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Global Observation of Forest and Land Cover Dynamics

The use of remote sensing in national forest monitoring for forest GHG inventories

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GOFC-GOLD
Wageningen University

Expert Meeting on National Forest GHG Inventories - a Stock Taking"
Yokohama, Japan, 23-25 February 2010

What is GOFC-GOLD?

- A technical panel of the UN Global Terrestrial Observing System (GTOS)
- A coordinated international effort:
  - to ensure a continuous program of space-based and field forest observations for global monitoring of terrestrial resources
- A network of participants implementing coordinated research, demonstration and operational projects
- A vision to share data, information and knowledge
- GOFC-GOLD operates through:
  - Executive committee, Science and technical board
  - Implementation teams and 3 project office (CA, US, Germany)
  - **Dedicated working groups**
  - 6 Regional networks

Outline

1. Experiences using remote sensing for LULUCF
2. Practical guidance on the use of remote sensing for REDD MRV in developing countries (GOFC-GOLD Sourcebook)
3. Contribution to estimating the emissions from forest degradation
4. Activities of the international earth observation community to improve continuity and consistency of observations

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Requirements for consistent representation of lands

(Discussion: http://nofc.cfs.nrcan.gc.ca/gofc-gold/Report%20Series/GOLD_33.pdf)

Requirements under UNFCCC

Information on land areas essential to estimate GHG from LULUCF.

Six broad land-use categories: FL, CL, GL, WL, SL, OL.

Definitions may incorporate land cover type, land use based, or a combination of the two.

IPCC provides 3 “approaches” for representing land areas:

1) total area for each category, but no information on conversions
2) tracking of conversions between land-use categories
3) spatially explicit tracking of conversions

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Current use of RS techniques in GHG inventories

(Section 4: **http://nofc.cfs.nrcan.gc.ca/gofc-gold/Report%20Series/GOLD_33.pdf**)

- Workshop on "IPCC guidance on estimating emissions and removals of GHG from land uses" Helsinki, 12-15 May 2008
- GOFC-GOLD report on use of satellite data in LULUCF sector:
- **http://nofc.cfs.nrcan.gc.ca/gofc-gold/Report%20Series/GOLD_33.pdf**

From National Inventory Reports (NIR) of *Annex-I countries*:

- Heterogeneous level of the information.
- 23 out of 38 countries (60%) explicitly indicated in their NIR the use of RS techniques or derived products, often only integrating other existing ground-based information (e.g., NFI or statistics).
- Several examples on the use of opical airphoto's, satellite data
- Few indications for use of airborne Lidar and Radar

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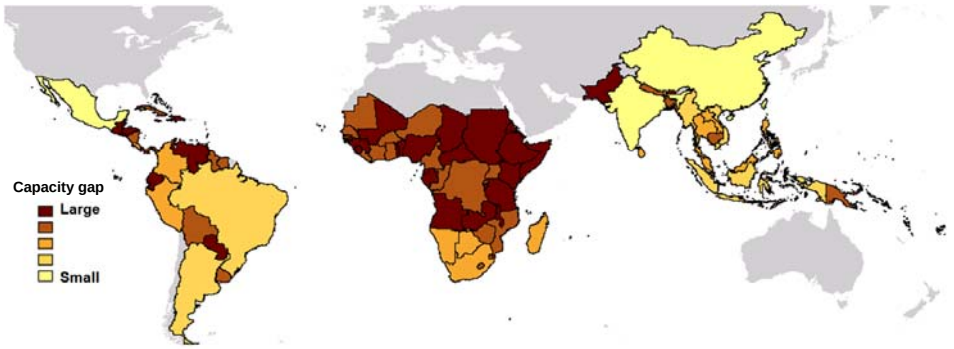
Variability in capacities for REDD monitoring



Consideration of factors:

1.Requirements for monitoring forest carbon on national level (IPCC GPG)
2.Existing national capacities for national forest monitoring
3.Progress in national GHG inventory and engagement in REDD
4.REDD particular characteristics: importance of forest fires, soil carbon, deforestation rate etc.
5.Specific technical challenges (remote sensing): cloud cover, seasonality, topography, remote sensing data availability and access procedures

