Overview of the honey bee colony model ApisRAM: a model for integrating multiple stressor effects on bees

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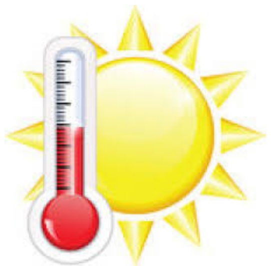
Multiple stressors – surely we can just sum effects?

 +  +  + 

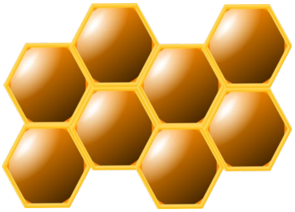
= **Overall Stress**

Unfortunately no, observations from the real world show that this is too simplistic.

...the reason is feedbacks & interactions



Bees forage when the weather is good to fill the colony’s food resources



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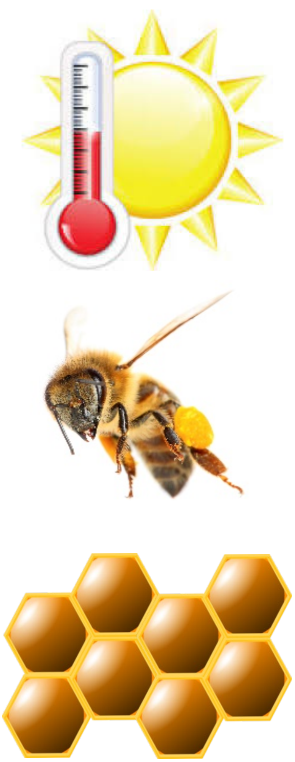

These resources are used in the winter to keep the bees warm and alive!

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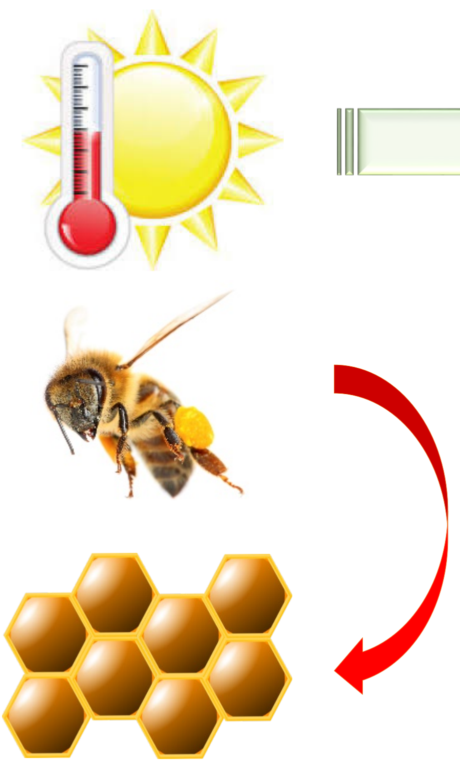

Anything interfering with this process can reduce the colony fitness over winter

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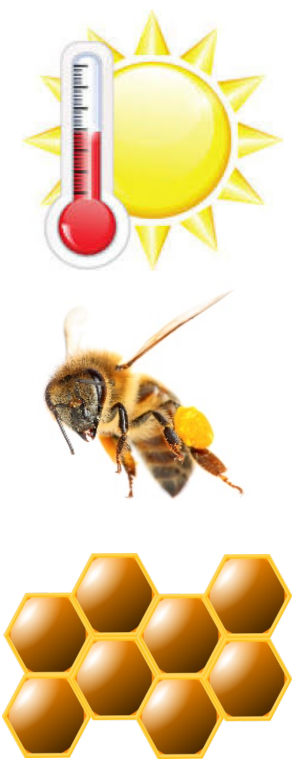
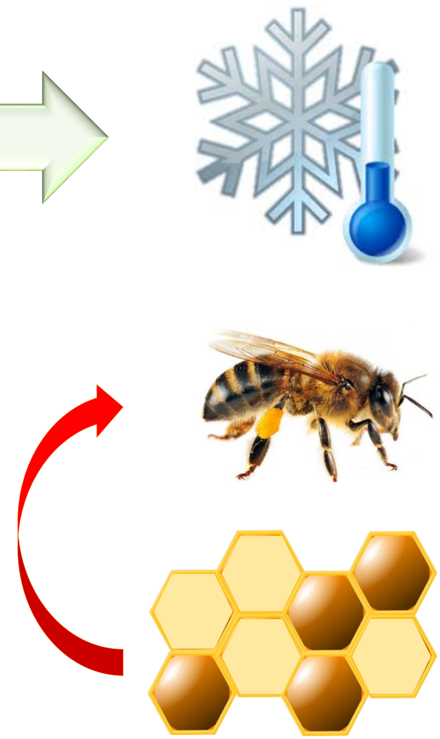


