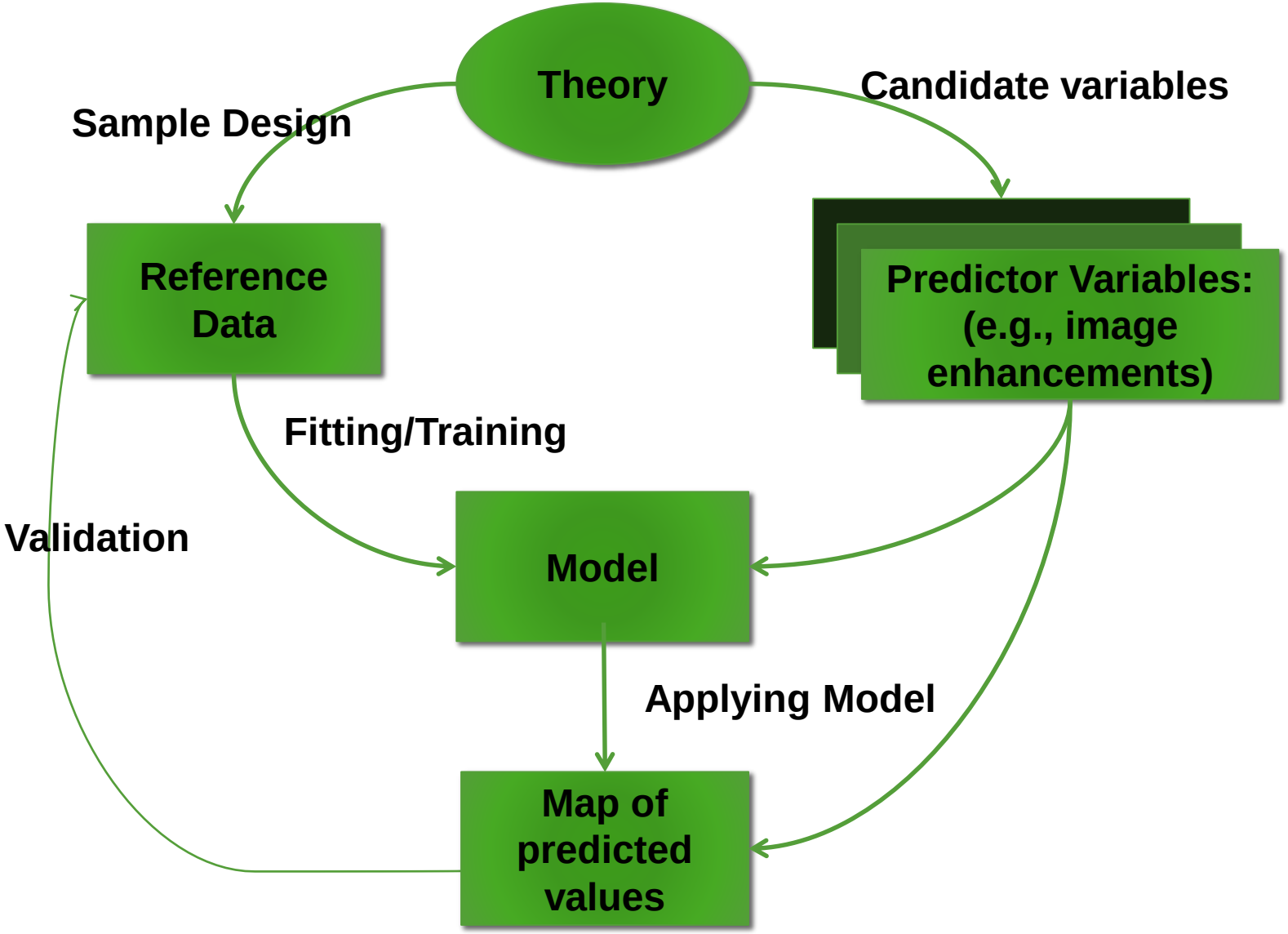
- The schema categorizes and labels the land cover theme (e.g. vegetation cover)
- A well-designed classification scheme is critical to deriving acceptable and useful information
- The complexity will affect project accuracy and cost
- It's not easy—but time spent creating a well designed classification scheme is always well spent!



