Module 2.1 Monitoring activity data for forests using remote sensing

Module developers:

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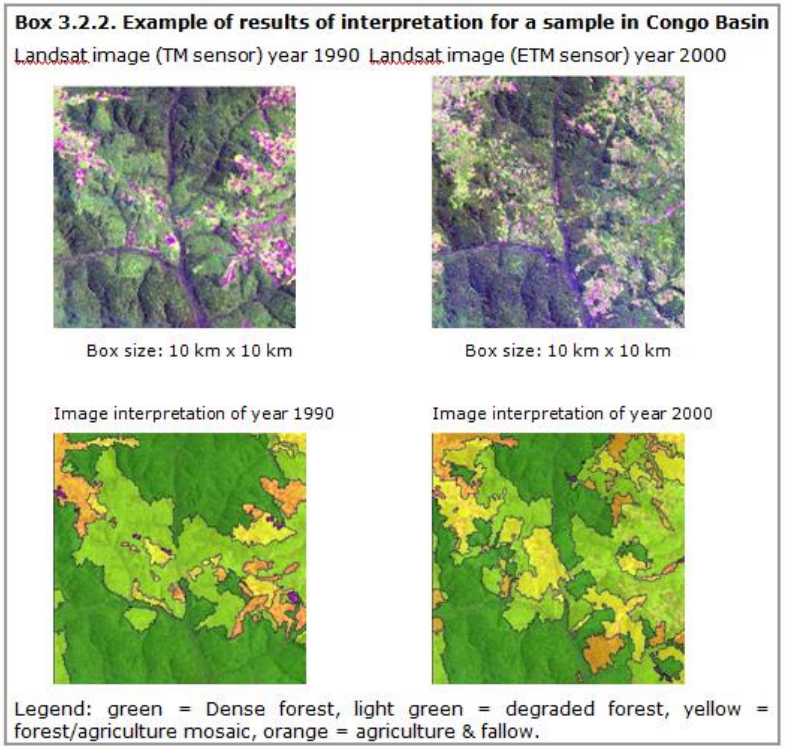
After the course the participants should be able to:

- Differentiate between different (remote sensing) approaches to monitor changes in forest areas
- Perform forest area change analysis using Landsat satellite data



Source: GOFC-GOLDSourcebook 2014, Box 3.2.2.

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GOFC-GOLD Global Observation of Forest and Land Cover Dynamics

FOREST CARBON PARTNERSHIP FACILITY

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Outline of lecture

1. Introduction
2. Selection of a monitoring approach
3. Image classification and analysis
4. Accuracy assessment
5. Limitations to using satellite data

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IPCC requirements for measuring and reporting of changes in forest area

- IPCC methodologies aim for full, accurate, transparent, consistent, and comparable reporting of GHG emissions and removals (e.g., of changes in forest areas).

- Reporting also includes a detailed description of the used inventory approach and planned improvements (Module 3.3)

- For activity data, spatially explicit land conversion information, derived from sampling or wall-to-wall mapping techniques, is encouraged.

Key role for earth observation in monitoring tropical forests

- Fundamental requirement of national monitoring systems are that they:
  i. Measure changes throughout all forested area
  ii. Use consistent methodologies at repeated intervals to obtain accurate results and
  iii. Verify results with ground-based or very high resolution observations
- The only practical solution to implement such monitoring systems in tropical countries often with low accessibility to forest areas is through interpretation of remotely sensed data supported by ground-based observations.

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Required activity data

- Depending on national decisions on the approach to be used, the following types of activity data/maps may be needed for reporting on the changes in forest cover:
  - Forest/nonforest map (+ change maps)
  - National land-cover/land-use map (+ change maps)
  - Forest stratification
  - Map of changes within forest land (see Module 2.2)
- A monitoring approach suitable for producing the required activity data in the particular conditions of the country needs to be selected.

