Design of adaptive spatial strategies for weed sampling in crop field

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MOTIVATION

Weeds are both
• Pests of crop fiels (yield losses)
• Ressources for ecological services (pollinisation, ...)

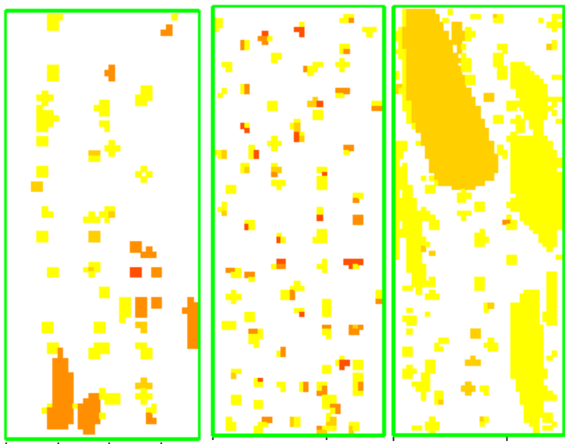
To manage weeds, need to acquire informations on weeds spatial repartition

➢weeds mapping
➢which sampling strategy?

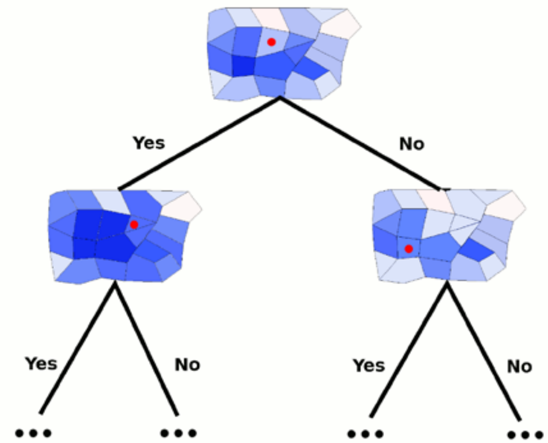


Design of adaptive sampling strategies by optimisation

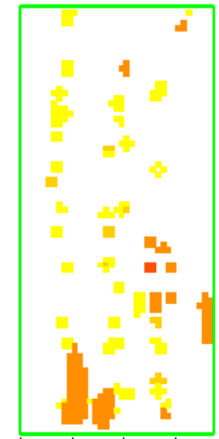
INGREDIENTS



Possible abundance maps



Adaptive strategy S



Estimated abundance map

What we need	Notation
Abundance spatial distribution	M
Sampling strategy quality: expected number of well reconstructed quadrats	Q(S | M)
Strategy cost (time)	C(S)
Maximal allowed budget	B

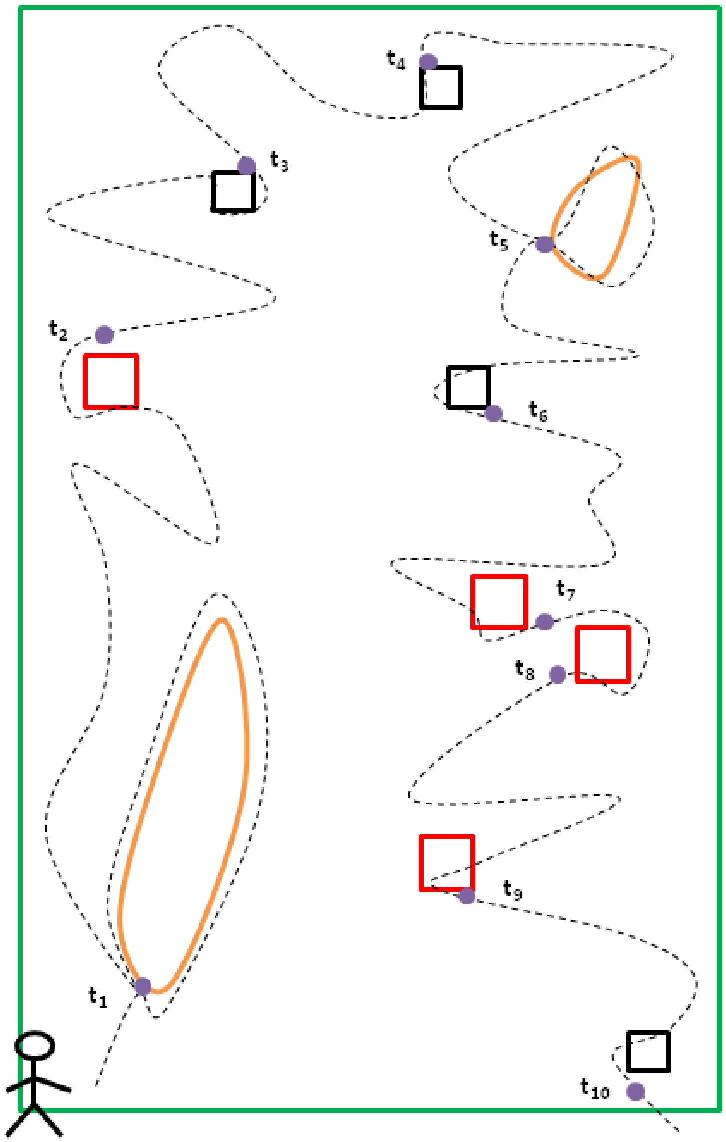
➢ **Optimisation problem**

Find S maximising Q(S | M)

