Virtual Prairies with Boinc

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General overview of the project – presentation of the ViP project

❖ Prairial ecosystems are highlighted as key elements for supporting ecological services (recent EU agricultural policy, French Grenelle de l'environnement)

❖ Creation of new prairial systems in landscape as surrogates of the degraded permanent grassland (herbal strips along crop fields,) for optimizing ecological services provided

❖ Most prairies are constitued of clonal plants which are difficult to study at the prairie scale with a high precision (individual level)

❖ Owing to recent advances in computer technology, virtuality can be a realistic tool for studying plant colonization patterns at a prairie scale

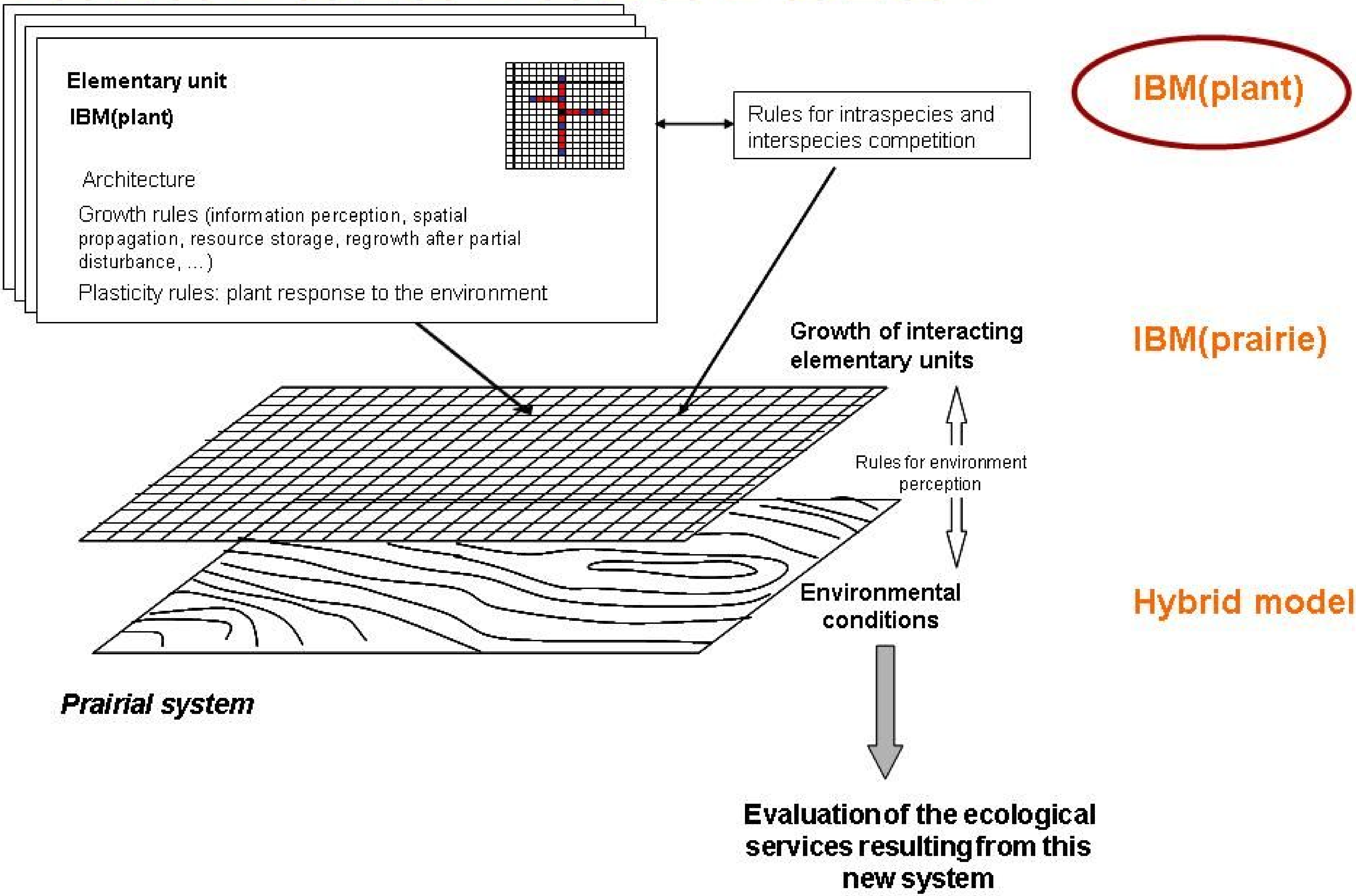
Main steps in the ViP project

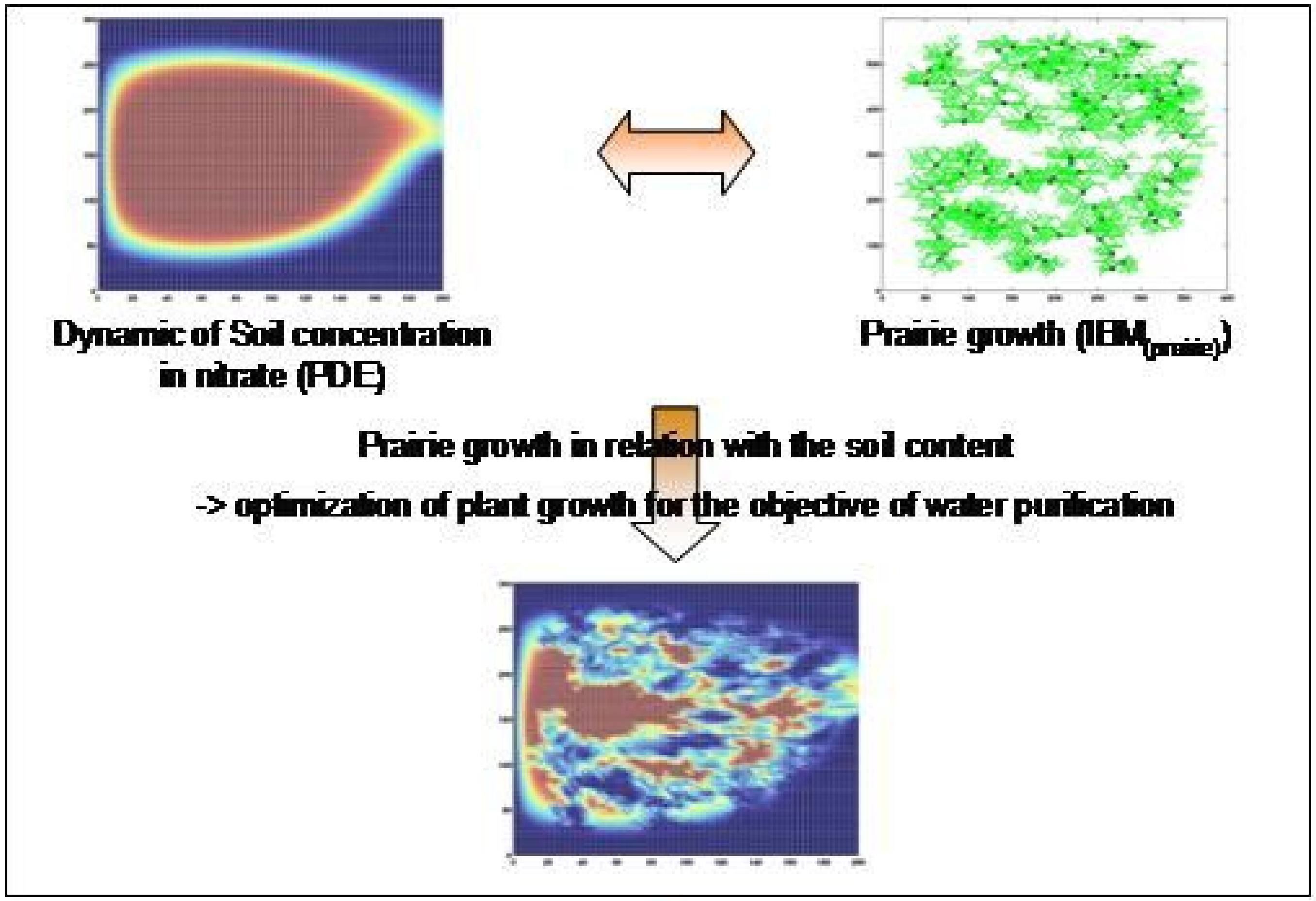
Construct a virtual prairie linked with environmental parameters

