Modelling albedo and the energy budget using the STICS soil-crop model – Application to two Sub-Saharan sites

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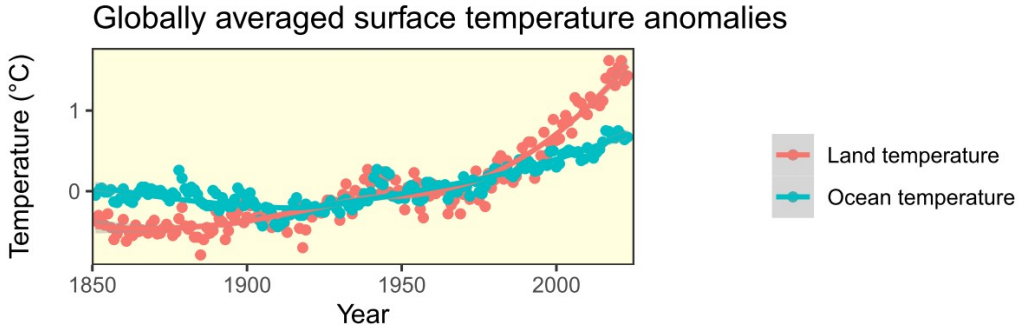
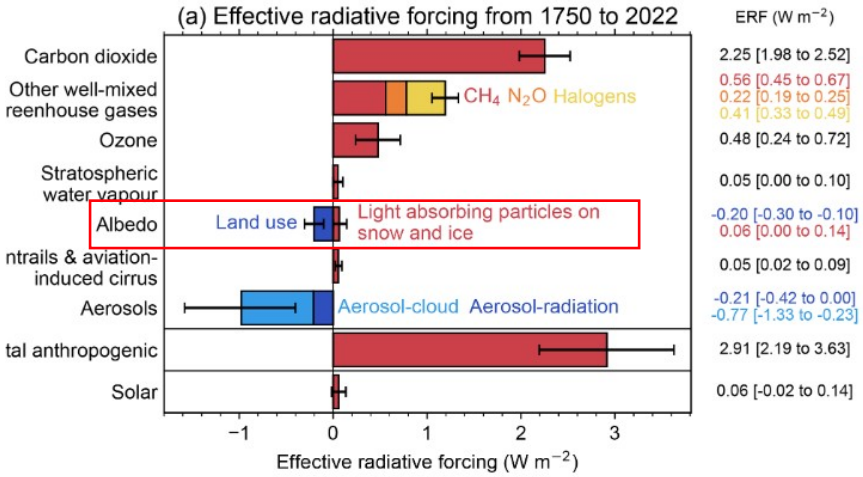
General context

- Increase of global mean surface T° : **+0.85 °C** [1880 - 2012]
- Increase of atmospheric CO_2 : **418 ppm**
- Radiative forcing of earth: **+2.3 W.m^{-2}**





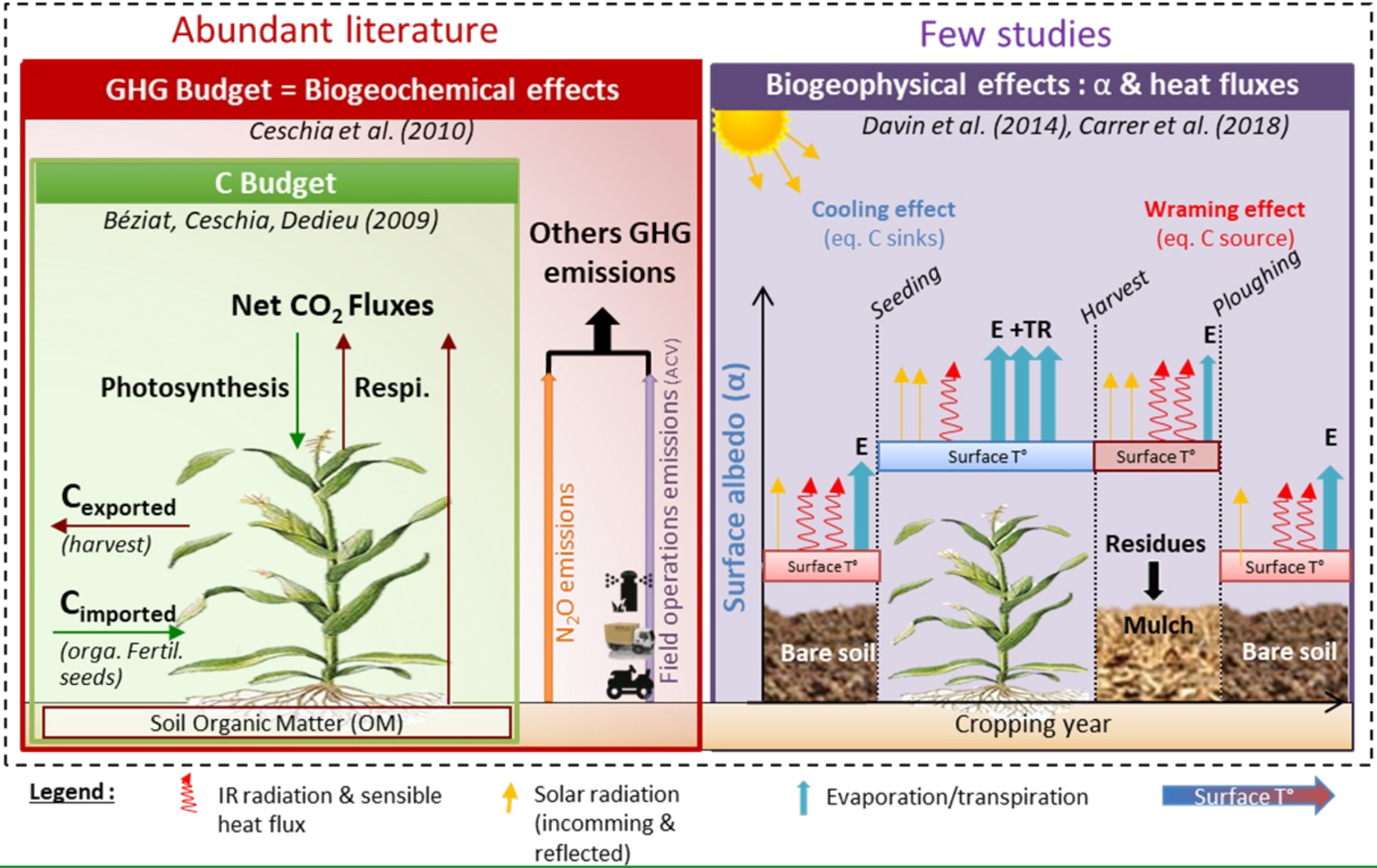
Forster et al. 2022

- Under-estimation of land use change impact on the climate
- In recent years, though, methodological advances allowing to convert albedo effects in CO_2-eq raised awareness of the potential significative effects of RF_α on climate mitigation (*Bright et al. 2015*).
- As a consequence, recent studies showed that for some management changes RF_α had impacts of the same order of magnitude than biogeochemical effects.

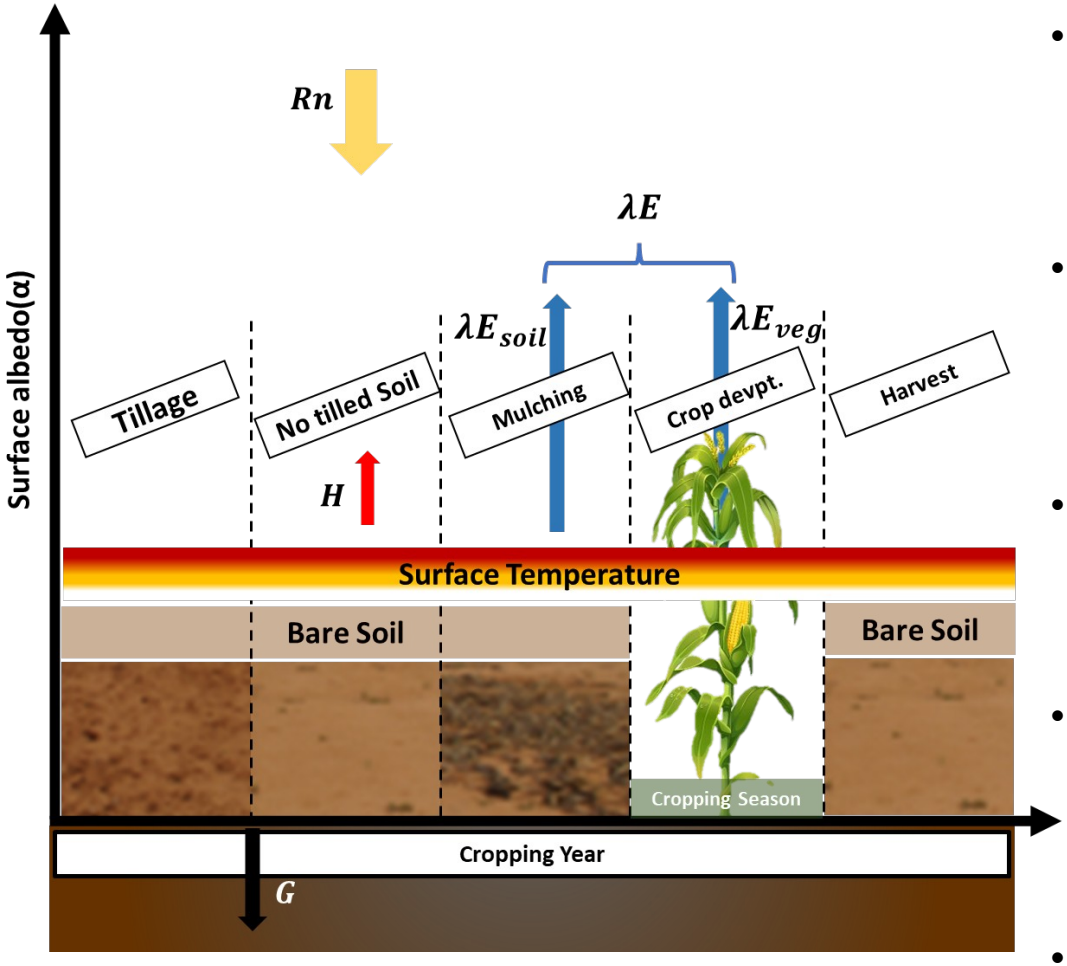
Biogeochemical vs biogeophysical processes

