


New features in PHENOFIT5 to better integrate the major components of forest trees fitness

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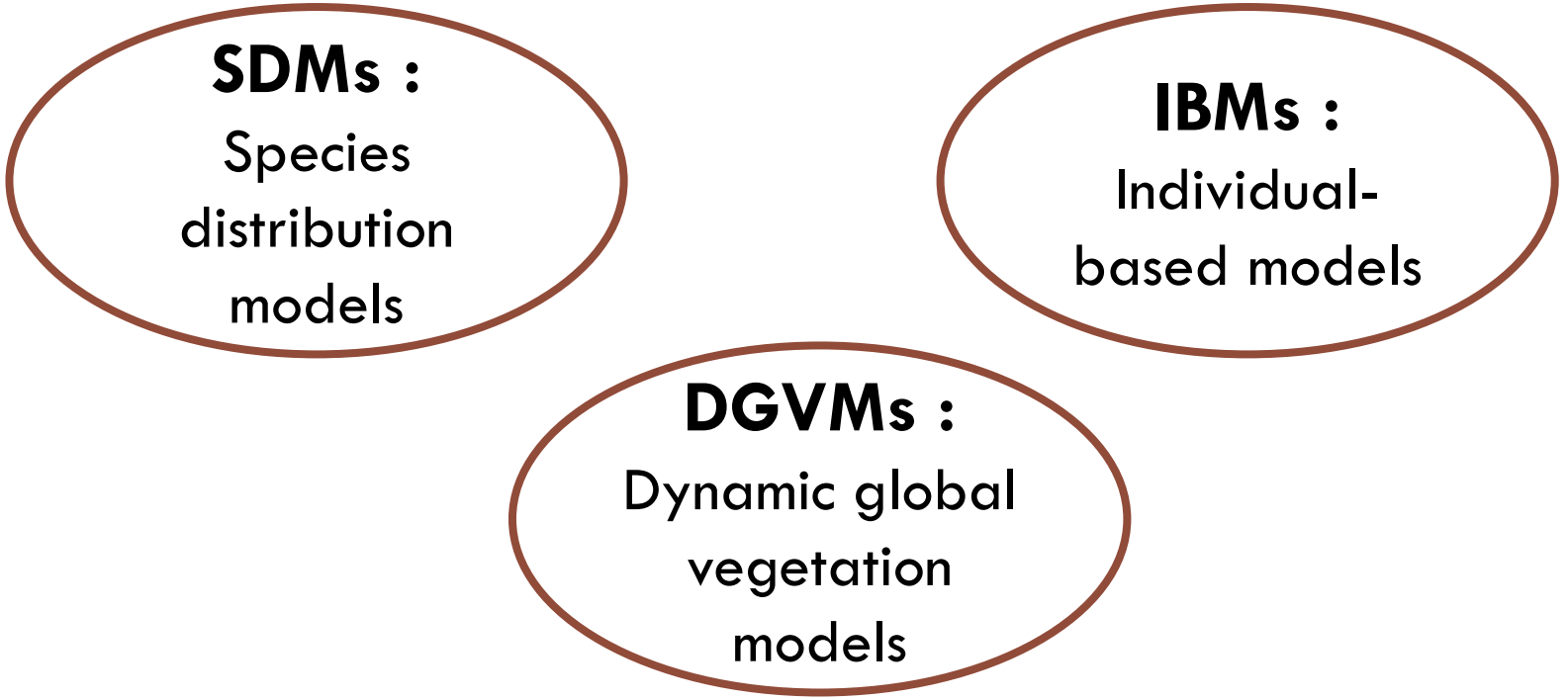
SESSION THEME

What can we learn from models about the impact of climate change on forests?

IMPACTS OF CLIMATE CHANGE ON FORESTS

Report from Academie des Sciences 2023

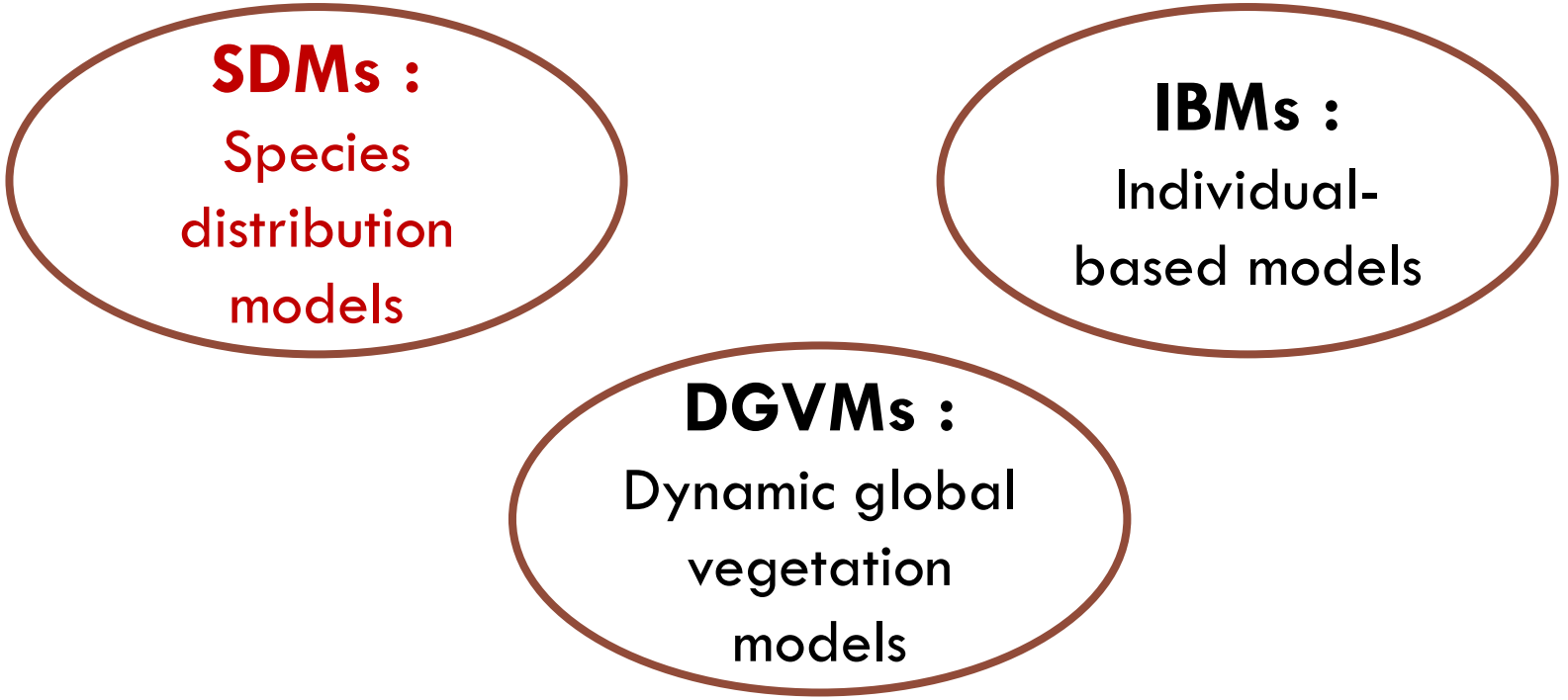
FOREST MODELS CAN PREDICT THOSE IMPACTS



Forest model types

Maréchaux et al. 2021

FOREST MODELS CAN PREDICT THOSE IMPACTS

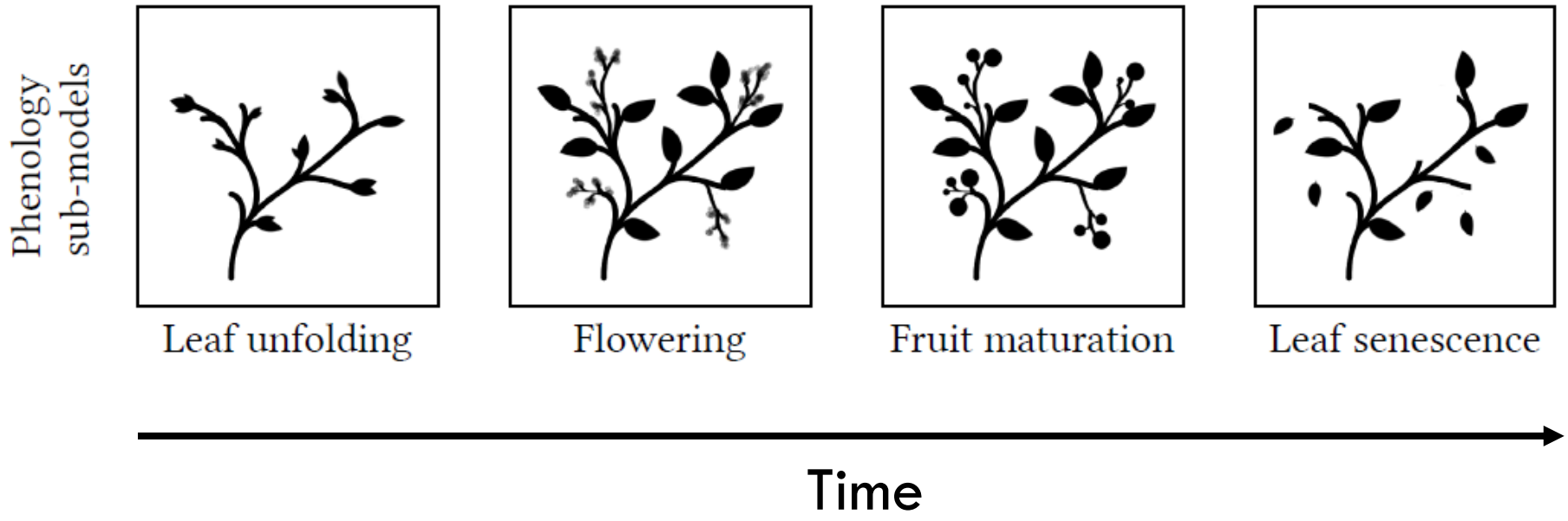


Forest model types

Maréchaux et al. 2021

PHENOFIT: A PROCESS-BASED SDM

Predict potential species distribution **based on eco-physiological processes** taking into account **phenology**.



