Carrefours de l'innovation agronomique

ÉCOPHYTO
RECHERCHE & INNOVATION

« **Leviers territoriaux** pour réduire l'utilisation et les risques liés aux produits phytopharmaceutiques »

Restitution finale

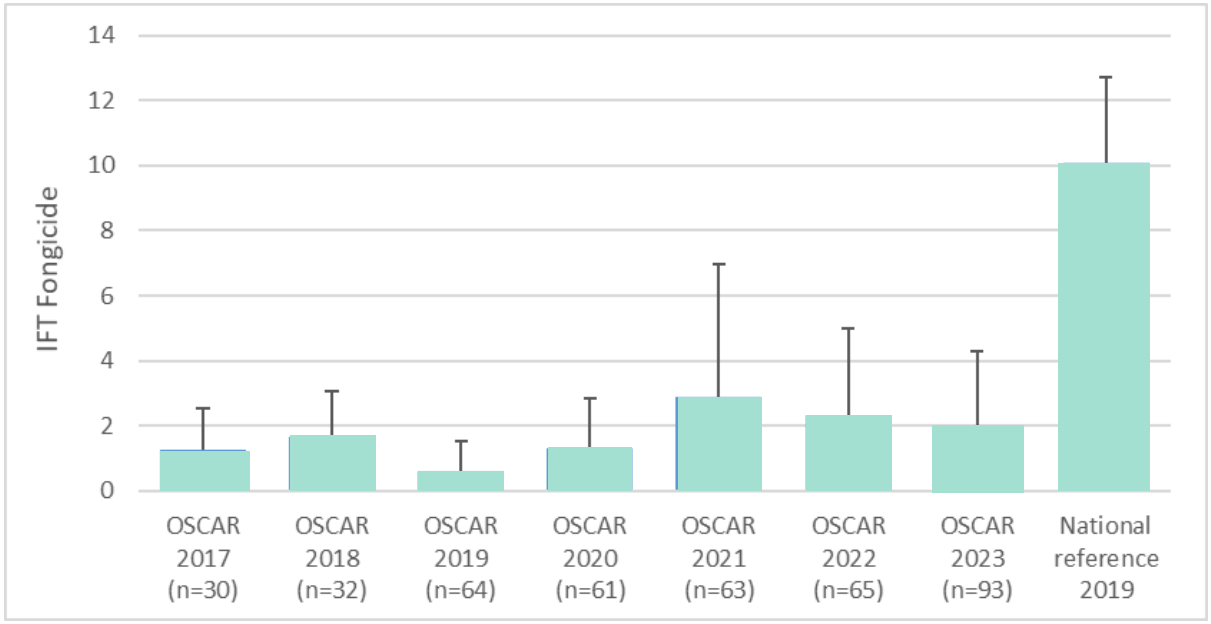
MÉDÉE

Vers des Mosaïques agricoles économes en pesticides : de la modÉlisation à la concertation territoriale pour le DÉploiEment des cépages Résistants

- Frédéric Fabre (INRAE) & Adeline Alonso-Ugaglia (BSA)

01. Contexte
R genes are not eternal

- **Deployment of plant resistance is a relatively low-input, cost-effective way to protect agricultural crops from plant pathogens**
- **The reduction of the IFT fungicide obtained with R grapevine ranges from 77 to 92% from 2017 to 2023**



Observatoire national du déploiement des cépages résistants

01. Contexte
R genes are not eternal

- **Deployment of plant resistance is a relatively low-input, cost-effective way to protect agricultural crops from plant pathogens**
- **The reduction of the IFT fungicide obtained with R grapevine ranges from 77 to 92% from 2017 to 2023**

- **But pathogen may adapt and R genes are not eternal**

- **R cultivars (as many natural ressources) are a common goods :**
  - **R cultivars are at risk of being collectively overexploited (criteria Rivalrous).**
  - **Non-excludable : R cultivars can be planted by everyone (criteria Non-excludable)**

01. Contexte
How to manage common goods ?

- **(Myth of) “the tragedy of commons” (Garrett Hardin, 1915-2003)**

- **For a long time, attempts were made to transform Common Goods into Private Goods (privatisation, transferable individual property rights markets, etc.) or Public Goods (regulated management or nationalisation, taxation, etc.).**

Stockholm, 10 December 2009

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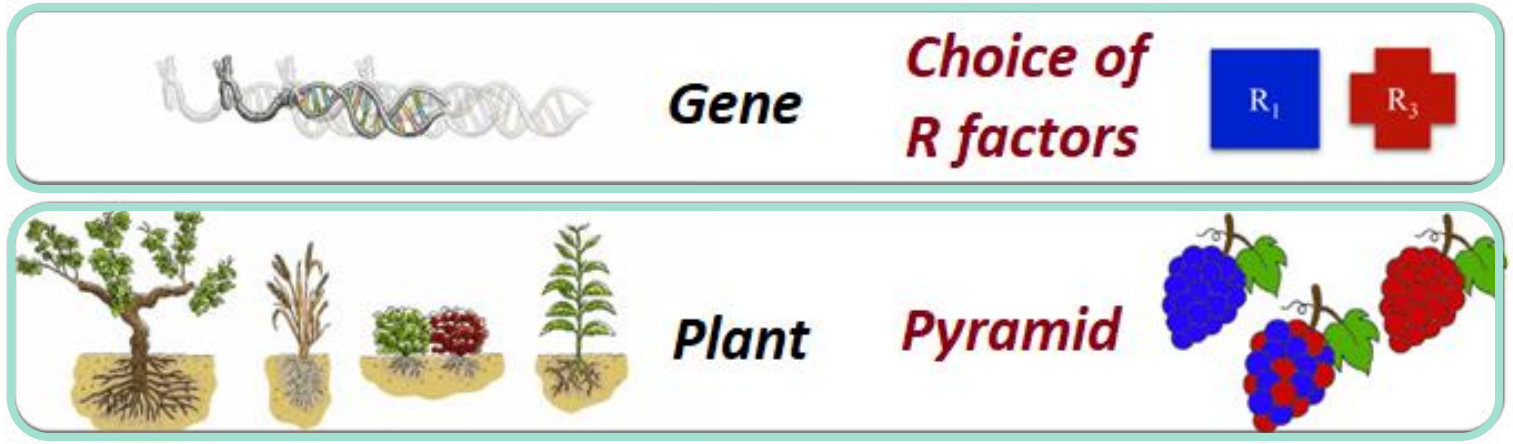
- **Elinor Ostrom (1933-2012), nobel prize in Economic Sciences « for demonstrating that Commons Goods need to be effectively managed as Common Goods by user association. »**

- **Need for deployment strategies that control epidemics (epidemiological control) and slow down the adaptation of pathogens (evolutionary control)**