Example Classification Scheme

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

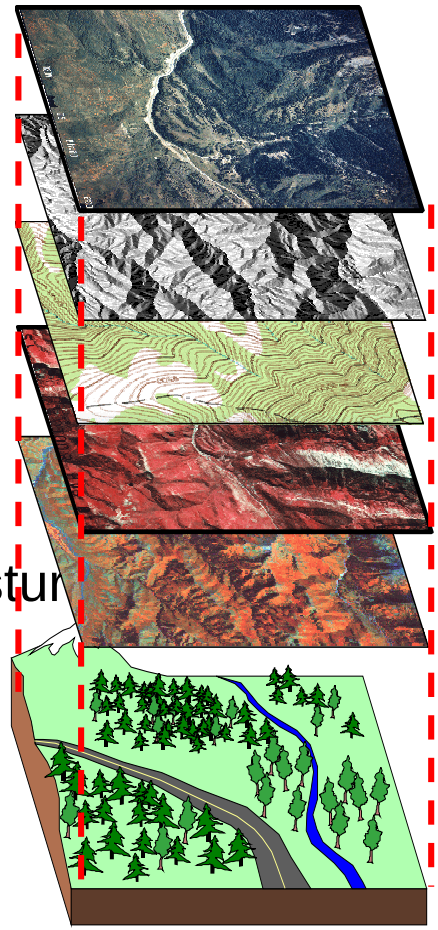
Supervised Classification Process



Adapted from Guisan and Zimmerman (2000) & Franklin (2009)