Anything that lowers the number of bees means less chance of being able to keep warm by consuming resources



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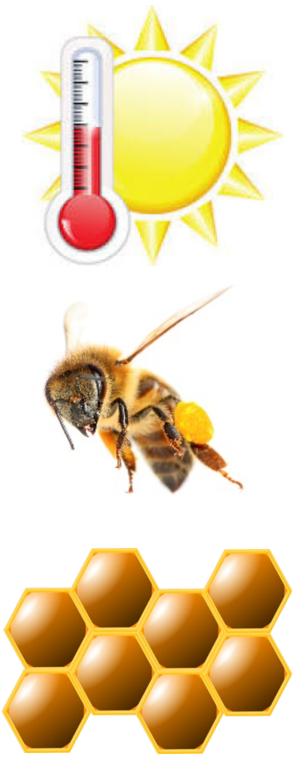
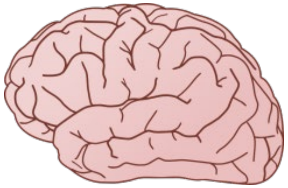


But the bees ‘know’ this and will try to compensate for any problems they encounter as they go through the season

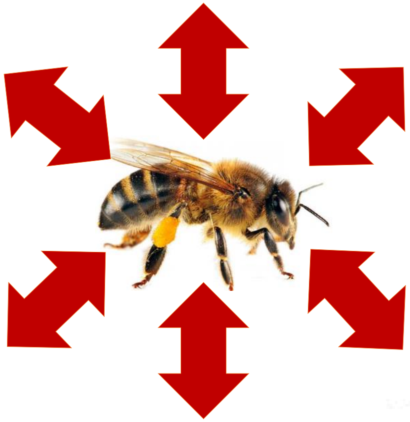
Balancing these factors is a complex thing

…but the bees do it – so do we think the hive operates with a hive intelligence solving these problems?



Probably, yes, but we don't think it is a central brain.

Rather it is the emergent response of all the bees reacting to their surroundings
- but also influencing them.

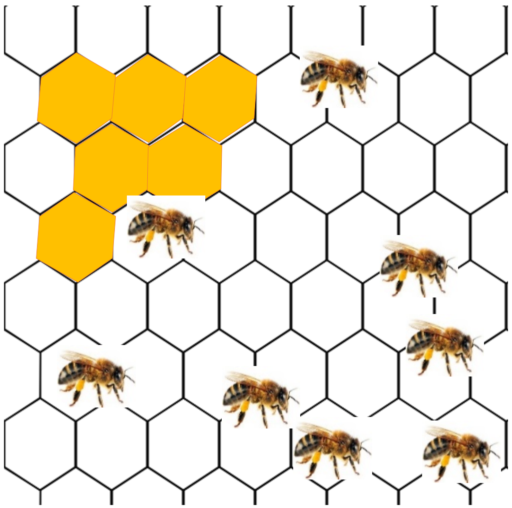


ApisRAM design I: The IBM

1. Behaviour occurs at the individual level
2. Behaviour depends on the individual bee's situation
3. Behaviour depends on individual motivation not a systems response
4. From the bee's perspective these decisions are 'selfish'

Selfish, not in this way, but in that decisions benefit the individual bee at that time

Design II: Selfish bees and temperature



When its cold bees move towards the warm, and form a cluster while they metabolise resources to keep warm.

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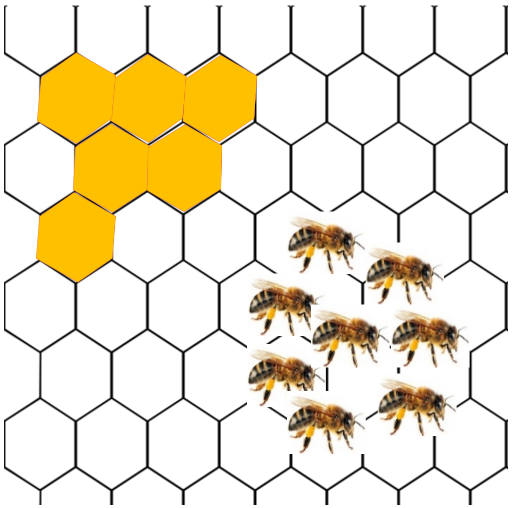

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The cluster of bees also insulates, so we have a feedback interaction, the colder it is the tighter the bees cluster, the more heat they conserve.

