Large-scale Multi-criteria Evaluation of Agroecological Strategies with the STICS Model

Mathieu Delandmeter, Bruno Basso, Jérôme Bindelle, Benjamin Dumont

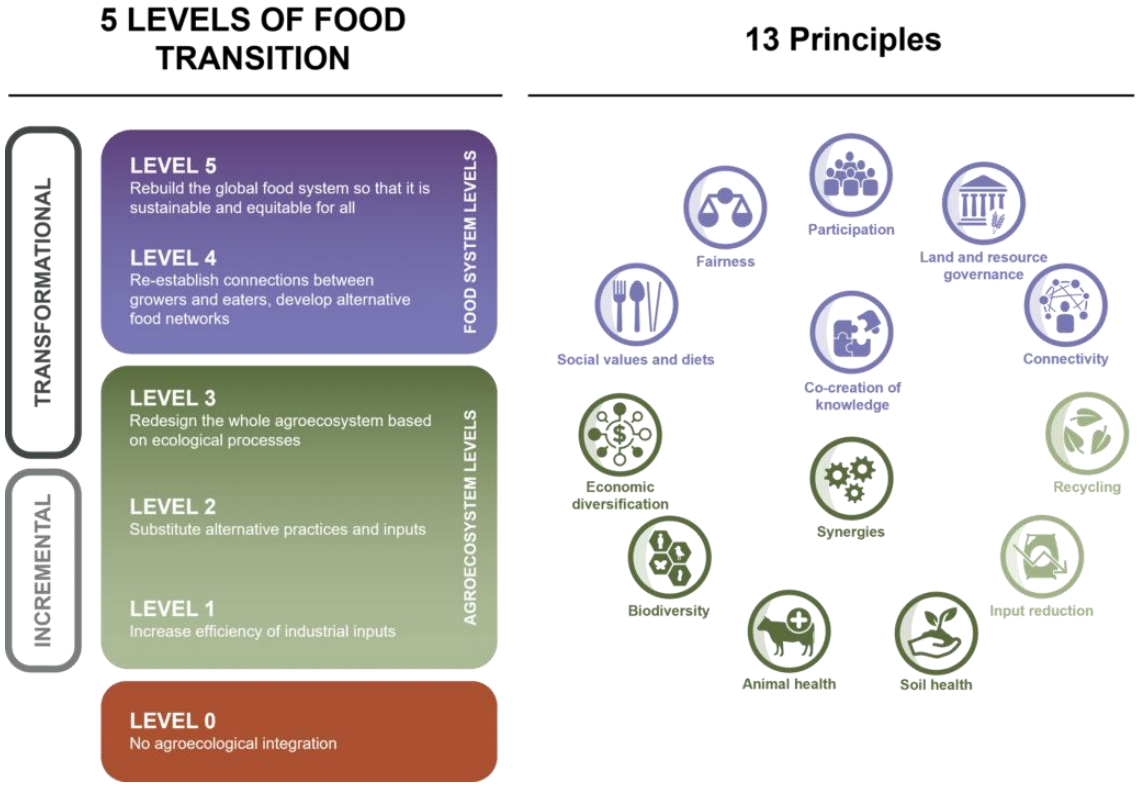
Basso Lab

Dept. Earth and Environmental Sciences

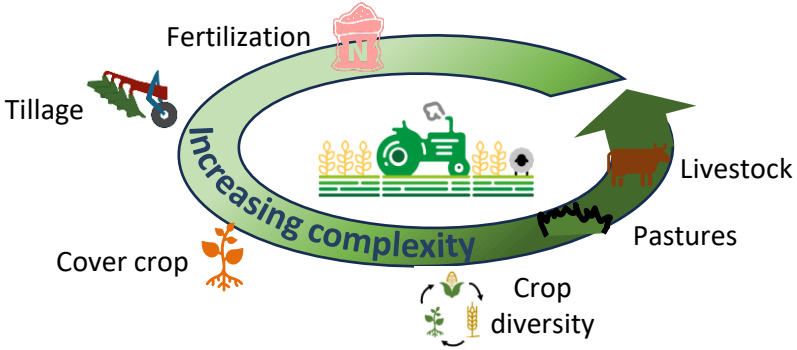
Michigan State University

XIVth STICS seminar, 17-19 March 2026, organized by ULiege-GxABT & INRAE

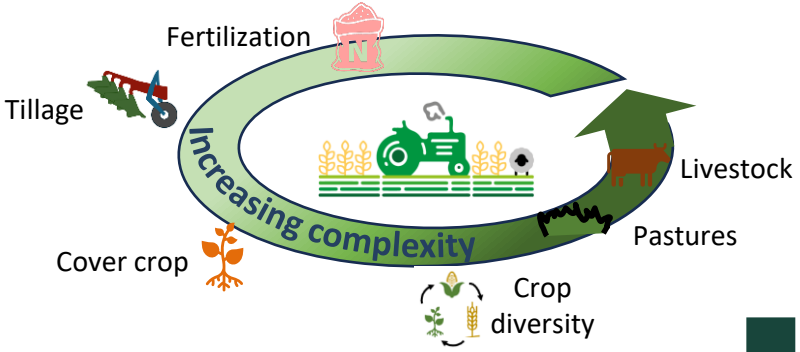
Modelling agroecology



1. Cropping systems design



1. Cropping systems design



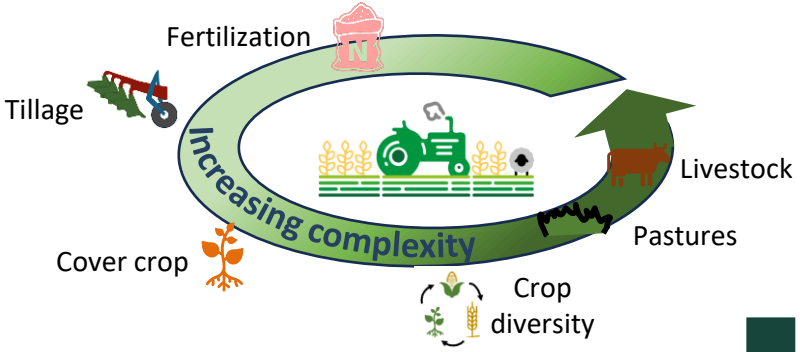
2. Cropping systems modelling