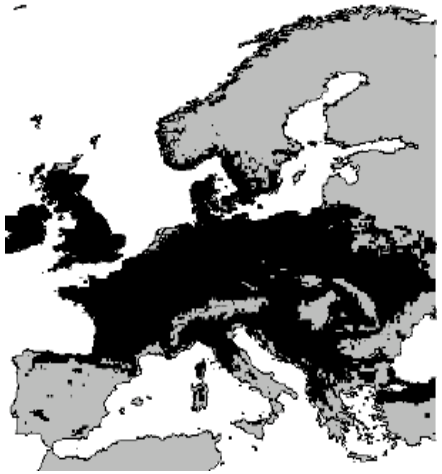
Chuine & Beaubien 2001, Figure Van der Meersch 2023

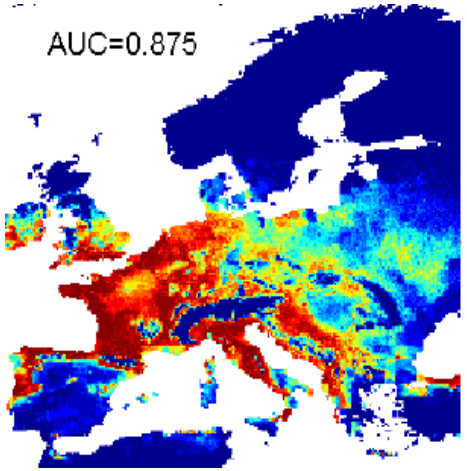
PHENOFIT: A PROCESS-BASED SDM

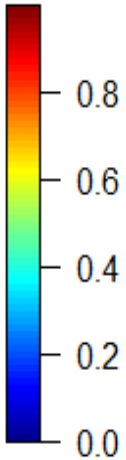
Observed
presence / **absence**

PHENOFIT Fitness

Chêne sessile
(Quercus petraea)



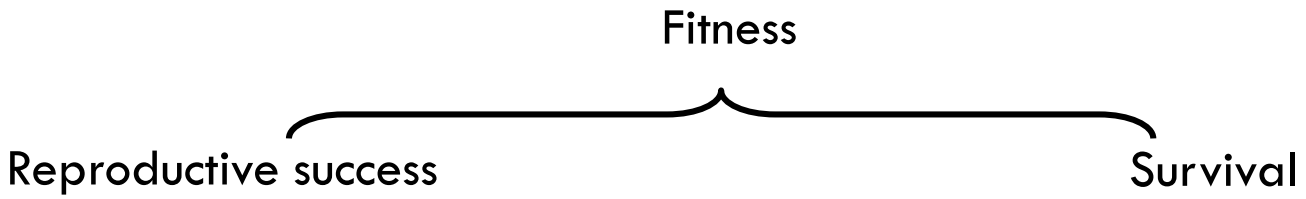




Potential species distribution trough fitness

Chuine & Beaubien 2001, Duputié et al. 2015

FITNESS



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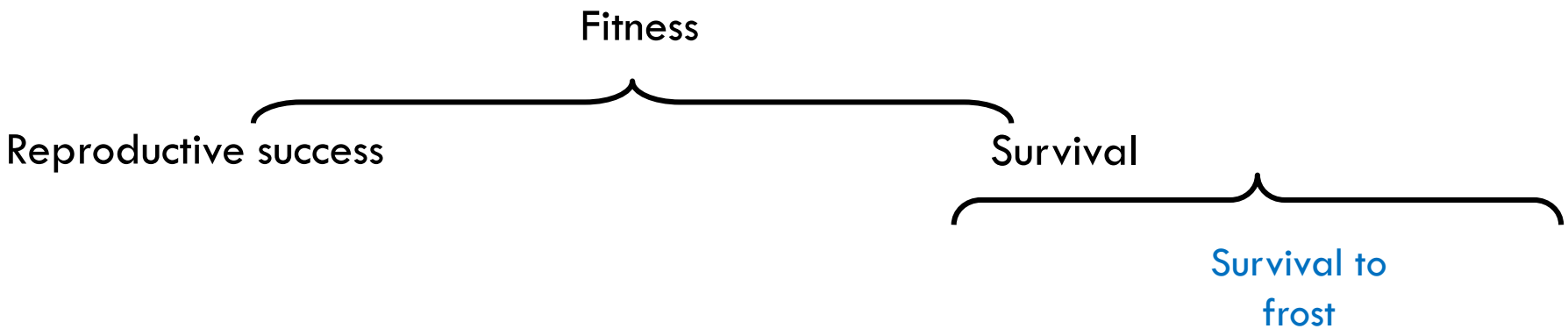

Figure Van der Meersch 2023

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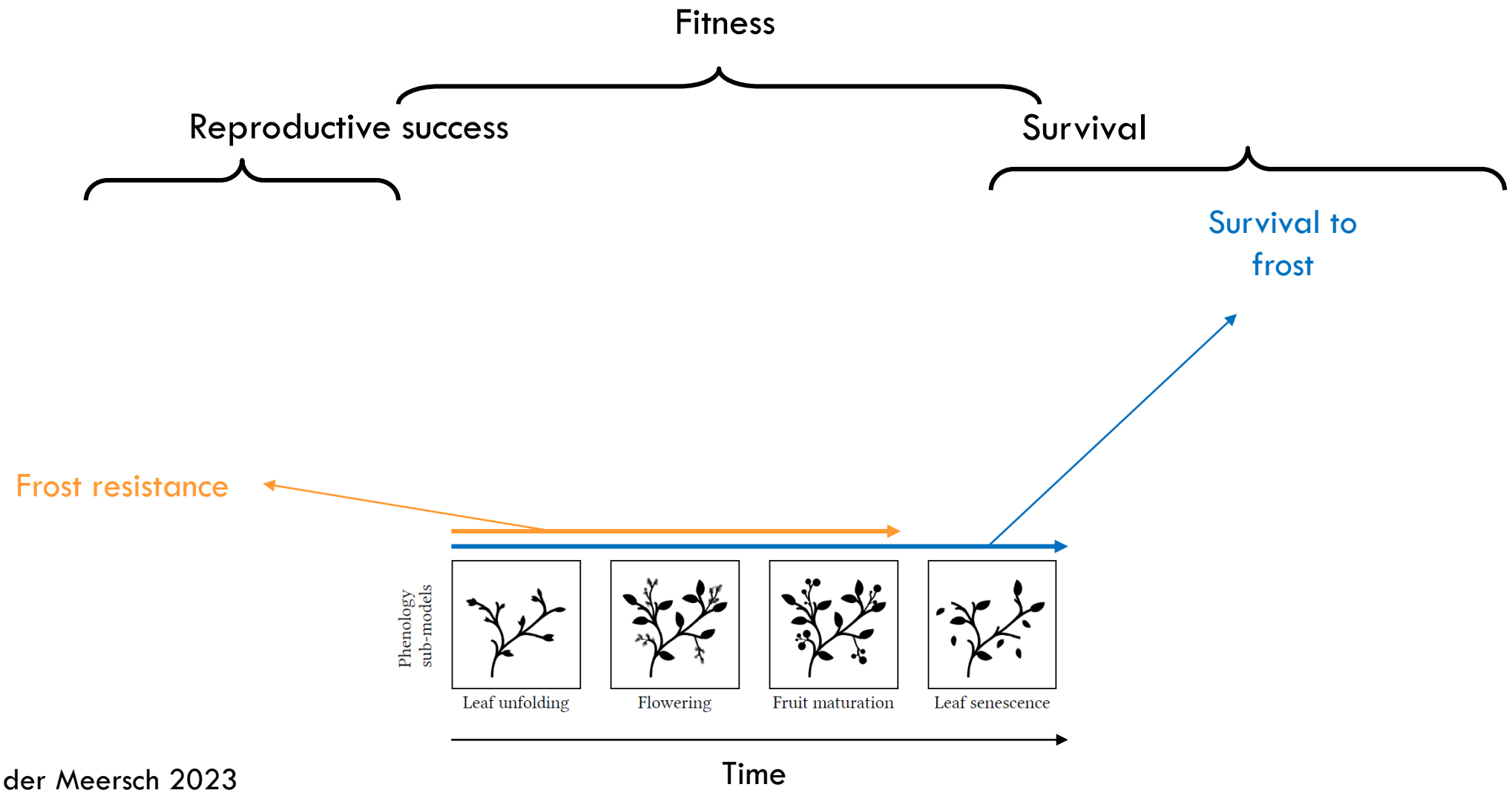

Figure Van der Meersch 2023

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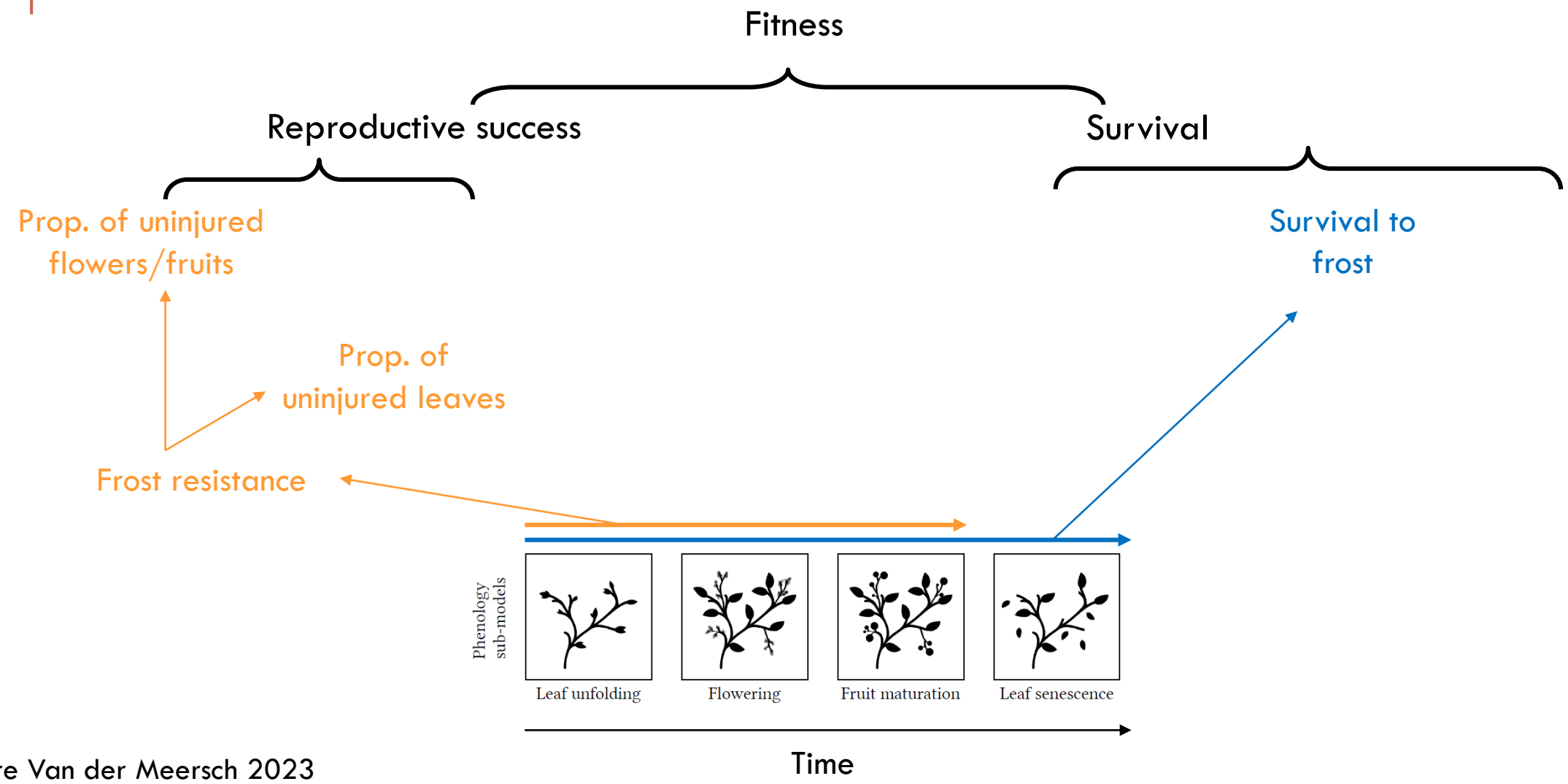

