ECEM - EAML, 27/09/2004

A domain specific language for patchy landscape modelling: the Brittany agricultural mosaic as a case study

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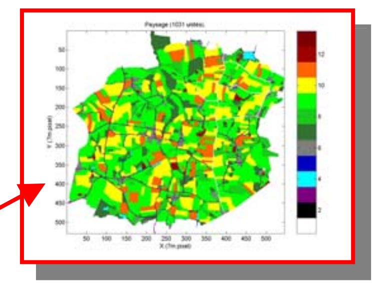
Plan

1. Scientific context (landscape modelling needs in ecology, state-of-the-art of the landscape models and platforms)
2. What is a landscape? (landscape ecology and the "categorical" property)
3. The *L1* platform principle and architecture

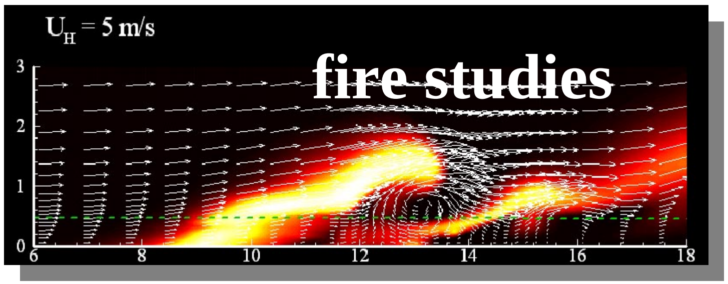


4. The Brittany *L1* application and the agricultural simulations
5. Results and comparison of the simulations
6. Discussion (limits and perspectives)

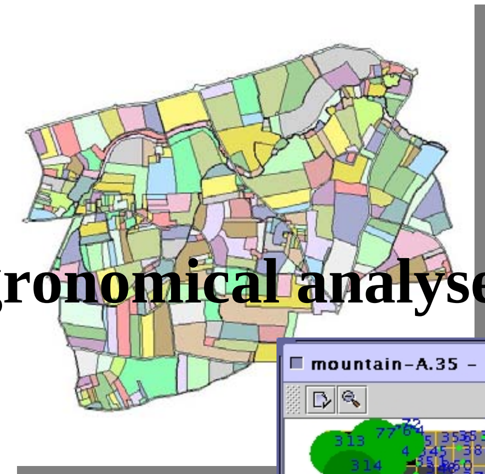
1. Landscape modelling needs in Ecology

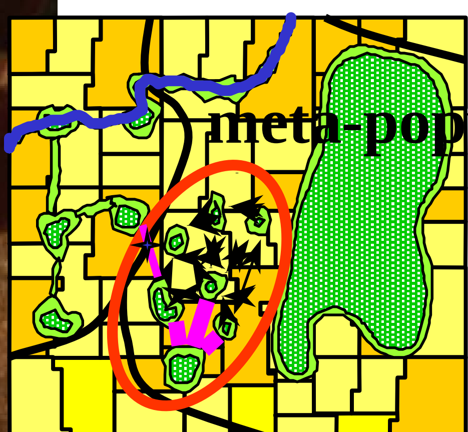
Ecology needs landscape models, either to understand the landscape dynamics for themselves or to have dynamical mosaics capable to support various phenomena:

Gaucherel et al. 2003

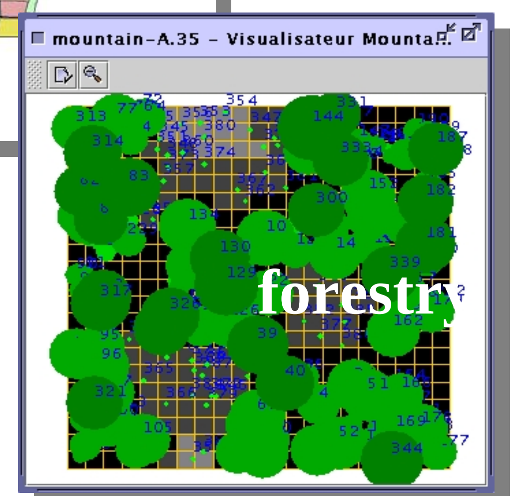


Dupuy et al. 2002





gene dispersion studies …



Pain et al. 2000

De Coligny et al. 2002

1. Model review and Standpoint

- Interpolations (GIS, geostatistics…) **Kyriadis, 2003**
- Landscape Neutral models **With, 1997**
- Explicit Process models **Costanza et al., 1990 & 2003**

A platform is designed around a kernel, which provides an organisational data structure and is able to manipulate a generic landscape (⇒ advantages).

- *Specific model*

TELSA, LANDIS…

- *« Domain specific language » or platform*

SELES, SME, *L1*…

- *Programming language*

C, C++…

Fall et al., 2001

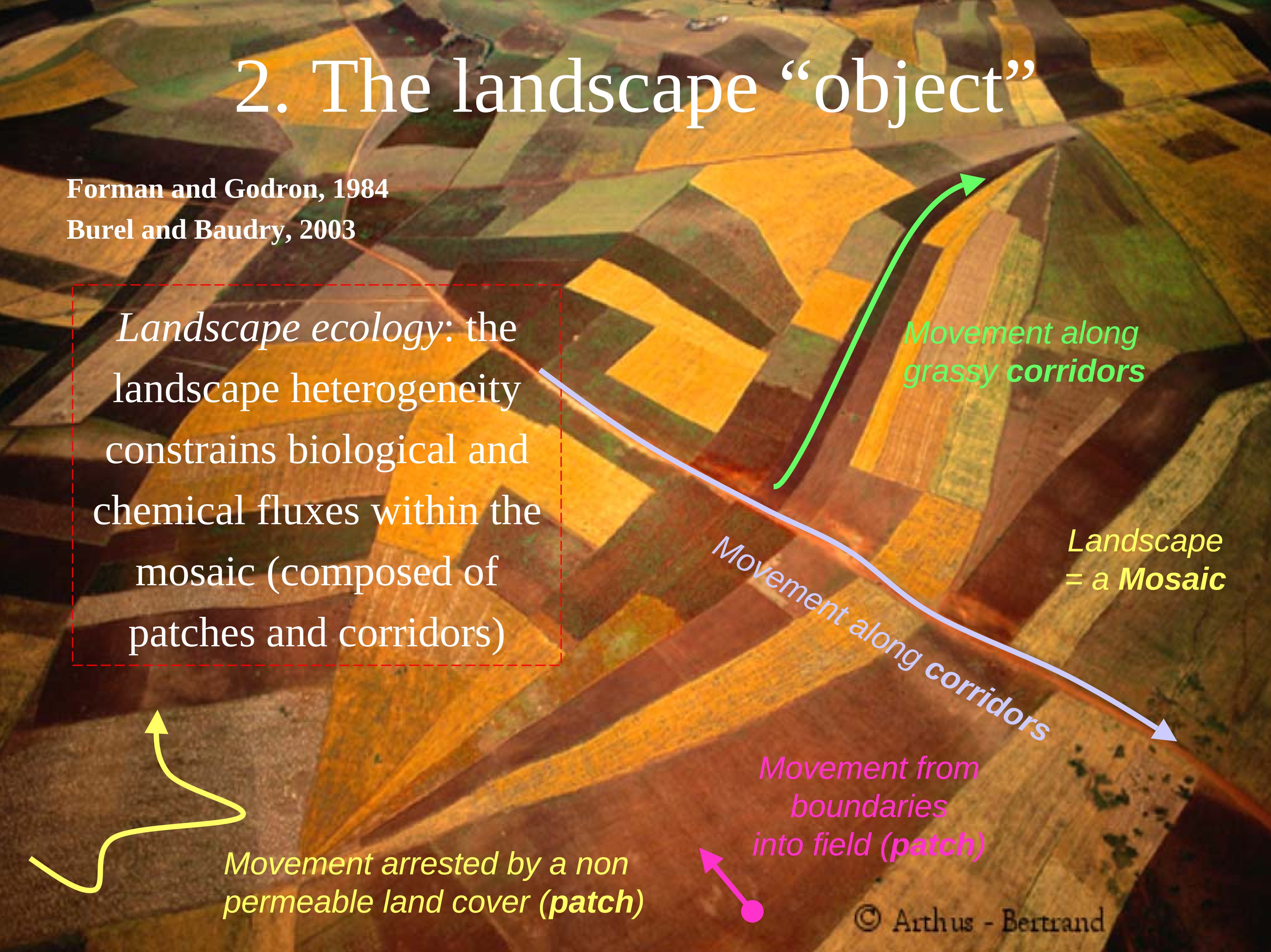
Our modelling **goals**:

- to elaborate a landscape model **platform**;
- to achieve **dynamical** and spatially explicit landscape simulations;
- to implement fully **mecanistic** driving processes for landscape evolutions;
- to apply attributive **and geometrical** modifications.