Source: http://princes.3cdn.net/8453c17981d0ae3cc8_g0m6vsqxd.pdf

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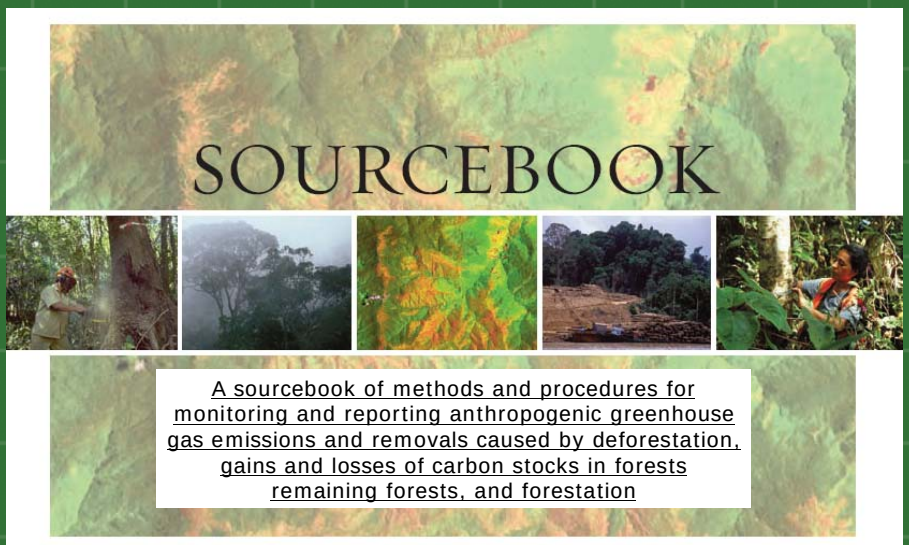
GOFC-GOLD REDD Sourcebook



http://www.gofc-gold.uni-jena.de/redd

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Sourcebook objectives

1. To provide transparent methods that are designed to produce estimates of changes in forest area and carbon stocks in a format that is user-friendly
2. To complement the IPCC GPG-LULUCF (2003) and IPCC Guidelines-AFOLU (2006) by providing additional explanations and enhanced methods
3. To support REDD early actions at national level

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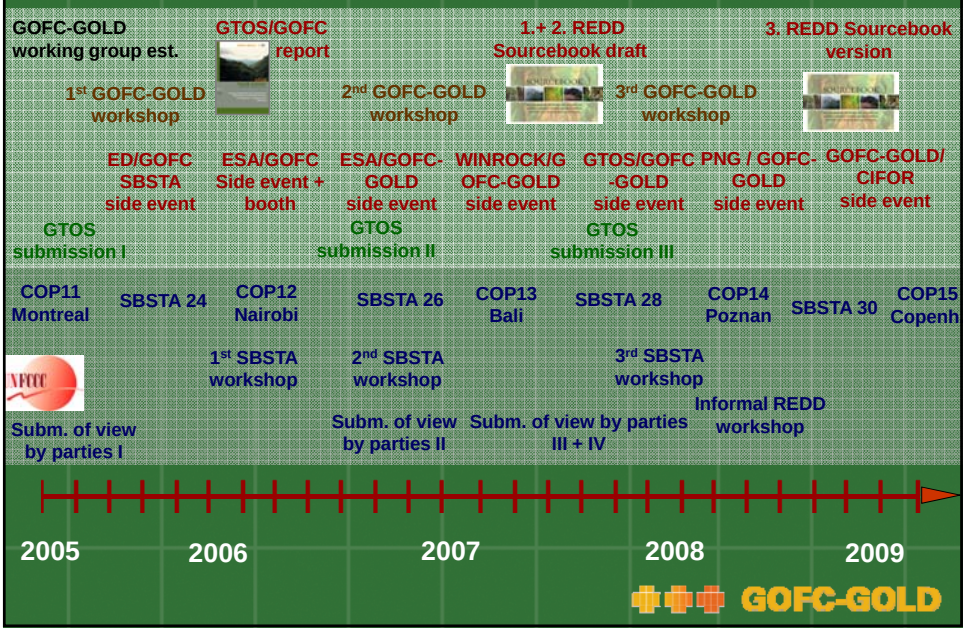
Earth observation contribution to UNFCCC-REDD



A community effort

Core author team

- Frédéric Achard, Sandra Brown, Ruth De Fries, Giacomo Grassi, Martin Herold, Danilo Mollicone, Devendra Pandey, Carlos Souza Jr.,

Contributors:

- Olivier Arino, Gregory P. Asner, Luigi Boschetti, Barbara Braatz, Michael Brady, Emilio Chiuvieco, Ivan Csiszar, Michael Falkowski, Sandro Federici, Scott Goetz, Nancy Harris, Yasumasa Hirata, Hans Joosten, Chris Justice, Josef Kellndorfer, Stephen Kull, Werner Kurz, Eric Lambin, Suvi Monni, Erik Næsset, Ross Nelson, Marc Paganini, Tim Pearson, David Shoch, Florian Siegert, Margaret Skutsch, Allan Spessa, Patrick Van Laake, Michael Wulder

Registered users : 830 (voluntary)

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Some impacts

- Facilitate a process of cooperation and communication of remote sensing technical community
- Commonly cited and referred in country readiness activities (i.e. Worldbank R-PIN, R-PP, bilateral programs) and dedicated submissions to UNFCCC on REDD and LULUCF
- Significant contributions to key publications, expert meetings and projects, i.e.:
  - UNFCCC technical paper on REDD and expert meetings
  - FAO FRA special study on Forest Degradation & report

