Plant Health Institute Montpellier

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LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

AMAP lab
BotAnique et Modelisation de l'Architecture des Plantes et des végétations

Coupling plant growth models, application on pest & disease models: an interaction structure proposal

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Founds: ½ Cirad, ½ Project EU DESIRA Robust
Certification: #DigitAg
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Robusta coffee tree and climate change in Uganda

- 7th largest producer worldwide
- Pest crisis: Coffee Wilt Disease (CWD), **50% production losses** (late 90s-2010)
  - Selection (clones)
- **Re-emergence** of pests and fungal diseases

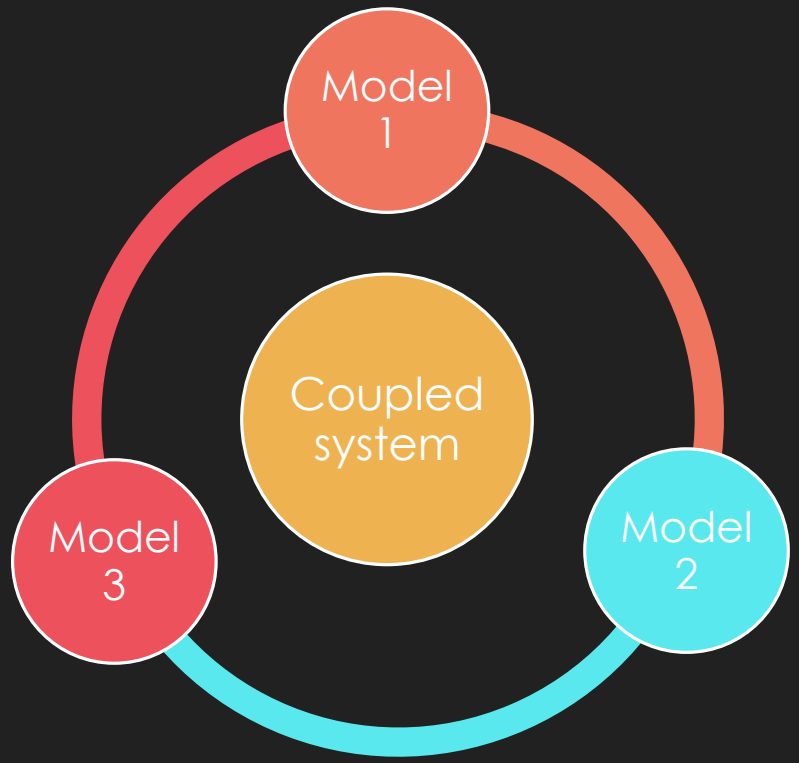
Problematic

Estimation of the production of a plant subjected to a Pests & Diseases attack

- Harvest estimation on the **short term** is privileged
- The response of the plant to the attack is unknown on the **long-term**

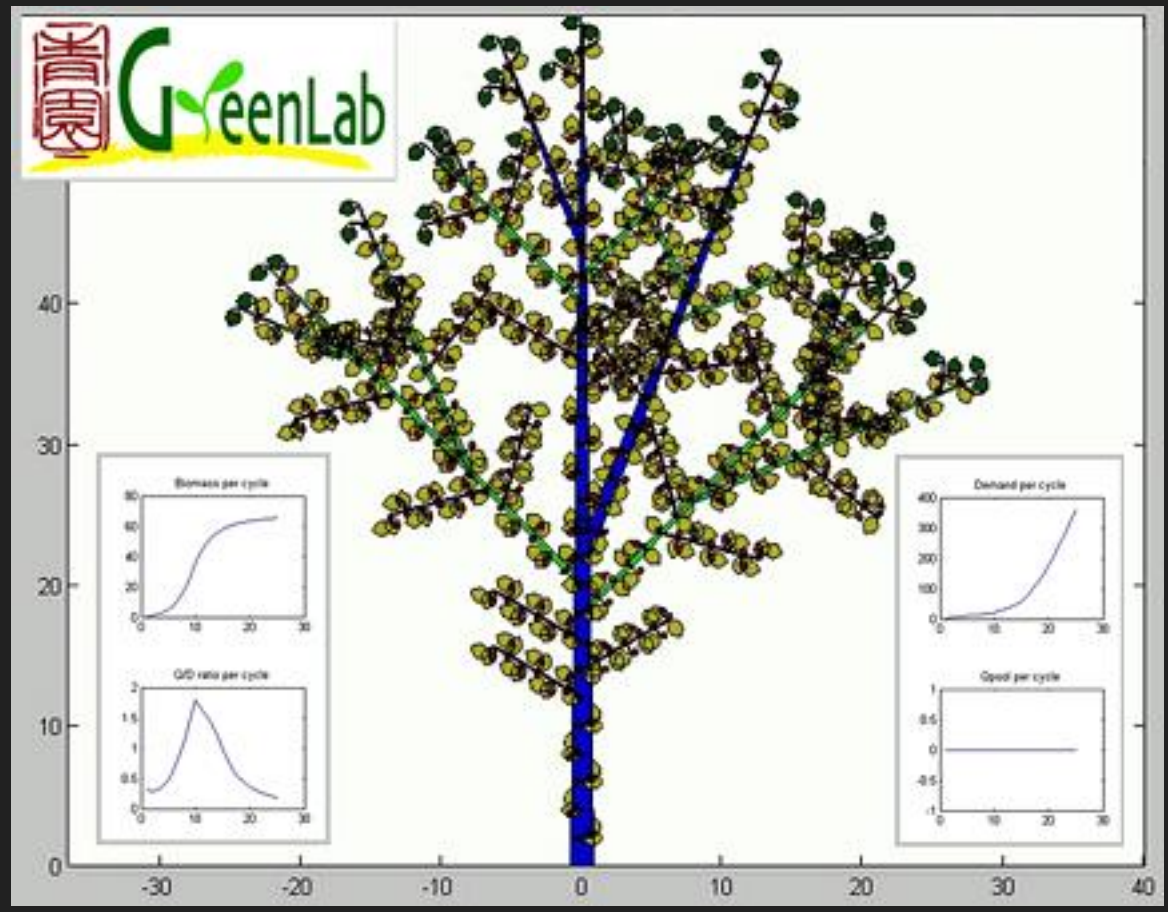
Objectives

- Assessing the variation in **production** and **the mechanisms** related to it
- Establishing a **coupled system**