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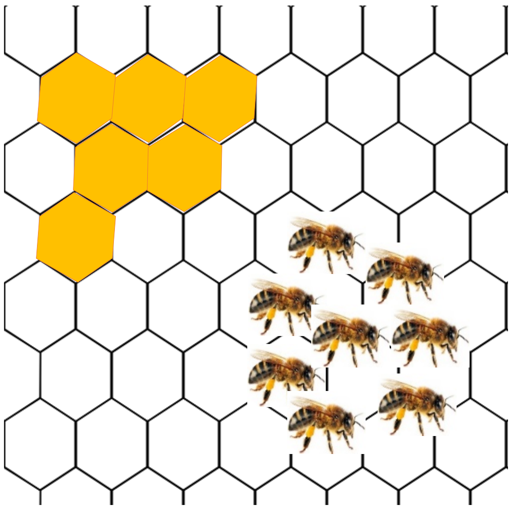

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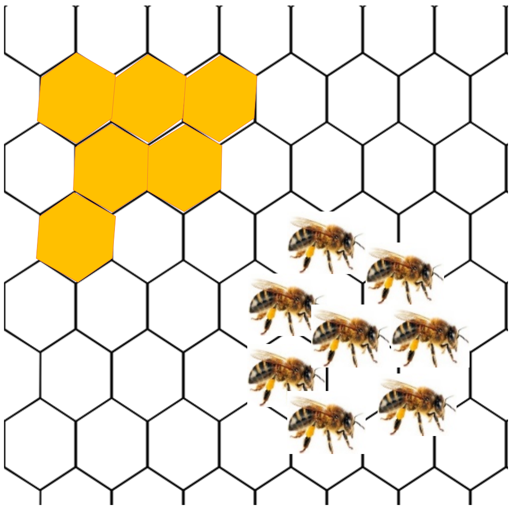

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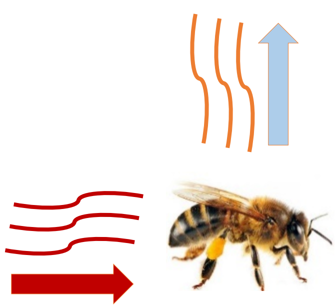


Each bee is a like a small mobile heater but needs to be refuelled.

Calculating the effect of each individual bee on each other is very complicated, but can be done by using efficient computational algorithms.

In hive activities & bee development

Development

- Three castes
  - Worker, Drone, Queen
- Life stages
  - Egg -> Larva -> Pupa -> Adult

