Forest Resource Sharing through Mycorrhizal Networks

The Fungal Friends

Chaitanya, Malou, Maurits, Steven

Theoretical Background

Mycorrhizal networks:
The Wood Wide Web

The Biology

Obligate symbiosis fungi and trees	Networks link roots different trees	Scale-free network

Simard et al. (2012), Babikova et al. (2013), Simard (2018).

Theoretical Background

Mycorrhizal networks:
The Wood Wide Web

The Biology

The Role of Mycorrhizal Networks

Resource Transfer	Sending defense signals	And more...

Simard et al. (2012), Babikova et al. (2013), Simard (2018).

Theoretical Background

Mycorrhizal networks:
The Wood Wide Web

The Biology

The Role of Mycorrhizal Networks

Motivation

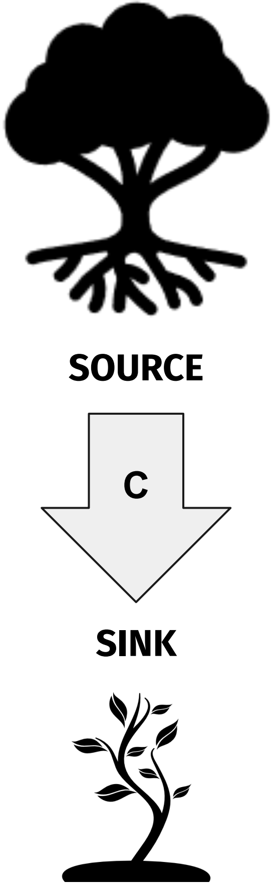
Resilience and Adaptation	Complex Adaptive System	Forestry in a changing climate

Simard et al. (2012), Babikova et al. (2013), Simard (2018).

Hypothesis and Research Objective

The Source-Sink Gradient Hypothesis

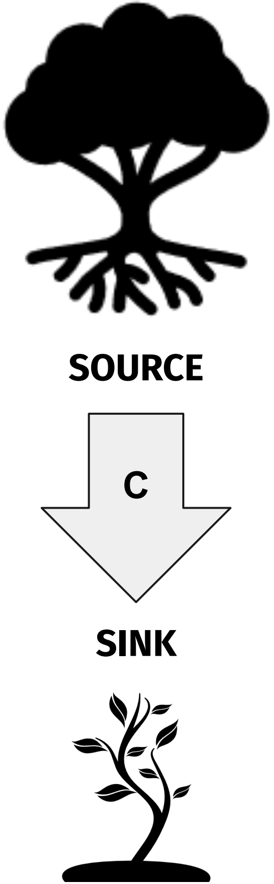
- Carbon Transfer along gradients
- Facilitation and Competition
- Survival young trees during stress



Simard et al. (2012), Figueiredo et al. (2021)

Hypothesis and Research Objective

Research Objective
Investigate the dynamics of carbon source-sink gradients on a mycorrhizal network and how this can facilitate sapling growth and success.



Methods: Data Used

New Phytologist

Research

Architecture of the wood-wide web: *Rhizopogon* spp. genets link multiple Douglas-fir cohorts

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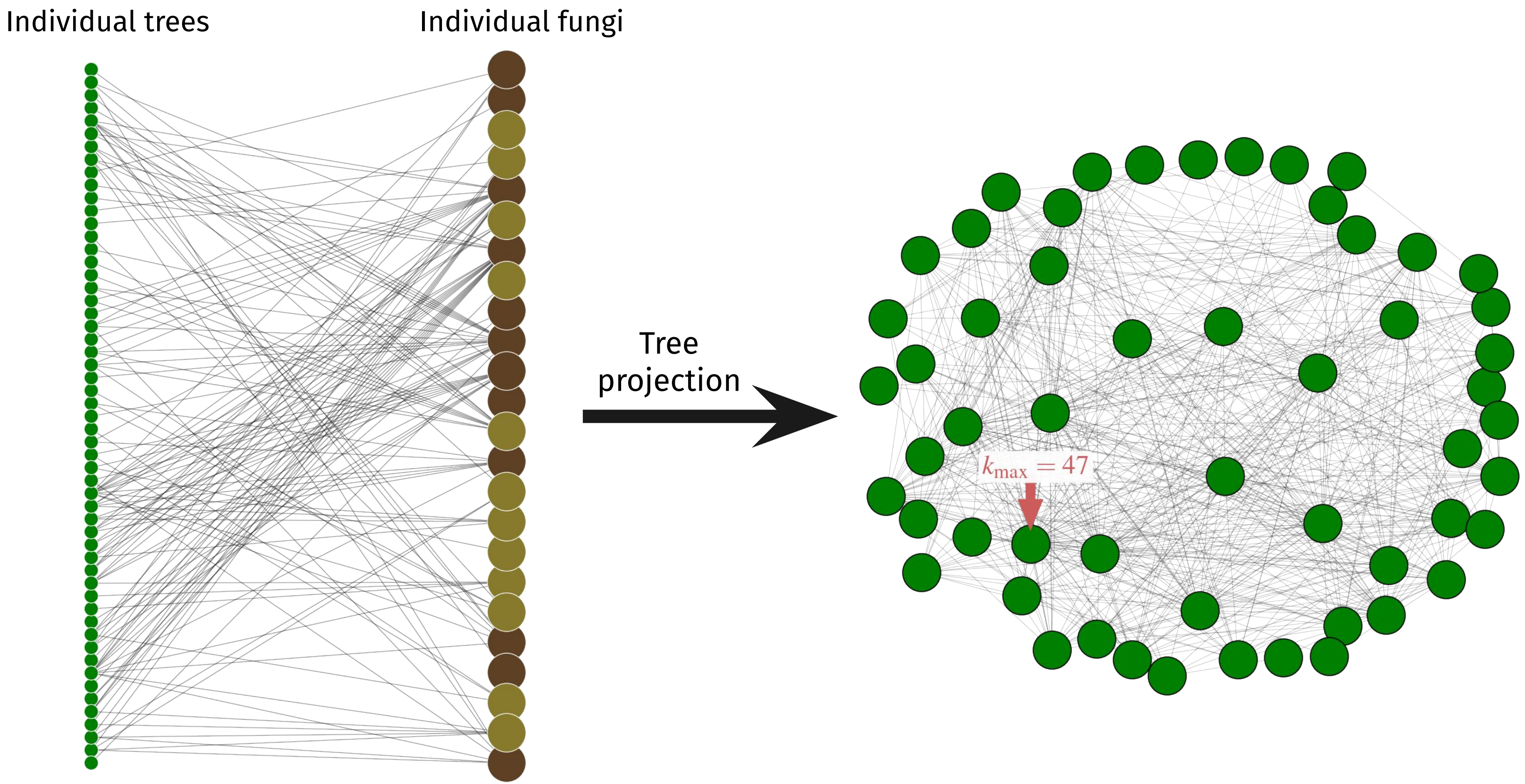
Summary

