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Long term response of two models of soil organic carbon dynamics over a wide range of agro-pedo-climatic conditions

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International Symposium on Soil Organic Matter 2011 Organic matter dynamics – from soils to oceans

July 2011

The Climator Project

Analysis of the sources of uncertainty and variability

- Provide methods and results on the impact of climate change on various cropping systems, at the field scale for contrasted French climates.
- A simulation prospective exercise under future climate hypothesis :
  - accounting for current crops
  - accounting for uncertainties by ensemble modeling
- Translate the future climate hypothesis in quantitative impacts to distinguish positive effects, negative effects and non-significant effects on agriculture and forest

SOC trends in cropping systems by 2100

Questions

1. Expected behavior of five selected cropping systems in France by 2100
   - SOC changes *vs*. carbon input changes.
2. Uncertainty regarding this expectation
   - Soil properties.
   - Agronomical constraints.
   - Climate.
3. Are these assertions model dependent?

2 climatic series +one reference x 12 sites x 3 soils x 5 cropping systems + several cultivars for each system x 4 models

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Climates

- Continuous 1950 $\Rightarrow$ 2100 temperature, precipitation and PET series
- One SRES scenario (A1B)
- One GCM (Arpege)
- Two downscaling methods (QQ and WT)

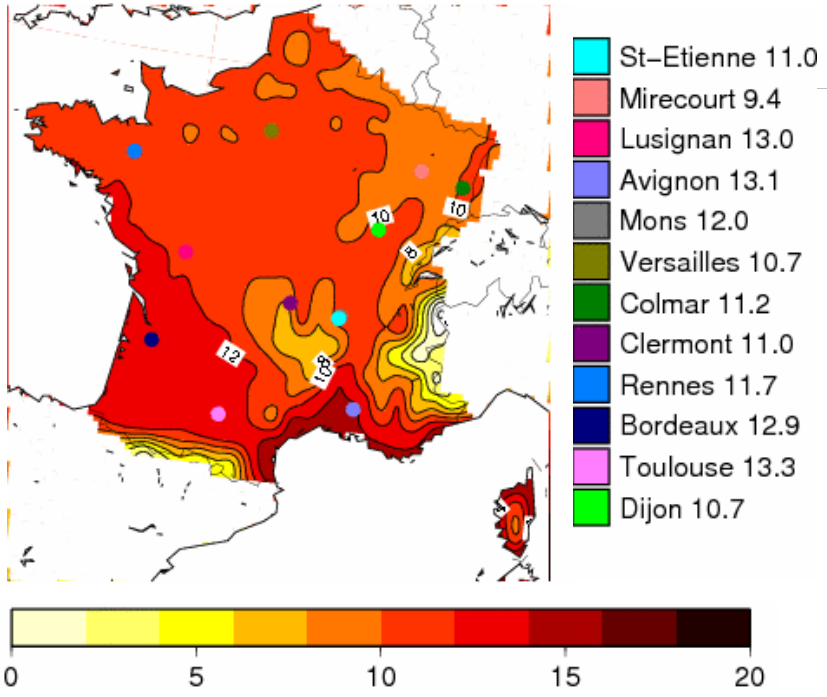
+

one constant climate (repeated 1970-1999 years sampled randomly)