Under constraint C(S) <B

Integrated weed management long-term experiment

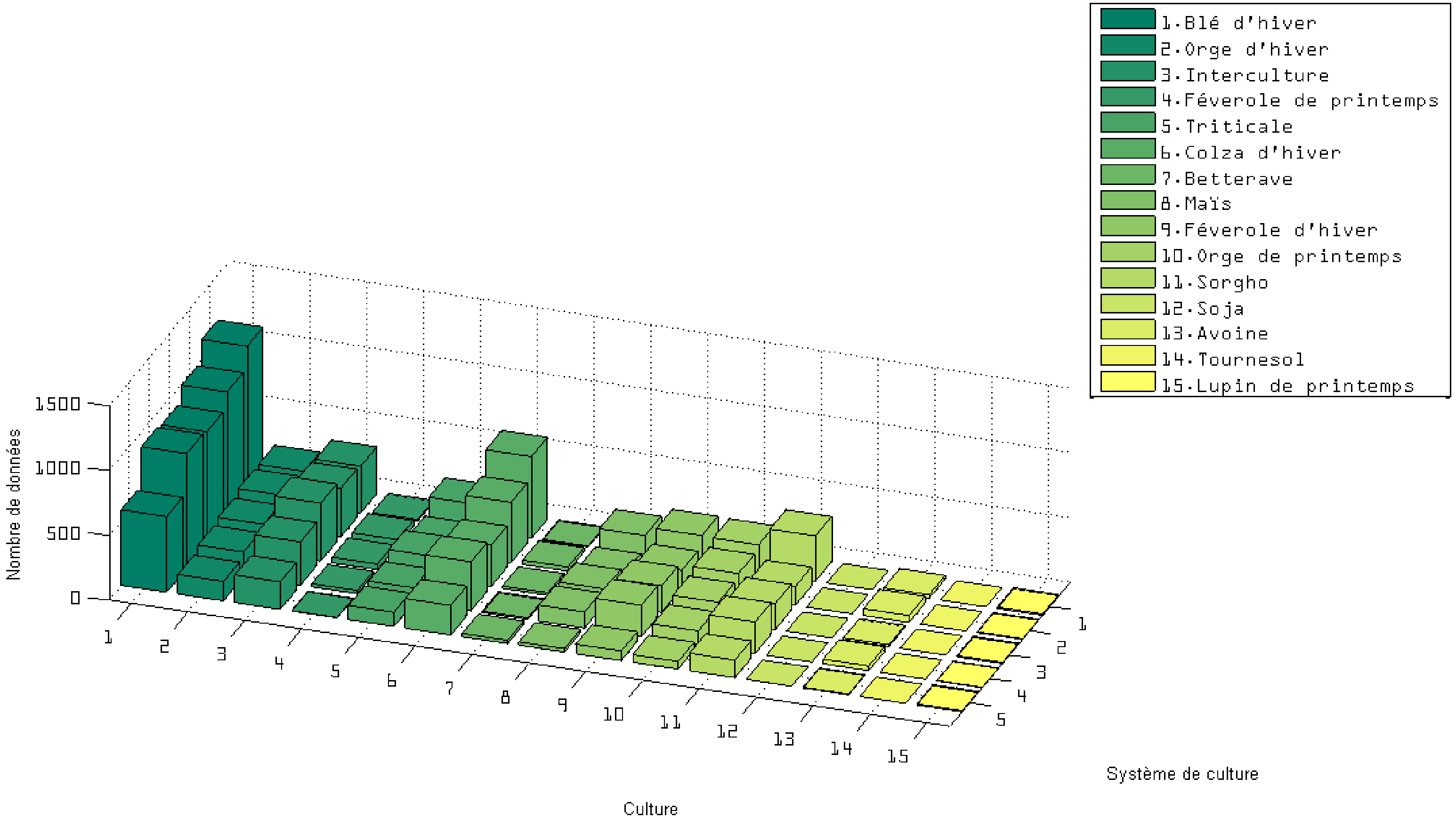
DATA ACQUISITION



3 types of data

- counts on 0.36 m^2 quadrats
- abundance class on 4 or 16 m^2 spots
- Abundance on patches

SEVEN CROPS CONSIDERED



- Blé d'hiver
- Orge d'hiver
- Colza d'hiver
- Féverole d'hiver
- Orge de printemps
- Sorgho
- Maïs
- Période d'interculture

