# Generating Data from National Forest Monitoring and Carbon Accounting (REDD MRV)

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"Estimating the Opportunity and Implementation Costs of REDD+ for the National Planning Process"
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# Session Objectives

You will understand:

- Function and Purpose of REDD MRV
- Basic methods and technologies used to map Land (Forest) Cover & Carbon
- Approach to estimate and report emissions national through MRV
- How REDD MRV activities at the national level can be harnessed to perform and improve OCA

# REDD Readiness requires operational Forest Monitoring and 'Baselines'

Two important technical activities for national REDD preparation

1. Forest Monitoring and Mapping; Carbon Accounting *(Measurement, Reporting, Verification - MRV)*
   - Remote Sensing
   - Field-based Sampling and/or Inventory Information
2. Reference Emission Levels (REL) and Reference Levels (RL)
   - 'Baselines' for GHG emissions and forest carbon stocks
     - Historical Analysis (multi-temporal satellite image analysis)
     - Modeling (forward-looking)
   - REL/RL will be result of climate negotiations, informed by technical studies
   - Can be regional/jurisdictional (sub-national implementation on an interim basis)

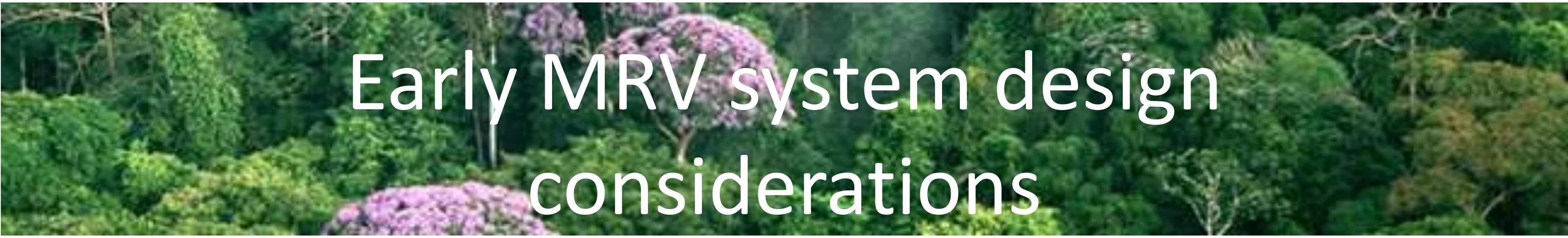
# Why REDD MRV?

- Let’s recall: REDD+ activities

  Bali Action Plan calls for *“policy approaches and positive incentives on issues relating to reducing emissions from* ***(1) deforestation and (2) forest degradation****; and the role of* ***(3) conservation*****,** ***(4) sustainable management of forests*** *and* ***(5) enhancement of forest carbon stocks*** *in developing countries*”.

- REDD MRV system
  - Tracks changes in forest carbon associated with drivers of forest cover change
  - Compares trends in forest carbon to a ‘baseline’ (REL/RL)
  - Measures performance (of REDD policies)
  - Generates data for carbon accounting and reporting
- But it encompasses more than just carbon:
  - Monitoring of drivers (for policy design/intervention)
  - ‘co-benefits’: biodiversity; water; livelihoods, community participation etc.
- MRV system will not (necessarily) generate land-use maps (needed for OCA), but rather forest carbon maps and emission estimates

# Early MRV system design considerations



**First countries need to …**

- Identify the drivers of forest cover change
- Choose REDD+ options (which activities?)
- Assess capacities
- Understand (and ultimately quantify) forest trends

**… and then design the MRV system accordingly:**

- What will be monitored (D, D, or +)? And how?
- Develop data and capacity
- Institutional arrangements: Who does what (best)?
- Use info from monitoring for policy design: no performance – no payment

Core activities and design ideas are defined in country-owned REDD readiness preparation proposals (R-PPs)

# Significance of Emission Sources

- Five Carbon Pools (IPCC)
  1. Above-Ground
  2. Below-Ground
  3. Soil
  4. Litter
  5. Dead Wood

- Do all pools need to be monitored with the same intensity? Typically not …
  - Different land conversion affects carbon pools differently
  - Typically above-ground (standing biomass) contribute the most to terrestrial emission
  - For soils, observable C-stock changes after land conversion occur in top 20-30cm
  - Big trees contain most of the carbon
  - Conservativeness: including soils increases uncertainty and decreases quality of estimate
  - If pool contributes > 25% (rule of thumb) consider advanced monitoring (has costs)

- Thus, REDD Forest Monitoring Activities need to focus on
  - Areas undergoing (rapid) change
  - Important forest carbon stocks
  - Relevant Carbon Pools
  - Use same pool for REL/RL and MRV

# Estimating Emissions: Basic Formula

**'Activity data':** Forest cover and forest cover change (area, composition)

(100ha)

×

**'Emission factors':** Forest carbon density (carbon stock)

(80t C/ha)

=

GHG Emissions

(8000t C)

## 3 Approaches

1. total net area change (no info on conversion)
2. Tracking land-use conversions by category
3. Tracking land-use conversions spatially explicitly

## 3 Tiers

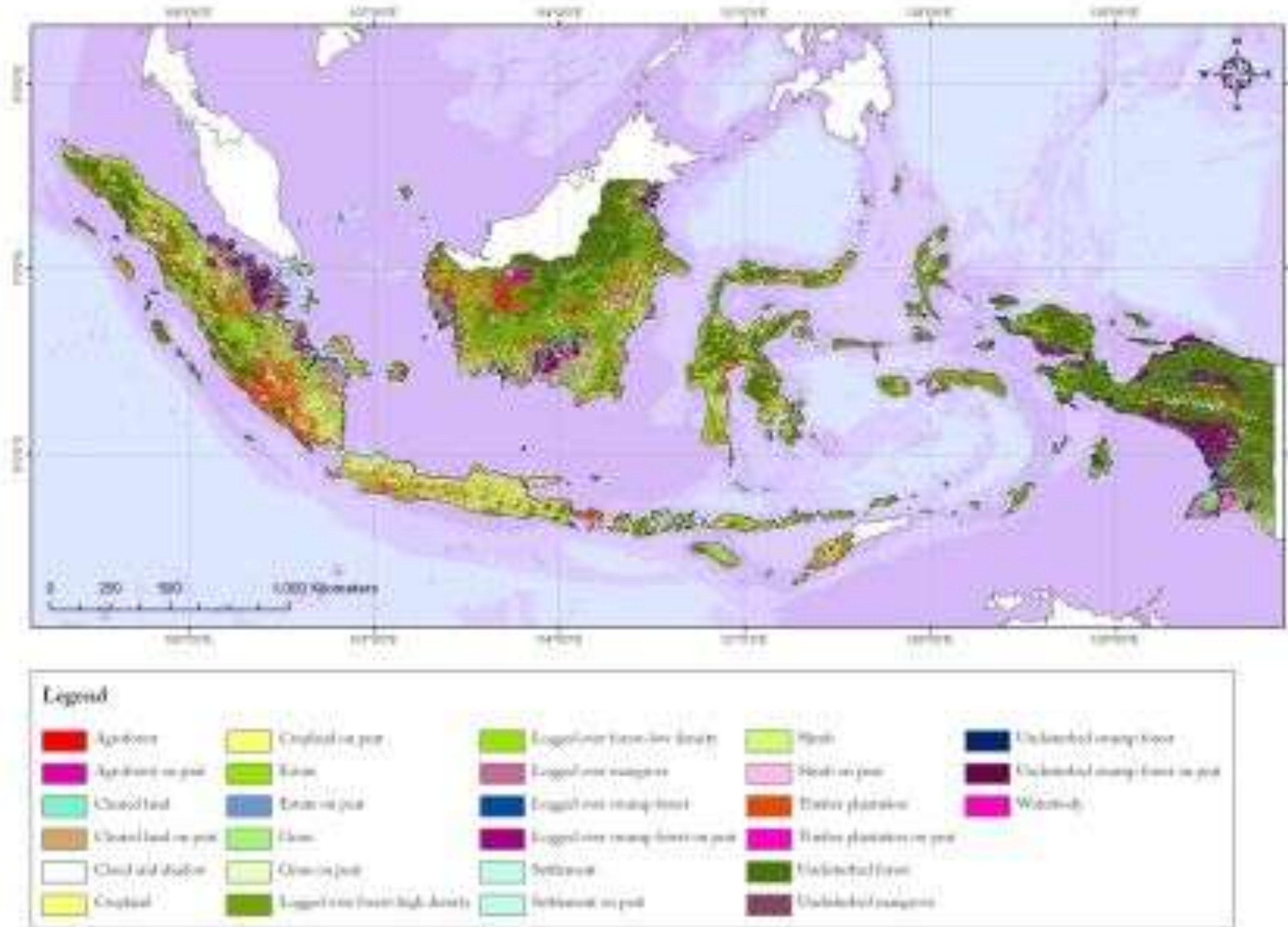
1. IPCC default factors (broad land categories)
2. Country-specific factors
3. Detailed national inventory of C stock