Individual behaviors of plant can modify the whole prairie structure (emergent properties of the group of individuals)

Individual based model for taking care of individual behaviors

Main steps in the ViP project



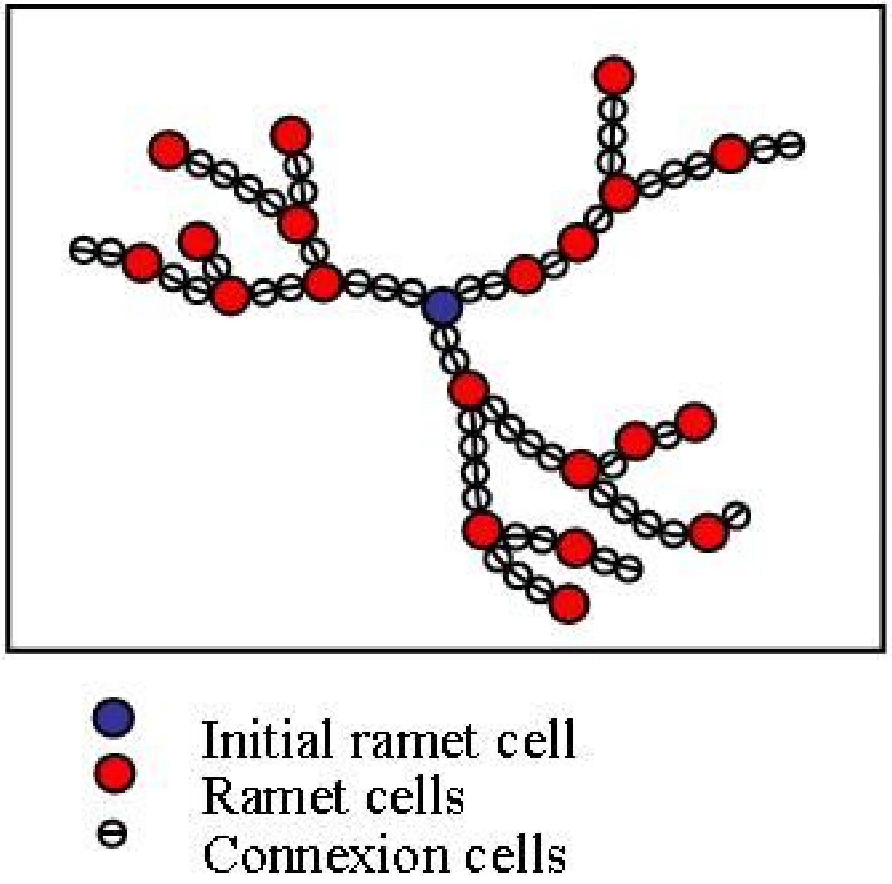


Evaluation of the capacity of the prairie for nitrate epuration

Practical recommendations in prairie engineering for optimizing water purification

The properties of clonal plants

❖ Network of ramets connected through underground or aboveground connexions



❖ Spatial colonisation through this particular architecture (phalanx vs. guerilla strategies…)

The properties of clonal plants

- ❖ Network of ramets connected through underground or aboveground connexions

- ❖ Spatial colonisation through this particular architecture (phalanx vs. guerilla strategies…)

- ❖ Information sharing (nutrient, water, hormones, …ect.) within a certain distance in the clone (from short distance to the whole clone level)

- ❖ Resource storing in connexions

- ❖In heterogenous habitats, potential intra-clonal specialization of ramets

Main goals of this study

Step 1: Simulating one individual clonal plant

❖ Detect trade-offs in plant clonal traits

❖ Detect which process(es) (growth, architecture, resource strategy) is/are the most important for plant success

❖ Determine the combination of clonal traits that promotes plant performance

Model description

- Plant metabolism

  Energy increment and cost for one cell :

  connexion cell is less costly than ramet cell

- Plant form

  Structural constraints:

  number of active buds for rhizome/stolon development

  inter-ramet distance and variation in inter-ramet distance

Model description

- Plant metabolism
- Plant form

Structural constraints:

