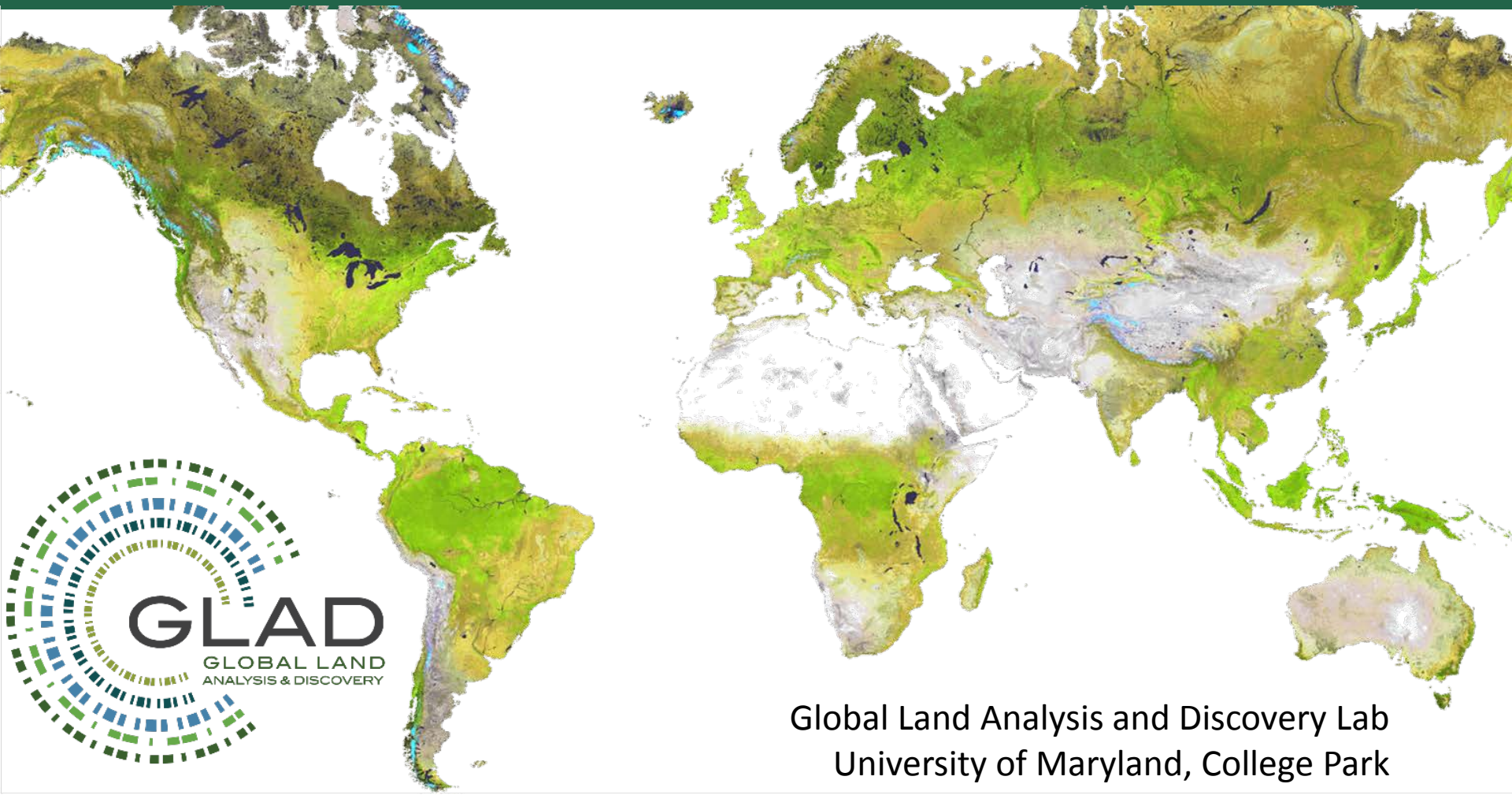
National Forest Assessment and Monitoring Using the Satellite Data Archives

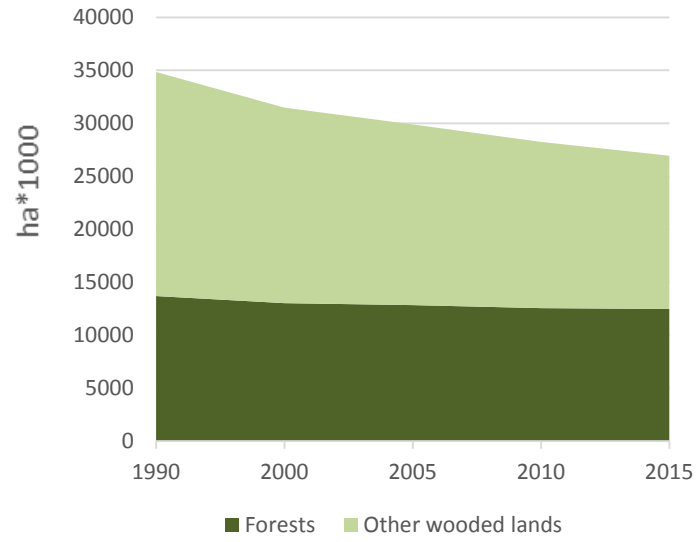


GLAD
GLOBAL LAND
ANALYSIS & DISCOVERY

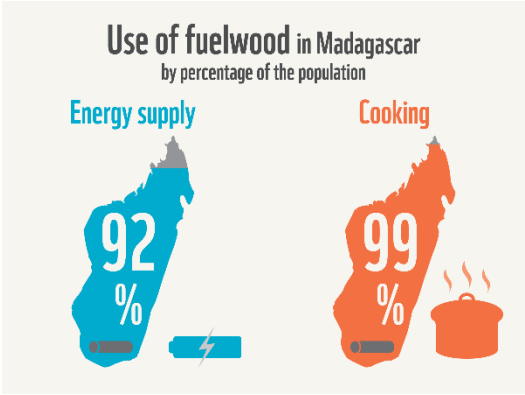
Global Land Analysis and Discovery Lab
University of Maryland, College Park

UNIVERSITY OF MARYLAND

Forests of Madagascar



- **Forest use provides substantial contribution to the national GDP**. Agriculture and forestry combined accounting for 27% of GDP. Fuelwood is the major source of energy in the country.



WWF MWIOPO

- **Trees outside forests plays important role in the country's total tree cover.** TOF makes up to 54% of the total area covered with woody vegetation in 2015.
- **Forests are heavily degraded and their area is shrinking.** The forest area has declined dramatically in the last decades.

	1990	2000	2005	2010	2015
Forest area (1,000 ha)	13,692	13,023	12,838	12,553	12,473

FAO FRA 2015

National Tree Cover (Forest and TOF) Area

Sources of national data on tree cover area in Madagascar

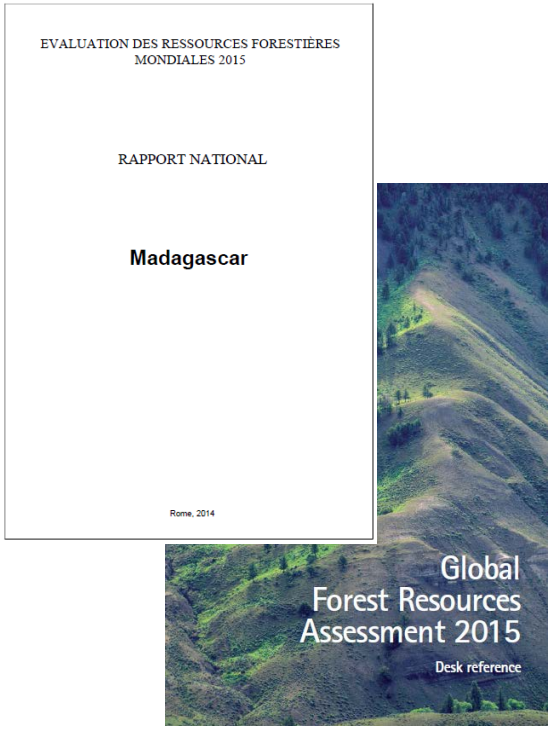
- 1970s forest cover from Landsat MSS (Faramalala, 1988; Mayaux, 2000; Harper et al., 2007).
- Forest area c. 1990 and c. 2000 (Harper et al., 2007)
- Forest area 2005 (CI, 2005).
- Forest area 2010 (ONE, FTM, MNP).

National Forest Inventory and Land Management

- Quantification and monitoring of forest resources.
- Land cadaster and management.
- Assessment of forest ecosystem services, habitat mapping, and conservation status assessment.
- Forest restoration projects management.

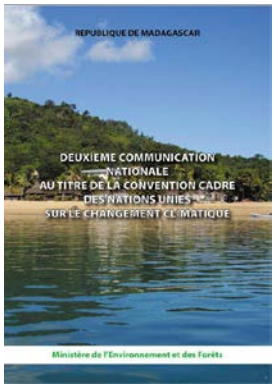
International Reporting

FAO FRA National reports



UNFCCC GHG Emissions Reporting, NFMS for REDD+ activities

- Measurement of the reference emission and deforestation levels.
- Operational monitoring of forest cover change for emissions reporting.



Tree Cover Area and CO_2 Emissions Reporting

- Forests act as both sink and source for CO_2 emission. In Madagascar, LULUCF serves as a major sink of the CO_2 that outweigh national emissions. In the year 2000 Madagascar remains a carbon sink with a net emission ($\Sigma_{Emissions} + \Sigma_{Absorptions}$) of - 231,821 Gg CO_2

  Data from the: Madagascar. Second national communication to UNFCCC. 2010

- To calculate changes (emission or removal) in the forest and other woody biomass stocks, **total** plantation area, forest, and trees outside the forest should be considered.
- Emissions reporting should be provided **periodically and consistently** (biannual reporting).
- **Uncertainty measurement** is required for all estimations.

Tree Cover Area and CO_2 Emissions Reporting

- Basic IPCC equation to calculate carbon emissions from LC change (IPCC, 2006, vol.1, ch.1.2):

$$\textit{Emissions} = \textit{Activity Data} * \textit{Emission Factor}$$

- Using emission factors specific for forest types may improve the GHG emission accuracy. The equation for multiple forest types (strata) is:

$$E = \sum AD_i * EFi \qquad i - stratum - specific\ data$$

- Remotely sensed data enable mapping and monitoring of forest cover and change over large areas (**Activity Data**) at regular intervals, providing information on where and how changes are taking place at annual or even finer time scales. Long-term satellite data archives are the only datasets available for estimating historical activity data.
- The most promising and robust ways to map aboveground carbon stock across landscapes (**Emission Factor**) rely on the synergistic use of field measurements and remote sensing data.

Tree Cover Area: National Monitoring

Objective

Providing timely spatial information on tree cover area and change

Requirements

Monitoring institution:

- Free data. Low-cost, easy to implement data processing and analysis methods.
- Fast data processing to allow timely updates.
- Complete ownership and replicability of results.