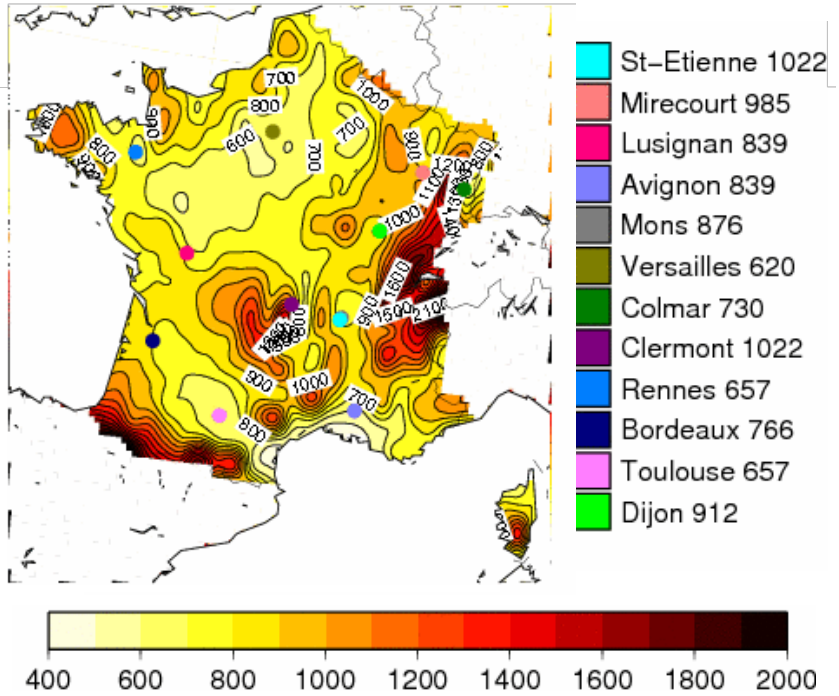
Multi-sites approach

The spatial approach relies on 12 sites standing for French climate variability

Mean annual temperature in degrees Celsius



Mean annual precipitation in mm/yr

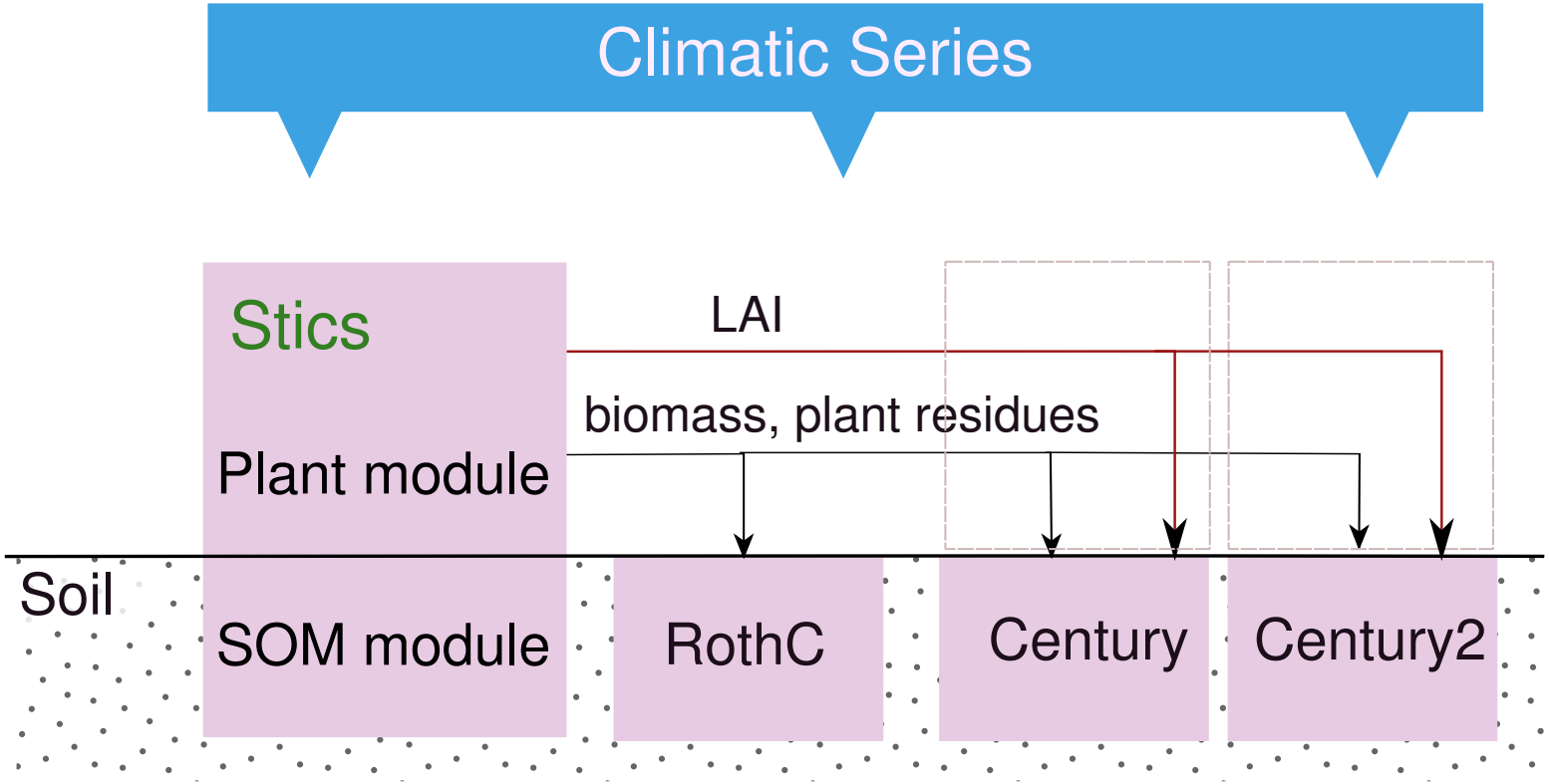


Soils, cropping systems & cultivars

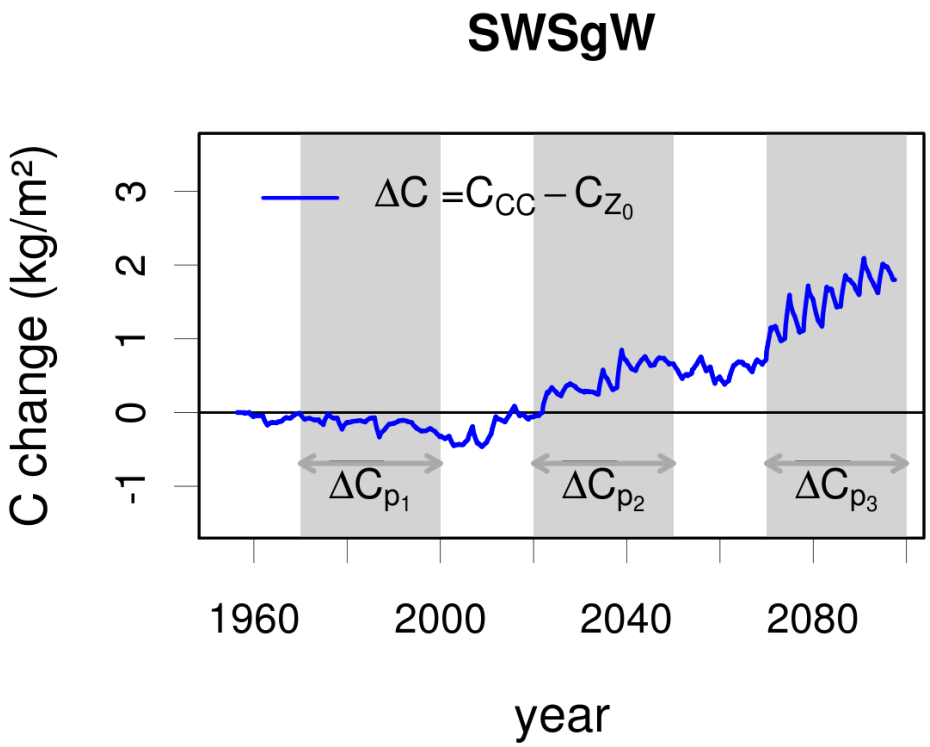
Soil	Soil 1	Soil2	Soil3
clay content(%)	12.6	19.6	24.4
Classification	Brown, sligthly leached, truncated	leached hydromorphic	leached modal
AWR (mm)	226	104	317
OM(%)	1.8	1.4	2.3

- 5 systems
  1. MWRW : Maize, Soft wheat, Rapeseed, Durum wheat
  2. SWSgW : Sunflower, Soft wheat, Sorghum, Durum wheat
  3. W : Durum wheat
  4. S : Sunflower
  5. IM : Irrigated Maize
- two cultivars for each specie

Models indirect coupling



Simulation and data analysis protocol



Initialization

- Observed SOC (stocks for the 0-30cm layer)