STICS

Soil-crop models

SALUS

1. Cropping systems design



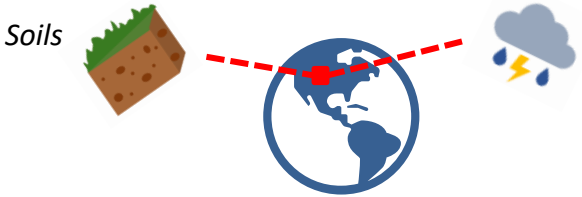
2. Cropping systems modelling

STICS

Soil-crop models

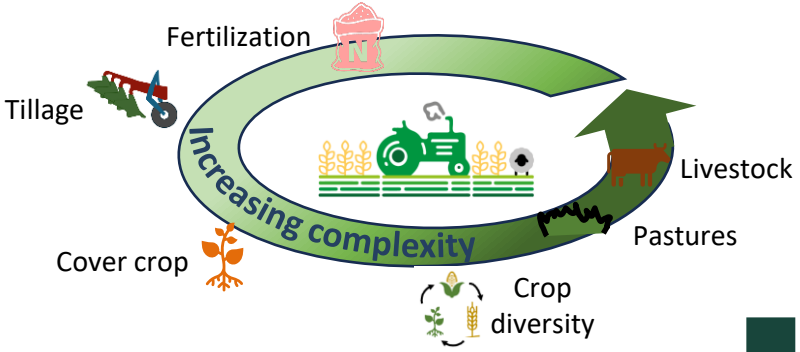
SALUS

3. In contrasted pedoclimatic conditions



Single-site and large scale simulations in Belgium, Brazil, USA

1. Cropping systems design



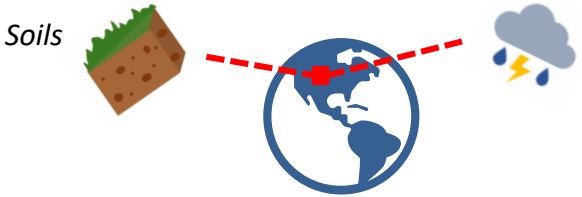
2. Cropping systems modelling

STICS

Soil-crop models

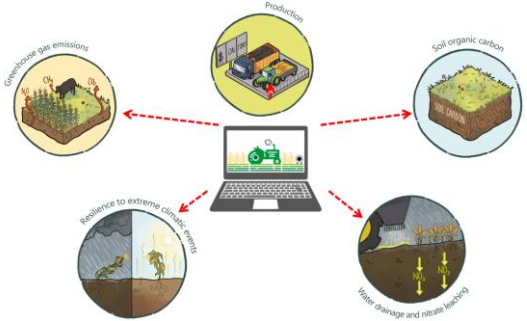
SALUS

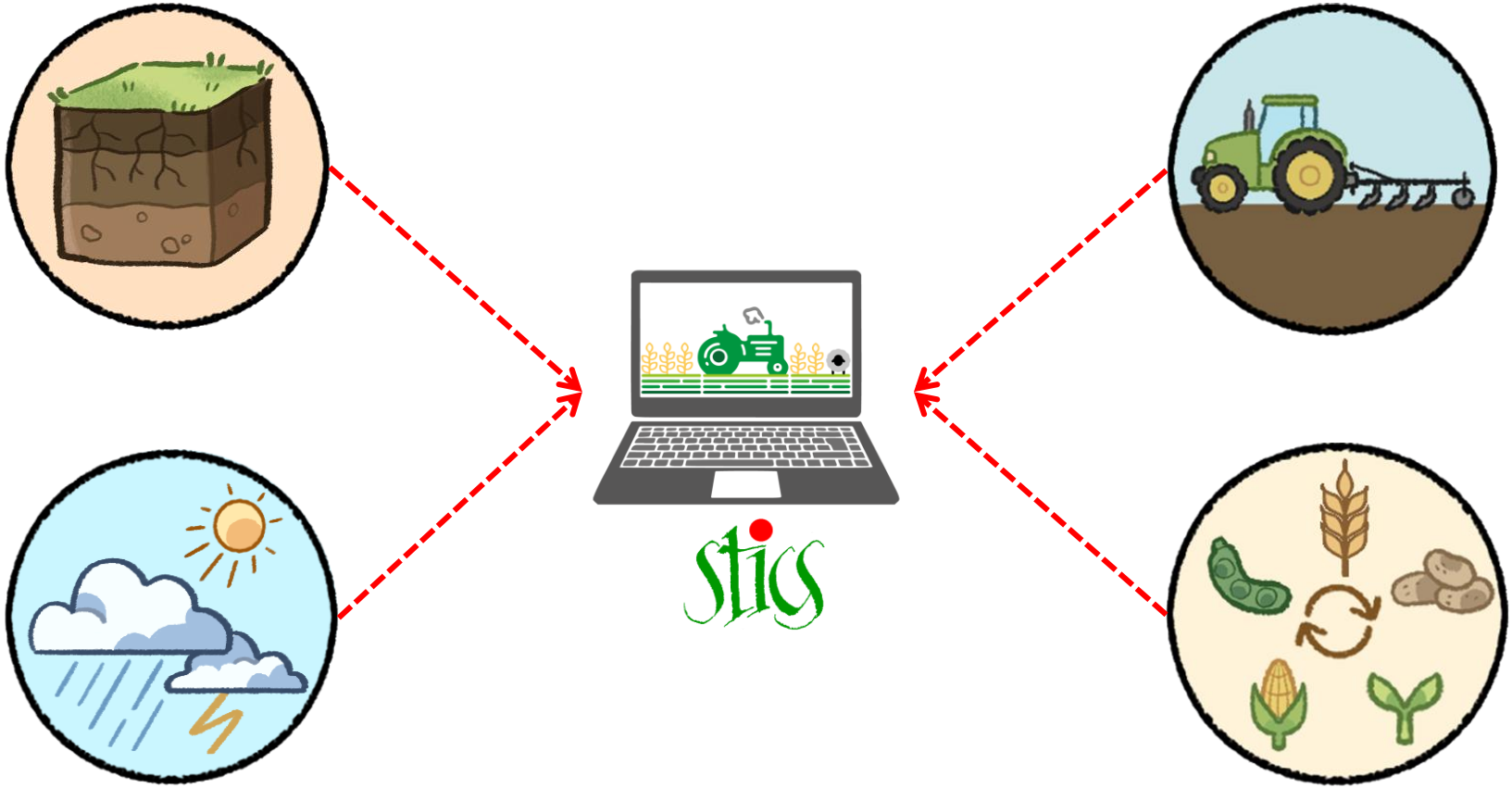
3. In contrasted pedoclimatic conditions