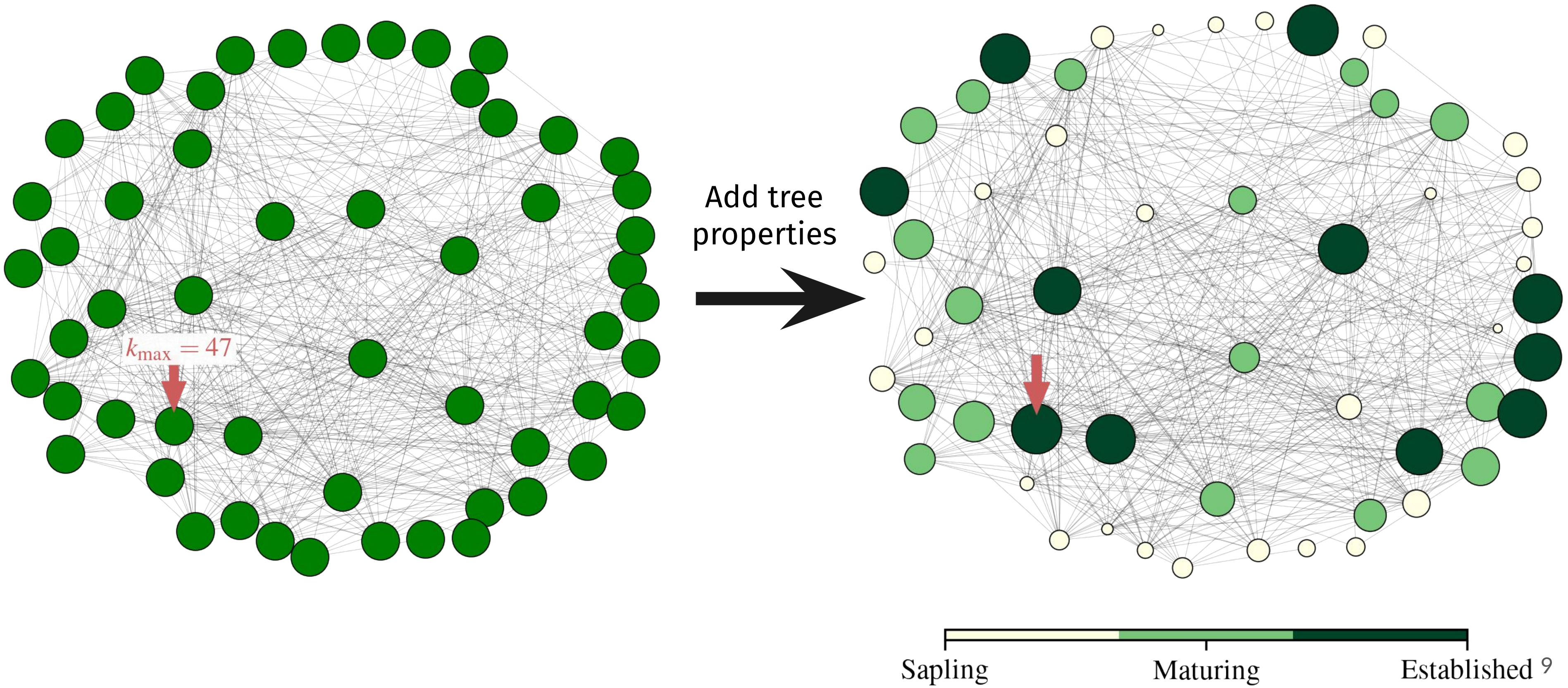
- The role of mycorrhizal networks in forest dynamics is poorly understood because of the elusiveness of their spatial structure. We mapped the belowground distribution of the fungi *Rhizopogon vesiculosus* and *Rhizopogon vinicolor* and interior Douglas-fir trees (*Pseudotsuga menziesii* var. *glauca*) to determine the architecture of a mycorrhizal network in a multi-aged old-growth forest.
- *Rhizopogon* spp. mycorrhizas were collected within a 30 × 30 m plot. Trees

Beiler et al. (2010)

Methods: Network Set-up

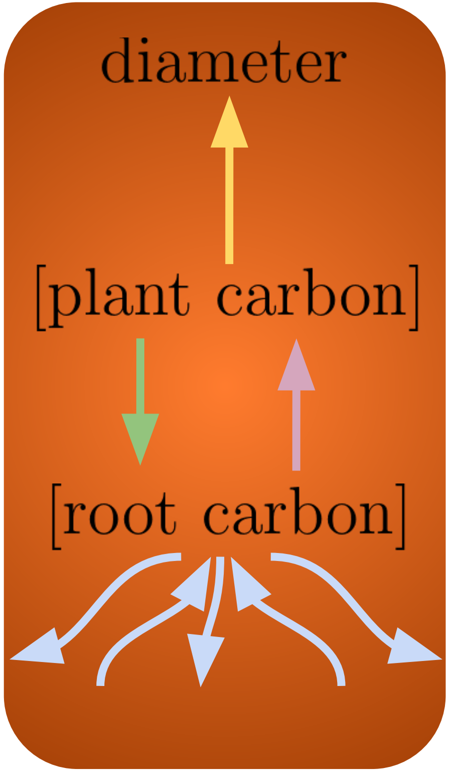


Methods: Network Set-up



Methods: The Model

Tree i



$$\frac{d[\text{root carbon}]_i}{dt} = \text{diffusion} + \text{deposition} - \text{uptake}$$

$$\frac{d[\text{plant carbon}]_i}{dt} = \text{uptake} - \text{deposition} - \text{growth}$$

$$\frac{d\text{diameter}_i}{dt} = \text{growth}$$

Methods: Mathematical Model

$$\frac{d[\mathrm{C}]_{r_i}}{dt} = D_C \sum_{j\in\mathcal{N}(i)} \left([\mathrm{C}]_{r_j} - [\mathrm{C}]_{r_i}\right) + f[\mathrm{C}]_{p_i} - e^{A-d_i^2/\sigma} d_i [\mathrm{C}]_{r_i}$$

$$\frac{d[\mathrm{C}]_{p_i}}{dt} = e^{A-d_i^2/\sigma} d_i [\mathrm{C}]_{r_i} - f[\mathrm{C}]_{p_i} - g\frac{1}{1+c^{-d_i k}}[\mathrm{C}]_{p_i}$$

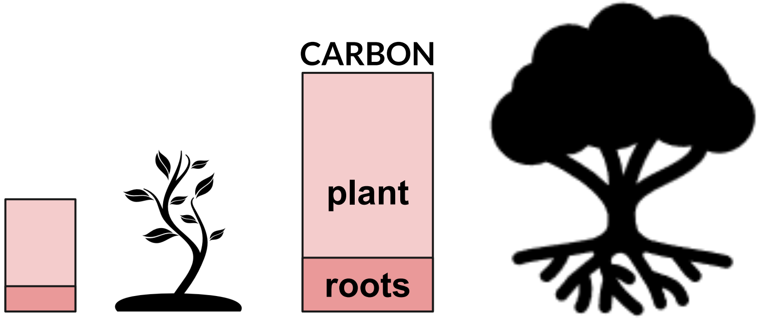
$$\frac{dd_i}{dt} = \rho g\frac{1}{1+c^{-d_i k}}[\mathrm{C}]_{p_i}$$

Issartel and Coiffard (2011), Hinckley et al. (2011)