GreenLab growth Model

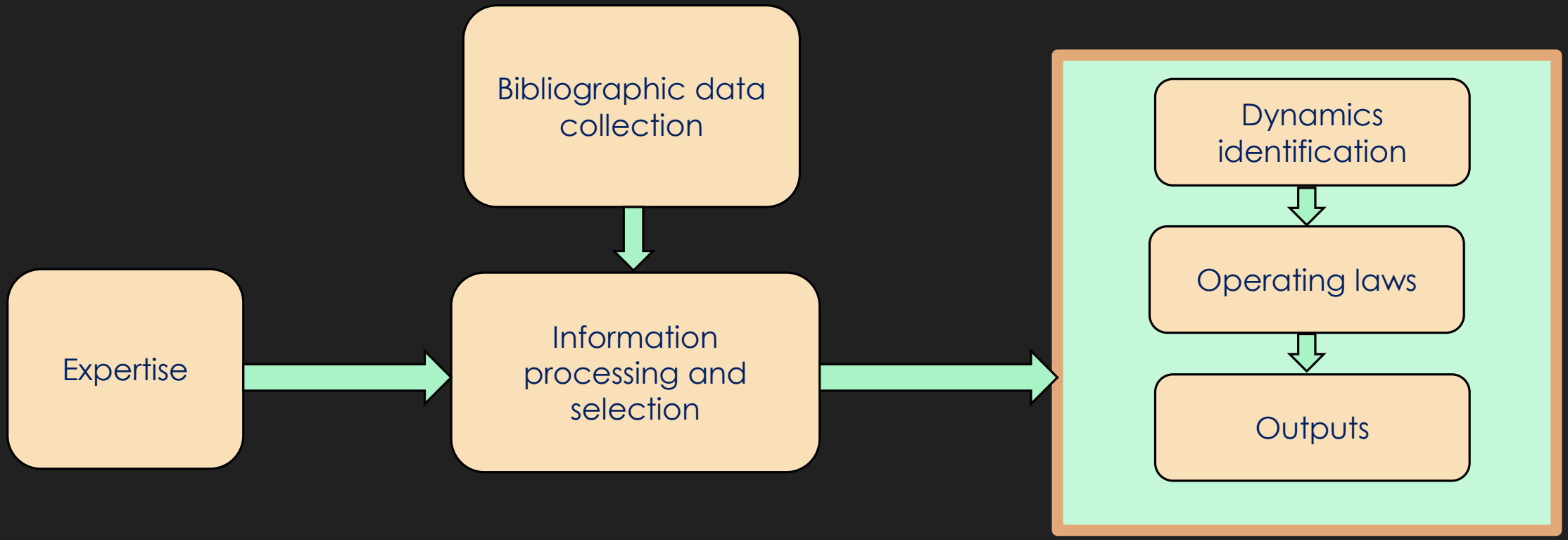
- Inherits from both **PBM** and **FSPM**
- Allows **individual** to **plot** scale
- **Quantification** of structure
- **Recurrence** equations for organogenesis and growth



M. Jaeger, UMR AMAP, CIRAD

Pest & Diseases Models

- Building **knowledge-based** P&D models
  - Inspired by E. Lasso et al, *IEEE Access*, 2021.

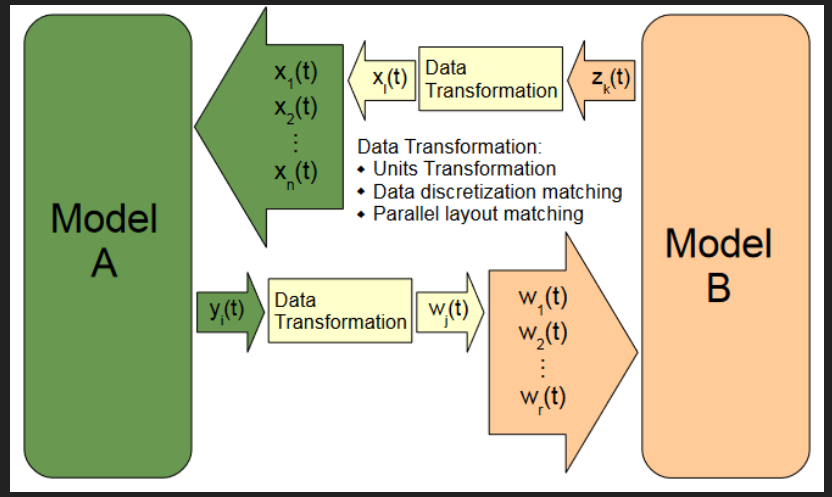


Problems to “link” P&D and Plant models

- What are the nature of the interactions ?
  - Which organs are affected? How? Is cohort assumption still relevant for the interaction? ...
- How to operate different cycles and synchronize them?
- Quantification of interactions between models
  - Calibration and validation
- How to simulated feedbacks due to model’s dynamics behaviours ?
  - Are the feedback resulting from implicit dynamics ?

=> Modelling/simulating dynamic complex systems

Complex systems formalisms / tools



- Models exchange computational variables and fields at **predetermined** coupling intervals.
- Leads to a **stiff interactions** with overlapping data
- Considered as a **weak coupling** formalism nowadays

Cecchis, D et al. 2012

OpenAlea

- Free, open environment (CIRAD/Inria, France) for **integrating** structural and functional plant models at different scales
- Various **analysis, modelling and simulation tools**
- **Accessibility** of the modules and tools to the community

