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A multidisciplinary modelling approach to understand the effects of landscape dynamics on biodiversity

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Cedric Gaucherel, Vincent Martinet, Pablo Inchausti, Noémie Schaller, Laure Bamière, et al.. A multidisciplinary modelling approach to understand the effects of landscape dynamics on biodiversity. Colloque LandMod 2010: International Conference on Integrative Landscape Modelling, Institut National de Recherche Agronomique (INRA). UMR Laboratoire d'étude des Interactions Sol - Agrosystème - Hydrosystème (1221)., Feb 2010, Montpellier, France. hal-01172968

HAL Id: hal-01172968

<https://hal.science/hal-01172968v1>

Submitted on 4 Jun 2020

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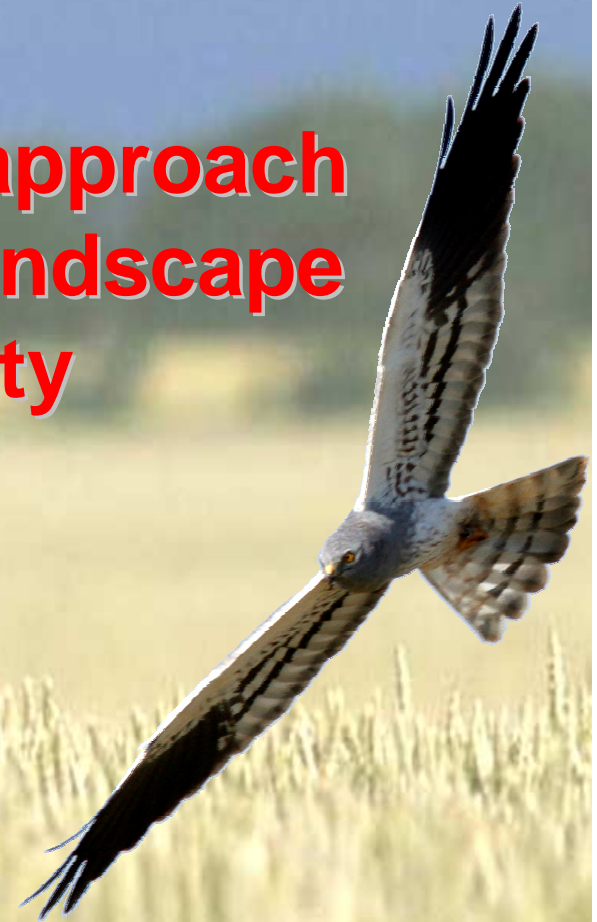
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A multidisciplinary modeling approach to understand the effects of landscape dynamics on biodiversity

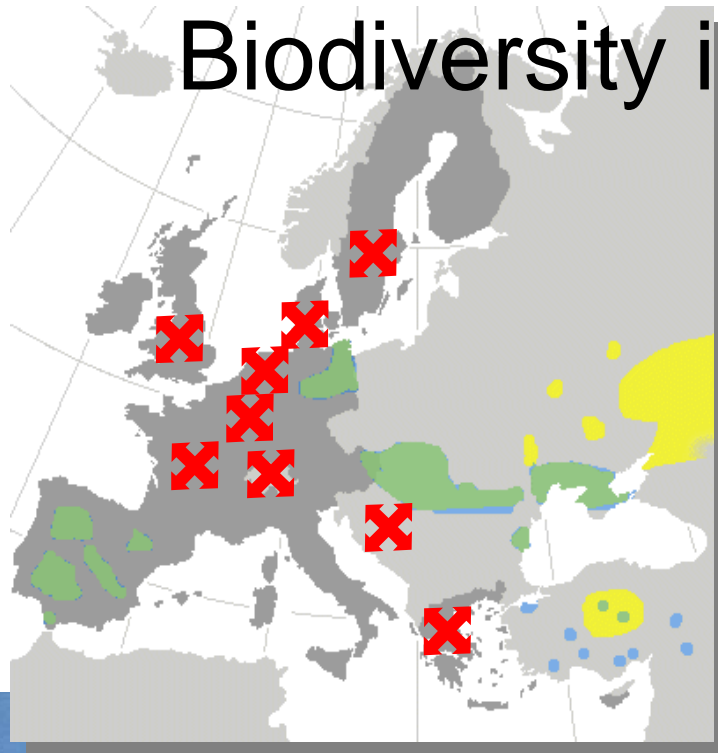
ANR BiodivAgriM Project

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Sheeren, A. Gibon, A. Joannon, M.
Castellazzi, H. Boussard, F.
Barraquand, E.G. Lazrak, J.F. Mari,
T. Houet, V. Bretagnolle*