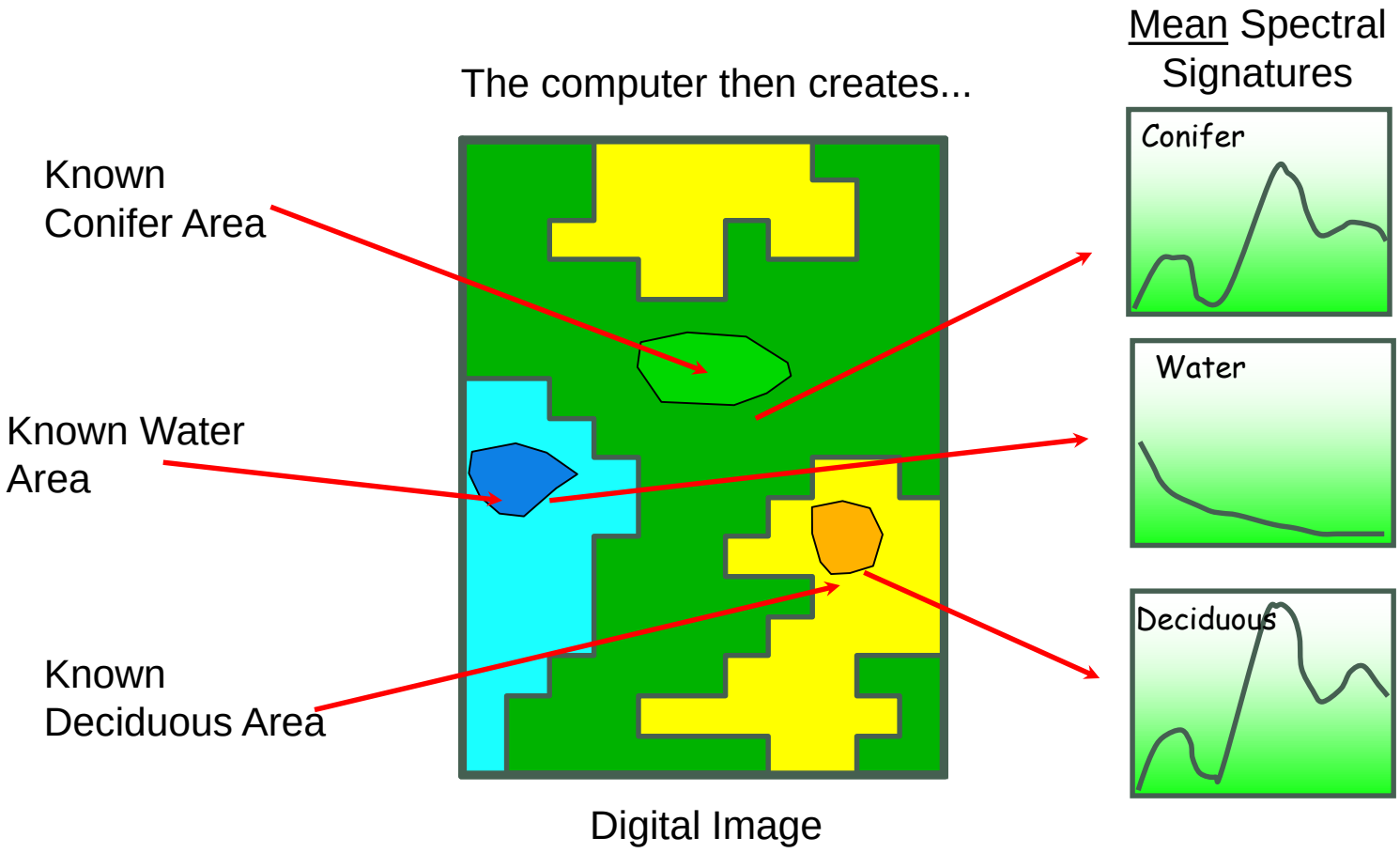
Inputs for Supervised Classification

- Training or reference data (point data)
  - Examples of each class (e.g., Conifer, Aspen, Grass, Shrub, Road, Sagebrush, Shadow, Water, Soils)
- Predictor variables such as:
  - Multispectral imagery
  - Panchromatic imagery
  - Topographic variables: Elevation, Slope, & Aspect.
  - Bioclimatic variables: Temperature, Precipitation, Moistur Index, Potential Global Radiation, Vapor Pressure, Humidity, Degree Days.
- Derived Predictor variables such as:
  - NDVI
  - Tasseled Cap transformations (soil brightness, greenness, wetness)