number of active buds for rhizome/stolon development

inter-ramet distance and variation in inter-ramet distance

Model description

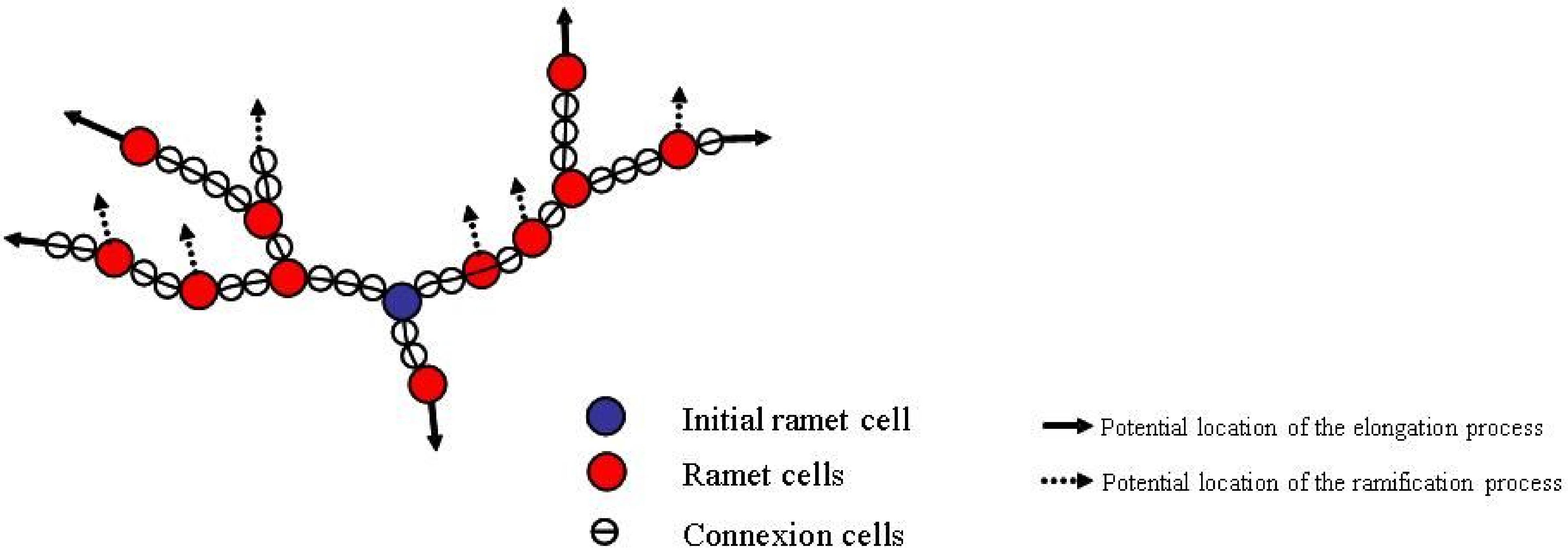
❖ Plant spatial colonisation

2 processes: Elongation or Ramification

- Proba of extension vs. ramification is fixed at the beginning

-The choice of the rhizome/stolon which will elongate or branch depends on the length and the generation of it

-The location of the new cell along the rhizome/stolon will be at the end of the rhizome/stolon when elongation or is function of the position of the cell along the rhizome/stolon

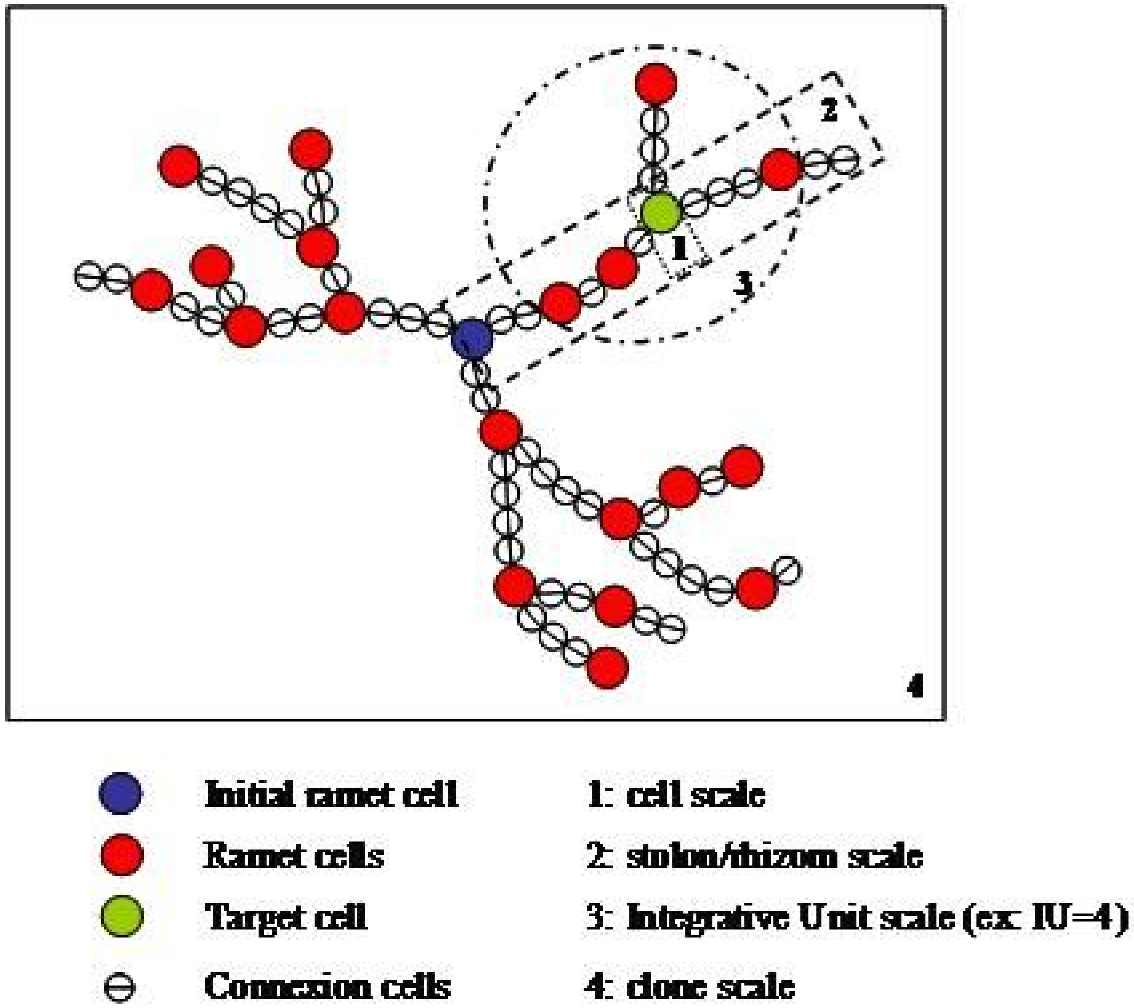


Model description

Plant resource strategy

% of energy stored in the connexions per time step

Number of cells of the IU (Integrative Unit = distance along which resource is shared)



Comparing virtual plants to real ones

Experimentations in ecology

Literature survey

Existing potential range for input parameters (min-max values)

12 input parameters (Plant growth, Plant form, Plant space colonization, resource strategy) with 3-4 values each

