MODIMIV: Integrated modelling of of microbial-plant interactions in multi-species agroecosystems

Gianni Bellocchi - INRAE - Unité mixte de recherche sur l'écosystème prairiale (Clermont-Ferrand)

UREP Ecosystème Prairial

VetAgro Sup

INRAE UMR1048 SCIENCE ACTION DÉVELOPPEMENT ACTIVITÉS PRODUITS TERRITOIRES [SADAPT]

EmmaH

crea Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

LIEC

INRAE - Unité de recherche pluridisciplinaire Prairies et Plantes fourragères

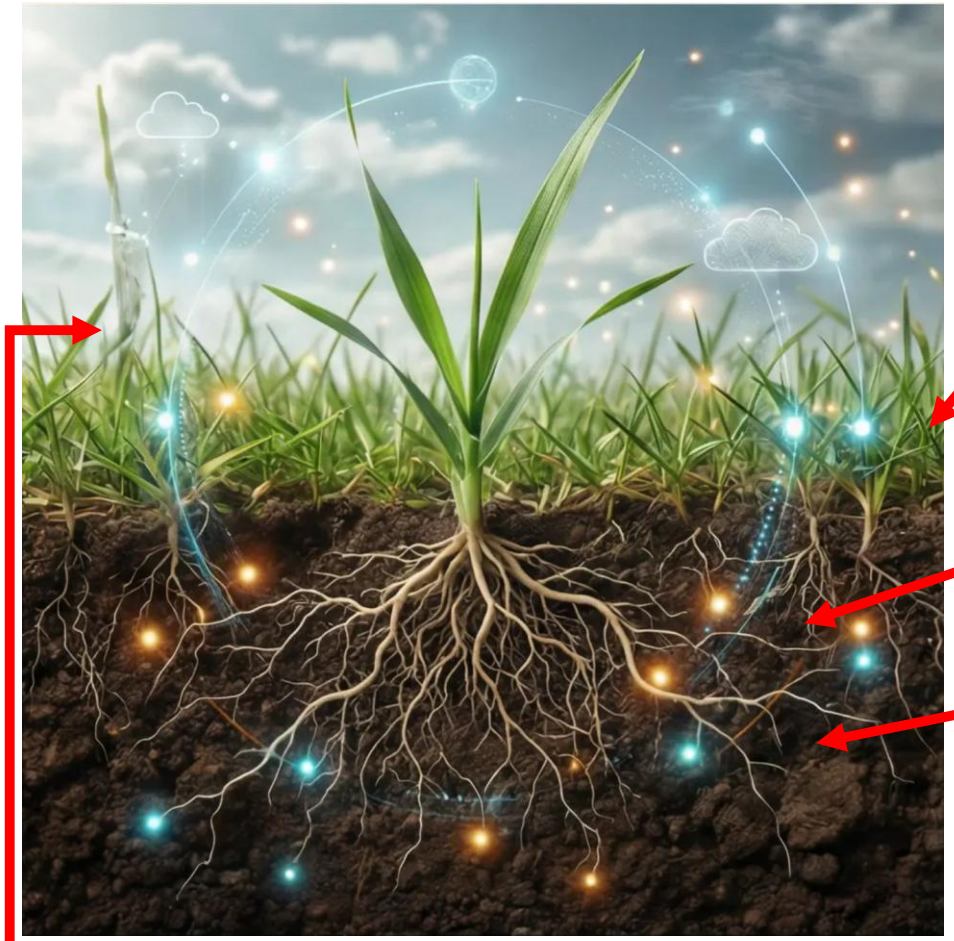
Agriculture and Environment

Animal Production and Aquaculture

Biosefair

Valpré-Ecully (France), 21-22/05/2026

A complex multi-scale ecosystem



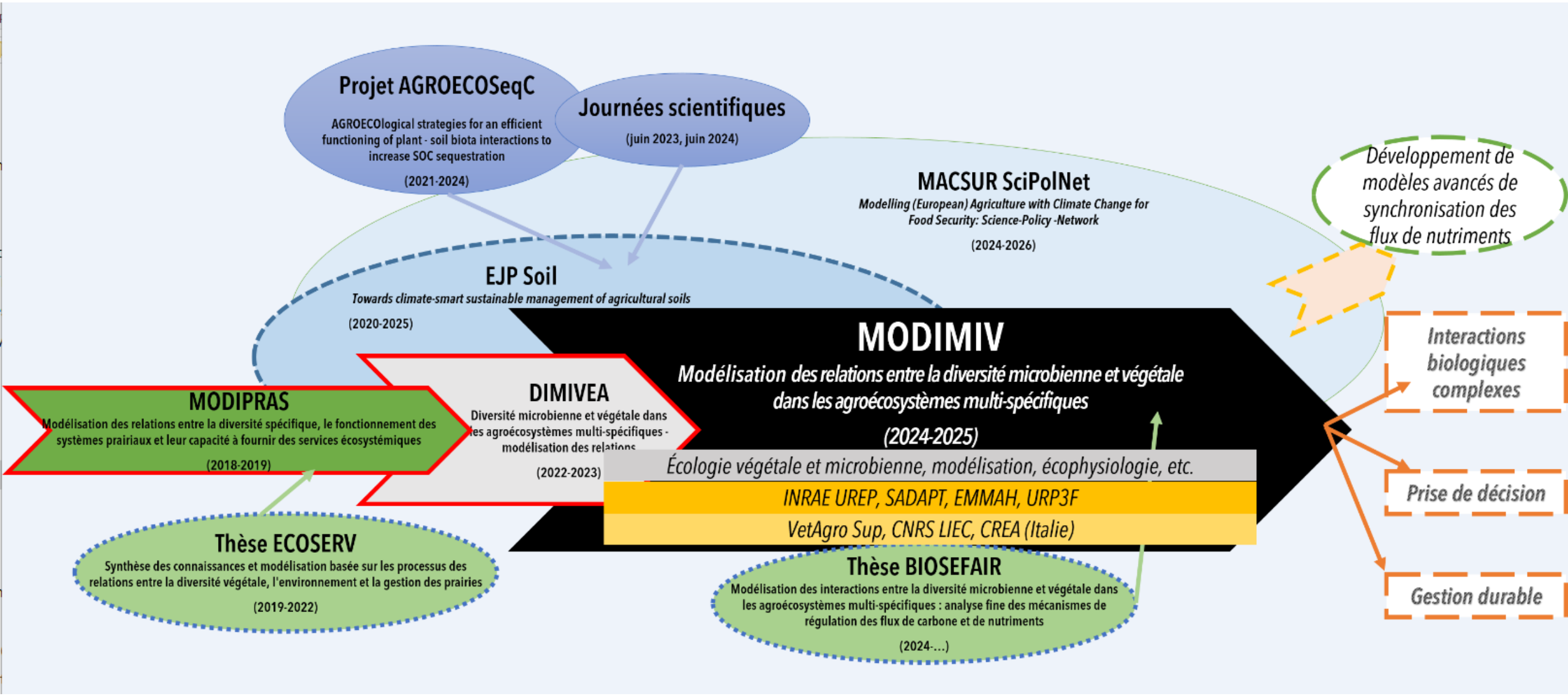
Imagine a single blade of glass.

Beneath it, the rhizosphere - a living foundation where roots weave …

… through a dark cathedral of carbon where microbes dance.

Above it, Atlantic winds whisper climate secrets from centuries past.

Between them, our models bridge scales no human eyes can see.


Projet AGROECOSeqC
AGROECOlogical strategies for an efficient functioning of plant - soil biota interactions to increase SOC sequestration
(2021-2024)
Journées scientifiques
(juin 2023, juin 2024)
MACSUR SciPolNet
Modelling (European) Agriculture with Climate Change for Food Security: Science-Policy -Network