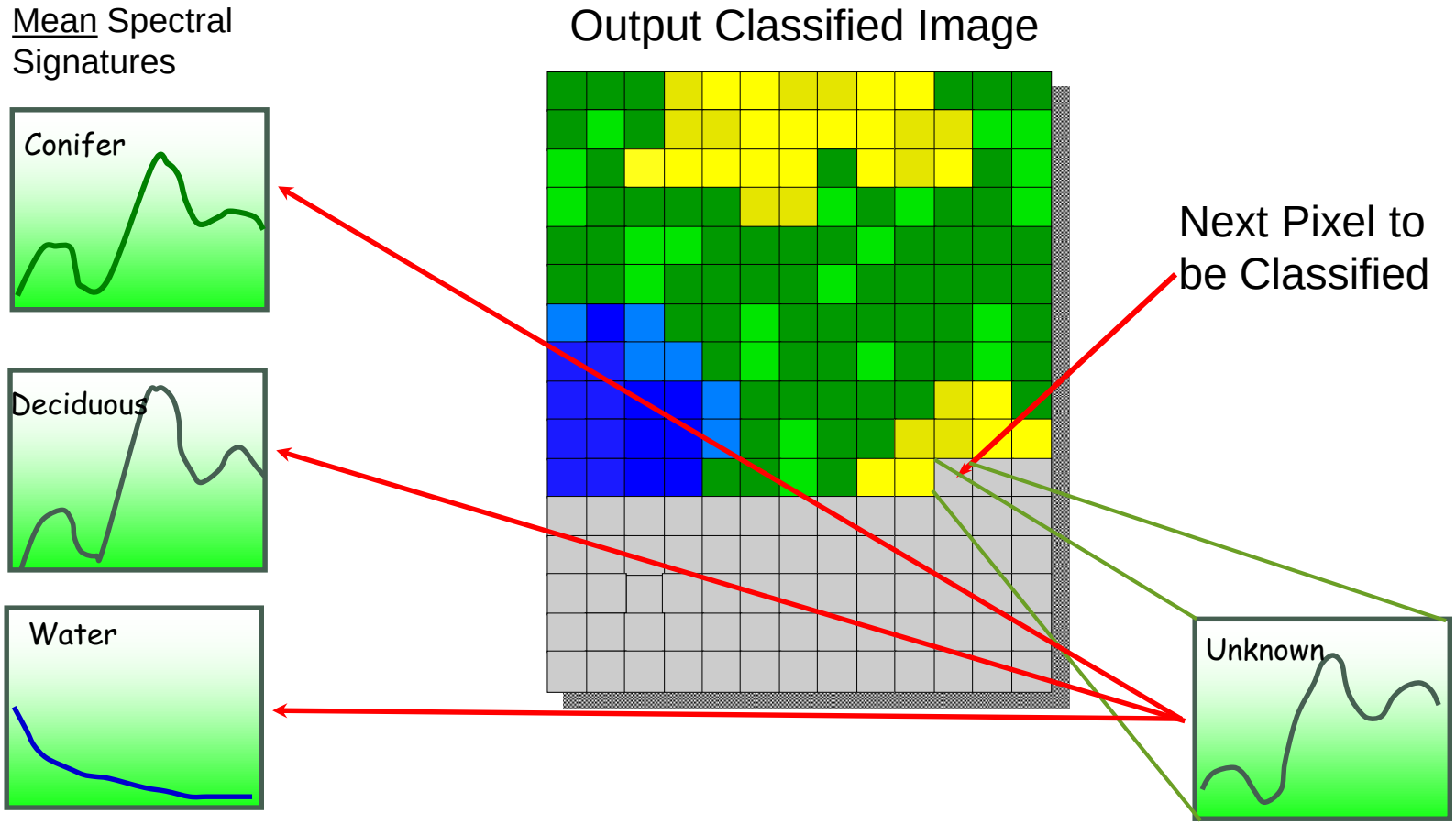
Supervised Classification

Supervised classification requires the analyst to create reference data, either in the field or from an image data source.



