Role of landscape composition and aggregation on trade-off between food production and conservation of biodiversity

Case of the crop-weed-pollinators system

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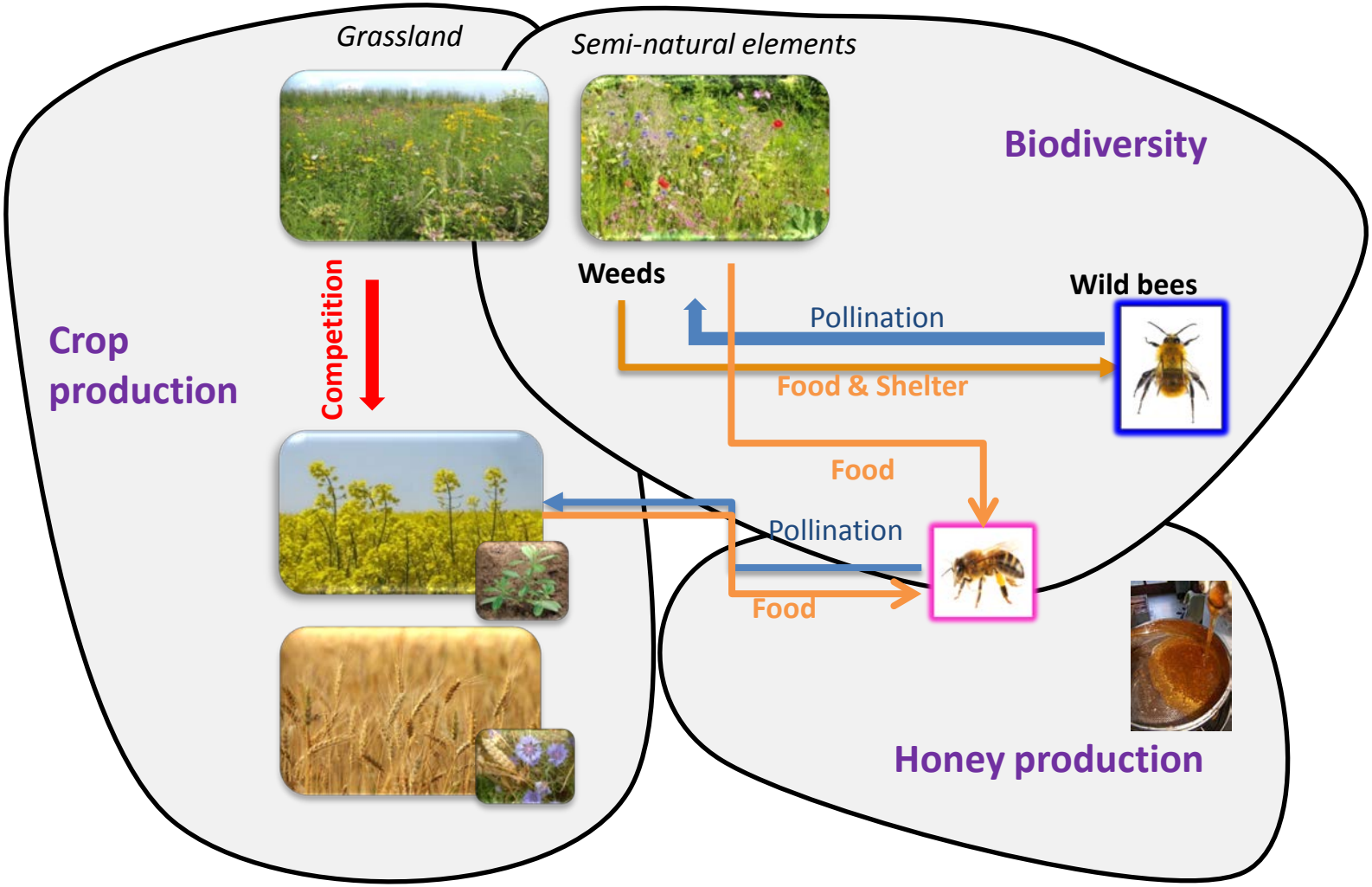
The crop-weeds-pollinators system



Adapted from Bretagnolle & Gaba 2015

Which farmland landscape can promote the best outcomes for biodiversity & production?

Objective of the study

1. We assess how landscape composition (proportion of crops fields and grasslands) and structure (the level of spatial aggregation) affect crop/honey production and biodiversity.

