Satellite Land Monitoring Systems: Getting activity data from remote sensing

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Outline

- IPCC framework for consistent land representation
- Annex I countries methodological approaches to report activity data
- Efforts to improve earth observation methodologies
- Methodological solutions for non-Annex I countries

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IPCC FRAMEWORK FOR CONSISTENT LAND REPRESENTATION

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Systems for land representation should be:

- **adequate**, i.e., capable of representing land-use categories, and conversions between land-use categories, as needed to estimate carbon stock changes and greenhouse gas emissions and removals;
- **consistent**, i.e., capable of representing land-use categories consistently over time, without being unduly affected by artificial discontinuities in time-series data;
- **complete**, which means that all land within a country should be included, with increases in some areas balanced by decreases in others, recognizing the bio-physical stratification of land if needed (and as can be supported by data) for estimating and reporting emissions and removals of greenhouse gases; and
- **transparent**, i.e., data sources, definitions, methodologies and assumptions should be clearly described.

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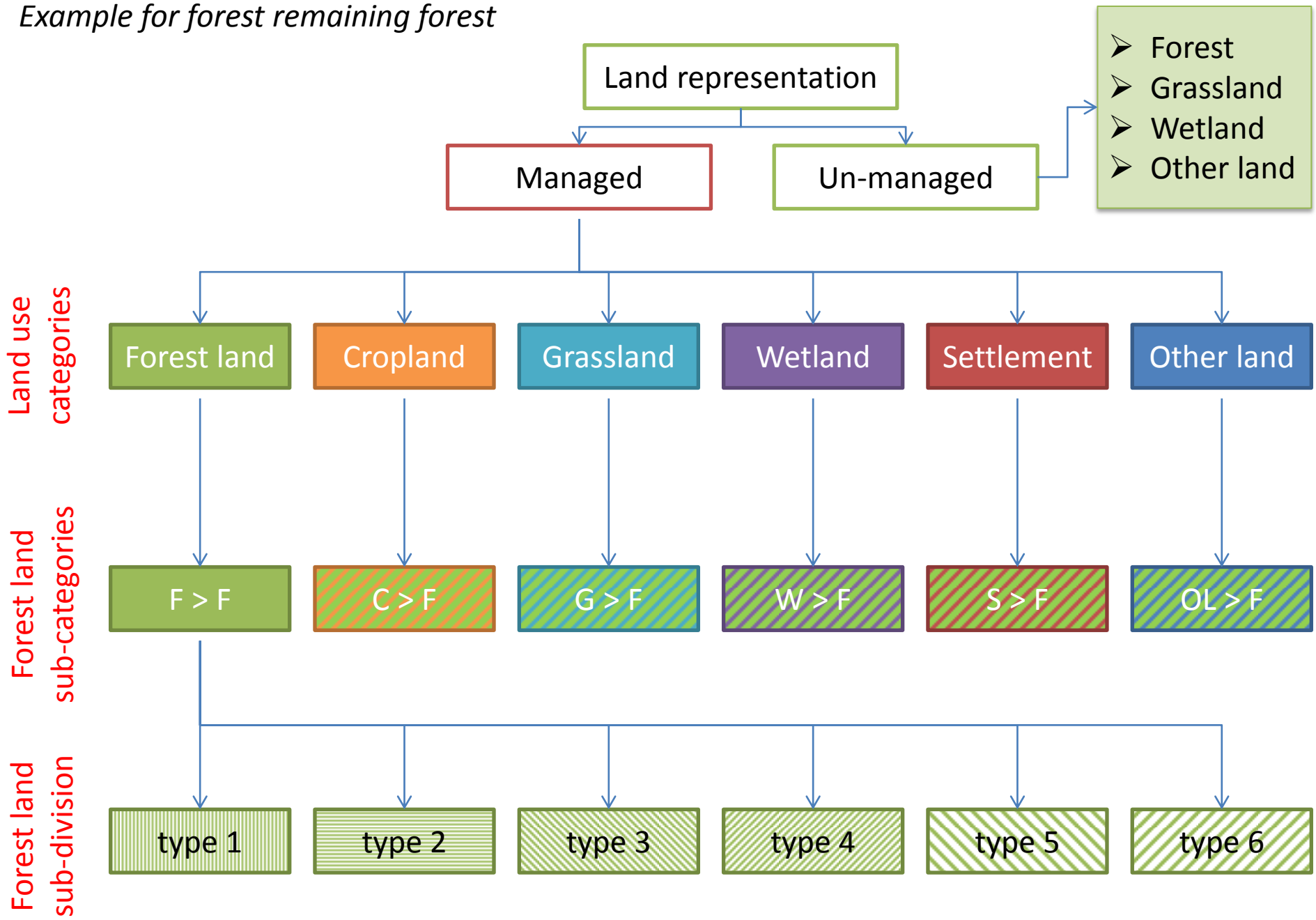
Land representation follow the framework of:

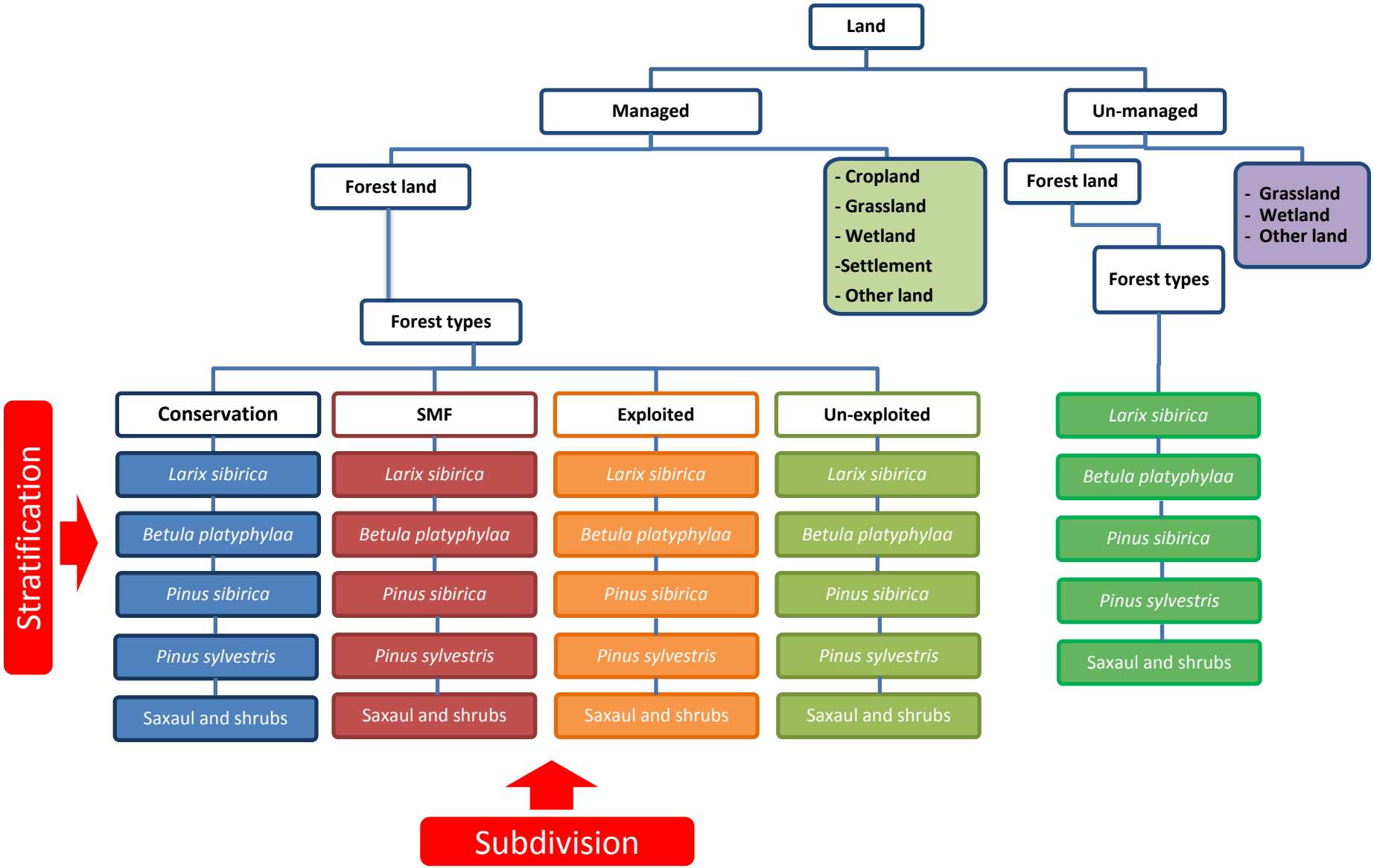
- **Land-use category** - is the broad land use (one of the six land-use categories described below) reported as either land remaining in a land-use category (i.e., remaining in the same use throughout the inventory timeseries) or land converted to a new land-use category (representing a change in land use).
- **Land use sub-category** - refers to special circumstances (e.g., areas of grazing within Forest Land) that are estimated and reported separately but do not duplicate land in the broad land-use category.
- **Land-use sub-division** Land-use categories and sub-categories may be further stratified on the basis of land-use practices and biophysical characteristics in order to create more homogeneous spatial units as may be used for emissions estimation

IPCC Land Representation Framework

Example for forest remaining forest



Potential Mongolia's Forest Land Stratification & GHG Reporting Sub-Divisions for REDD+



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Within the IPCC Land Representation Framework there are three methodological approaches:

- Approach 1: Basic land-use data
- Approach 2: Survey of land use and land-use change
- Approach 3: Geographically explicit land use data

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APPROACH 1: BASIC LAND-USE DATA

Approach 1 uses area datasets likely to have been prepared for other purposes such as forestry or agricultural statistics. The absence of a unified data system can lead to double counting or omission, since the agencies involved may use different definitions of specific land use for assembling their databases. Coverage must obviously be complete enough to include all land areas affected by the activities set out in the *IPCC Guidelines,* but might not extend to categories such as unmanaged ecosystems, wetlands or settlements.

TABLE 3.2
EXAMPLE OF APPROACH 1: AVAILABLE LAND USE DATA WITH COMPLETE NATIONAL COVERAGE

Time 1			Time 2			Net land-use conversion between Time 1 and Time 2		
F	=	18	F	=	19	Forest Land	=	+1
G	=	84	G	=	82	Grassland	=	-2
C	=	31	C	=	29	Cropland	=	-2
W	=	0	W	=	0	Wetlands	=	0
S	=	5	S	=	8	Settlements	=	+3
O	=	2	O	=	2	Other Land	=	0
Sum	=	140	Sum	=	140	Sum	=	0

Note: F = Forest Land, G = Grassland, C = Cropland, W = Wetlands, S = Settlements, O = Other Land. Numbers represent area units (Mha in this example).

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APPROACH 2: SURVEY OF LAND USE AND LAND-USE CHANGE

The essential feature of Approach 2 is that it provides a national or regional-scale assessment of not only the losses or gains in the area of specific land categories but what these changes represent (i.e., changes from and to a category). Tracking land-use changes in this explicit manner will normally require estimation of initial and final land-use categories, as well as of total area of unchanged land by category. The final result of this approach can be presented as a non spatially explicit land-use change matrix.

TABLE 3.6
SIMPLIFIED LAND-USE CONVERSION MATRIX FOR APPROACH 2 EXAMPLE

Net land-use conversion matrix

Final \ Initial	F	G	C	W	S	O	*Final sum*
F	**15**	3	1				***19***
G	2	**80**					***82***
C			**29**				***29***
W				**0**			***0***
S	1	1	1		**5**		***8***
O						**2**	***2***
Initial sum	***18***	***84***	***31***	***0***	***5***	***2***	***140***

Note:
F = Forest Land, G = Grassland, C = Cropland, W = Wetlands,
S = Settlements, O = Other Land

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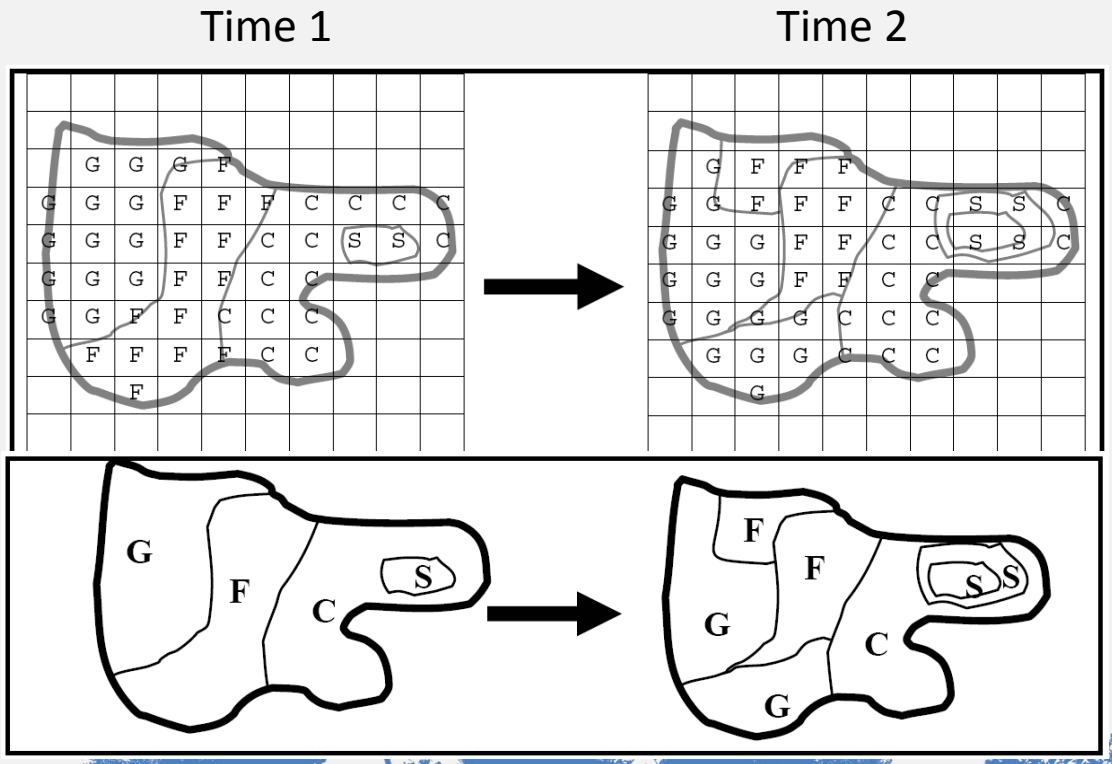
APPROACH 3: GEOGRAPHICALLY EXPLICIT LAND USE DATA

Approach 3 requires spatially explicit observations of land use and land-use change. The data may be obtained either by sampling of geographically located points, a complete tally (wall-to-wall mapping), or a combination of the two. Approach 3 is comprehensive and relatively simple conceptually but data intensive to implement.