Single-site and large scale simulations in Belgium, Brazil, USA

4. Cropping systems comparison

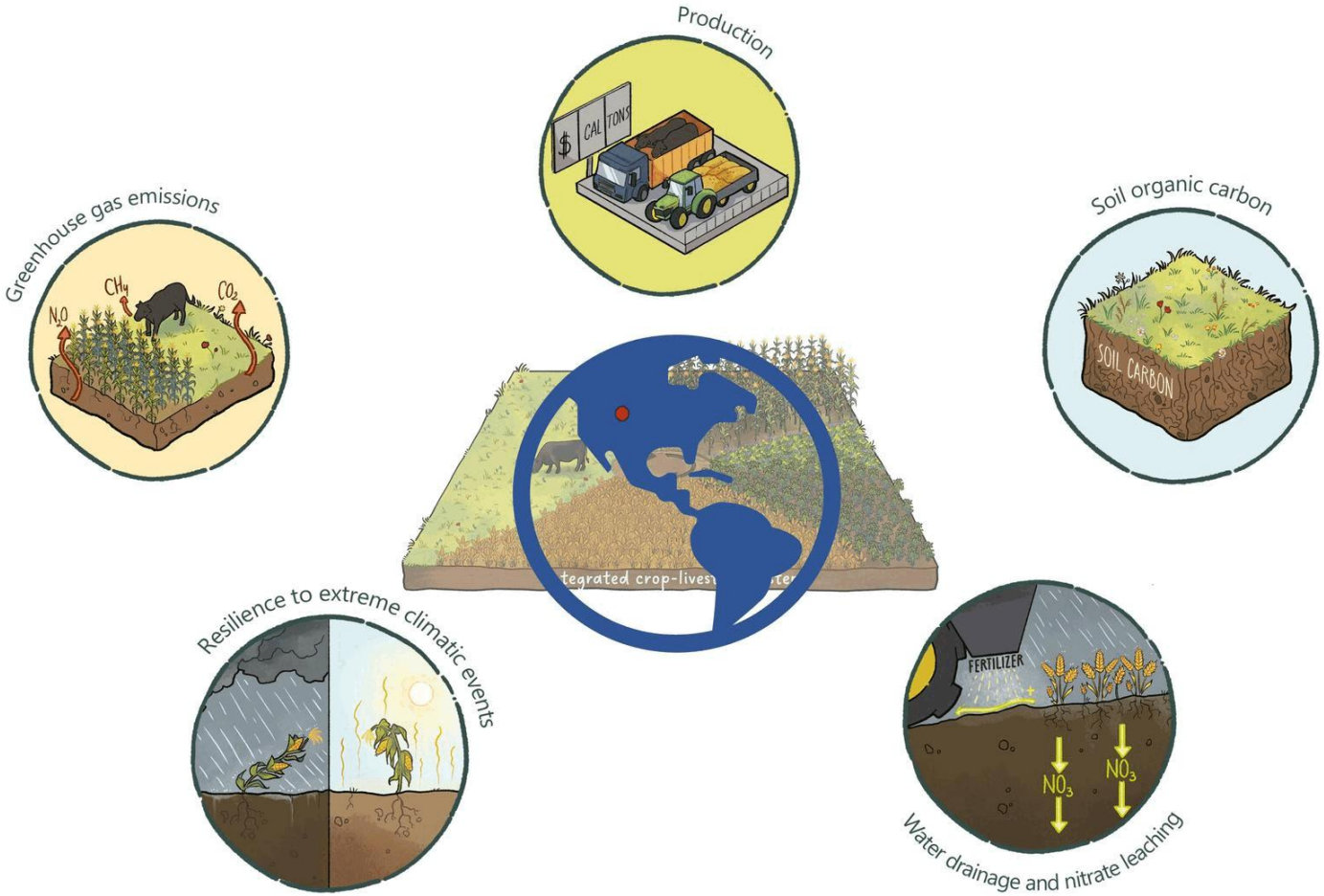



STICS

STICS

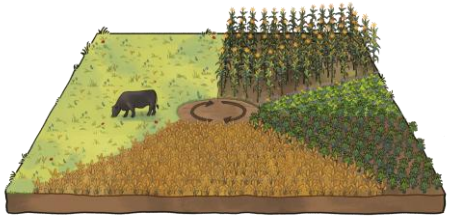
High Performance Computers

STICS


Production
$
CAL
TONS
Greenhouse gas emissions
CH_4
CO_2
N_2O
Soil organic carbon
SOIL CARBON
tegrated crop-lives
Resilience to extreme climatic events
FERTILIZER
NO_3
NO_3
Water drainage and nitrate leaching

Increasing scales

Field



Farming system

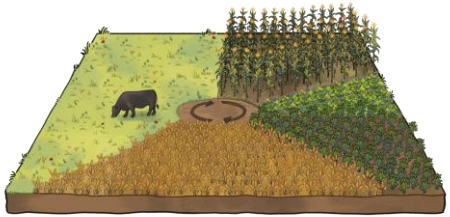
Food system

Agroecological transformation

Increasing scales

Spatial scale

Field



Farming system

Food system

Agroecological transformation

Increasing scales

Field

Agroecological transformation

Tillage and crop residue management

Methodology

14-year field experiment

+

Soil-crop model

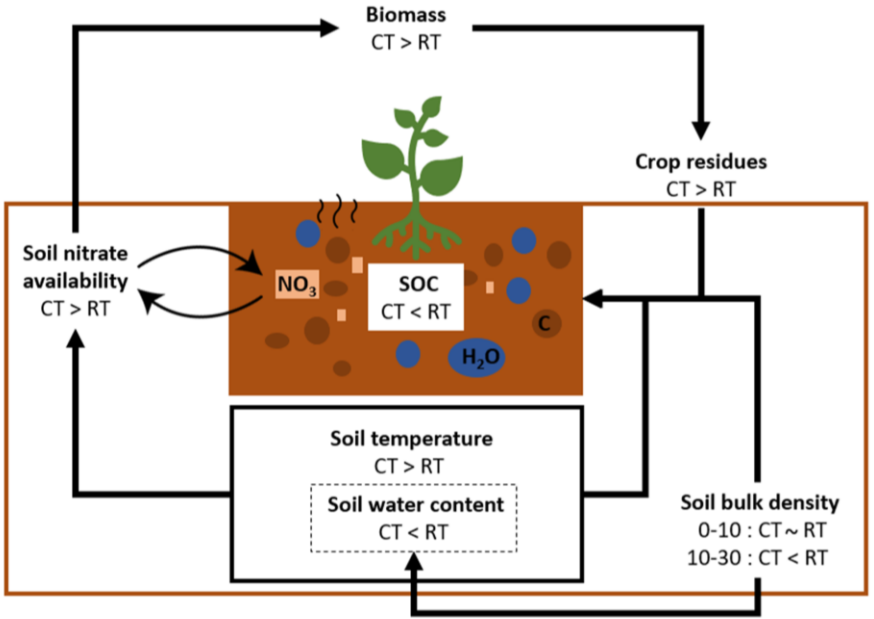
What if tillage is…

Conventional (CT) vs Reduced (RT)

What if crop residues are…

Incorporated (IN) vs Exported (OUT)

Main messages



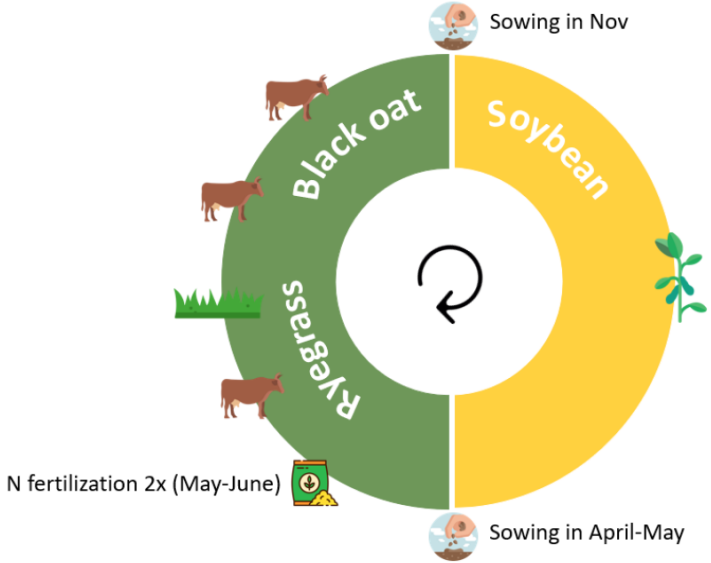
Increasing scales

Field

Agroecological transformation

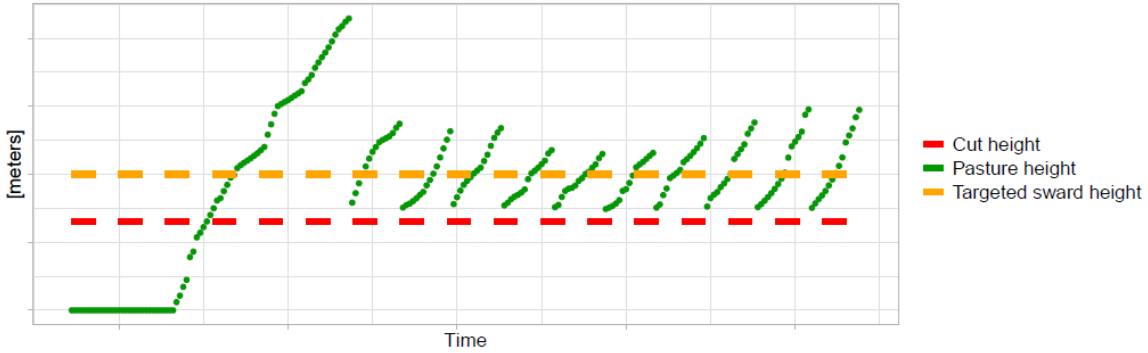
Grazing intensity in crop-livestock systems