Stressors

- Thermal
- Nutrition
- Pesticides
- Disease/*Varroa*

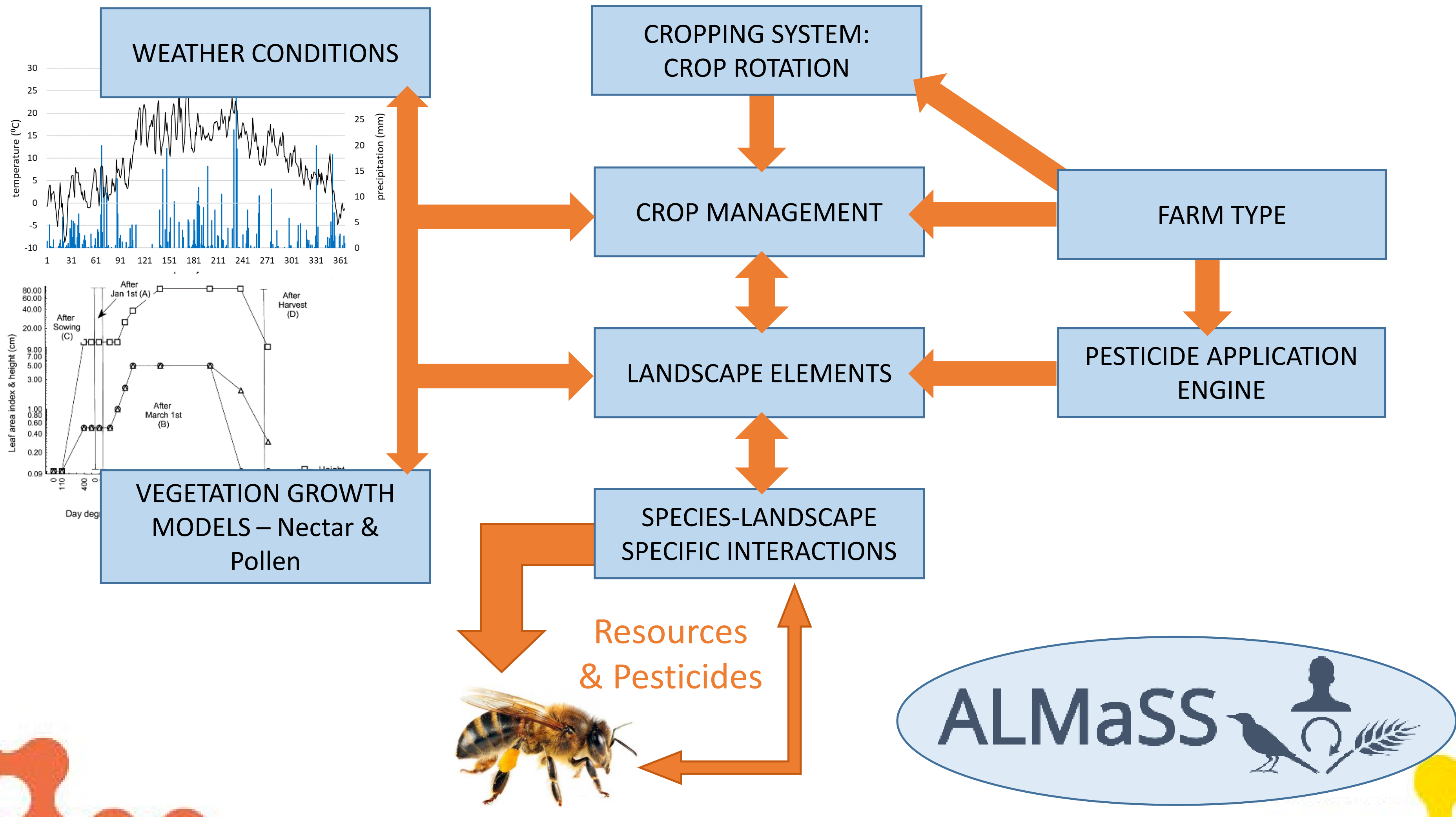
Activities

- Feeding
- Cleaning cell
- Capping brood
- Attending brood
- Receiving nectar
- Deposting nectar
- Ripening nectar
- Capping honey
- Packing pollen
- Comb building
- Ventilating entrance
- Warming up
- Guarding
- Removing debris

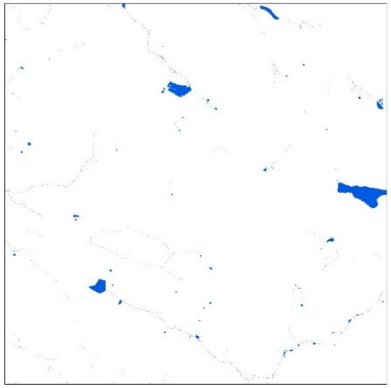
Design III: Context

Once we have the bees behaving sensibly in the colony, the next step is consider the landscape context the colony finds itself.

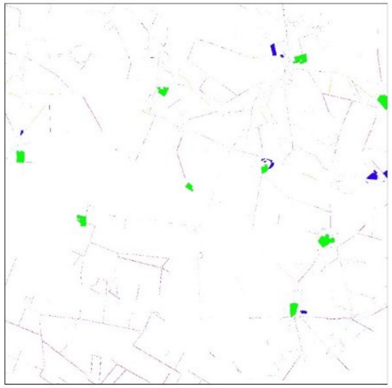
ALMaSS Landscape modelling



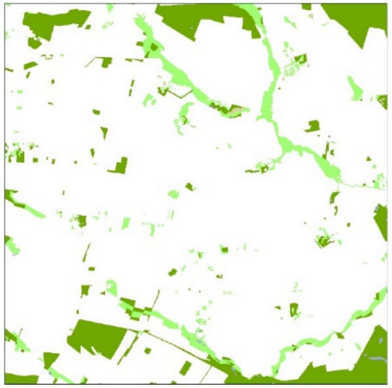
Mapping data used to create the landscape model



