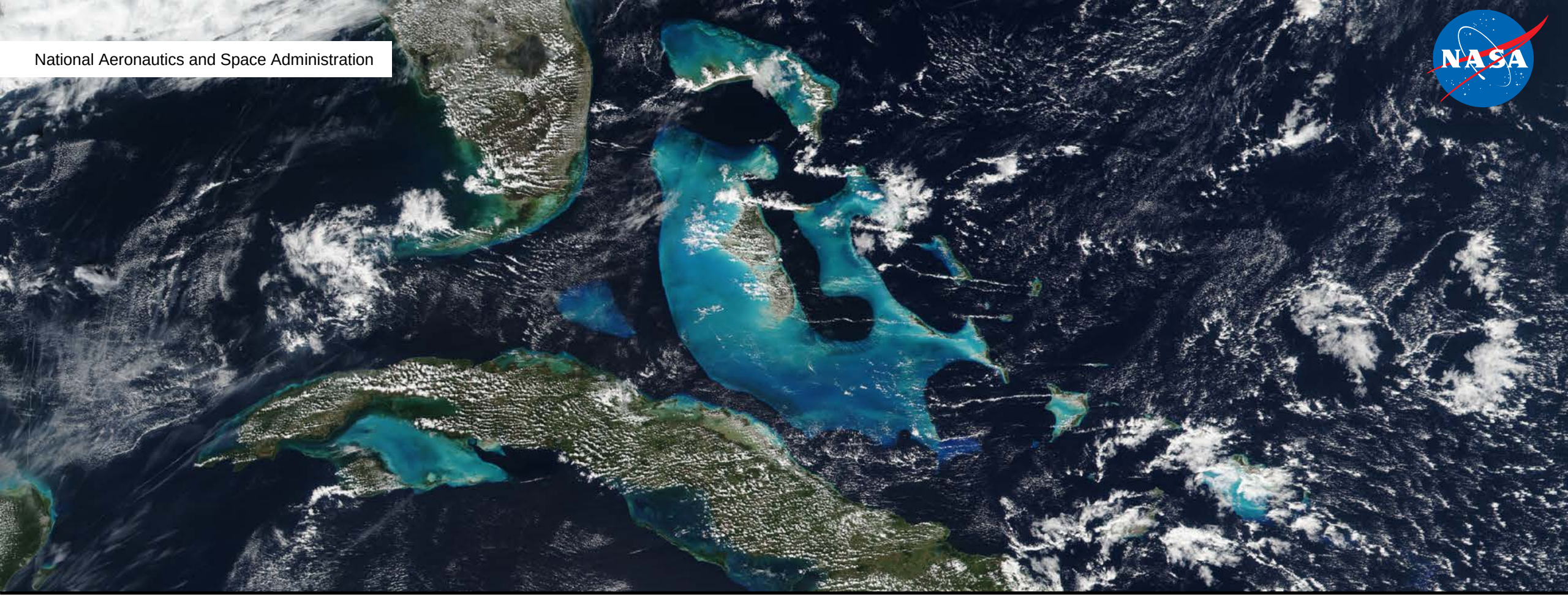
National Aeronautics and Space Administration



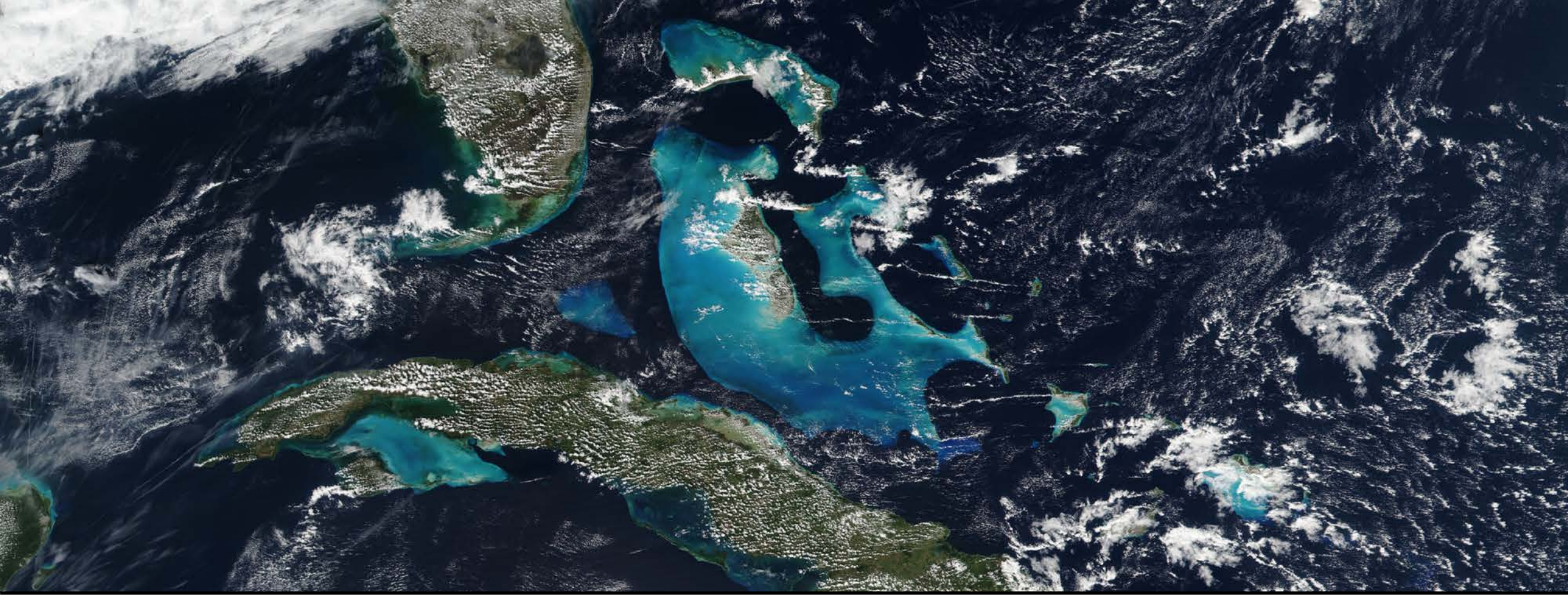
Remote Sensing of Land Indicators of Sustainable Development Goal (SDG) 15

Brock Blevins

Agenda

- Introduction to the Sustainable Goals Framework
- Related Forest Conservation Efforts
- State of the World's Forests
- The Role of Remote Sensing for SDG 15
- Remote Sensing Data Sources for Land Cover

- ARSET Training Webpage: https://arset.gsfc.nasa.gov/all/workshops/GGIM-SDGs-18



Overview of the United Nations Sustainable Development Goals

UN Sustainable Development Goals (SDGs)

Transforming Our World: The 2030 Agenda for Sustainable Development

- A plan of action for people, planet and prosperity
- All countries and all stakeholders, acting in collaborative partnership, will implement this plan
- 17 SDGs and 169 targets under this agenda
- Balance the three dimensions of sustainable development:
  – economic, social, and environmental
- In this webinar series, our focus will be Goal 15: Life on Land

Text adapted from "Transforming our world: the 2030 Agenda for Sustainable Development"

SDG Indicators

- Used to monitor progress towards SDGs at local, regional, and global levels
- Turns SDGs and targets into a management tool:
  - develop implementation strategies
  - measure progress (report card)
- 100 Global Monitoring Indicators
  - includes suggestions for complementary national indicators (CNIs)
- Each country chooses the number and range of CNIs to collect and analyze data

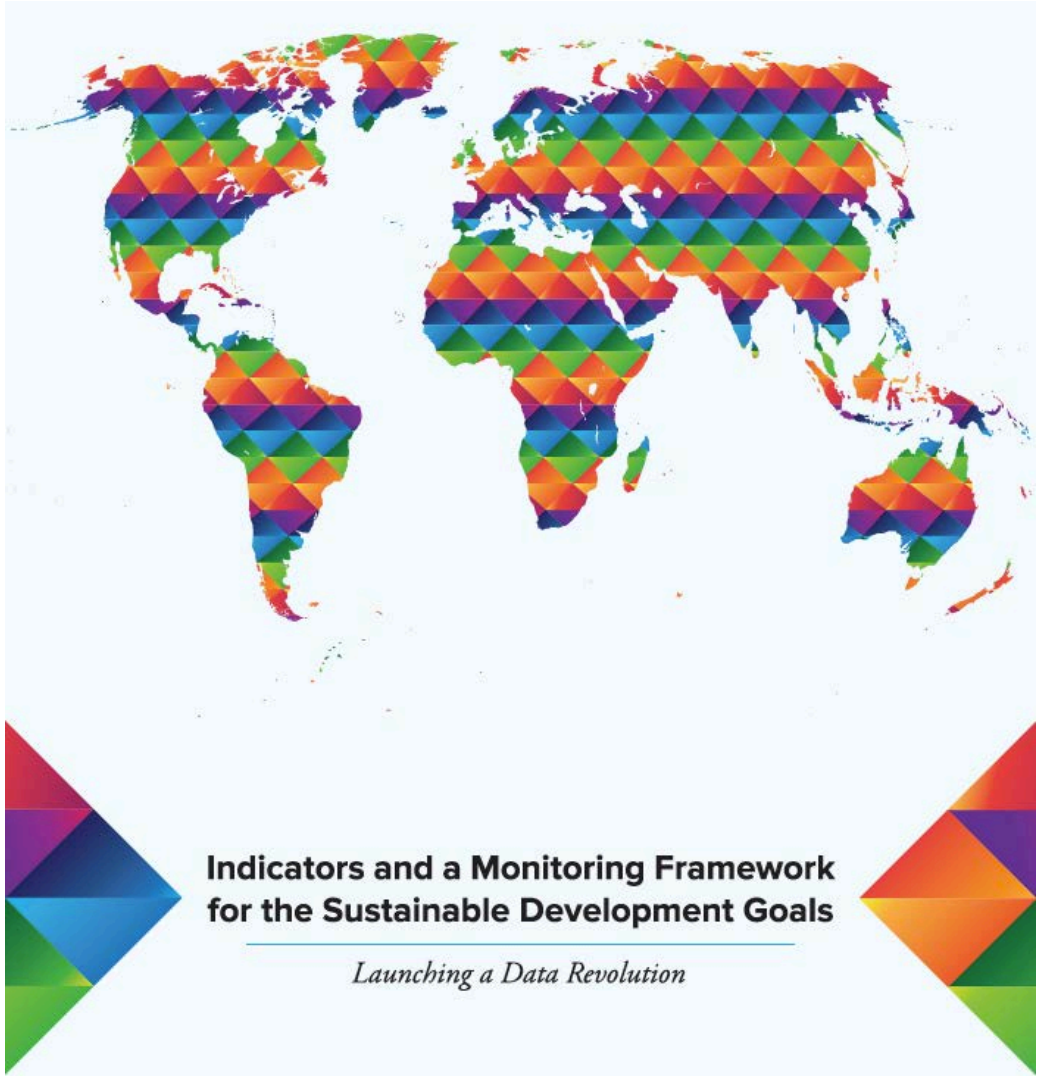
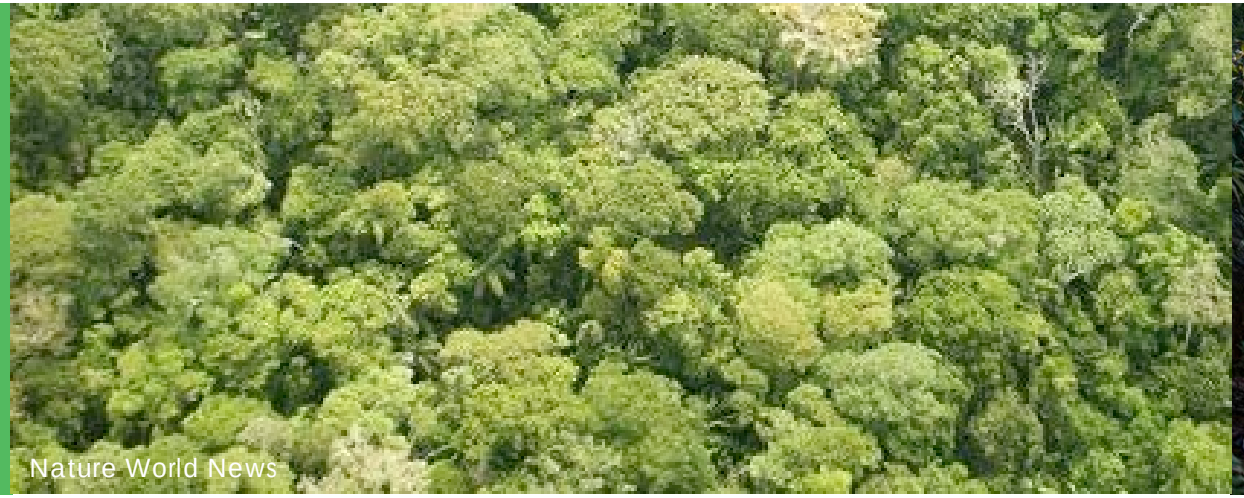


Image: http://unsdsn.org/resources/publications/indicators/

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



SDG: Target 15.3

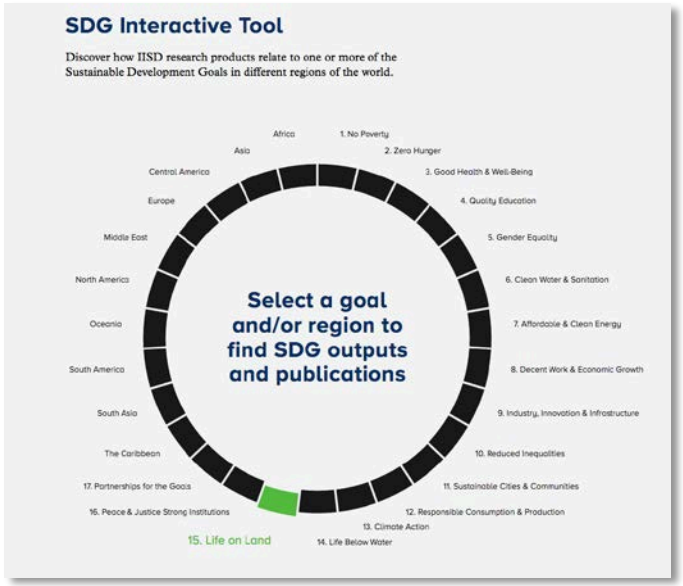
- By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world
  - Indicator: 15.3.1: Proportion of land that is degraded over total land area
    - Subindicators: Land Cover and Land Cover Change, Land Productivity, Carbon Stocks