Forest definition

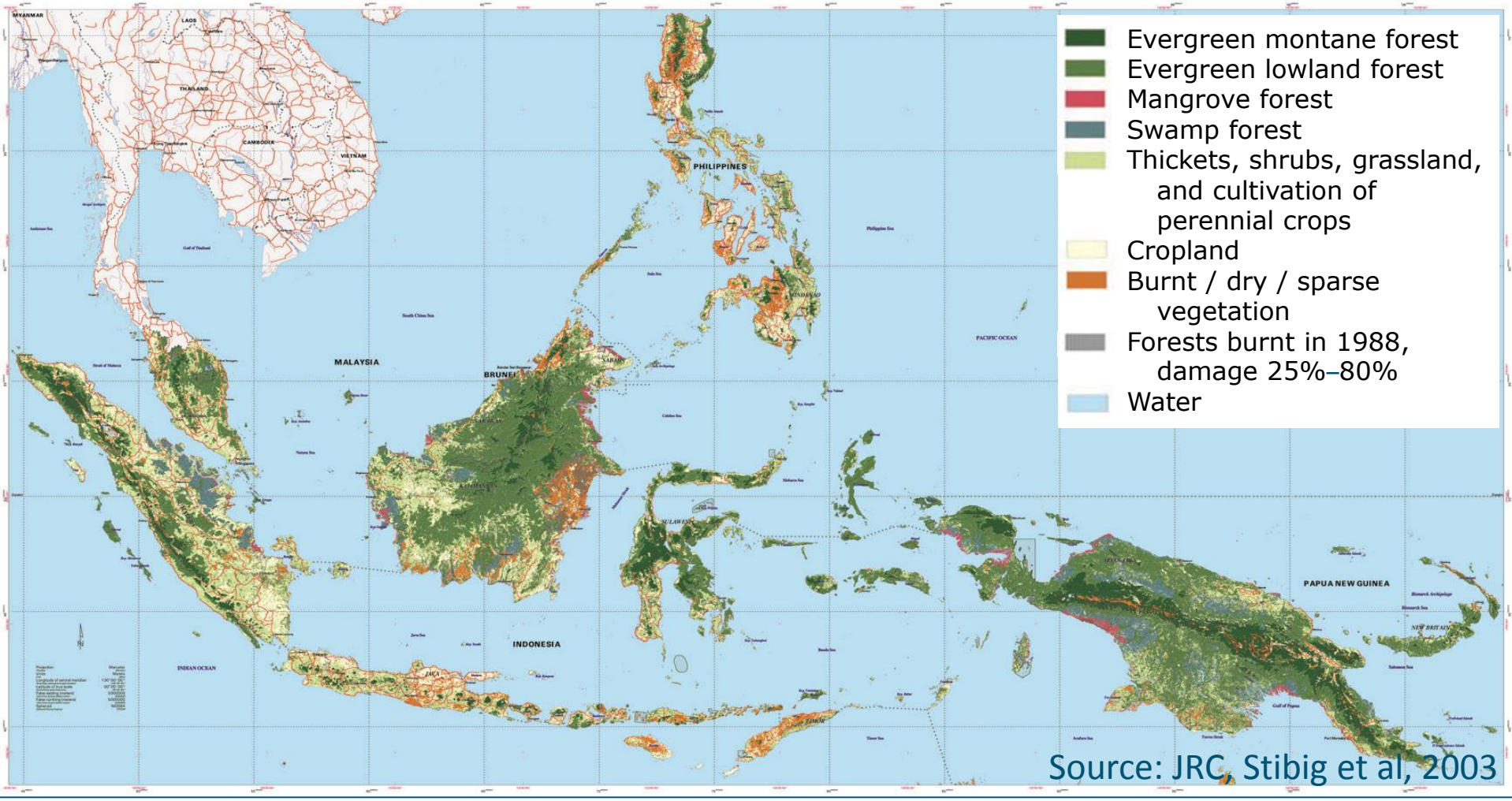
- No agreement on a forest definition currently exists under REDD+.
- Countries can choose their own forest definition as long as they clearly describe the definition.
- KP criteria:
  - Minimum forest area: 0.05 to 1 ha
  - Minimum height of 2–5 m
  - Minimum tree crown cover: 10–30 %