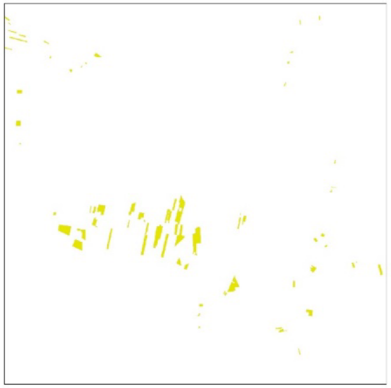
WATER



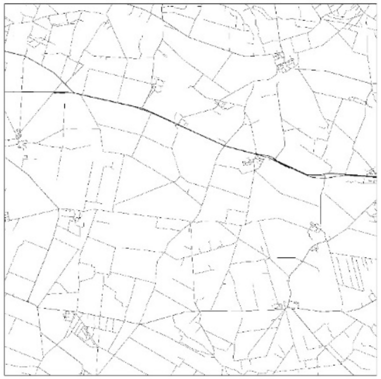
CULTURAL FEATURES



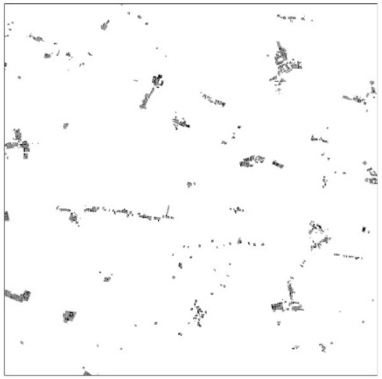
NATURE



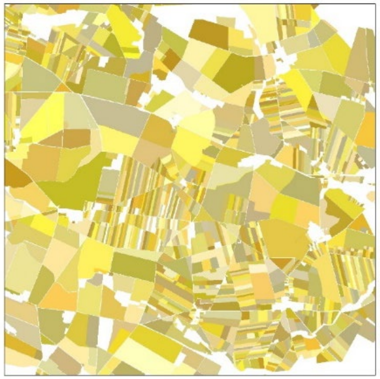