01. Contexte
Many options for deployment strategies

Choices for breeders



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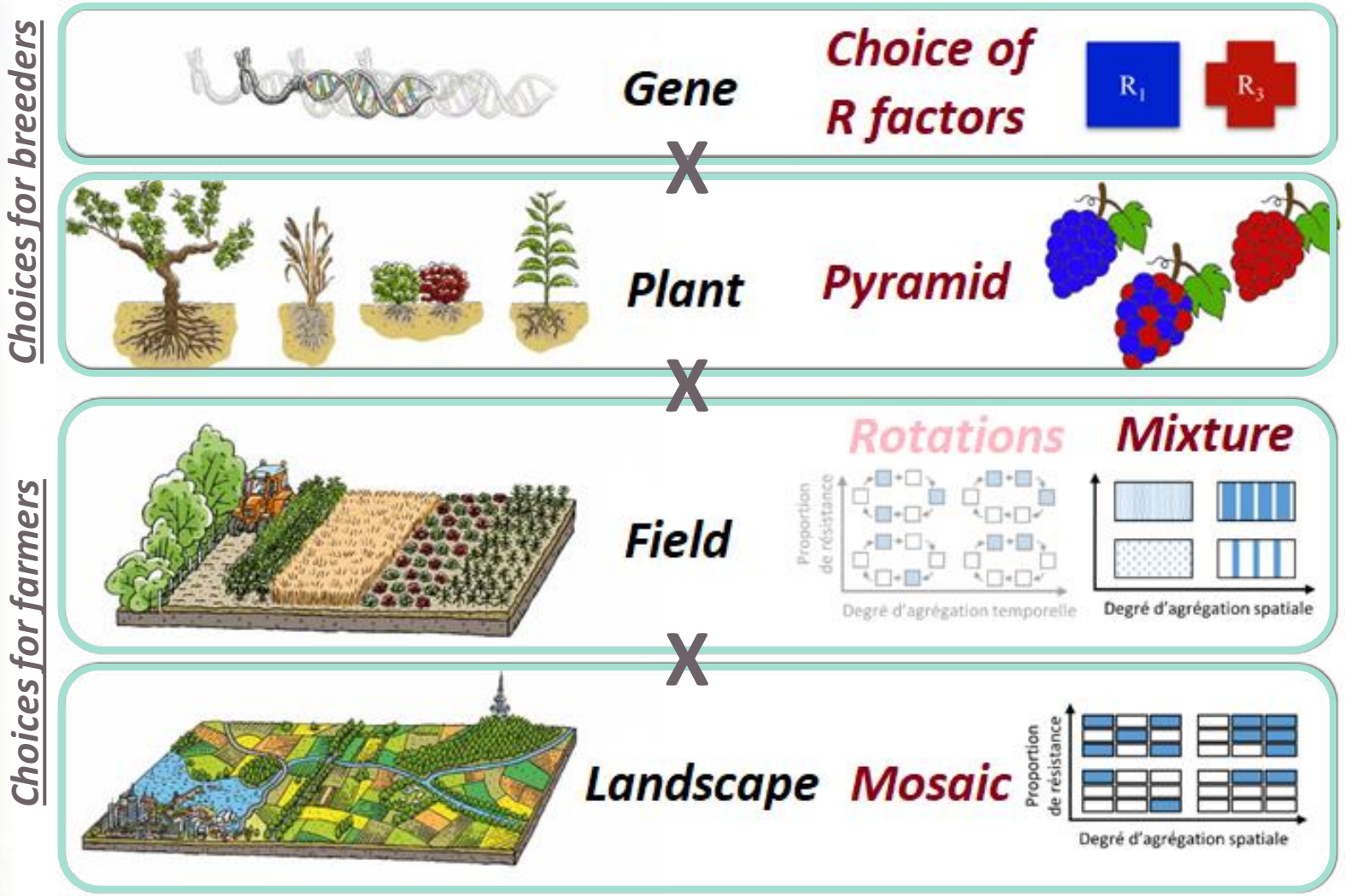


- A large factorial design, easier to explore with mathematical models, all the more valuable given the large spatial and temporal scales involved
- The model *landsepi* already exist for rust on cereals

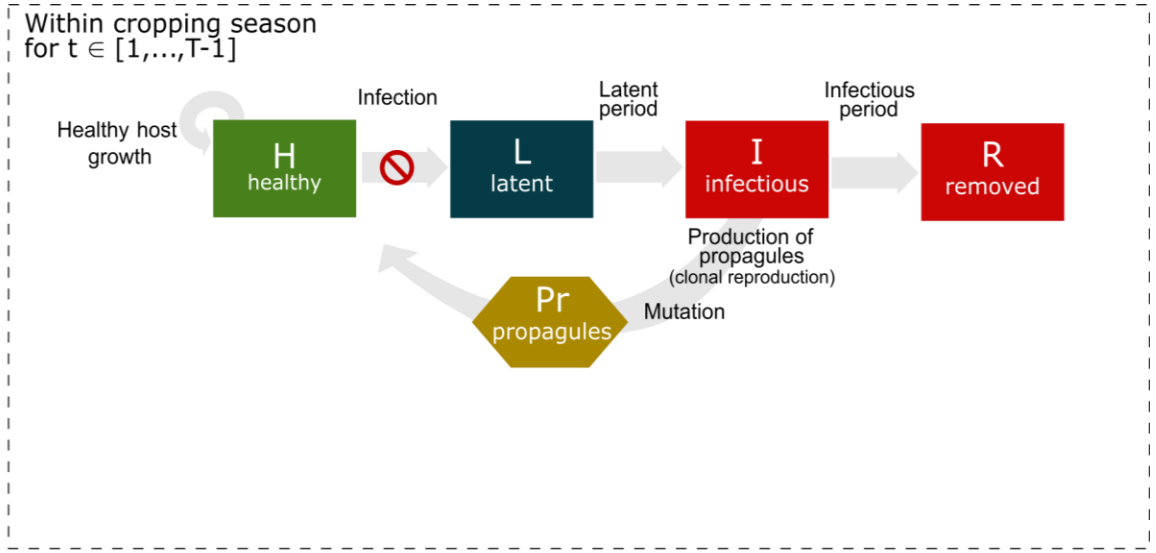
....

01. Objectifs

- **Objective 1: Adapting the mathematical model *landsepi* to the management of grapevine downy mildew.**

- **Objective 2: Exploring possible deployment strategies of R varieties in the territory of the wine cooperative “Nous les vignerons de Buzet” through participative workshops**

02. Résultats
Adaptation of landsepi to downy mildew



The R package *landsepi* provides a modelling framework to simulate the spread and evolution of a pathogen in the agricultural landscape over multiple cropping seasons