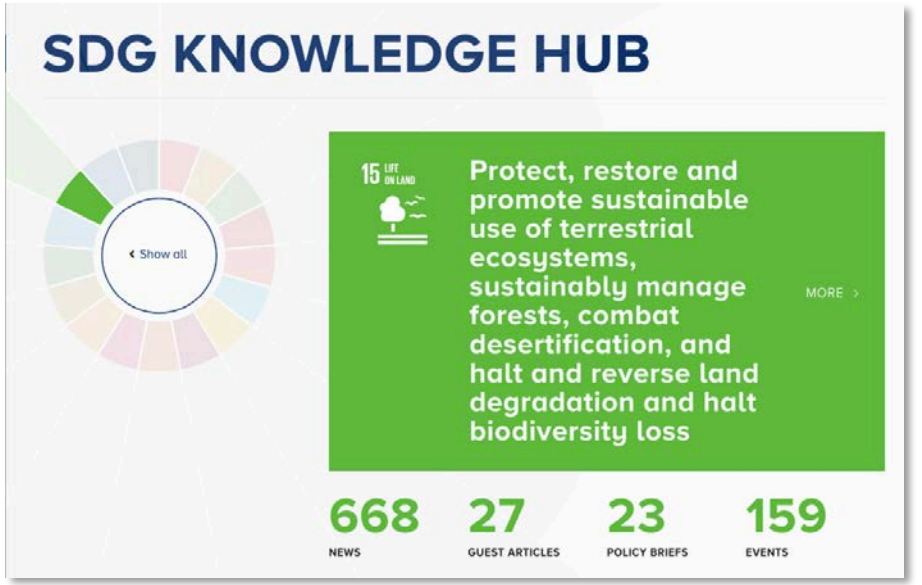
Agency Coordination

IISD Knowledge Hub

http://sdg.iisd.org/

- Provides tools and resources about the SDGs
- Collects news, events, policy briefs for specific goals
- Also provides information on events, actors, and regions

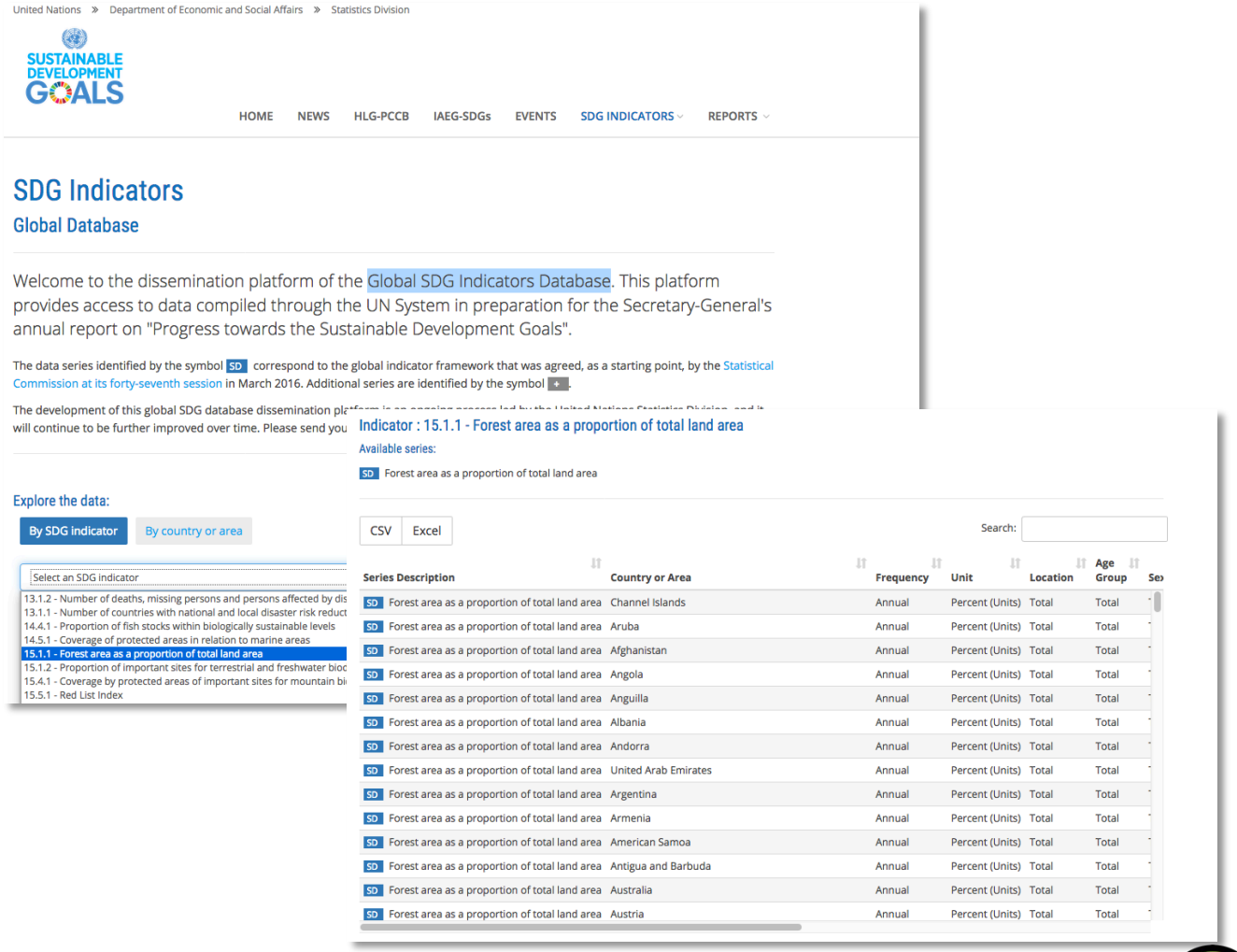




United Nations: Statistics for SDGs

https://unstats.un.org/sdgs/indicators/database/

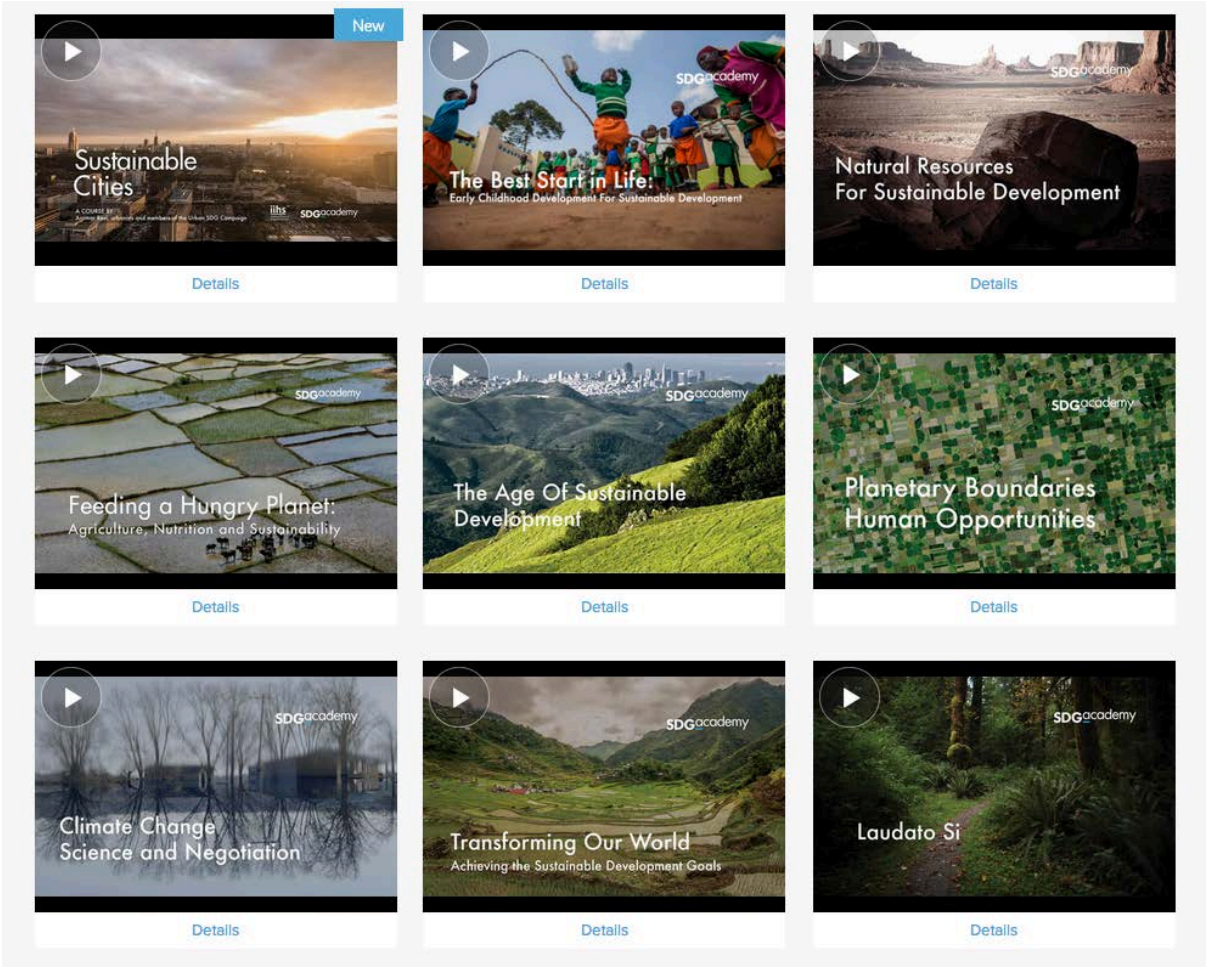
- Access SDG data for specific countries
- Obtain metadata and methodology for calculating indicators
- Groups information based on regions



Sustainable Development Solutions Network (SDSN)

http://courses.sdgacademy.org/

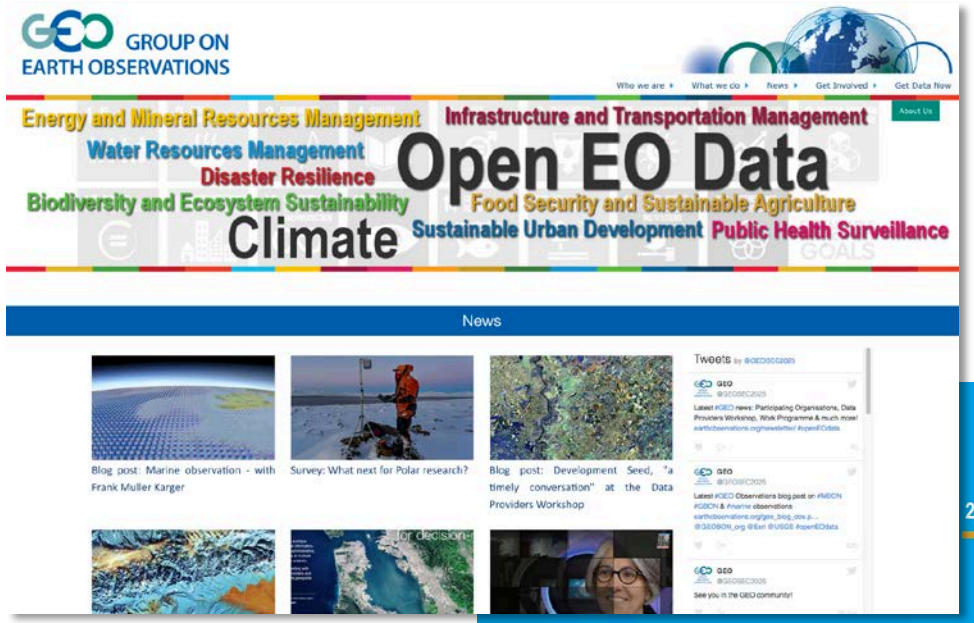
- Analytical and technical recommendations for SDGs
- SDG Academy
  - Free online courses about SDGs



Group on Earth Observations (GEO)

http://www.earthobservations.org/geo_sdgs.php

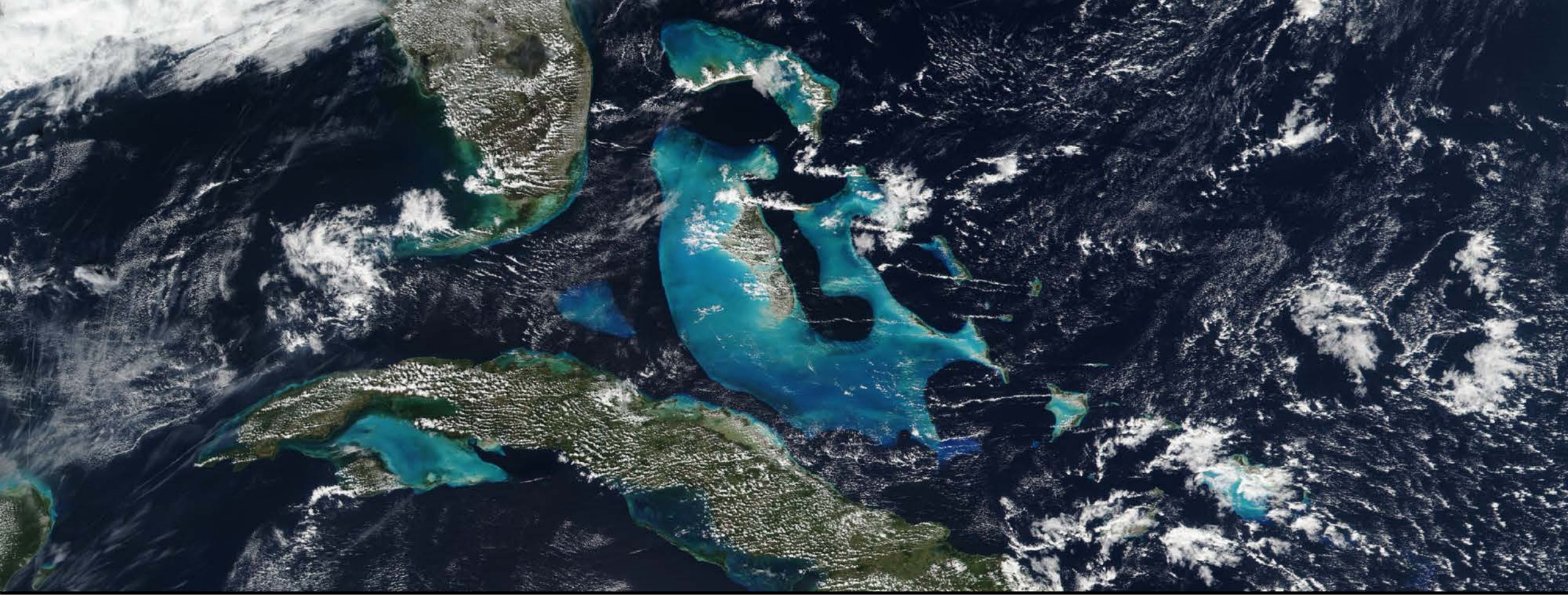
Initiative to support efforts to integrate Earth observations and geospatial information into national development and monitoring frameworks for the SDGs



Food and Agriculture Organization (FAO)

http://www.fao.org/sustainable-development-goals/en/

- FAO's priorities for the SDGs are:
  - End poverty, hunger and malnutrition
  - Enable sustainable development in agriculture, fisheries and forestry
  - Combat and adapt to climate change



Related Forest Conservation Efforts

The New York Declaration on Forests

http://forestdeclaration.org/

- Many world leaders endorsed a timeline to cut natural forest loss in half by 2020 and to strive to end it by 2030
- Ten main goals
- Concrete actions and plans
  - Includes
    - commodity traders
    - indigenous peoples
    - commitments from country governments multilateral programs
    - new procurement policies for use of forests