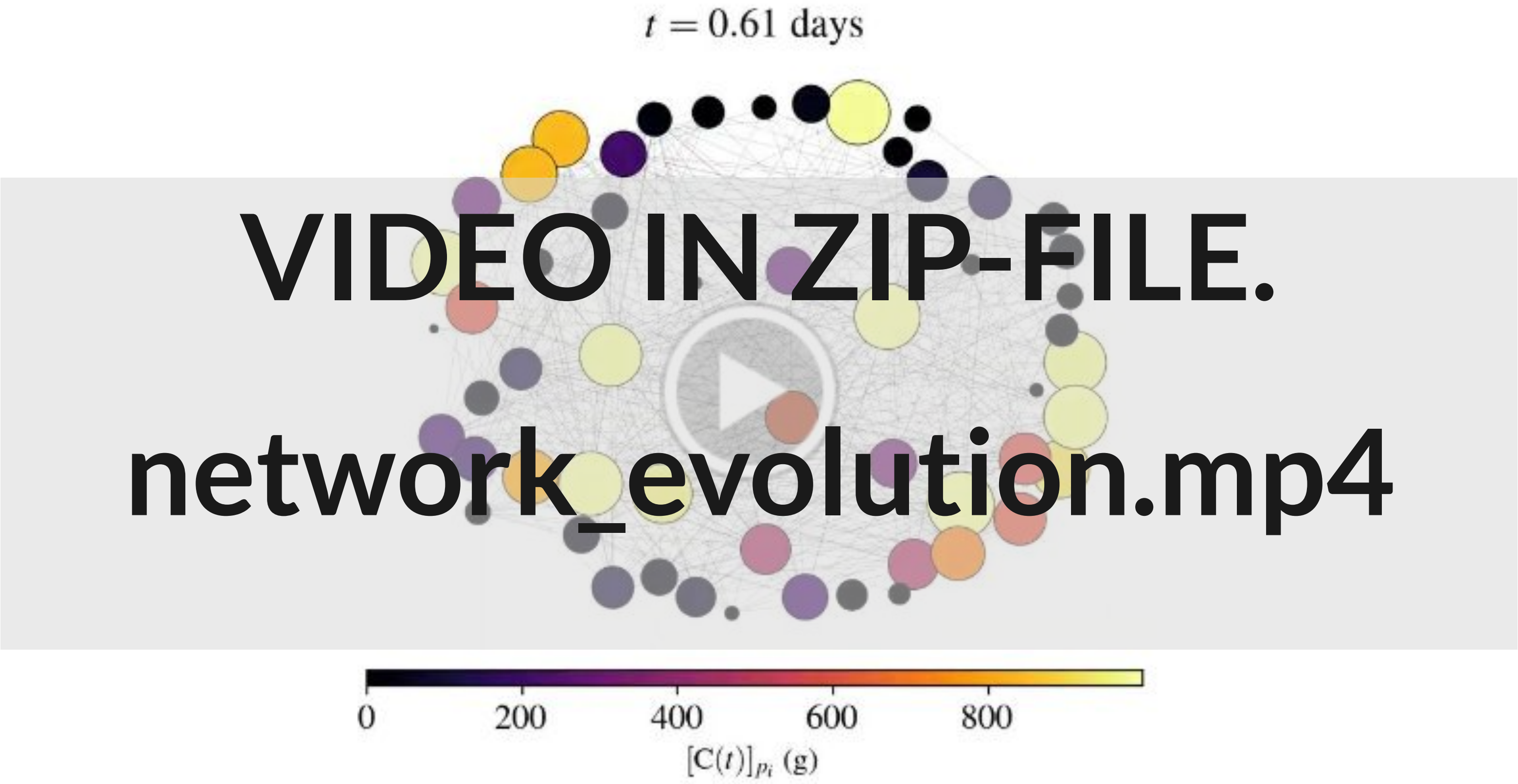
Methods: Experimental Set-up

Experimental Set-up

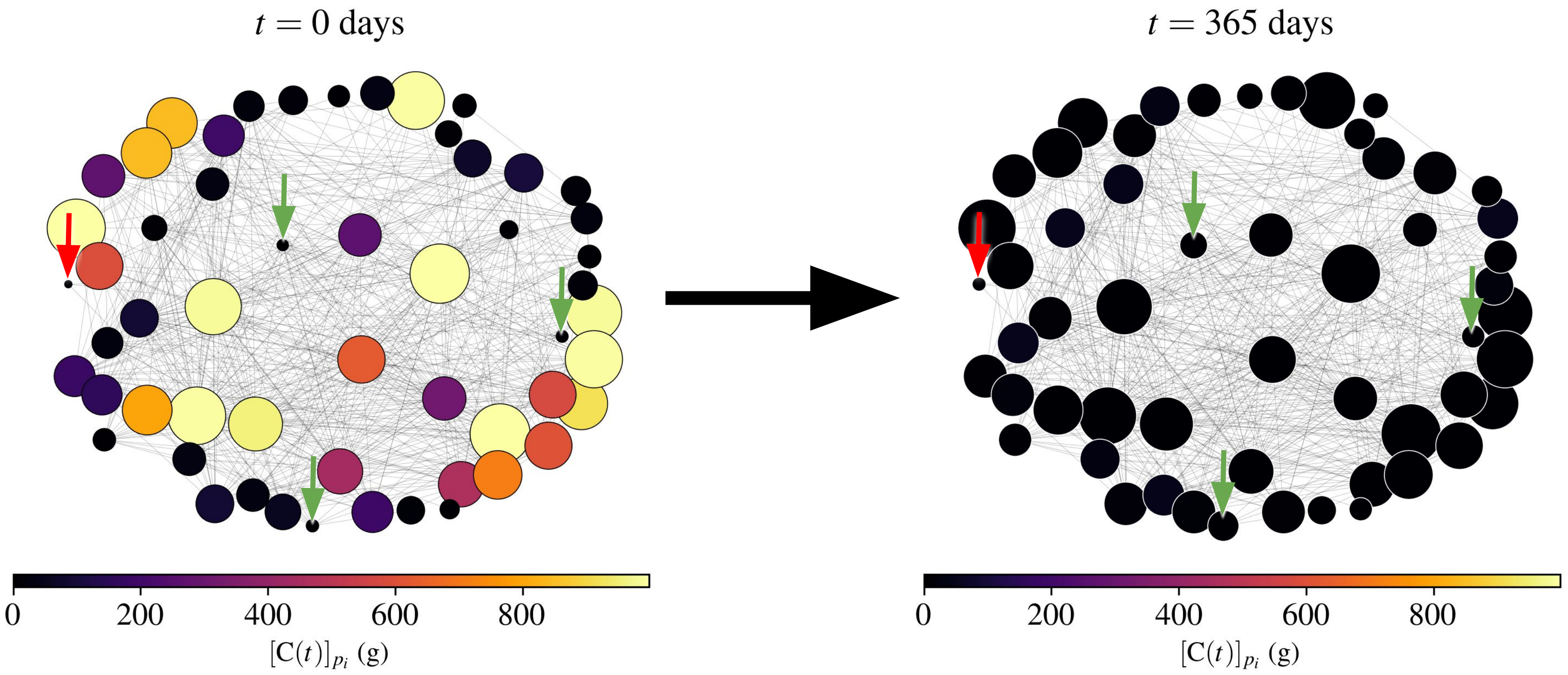
- Heterogeneous carbon distribution
- Numerically solve ODEs
  - Until convergence carbon reserves



Metrics	
Biomass growth	Sapling success
In terms of plant diameter	*Minimum growth threshold*