Figure Van der Meersch 2023

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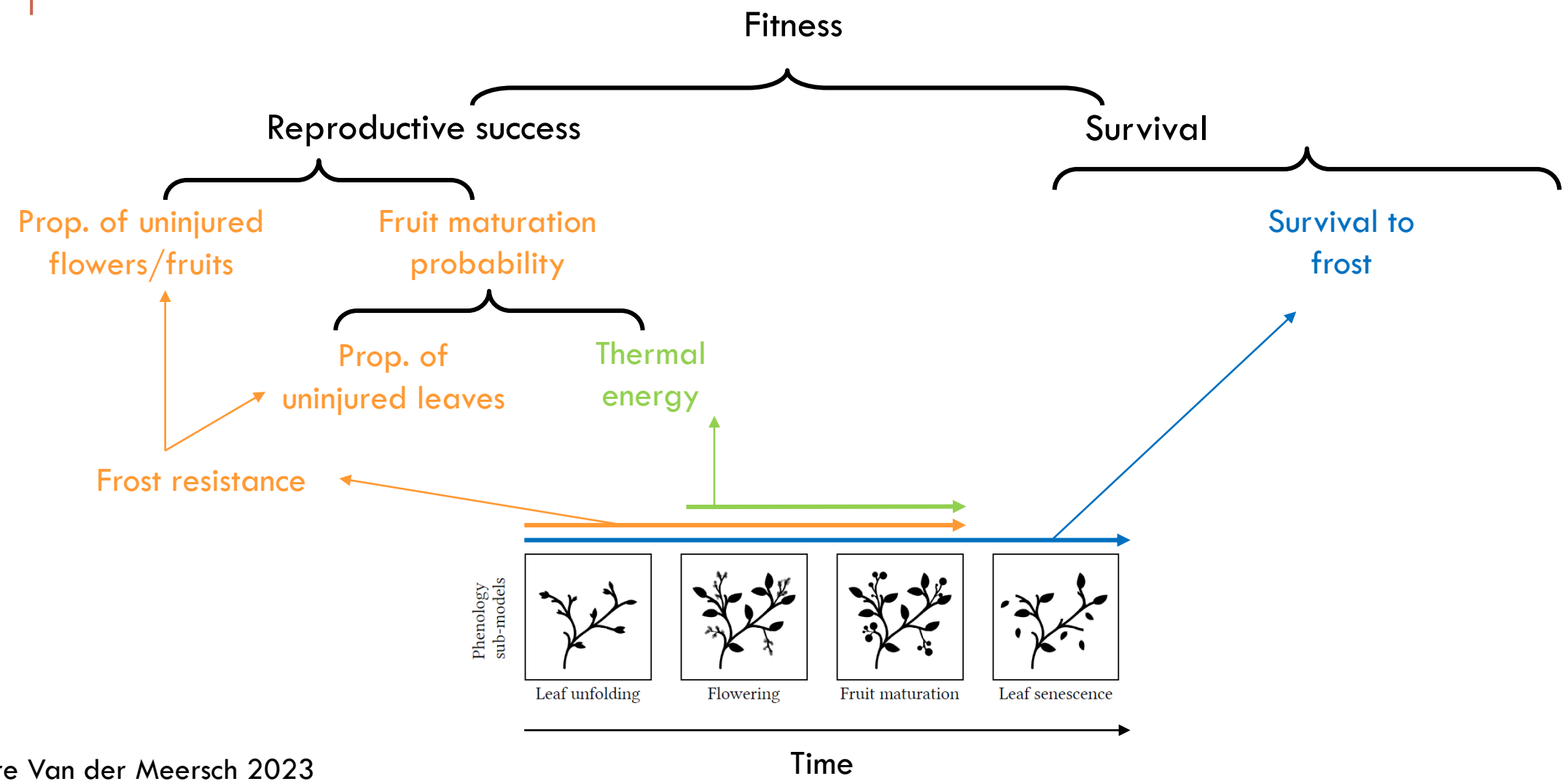

Figure Van der Meersch 2023

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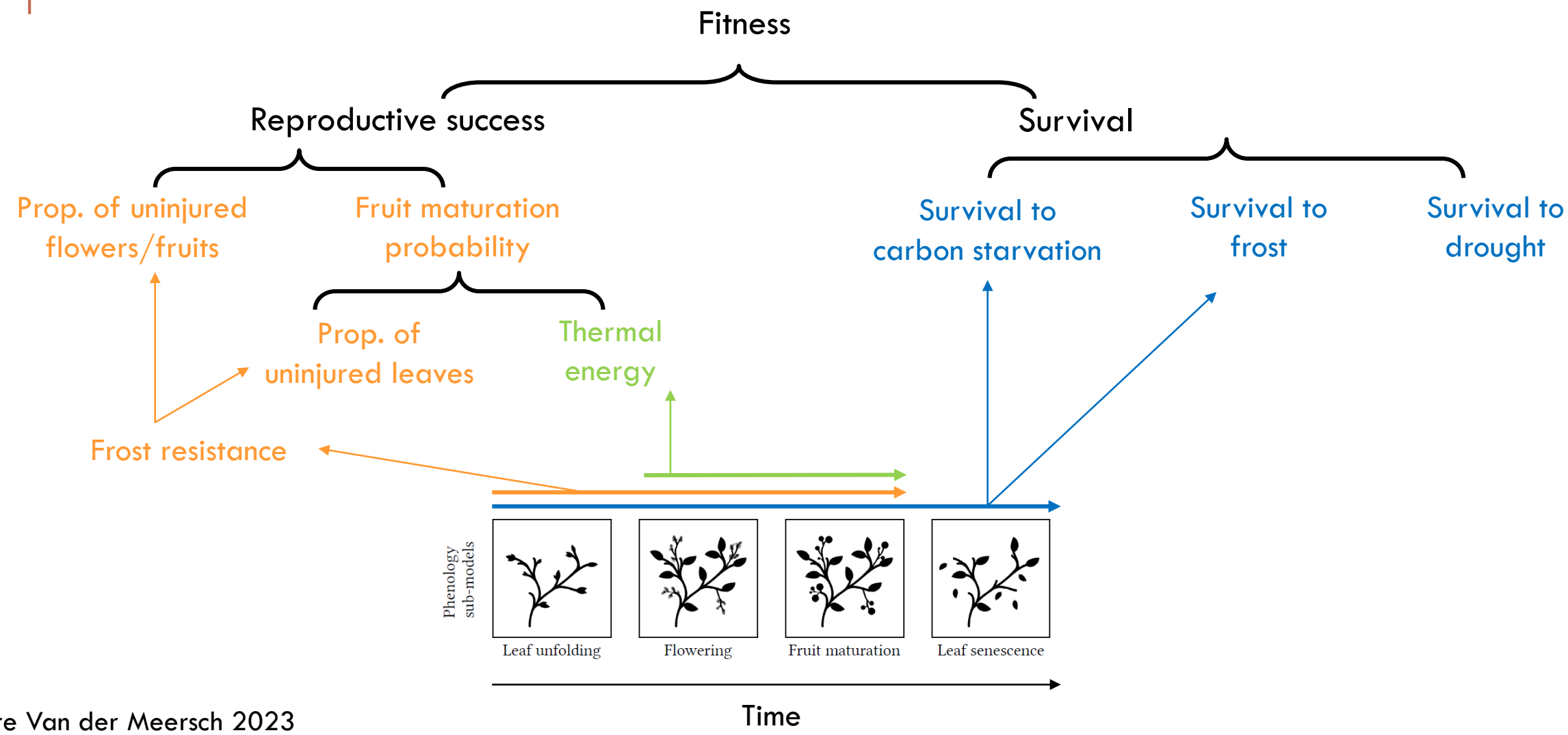