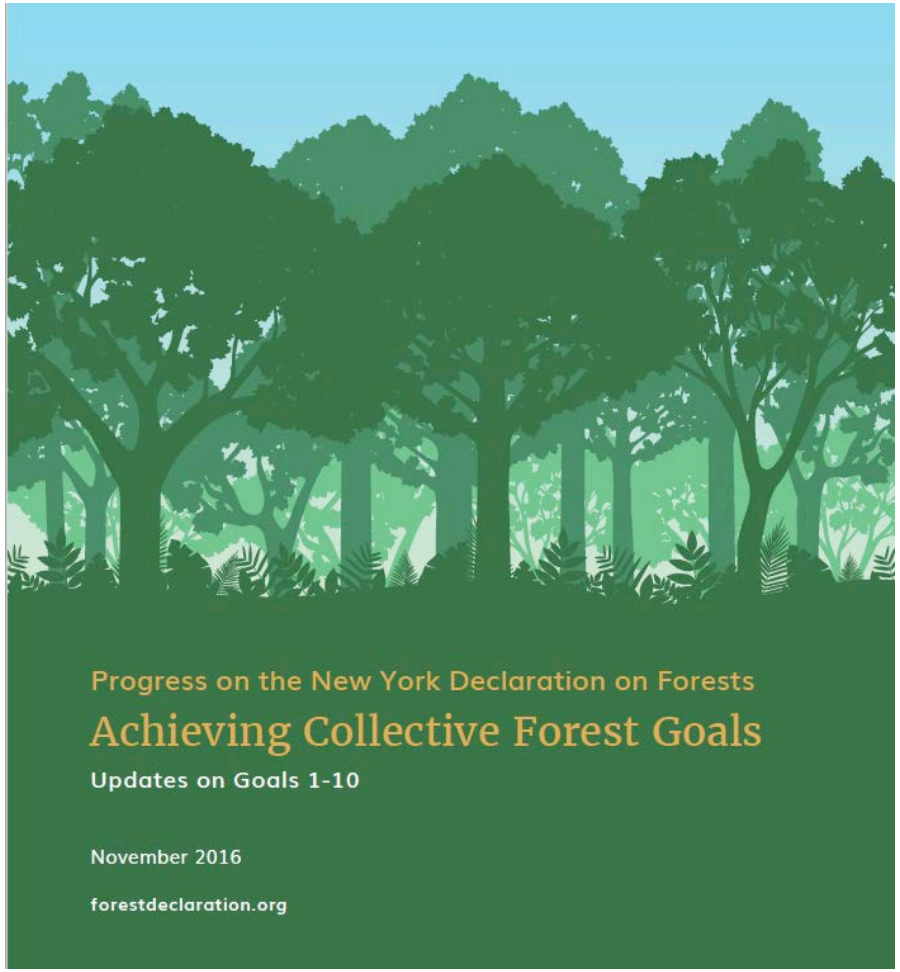
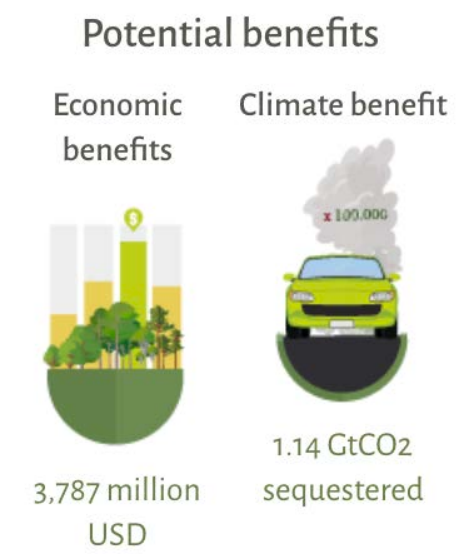


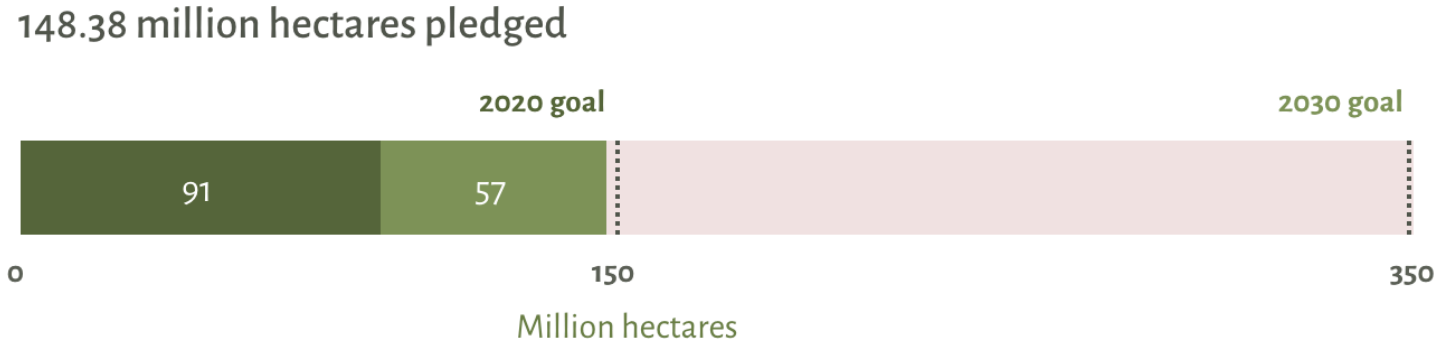
Image Credit: UNDF

The Bonn Challenge

http://www.bonnchallenge.org/

- Global effort to restore 150 million hectares of the world's deforested and degraded land by 2020 and 350 million hectares by 2030
- Uses the Forest Landscape Restoration Approach (FLR)
- Vehicle for assisting in implementation of existing international commitments like REDD+





The United Nations REDD Program

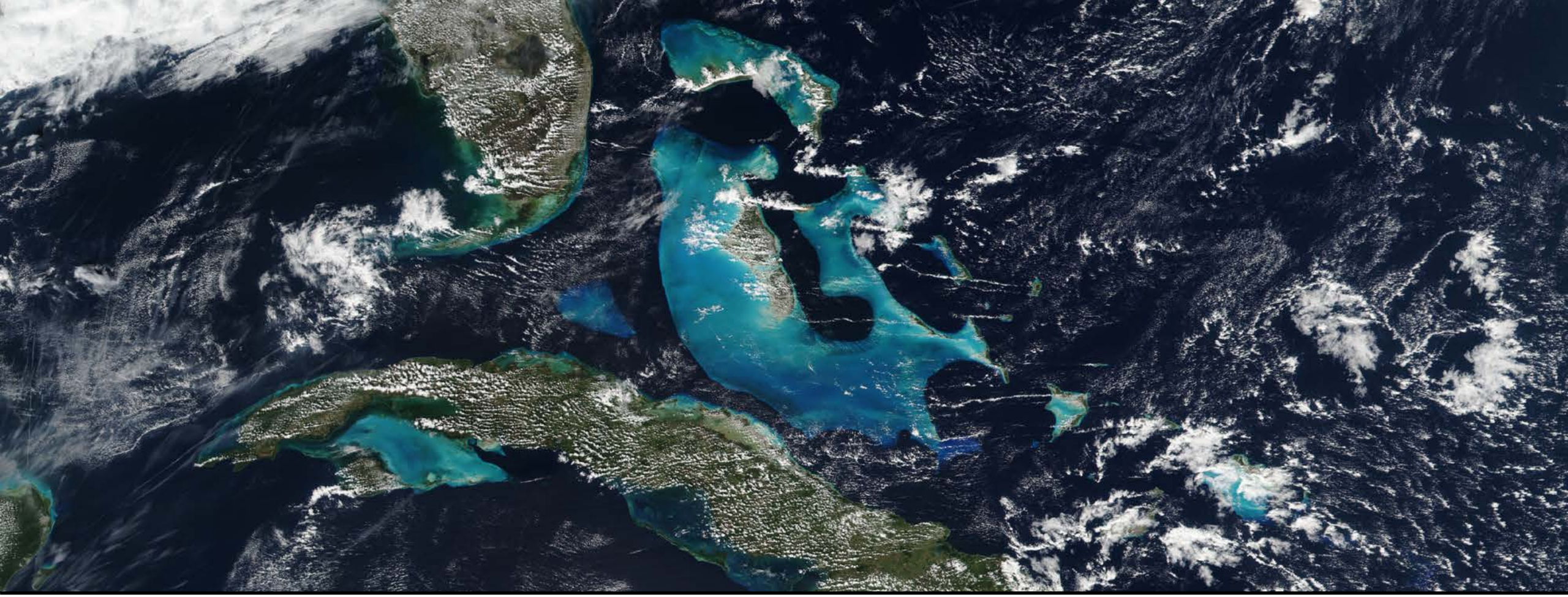
http://www.un-redd.org/

- Reducing Emissions from Deforestation and Forest Degradation (REDD+)
- Climate change mitigation solution
- Incentivizes developing countries to keep forests by offering results-based payments for actions to reduce or remove forest carbon emissions
- Includes:
  - Reducing emissions from deforestation
  - Reducing emissions from forest degradation

  } REDD

  - Conservation of forest carbon stocks
  - Sustainable management of forests
  - Enhancement of forest carbon stocks

  } REDD+

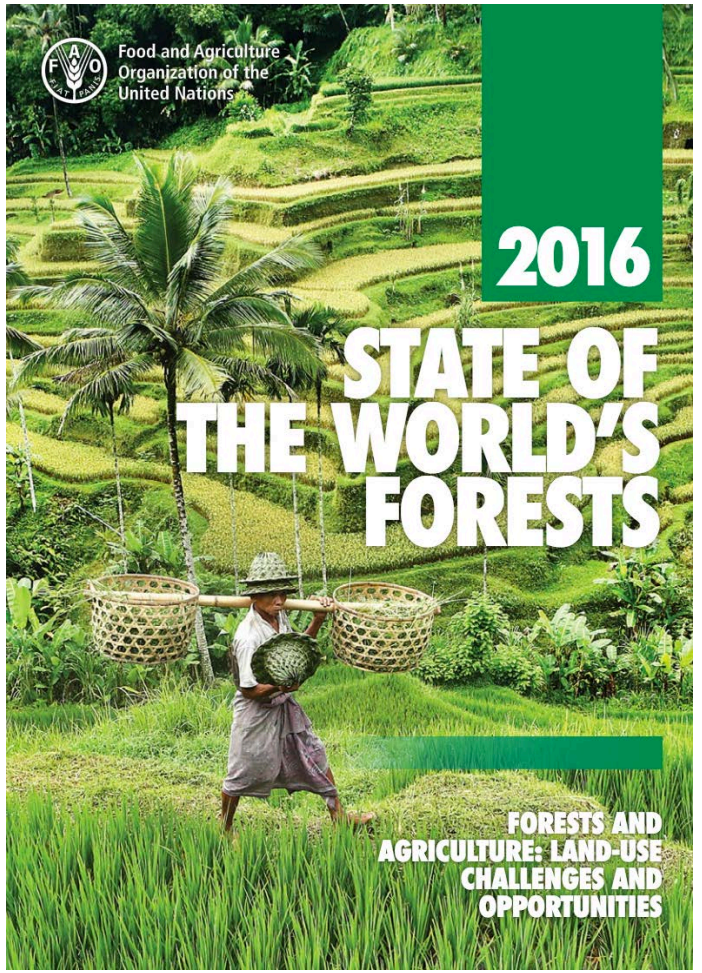


State of the World's Forests

FAO 2016 Report

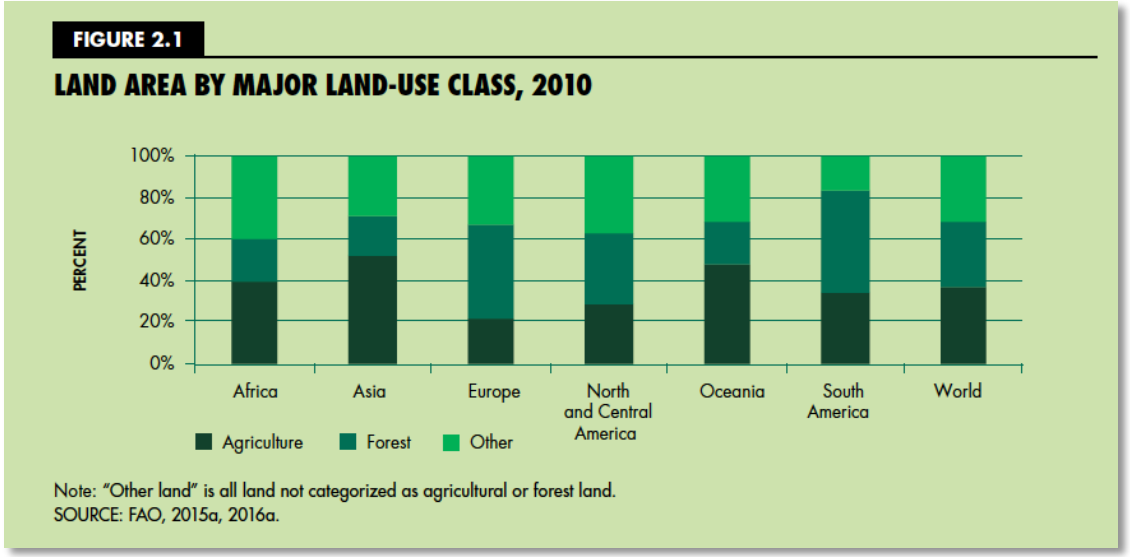
http://www.fao.org/publications/sofo/2016/en/

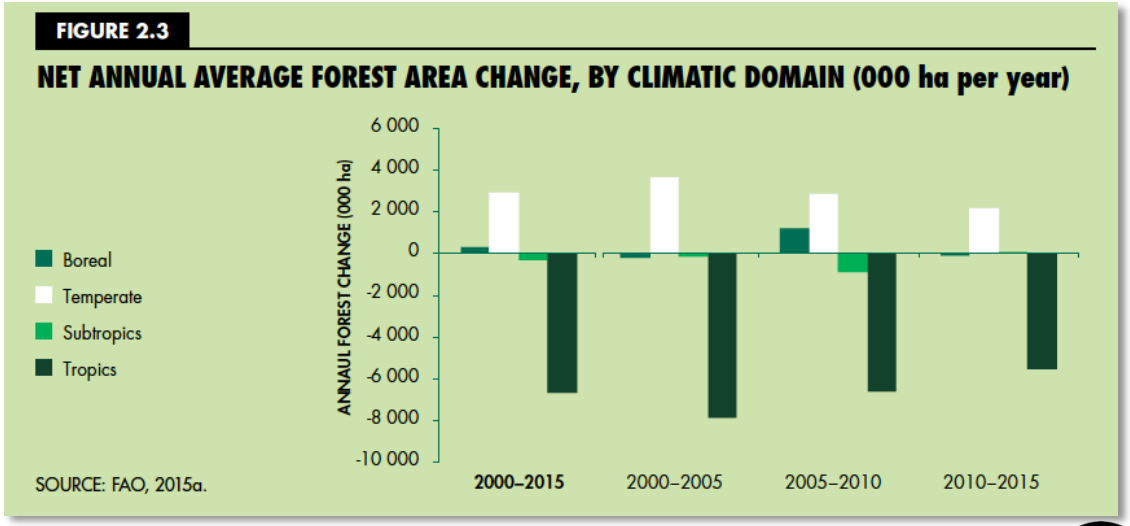
- Explores the relationship between forests, agriculture, and sustainable development
- Agriculture: major driver of deforestation globally
- Case studies of countries that have reconciled increased agricultural productivity and halting deforestation
- Focus on integrated land use planning