2. The landscape “object”

Forman and Godron, 1984
Burel and Baudry, 2003

Landscape ecology: the landscape heterogeneity constrains biological and chemical fluxes within the mosaic (composed of patches and corridors)

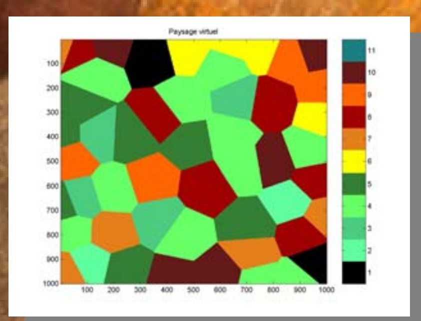


2. Categorical landscape, Standpoint

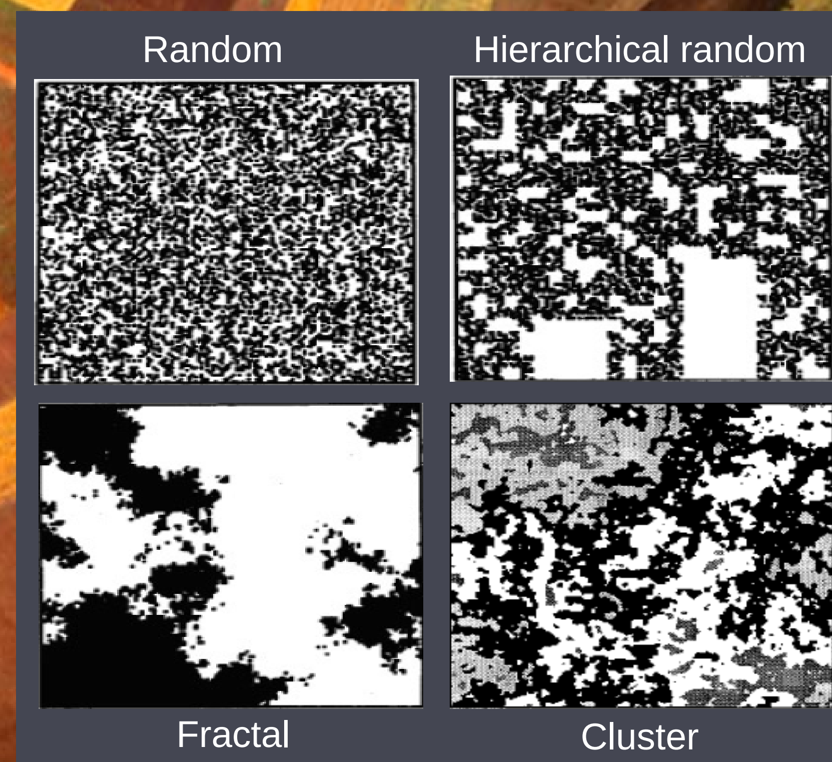
Most of the landscapes are **patchy**. Landscape ecology stresses the relative homogeneity of a patch with rather sharp adjacent boundaries, while most of the landscape models work with grid-based (raster mode) mosaics.