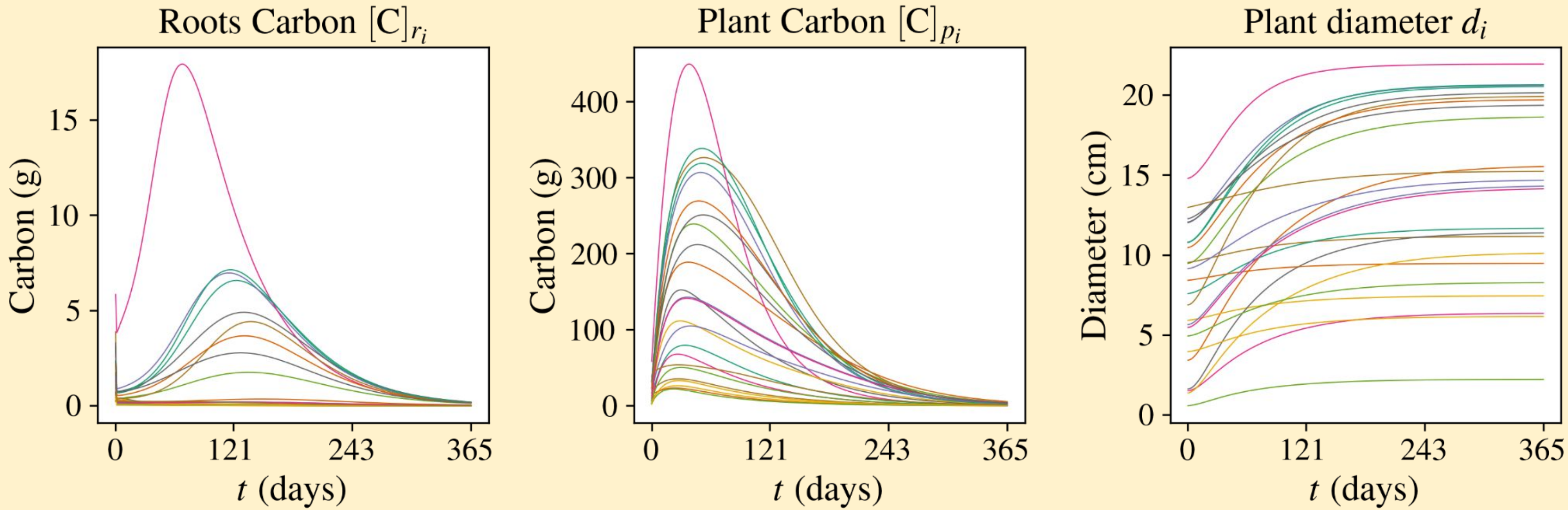

$t = 0.61$ days
VIDEO IN ZIP-FILE.
network_evolution.mp4
0
200
400
600
800
$[C(t)]_{p_i}$ (g)