FIVE CROPPING SYSTEMS

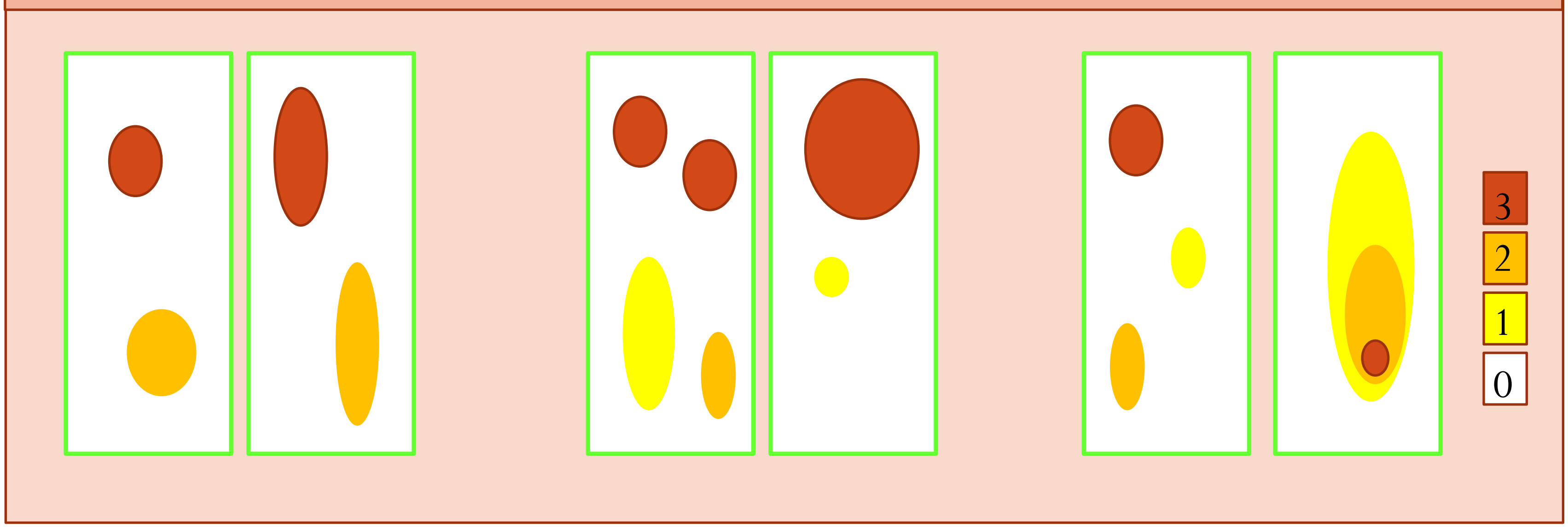
	Intitulé du système de culture	Objectifs Agro-environnementaux	Succession culturale	Itinéraires techniques	Désherbage
1	**Agriculture "raisonnée"**	maximiser les résultats économiques.	Raisonné chaque année en fonction du precedent et de la marge brute espérée	Raisonné technique par technique	Chimique, optimisation prix-efficacité
2	**Protection Intégrée, Techniques culturales simplifiée**	limiter les temps de travaux et réduire les pointes de travail ; réduction modérée des impacts environnementaux liés au herbicides	succession culturale diversifiée par l'introduction d'une culture de printemps (Soja, Tournesol)	labour interdit et remplacé par des travaux superficiels. Interculture à effets allélopathiques, faux-semis, réduction modérée des niveaux de fertilisation, utilisation de variétés concurrentielles...	désherbage uniquement chimique, mais raisonné en fonction de critères écotoxicologiques et en foncti de l'état malherbologique.
3	**Protection intégrée sans désherbage mécanique**	réduire les impacts environnementaux liés au herbicides de façon plus ambitieuse	succession culturale très diversifiée, incluant blé, orge de printemps, colza, tournesol, soja, maïs...	toutes les connaissances sur les effets des pratiques culturales sont mobilisées pour contribuer à réguler les infestations. Travail du sol raisonné en fonction de la biologie des espèces présentes, ce qui conduit à labourer environ un an sur deux.	désherbage uniquement chimique, mais raisonné en fonction de critères écotoxicologiques et en foncti de l'état malherbologique.
4	**Protection intégrée avec désherbage mécanique**	réduire les impacts environnementaux liés au herbicides de façon encore plus ambitieuse culture de betterave	comme système 3, avec betterave	comme système 3	désherbage de préférence mécanique (herse étrille, bineuse); désherbage chimiqu indispensable
5	**Protection intégrée sans désherbage chimique**	aucun herbicide de synthèse		techniques agronomiques innovantes (cultures associées, couverture permanente du sol...).	désherbage mécanique uniquement

Model of abundance spatial distribution

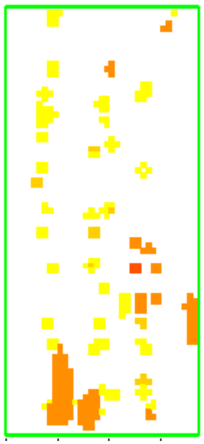
MARKOV RANDOM FIELD FOR ABUNDANCE SPATIAL DISTRIBUTION

We compared 8 MRF models by combining the following model properties

Isotropy/Anisotropy of spatial structure	Uniform/ non uniform weights on abundance classes	Abrupt/Smooth spatial variation



PROCEDURE FOR MODEL SELECTION



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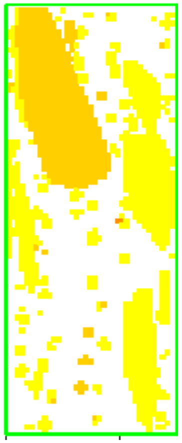

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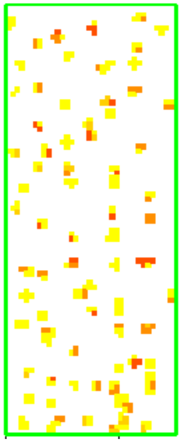


-parcel D1
- soja
- 4 months after sowing
- cropping system3

Parameter estimation and BIC evaluation

↓

BIC(M1), … BIC(M8)