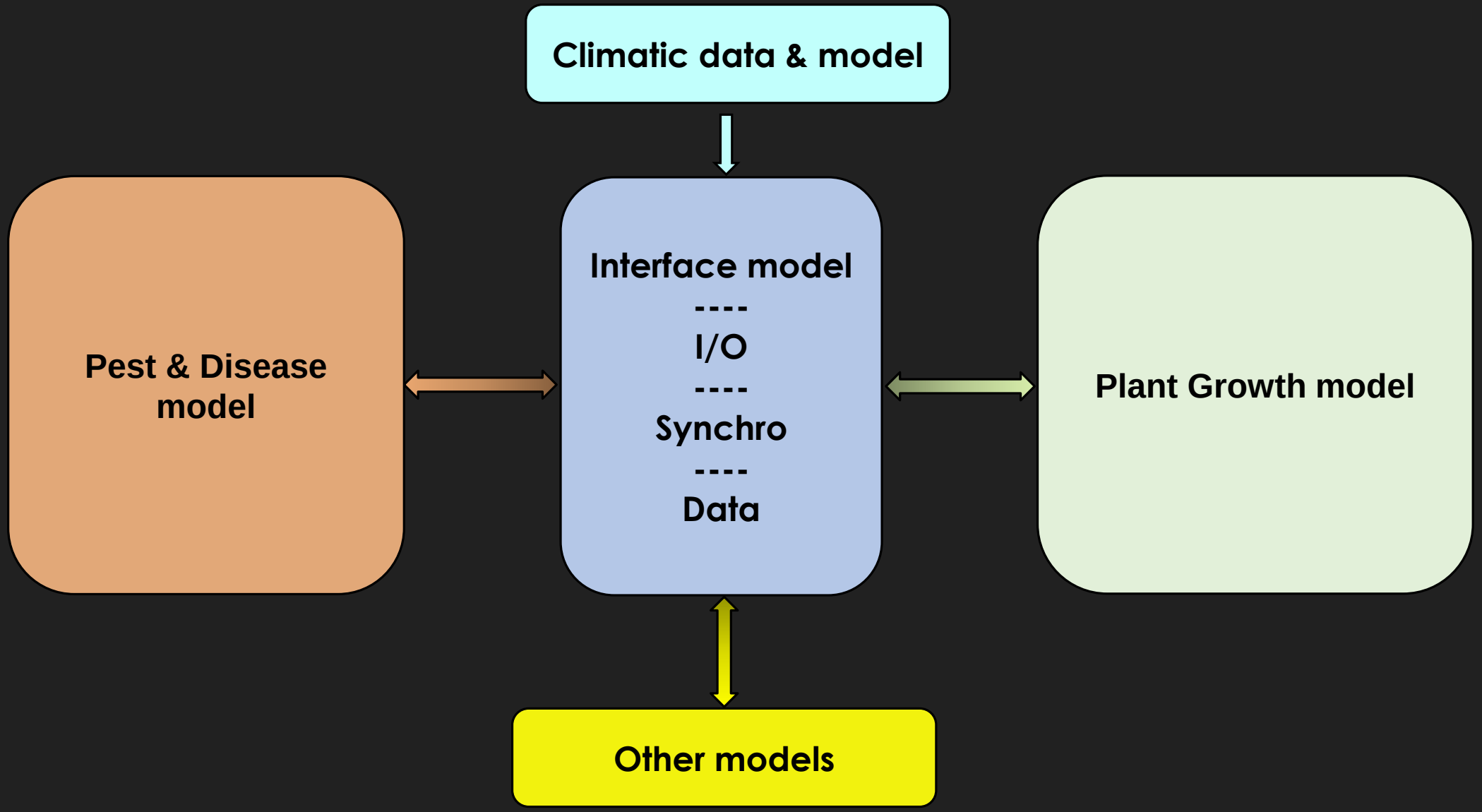
Our proposal

Designing a specific structure handling the interactions in an independent way

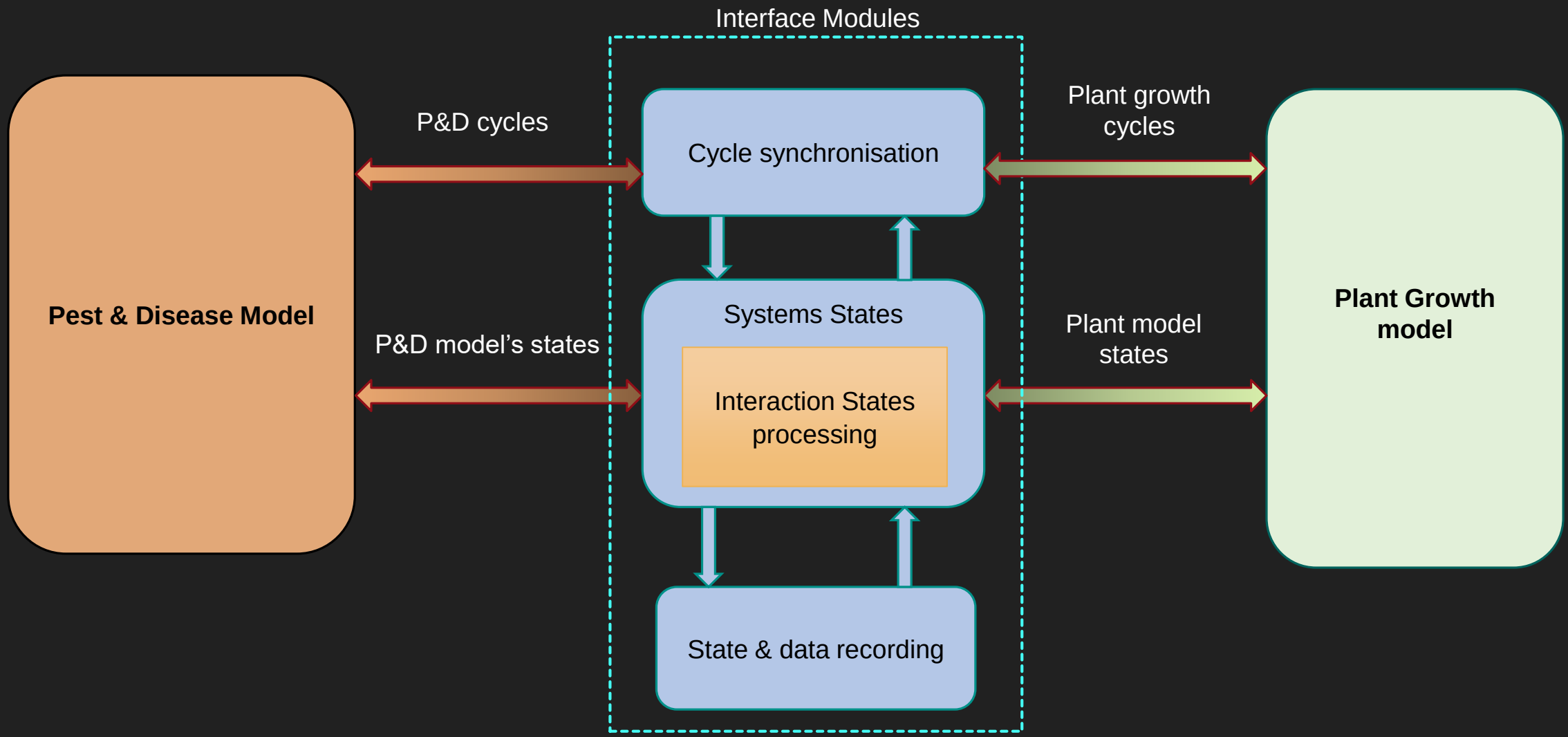
- The components interact via information exchange
- Cohorts based scale approach for both P&D and plant model