Results: Model Dynamics

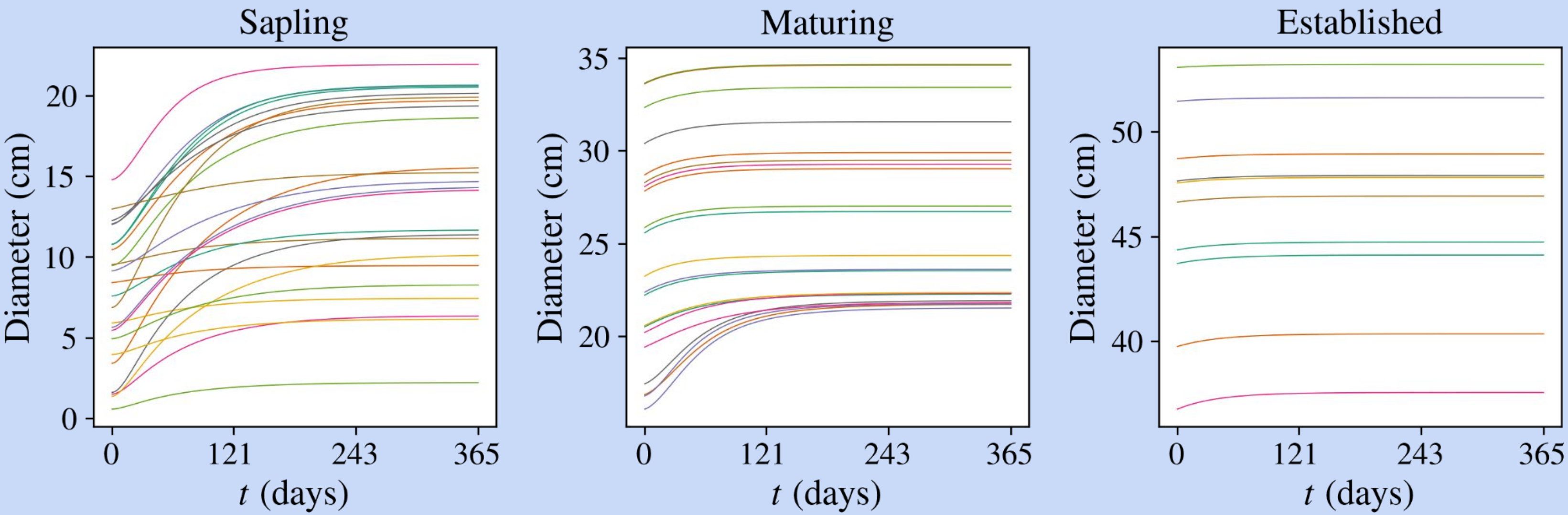


Results: Model Dynamics

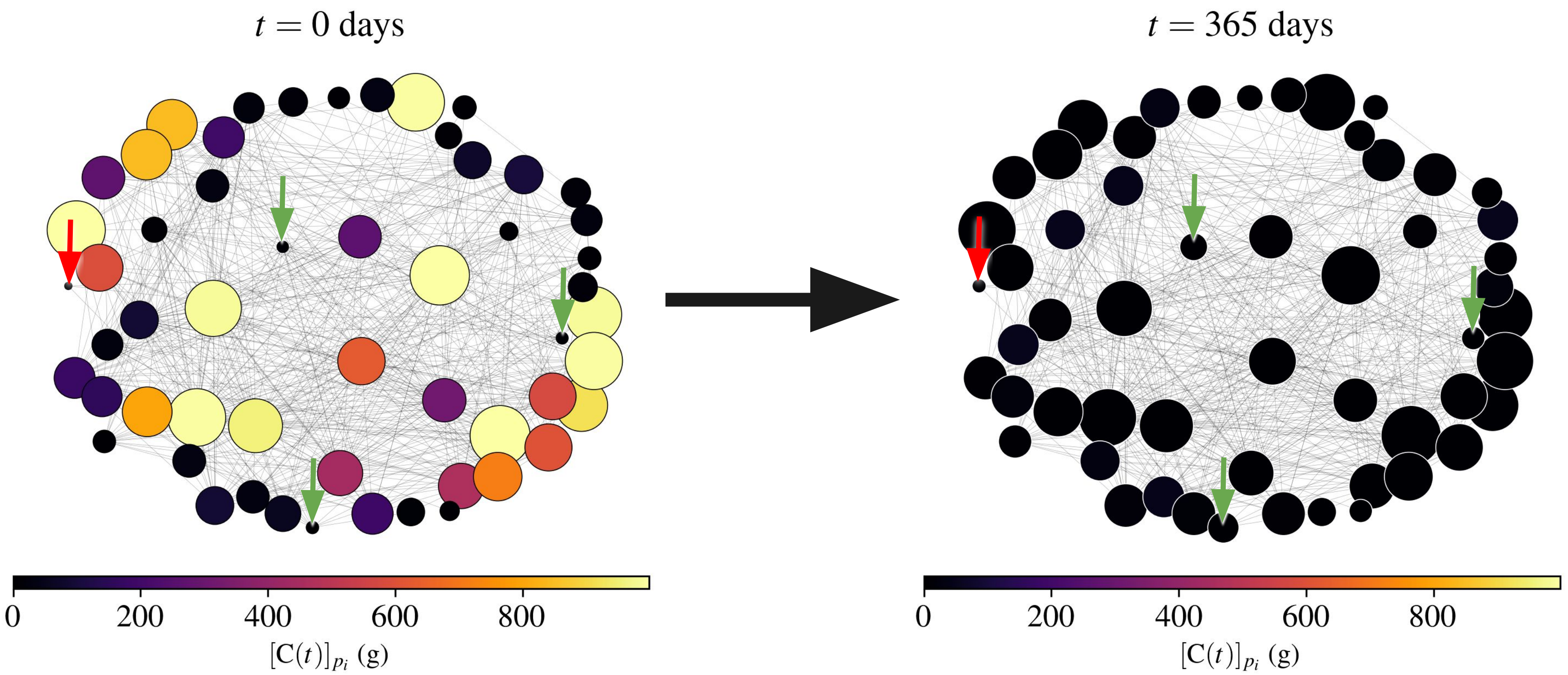
Saplings



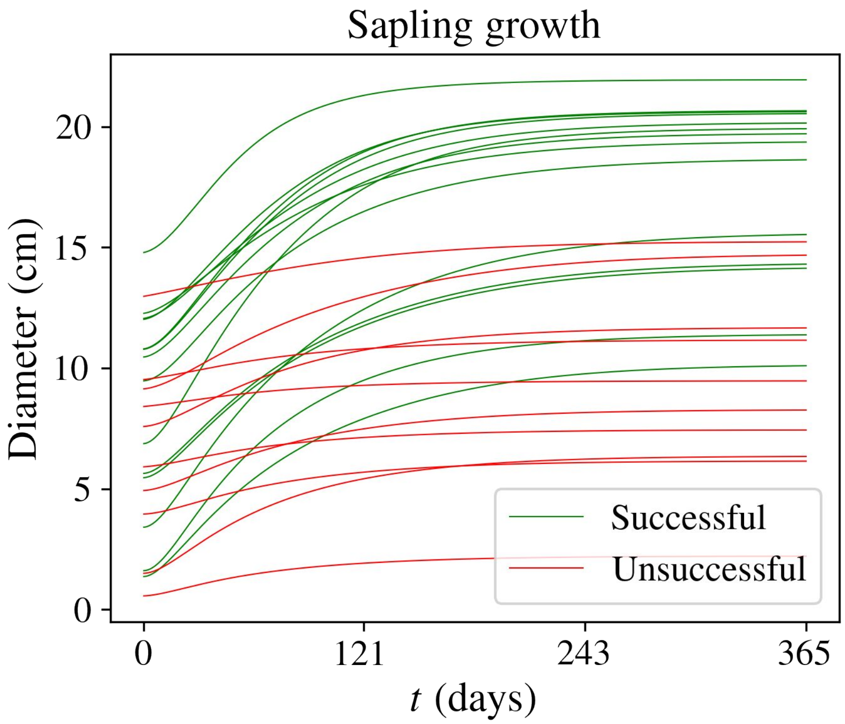
Diameter evolution per cohort



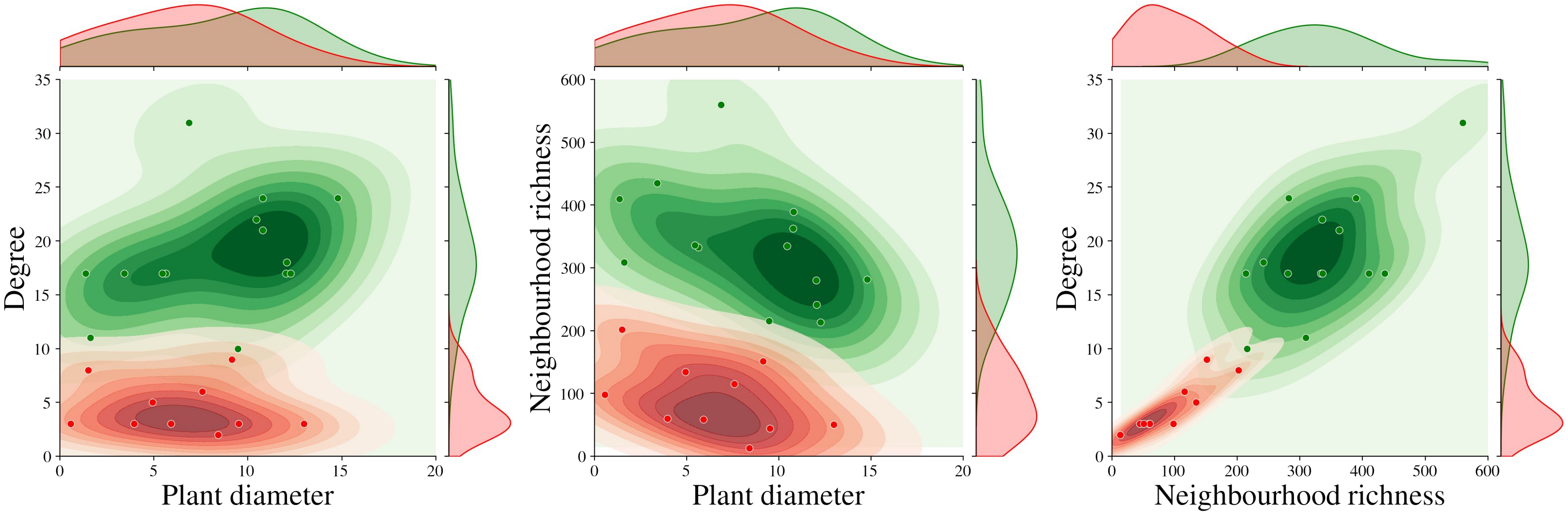
Results: Successful Saplings



Results: Successful Saplings

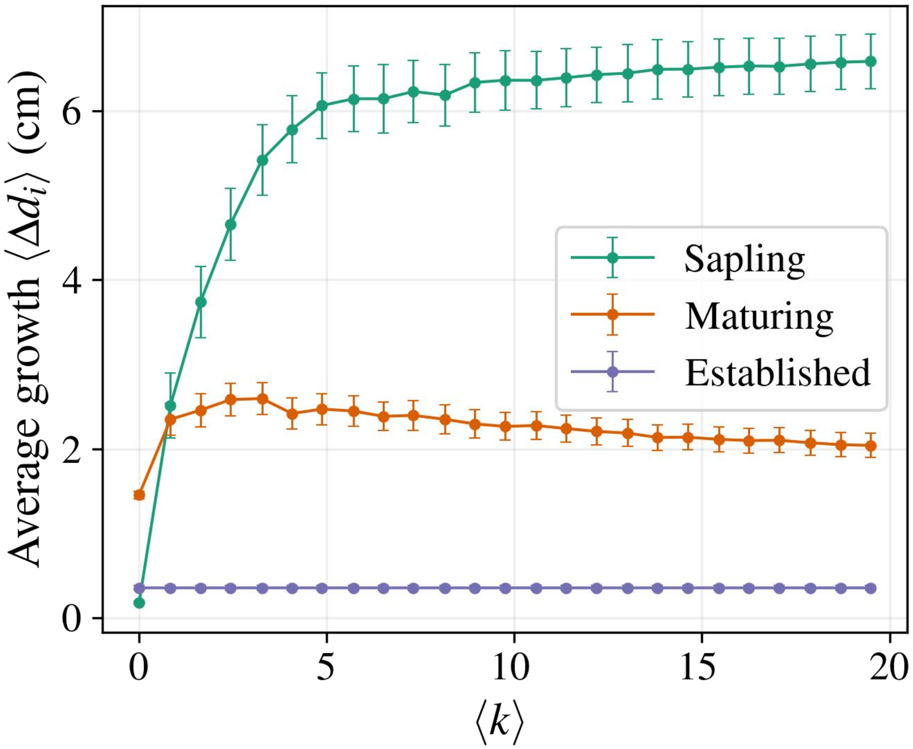


Results: Successful Saplings

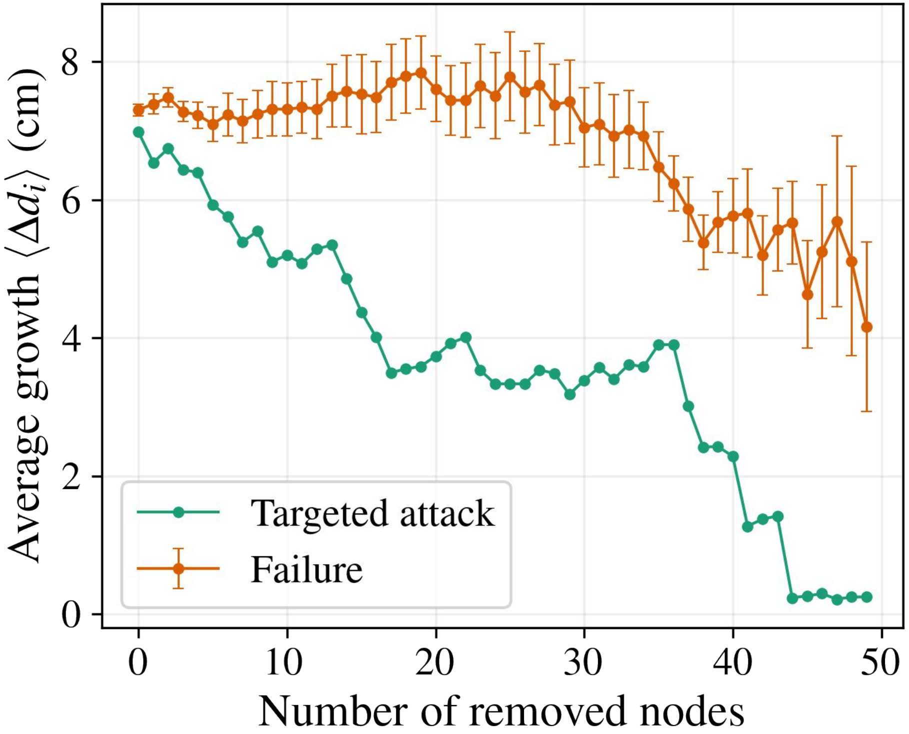


	Diameter	**Degree**	**Neighbourhood richness**
p-value	0.27	**< 0.001**	**< 0.001**

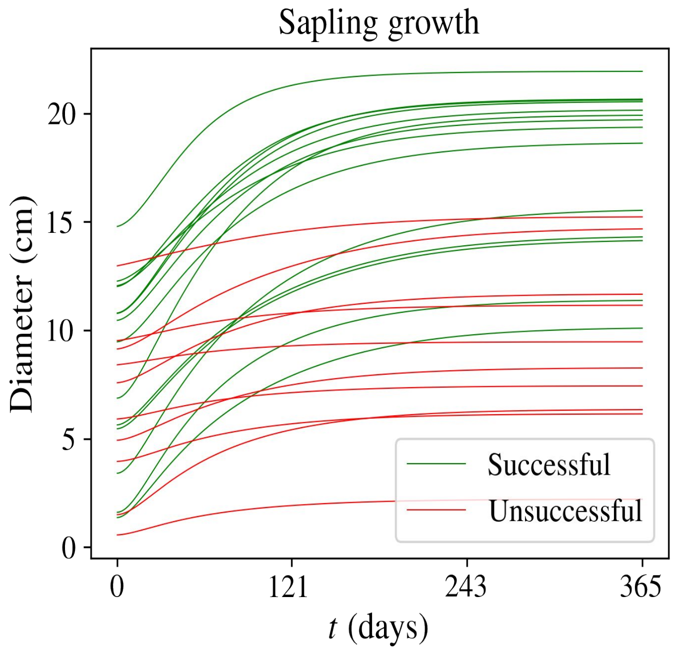
Results: Changing network properties