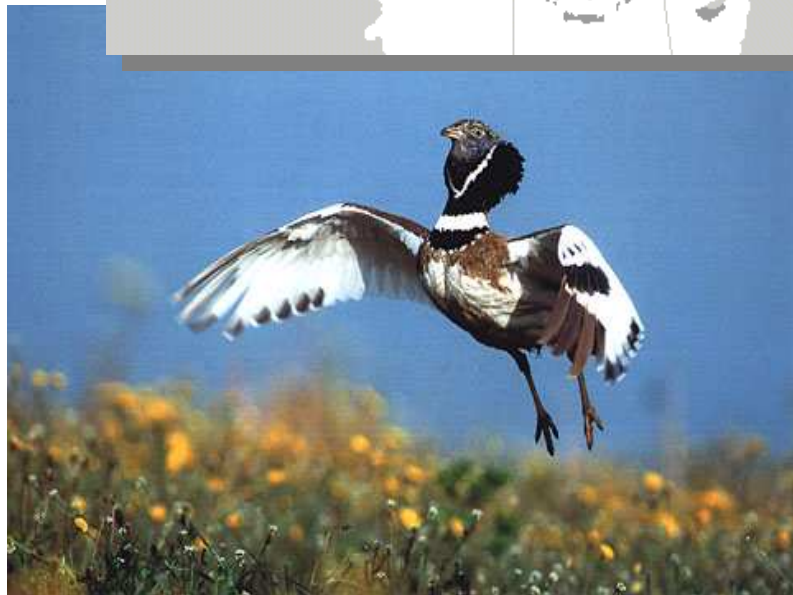
LANDMOD2010, Mpl 04/02/2010



Observed decline of specific Biodiversity in Agro-ecosystems



Over the last 40 years, agricultural extension and intensification of land use has induced profound changes in distribution and dynamics of farmland biodiversity (e.g. **Bustard** patrimonial species) and in the functioning of European agroecosystems:



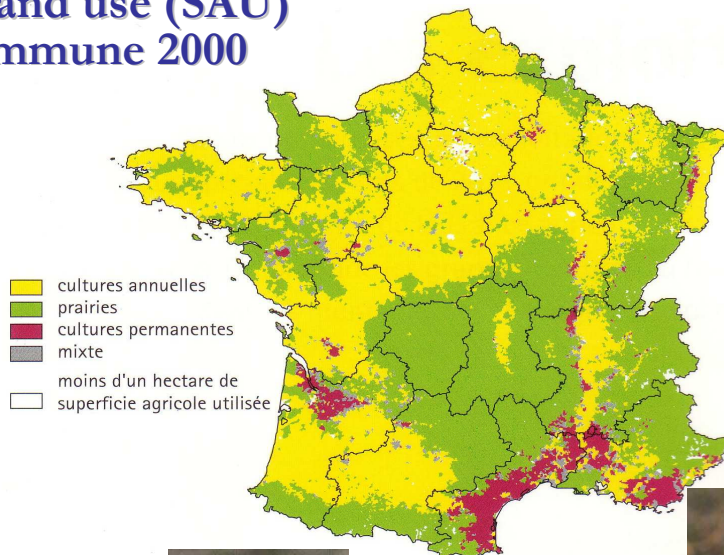
Bigal and McCracken, 1996
Robinson and Sutherland, 2002
Gregory et al., 2004



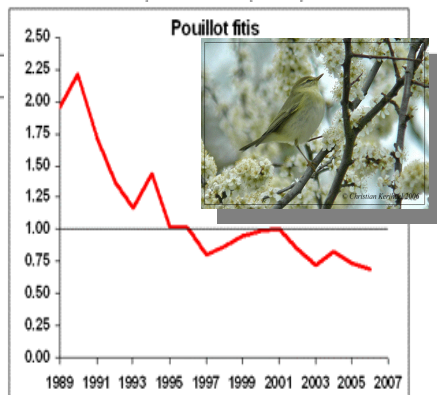
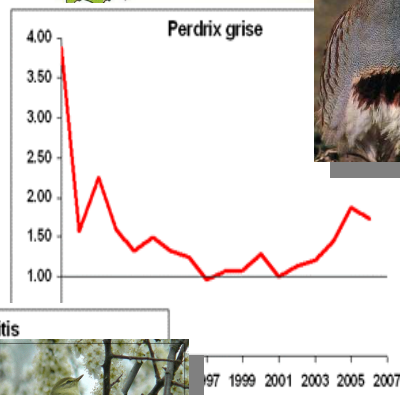
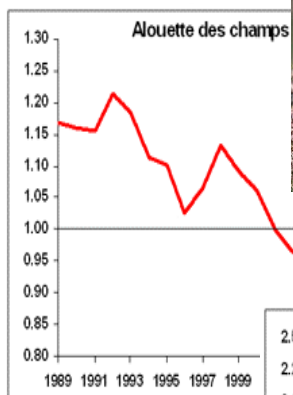
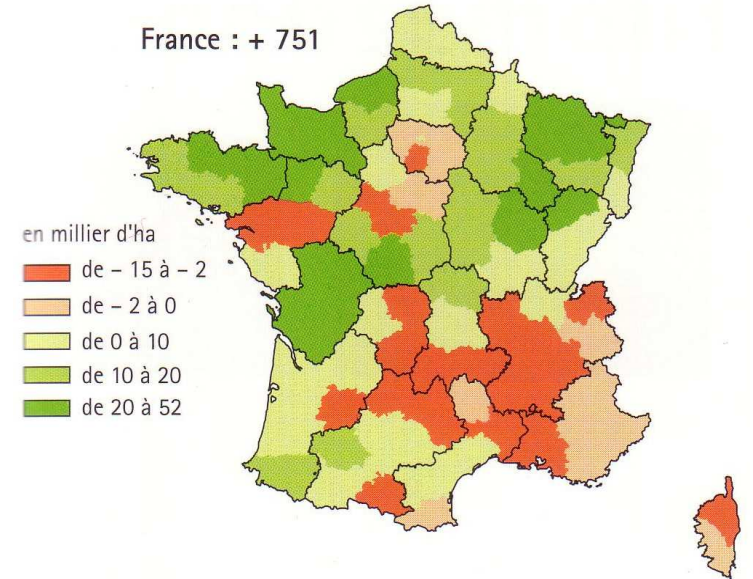
Simplification/specialisation of agricultural landscapes, abandonment of less fertile farmland areas, increase in the input of pesticides and fertilisers per unit area