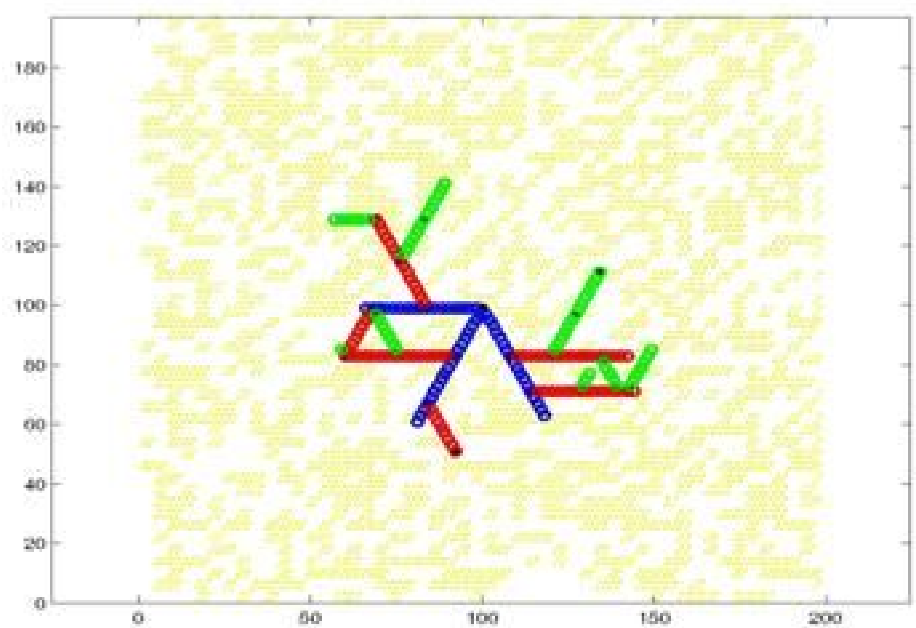
Comparing virtual plants to real ones

Experimentations in ecology

Literature survey

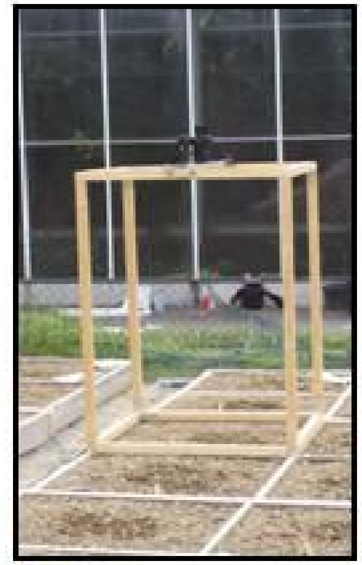
Existing potential range for input parameters (min-max values)

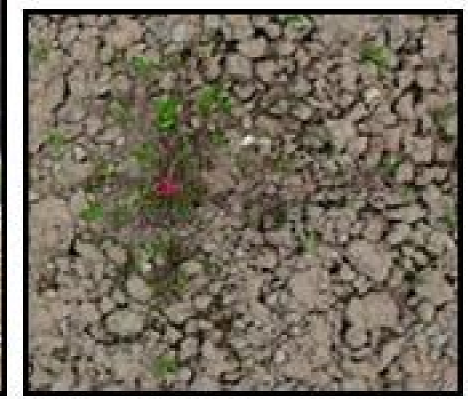
5 Output parameters

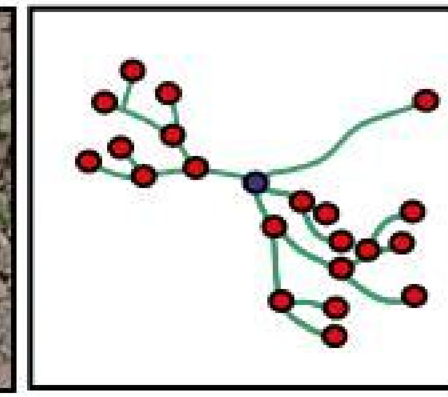


5 output parameters characterising plant performance (Biomass, nb of ramets, space colonization)

Comparing virtual plants to real ones



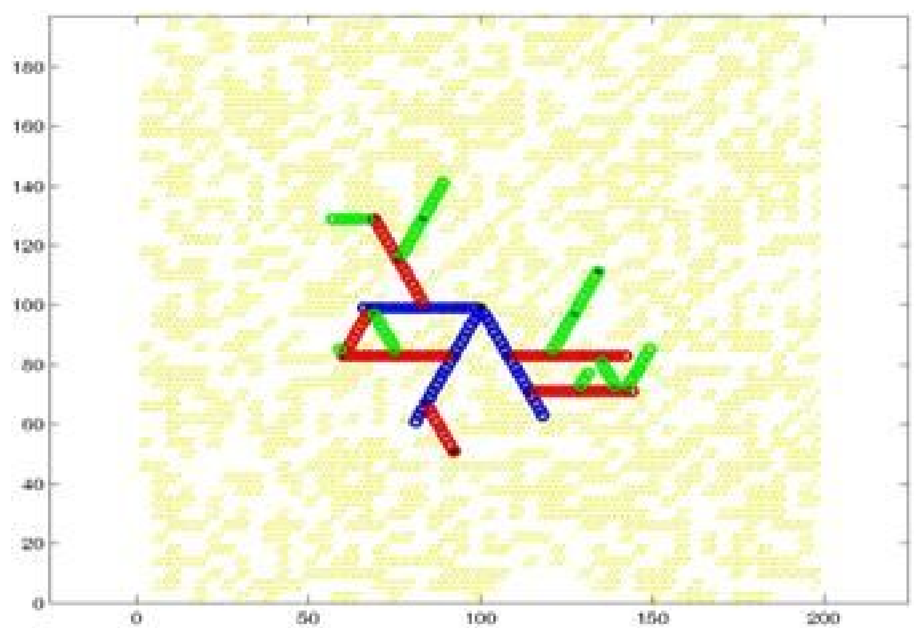




Comparison with real plant patterns

Input parameters

Output parameters



Model description

- Short term growth (100 time steps)
- Growing patterns in grids
- No sexual reproduction, no disintegration
- For each combination of the 12 input parameters, Mean and SD for the five output parameters based on 1000 replications of the simulation

Model simulations using Volunteer Computing

- An emergent technic well adapted for large scale simulations in Ecology:
  - Large Parameter Space
  - Stochastic Evolution
  - Social Impact

- Plateforme BOINC → ViP Project (first green project using these technics)

- 2sd Simulation campaign for the first step of the project: 22M simulations with 800 volunteers worldwide, 3 weeks vs. 8 years on a single processor

- Remark: we did plant 22 billion individuals .....

Results – Are there trade-offs between plant traits ?