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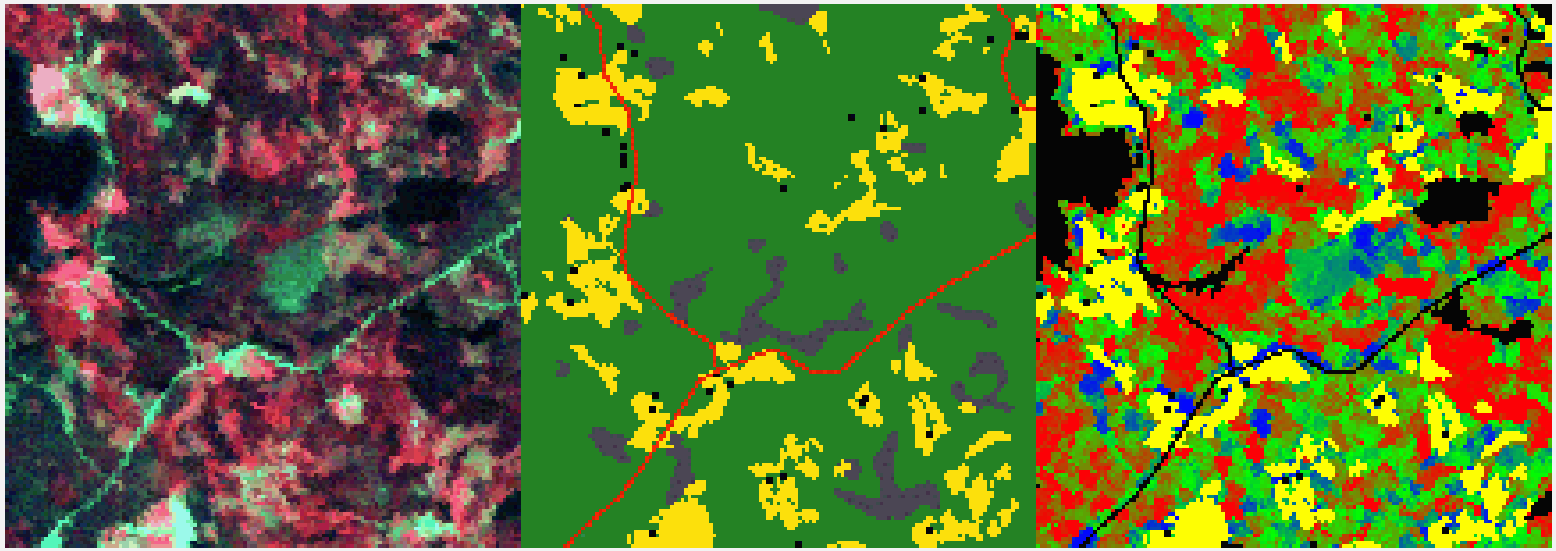
APPROACH 3: GEOGRAPHICALLY EXPLICIT LAND USE DATA

By wall-to-wall mapping



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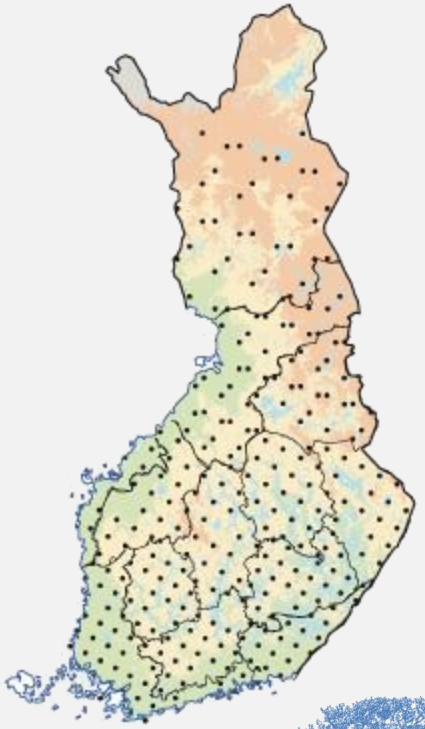
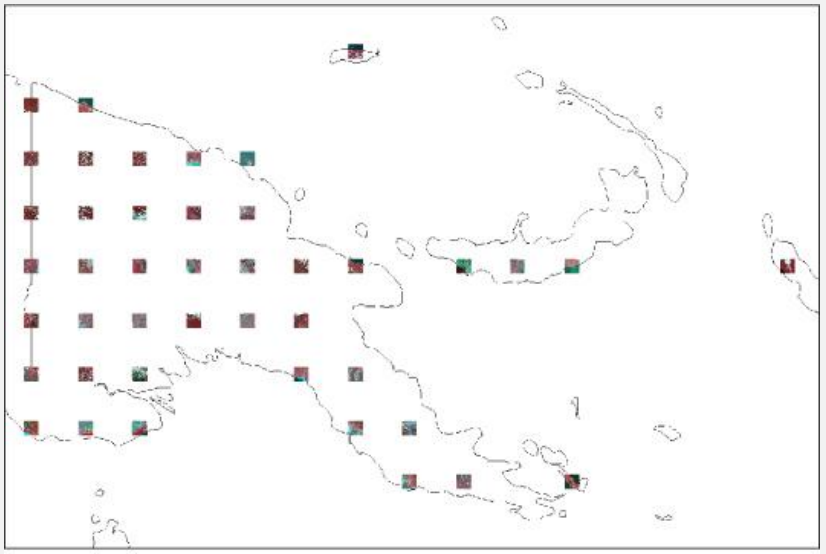
APPROACH 3: GEOGRAPHICALLY EXPLICIT LAND USE DATA

by sampling of geographically

located points or area subsets





Sample frame: geographical grid (a sample at each $1^\circ \times 1^\circ$)
Sample size: 20×20 km^2 (with extracts of Landsat imagery for year 2000)

Activity Data in the GHG Inventory

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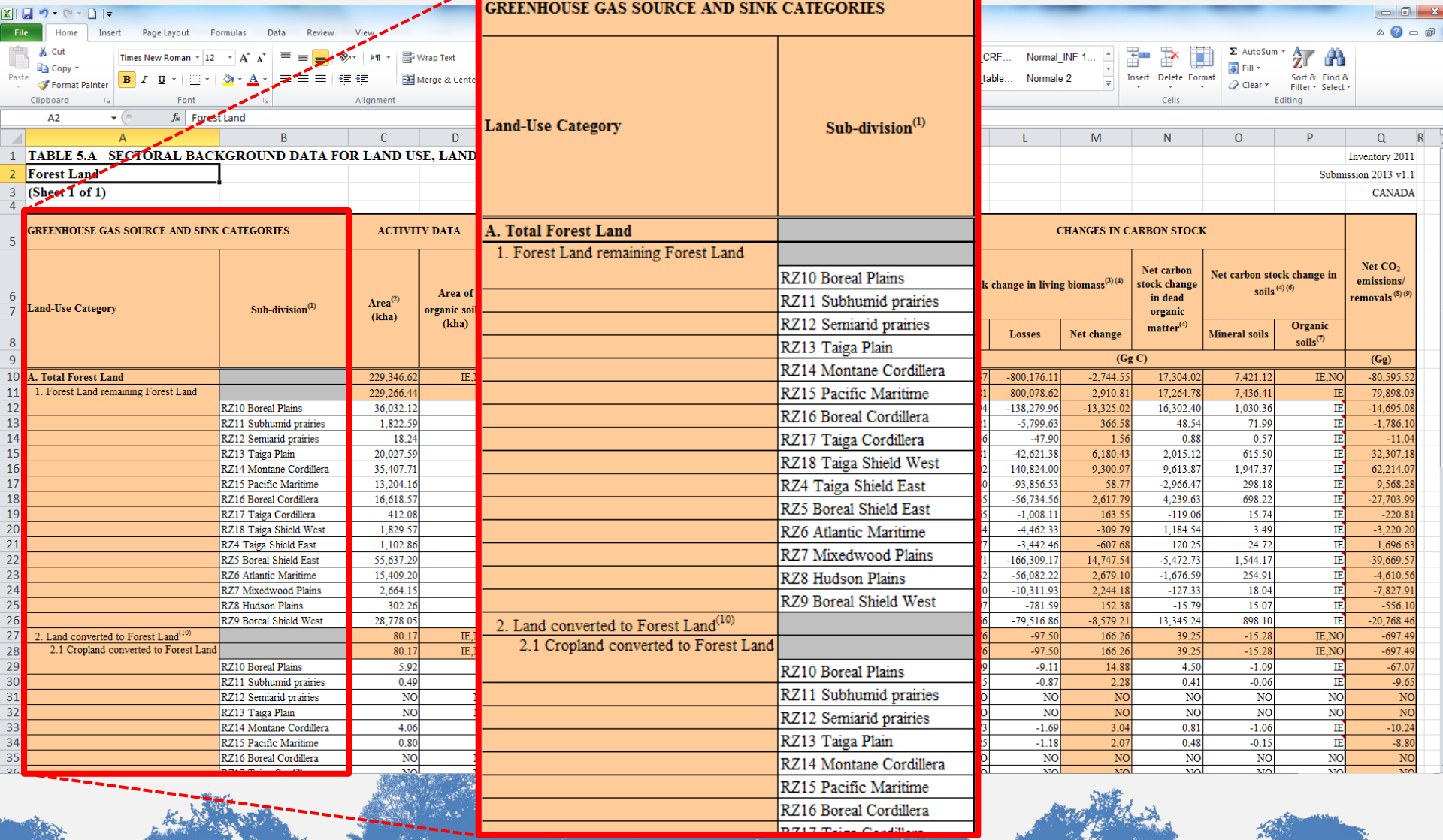

TABLE 5.A SECTORAL BACKGROUND DATA FOR LAND USE, LAND

Forest Land

(Sheet 1 of 1)

Inventory 2011

Submission 2013 v1.1

CANADA

GREENHOUSE GAS SOURCE AND SINK CATEGORIES		ACTIVITY DATA		CHANGES IN CARBON STOCK					
Land-Use Category	Sub-division[1]	Area[2] (kha)	Area of organic soil (kha)	k change in living biomass[3][4]		Net carbon stock change in dead organic matter[4]	Net carbon stock change in soils[4][6]		Net CO_2 emissions/ removals[8][9]
				Losses	Net change		Mineral soils	Organic soils[7]	
				(Gg C)					(Gg)
A. Total Forest Land		229,346.62	IE,	7	-800,176.11	-2,744.55	17,304.02	7,421.12	IE,NO	-80,595.52
1. Forest Land remaining Forest Land		229,266.44		1	-800,078.62	-2,910.81	17,264.78	7,436.41	IE	-79,898.03
	RZ10 Boreal Plains	36,032.12		4	-138,279.96	-13,325.02	16,302.40	1,030.36	IE	-14,695.08
	RZ11 Subhumid prairies	1,822.59		1	-5,799.63	366.58	48.54	71.99	IE	-1,786.10
	RZ12 Semiarid prairies	18.24		6	-47.90	1.56	0.88	0.57	IE	-11.04
	RZ13 Taiga Plain	20,027.59		1	-42,621.38	6,180.43	2,015.12	615.50	IE	-32,307.18
	RZ14 Montane Cordillera	35,407.71		2	-140,824.00	-9,300.97	-9,613.87	1,947.37	IE	62,214.07
	RZ15 Pacific Maritime	13,204.16		0	-93,856.53	58.77	-2,966.47	298.18	IE	9,568.28
	RZ16 Boreal Cordillera	16,618.57		5	-56,734.56	2,617.79	4,239.63	698.22	IE	-27,703.99
	RZ17 Taiga Cordillera	412.08		5	-1,008.11	163.55	-119.06	15.74	IE	-220.81
	RZ18 Taiga Shield West	1,829.57		4	-4,462.33	-309.79	1,184.54	3.49	IE	-3,220.20
	RZ4 Taiga Shield East	1,102.86		7	-3,442.46	-607.68	120.25	24.72	IE	1,696.63
	RZ5 Boreal Shield East	55,637.29		1	-166,309.17	14,747.54	-5,472.73	1,544.17	IE	-39,669.57
	RZ6 Atlantic Maritime	15,409.20		2	-56,082.22	2,679.10	-1,676.59	254.91	IE	-4,610.56
	RZ7 Mixedwood Plains	2,664.15		0	-10,311.93	2,244.18	-127.33	18.04	IE	-7,827.91
	RZ8 Hudson Plains	302.26		7	-781.59	152.38	-15.79	15.07	IE	-556.10
	RZ9 Boreal Shield West	28,778.05		6	-79,516.86	-8,579.21	13,345.24	898.10	IE	-20,768.46
2. Land converted to Forest Land[10]		80.17	IE,	6	-97.50	166.26	39.25	-15.28	IE,NO	-697.49
2.1 Cropland converted to Forest Land		80.17	IE,	6	-97.50	166.26	39.25	-15.28	IE,NO	-697.49
	RZ10 Boreal Plains	5.92		9	-9.11	14.88	4.50	-1.09	IE	-67.07
	RZ11 Subhumid prairies	0.49		5	-0.87	2.28	0.41	-0.06	IE	-9.65
	RZ12 Semiarid prairies	NO		O	NO	NO	NO	NO	NO	NO
	RZ13 Taiga Plain	NO		O	NO	NO	NO	NO	NO	NO
	RZ14 Montane Cordillera	4.06		3	-1.69	3.04	0.81	-1.06	IE	-10.24
	RZ15 Pacific Maritime	0.80		5	-1.18	2.07	0.48	-0.15	IE	-8.80
	RZ16 Boreal Cordillera	NO		O	NO	NO	NO	NO	NO	NO