2. We investigate which landscape composition and structure enable to reach a trade-off between crop/honey production and biodiversity.

The stochastic spatio-temporal model: a dynamic Bayesian network model

Assumptions

Weeds :

- can be present in crop fields and grassland
- can reduce crop production in oilseed rape and winter wheat due to competition for resources
- no competition between weed species

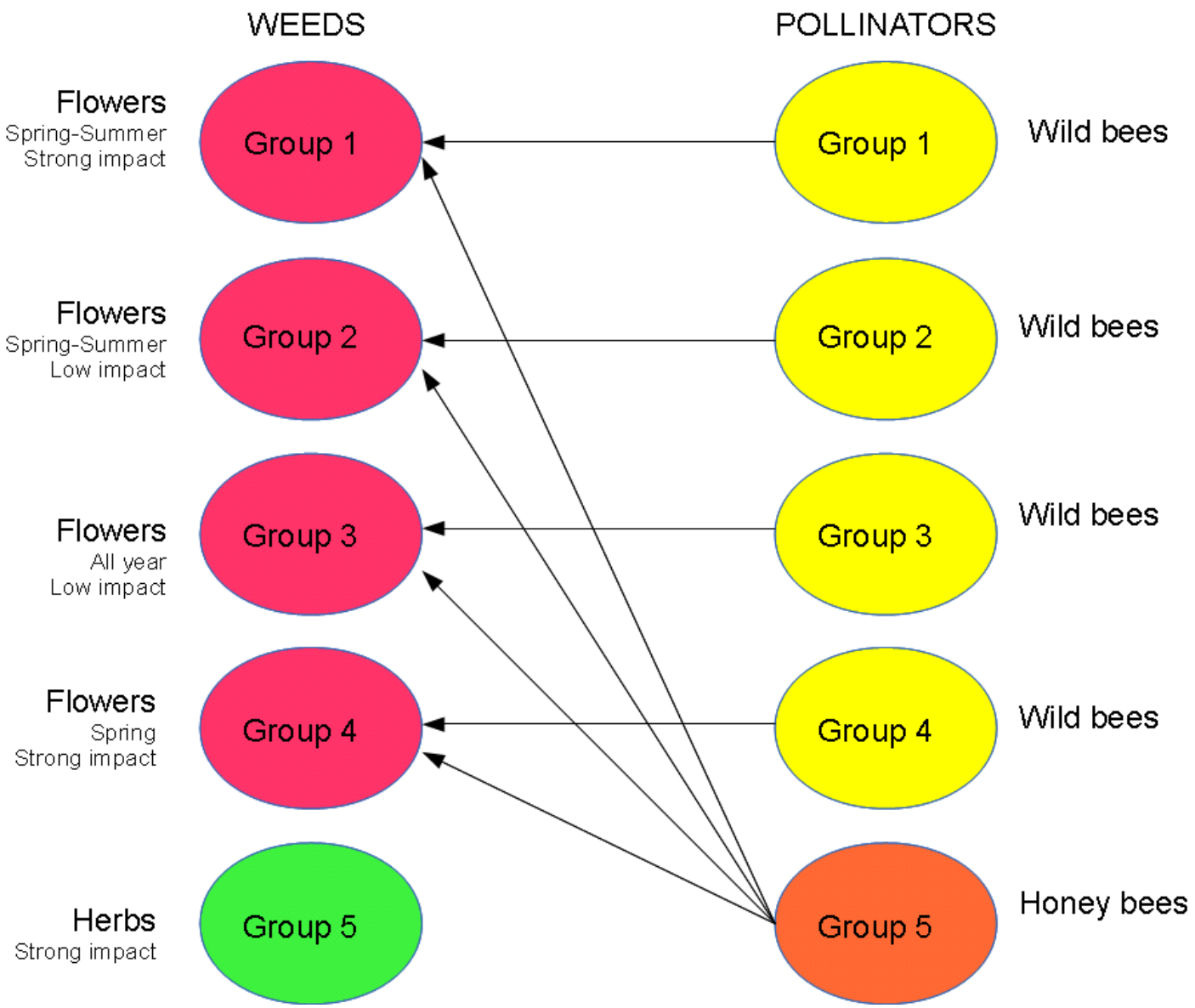
Honey bees:

- forage on weed and rape flowers.
- are directly related to honey production.
- can increase oilseed rape production.