10 cm 20 cm 30 cm 40 cm Ungrazed



UFRGS

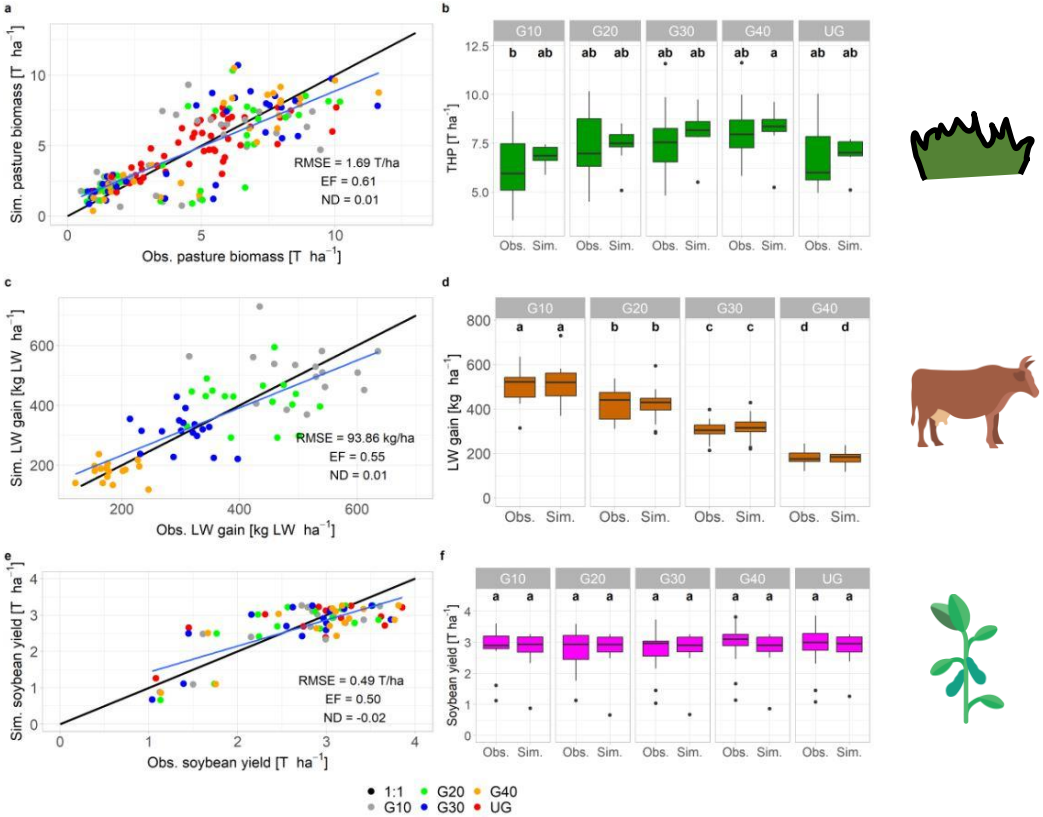
Grazing intensity in crop-livestock systems



Based on Graux et al. (2020)

UFRGS

Grazing intensity in crop-livestock systems



UFRGS

Increasing scales

Field

Farming system

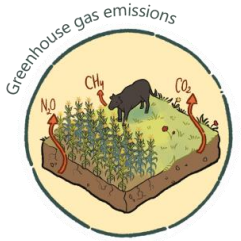
Agroecological transformation

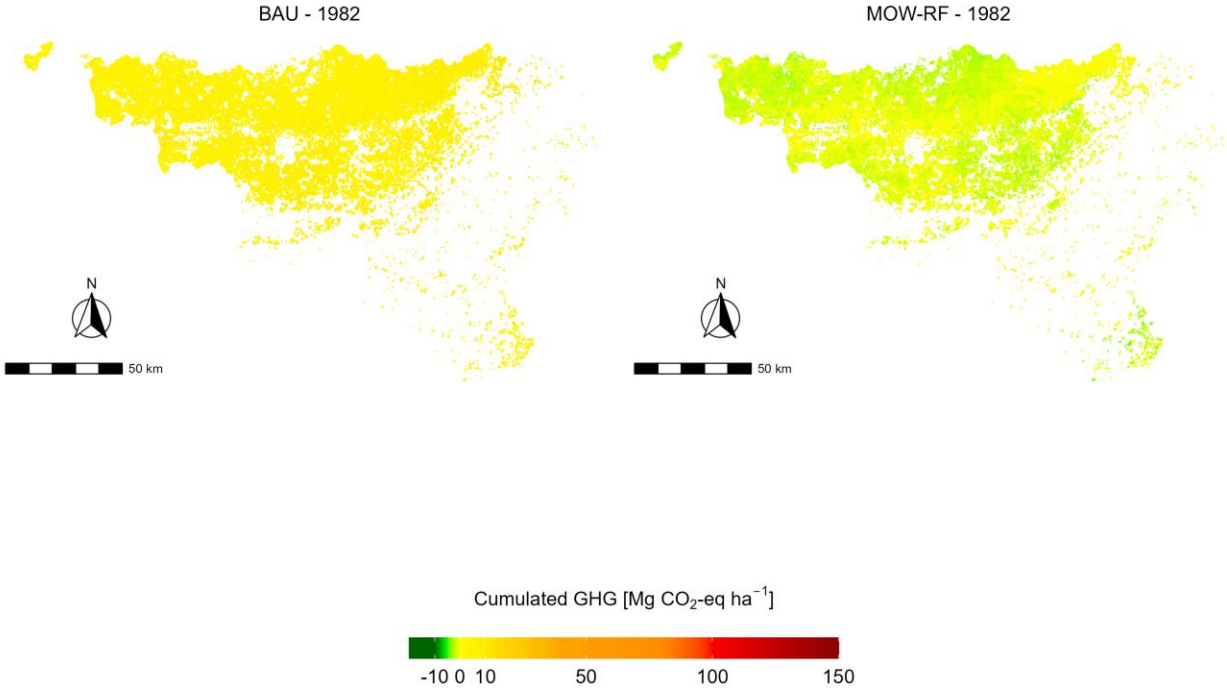
A gradient of increasingly complex crop rotations

Agroecological levers

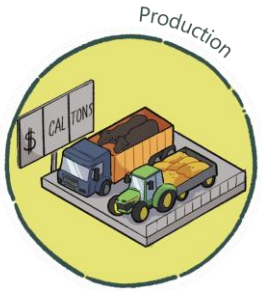
- Reduced N fertilization (RF)
- Crop diversity
- Pastures integration
- Livestock integration

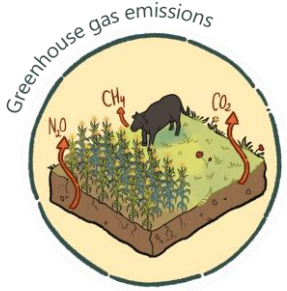
A gradient of increasingly complex crop rotations