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	
Land-Use Category	Sub-division[1]
A. Total Forest Land	
1. Forest Land remaining Forest Land	
	RZ10 Boreal Plains
	RZ11 Subhumid prairies
	RZ12 Semiarid prairies
	RZ13 Taiga Plain
	RZ14 Montane Cordillera
	RZ15 Pacific Maritime
	RZ16 Boreal Cordillera
	RZ17 Taiga Cordillera
	RZ18 Taiga Shield West
	RZ4 Taiga Shield East
	RZ5 Boreal Shield East
	RZ6 Atlantic Maritime
	RZ7 Mixedwood Plains
	RZ8 Hudson Plains
	RZ9 Boreal Shield West
2. Land converted to Forest Land[10]	
2.1 Cropland converted to Forest Land	
	RZ10 Boreal Plains
	RZ11 Subhumid prairies
	RZ12 Semiarid prairies
	RZ13 Taiga Plain
	RZ14 Montane Cordillera
	RZ15 Pacific Maritime
	RZ16 Boreal Cordillera

Activity Data for GHG Inventory

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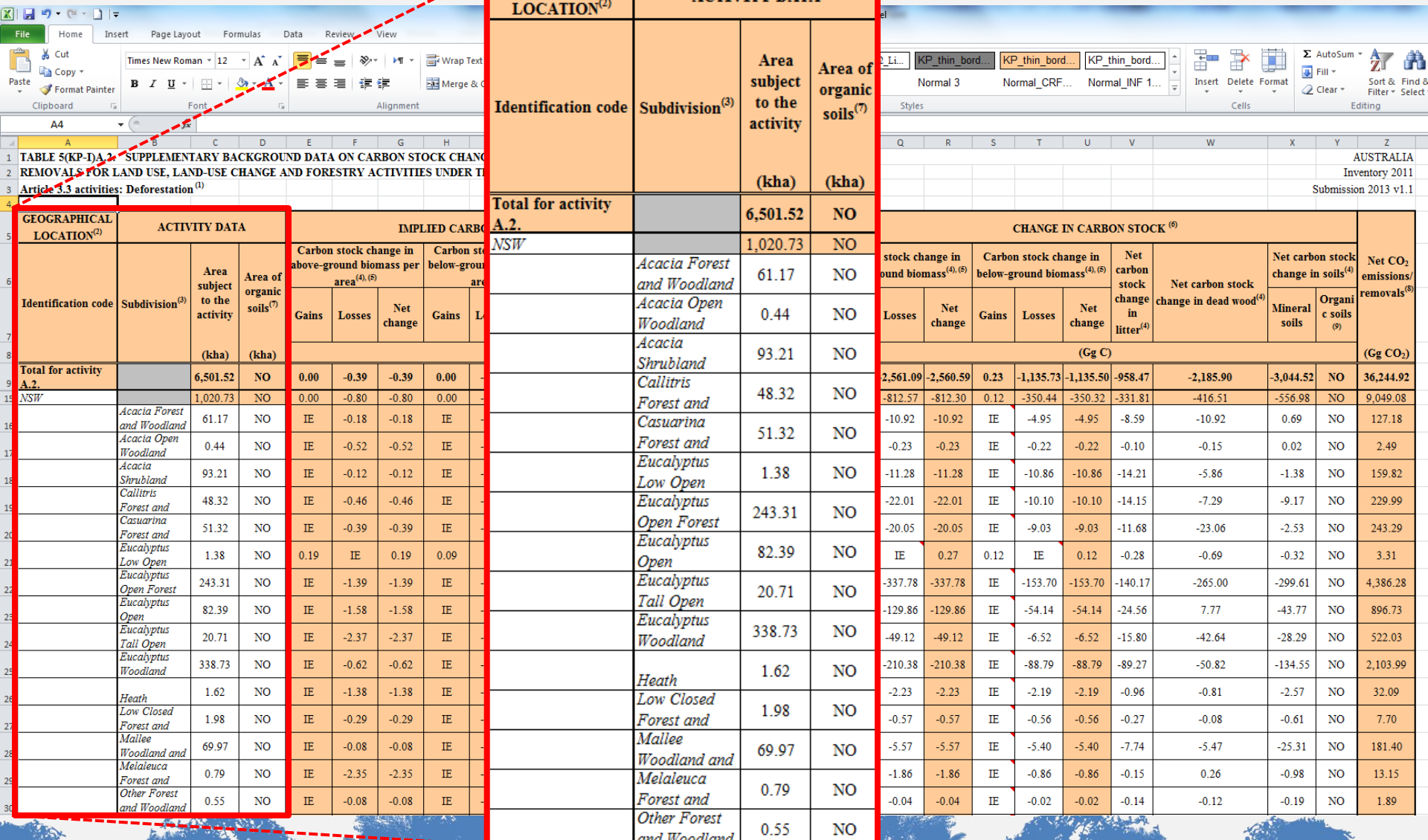


TABLE 5(KP-I)A.2 SUPPLEMENTARY BACKGROUND DATA ON CARBON STOCK CHANG
REMOVALS FOR LAND USE, LAND-USE CHANGE AND FORESTRY ACTIVITIES UNDER T
Article 3.3 activities: Deforestation (1)

AUSTRALIA
Inventory 2011
Submission 2013 v1.1

GEOGRAPHICAL LOCATION(2)	ACTIVITY DATA			IMPLIED CARBO				
Identification code	Subdivision(3)	Area subject to the activity	Area of organic soils(7)	Carbon stock change in above-ground biomass per area(4), (5)			Carbon st below-grou are	
		(kha)	(kha)	Gains	Losses	Net change	Gains	L
Total for activity A.2.		**6,501.52**	**NO**	**0.00**	**-0.39**	**-0.39**	**0.00**	
NSW		1,020.73	NO	0.00	-0.80	-0.80	0.00	
	Acacia Forest and Woodland	61.17	NO	IE	-0.18	-0.18	IE	
	Acacia Open Woodland	0.44	NO	IE	-0.52	-0.52	IE	
	Acacia Shrubland	93.21	NO	IE	-0.12	-0.12	IE	
	Callitris Forest and	48.32	NO	IE	-0.46	-0.46	IE	
	Casuarina Forest and	51.32	NO	IE	-0.39	-0.39	IE	
	Eucalyptus Low Open	1.38	NO	0.19	IE	0.19	0.09	
	Eucalyptus Open Forest	243.31	NO	IE	-1.39	-1.39	IE	
	Eucalyptus Open	82.39	NO	IE	-1.58	-1.58	IE	
	Eucalyptus Tall Open	20.71	NO	IE	-2.37	-2.37	IE	
	Eucalyptus Woodland	338.73	NO	IE	-0.62	-0.62	IE	
	Heath	1.62	NO	IE	-1.38	-1.38	IE	
	Low Closed Forest and	1.98	NO	IE	-0.29	-0.29	IE	
	Mallee Woodland and	69.97	NO	IE	-0.08	-0.08	IE	
	Melaleuca Forest and	0.79	NO	IE	-2.35	-2.35	IE	
	Other Forest and Woodland	0.55	NO	IE	-0.08	-0.08	IE	

GEOGRAPHICAL LOCATION(2)	ACTIVITY DATA		
Identification code	Subdivision(3)	Area subject to the activity	Area of organic soils(7)
		(kha)	(kha)
Total for activity A.2.		**6,501.52**	**NO**
NSW		1,020.73	NO
	Acacia Forest and Woodland	61.17	NO
	Acacia Open Woodland	0.44	NO
	Acacia Shrubland	93.21	NO
	Callitris Forest and	48.32	NO
	Casuarina Forest and	51.32	NO
	Eucalyptus Low Open	1.38	NO
	Eucalyptus Open Forest	243.31	NO
	Eucalyptus Open	82.39	NO
	Eucalyptus Tall Open	20.71	NO
	Eucalyptus Woodland	338.73	NO
	Heath	1.62	NO
	Low Closed Forest and	1.98	NO
	Mallee Woodland and	69.97	NO
	Melaleuca Forest and	0.79	NO
	Other Forest and Woodland	0.55	NO

CHANGE IN CARBON STOCK (6)										Net CO_2 emissions/ removals(8)
stock change in ound biomass(4), (5)		Carbon stock change in below-ground biomass(4), (5)			Net carbon stock change in litter(4)	Net carbon stock change in dead wood(4)	Net carbon stock change in soils(4)			
Losses	Net change	Gains	Losses	Net change			Mineral soils	Organic soils (9)		
(Gg C)										(Gg CO_2)
2,561.09	-2,560.59	0.23	-1,135.73	-1,135.50	-958.47	-2,185.90	-3,044.52	NO		36,244.92
-812.57	-812.30	0.12	-350.44	-350.32	-331.81	-416.51	-556.98	NO		9,049.08
-10.92	-10.92	IE	-4.95	-4.95	-8.59	-10.92	0.69	NO		127.18
-0.23	-0.23	IE	-0.22	-0.22	-0.10	-0.15	0.02	NO		2.49
-11.28	-11.28	IE	-10.86	-10.86	-14.21	-5.86	-1.38	NO		159.82
-22.01	-22.01	IE	-10.10	-10.10	-14.15	-7.29	-9.17	NO		229.99
-20.05	-20.05	IE	-9.03	-9.03	-11.68	-23.06	-2.53	NO		243.29
IE	0.27	0.12	IE	0.12	-0.28	-0.69	-0.32	NO		3.31
-337.78	-337.78	IE	-153.70	-153.70	-140.17	-265.00	-299.61	NO		4,386.28
-129.86	-129.86	IE	-54.14	-54.14	-24.56	7.77	-43.77	NO		896.73
-49.12	-49.12	IE	-6.52	-6.52	-15.80	-42.64	-28.29	NO		522.03
-210.38	-210.38	IE	-88.79	-88.79	-89.27	-50.82	-134.55	NO		2,103.99
-2.23	-2.23	IE	-2.19	-2.19	-0.96	-0.81	-2.57	NO		32.09
-0.57	-0.57	IE	-0.56	-0.56	-0.27	-0.08	-0.61	NO		7.70
-5.57	-5.57	IE	-5.40	-5.40	-7.74	-5.47	-25.31	NO		181.40
-1.86	-1.86	IE	-0.86	-0.86	-0.15	0.26	-0.98	NO		13.15
-0.04	-0.04	IE	-0.02	-0.02	-0.14	-0.12	-0.19	NO		1.89

Which approach should be used for non-Annex I :

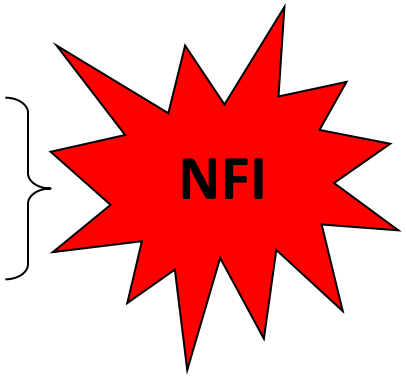
IPCC indication: Countries should characterize and account for all relevant land areas in a country consistently and as transparently as possible. Data should reflect the historical trends in land-use area.

IPCC 2003 LULUCF Guidance suggests three Approaches*:

Approach 1: Basic land-use data

Approach 2: Survey of land use and land-use change

Approach 3: Geographically explicit land use data



In almost all the developing countries there are no NFIs that could be use to assess historical trends in land-use area, the only way to represent land in a consistently and transparently approach with a time frame of 20 years backward is the use of satellite remote sensing data which allows to follow the Approach 3. Thus NFI will not be directly used to assess activity data.