- Being able to add multiple models or modules to the interaction
- Avoiding the complexity that comes with coupling multiple models

Structure of the interaction I Genericity

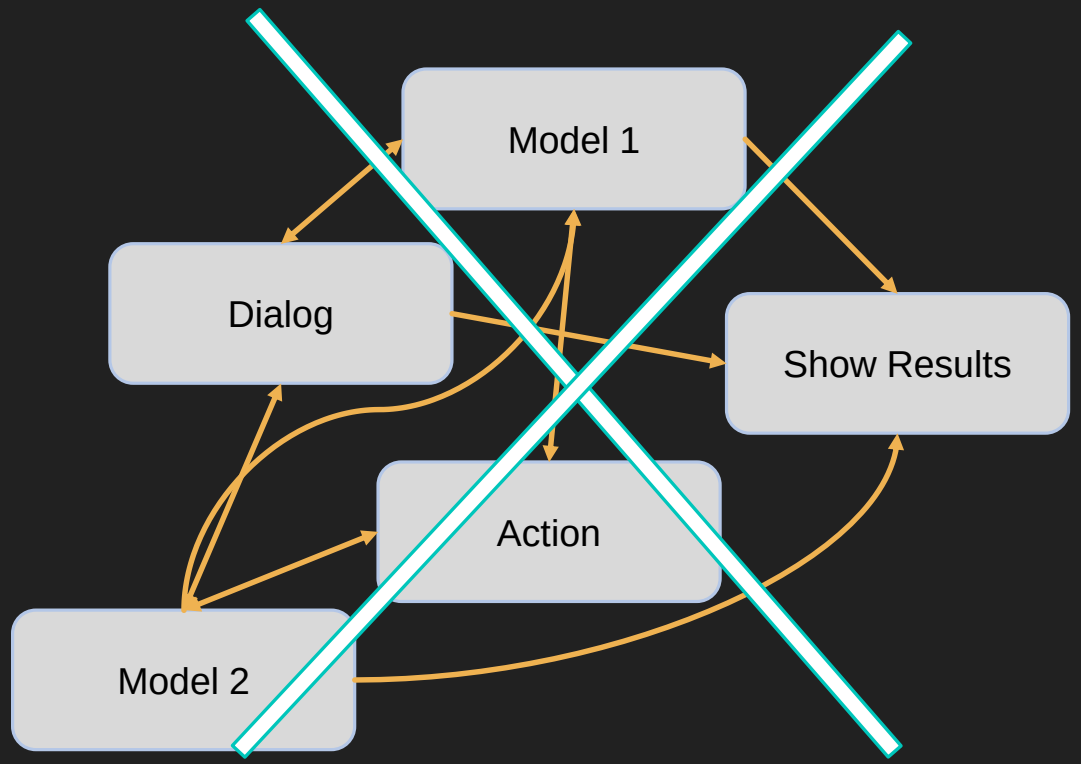


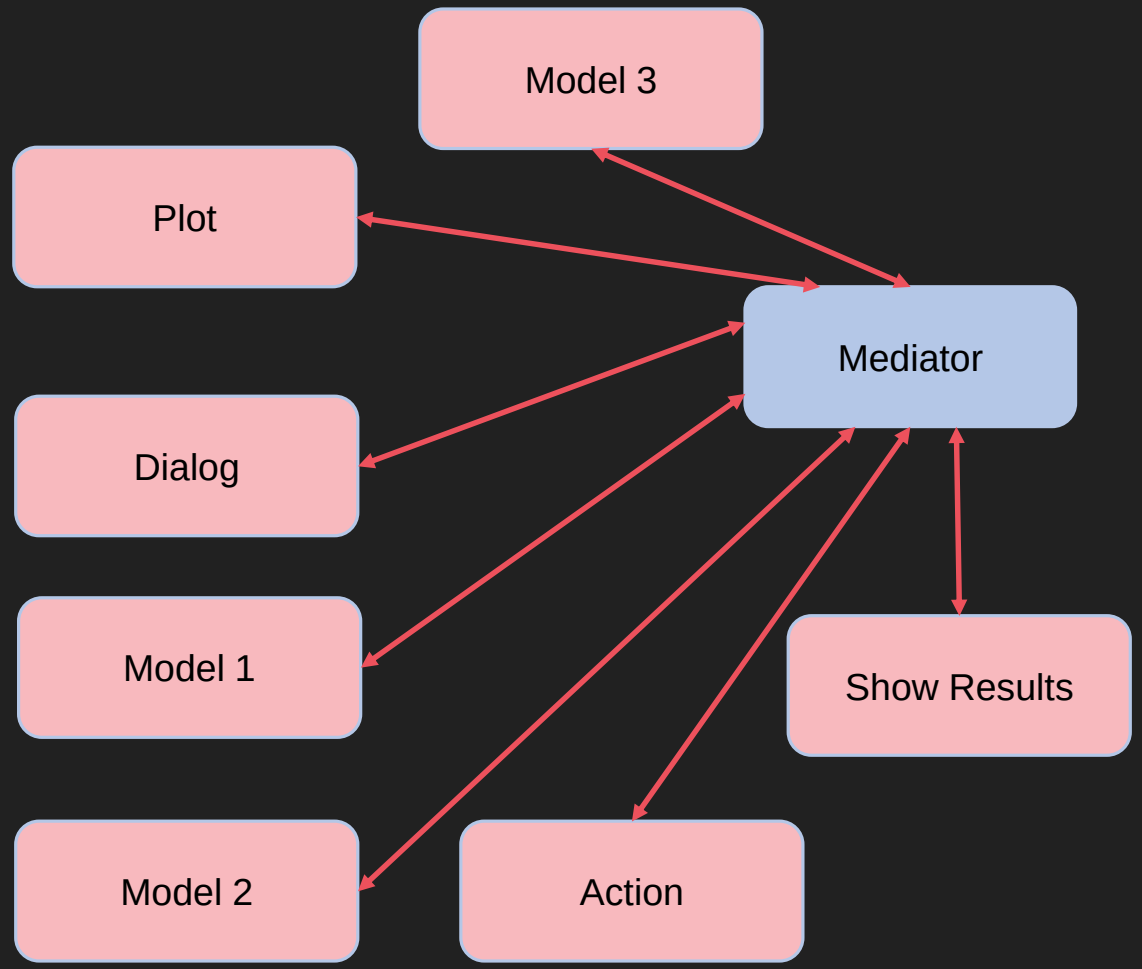
Structure of the interaction II Components