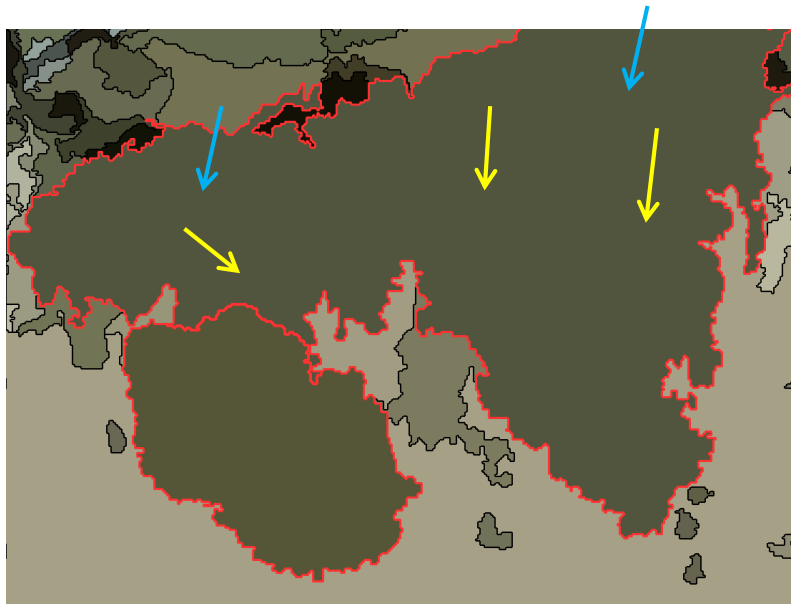
Supervised Classification

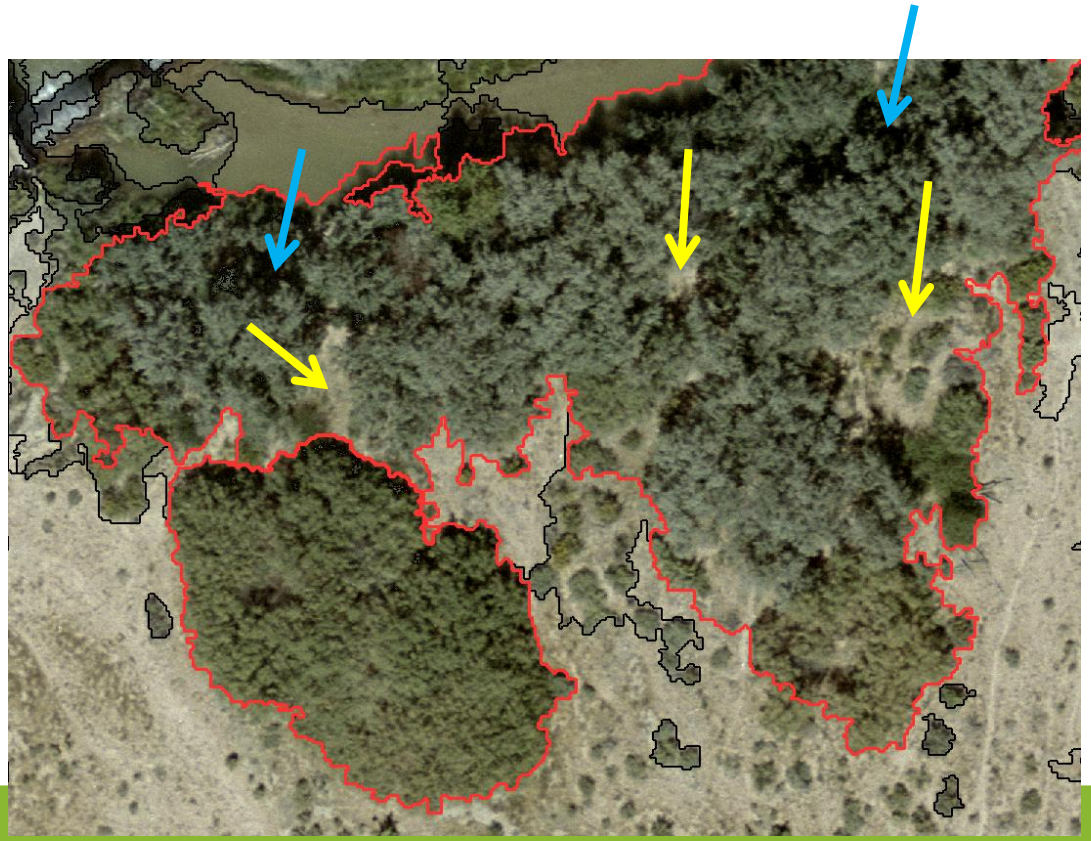
Using information provided by the reference data, the algorithm classifies all remaining pixels in the image



Object-based Image Analysis

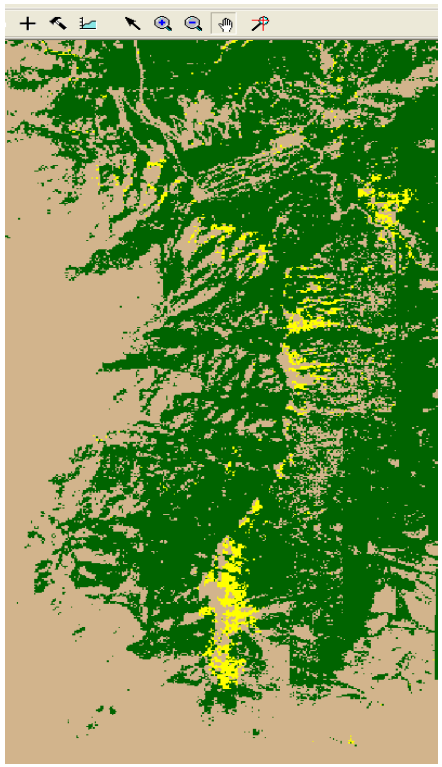
- Classify image “objects” or “segments” instead of pixels
- Filter out “noise” present in pixel groups
- Use when dealing with features that have a range of spectral values (high texture)