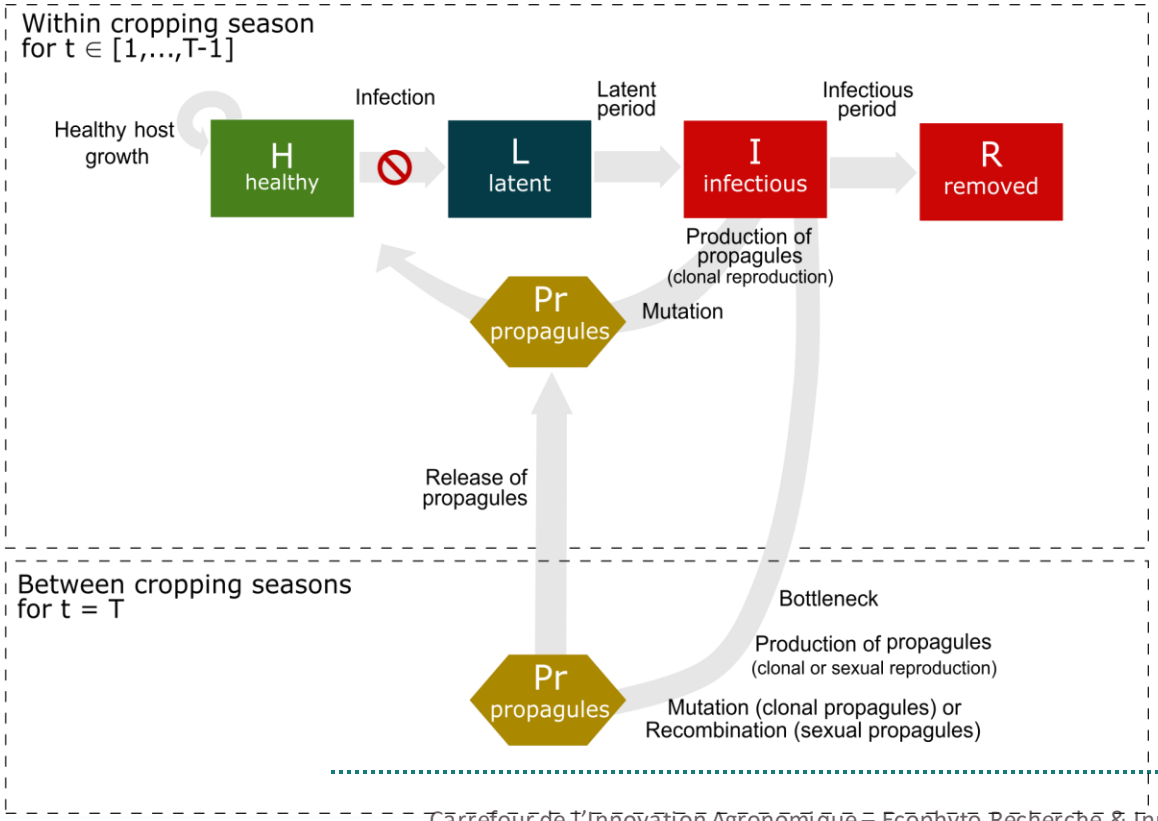

Julien Papaïx


Loup Rimbaud


Jean-François Rey

02. Résultats
Adaptation of landsepi to downy mildew

- Adding the possibility for sexual reproduction between seasons



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02. Résultats
Adaptation of landsepi to downy mildew

- Finding the best set of parameters for downy mildew

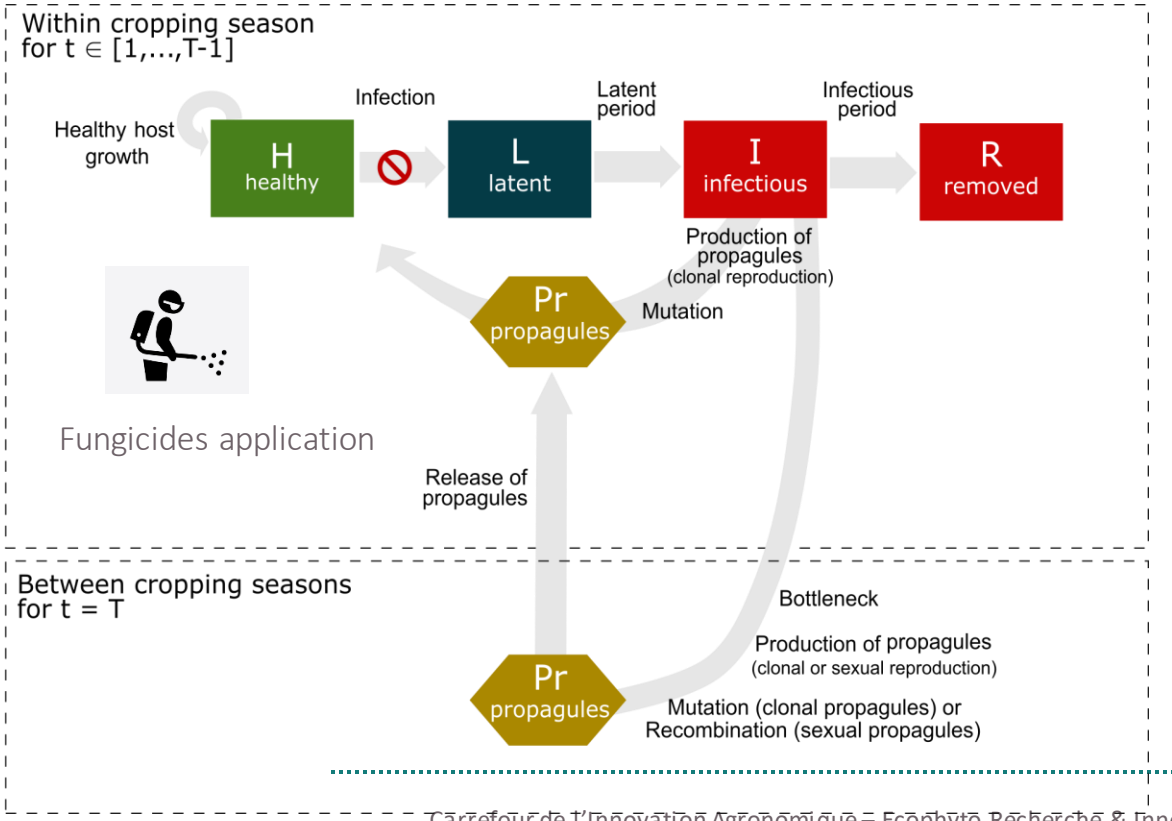
Table 2: Summary of model parameters and numerical simulation plan (factors in bold are varied according to a complete factorial design).