Drastic Land Use changes in France

Main land use (SAU) per commune 2000

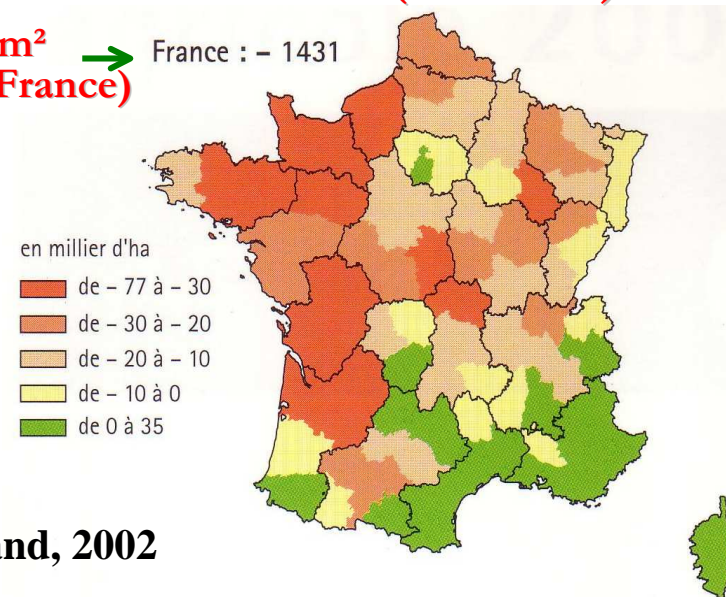


Large harvesting (1988-2000)



14.310 km²
(2,6 % de la France) →

Grasslands (1988-2000)



Donald et al., 2001
Benton et al., 2002
Robinson & Sutherland, 2002

The *BiodivAgriM* ANR project

~ 40 researchers, 2008 - 2011

Context

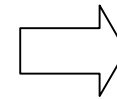
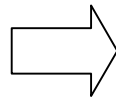
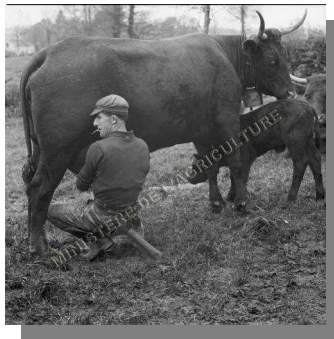
- Agroecosystems are mainly private properties, whose dynamics need to be better understood in order to preserve their biodiversity.
- Nine French research teams have recently joined their skills in a multi-disciplinary project, *BiodivAgriM*, whose main goal is to test, validate, and predict the consequences of different scenarios of landscape changes on the distribution, abundance and persistence of biodiversity in agroecosystems.

Modelling stakes

- A central goal of this project was to generate a multi-purpose modelling platform (WP4), which would make it possible to couple different spatially explicit models toward the same objective: to understand the impacts of agricultural practices on biodiversity.
- Such a modelling approach was a real challenge. We thought about either a unique integrated platform or different models to be coupled or compared.