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Coarse outline (200 pages)

Sourcebook section 2

Guyana REDD MRV development roadmap

http://www.forestry.gov.gy/Downloads/Terms_of_Reference_for_Guyanas_MRVS_Draft.pdf

	National strategy (2010/11) ➔	Country readiness (2011/12) ➔	Implementation (post 2012/13)➔
Objectives	**Gather and integrate information & fill data gaps for national REDD opportunities, scoping and policy development**	**Develop capacities, conduct historical monitoring, and implement a (minimum) IPCC Tier 2 national forest carbon monitoring, establish the reference level and report on interim performance**	**Establish consistent and continuous MRV supporting national REDD+ actions and international IPCC GPG-based reporting and verification**
Key results and national capacities developed	1. Comprehensive MRV roadmap developed and national MRV steering body operational 2. Improved national capacities on LCDS, REDD, IPCC-LULUCF, and carbon dynamics 3. Framework and capacities to demonstrate REDD implementation and interim performance 4. All data available and accessible (including acquisition of new forest carbon data) on drivers and processes needed for developing a national REDD policy and interim implementation plan 5. Established communication and participation mechanism to involve relevant stakeholders nationally and internationally 6. Approaches for setting reference levels, linking MRV and policy, and MRV co-benefits and synergies are explored and defined	1. Capacities in place for consistent and continuous acquisition and analysis of key data for Tier 2 nationally and Tier 3 for demonstration/activity sites including international reporting using IPCC LULUCF; uncertainty assessment MRV improvement plan developed 2. Reference level established based on historical data, and future developments using internationally accepted methods 3. All data available and accessible for an updated national REDD implementation plan 4. Regular reporting on REDD demonstrations and interim performance 5. Continued engagement with key national stakeholders for REDD implementation and assuring long-term sustainability of MRV capacities (i.e. universities) 6. Monitoring system explored to cover key variables for other ecosystem services	1. IPCC key category analysis and assessment for Tier 3 approaches completed and implemented (if desired) 2. Independent international review of full MRV system completed 3. Capacity in place and implementation to deliver verification and compliance assessment for REDD results-based compensation 4. National data infrastructure of forest greenhouse gas inventory and assessment in place for regular reporting 5. Implementation plan to use new and proven technologies to reduce uncertainties and increase efficiency of MRV system 6. Framework developed that links REDD into LCDS monitoring, reporting and verification system

Monitoring deforestation at national scale

- Satellite monitoring: National examples from Brazil, India and several national REDD case studies
- 1990, 2000, 2005 + free Landsat data as minimal option
- Starting point to develop more detailed monitoring system:
  - Motivation to use more detailed data than 1990-00-05
  - Identify hot spots of forest loss
  - Stratified approach to estimate area change in future or for monitoring degradation
  - Establish or enhance national capacities
  - Develop understanding of historical (spatial) processes
  - Remote sensing data output to guide further field work related to carbon accounting (i.e. stratification)

Availability of current optical mid-resolution (10-60 m) sensors

Nation	Satellite & sensor	Resolution & coverage	Cost for data acquisition (from archive)	Feature
USA	Landsat-5 TM (since 1984)	30 m 180×180 km²	All US archived data are free	Images every 16 days to any satellite receiving station. Operating beyond expected lifetime.
USA	Landsat-7 ETM+ (since 1999)	30 m 60×180 km²	All US archived data are free	On April 2003 the failure of the scan line corrector resulted in data gaps, with serious data quality issues
USA/ Japan	Terra ASTER	15 m 60×60 km²	80 US$/scene 0.02 US$/km²	Data is acquired on request and is not routinely collected for all areas
India	IRS-P6 LISS-III & AWIFS	23.5 & 56 m		AWIFS images can be acquired on a routine basis.
China/ Brazil	CBERS-2 HRCCD	20 m	Free for developing countries	Experimental; Brazil uses on-demand images to bolster their coverage.
Algeria/ China/ Nigeria/ Turkey/ UK	DMC	32 m 160×660 km²	3000 €/scene 0.03 €/km²	Commercial; Brazil uses alongside Landsat data
France	SPOT-5 HRVIR	5-20 m 60×60 km²	2000 €/scene 0.5 €/km²	Commercial Indonesia & Thailand used alongside Landsat data

What analysis approach should be used to assess change at repeated intervals?:
4) DATA INTERPRETATION