Notation	Parameter	Value	Source
Simulation Factors			
Y	Number of cropping seasons	50 years	Fixed
T	Number of time steps in a cropping season	120 days	Fixed
J	**Number of fields in the landscape**	**[155; 154; 152; 153; 156]**	**Varied**
V	Number of host cultivars	[2[a],3[b]]	Fixed
Initial conditions and seasonality (same value for all cultivars)			
C_v^0	Plantation host density of cultivar v (in pure crops)	1 m^{-2}	Fixed
C_v^{max}	Maximal host density of cultivar v (in pure crops)	20 m^{-2}	Fixed
δ_v	Host growth rate of cultivar v	0.1 day^{-1}	[1]
Φ	Initial probability of infection of susceptible hosts	5.10^{-4}	Fixed
λ	Off-season survival probability of pathogen spores	10^{-4}	Fixed
Pathogen aggressiveness components			
e_{max}	Maximal expected infection rate	0.9 $spore^{-1}$	[2,3]
Γ_{min}	Minimal expected latent period duration	7 days	See note S2
Γ_{var}	Variance of the latent period duration	8 days	See note S2
Υ_{max}	Maximal expected infectious period duration	14 days	See note S2
Υ_{var}	Variance of infectious period duration	22 days	See note S2
r_{max}	Maximal expected propagule production rate	2 $spores.day^{-1}$	See note S2
Sexual reproduction			
R	**Pathogen reproduction system**	**[purely clonal,mixed]**	**Varied**
p_{inh}	Probability of a sexual propagule inheriting the genotype at locus g from parent Par_1 genotype	0.5	Fixed
Pathogen dispersal			
$g(\cdot)$	Dispersal kernel	Power-law function	See note S1
μ_{mean}	Mean dispersal distance	20 m	[4]
a	Scale parameter	40	[4]
b	Width of the tail	7	[4]
Contamination of healthy hosts			
$\pi(\cdot)$	Contamination function	Sigmoid	See note S1
σ	Related to the position of the inflection point	3	[4]
κ	Related to the position of the inflection point	5.33	[4]
Host-pathogen genetic interaction			
G	Total number of major genes	2	Fixed
τ_g	**Mutation probability for infectivity gene g**	**[10^{-7}; 10^{-4}]**	**Varied**
ρ_g	Efficiency of major gene g	1	
θ_g	**Cost of infectivity of infectivity gene g**	**[0;0.25;0.5]**	**Varied**
Landscape organisation			
	Resistance deployment strategy	**MIxture; MOsaic; PYramiding; ROtation**	**Varied**
α	Level of spatial aggregation	0	Fixed
φ_1	**Cropping ratio of fields in which resistance is deployed**	**[0.17; 0.33; 0.5; 0.67; 0.83]**	**Varied**
φ_2	Relative cropping ratio of RC_2	0.5[c]	Fixed

[a] : pyramiding; [b]: mixture, mosaic, rotation; [c]: for mixture and mosaic only. Source: [1] Bove and Rossi (2020); [2] Bove et al. (2019); [3] Boso and Kassemeyer (2008); [4] Rimbaud et al. (2018b).

02. Résultats
Upgrading of landsepi

- Modelling (contact) fungicide application



02. Résultats
Upgrading of landsepi

- Adding economic outputs with margin at field, farm and cooperative scale (including costs of treatment and planting, reduction of price maket…)

Evolutionary output: Nb of years to the establishment of the adapted pathogen

Epidemiological output: Average proportion of infected hosts

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Evolutionary output: Nb of years to the establishment of the adapted pathogen

Epidemiological output: Average proportion of infected hosts

Environnemental output: Nb of fungicide applications

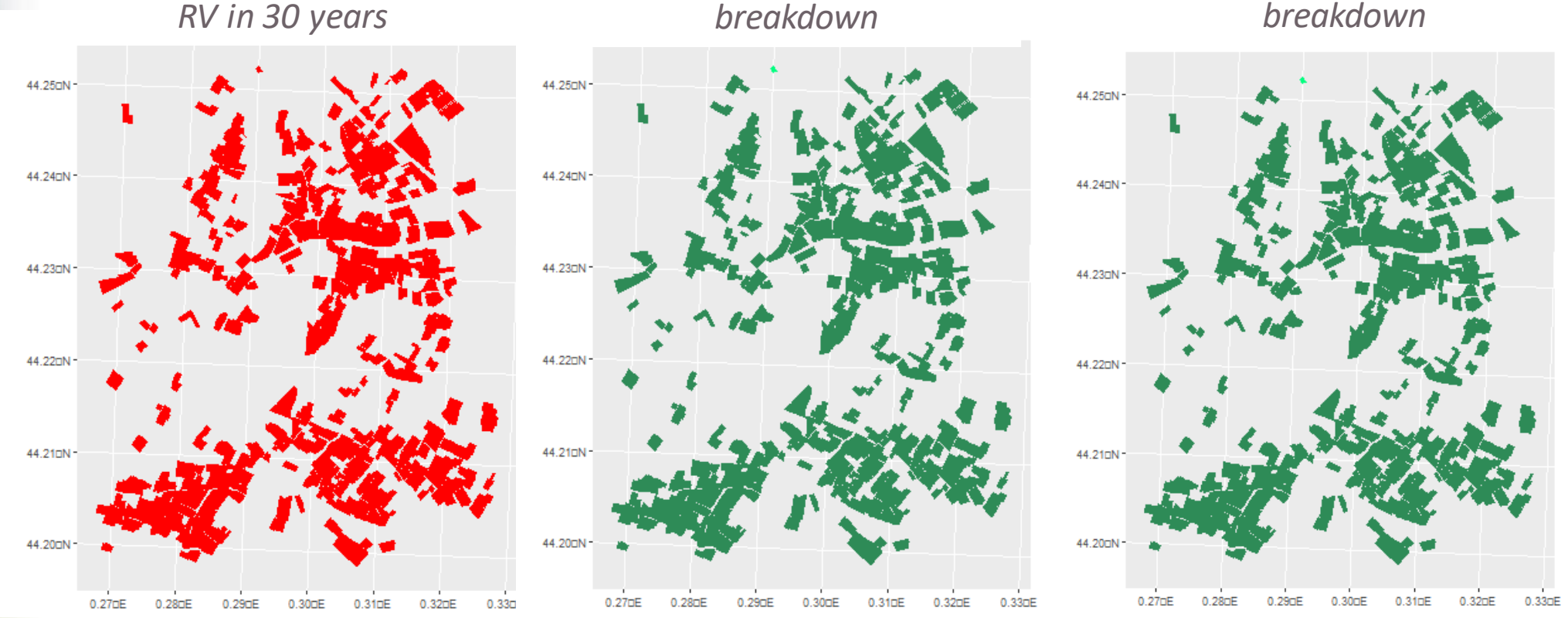
Economic output: Margin variations (%) respect to the scenario with 100% SC

02. Résultats
Upgrading of landsepi

90% of the fields planted with RV in 30 years

A simulation with a R breakdown

A simulation without breakdown

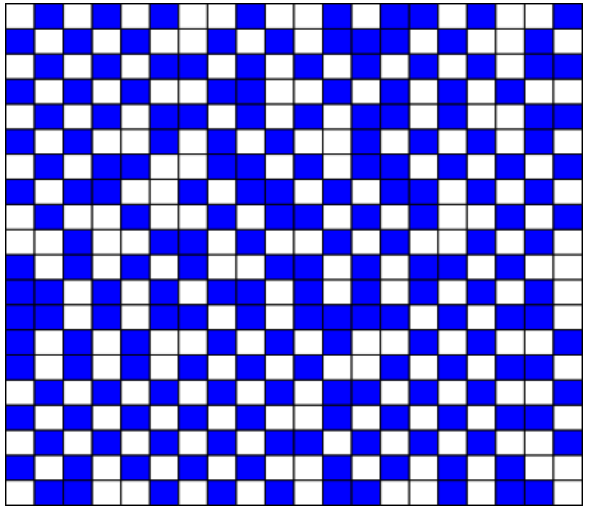


02. Résultats
Hybrid versus simple strategies

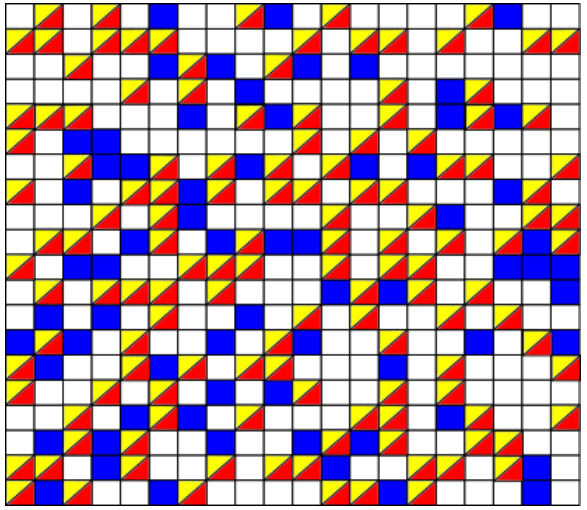
- Since 2018, winegrowers can use cultivars with monogenic R (Rpv1 or Rpv3) along with pyramided R (Rpv1 & Rpv3) cultivars.
- Effects of this coexistence on epidemiological and evolutionary control ?