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ANNEX I COUNTRIES METHODOLOGICAL APPROACHES TO REPORT ACTIVITY DATA

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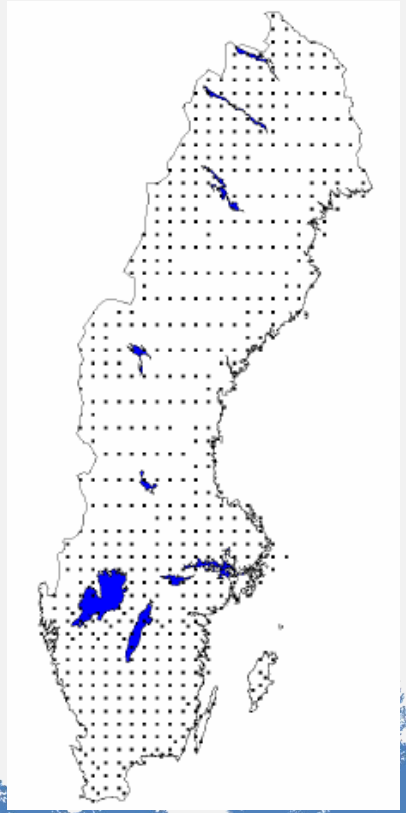
All Annex I countries use IPCC Approach 3 to assess activity data:

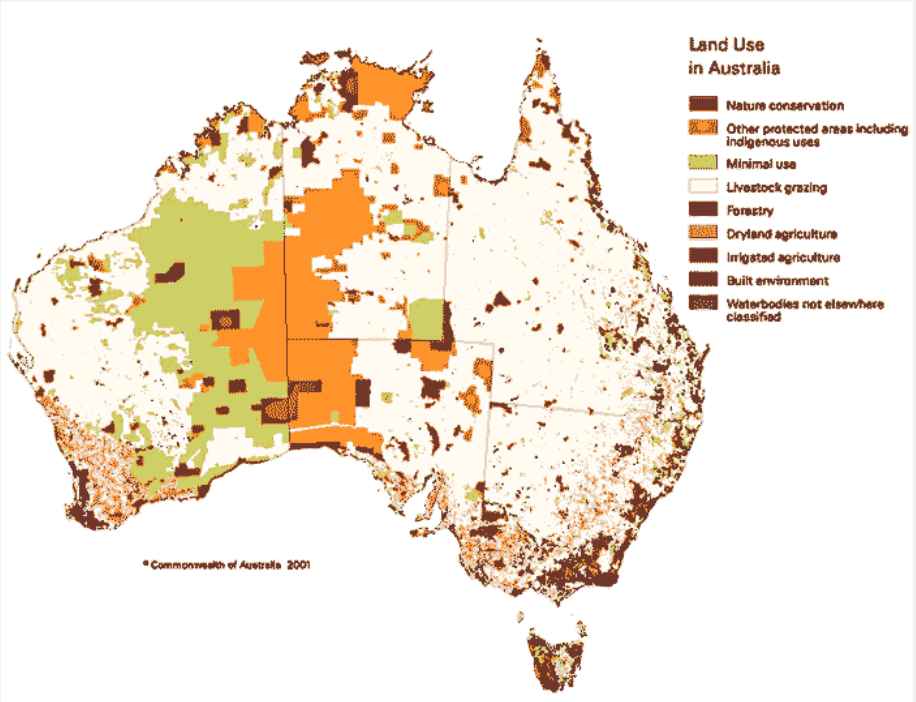
Most countries use sampling approaches

Few countries use wall to wall approaches

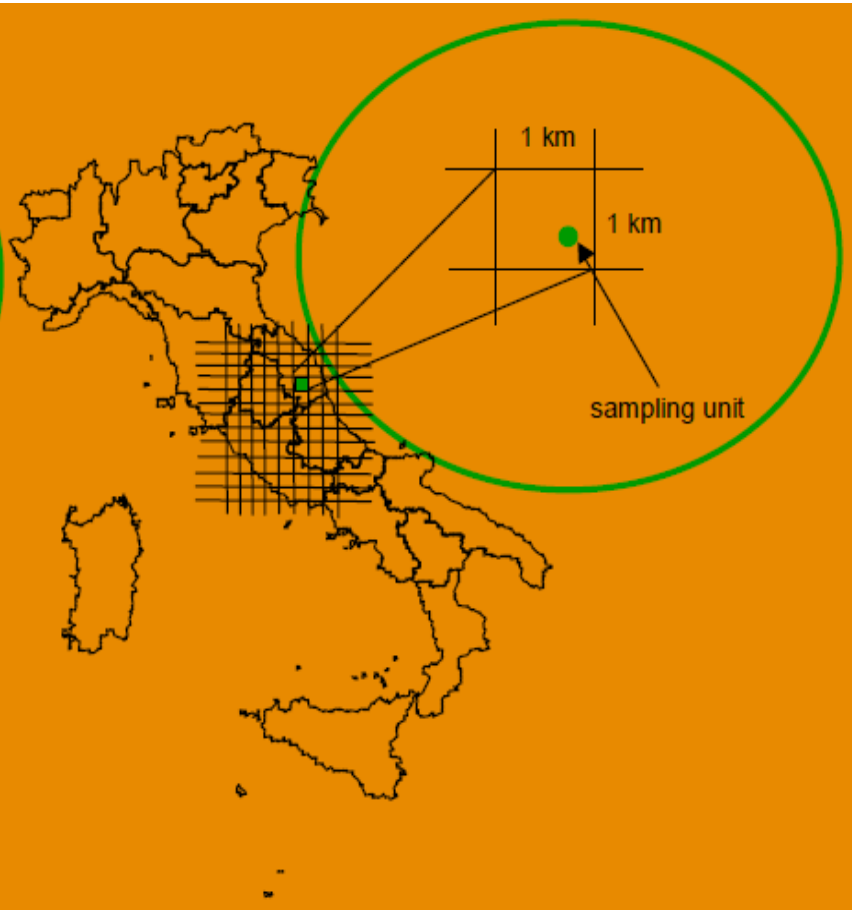
Sweden



Australia



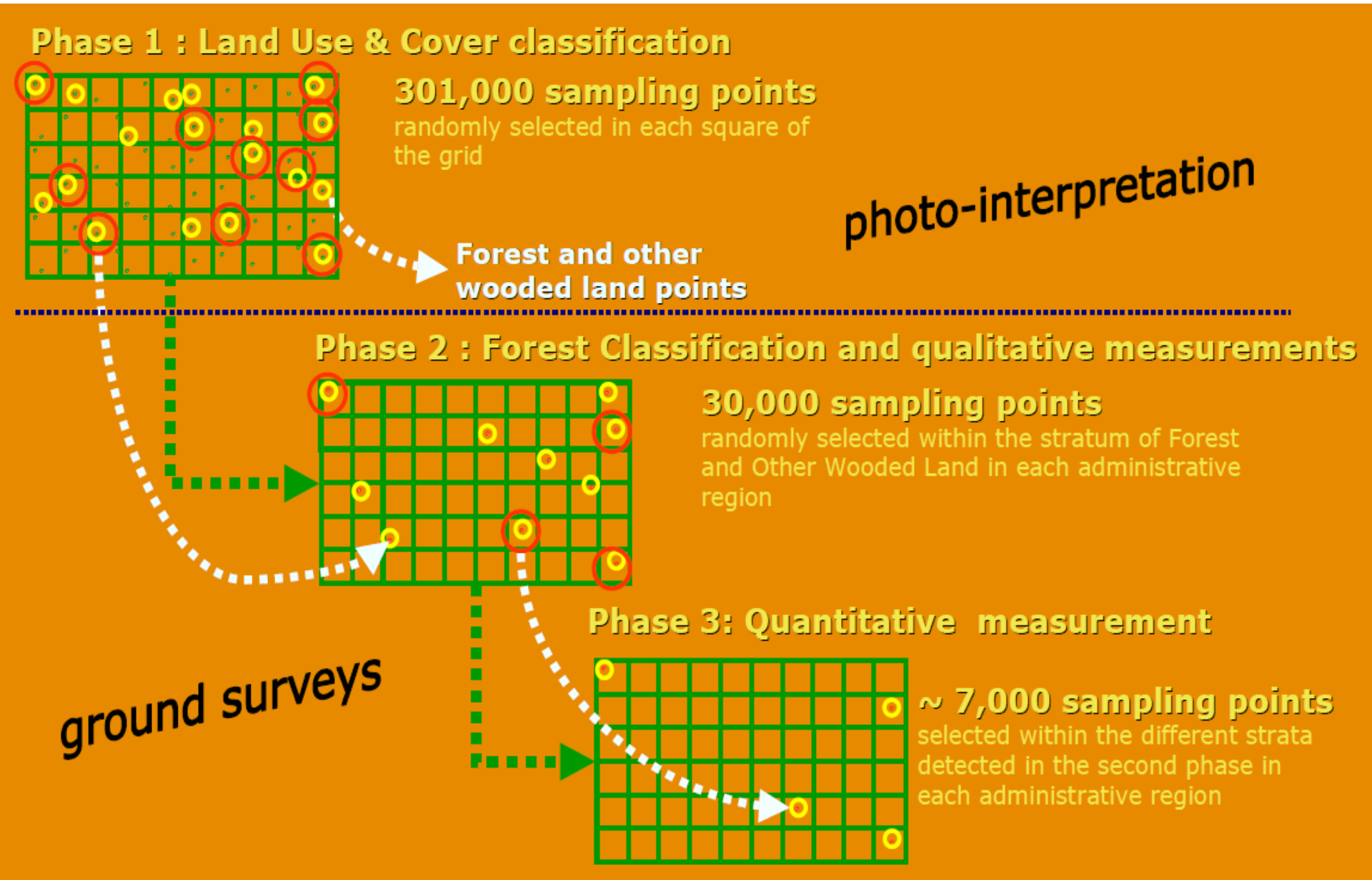
The Italian sampling system (within NFI)



IFNI85
30,000 sampling units
Aligned Systematic Sampling
One-phase Sampling Design

INFC2005
300,000 sampling units
Unaligned Systematic Sampling
Three-phase Sampling Design

The Italian sampling system (within NFI)



Inventory concept

There are more than 500 million trees in Switzerland - far too many to investigate individually. Random sampling, however, yields adequate information. For that purpose a 1km-grid was mapped over Switzerland in the first NFI. The intersections defined the location of the sample plots in the forest.

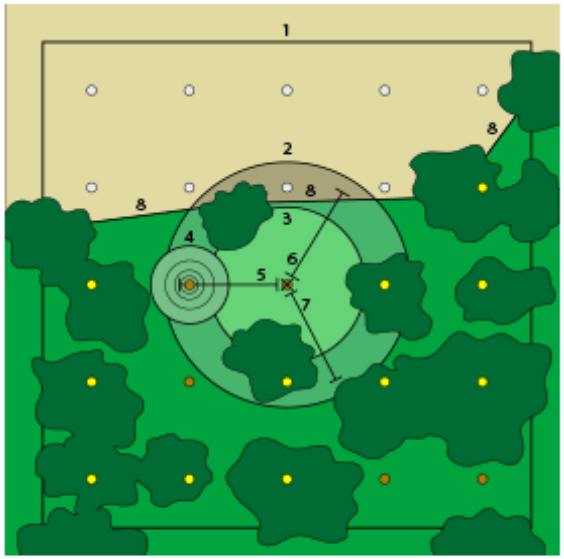
Since the second NFI, only half of these plots, roughly 6500, have been located in the field. The grid, which originally had a mesh size of 1 km, was extendend to 1.4 km. To compensate for this reduction, the aerial photos were interpreted in a grid of 500 m.

The same methods have been carried out since switching from a periodic to a continuous survey in the fourth NFI, but the sample plots are now located over a period of nine years. Thereby another ninth of the sample plots, which are evenly distributed all over Switzerland, are surveyed every year.

Circles and radii of sample plots

The center of the sample plot is marked by a metal pole in the ground. Roughly 130,000 sample trees were measured in the NFI1 and marked so as they can be found again in later inventories. Thanks to the exact sketches, about 98% of the sample plots could be found directly during the NFI2 without having to search for them. In the NFI4, the position of the centers of the sample plots are located exactly with a GPS.

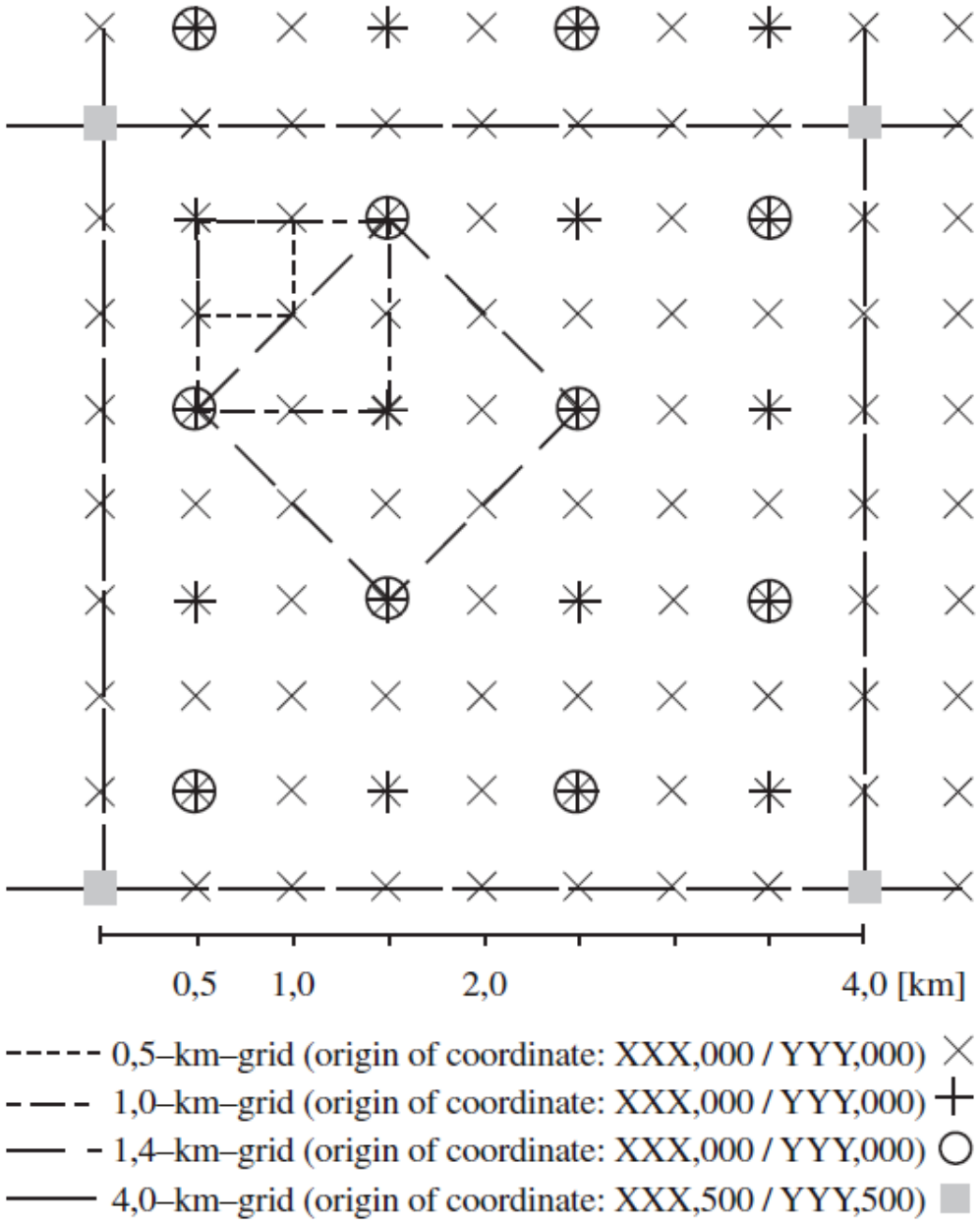
Within a 200 m^2 circle, every tree which has a diameter larger than 12 cm is recorded, and within a 500 m^2 circle, every tree which has a diameter larger than 36 cm is recorded. These diameters are measured at a height of 1.3 m (diameter at breast height DBH). The radii are 7.98 m (r_1) and 12.62 m (r_2) on level terrain.