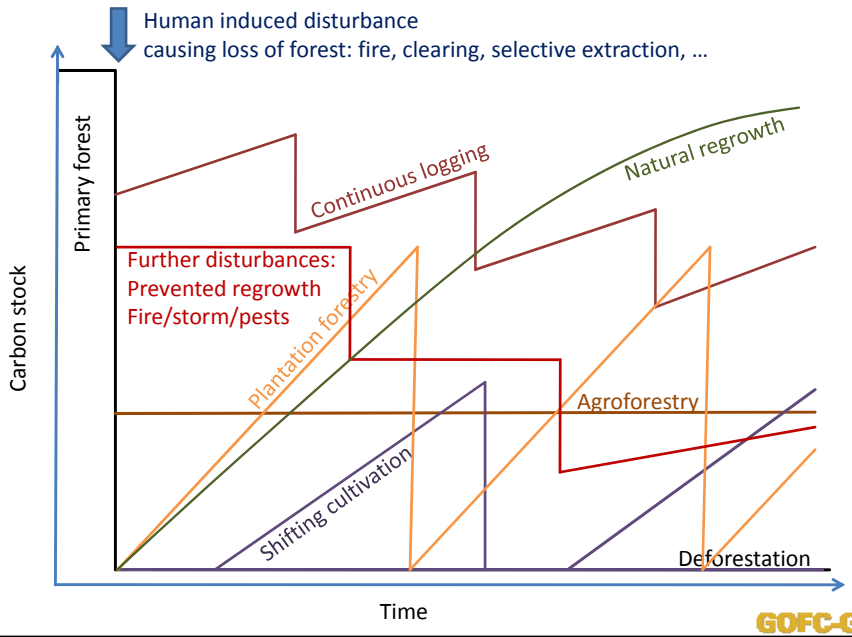
Table 3.3. Main analysis methods for moderate resolution (~ 30 m)

Method for delineation	Method for class labeling	Practical minimum mapping unit	Advantages / limitations
Dot interpretation (dots sample)	Visual interpretation	< 0.1 ha	- closest to classical forestry inventories - very accurate although interpreter dependent - no map of changes
Visual delineation (full image)	Visual interpretation	5 – 10 ha	- easy to implement - time consuming - interpreter dependent
Pixel based classification	Supervised labeling (with training and correction phases)	<1 ha	- difficult to implement - training phase needed