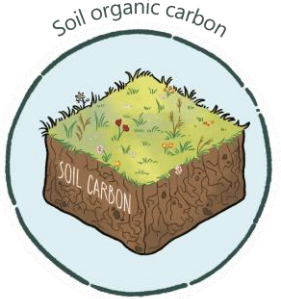


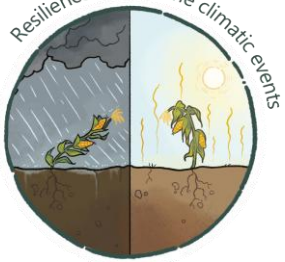


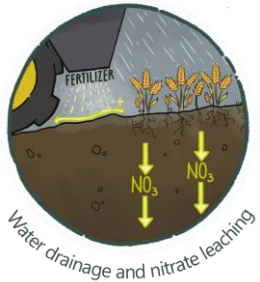
Trade-offs and synergies



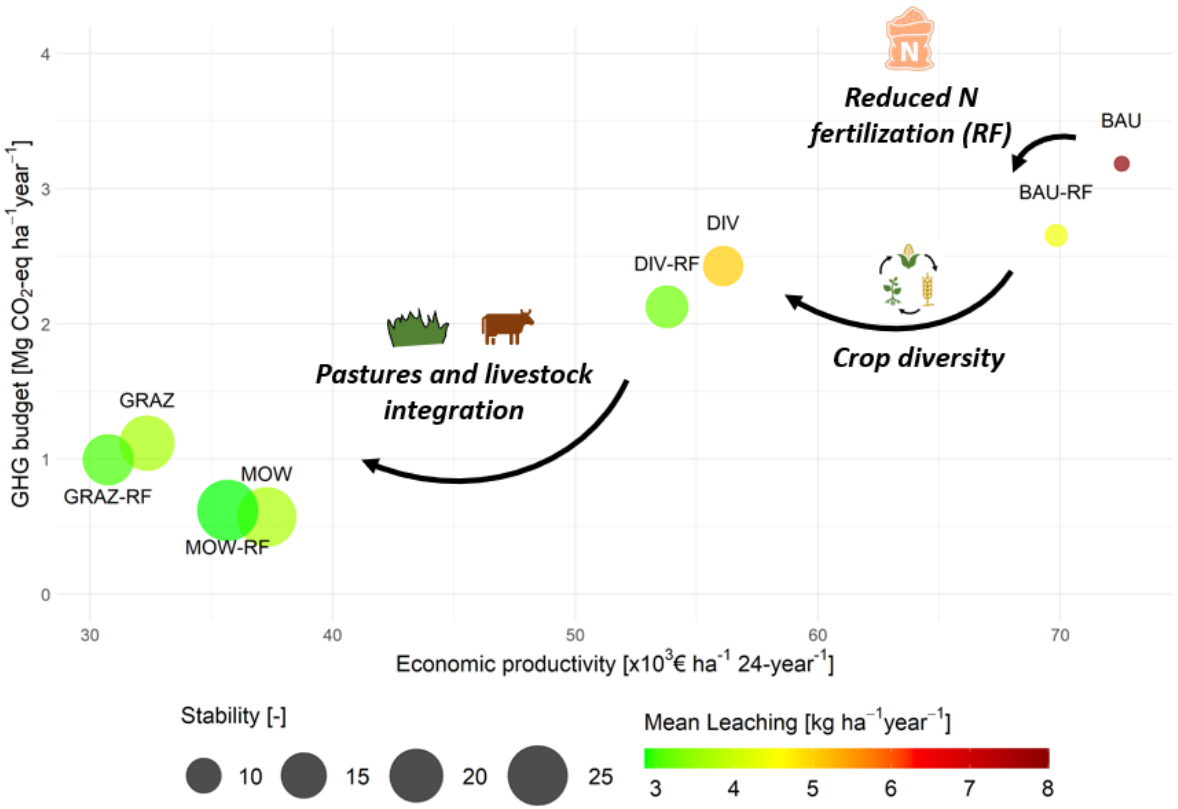






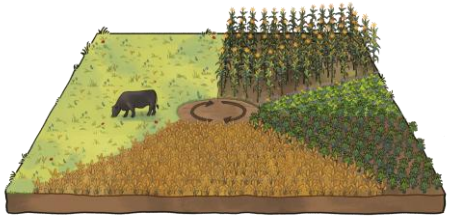


Trade-offs and synergies



Increasing scales

Field



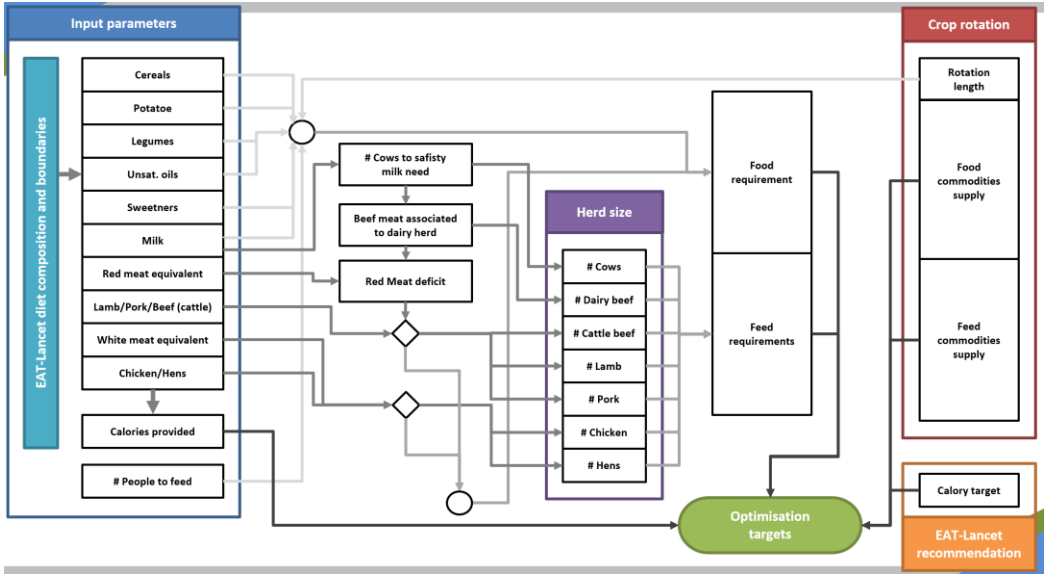
Farming system

Food system

Agroecological transformation

At the “food system” scale

MICHIGAN STATE UNIVERSITY



Agronomy for Sustainable Development (2026) 46:11
https://doi.org/10.1007/s13593-026-01084-z

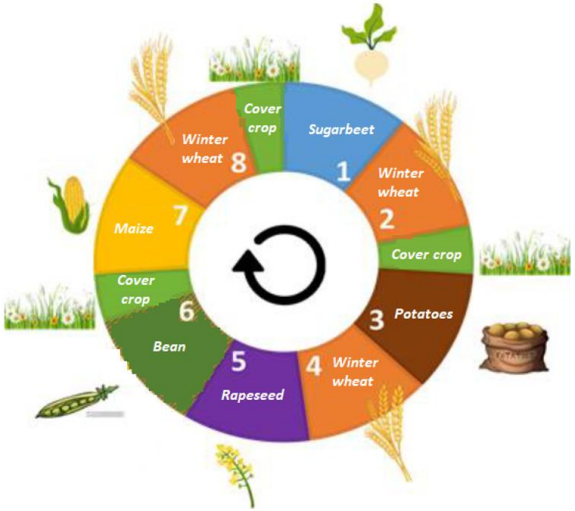
RESEARCH ARTICLE

Designing crop rotations to support sustainable and healthy diets

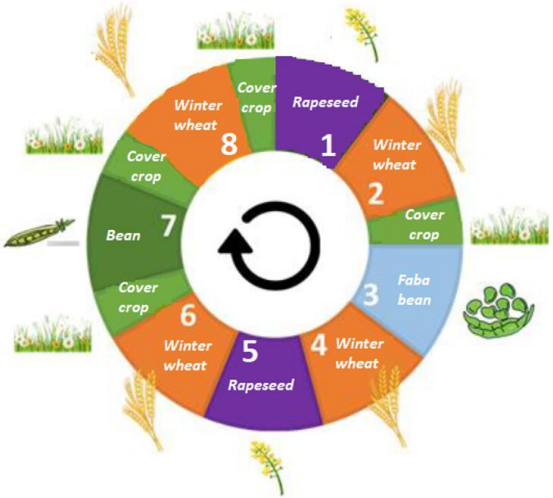
Caroline De Clerck[1] · Tom Desmarez[2] · Mathieu Delandmeter[2] · Paulo César de Faccio Carvalho[3] · Benjamin Dumont[2] · Jérôme Bindelle[4]