IPCC

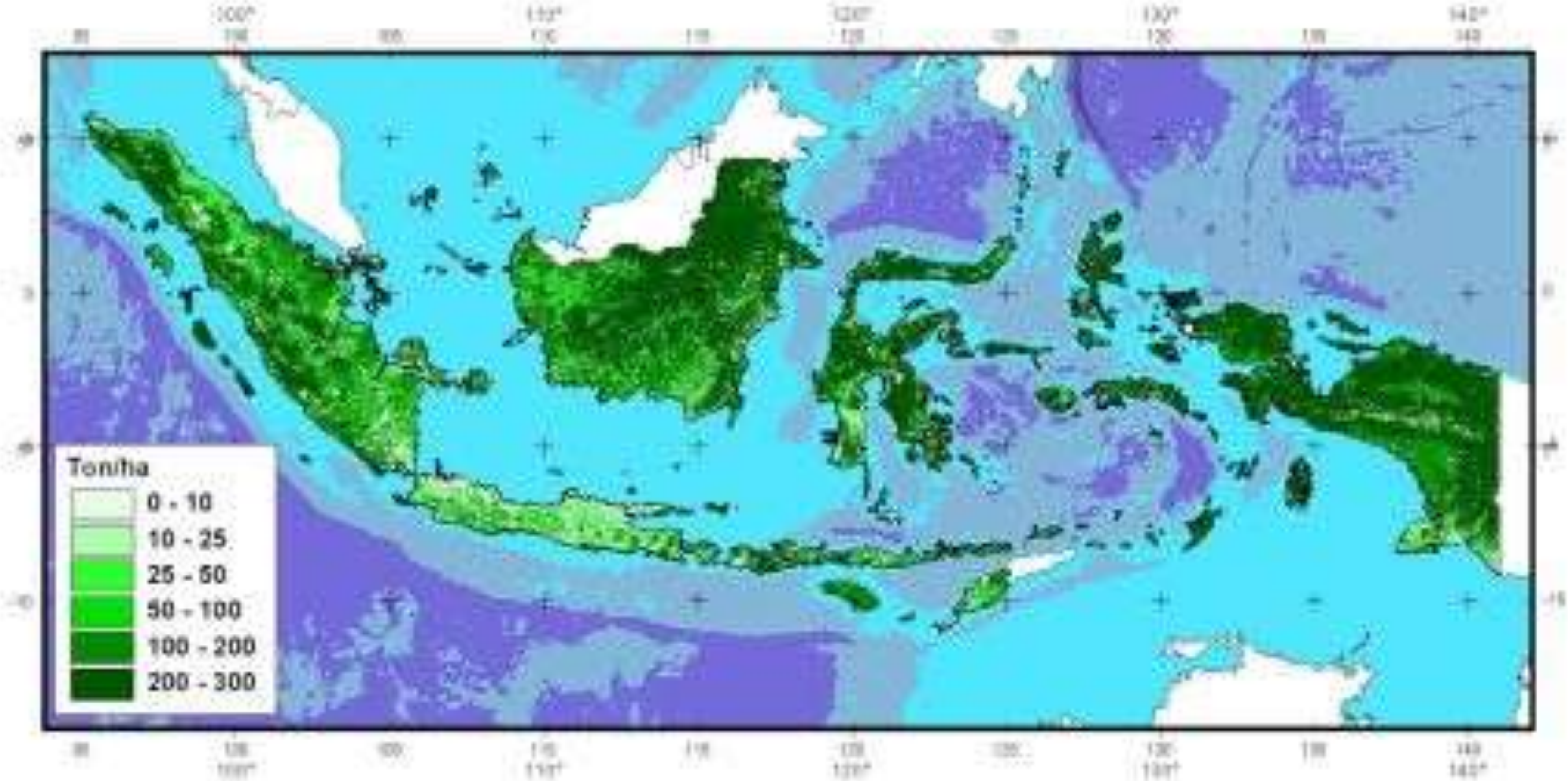
# LAND COVER MAP OF INDONESIA IN 1990

# LAND COVER MAP OF INDONESIA IN 2000

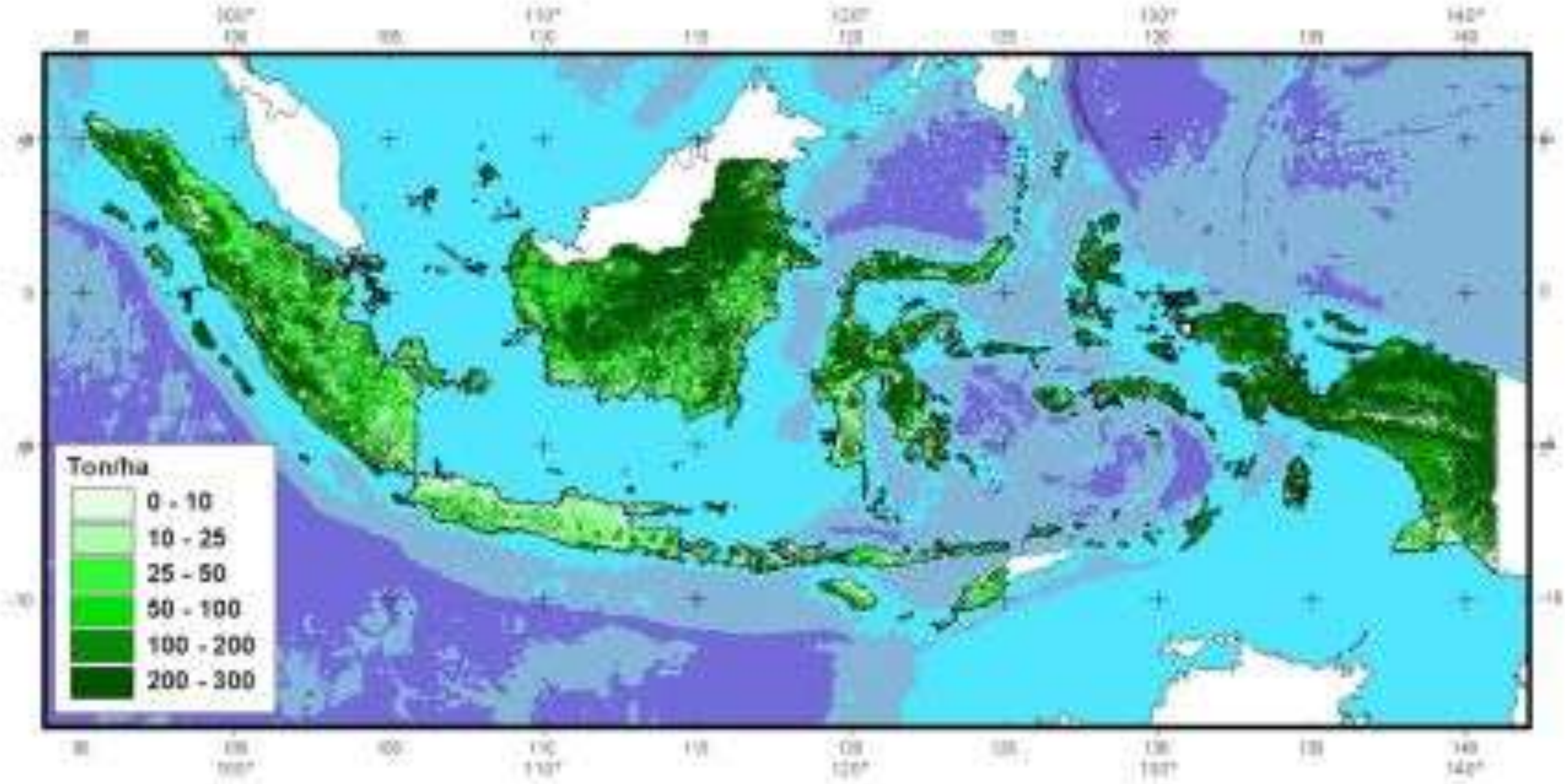
# LAND COVER MAP OF INDONESIA IN 2005



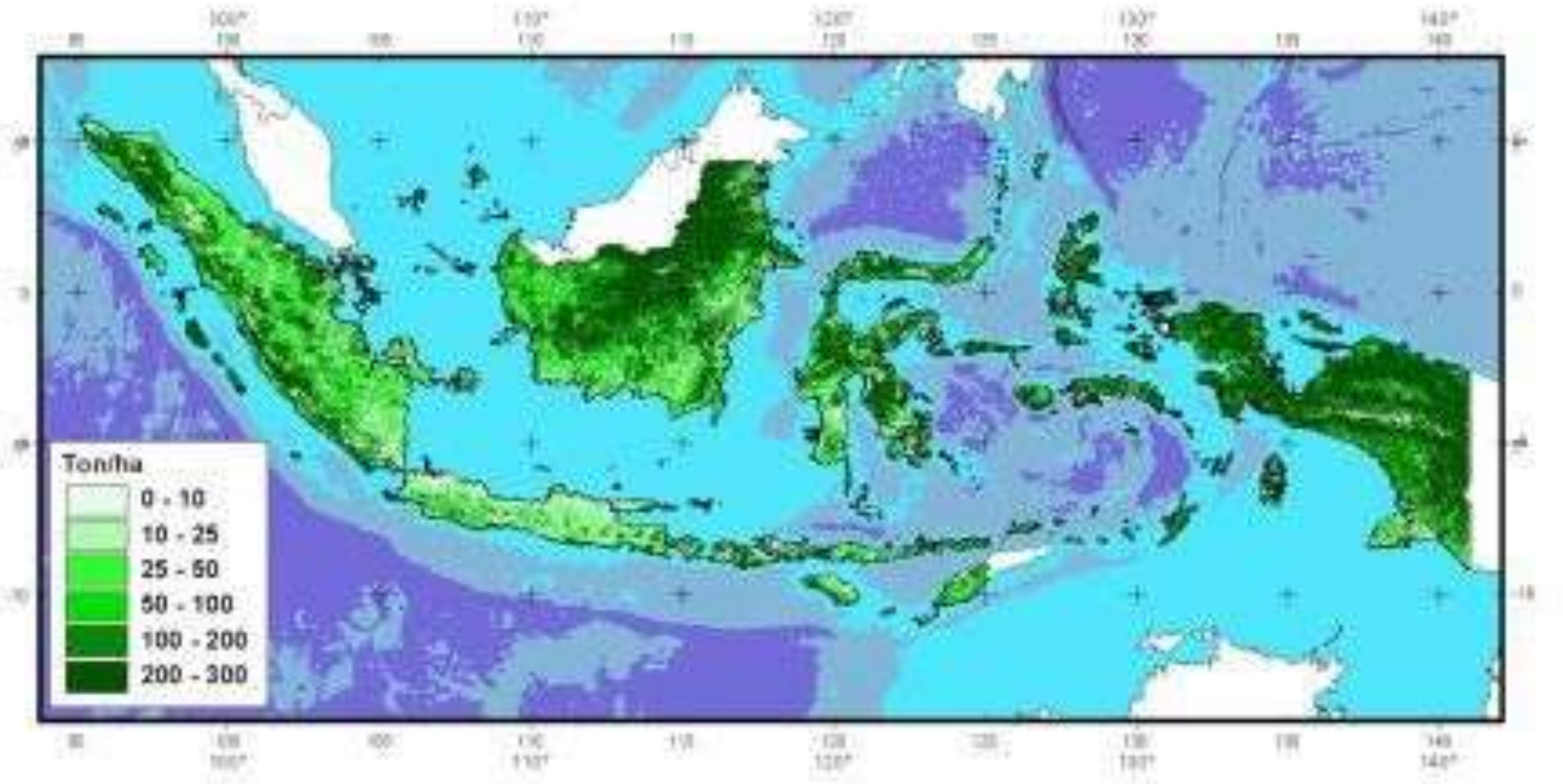
# Above ground C-stock map of Indonesia in 1990



# Above ground C-stock map of Indonesia in 2000



# Above ground C-stock map of Indonesia in 2005

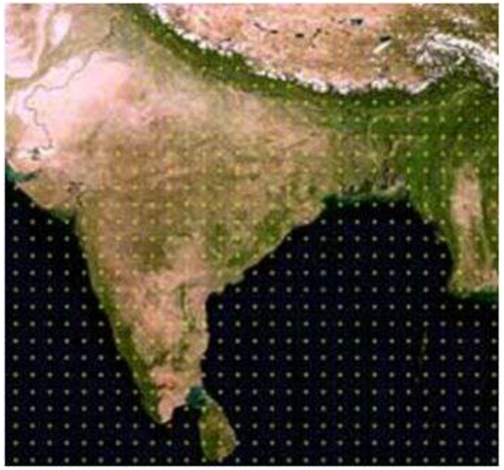


# What does this entail?

1. Mapping forests and forest cover change using satellites
   - Cost-effective
   - Determine forest/non-forest area and canopy density
   - Only above-ground biomass
   - Many new sources of satellite data
2. Forest carbon density
   - Derived from ‘inventories’ (is a national forest inventory necessary?!) and field methods
   - Many countries have not had a forest inventories in decades
   - REDD requires information on carbon (not volume or biomass)
3. Estimate and report emissions
   - Following established protocols (IPCC good practice guidance and IPCC guidelines)
   - Complex: needs capacity building and simple ‘tools’ to get started