Further analysis

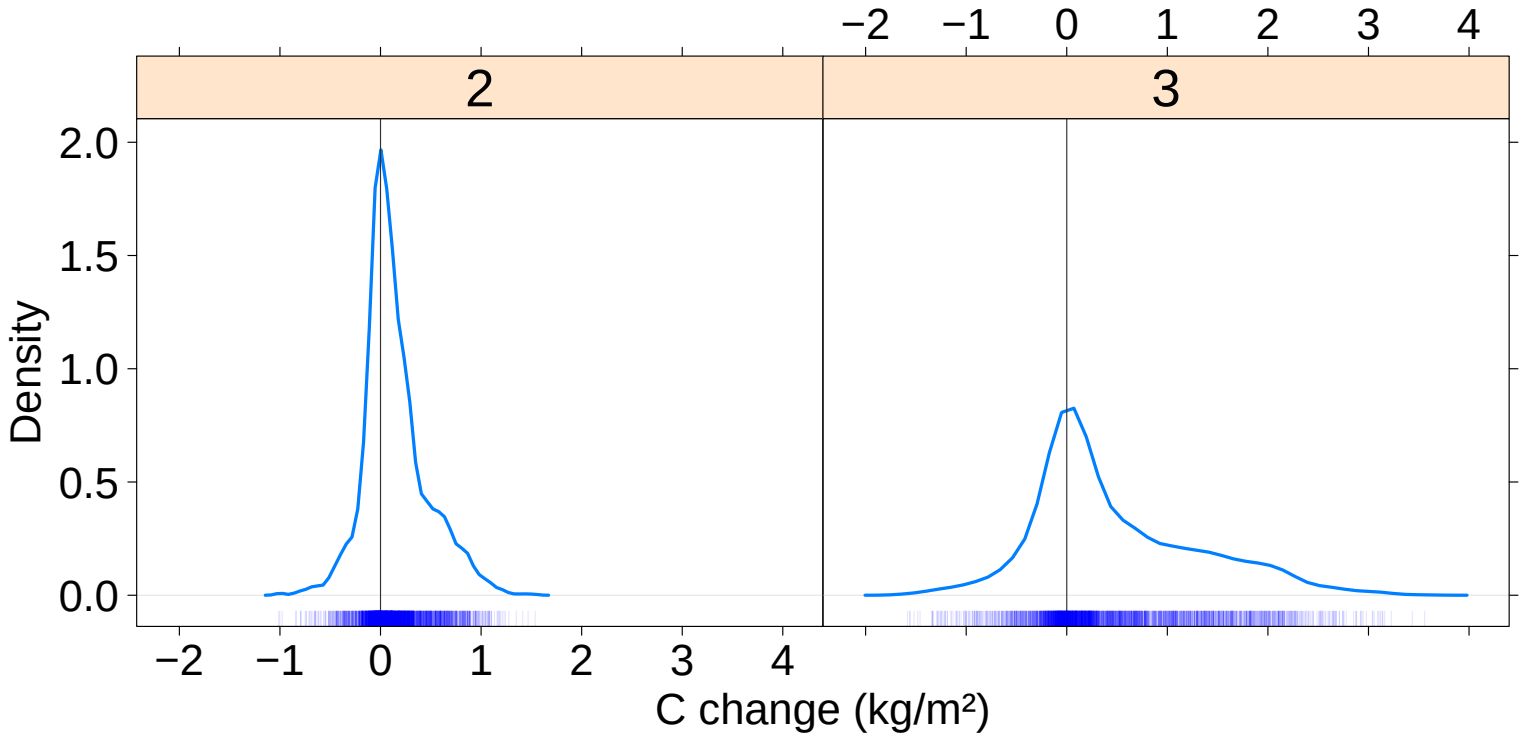
- near future :

$$\Delta C_{p_2} = \overline{\Delta C_{p_2}} - \overline{\Delta C_{p_1}}$$

- distant future :

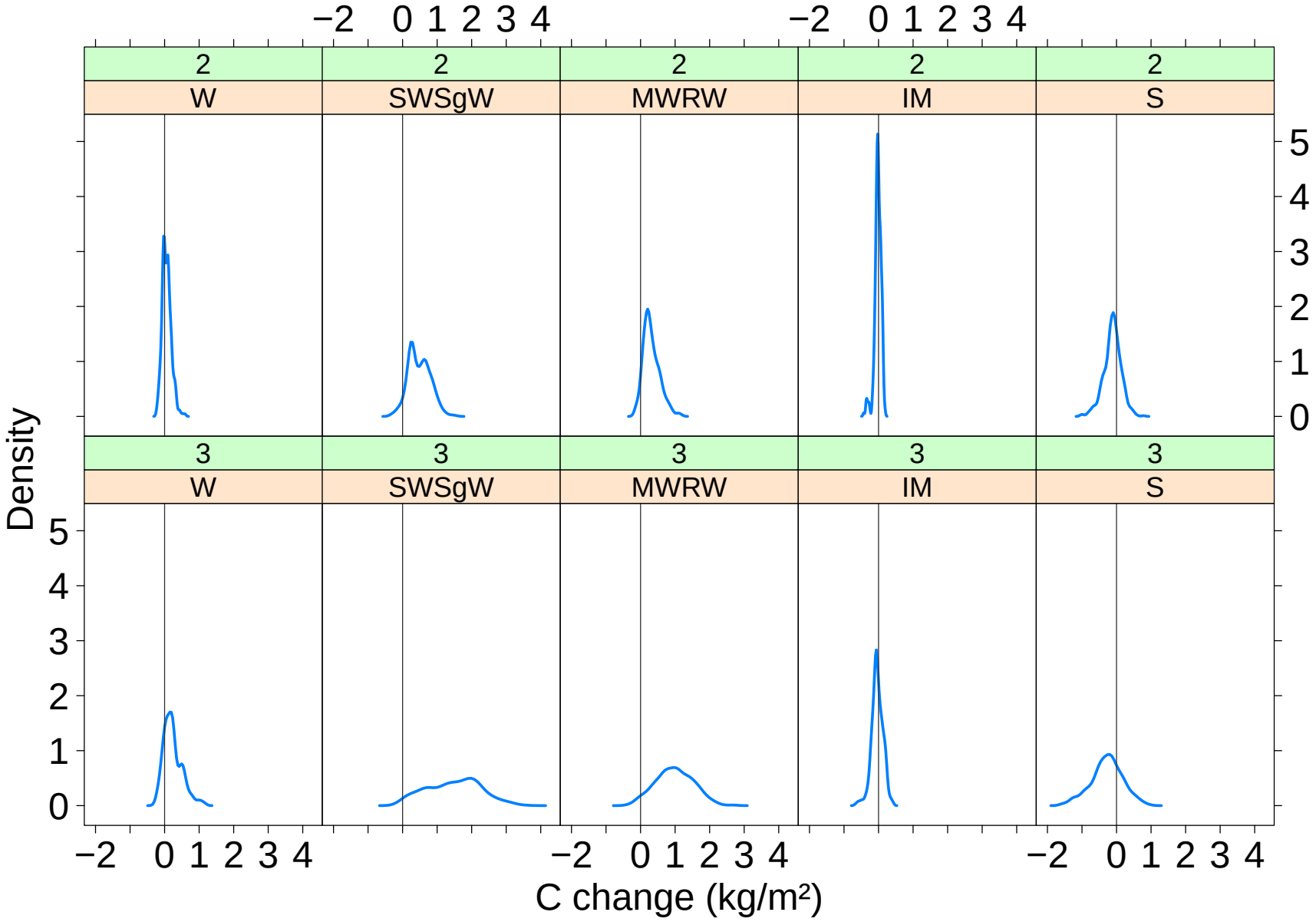
$$\Delta C_{p_3} = \overline{\Delta C_{p_3}} - \overline{\Delta C_{p_1}}$$