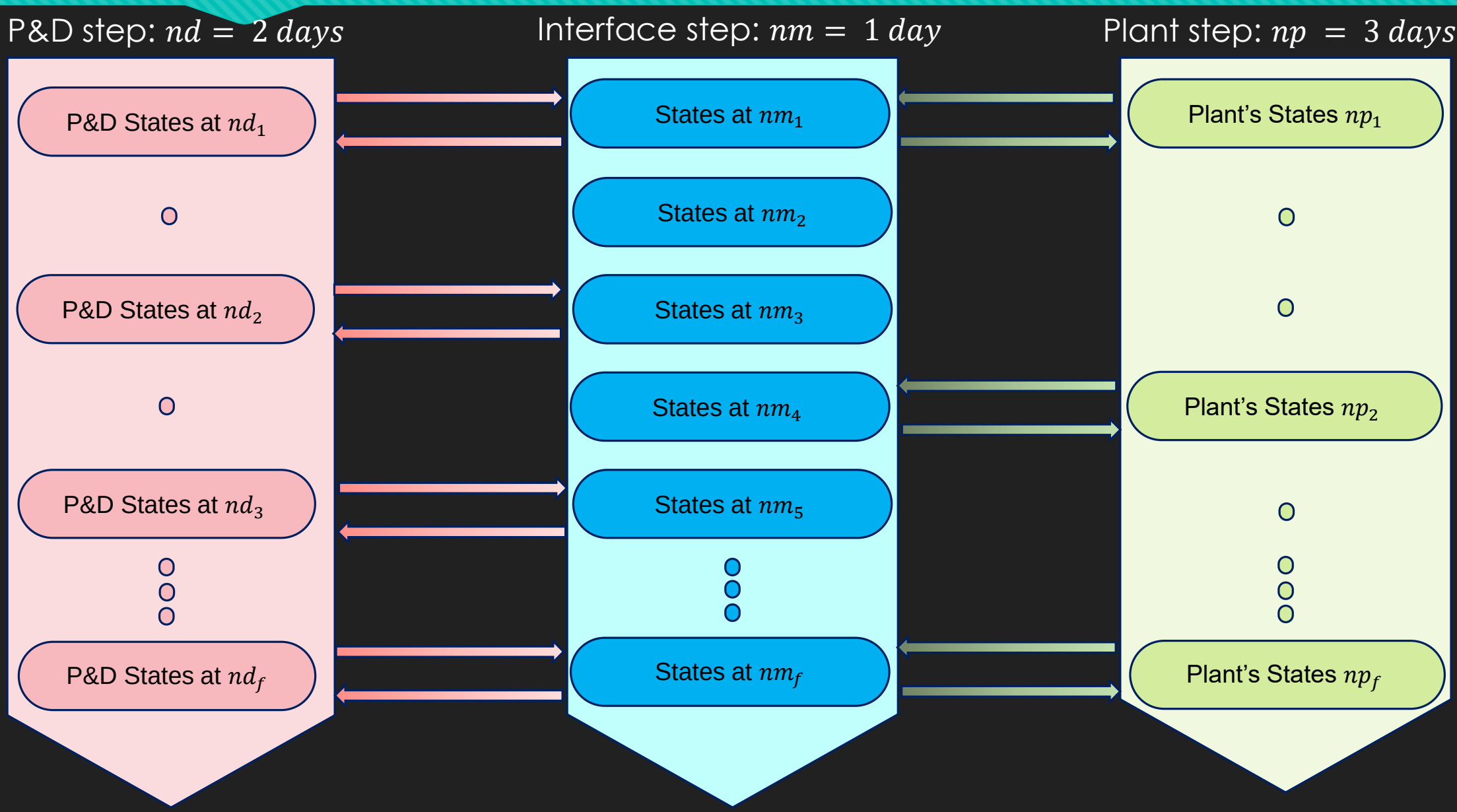
Cycle synchronisation module: Mediator

Gamma *et al.*,1995





System states module: System States



State & data recorder

P&D model's States and data

- ❑ Pest or disease population
- ❑ Population evolution
- ❑ **Number of Attacked organs**
- ❑ Number of fruits

