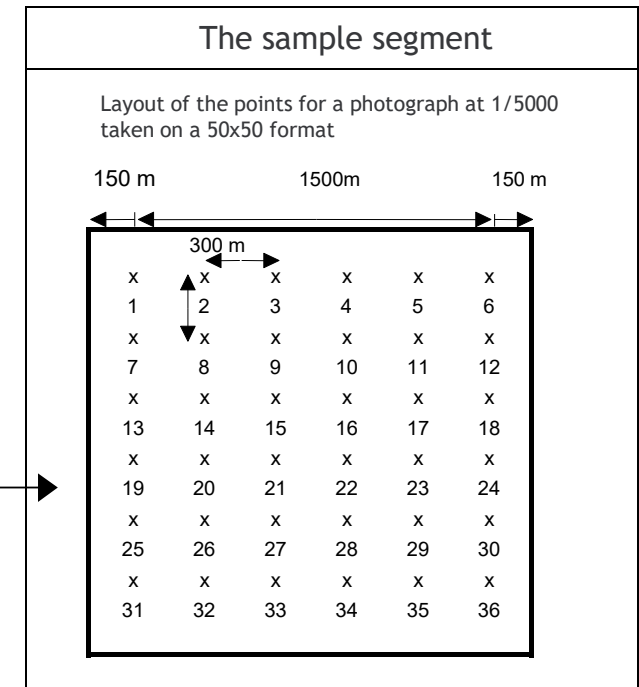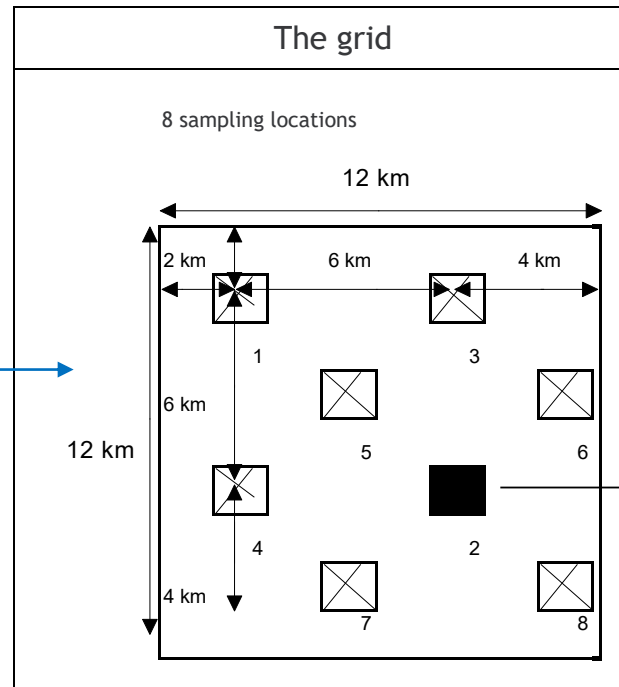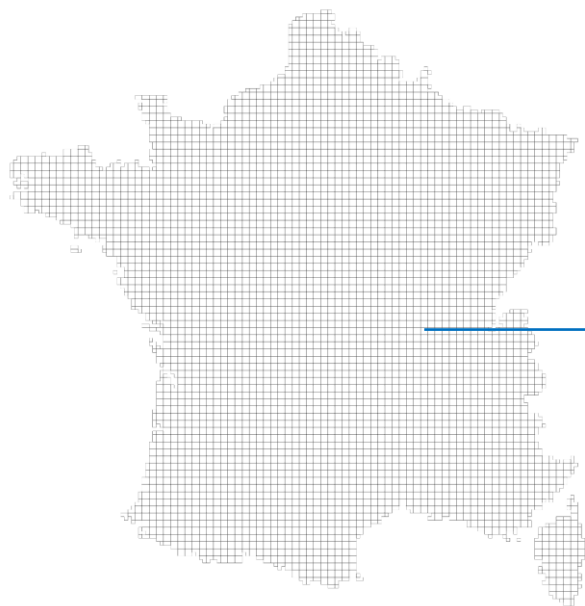CITEPA

# FRENCH LAND USE CHANGE MONITORING

## Moving from a statistical approach to a spatially explicit multi-source approach

Colas ROBERT & Mélanie JUILLARD

# 1. Context : Current approach – approach 2

- statistical sampling, field survey : "Teruti"

- Land cover and land use information

- False positives and artifacts

## The grid

8 sampling locations

12 km

2 km    6 km    4 km

1            3

6 km

12 km        5        6

4            2

4 km

7            8

## The sample segment

Layout of the points for a photograph at 1/5000 taken on a 50x50 format

150 m        1500m        150 m

300 m

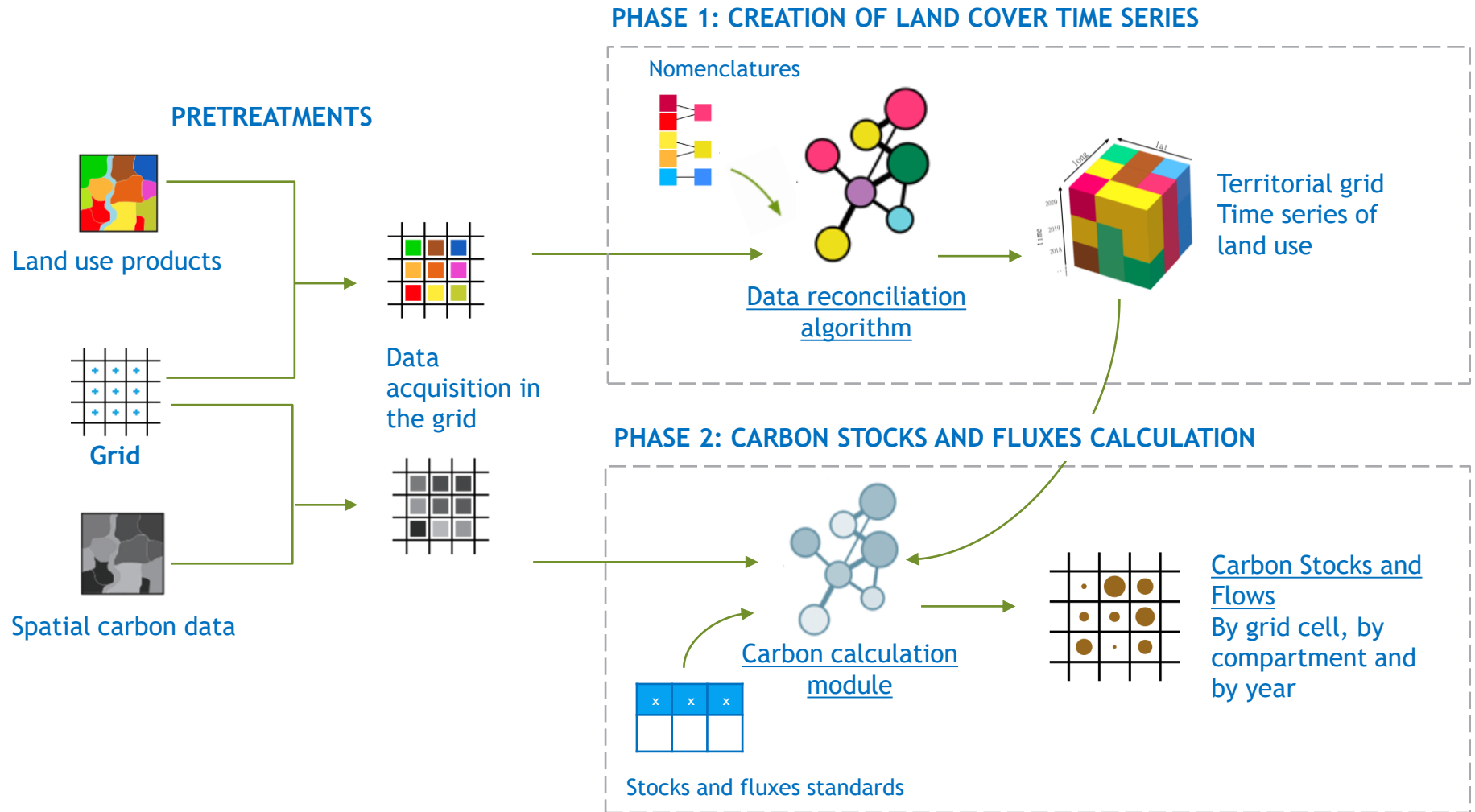| x | x | x | x | x | x |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| x | x | x | x | x | x |
| 7 | 8 | 9 | 10 | 11 | 12 |
| x | x | x | x | x | x |
| 13 | 14 | 15 | 16 | 17 | 18 |
| x | x | x | x | x | x |
| 19 | 20 | 21 | 22 | 23 | 24 |
| x | x | x | x | x | x |
| 25 | 26 | 27 | 28 | 29 | 30 |
| x | x | x | x | x | x |
| 31 | 32 | 33 | 34 | 35 | 36 |