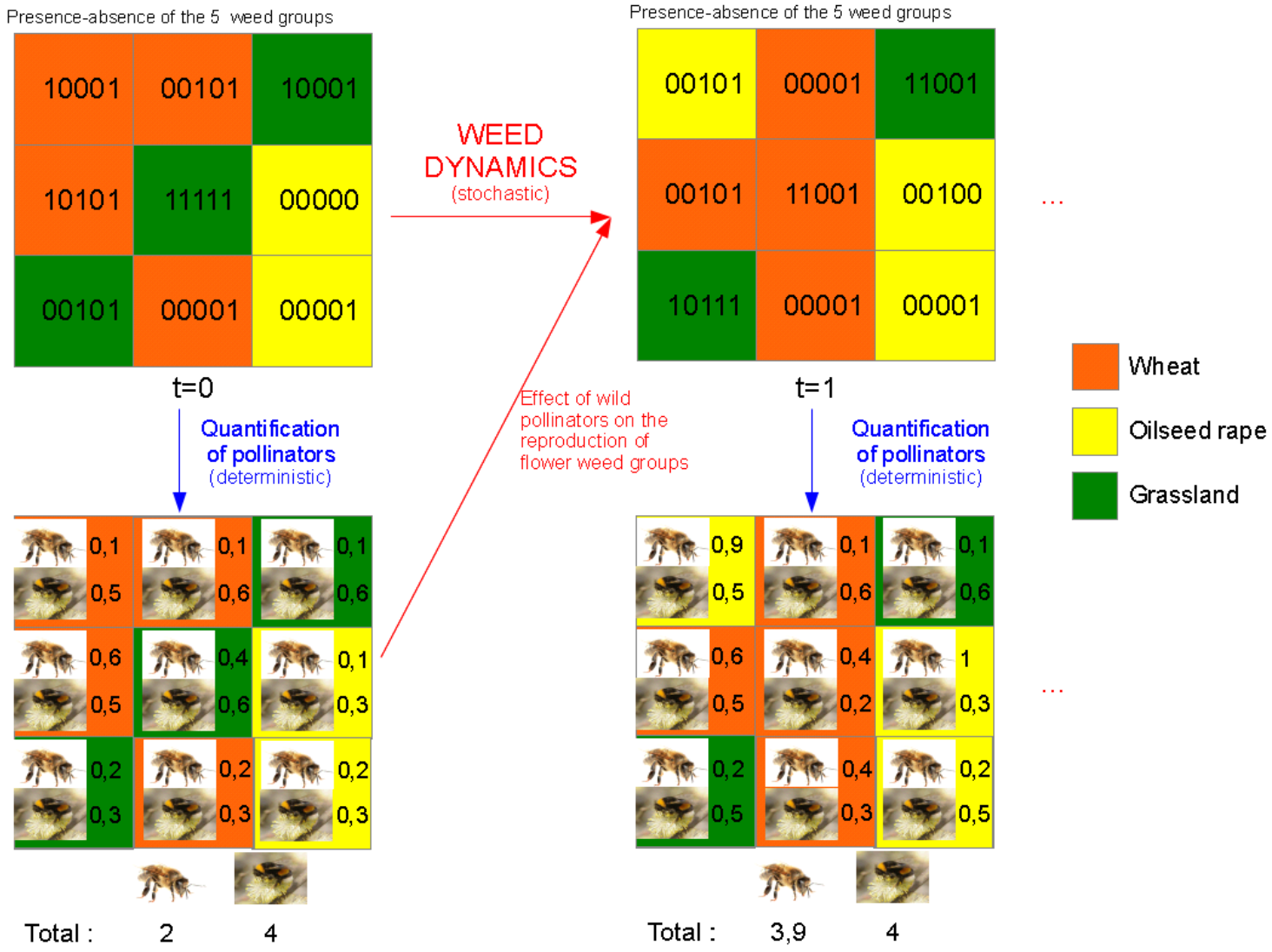
Wild bees:

- forage on weed flowers.
- reproduce in grassland habitats.
- pollinate weeds in grassland