Trends in Land Use Change

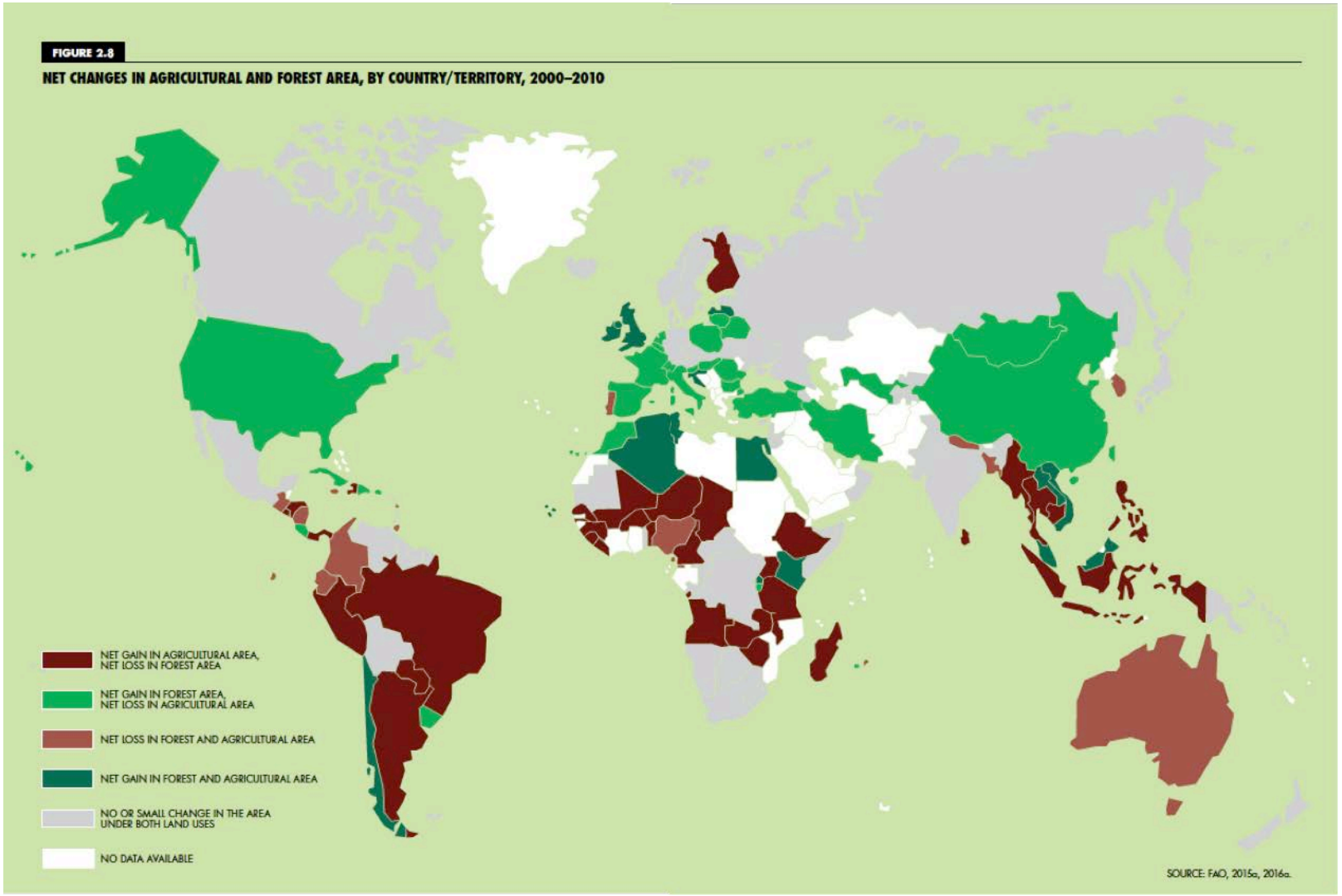
- Forests account for large portion of total land area in Europe, North America, Central America, and South America
- Global forest area fell by 3.1% from 1990-2015
- Net forest loss of 7 million hectares per year in tropical countries in 2000-2010





Trends in Land Use Change

- Strong correlation between agricultural expansion and deforestation in South America, sub-Saharan Africa, and South and Southeast Asia
- Largest annual net loss of forest area occurred in low-income countries

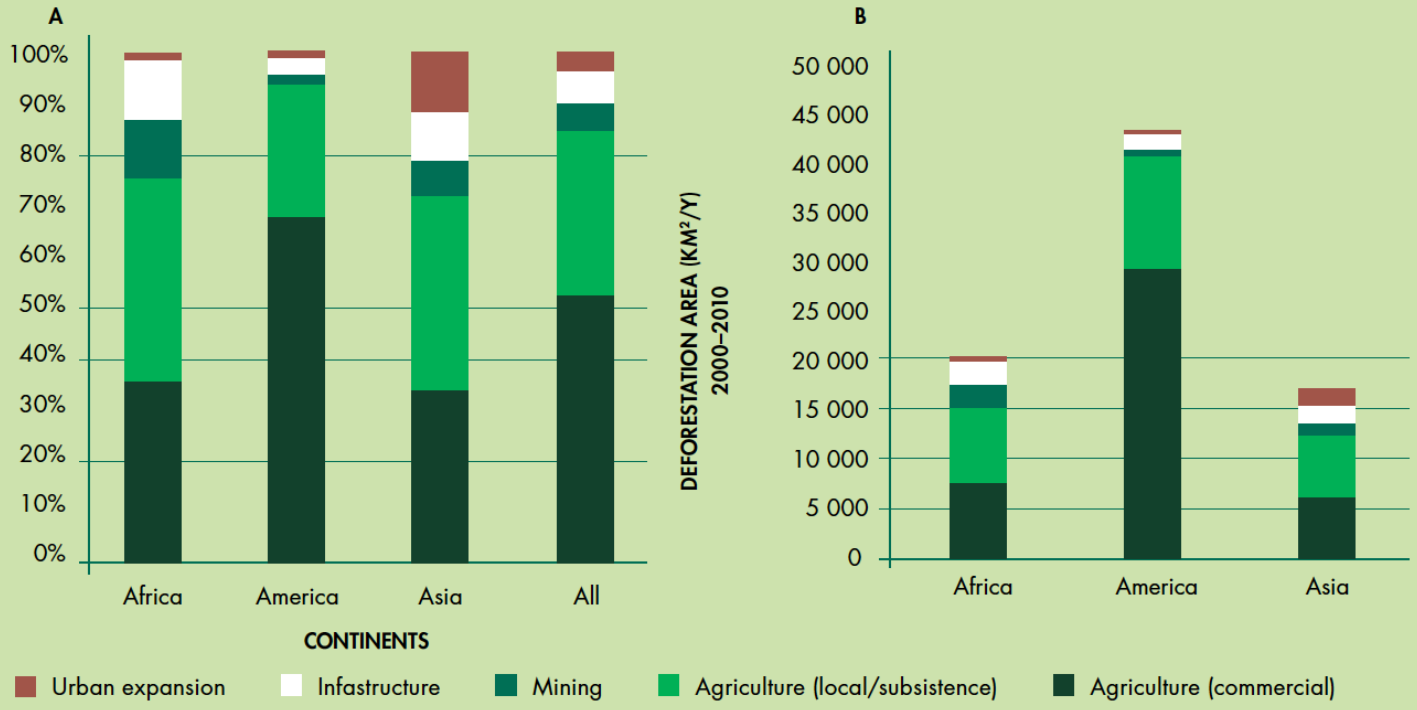


Drivers of Land Use Change

- Commercial and subsistence agriculture accounts for 73% of deforestation in tropics and subtropics
- Other factors affecting forest conversion:
  - Population
  - Changing food consumption patterns
  - Technological advancements
  - Policy interventions

FIGURE 2.9

ESTIMATE OF (A) PROPORTION OF TOTAL AREA OF LAND-USE CHANGE ASSOCIATED WITH VARIOUS PROXIMATE DRIVERS OF DEFORESTATION, AND (B) ABSOLUTE NET FOREST AREA CHANGE ASSOCIATED WITH PROXIMATE DRIVERS OF DEFORESTATION, BY REGION, 2000–2010



SOURCE: Adapted from Hosonuma *et al.*, 2012.

Management of Land Use Change

- International policies and frameworks to address deforestation
  - SDGs
  - Paris Agreement on Climate Change
- Legal frameworks for managing land use change are usually complex and vary among countries
- Difficult to ensure legal compliance
- Land use planning, investments, adequate monitoring of land use change, and coordinated efforts are key in addressing forest loss

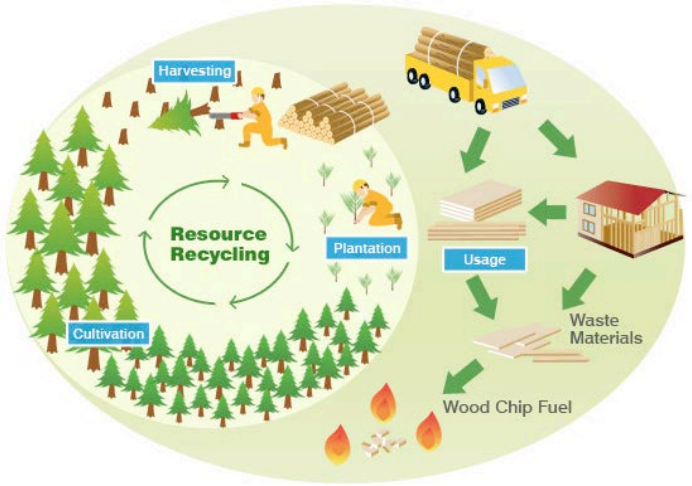
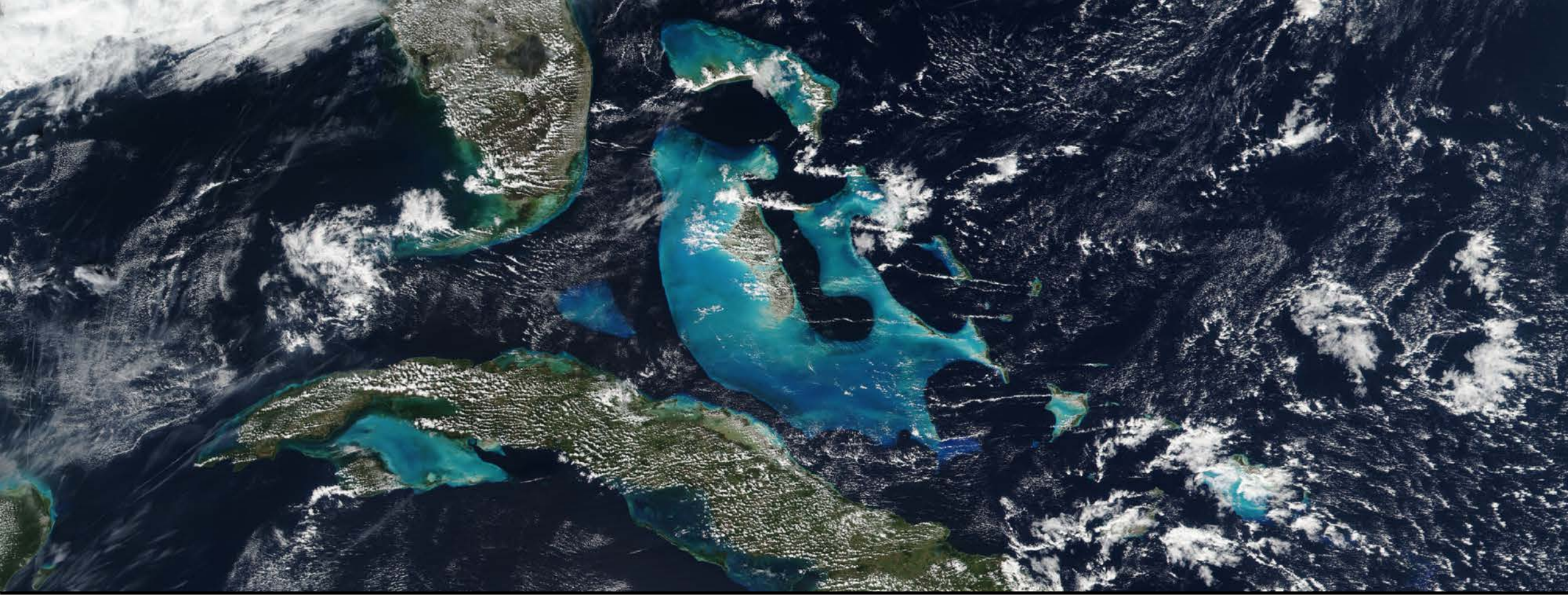


Image Credits: (top) Dalmann UK, (bottom) FAO



Remote Sensing for SDGs

Multi-Data Framework

- SDGs recognize need for reporting based on multiple data types
  - "…***to explot the contribution to be made by a wide range of data, including Earth Observation and geospatial information, while ensuring national ownership in supporting and tracking progress***."
- Earth observation data are often continuous in their spatial and temporal resolutions
  - Essential in capturing changes and progress related to SDGs over time

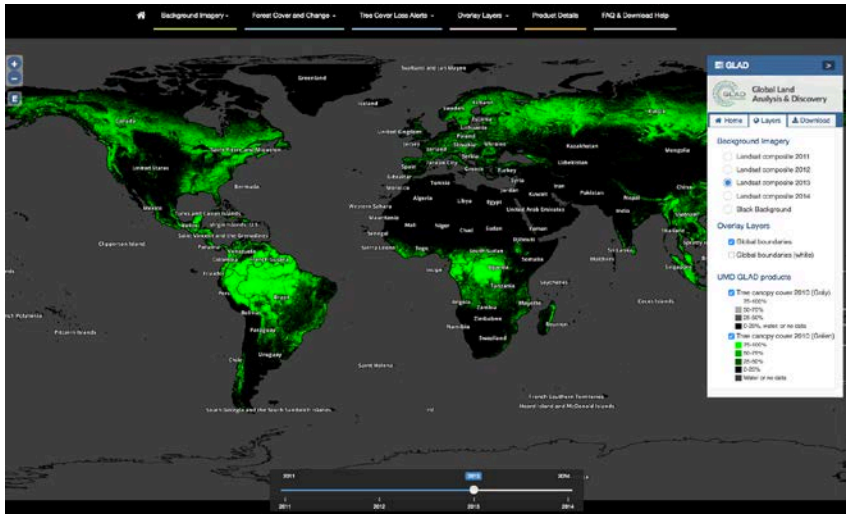


Image Credit: National Park Service (left), Global Land Analysis and Discovery (bottom)