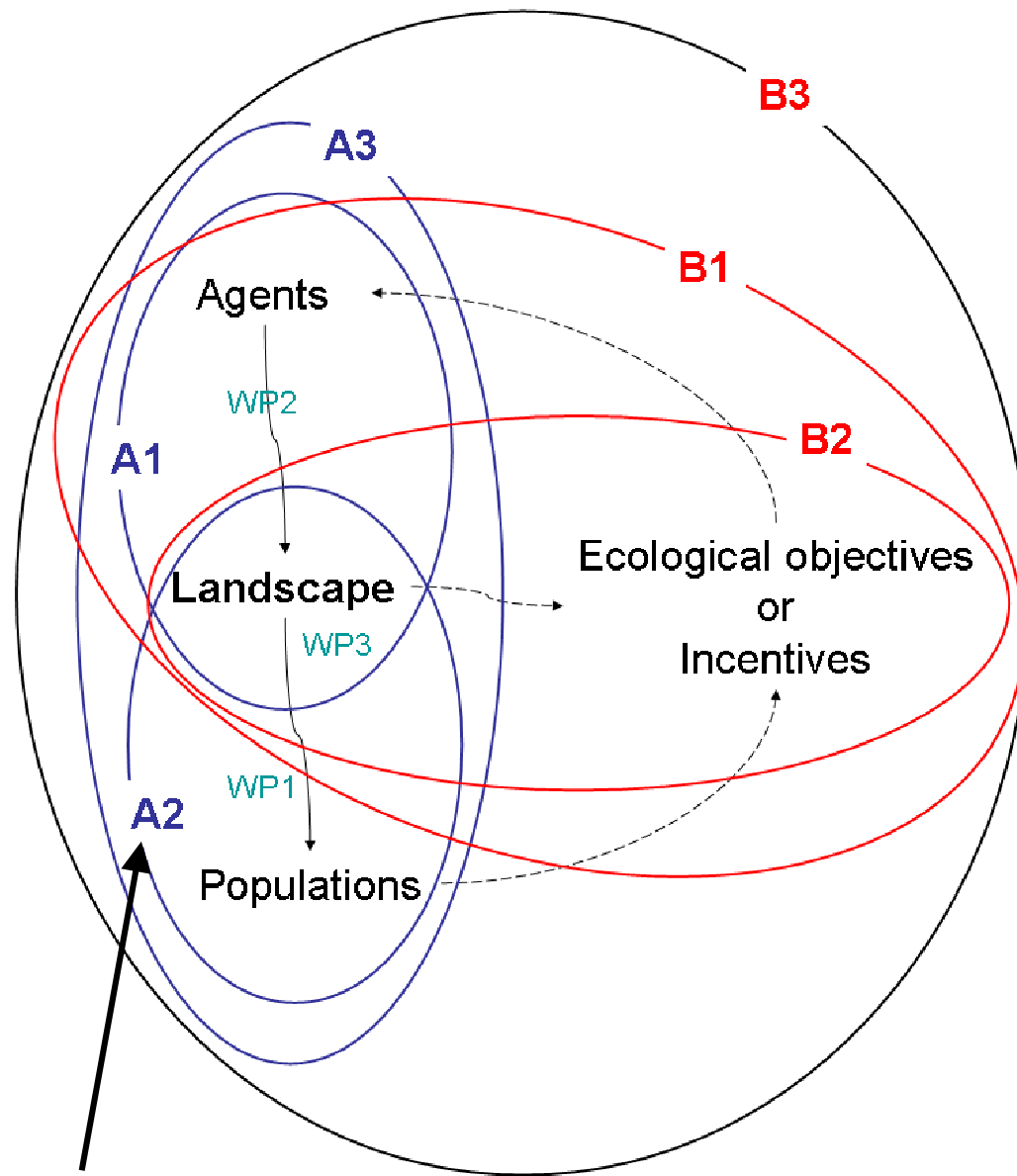
Some questions addressed

1. Do our present system of incentives and constraints on agricultural activities generate landscape mosaics allowing biodiversity conservation?
2. How will be impacted species abundances, depending on these system choices?
3. How land covers and land uses do constrain the dynamics and persistence of bird or small mammal populations?
4. How land cover drivers such as crop rotations, irrigation, soil fertility and cropping systems influence landscape structure?



5. Should we build several specific models, or build a global modelling platform coupling the various models developed for each question?

The (modeling) WP4 architecture



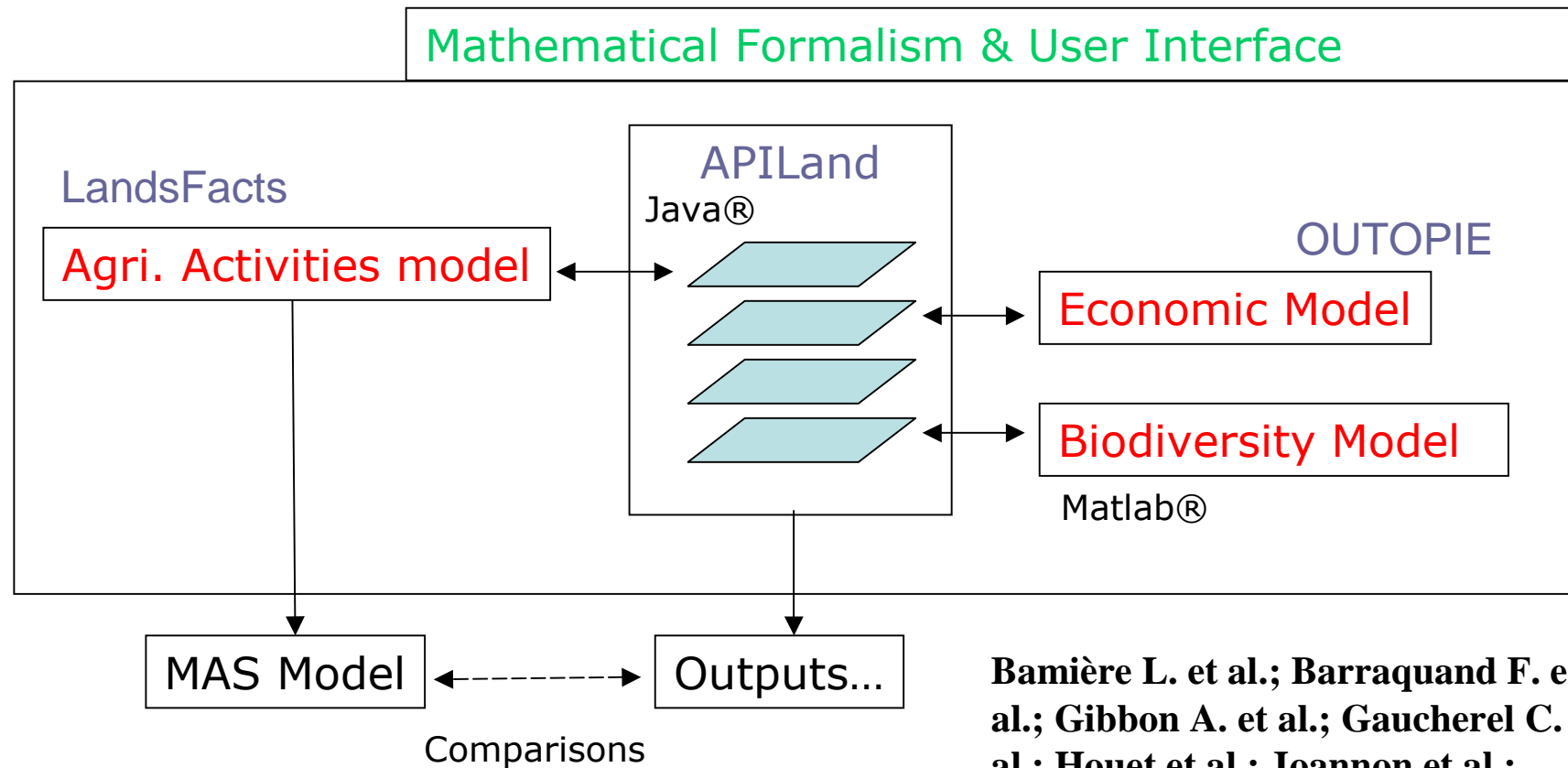
An illustration follows...