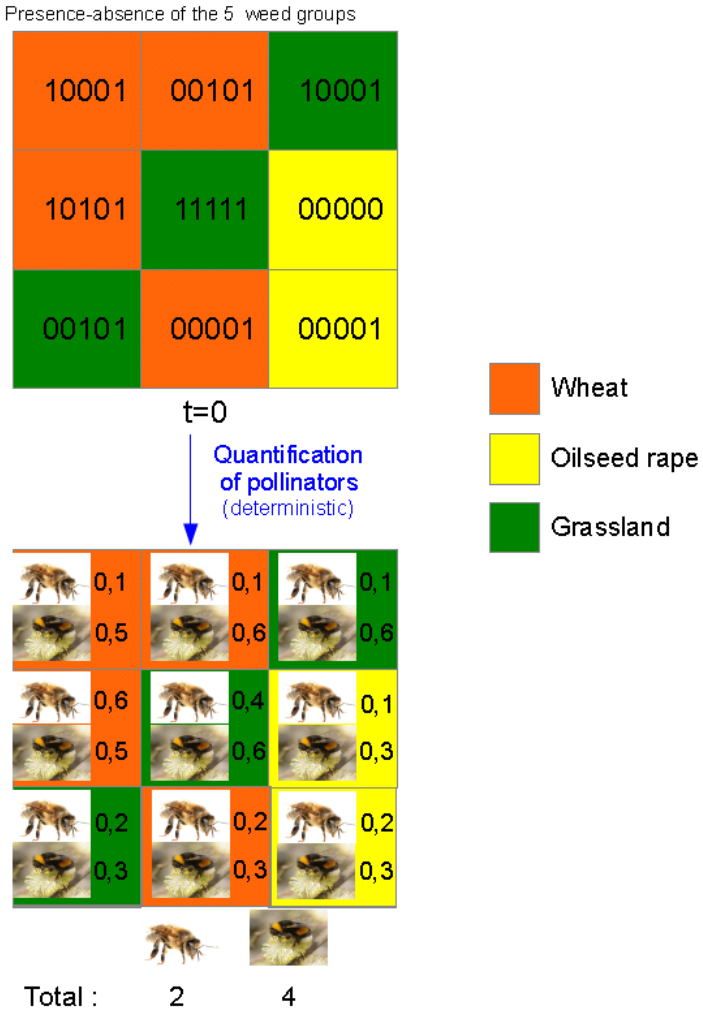
Weeds-Pollinators food web



Weeds, bees and wild pollinators spatio-temporal dynamics



Abundance score of pollinators



Based on the notions of habitability score and floral ressources score of a field (inspired from Lonsdorf et al. 2009)

- score in [0,1] to interpret as a probability to visit field p at time t
- the more habitat and the more floral ressources in the neighbourhood of p, the larger the score
- importance of neighbourhood fields decreases exponentially with distance to field p

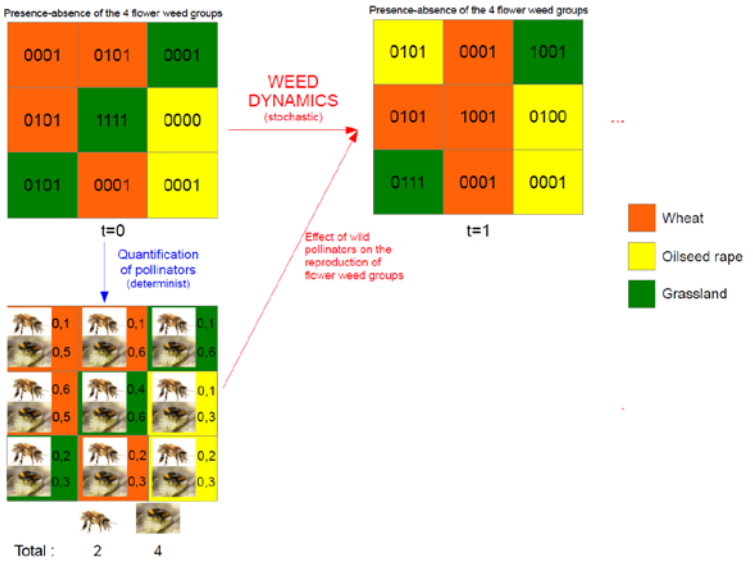
Abundance score of pollinators

		
Habitat score	Always 1 Assumption of Unlimited access to beehives	1 for grassland 0 for wheat and oilseed rape
Floral ressources score	Depend on season	1 if the weed group foraged by the wild pollinator 0 otherwise

A dynamic Bayesian network model for weeds dynamics

Probability of presence of weed species s in field p at time t depends on informations in field p and neighbouring fields at t-1