…

…

-parcel A1
- corn
- 3 months after sowing
- cropping system1

Parameter estimation and BIC evaluation

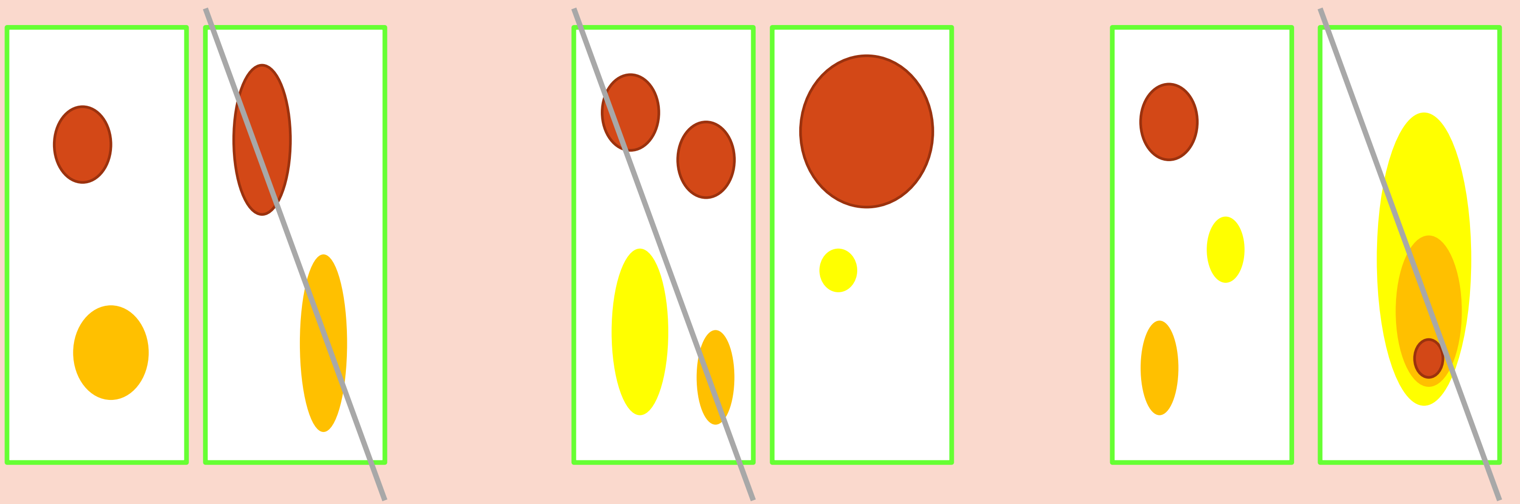
↓

BIC(M1), … BIC(M8)

RESULTS OF MODEL SELECTION

BEST MODEL

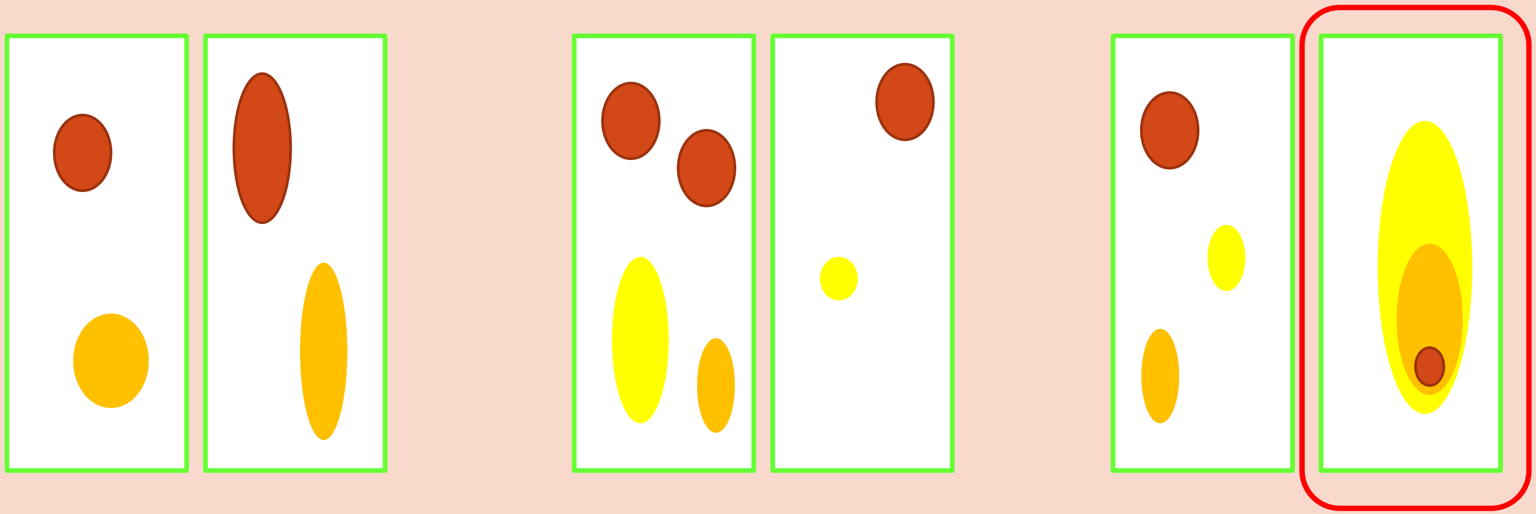
Isotropy/ Anisotropy of spatial structure	Uniform/ **non uniform weights on abundance classes**	**Abrupt**/Smooth spatial variation



RESULTS OF MODEL SELECTION

WORSE MODEL: as expected from literature ...