CULTIVABLE/UNUSED



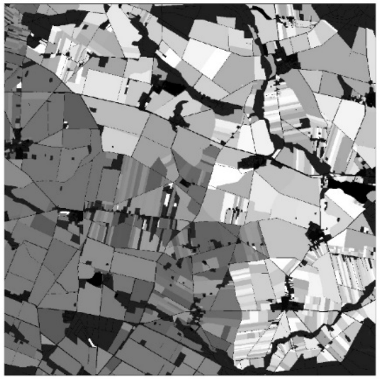
ROADS



BUILT-UP

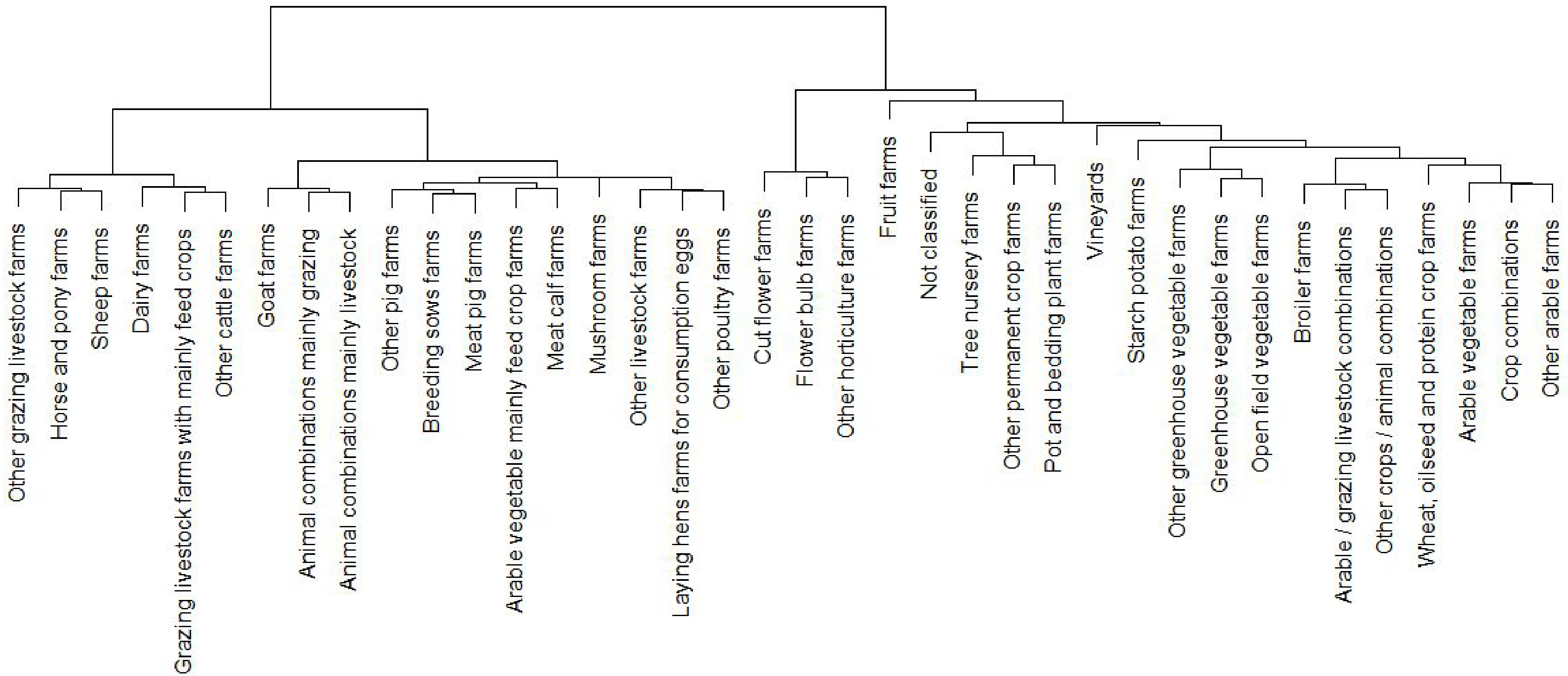


FIELDS



Farm classification, and rotations

NL example: national classification using subsidy data