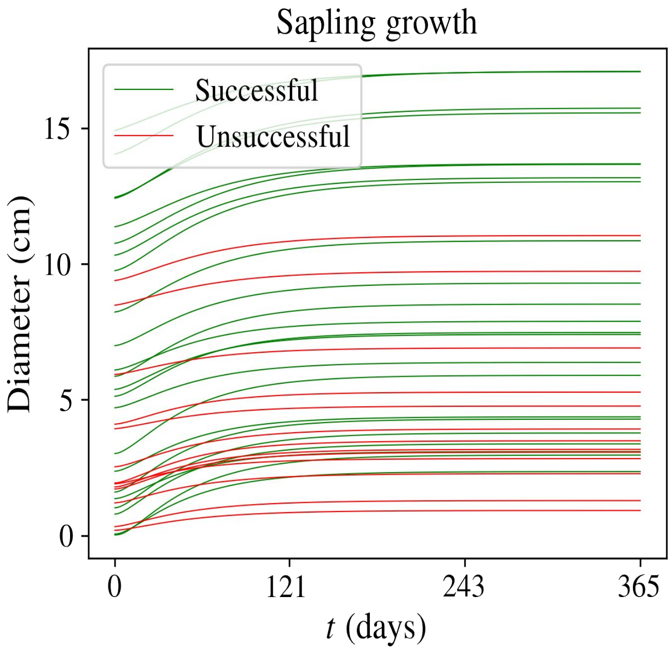
Results: Changing network properties



Results: Scale Free Network



Forest



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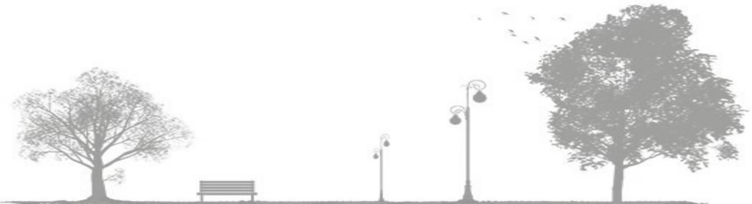
Discussion and Future Work

Discussion

- Correspondence with source-sink gradients hypothesis
- Degree and neighbourhood richness are good predictors of sapling success.
- Benefit for saplings and maturing trees
- Sensitive to targeted attack

Future work

- Better understanding network topology of forests
- Other hypotheses: *Fungi as decision-maker*