- Compare these strategies in landscapes with 400 fields of 1ha with given proportion of each cultivars in 700 productions situations/ state of nature

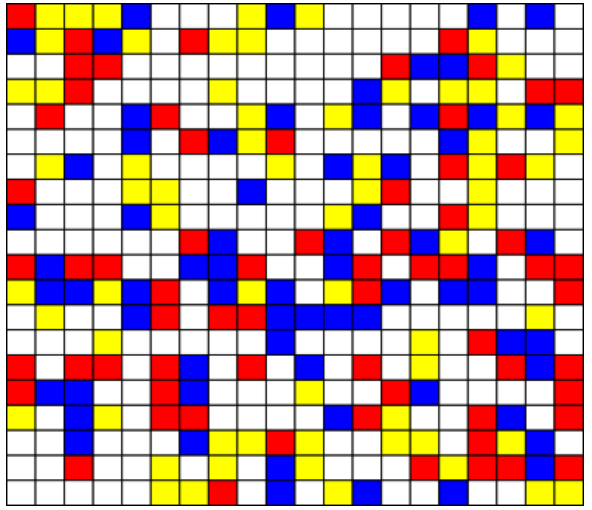
Pyramid



Pyramid + Mixture

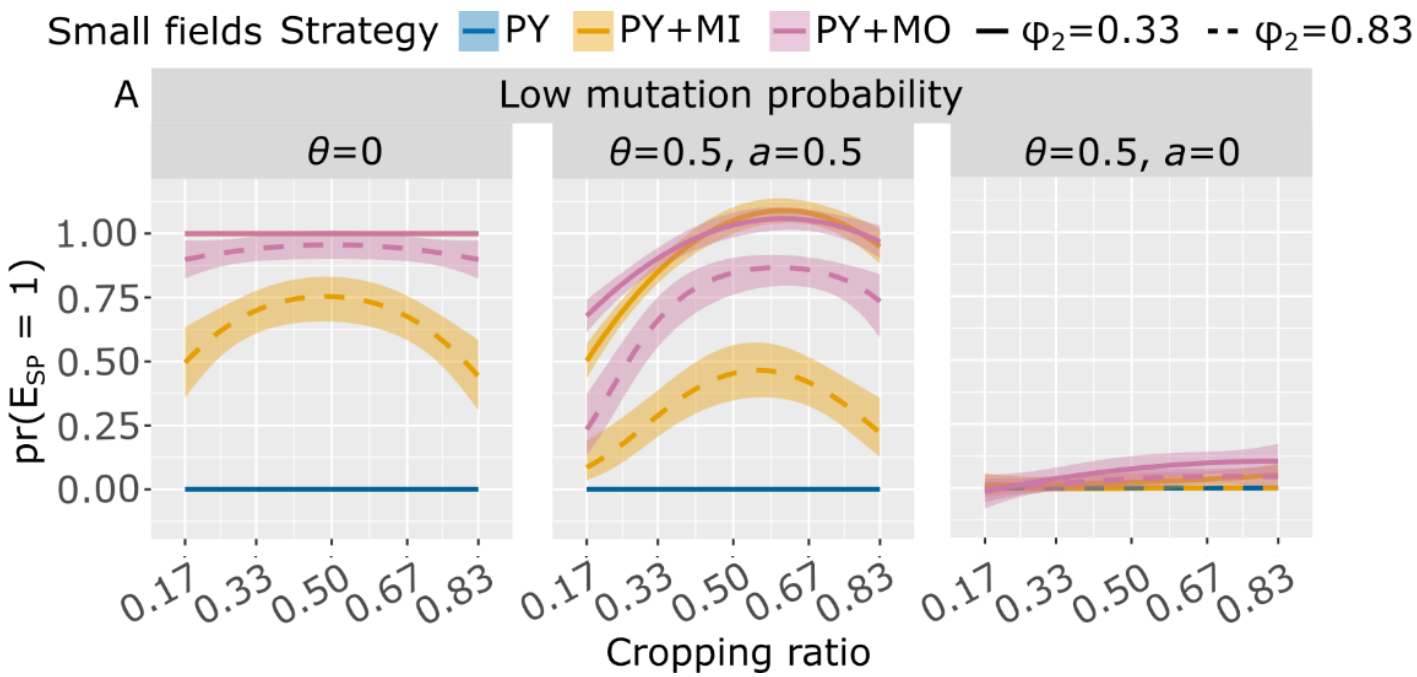


Pyramid + Mosaic



02. Résultats
Hybrid versus simple strategies

- **It depends…but most often concurrently deploying pyramided and monogenic R cultivars drastically decrease of the evolutionary and epidemiological control**
- **Even with low proportion of monogenic R cultivar in the landscape**