At the “food system” scale

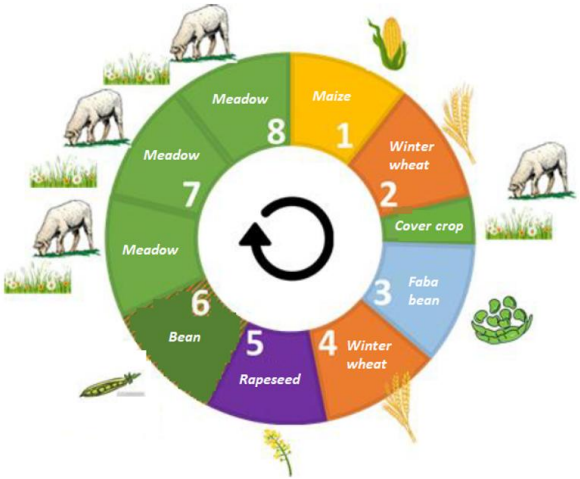
MICHIGAN STATE UNIVERSITY



Business-as-usual (BAU)

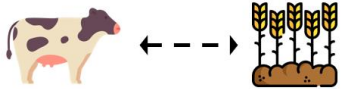


Vegan



Integrated Crop-Livestock (ICLS)

Animal-crop flow:

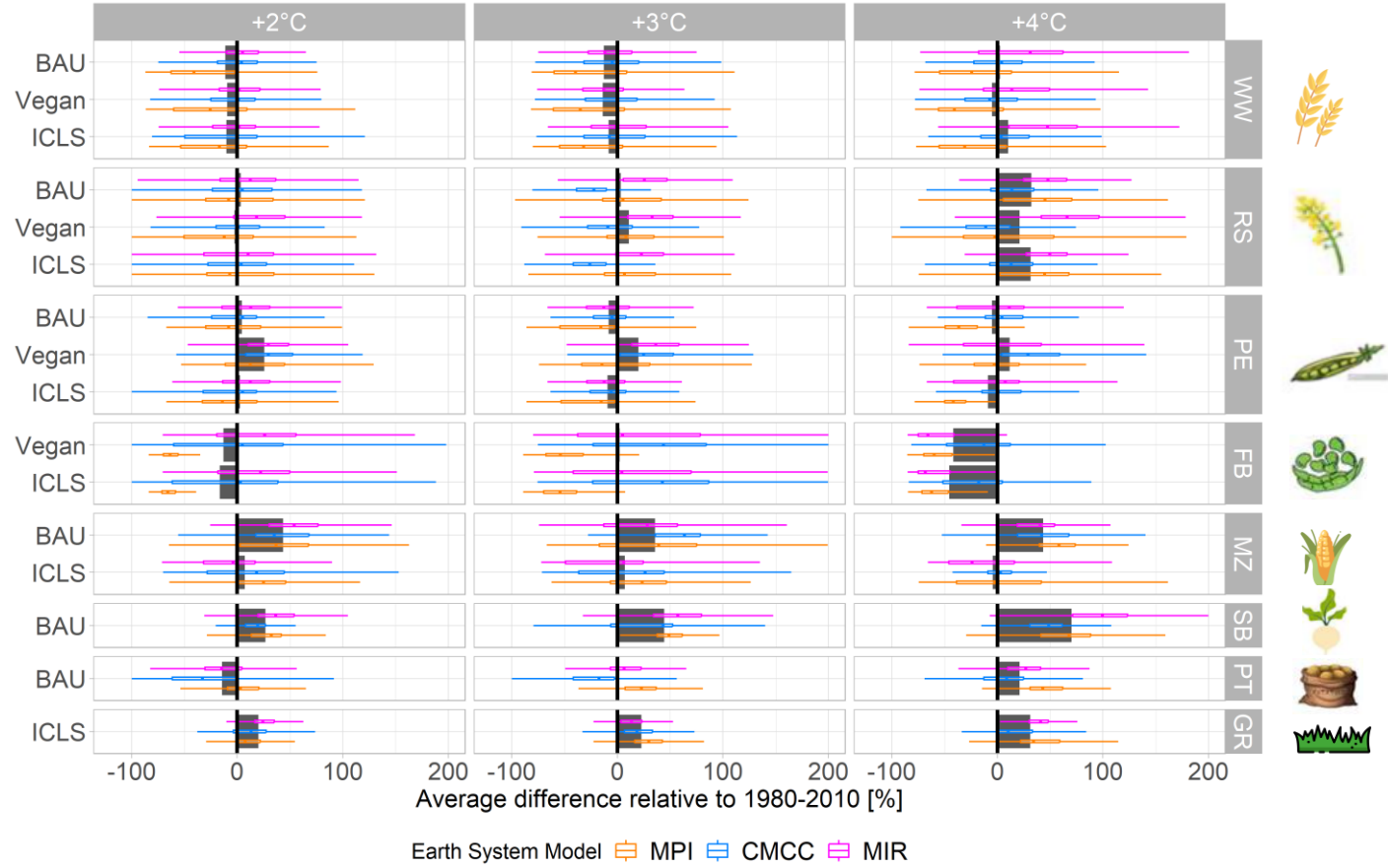


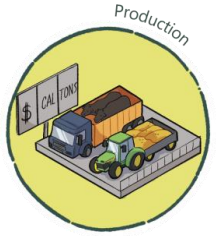
External connexion

No connexion (no animals)