1 NFI3 sample plot
2 circle for survey of trees with a DBH greater than 36 cm.
3 circle for survey of trees with a DBH greater than 12 cm
4, 5 circle for survey of young forest
5, 6, 7 transect for survey of deadwood
X sample plot center

Movie of the first NFI (1983) (in German)

Swiss NFI sampling design



For the aerial photo sample plots, a square sample grid with a 0.5 km mesh width (0.5-kmgrid) was chosen. For the terrestrial sample plots a coarser grid with 1.4 km (= √2 km) mesh width (1.4-km-grid) was chosen. The 1.4-km-grid and the 1.0-km-grid of the NFI1 are subsets of the 0.5-km-grid. The second terrestrial grid – a 4.0-km-grid shifted by 0.5 km – was taken as an independent sample in order to verify the representativeness of the NFI2 sample plots.

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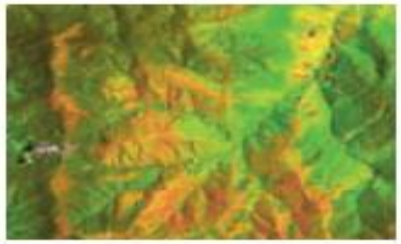
EFFORTS TO IMPROVE EARTH OBSERVATION METHODOLOGIES

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

SOURCEBOOK



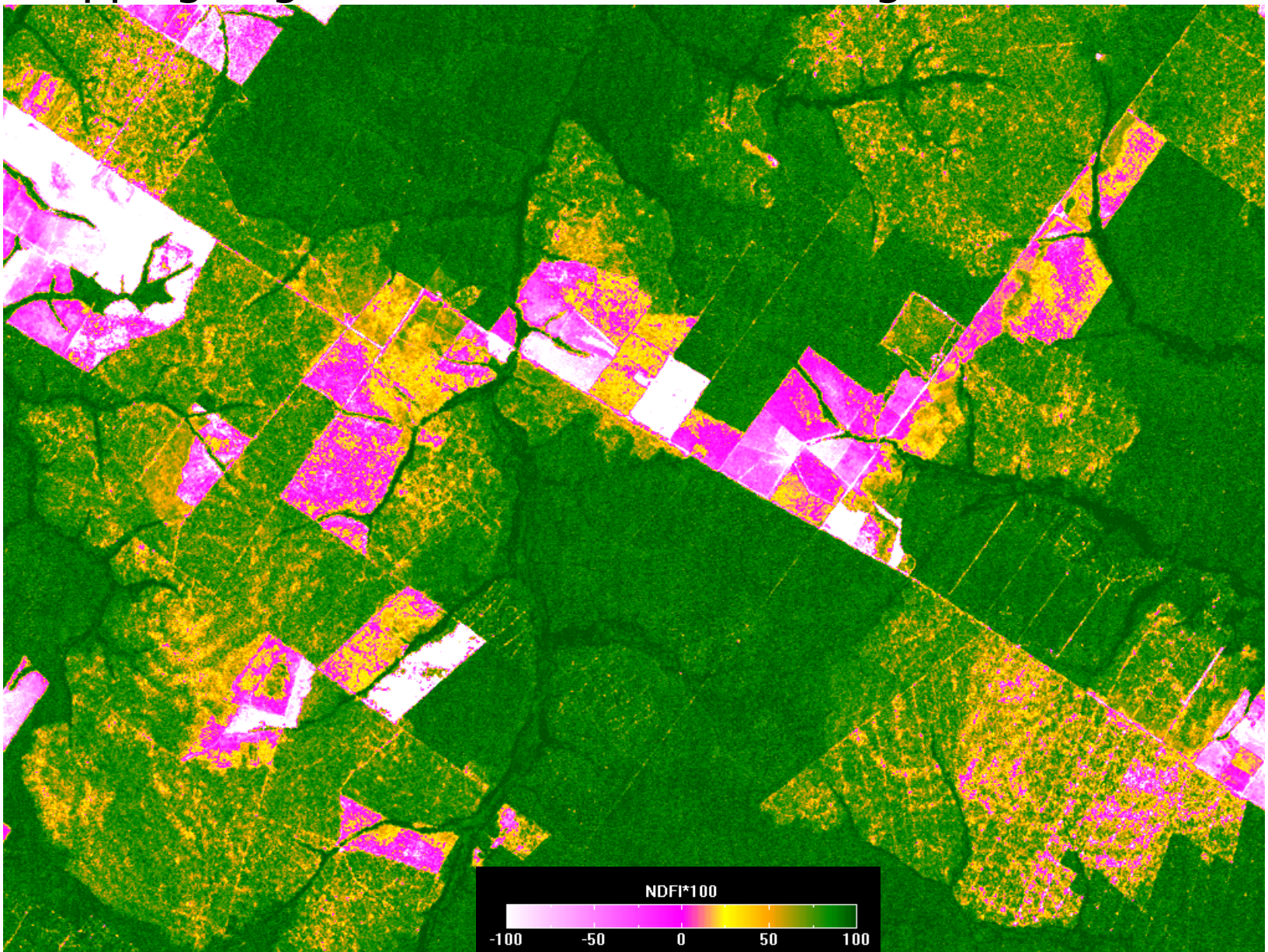


Reducing Greenhouse Gas Emissions from Deforestation and Degradation in Developing Countries: A Sourcebook of Methods and Procedures for Monitoring, Measuring and Reporting

GOFC-GOLD

Changes in forest area

Mapping degradation with Landsat Image (Souza Jr. et al., 2005)



2000

Changes in forest area

Mapping degradation with Landsat Image (Souza Jr. et al., 2005)

2001

Changes in forest area

Mapping degradation with Landsat Image (Souza Jr. et al., 2005)