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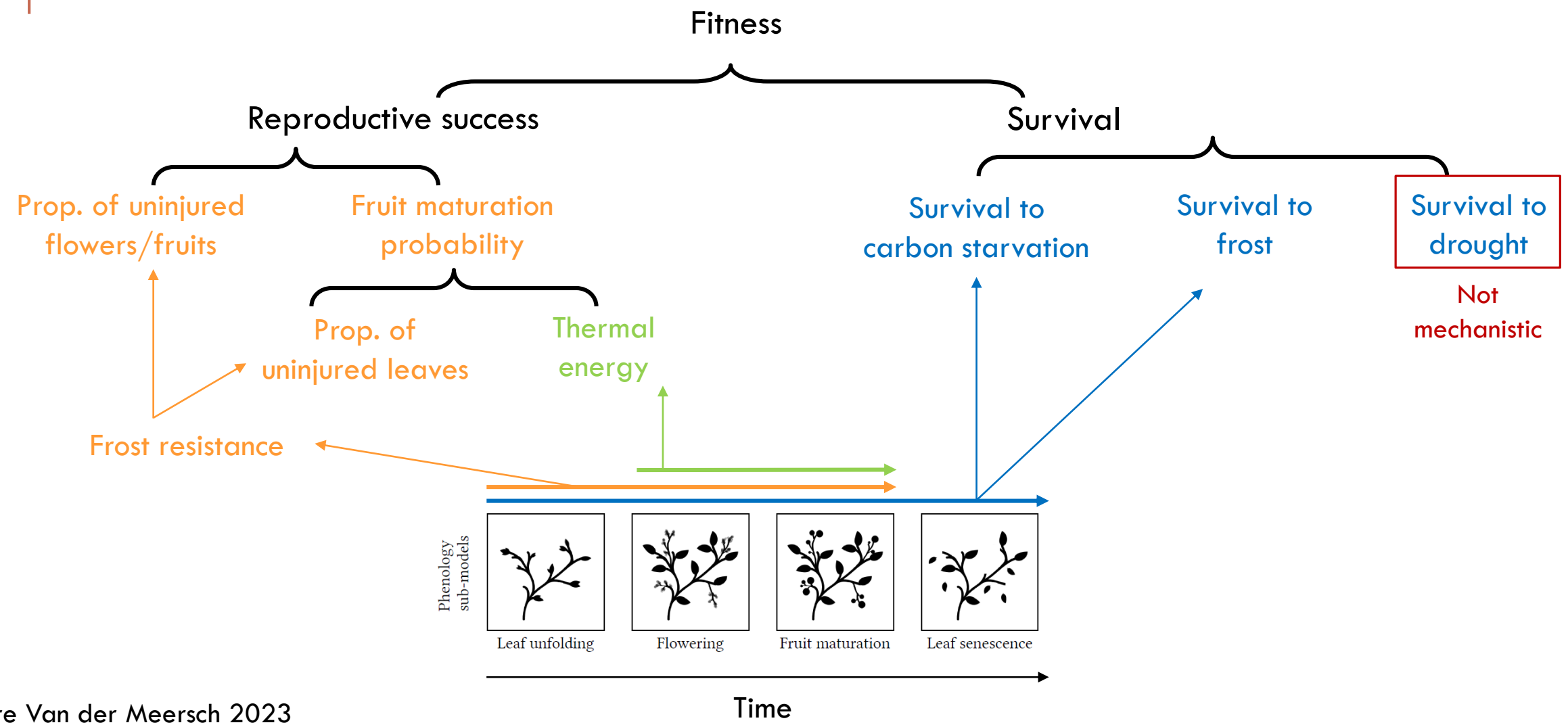

Figure Van der Meersch 2023

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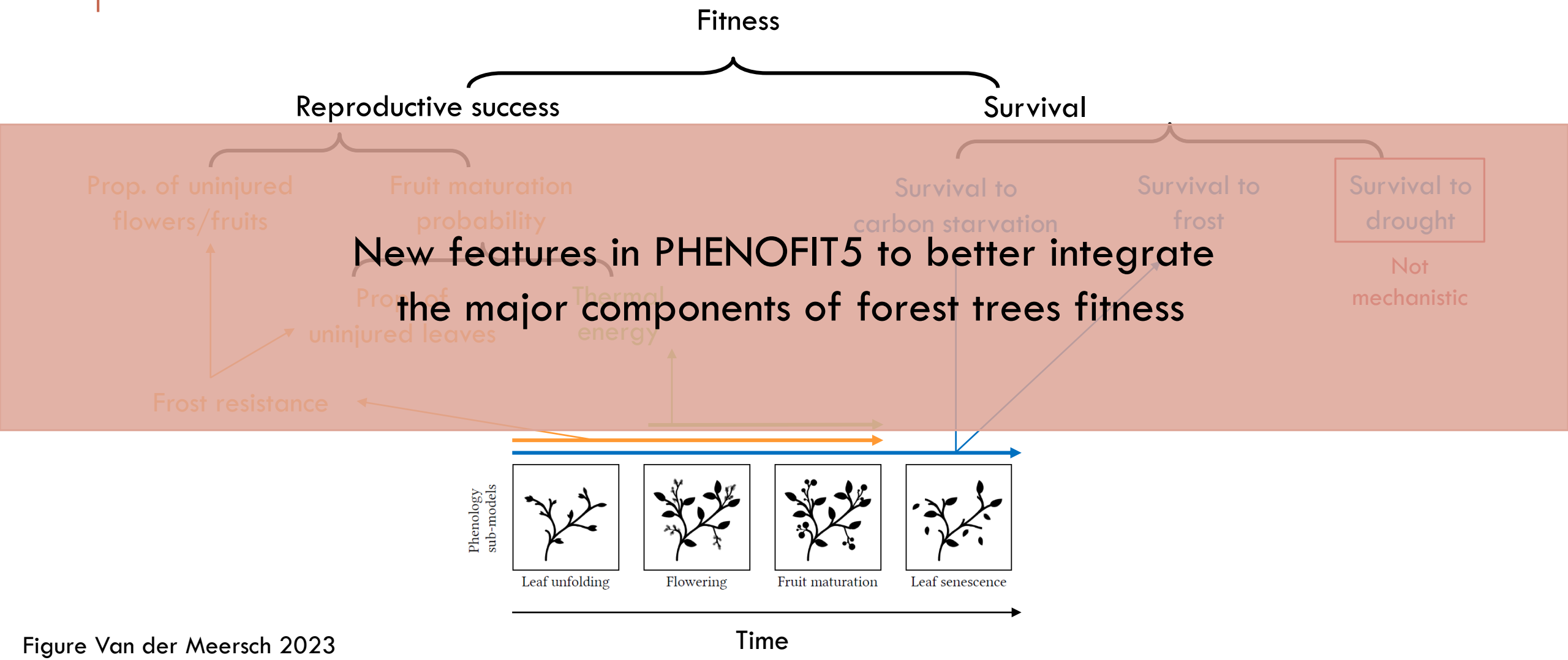
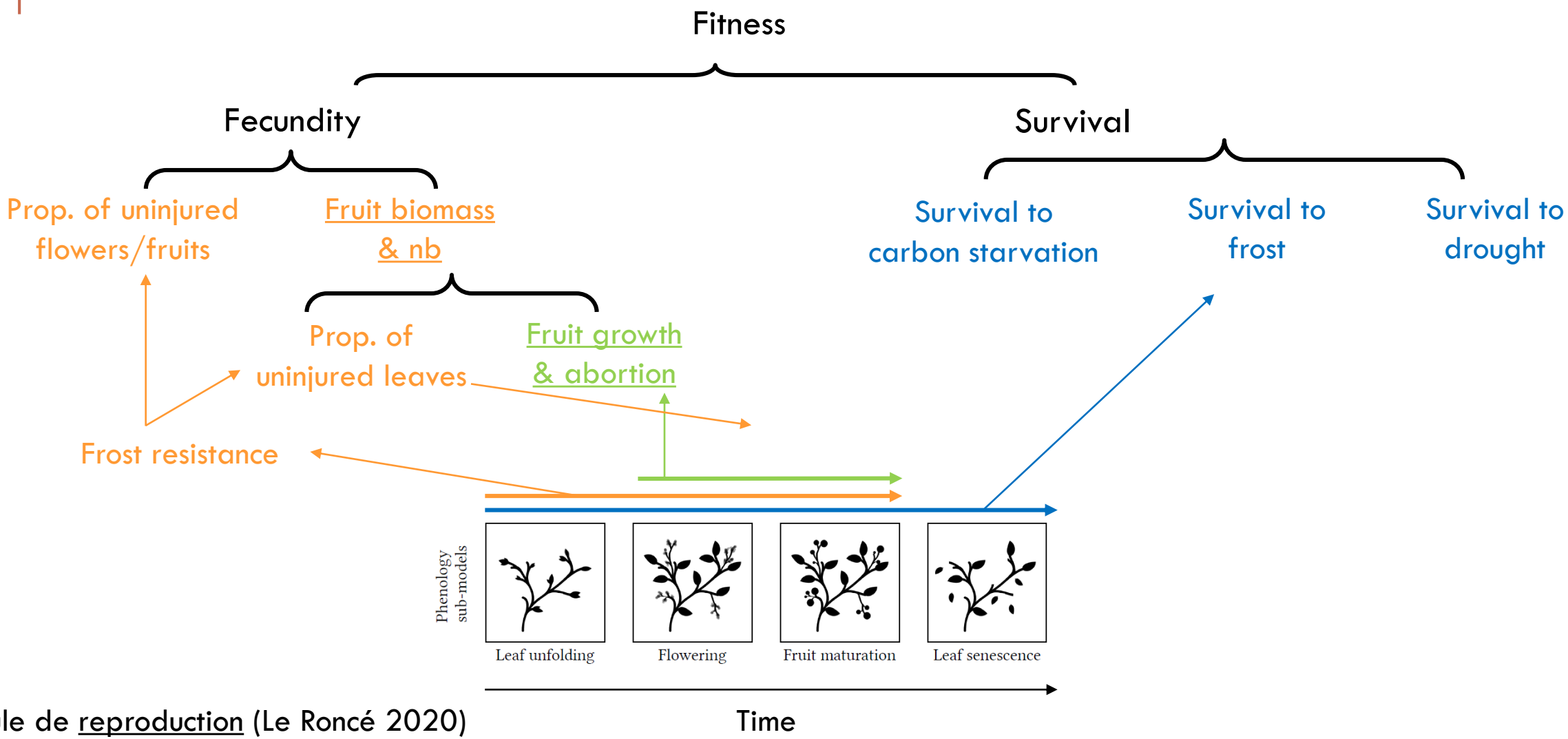


New features in PHENOFIT5 to better integrate the major components of forest trees fitness