Climate data

- ❑ **Temperature**
- ❑ **Humidity**

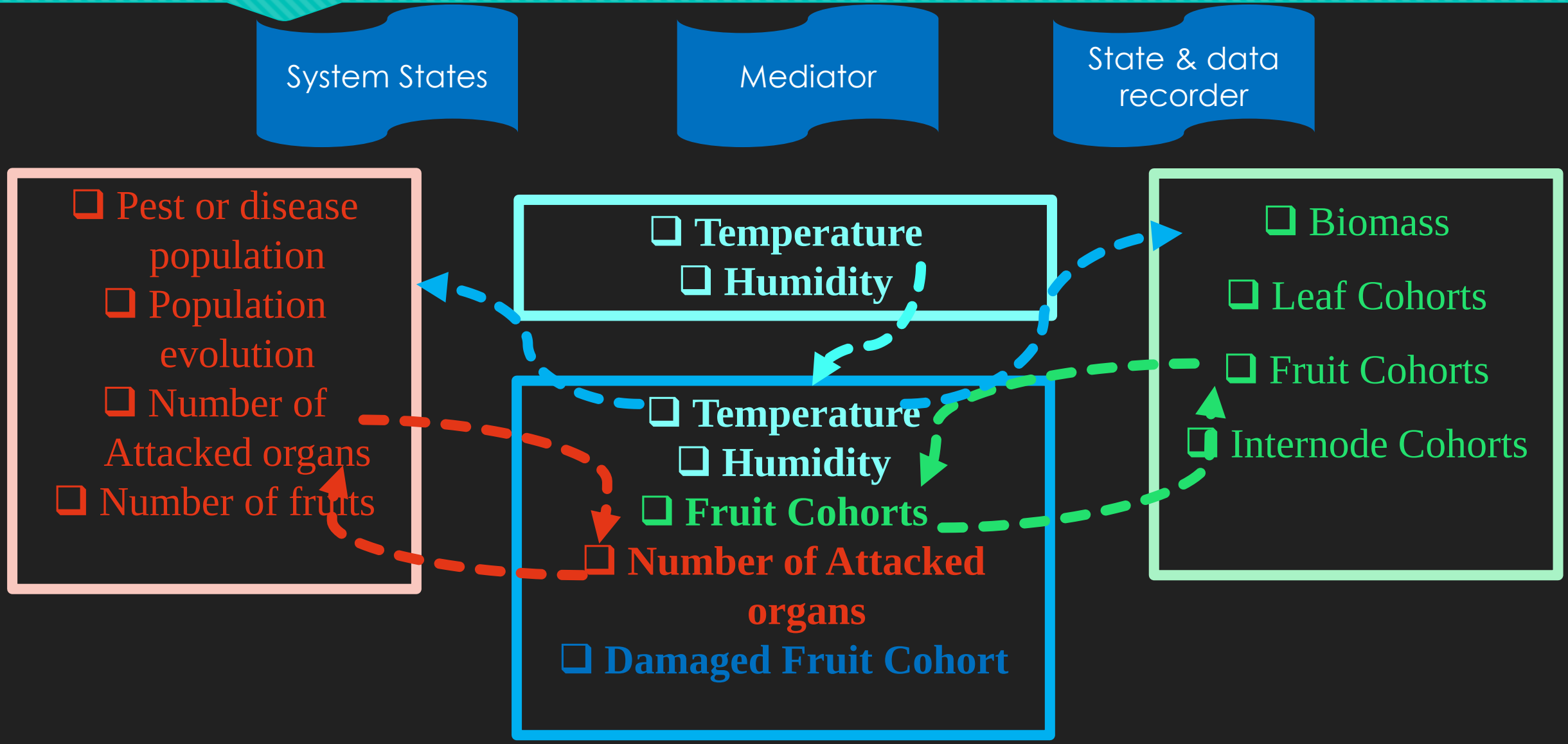
Platform States and data

- ❑ **Temperature**
- ❑ **Humidity**
- ❑ **Fruit Cohorts**
- ❑ **Number of Attacked organs**
- ❑ **Damaged Fruit Cohort**

Plant growth model States and data

- ❑ Biomass
- ❑ Leaf Cohorts
- ❑ **Fruit Cohorts**
- ❑ Internode Cohorts

State & data recorder with state and cycles

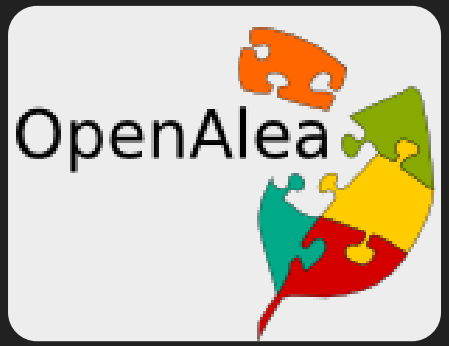


Working environment

Julia and OpenAlea

- Modelling/development oriented language
- Open source
- Compatibility with other environments
- Can call algorithms (models) written in other languages (R, Python, MATLAB…)

```
mutable struct ScolyteGroup
    Born::String
    eggday::Int64
    PopulationInFruits::String
    population::Float64
    DevelopementRate::String
    developement::Float64
    Lifeexp::String
    lifeSpan::Float64
    function ScolyteGroup(eggday, population, developement, lifeSpan)
        Born = "eggday-->"
        PopulationInFruits = "population-->"
        DevelopementRate = "developement-->"
        Lifeexp = "biological age-->"
        new(Born, eggday, PopulationInFruits, population, DevelopementRate, developement, Lifeexp, lifeSpan)
    end
end
```



A first implementation of the formalism

Climatic data & model

P&D Model

Coffee berry borer

Cycle : Day

Interface model

I/O

Synchro

Data

Reduced coffee growth model (fructification)

Coffee Arabica

Cycle : Week

Human intervention model (Crop harvest)

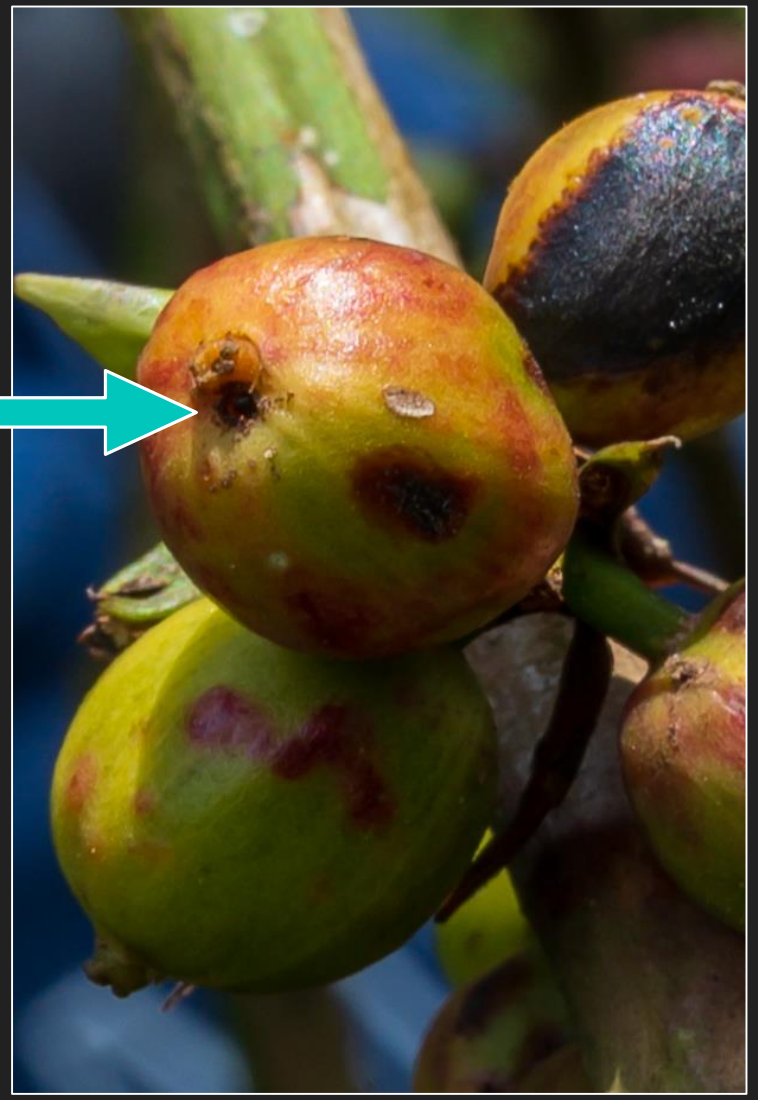
Cycle : Asynchronous

Interaction of Coffee Berry Borer with the coffee tree

- CBB
  - Coffee seeds = a food source
  - Attacks immature and mature coffee berries

