

# Operational Land cover / use mapping from local to continental scale



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## WORKFORCE

WORLD > 700 EMPLOYEES



**FRANCE** 420 pers. > 50 SIRS  
**EUROPE\*** 100 pers.  
**AMERICAS** 150 pers.  
**ASIA/PACIFIC** 30 pers.

\* HORS FRANCE

## TURNOVER

2017

125 M€

CLS

6 M€

SIRS



# IDENTITY



## MISSION

Support decision making in land resource management from local to International level

## EXPERIENCE

30 years in developing EO based solutions for land applications

## SOLUTIONS

Monitoring  
Control  
Rapid mapping  
Capacity building

## MEANS

Integrated semi-automatic processing chain combined with experienced thematic experts



# Market Segment

AGRICULTURE



HYDROGRAPHY



RISK MANAGEMENT



FOREST



URBAN PLANNING



ENVIRONMENT





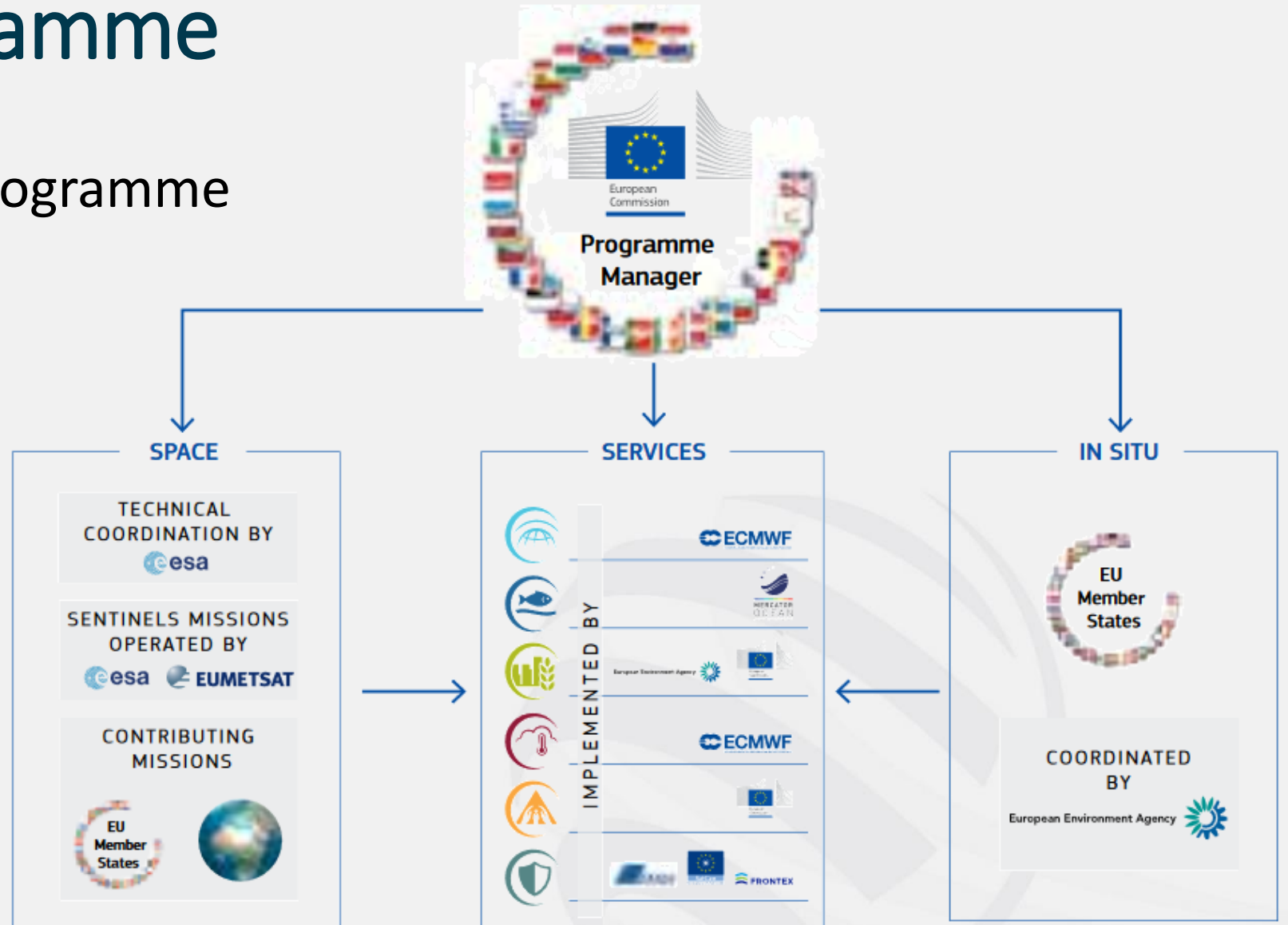


# Land Cover Mapping Activities: from Continental to Local Scale



## EU Earth Observation Programme

- Space
  - Sentinel Constellation
  - Contributing Missions
- Services
- In Situ data





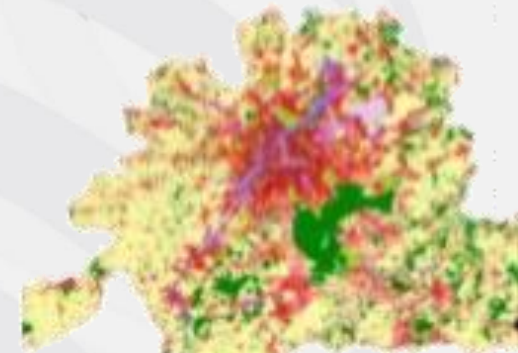


**From global...**

e.g. Vegetation dynamics, Bio-physical parameters, energy balance

**...to pan-European...**

e.g. bio-diversity, water bodies, land-use, land change

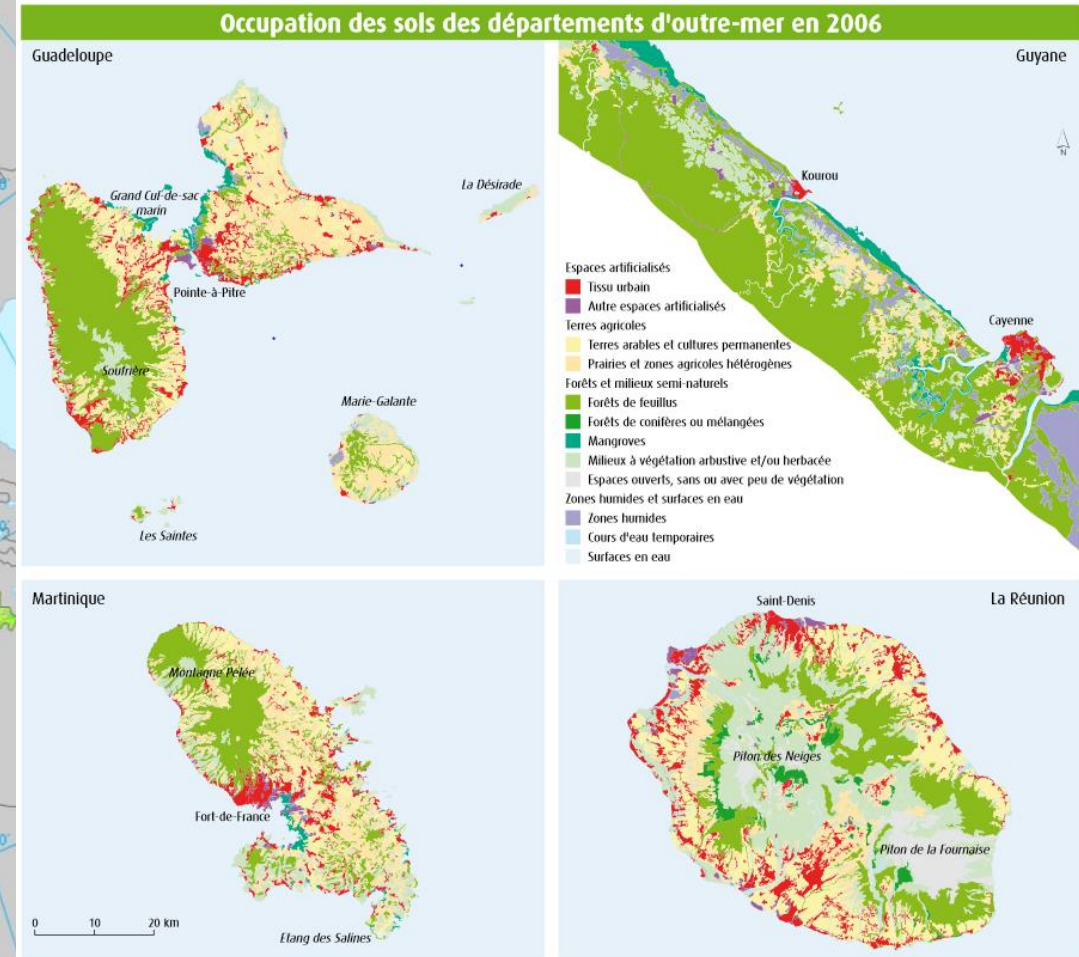
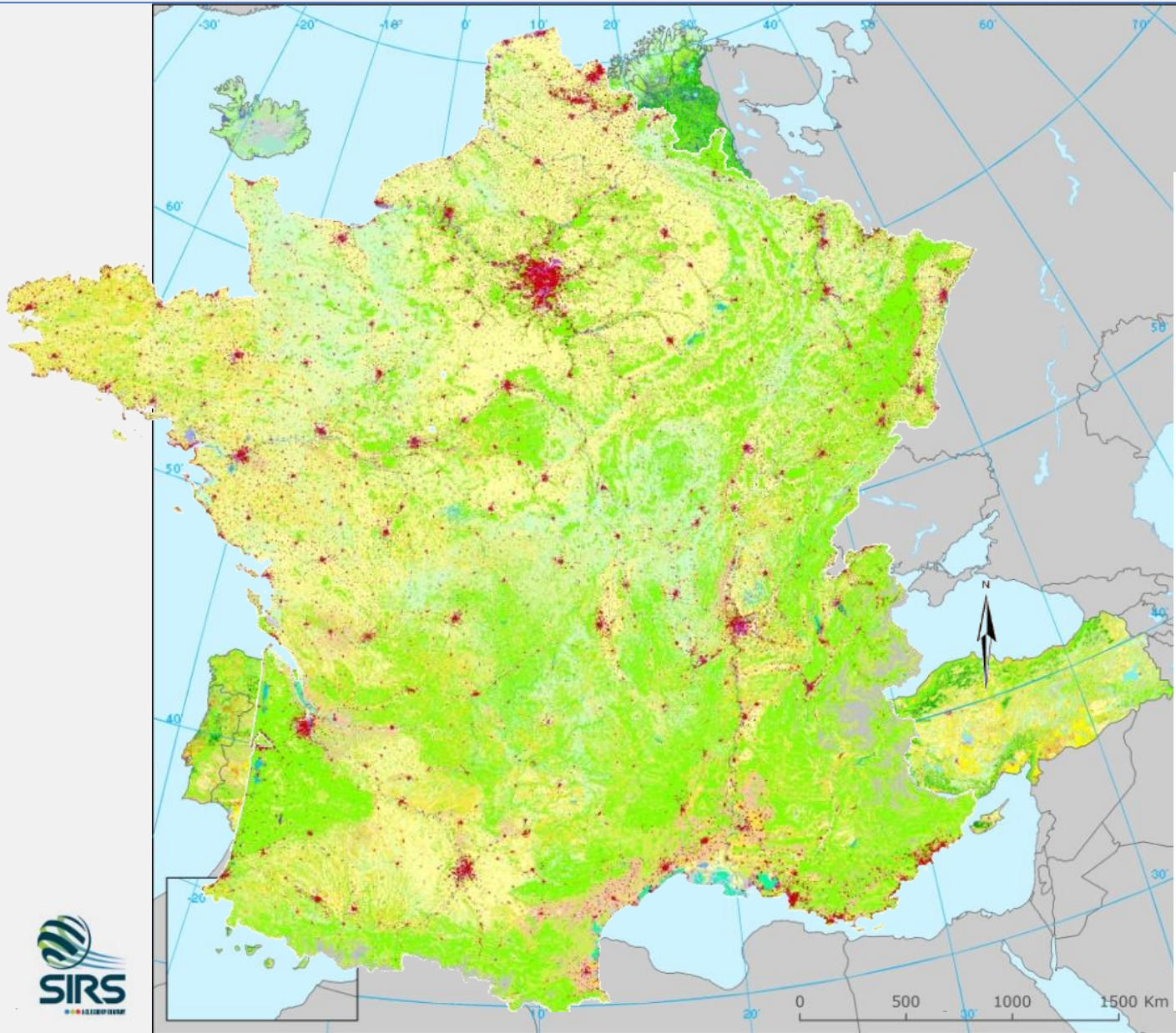


**...to local**

e.g. urban land-use



# CORINE Land Cover time series: 1990 – 2000 – 2006 – 2012 – 2018



Source : UE-SOeS, CORINE Land Cover, 2006.



Imperviousness and imperviousness change products

- Degree of Imperviousness and Imperviousness Change (0-100%)
- 2006-2009-2012-2015-2018
- 20 m and 100 m (2018: 10m)
- Built-up Component 2018

Forest

- Tree Cover Density (0-100%)
- Dominant Leaf Type
- 2012 – 2015 - 2018
- 20 m and 100 m (2018: 10m)

Grassland

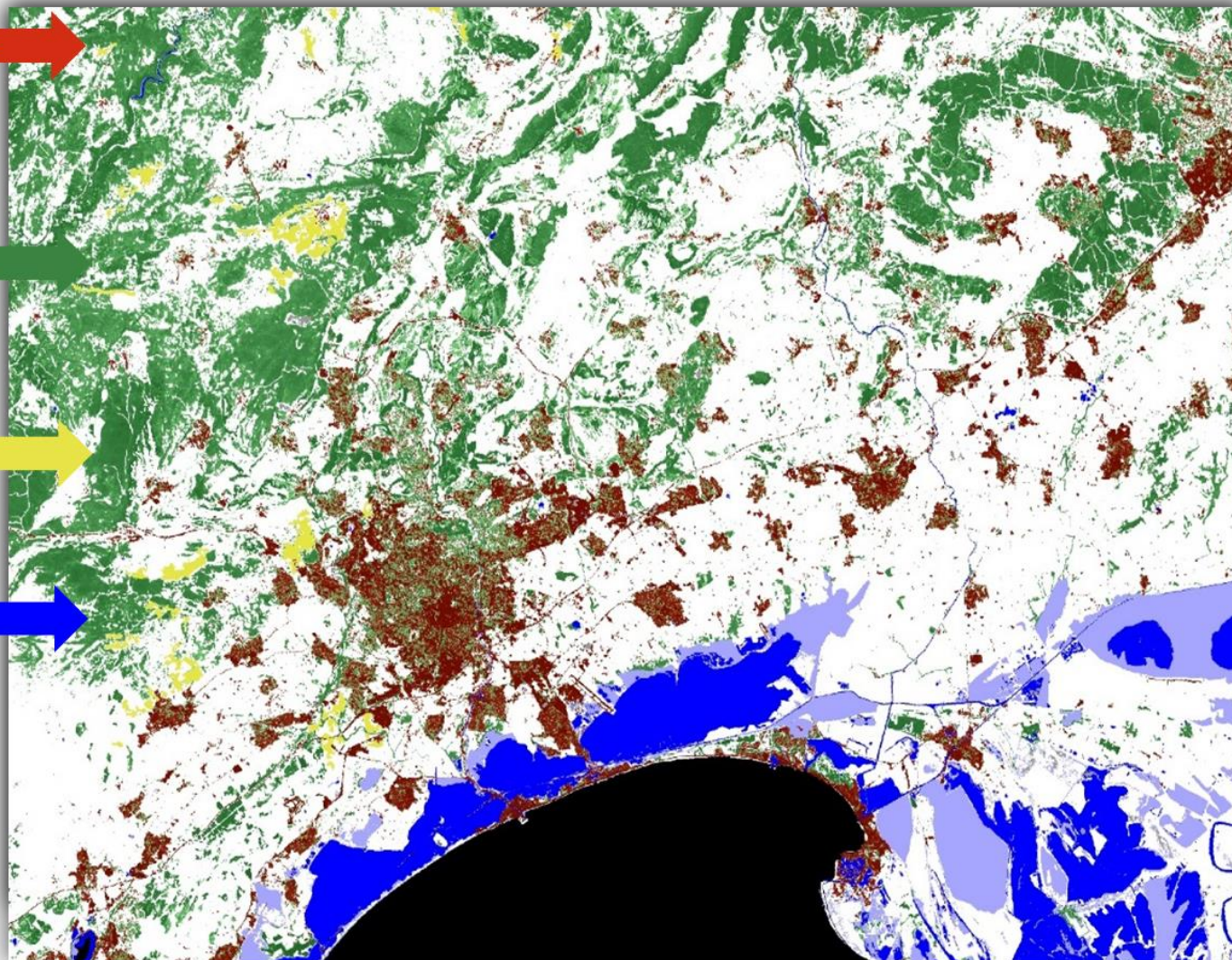
- Grassland (binary)
- 2015 - 2018
- 20 m and 100 m (2018: 10m)