Isotropy/Anisotropy of spatial structure	Uniform/ non uniform weights on abundance classes	Abrupt/**Smooth spatial variation**



Model of cost:
time for sampling and moving

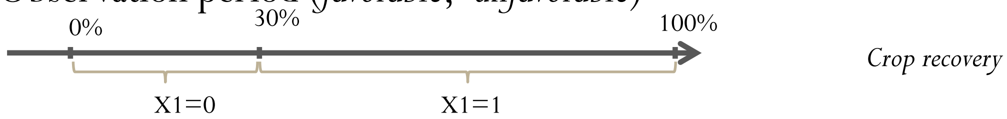
FACTORS INFLUENCING TIME FOR SAMPLING AND MOVING

Observer, brightness, soil type, sampled weed species, weed growth, weed abundance, crop, crop growth, number of weeds species in the sampled quadrat, cropping system, distance between two successive sampled quadrats, date, …

- From expert knowledge, many factors can influence the time spent for sampling and moving in the field

A REGRESSION MODEL

-$\mathbf{X_1}$ in {0,1} : Observation period (*favorable*, *unfavorable*)



-$\mathbf{X_2}$: Estimation of number of weeds in the quadrat (sum, over each weed species present in the quadrat, of abundance class mid value)

-$\mathbf{X_3}$: Number of weeds species on quadrat

-$\mathbf{X_4}$: Distance from previous quadrat (meters)

-$\mathbf{X_5}$ in {1,2,3,4,5} : cropping system

- $\mathbf{X_6}$: Crop

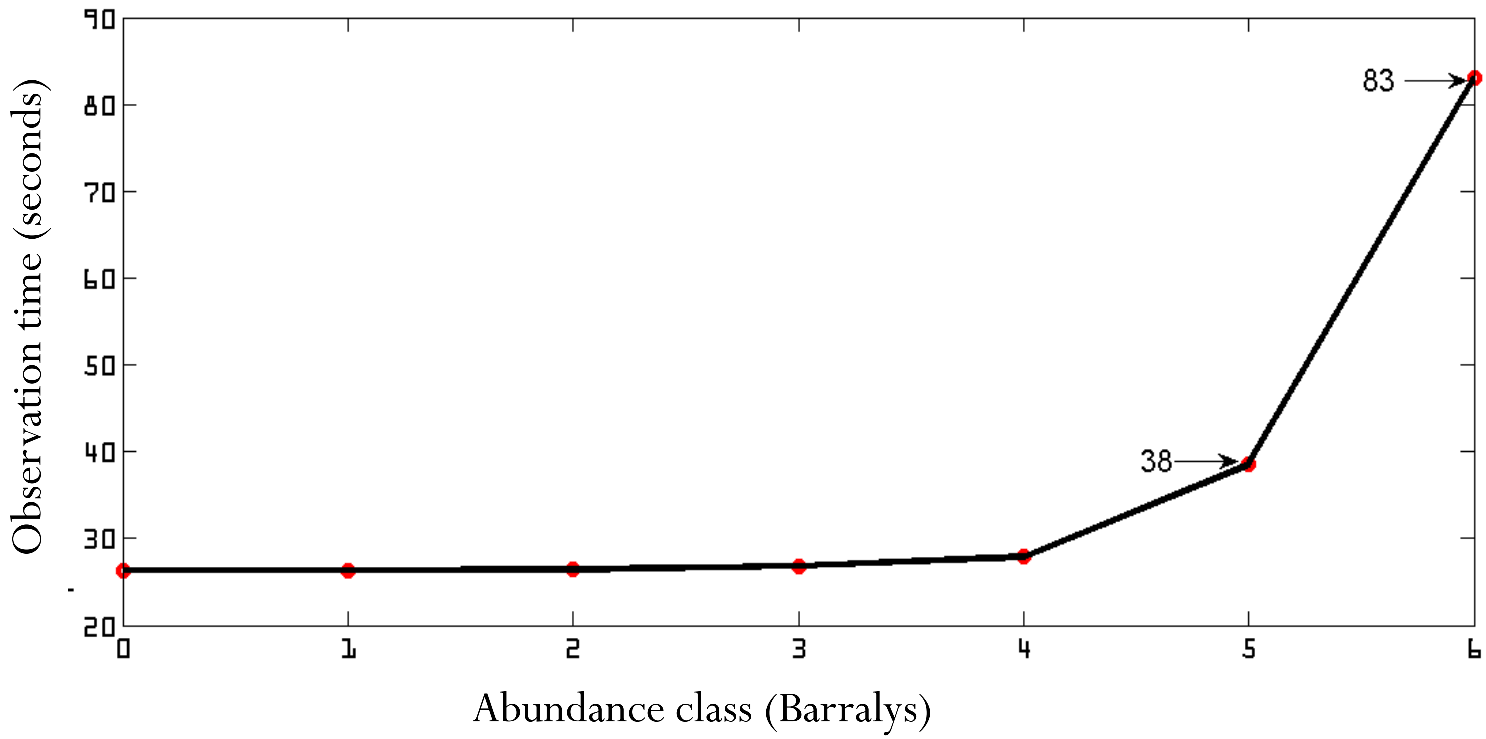
- C(quadrat)= $\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_1 * X_4 + \beta_8 X_1 * X_5$
- C(S) = $\sum$ C(quadrat)

SOME RESULTS: INFLUENCE OF CROP

Crop	**Inter-culture**	**Orge d'hiver**	**Blé d'hiver**	**Féverole d'hiver**	**Colza d'hiver**	**Sorgho**	**Orge de printemps**	**Maïs**
Time	8.13 s	11.6 s	13.41 s	15.08 s	19.52 s	19.95 s	26.21 s	26.35 s