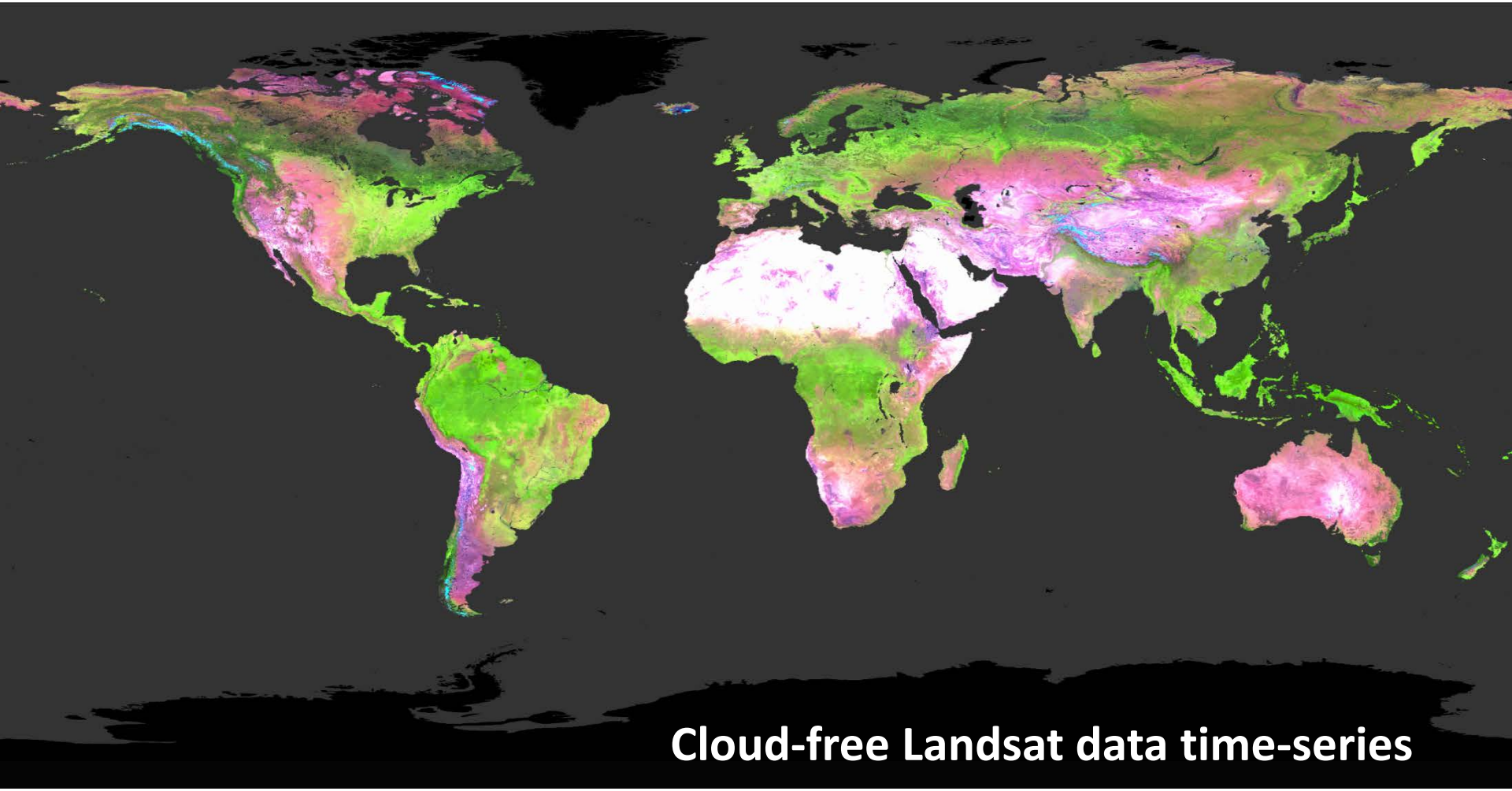
National reporting:

- Reporting format and timing is aligned with national forest policies and suitable to quantify their effects.
- Spatial and temporal consistency at national scale.
- Known uncertainty. Accuracy is suitable for MRV.

International reporting:

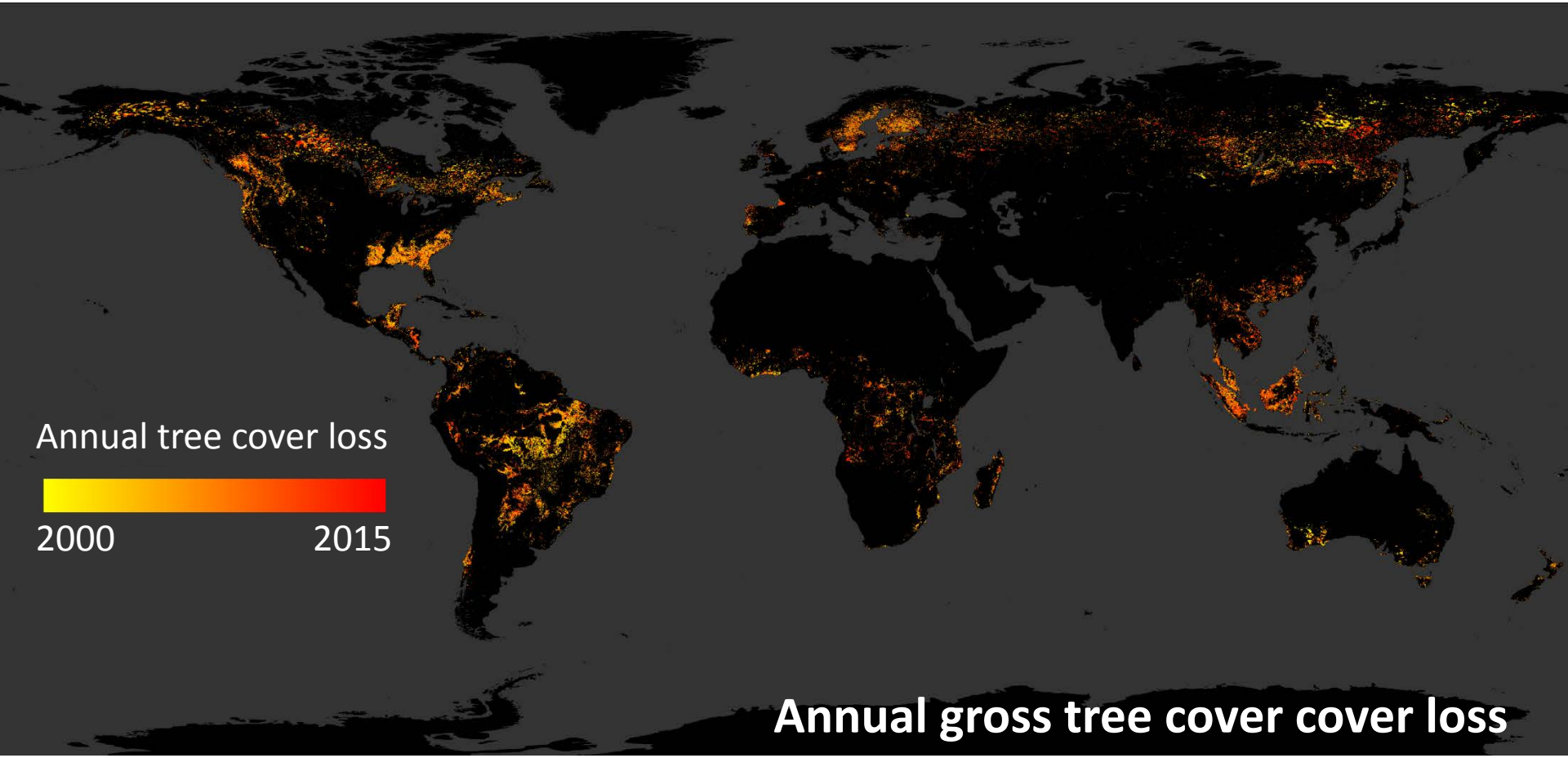
- Transparency and replicability of methods and data.
- Consistency between countries.
- Known uncertainty estimated using good practices.

GLAD Tree Cover Monitoring Data



Spatial and temporally consistent Landsat surface reflectance data time-series provides the basis of annual land cover monitoring. Landsat data archive is the only data source that allowing global historical tree cover change monitoring.

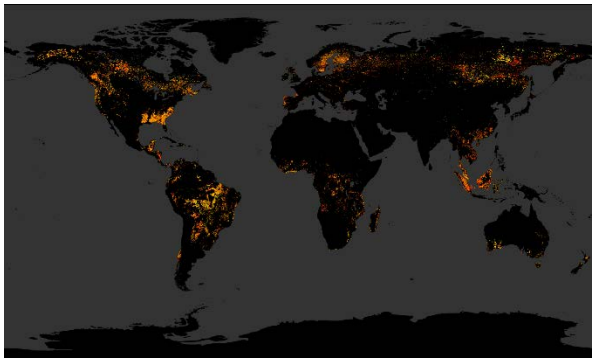
GLAD Tree Cover Monitoring Data



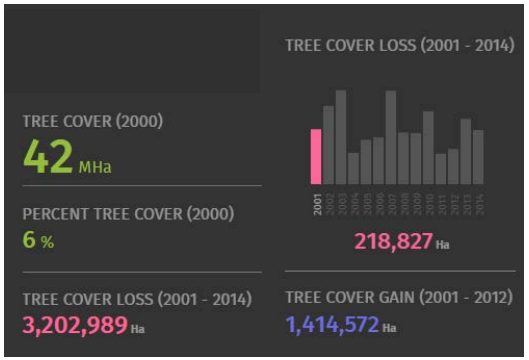
Global maps of tree cover, it loss and gain, are readily available. The UMD/GLAD maps are produced on a consistent basis and are updated annually. These maps, however, **may have limitations** in the regions with heterogeneous landscape and small-scale tree cover dynamics.

GLAD Tree Cover Monitoring Data

Wrong way



Direct area extraction from the global map



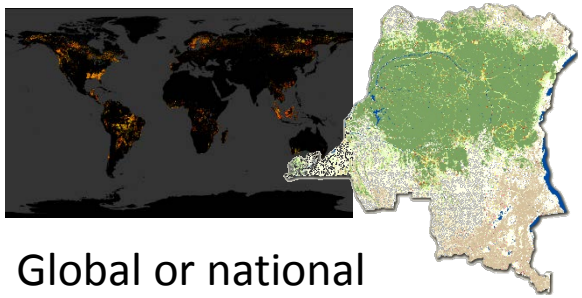
Global forest extent and change products provides spatially consistent, wall-to-wall data…

However:

- All maps derived from remotely sensed data contain errors due to data limitation, classification/change detection algorithm limitation, analyst errors and bias, etc.
- Errors on the global overview maps usually introduce bias in area estimations. Most of the overview maps provide “conservative” estimates of rare classes, i.e. they underestimate forest change.
- The global map errors may be spatially biased (e.g. due to different characterization model sensitivity within different environments). Its quality may not be suitable in a particular region.
- The uncertainty of classification may not be estimated from the map alone.

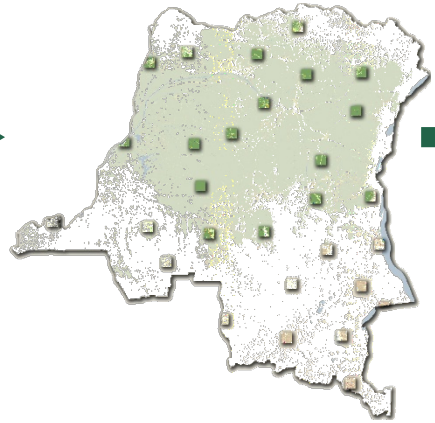
GLAD Tree Cover Monitoring Data

Good practice



Global or national
wall-to-wall TC change maps

Statistical
sampling



Sample-based:

- Map accuracy
- Area
- Uncertainty

Spatially exhaustive (wall-to-wall) maps

- Provide information on spatial allocation of forest cover and change.
- Allow sampling design/area estimation with improved efficiently and precision.
- Global maps may have limitations and should be substituted with regional/national maps when possible.

Sample-based assessment (reference sample data)

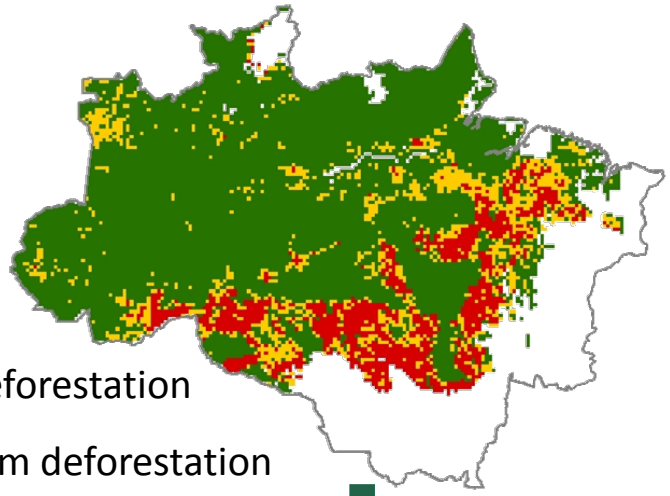
- Provides highest quality determination of the forest cover and change conditions per sample unit
  - Serves as reference data for map **accuracy assessment.**
  - Allows **unbiased area estimation** with known **uncertainty.**