	Unsupervised clustering + Visual labeling	<1 ha	- difficult to implement - noisy effect without filtering
Object based segmentation	Supervised labeling (with training and correction phases)	1 - 5 ha	- more reproducible than visual delineation - training phase needed
	Unsupervised clustering + Visual labeling	1 - 5 ha	- more reproducible than visual delineation

TECHNICAL CAPACITY

Reproducibility, consistency, transparency, and accuracy assessment more important than method

Forest degradation and carbon stocks



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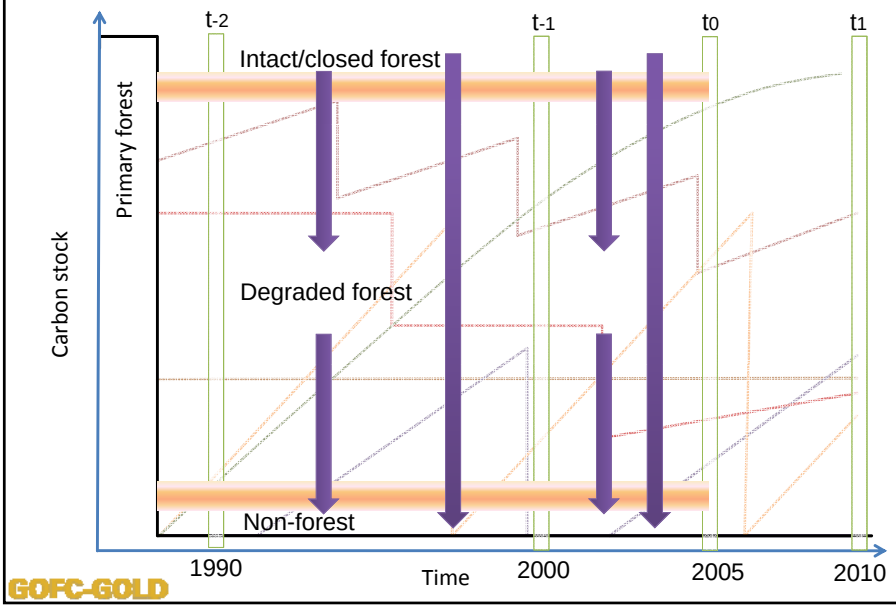
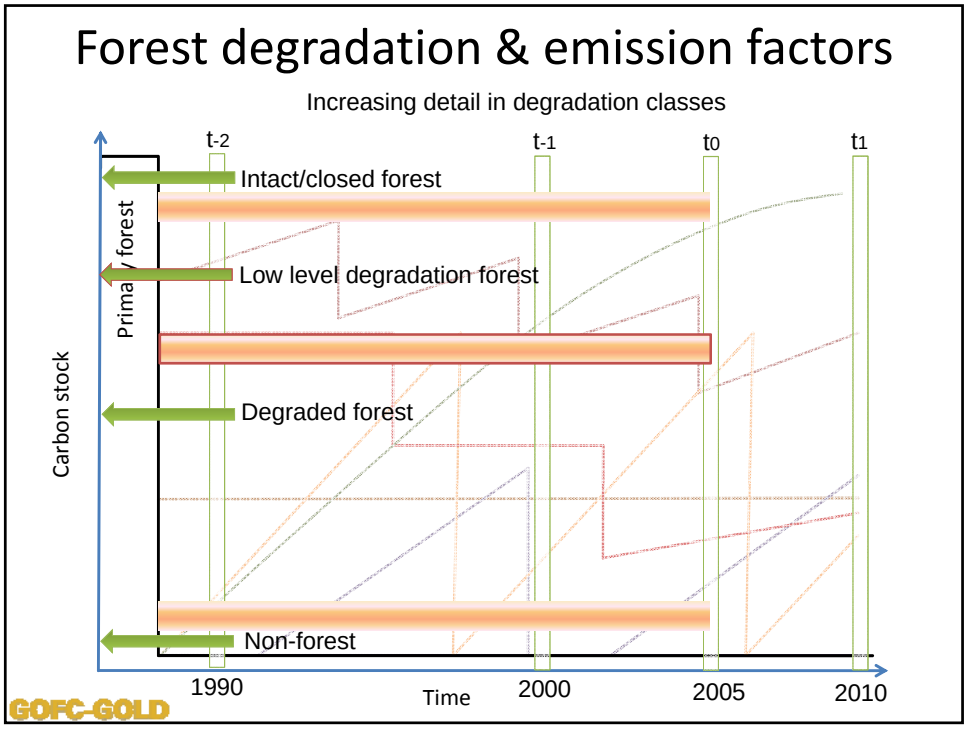
Degradation monitoring remarks

