

Use of multi-temporal satellite imagery over large territories for monitoring the state of the boreal forest of North-Western Quebec, Canada

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Context

- ❑ Increasing public concerns toward sustainable forest management in the boreal forest demands
 - ❑ Up to date information about the state of forests
 - ❑ Accurate surveying methods
 - ❑ Verifiable, specific in time and space
 - ❑ Cover larges areas at a reasonable cost
- ❑ Satellite imagery = Powerful tool for broad-scale forest monitoring (ex. North-western Québec)

Context and Issues

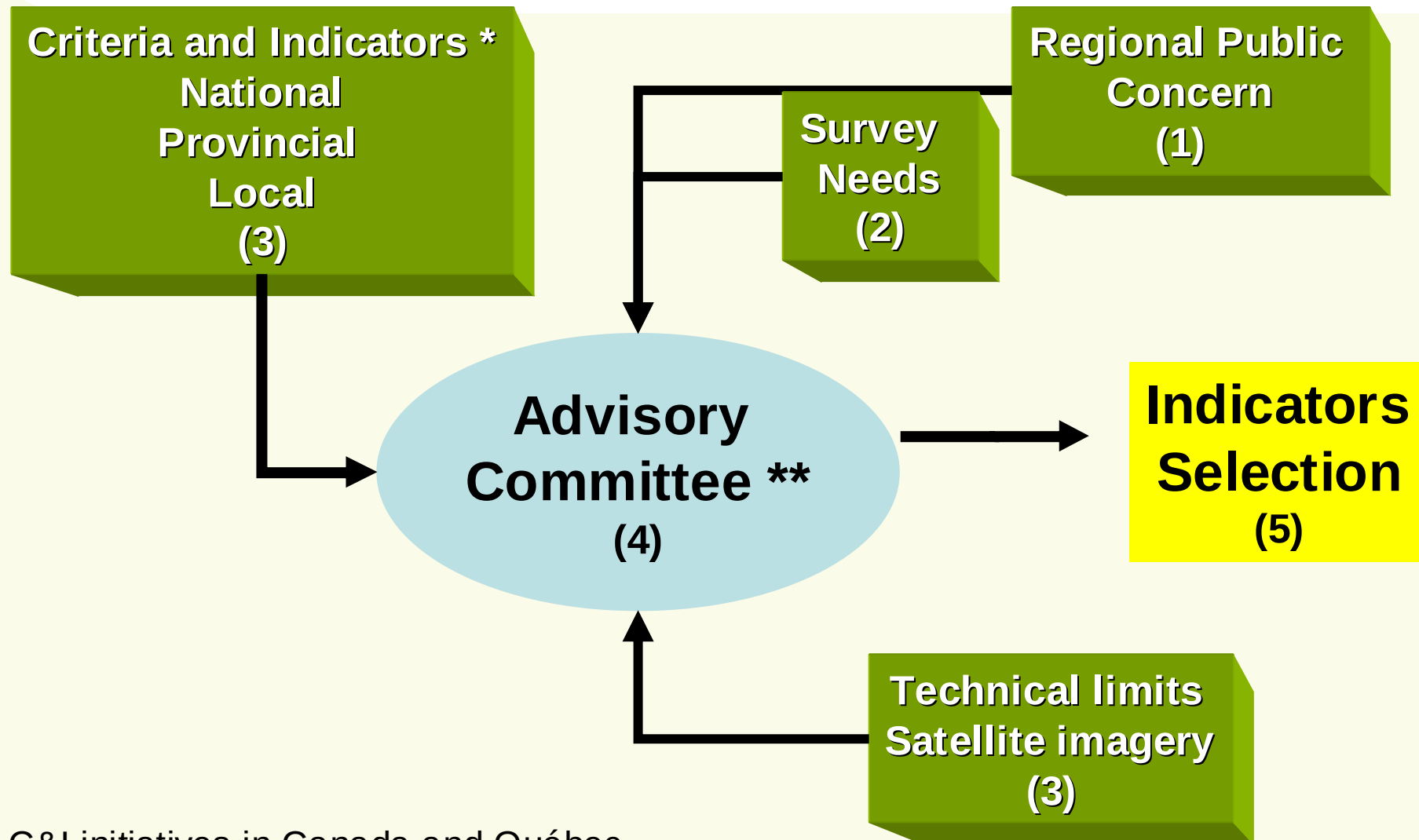
- ❑ Forest industries
 - ❑ Pressure
- ❑ Forest resources protection
 - ❑ Certification – demands
- ❑ Natural disturbances
 - ❑ Monitoring
- ❑ Ecological integrity of forest ecosystem
- ❑ Balancing ecological and socio-economic values



Objectives

- ❑ Use indicators of sustainable forest management (ISFM) extracted from satellite imagery to monitor the state of the boreal forest in North western Quebec (NWQ)
- ❑ Quantify the multi-temporal evolution of these ISFM over a period of 20 years (1985 to 2005)
- ❑ Produce different portraits of the state of the forest in NWQ and establish monitoring mechanisms.