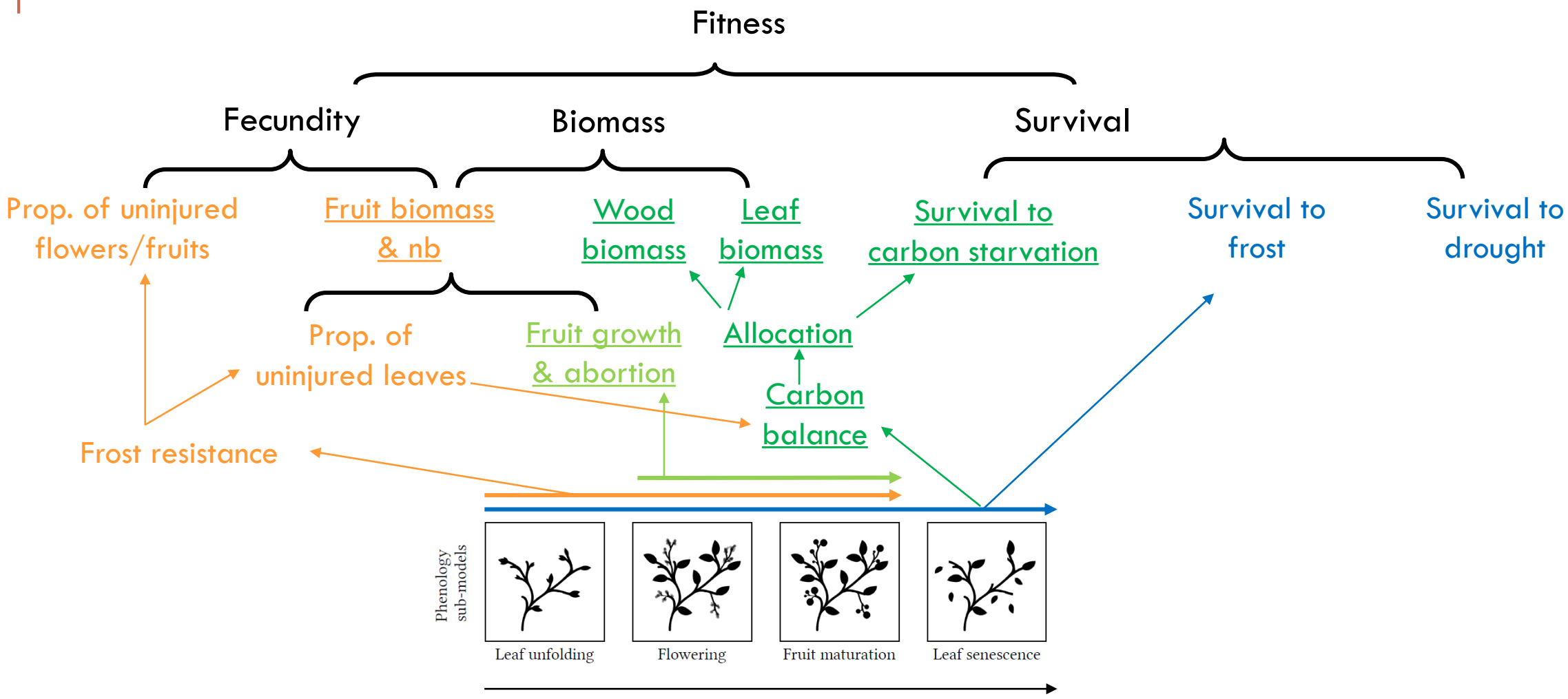
Figure Van der Meersch 2023

PHENOFIT5



Module de reproduction (Le Roncé 2020)

PHENOFIT5



Module de reproduction (Le Roncé 2020)

Module: modèle SIERRA (Mouillot 2001)

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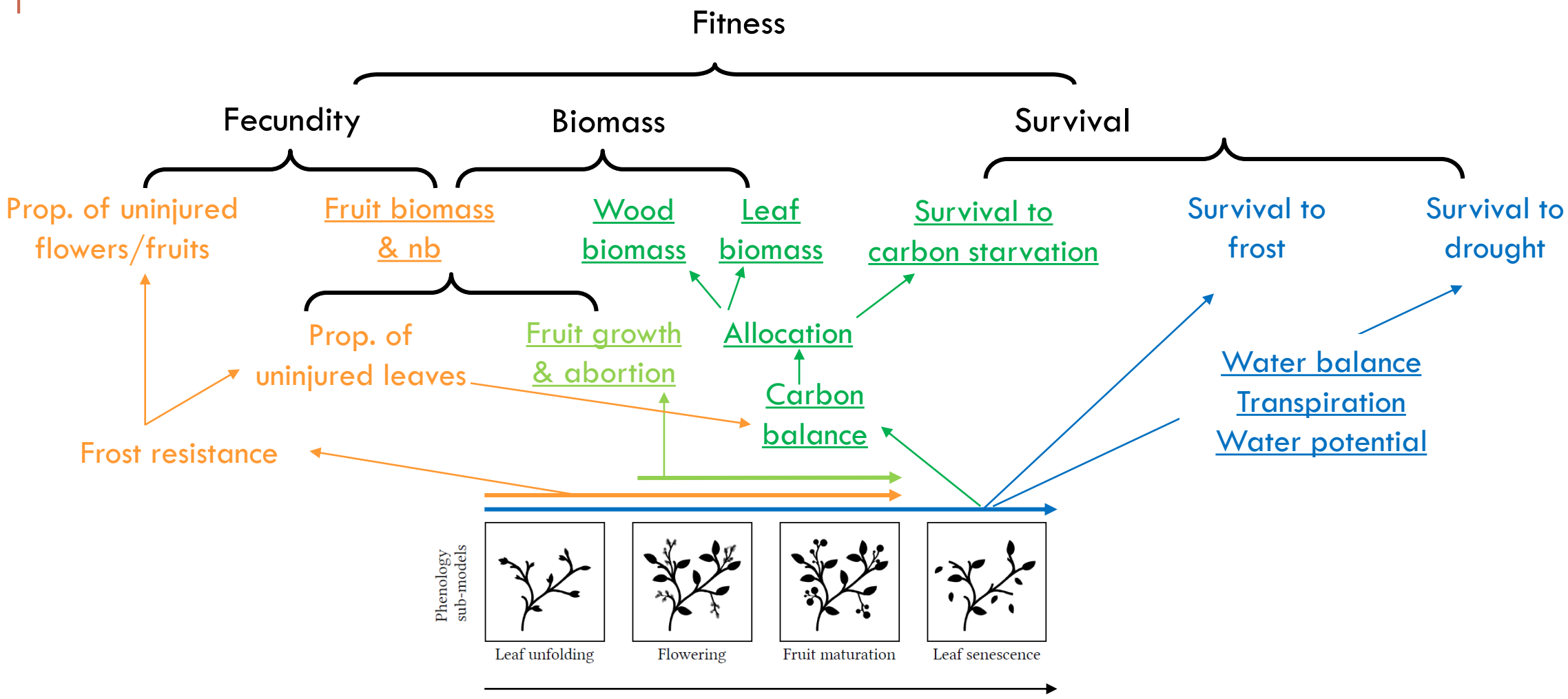

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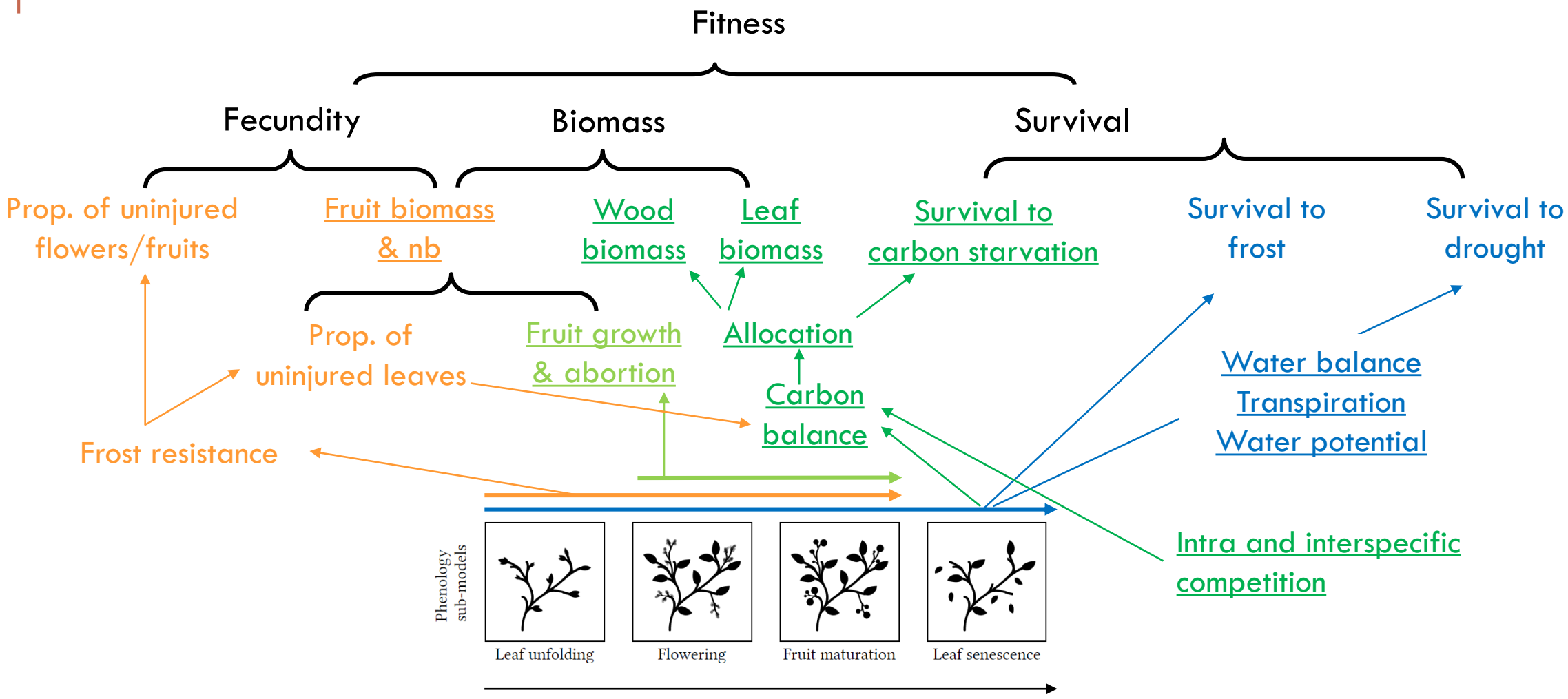