Water and Wetness

- Permanent/Temporary Water
- Permanent/Temporary Wetness
- 2015: based on 2009-2016 time series - 2018
- 20 m and 100 m (2018: 10m)

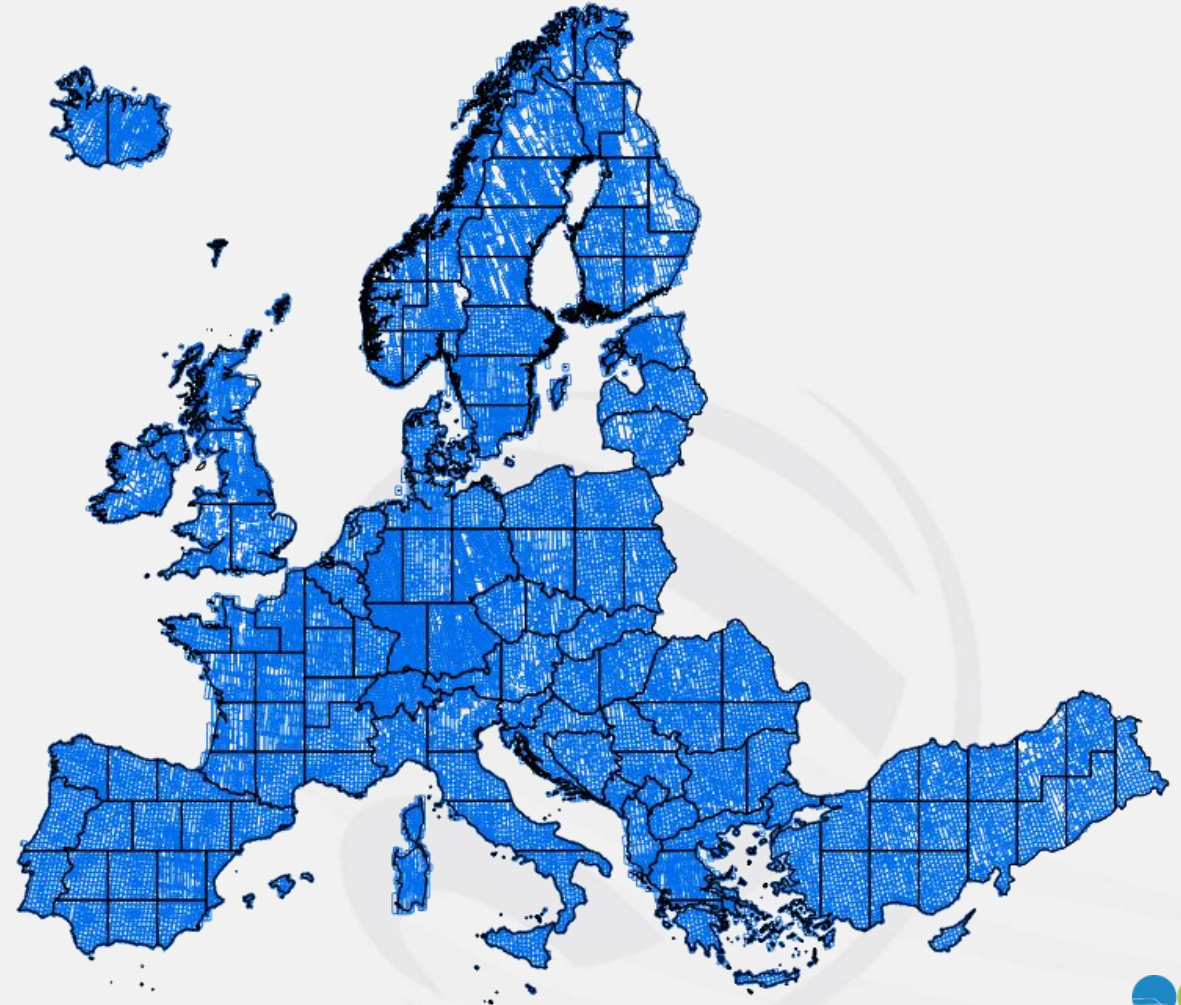
Small Woody Features

- Linear and patchy structures (binary)
- 2015 – 2018 (based on VHR)



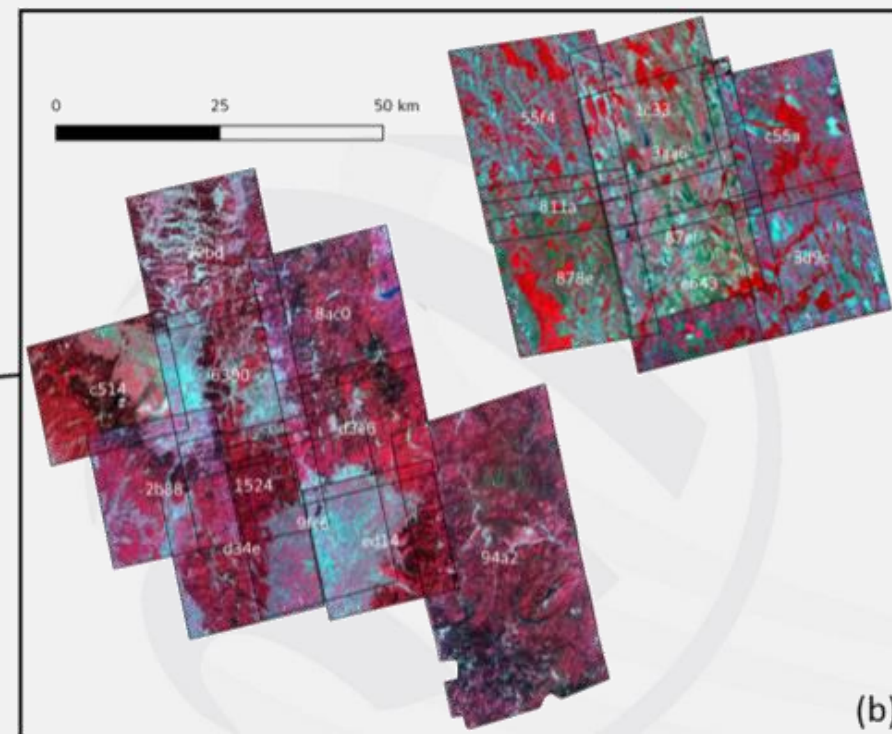
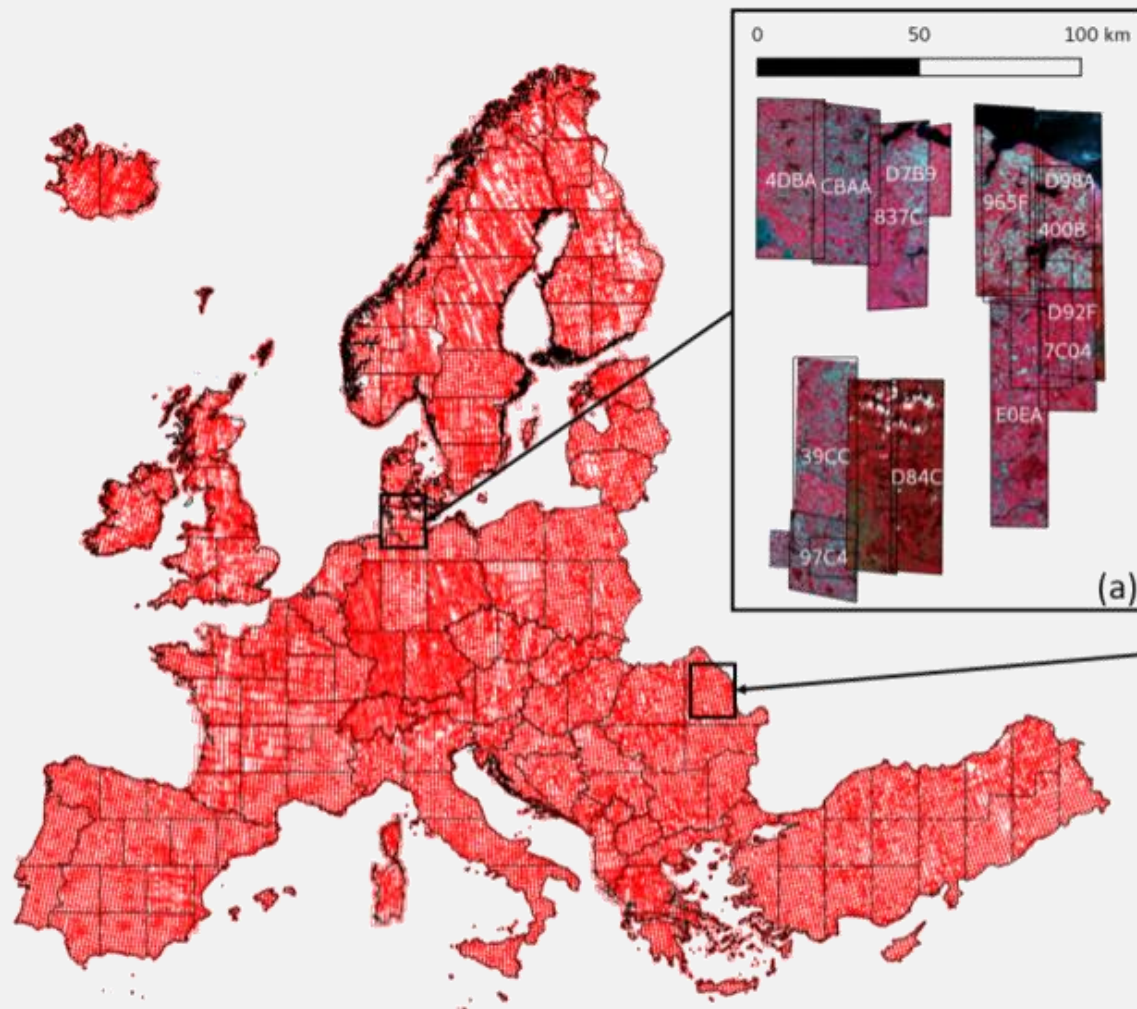


- Identification of linear elements (hedgerows) and isolated patches over EEA39 ~ 6million km<sup>2</sup>
- Data source
  - About 37,500 VHSR images
  - Volume > 300TB
  - Multi-sensor:
    - Pléiades
    - GeoEye
    - Worldview
    - DEIMOS
    - SPOT-6/7



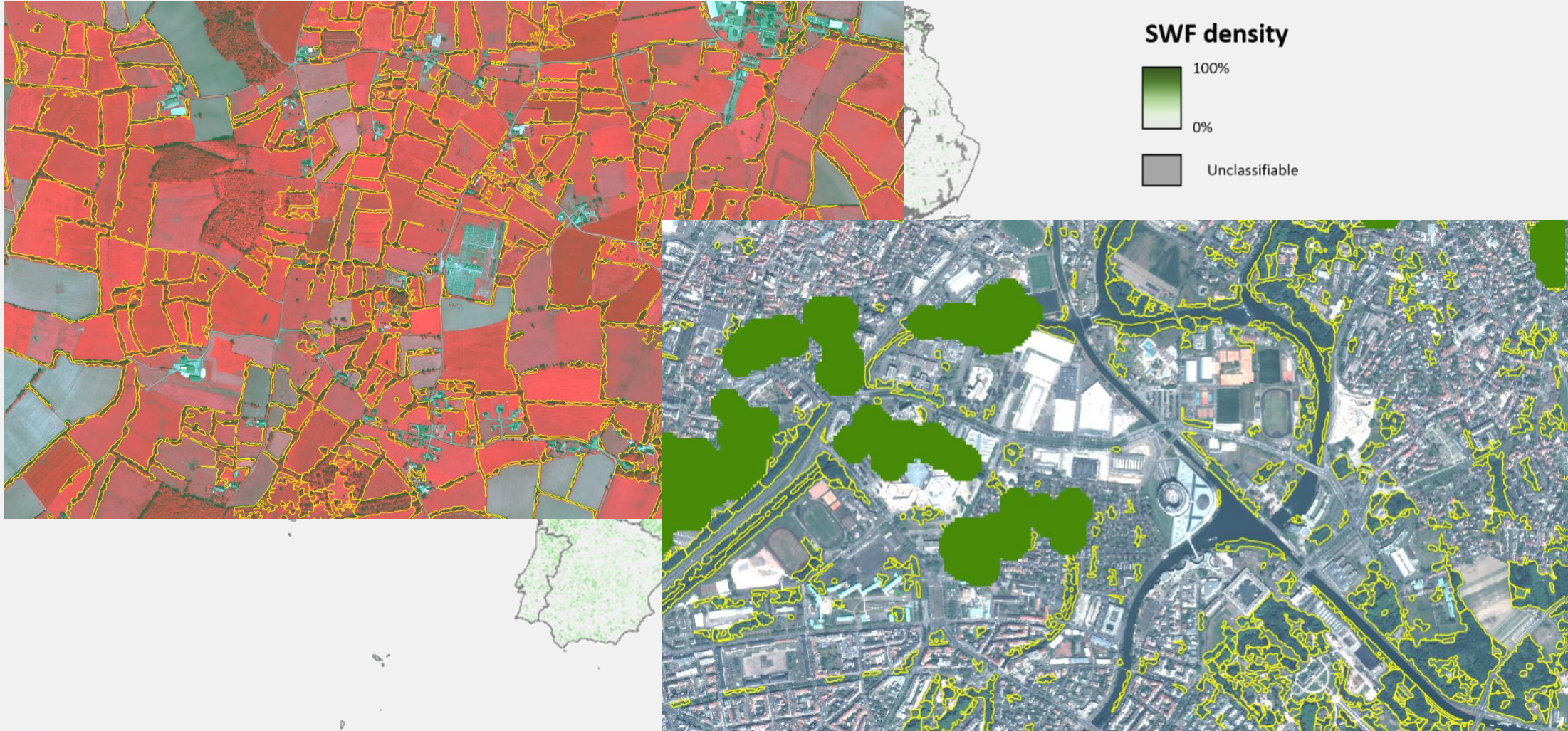


# High Resolution Layer SWF2015





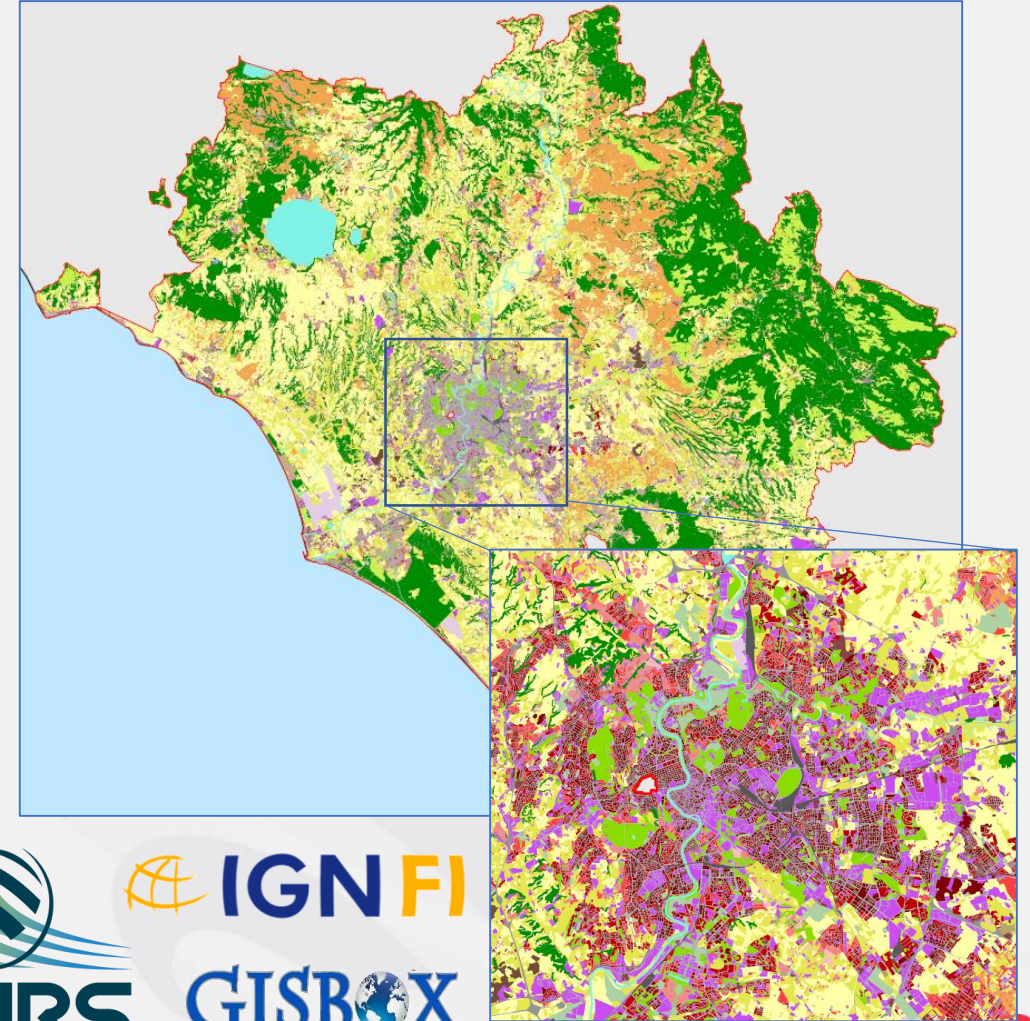
# High Resolution Layer SWF2015





# Hot Spots - Urban Atlas

- First implementation of the Local Component of the Copernicus Land Monitoring Service with the Urban Atlas 2006, then 2012 update and further extension and now 2018 update
- EC DG Regio led initiative to complement the Urban Audit
- Provides **harmonised Land Use/Land Cover maps** according to a common classification across Europe
- Urban Planning Tool to:
  - Monitor effects (positive or negative) of structural investment decisions
  - Compare between cities based on a common language
  - Monitor Urban sprawl more accurately