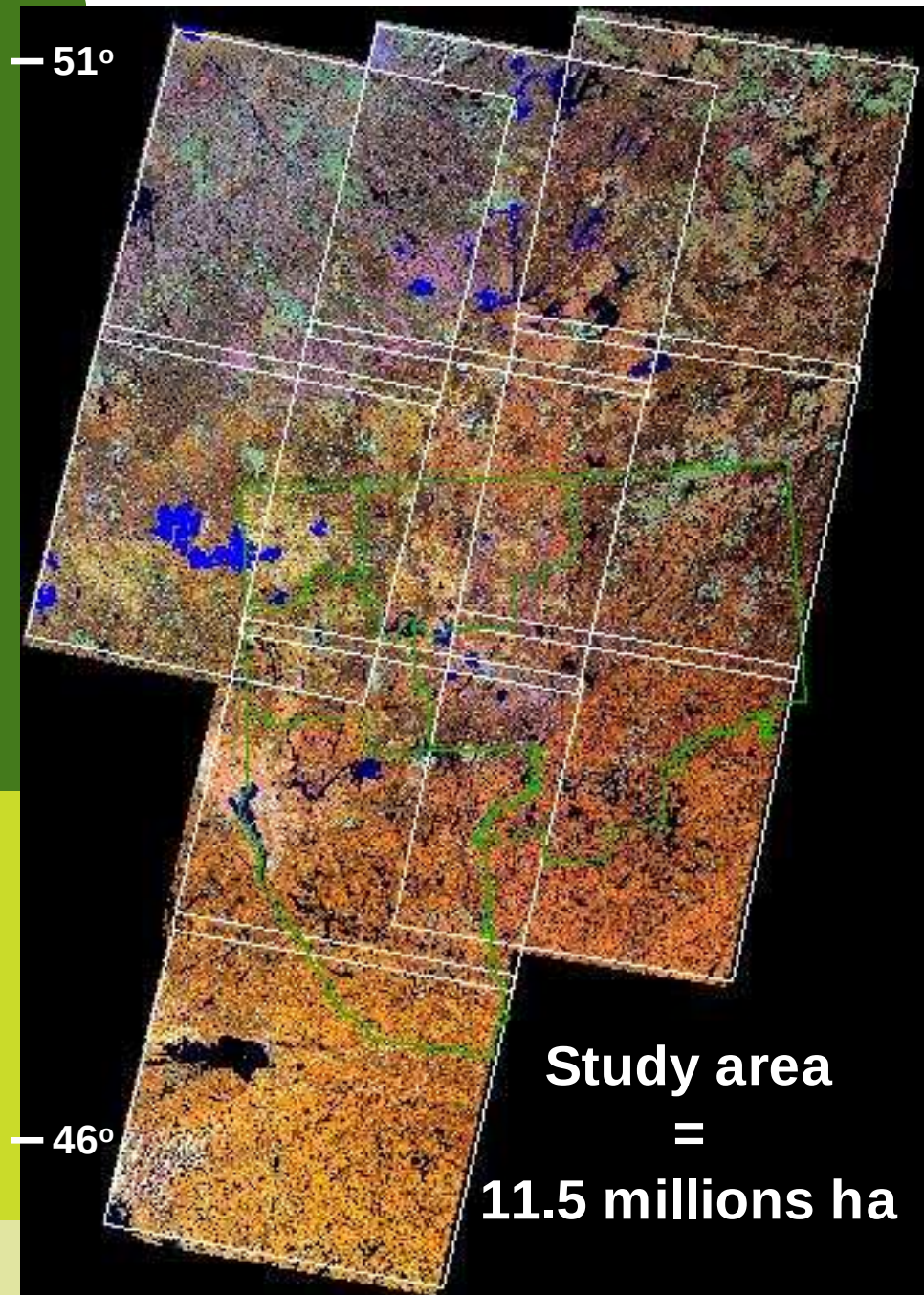
Methods- Indicators of Sustainable Forest Management (ISFM)