Characteristics of Earth Observations

- Available for large regions
  - Only source of global information for some parameters
- Long time series and data continuity
  - Track progress
  - Establish baseline and trends
- Consistency and comparability
  - Among multiple countries
- Diversity of measurements
  - Many different physical parameters
- Complementarity with traditional statistical methods
  - Cross-check with in-situ data
- Mostly free and open access

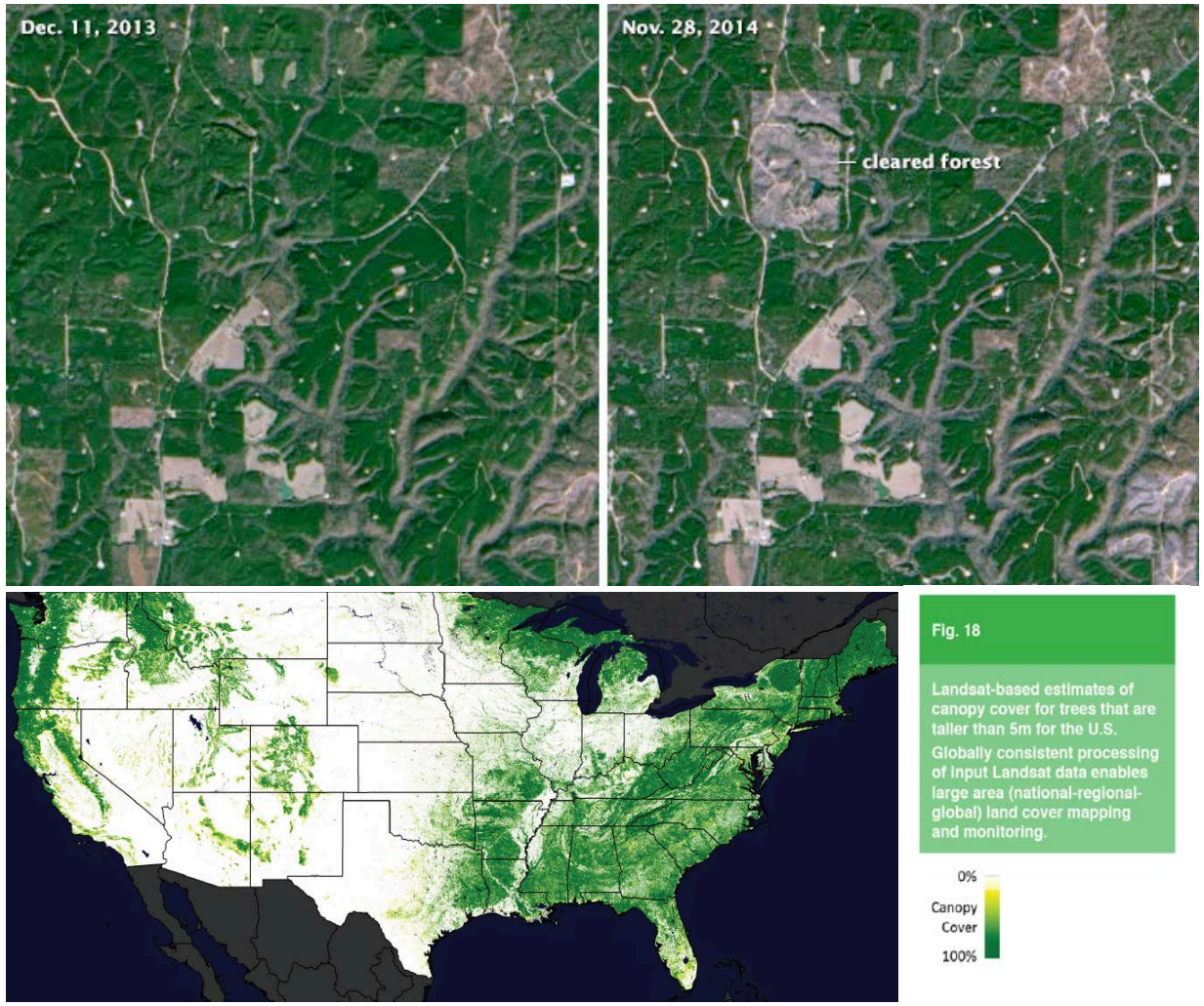


Image Credit: (bottom) Group on Earth Observations

Remote Sensing Data Sources

Considerations

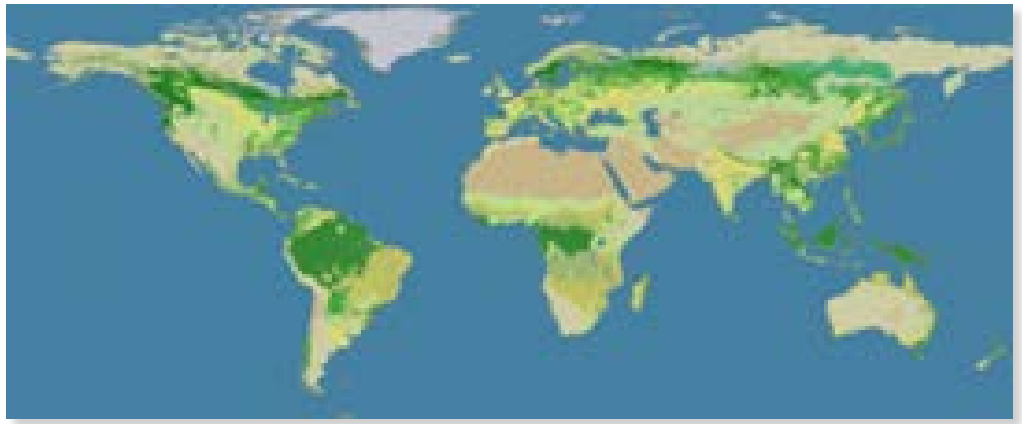
- What **geographical, phenological, and atmospheric** (especially persistent cloud cover) conditions exist?
- What is the **spatial resolution** of the data and how appropriate is it, relative to the scale of the land-cover changes to monitor?
- What is the **temporal resolution** in terms of potential frequency of acquisition of non-cloudy observations compared to the desired frequency of monitoring?
- What are the **spectral regions**, and bands within them, and how do these relate to the potential for distinguishing the land-cover types of interest, and changes among them?
- What is the **longevity of the image archive length** – does this meet the historical mapping needs?
- What are the **cost implications** of these data in terms of purchase and analysis?
- What are the **future satellite development** and launch commitments?

Remote Sensing Data Sources

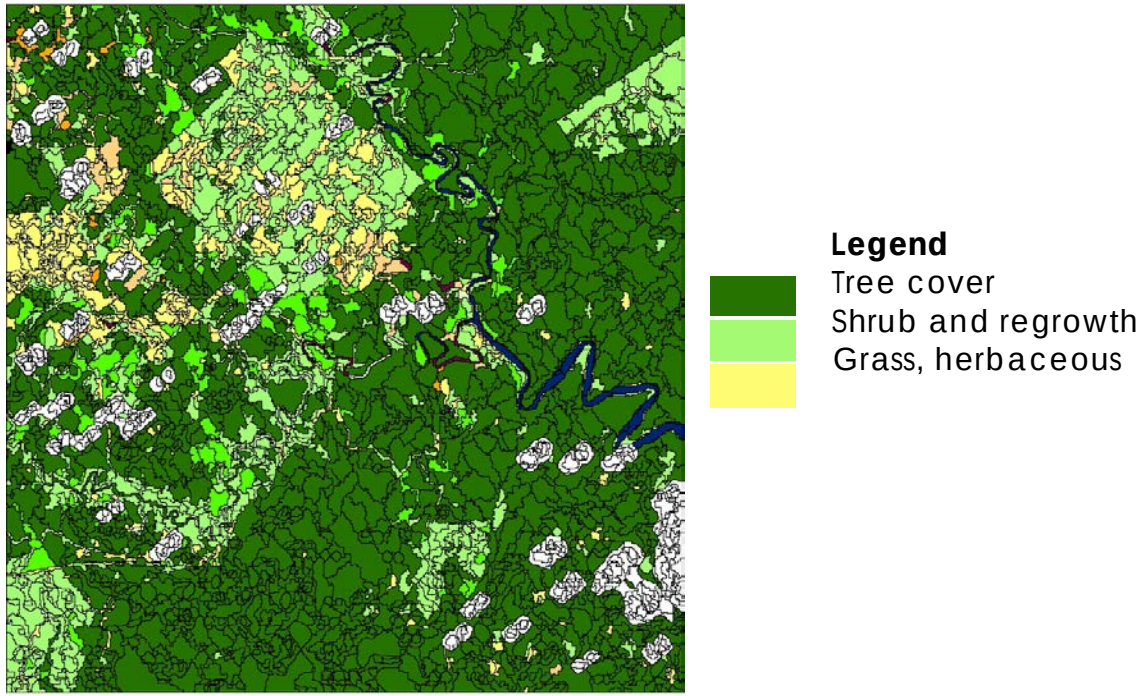
Overview

- Coarse spatial resolution (optical)
- Medium spatial resolution (optical)
- High spatial resolution (optical)
- Synthetic Aperture Radar
- LiDAR

MODIS Land Cover Map



Landsat Land Cover Map

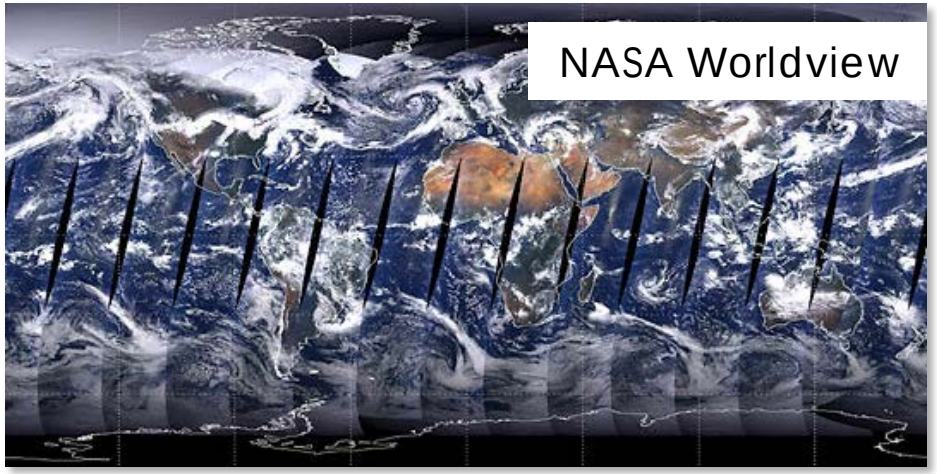


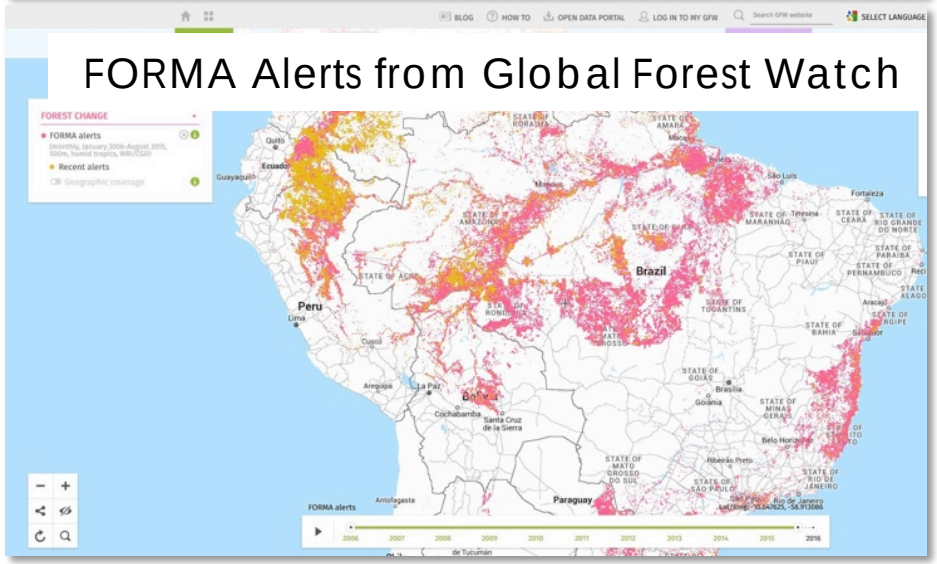
Sources: USGS 2015, GLS dataset; Bodart et al. 2011; and Raši et al. 2011.

Remote Sensing Data Sources

Coarse Spatial Resolution (Optical)

- Greater than 250 m
- Ex: MODIS, CBERS-2
- High temporal resolution useful for early warning and detection of forest clearing and degradation
- Example: FORMA
  - a monitoring system that issues monthly forest loss alerts for the humid tropics.
  - Generates alerts of likely forest clearing activity every 16 days at 500 m spatial resolution (Hammer et al. 2014)





Remote Sensing Data Sources

Medium Spatial Resolution (Optical)

- 10 m – 80 m spatial resolution
- Most common: Landsat (30 m) and more recently, Sentinel 2
- Benefits:
  - Historical archive (early 1980s)
  - Easily accessible and freely available
  - Global coverage
- Limitations: Areas of persistent cloud cover
- Example: Global Forest Watch (Hansen et al. 2013)

Image Credit: (top) Copernicus data (2015)/ESA; (bottom) Landsat NASA/USGS

Remote Sensing Data Sources

High Spatial Resolution (Optical)

- Better than 10 m spatial resolution
- Examples: Worldview 2 and 3
- Primarily used for accuracy assessment or hot spot assessment
- Benefits
  - Forest activity data can be monitored more accurately and with greater differentiation
- Limitations
  - Higher acquisition and processing costs
  - Spatial and temporal coverage may not be adequate