Forman et al., 1981

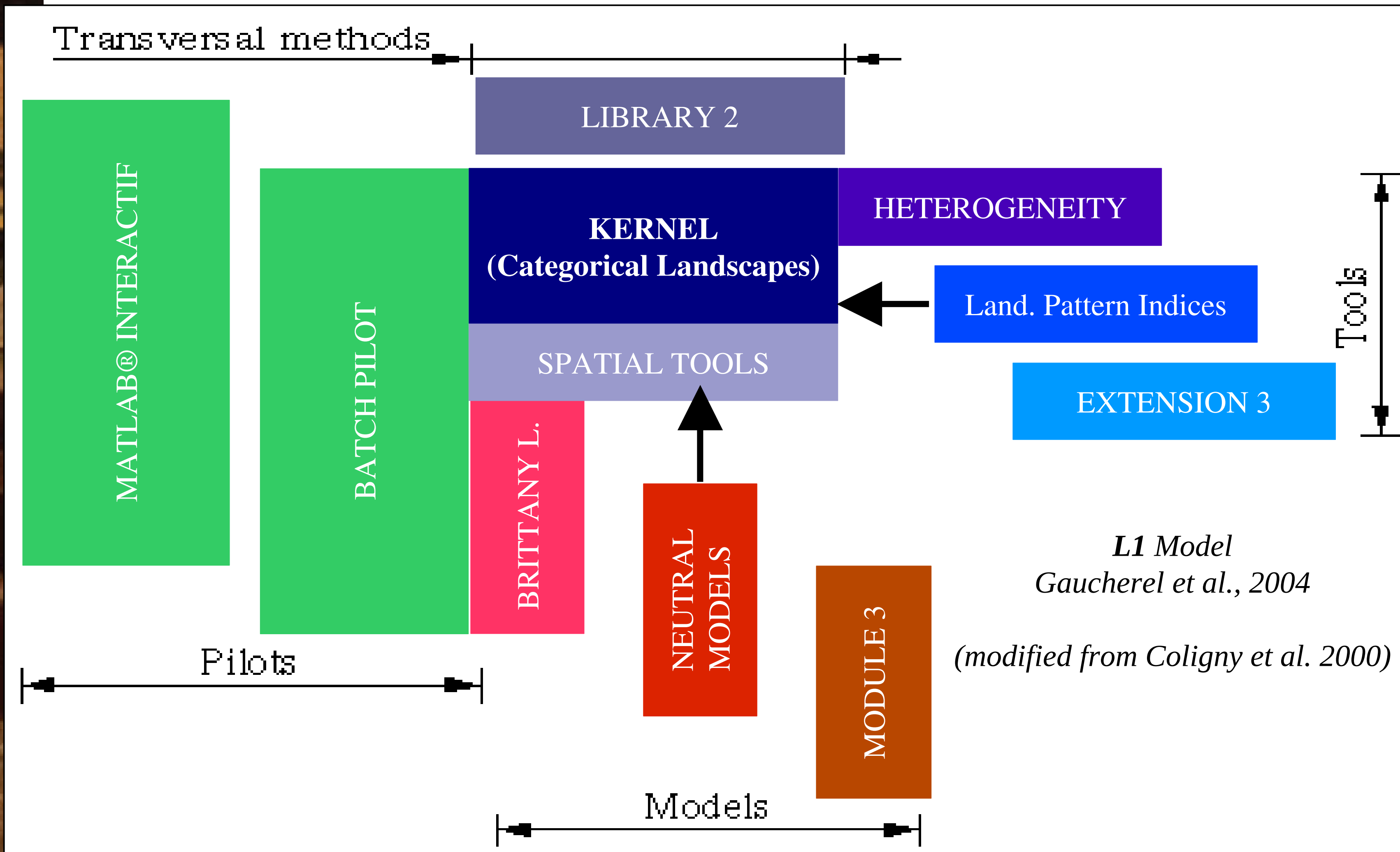
A last **goal:**



Ex: With 1998 & Saura 2000



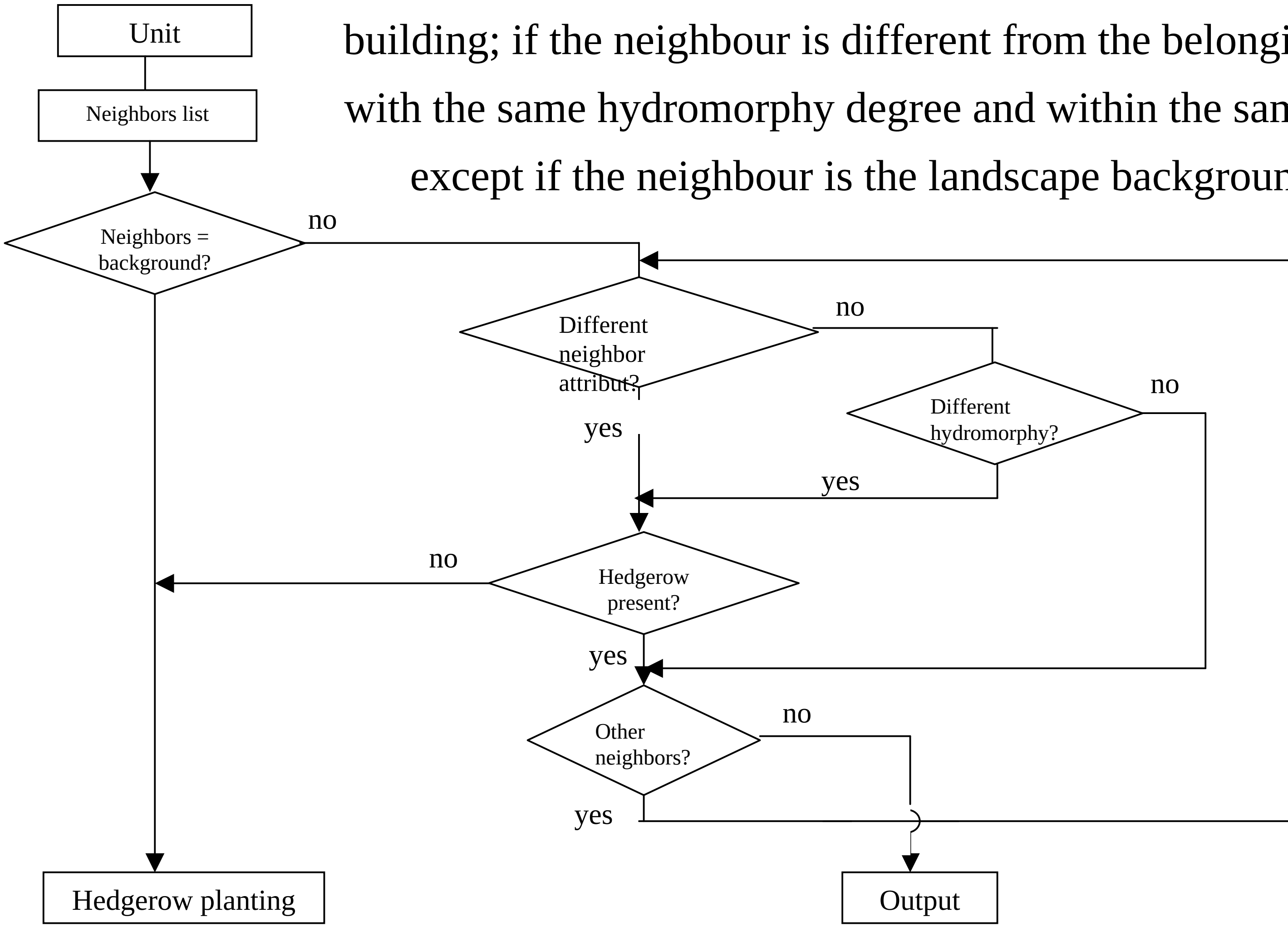
3. The *L1* architecture



The *L1* Kernel = the landscape “**skeleton**”

3. The *L1* modularity (example of an action)

Hedgerow planting: around an agricultural unit, a road or a building; if the neighbour is different from the belonging unit; with the same hydromorphy degree and within the same farm, except if the neighbour is the landscape background…



This is an example of a geometrical action (landscape unit appearing)

3. A landscape skeleton for generic landscape simulations

A. A generic landscape is driven by human **decisions** and natural constraints…

- Climate, water resources / European laws, farmer choices…

B. … decomposed in many single key **processes** …

- Temperature elevation / Land use change, hedgerow removal…

C. … resulting from a set of **actions** …

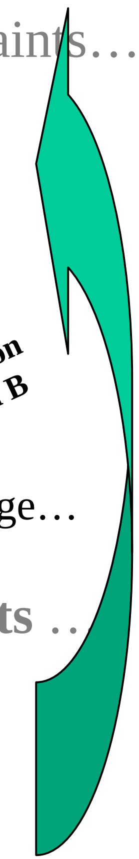
- Appearing, disappearing, shape change (homothetical or not), fragmentation, merge…

D. … that manipulate (on composition and configuration) landscape **units** …

- Tree, river arm / agricultural patch (maize field) or mountain section (in 3D)…

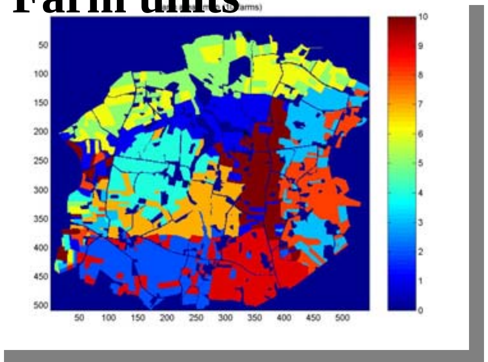
E. … finally constituting a landscape mosaic with its **properties**.

- A dynamic landscape in 2D or 3D… / with its heterogeneity properties (fragmentation…)



3. Data layers and Driving decisions

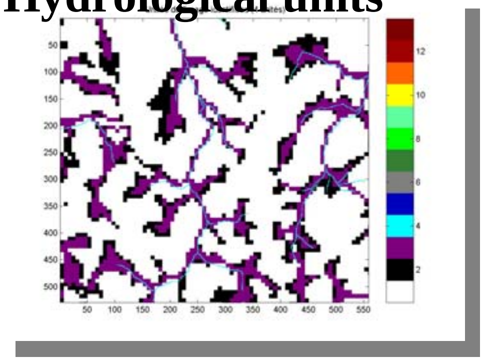
Farm units



Farming systems :

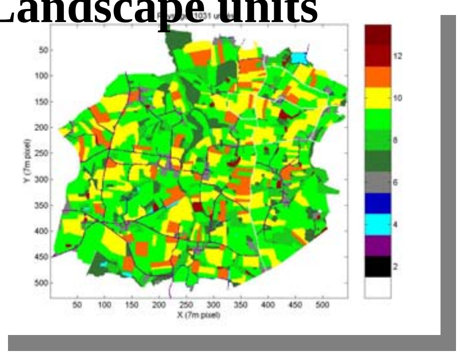
1. Small dairy farm
2. Specialised dairy farm
3. Dairy farm with cash crops production

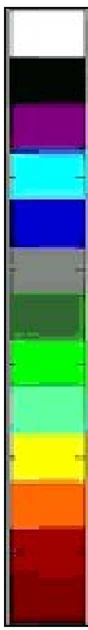
Hydrological units



1. Low hydromorphical zone
2. Medium hydromorphical zone
3. Bottomland waterlogged zone
4. Rivers

Landscape units



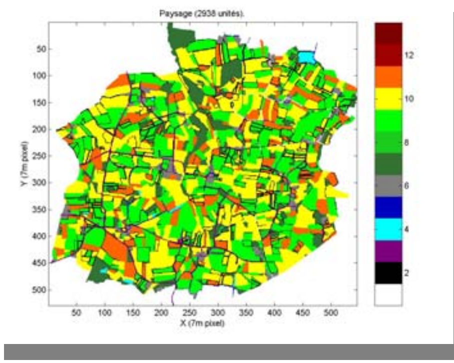


1. Background
2. Hedgerow
3. Road
4. river, lake
5. Track
6. Building
7. Forest
8. permanent grassland
9. temporary grassland
10. Maize
11. Cereals
12. set-aside
13. Bare soil

1 Decision

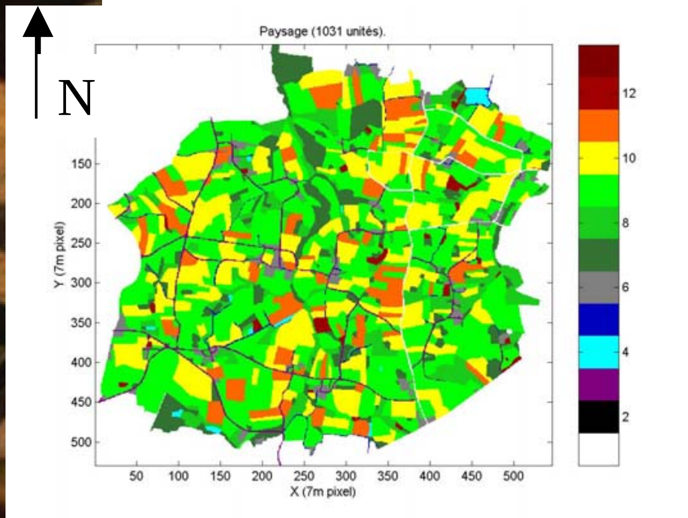
→ n Processes

→ n * (m geometrical or attributive Actions)