2003

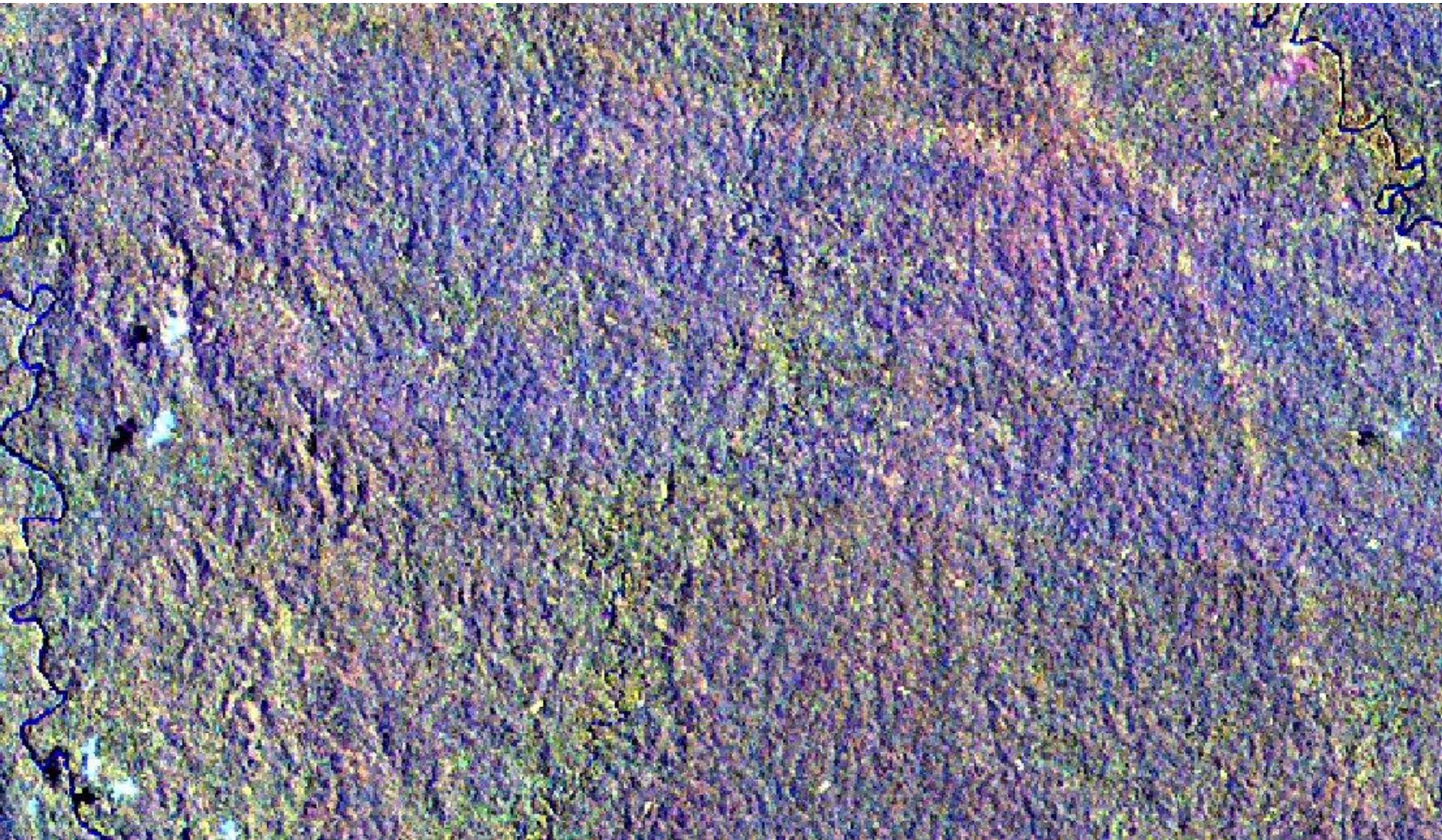
Changes in forest area

Degradation: to assess as a forest land remaining forest land

Intact
Vs
Non-intact

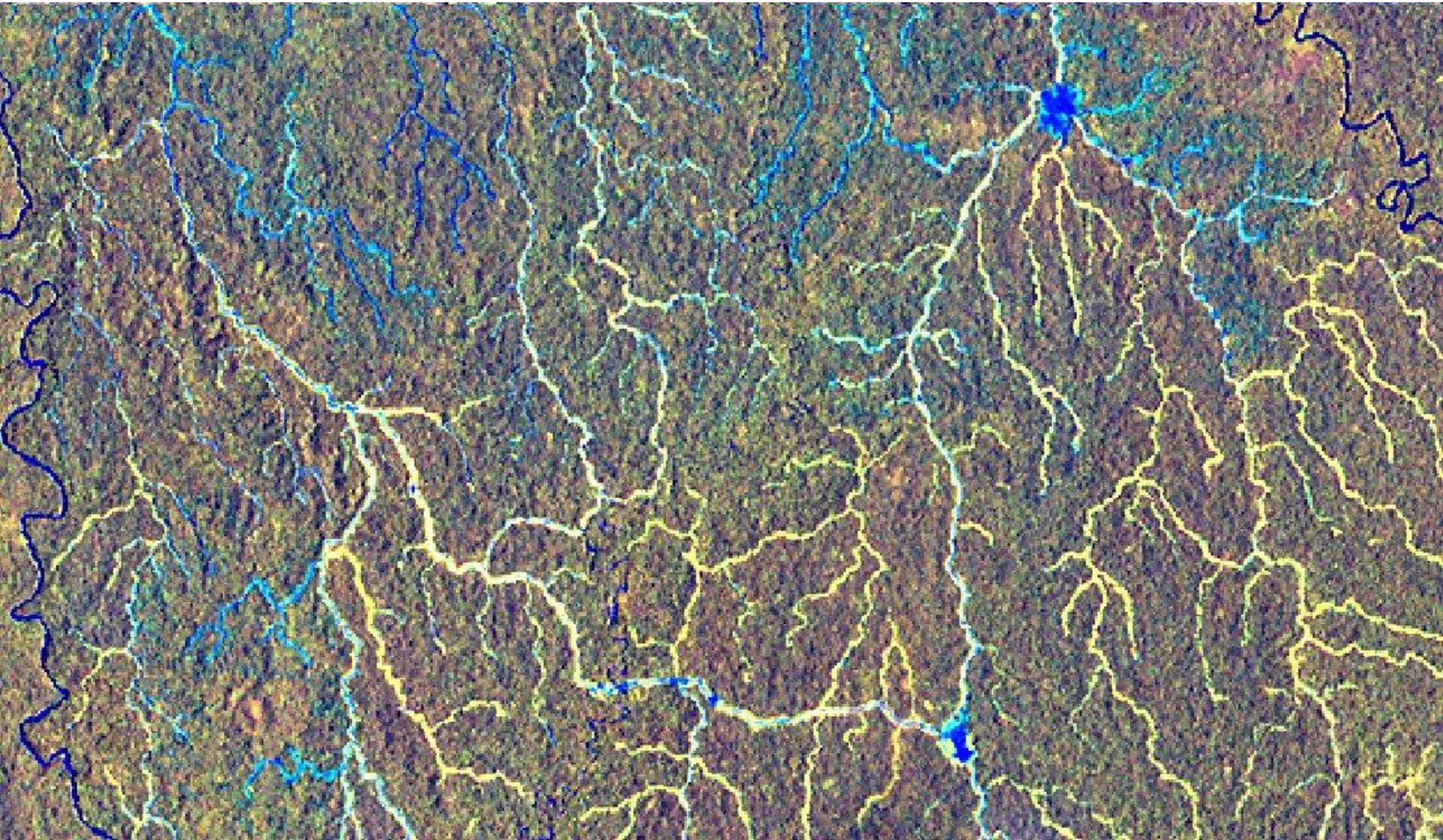
Changes in forest area

Degradation: to assess as a forest land remaining forest land



Changes in forest area

Degradation: to assess as a forest land remaining forest land



UN-REDD PROGRAMME

FAO UNDP UNEP

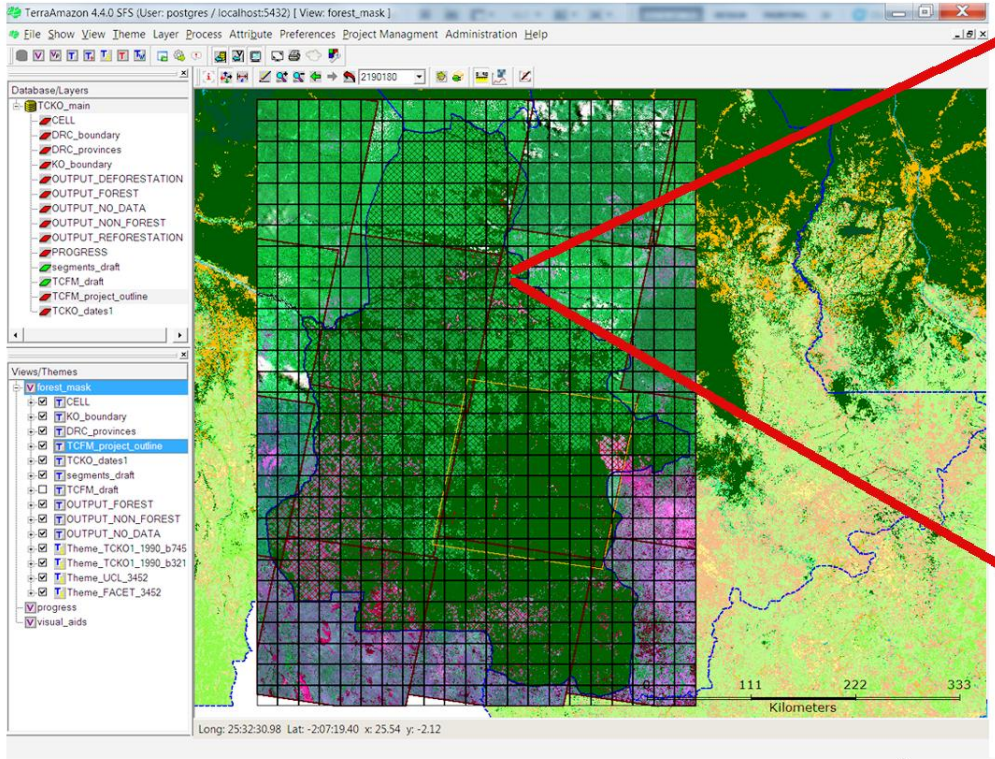
METHODOLOGICAL SOLUTIONS FOR NON-ANNEX I COUNTRIES

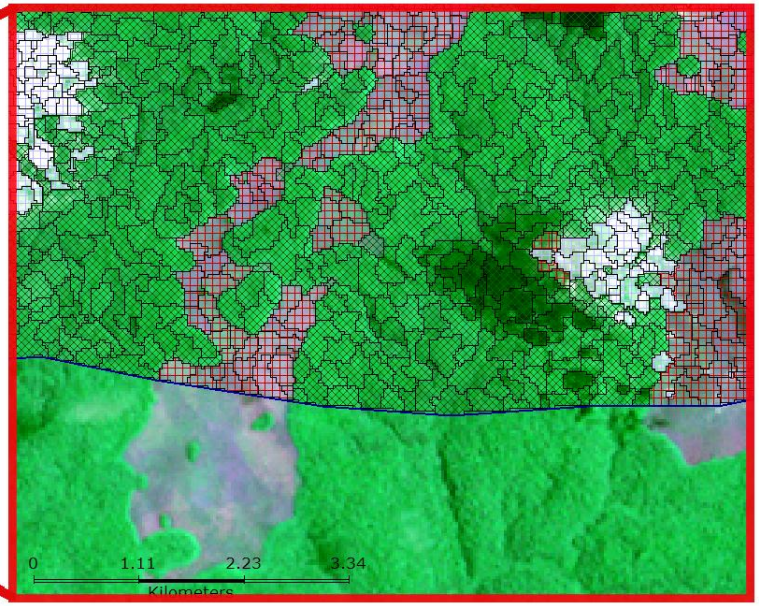
Wall to wall mapping approach

Satellite data, maps, algorithms, expertise

Basic image interpretation
Database
Storage
Review / Revision
Validation

TerrAmazon Projects