- Presence of species s
- Culture choice
- Honey/wild bees scores



Model: generalisation of Dorazio et al. 2000

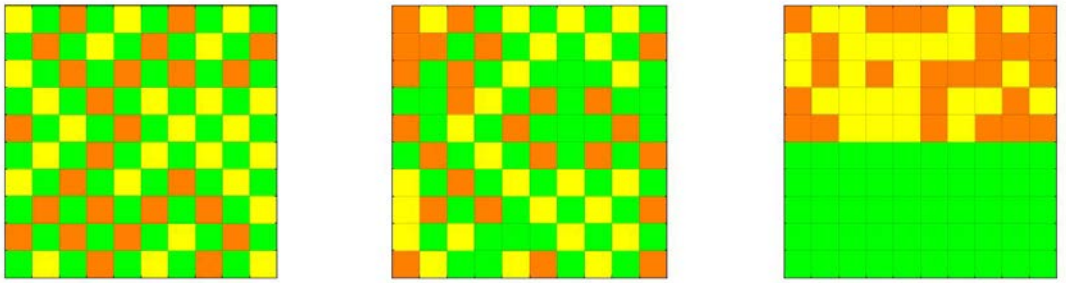
- Bernoulli distribution
- Take into account local persistence and local colonization

Simulation study

Characterization of landscape characteristics

A landscape
⇒ a regular grid of 10 by 10 fields
⇒ a composition: proportion of wheat/rape/grassland fields
⇒ a structure defined by spatial aggregation using the **AI measure**

AI = ratio between the number of borders shared by fields of the same crop and the maximal number of borders possible for the same number of fields.
(He et al. 2000)



AI global	0	0.17	1
AI oilseed rape-wheat	0	0.22	1
AI grassland	0	0.2	1

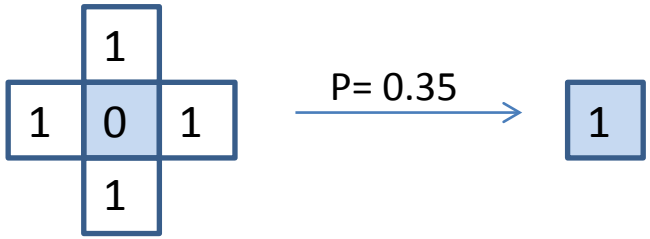
Nine landscape compositions

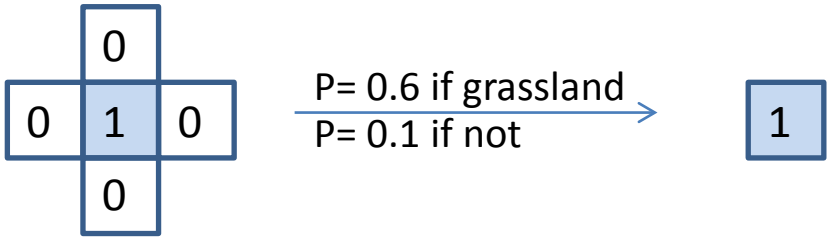
Nb	Oilseed rape	Wheat	Grassland
1	30	70	0
2	50	50	0
3	70	30	0
4	25	50	25
5	37	37	26
6	50	25	25
7	15	35	50
8	25	25	50
9	35	15	50

Increasing proportion of grasslands

Model parameters:
a possible scenario (among others)

❖ Weeds dynamics:





❖ Competition between weeds and cereal production:

20% (10%) of production loss for weeds with strong (low) impact

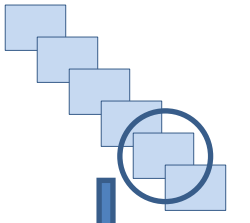
❖ Influence of honey bees of rape production:

Without honey bees, only 70% of the maximal margin can be reached

Simulation study

N°	Oilseed rape	Wheat	Grassland
1	30	70	0
2	50	50	0
3	70	30	0
4	25	50	25
5	37	37	26
6	50	25	25
7	15	35	50
8	25	25	50
9	35	15	50

Between 40 and 100 landscapes with varying AI generated using Multiland



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40 trajectories of length 20 simulated