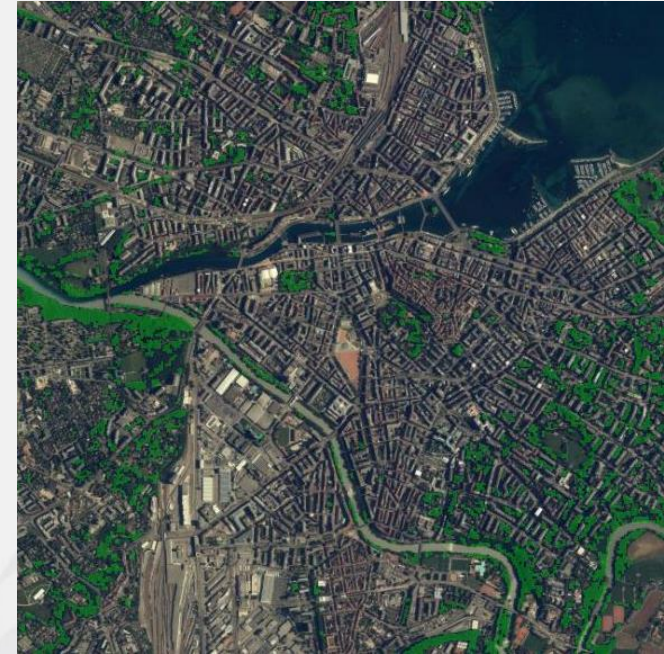
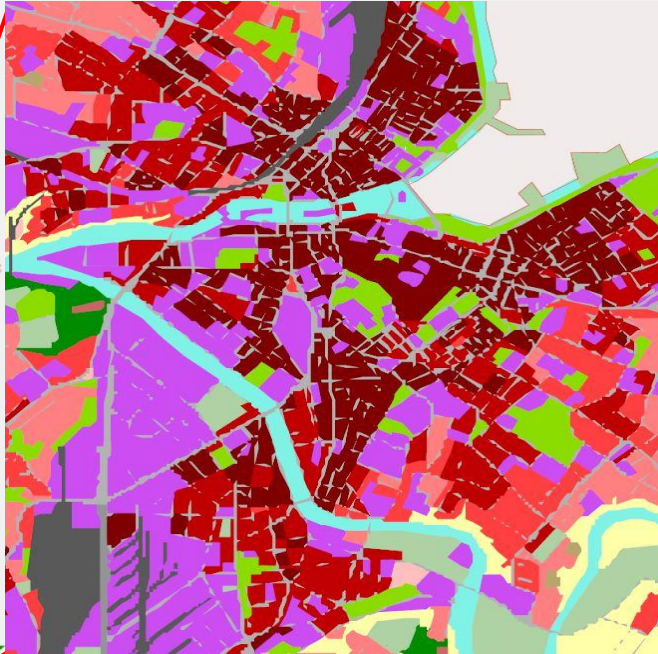
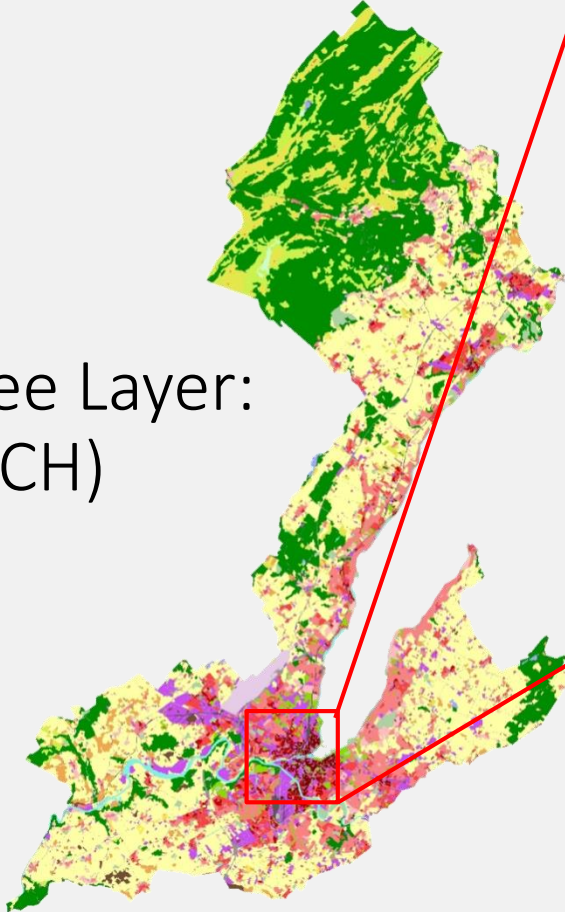
# Hot Spots - Urban Atlas





# Hot Spots - Urban Atlas

Street Tree Layer:  
Geneva (CH)

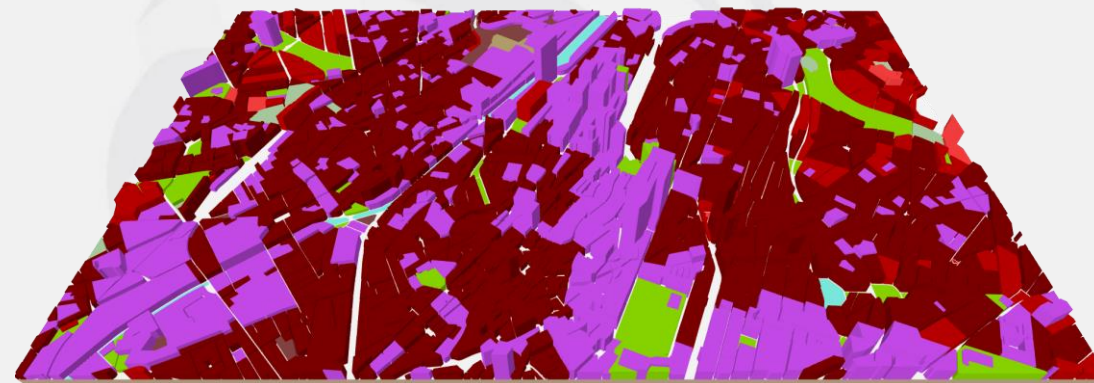
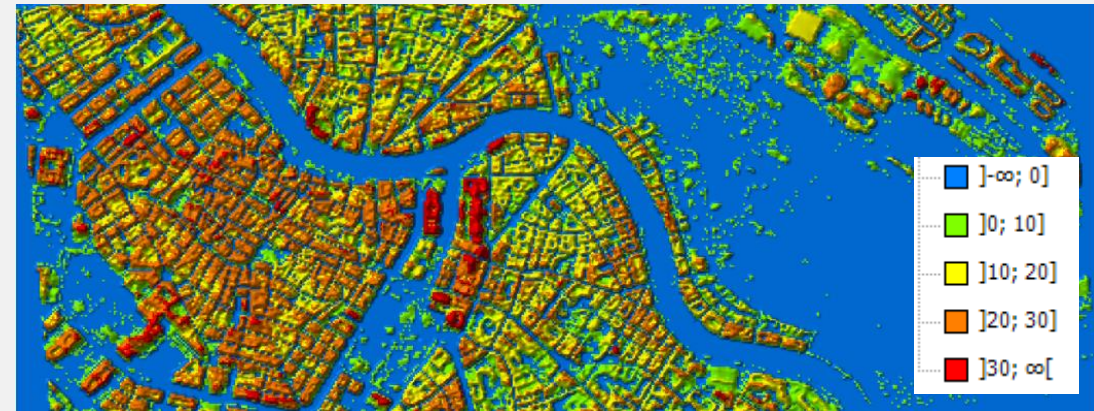




# Hot Spots - Urban Atlas

Digital Height Model for EU capital cities

Product Name	Digital Height Model
Base data	IRS-P5 Cartosat-1
Spatial Resolution	10 x 10m
Projection	ETRS89 Lambert Azimuthal Equal Area (LAEA) (EPSG 3035)
Delivery Format	GeoTiff
Vertical Accuracy	3 m Mean Absolute Error
Horizontal Accuracy	Half a pixel
Temporal Description	Reference year 2012 (2010-2014)
Metadata	INSPIRE conform xml
Base geometry	UA 2012 classes



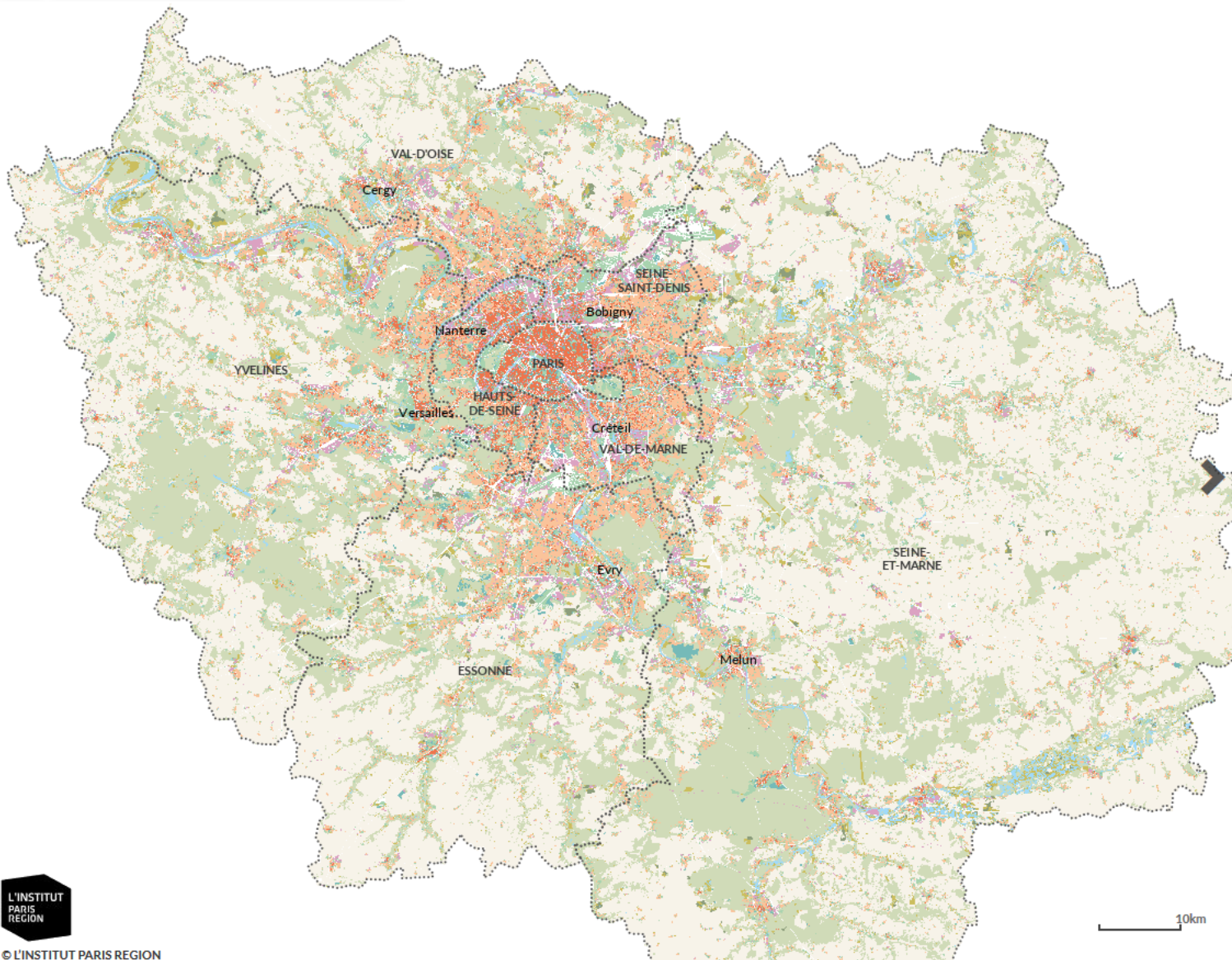


# Land Cover / Use mapping (MOS) of the Île de France region

**Aim :** Precise land cover / use mapping and understanding change dynamics

- Support : images aériennes et bases exogènes
- Echelle de production : 1/2 000,
- Nomenclature : type CORINE land Cover adapté,
- Précision géométrique : 3 mètre.
- Temps de Production : 6 mois par millésime de mise à jour
- Surface 12 500 km<sup>2</sup>
- Millésime : 1949-2003-2008-2012-2017.
- Fiabilité : > 95%



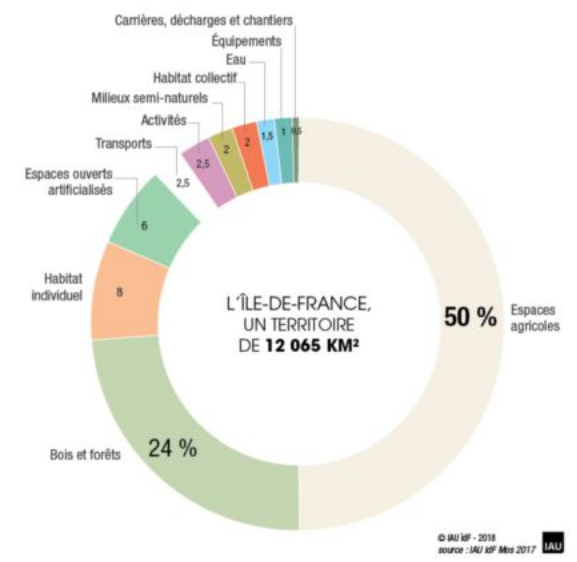


## OCCUPATION DU SOL 2017

Le Mos (Mode d'occupation du sol) est un inventaire cartographique de l'occupation du sol couvrant l'ensemble du territoire d'Île-de-France.

Pour commencer à naviguer sur cette carte, cliquer sur une commune.