# From approach 2 to approach 3 : main objectives

- Create consistent land cover time series (1990-2021), with relevant thematic resolutions for carbon calculations.

- Focus on **accuracy of land use changes**

- Take advantage of the best available products within **a multi-source model while ensuring the temporal/spatial consistency of the result.**
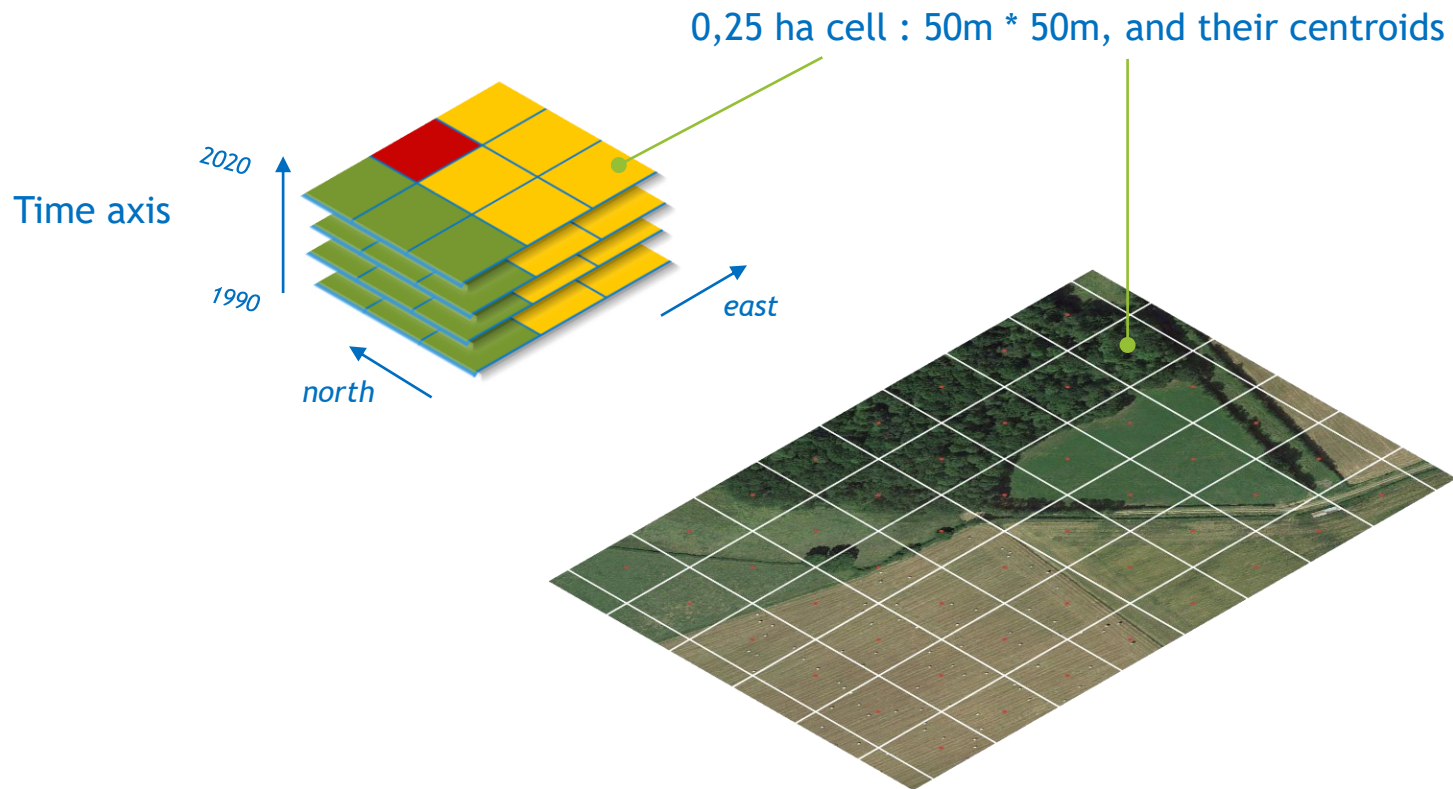
- Meet LULUCF regulation requirements.