* C&I initiatives in Canada and Québec
CCFM, CMFN, NRCan, MRNF

** Forest companies, regional working groups and public

Dataset and image processing

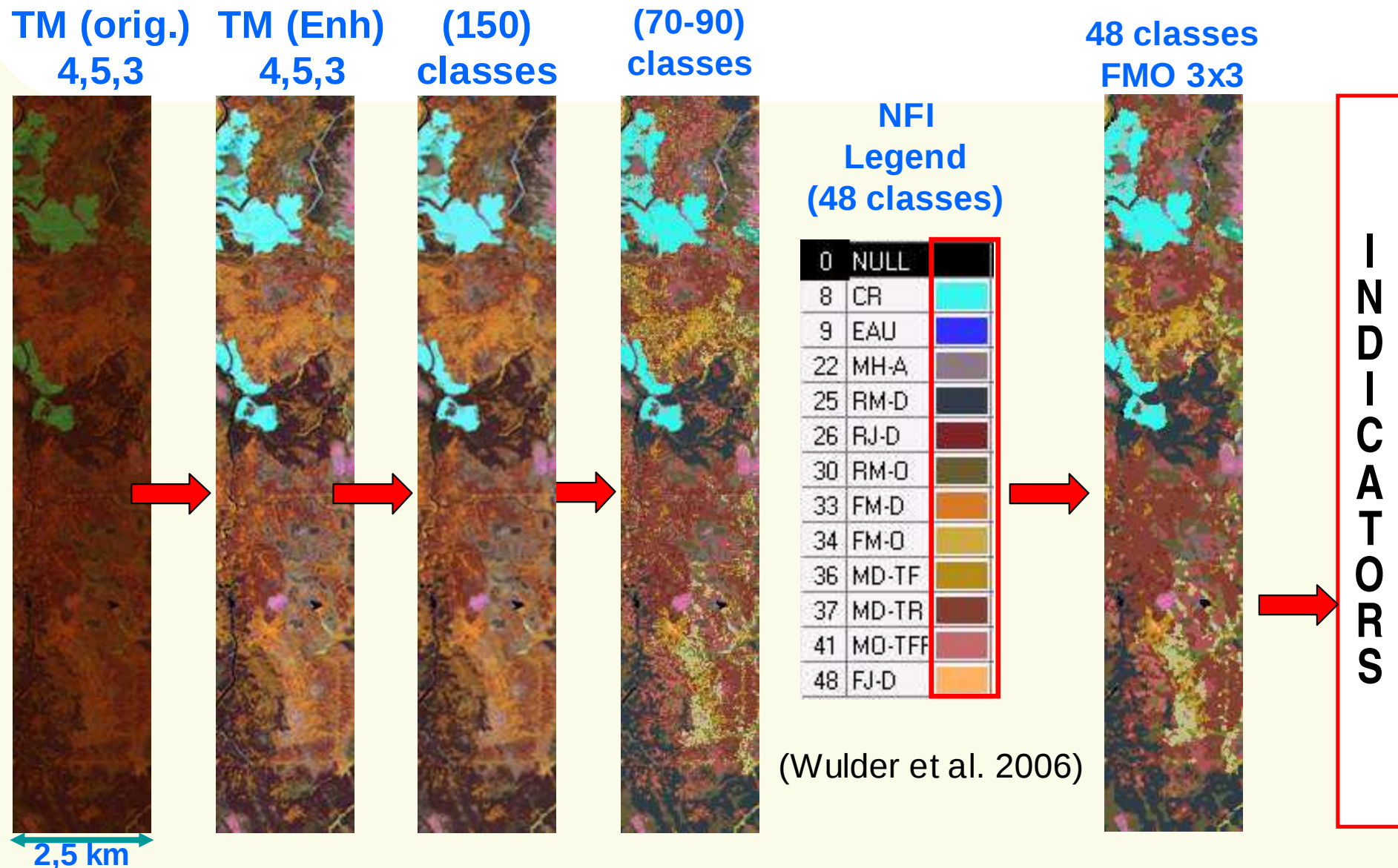


□ 32 Landsat TM/ETM images
(30 x 30 m):

- Atmospheric corrections
- Radiometric corrections
- Spatially orthorectified
- DN → Reflectance (Markham and Barker, 1986).
- 4 Mosaics (85,95,00,05)

□ Each mosaic was classified
by ECM classification (Beaubien et al.
1999)

Enhancement Classification Method (ECM)



ECM is an "hybrid" classification routine using unsupervised & supervised kmeans clustering. By a supervised iterative generalization process using modal filters

Validation & accuracy assessment

Reference data

53000 digital aerial photos:

- ❑ Summer 2005
- ❑ Transect= 1000 km
- ❑ Resolution= 30 x 30 cm
- ❑ Overlapping= 80 %

3000 sites were selected using a stratified random sampling design

$$n = [(z/m)^2] * p * (1 - p)$$

Source: Cochran (1977)

- ❑ Spatial and gradient distribution
- ❑ Variation in spectral properties of each class