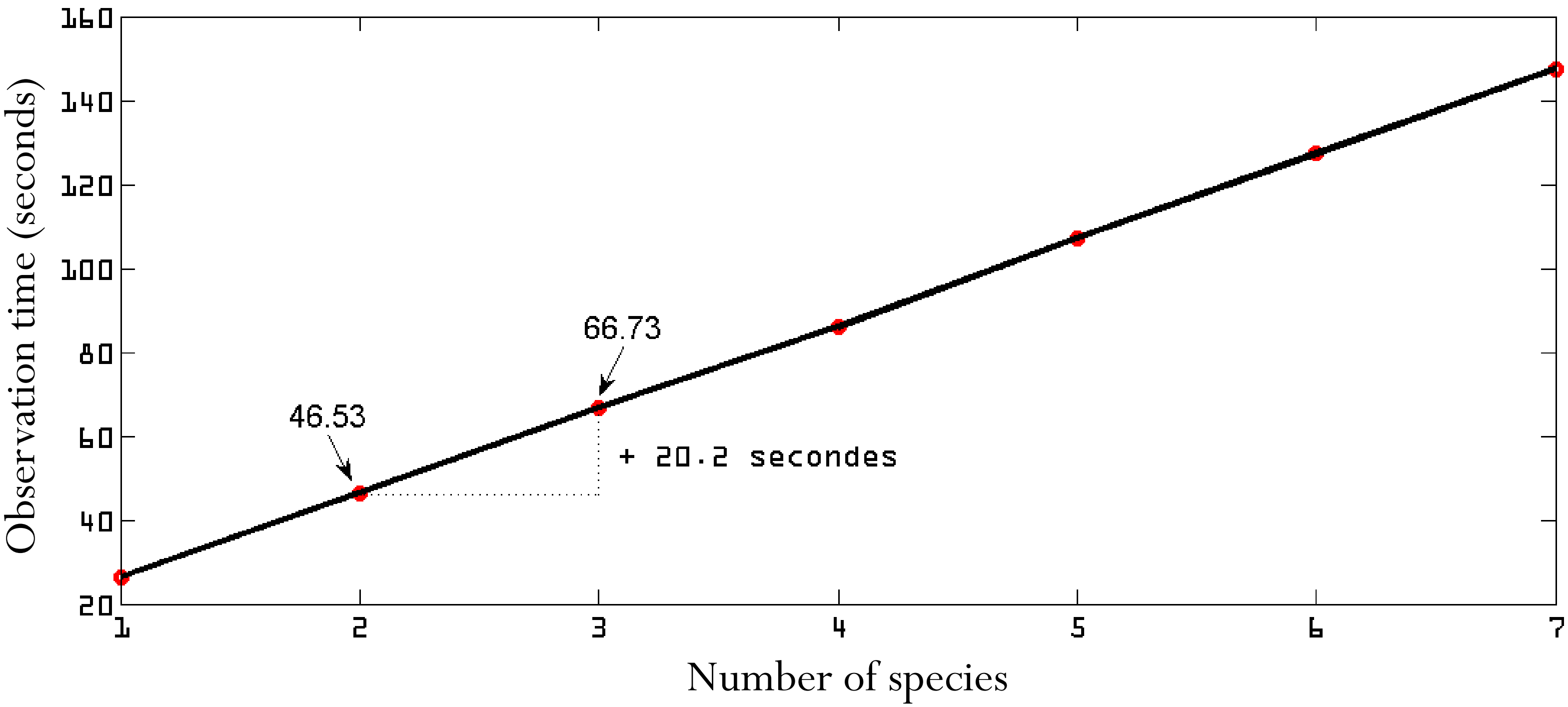
Observation time for one species with abundance class 1, during favorable period and for first cropping system

SOME RESULTS: INFLUENCE OF ABUNDANCE CLASS



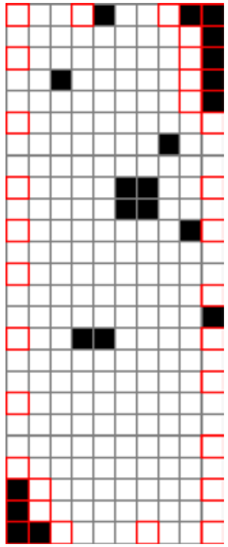
Observation time during favorable period, in corn fields, for first cropping system

SOME RESULTS: INFLUENCE OF NUMBER OF SPECIES



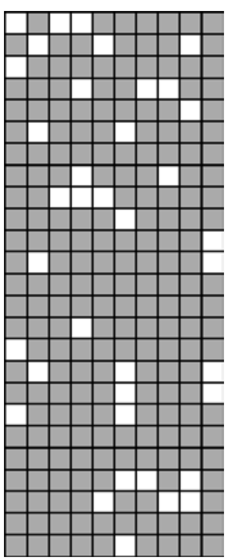
Observation time for abundance class 1, in corn fields, during favorable period and for first cropping system