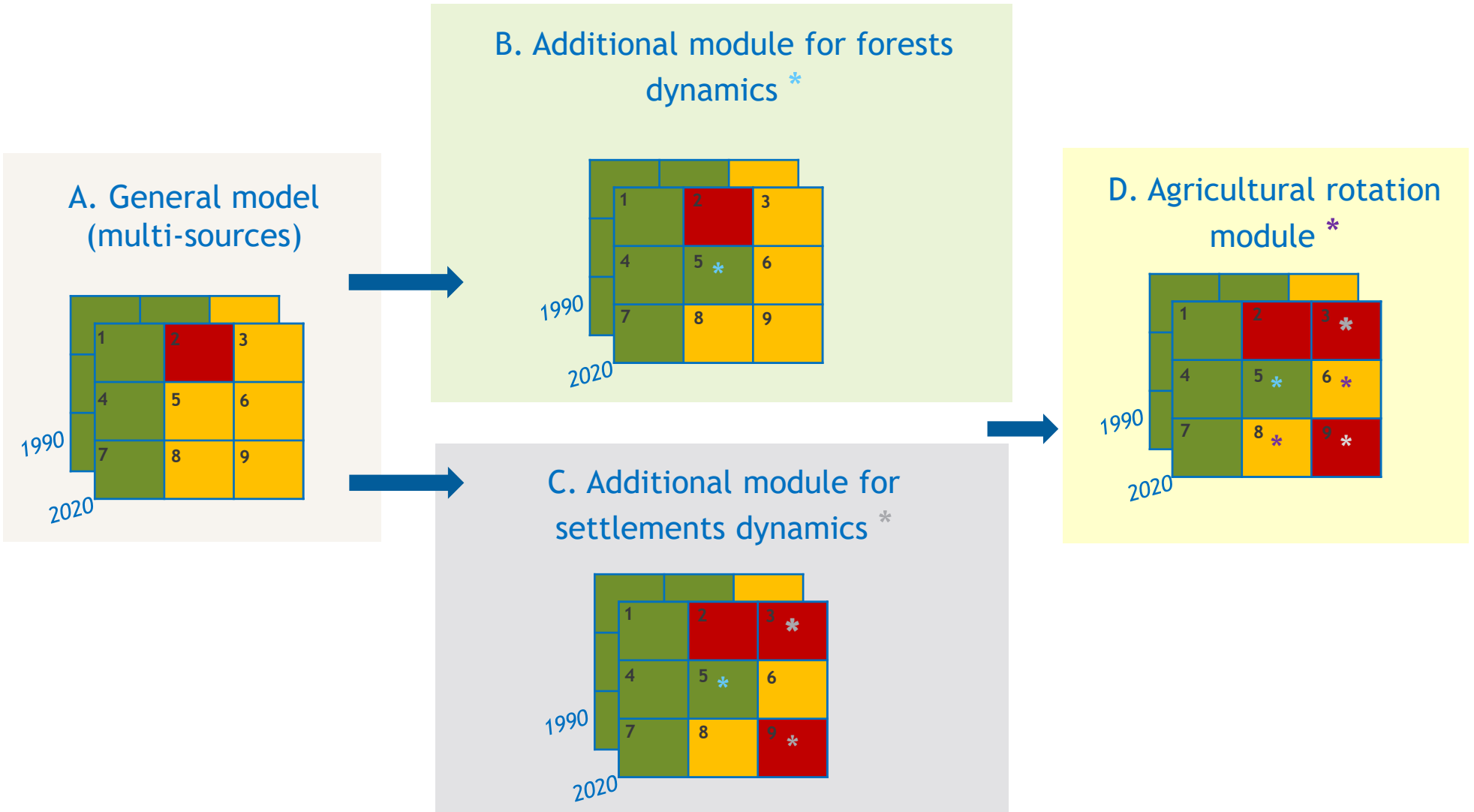# General concept of the spatially explicit inventory



**PHASE 1: CREATION OF LAND COVER TIME SERIES**

Nomenclatures

Data reconciliation algorithm

Territorial grid Time series of land use

**PRETREATMENTS**

Land use products

Grid

Spatial carbon data

Data acquisition in the grid

**PHASE 2: CARBON STOCKS AND FLUXES CALCULATION**

Carbon calculation module

Stocks and fluxes standards

Carbon Stocks and Flows
By grid cell, by compartment and by year

CITEPA

# Basic mapping unit : 0,25 ha grid

0,25 ha cell : 50m * 50m, and their centroids

Time axis

2020

1990

north

east

- Each cell (and thus each centroid) is characterized by a unique identifier: IDU (e.g.: D21_0000001)

- For the metropolitan territory : around **220 million cells** (= 54.9 M°ha).

# Architecture of the modules



A. General model (multi-sources)

B. Additional module for forests dynamics *

C. Additional module for settlements dynamics *

D. Agricultural rotation module *

# Cartographic products used : both status maps + change maps

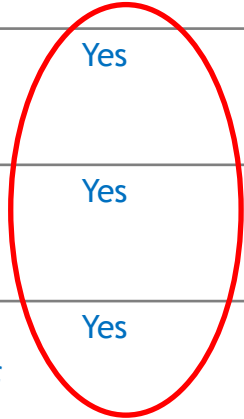| Data | Data producer | Product year | Perimeter | Pertinent use | Continuous or discontinuous | Change product ? |
|---|---|---|---|---|---|---|
| **BD Forêt** | IGN | *variable* | *National* | *Forests* | *only covers forest lands* | / |
| **RPG (LPIS)** | IGN | 2010 to 2020 | *National* | *Agricultural lands* | *only covers agricultural lands* | / |
| **Urban Atlas** | EEA/ Copernicus | 2006-2012, 2012-2018 (& annual : 2018) | European | *Settlements* | *Continuous, but only available for urban areas* | Yes |
| **Corine Land Cover** | EEA/ Copernicus | 1990-2000, 2000-2006, 2006-2012, 2012-2018 | European | *all* | *Continuous* | Yes |
| **Natura 2000** | EEA/ Copernicus | 2006-2012, 2012-2018 (& annual : 2018) | European | *Natural areas* | *Continuous, but only available for specific areas* | Yes |
| **BDcarto** | IGN | 2018 | *National* | *all* | *Continuous* | / |