# How does Remote Sensing Work?

- Different platforms
  - Satellite-based and Air-borne
- Different Sensor Technologies
  - Optical, Radar, Lidar, Thermal, Infrared, Microwave, etc.
  - Resolution
    - Spatial ("kilometers" - "meters" - "centimeters")
    - Temporal ("days" – "weeks")
    - Spectral
  - Active vs. Passive
- Mapping Forests
  - Wall-to-wall vs. sampling
  - Strategic /long-term resource mapping
  - Rapid/targeted assessments

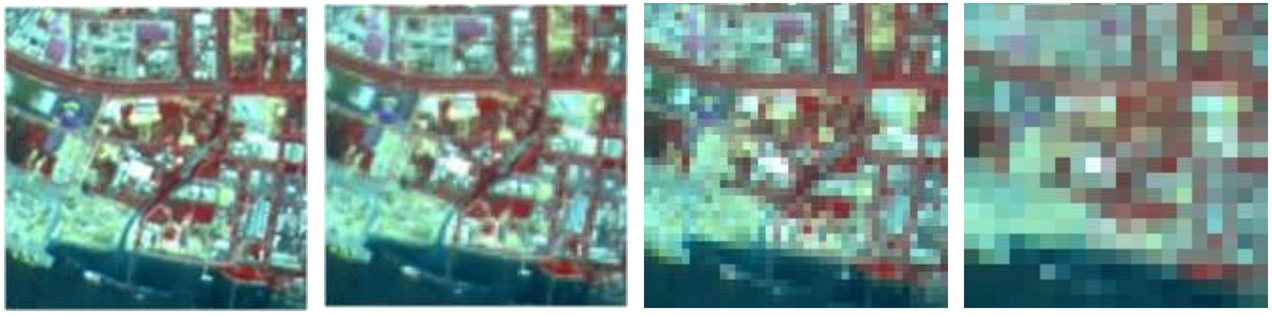


Source: GOFC-GOLD Sourcebook

# Resolution

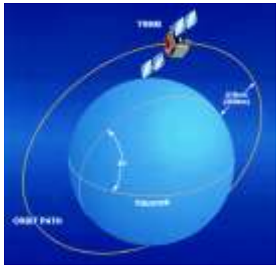
- **Spatial**

  ***"Pixel Size"***



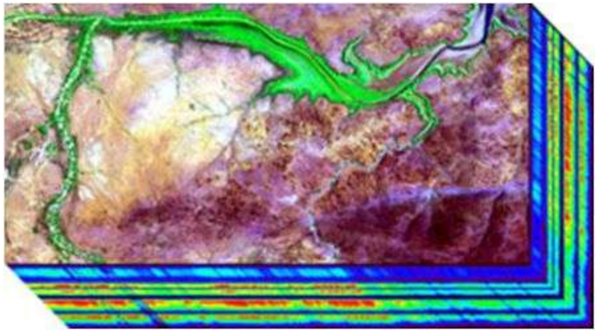
- **Temporal**

  ***"Revisit Interval"***



- **Spectral**

  ***"Information Content"***



# Satellite Instruments: Trade-Offs

# Satellite-data: trade-offs in spatial scale, coverage and costs

**Optical sensors at multiple resolutions for deforestation monitoring**

| Sensor & resolution | Examples of current sensors | Minimum mapping unit (change) | Cost | Utility for monitoring |
|---|---|---|---|---|
| Coarse<br>(250-1000m) | SPOT-VGT<br>(1998- )<br>Terra-MODIS<br>(2000- )<br>Envisat-MERIS<br>(2004 - ) | ~ 100 ha<br>~ 10-20 ha | Low or free | Consistent pan-tropical annual monitoring to identify large clearings and locate “hotspots” for further analysis with mid resolution |
| Medium<br>(10-60m) | Landsat TM or ETM+,<br>SPOT HRV<br>IRS AWiFs or LISS III<br>CBERS HRCCD | 0.5 - 5 ha | <$0.001/km$^2$ for historical data<br>$0.02/km$^2$<br>to $0.5/km$^2$ for recent data | Primary tool to map deforestation and estimate area change |
| Fine<br>(<5m) | IKONOS<br>QuickBird<br>Aerial photos | < 0.1 ha | High to very high<br>$2 -30 /km$^2$ | Validation of results from coarser resolution analysis, and training of algorithms |

COST

COVERAGE

Source: GOFC-GOLD Sourcebook

# Remote Sensing: Forest Application (1)

- Benefits of Remote Sensing
  - Spatially Continuous Data Acquisition: Routine Revisiting Capabilities, Regional Coverage
  - Digital Data Processing, Manipulation, Integration (GIS); Modeling
  - Cost-effective (but needs capacity building)
- Primary Use of Remote Sensing in Forest Mapping
  - Forest reference map (Forest/non-forest)
  - Identification of land cover  categories (land use)
  - Change detection (area change)
  - Complement on-the-ground inventories (extrapolate carbon density from plots to larger regions)
  - What satellite really measure is tree density (not ‘forests’)