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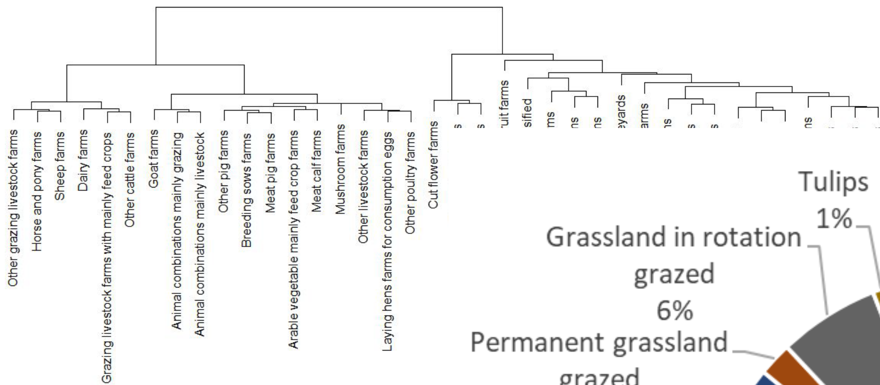
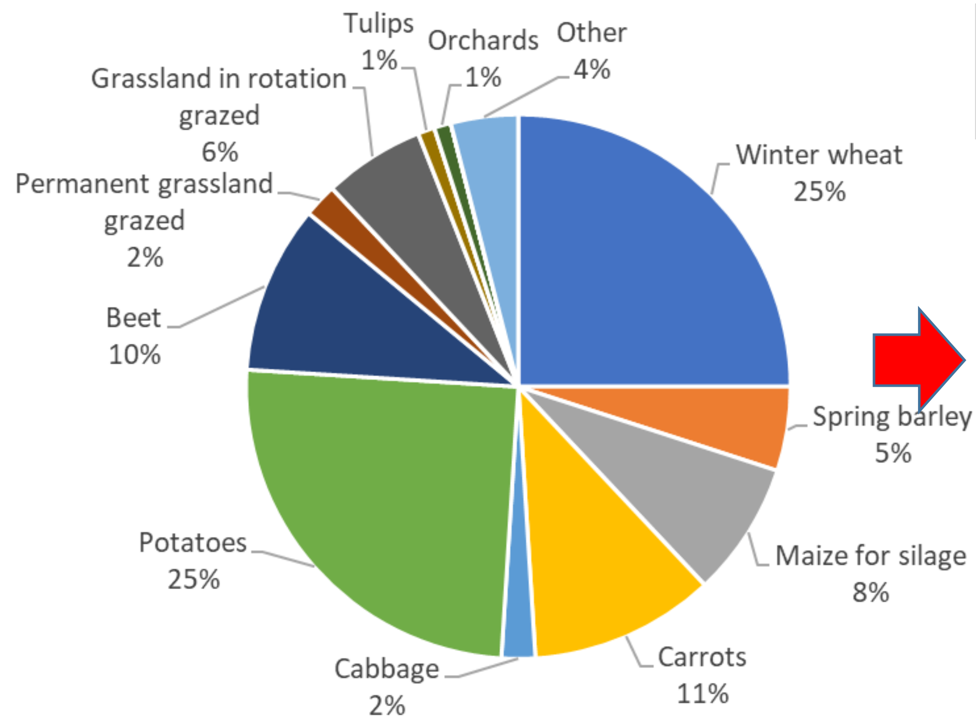
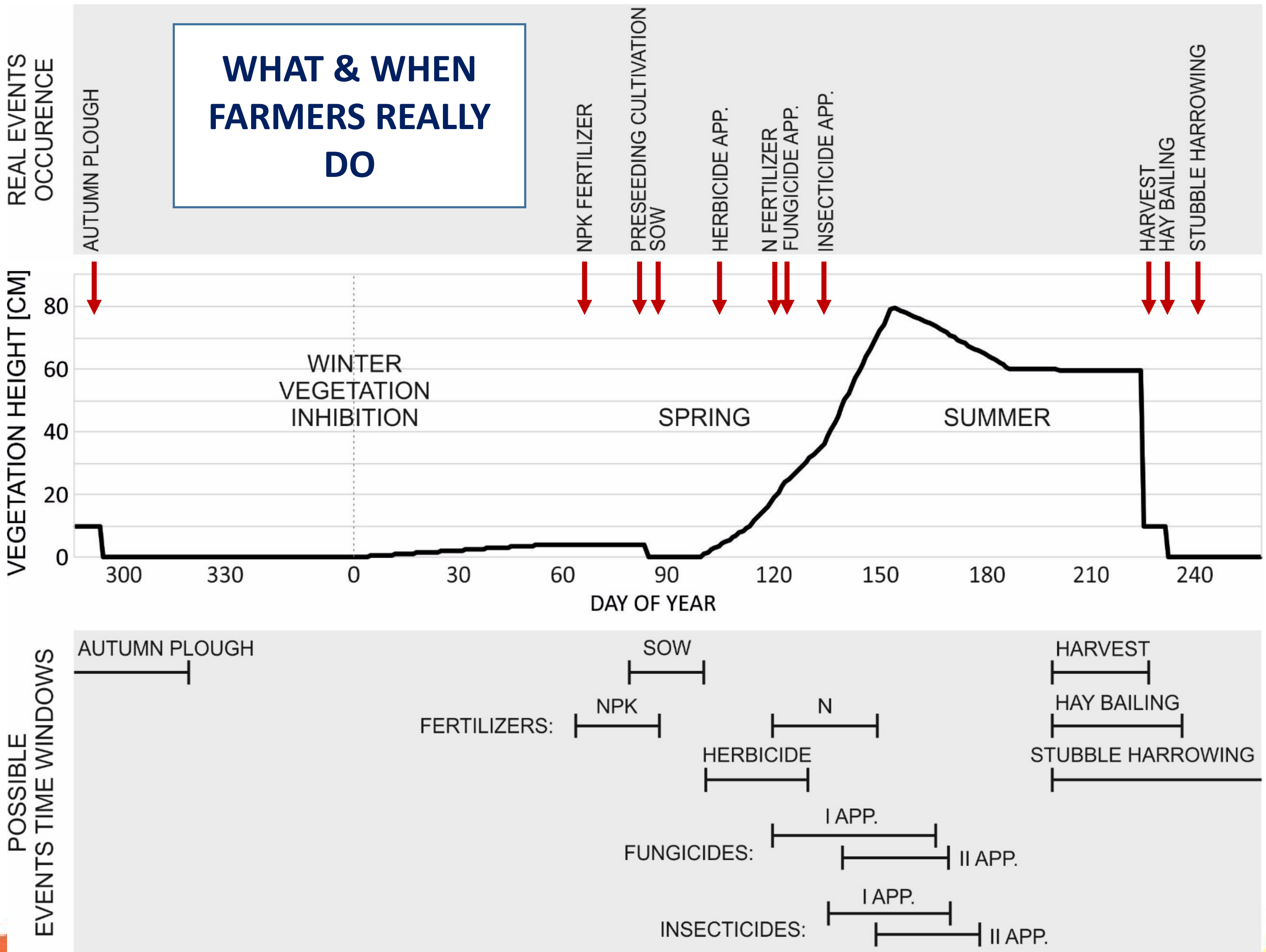