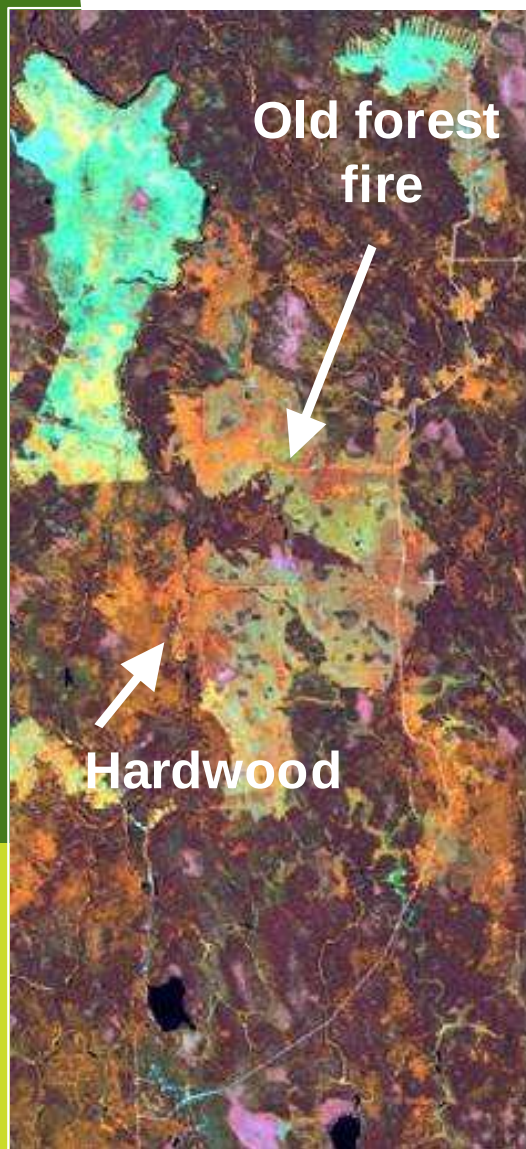
- ❑ Labelled by 3 photo interpreters

Validation & accuracy assessment (continued)

Procedures were generated for each indicator (Banko 1998)

- ❑ Confusion Matrix
- ❑ Overall accuracy; omission & commission errors
- ❑ Producers' and user's accuracies
- ❑ Kappa coefficient