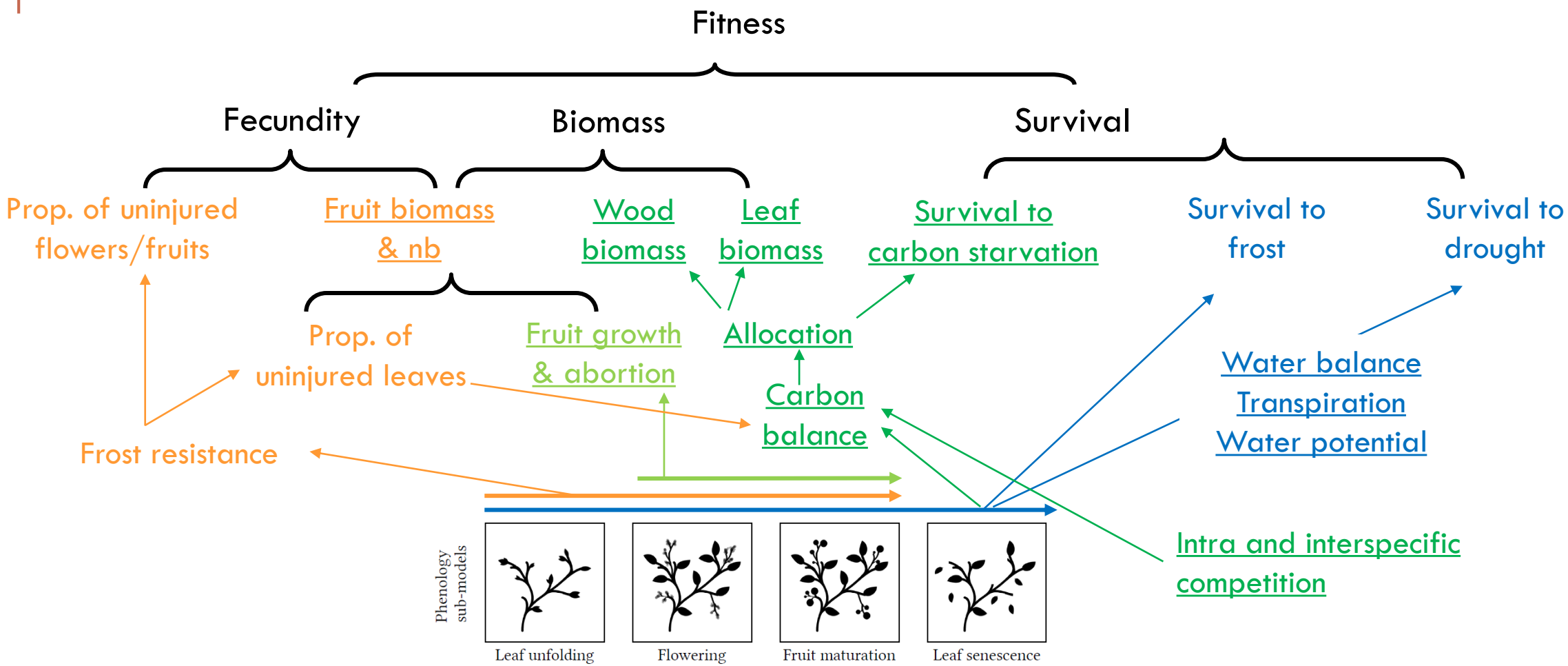
Module de reproduction (Le Roncé 2020)

Module: modèle SIERRA (Mouillot 2001)

RUN PHENOFIT5

Model inputs

Species parameters Local environment



RUN PHENOFIT5

Model inputs:

Species parameters

- Phenological dates
- Growth
- Reproduction
- Stress resistance (frost, drought)

~ 60 parameters

Local environment:

- Daily meteorological data:
  - Temperatures min, max
  - Precipitation
  - Evapotranspiration
- Photoperiod
- Soil water holding capacity

Initial condition : Wood biomass, species, age…

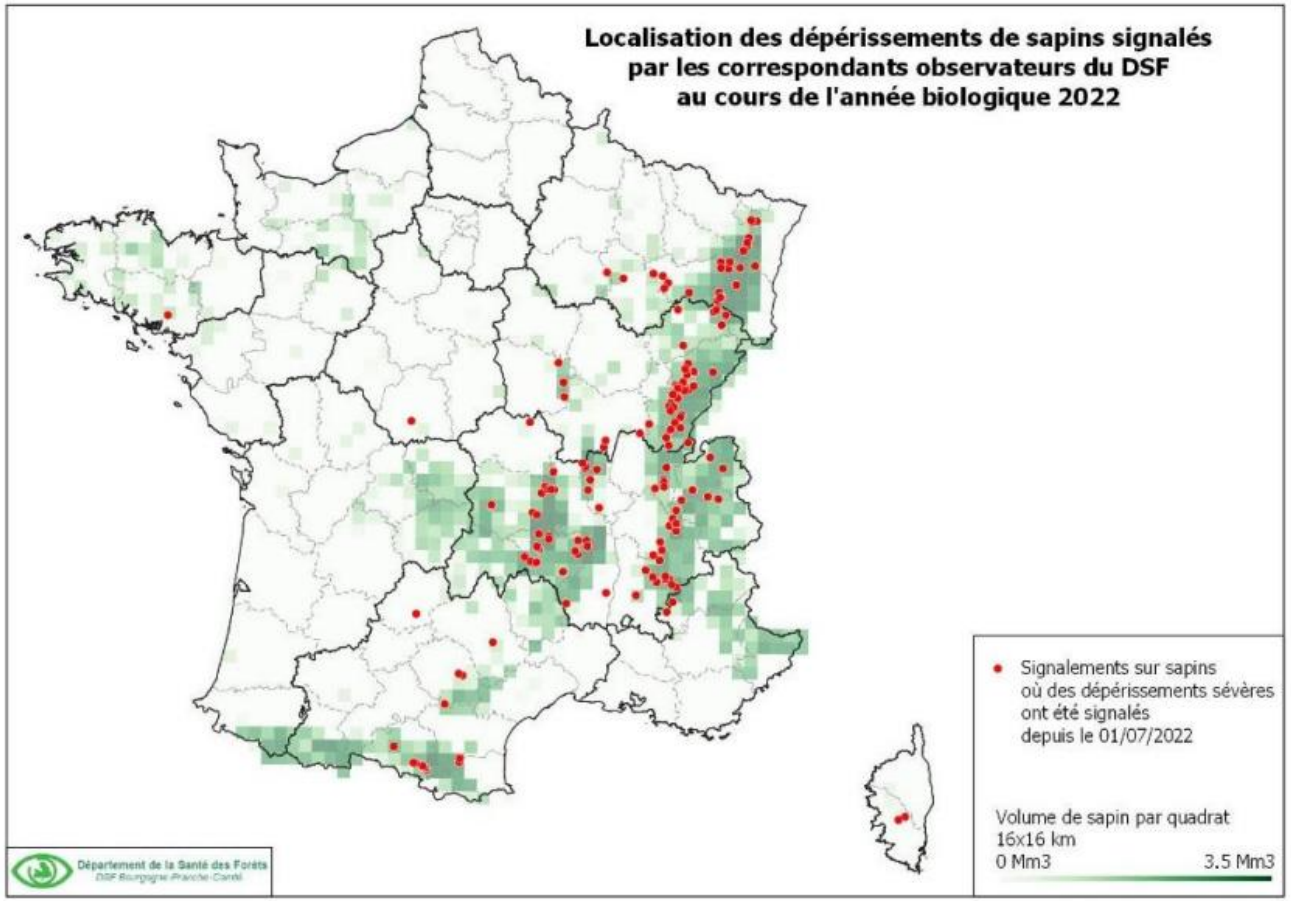
MY CURRENT PROJECT

Can we predict selection on forest trees under future climate using a phenological model?