Internal connexion

At the “food system” scale

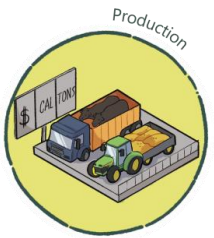


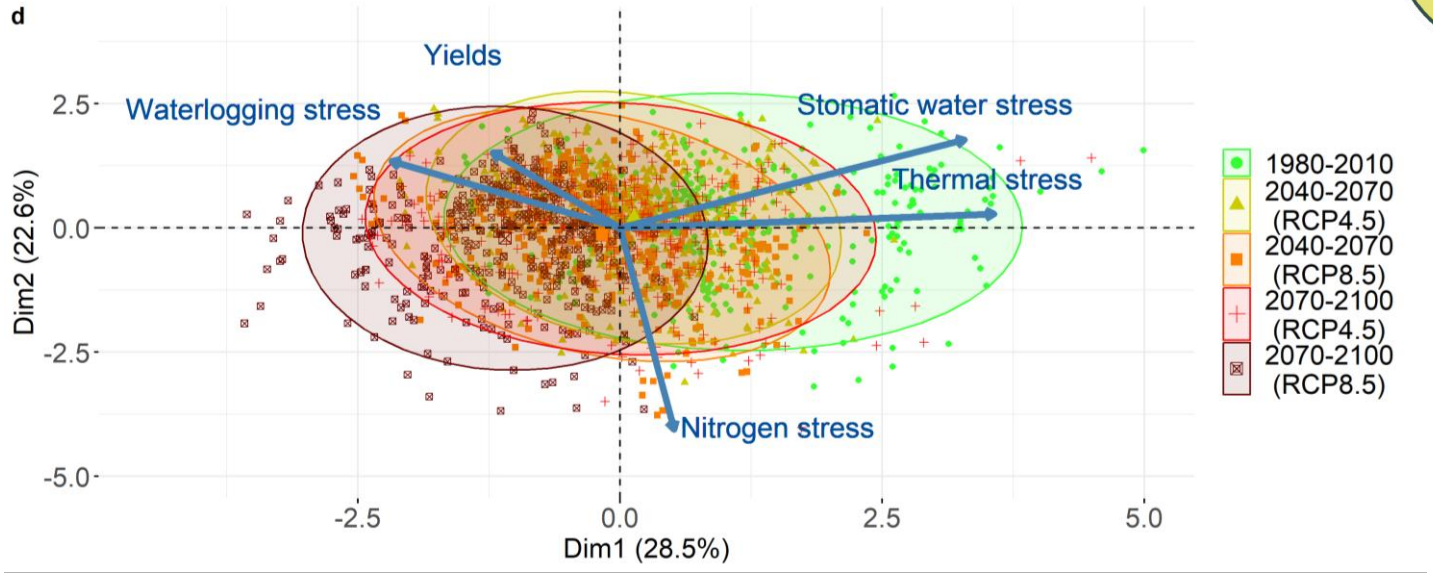


At the “food system” scale

MICHIGAN STATE UNIVERSITY

Behind crop yield evolution, crop stresses…





Resistance to Extreme Climate

1. Characterize 3-month periods as being *normal* or *moderately/extremely* dry or wet, relatively to historical climatic conditions

Resistance to Extreme Climate

1. Characterize 3-month periods as being *normal* or *moderately/extremely* dry or wet, relatively to historical climatic conditions
2. Characterize the yield according to the period preceding flowering or harvest

Resistance to Extreme Climate

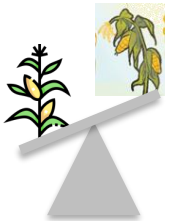
1. Characterize 3-month periods as being *normal* or *moderately/extremely* dry or wet, relatively to historical climatic conditions
2. Characterize the yield according to the period preceding flowering or harvest

3. Compute the average yield under *normal* climatic conditions

Resistance to Extreme Climate

1. Characterize 3-month periods as being *normal* or *moderately/extremely* dry or wet, relatively to historical climatic conditions
2. Characterize the yield according to the period preceding flowering or harvest

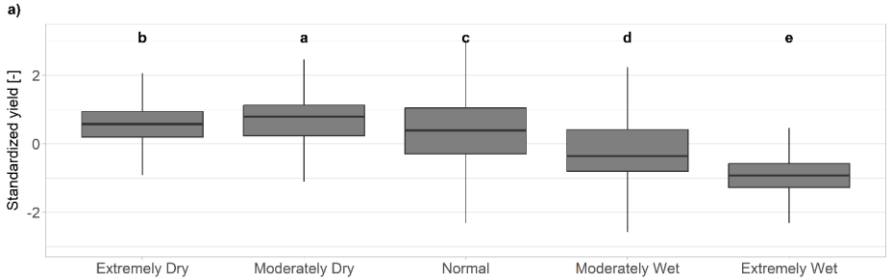
3. Compute the average yield under *normal* climatic conditions

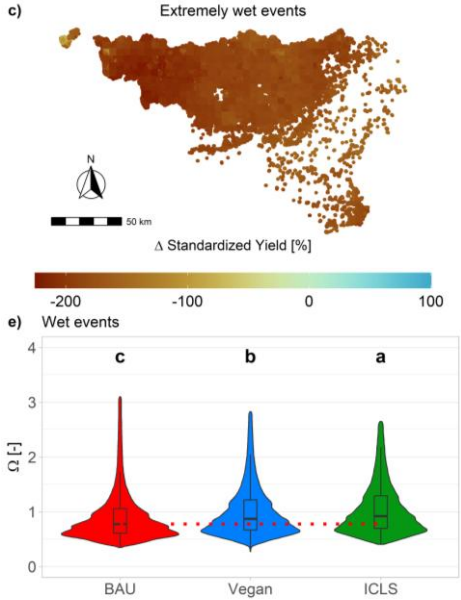


4. Compare yields under extreme climatic conditions versus normal conditions → the *resistance* being the ability to maintain productivity near normal levels