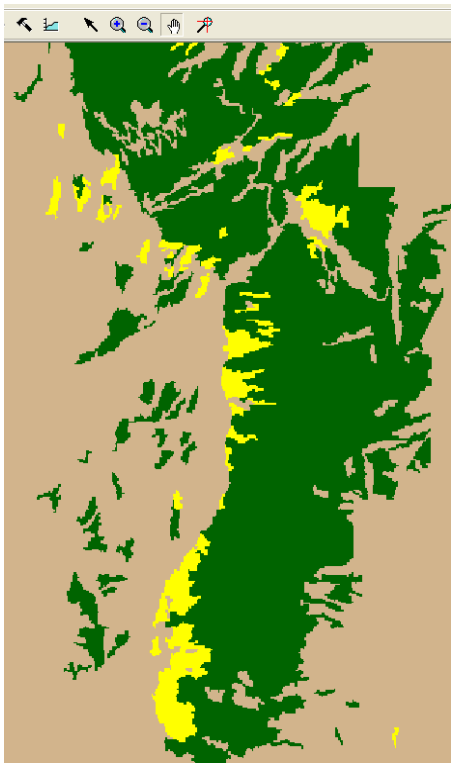




Why object-based classification?

- Can use information about object in classification (size, shape, context, texture, etc.)
- Eliminates the pixel-based speckling or “salt and pepper” that we sometimes see





Measures of Accuracy

Comparison of reference data to map predictions to assess map accuracy.

Reference Data

Classification	H	C	O	Σ Row
H	28	14	15	57
C	1	15	5	21
O	1	1	20	22
Σ Col	30	30	40	100

Overall accuracy:
63/100 = 63%

User's Accuracies:

Hardwood = 28/57 = 49%
Conifer = 15/21 = 71%
Other = 20/22 = 91%

Producer's Accuracies:

Hardwood = 28/30 = 93%
Conifer = 15/30 = 50%
Other = 20/40 = 50%

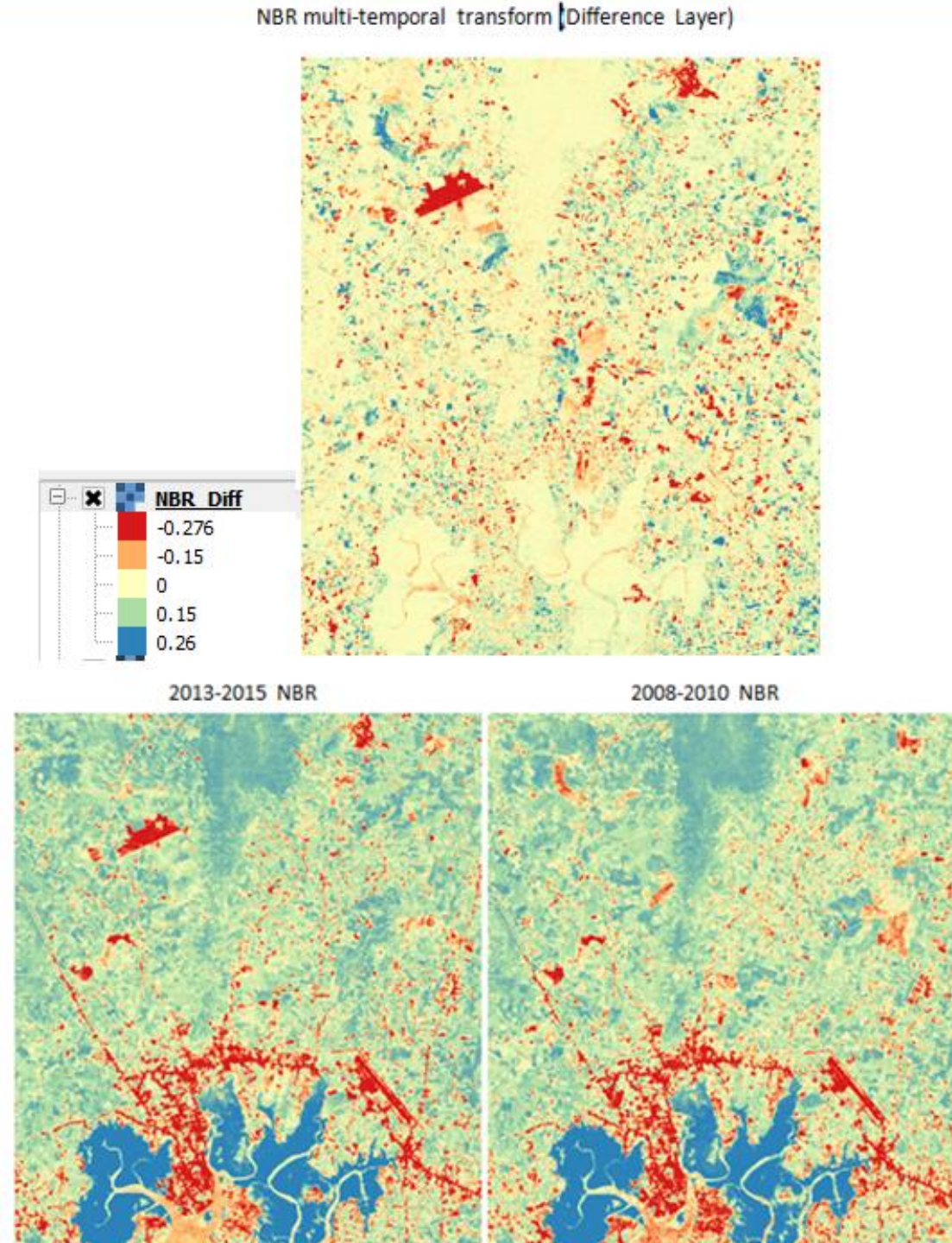
Workflow

Module 1: Project Planning and Documentation
Module 2: Acquiring Data with Google Earth Engine
Module 3: Land Cover Mapping (time 1)
Module 4: Mapping and Classifying Areas of Change (time 2)

- Calculate multi-temporal image transforms, e.g. difference of vegetation indices
- Collect reference data, include change areas as land cover category
- Train machine learning algorithm
- Classify imagery to create a land cover change map
- Assess map accuracy, update change estimates

Process

- Create multi-temporal transform image (difference image)
- Generate reference data for change categories
- Image classification