- More severe degradation (area/intensity) result in more distinct indicators for efficient national monitoring
- Monitoring degradation nationally benefits from understanding and emission significance of human processes (issue of key categories)
- Inventory based approaches and long-term field observations
- Remote sensing to detect degraded area:
  - Direct detection of degradation (i.e. canopy damage)
  - Indirect approaches (detection of human infrastructure)
- Operational fire monitoring systems

Forest degradation and area changes




Forest degradation & emission factors
Increasing detail in degradation classes
t-2
t-1
t0
t1
Intact/closed forest
Primary forest
Low level degradation forest
Degraded forest
Non-forest
Carbon stock
1990
Time
2000
2005
2010
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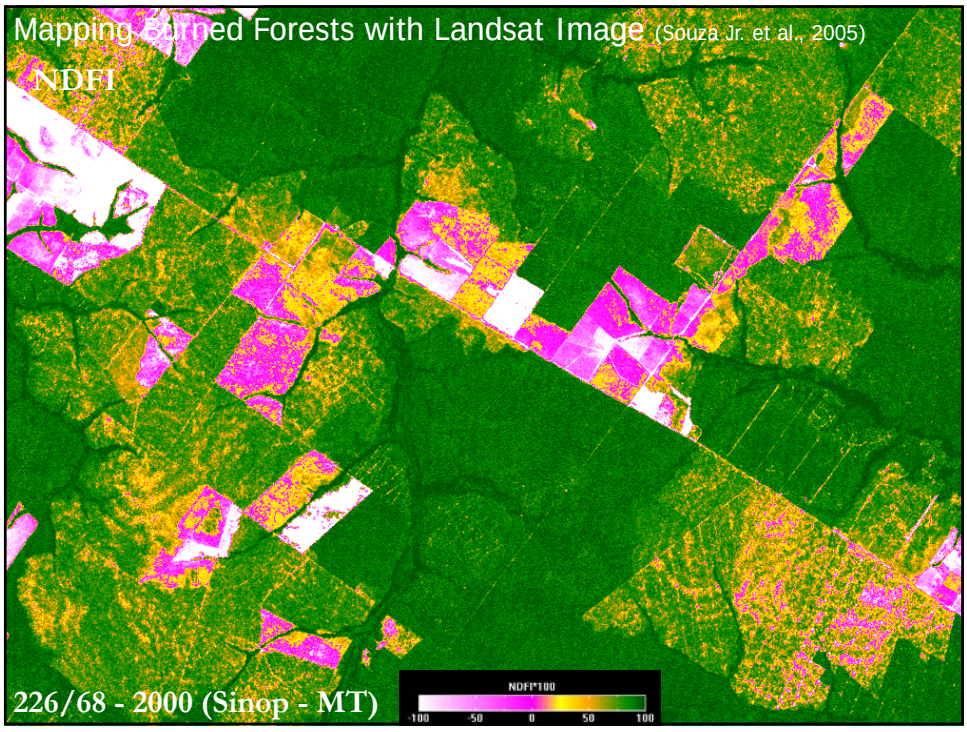
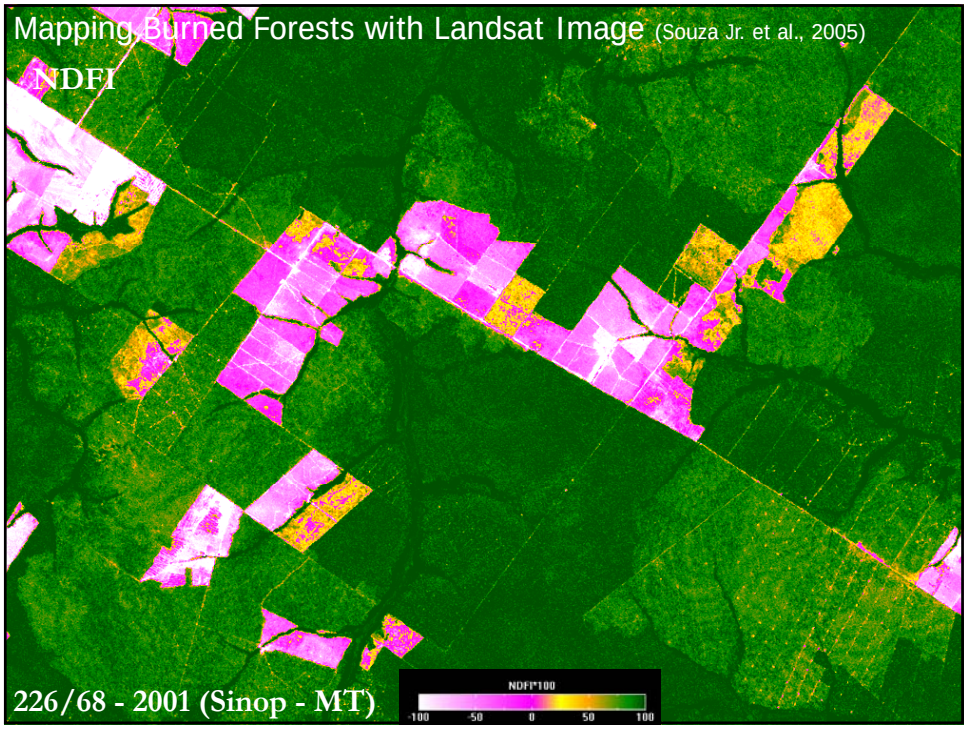

Mapping Burned Forests with Landsat Image (Souza Jr. et al., 2005)
NDFI
226/68 - 2000 (Sinop - MT)
NDFI*100
-100
-50
0
50
100