(2024-2026)
Développement de modèles avancés de synchronisation des flux de nutriments
EJP Soil
Towards climate-smart sustainable management of agricultural soils
(2020-2025)
MODIMIV
Modélisation des relations entre la diversité microbienne et végétale dans les agroécosystèmes multi-spécifiques
(2024-2025)
MODIPRAS
Modélisation des relations entre la diversité spécifique, le fonctionnement des systèmes prairiaux et leur capacité à fournir des services écosystémiques
(2018-2019)
DIMIVEA
Diversité microbienne et végétale dans les agroécosystèmes multi-spécifiques - modélisation des relations
(2022-2023)
Écologie végétale et microbienne, modélisation, écophysiologie, etc.
INRAE UREP, SADAPT, EMMAH, URP3F
VetAgro Sup, CNRS LIEC, CREA (Italie)
Interactions biologiques complexes
Prise de décision
Gestion durable
Thèse ECOSERV
Synthèse des connaissances et modélisation basée sur les processus des relations entre la diversité végétale, l'environnement et la gestion des prairies
(2019-2022)
Thèse BIOSEFAIR
Modélisation des interactions entre la diversité microbienne et végétale dans les agroécosystèmes multi-spécifiques : analyse fine des mécanismes de régulation des flux de carbone et de nutriments
(2024-...)