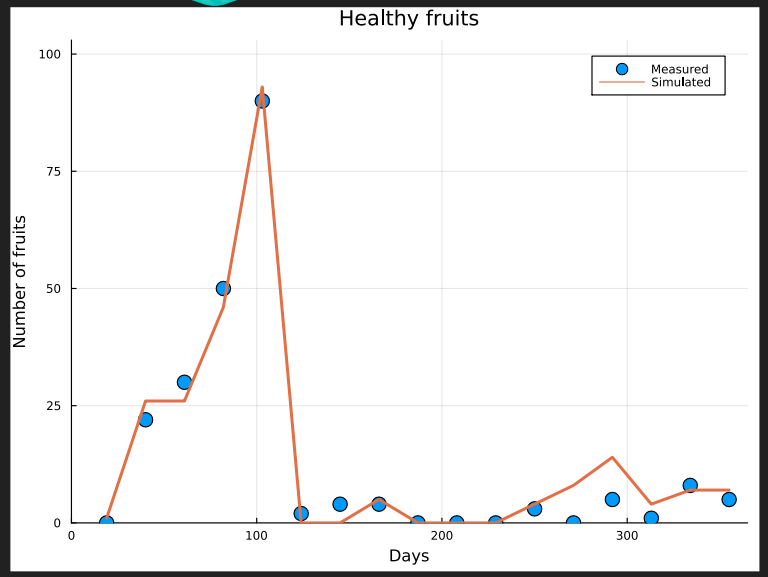
- Premature fall of young berries
- A vulnerability to infections
- Partial loss of the yield