Correlations in the output parameters:

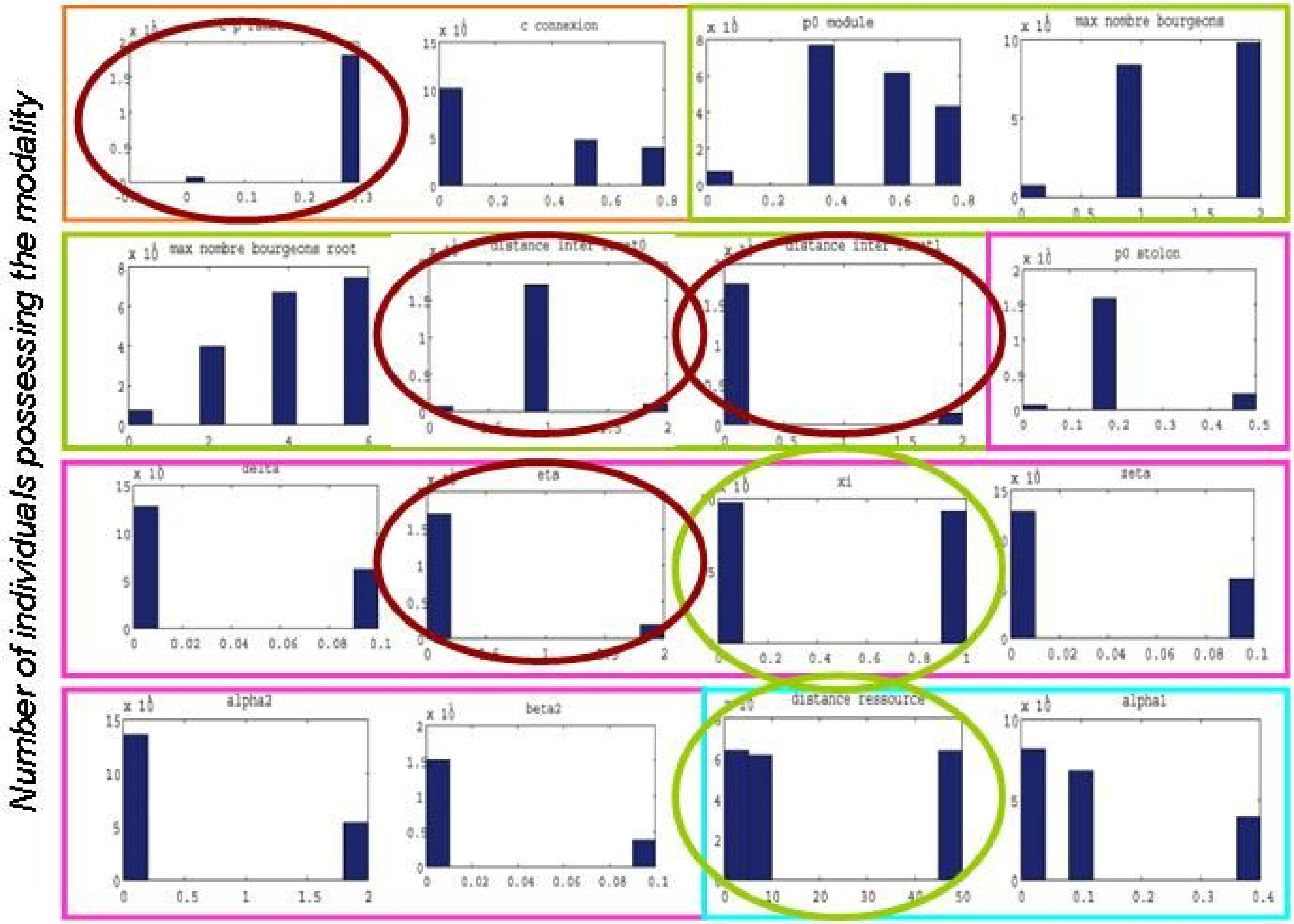
	Biomass	Nb stolons	Nb ramet cells	Nb connexion cells	Max length of one stolon
Biomass	-				
Nb stolons	0.52	-			
Nb ramet cells	0.79	0.66	-		
Nb connexion cells	0.56	0.66	0.71	-	
Max length of one stolon	0.55	0.40	0.73	0.86	-

- *No negative correlations*
- *No particular biomass effect except for nb. ramet cells*
- *Max length of stolons depends strongly on inter-ramet distance*
- *Nb stolons and max length of stolons vary independently*

→ *Determine to which extent these results are real emergent properties*

Results – What clonal properties involved in plant fitness ?

Selection of the top-1% of plants which perform at best for one output parameter (ex of biomass)



Parameters that are strongly influent

Parameters that are neutral

Parameters with more complex value distribution

-- Plant metabolism -- Plant growth form -- Plant spatial colonization -- Plant resource strategy

Results – What combination of traits promotes plant performance ?

3 different strategies for reaching the same goal: ex of max biomass

Low cost connexion

6 buds available for branching at the initial cell

Ramification less sensible to stolon length

Dist interramet of 2 cells with potential variability

Ramification highly sensible to stolon length

4 buds available for branching at the initial cell

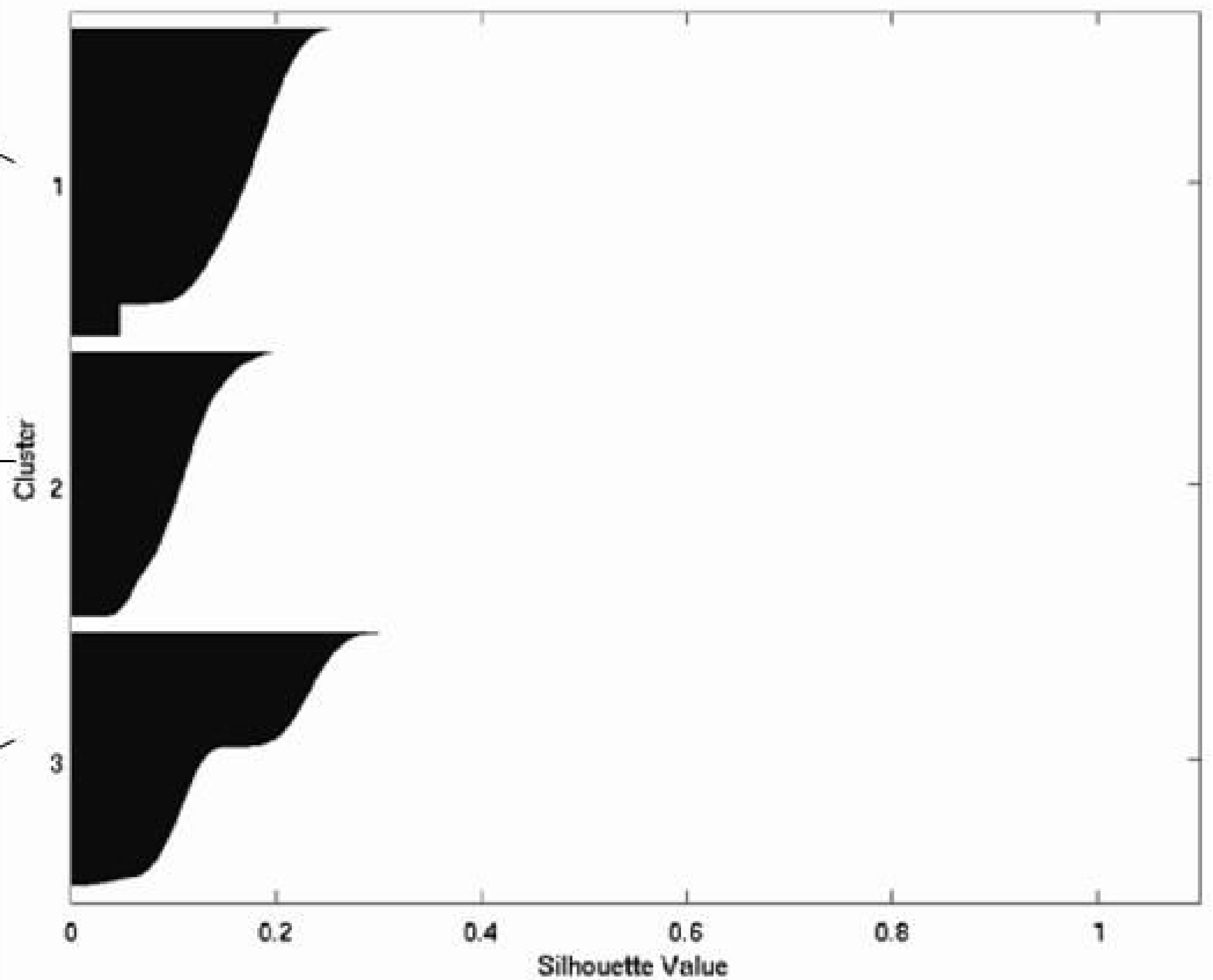
Dist interramet of 1 cell with potential variability