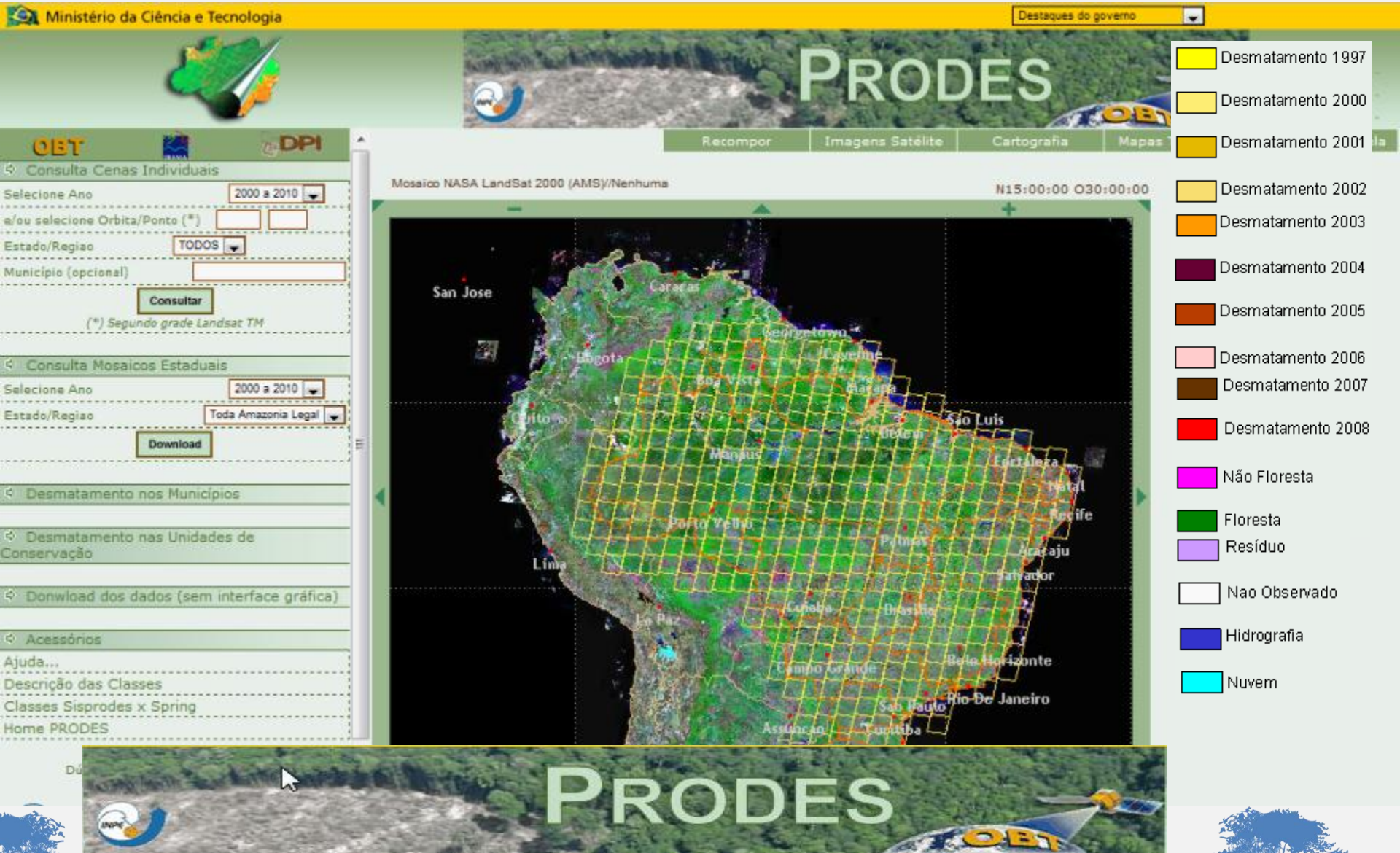




pre-classified segments within the project area

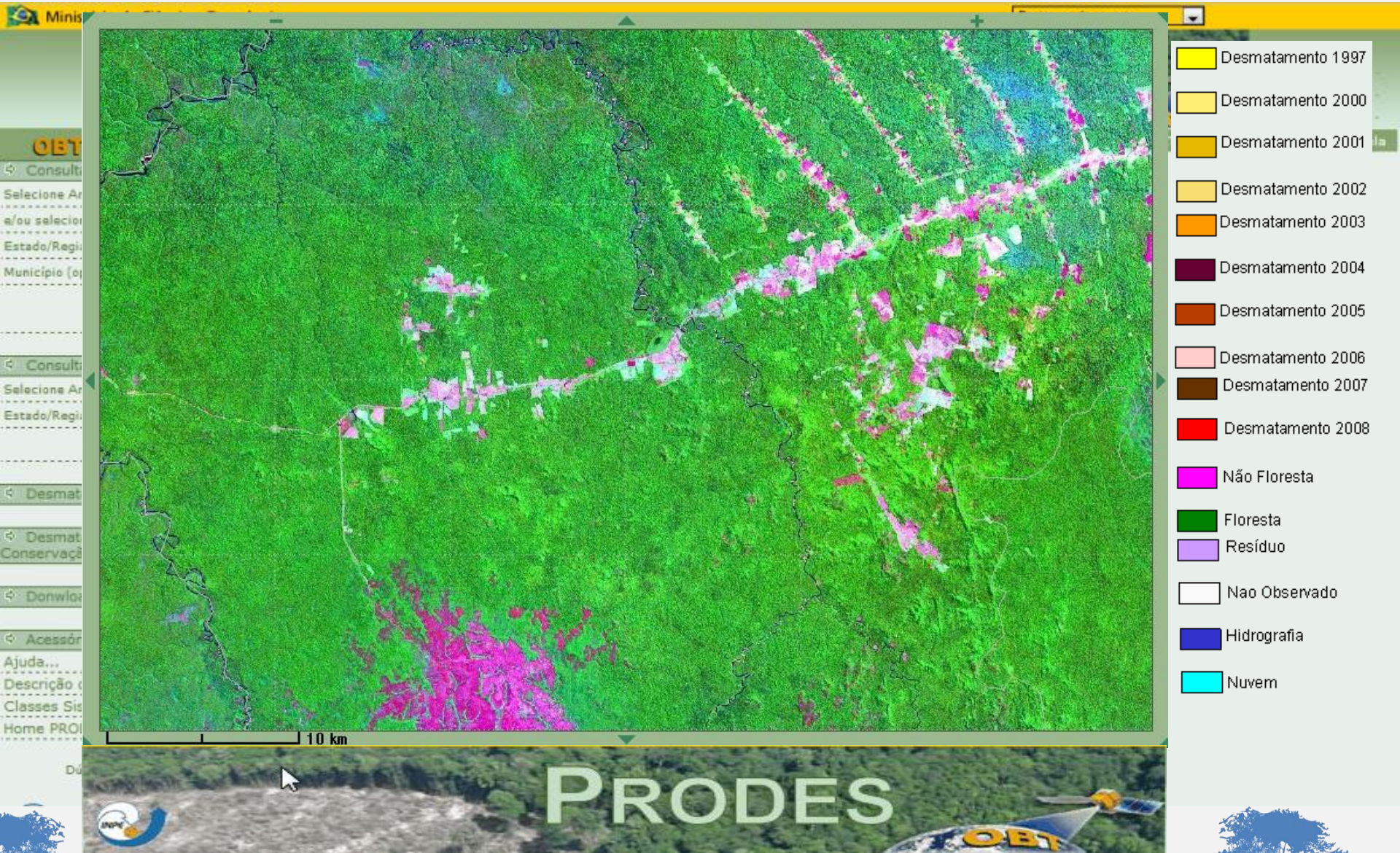
Brazil's PRODES System

Mapping deforestation & distributing data transparently online



Brazil's PRODES System

Mapping deforestation & distributing data transparently online



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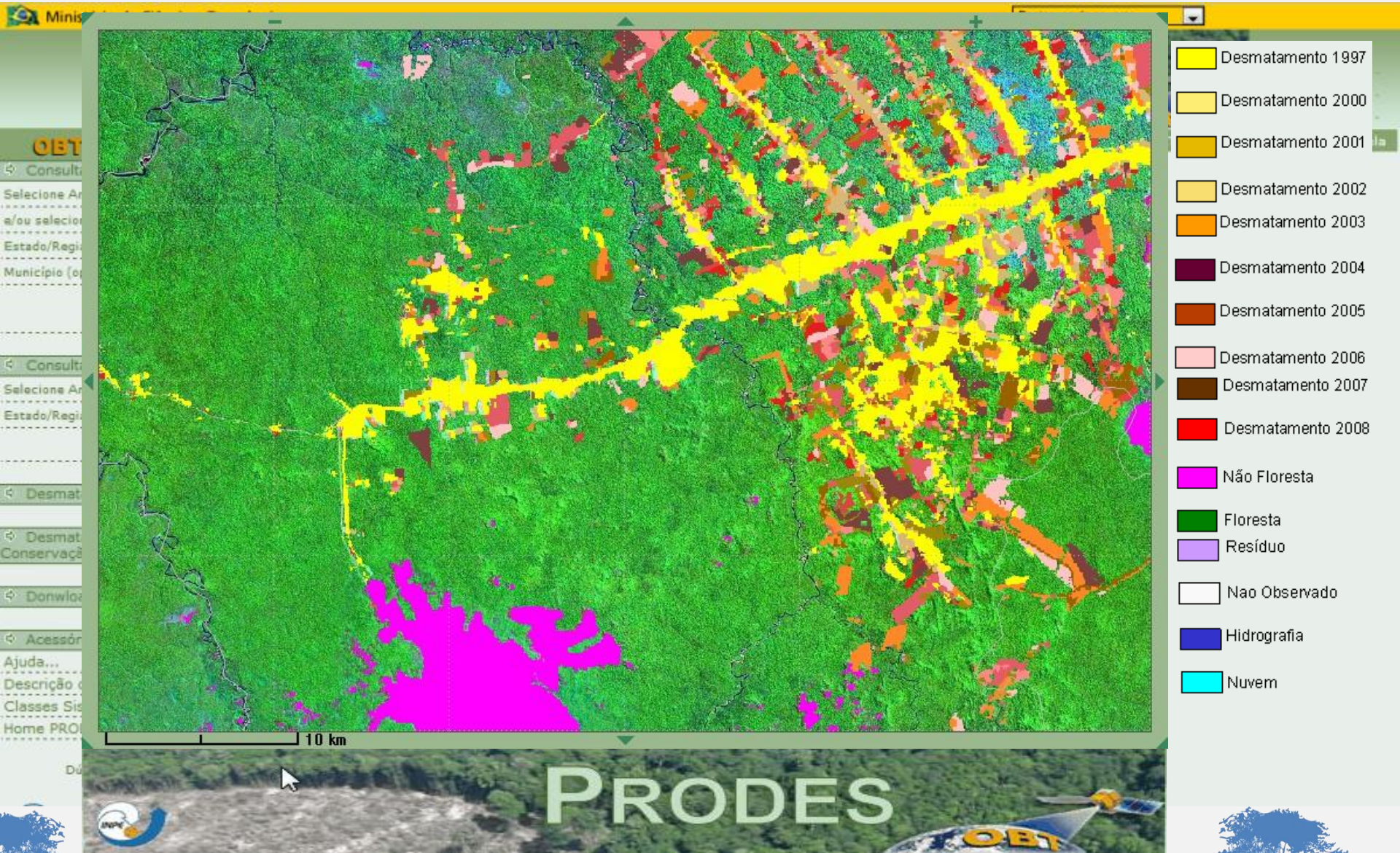
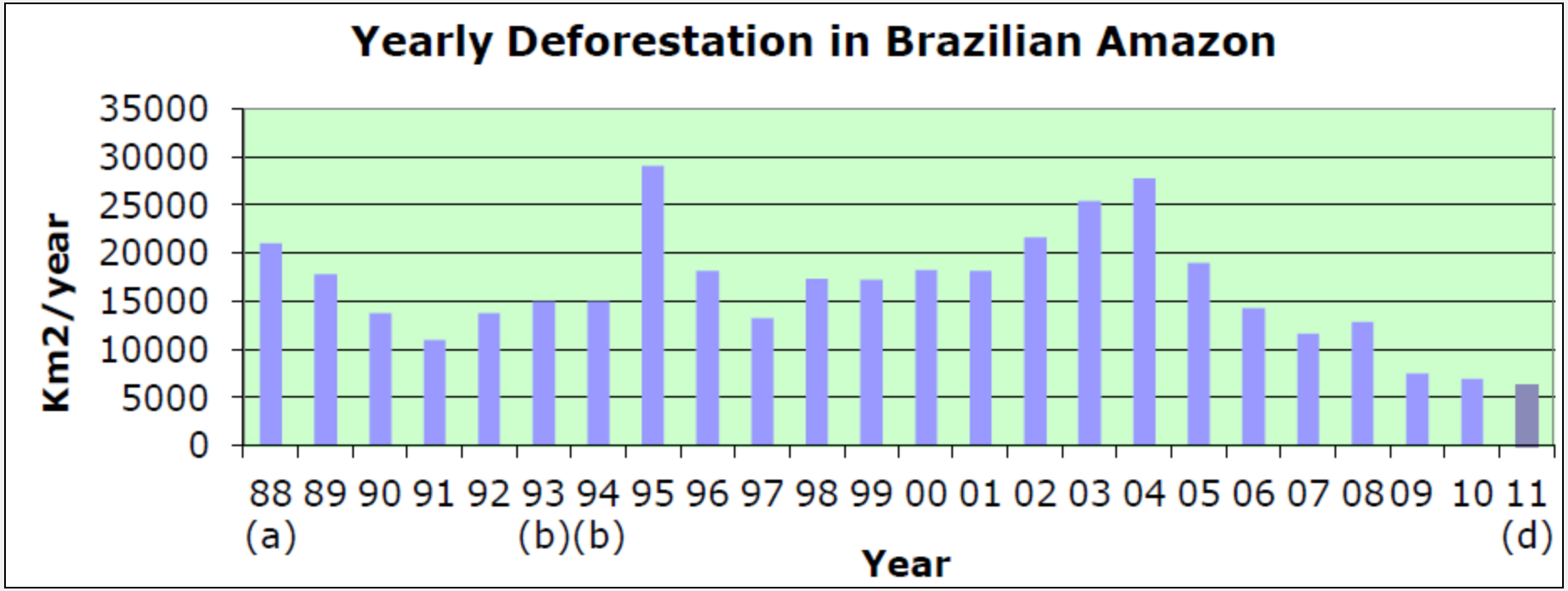


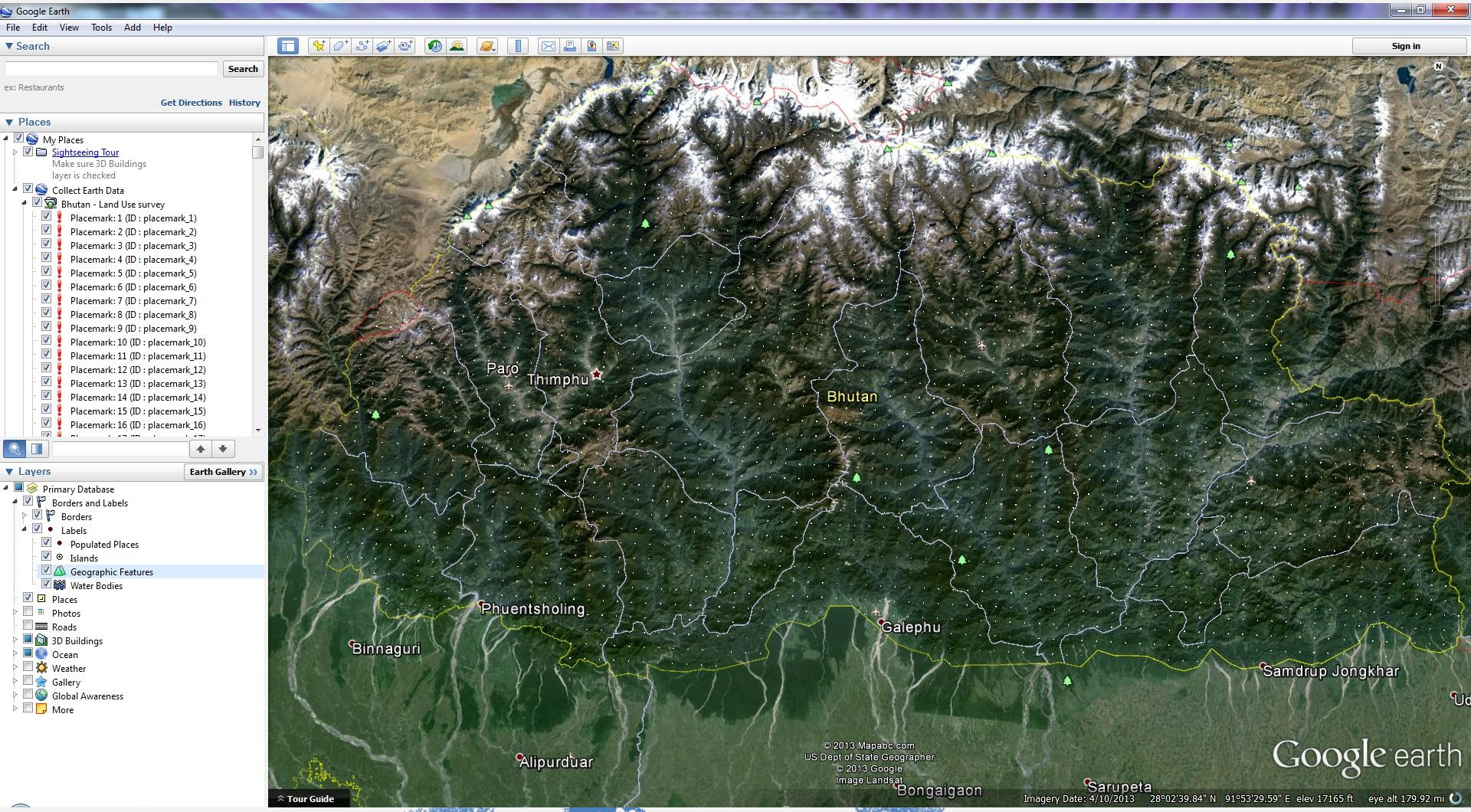
Brazil

Amazonian deforestation rates 1988-2011



Sampling approach:
Open Foris Collect Earth – Bhutan

UN-REDD PROGRAMME



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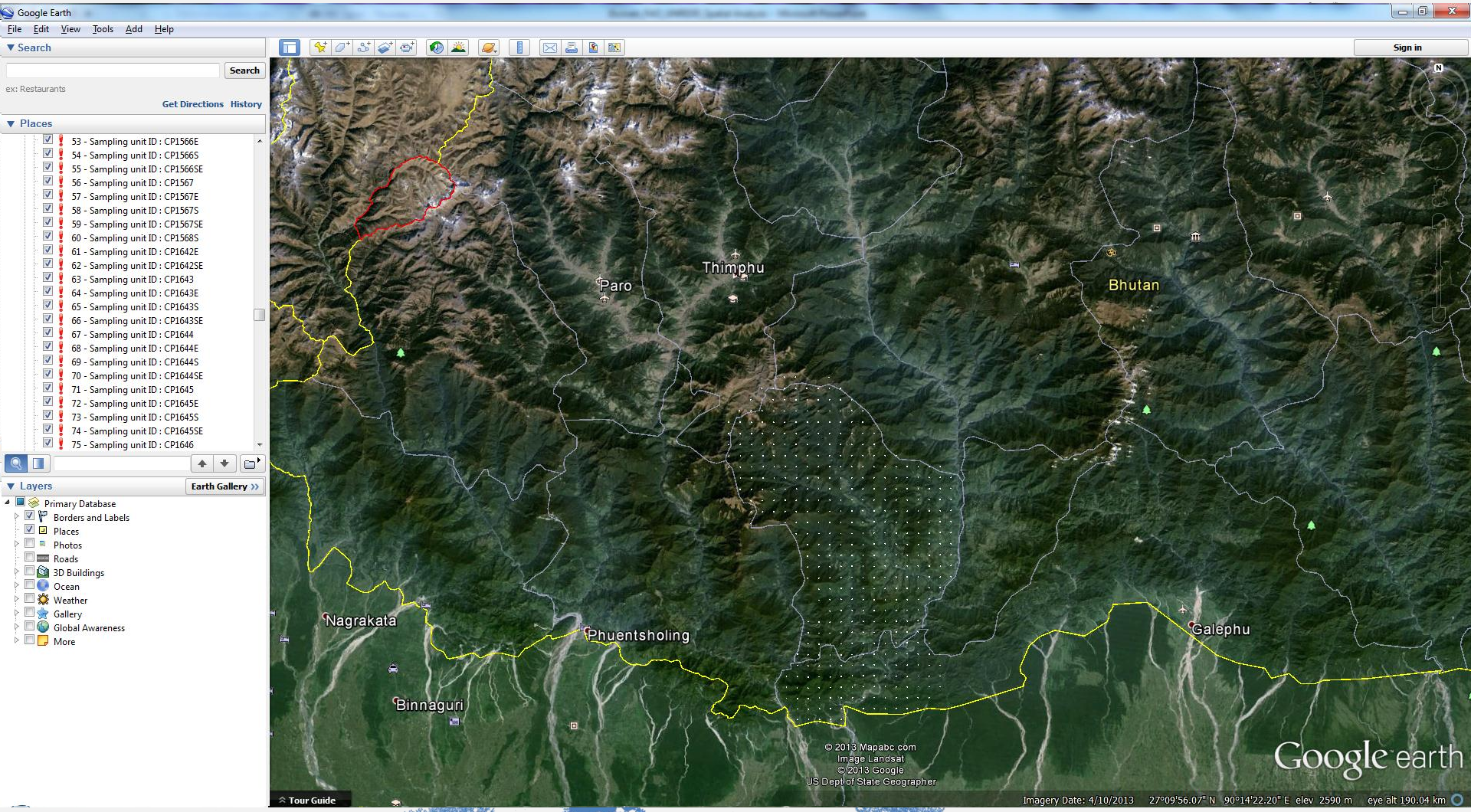