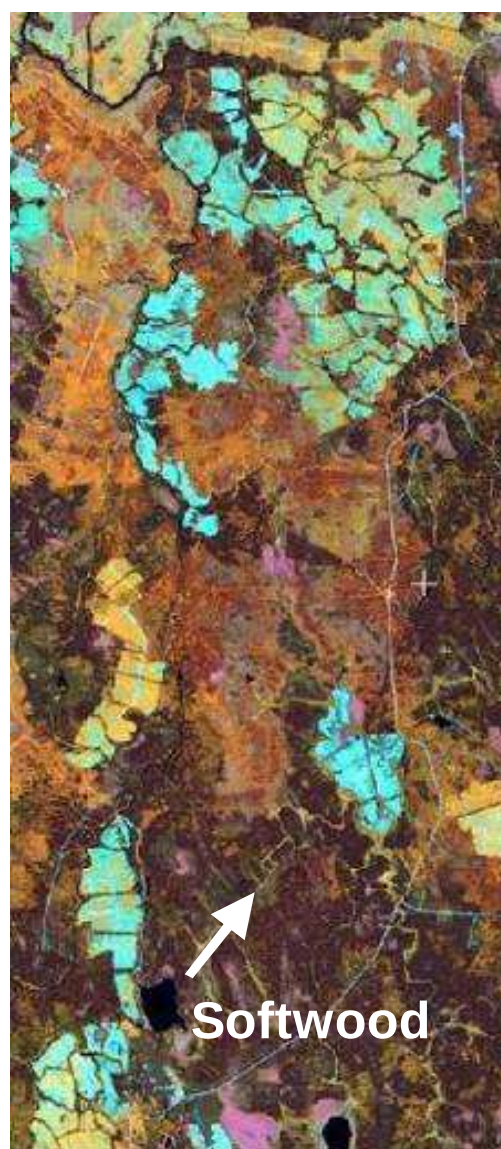
RESULTS



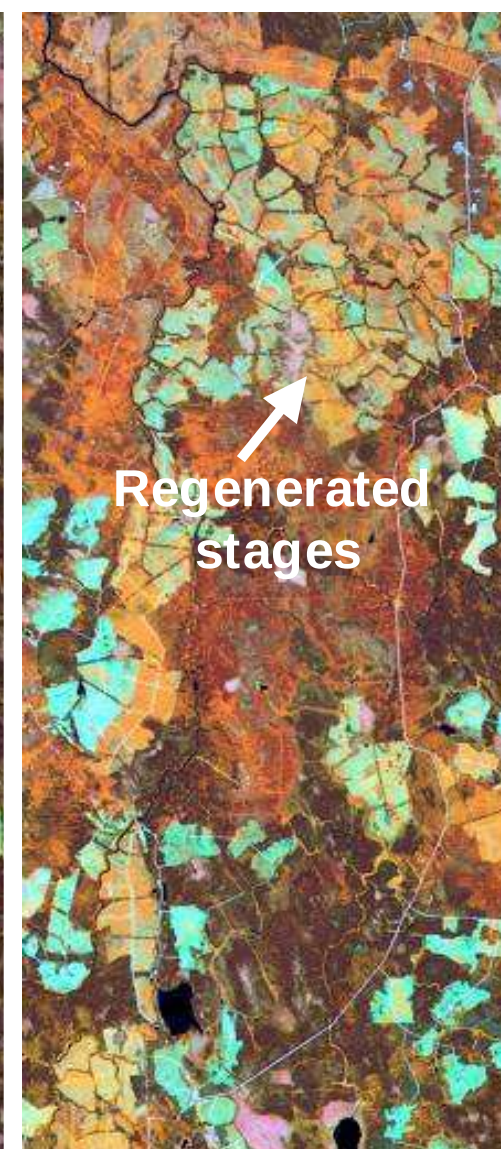
1985



1995



2000



2005

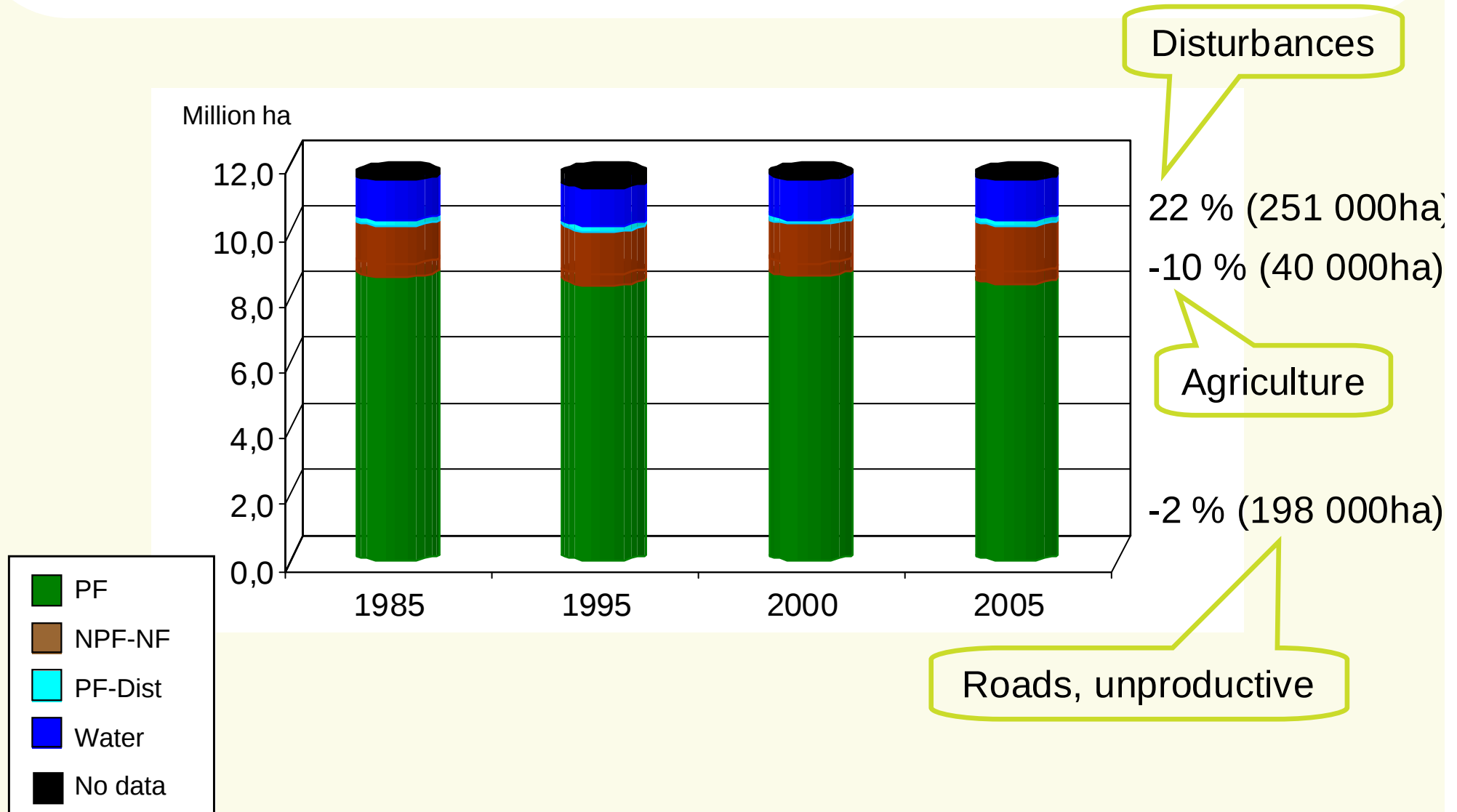
Results- Selection of indicators

4 ISFM were selected

INDICATORS		CLASSES OF INDICATORS
1	Forest Non forest	Productive forest (PF); Non- Productive forest (NPF); Potentially forested areas after disturbance (PF-Dist) & Non-Forest (NF)
2	Forest development stage	Regenerating and vegetating surfaces (RS & VS); Young Stands (YS) & Mature and over mature Stands (MS-OMS)
3	Forest cover type	Coniferous (CC); Deciduous (DC) & Mixed stands (MS)
4	Forest cover density class	Dense cover (DC) & Open cover (OC)