Computation of average spatio-temporal scores over the last 6 time steps

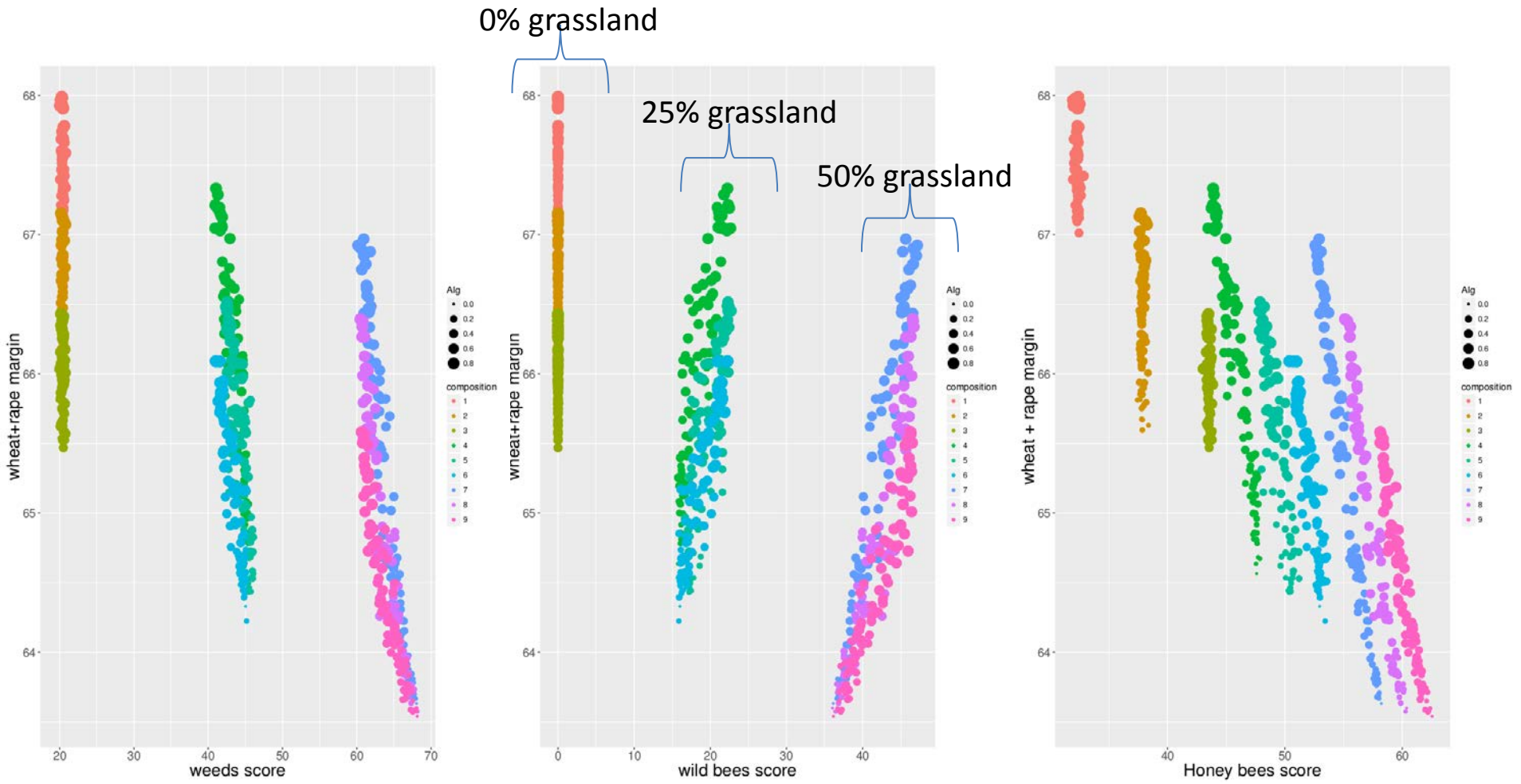
Results

Landscape composition or landscape aggregation: which one impacts more crop/honey production and biodiversity?