Sampling Design

Random sampling

Systematic sampling

Stratified sampling

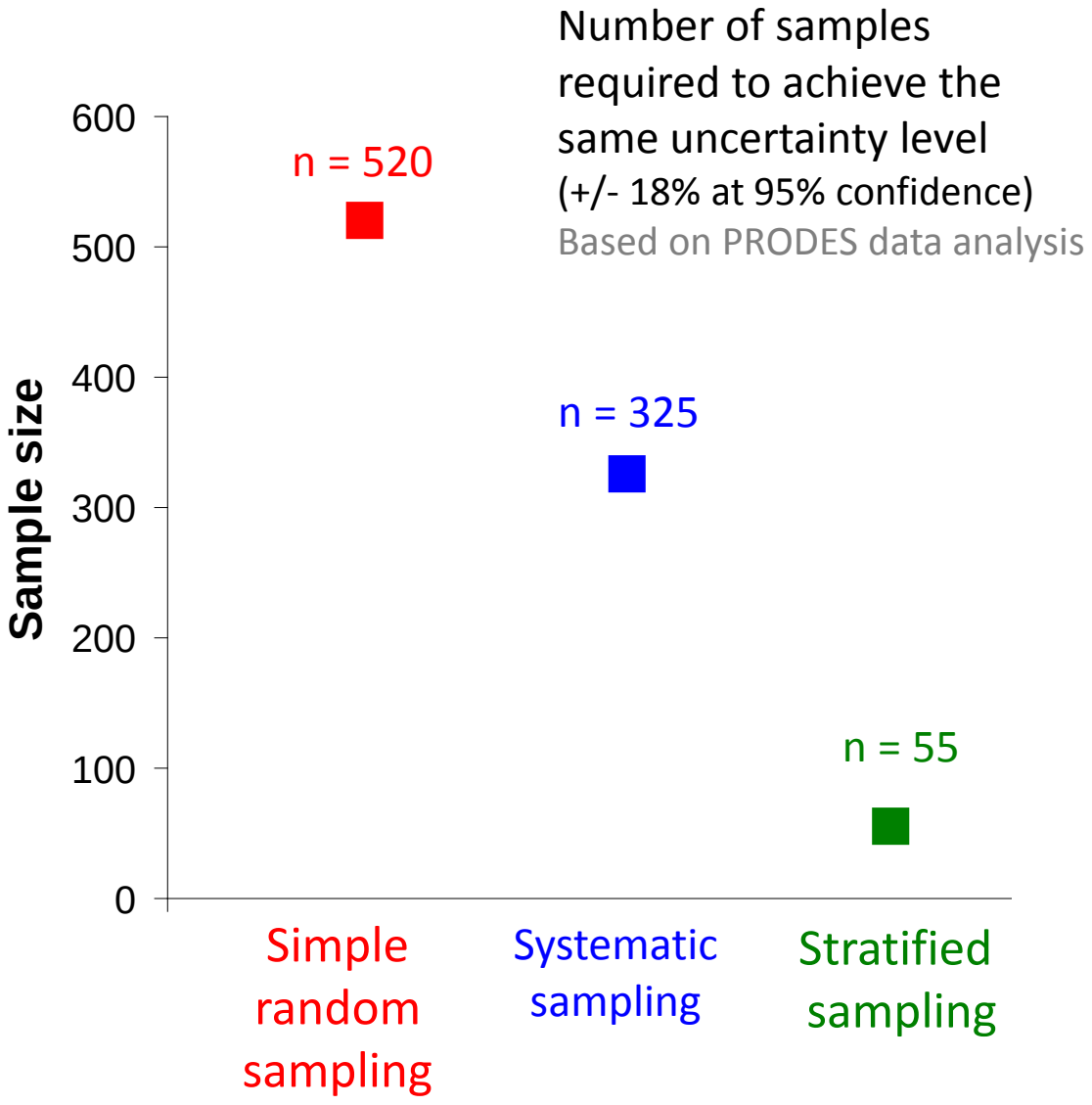


Strata

- low deforestation
- medium deforestation
- high deforestation

Broich et al. (2009)

Sampling Design



Wall-to-wall forest cover and change products may be used to create a **stratified sampling design** which is much **more efficient** that random or regular sampling:

- Lower uncertainty of sample-based estimate;
- Smaller number of samples needed;
- Reduce requirement for commercial high spatial resolution data.

Broich et al. (2009)

GLAD Tree Cover Monitoring Approach

GLAD

Global consistently processed annual Landsat data

Global tree cover and tree cover change maps (strata)

OR

National tree cover and tree cover change maps (strata)

NFMS

Stratified sampling design

- Sample-based estimates of tree cover area and change.
- Tree cover and change by regions, forest types, or AGB strata.
- Change by year, disturbance type, gross and net change.
- Accuracy of the national wall-to-wall maps.

*All estimates with known uncertainty

National reporting and management.
Support for NFI (plot location, extrapolation of field data).
International reporting (FAO FRA, REDD+, IPCC/UNFCCC).

GLAD Tree Cover Monitoring Approach

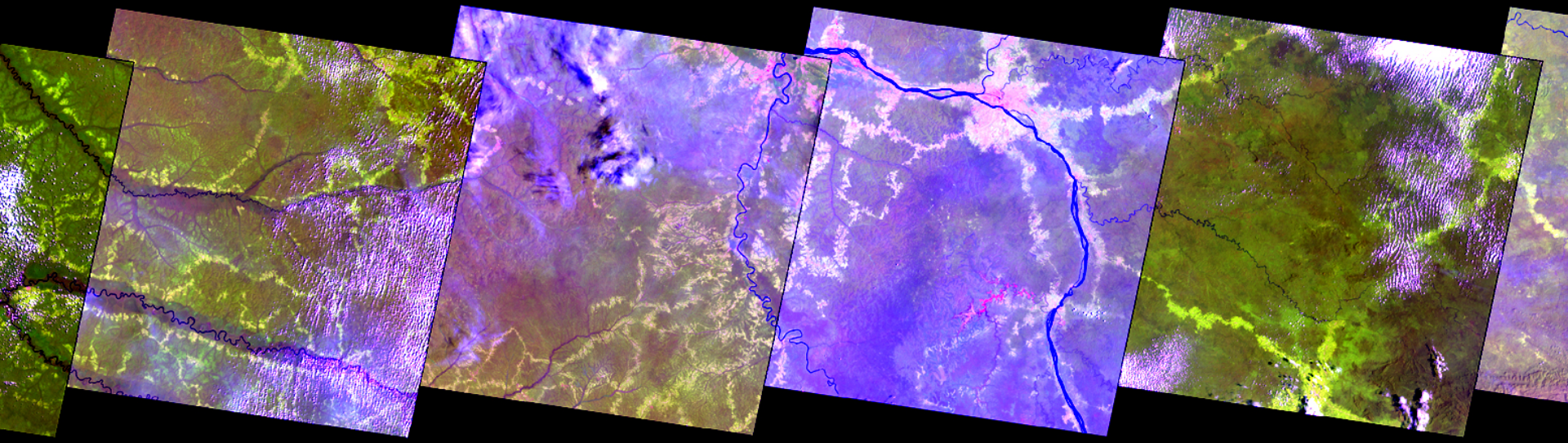
The GLAD system objective is to provide **timely spatially consistent information on national tree cover area and change**.

The GLAD system benefits:

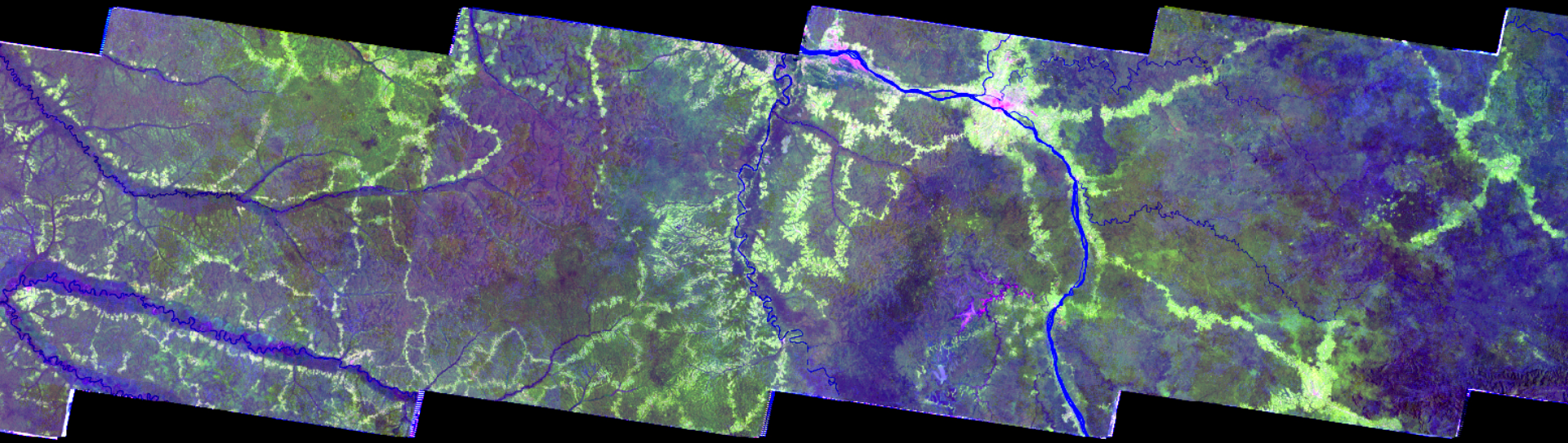
- **Globally spatially and temporally consistent analysis-ready data** based on Landsat (+Sentinel-2) data archive (annually updated, distributed free-of-charge).
- **Efficient data characterization methods and tools** (for mapping and sampling) using purposely developed software.
- **Timely update** of national products (i.e. at annual intervals). Availability of the near-real-time data (weekly forest change alerts product).
- Outputs are suitable for the **national and international reporting.** All estimates includes “good practice” uncertainty estimation.
- In-country data characterization that ensure **complete product ownership** and **replicability**.
- **Harmonization** of input data and products between agencies and regions.

GLAD Landsat Level 3 Data Products

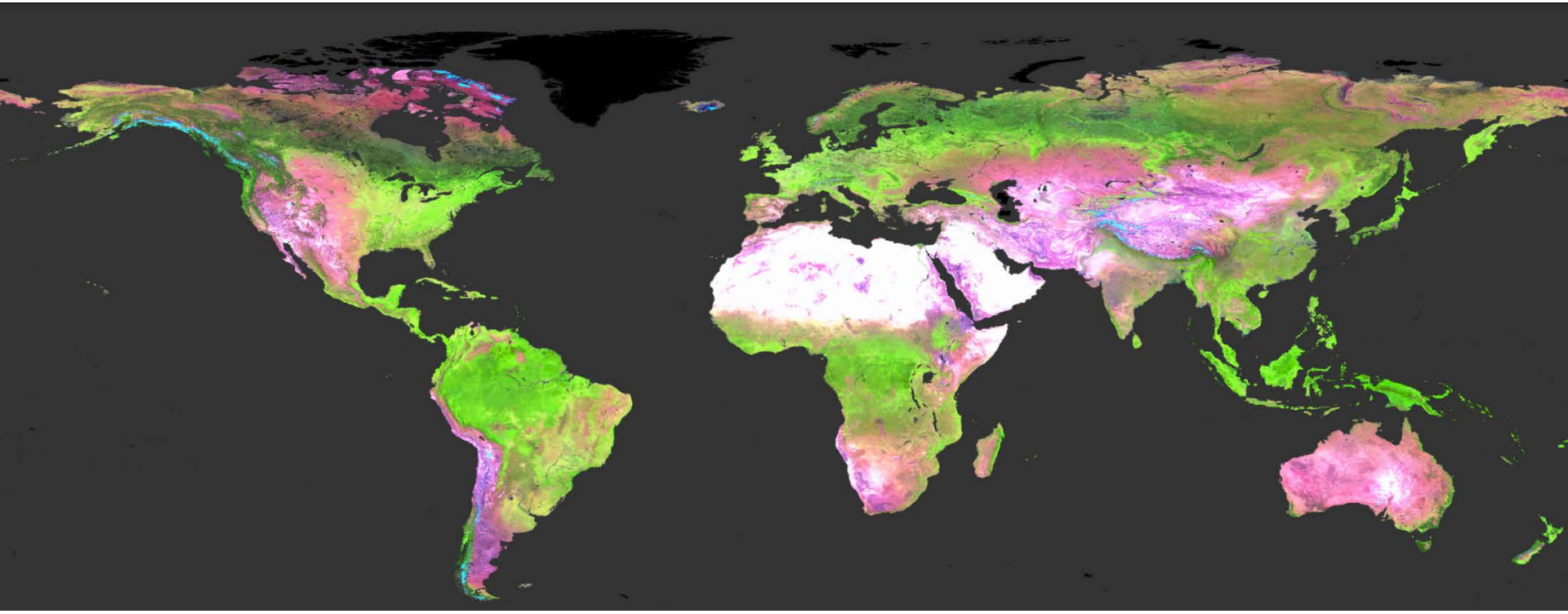
Landsat source L1T data (Collection 1 data)