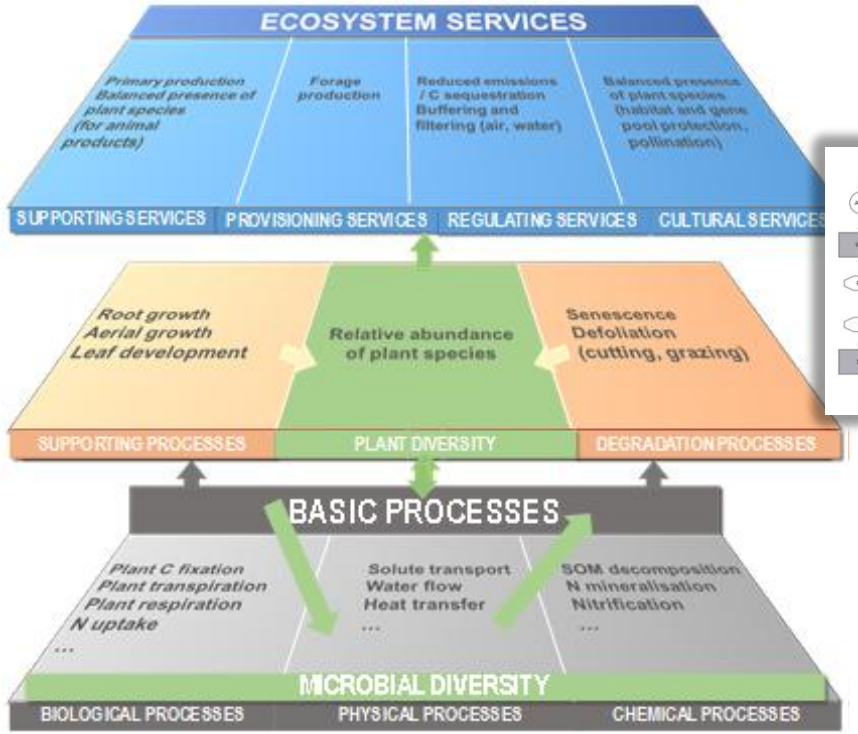
Clermont-Ferrand

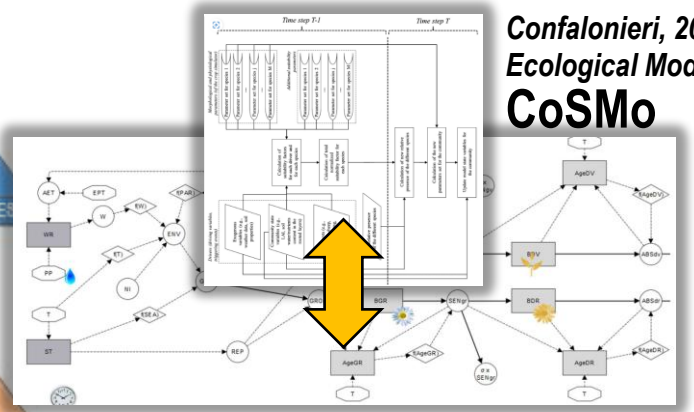
05-06/02/2024

Integrated modelling of microbial-plant interactions in multi-species agroecosystems: the project MODIMIV

Interactions between plant and soil microbial diversity are essential for regulating C and N cycling in agroecosystems.

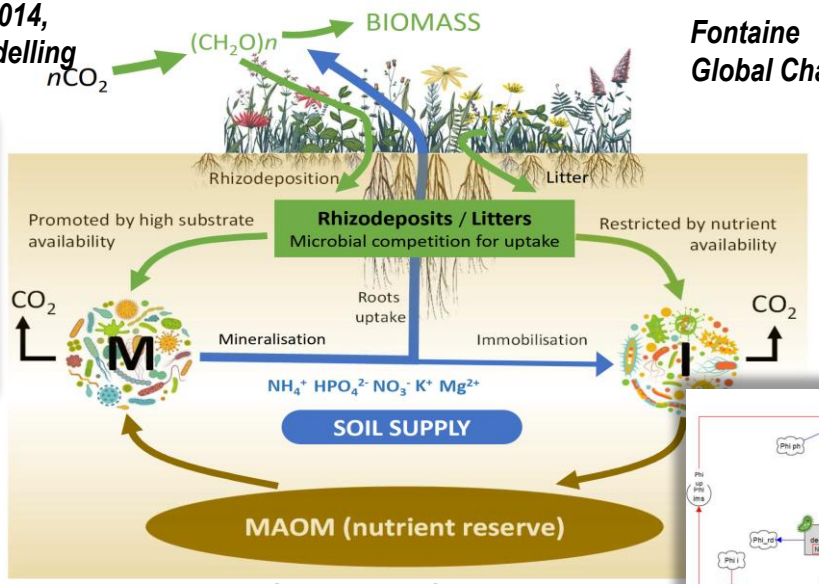
MODIMIV develops integrated, explicit and dynamic simulators of these interactions in multi-species vegetation covers (e.g. grassland systems) to better simulate C and N fluxes while synchronising nutrient supply and demand.