Net effect on climate (RFnet) of the cropland plot(s)

Ceschia et al. (2017), Kaye & Quemada (2017), Lugato et al. (2020)



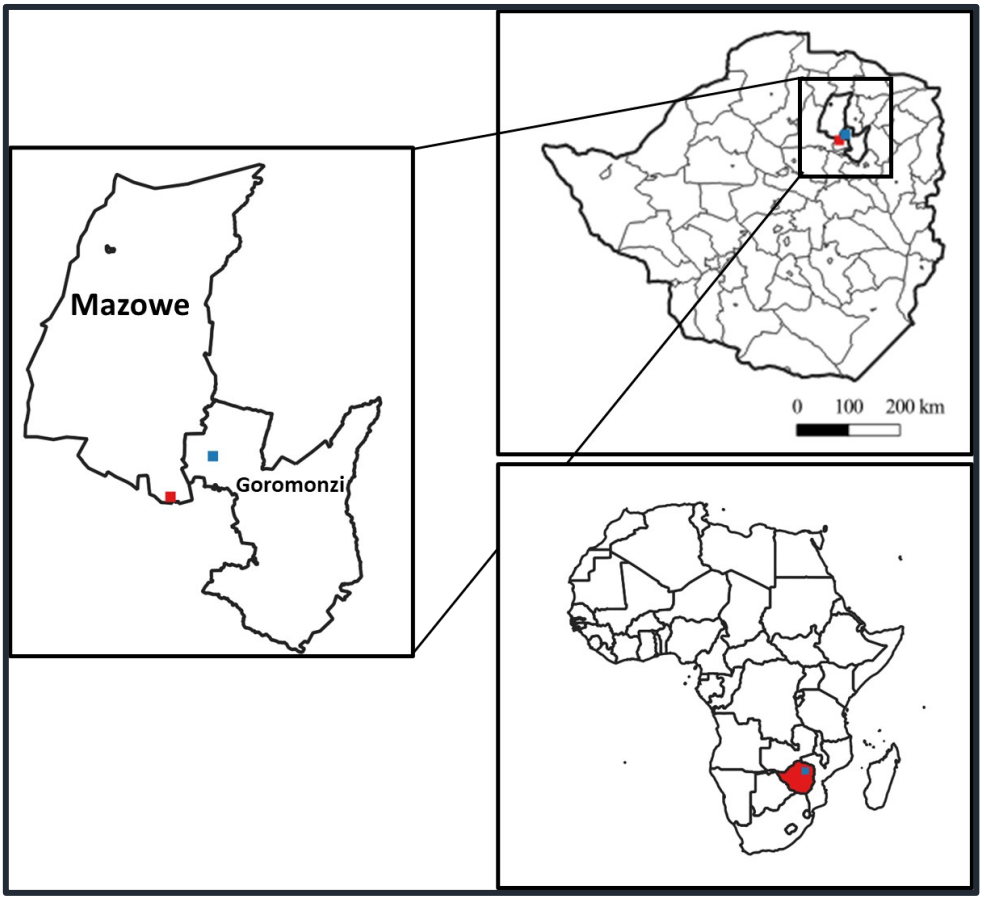
Global objectives



Rn = Net radiation, H = sensible heat flux, G = Ground heat flux, λE = Latent heat flux

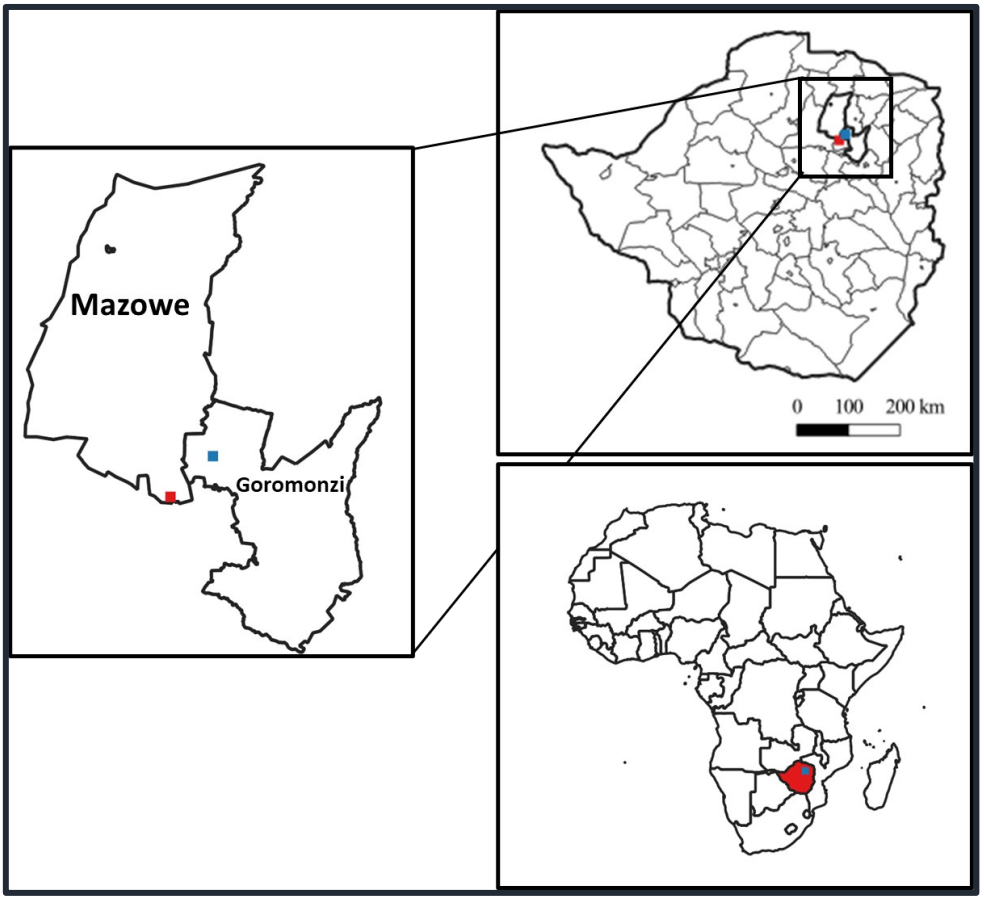
- Quantify the effect of the no tillage and crop residues on albedo and surface temperature dynamics
- Study the interaction between the soil type and the cropping system on albedo dynamics
- Investigate the change in albedo in relation to crop development and to soil water dynamics
- Quantification of different components of energy budget for each cropping system
- Evaluate and improve the albedo and energy partioning module for the soil-crop model **STICS**

Study sites & data



- **DTC (*abruptic LIXISOL)***
- **UZF (xanthic Ferralsol)**

Study sites & data



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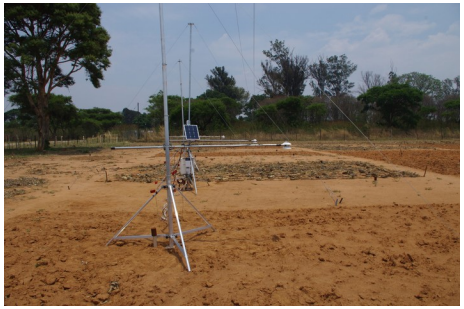
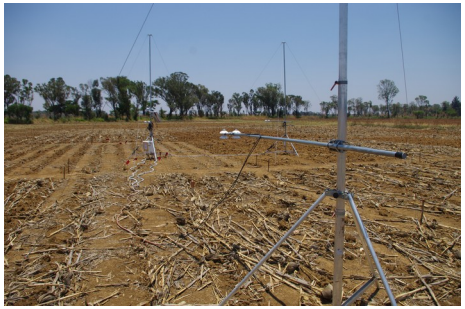
❑ **Instrumented sites**