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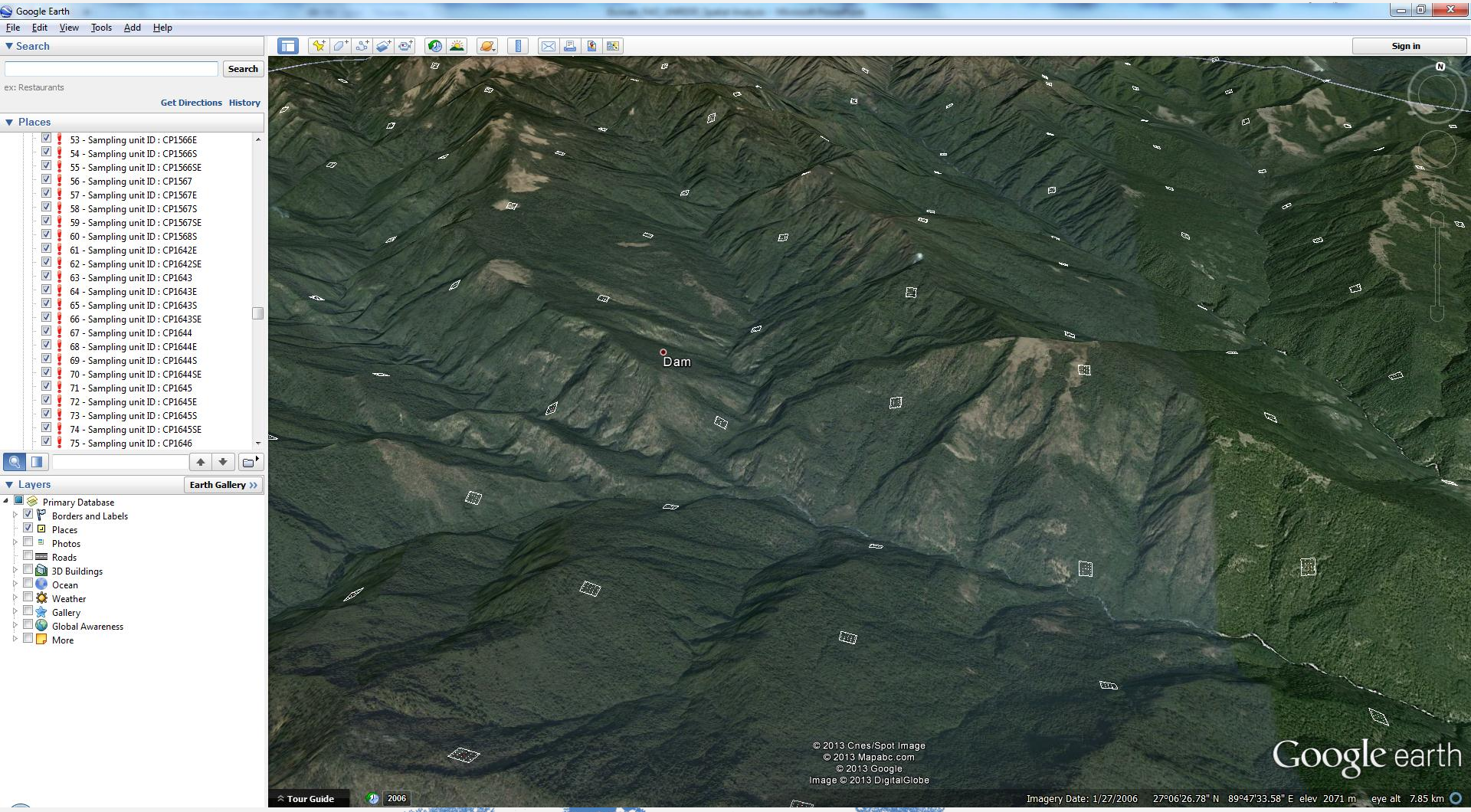
UN-REDD PROGRAMME



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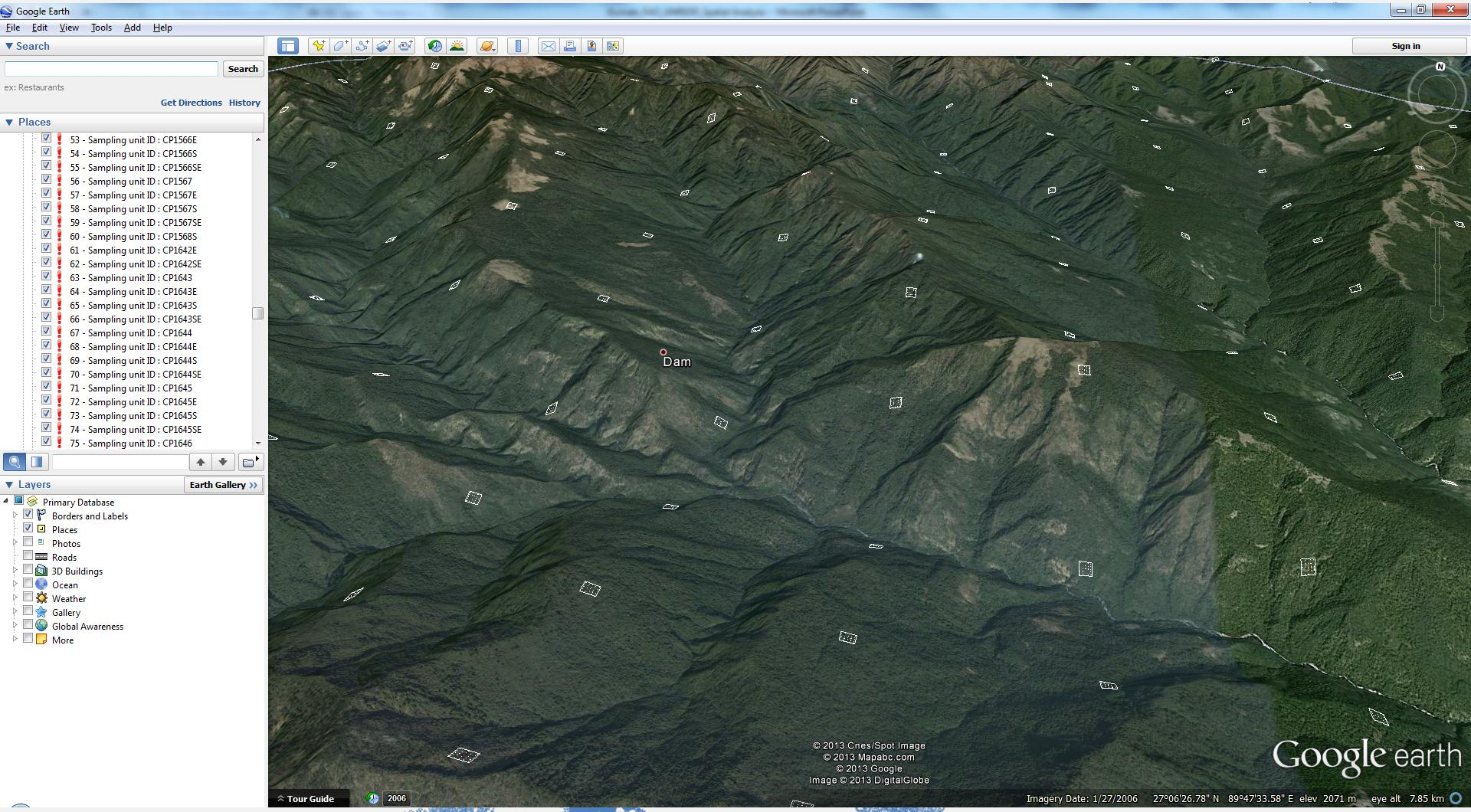
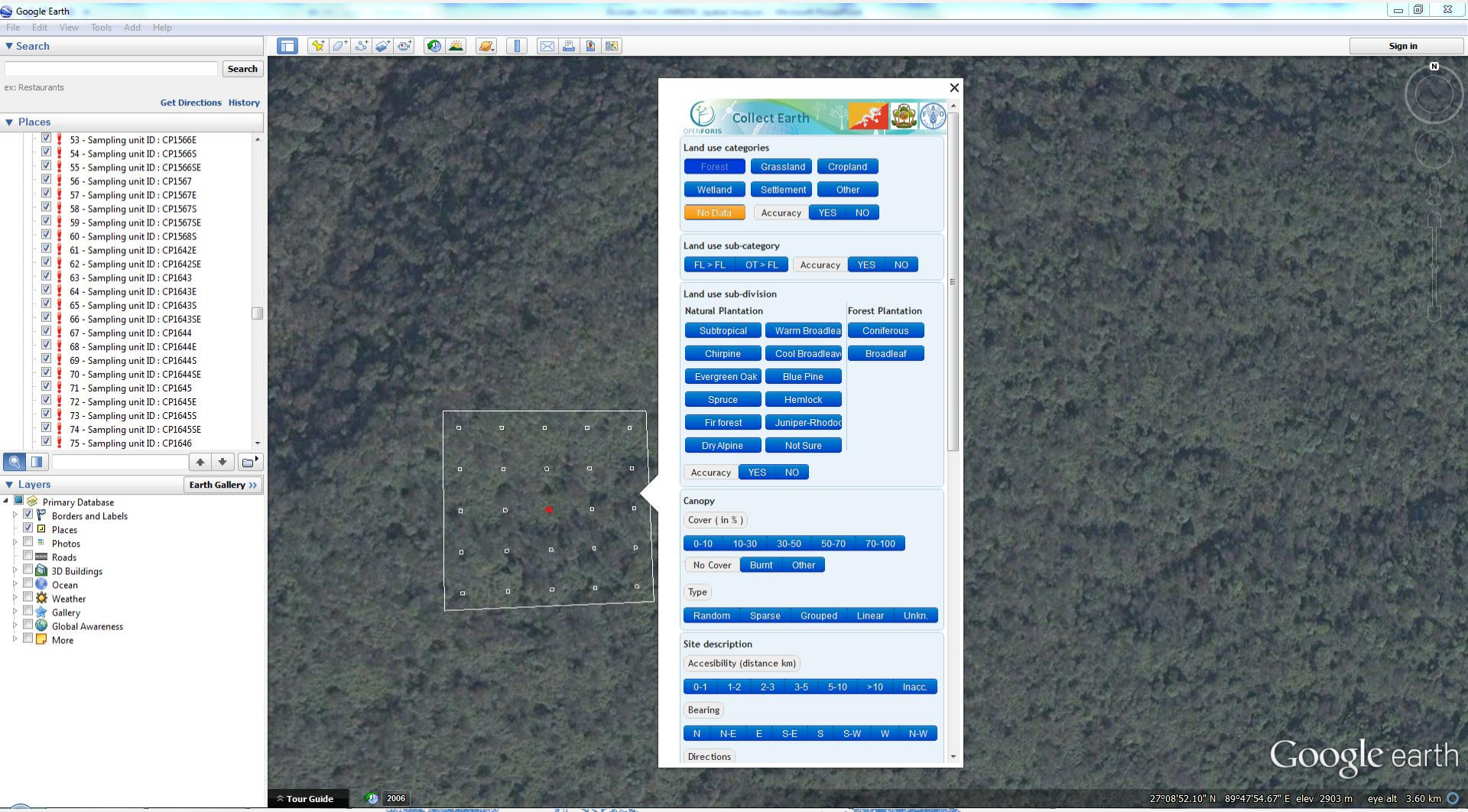
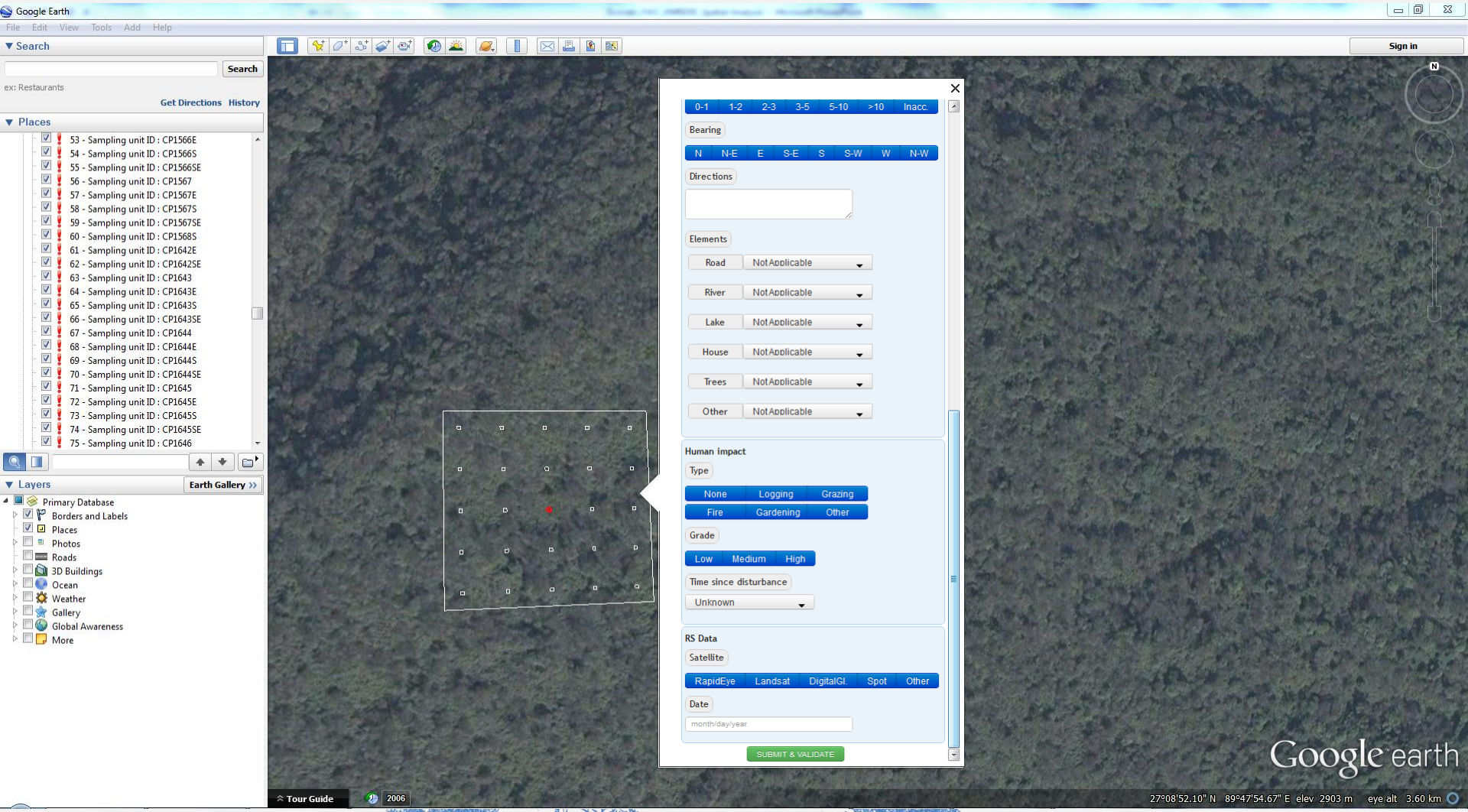


Open Foris Collect Earth – Bhutan



Open Foris Collect Earth – Bhutan




Thank you for your attention