Confalonieri, 2014, Ecological Modelling

CoSMo



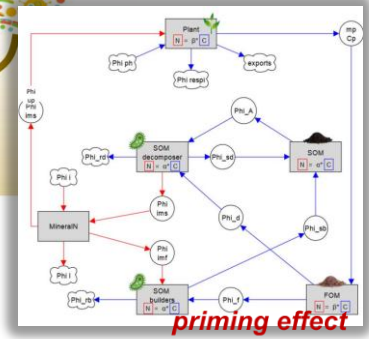
Fontaine et al., 2024, Global Change Biology

EJP SOIL AGROECOSeqC

ModVege

Piseddu et al., 2022, Agronomy

SYMPHONY



priming effect

Perveen et al., 2014, Global Change Biology

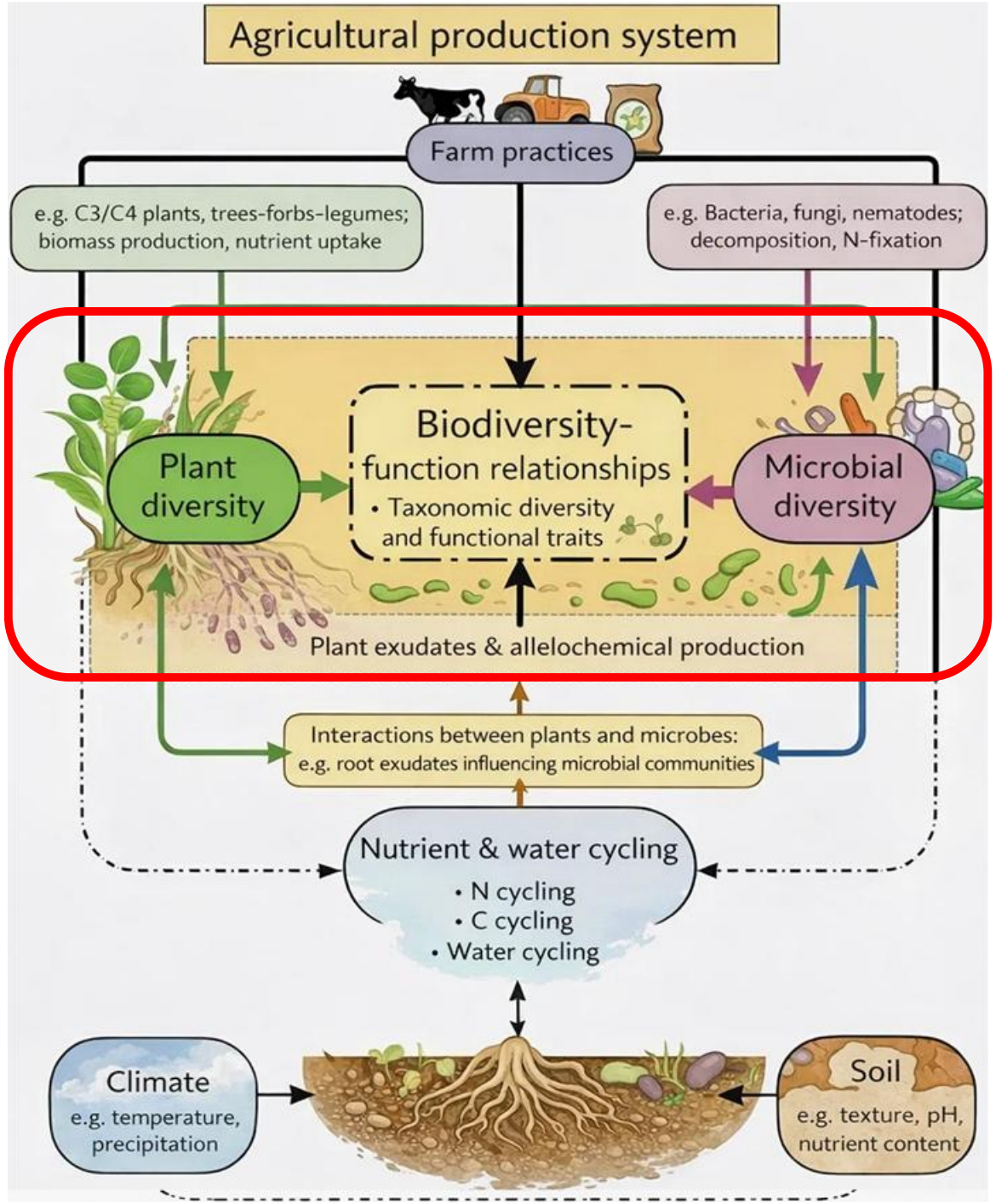
Varying C-N ratios
Nutrient recycling
Root growth and exudates, …

$$\lambda_{W,S} = \frac{I}{1 + f_N/\sigma_C \bullet d\sigma_C/dF_N}$$

G. Bellocchi[1], L. Adam[1], G. Alvarez[2], A. Bérard[3], J. Bloor[1], M. Carozzi[4], D. Cavalli[5], A. Cébron[6], S. Fontaine[1], R. Martin[1], A. Rodriguez[7], D. Warren Raffa[8], A. Trinchera[8]

[1]INRAE-UREP, [2]VetAgro Sup, [3]INRAE-EMMAH, [4]INRAE-SADAPT, [5]CREA-ZA, [6]CNRS-LIEC, [7]INRAE-UR P3F, [8]CREA-AA

BIOSEFAIR



Expanding perspectives on dynamic modelling of plant-microbe interactions for sustainable management of multispecies plant covers. A review