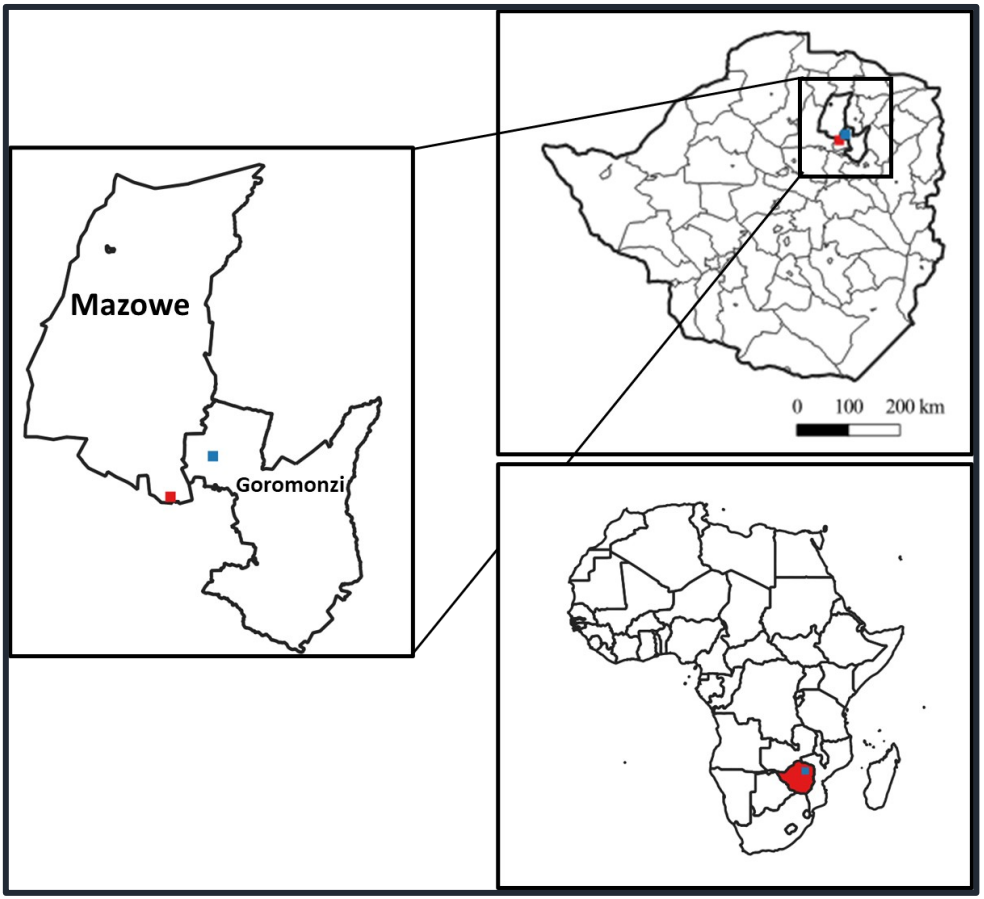


DTC



UZF

Study sites & data



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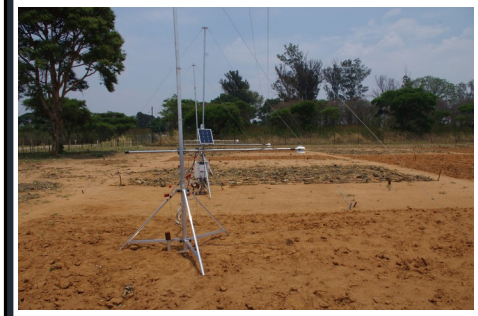
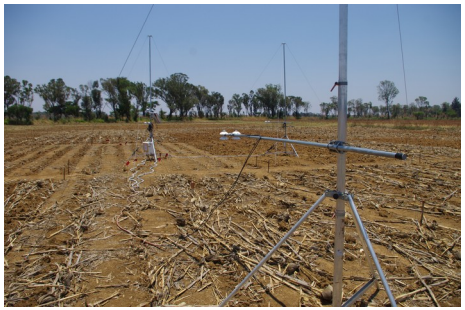
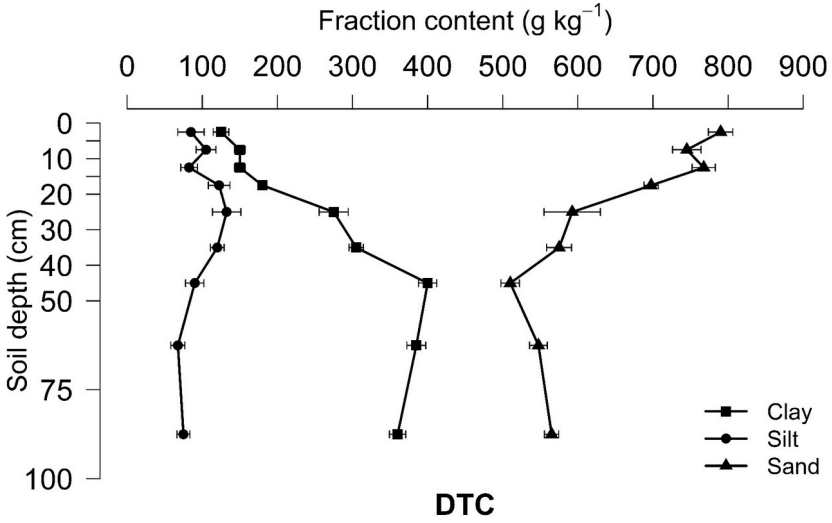




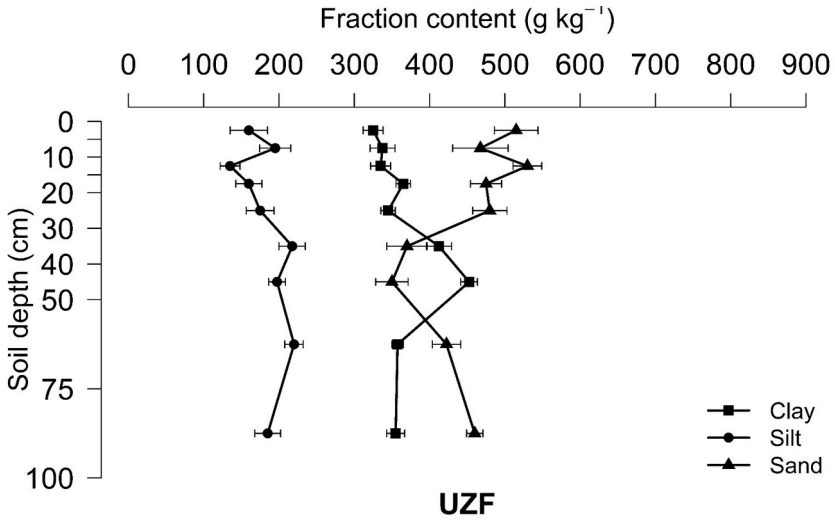
DTC Variables measured	***UZF*** Frequences
Radiation flux	Every minutes
Thermal fluxes	Every minutes
Soil humidity	Every 5 minutes
Soil temperature	Every 5 minutes
Leaf Area Index	Every two weeks
Green Cover	Every two weeks
Height	Every two weeks
Sap flow	Every minutes

Study sites & data

- Long-term experiments on CA in Zimbabwe managed by **CIMMYT**
- Established since 2013 on 2 different soil types. Main crop is maize
- 8 differents treatments repeated 4 times, 3 selected for this study:
  - Conventional tillage (**CT**)
  - No-tillage (**NT**)
  - No-tillage + mulch (**NTM**)



abruptic Lixisol (DTC)



xanthic Ferralsol (UZF)