SOC changes

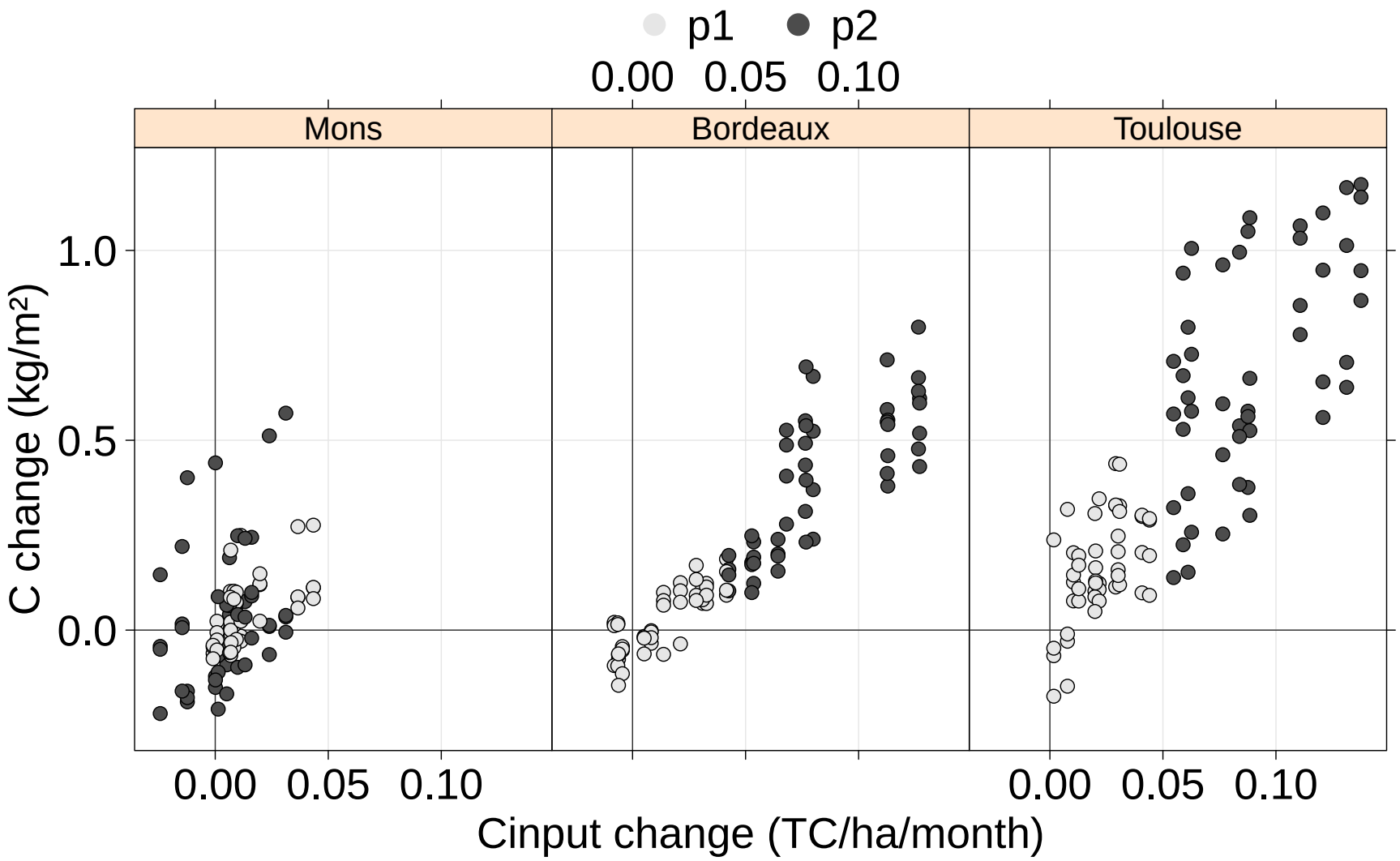


- The range of SOC change is $[-1.6, +3.5] kg/m^2$.
- 1st and 3rd quintiles : -0.06 and 0.963 kg/m^2.