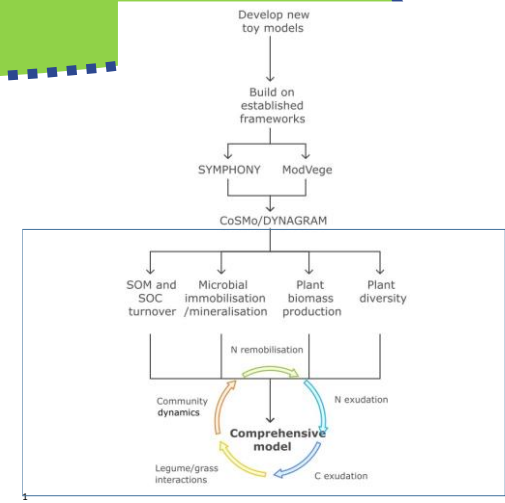
Rodríguez, A.[1,2], Adam, L.[1], Alvarez, G.[1], Bérard, A.[3], Bloor, J.M.G.[1], Carozzi, M.[4], Cavalli, D.[5], Cébron, A.[6], Fontaine, S.[1], Martin, R.[1], Trinchera, A.[7], Warren Raffa, D.[7], Bellocchi, G.[1]

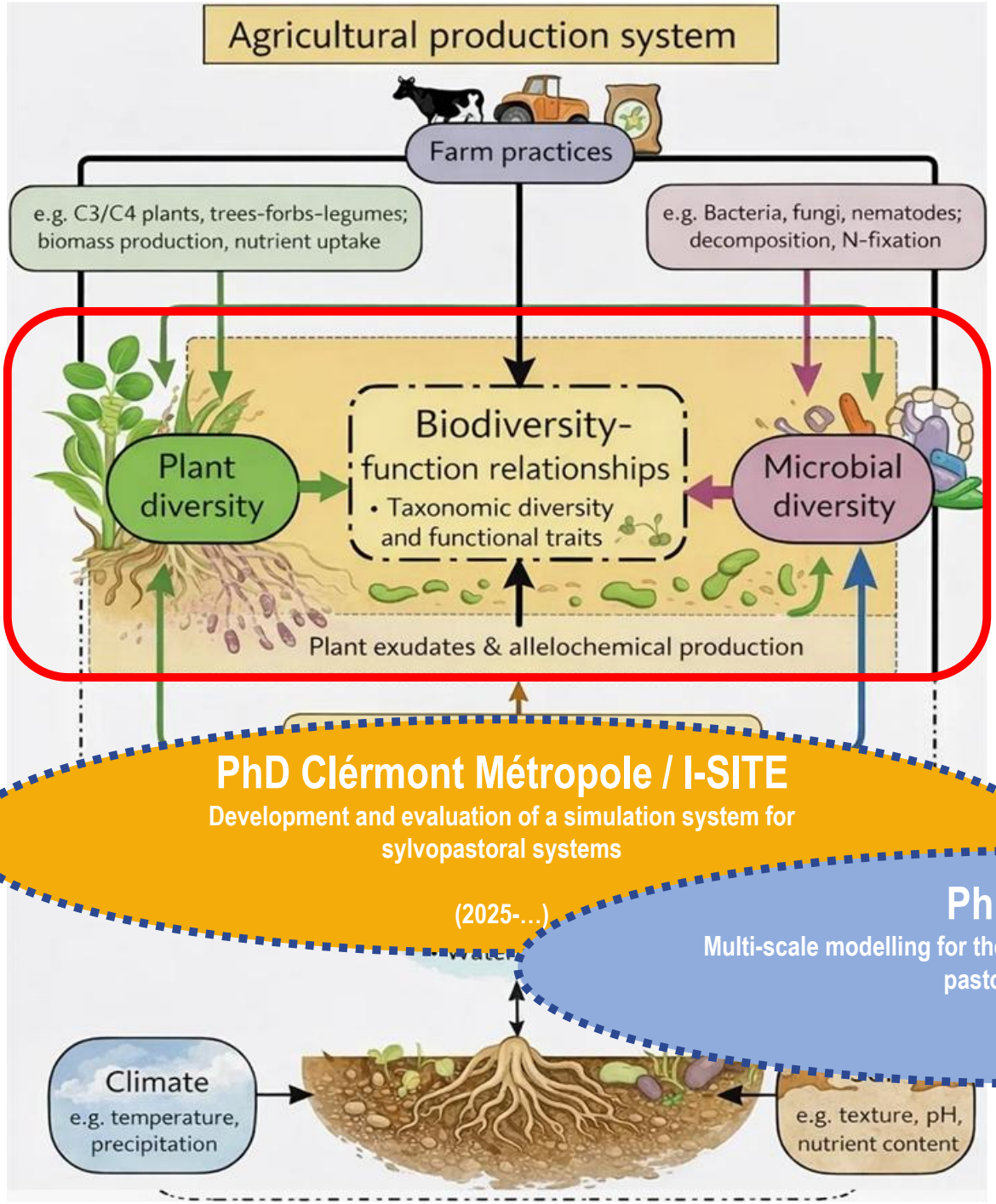
Rodríguez et al. (under revision)