Initial Landscape + Driving Decisions = Final Landscape

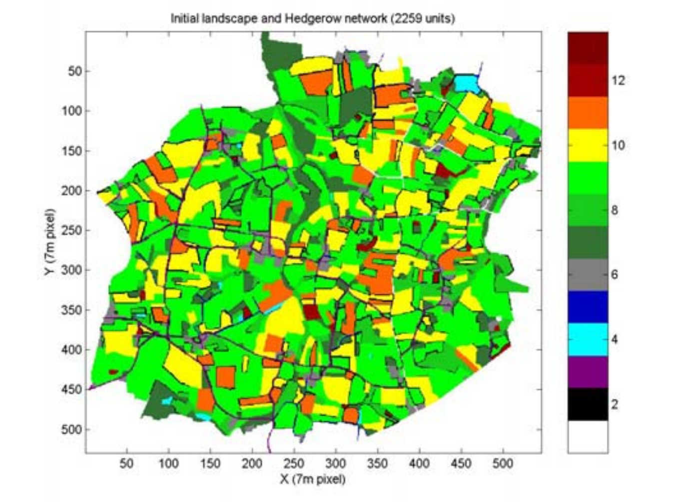
4. Application: a Brittany landscape



• Located Western France

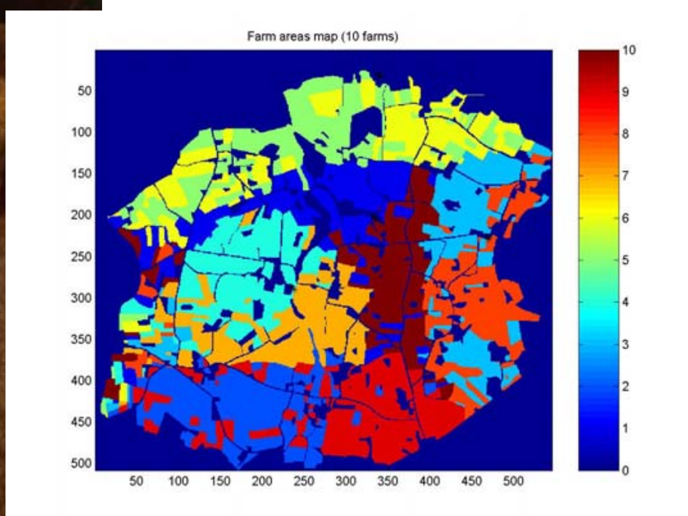
• 4 km² area, 7 m pixel size

• Over 30 years



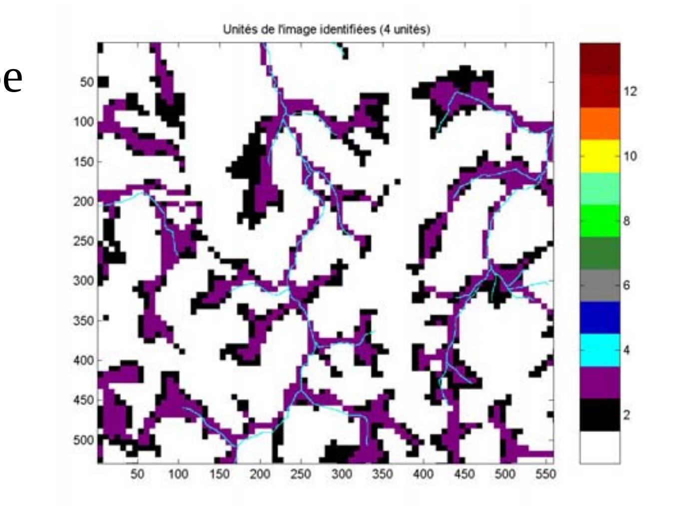
• Agricultural context of dairy production (extensive grasslands, and few intensive cereal fields and forests)

• total hedgerow network length: ~ 90 km



• ~ 1000 landscape units (patches)

• Farms (10) and hydromorphy distributions modelled



4. Driving Decisions/Processes/Actions

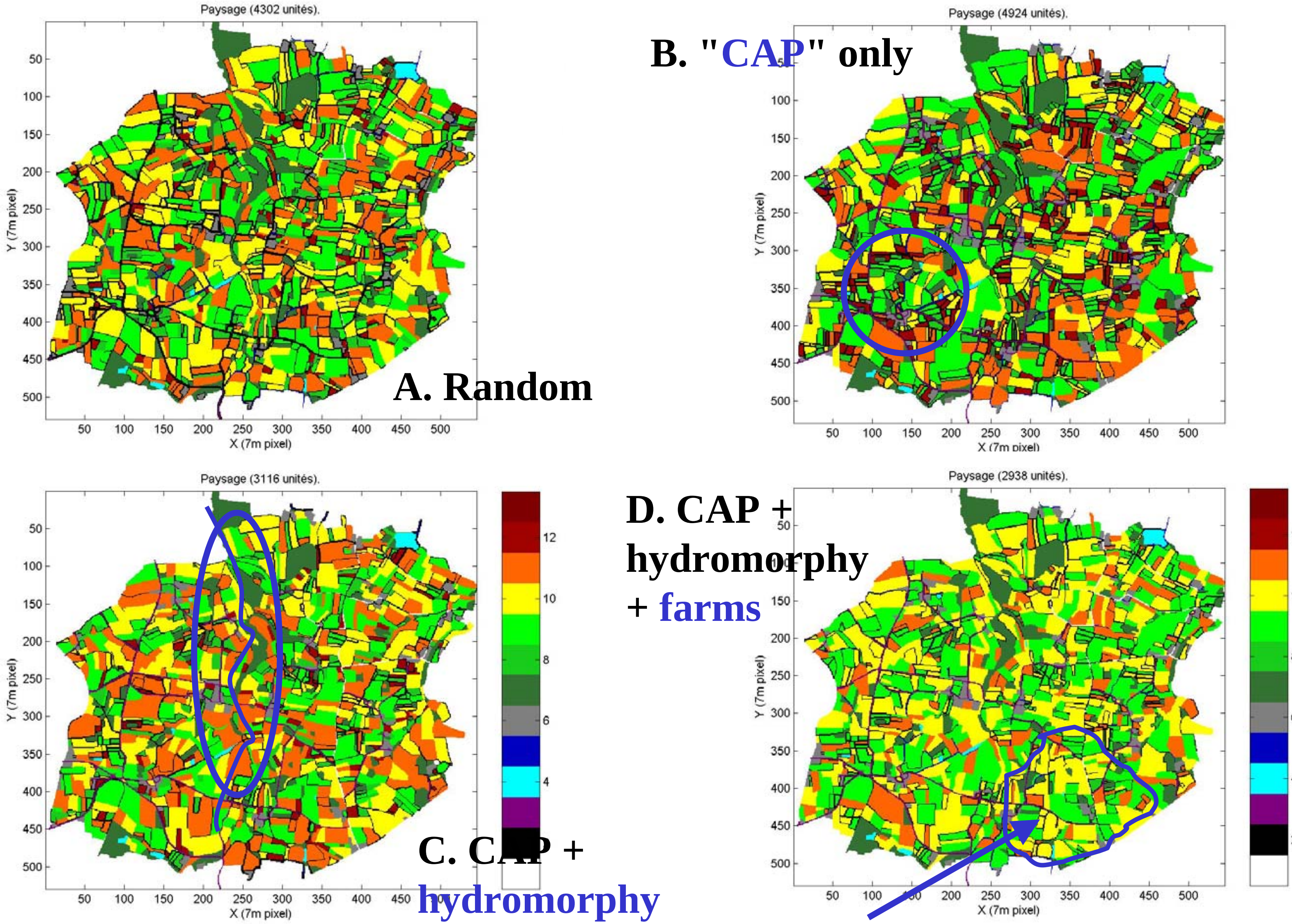
• Context: The European Common Agricultural Policy (from 1962) and the 1992 reform, effective through the farm land use allocations;
• Four main Processes and Actions involved (either on hedgerow or agricultural units, only);
• Realisation criteria: random actions among possible or random under hydromorphy and farm constraints, applied on randomly chosen units (no MC).

1. increase of the farm and the landscape unit surfaces (acting as a patch aggregation, over ~$1/100^e$ of the agricultural units): ‘a’
2. land use changes (rotations of all the agricultural units): random ‘i’ or not ‘h’
3. planting and removal of hedgerows (appearing or disappearing, over ~$1/100^e$ of the hedgerow units): ‘j’ and ‘k’ respectively
4. increase of the set-aside, woodland and grassland surfaces (rotations of ~$1/4^{th}$ all the agricultural units): ‘l’ and ‘m’.