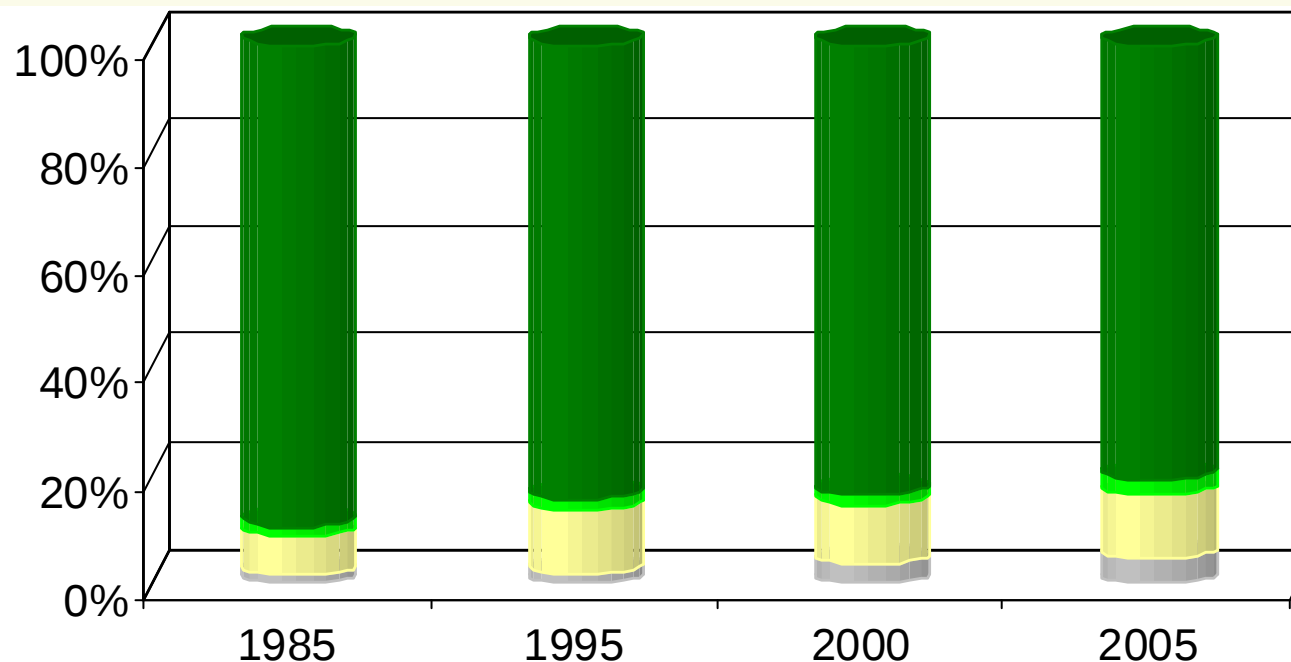
Classification maps + statistics → ecoregions, climatic districts, administrative units

Indicator 1: Forest – Non Forest (1985 to 2005)



Indicator 2- Stage of development (1985 to 2005)

8.5 Millions ha



Forest matrix changes

-12 % (905 000ha)

79 % (50 000ha)

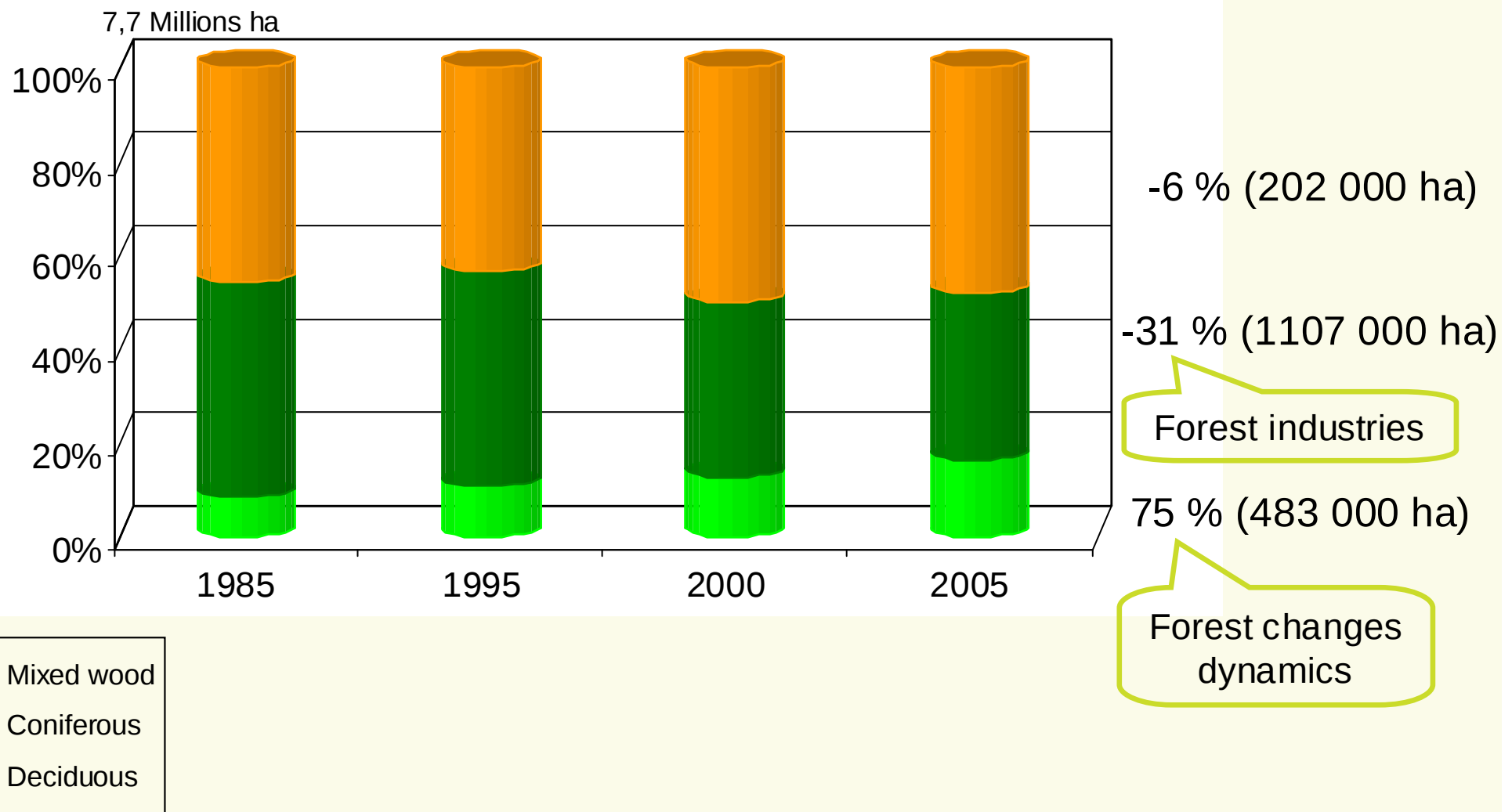
61 % (380 000ha)