PhD Biosefair / VetAgro Sup

Modelling the interactions between microbial and plant diversity in multi-specific agrosystems: Detailed analysis of the regulatory mechanisms governing carbon and nitrogen fluxes

(2024-…)





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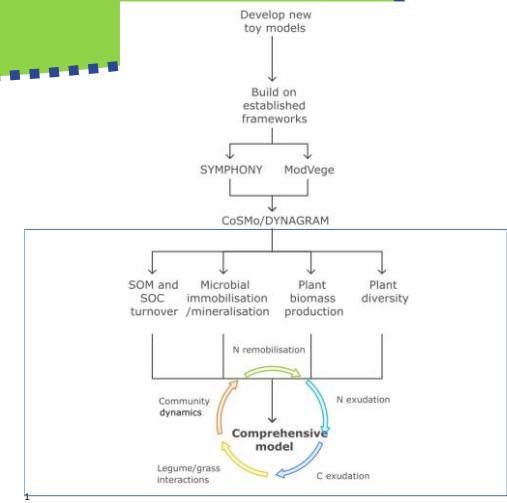

PhD Clérmont Métropole / I-SITE

Development and evaluation of a simulation system for sylvopastoral systems

(2025-…)

PhD TSARA

Multi-scale modelling for the sustainable management of Sahelian pastoral ecosystems

(2026-…)

PhD ELTE / French Institute of Budapest

Extending grassland ecosystem models using remote sensing data and artificial intelligence methods

(2026-…)

1 Introduction

1.1 Sustainable agroecosystem management and the role of modelling

1.2 Integrated models for ecosystem service prediction in agriculture

1.2.1 Plant biodiversity in models: current [illegible] aches and traits

1.2.2 Microbial biodiversity in m[illegible] nd integration challenges

1.3 Goals and outline

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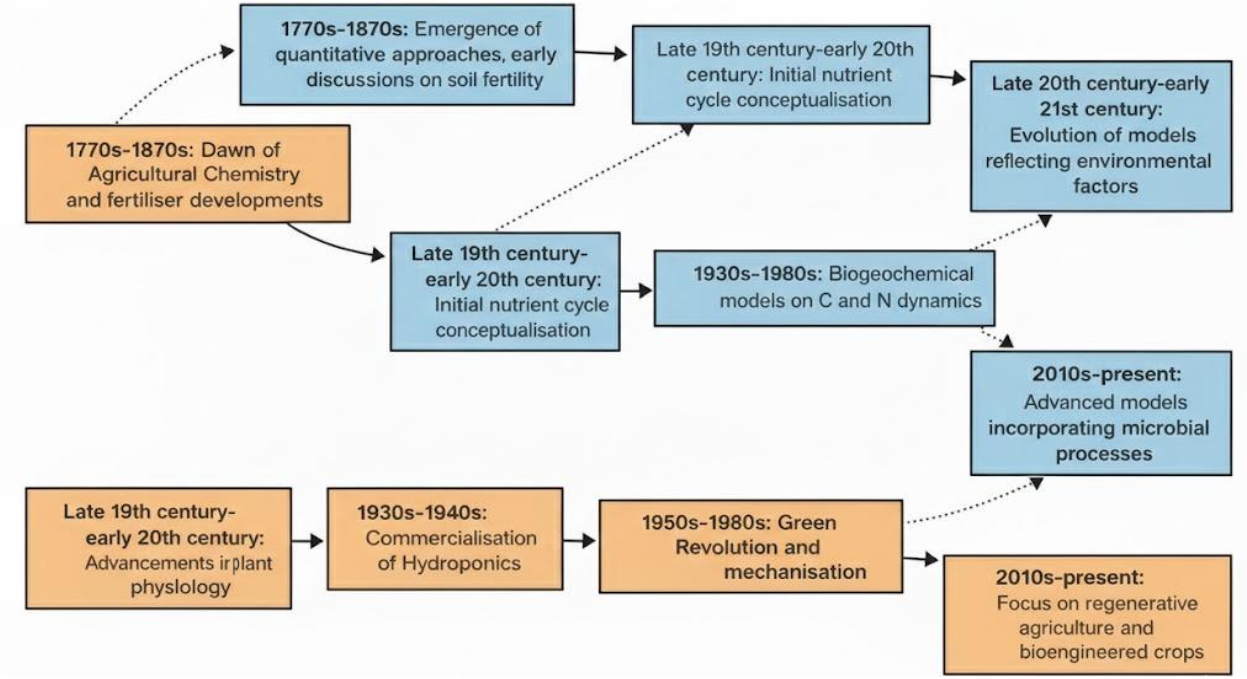
5.4.2 Interdisciplinary collaborations, data integration and upscaling