We managed to organize available models amongst the teams involved in this project within a coherent scheme, thus articulating the specific issues related to landscape in biology, ecology, socio-economy, geography, and agronomy disciplines.

How feasible is a generic model?

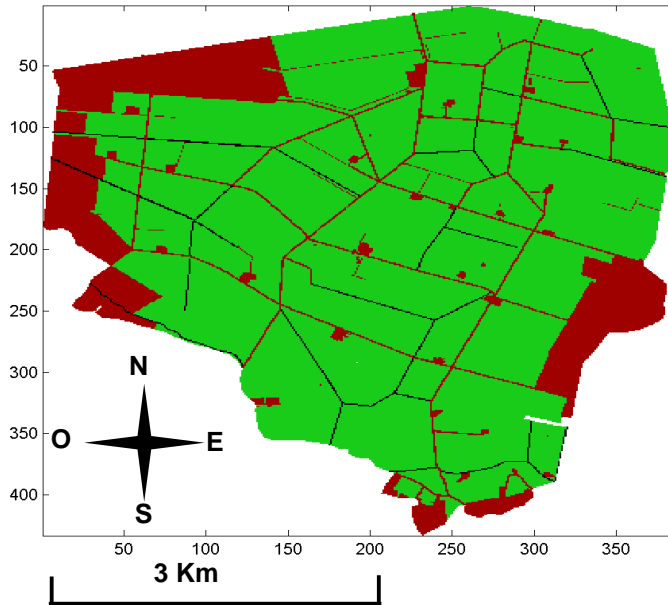
It rapidly appeared difficult to build from scratch an integrated modelling platform, wanted by mathematical and computing scientists, while ecologists and socio-economists needed more time to improve their understanding of processes.

DYPAL



Bamière L. et al.; Barraquand F. et al.; Gibbon A. et al.; Gaucherel C. et al.; Houet et al.; Joannon et al.; Lazrak et al.; Sheeren et al. (2009) ...

Illustration: A2 model coupling



Context:

Conservation of a patrimonial carab species in agricultural zones ;

Objectives:

To identify landscape structures favourable to the species, by the use of a “*landscape language*” ;

Gaucherel et al. 2006

Gaucherel, Boudon, Houet, Godin, Submitted.

Hypotheses :

Intermediate hedgerow isolation and higher landscape contagion (connectivity) are *favourable* to the carab species conservation;

Method:

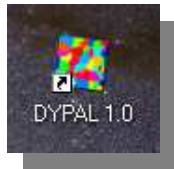
Modelling the landscape language associated to various landscape *configurations*, and model population dynamics on them.



Study site: *Polders in Brittany (1164 landscape units, fields + dykes 4%); mainly intensive agriculture.*

Landscape model: DYPAL

In progress: a model to translate dynamical equations into simulations, with the Free / Opensource / Interactive Java® version (*DYPAL* prototype);

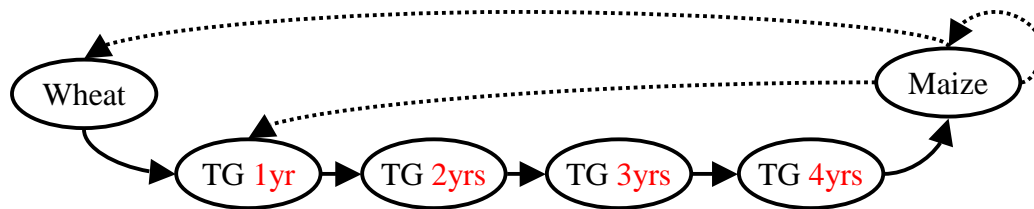


The screenshot displays the DYPAL 1.0 software interface. The main window shows a sequence of landscape images from "Initial landscape" to "Final landscape". A "Unit chain merging" dialog box is open, showing parameters for "Time Features" (Execution: Parallel/Sequential, Occurrence probability: 100%, Starting step: 0, Duration: 1, Frequency: 1, Total duration: 0) and "Spatial Features" (Neighbouring unit to be merged: Random, Landscape unit number: 10, Colour choice (more) nbr: 3 unitNbr: -1). A large, colorful landscape map is visible in the background. A blue arrow points to the map with the text "POSTDOCTORAL OFFER".