Utility of optical sensors at multiple resolutions for deforestation monitoring

Resolution	Examples of sensors	Minimum mapping unit (change)	Cost	Primary utility for deforestation monitoring
Coarse (250-1000 m)	SPOT-VGT Terra-MODIS Envisat-MERIS Suomi NPP - VIIRS	~ 100 ha ~ 10-20 ha	Low or free	Consistent pan-tropical annual monitoring to identify large clearings and locate "hotspots" for further analysis.
Medium (10-60 m)	Landsat TM, ETM+ and OLI Terra-ASTER IRS AWiFs or LISS III CBERS HRCCD DMC SPOT HRV ALOS AVNIR-2 Sentinel-2 MSI (2015→)	0.5 - 5 ha	Landsat & CBERS are free; for others: <$0.001/km² for historical data $0.02-0.5/km^2 for recent data	Primary tool to map deforestation and estimate forest area change.
Fine (<5 m)	RapidEye IKONOS QuickBird Aerial photos	< 0.1 ha	High to very high $2 -30 /km²	Validation of results from coarser resolution analysis, and training of algorithms.

Source: GOFC GOLD Sourcebook 2014, table 2.1.1.

Example of forest cover map for insular Southeast Asia derived from 1 km SPOT VGT imagery



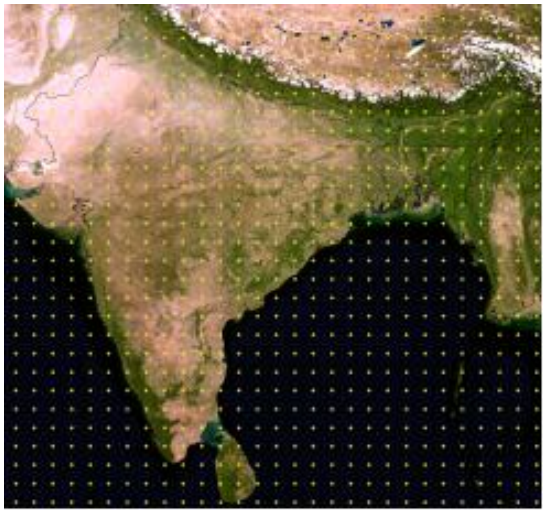
Source: JRC, Stibig et al, 2003

Decision for wall-to-wall versus sample coverage

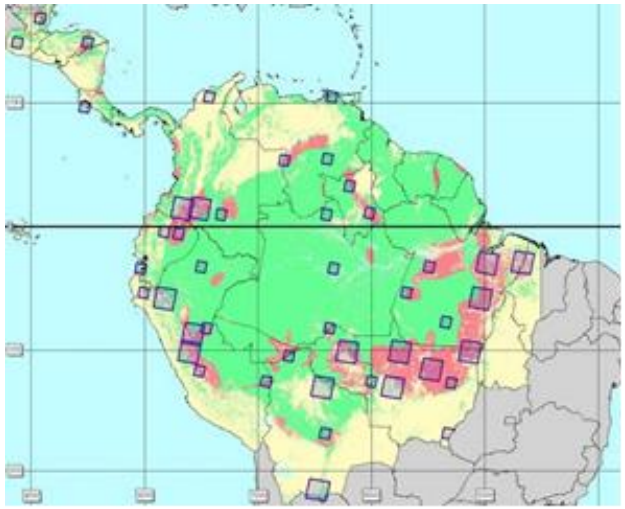
- Wall-to-wall is a common approach if appropriate for national circumstances.
- If resources are not sufficient to complete wall-to-wall coverage, sampling is more efficient for large countries.
- Recommended sampling approaches are systematic sampling and stratified sampling. See GOFC-GOLD Sourcebook (2012, box 2.1.2), next slide.
- A sampling approach in one reporting period could be extended to wall-to-wall coverage in the subsequent period.