GLAD Landsat data composites and metrics

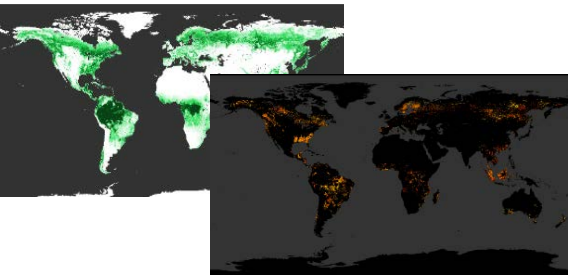


GLAD Landsat Level 3 Data Products



Spatially and temporally consistent inputs for…

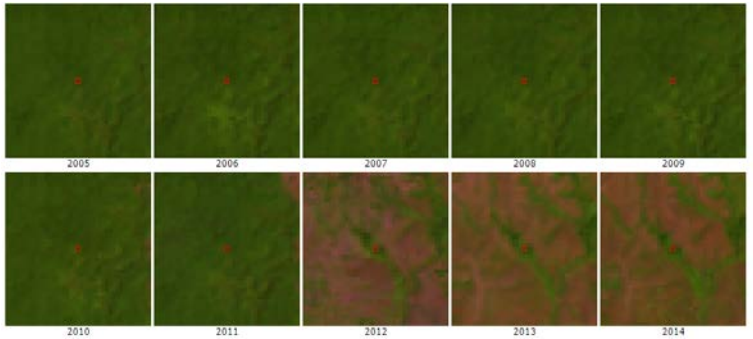
Wall-to-wall mapping



Global LC/LCC mapping

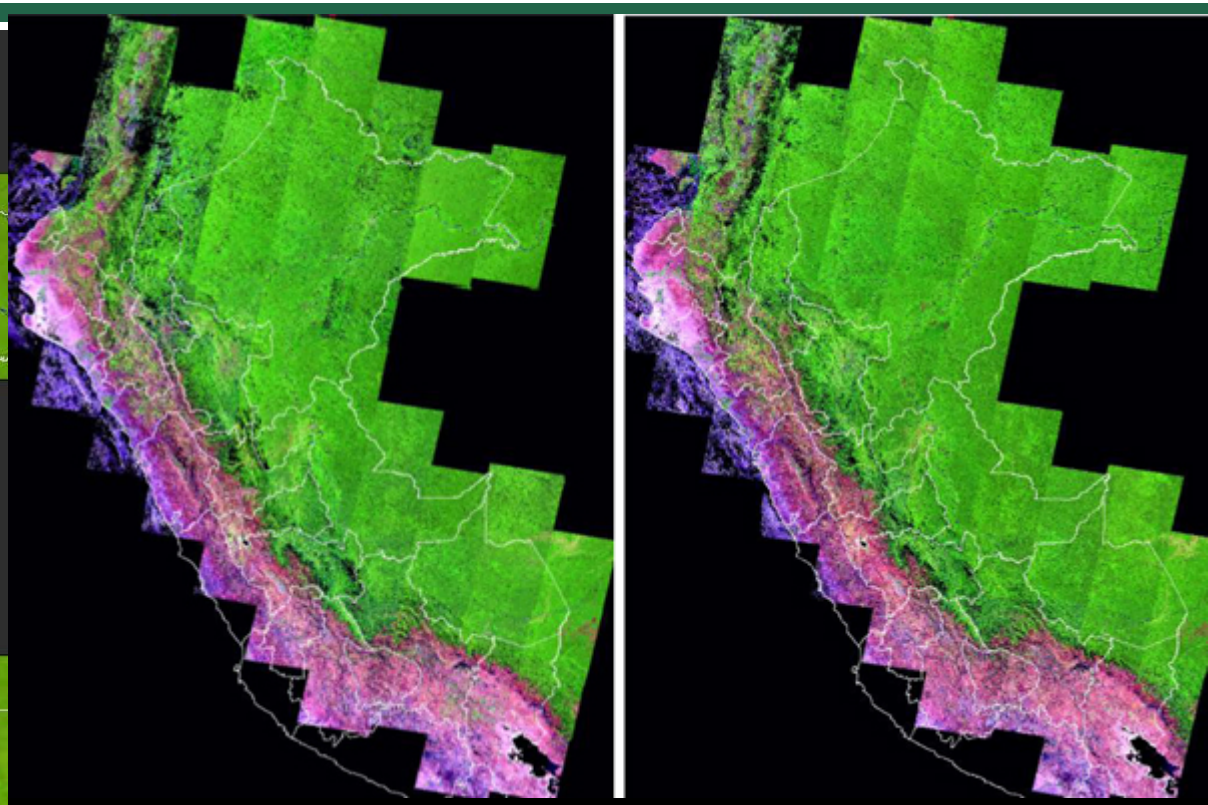
National mapping and change detection

Sample-based analysis



National Forest Monitoring: Peru

GLAD spectrally, spatially, and temporally consistent wall-to-wall national data



CLASlite scene-based national data compilation

Circa 2000 image composite

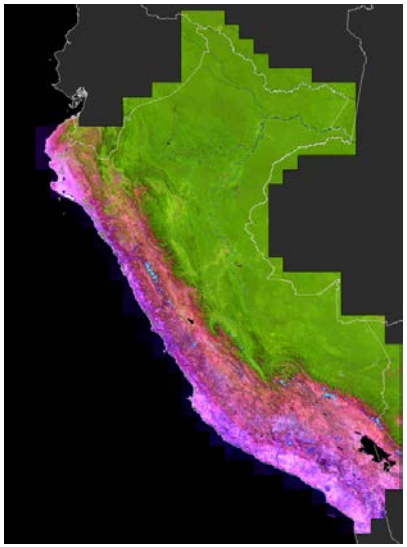
Circa 2011 image composite

National Forest Monitoring: Peru

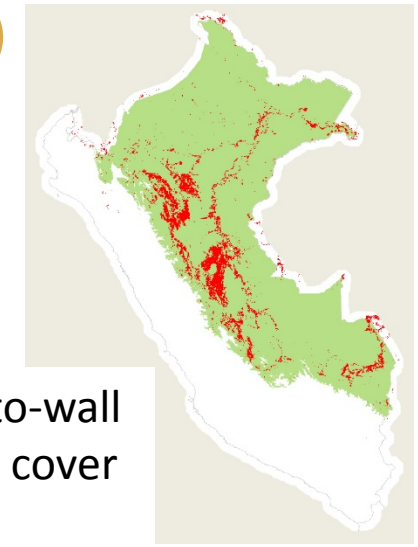
1

GLAD

Landsat data composites and metrics

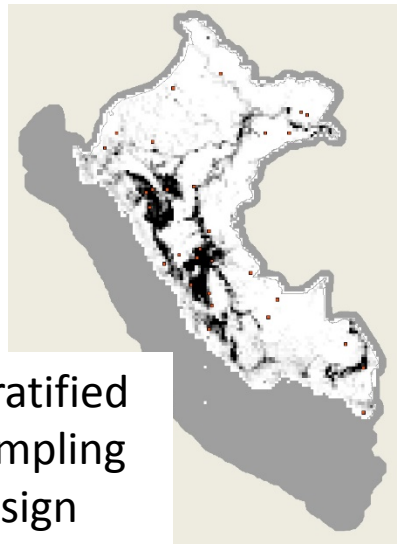


2



Wall-to-wall forest cover loss

3

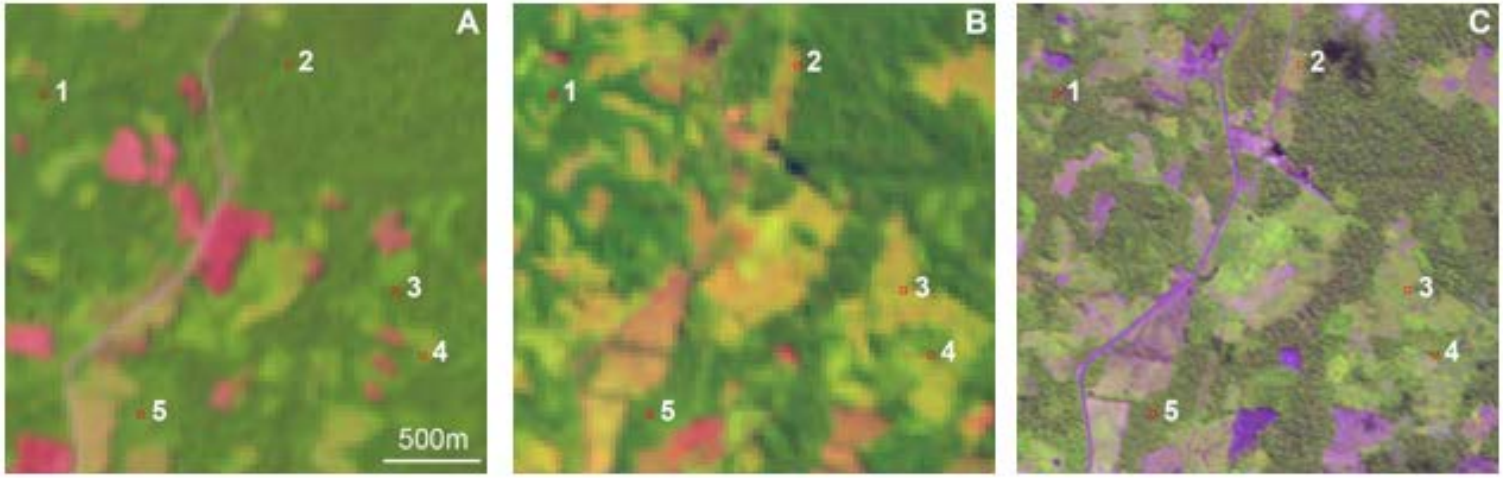


Stratified sampling design

MINAM

4

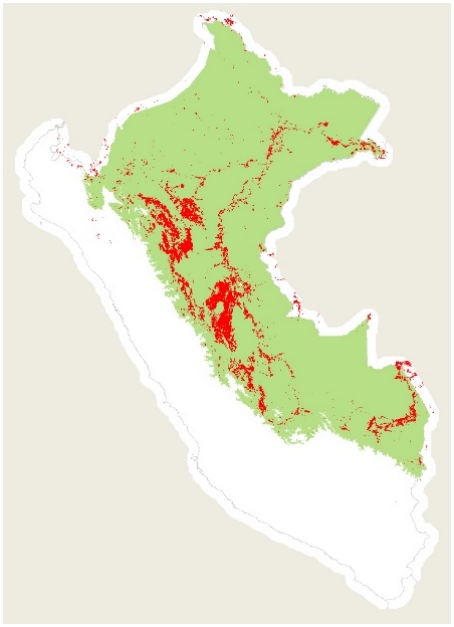
Sample block analysis using Landsat and RapidEye data



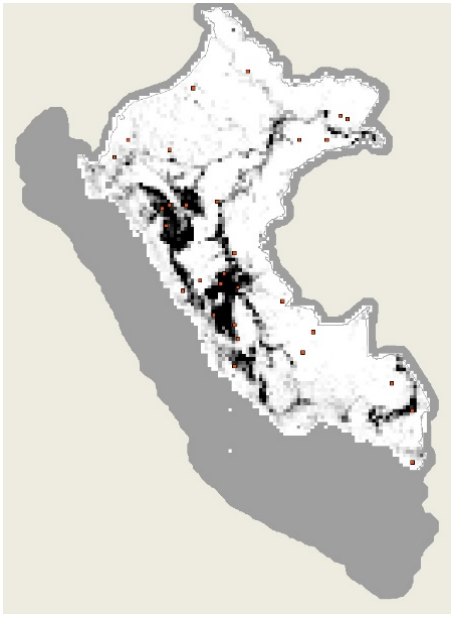
National Forest Monitoring: Peru

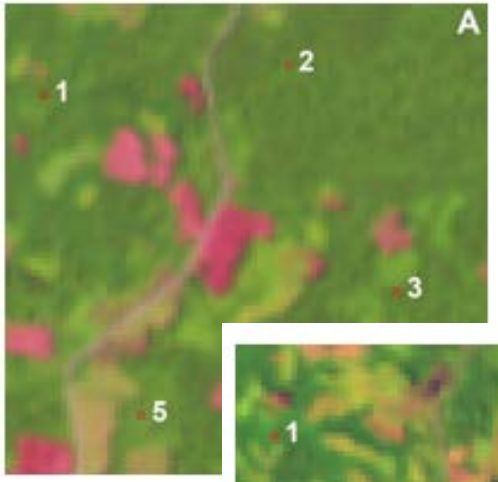
Two-stage cluster sampling design to reduce high spatial resolution data cost