02. Résultats
Beyond square fields in a square landscape

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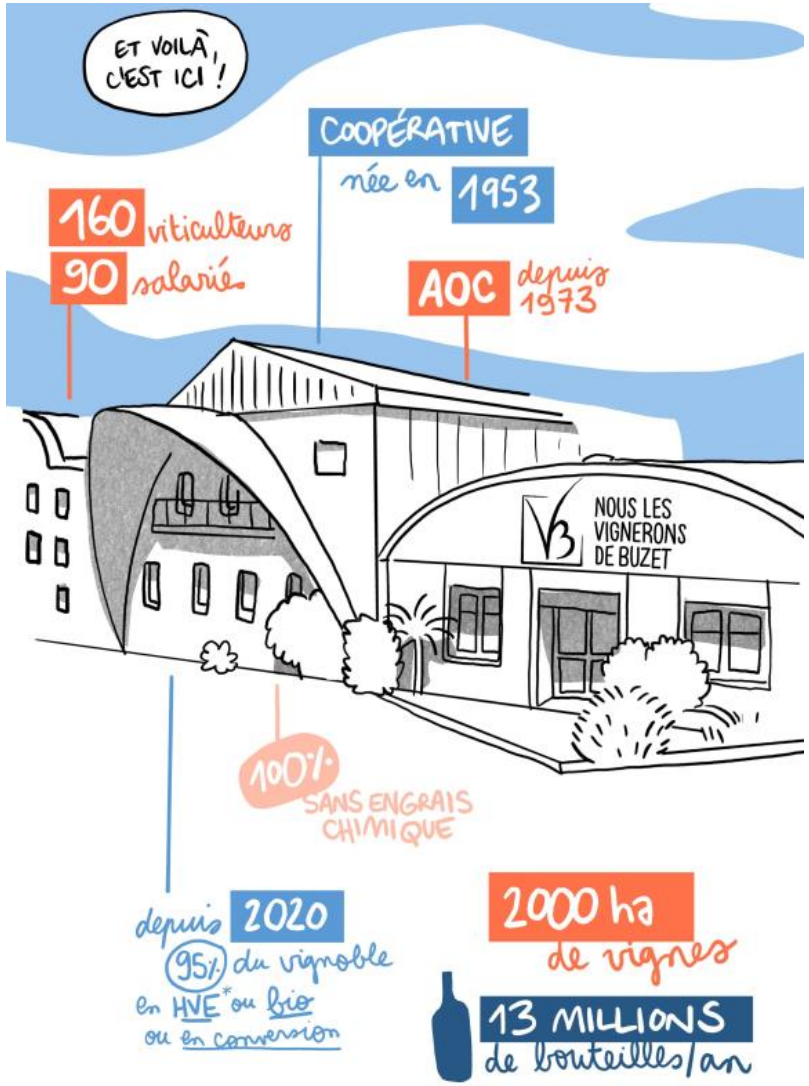
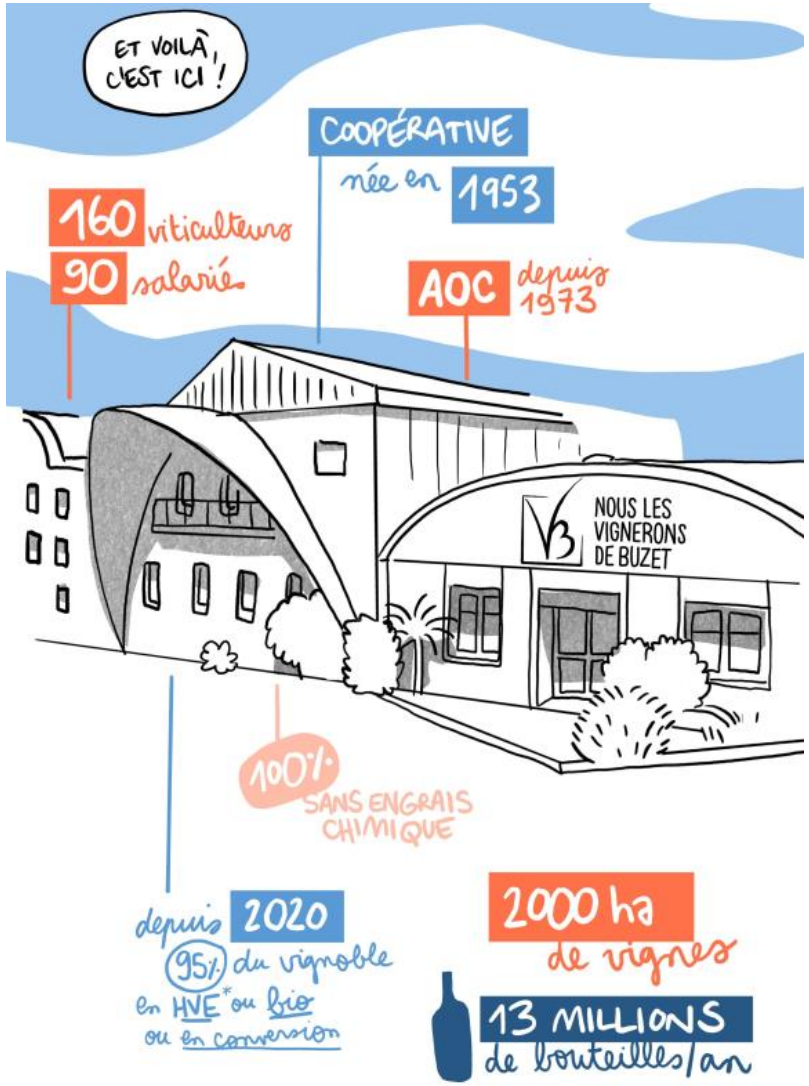


- Cooperative listened by its members
- A player capable of driving forward actions on a territory
- The user association promoted by Elinor Ostrom