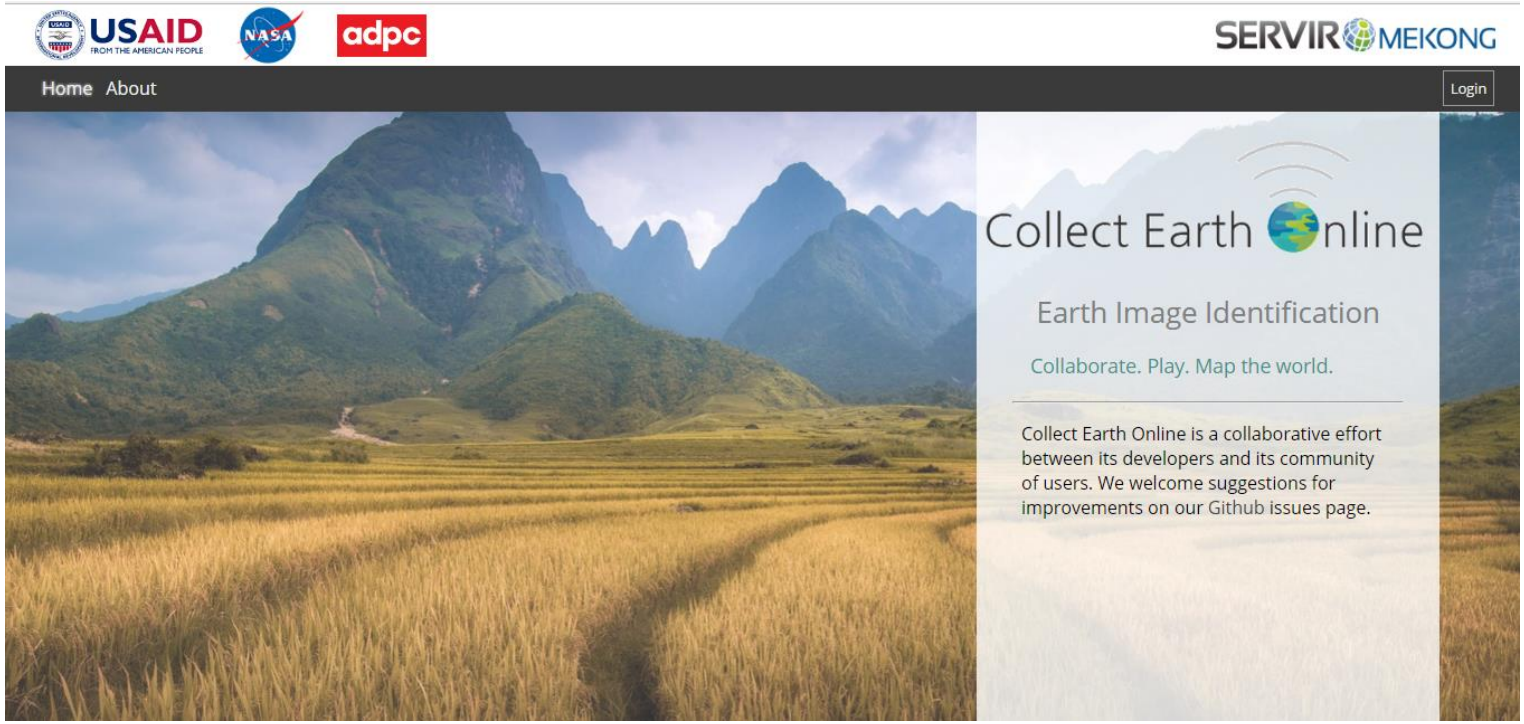


Product

- Change map that includes forest loss and forest gain categories

Watch for instructions on…

- Downloading cloud free Sentinel 2 composites
- Collecting reference data with [Collect Earth Online](https://sig-gis.com/projects/collect-earth-online/)
  https://sig-gis.com/projects/collect-earth-online/



Conclusions and Questions

- Today was a quick overview.
- Refer to online training materials to learn more:
  - Presentations include more in depth theoretical background and considerations
  - Exercises include instructions on to complete each step of the process

- Link to material: https://www.servirglobal.net/Global/Articles/Article/2549/forest-cover-change-detection-training

Thanks to everyone involved!

SilvaCarbon and U.S. Forest Service International Programs:

- Identifying regional capacity building needs and organizing workshops
- Coordinating collaborative development of training material

BEEODA, Boston University.

- Developing the change detection workflow in QGIS and accuracy assessment methodology

SERVIR

- Reviewing and hosting materials

Google Earth Engine Team

- Reviewing the Google Earth Engine training material

U.S. Forest Service Geospatial Technology & Applications Center (GTAC):

- Compiling training material into a complete online course
- Developing case study, project planning, and data processing workflow


- **SilvaCarbon** provides technical assistance to build capacity in measuring, monitoring, and reporting forest and terrestrial carbon.
- **U.S. Forest Service International Programs** promotes sustainable forest management and biodiversity conservation internationally by linking the skills of the field-based staff of the U.S. Forest Service with partners overseas.
- **U.S. Forest Service Geospatial Technology & Applications Center (GTAC)** supports the GIS, remote sensing, cartographic, and photogrammetric needs of the U.S. Forest Service.
- **BEEODA** is a suite of open-source software and educational materials for processing and analyzing earth observation data. It is developed and maintained by Dr. Olofsson, Dr. Holden and Dr. Bullock from the Dept. of Earth & Environment, Boston University.
- **SERVIR** works to help developing countries use information provided by Earth observing satellites and geospatial technologies to assess environmental conditions to improve their planning and actions.
- **Google Earth Engine Team** organizes the world's information and makes it universally accessible and useful. More generally, Google strives to make the world a better place through the use of technology.

Please provide feedback

Help us refine our materials and prioritize development of new training resources.

Fill out survey here:
https://www.surveymonkey.com/r/PZZGYN6

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Please contact Sarah Marlay,
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Question and Answer Summary

- Webinar recording will be shared on the website
- Python and JavaScript options available for working with GEE. Python information available here and here.
- Time series analysis: refer to Earth Engine to conduct time series analysis, available here and here. Additional Earth Engine training materials available here.
- Will we add material on change detection with Sentinel 1?
  - We're interested.
- Will material be available in other languages?
  - We're interested. Contact us if you'd like to assist with this effort.