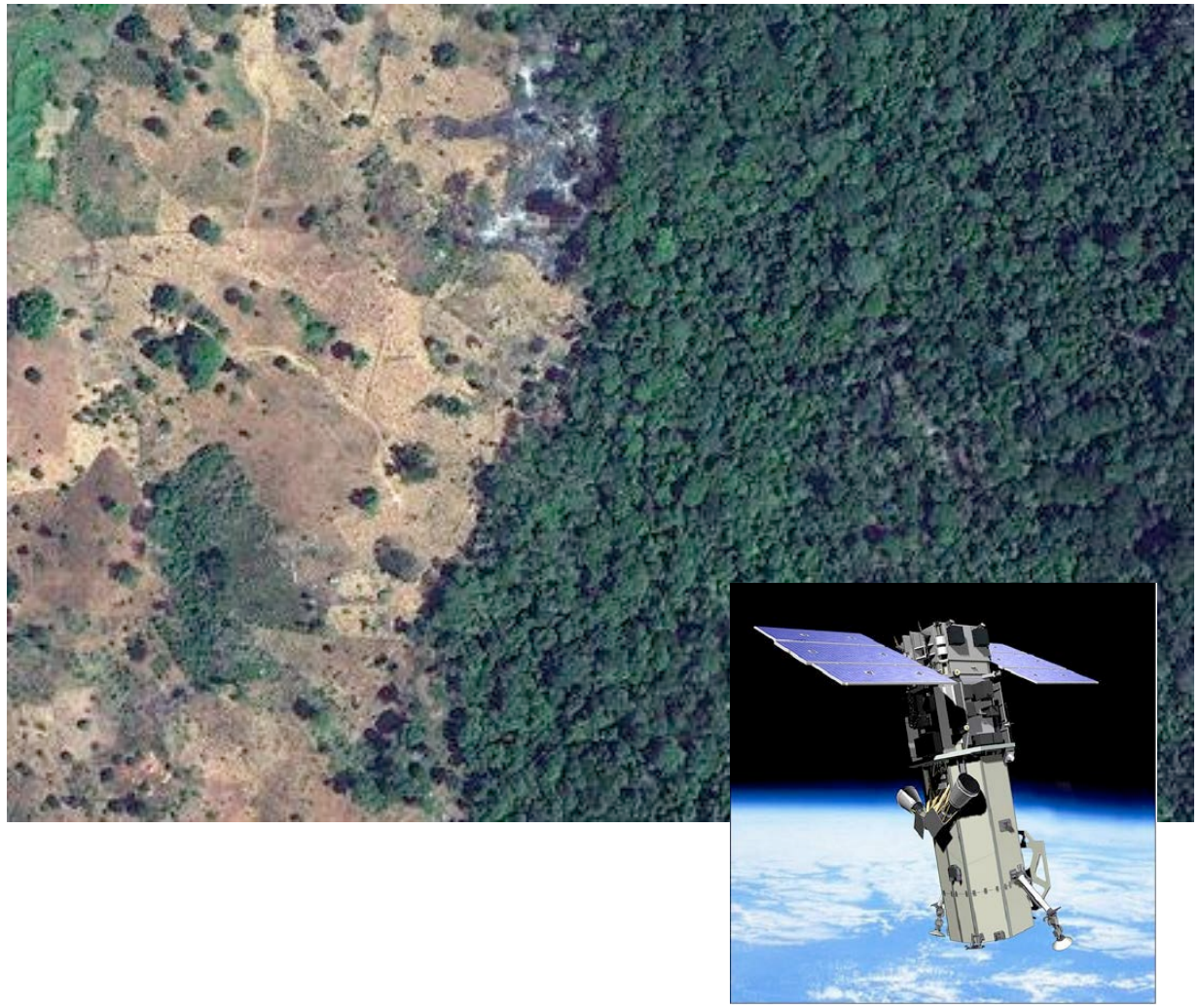


Image Credits: (top) Digital Globe and Norsk Reanesentral; (bottom) Digital Globe

Remote Sensing Data Sources

Synthetic Aperture Radar

- Two types:
  - shorter wavelengths (C- and X-band SAR)
  - longer wavelengths (L-band SAR)
- Can detect forest/non-forest and changes
- Benefits:
  - Useful in areas of persistent cloud cover
  - Can provide information on forest structure; complementary to optical data
- Limitations:
  - Difficult to process
  - Not currently used operationally

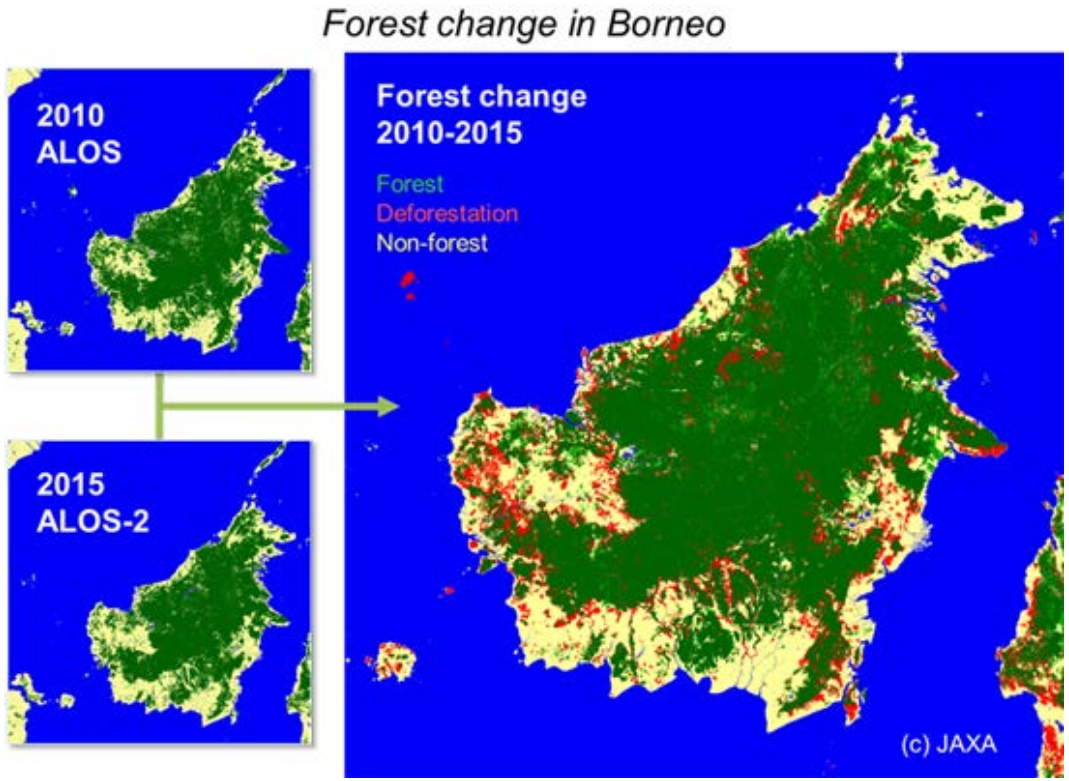
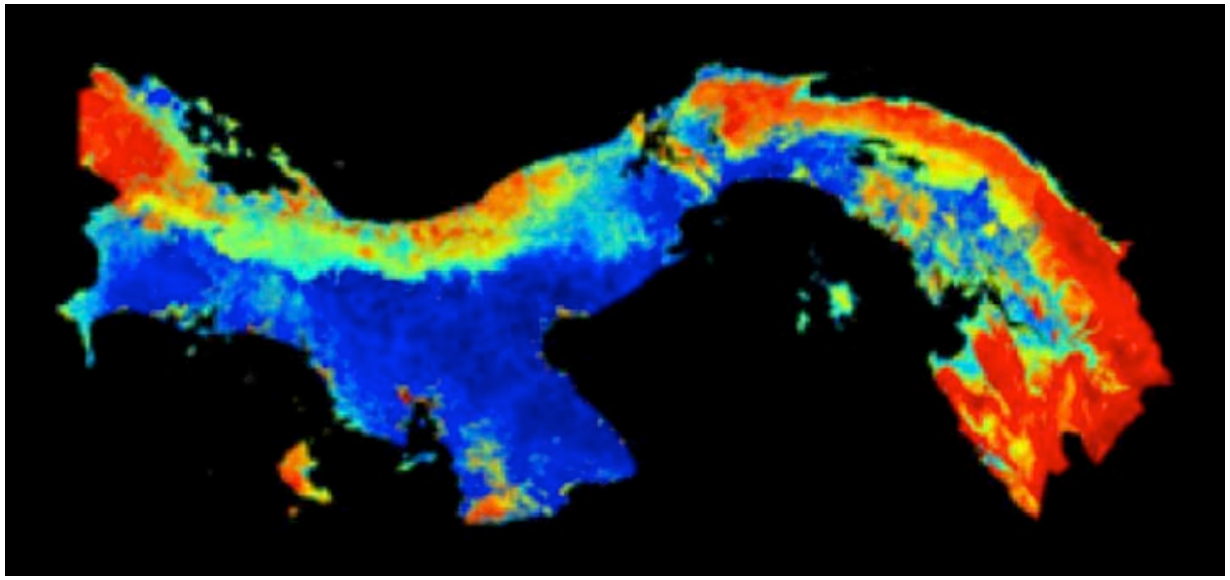


Image Credit: Masanobu et al. 2014

Remote Sensing Data Sources

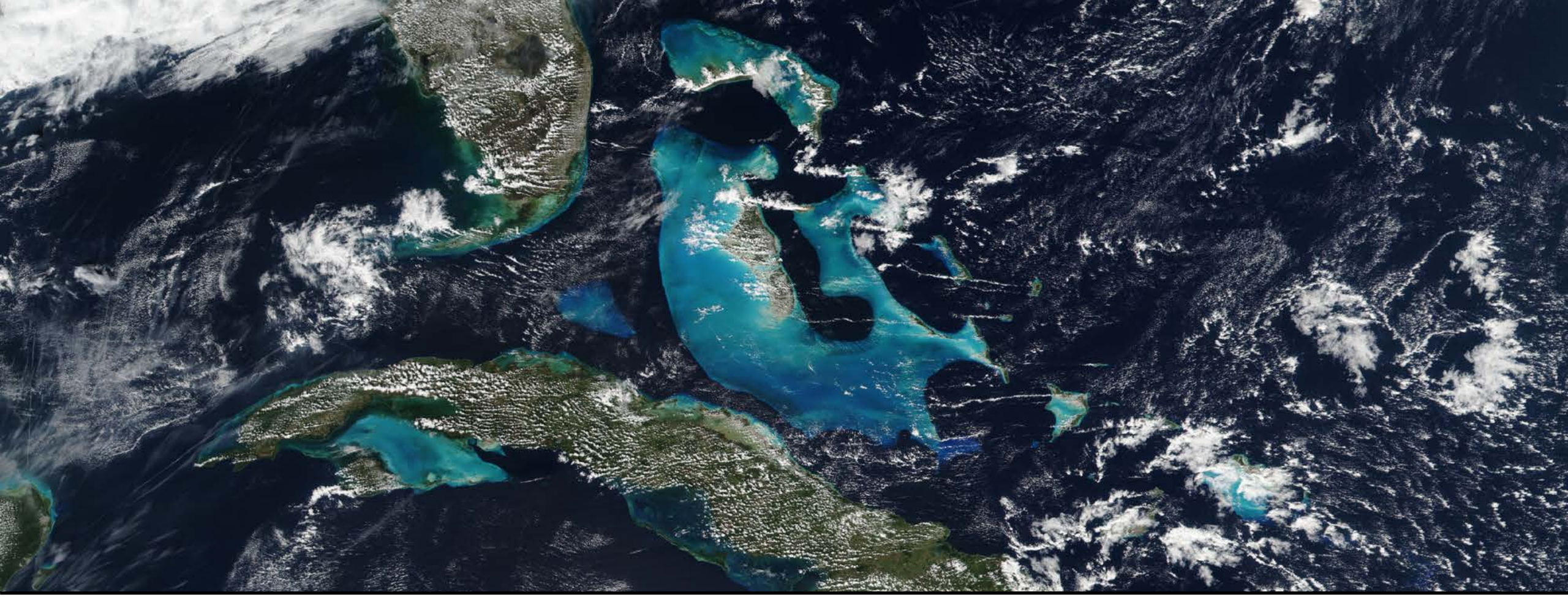
LiDAR

- Provides information on forest structure (e.g. tree height, canopy volume) and biomass
- Currently acquired using aircraft platform – no operational LiDAR satellites
- Benefits
  - Provides detailed information of forest structure
  - Verification of biomass estimates, reduces need for ground sampling
- Limitations
  - Expensive to acquire & process



National carbon map of Panama by integrating field data with satellite imagery and LiDAR

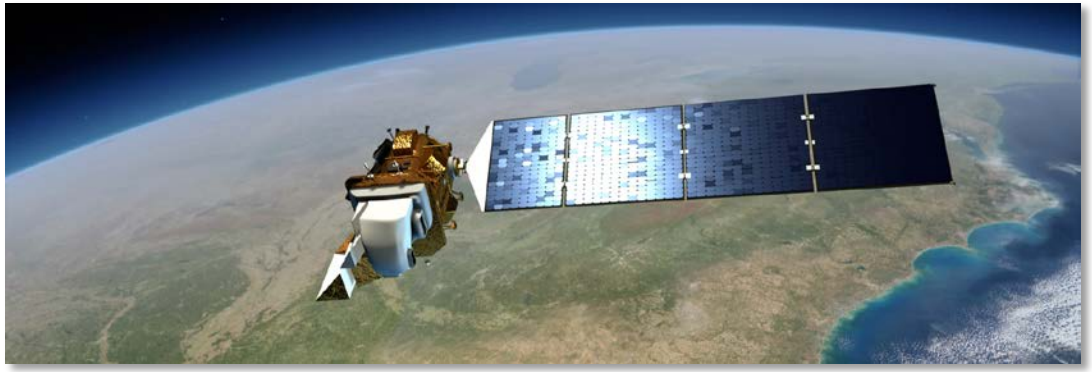
Image Credit: Carnegie Institution

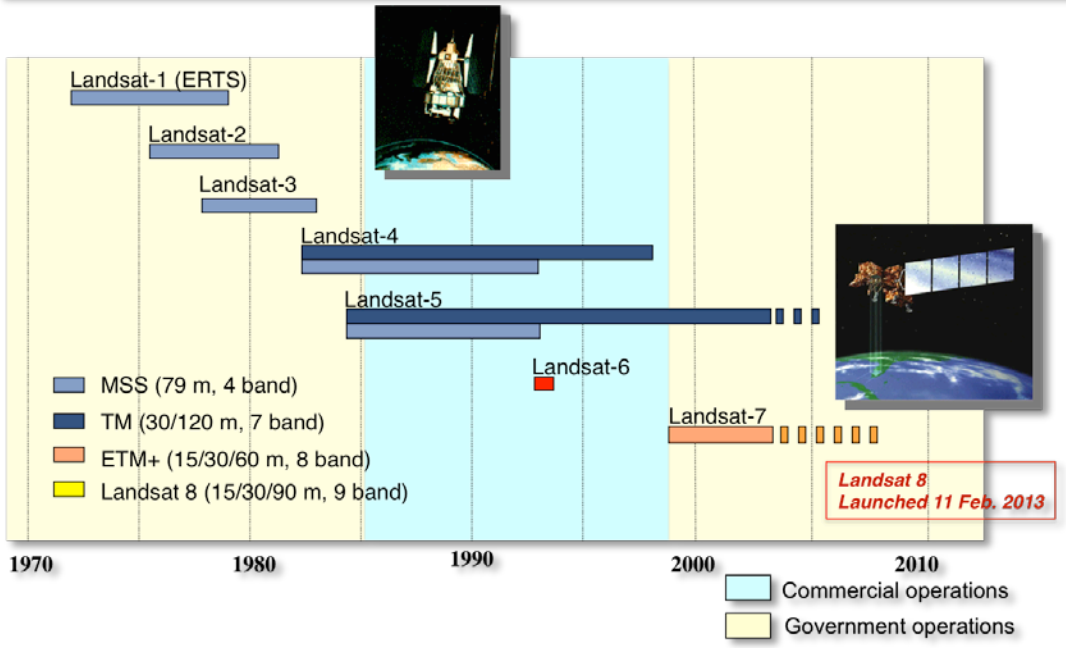


Remote Sensing Data Sources for Assessment of Land Cover

Landsat

- First Landsat launched in 1972
- Landsat 8 launched in 2013
- NASA created and launched
  – USGS maintains data
- Passive sensor: obtains values of reflectance from Earth's surface
- 30 meter pixels, 15 meter panchromatic band
- Entire image of the Earth every 16 days