© C. Gaucherel, F. Escandel & C. Le Brouster, INRA

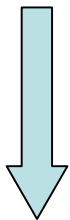
The landscape “language”

Intensive dairy and beef livestock production



Agricultural rotations located **nearby the farmstead** < 500 m

Gaucherel, Houet, Boudon, Godin Submitted



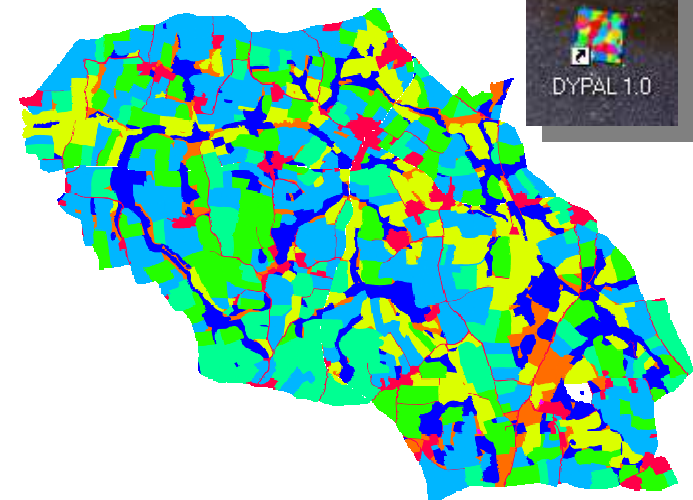
Language inspired from « formal grammars » (e.g. *L-systems*).

$$\left\{ \begin{array}{l} M(l,t,a,d):(d < 0.5) \& (l = 1) \rightarrow M(2,1,a,d) \\ M(l,t,a,d):(d < 0.5) \& (l = 2) \& (t < 4) \rightarrow M(2,t+1,a,d) \\ M(l,t,a,d):(d < 0.5) \& (l = 2) \& (t = 4) \rightarrow M(3,1,a,d) \\ F(f) < M(l,t,a,d):(d < 0.5) \& (l = 3) \& (S_1(f) < 15) \rightarrow M(1,1,a,d) \\ F(f) < M(l,t,a,d):(d < 0.5) \& (l = 3) \& (S_2(f) < 55) \rightarrow M(2,1,a,d) \end{array} \right.$$

Chomsky 1956; Lindenmayer 1971; Barbier de Reuille 2006

- Common use of transition matrices (Markov) or rule-based models (MAS, SIG).

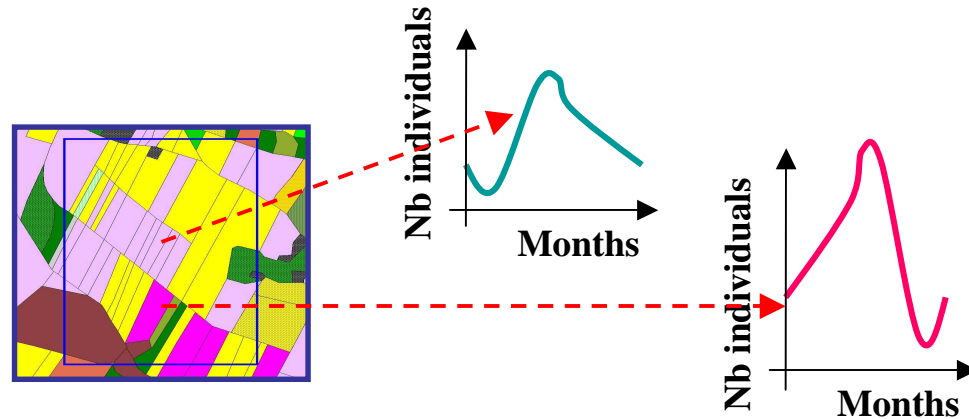
- Yet, to our knowledge, no real attempts to formalize (equations) patchy landscape dynamics exist.