6 Conclusion

Foundations, scope and metrics

Historical foundations and contemporary advances

Challenges, outlook and interdisciplinary perspectives



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Foundations, scope and metrics

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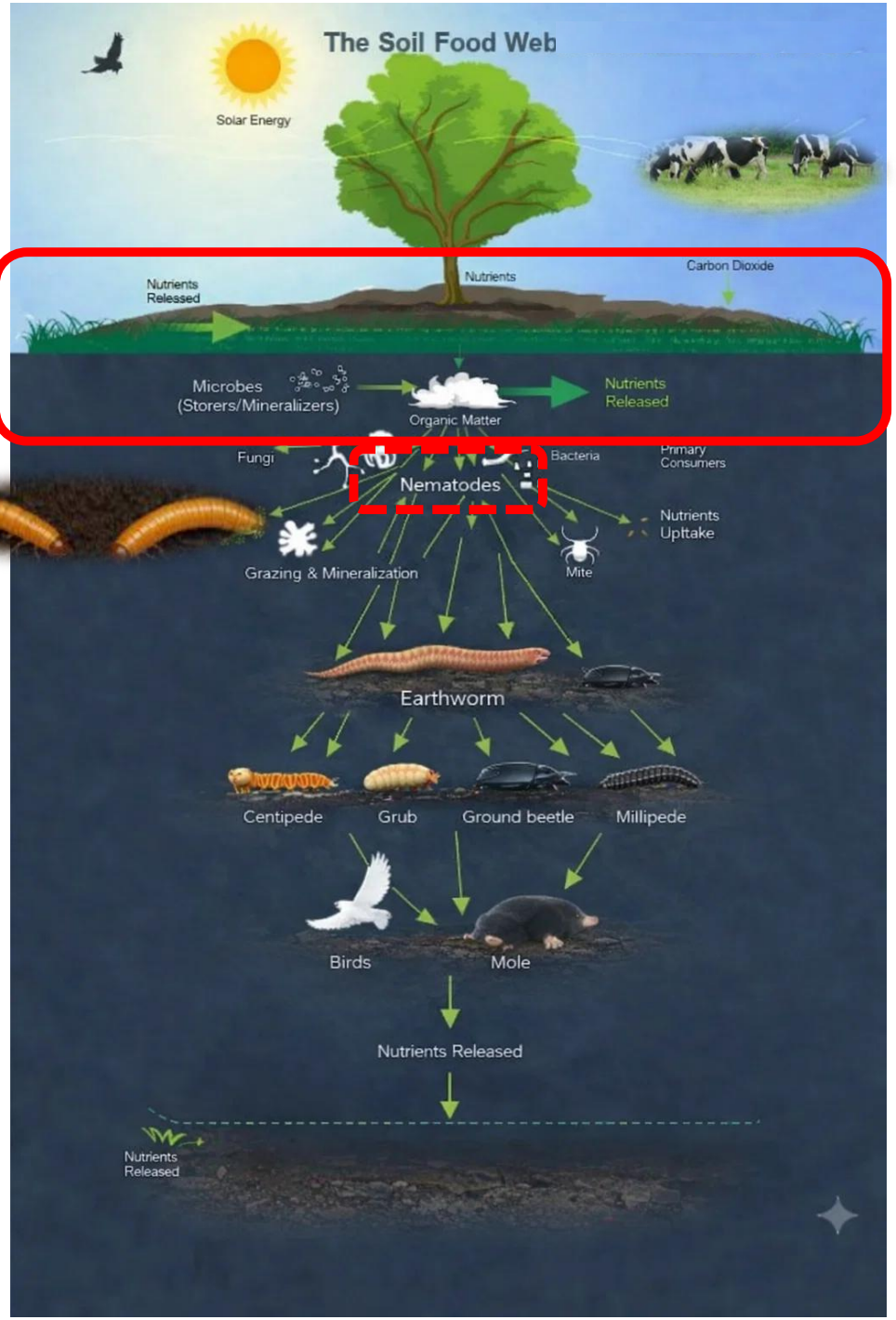
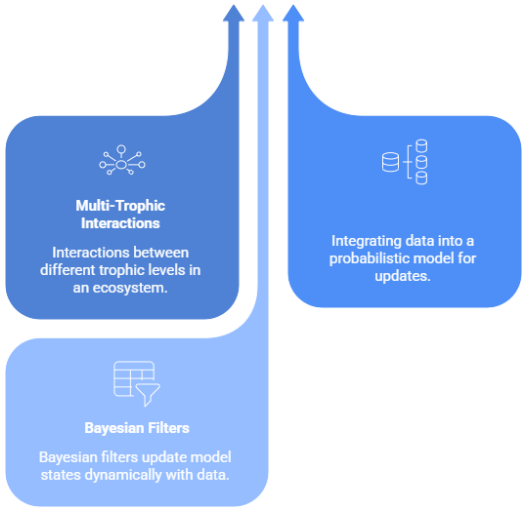
Challenges, outlook and interdisciplinary perspectives