Shumba et al., 2023

Modelling approach

STICS

↓

Dynamic cropping system model

↓

Daily timestep

↓

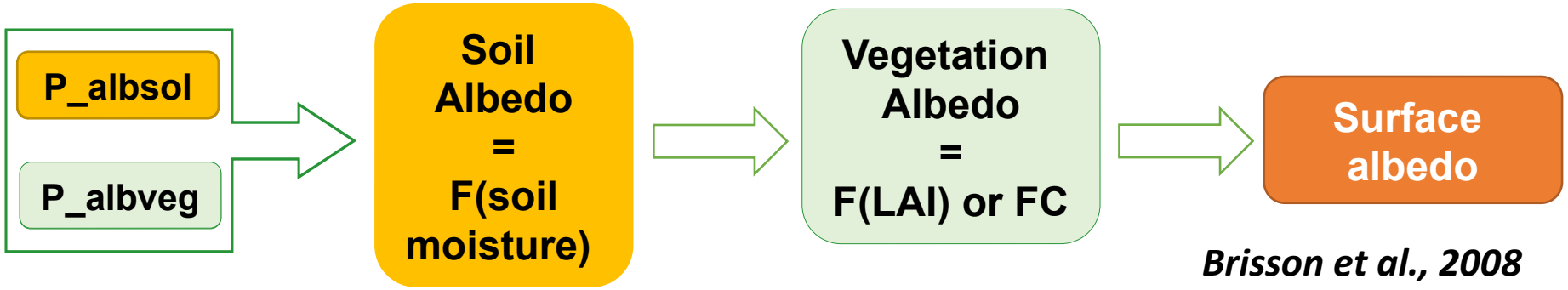
Field scale

Why modelling albedo and energy partioning at field scale

- Few relevants studies on the determinants of changes albedo at field scale under conservation agriculture in sub Saharan Africa
- Land management effect on albedo change (*Davin et al., 2014 ; Luyssaert et al., 2014, hirsch et al., 2018*)
- To have a good process understanding of the effect of land management on albedo change
- Importance of coupled effect (biogeochemical vs biophysical effects)
- Assess the potential mitigating influence of biogeophysical impacts from conservation agriculture practices
- No consideration of albedo changes in global schemes.

Modelling approach of surface albedo : STICS

What is already done?



Brisson et al., 2008

Modelling approach of surface albedo : STICS

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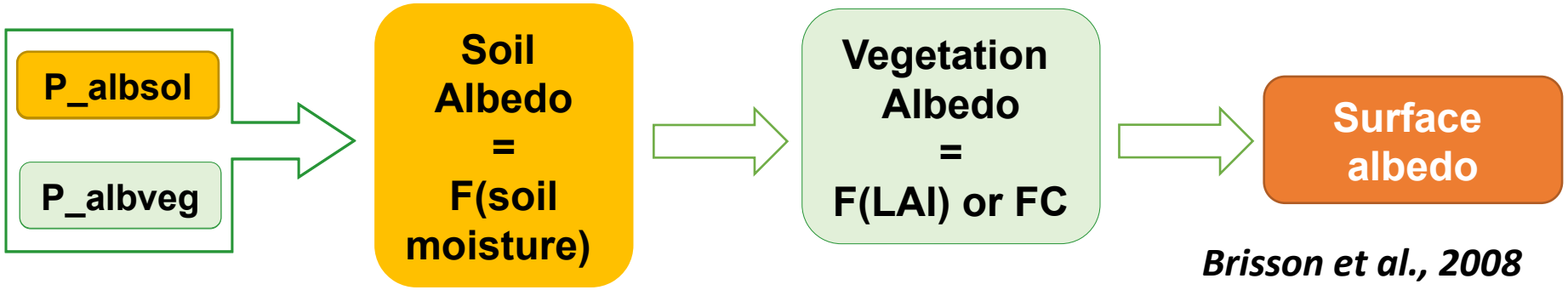
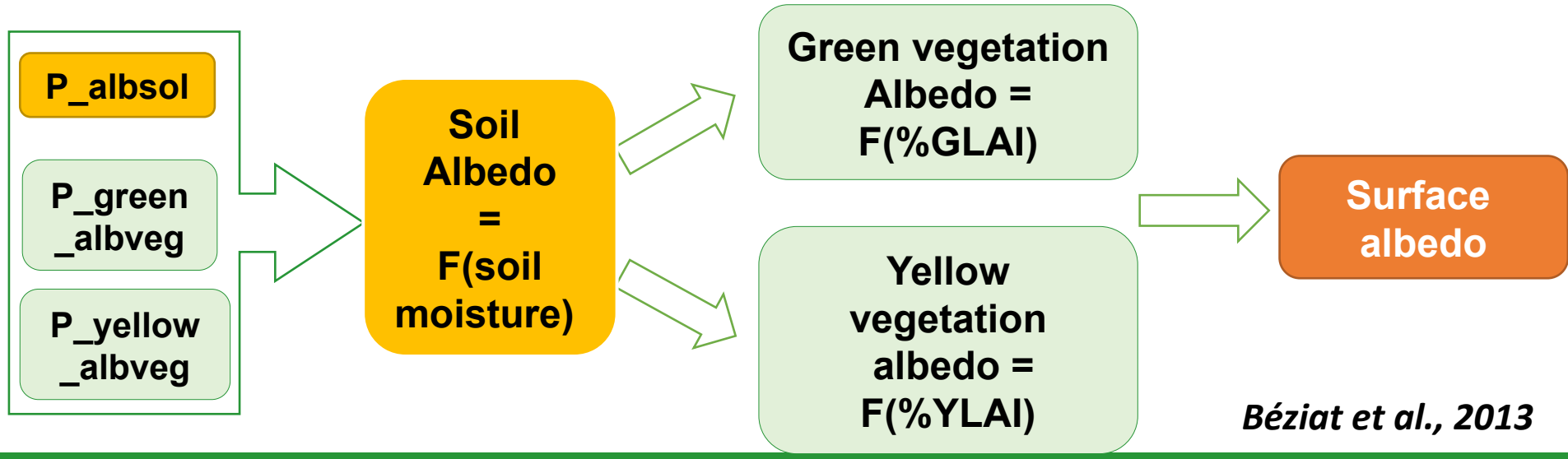


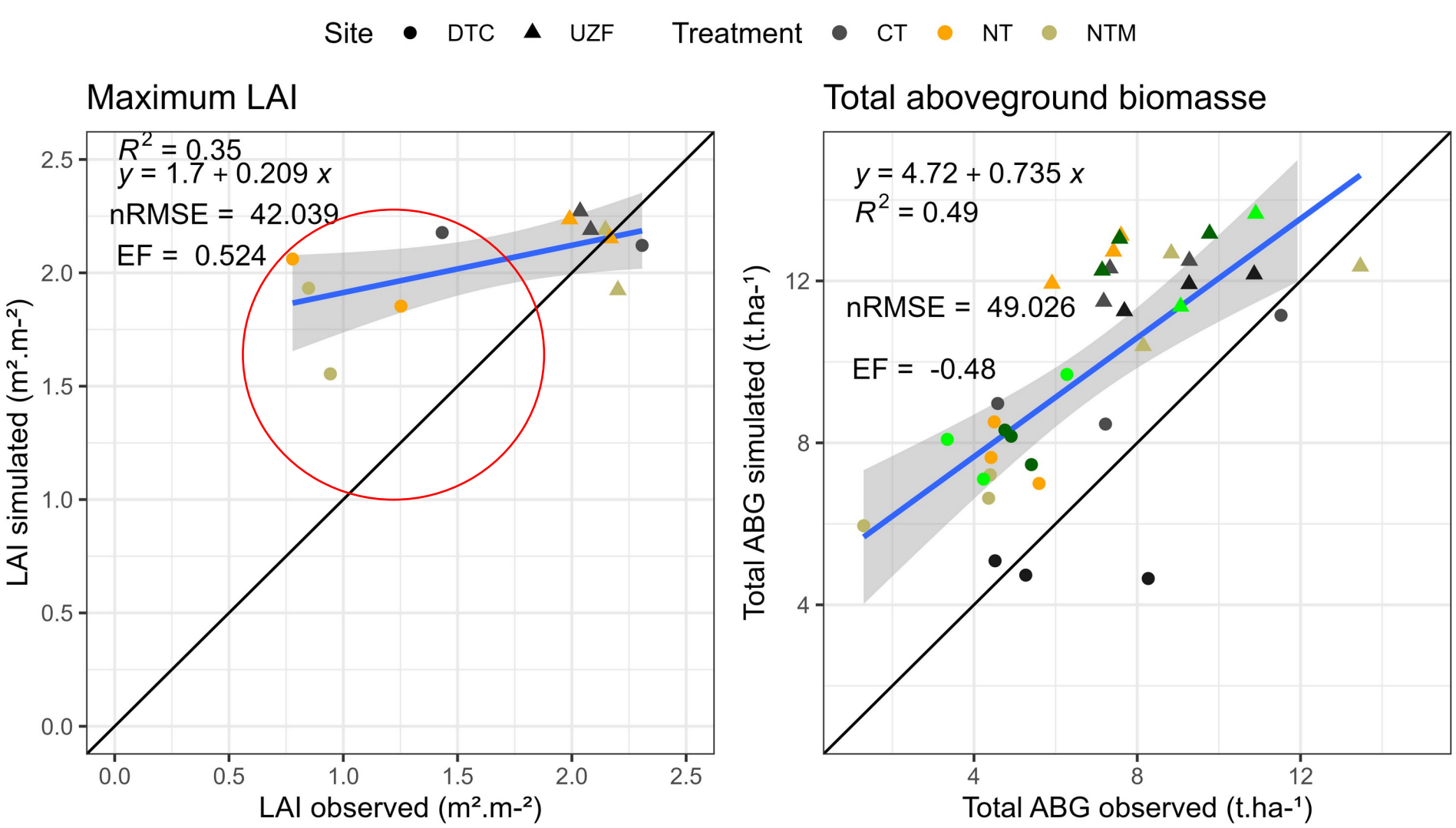
Brisson et al., 2008

What will be improved?