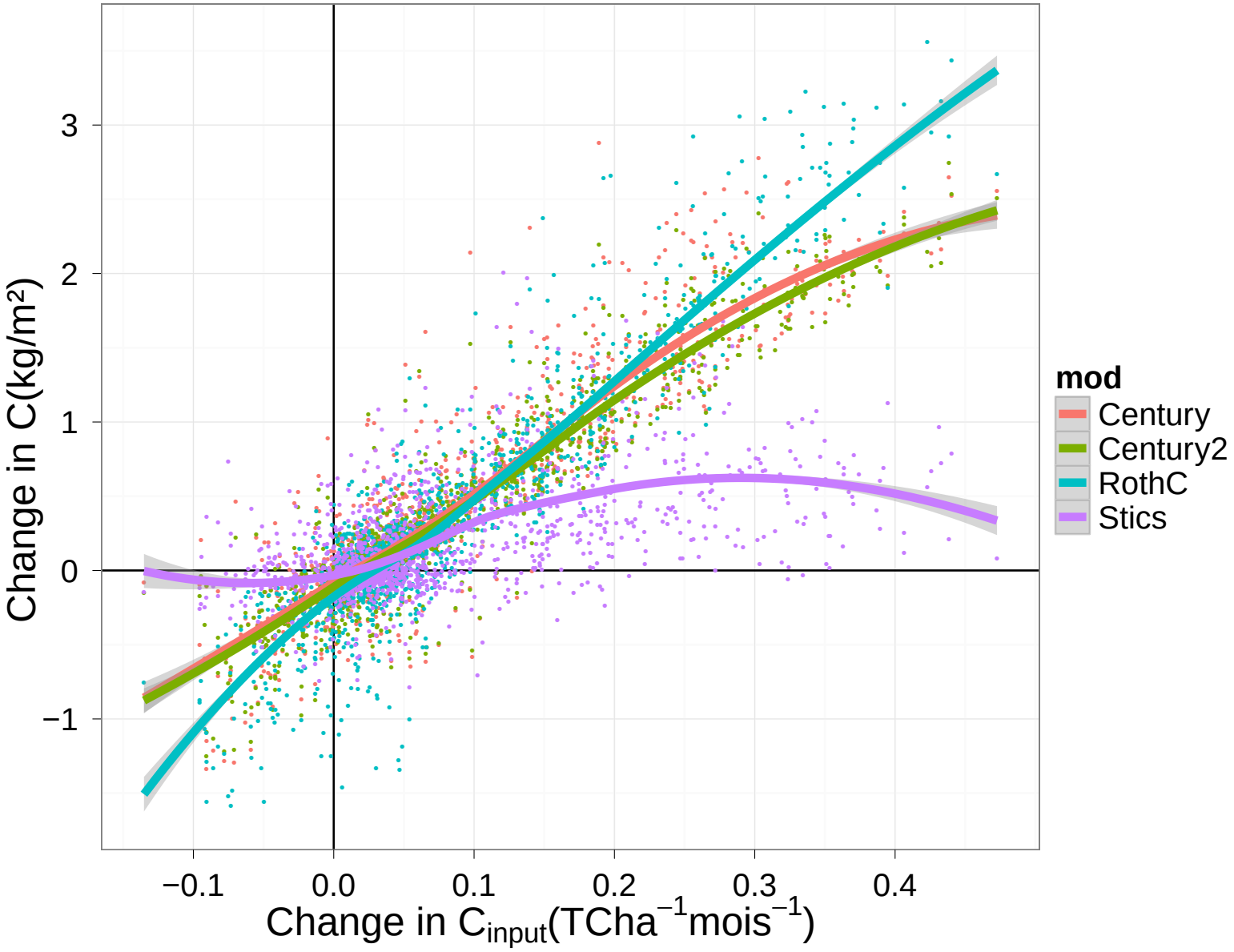
System Effect



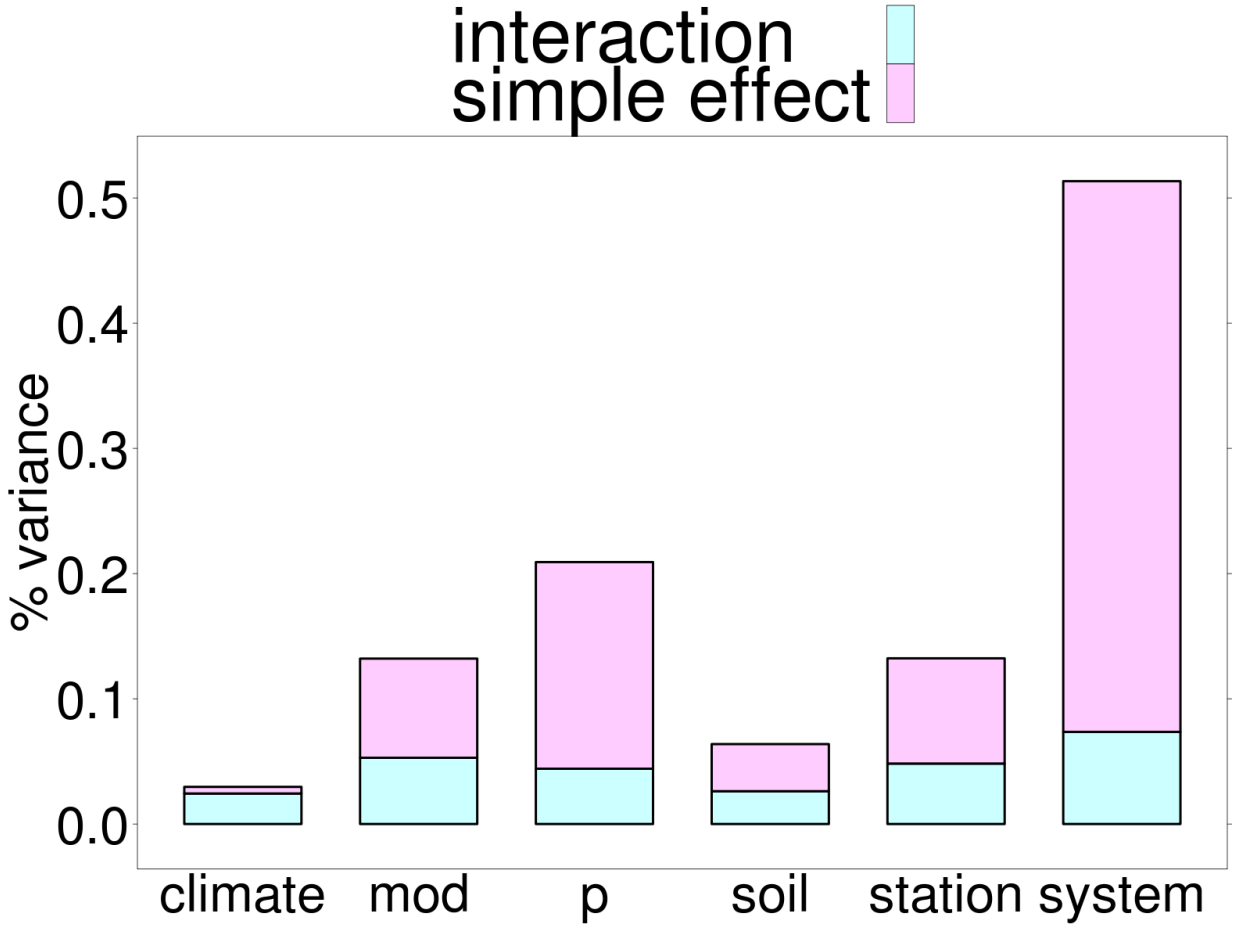
Climatic variability (Station Effect - W)



model dependency



Interactions *vs. simple effects*



Discussion & Conclusions

- Most SOC stocks remained stable (median value of $0.2 kg/m^2$).
  - The range of SOC change is $[-1.6, +3.5] kg/m^2$.
  - 1st and 3rd quintiles : -0.06 and 0.963 kg/m^2.
- The main driver is the nature of the cropping system : The gradation observed in the storage capacity of rotations is largely explained by the different quantity of residues applied (straw and roots for SWSgW), and the behavior of crops facing climate change.
- Climate locally had a great influence.
- Downscaling methods yielded the same results.
- Considered soil variability had a relatively low impact.
- Some conclusions may change depending on the model.