189 % (247 000ha)

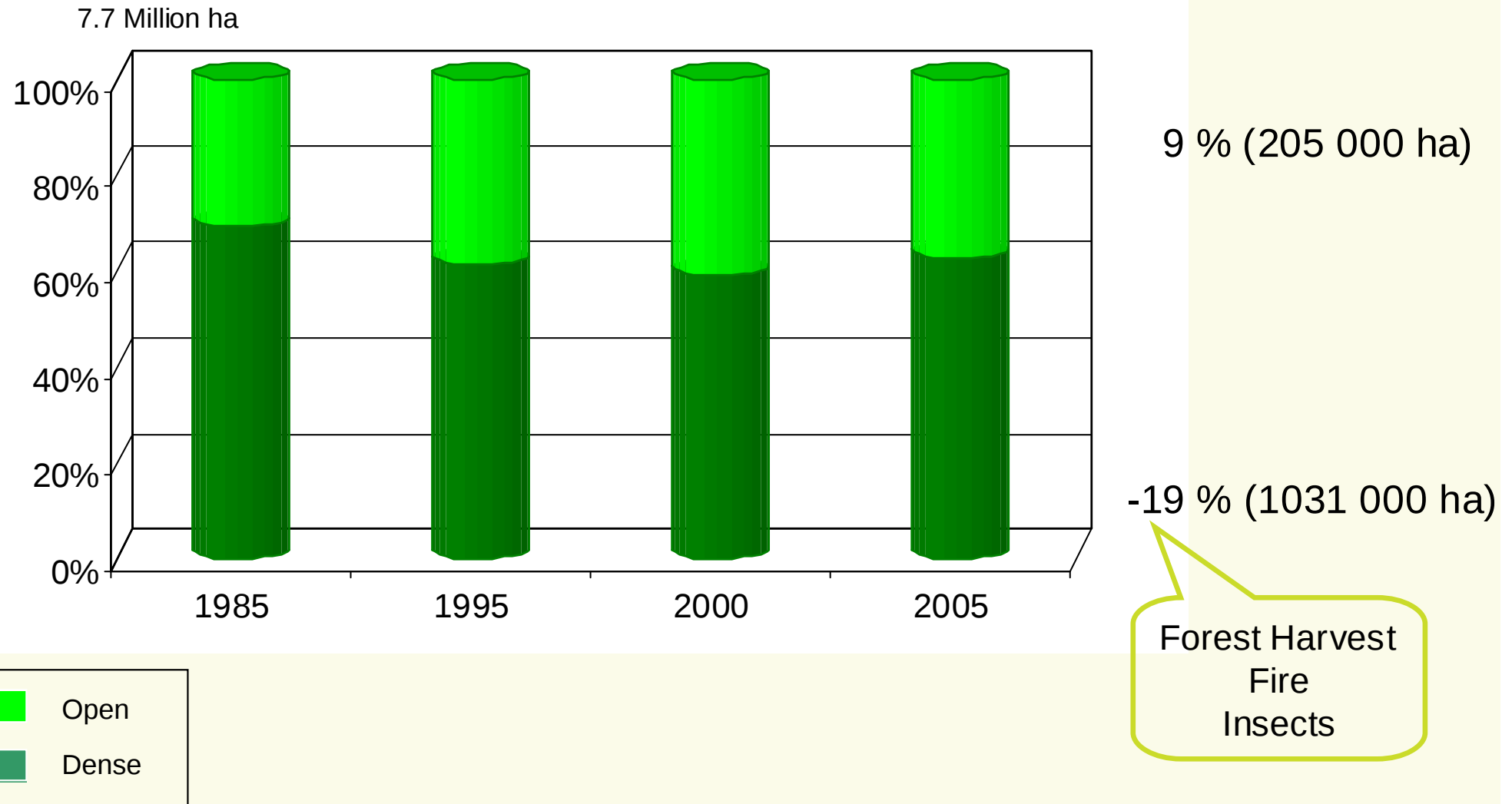
Disturbances
(fire, harvesting)