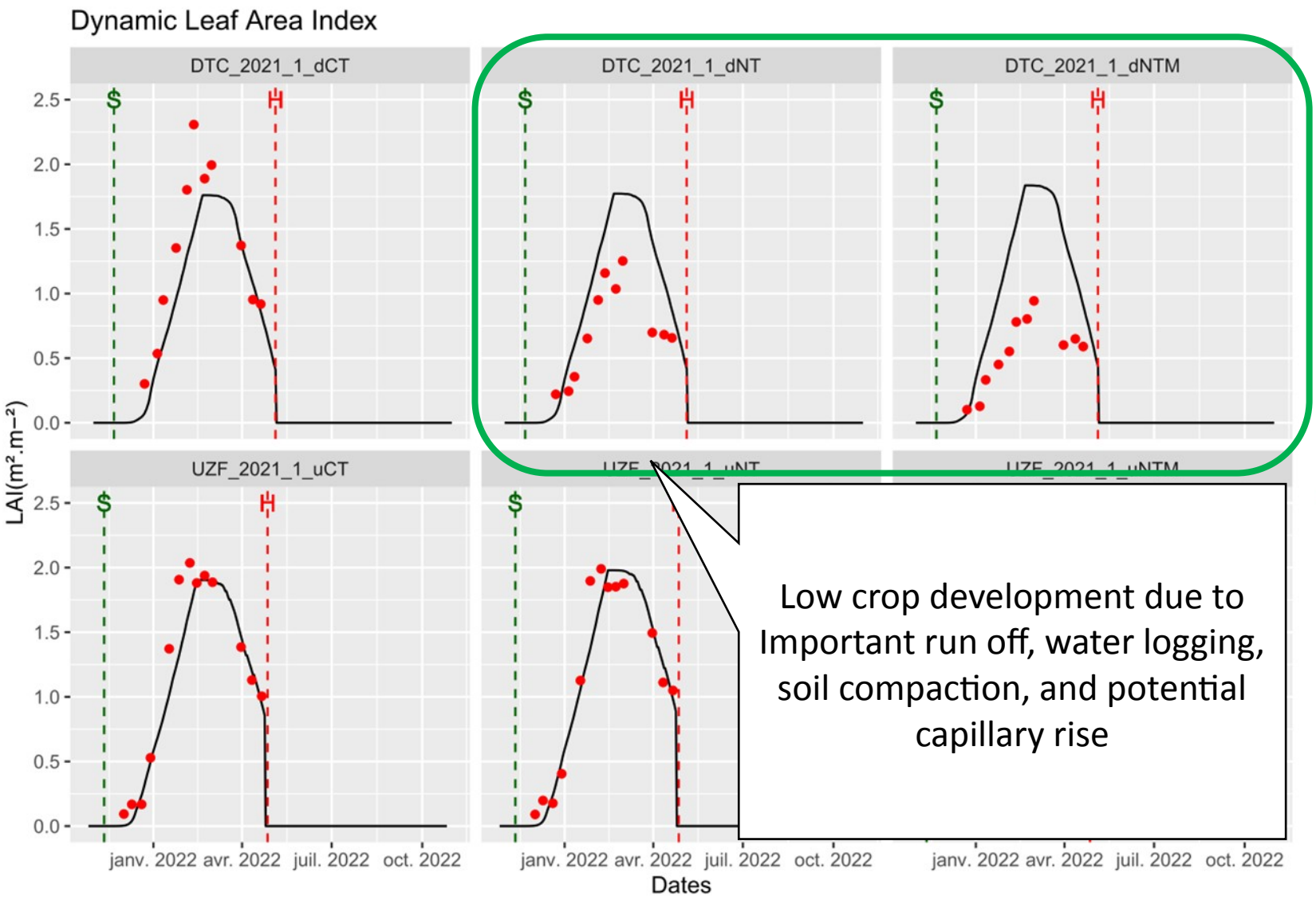


Béziat et al., 2013

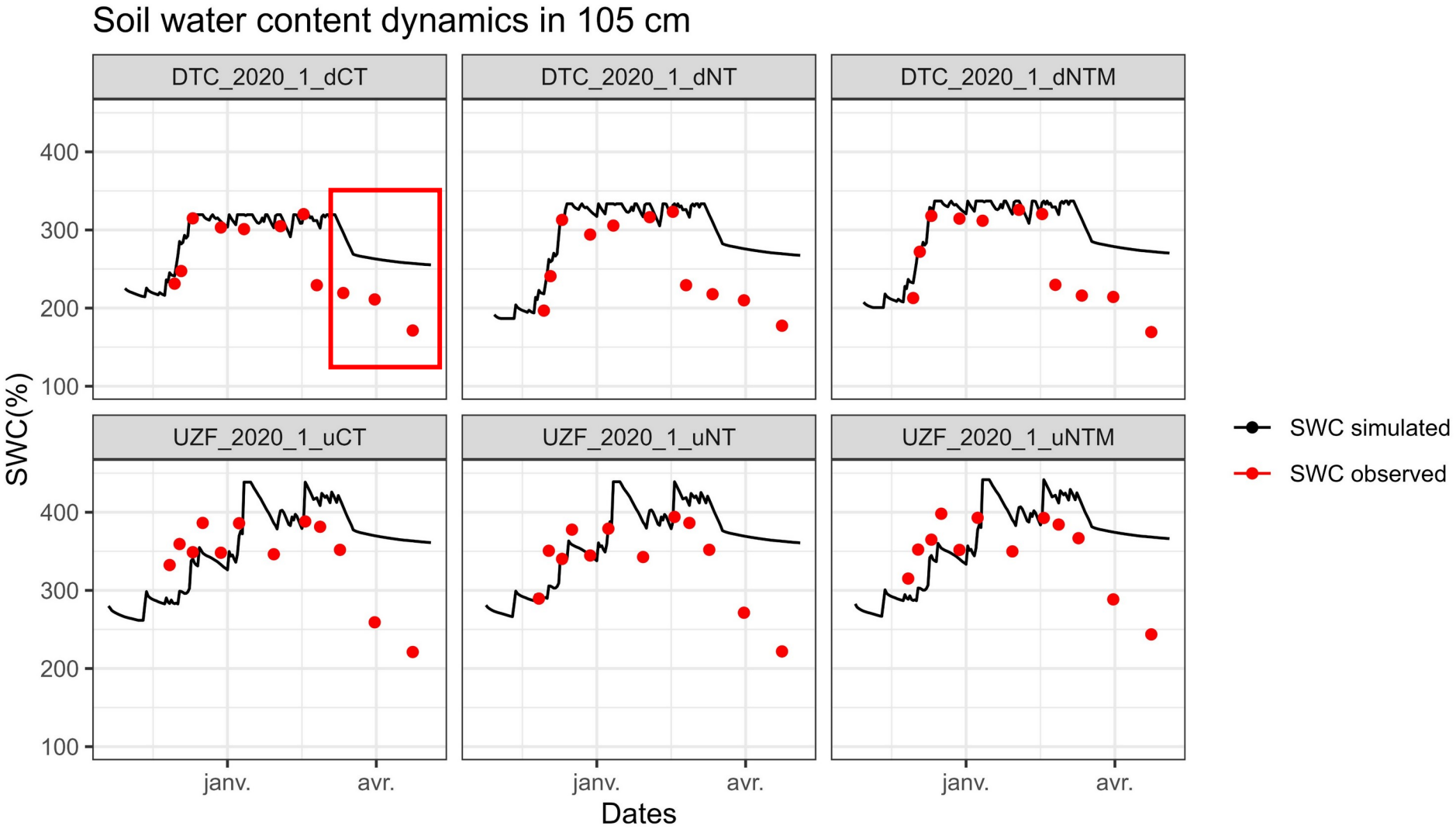
Calibration of leaf area Index and AGB



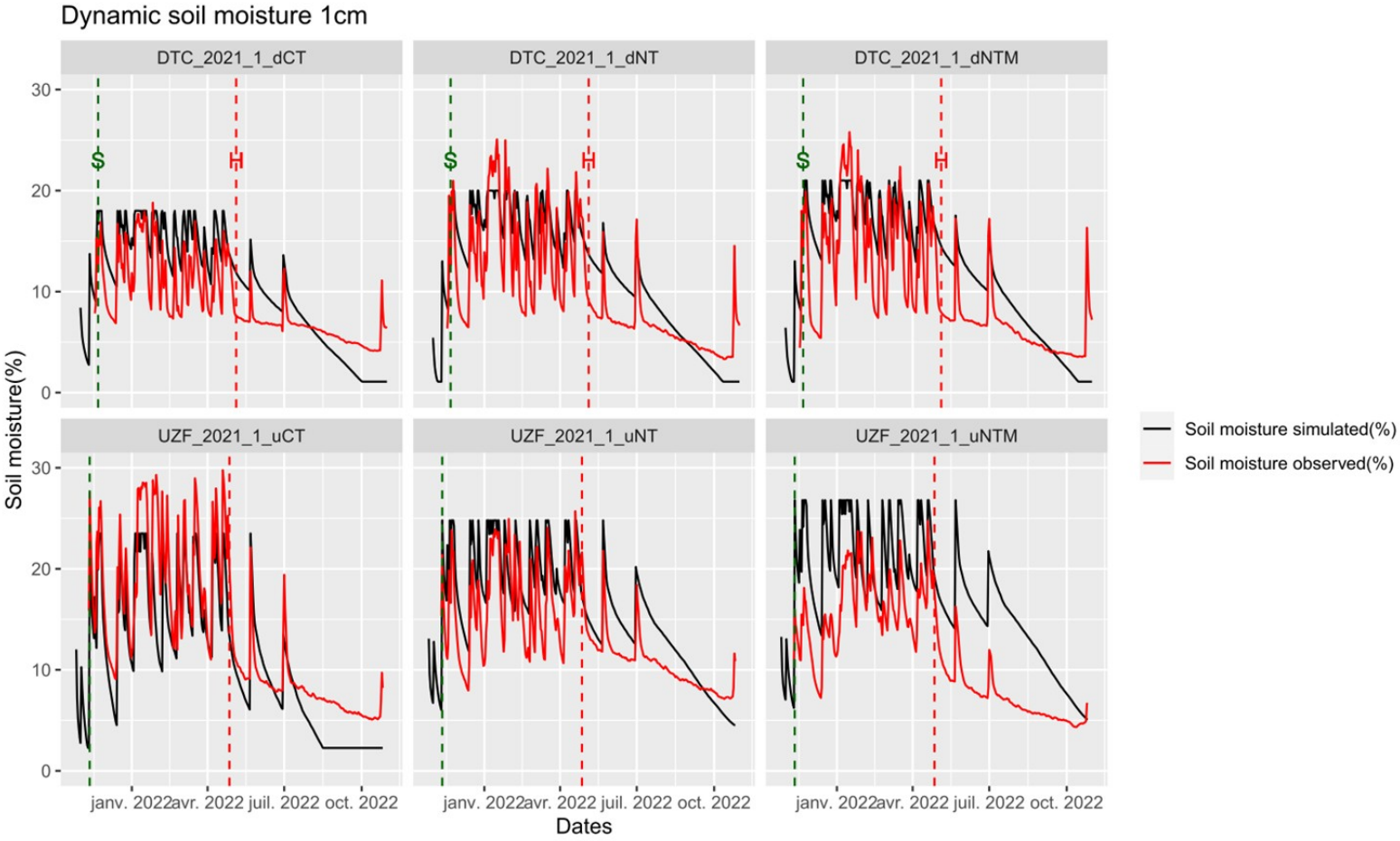
Calibration of leaf area Index dynamics