Systematic and stratified sampling

- Systematic sampling obtains samples on a regular interval, e.g., one every 10 km.
- Stratified samples are distributed based on proxy variables derived from coarse resolution satellite data or by combining other geo-referenced or map information.



Systematic sampling design



Stratified sampling design

Source: GOFC-GOLD Sourcebook 2013, box 2.1.2.

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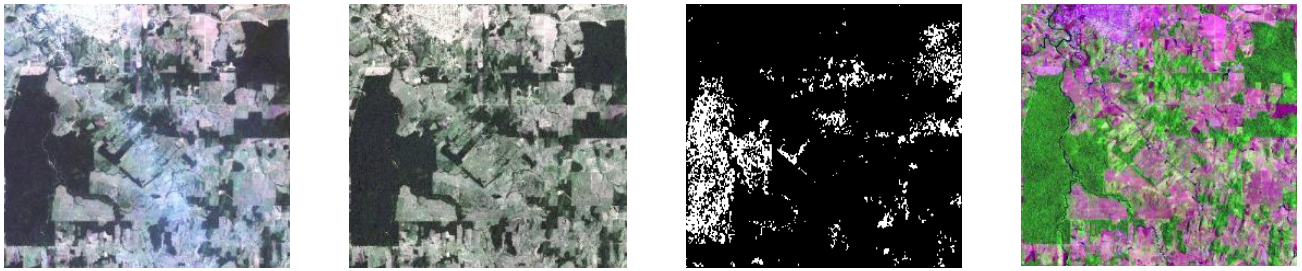
Processing of the satellite data

- Geometric corrections:
  - Location error should be < 1 pixel; baseline datasets (e.g.; GLS) can be used as alternative to GCPs or image-to-image registration
- Cloud and cloud shadow masking:
  - Automated or visual methods to ensure meaningfulness of image interpretation
- Radiometric corrections:
  - Depend on the used image interpretation method, not needed for visual single scene interpretation but crucial for automated multitemporal analysis

Radiometric and atmospheric correction: Example of the EC Joint Research Centre automated preprocessing chain