02. Résultats
Beyond square fields in a square landscape



02. Résultats
Participative workshops with the cellar staff

Whp 01

Understanding the issues and sharing objectives

Whp 02

Design of deployment strategies for VDB

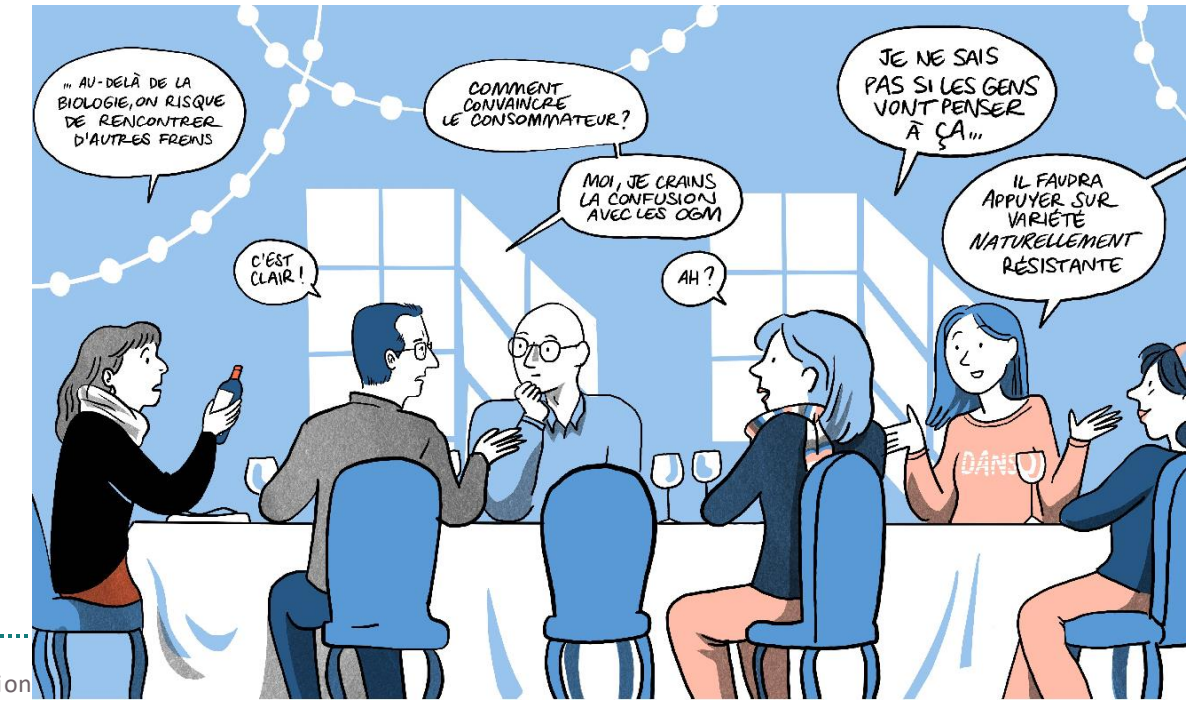
Whp 03

Results of the deployment strategies for VDB

Whp 04

Summary and conclusion

Think+
THE ECO-INNOVATIVE AGENCY



02. Résultats
Design of strategies in the real vineyard map

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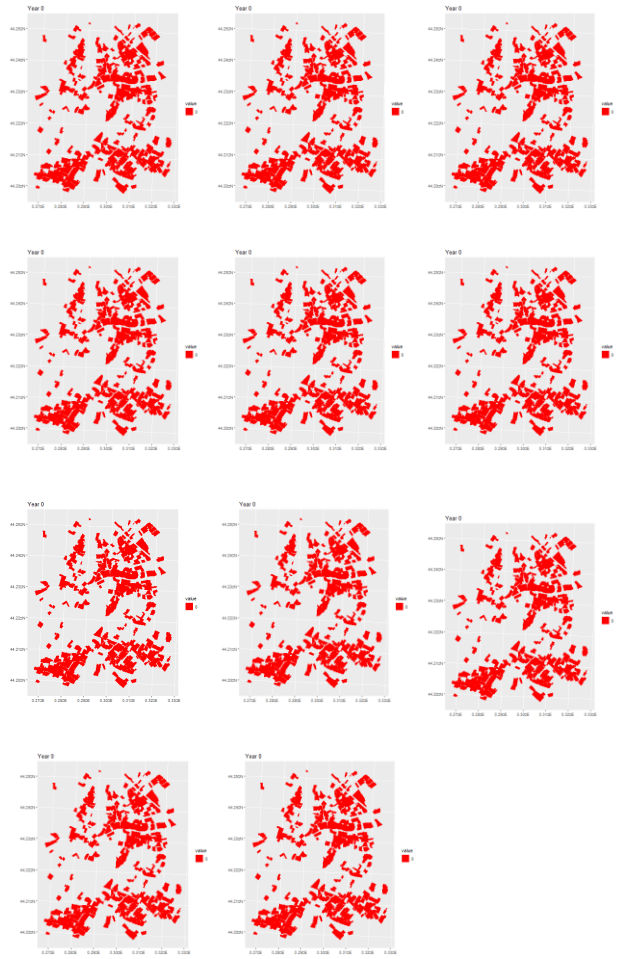
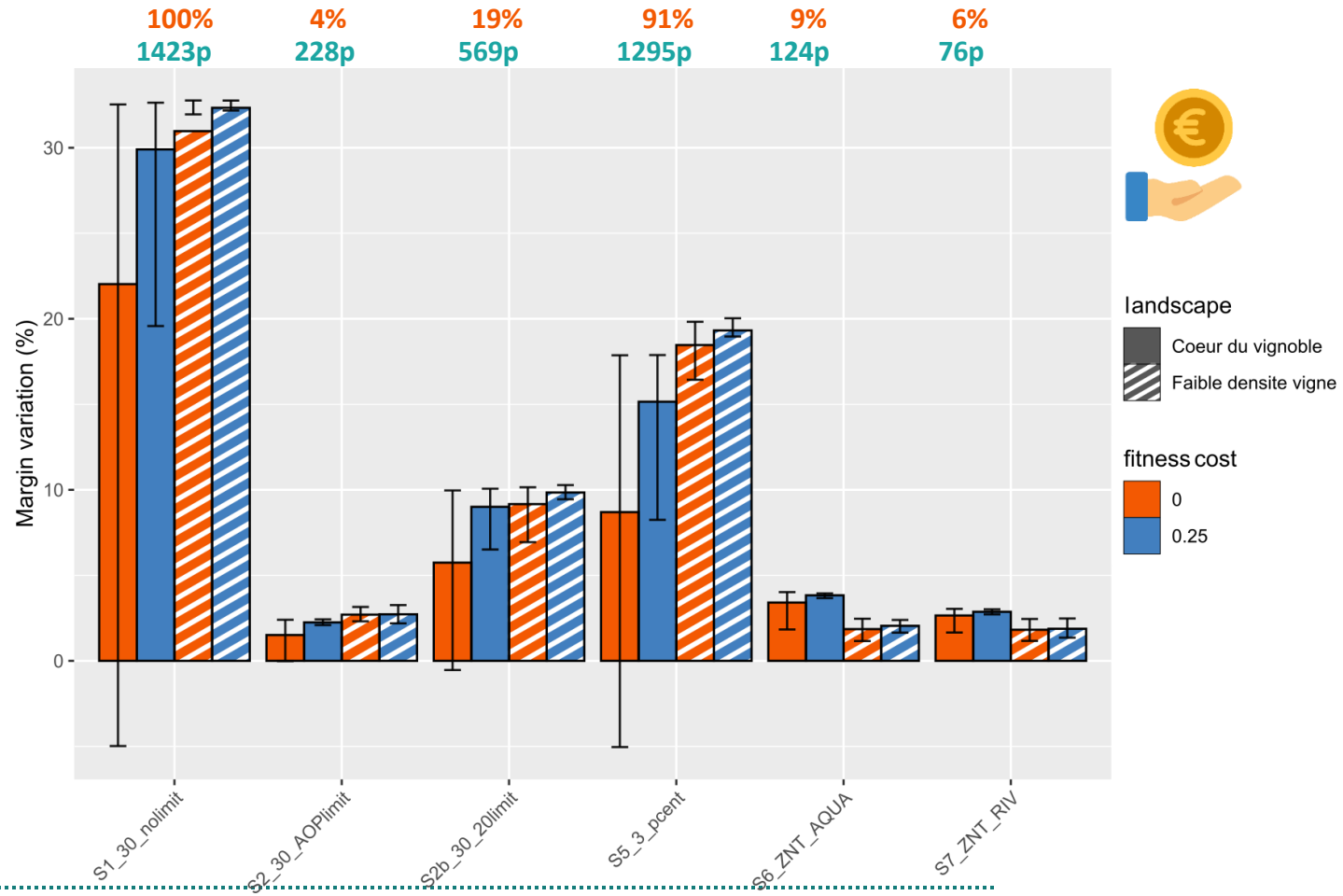
Design of strategies in the real vineyard map

Scenario	Type of planting	% of planting over 30 years	
		Svar	Rvar
S0	Planting fields with Svar if age > 35 y	92%	0%
S1	**Rvar if age > 30**	**0%**	**100%**
S2	Svar or Rvar if age > 30 & AOP limit	97%	3%
S2b	Svar or Rvar if age > 30 & 20% limit	82%	18%
S3	**Rvar if age > 40**	**0%**	**88%**
S4	Svar or Rvar if age > 40 & AOP limit	85%	3%
S4b	Svar or Rvar if age > 40 & 20% limit	70%	18%
S5	**Rvar in 3% of the oldest fields**	**0%**	**91%**
S6	Svar if age > 35 & CR in ZNT aqua	83%	9%
S6b	Svar if age > 35 & CR in ZNT aqua – no trt	83%	9%
S7	Svar if age > 35 & CR in ZNT neighb	87%	5%
S7b	Svar if age > 35 & CR in ZNT neighb – no trt	87%	5%