- Young Stands
- Mature, over mature stands
- Regenerating areas
- Revegetating areas

Indicator 3– Forest cover type (1985 to 2005)



Indicator 4 – Stands density (1985 to 2005)



Accuracy assessment: Indicator 1

PF/NPF		Labelled classes (areial photos)						<i>User's acc</i>	<i>Commission</i>	
Classified Landsat image	Classes	PF	NF	NPF	PF-Dist	Water	Total			
	PF	1861	19	71	41	15	2007			
	NF	22	87	2	5		116			
	NPF	71	4	104		3	182			
	PF-Dist	7	3	2	7		19			
	Water	3	2			151	156			
	Total	1964	115	179	53	169	2480			
<i>Producer's acc</i>		94.76%	75.65%	58.10%	13.21%	89.35%				
<i>Omission</i>		5.24%	24.35%	41.90%	86.79%	10.65%				

Overall accuracy: 89 %
Kappa (south): 0.69

REF:Banko 1998

Overall accuracies

Indicator/ Regions	Overall accuracy (%)			
	Forest Non Forest	Stage of development	Forest cover types	Density class
NWQ	87	70	62	65

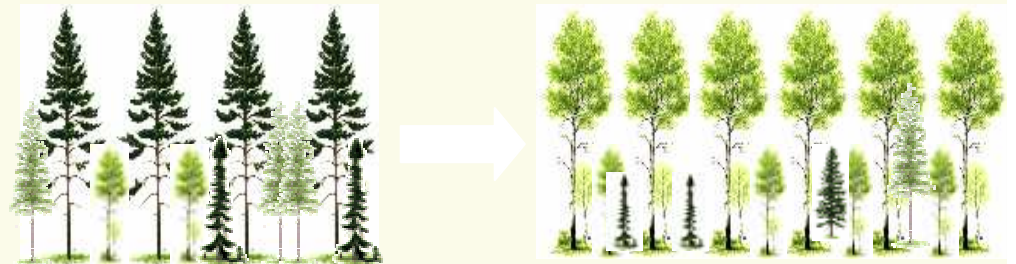
Kappa (South):	0.69	0.49	0.49	0.47
Kappa (North):	0.67	0.59	0.57	0.62

Conclusions- key findings

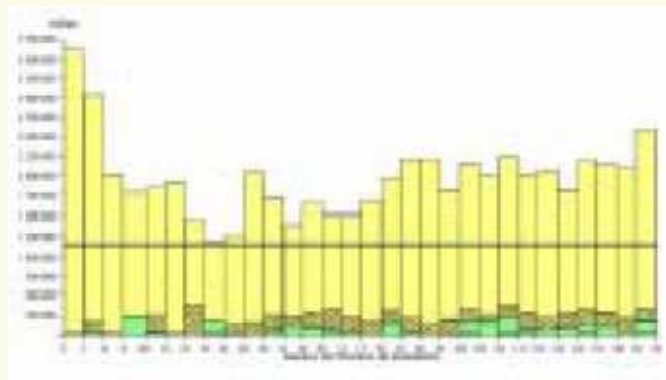
- Decrease in productive forest



- Significant decrease in coniferous



- Shift in forest class age distribution



- Decrease in dense stands



Conclusions

- ❑ **4 ISFM were mapped and quantified between 1985 and 2005 in the NWQ region with high accuracy**
 1. Forest – non forest
 2. Stage of development
 3. Forest cover type
 4. Stands density
- ❑ **Potential of multi-temporal satellite imagery data to provide accurate information**
 - ❑ Complementary source of information (MRNF)
- ❑ **Results will be available for:**
 - ❑ Planning forest management & policies decisions in NWQ
 - ❑ Public consultation (web ATLAS)

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**Advisory
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Questions?

VALIDATION - Taille de l'échantillonnage

- 500 photos / MRC sélectionnées de façon aléatoire en fonction d'un intervalle de confiance de 90%, une marge d'erreur de 0.03 et une précision globale visée de 80%

$$n = [(z/m)^2] * p * (1 - p)$$

where n = total sample size

z = percentile of the standar normal (1.65 avec 90% confidence interval)

m = margin of error (0.03)

p = assumed population proportion (0.8)

Source: Cochran (1977)