answer:
landscape composition →

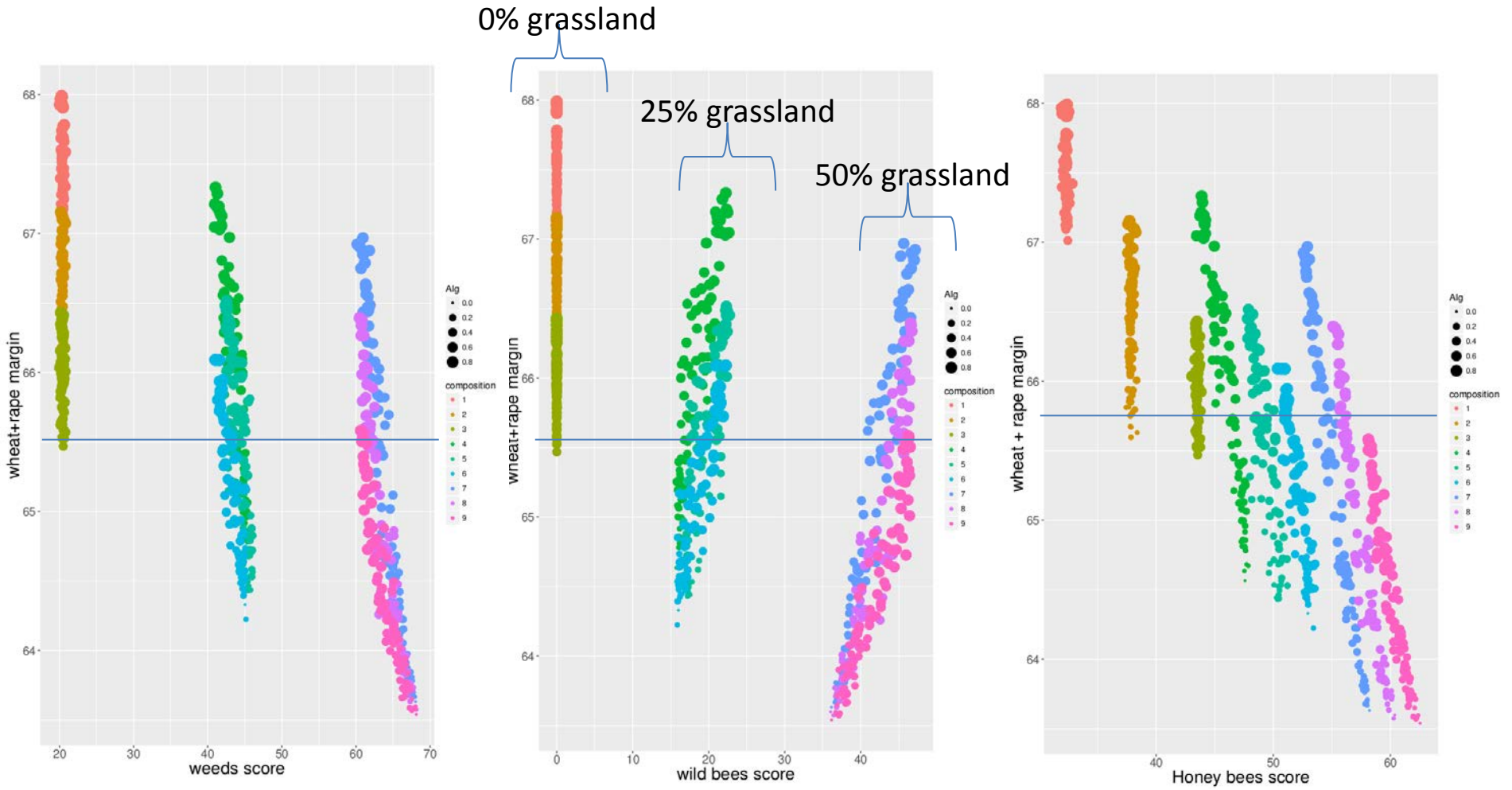
Score	Linear model	quality (R^2)	AIC
Wheat margin	Full	**0.99**	**74921**
	Grassland	**0.99**	93184
	AI	0.21	112726
Oil seed rape margin	Full	**0.99**	**63113**
	Grassland	**0.99**	79991
	AI	0.35	67177
Honey abundance	Full	**0.99**	**149247**
	Grassland	**0.99**	152597
	AI	0.061	208183
Wild bee abundance	Full	**0.99**	**78391**
	Grassland	**0.99**	135123
	AI	0.0008	249594
Weeds occurence	Full	**0.99**	**95208**
	Grassland	**0.99**	135123
	AI	0.05	249594

Which composition x structure leads to the best trade-off? (1)



➢ For a given composition, larger AI leads to better trade-off, in the Pareto sense.