Connexion with a higher cost

4 buds available for branching at the initial cell

Dist interramet of 1 cell with no variability

Ramification less sensible to stolon length



Results - summary

Are there trade-offs between plant traits ?

No but there can be some positive correlations

What clonal properties involved in plant fitness ?

Depends on the output parameter considered

What combination of traits promotes plant performance ?

No single strategy but a few different strategies

What is next ?

Step 2: Simulating interacting plants at a prairie scale

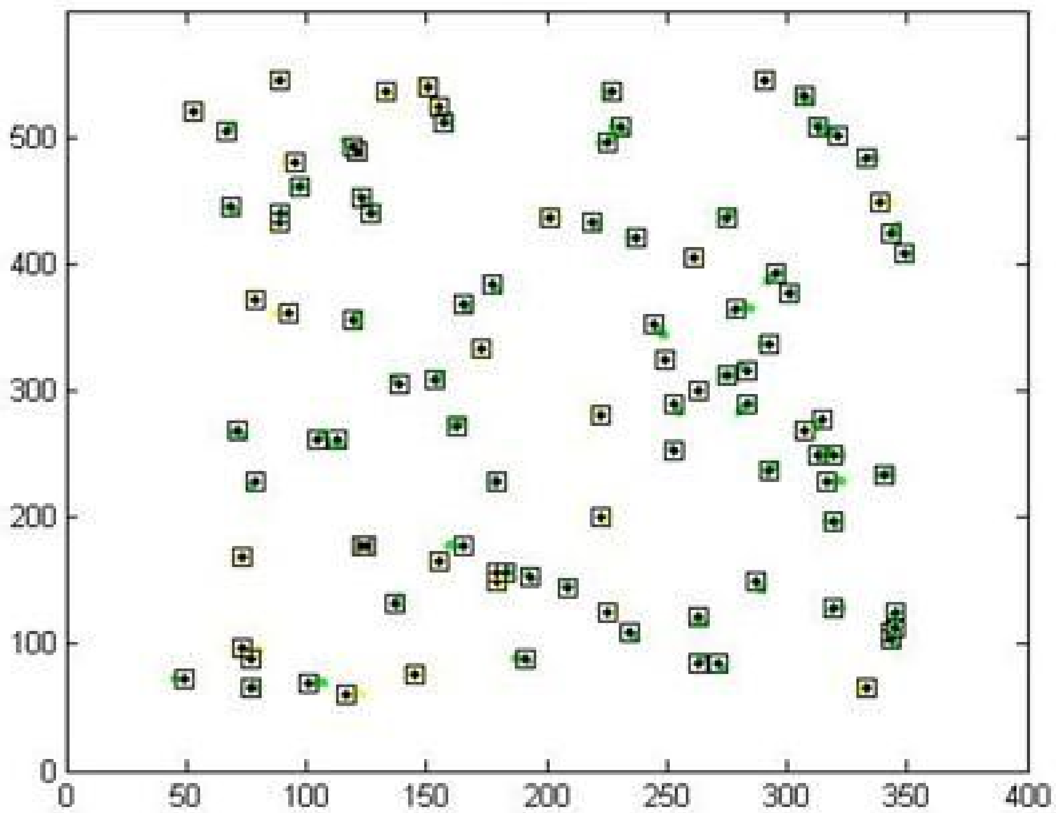
❖ Detect how competition affects the number and the type of plant best strategies

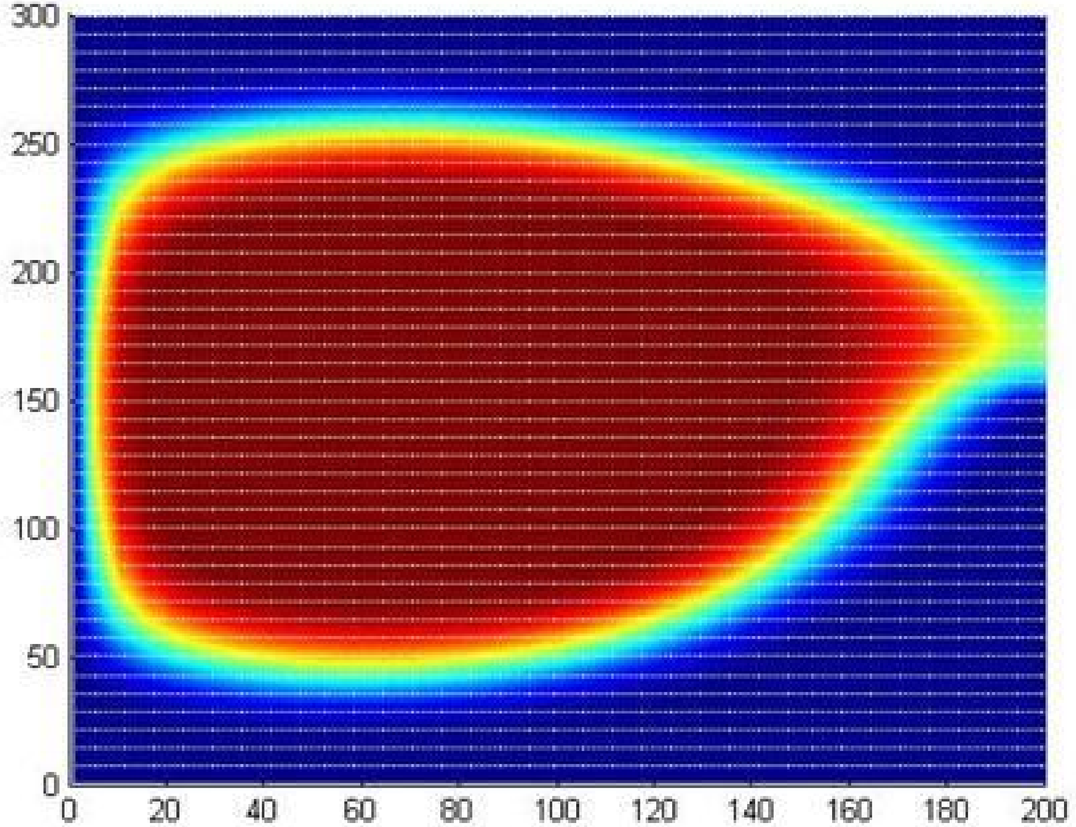
❖ Detect if plant performance depends on the diversity of traits of plants in the neighbourhood