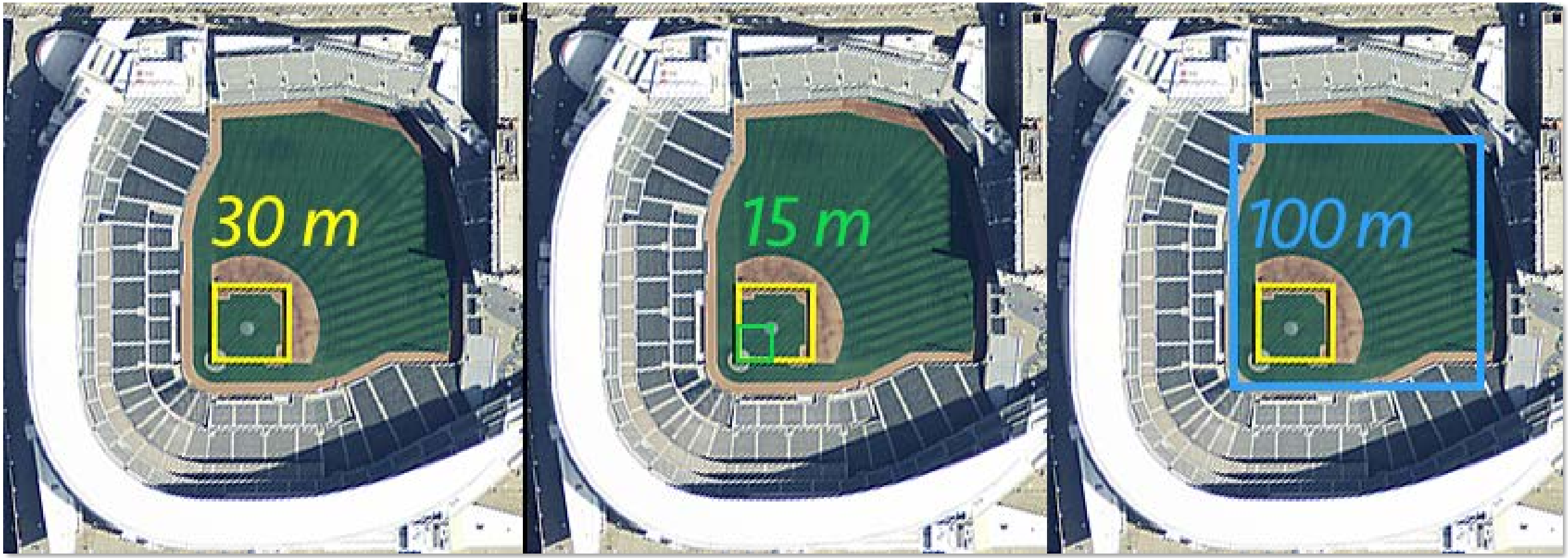




Landsat Bands

Landsat-7 ETM+ Bands (µm)			Landsat-8 OLI and *TIRS* Bands (µm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	*100 m TIR-1*	*10.60 – 11.19*	Band 10
			100 m TIR-2	*11.50 – 12.51*	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9

Landsat Spatial Resolution

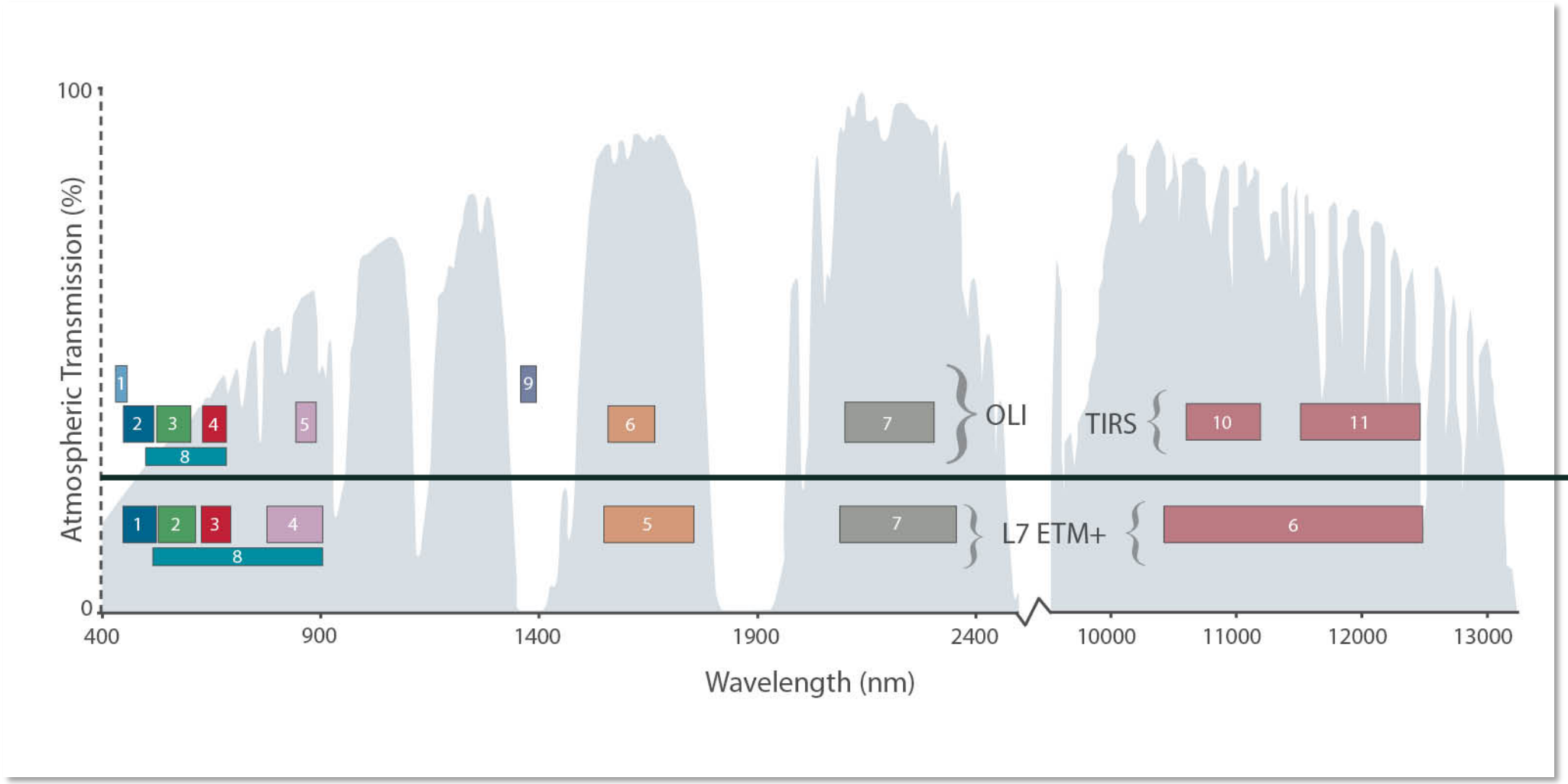


VIS-NIR-SWIR=30 m

Panchromatic = 15 m

Thermal IR = 100 m
(resampled to 30 m to match OLI spectral bands)

Landsat Bands



Where to Obtain Landsat Images

LandLook Viewer: https://landlook.usgs.gov/viewer.html

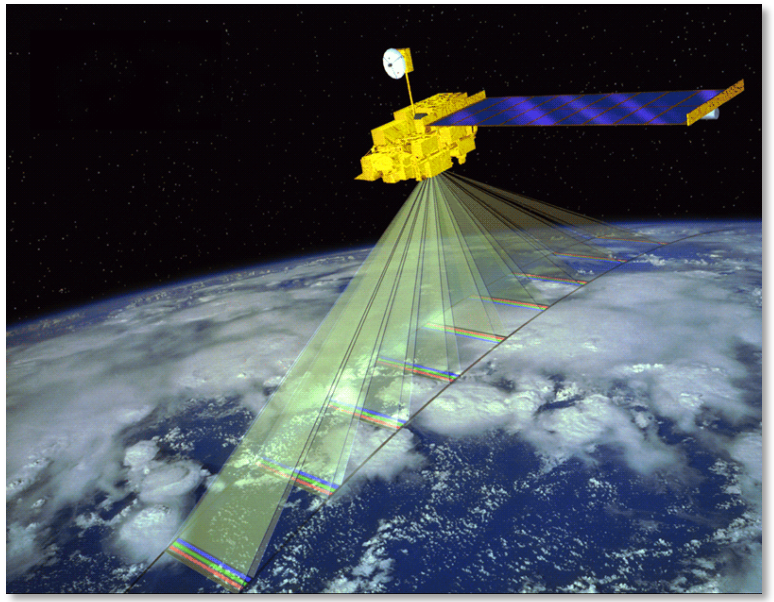
GloVis: https://glovis.usgs.gov/app

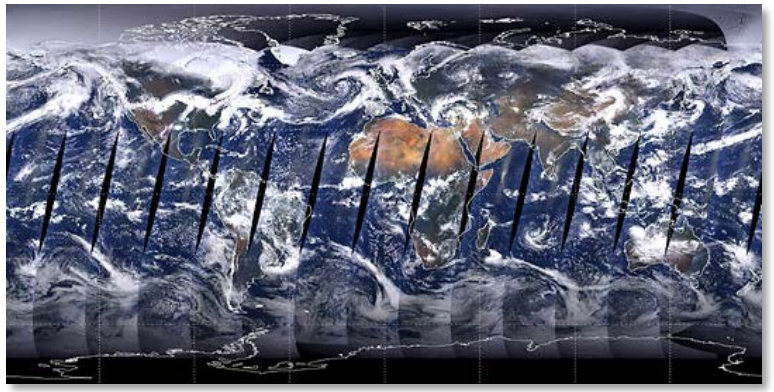
Global Land Cover Facility: http://glcf.umd.edu/data/landsat/

Earth Explorer: http://earthexplorer.usgs.gov/

MODIS

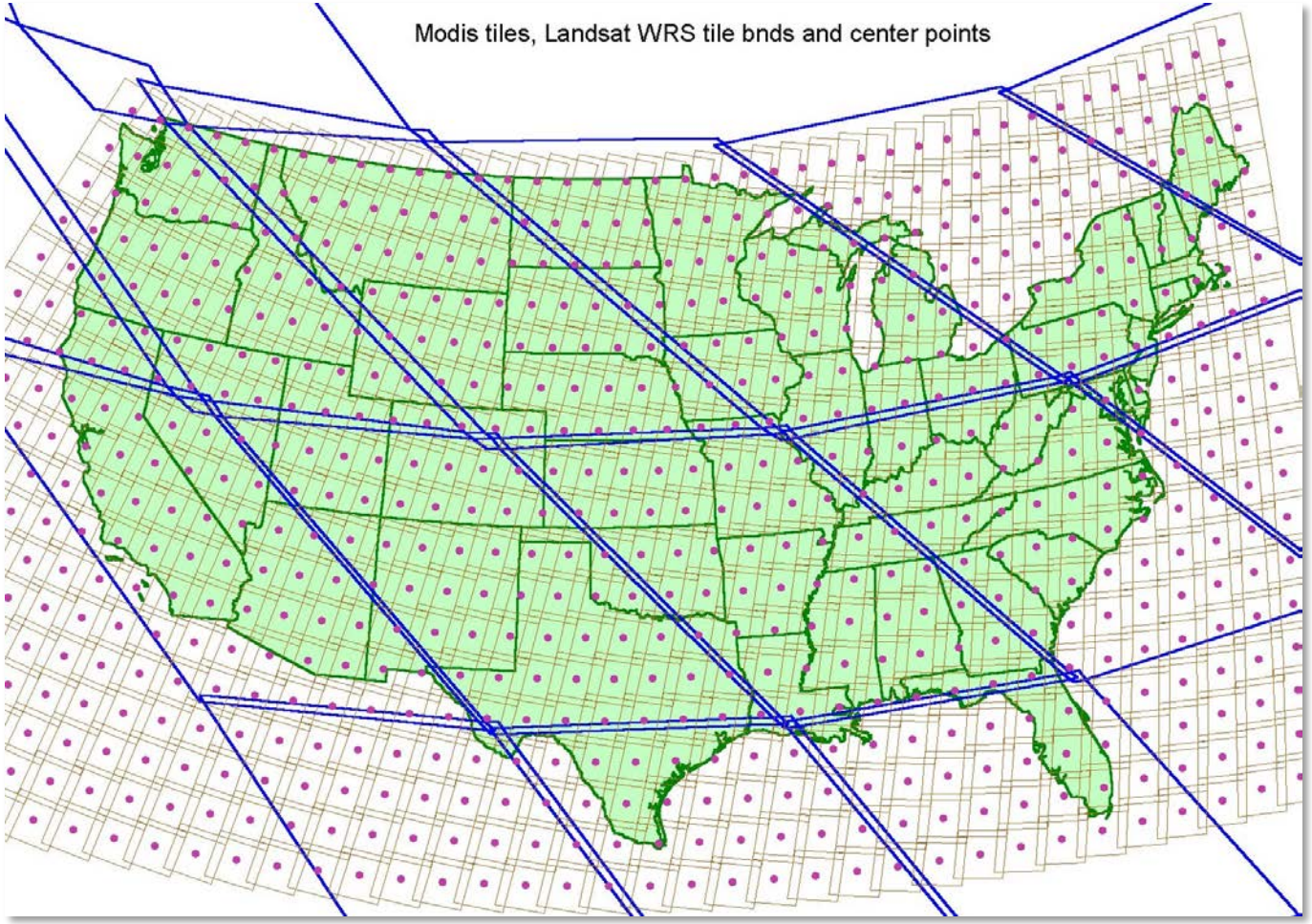
- Spatial Resolution
  - 250 m, 500 m, 1 km
- Temporal Resolution
  - Daily, 8 day, 16 day, monthly, quarterly, yearly
  - 2000–present
- Data Format
  - Hierarchal data format – Earth Observing System Format (HDF–EO8)
- Spectral Coverage
  - 36 bands (major bands include red, blue, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1000 m





MODIS vs. Landsat Images

- Large swaths!