# Remote Sensing: Forest Application (2)

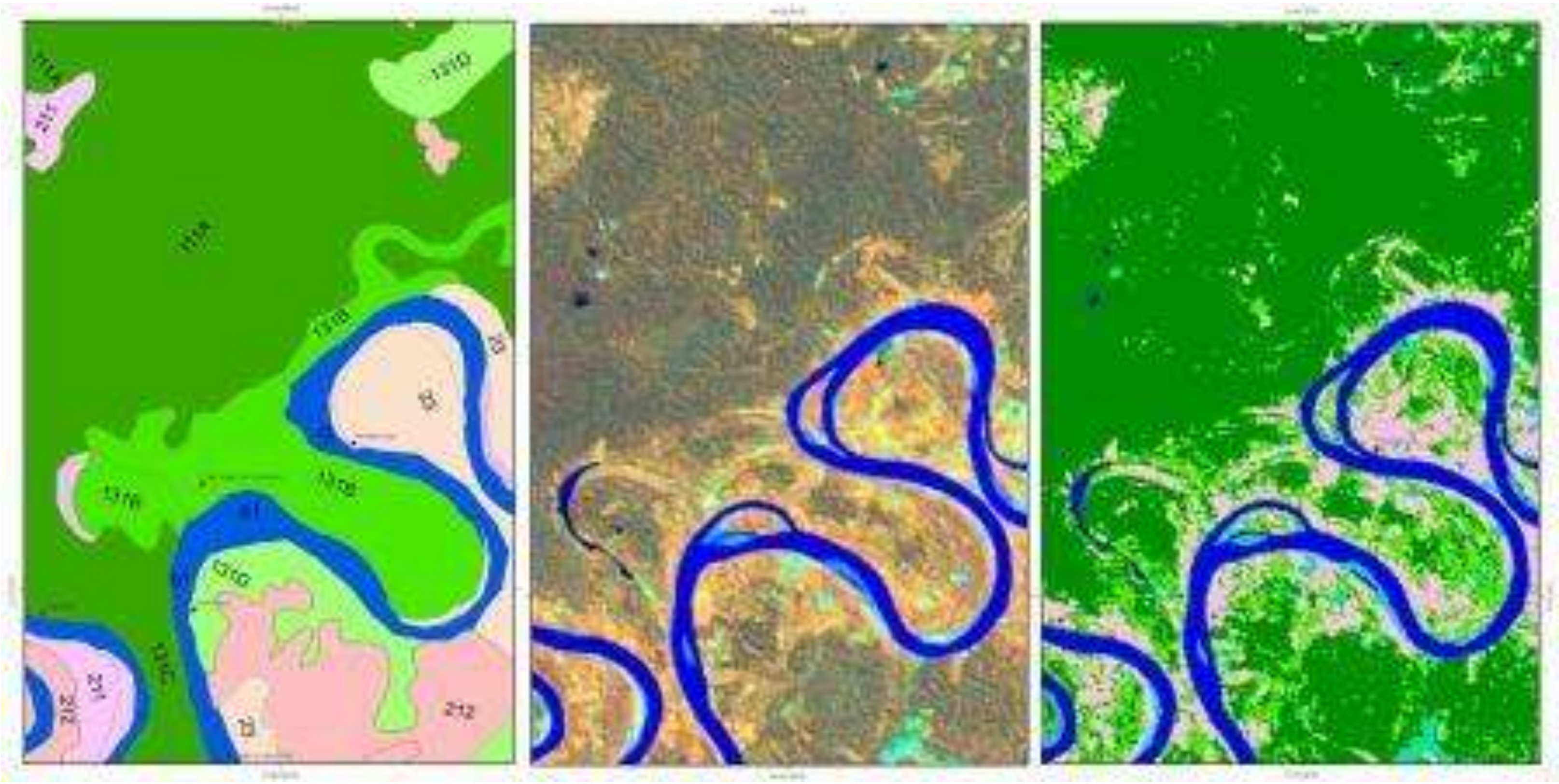
- Remote sensing **cannot**
  - measure carbon directly
    - needs to be inferred from spectral properties and combined with ground-data
  - see into the soil and (much) below the canopy
    - some new technologies, notably Lidar, are capturing below-canopy properties
  - measure tree height
    - unless terrain data is available, e.g. with radar
  - measure biodiversity
    - though, advanced (airborne) sensors can distinguish some species
  - Cannot see through clouds (optical)
    - radar can, but has other limitations

# From Land Cover to Land Use

- Basic steps to map land cover using remote sensing
  - Image Acquisition and Pre-processing
  - Image Classification
    - Visual interpretation (labor intensive, difficult to repeat)
    - Semi-automated methods (supervised, unsupervised, segmentation)
  - Accuracy Assessment
    - Ground-truthing
    - Hi-resolution imagery

- To be used for Land Use mapping, land use needs to be inferable from land cover (physical landscape properties)
  - Can be (partially) accomplished through multi-temporal observations (seasonality), but needs expert interpretation and in situ information
  - Number of classes that can be distinguished is limited (mixed classes and mixed uses)

# Visual vs. Automated Classification

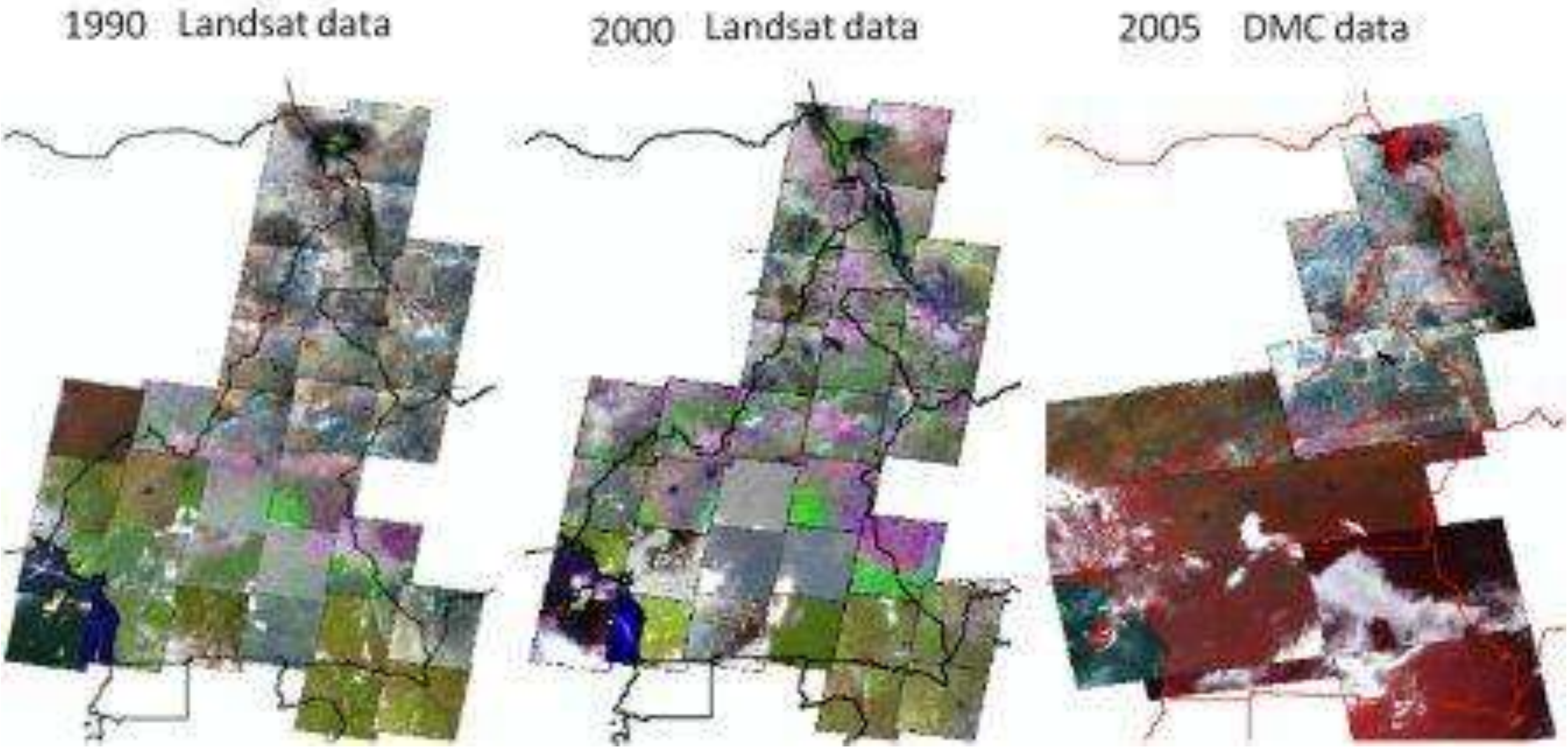


Visual/Manual Image Mosaic Semi-automated

# Validation: assessing map quality

- Sources of Uncertainty
  - Quality of satellite data, cloud contamination
  - Different sensors for different dates
  - Radiometric and geometric preprocessing
  - Inconsistent carthographic and thematic standards
  - Interpretation procedure
  - Post-processing of the maps
  - Availability and quality of ground-truth data
- Accuracy Assessment
  - *In situ* ground-truthing
  - High-resolution imagery or aerial photgraphy
  - Google Earth