❖ Determine the emergent properties at a prairie scale (e.g. hundreds of interacting individuals of different species)

What is next ?

Step 3: Simulating a prairial system interacting with environmental conditions





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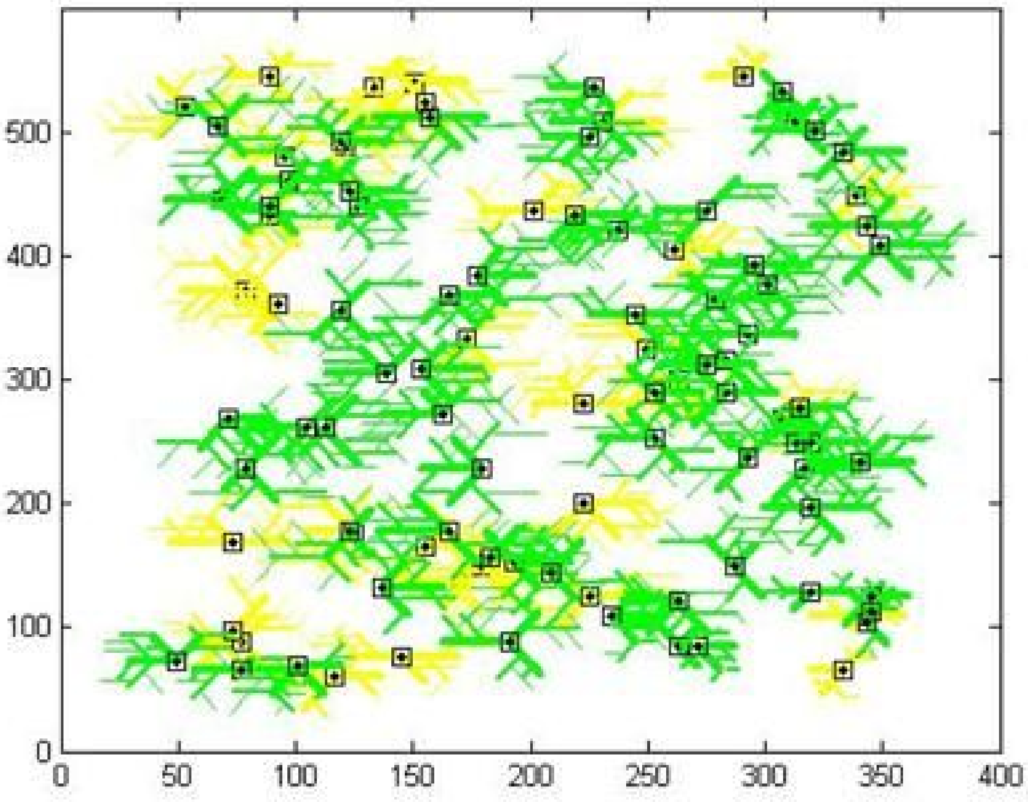