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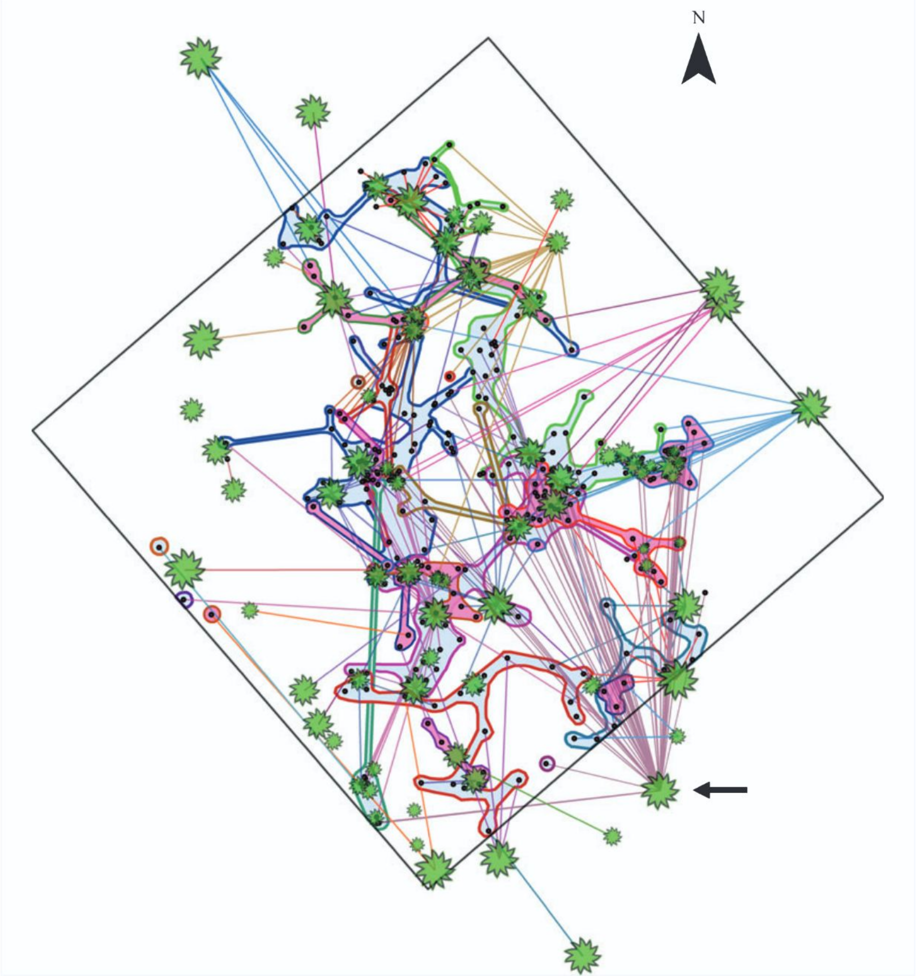
Appendices

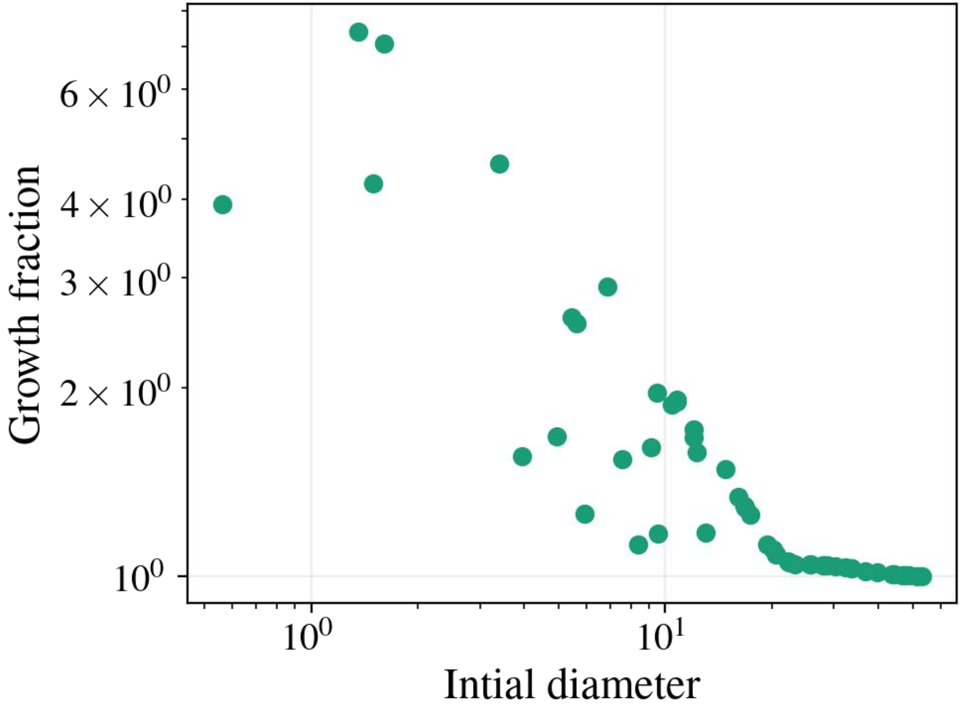
Appendix I: Forest Sampling Map



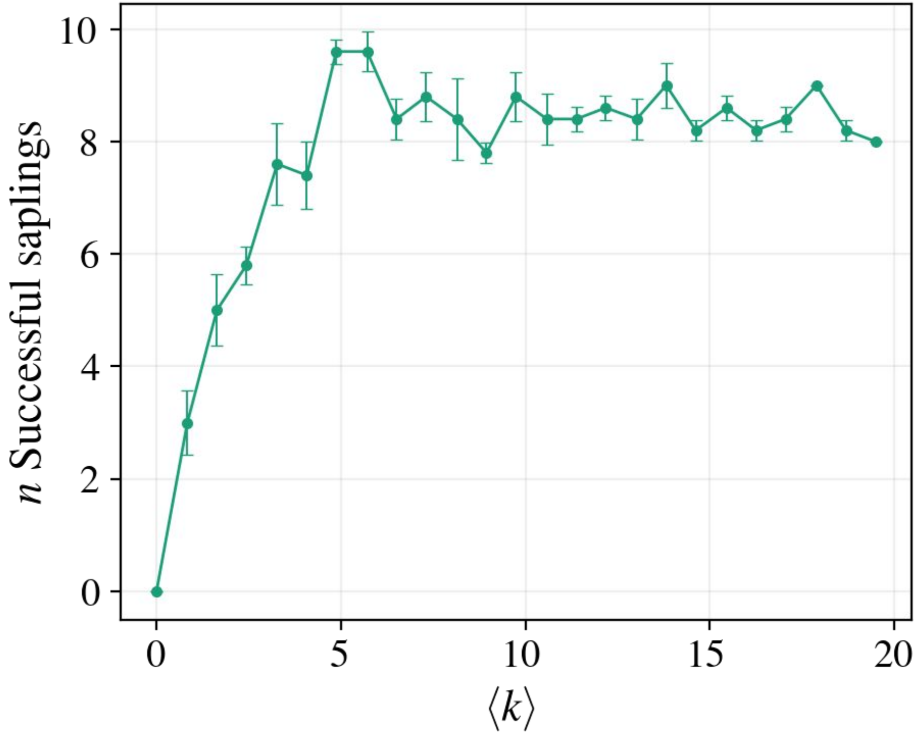
Appendix II: Model Parameters

Symbol	Description	Value
D_C	Carbon diffusion coefficient	0.0005
f	Fraction of plant carbon transferred to root	0.0005
A	Root uptake coefficient	0.55
σ	Root uptake conversion factor	55
g	Growth speed	0.004
c	Logistic growth base	0.82
k	Growth conversion factor	0.6
ρ	Carbon to diameter conversion factor	0.01