Calibrated ETM **De-hazed** **Forest mask** **Normalized**



**Year 2000 data >>>>

Main analysis methods for moderate resolution (~ 30 m) imagery

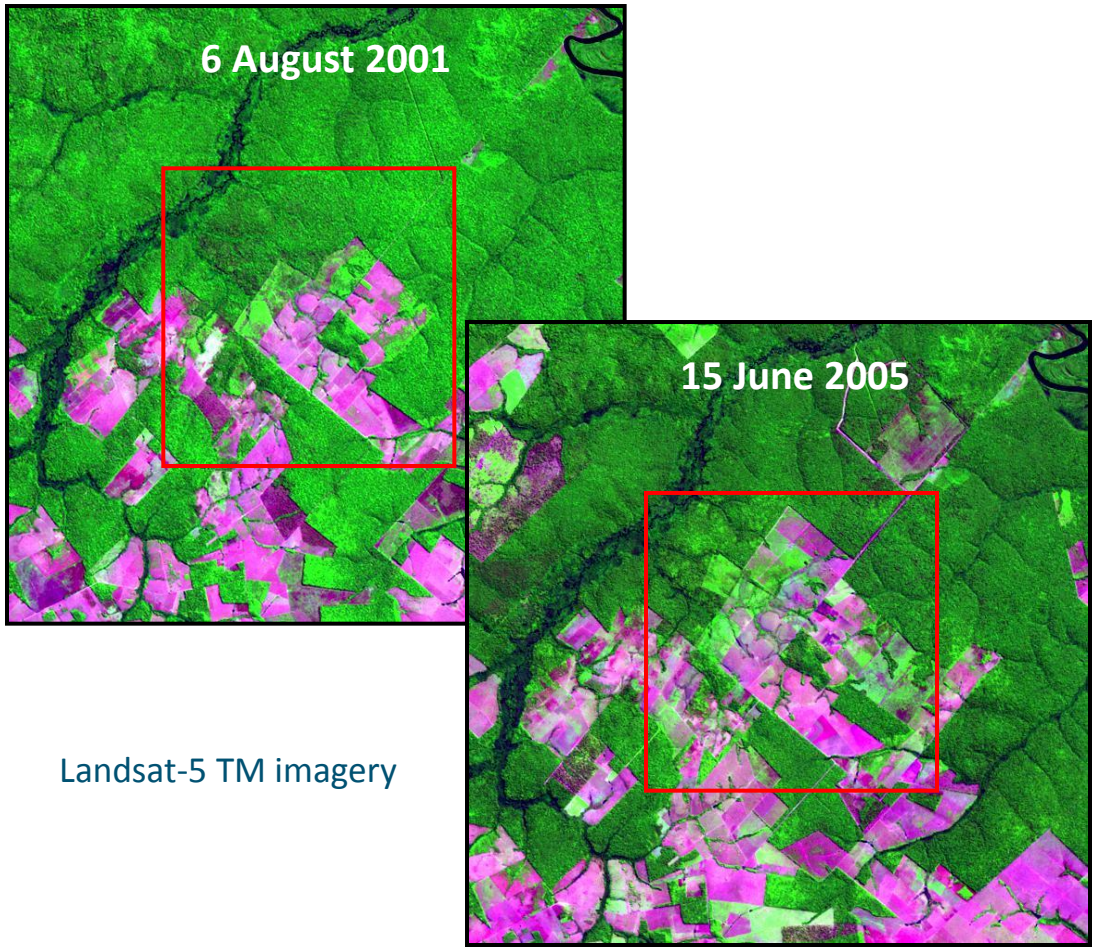
Method for delineation	Method for class labeling	Practical minimum mapping unit	Principles for use	Advantages / limitations
Point interpretation (points sample)	Visual interpretation	< 0.1 ha	- multiple date preferable to single date interpretation - On screen preferable to printouts interpretation	- closest to classical forestry inventories - very accurate although interpreter dependent - no map of changes
Visual delineation (full image)	Visual interpretation	5 – 10 ha	- multiple date analysis preferable - On screen digitizing preferable to delineation on printouts	- easy to implement - time consuming - interpreter dependent
Pixel based classification	Supervised labeling (with training and correction phases)	<1 ha	- selection of common spectral training set from multiple dates / images preferable - filtering needed to avoid noise	- difficult to implement - training phase needed
	Unsupervised clustering + Visual labeling	<1 ha	- interdependent (multiple date) labeling preferable - filtering needed to avoid noise	- difficult to implement - noisy effect without filtering
Object based segmentation	Supervised labeling (with training and correction phases)	1 - 5 ha	- multiple date segmentation preferable - selection of common spectral training set from multiple dates / images preferable	- more reproducible than visual delineation - training phase needed
	Unsupervised clustering + Visual labeling	1 - 5 ha	- multiple date segmentation preferable - interdependent (multiple date) labeling of single date images preferable	- more reproducible than visual delineation

Source: GOFC-GOLD Sourcebook 2013, table 2.1.3.