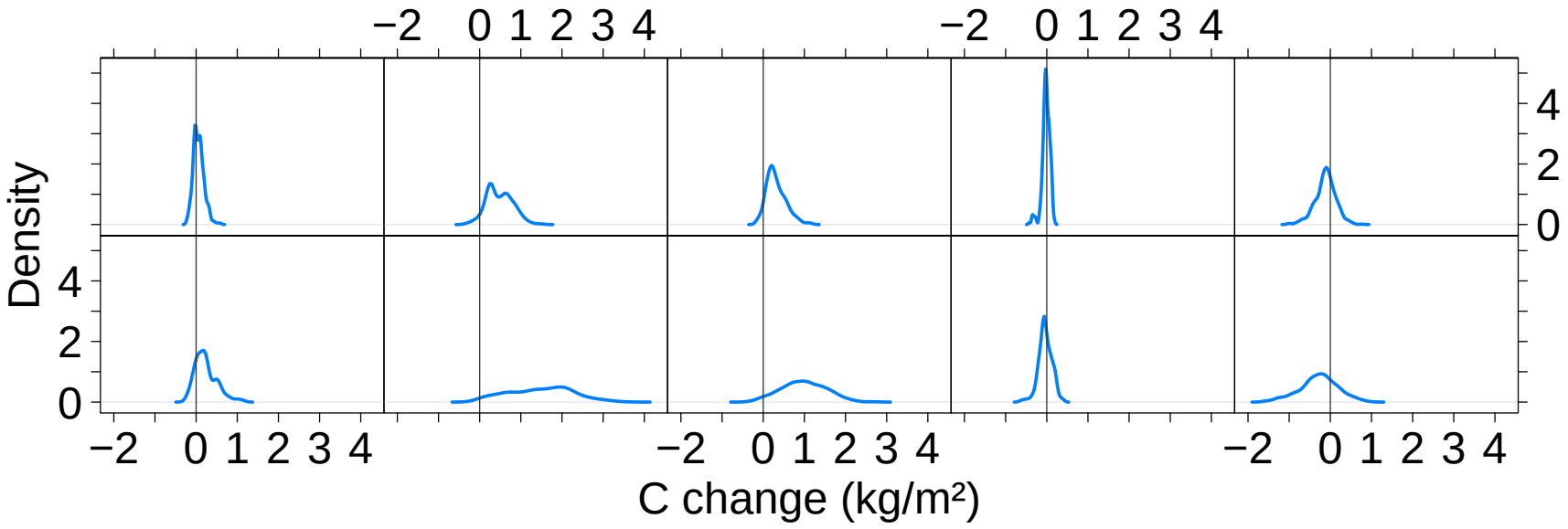
Perspectives

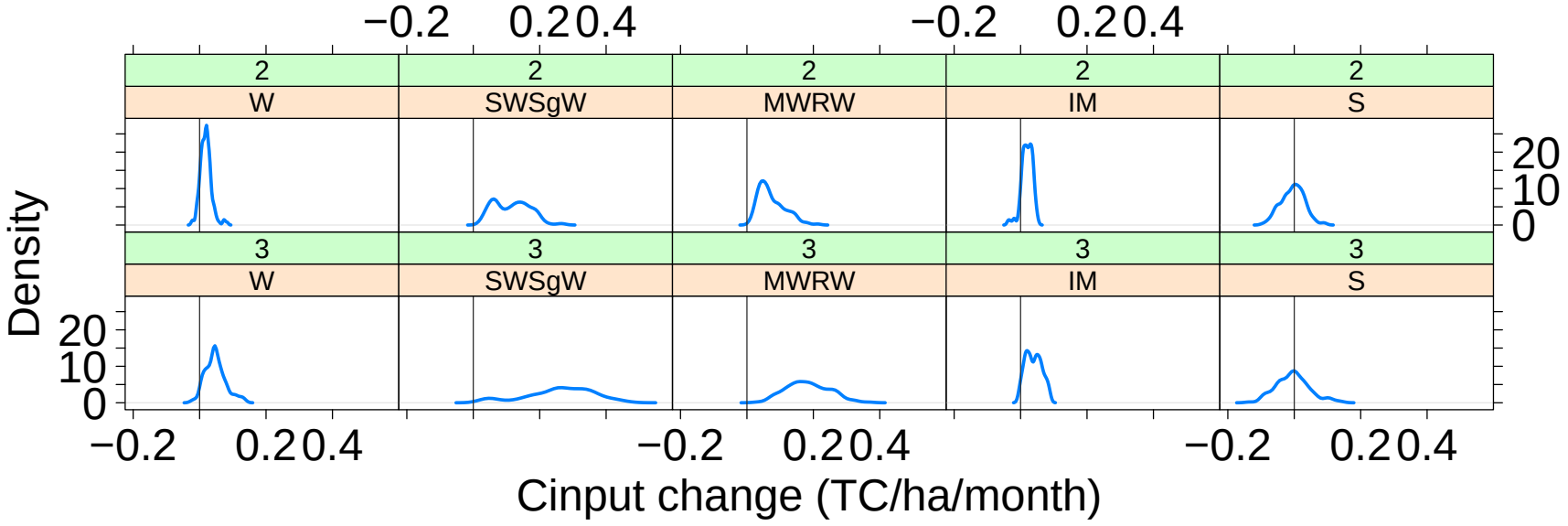
- Filter out the cultivars according to their respective feasibility.
- work out the interpretation of models differences.
- increase to range of studied soils.
- Other systems such as grasslands and forest.