# Data quality: clouds in multi-temporal imagery




REDD-PILOT project in Cameroon: TOTAL of 40% of clouds in the forest zone across 3 dates (courtesy of GAF-AG)

# Uncertainty: mixed categories and systems

Complex mosaic

Shaded Cocoa in Central Africa

# Overall and Class Accuracy

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Google | Users |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 40 | | | | | 3 | | | | 43 | 93.0 |
| 2 | | 31 | | | | 2 | | | | 33 | 93.9 |
| 3 | | | 29 | | 1 | 3 | | | | 33 | 87.9 |
| 4 | | | | 28 | | 4 | 1 | | 1 | 34 | 82.4 |
| 5 | | | | | 24 | 2 | | | | 26 | 92.3 |
| 6 | 1 | 4 | 1 | 4 | 1 | 36 | 3 | 3 | 3 | 56 | 64.3 |
| 7 | | | | 3 | | | 30 | | | 41 | 73.2 |
| 8 | 1 | | | | | | 4 | 26 | | 31 | 83.9 |
| 9 | | | 1 | 2 | | | 3 | | 21 | 27 | 77.8 |
| Landsat | 42 | 35 | 31 | 37 | 26 | 50 | 41 | 37 | 25 | 324 | |
| Producers | 95.2 | 88.6 | 93.5 | 75.7 | 92.3 | 72.0 | 73.2 | 70.3 | 84.0 | | |

LCC Notes: 1-Forest, 95% canopy; 2-Forest, 80% canopy; 3-Forest, 65% canopy; 4-Forest, 50% canopy; 5-oil palm; 6-shifting cultivation; 7-short rotation fallow; 8-large cattle ranches; 9- without vegetation.

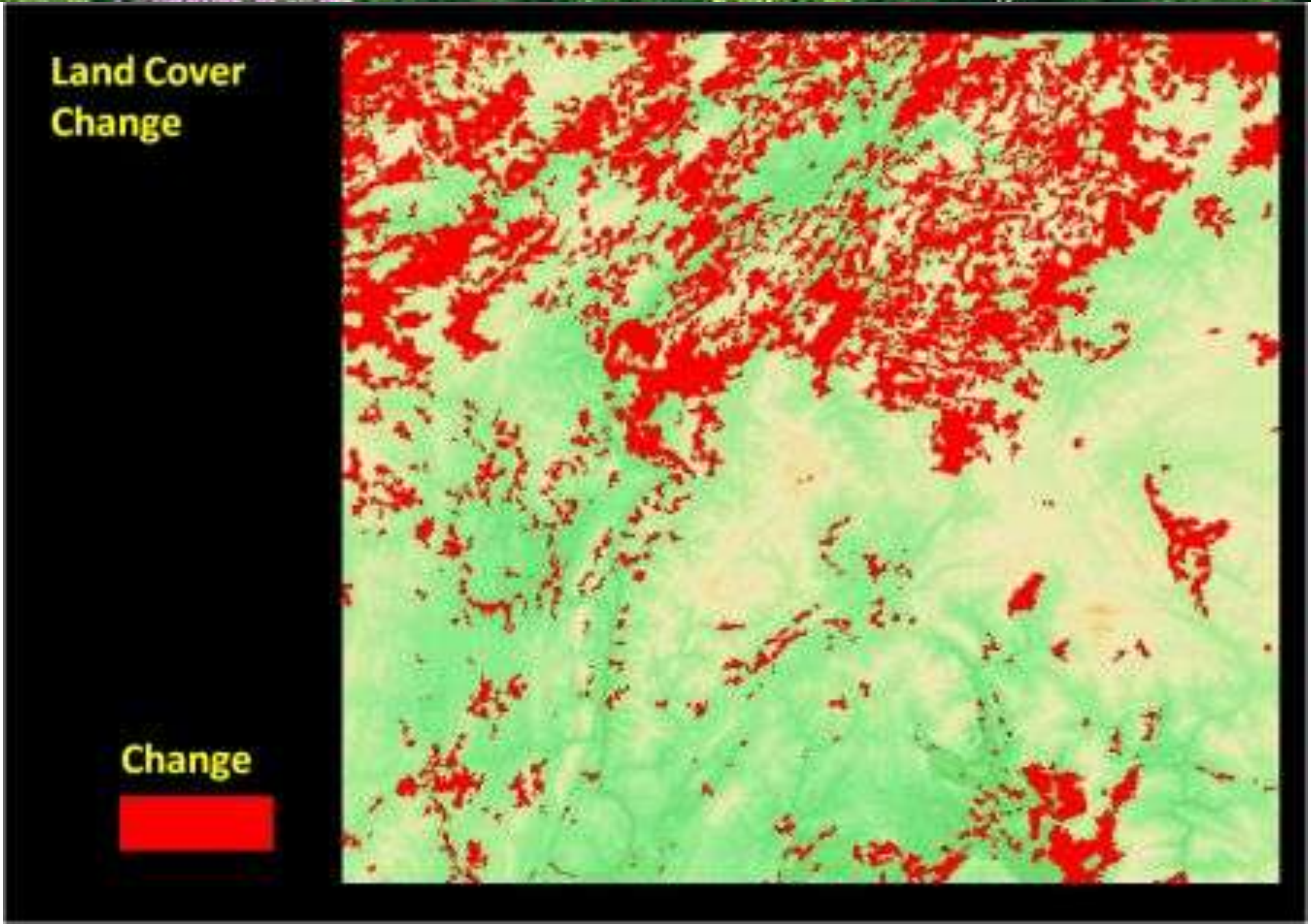
*Source: White and Hyman, 2009.*

# Emerging Technologies

- Several new remote sensing technologies are promising in the context of REDD+
  - Radar
  - Lidar


- Web-based mapping and cloud-computing
- Hand-held devices

# Land Use Change Analysis



# Linking Forest Cover Change to Land Use and Carbon

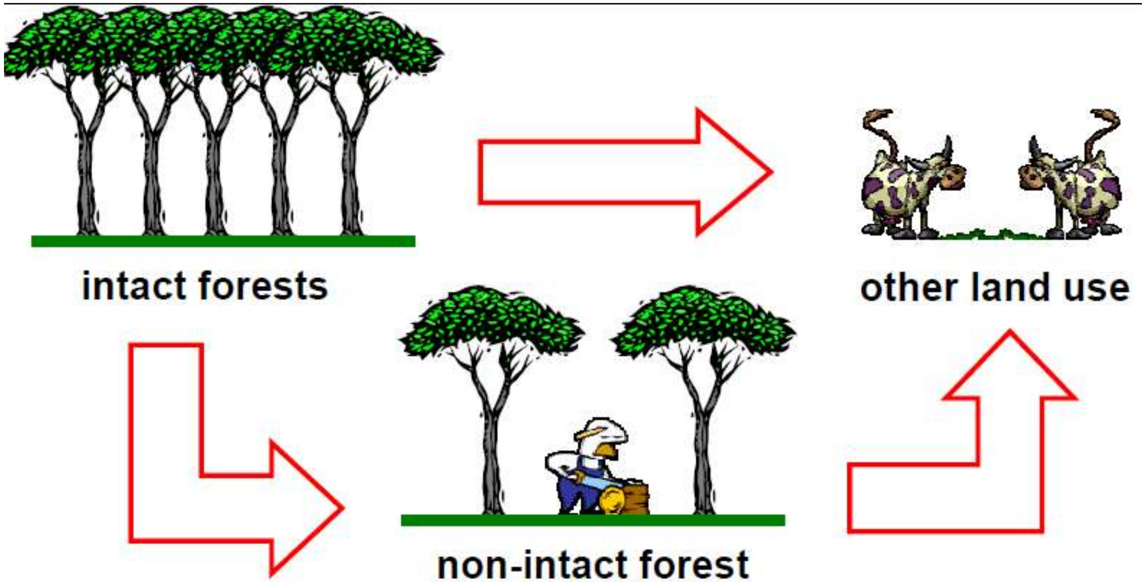
- Forest Cover Change ≠ Land use Change
- Minimum mapping unit and resolution
  - Physical and socio-economic data need to match
  - Variability of carbon density with land use classes
    - Split/aggregate classes
- Stratification
  - Where is the frontier? Understand LUC there
  - Carbon density (not forest ‘classes’)