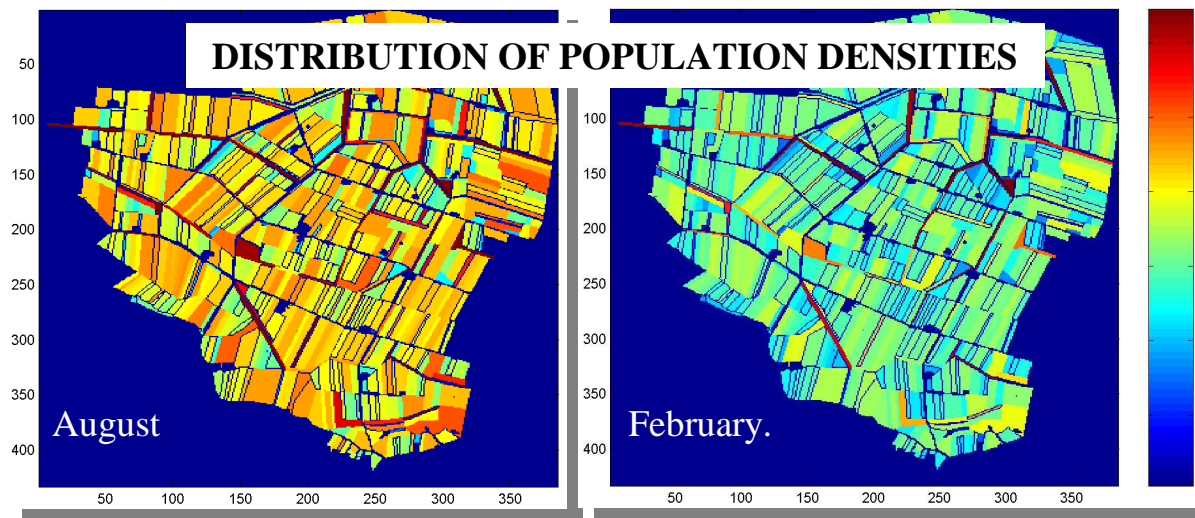
The population dynamics model

Coupling of population and landscape models, by focusing on **migratory fluxes** between each landscape pair - unit and by studying their joined dynamics.

Use of **Spatialized coupled Leslie** matrices (each associated to local populations in fields and dykes) :



$$Nbmig_{in \rightarrow out} = Nbind_{in} * Txmig_{(in \rightarrow out)} * LinCom_{(in-out)} / (Surf_{in} / Surf_{out})$$

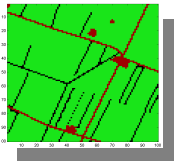


High density
↑
Low density

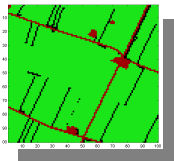
Close to metapopulation models, except that the whole landscape (and its complexity) is considered.

Spatialized population dynamics

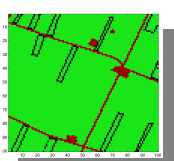
Types : n°1



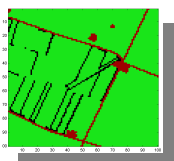
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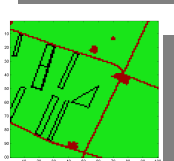
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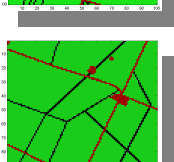
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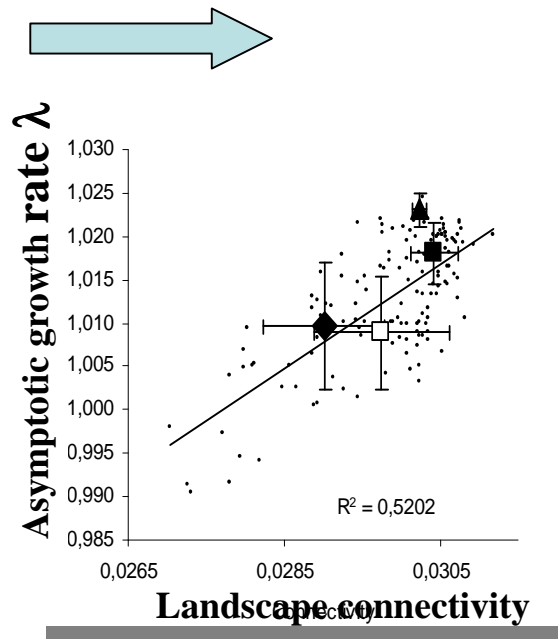


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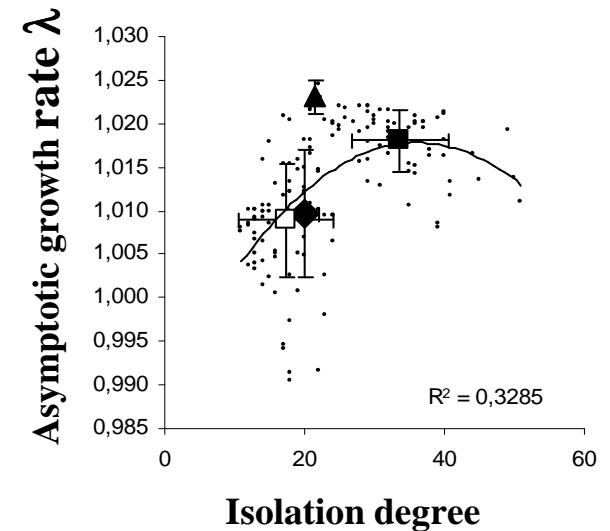


Choice of (static) landscape compositions/configurations...