02. Résultats
Margin variation at cooperative scale



02.bis Difficultés rencontrées

- **Many biological details matter a lot** (G*G matrix, mutation probability, severity-damage relationship….). Some parameters are difficult to measure experimentally

- The model is not validated. It is only a tool to **help designing strategies in a complex system** “all other thinks being equal”

02.bis Difficultés rencontrées

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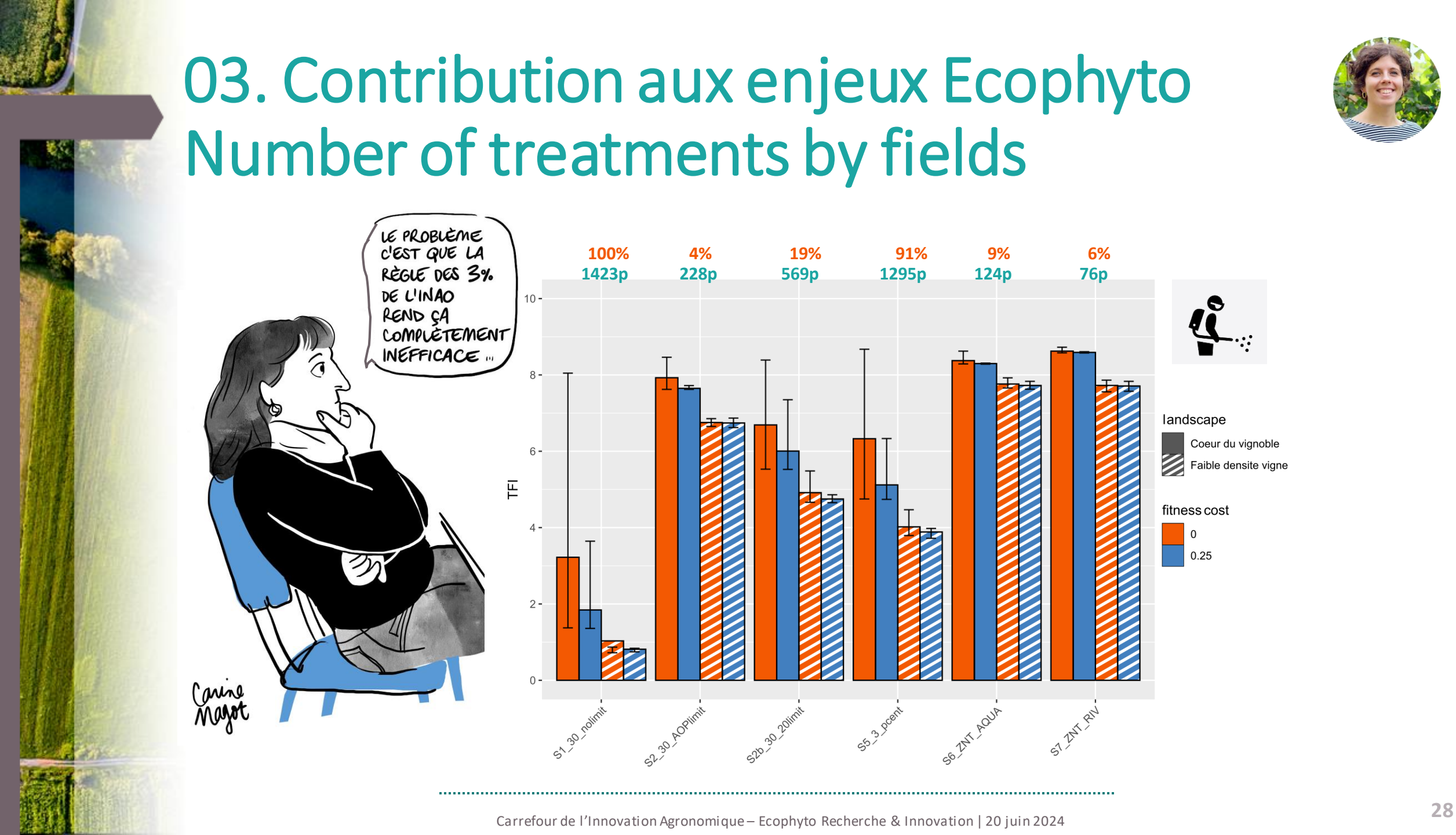
- The model is not validated. It is only a tool to **help designing strategies in a complex system** “all other thinks being equal”

- "The 'all else being equal' stance presents **numerous operational limitations** when considering **all the issues a cooperative faces** regarding the deployment of new grape varieties."

03. Contribution aux enjeux Ecophyto
Number of treatments by fields



04. Valorisation & transfert de résultats

- **Two scientific articles published, one in progress**
- **A new open-access version of landsepi**
- **A popular science comic strip**

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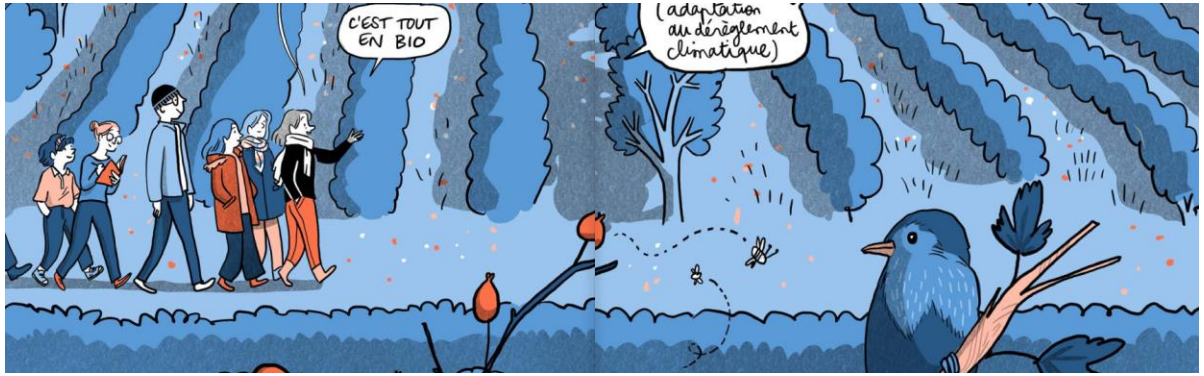
- Two scientific articles published, one in progress
- A new open-access version of landsepi
- A popular science comic strip
- Four morning workshops (and a warm welcome) by the "Nous les vignerons de Buzet" teams
- A group of engineering students trained in these issues
- And field visits!



05. Perspectives issues du projets

- **Experiment more to measure better** (fitness cost, mutation rate) : on going projects ANR Combine & ANR Endurance

- **Multiply these participatory workshops** to support the wine sector in acquiring the best practices and knowledge on resistant varieties : developing training tools, serious games ?

- **Common goods are a background:** we did not formally tested the added value of user associations (but could be nice to do it !)

Consortiums & Partenaires

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Carine Magot
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Julien Papaïx

Loup Rimbaud

Jean-François Rey

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Remerciements

Pub !
Envie de promouvoir l'agroforesterie au vignole ?

- **Devenez associé** en participant à l'achat de terre (2000 € / part)

- **www.lapossiblerie.fr**