**All vector products**

# Cartographic products used
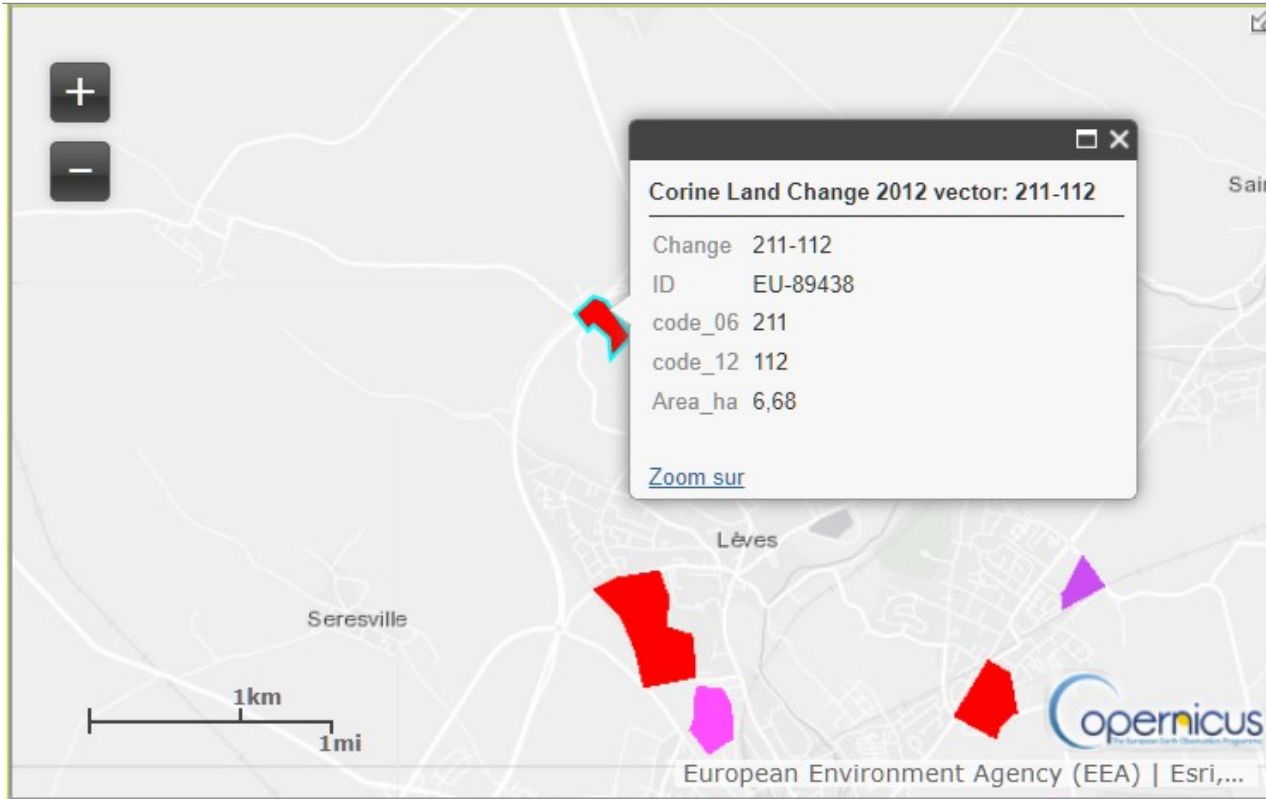


| ...ontinus or discontinus | Change product ? |
|---|---|
| ...scontinus (only covers ...rest lands) | / |
| ...scontinus (only covers ...ricultural lands) | / |
| ...ontinus, but only ...vailable for urban ...eas | Yes |
| ...ontinus | Yes |
| ...ontinus, but only ...vailable for specific ...eas | Yes |
| ...ontinus | / |

Corine Land Change 2012 vector: 211-112

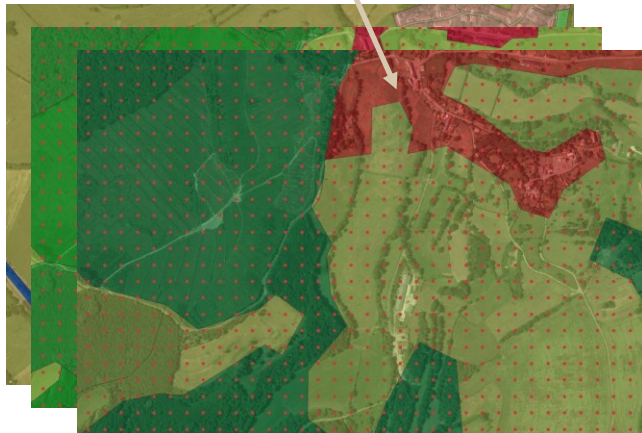Change 211-112
ID EU-89438
code_06 211
code_12 112
Area_ha 6,68

Zoom sur

# Cartographic products used
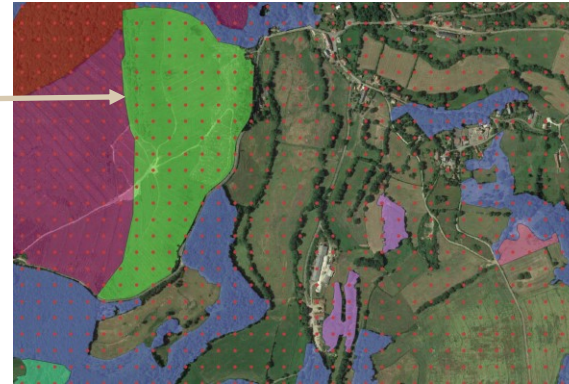


Closed Douglas Fir Forest

Closed forest without tree cover

Closed mixed hardwood forest

(…)

Discontinus and highly pertinent product **for forest land use** : 'BD Forest' *(French national forest inventory)*
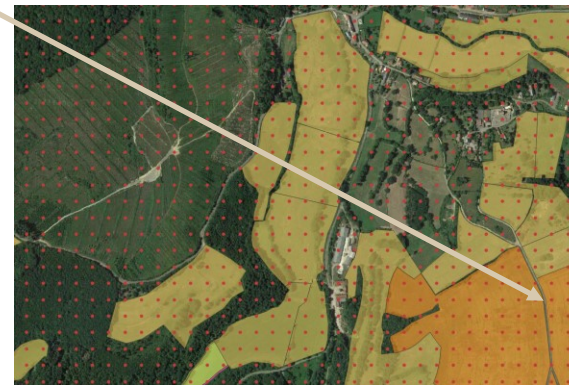
Temporary grassland

Wheat

(…)

Discontinus and highly relevant **for agricultural land use** : 'RPG' *(used for CAP declarations)*

Continus products (Copernicus : Urban Atlas, Natura 2000 -when available on the area-, Corine Land Cover) ; Bdcarto (French generalist product) **for settlements and the remaining unfilled areas**

# General approach

**Step 1** : Intersection of centroids with products to collect land use information

**Step 2** : Assignation of a reference use for each centroid, based on available information, and a hierarchy established between products

**Step 3** : Land use change application by period for the relevant centroïds thanks to :
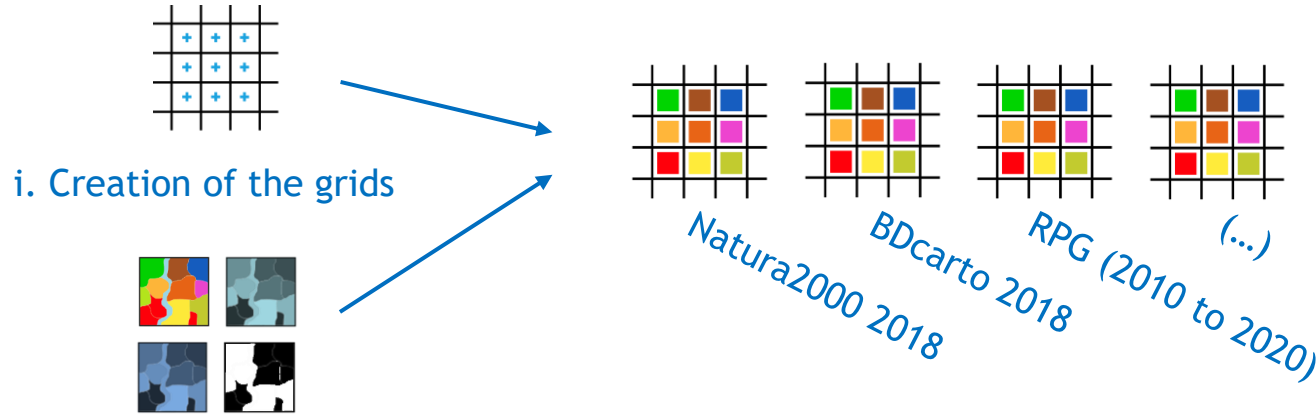
        a. Change products (Urban Atlas, Natura2000, CLC) (general model : A)

        b. Additional afforestation/deforestation dynamics (module B)
        c. Additional module for artificialization dynamics (module C)
        d. Agricultural rotation (module D)

# Intersections

Acquisition of land use data for all centroids, from all products and all available years for each product.