Soil water dynamics : actual formalism



Topsoil moisture dynamics 1cm : actual formalism



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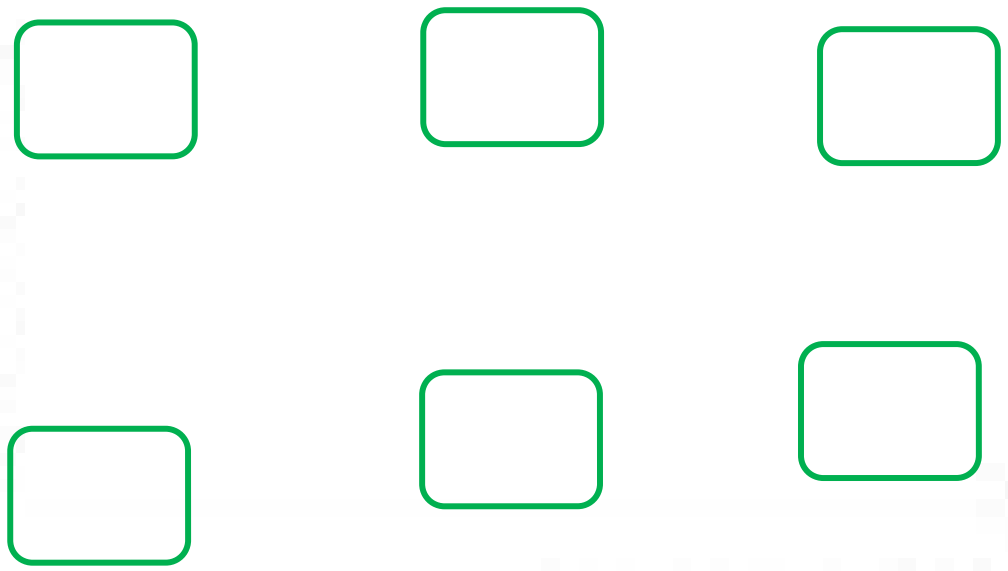
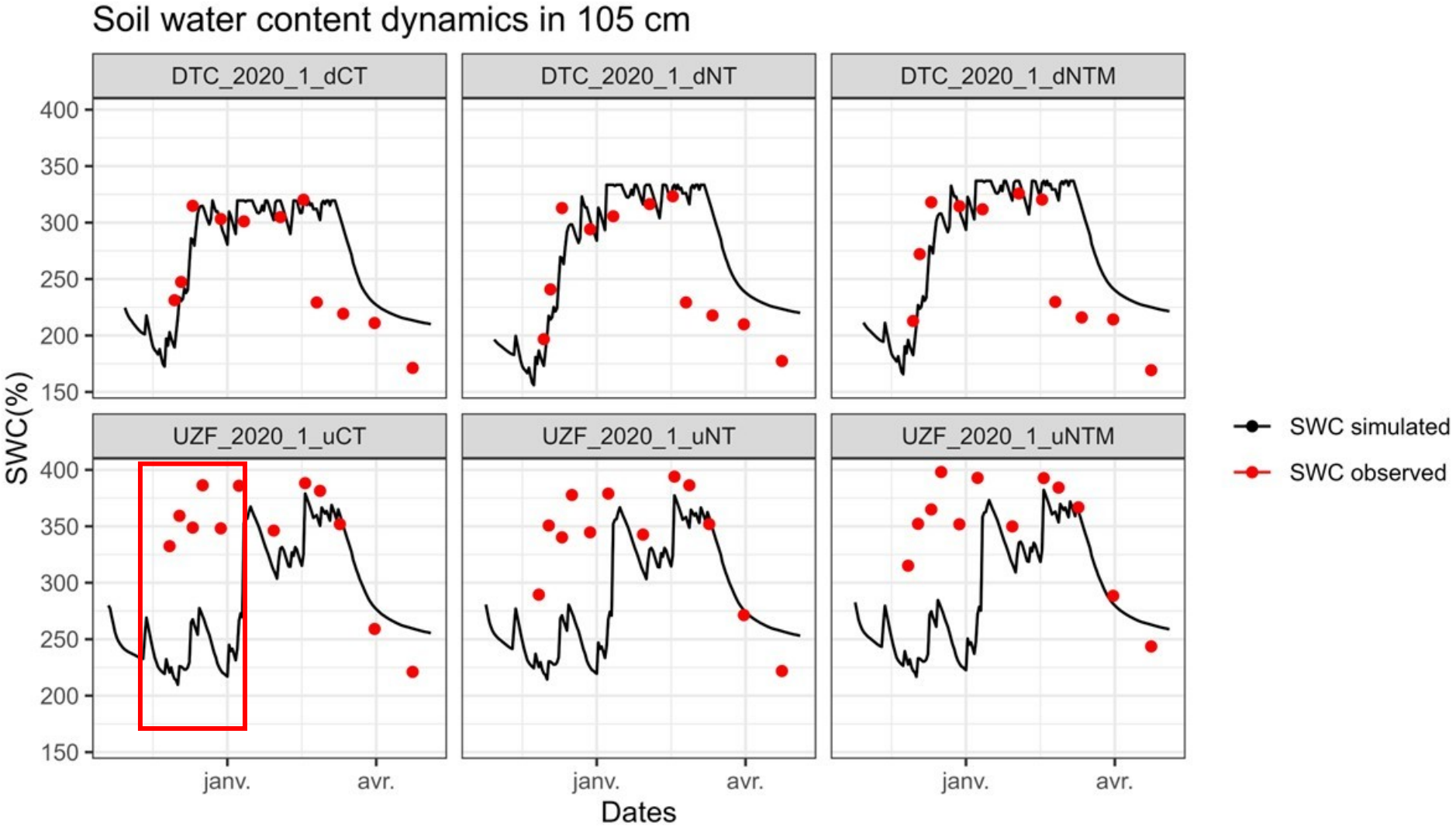
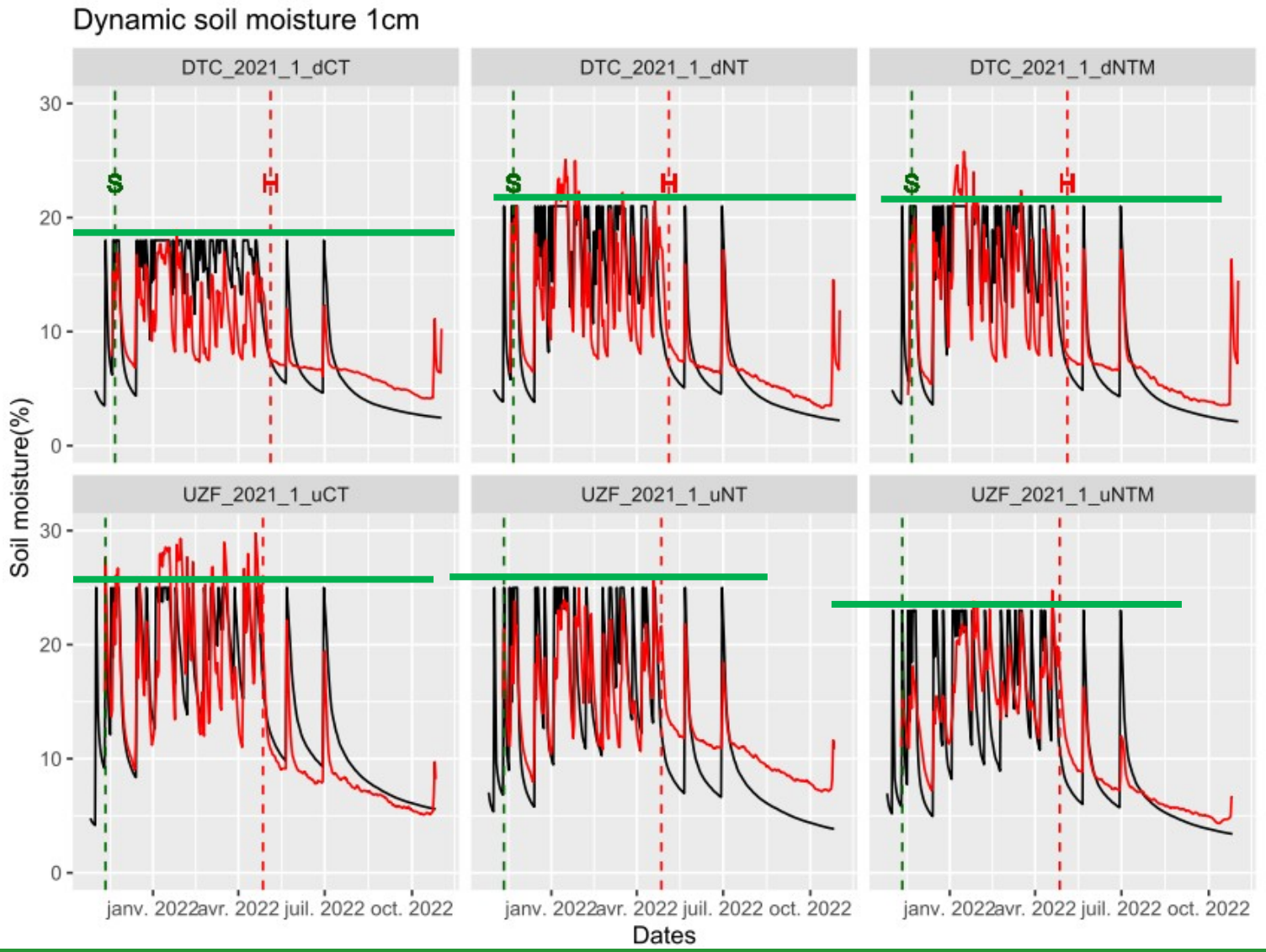