Which composition x structure leads to the best trade-off? (2)

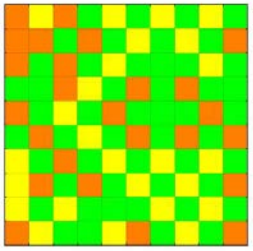


➢ It is possible to replace rape/wheat field by grassland and to maintain the **per field** margin, if increasing the AI

Conclusions

- On the modeling approach:
  - First study on food production/biodiversity conservation trade-off in a landscape with an explicit representation of space and spatio-temporal dependencies

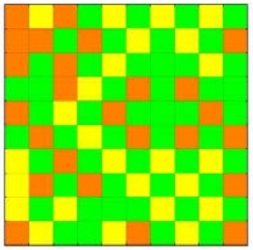
- On the simulation study
  - The proportion of grassland in the landscape seems to be the most influent of the two landscape characteristics
  - For a given proportion of grassland, larger AI leads to better trade-off




Conclusions

But … conclusions derived under several assumptions

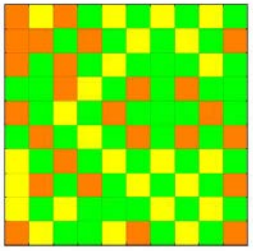
- Influence of model parameters values? (work in progress)
- Realism of some assumptions?
  - Honey and wild bee scores are potential scores, if bees are there.
  - There is not explicit modeling of the weed seed bank dynamics
  - No crop rotation: the landscape remains the same at each time step
  - No competitions between weed species




Perspective

Can we do optimization instead of simulation?

- An original approach : Combining Integer Linear Programming and interactive multi-objective optimization methods
- Agreenskills post-doc proposal of Yann Dujardin, in collaboration with DYNAFOR (INRA Toulouse) and CSIRO-UQ (Brisbane)

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How landscape composition and structure affect crop/honey production and biodiversity?

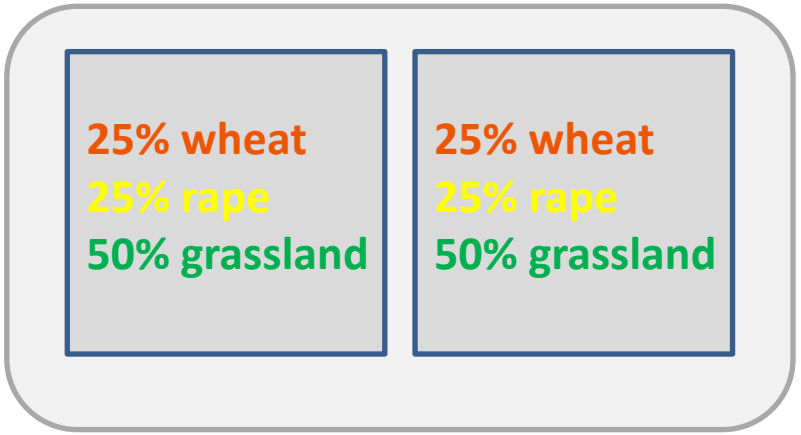
Score	AI	Grassland	Interaction	quality (R^2)
Wheat margin	-0.24	**-11.52**	9.67	0.78
Rape margin	3.72	2.97	**-5.00**	0.43(*)
Honey abundance	-0.99	**43.94**	-9.70	0.87
Wild bee abundance	-0.63	**94.31**	15.57	0.99
Weeds	1.61	**73.60**	21.53	0.99

Coefficients of linear model

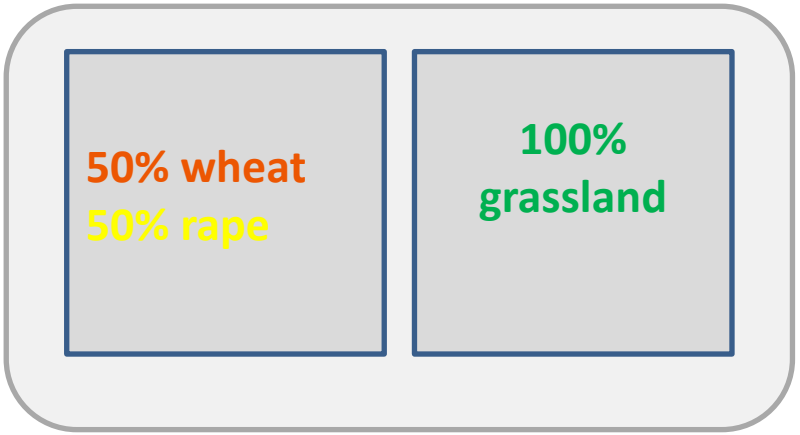
- The proportion of grassland in the landscape is the most influent of the two landscape characteristics

Which composition x structure leads to the best trade-off? (3)

Situation A:
grassland connected to arable fields



Situation B:
grassland separated from arable fields



Which composition x structure leads to the best trade-off? (3)

- Sligth advantage to separated areas for grassland and for cereal fields