Multidate image segmentation

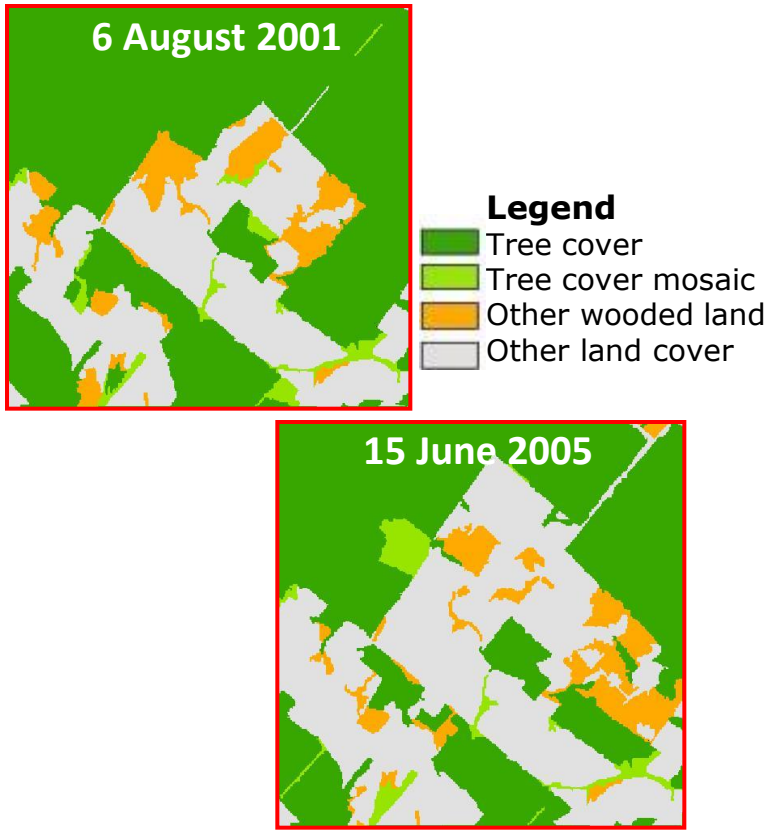
- Automated segmentation reduces processing time and increases detail.
- It is objective and repeatable.
- It delineates changed areas as separate segments.
- Ideally, analysis process would include:
    i. Multidate image segmentation on image pairs
    ii. Training area/class signature selection
    iii. Supervised clustering of individual images
    iv. Visual verification and potential editing

Example of forest cover change derived from Landsat TM imagery over a site in Brazil



Landsat-5 TM imagery

Land cover maps of 2001 to 2005



Sources: USGS 2015, GLS dataset; Eva et al. 2012.

Visual verification

- Visual verification (or classification) is indispensable.
- Verification should take advantage of image pairs.
- Single image pairs are preferred over image mosaics.