# From Land Cover to Emissions: Sources of Uncertainty

- Estimates of Forest Cover depend on
  - Technology used
  - Definition of Land Cover classes and forest
  - Methodology used
- Estimates of Deforestation rate depend on
  - Forest cover data
  - Definition of Deforestation (forest definition defines boundary between ‘deforestation’ and ‘degradation’)
  - Spatial and temporal scale, baseline period
- Estimates of Emissions depend on
  - All of the above
  - Quality of Carbon stock data (Tier)
  - Pools monitored
  - Deforestation and Degradation
  - Net or Gross? (Regeneration/regrowth)

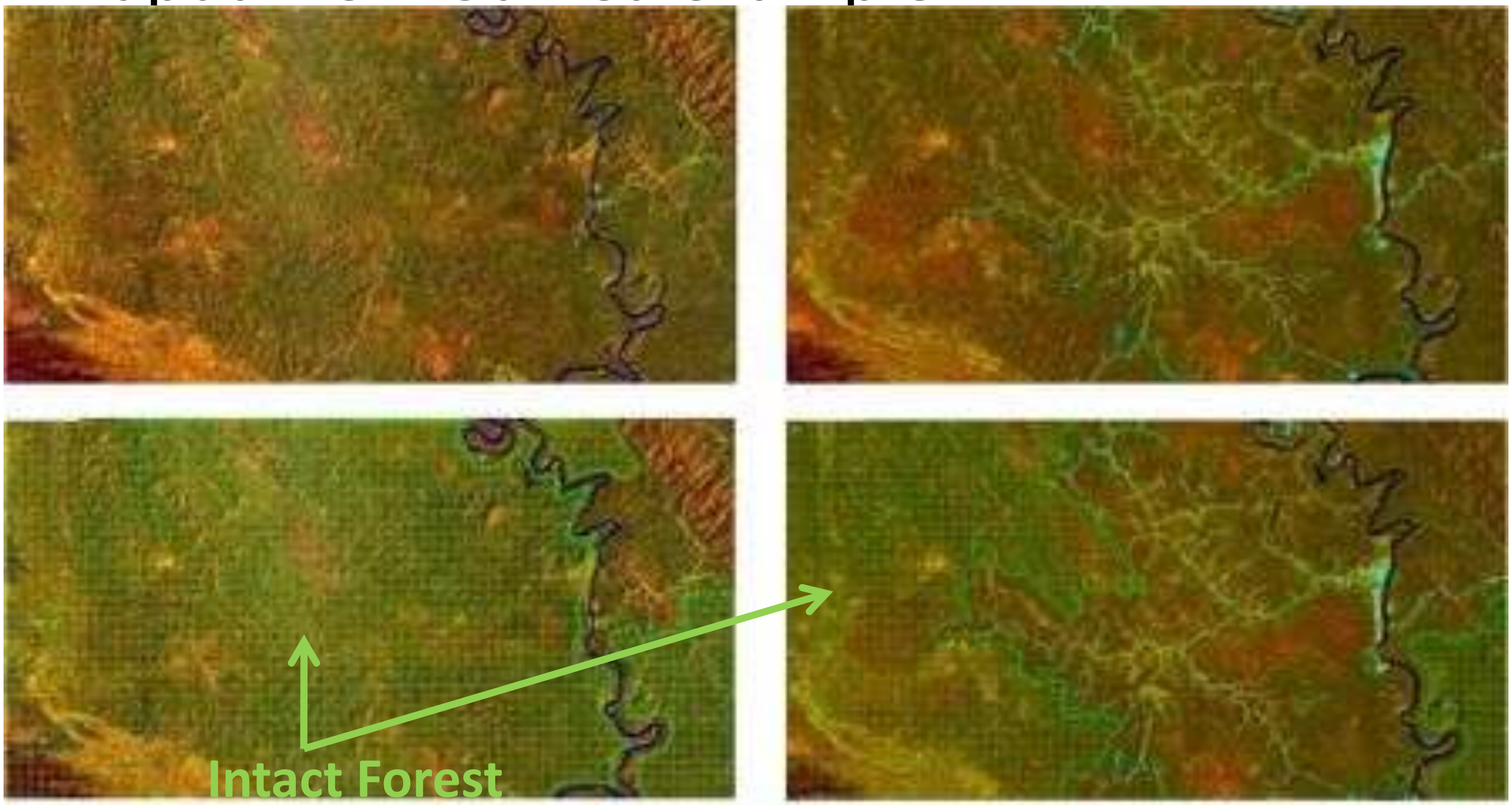
# Degradation

- Usually associated with
  - Selective logging
  - Open forest fires
  - Collection of fuel wood and non-timber forest products
  - Charcoal, grazing, shifting cultivations
- Deforestation
  - change of land use;
- Degradation
  - many definitions, none for REDD+ yet
  - No change in land use