Forest cover loss within primary humid tropical forests, 2000-2011

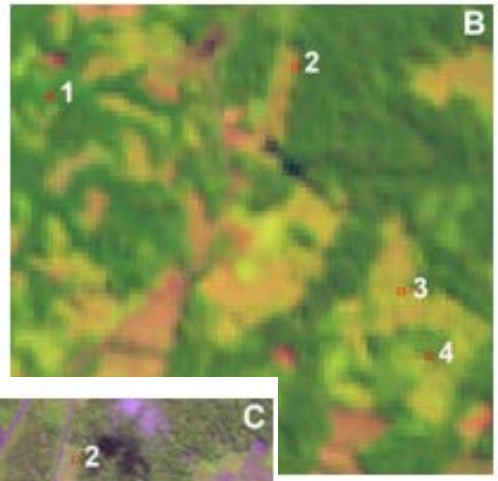


Stratified sampling design (sampling grid of 12x12 km blocks, 30 blocks sampled)

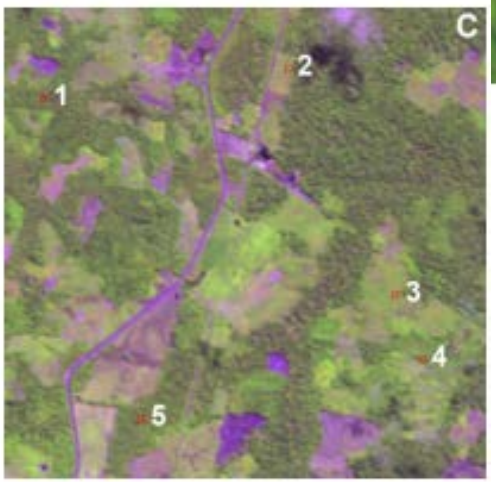




Landsat 2000



Landsat 2011

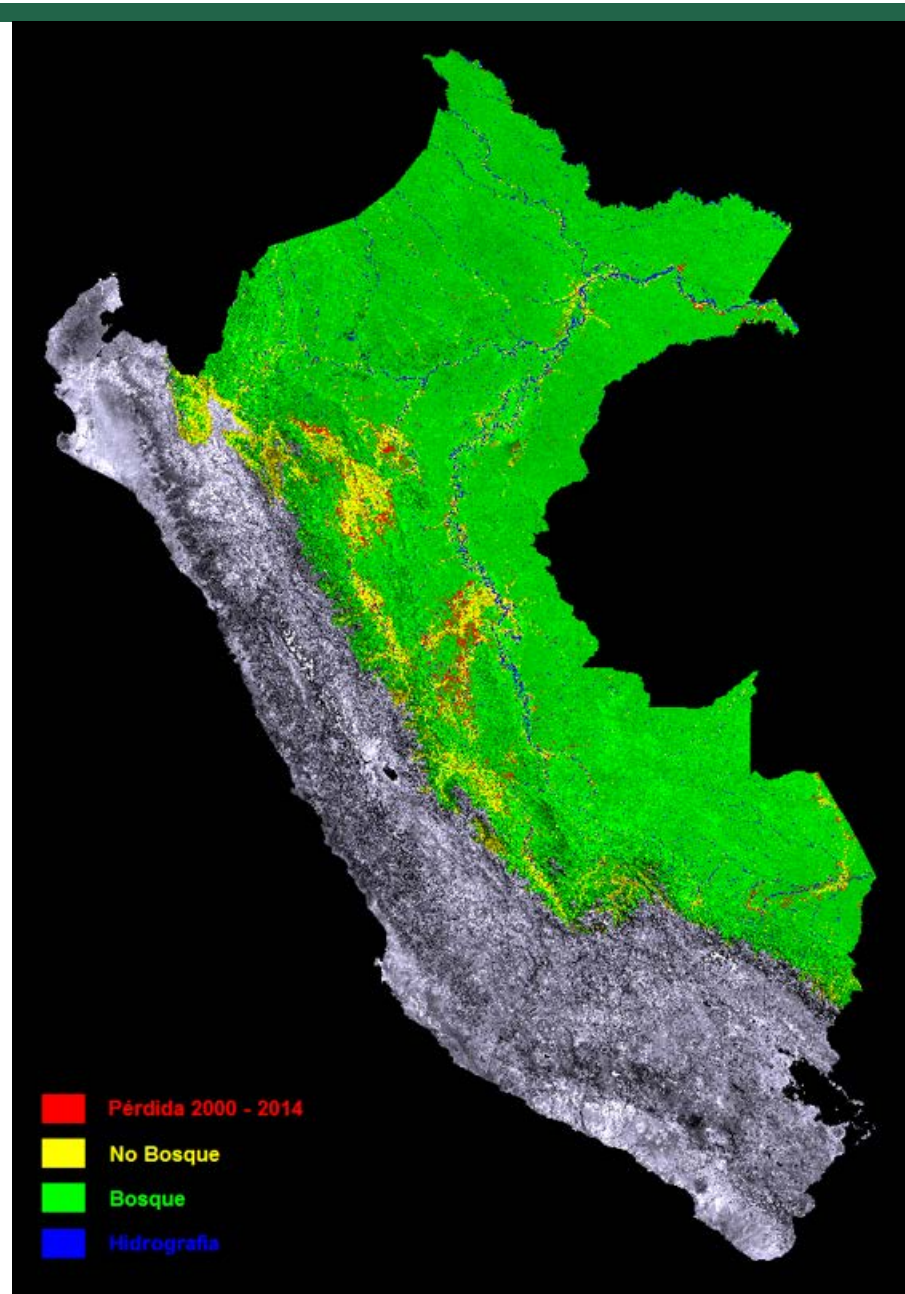


RapidEye 2011

Total number of 12x12 km blocks within humid tropical forests: 5532. Sampled blocks: 30 (0.5%).
Forest loss area estimated with SE of +/- 6.6%.
Mapped loss area is 15% lower than the sample-based area.

National Forest Monitoring: Peru

Forest cover change for Peru by MINAM, baseline 2000-2011, annual update 2013-2016



PERÚ Ministerio del Ambiente | Viceministerio de Desarrollo Estratégico de los Recursos Naturales | Programa Nacional de Conservación de Bosques para la Mitigación del Cambio Climático

NIVEL NACIONAL - BOSQUE HÚMEDO AMAZÓNICO

BOSQUE - NO BOSQUE Y PÉRDIDA DE BOSQUE 2000 - 2014 POR DEPARTAMENTOS

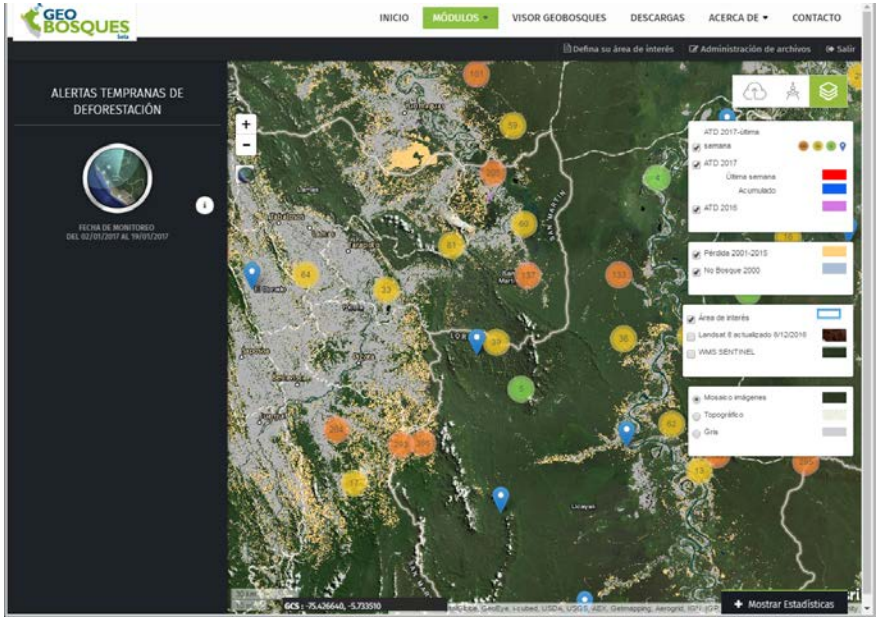
DEPARTAMENTO	NO BOSQUE AL 2000[2]	PÉRDIDA DE BOSQUE[3] 2001 - 2014 (MONITOREO DE LA PÉRDIDA)														HIDROGRAFÍA[1]	BOSQUE AL 2014[4]	
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	TOTAL 2001-2014		
	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	%
TOTAL	5,656,910	83,995	79,832	72,874	93,146	147,624	74,502	106,186	105,704	152,161	136,205	123,563	149,477	150,289	177,571	1,653,129	100.00	1,819,384	69,179,377	100.00

National Forest Monitoring: Peru

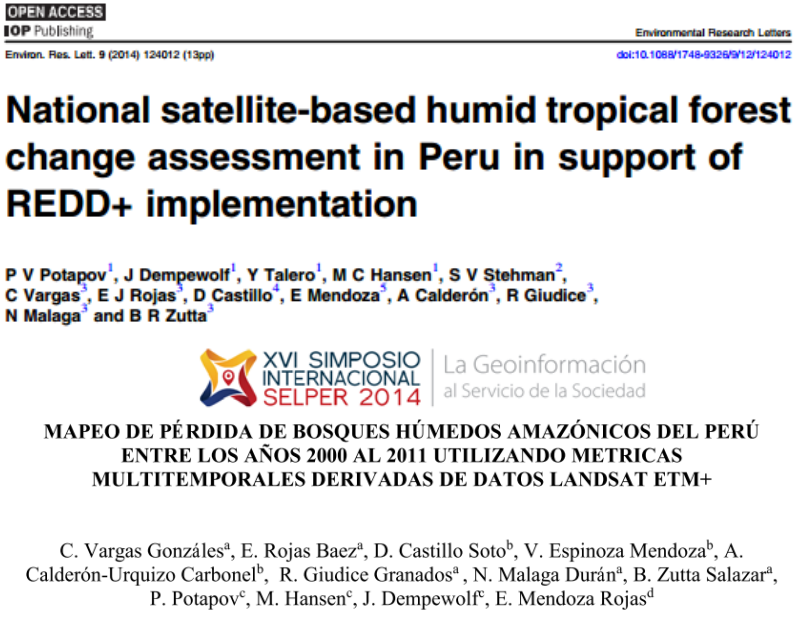
National reports

Software use and image analysis training

National forest data portal (include forest alerts)



Joined scientific publications



OPEN ACCESS
IOP Publishing
Environmental Research Letters
Environ. Res. Lett. 9 (2014) 124012 (13pp)
doi:10.1088/1748-9326/9/12/124012

National satellite-based humid tropical forest change assessment in Peru in support of REDD+ implementation

P V Potapov[1], J Dempewolf[1], Y Talero[1], M C Hansen[1], S V Stehman[2], C Vargas[3], E J Rojas[3], D Castillo[4], E Mendoza[5], A Calderón[3], R Giudice[3], N Malaga[3] and B R Zutta[3]