***4 simulations** (of increasing complexity):*

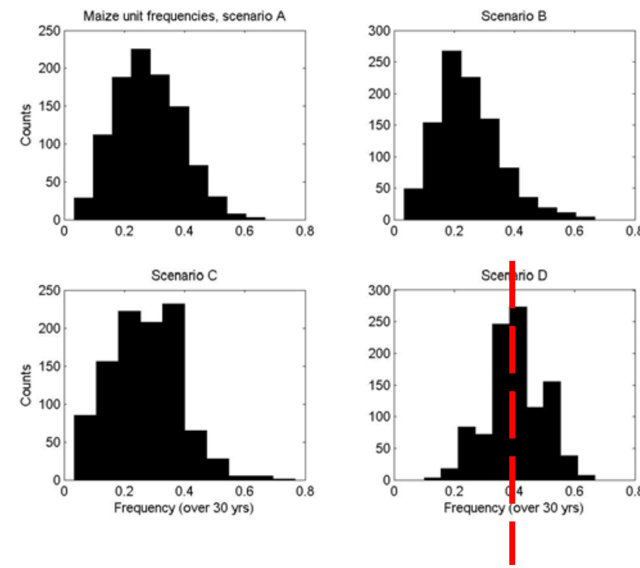
A. Random processes: ‘i a j k’
B. A + Simplified CAP and CAP reform (starting in year 12): ‘i a j k’ + ‘l m’
C. B + Land hydromorphy constraints: ‘i a j k’ + ‘l m’
D. C + Farm land use allocations: ‘h a j k’

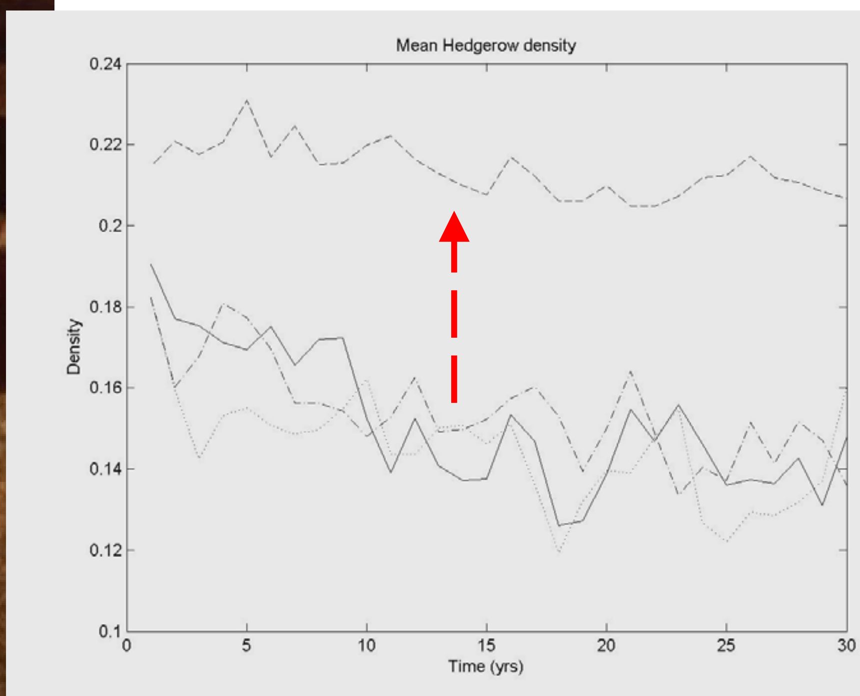
5. Results (the 4 Brittany simulations)

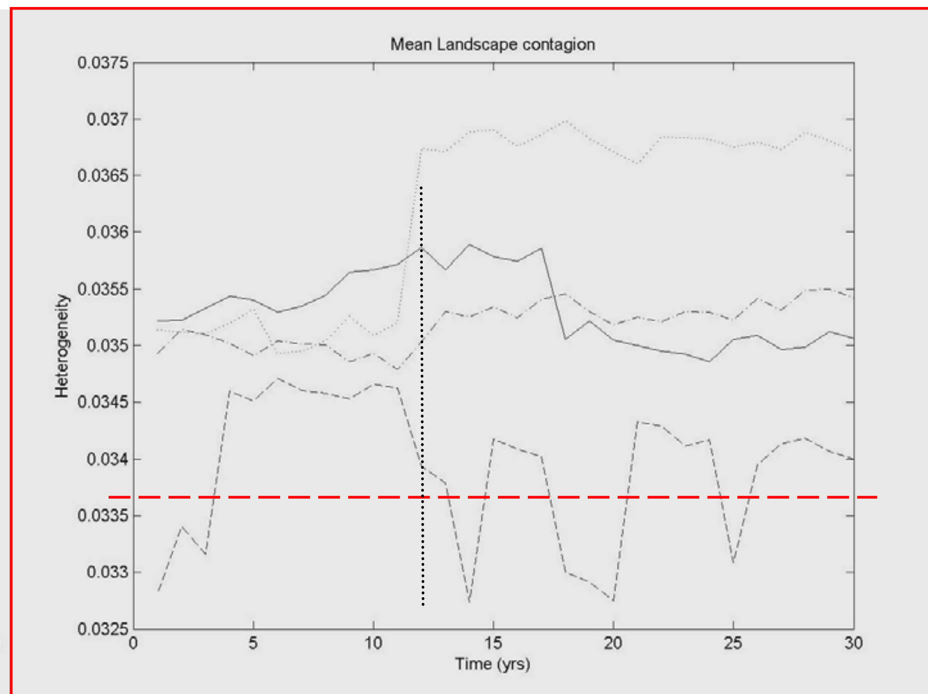


5. Control curves and global analyses

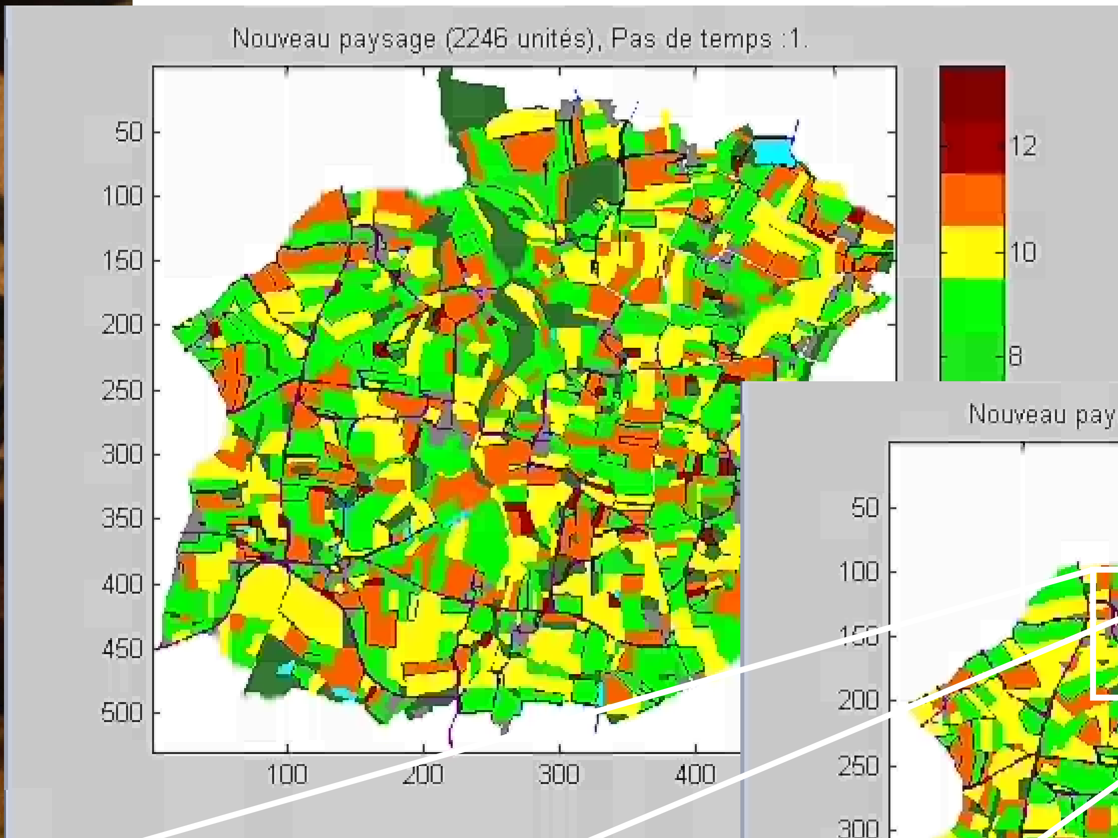
Simulations A to D are progressively complexified. One run of the D simulation reproduces efficiently the landscape contagion heterogeneity, the hedgerow density and the maize land cover frequency.