**Intersection of centroids and products**

i. Creation of the grids

ii. Pre-processing of cartographic products

Natura2000 2018

BDcarto 2018

RPG (2010 to 2020)

(...)

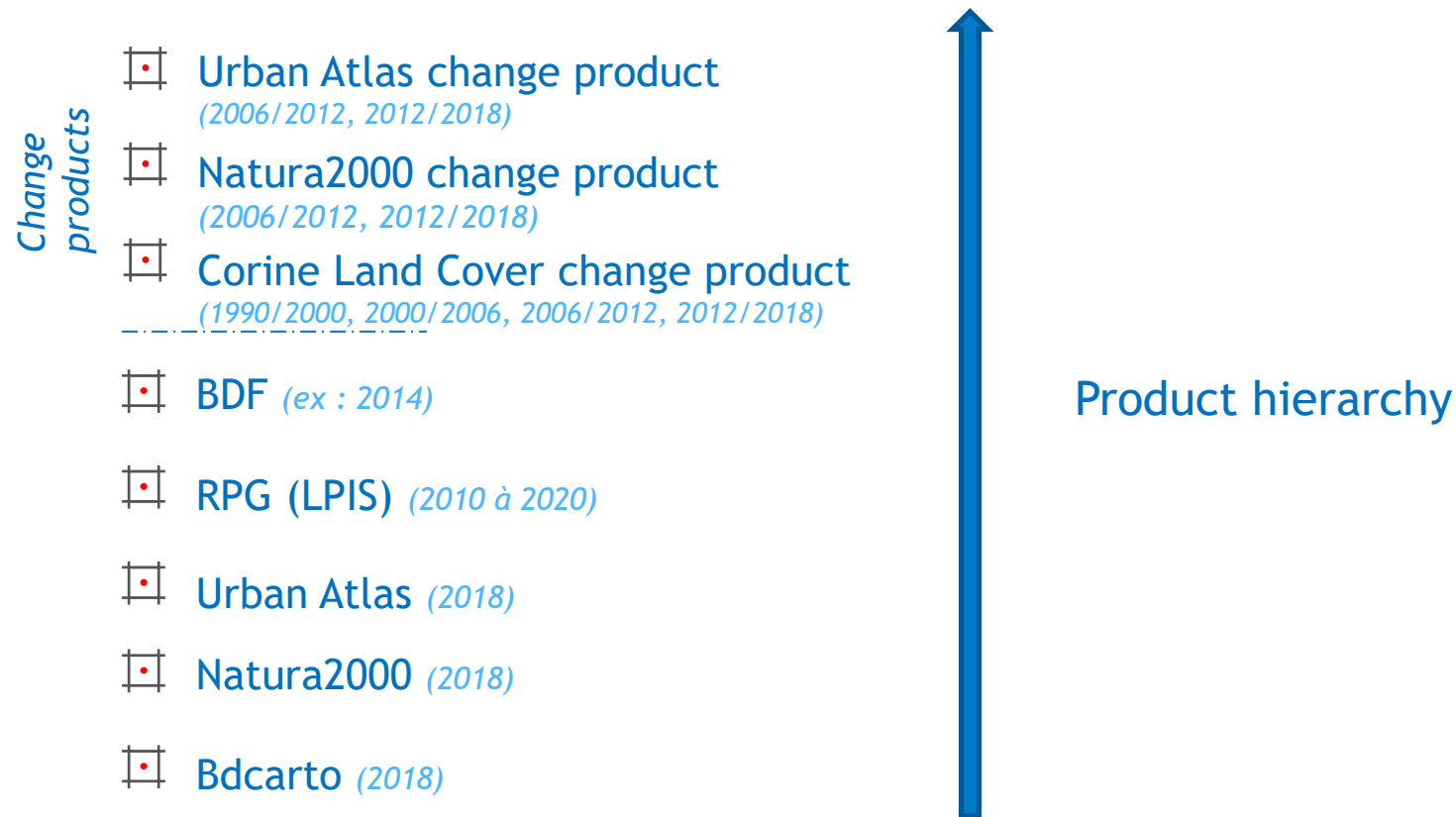| IDU | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D58_0000384 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| D58_0000385 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| D58_0000386 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| D58_0000387 | 13 | 13 | 13 | 13 | 13 | 11 | 19 | 16 | 16 | 16 | 8 |
| D58_0000388 | 13 | 13 | 13 | 13 | 13 | 11 | 19 | 16 | 16 | 16 | 8 |
| D58_0000389 | 13 | 13 | 13 | 13 | 13 | 11 | 19 | 16 | 25 | 16 | 8 |

*Centroid identifier*          *Product land use code*

# Selection of reference use per centroid

Products are ranked in a hierarchy. The reference land use of the centroid is set as the highest ranked product usage available for the centroid. Other information is not kept.

*Change products*

⊡ Urban Atlas change product
*(2006/2012, 2012/2018)*

⊡ Natura2000 change product
*(2006/2012, 2012/2018)*

⊡ Corine Land Cover change product
*(1990/2000, 2000/2006, 2006/2012, 2012/2018)*

⊡ BDF *(ex : 2014)*

⊡ RPG (LPIS) *(2010 à 2020)*

⊡ Urban Atlas *(2018)*

⊡ Natura2000 *(2018)*

⊡ Bdcarto *(2018)*

Product hierarchy

# Selection of reference use per centroid



1- Not subject to any change.

## Product hierarchy

<table>
<tr><td rowspan="6"><em>Change products</em> ↑</td><td>Urban Atlas change product</td><td></td></tr>
<tr><td>Natura2000 change product</td><td>1-</td></tr>
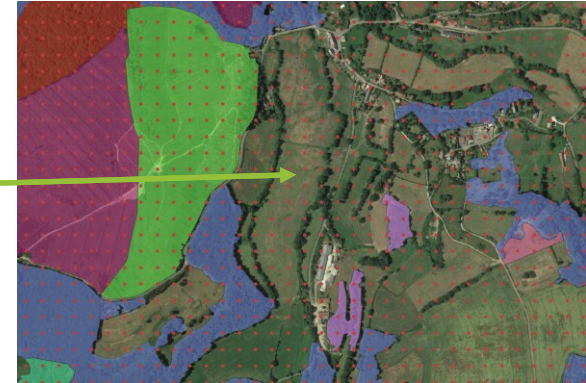<tr><td>Corine Land Cover change product</td><td></td></tr>
</table>

BDF
RPG (LPIS)
Urban Atlas
Natura2000
BDcarto

# Selection of reference use per centroid



1- Not subject to any change.