At the “food system” scale

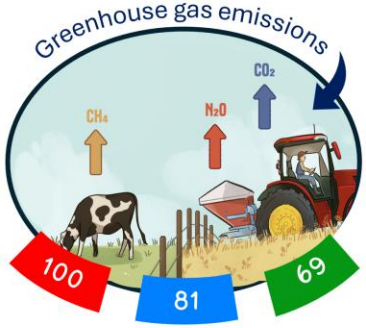
MICHIGAN STATE UNIVERSITY

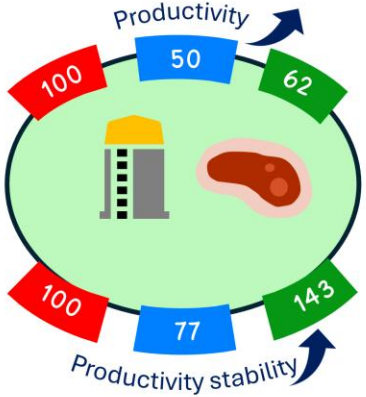


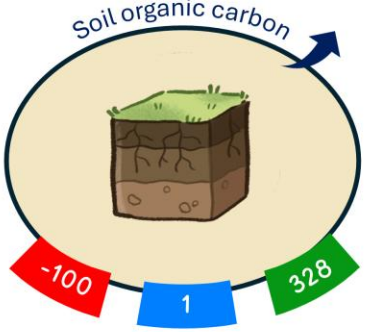


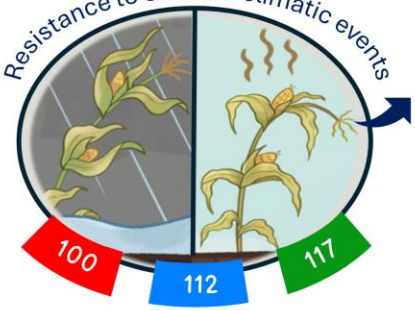
At the “food system” scale

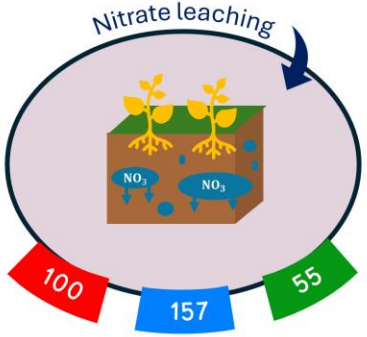
MICHIGAN STATE UNIVERSITY











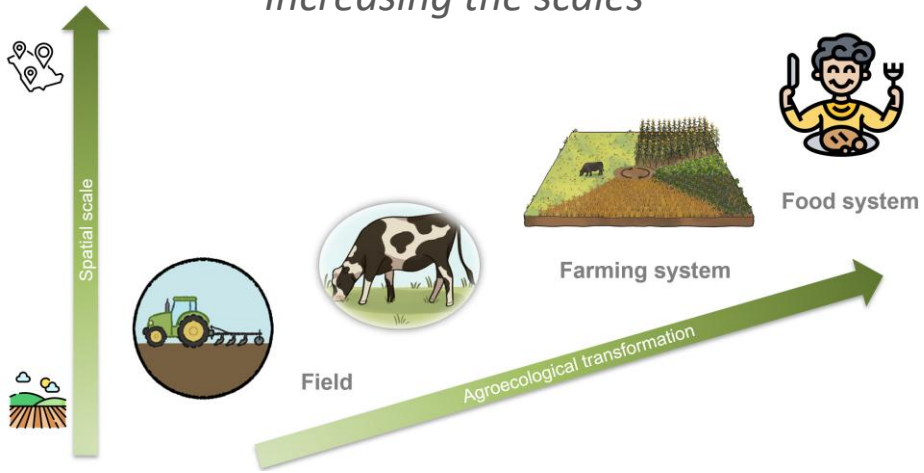
Business-as-usual

Vegan

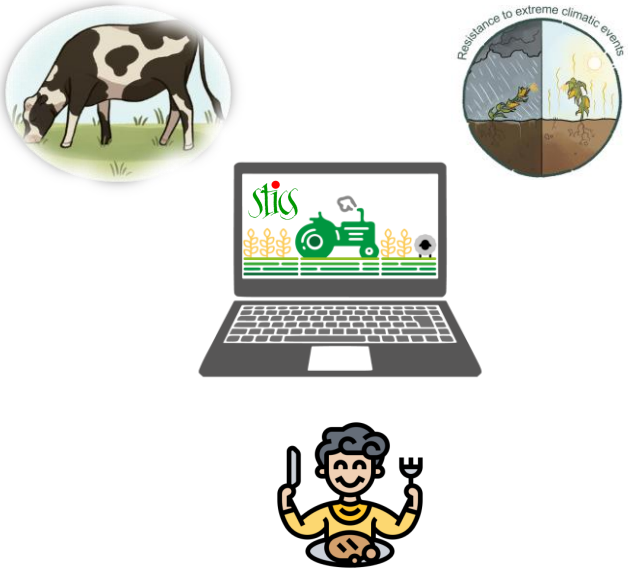
Integrated crop-livestock

Conclusion

Increasing the scales



Coupling STICS



Challenges

- Redesign STICS to improve its efficiency to conduct large scale simulations → *minimize redundancy*

Challenges

- Redesign STICS to improve its efficiency to conduct large scale simulations → *minimize redundancy*

- Improve the SOC dynamics to simulate contrasting tillage practices
  - SOC outputs for each layer, or even for each 5 cm-layer
  - Mineralization, compaction, fragmentation
  - Dynamic water retention parameters (hccf, hminf), recomputing pedotransfer functions each year with SOC as input

Challenges

- Redesign STICS to improve its efficiency to conduct large scale simulations → *minimize redundancy*

- Improve the SOC dynamics to simulate contrasting tillage practices
  - SOC outputs for each layer, or even for each 0-5 cm layer
  - Mineralization, compaction, fragmentation
  - Dynamic water retention parameters (hccf, hminf), recomputing pedotransfer functions each year with SOC as input

- Improve the animals grazing simulation

Challenges

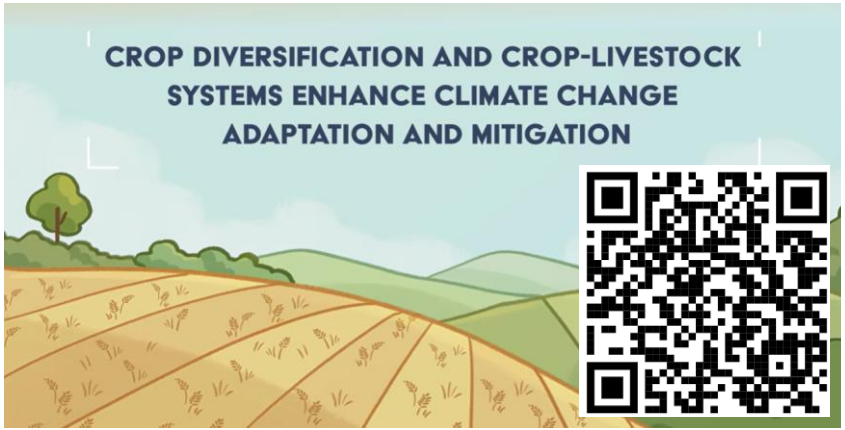
- Redesign STICS to improve its efficiency to conduct large scale simulations → *minimize redundancy*

- Improve the SOC dynamics to simulate contrasting tillage practices
  - SOC outputs for each layer, or even for each 0-5 cm layer
  - Mineralization, compaction, fragmentation
  - Dynamic water retention parameters (hccf, hminf), recomputing pedotransfer functions each year with SOC as input

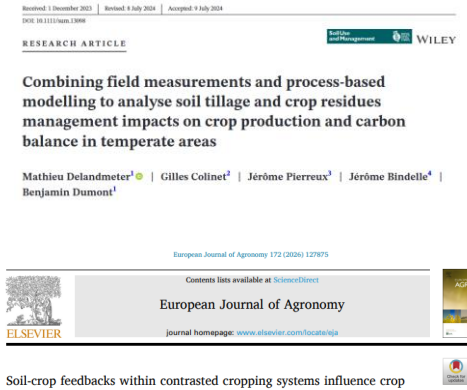
- Improve the animals grazing simulation

- Always push further towards the simulation of agroecological, complex systems

More information?

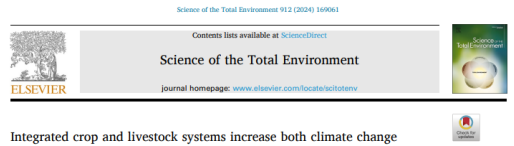


https://www.youtube.com/watch?v=2uhIJEhXPAg



Combining field measurements and process-based modelling to analyse soil tillage and crop residues management impacts on crop production and carbon balance in temperate areas

Mathieu Delandmeter[1] | Gilles Colinet[2] | Jérôme Pierreux[3] | Jérôme Bindelle[4] | Benjamin Dumont[1]



Integrated crop and livestock systems increase both climate change adaptation and mitigation capacities

Mathieu Delandmeter[a,*], Paulo César de Faccio Carvalho[b], Carolina Bremm[b], Carolina dos Santos Cargnelutti[b], Jérôme Bindelle[c], Benjamin Dumont[a]

Soil-crop feedbacks within contrasted cropping systems influence crop resistance to extreme climate events

Mathieu Delandmeter[a,*], Caroline De Clerck[a], Jérôme Bindelle[b], Benjamin Dumont[a]

Livestock Integration Into Cropping Systems Enhances Their Climate Change Resistance and Mitigation While Reducing Their Environmental Impacts

Mathieu Delandmeter[1,2] | Bruno Basso[2,3] | Xavier Fettweis[4] | Christophe Lacroix[1] | Pierre Aubry[4] | Jérôme Bindelle[1] | Benjamin Dumont[1]

Boosting ecosystem services and farm economics with crop diversity and livestock integration using a validated modeling approach

Mathieu Delandmeter[a,b,*], Bruno Basso[c,*], Neville Millar[d], Lydia Price[e], Tommaso Tadiello[d], Jason Rowntree[e], João Paulo Sacramento[d], Prateek Sharma[e], Jérôme Bindelle[a] and Benjamin Dumont[a]

delandme@msu.edu

Basso Lab

MICHIGAN STATE UNIVERSITY

fnrs LA LIBERTÉ DE CHERCHER

LIÈGE université Gembloux Agro-Bio Tech

Crop Science