Key area	Focus and objectives	Ecological question	Contribution of model development
Integrating plant diversity	Represent species composition, traits, and interactions	What demographic traits determine the resilience of populations to disturbance?	Improves predictions of how plant traits drive ecosystem stability
Incorporating microbial diversity	Represent microbial roles in nutrient cycling and stress responses	How does below-ground biodiversity affect above-ground biodiversity?	Enables quantification of soil–microbe–plant interactions
Accounting for temporal and spatial variability	Integrate short- and long-term dynamics; scale from rhizosphere to landscapes	How do spatial and temporal heterogeneity influence diversity at different scales?	Improves accuracy of biodiversity and ecosystem service predictions
Ensuring model accuracy and reproducibility	Clarify equations, test feedback, reassess assumptions	Can biodiversity be effectively represented in models of ecosystem services to guide the design future agroecosystems?	Test whether trait-based simplifications explain stability
Leveraging technological advances	Use sensors, computational tools, and ML for real-time calibration	How can relationships between management practices and ecosystem services in agroecosystems be better investigated?	Enables real-time tracking of management impacts on biodiversity
Promoting interdisciplinary collaboration	Foster cross-disciplinary integration and align terminology	What can we learn from model communities of microorganisms about communities of macroorganisms?	Bridges microbial and macroorganism ecology for ecosystem assessment

Rodríguez et al. (under revision)



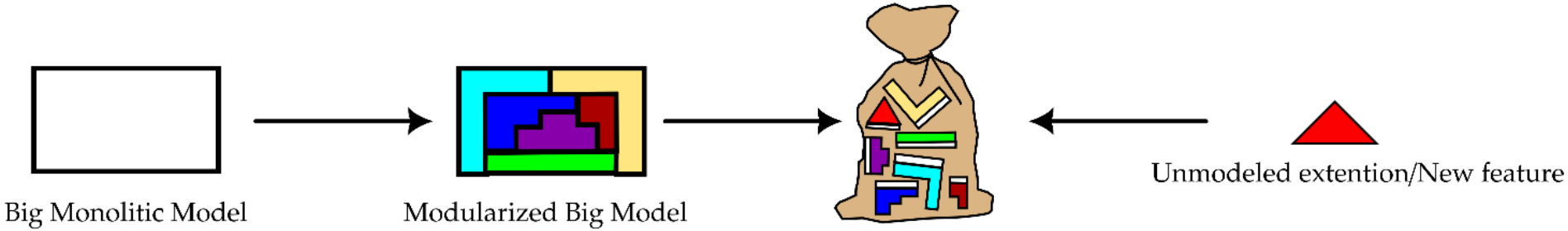
Nematode group	Mechanism and main impact	Link to existing modelling	Integration level
Phytophagous nematodes ($Nema_{Phy}$)	Root biomass consumption: a stress factor (s_{Phy}) reduces the plant's efficiency in acquiring N and C.	Decreases the N acquisition rate and the C supplied to storers/mineralisers	Plant dynamics (stress)
Bacteriophagous nematodes ($Nema_{Bac}$)	Population regulation (top-down mortality) of storers/mineralisers: the N mineralisation flux reduced by grazing (rapid excretion of excess N).	Accelerates the conversion of microbial N intro mineral N (fast N loop)	Microbial and N dynamics (key)
Trophic health index (α)	Use the nematode population ratio (e.g. $Nema_{Bac}/Nema_{Phy}$) as a factor modulating the efficiency of existing functions (e.g. mineralisation rate).	Infuences mineralisation efficiency - $MineralisationRate \cdot (1+k \cdot \alpha)$ - or plant C-N allocation.	Modulation factor (emergent)



Building a Dynamic Digital Twin

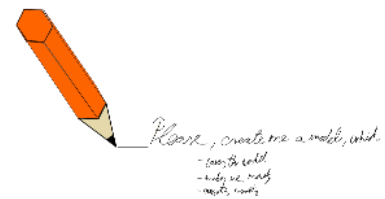
PEPR SolsVivants

TWIN-BIOT

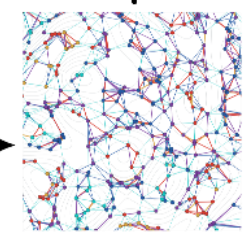


Artificial Process Modeling (APM) for the AI Scientist

From monolithic scientific codes to composable, knowledge-grounded world models



Human Input



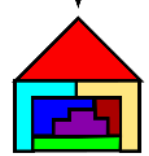
AI model

Roland Hollos

HUN REN Hungarian Research Network

Simplified model

New simple model



Extended model

The use of AI at the HUN-REN Centre for Agricultural Research is expected to deliver even higher-quality results in the future. As part of HUN-REN Headquarters' AI 4 Science programme, ambassadors are supporting the work of researchers across the network's research centres.

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