ANR FLORES

LOCAL ADAPTATION TO CLIMATE CHANGE

- **Genetic adaptation**



Burrows et al. 2011

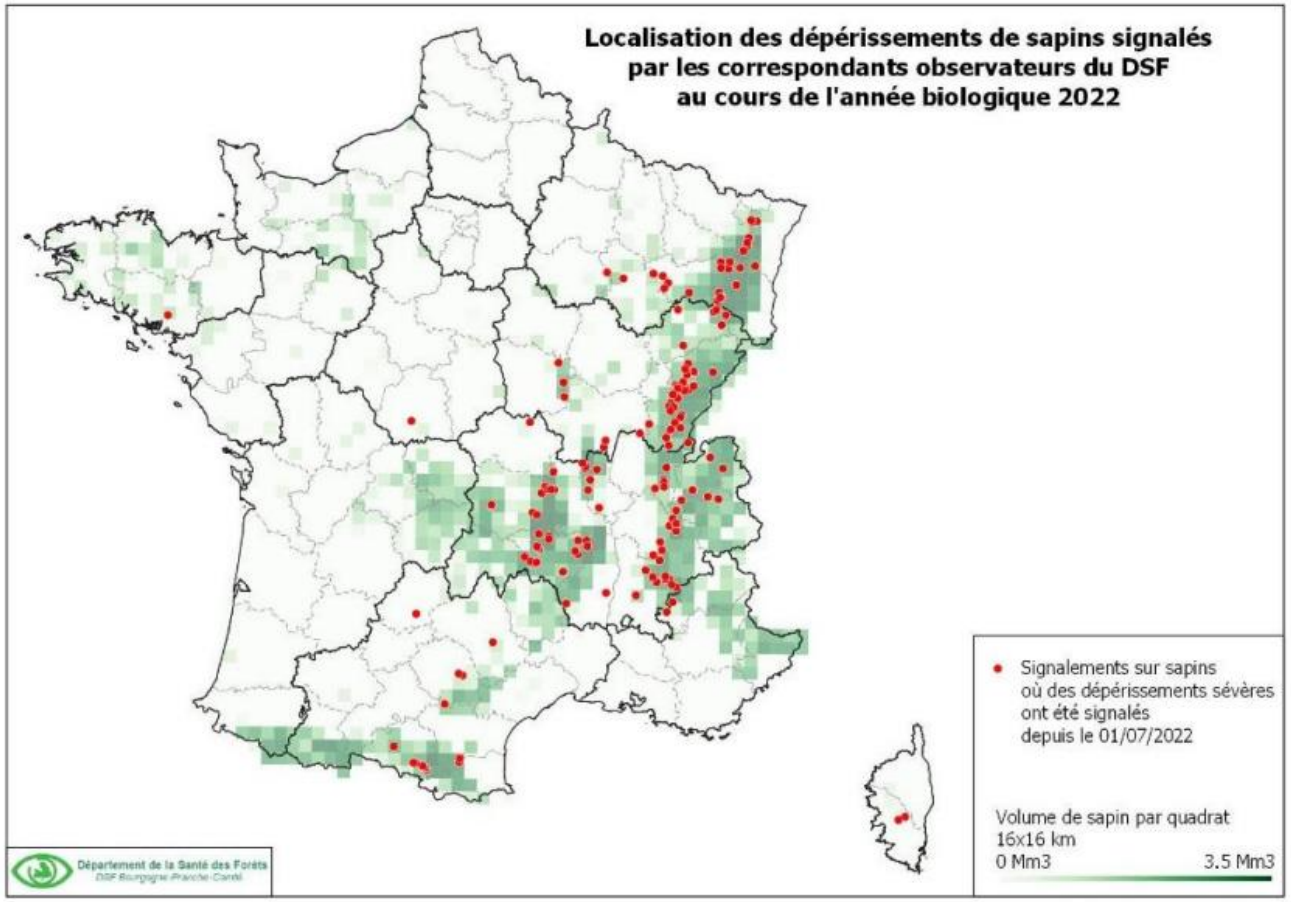
Département de la Santé des Forêts 2022

LOCAL ADAPTATION TO CLIMATE CHANGE

- **Genetic adaptation**

Speed of adaptation << Speed of climate change

for long-lived organism as trees



Burrows et al. 2011

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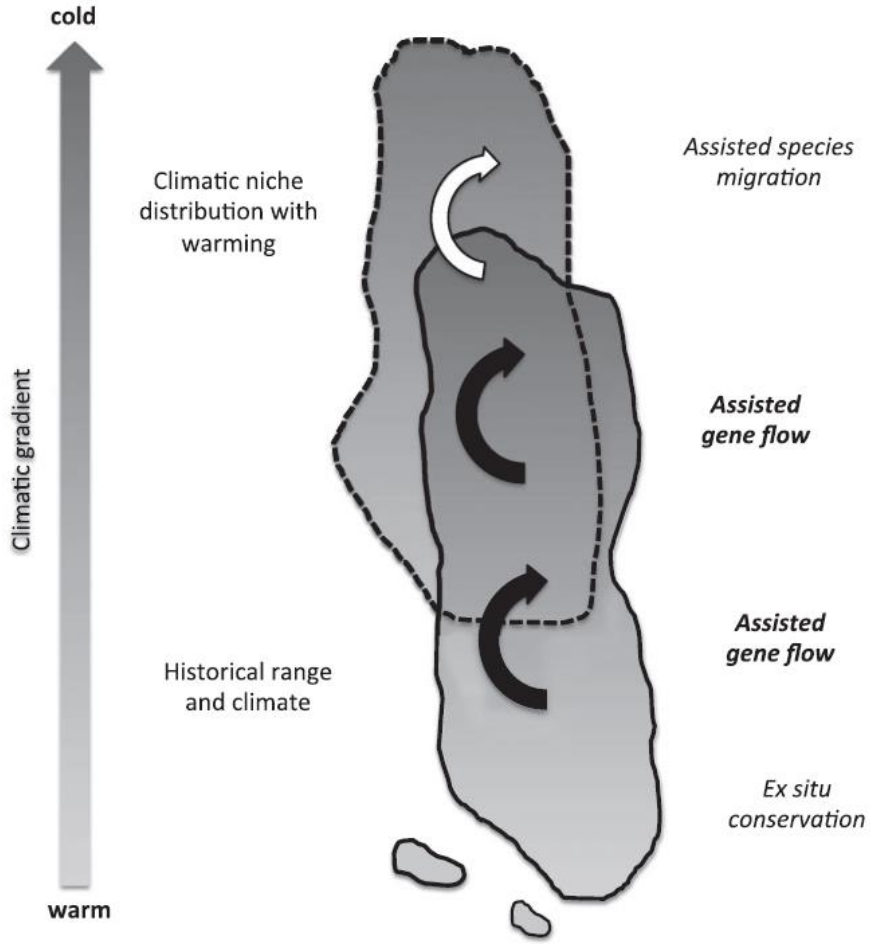
ASSISTED GENE FLOW (AGF) TO THE RESCUE?

Managed translocation of individuals between populations within the current range of a species, to facilitate their adaptation to a warmer climate and local persistence.



Aitken & Bemmels (2015); Gaitán-Espitia & Hobday (2020)

ASSISTED GENE FLOW (AGF)

Aim:

↗ genetic diversity (heterosis)

↗ the frequency of particular genetic variants

Risks:

- Translocation failure
- Introduction of disease
- Loss of local genetic diversity

Aitken & Bemmels (2015); Gaitán-Espitia & Hobday (2020)

ASSISTED GENE FLOW (AGF)

Aim:

↗ genetic diversity (heterosis)

↗ the frequency of particular genetic variants

Risks:

- Translocation failure
- Introduction of disease
- Loss of local genetic diversity

➢ Can we optimize AGF strategies with the help of models?

Aitken & Bemmels (2015); Gaitán-Espitia & Hobday (2020)

PREDICT SELECTION ON FOREST TREES UNDER FUTURE CLIMATE

Aim : identify interesting provenances for assisted gene flow for wood industry

Abies alba

(Abies cephalonica

Abies nordmanniana

Abies bornmulleriana)

Mediterranean firs

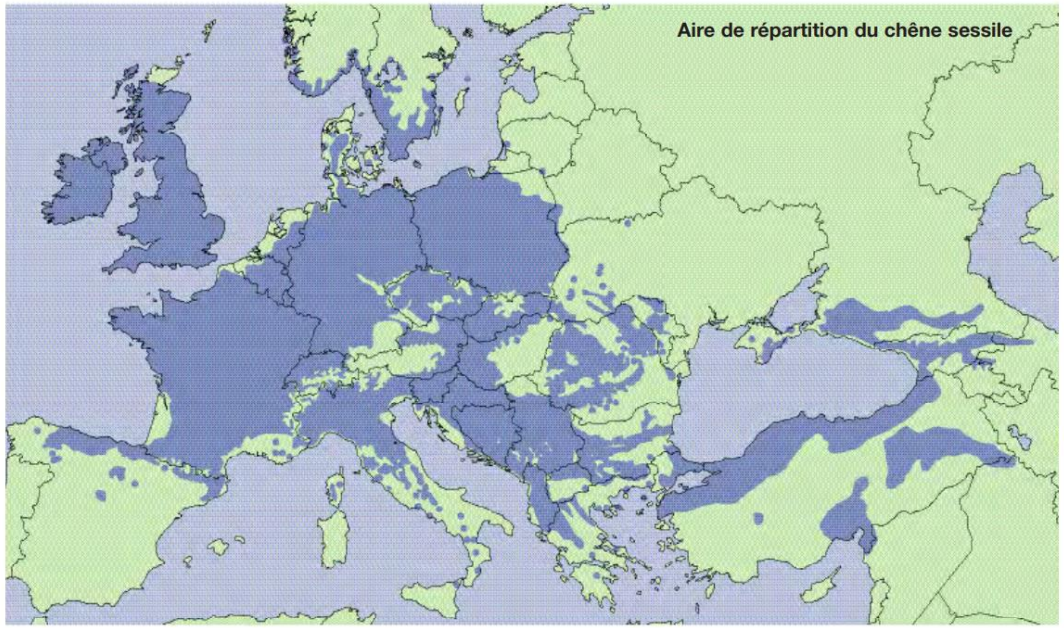
Quercus petraea

Quercus robur

Quercus pubescens

Quercus ilex

European oaks

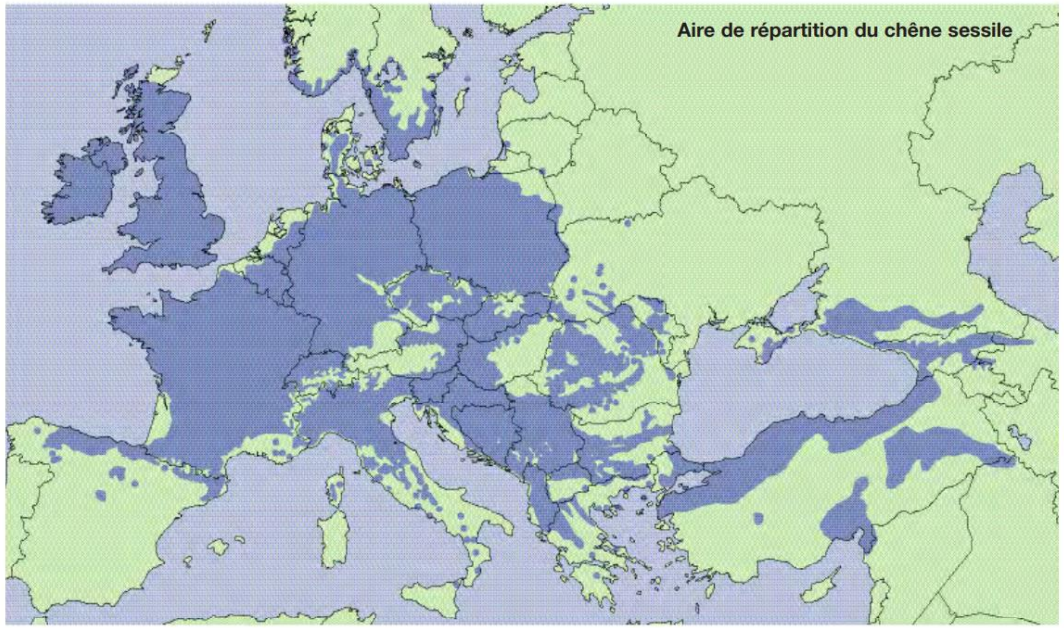


Current distribution range of *Quercus petraea* (Euforgenus)