Green book of the climator project

http :
//www.international.inra.fr/research/green_book_of_the_climator_project

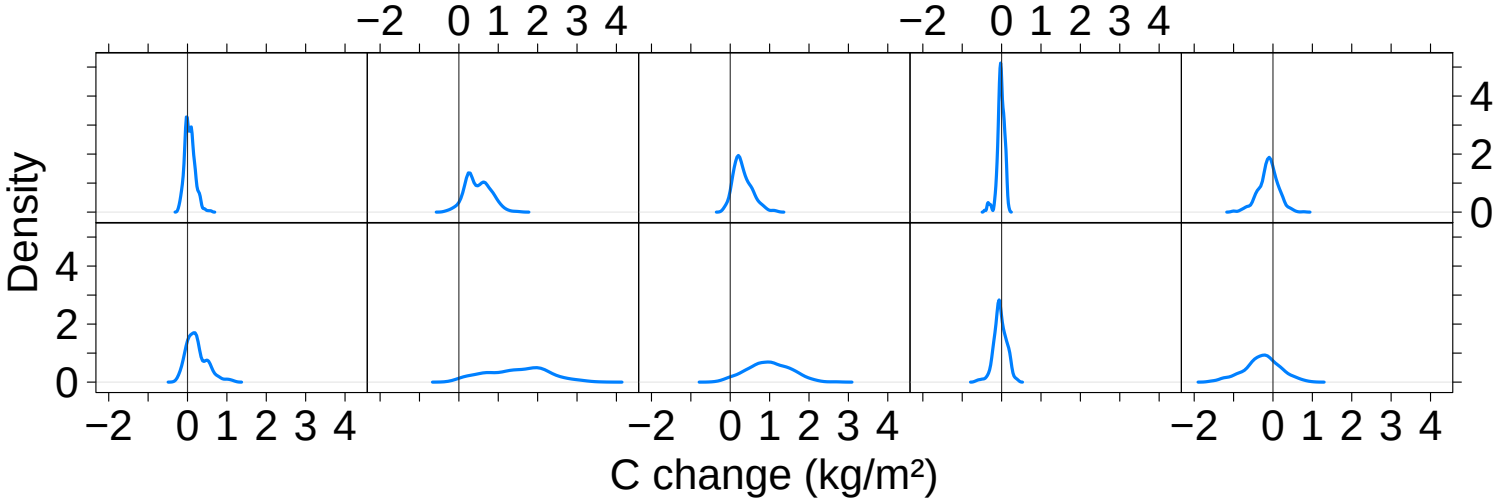
More about the system Effects

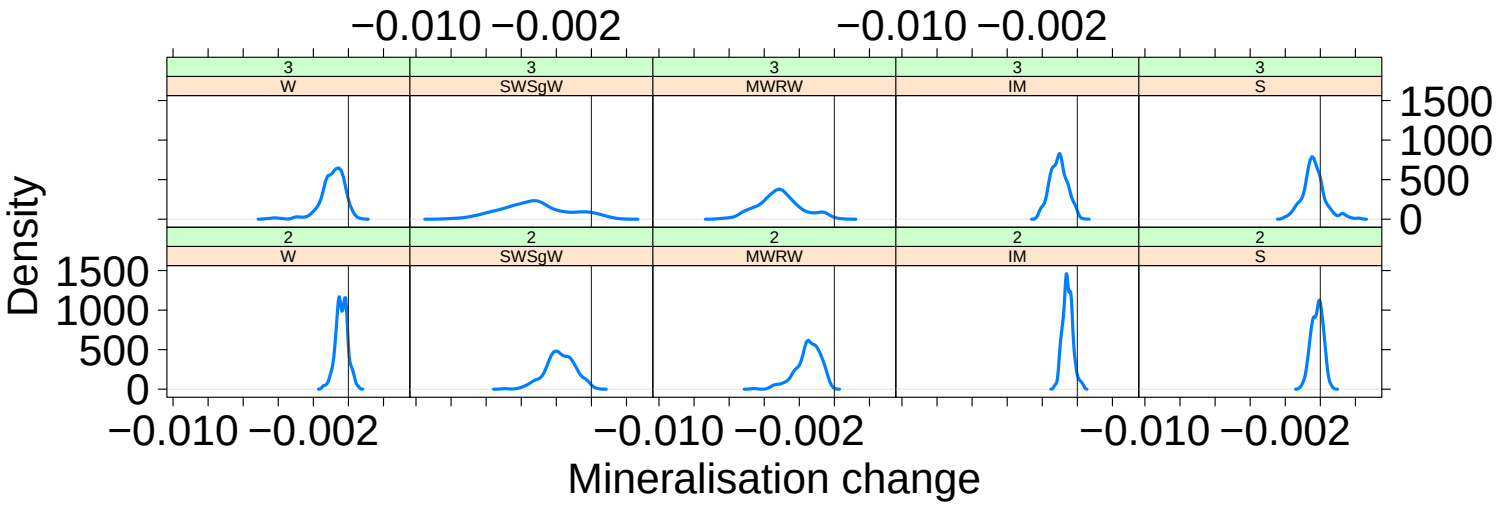




- Uncertainty: which cannot be determined by our current knowledge with confidence
  Unpredictable : greenhouse gases concentration scenarios
  Lacking knowledge : climate models, downscaling methods, crop models
- Variability : which is neither uncertain nor constant
  Endured: climatic inter-annual variability
  Chosen : management practices, genotype choice
  Endured or chosen (depending on the decision scale) : locations and soil