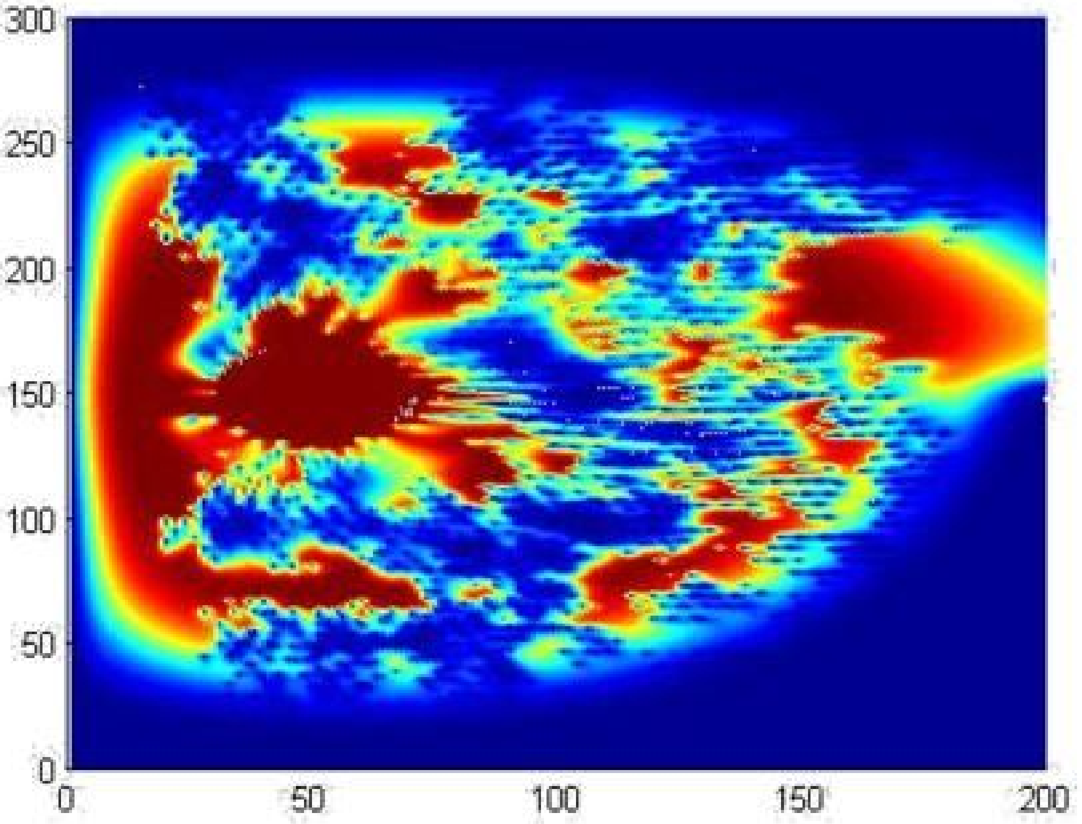

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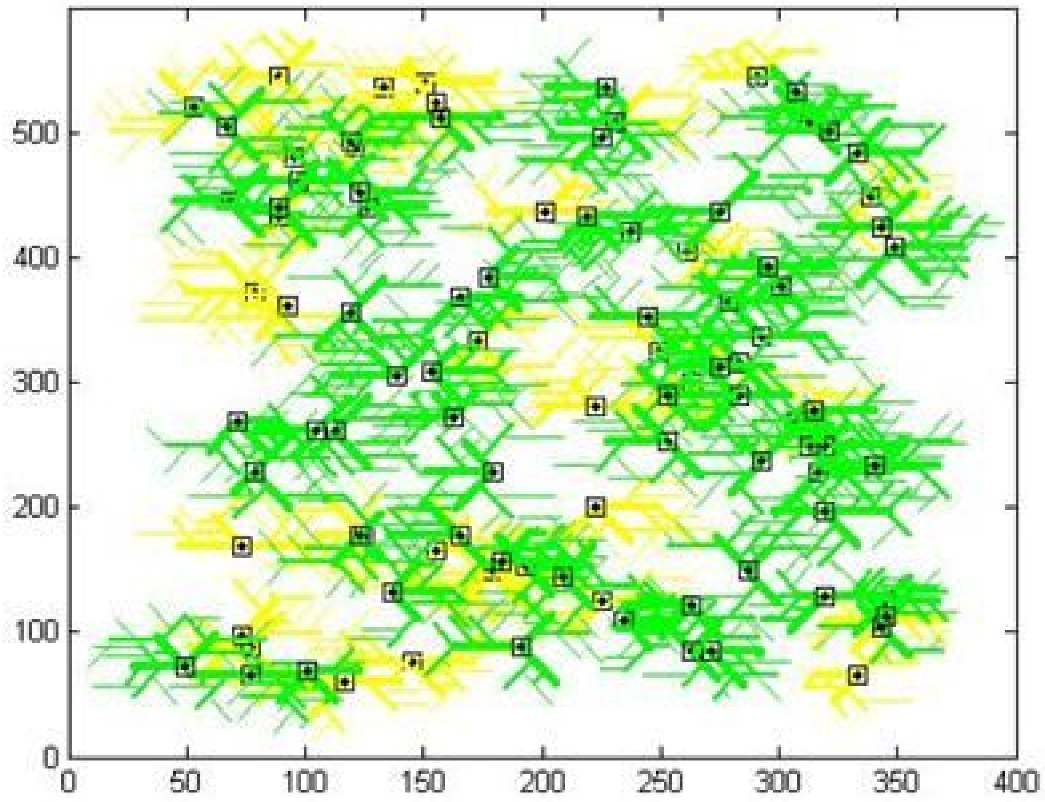

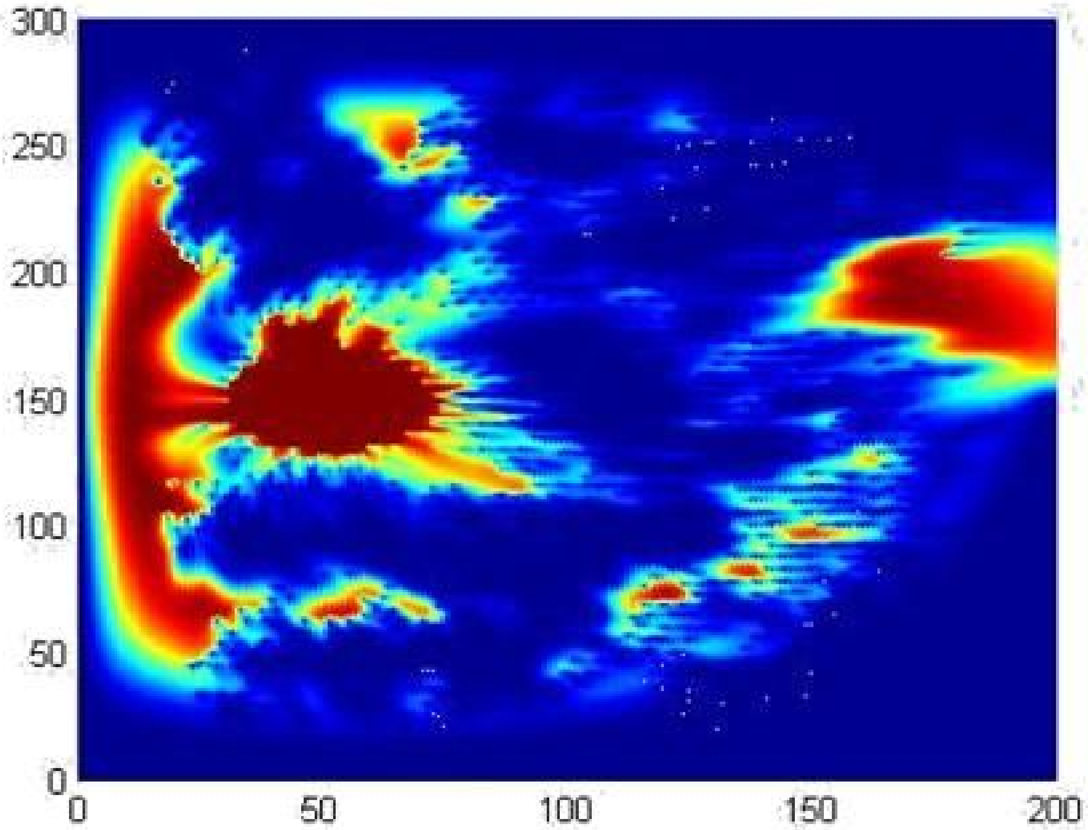

Conclusion and perspectives

- ❖ Promising results but a lot to do...
- ❖ Precise validation of results in the field
- ❖ Develop data-mining tools such as geostatistical analyses to compare spatial patterns of plant colonisation between virtual and real experimental patterns
- ❖ Terrific play ground for statistical methods, genetic algorithm, game theory, image analysis, hybrid models, data assimilation ....
- ❖ Exciting International/Interdisciplinary project
- ❖ Volunteer Computing makes the difference!
- ❖ ANR SYSCOM starting 01/09

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>> 800 volunteers worldwide

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How to volunteer into the Virtual Prairie project ?

http://vcsc.cs.uh.edu/virtual-prairie/