Mapping Burned Forests with Landsat Image (Souza Jr. et al., 2005)
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226/68 - 2001 (Sinop - MT)
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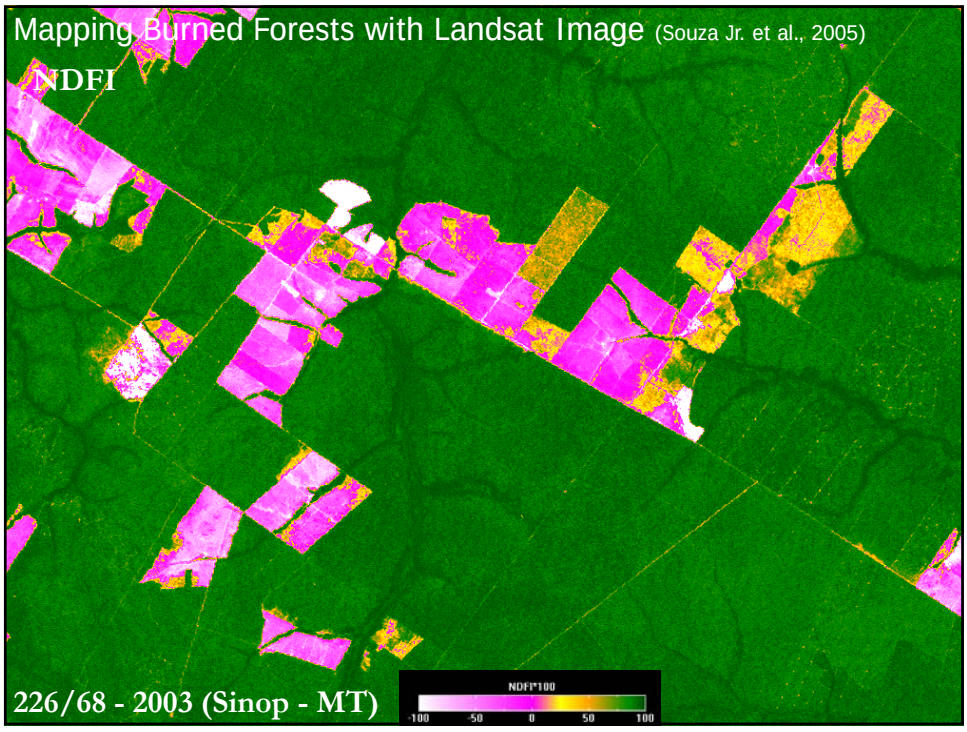
Mapping Burned Forests with Landsat Image (Souza Jr. et al., 2005)
NDFI
226/68 - 2003 (Sinop - MT)
NDFI*100
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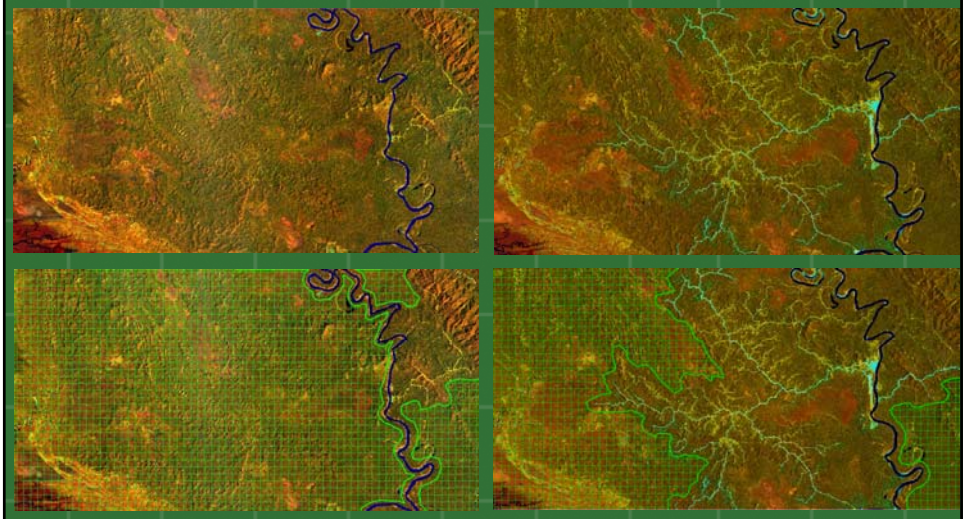
Example for indirect approach

Landsat 1990

Landsat 2000



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Direct approaches to detect forest degradation

Highly Detectable	Detection limited & increasing data/effort	Detection very limited
• Deforestation • Forest fragmentation • Recent slash-and-burn agriculture • Major canopy fires • Major roads • Conversion to tree monocultures • Hydroelectric dams and other forms of flood disturbances • Large-scale mining	• Selective logging • Forest surface fires • A range of edge-effects • Old-slash-and-burn agriculture • Small scale mining • Unpaved secondary roads (6-20-m wide) • Selective thinning of canopy trees	• Harvesting of most non-timber plants products • Old-mechanized selective logging • Narrow sub-canopy roads (<6-m wide) • Understory thinning and clear cutting • Invasion of exotic species

(using Landsat-type observations)

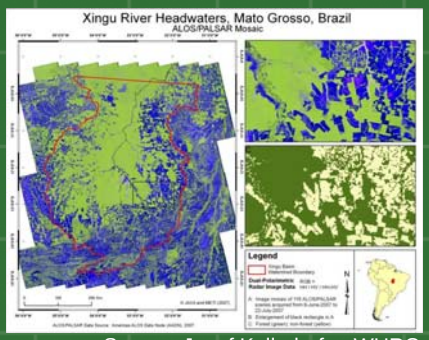
Peres et al., (2006) TREE

The role of LIDAR observations

- LIDAR (LIght Detection And Ranging) sensors:
  - directly measure three-dimensional distribution of vegetation canopy components and sub-canopy topography
- Tool for a range of forest inventory information
  - primarily for estimation of tree/stand heights, also volume, crown closure and biomass
- Most operational examples using airborne systems (footprint size of 0.1 – 2 m)
- Global space-borne ICESAT/GLAS with limitations caused by 70 m footprint diameter

Synthetic Aperture Radar (SAR) observations

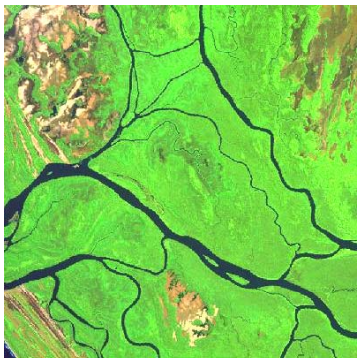
- Active system independent of atmosphere
- Data of several space-borne systems archived
- ALOS L-band global observations strategy since 2007
- Requirements and status of preprocessing
- Baseline forest mapping
- Cloudy areas
- Project case studies