New sampling strategies

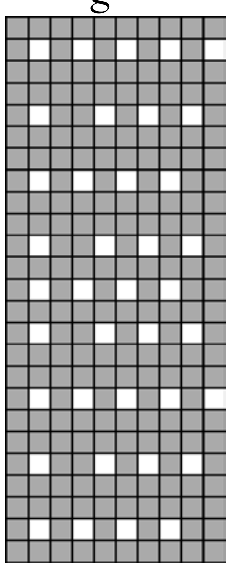


CLASSICAL SAMPLING STRATEGIES

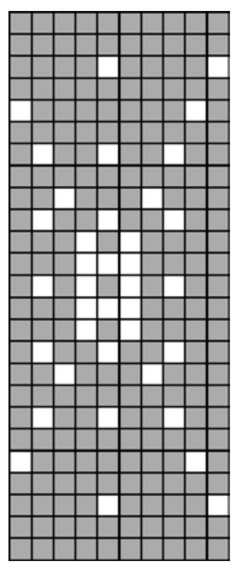
Random



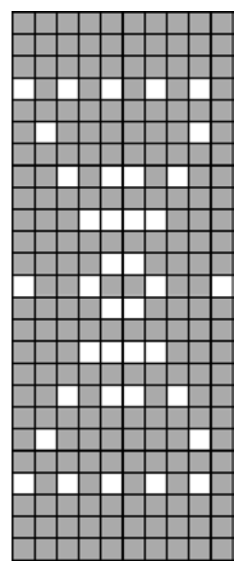
Regular



Star 1



Star 2

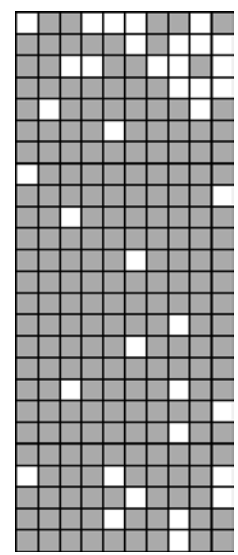


NEW SAMPLING STRATEGIES

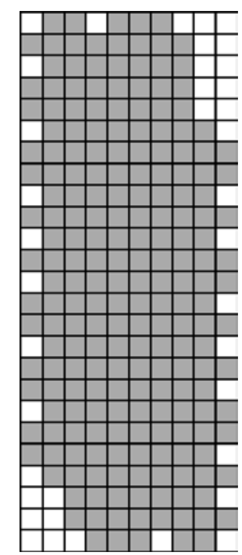
- **Optimisation problem**

Find S maximising Q(S | M)
= expected number of well
classified quadrats
Under constraint C(S) <B

Simulation based



Heuristic



Adaptive is better!

- Maps simulated with model parameters learnt on a real weeds occurrence map
- 250 quadrats in total and 15% sampled
- Cost not yet included

Star 1	Star 2	Regular	Random	Sim. Based	Heuristic
9.7	9.9	11.2	16.3	**26.2**	**49.4**

Percentage of occupied quadrats recovered. Mean results over 2000 maps

CONCLUSION/DISCUSSION

- Model of map distribution
  - MRF modelisation of weeds abundance maps is new
  - An alternative to classical Poisson point processes with smooth spatial variations

- Model of cost
  - First model to explain sampling time
  - More validation needed
  - But time measurements are rare!

- Design of adaptive sampling strategies by optimisation
  - Quite complex from a methodological point of view!
  - Adaptive strategies are clearly better to build weeds map

Many thanks to:

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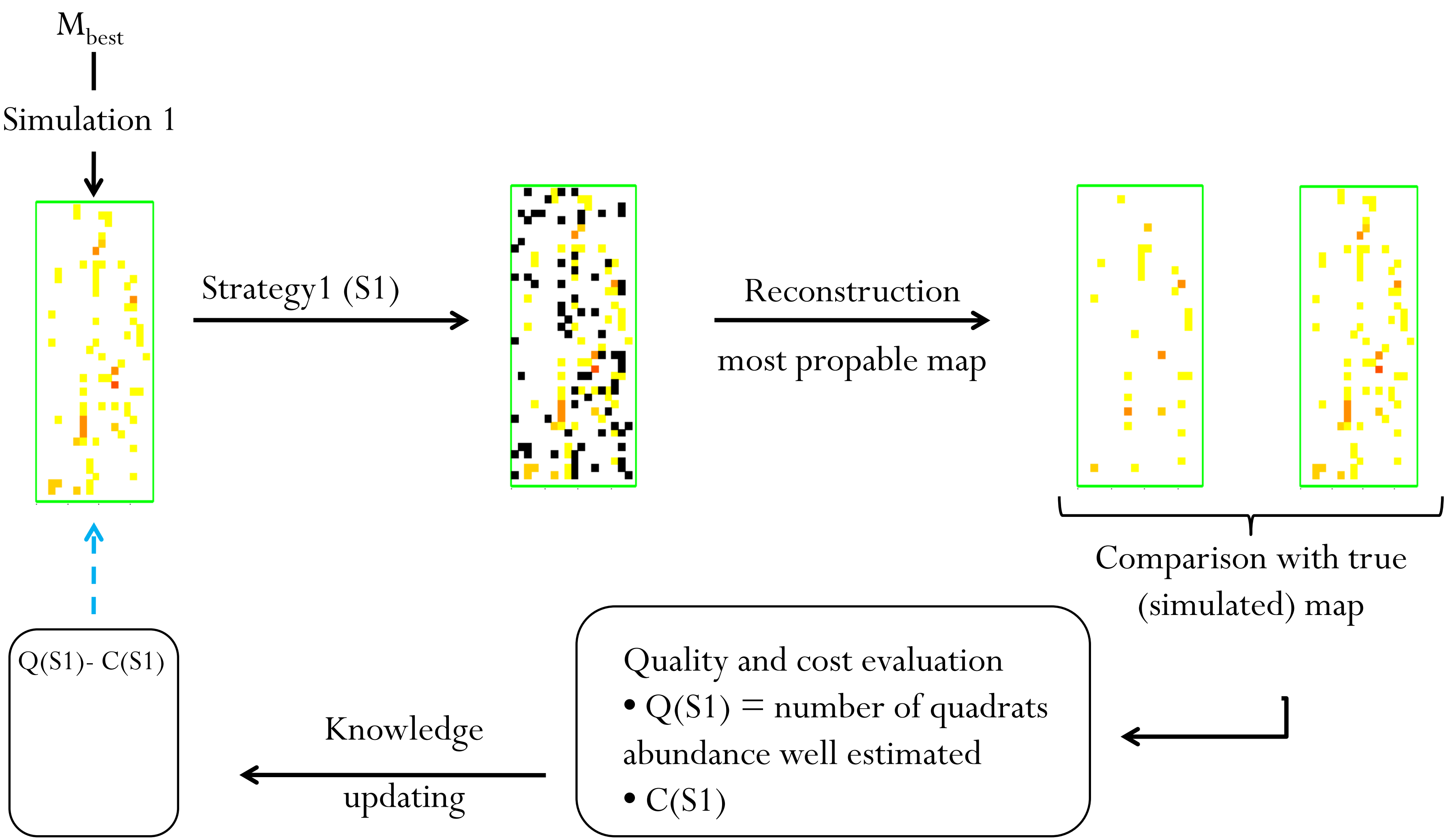
Nicolas MUNIER-JOLAIN