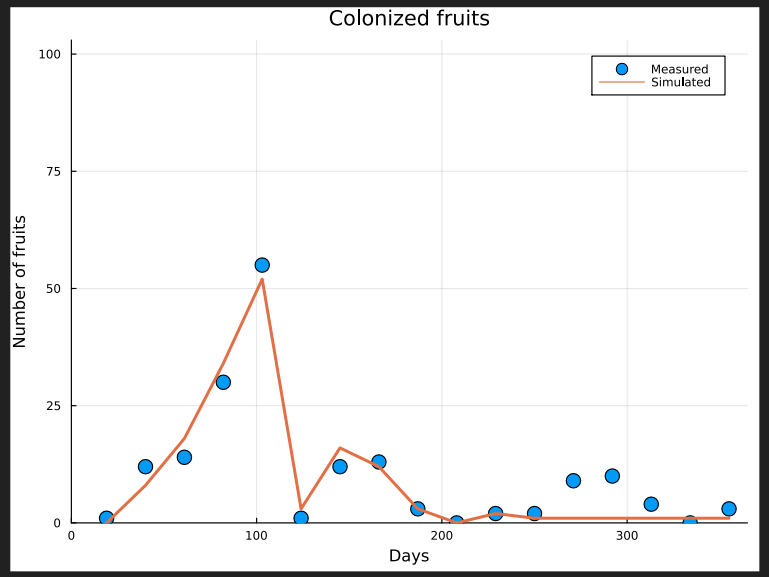
Entry point of the CBB



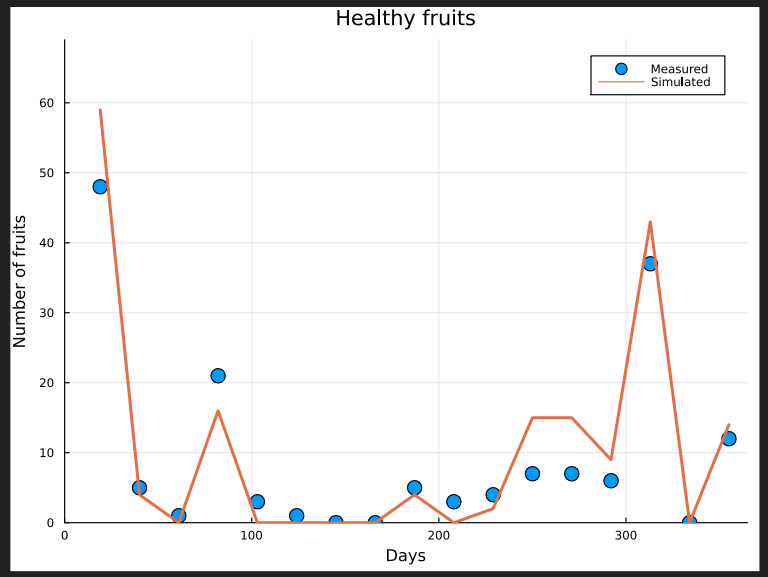
Results

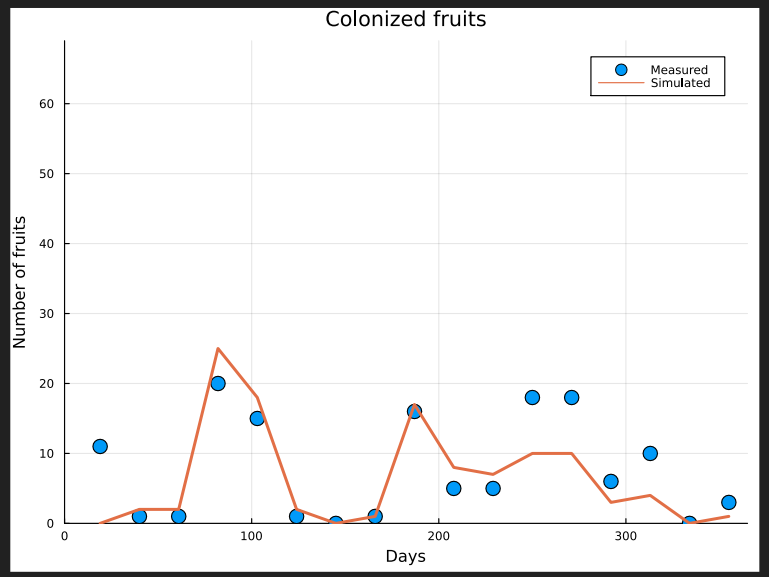
Tree 1





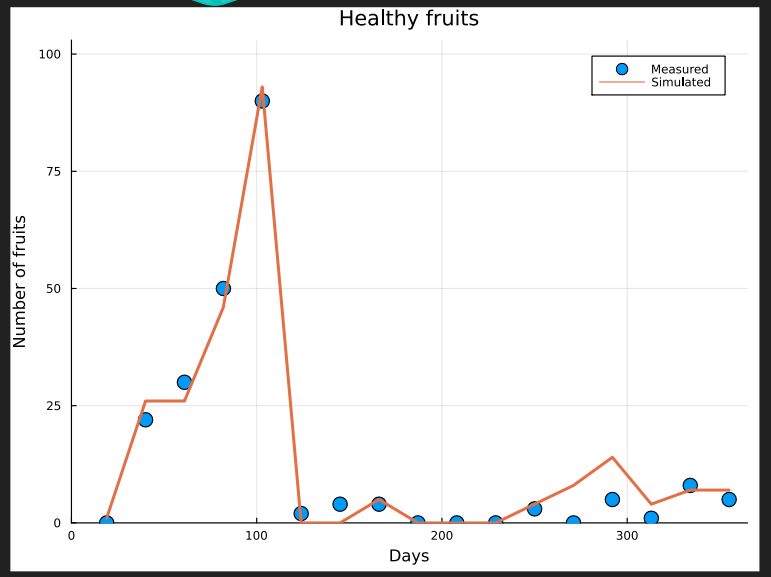
Tree 2

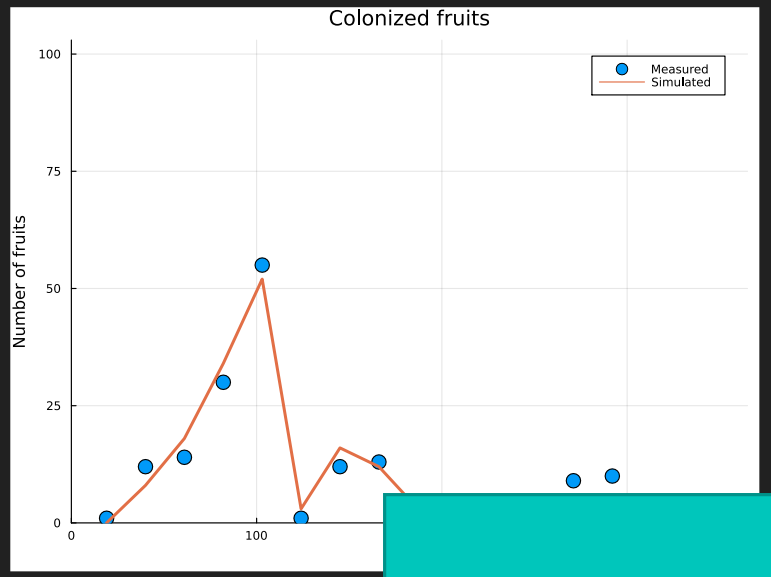




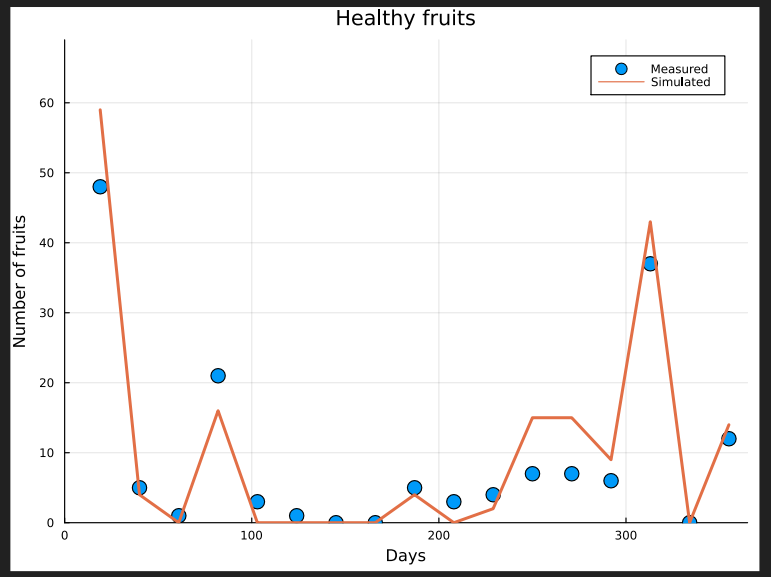
Results

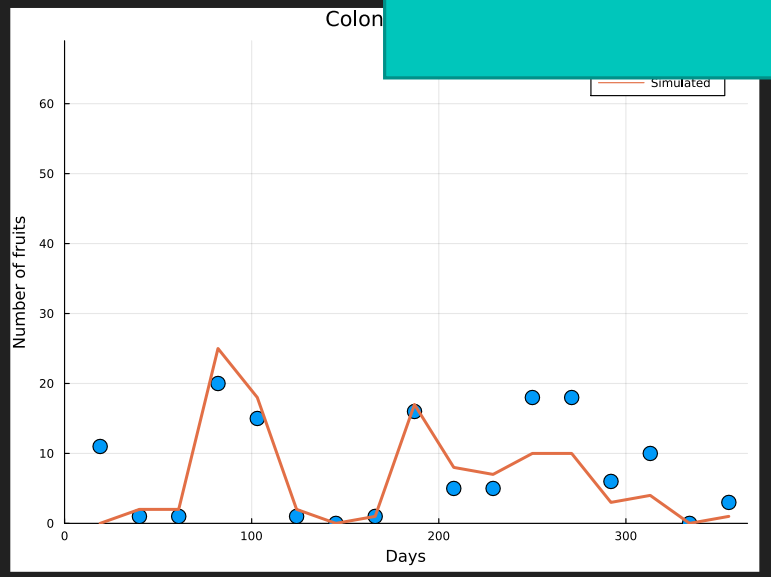
Tree 1





Tree 2





The simulation fits the field data

Perspectives

- **Complete** and **improve** the framework
- Applications :
  - Implementation using **Greenlab** as plant model
  - Other P&D integration (RB, BTB...)
- Validation using Field data (**Uganda**)

Conclusion

- **Generalized** framework proposal
- Integration of **multiple** cohorts based **models**
- **Modular** structure
- First implementation

Thank you for your attention

With Support from :

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