PREDICT SELECTION ON FOREST TREES UNDER FUTURE CLIMATE

Aim : identify interesting provenances for assisted gene flow for wood industry

1. Calibrate and validate the model PHENOFIT 5 for species of interest

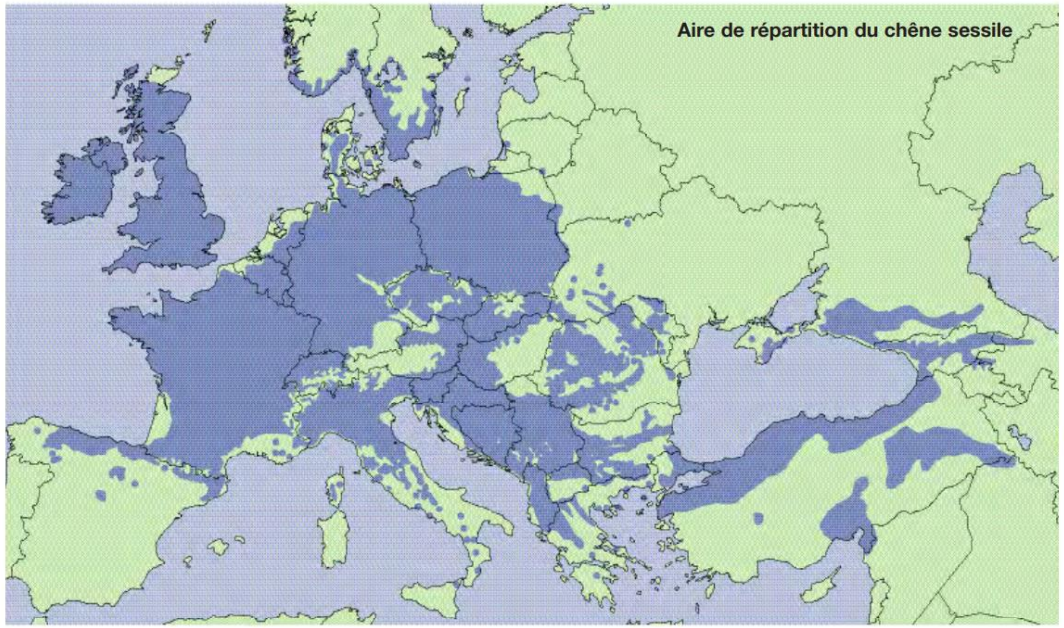


Current distribution range of *Quercus petraea* (Euforgenus)

PREDICT SELECTION ON FOREST TREES UNDER FUTURE CLIMATE

Aim : identify interesting provenances for assisted gene flow for wood industry

1. Calibrate and validate the model PHENOFIT 5 for species of interest
2. Predict optimal phenotypes under various climatic scenario and regions
3. Identify genetic material for AGF



Current distribution range of *Quercus petraea* (Euforgenus)

PHENOFIT5 CALIBRATION

Model inputs:

Species parameters

- Phenological dates
- Growth
- Reproduction
- Stress resistance (frost, drought)

~ 60 parameters

- Literature
- Online databases (TRY, Oak provenance…)
- Datasets from collaborators

Environment:

- Daily meteorological data:
  - Temperatures min, max
  - Precipitation
  - Evapotranspiration
- Photoperiod
- Soil water holding capacity

Global scale

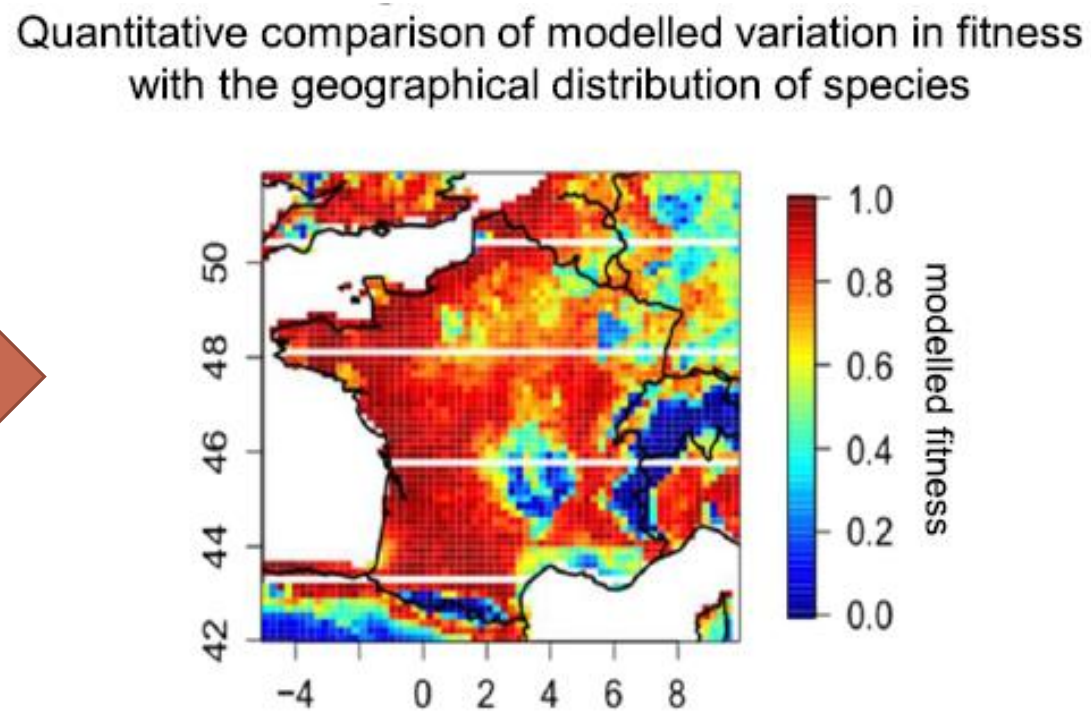
Local scale

PHENOFIT5 GLOBAL SCALE VALIDATION

Environment:

- Historical daily meteorological data: **ERA5LAND over France/Europe (~9km resolution)**
- Photoperiod
- Soil water holding capacity

Simulation



Initial condition : forest ~60 years, mean wood and leaf biomass over Renecofor sites…

Figure from Gauzere et al. 2020

PHENOFIT5 LOCAL SCALE VALIDATION

Environment:

- Historical daily meteorological data: **ERA5LAND over France/Europe (~9km resolution)**
- Photoperiod
- Soil water holding capacity

Simulation

Comparison of the outputs with observed sites values:

- Wood and leaf biomass at Tf
- Species proportion

Initial condition : for each Renecofor sites :

- Wood and leaf biomass at T0
- Proportion with second species

PREDICT SELECTION ON FOREST TREES UNDER FUTURE CLIMATE

Aim : identify interesting provenances for assisted gene flow for wood industry

1. Calibrate and validate the model PHENOFIT 5 for species of interest
2. Predict optimal phenotypes under various climatic scenario and regions
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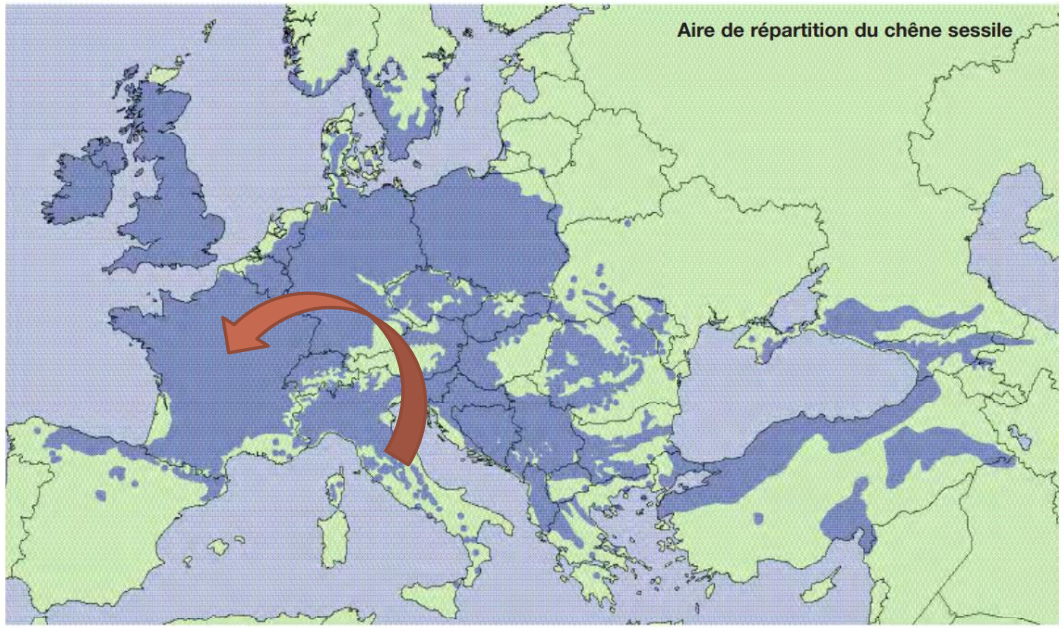

Current distribution range of *Quercus petraea* (Euforgenus)

TAKE-HOME MESSAGE

- Phenofit: a species distribution model **based on eco-physiological processes (phenology)**
- Upgraded version to better integrate composants of tree fitness (reproduction, competition and drought resistance modules)
- Predict optimal phenotypes under future climate to optimize assisted gene flow strategies

THANKS TO MY COLLABORATORS!

ANR FLORES

Gene flow to the rescue :

Isabelle Chuine Ophélie Ronce

URFM: Caroline Scotti-Santaigne, Bruno Fady, Alice Copie, Frederic Jean…

ONF: Yves Rouselle

Thanks for sharing data sets/values :

Puechabon team
Marie-Claude et Samuel Venner
Georges Kunstler
Marta Benito

ANR FLORES

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THANKS FOR YOUR ATTENTION!

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THANKS TO MY COLABORATORS!

Institut des Sciences de l'Evolution-Montpelli

PHENOFIT 5 Inputs

Phenology

dates of leaf unfolding, flowering, fruit maturation, leaf coloring

Resistance to stress

Minimum temperature resistance of dormant buds, young leaves, mature leaves, flowers, fruits
Psi99, Psi88, Psi50, PLC50

Growth

SLA, WUE, maximum leaf/wood maintenance respiration rate
Allometry: male flower, female flower, leaf, wood biomass, crown cover
Biomass distribution and maximum root depth per age classes (seedlings, juveniles, adults)

Reproduction

Mean Weight of fruit, male flower, female flower, young Fruit
Auto incompatibility rate, mean fertilization rate