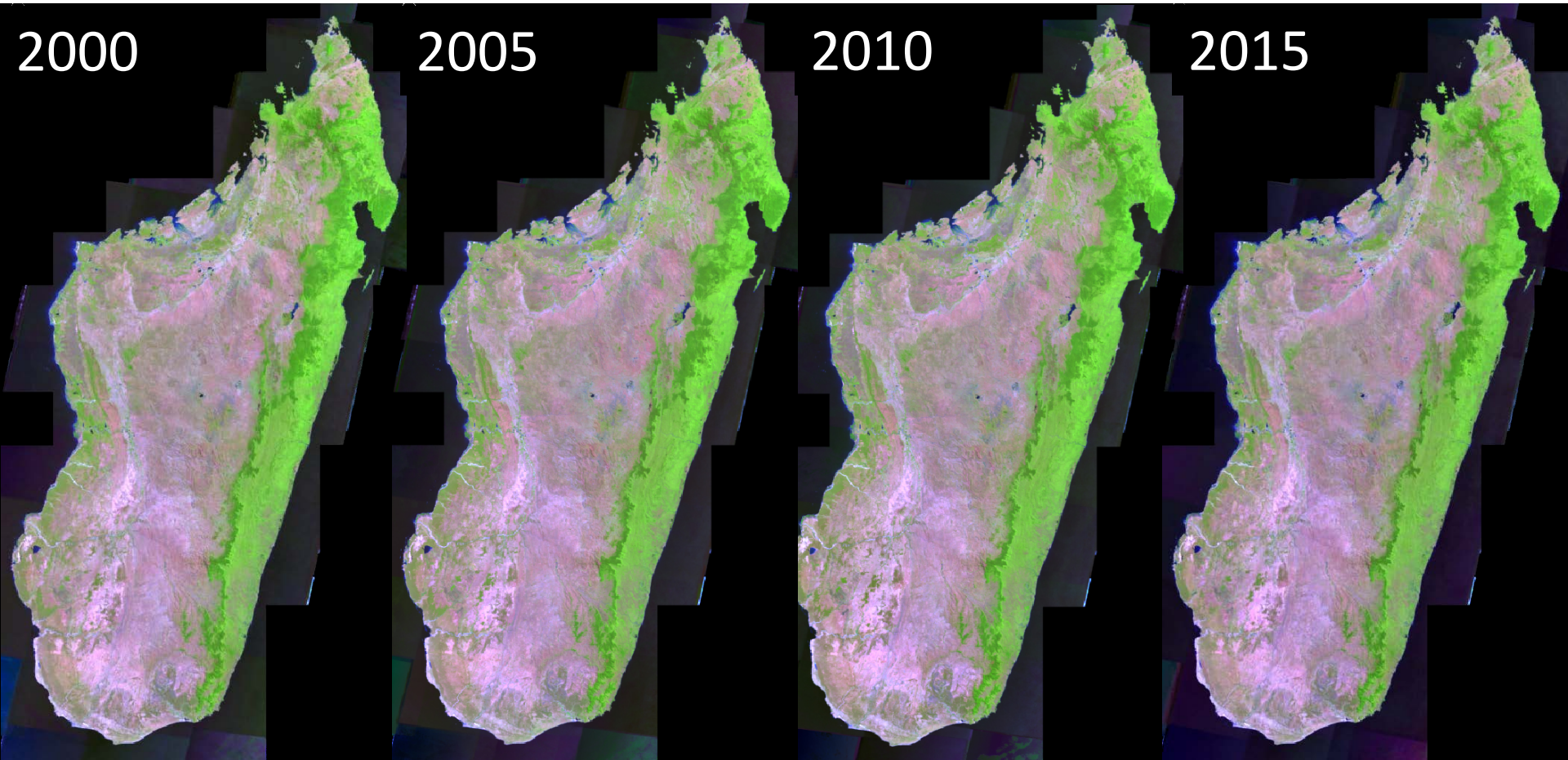
XVI SIMPOSIO INTERNACIONAL SELPER 2014 | La Geoinformación al Servicio de la Sociedad

MAPEO DE PÉRDIDA DE BOSQUES HÚMEDOS AMAZÓNICOS DEL PERÚ ENTRE LOS AÑOS 2000 AL 2011 UTILIZANDO METRICAS MULTITEMPORALES DERIVADAS DE DATOS LANDSAT ETM+

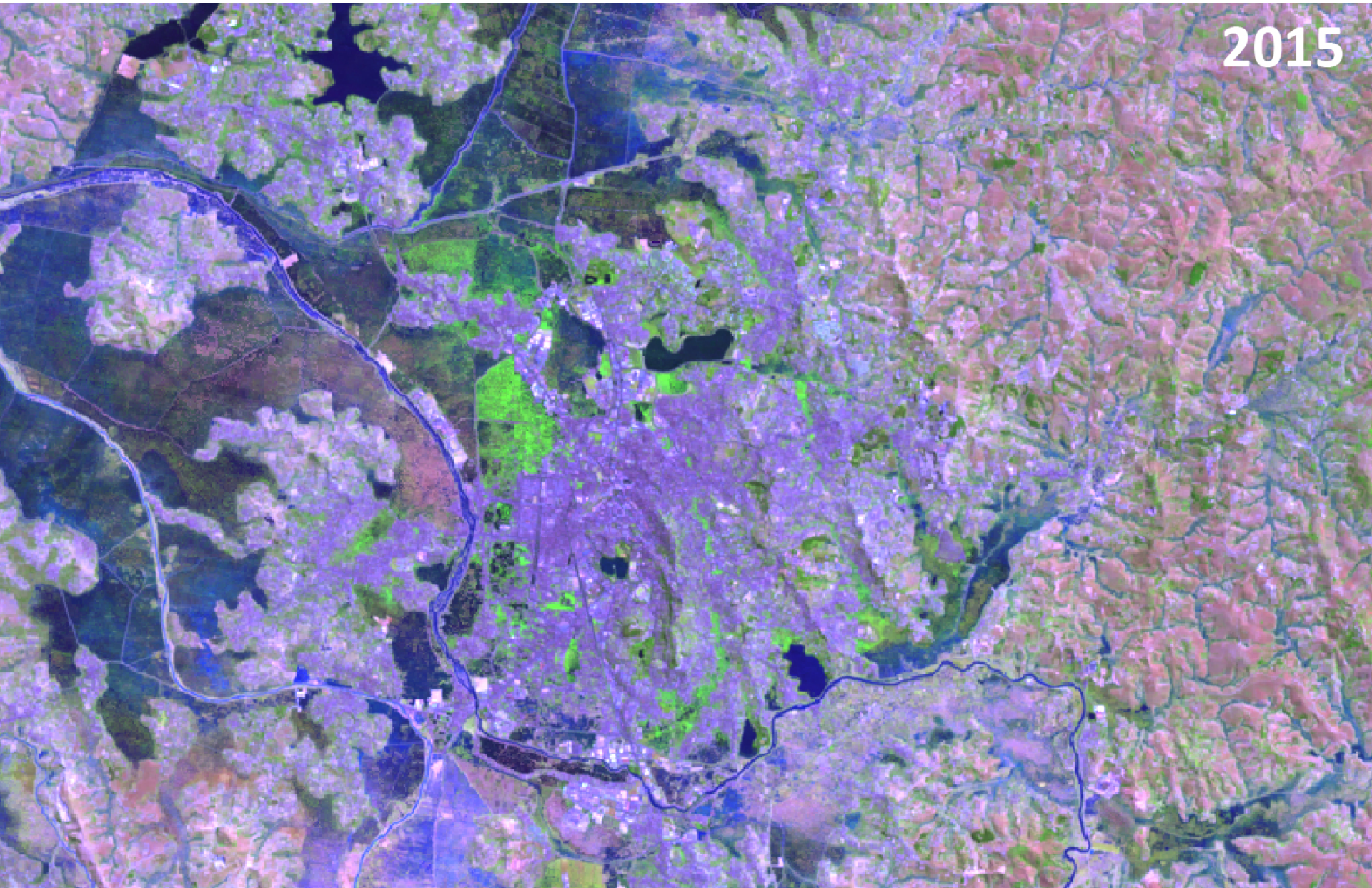
C. Vargas Gonzáles[a], E. Rojas Baez[a], D. Castillo Soto[b], V. Espinoza Mendoza[b], A. Calderón-Urquizo Carbonel[b], R. Giudice Granados[a], N. Malaga Durán[a], B. Zutta Salazar[a], P. Potapov[c], M. Hansen[c], J. Dempewolf[c], E. Mendoza Rojas[d]

National Tree Cover Monitoring: Madagascar

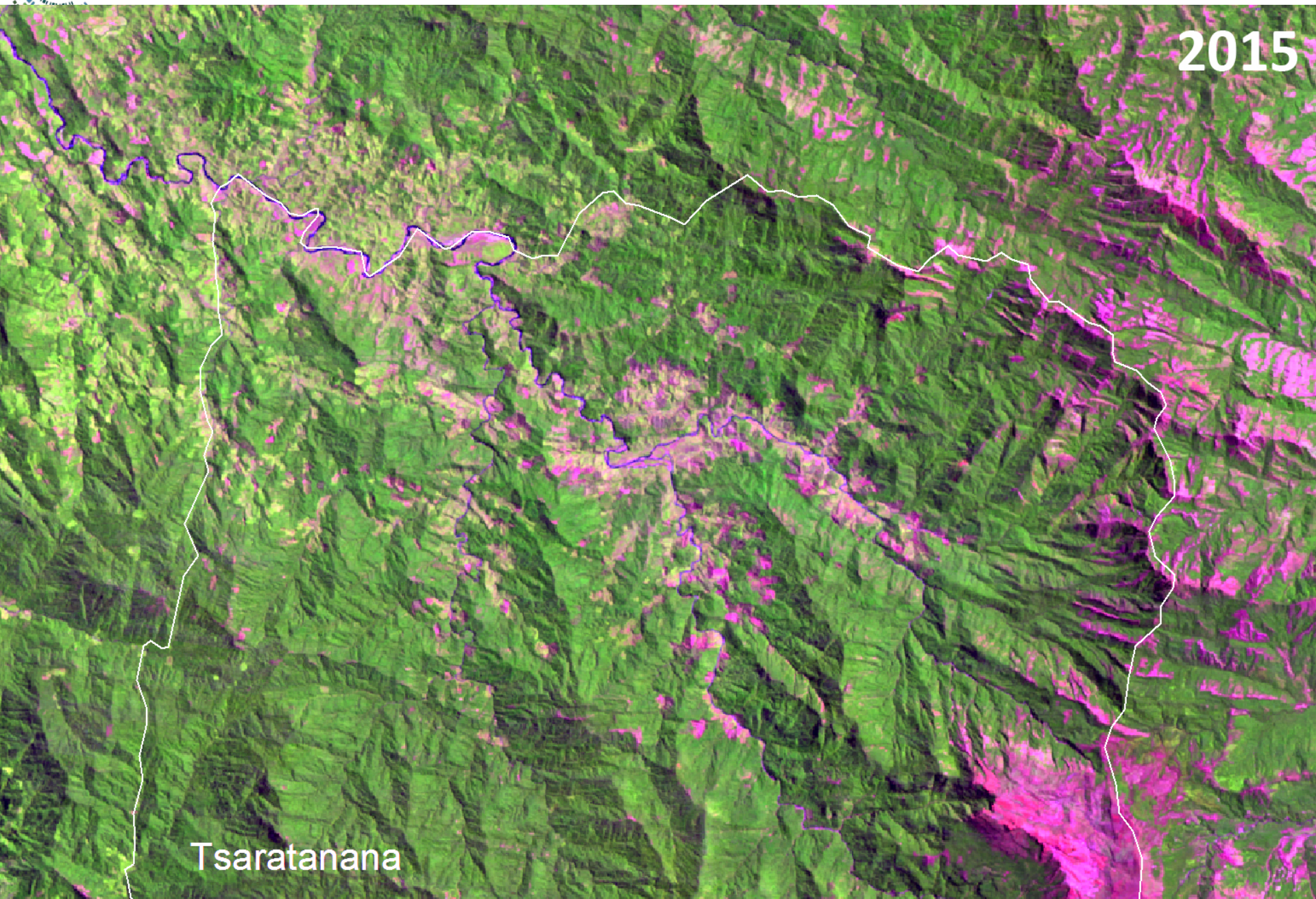
Landsat L1T data archive → Automatic cloud and shadow screening → Reflectance normalization (for atmospheric scattering and surface anisotropy) → 16-day normalized cloud-free reflectance composites → Annual and multi-year spectral metrics