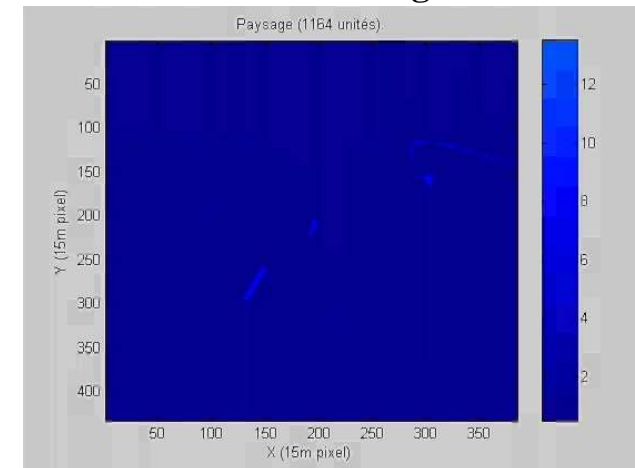
- Observed optimum for the population (significant $r^2 \sim 0.33$) along with the habitat clustering (due to pendular movement of the species).



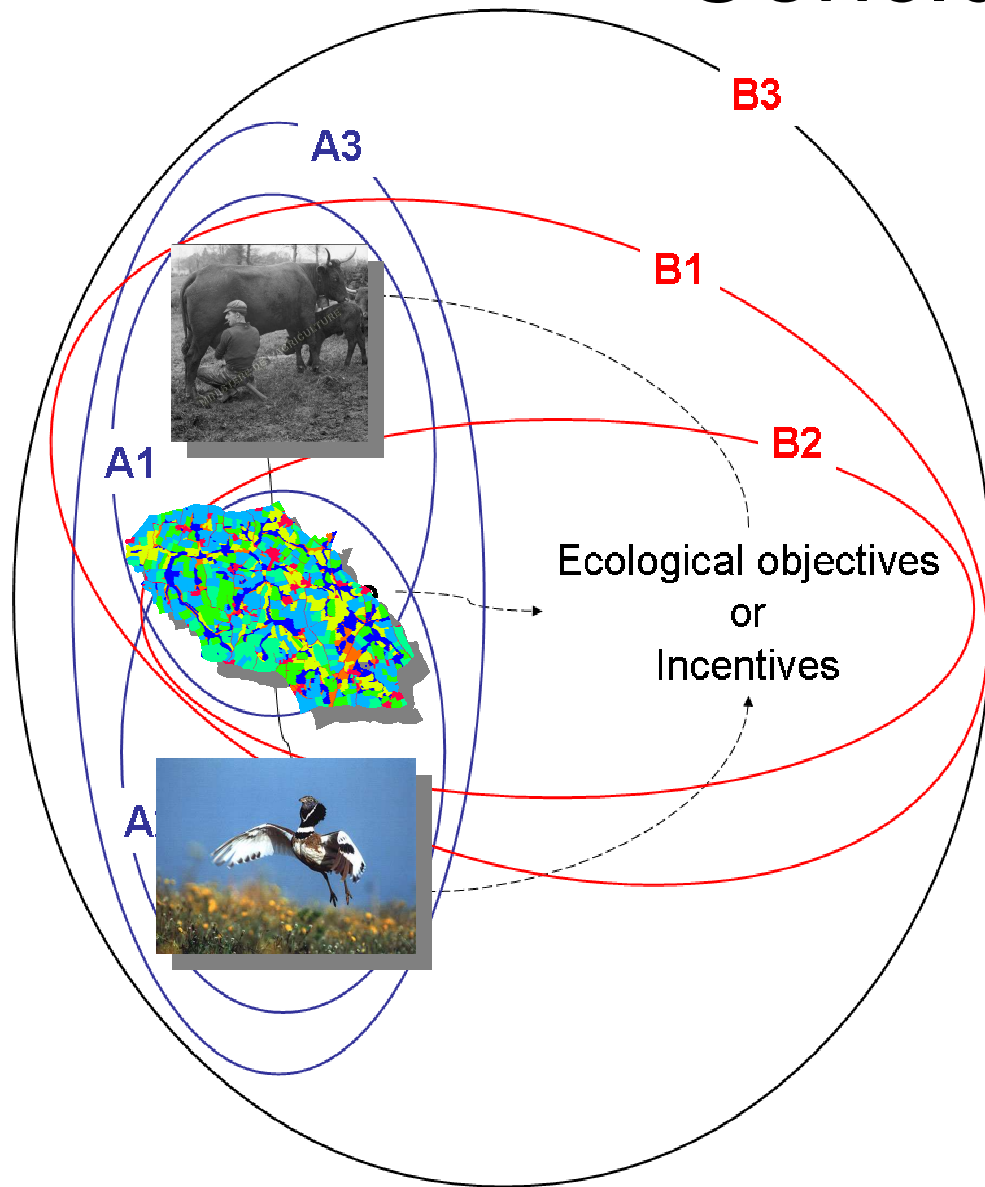
Rétho et al. 2007



Configuration/Composition
Soon dynamical landscape...



Conclusion



- A central goal of the BiodivAgriM project was to generate a multi-purpose modelling platform (WP4), which would allow to couple various spatially explicit models toward the same objective: to understand the impacts of agricultural practices on specific biodiversity.
- No doubt that some of our models would test, validate, and predict the consequences of different scenarios of landscape changes on the distribution, abundance and persistence of biodiversity in agroecosystems.
- Such a modelling approach was a real challenge. The topic is probably not mature enough to build a unique integrated platform (If ever needed?).