- It’s important to have a good simulation of topsoil moisture to simulate surface albedo
- The actual formalism of soil evaporation doesn’t have enough capacity to simulation rapid decline of topsoil moisture
- The latter have an impact in quality of simulation of albedo

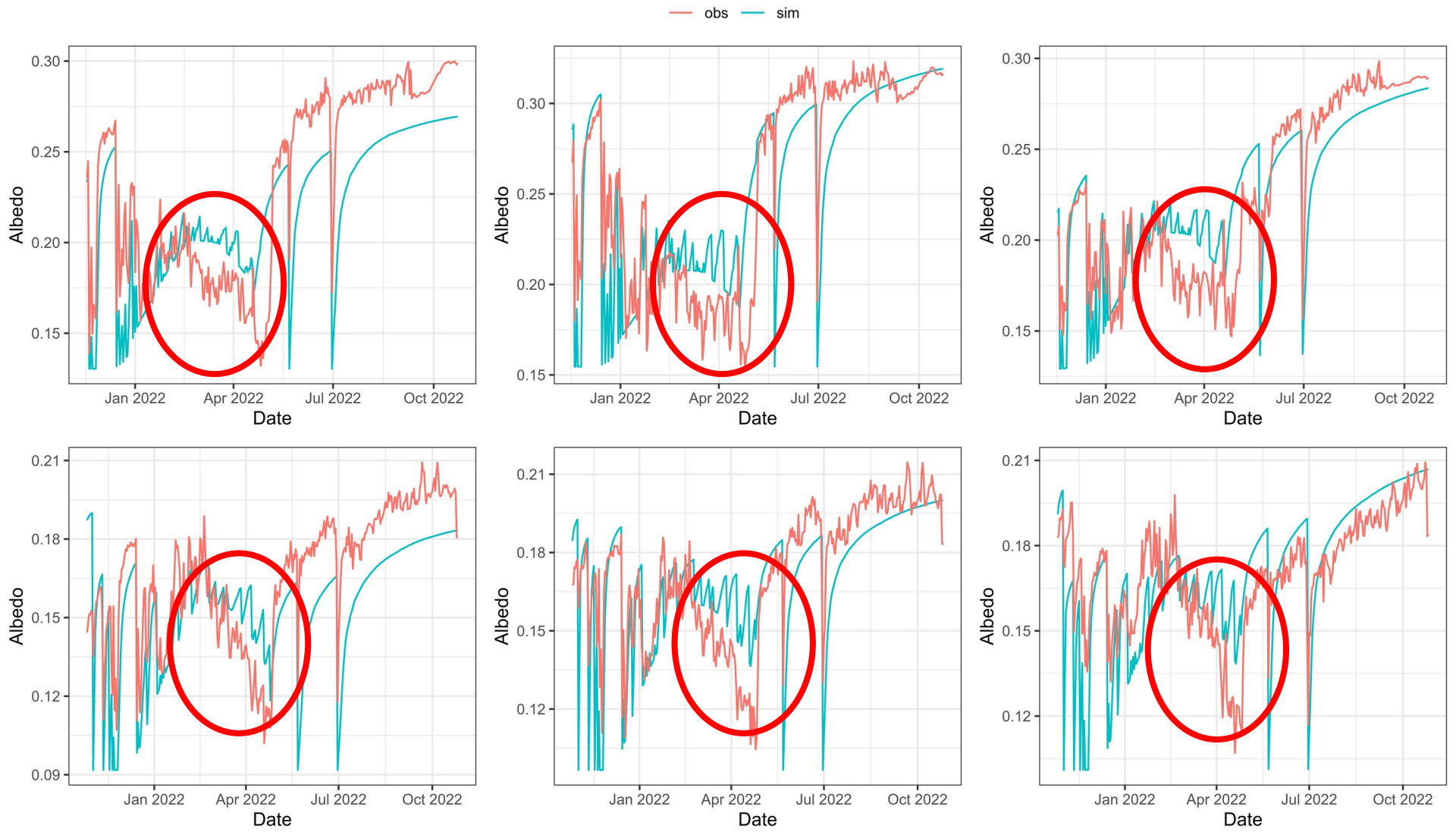
Soil water dynamics : new formalism



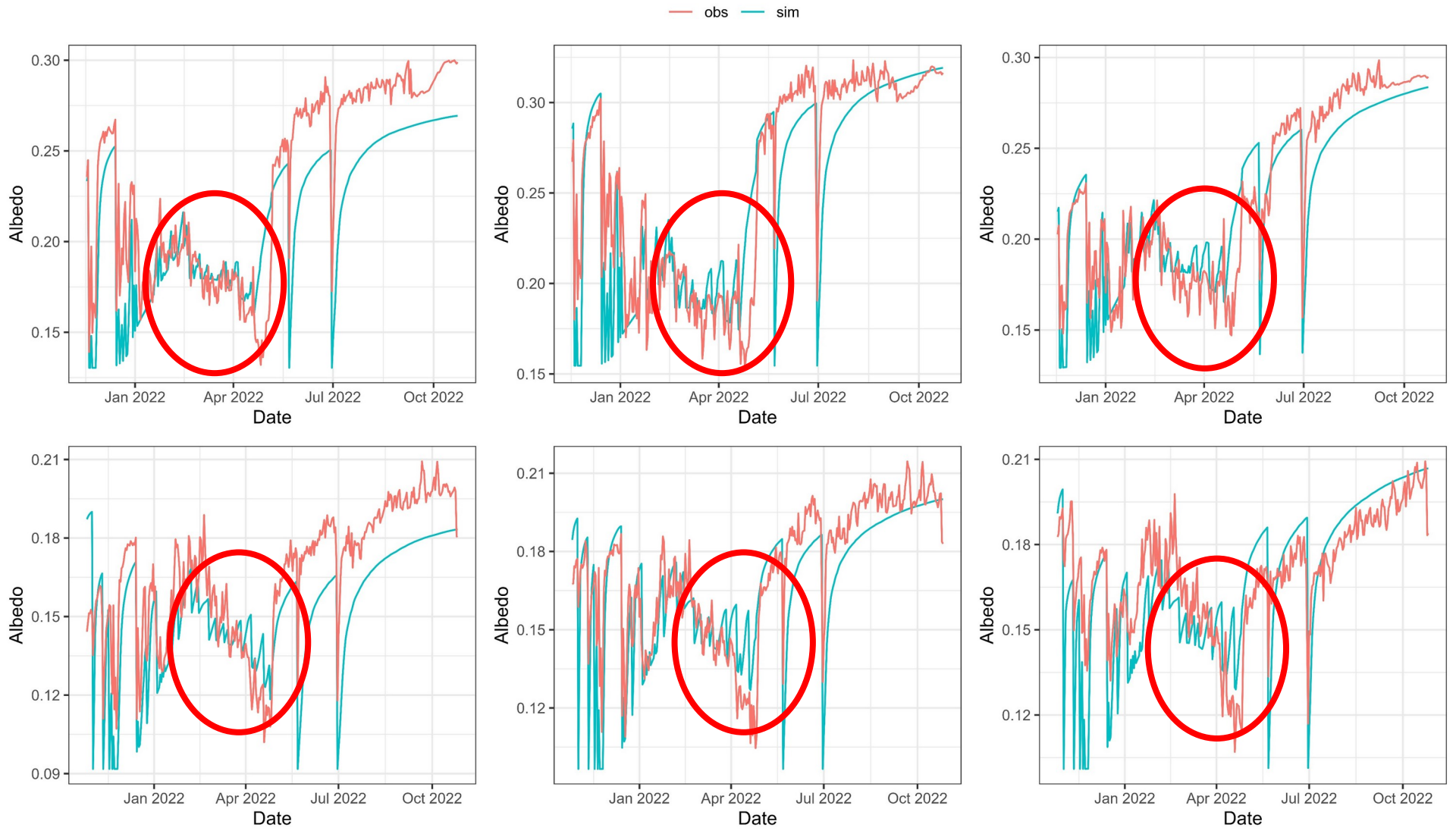
Water dynamics 1cm: new formalism soil evaporation



Surface albedo dynamics: new formalism soil evaporation+ actual formalism of surface albedo



Surface albedo dynamics: new formalism soil evaporation+ new formalism of surface albedo



Actual formalism

- Yellow leaves albedo doesn't taking into account
- Soil evaporation is not well simulated in SSA condition
- Biomass at haevest is not well simulated in the No tillage and mulch treatments usually

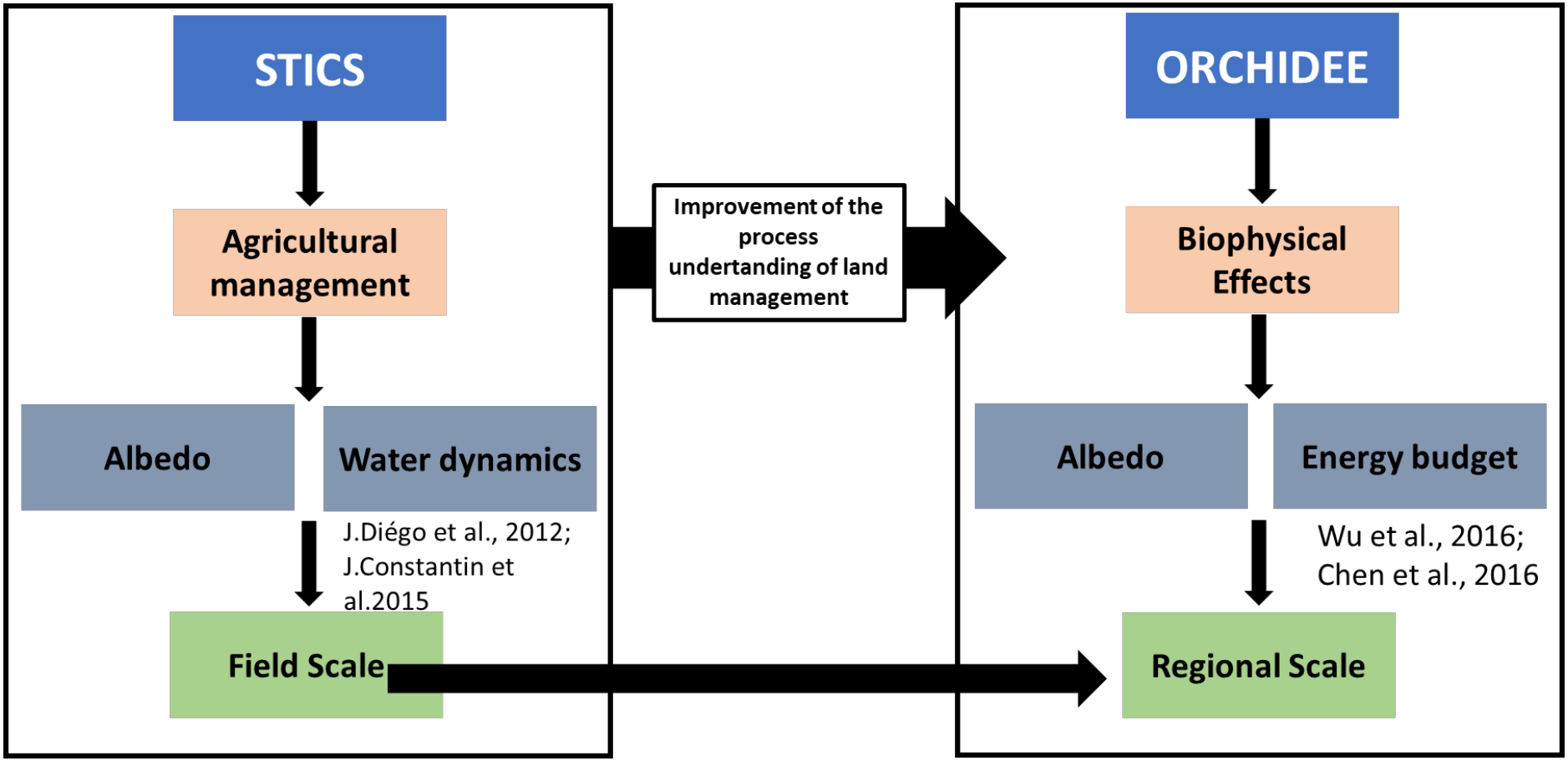
New formalism

- Yellow leaves integrated in the computation of surface albedo
- New module of soil evaporation (is going to be integrated)
- Weekness is that every rain events the soil moisture reach the field capacity (need to be changed)
- Biomass is not well simulated (overestimated)

Perspectives

- Tested the hability of STICS to simulate energy partioning (Net radiation, sensible heat flux, latent heat flux)
- Evaluated the capacity of the model to simulate ground heat flux (G) based on soil temperature profile outputs
- Looked for the accuracy of STICS to reproduce daily dynamics of longwave radiation under CA

Forward


STICS
Agricultural management
Albedo
Water dynamics
J.Diégo et al., 2012; J.Constantin et al.2015
Field Scale
Improvement of the process undertanding of land management
ORCHIDEE
Biophysical Effects
Albedo
Energy budget
Wu et al., 2016; Chen et al., 2016
Regional Scale

Thank you for your attention

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