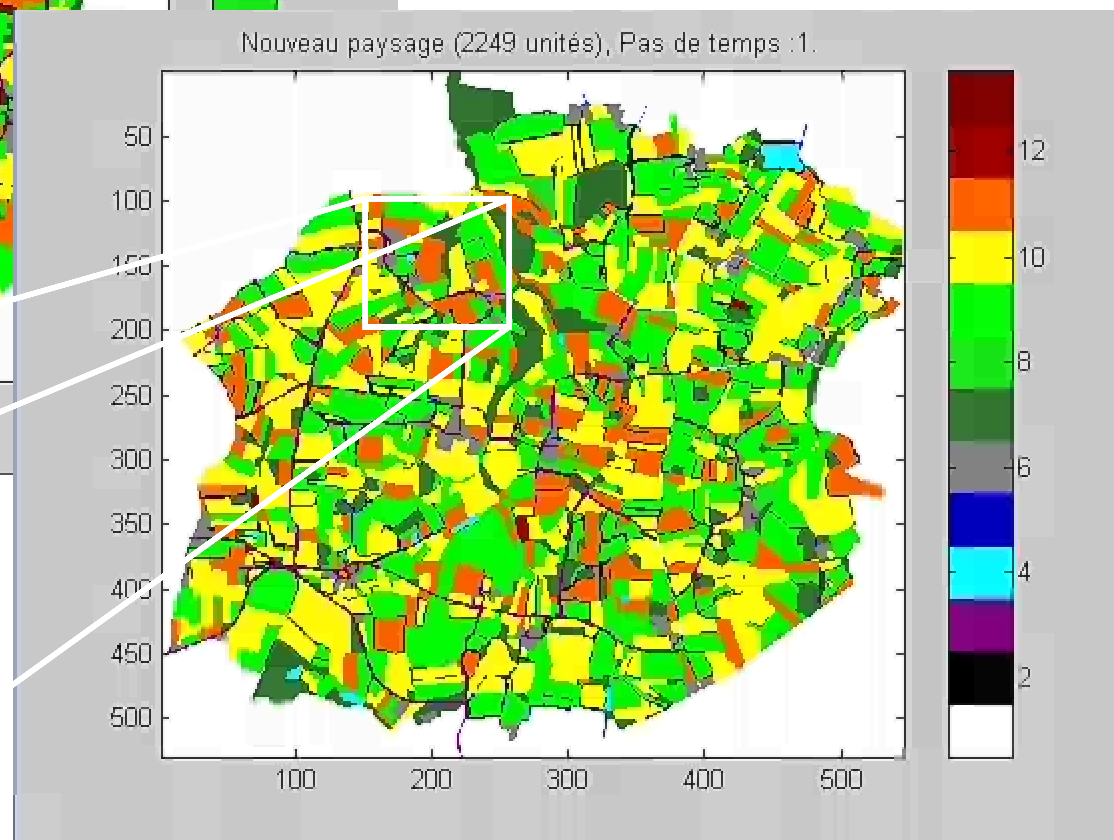
5. Dynamic and local analyses

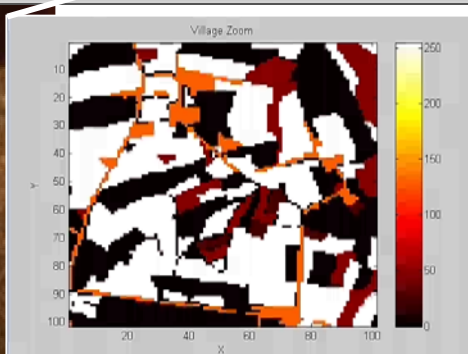


Simulations B

and D movies

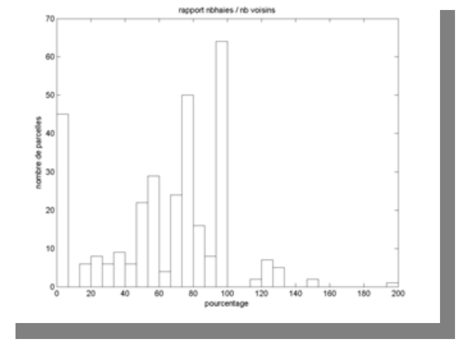
+ (*sensitivity analyses*).





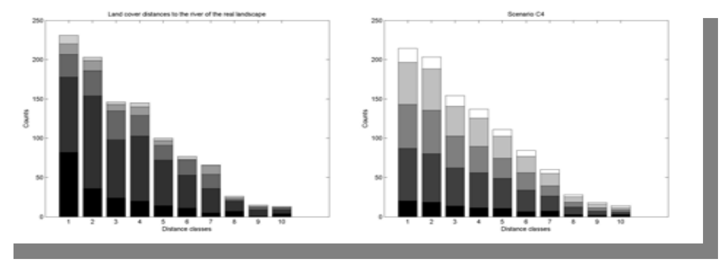
5. Sensitivity analysis

• Control of the hedgerow numbers and lengths for each landscape unit;

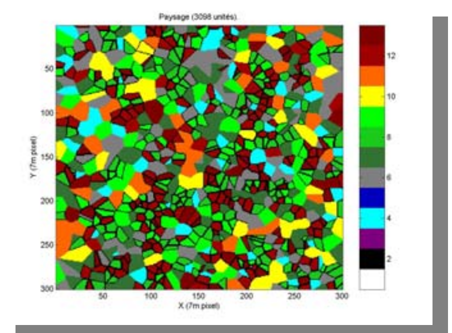


• Influence of the hydromorphy degree on land use changes;

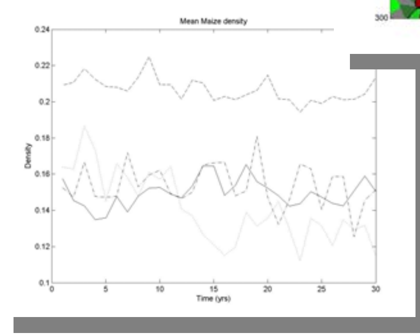
Difficult…



• Influence of the initial landscape configuration on the landscape evolution;



• Control of the land uses allocation within the farms along the simulations.



6. Discussion

The *L1* Brittany application already gives **realistic** landscape evolutions. We achieved our **goals**:

1. to elaborate a landscape model **platform**;
2. to dedicate it to **categorical** landscapes;
3. to model **dynamical** and spatially explicit landscapes;
4. to implement **mecanistic** driving processes to simulate landscape evolutions;
5. to apply attributive **and geometrical** modifications on units.

6. Limits and Perspectives

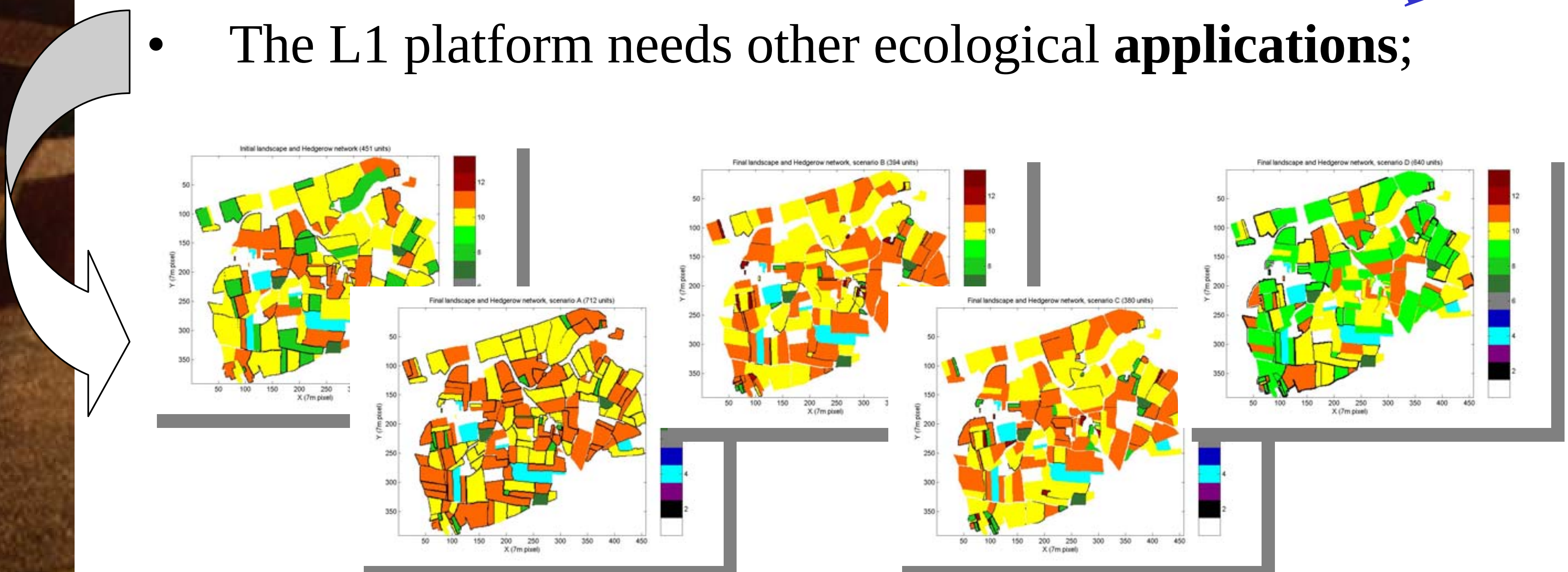
- The Brittany application needs more "complexity" (grassland ages, farmstead influence, farm types…);

Done

- The L1 platform needs **improvements** (object-oriented, vector mode and open-source…);