And UMR Agro-écologie (ex UMR BGA)

How to solve the optimisation problem?

- by learning strategies quality from simulations: **Reinforcement learning**



How to solve the optimisation problem?

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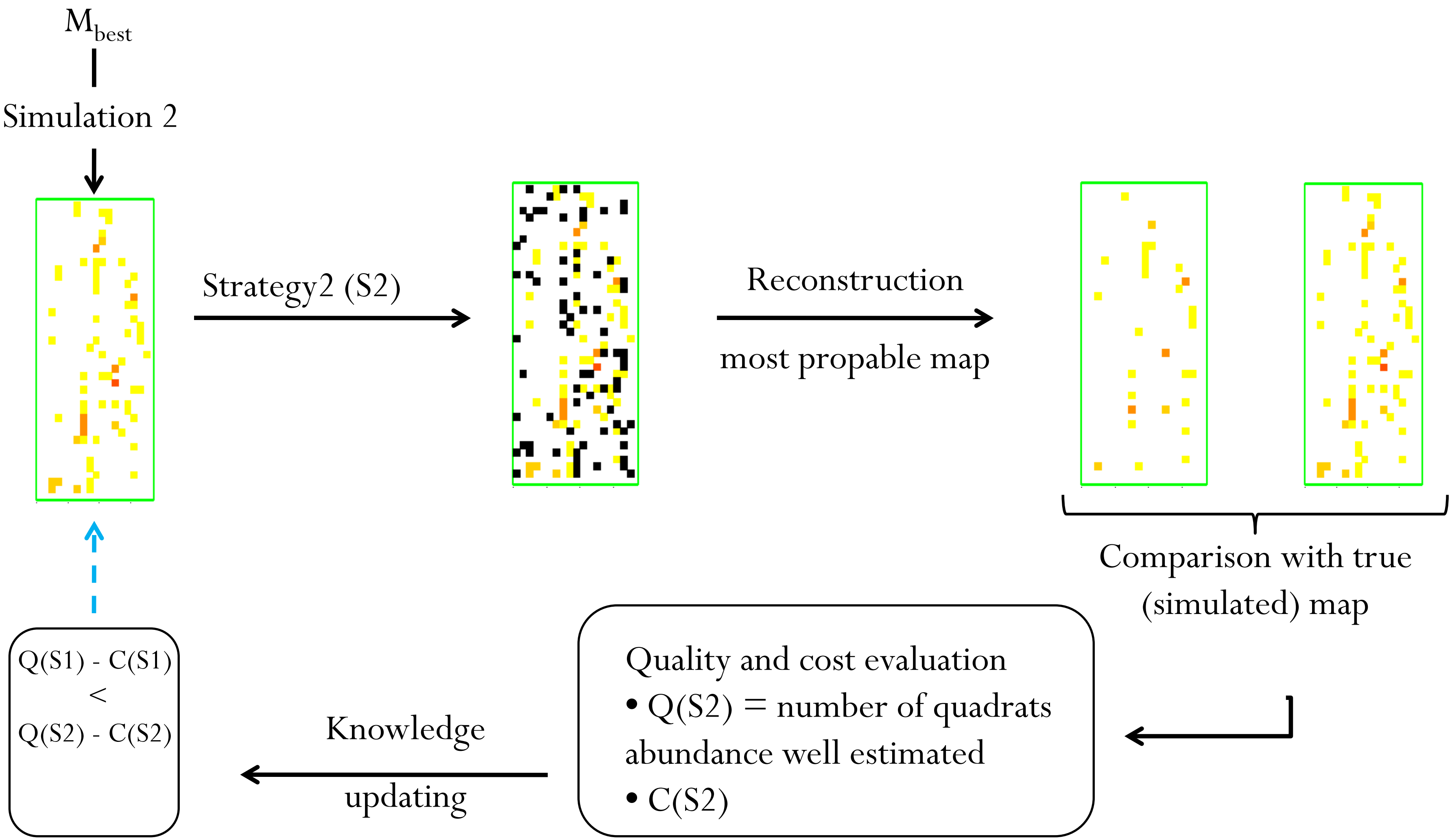

PLAN

1. Design of adaptive sampling strategies by optimisation
2. Integrated weed management long-term experiment
3. Model for weed spatial distribution
4. Model for sampling cost
5. New sampling strategies
6. Conclusion