2- 'BD Forest' : no info given for this centroid

## Product hierarchy



*Change products*

Urban Atlas change product
Natura2000 change product          1-
Corine Land Cover change product

BDF                    2-
RPG (LPIS)
Urban Atlas
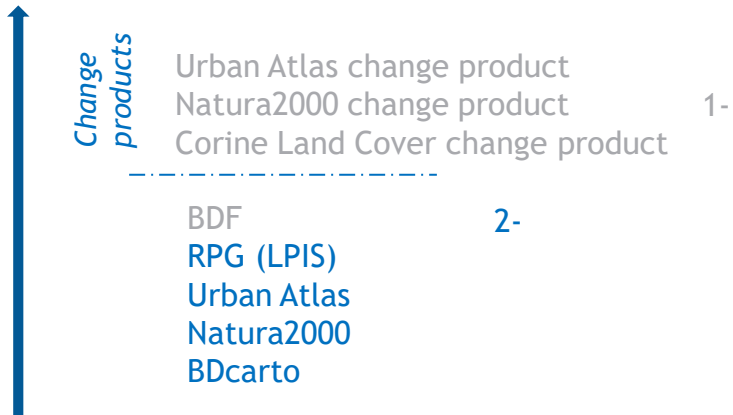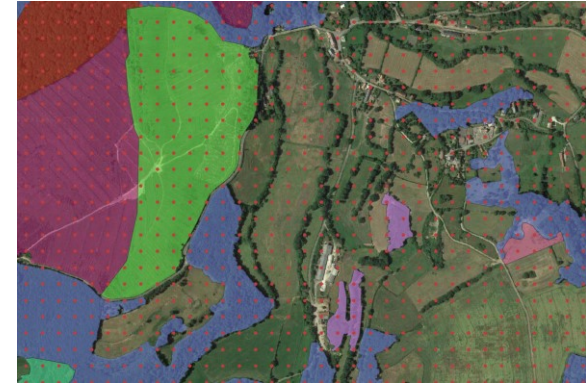Natura2000
BDcarto

# Selection of reference use per centroid



1- Not subject to any change.



2- 'BD Forest' : no info given for this centroid

## Product hierarchy

*Change products*

Urban Atlas change product
Natura2000 change product          1-
Corine Land Cover change product

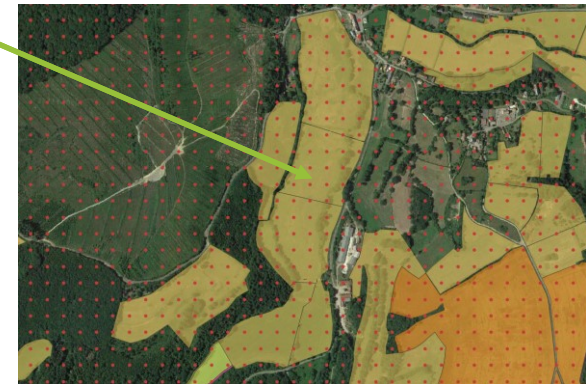BDF                    2-
**RPG (LPIS)**         3-
Urban Atlas
Natura2000
BDcarto



3- 'RPG' (LPIS) : available
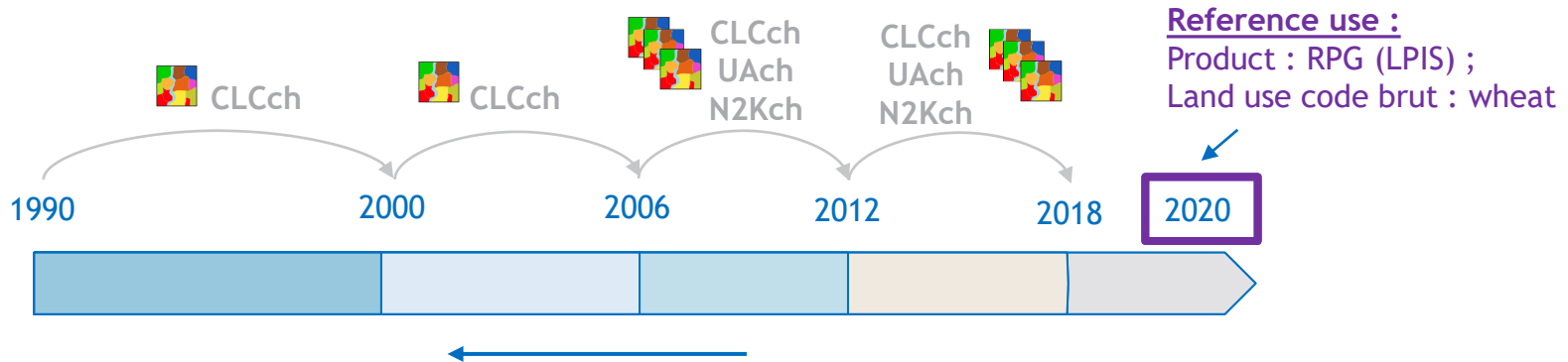→ **selected for the reference use of the centroid**

# Detection of changes by change products

**Case n°1 :** The centroid has a reference land use that does <u>not come from a change product</u>.

⇒ **This means that there was no change signal at this location** (otherwise the change product at the top of the product hierarchy would have been chosen).

**Then the reference land use category is extended to the entire time series.**



CLCch    CLCch    CLCch UAch N2Kch    CLCch UAch N2Kch

<u>Reference use :</u>
Product : RPG (LPIS) ;
Land use code brut : wheat

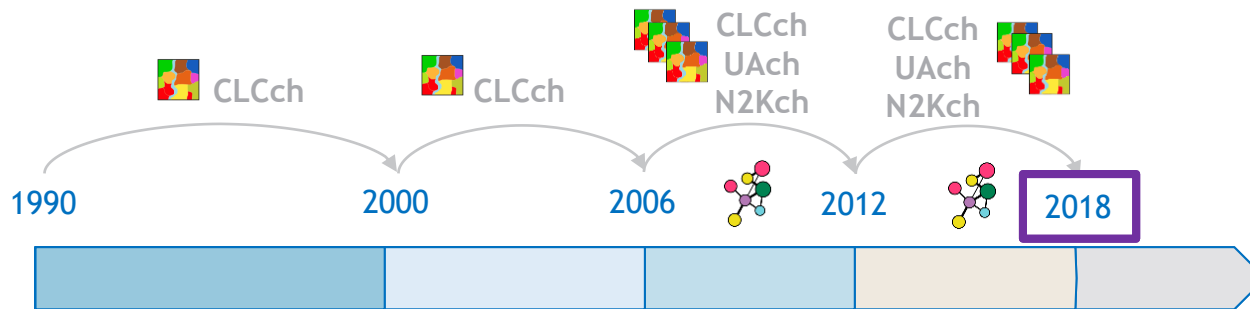1990    2000    2006    2012    2018    2020

**<u>The reference usage is maintained (backwards)
over the entire period.</u>
<u>There is no land use change for this zone</u>**

# Detection of changes by change products

**Case n°2 :** The centroid's reference land use category comes from <u>a change product</u> :
then the changes will be applied.