Where to Obtain MODIS Products

Land Process Distributed Active Archive (LPDAAC): http://lpdaac.usgs.gov/

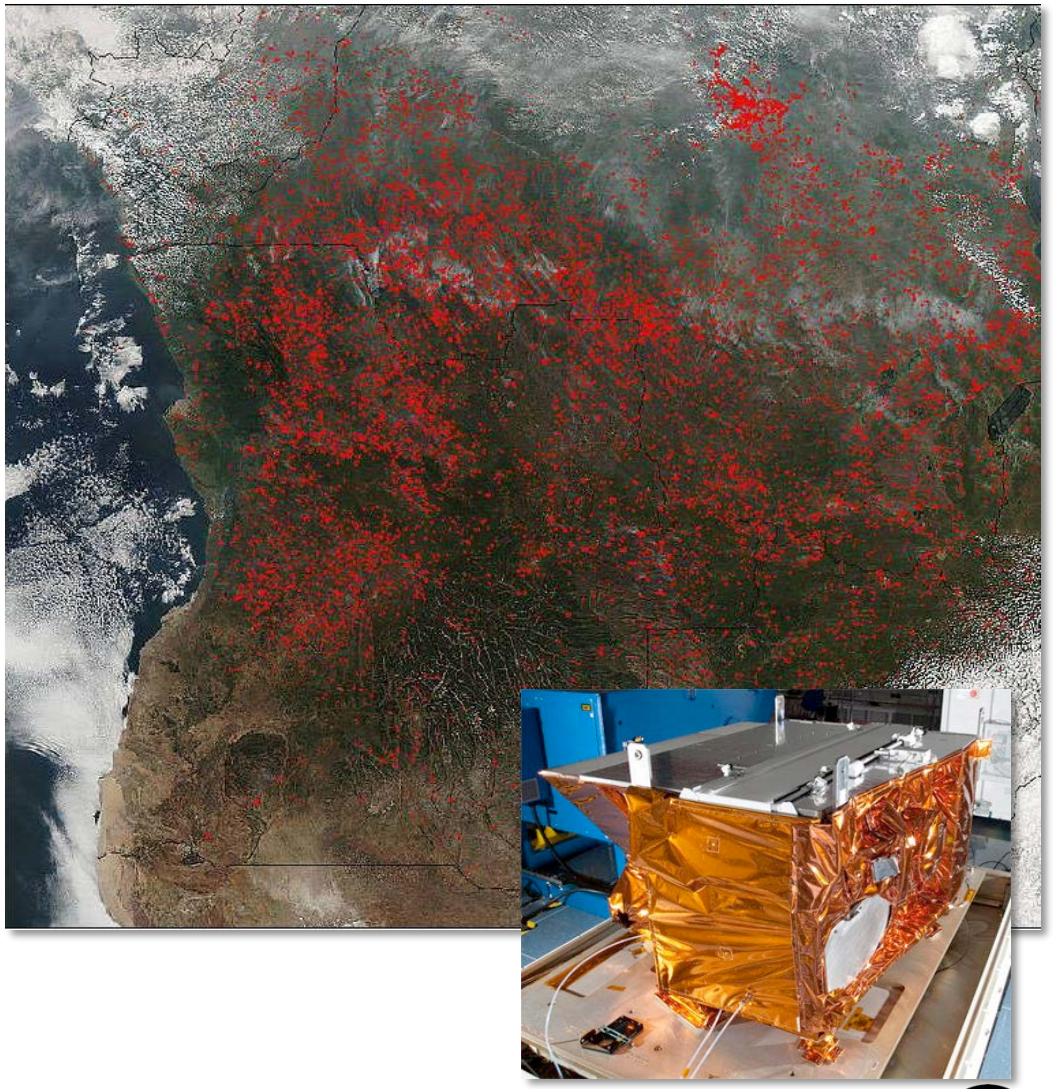
Worldview: https://worldview.earthdata.nasa.gov

Earthdata Search: https://search.earthdata.nasa.gov/

National Snow and Ice Data Center: http://nsidc.org/data/modis/data_summaries#snow

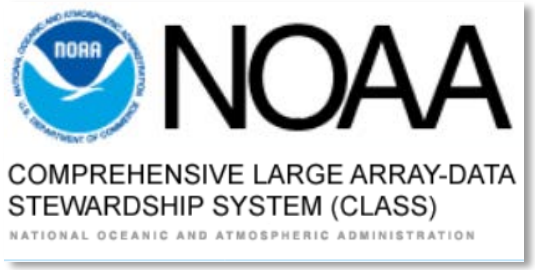
Suomi NPP: VIIRS

- Visible Infrared Imaging Radiometer Suite (VIIRS): instrument aboard Suomi National Polar-orbiting Partnership (NPP)
- Collects visible and infrared imagery and radiometric measurements
- Launched 2012
  - NOAA took control of operations in 2013
- Daily temporal resolution
  - Global coverage
- Spatial resolution
  - 5 high resolution bands: 375 m
  - 16 moderate resolution bands: 750 m
  - 1 day/night band: can observe fires at night



Where to Obtain VIIRS Land Products

Worldview (Fires, Land Surface Temperature and Snow Cover): https://worldview.earthdata.nasa.gov



NOAA Comprehensive Large Array-Data Stewardship System (CLASS): https://www.bou.class.noaa.gov/saa/products/welcome

Level-1 and Atmosphere Archive & Distribution System Website: http://ladsweb.nascom.nasa.gov

Sentinel-2

- Launched June 2015
  - Sentinel-2B in March 2017
- 2 Identical satellites
- 13 spectral bands
- Spatial Resolution: 20 m
- Temporal resolution: global coverage approximately every 5 days
- Applications:
  - Agriculture: yield prediction/plant growth
  - Forestry: land cover changes

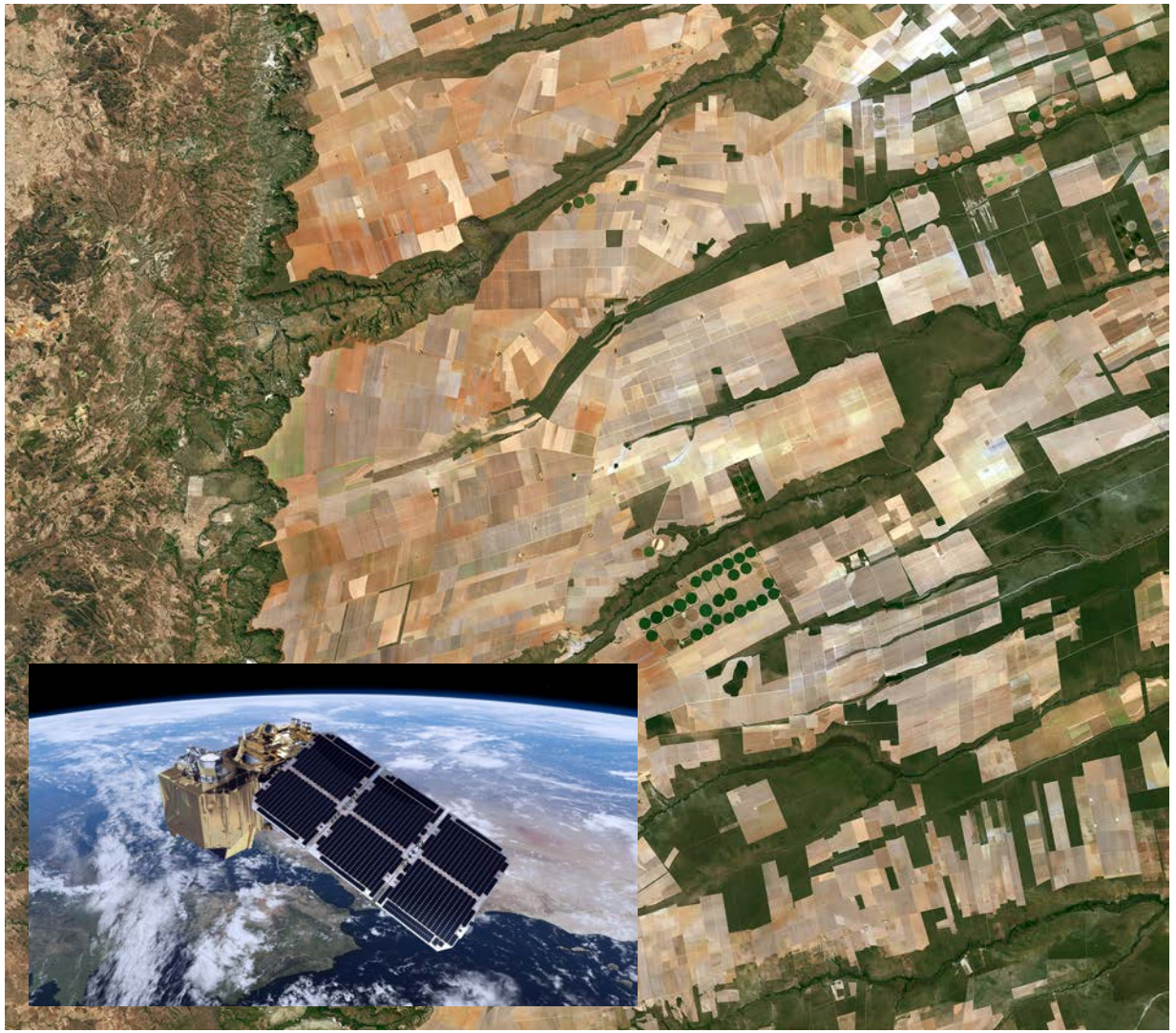
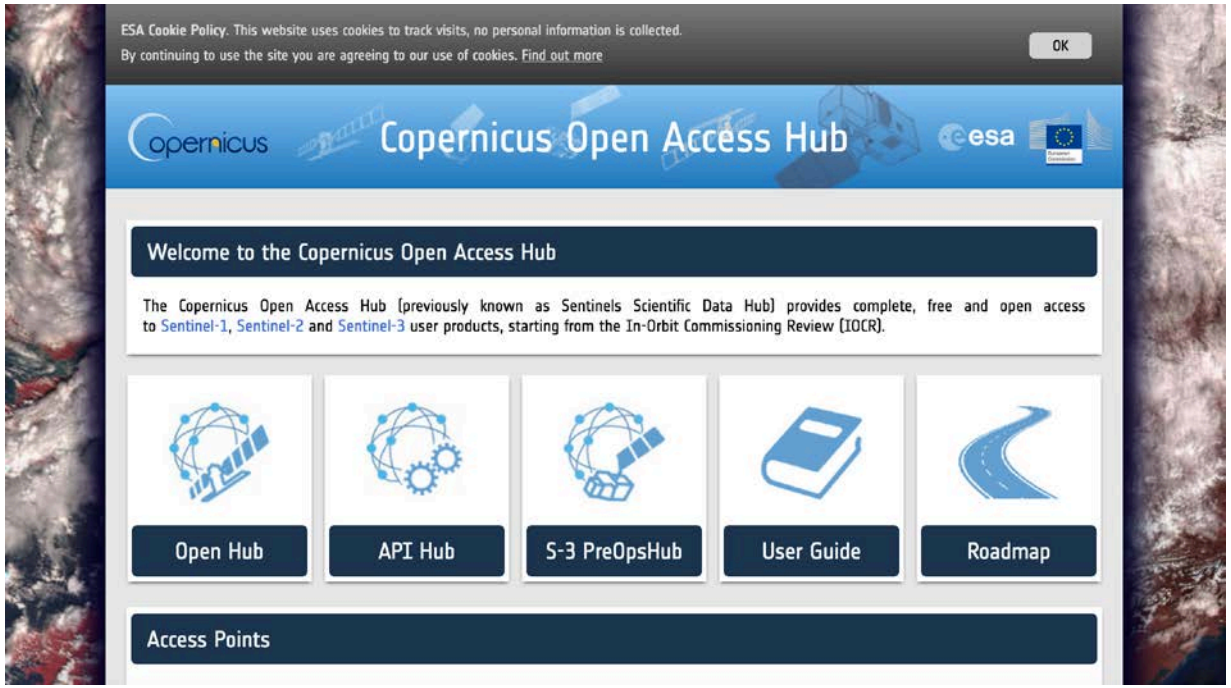
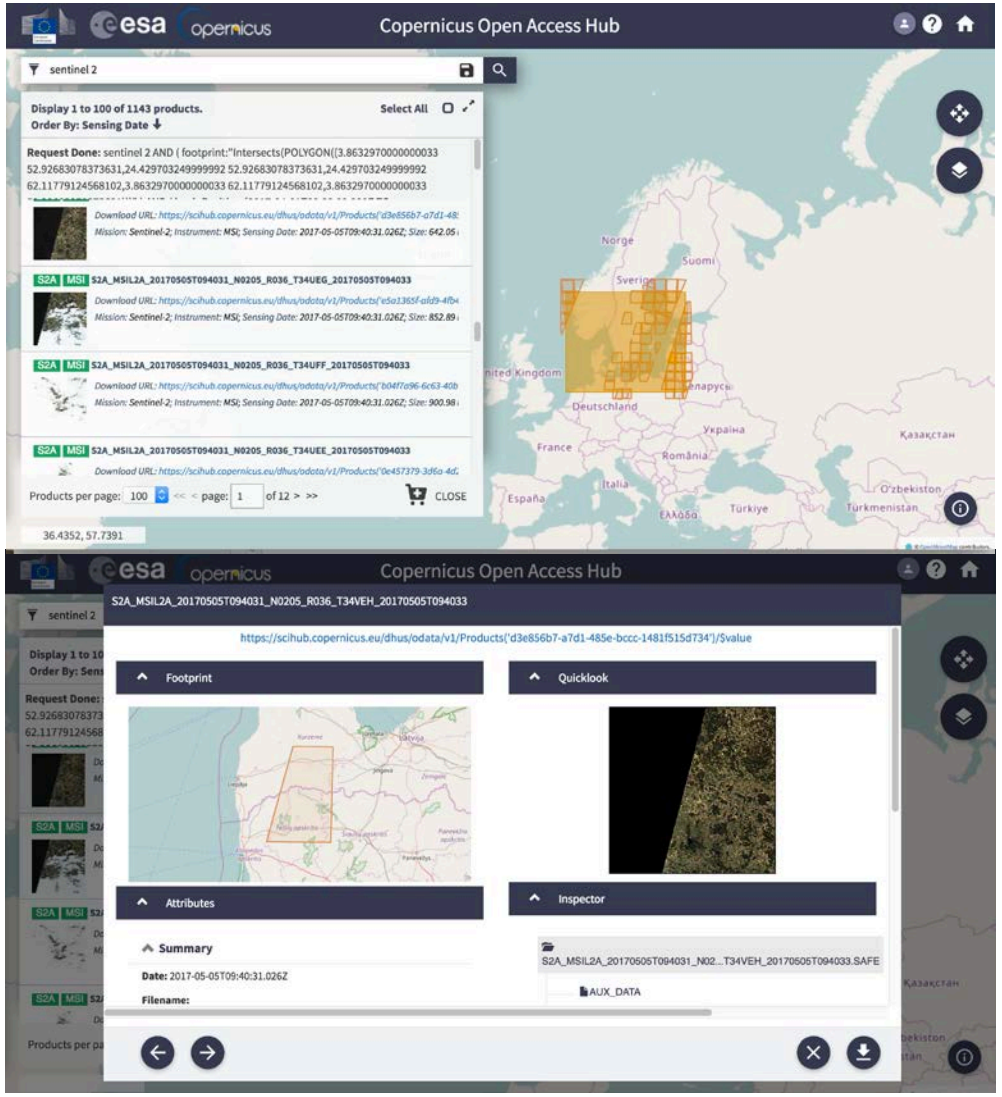


Image Credits: ESA

Accessing Sentinel-2

Copernicus Open Access Hub:
https://scihub.copernicus.eu/






APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank you!