Rotation input per farm type
NLMaizeSpring
NLCatchPeaCrop
NLBeetSpring
NLCabbage
NLSpringBarley
NLWinterWheat
NLWinterWheat
NLWinterWheat
NLCatchPeaCrop
NLGrassGrazed
NLGrassGrazed
NLMaizeSpring
NLCatchPeaCrop

Farm & Crop Management

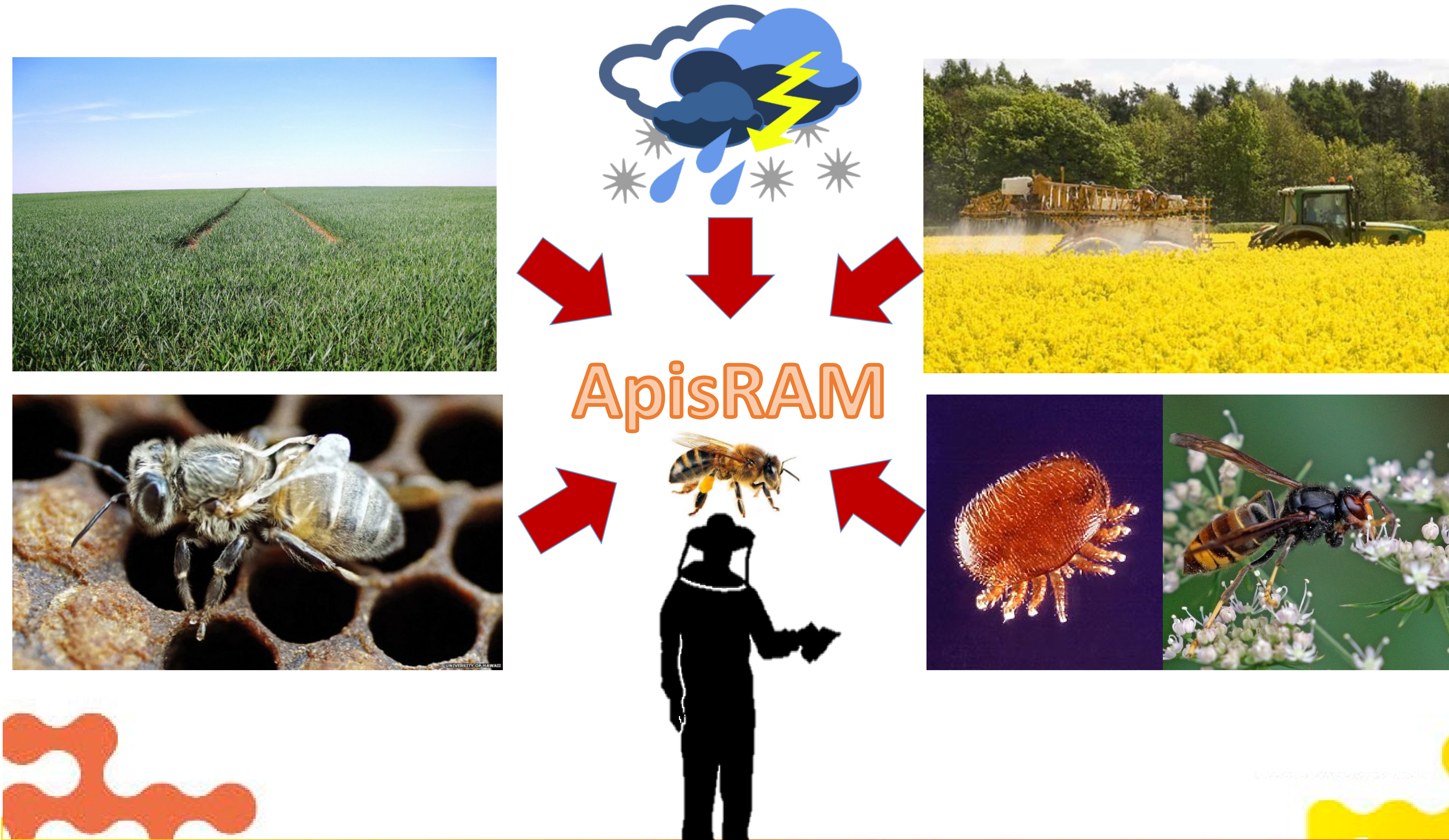
Spring Barley Example



Bee foraging, scouting, and communicating

- Model bees will scout for forage resources and communicating the information to the colony
- Foragers will be able to use this information to forage in the landscape
- However, foraging resources will also expose bee to pesticides and pesticide residues in pollen and necar which will be brought to the colony – this will depend on when and where they forage

Putting it all together



The ApisRAM vision

Biological agents
Beekeeping
Climate

Danish
Farming/
Environment

Polish
Farming/
Environment

Portuguese

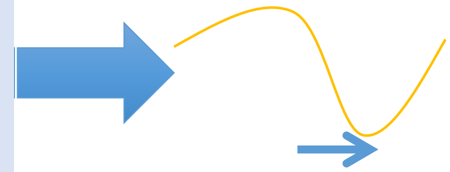
Romanian
Farming/

Spanish
Farming/
Environment

Currently available for: Denmark, Poland, The Netherlands and parts of Portugal.

H2020 projects will provide:
Germany (parts), France, Finland, Ireland, Italy, Sweden, Belgium & UK

Bee health in Poland, Denmark, Germany, Belgium, France ….



….time

Overall aims for ApisRAM

- Integrate multi-stressor impacts (pesticides and non-regulated stressors)
- Simulate interactions between components
- Predict complex system-dynamics, including the possibility to integrate mitigation options (e.g. width of sown field margins or restricted pesticide usage).
- Help to clarify the relative importance of different stressors, including how the impact of a pesticide on colony health might change with changing context, e.g. climate, and/or farming.

Current status

- ApisRAM is now designed and being implemented, a prototype model is expected in January 2020
- All ALMaSS development, including ApisRAM is open source
- The model is also supported by a parallel EFSA project on data collection that will provide data to improve and test the model from landscapes located in Denmark and Portugal
- The first version of ApisRAM to be released is expected in Spring 2021

Thank you for your attention!

Thanks to all the bee experts who have contributed to the project, especially Noa Simon Delso and Annette Bruun Rasmussen. Thanks also to the MUST-B working group and EFSA staff, especially Angelo Maggiore and Agnes Rortais for supporting the project.