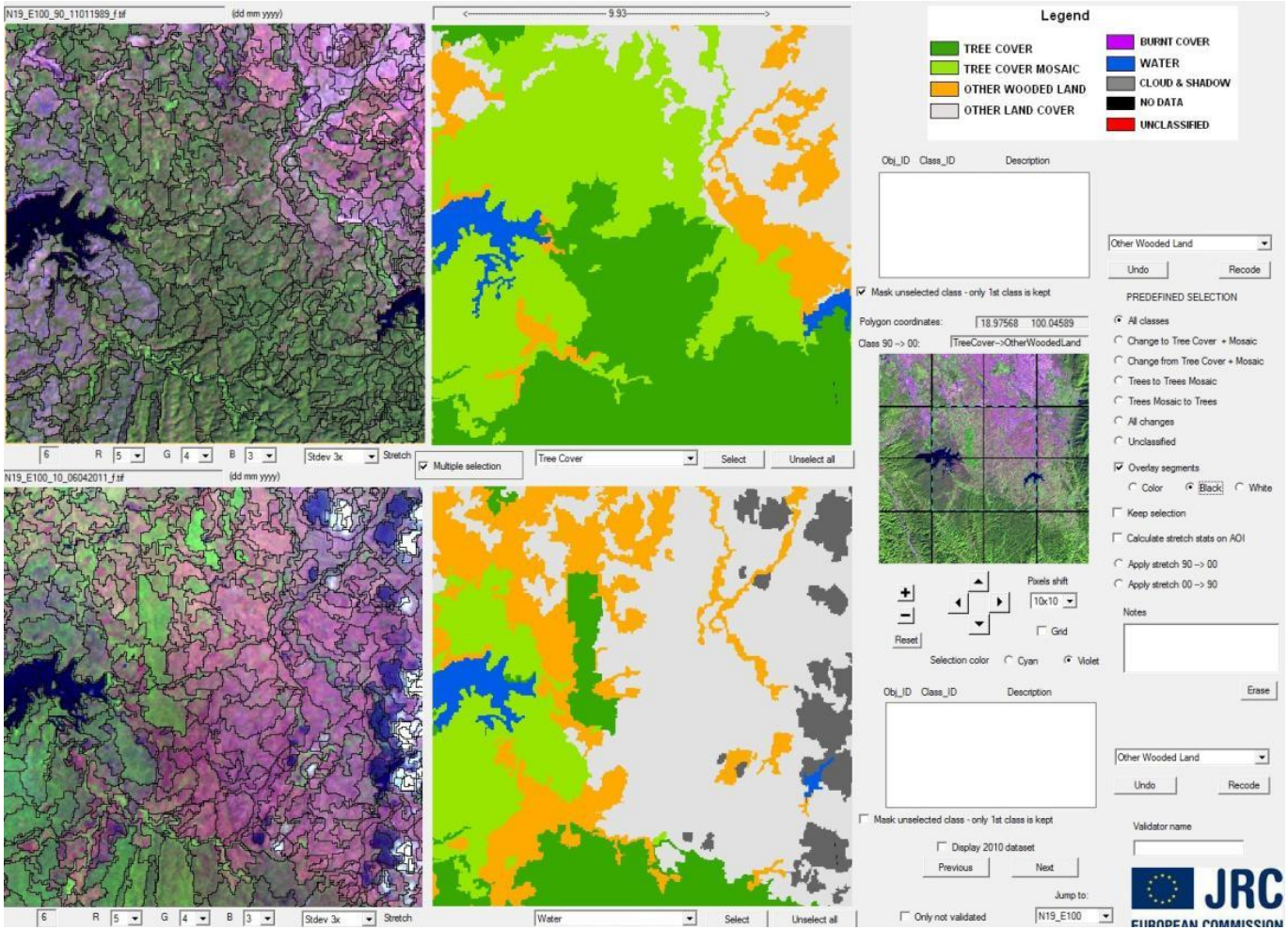
Table 3. Confusion matrix between land cover classes before and after expert review and revision for a sample of year 2000 sites (thousands of hectares).

	Tree	Wooded	Other	Water	No Data	Total	User's
Tree	6957	802	1599	61	33	9451	0.74
Wooded	564	1609	2336	10	2	4521	0.36
Other	580	793	12,684	28	21	14,107	0.90
Water	17	24	92	705	3	840	0.84
No Data	1	3	40	2	103	149	0.69
Total	8120	3230	16,751	805	162	29,069	
Producer's	0.86	0.50	0.76	0.87	0.63		**0.76**

Example of visual validation of the automated JRC-FAO assessment results

Expert validation with tailored validation Tool

Visual Control and Interpretation of automated mapping



Source: USGS 2015, GLS dataset; JRC; Simonetti et al. 2011

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Major sources of limitations

- Clouds and cloud shadows
- Other atmospheric effects (e.g., haze and smoke)
- Effect of topography on reflectance
- Insufficient observation frequency (e.g., humid tropics)
- Scarcity of historical data
- Tradeoff between spatial resolution and coverage
- Problems of intersensor comparability (e.g., in historical time series)

In summary

- The IPCC guidance and UNFCCC decisions provide general guidelines that should be used to develop national forest definitions and monitoring approaches for REDD+ activities.
- Numerous remote sensing data and methods can be used to monitor activity data for forests, preferably with:
  - Multidate image analysis to detect changes
  - Supervised, repeatable classification approaches
  - Visual verification and rigorous accuracy assessment of the resulting maps
- Even with the limitations of satellite observation, remote sensing is indispensable for monitoring activity data for forests in tropical countries.

Recommended modules as follow up

- Module 2.2 to proceed with monitoring activity data for forests remaining forests (incl. forest degradation)
- Module 2.8 for overview and status of evolving technologies, including, for example, radar data
- Modules 3.1 to 3.3 to learn more about REDD+ assessment and reporting