### La région Île-de-France en chiffres



Grâce à cette couche d'information, vous pouvez aller plus loin dans l'exploration de vos territoires. Le Mos permet de :

- décrire un territoire au plus près de sa géographie croisant ainsi des milliers d'informations visualisables en une seule carte
- dresser un portrait instantané d'une commune, d'une intercommunalité ou d'un département
- analyser les mutations et les évolutions d'un territoire depuis 1982, saisir les enjeux d'aménagement et mieux appréhender son avenir
- croiser des informations nouvellement collectées et utiliser cette «photographie» pour simuler des projets à venir

Vous souhaitez acquérir des données ?  
Contactez **Assad Ali Cherif** : [assad.ali-cherif@institutparisregion.fr](mailto:assad.ali-cherif@institutparisregion.fr) - 01 77 49 75 86



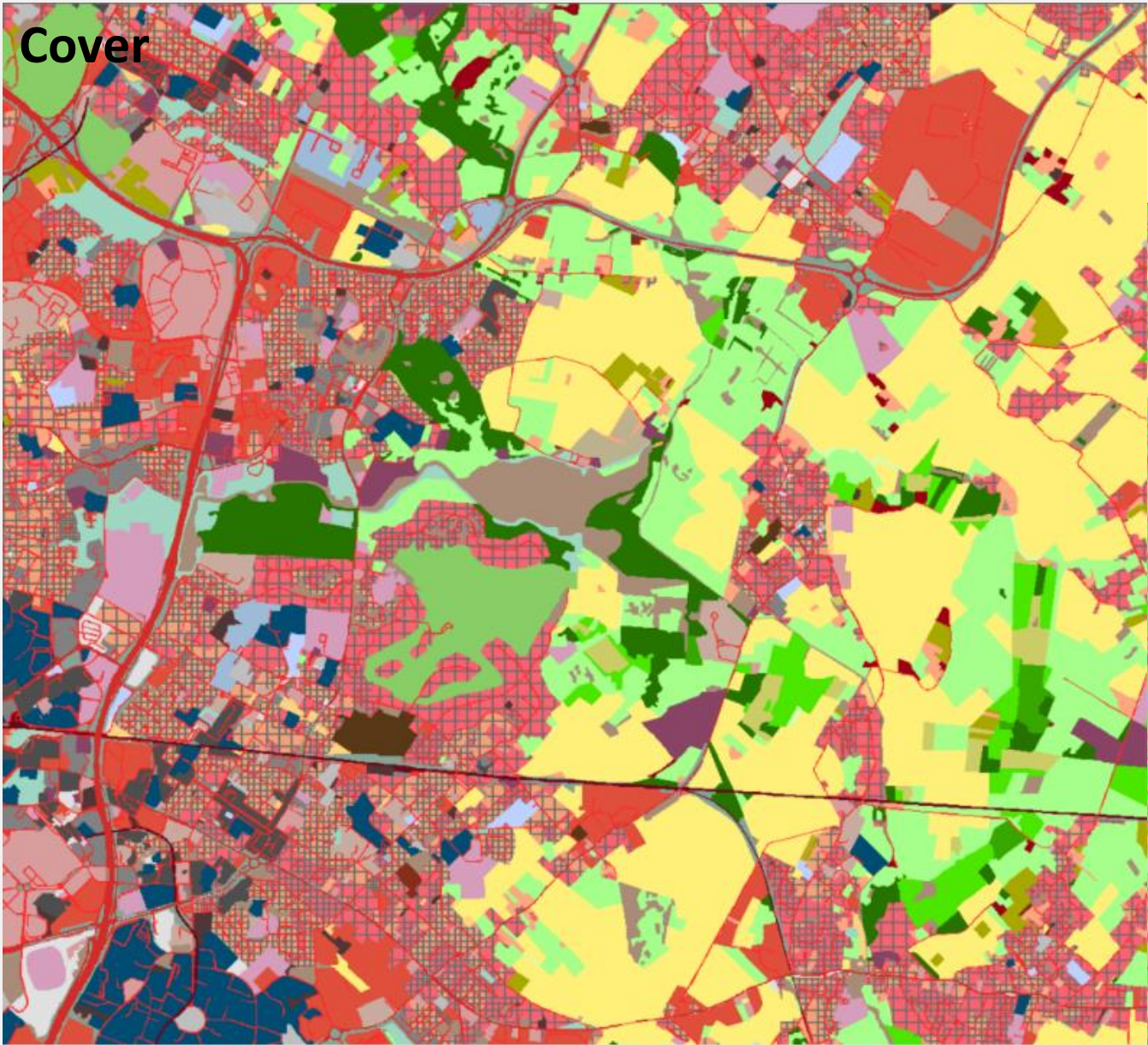
# Land Cover and Land Use (OCS 2D) mapping of the Nord - Pas de Calais Region

**Aim** : Provide harmonised land cover /use datasets at regional scale

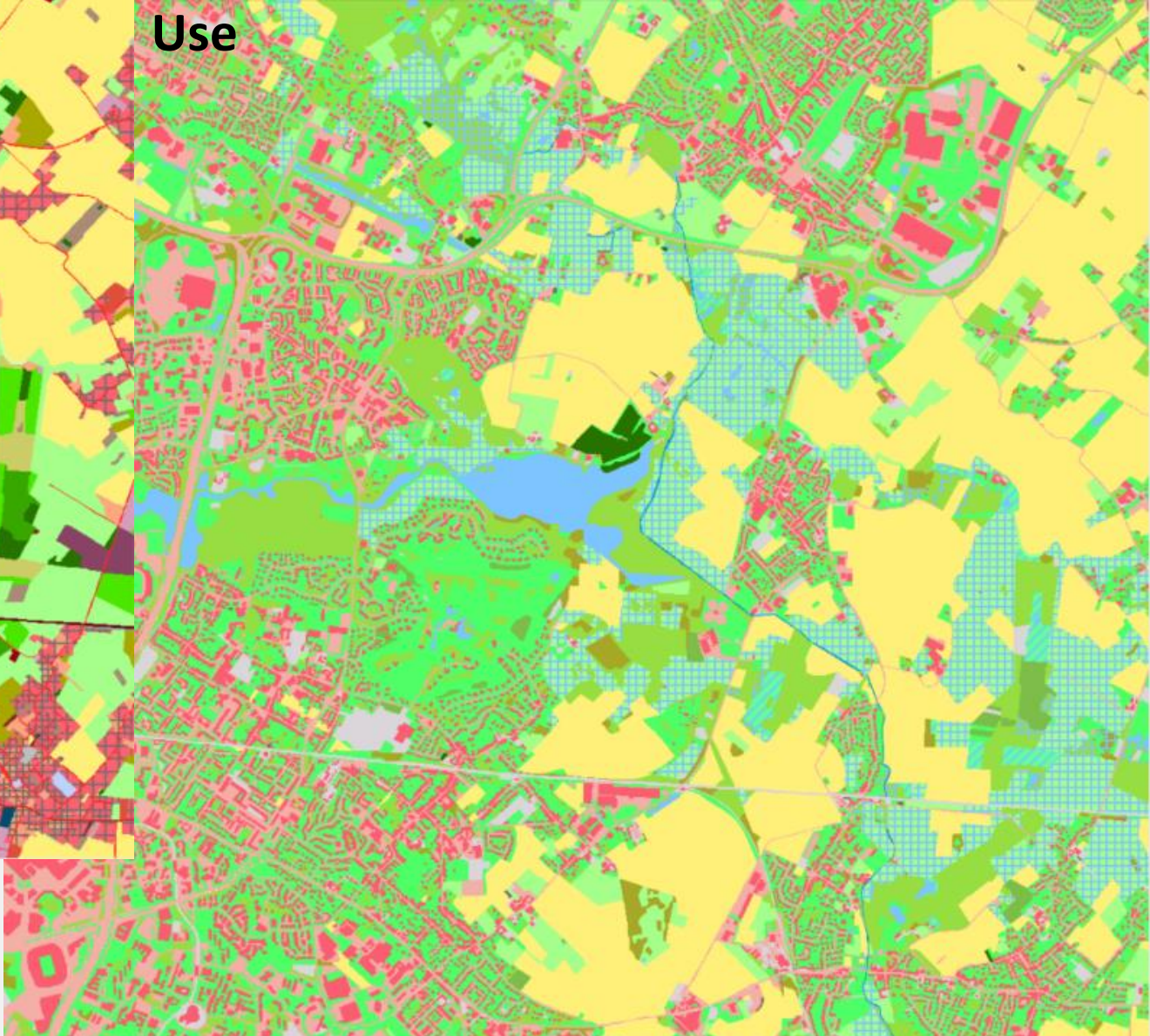
- Support : images aériennes et bases exogènes
- Echelle de production : 1/2 000,
- Nomenclature : 2 dimensions Couvert et Usage
- Précision géométrique : 1 mètre.
- Temps de Production : 18 mois
- Surface :13 000 km<sup>2</sup>
- Millésime :2005 et 2015.
- Fiabilité : 90 %



Cover



Use





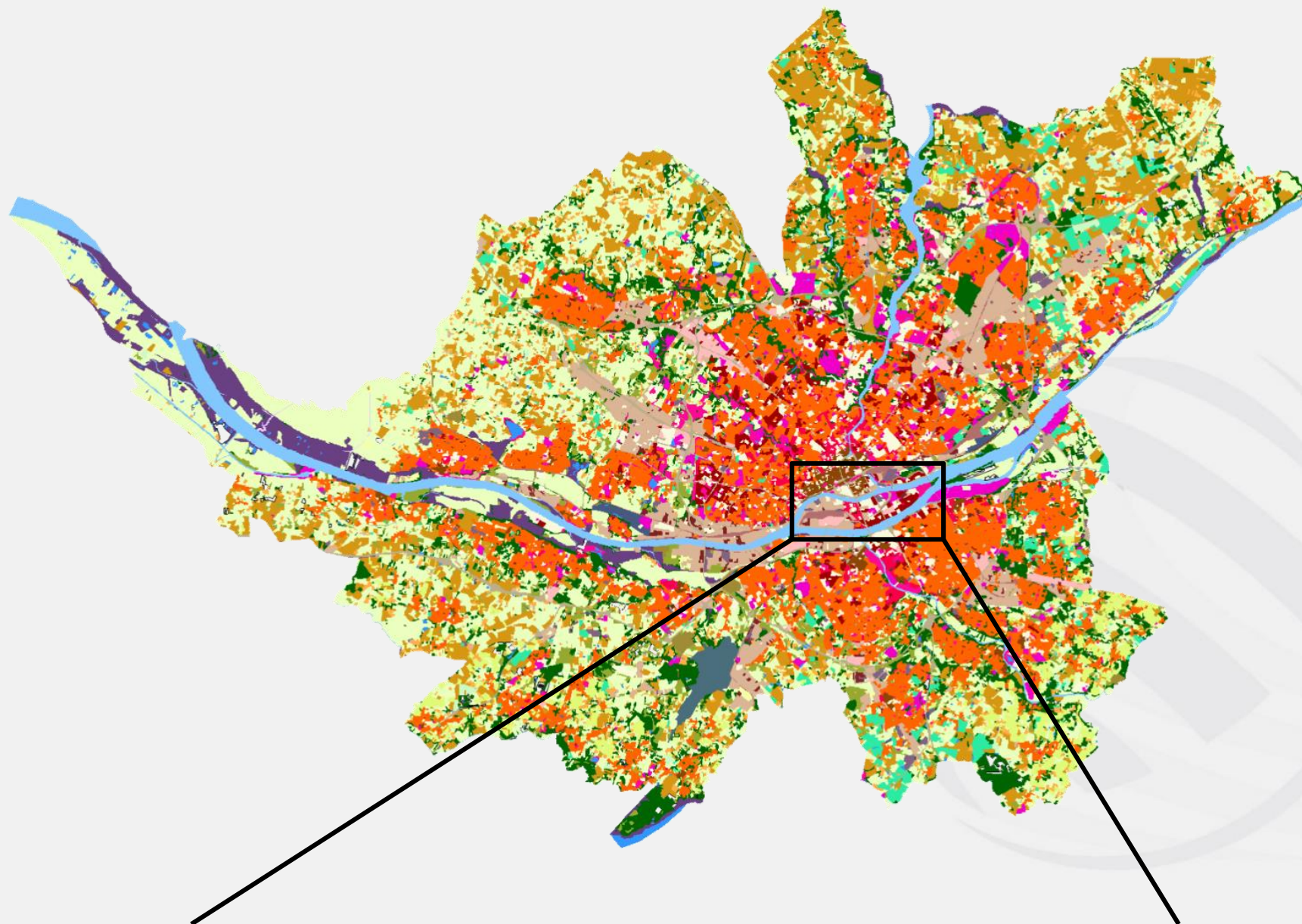
# Land Cover / Use dynamics for Nantes Metropole

**Aim :** Precise understanding of land cover and land use and drivers of change

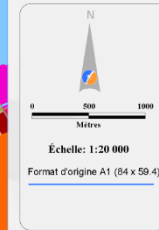
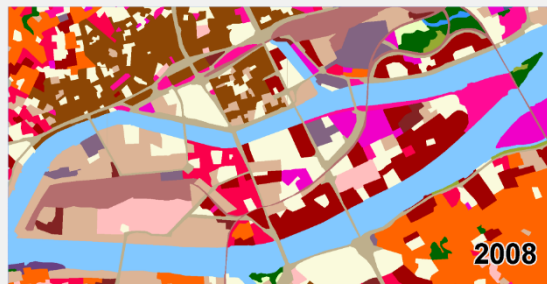
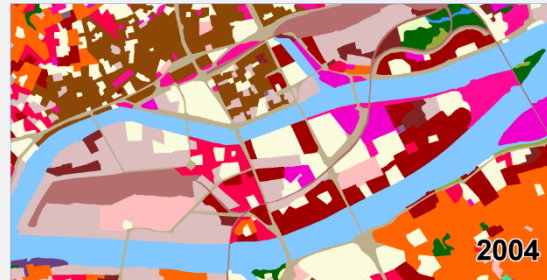
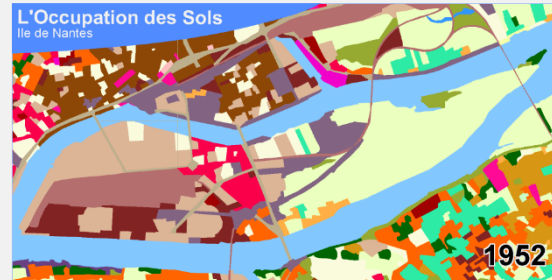
- Support : images aériennes et bases exogènes
- Echelle de production : 1/2 500,
- Nomenclature : CLC affinée
- Précision géométrique : 3 mètres
- Temps de Production : 2 semaines par millésime
- Surface : 500 km<sup>2</sup>
- Millésime 1949 – 1990-1999-2004-2008-2012-2016-2018
- Fiabilité : 90%