National Tree Cover Monitoring: Madagascar

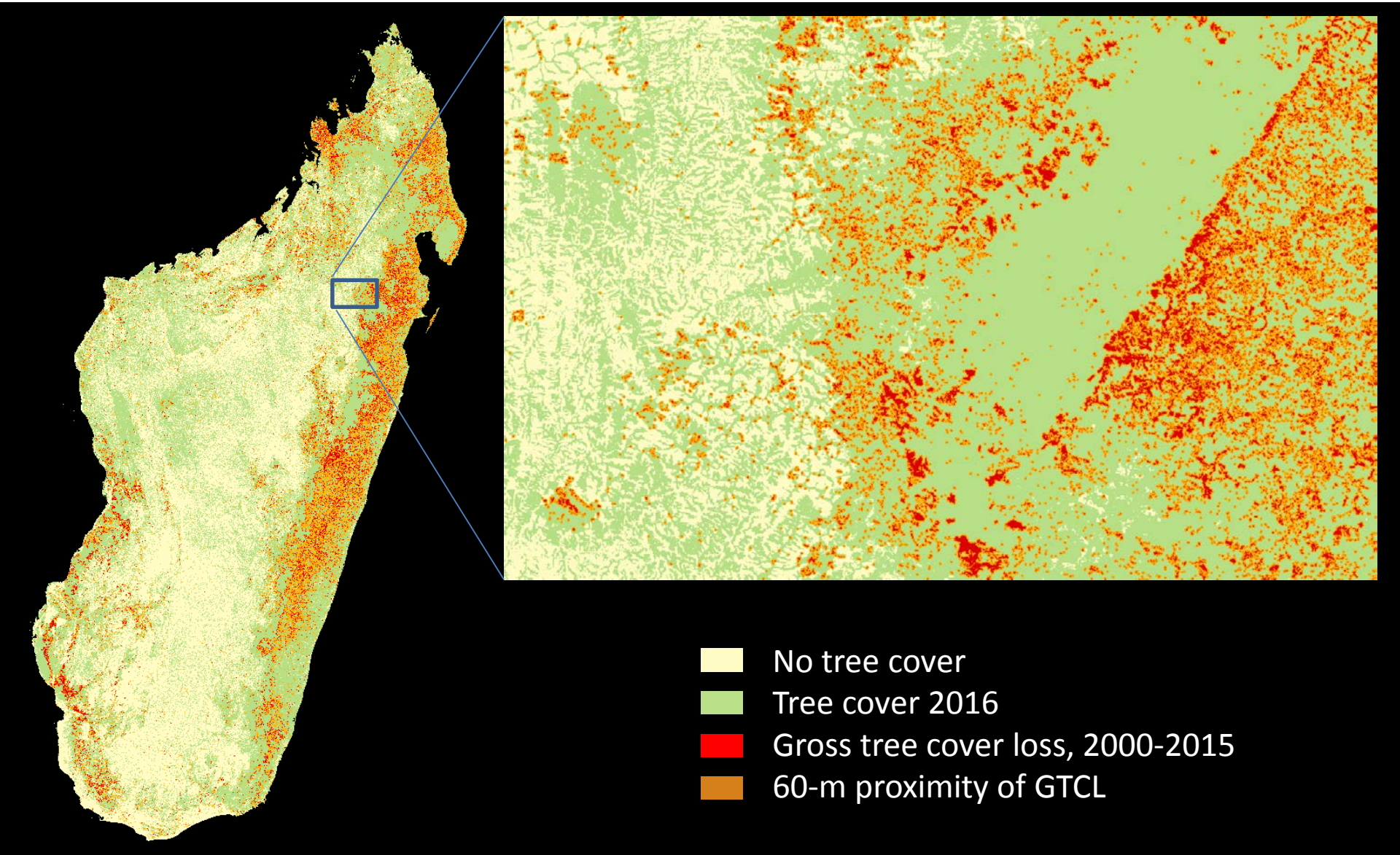


National Tree Cover Monitoring: Madagascar



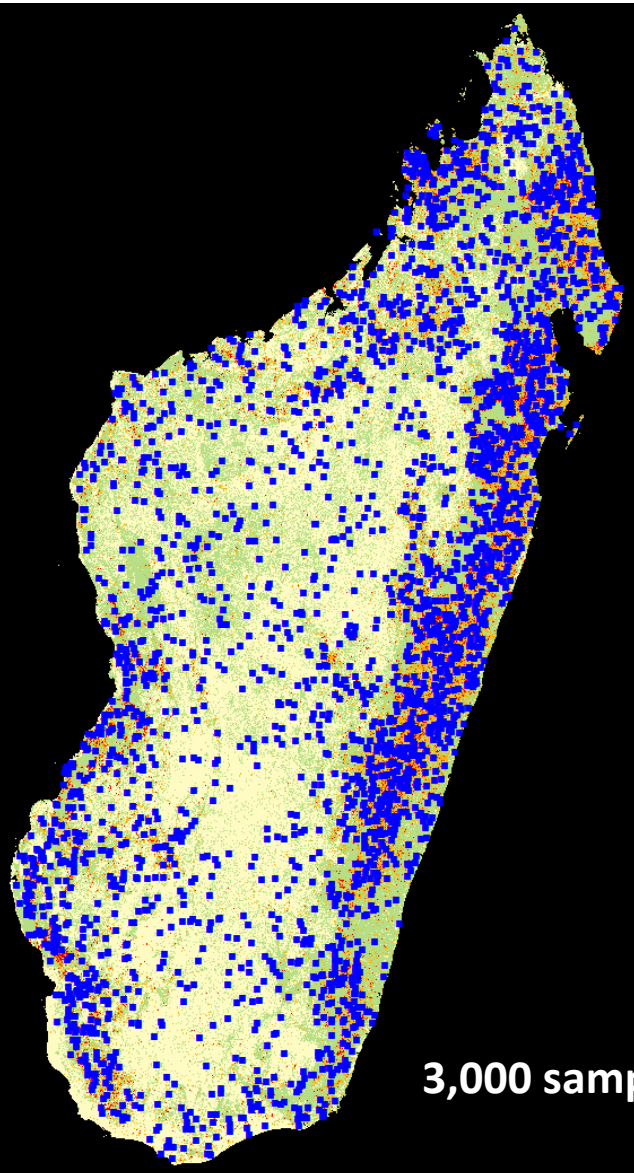
National Tree Cover Monitoring: Madagascar

Sampling design to quantify tree cover change in Madagascar, 2000-2015



National Tree Cover Monitoring: Madagascar

Sampling design to quantify tree cover change in Madagascar, 2000-2015

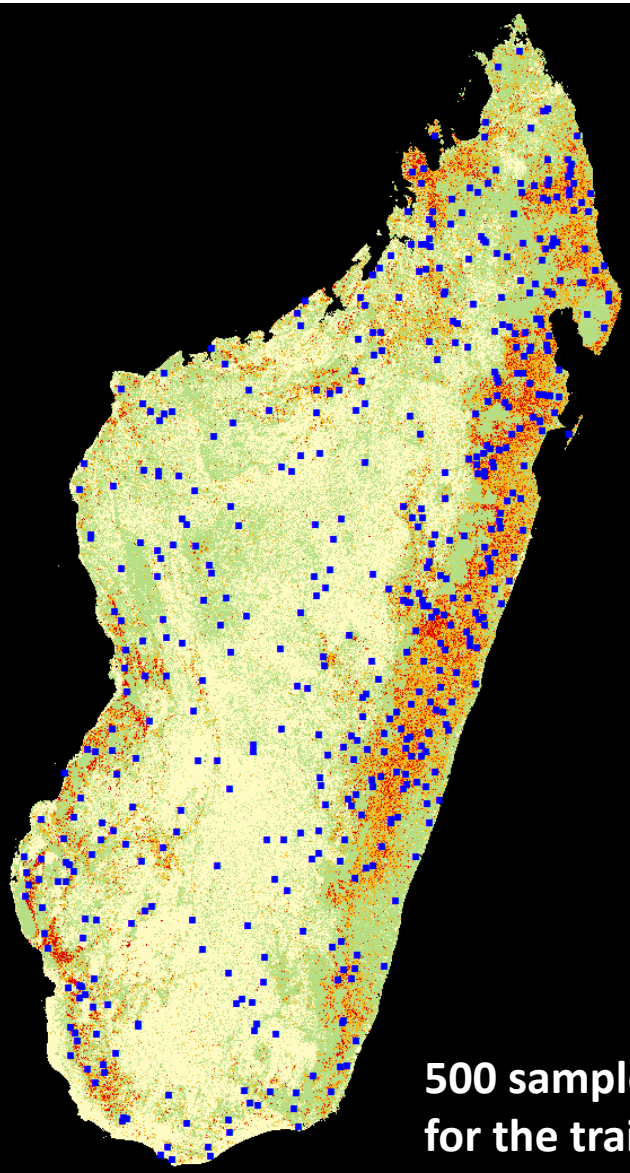


Stratum	area, ha	count, 30x30m pixels	% total	Total samples	Training goal
No loss / no trees	25,141,547	348008206	43	200	50
No loss / tree cover	23,815,964	327272139	40	800	150
Loss 2001-2015	2,658,505	36480651	4	1000	150
Buffer around loss	7,528,648	103251036	13	1000	150
Total	*59,144,663*	*815012032*		*3000*	*500*

- No tree cover
- Tree cover 2016
- Gross tree cover loss, 2000-2016
- 60-m proximity of GTCL

National Tree Cover Monitoring: Madagascar

Sampling design to quantify tree cover change in Madagascar, 2000-2015



Stratum	area, ha	count, 30x30m pixels	% total	Total samples	Training goal
No loss / no trees	25,141,547	348008206	43	200	50
No loss / tree cover	23,815,964	327272139	40	800	150
Loss 2001-2015	2,658,505	36480651	4	1000	150
Buffer around loss	7,528,648	103251036	13	1000	150
Total	*59,144,663*	*815012032*		*3000*	*500*

500 samples
for the training exercise

- No tree cover
- Tree cover 2016
- Gross tree cover loss, 2000-2016
- 60-m proximity of GTCL

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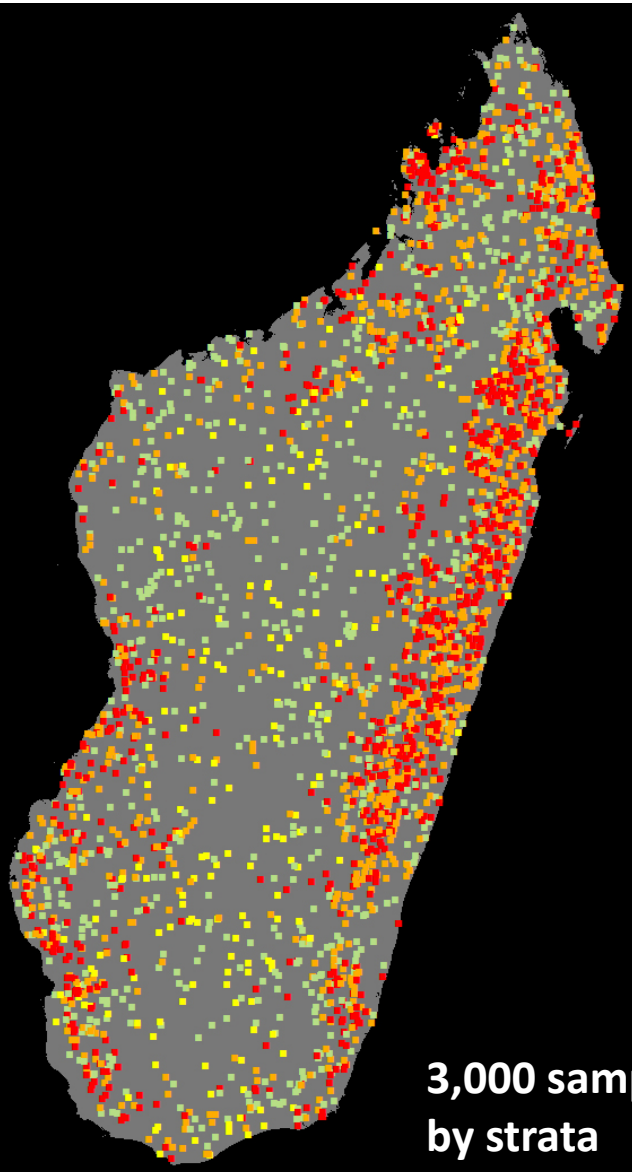
Sampling design to quantify tree cover change in Madagascar, 2000-2015