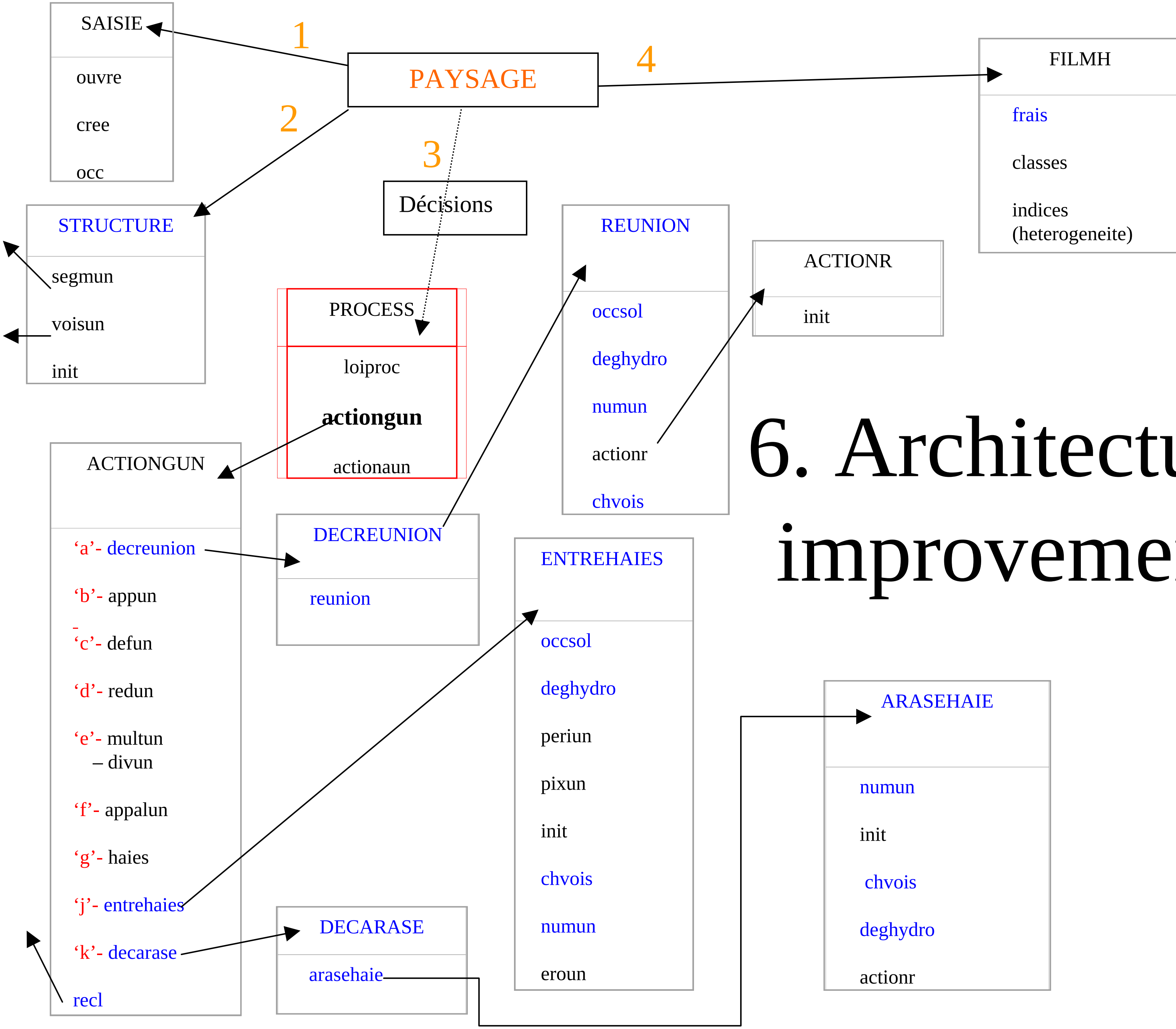
Done

- The L1 platform needs other ecological **applications**;



Modules in progress…

6. Architecture improvement

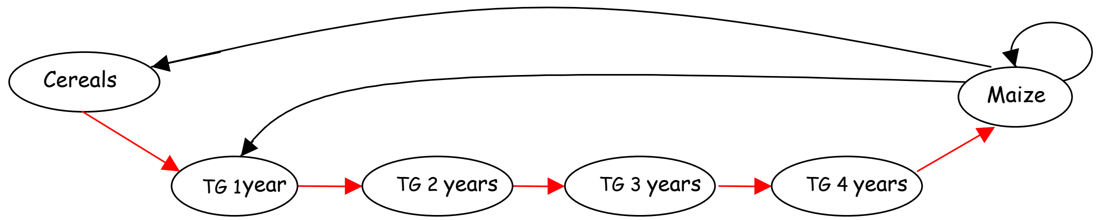


6. Other *L1* applications (agricultural)

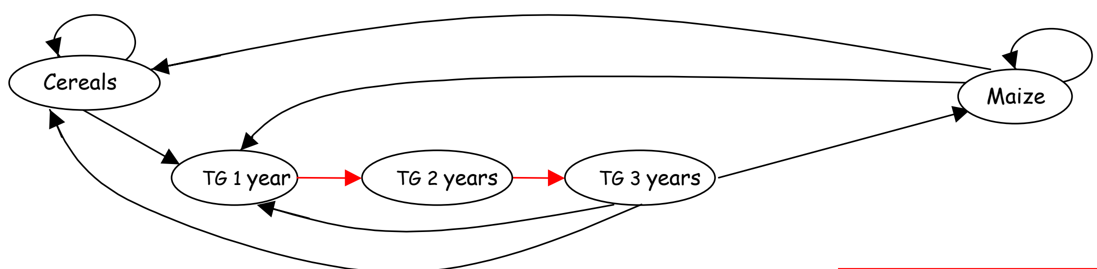
First zone: nearby farmstead

Soon: + farm types evolutions + farmer age…

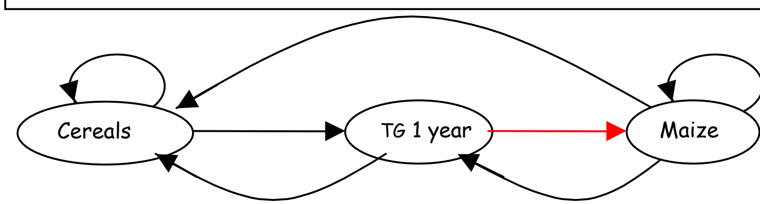
Gaucherel, Houet, Baudry, Hubert



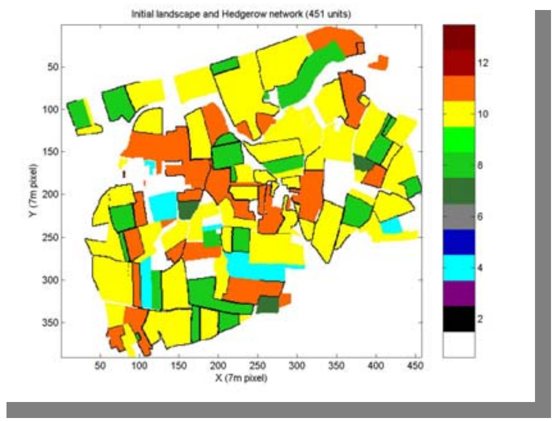
Second zone: between ~500 and 1500 m of the farmstead