# Urban and peri-urban land cover / use: City of Nantes, France 2012



# Land cover / land use change 1952 - 2012



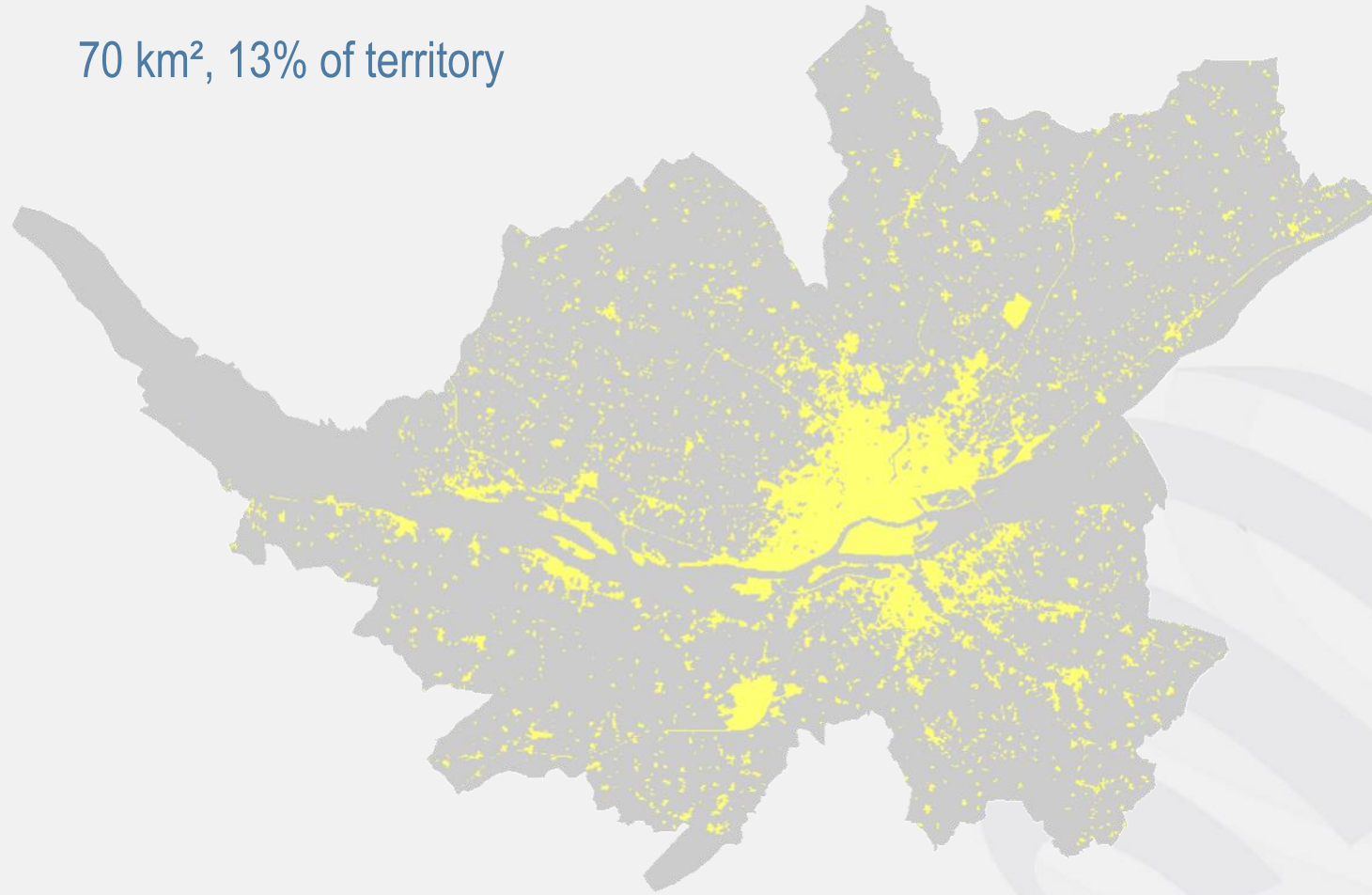
## Niveau 3





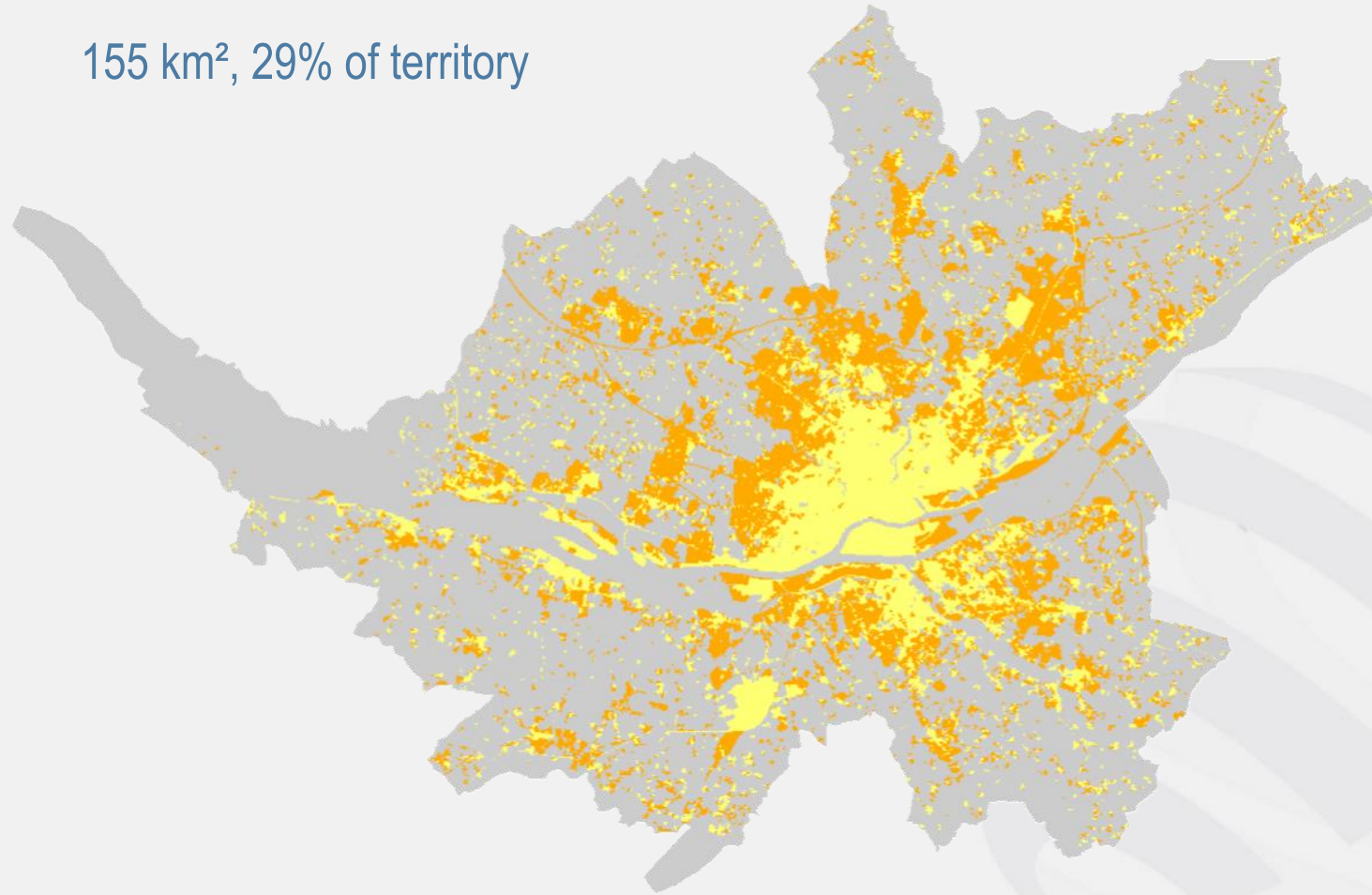
# Urban extent and change 1952

70 km<sup>2</sup>, 13% of territory



# Urban extent and change 1981

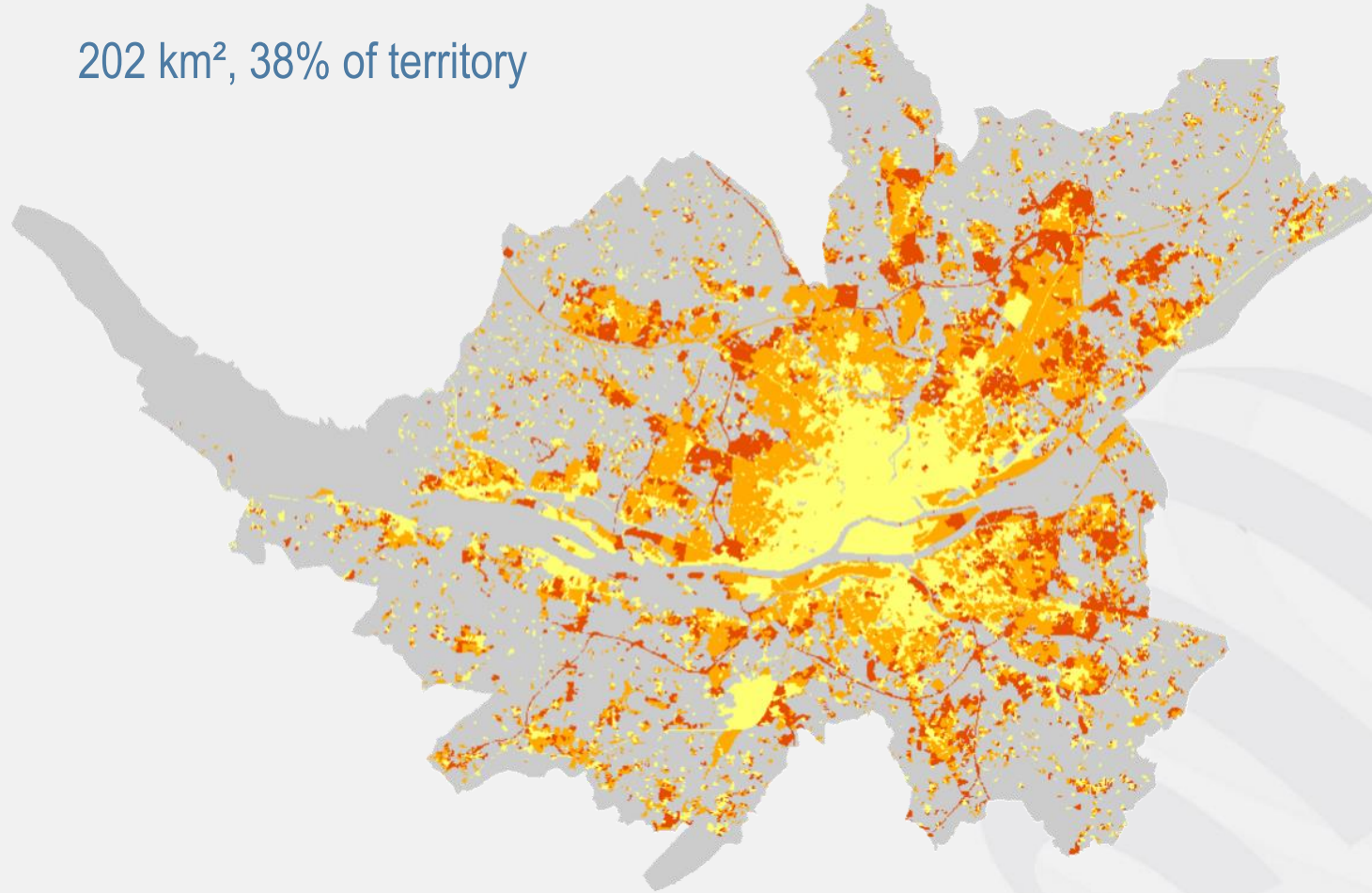
155 km<sup>2</sup>, 29% of territory





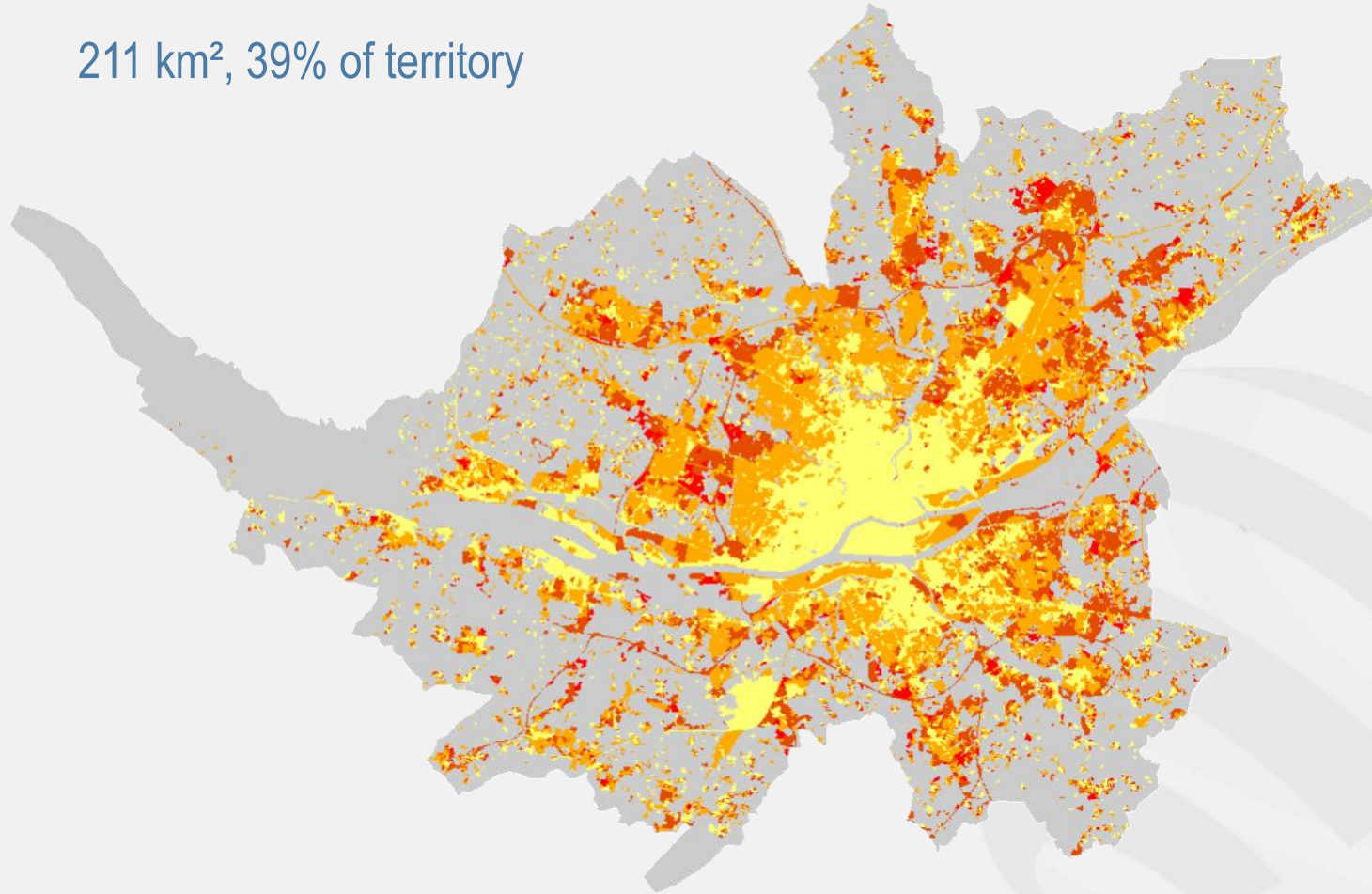
# Urban extent and change 1999

202 km<sup>2</sup>, 38% of territory



# Urban extent and change 2004

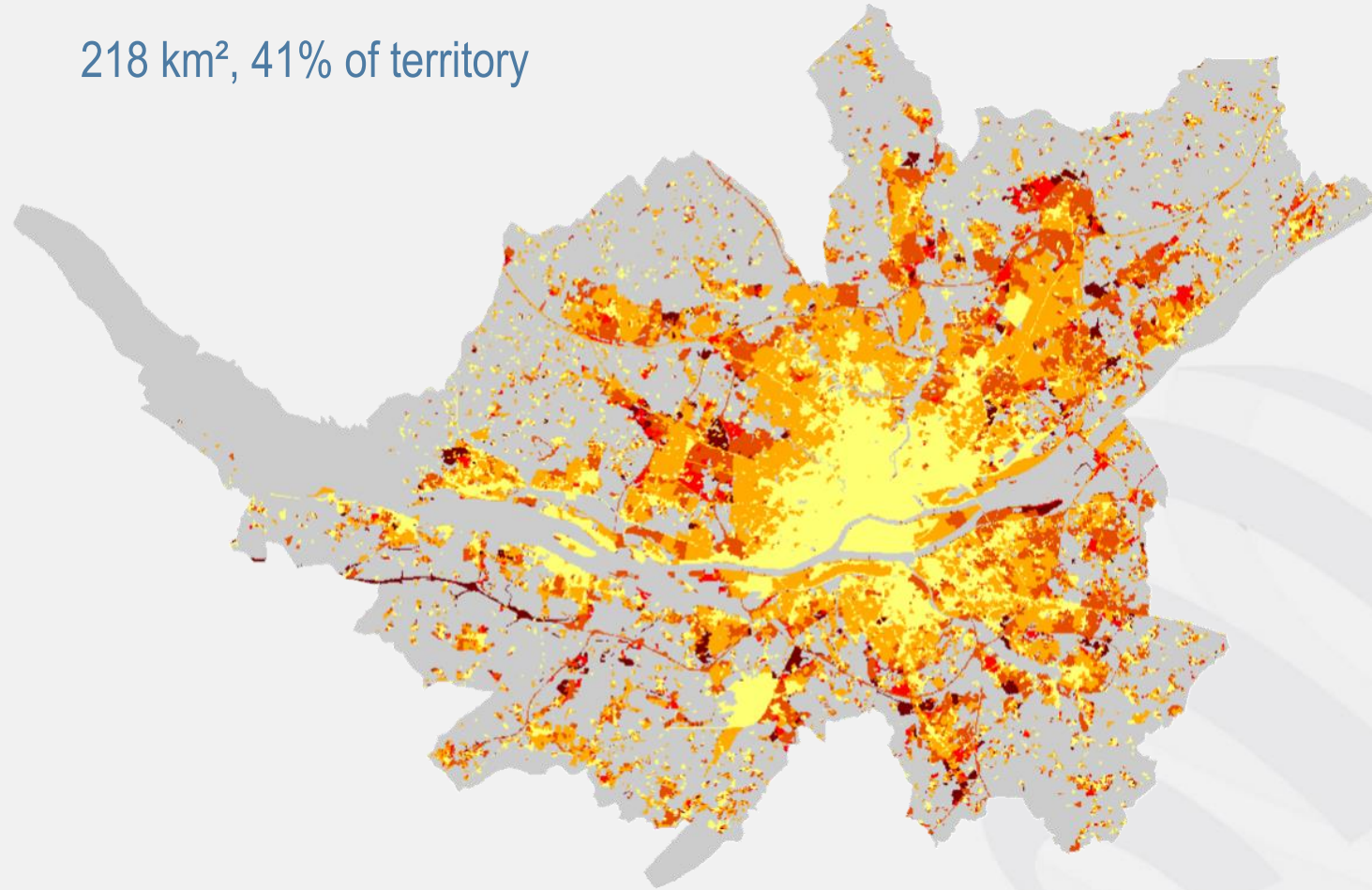
211 km<sup>2</sup>, 39% of territory





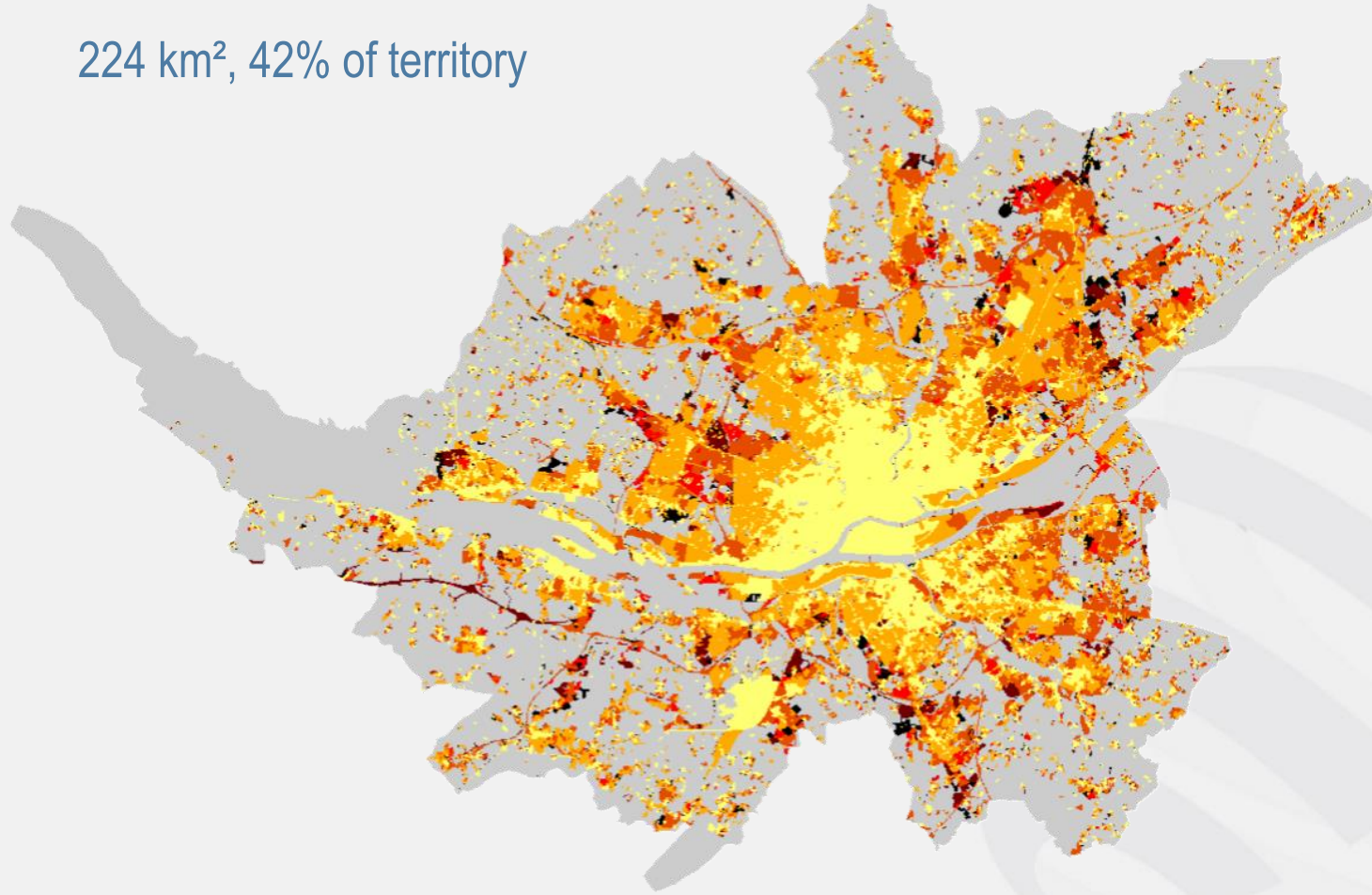
# Urban extent and change 2008

218 km<sup>2</sup>, 41% of territory



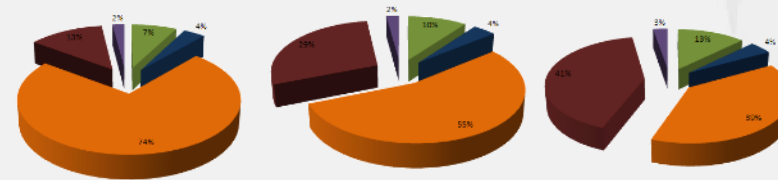
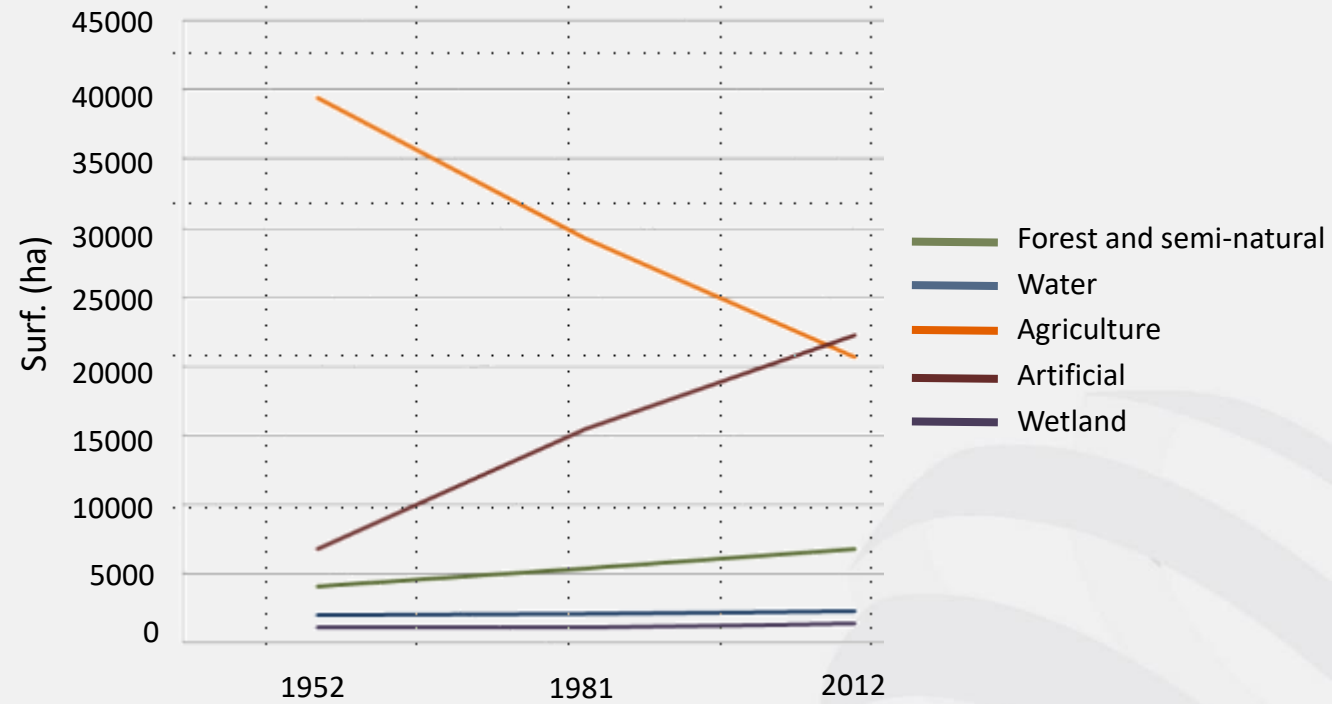
# Urban extent and change 2012

224 km<sup>2</sup>, 42% of territory

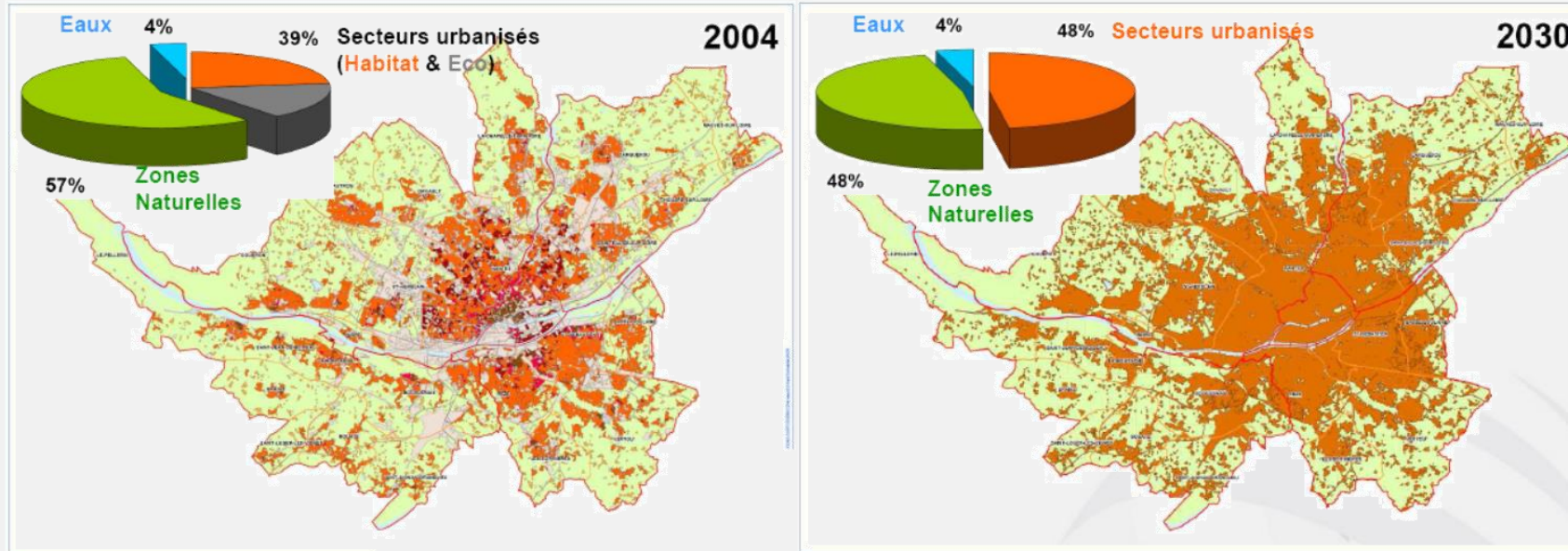




# Land cover /use flows



# Modelling of Urban Expansion



Modelling of urban expansion based on “business as usual” scenario considering the historical pattern of expansion from 1952 to 2012.