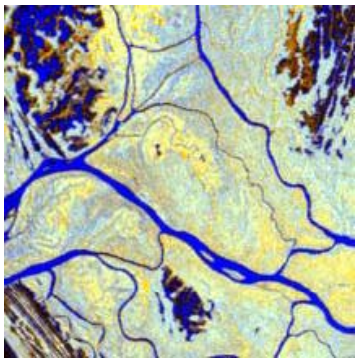
Source: Josef Kellndorfer, WHRC

JRC
EUROPEAN COMMISSION

Gabon (South 01˚ East 09˚)



Landsat year 2000

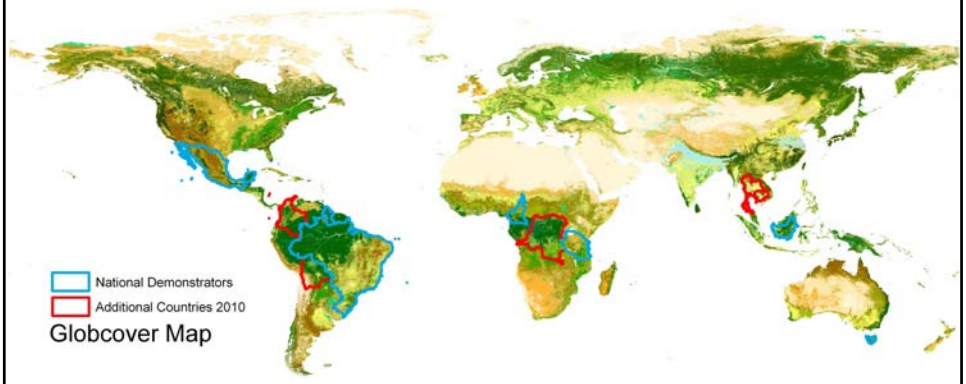


ALOS PALSAR year 2007

Remote sensing support for carbon estimation

- Direct quantitative biomass mapping from space remains a challenge for national level estimations
- Existing capabilities:
  - Satellite observation may help to map some specific forest types (i.e. mangroves, plantations etc.)
  - Targeted remote surveys to support carbon monitoring:
    - *Very high resolution satellite or airborne data of air-photo quality to assist field surveys*
    - *Sensitivity of LIDAR and long-wave RADAR observations*
    - *Integration of in-situ and satellite data for large scale biomass mapping*
    - *Direct estimation of emissions from fire radiative power*
  - Technologies are not operational globally but evolving

GEO FCT task demonstrator countries & sites



Need for demonstration of synergy and evolving technologies for national level cases

Accuracy assessment procedures

Consensus methods exist for assessing the accuracy of remote sensing-derived (singe-date) land cover maps:
http://nofc.cfs.nrcan.gc.ca/gofc-gold/Report%20Series/GOLD_25.pdf

- Implementation steps for robust approach:
  - **Sample design:** for selecting reference locations
  - **Response design:** reference condition label versus map labels
  - **Analysis design:** estimation formulas and accuracy reporting
- Often errors of omission and commission are not equal
- Use accuracy information on bias in the map to adjust area estimates and also to provide the confidence intervals
- "Accurate" estimates should remain the primary objective of any monitoring, but conservative estimations maybe useful for low quality data and for prioritizing resources (see section 4 of the GOFC-GOLD Sourcebook)

Final remarks

- Existing experiences for using remote sensing for national GHG inventories in Annex I countries and in evolving REDD MRV activities
- Continuity for suitable earth observation data ensured through efforts by space agencies and GEO
- GOFC-GOLD Sourcebook development will continue as expert community effort a living document
  - Continuous linkage with research projects, organizations and international processes to demonstrate progress
  - Further methods and technical details specified and added with evolving negotiations and decisions
  - 4th GOFC-GOLD Sourcebook workshops on 5-9. July 2010 in New York

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Acknowledgement

Sponsors of the Global Terrestrial Observing System:

FAO ICSU UNEP UNESCO WMO

Sourcebook authors:

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Support for GOFC-GOLD REDD working group :

esa START IHDP • IGBP • WCRP NASA

Canada The Nature Conservancy CSA ASC

Web resources

- **GOFC-GOLD:**
  - http://www.fao.org/gtos/gofc-gold/
- **GOFC-GOLD land cover project office:**
  - http://www.gofc-gold.uni-jena.de/
- **GOFC-GOLD REDD sourcebook:**
  - http://www.gofc-gold.uni-jena.de/redd
- **IPCC background paper on use of remote sensing in LULUCF sector (GOFC-GOLD 33):**
  - http://www.fao.org/gtos/gofc-gold/series.html
- **UNFCCC/SBSTA technical paper on costs of monitoring for REDD**
  - http://unfccc.int/resource/docs/2009/tp/01.pdf

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