CLCch

CLCch

CLCch
UAch
N2Kch

CLCch
UAch
N2Kch

CLCch : Corine Land Cover change product
UAch : Urban Atlas change product
N2Kch : Natura2000 change product

1990          2000          2006          2012          2018

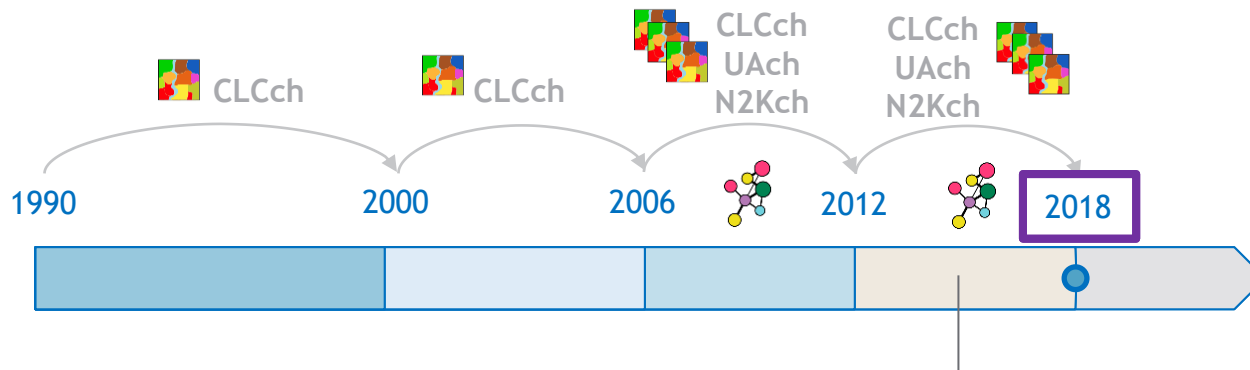4 possible change periods :
1990-2000
2000-2006
2006-2012
2012-2018

# Detection of changes by change products

**Case n°2 :** The centroid's reference land use category comes from <u>a change product</u> :
then the changes will be applied.

CLCch

CLCch

CLCch
UAch
N2Kch

CLCch
UAch
N2Kch

1990        2000        2006        2012        2018

- The initial and final use are filled in the centroid time series.
- **A change year is randomly selected,** years are completed before and after the change.

⦿ Compatibility check with the rest of the time series to ensure consistency.

- The same process is repeated for each period.

For the last 2 periods, 3 change products can cover the same location, specific rules have been established
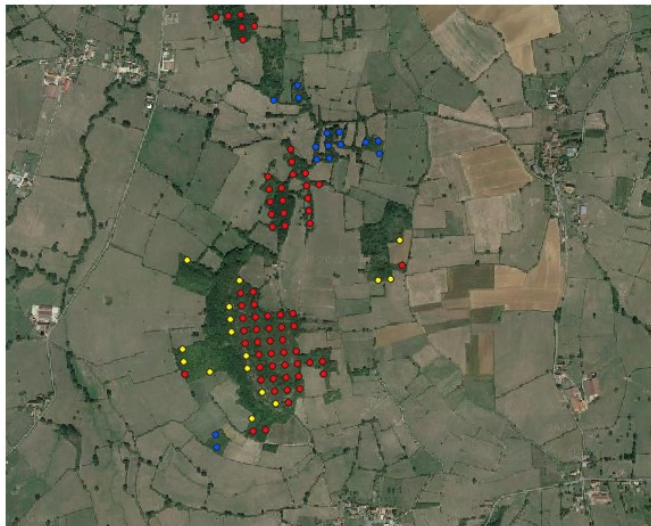(change product reconciliation algorithm)

# Addition of afforestation and deforestation dynamics

- Afforestation and deforestation dynamics are not well detected → additionnal module

**Concept :**
- Compare two editions of the French Forest map (IGN's 'BDForêt')

- Rules are added to limit false changes detection.



Ex : **Detection of additional afforestation** (red dots)

- Blue dots / yellow dots : not actually a real afforestation, just a difference of resolutions between the two editions of the forest maps => filtered

- bois_etape2
- bois_etape1
- bois_etape0

0    250    500 m

# Addition of artificialization dynamics (land converted to settlements)

Same observation than for forest dynamics :
- Low change detection with the general model, particulary in 1990-2006 → additional module

**Concept :**
- Draw urban patches from a building layer by using spatial buffers.
- Use the <u>date of appearance</u> of the buildings to create a dated dynamic of artificialization.
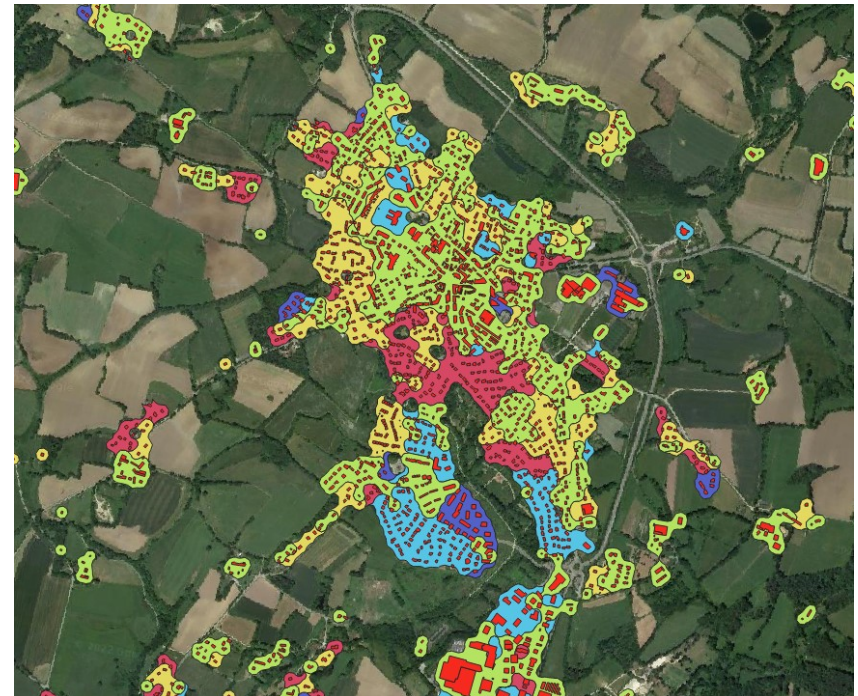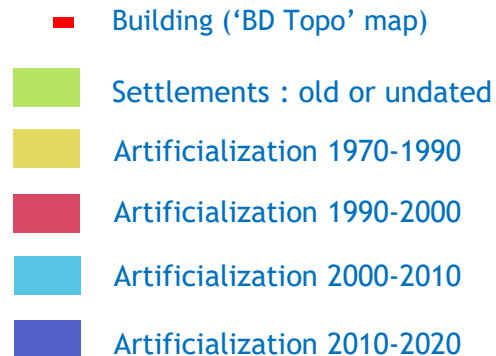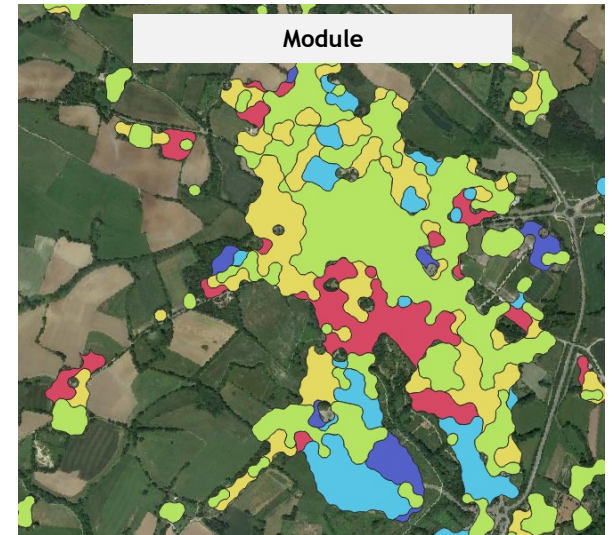