Carbon input *vs. SOM mineralisation*

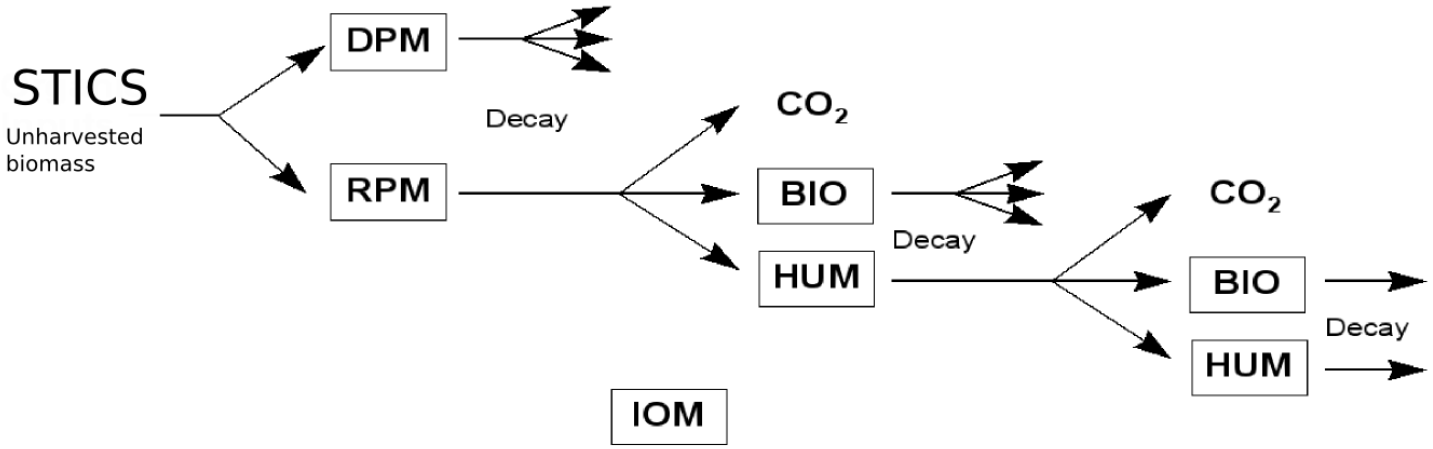




Mineralisation rate is estimated as $\frac{\Delta C^{t+1} - C^{t}_{in}}{C^{t}}$

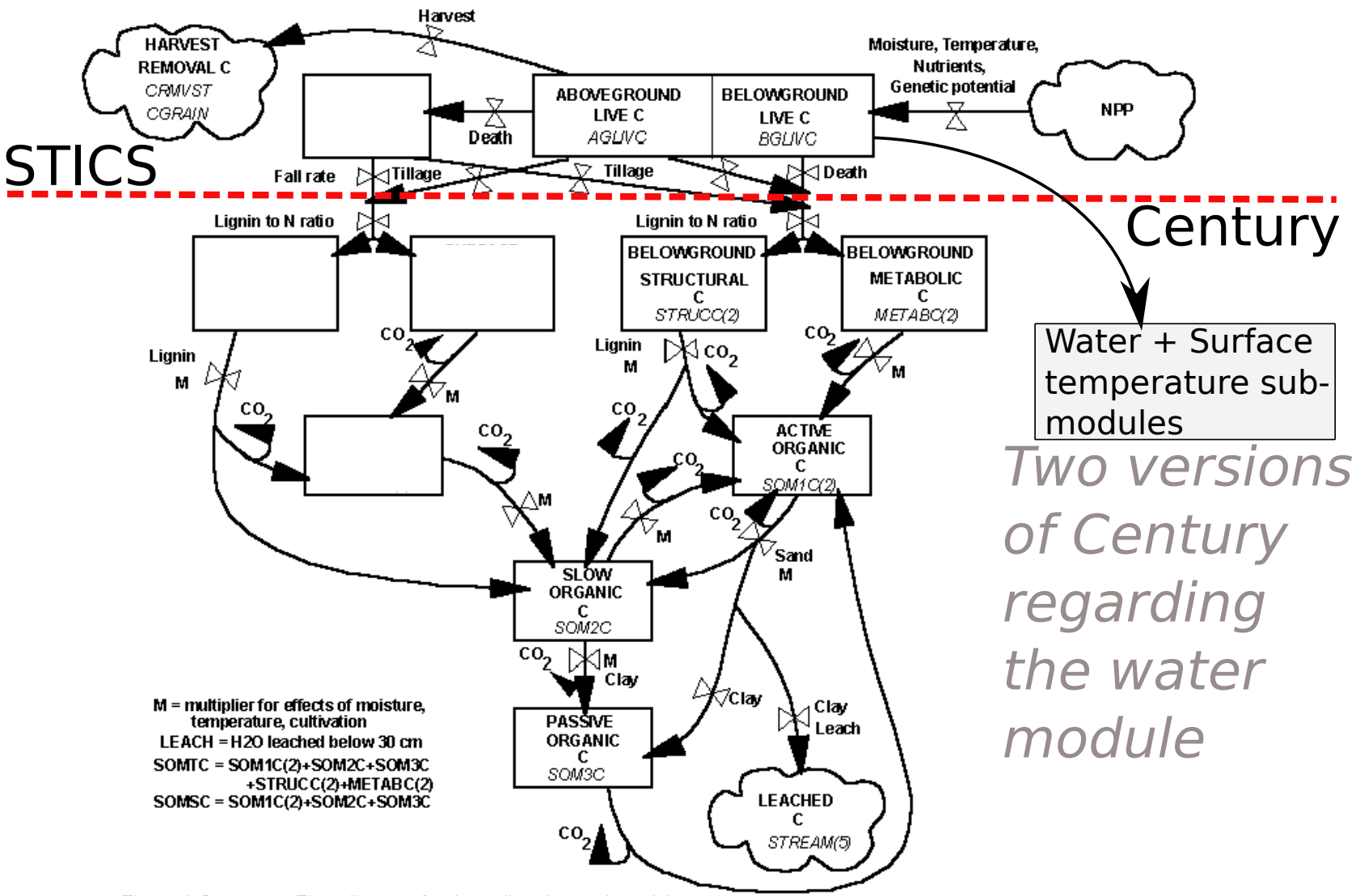
Stics to RothC

Figure 1 - Structure of the Rothamsted Carbon Model



RPM : Resistant Plant Material
DPM : Decomposable Plant Material
BIO : Microbial Biomass
HUM : Humified OM
IOM : Inert Organic Matter

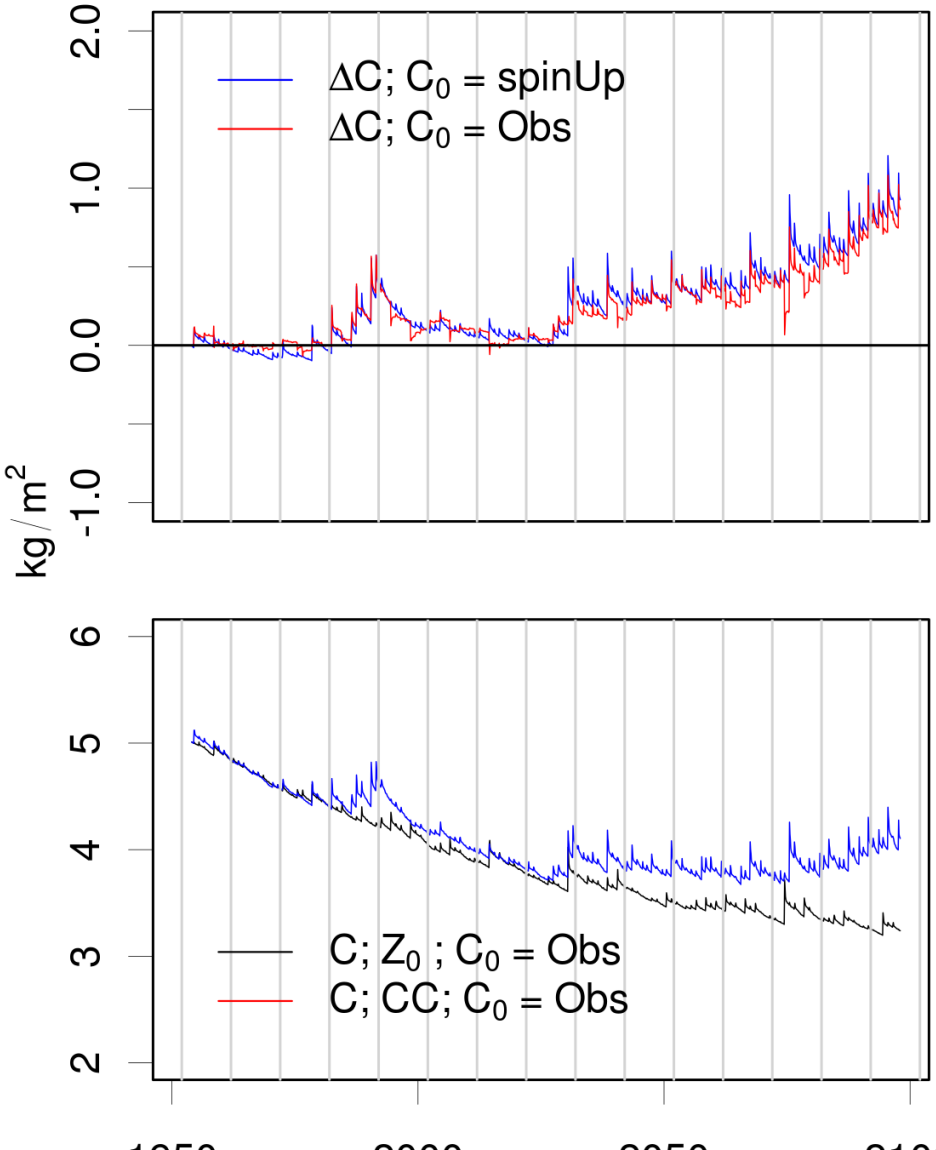
Stics to Century



Two versions of Century regarding the water module

Figure 1-2 Flow diagram for the soil carbon submodel.

Simulation and data analysis protocol



Usual Approach

Intial state = steady state

Initialization

- Observed SOC (stocks for the 0-30cm layer)

Climator approach

- Compute ΔC for a *stable climate (Z_0)*

- Estimate ΔC caused by climate change relatively to the Z_0 series

Further analysis

- near future :

$$\Delta C_{p_2} = \overline{\Delta C_{p_2}} - \overline{\Delta C_{p_1}}$$

- distant future :