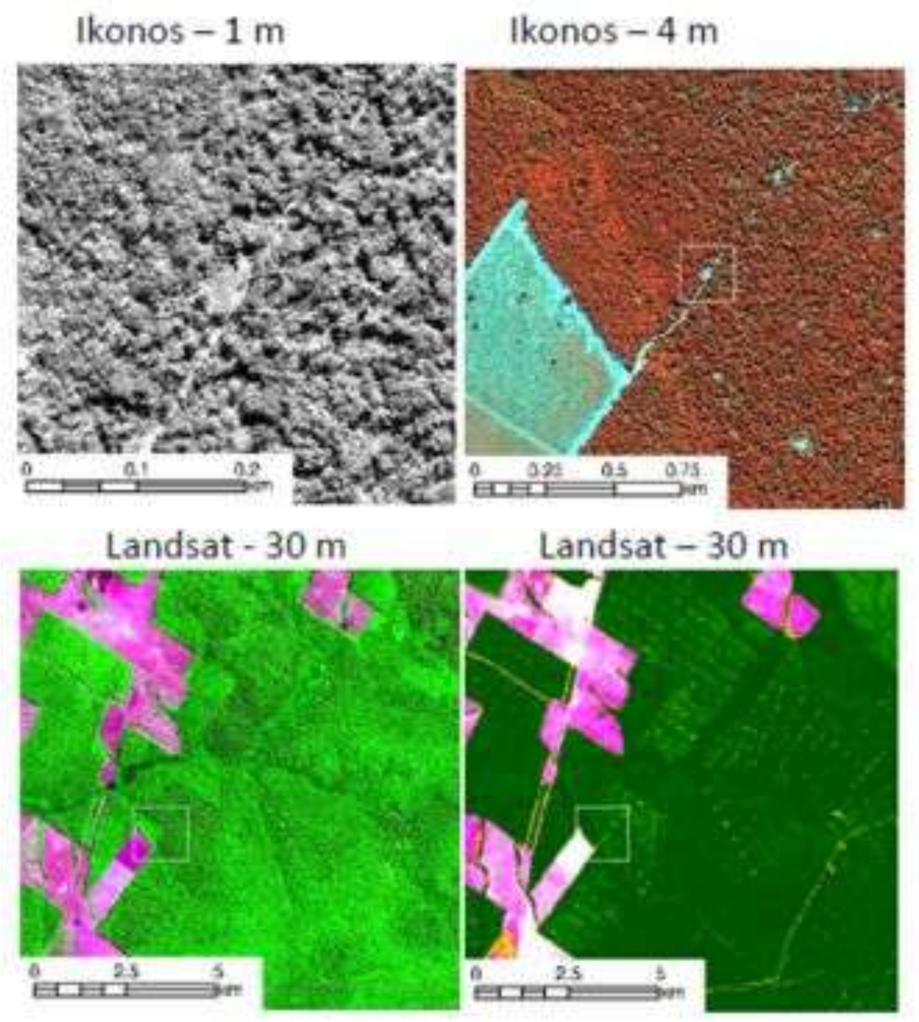
# Degradation

- Papua New Guinea example




Source: GOFC-GOLD Sourcebook

# Mapping forest degradation

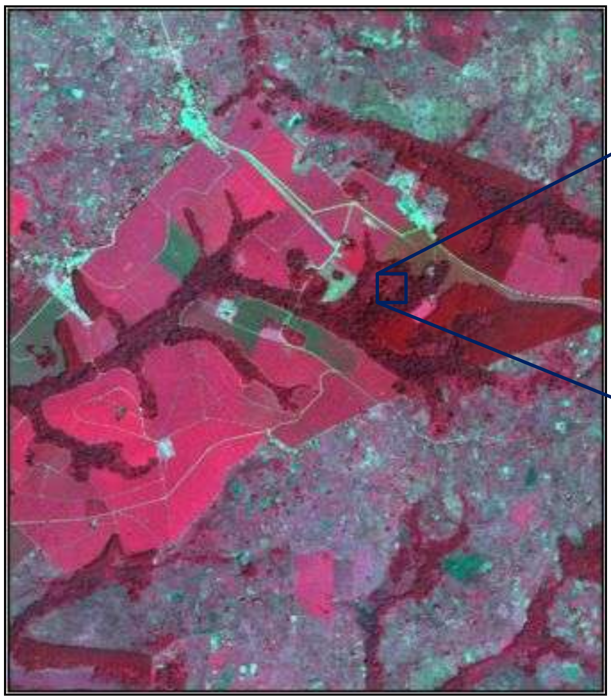


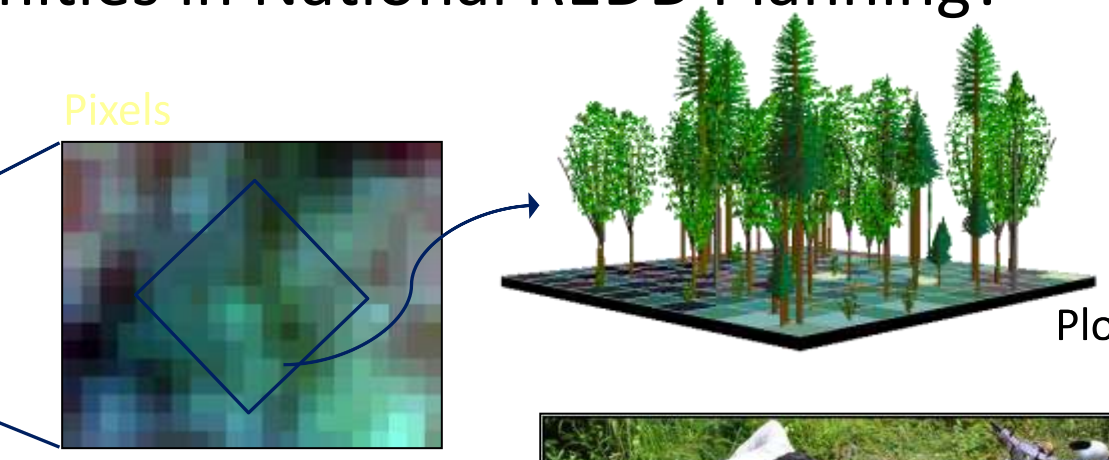

Souza Jr. (2007)

- Dominant process in many countries
- More difficult to monitor with satellites
  - (i.e. requires expert knowledge, field validation, advance processing techniques, time consuming)

# Role of Forest Communities in MRV

- Plots, People, Pixels
  - Role of Communities in National REDD Planning?






Credit: Baccini & Walker

# What many REDD countries have struggled with

- Components 3 (reference scenarios) and 4 have often been the weakest components
- The implementation realities of MRV are probably greater than expected in the R-PP (once getting into the details, costs can explode, but don’t have to)
- Consistency between reference scenarios and MRV system
- PROs and CONs of different monitoring technologies (satellites …)
- Confusing/inconsistent advice from ‘experts’
- Potential of R&D approaches vs. established robust techniques
- The relation and sequence of (i) drivers (ii) strategies (iii) reference scenarios (iv) MRV
- Getting the right external assistance and alignment of donor activities
- Monitoring of carbon and non-carbon (co-benefits)

# Implications of international process

- SBSTA – Subsidiary Body for Scientific and Technological Advice
  - Modalities; definitions
  - Reporting Cycles (link to NAMAs)
  - IPCC: update and complement Guidance and Guidelines
- National approach
  - interim: sub-national
- UNFCCC: “anthropogenic” emission
  - Proxy: ‘Managed’ land
- Financing, pricing and performance payments
  - Role of ‘markets’
- FCPF Carbon Fund: emission reduction programs

# Practical Considerations

- MRV entails 3 complex sets of tasks (areas change, carbon stock estimation, carbon accounting)
  - KISS is critical (“keep it simple”)
  - Step-wise approach: Improving over time (from approach 1-3 and tier 1-3)
  - UNFCCC negotiations and IPCC will provide guidance eventually, in the meantime work on basic capacities (‘no regrets’): use for planning and forest management (concessions, conservation …)
  - Learning-by-doing approach
- Coordination with others
  - UN-REDD (FAO), WWF, CI, WCS, Winrock et al.
  - Other MDB, bi-laterals

# More considerations

- Desired ‘national systems’ are the end-point of REDD-Readiness
  - Requires long-term (5-10? years) and sustained effort of technical assistance
- A critical first task is to perform a comprehensive review of capacity building and data needs (‘gap analysis’)
- Preliminary analysis should indentify the carbon pools that will be targeted by MRV
- REDD+ encompasses a total of 5 activities – each requires a tailored MRV approach
  - Which are the activities that have been identified/prioritized?
- Having intermediate outputs and demonstrating performance early will be essential to maintain momentum (donor interest, private sector, market development)
  - How can MRV efforts be phased?