3,000 samples by strata

Stratum	area, ha	count, 30x30m pixels	% total	Total samples	Training goal
No loss / no trees	25,141,547	348008206	43	200	50
No loss / tree cover	23,815,964	327272139	40	800	150
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- No tree cover
- Tree cover 2016
- Gross tree cover loss, 2000-2016
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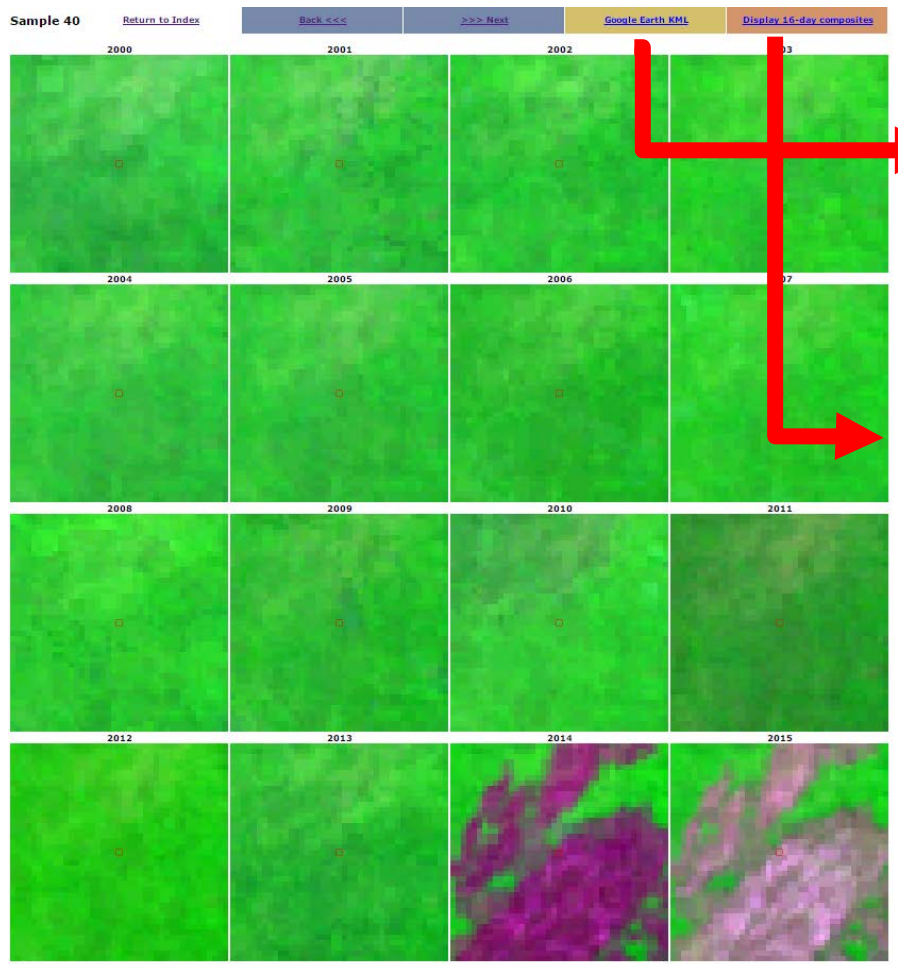
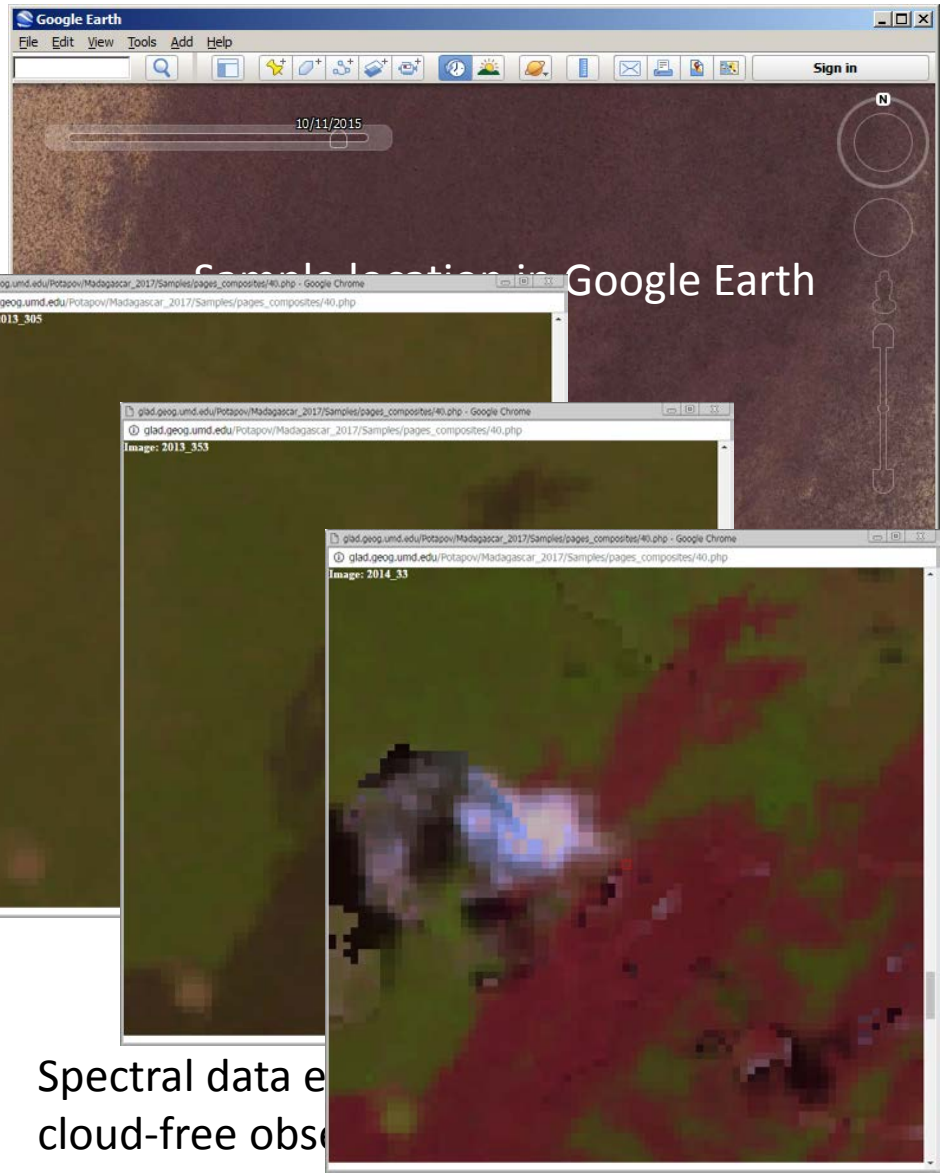
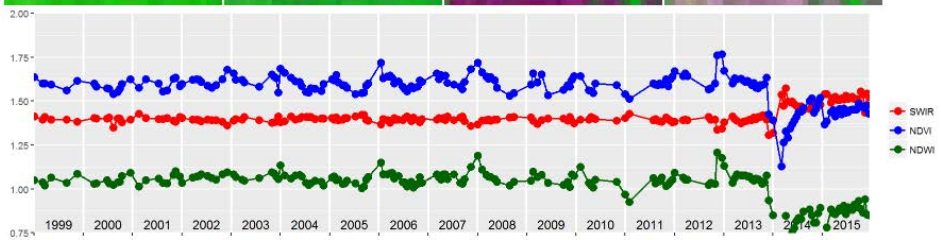
Reference data collection interface





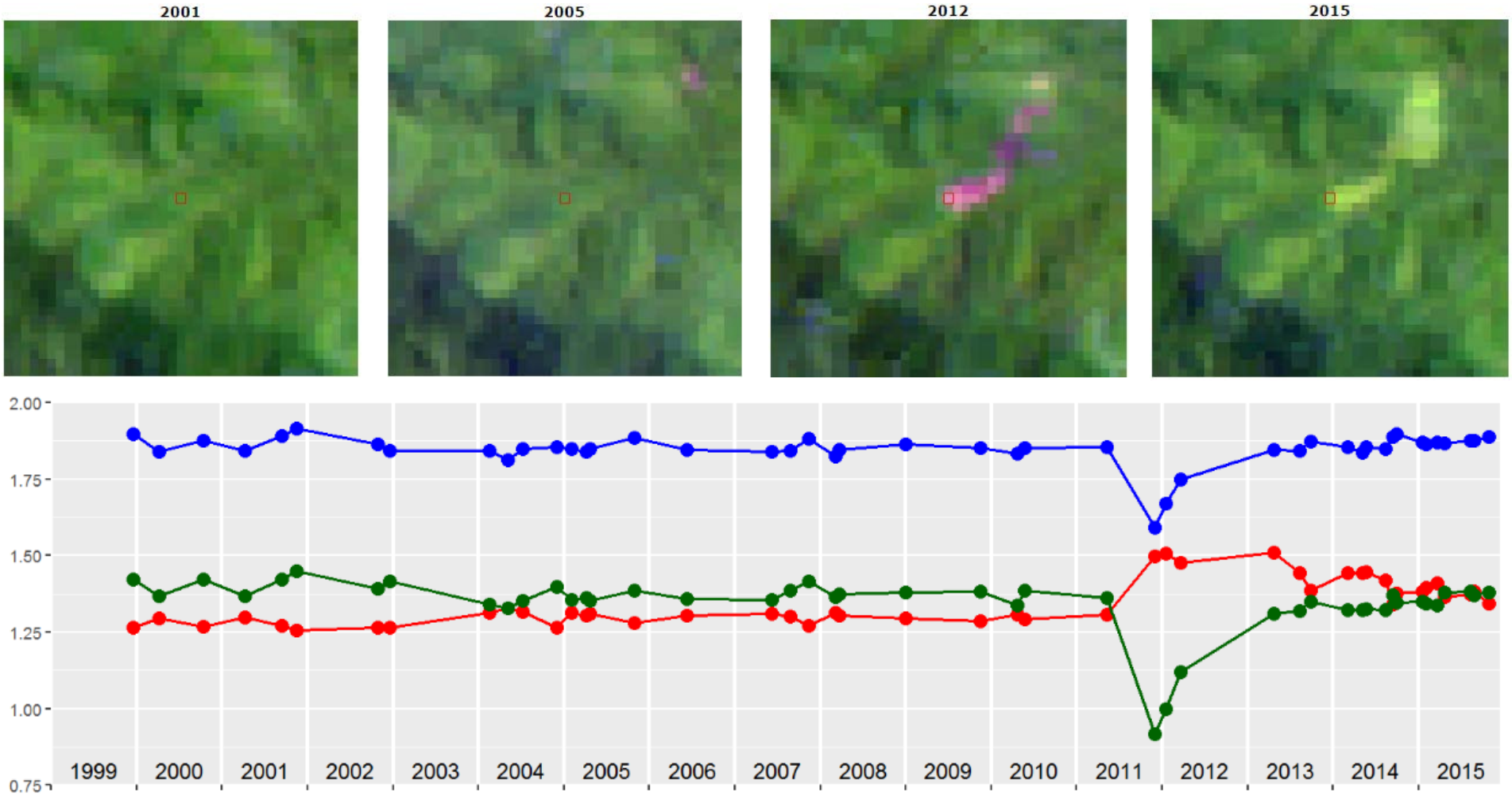
Sample location in Google Earth



Spectral data e
cloud-free obs

National Tree Cover Monitoring: Madagascar

Sampling reference data block example



National Tree Cover Monitoring: Madagascar

GLAD UMD

Madagascar national monitoring team

I. Sample-based TCC area assessment

2017

National TC change product

Stratified sampling design and reference data

Sample-based analysis of TC cover and change area, 2000-2015. National reporting.

II. National wall-to-wall TC/TCC mapping

2018

Automated Landsat data processing

Hardware/software complex for TC monitoring. Training on software use and data analysis

Mapping national TC/TCC. Validation of map accuracy using stratified sample data.

III. Operational annual TC monitoring

2019

Source Landsat data processing

Annual image data updates. Technical consultations

Operational update of national TC/TCC maps. Sample-based estimation of TC change area. National reporting and on-line map publication.

Using GLAD Methods at the National Scale

Country/Region	Project	Partners/Donors
Peru	Operational monitoring of humid tropical forest conversion in support of REDD+ and IPCC GHG reporting, 2000-current.	MINAM, SilvaCarbon
Colombia	Comprehensive land-cover monitoring for IPCC GHG reporting. 2000-ongoing.	IDEAM, SilvaCarbon
Ecuador	Forest cover change quantification 2000-2011.	SilvaCarbon
Mexico	Tree cover extent, structure, and change assessment, 1985-2014	CONABIO
Mesamerica	Tree cover cover change quantification 1985-2015 in support of REDD+.	NASA SERVIR, RFF
Democratic Rep. of the Congo	Forest monitoring 2000-current, forest type mapping, habitat modelling.	USAID, OSFAC, JGI
Rep. of the Congo	Forest monitoring 2000-current, forest type mapping.	USAID, CNIAF
Cameroon	Forest monitoring 2000-current.	USAID, SilvaCarbon
Vietnam	National tree cover monitoring in support of NFI	FIPI, SilvaCarbon
Bangladesh	Tree canopy cover monitoring 2000-current in support of REDD+ and NFI.	RIMS, SilvaCarbon
Low Mekong	Forest extent, structure, and change assessment, 2000-current, in support of RLCMS.	NASA SERVIR, ADPC
Indonesia	Forest cover change quantification 1980-2000, wetlands mapping.	USFS, MoF, LAPAN
Nepal	Tree canopy cover change assessment, 2000-2016	DFRS, ICIMOD, SilvaCarbon