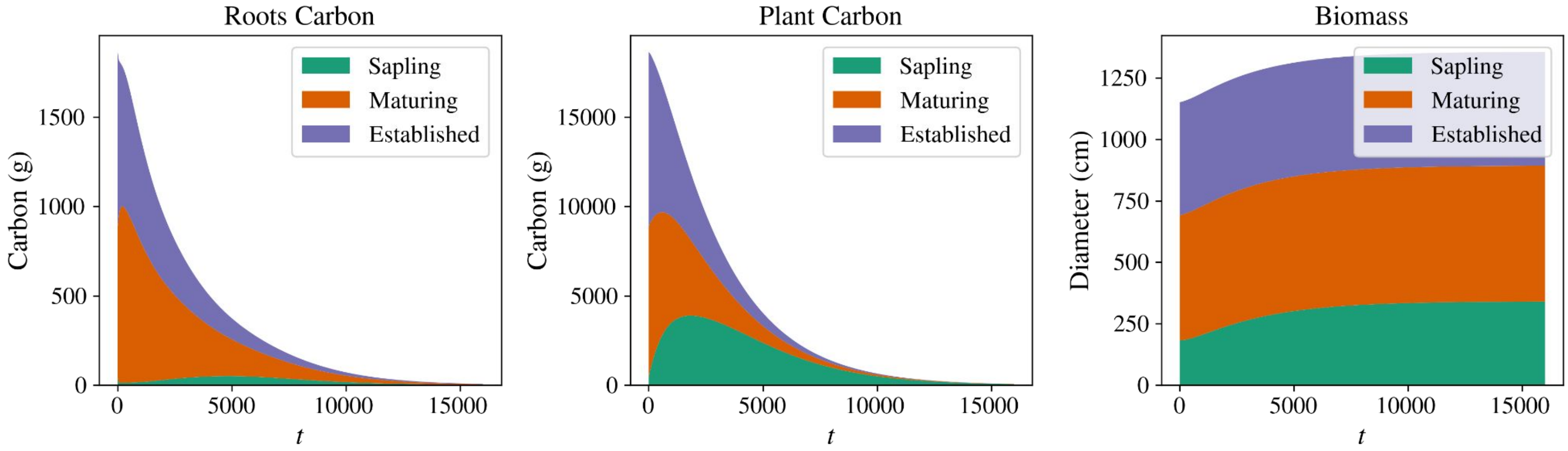
Appendix III: Initial Diameter vs. Growth



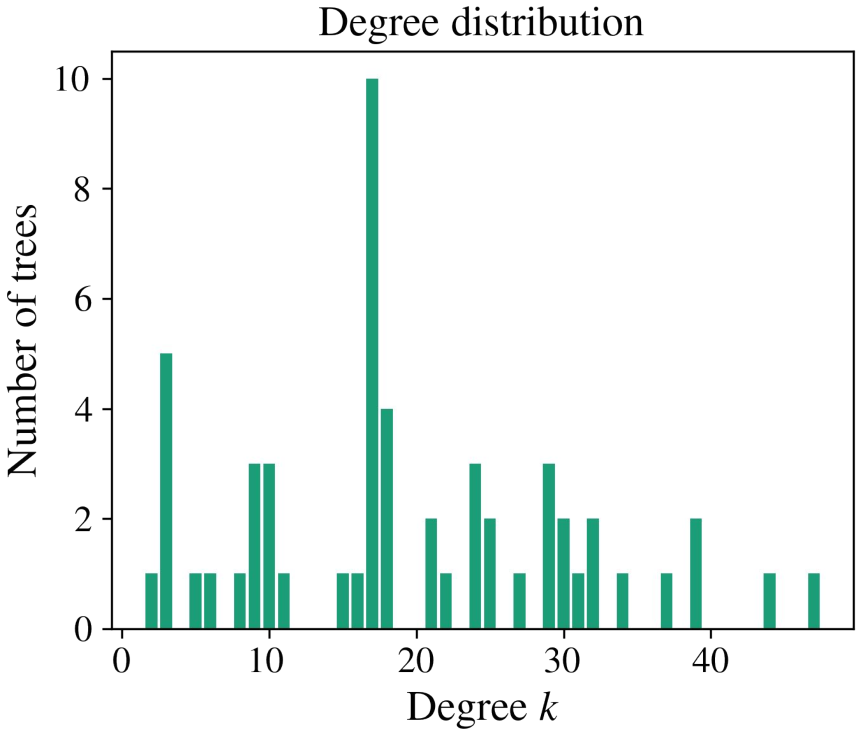
Appendix IV: Average Degree vs. n Successful Saplings



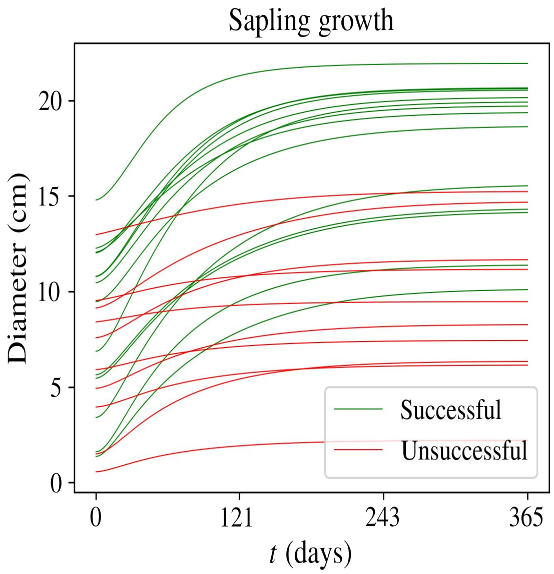
Appendix V: Stacked Plots Compartments



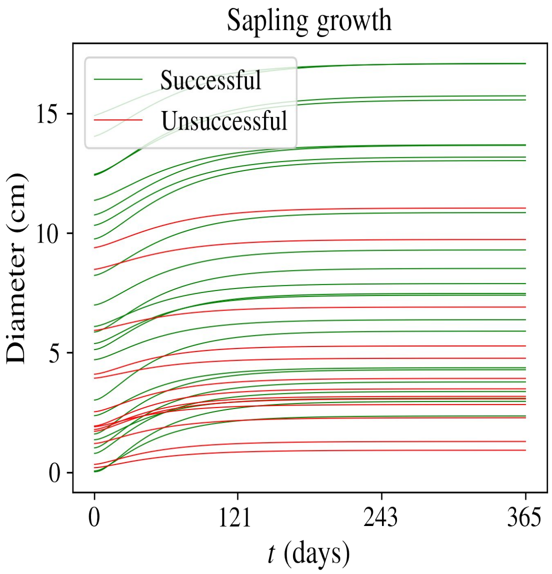
Appendix VI: Network Degree Distribution



Appendix VII: Network Topology Comparison



Forest



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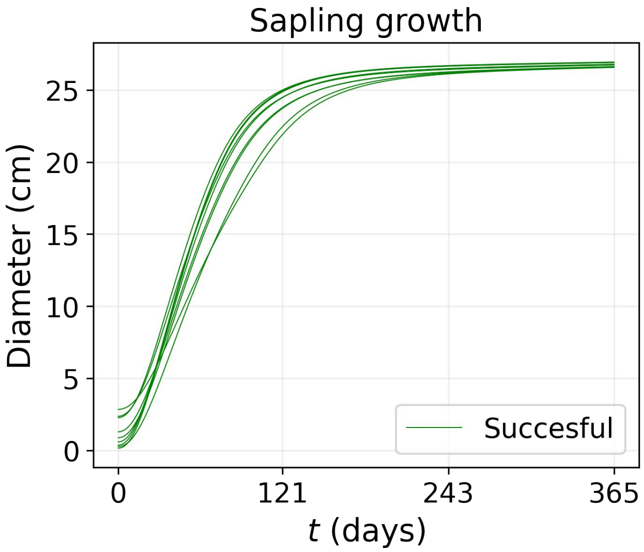

Random

Appendix VIII: Characteristic Time