# Habitat and habitat change mapping for the Nord – Pas de Calais Region

**Aim :** Identification of habitats, their dynamics and connectivity

- Support : images aériennes
- Echelle de production : 1/1 000,
- Nomenclature : type CORINE Biotope,
- Précision géométrique : 1 mètre.
- Temps de Production : 18 mois en création et 12 mois en mise à jour
- Surface 13 500 km<sup>2</sup>
- Millésime 2005-2009 et 2013.
- Fiabilité : > 85%







# 3D Urban Vegetation mapping over Grand Lyon

**Aim :** Precise urban vegetation mapping and vegetation type identification to assess their connectivity over public and private spaces

- Support : images aériennes et lidar,
- Echelle de production : 1/1 000,
- Nomenclature : type CORINE Biotope,
- Précision géométrique : 1 mètre.
- Temps de Production : 6 mois
- Surface 700 km<sup>2</sup>
- Millésime 2016.
- Fiabilité : > 92%



# Cartographie de la végétation en 3D sur le Grand Lyon

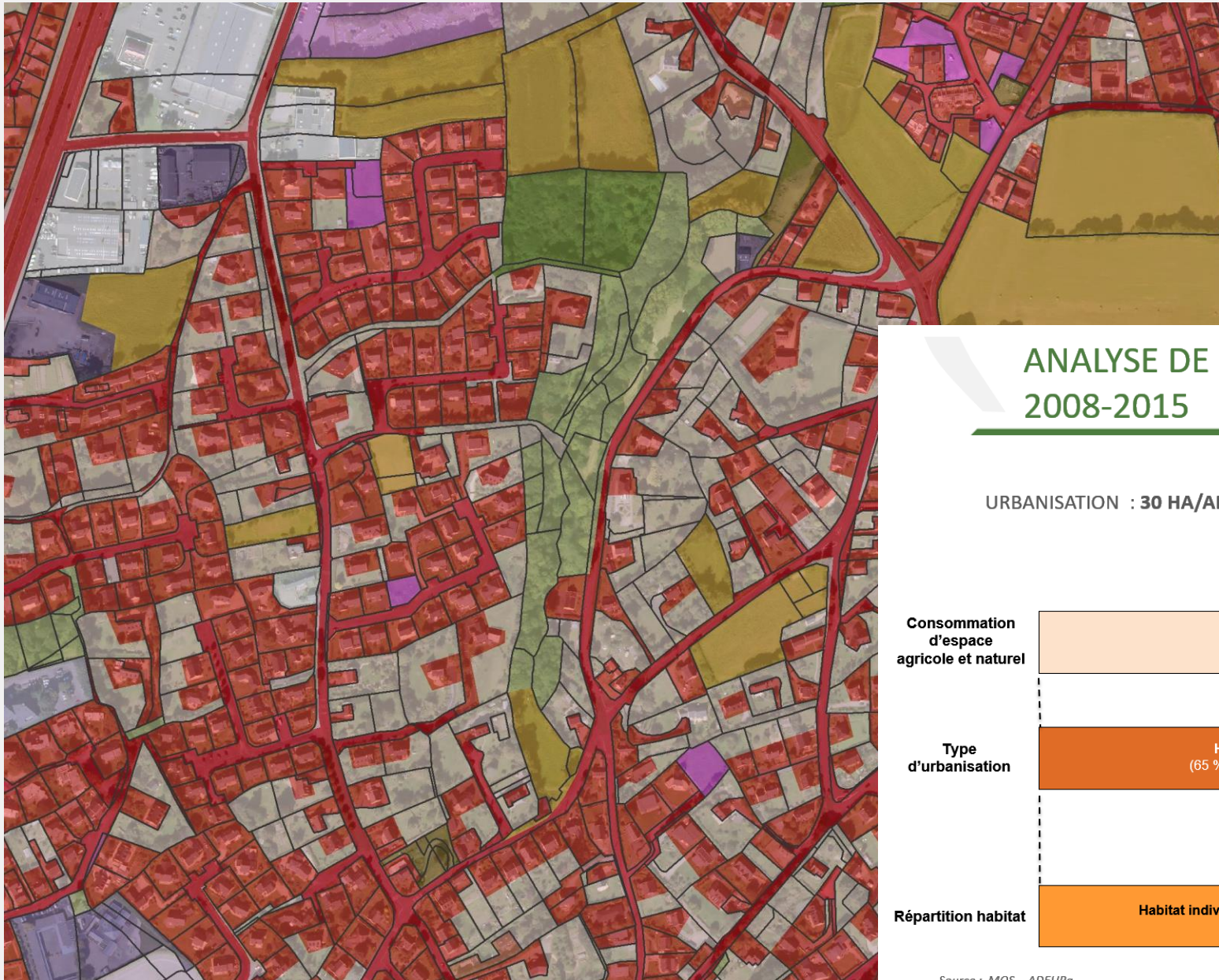




# Land Use mapping for land development

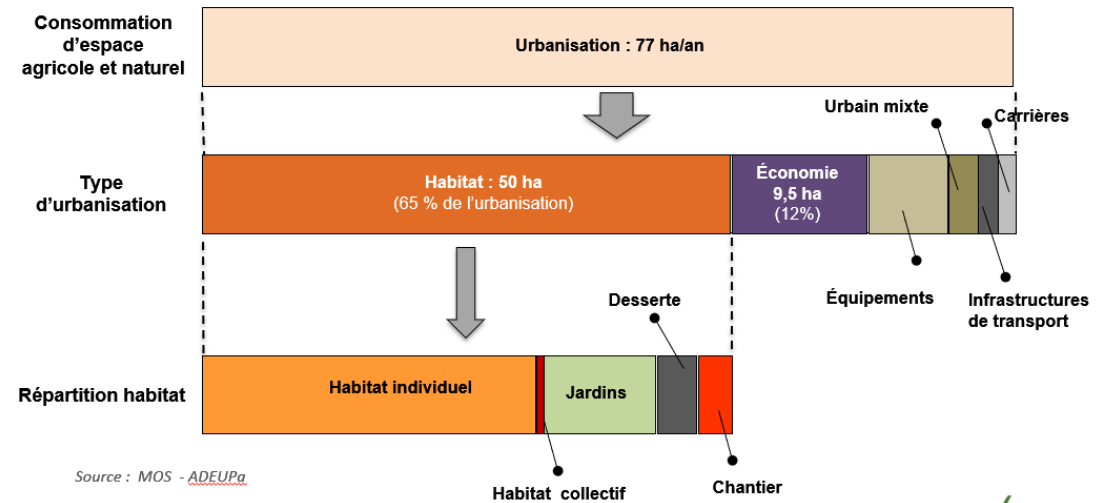
**Aim** : Precise knowledge of land development potential and drivers of change at land parcel level