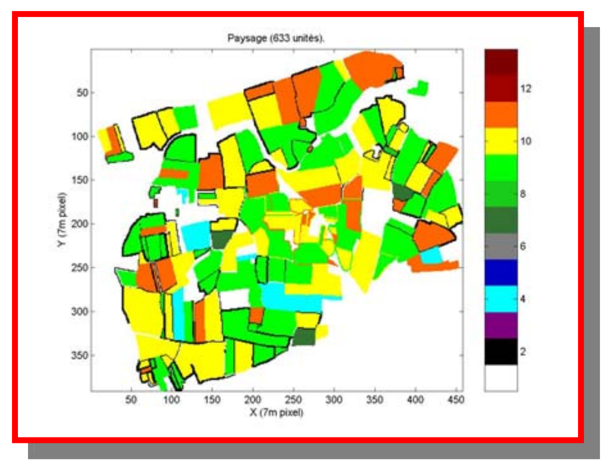


Third zone: ~1500 m of the farmstead and further



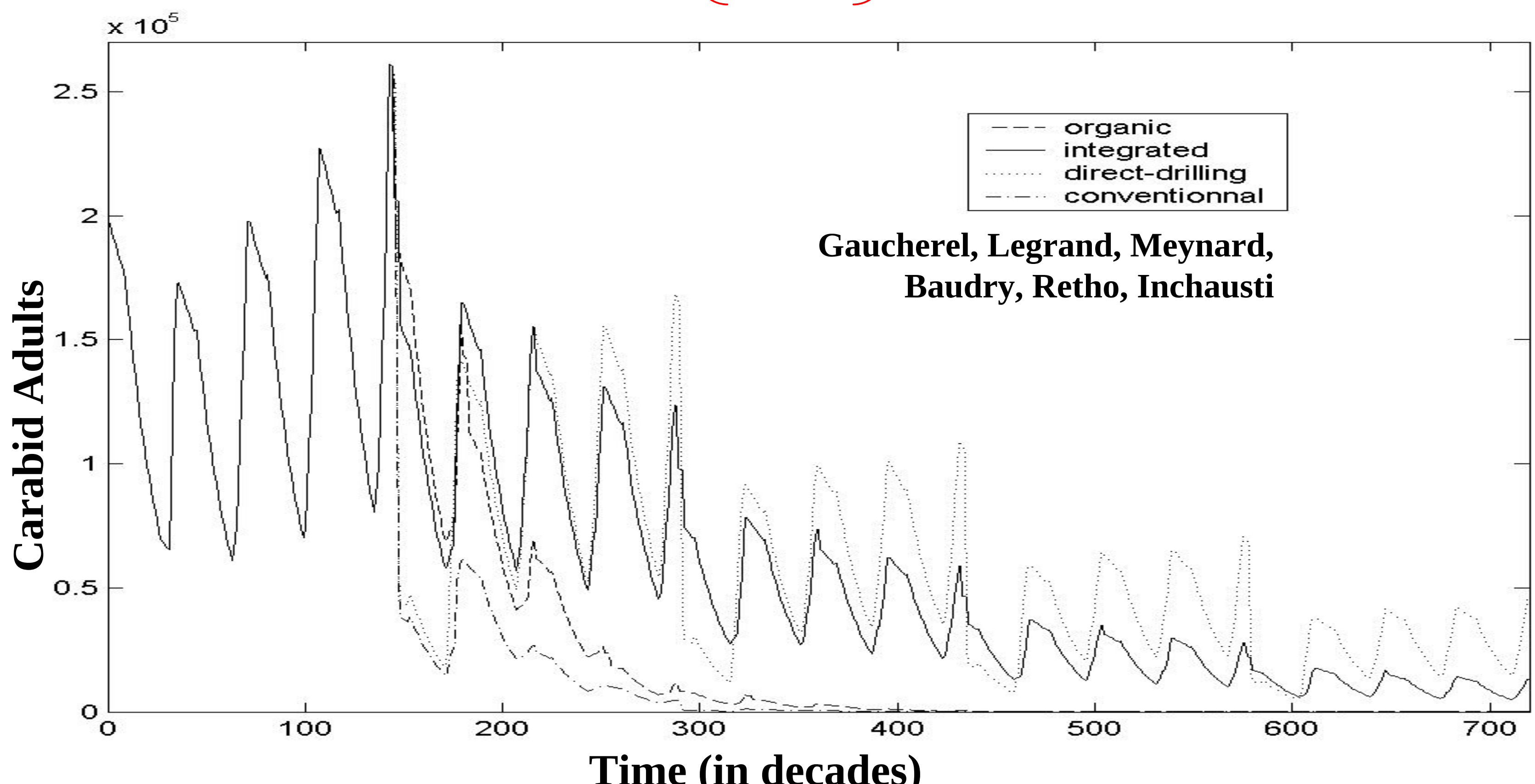
Compulsory change
Authorised change
TG : Temporary Grassland





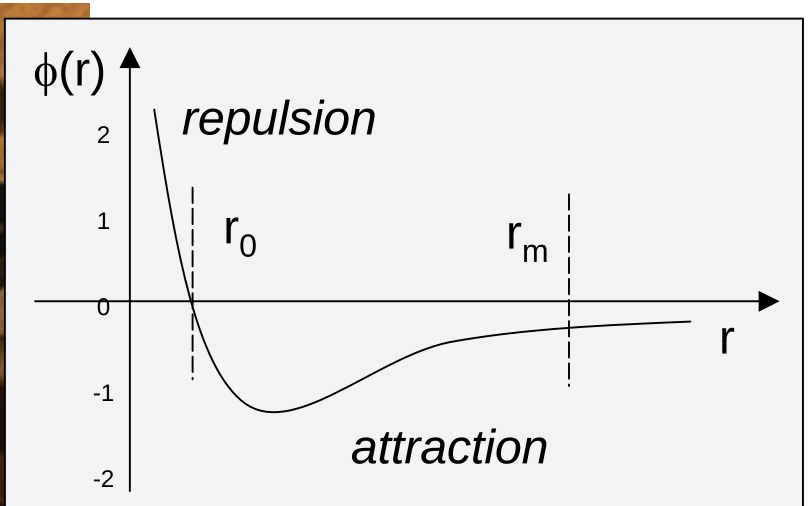
6. Other *L1* applications (meta-population)

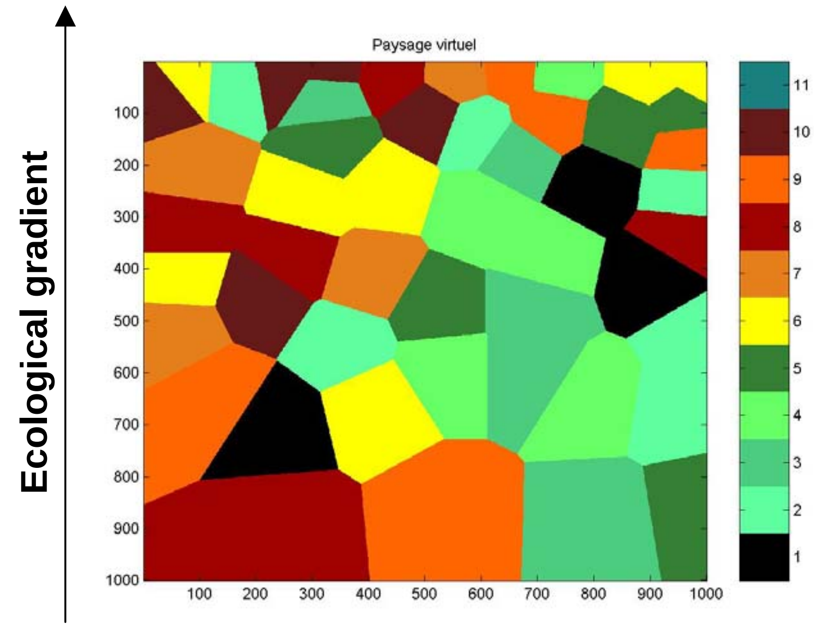
Population X_{t+1} = Agronomy · Spatially implicit · Periodical Leslie · Population X_t



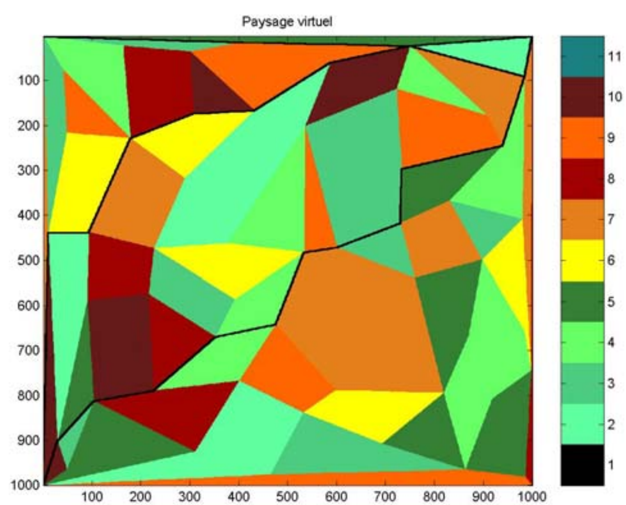
6. Other *L1* applications (neutral models)

Gibbs process adaptation to landscapes





The “Gibbs” L1 application



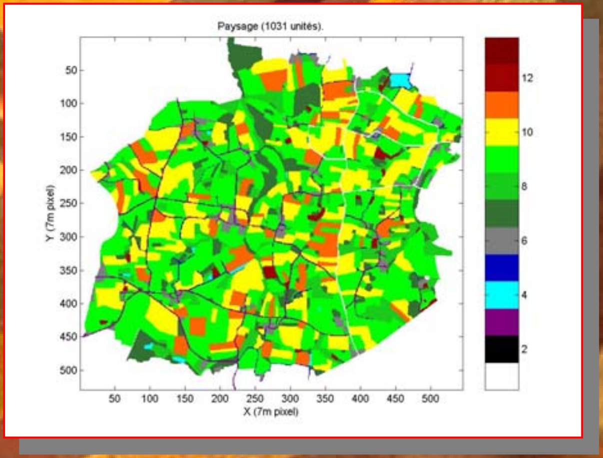
"Realistic" patchy landscapes

Automatic generation of realistic patchy landscapes with neutral models.

Gaucherel, Fleury, Auclair, Dreyfus

Conclusion

- We now have a functional prototype of a landscape model ***platform*** (*L1*) able to create ***categorical*** (patchy) landscapes with explicit processes (deterministic, empirical, stochastical…), as well as neutral models;



- Our aim is now to develop a ***perennial***, portable, open and dynamic software platform able to simulate very disparate rural landscapes.