■ Building ('BD Topo' map)

█ Settlements : old or undated

█ Artificialization 1970-1990

█ Artificialization 1990-2000

█ Artificialization 2000-2010

█ Artificialization 2010-2020

# Addition of artificialization dynamics



Legend:
- Building ('BD Topo' map)
- Settlements : old or undated
- Artificialization 1970-1990
- Artificialization 1990-2000
- Artificialization 2000-2010
- Artificialization 2010-2020

Panels: 2000-2005 — 56890 Plescop — 500 m; 2006-2010 — 56890 Plescop — 500 m; Module; 1950-1965; récent — 56890 Plescop

# Changes within the agricultural category (crop rotations)

- Agricultural dynamics with land cover maps can lead to wrong conclusions regarding land-use (e.g. grassland vs temporary grassland/fallows…)

- Additionnal module based on LPIS typical rotations known for 2015-2020

- Reconstruction of probable historical crop rotations for the past (Markov Chains) under the constraint of historical statistical areas by crop type.

- Includes perennial cropland

# Carbon Calculations



PHASE 1: CREATION OF LAND COVER TIME SERIES

PRETREATMENTS

Land use products

Grid

Spatial carbon data

Data acquisition in the grid

Nomenclatures

Data reconciliation algorithm

Territorial grid
Time series of land use

PHASE 2: CARBON STOCKS AND FLUXES CALCULATION

Carbon calculation module

Stocks and fluxes standards

Carbon Stocks and Flows
By grid cell, by compartment and by year

CITEPA
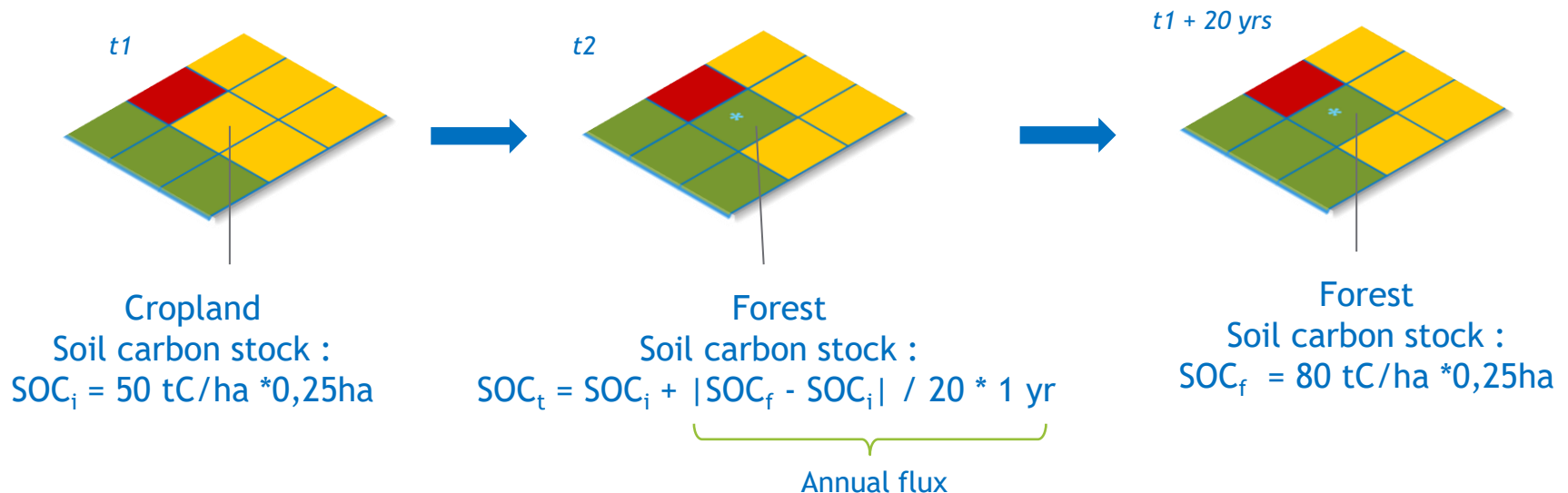
# Carbon fluxes calculation per cell – land use changes

- Reference Stocks values (tC/ha) for each C pool will be attributed to each land use category. They can be modulated for specific regions/ pedoclimatic zone...

- Land use change will cause a stock variation, calculated for each year of the transition period, per cell. This transition can be interrupted by another land use change.

- This stock transition can be interrupted by another land use change : stock variation starts from the current estimated stock.



t1

t2

t1 + 20 yrs

Cropland
Soil carbon stock :
$SOC_i = 50$ tC/ha *0,25ha

Forest
Soil carbon stock :
$SOC_t = SOC_i + |SOC_f - SOC_i| / 20 * 1$ yr

Annual flux

Forest
Soil carbon stock :
$SOC_f = 80$ tC/ha *0,25ha

# Carbon fluxes calculation per cell – other fluxes

- **Forest remaining forest**
    - Reliable data already used from NFI – not spatially explicit
    - Spatial disaggregation of regional NFI outputs – with simple or more complex hypothesis


- **Cropland and grassland remaining**
    - Currently simple tier 1 applied at national level
    - Possibility for spatially explicit tier 2 … or tier 3 per cell

**Thank you for your attention !**
**Merci !**