- Support : Base cadastrale, fichier foncier, images aériennes et bases exogènes
- Echelle de production : 1/2 000,
- Nomenclature : CLC adaptée en urbain
- Précision géométrique : cadastre
- Temps de Production : Quelques jours pour une collectivité
- Surface : 6 000 km<sup>2</sup> et une dizaine d'EPCI
- Millésime 2008 – 2015-2018
- Fiabilité : 85%



## ANALYSE DE LA CONSOMMATION D'ESPACE 2008-2015

URBANISATION : 30 HA/AN POUR L'HABITAT ET 7,5 HA/AN POUR L'ÉCONOMIE



Source : MOS - ADEUPa





# Need for Validation of land cover maps

# Why and how to validate land cover maps?

- Why:
  - Does the product meet the specifications?
  - To ensure the product is fit for purpose
- How:
  - Thematic accuracy
  - Geomatic accuracy
- How are specifications set?
- What is the use of an accuracy metric from a user perspective?




Remote Sensing of Environment  
Volume 115, Issue 2, 15 February 2011, Pages 715-724



## Satellite image-based maps: Scientific inference or pretty pictures?

Ronald E. McRoberts 

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<https://doi.org/10.1016/j.rse.2010.10.013>


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Remote Sensing of Environment  
Volume 151, August 2014, Pages 138-148



## Using the regression estimator with Landsat data to estimate proportion forest cover and net proportion deforestation in Gabon

Christophe Sannier <sup>a</sup> , Ronald E. McRoberts <sup>b</sup>, Louis-Vincent Fichet <sup>a</sup>, Etienne Massard K. Makaga <sup>c</sup>

 [Show more](#)

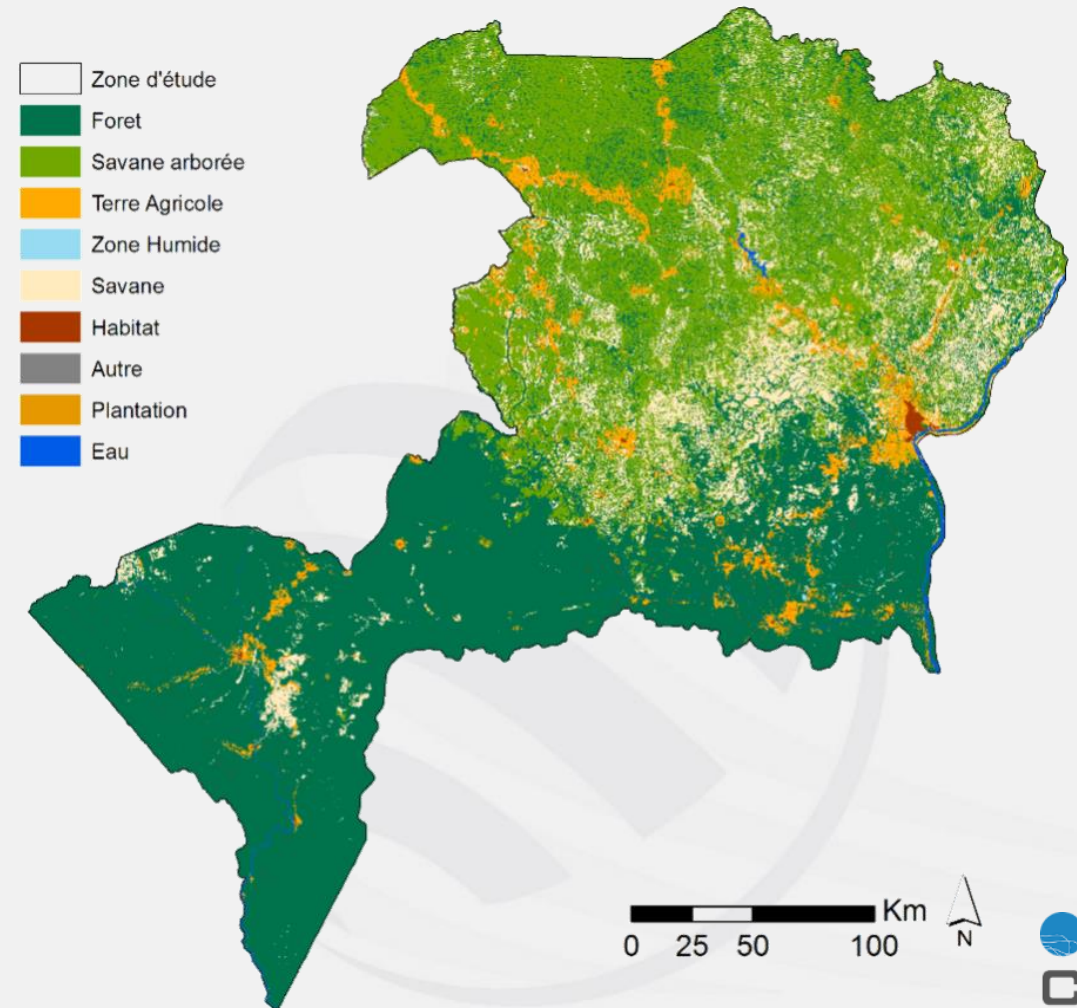
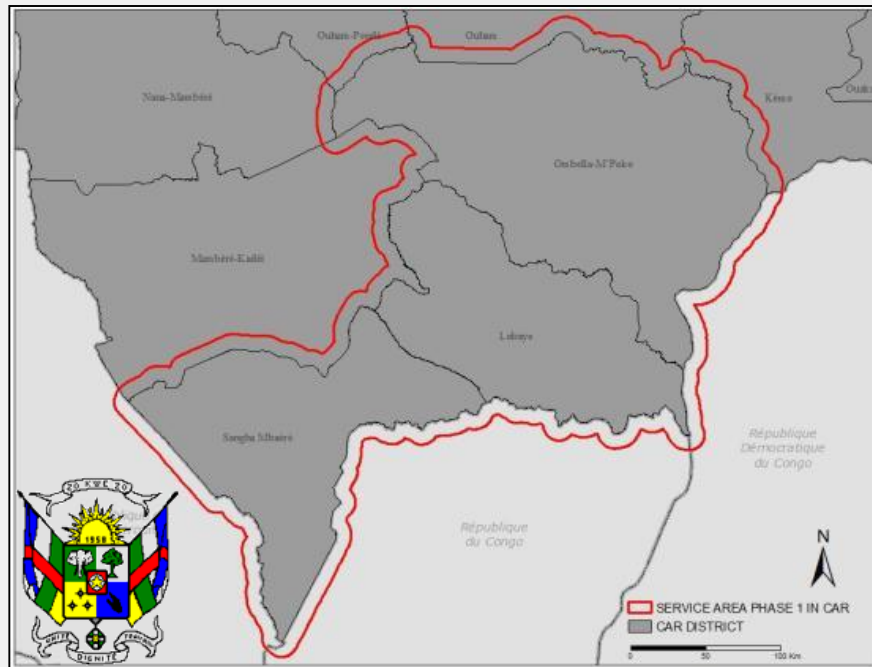
<https://doi.org/10.1016/j.rse.2013.09.015>

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# IPCC compliant land use map of Southwest massif in Central African Republic

- Collaboration with Ministry of Environment and Ecology (MEE). Bangui – Central African Republic
- Forest cover maps for: 1990. 2000 and 2010
- IPCC compliant Land use map for 2010



# IPCC compliant land use map of Southwest massif in CAR

In some cases, it may be preferable to separate different forest types

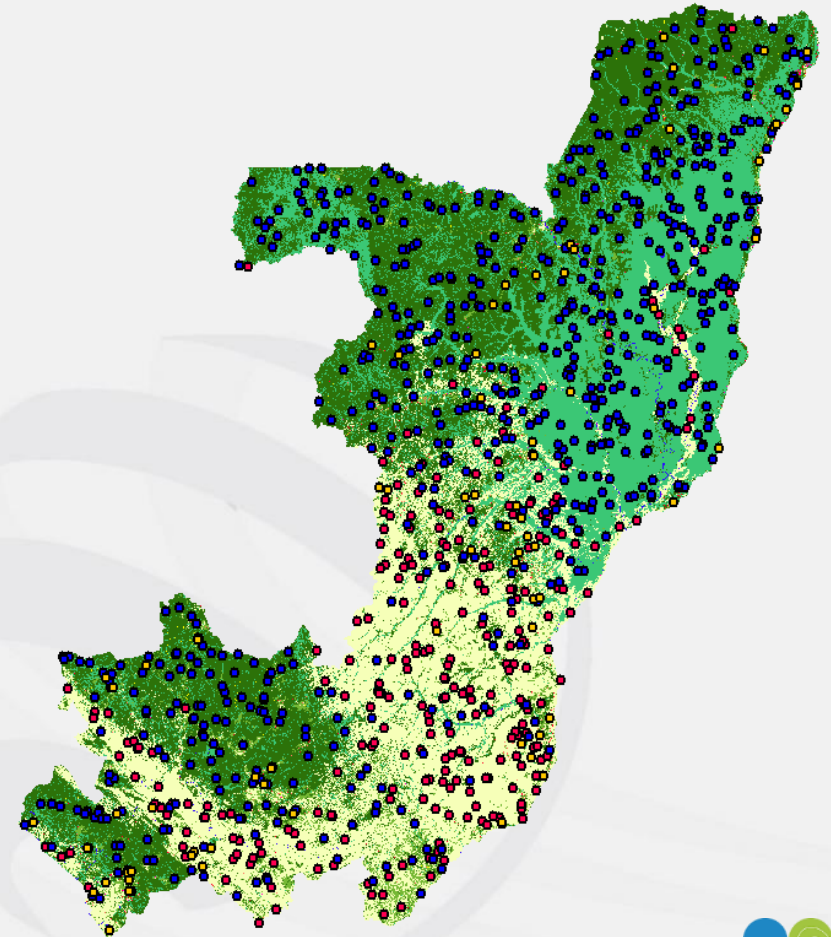
		REFERENCE							Total	User
		1	2	3	4	5	6	7		
MAP	Humid Forest 1	4897	319	66	42	7	1	0	5332	91.84%
	Dry Forest 2	343	4181	75	246	7	3	1	4856	86.10%
	Cropland 3	110	234	587	210	4	21	0	1166	50.34%
	Grassland 4	71	1445	83	491	8	5	0	2103	23.35%
	Wetland 5	10	5	3	3	97	0	0	118	82.20%
	Infrastructure 6	7	3	19	2	1	47	0	79	59.49%
	Other 7	1	5	3	5	2	0	8	24	33.33%
	Total	5439	6192	836	999	126	77	9	13678	
	Producer	90.03%	67.52%	70.22%	49.15%	76.98%	61.04%	88.89%		

Overall Accuracy: 75.36 % +/- 0.72% (95%CI)



# Stratified Random Sampling Design

- 2000-2012 Forest loss map produced by Ministry of Forestry Economy staff in collaboration with UMd used for stratification
- Sampling design according to Olofsson *et al.* (2014)
- 1000 pixels sampled
- Minimum of 75 pixel/point samples for smallest stratum: F loss
- Rest of samples allocated proportionally for F (662) and NF (263) strata



# Accuracy of Change – Republic of Congo

CNIAF / FAO 2000-2012 Forest Cover Map

		Reference			Total	User's accuracy
		Stable NF	Stable F	Change		
Map	Stable NF	276	6		<b>283</b>	0,977
	Stable F	20	691	1	<b>712</b>	0,970
	Change	1	2	2	<b>5</b>	<b>0,427</b>
Total		<b>297</b>	<b>699</b>	<b>3</b>	<b>1000</b>	
Producer's accuracy		0,930	0,988	<b>0,651</b>	Overall Accuracy	<b>0.969</b>

Change classes often problematic



# Area and Uncertainty estimates

- Forest cover and forest cover change estimates can be produced based on samples alone (Direct estimate)

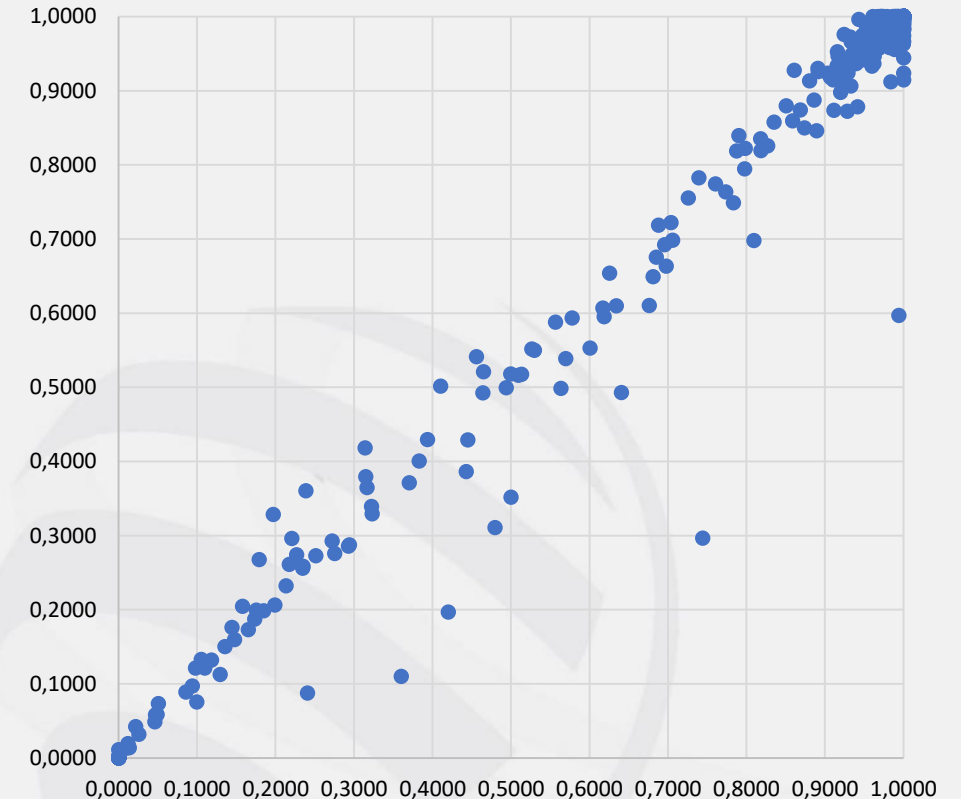
$$\hat{\mu} = \frac{1}{m} \sum_{i \in S_1} z_i \quad \text{Var}(\hat{\mu}) = \frac{1}{m(m-1)} \sum_{i \in S_1} (z_i - \hat{\mu})^2$$

- Observations from reference samples and the map can be combined to improve the precision of estimates (Model Assisted Regression):

$$\hat{\mu}^{MAR} = \hat{\mu}^{MAP} - \text{Bias}(\hat{\mu}^{MAP})$$

$$\text{Var}(\hat{\mu}^{MAR}) = \frac{1}{m(m-1)} \sum_{i=1}^m (\Delta_i - \bar{\Delta})^2$$

Classified vs Reference Forest Proportion



# Estimations 2000-2014

Area Sample 2000-2014 (ha)	Couvert Forêt 2000	Couvert Forêt 2014	Perte Couvert Forestier 2000-2014
Estimation directe	23 320 547	23 106 291	318 175
95% Intervalle Confiance	±455 938	±456 860	±92 923
Estimation Carte	23 985 590	23 779 467	206 123
Estimation Régression	23 430 221	23 212 287	321 853
95% Intervalle Confiance	±194 125	±202 899	±85 888

Point Sample 2014-2016 (ha)	Couvert Forêt 2014	Couvert Forêt 2016	Perte Couvert Forestier 2014-2016
Estimation directe	23 607 557	23 396 020	316 431
95% Intervalle Confiance	±642 934	±647 236	±194 925
Estimation Carte	23 985 590	23 779 467	206 123
Estimation Régression	23 328 538	23 124 596	308 836
95% Intervalle Confiance	±427 357	±460 605	±231 987

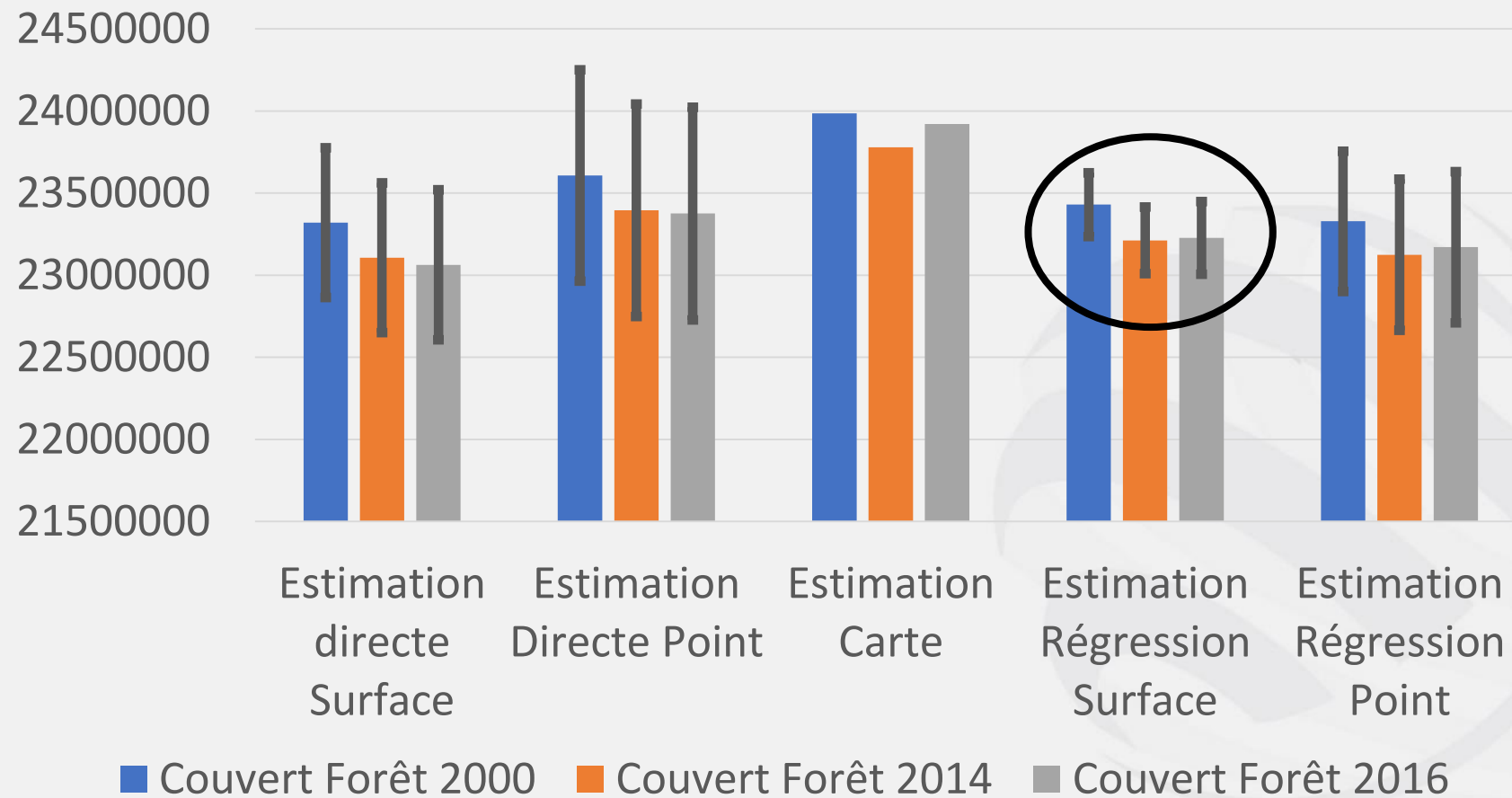


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95% Intervalle Confiance	<b>±194 125</b>	<b>±202 899</b>	<b>±85 888</b>

Point Sample 2014-2016 (ha)	Couvert Forêt 2014	Couvert Forêt 2016	Perte Couvert Forestier 2014-2016
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# Superficie du Couvert forestier du Congo





# Estimations 2014-2016

Area Sample 2014-2016 (ha)	Couvert Forêt 2014	Couvert Forêt 2016	Perte Couvert Forestier 2014-2016
Estimation directe	23 099 720	23 063 305	53 100
95% Intervalle Confiance	±455 365	±456 693	±20 705
Estimation Carte	23 941 404	23 920 637	20 767
Estimation Régression	23 271 194	23 227 807	60 072
95% Intervalle Confiance	±220 242	±221 876	±20 924

Point Sample 2014-2016 (ha)	Couvert Forêt 2014	Couvert Forêt 2016	Perte Couvert Forestier 2014-2016
Estimation directe	23 396 020	23 375 600	40 840
95% Intervalle Confiance	±647 236	±648 169	±56021
Estimation Carte	23 941 404	23 920 637	20 767
Estimation Régression	23 191 248	23 170 509	41 159
95% Intervalle Confiance	±461 313	±221 876	±20 924

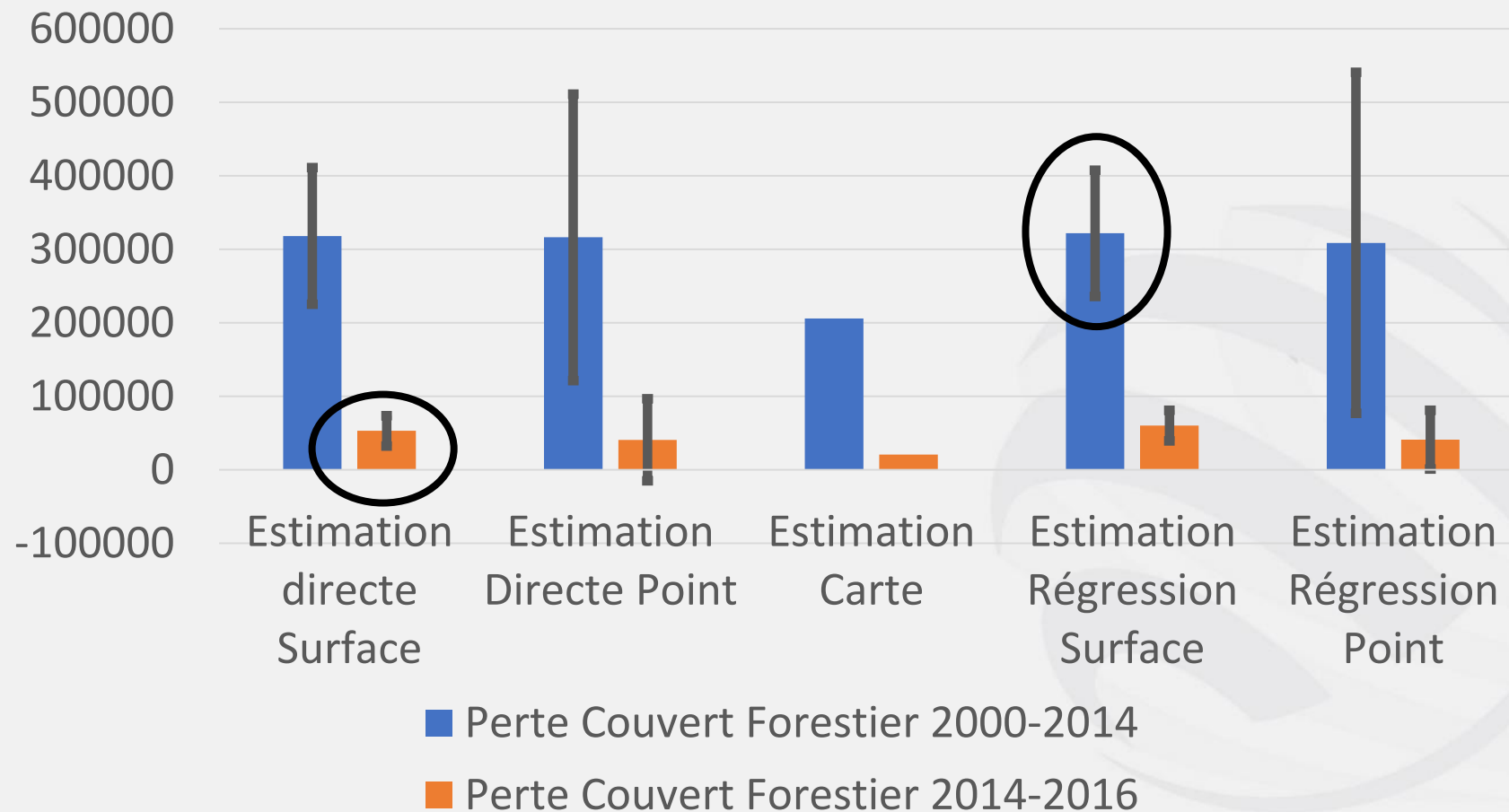
# Estimations 2014-2016

Area Sample 2014-2016 (ha)	Couvert Forêt 2014	Couvert Forêt 2016	Perte Couvert Forestier 2014-2016
Estimation directe	23 099 720	23 063 305	<b>53 100</b>
95% Intervalle Confiance	±455 365	±456 693	<b>±20 705</b>
Estimation Carte	23 941 404	23 920 637	20 767
Estimation Régression	<b>23 271 194</b>	<b>23 227 807</b>	60 072
95% Intervalle Confiance	<b>±220 242</b>	<b>±221 876</b>	±20 924

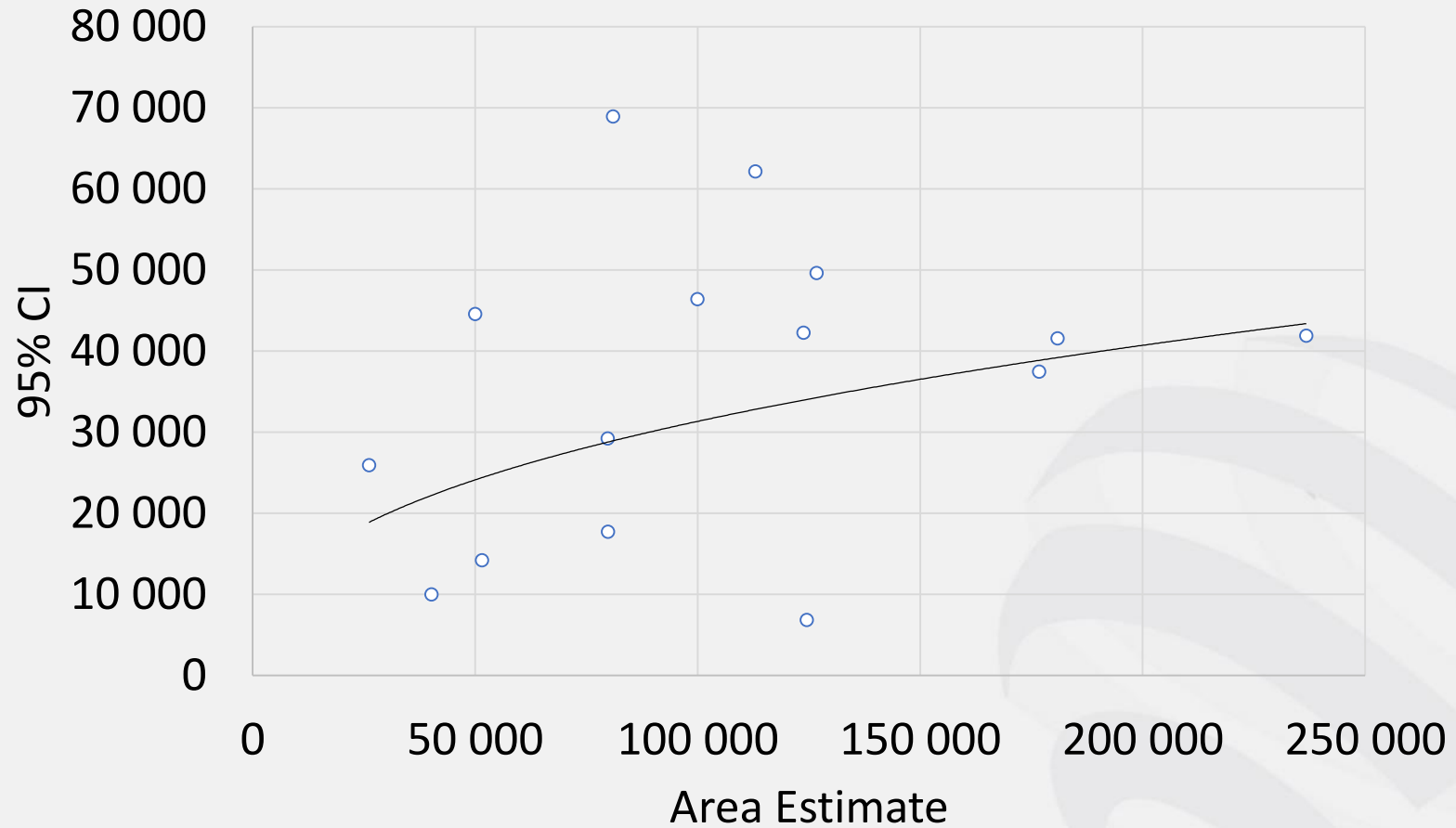
Point Sample 2014-2016 (ha)	Couvert Forêt 2014	Couvert Forêt 2016	Perte Couvert Forestier 2014-2016
Estimation directe	23 396 020	23 375 600	40 840
95% Intervalle Confiance	±647 236	±648 169	±56021
Estimation Carte	23 941 404	23 920 637	20 767
Estimation Régression	23 191 248	23 170 509	41 159
95% Intervalle Confiance	±461 313	±221 876	±20 924



# Evolution du couvert forestier du Congo



# Link between uncertainty and changed area estimate





# Impervious area estimates for EEA39

(km <sup>2</sup> )	Loss			Gain		
	0609	0912	1215	0609	0912	1215
HRL IMD Pixel Count	2.7	1.3	42	1393.1	1486.9	1011.6
Direct Expansion of HRL IMD reference data	3.5	12.5	12.0	1197.3	1565.5	1238.1
SE	1.2	7.9	7.8	127.9	259.7	188.3
CV	35.2%	62.9%	66.5%	10,7%	16.6%	15.2%

# Conclusions

1. Why is SIRS investing resources in land cover mapping? Land cover mapping is at the core of SIRS activities, but its importance decreases as (i) it gets closer to end-users (ii) the scale increases
2. Which are the approaches for land cover map production that you promote? Level of automation decreases as scale increases
3. What place do you give to land cover map validation? Validation / map accuracy assessment is essential, but still a poorly understood topic.
  - Land cover maps **should not** be **used directly** for providing land cover and land cover change statistics
  - But. wall to wall maps provide valuable additional information compared with pure sampling approach
  - Combination of land cover map with reference sampled data can reduce uncertainty level substantially
4. Who are your main categories of end users? Mainly institutional from local to pan-European and international users
5. What are the users' needs that you are not yet able to fulfill? Accurate change detection is still a major limitation

