PROGRAMME GESSOL
Fonctions environnementales & gestion du patrimoine sol

Integrating global soil-quality impacts into Life Cycle Assessment (ACV-SOL project)

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Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
Ministère de l'Écologie, de l'Énergie, du Développement durable et de l'Aménagement du territoire

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Agriculture and Agri-Food Canada

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

Context

Soil quality: “Capacity of soil to function” (Karlen et al., 1997)

Numerous interrelated soil properties

Complex link with agricultural management practices

No consensus on a Minimum Data Set (MDS) for soil-quality assessment

Few impacts on soil quality commonly considered in environmental analysis methods, especially in Life Cycle Assessment (LCA).

Several approaches developed to evaluate the impacts of agricultural activities on soil quality.

In LCA: SALCA-SQ (Oberholzer et al., 2006); SOM (Mila i Canals et al, 2007)

Objectives

The challenge:

- estimating complex soil-quality impacts that also depend on fluctuating soil characteristics,
- doing so for both on-farm and off-farm agricultural soils,
- and aggregating these impacts spatially and temporally.

- Develop a decision-aid tool for choosing soil-quality impacts for a given context that are compatible with LCA, which will determine which site properties (a "minimum data set") to consider when constructing life-cycle inventories
- Define algorithms that estimate soil-related impacts in the inventory based on these properties (agricultural practices under a variety of soil and climate conditions)
- Classify and characterize inventory elements into several midpoint indicators of impact (and possibly one endpoint indicator)

Aspects of soil quality

Major soil impacts worldwide:

- **EROSION**
- **LOSS OF SOM**
- **COMPACTION**
- Salinization
- Heavy-metal inputs
- Soil Sealing

Most soil-quality impacts of agricultural production are estimated at the field or farm level. Integrating soil-quality impacts throughout the life-cycle of an agricultural product requires a global approach.

Scale

Goal: global indicator(s) of soil-quality impacts

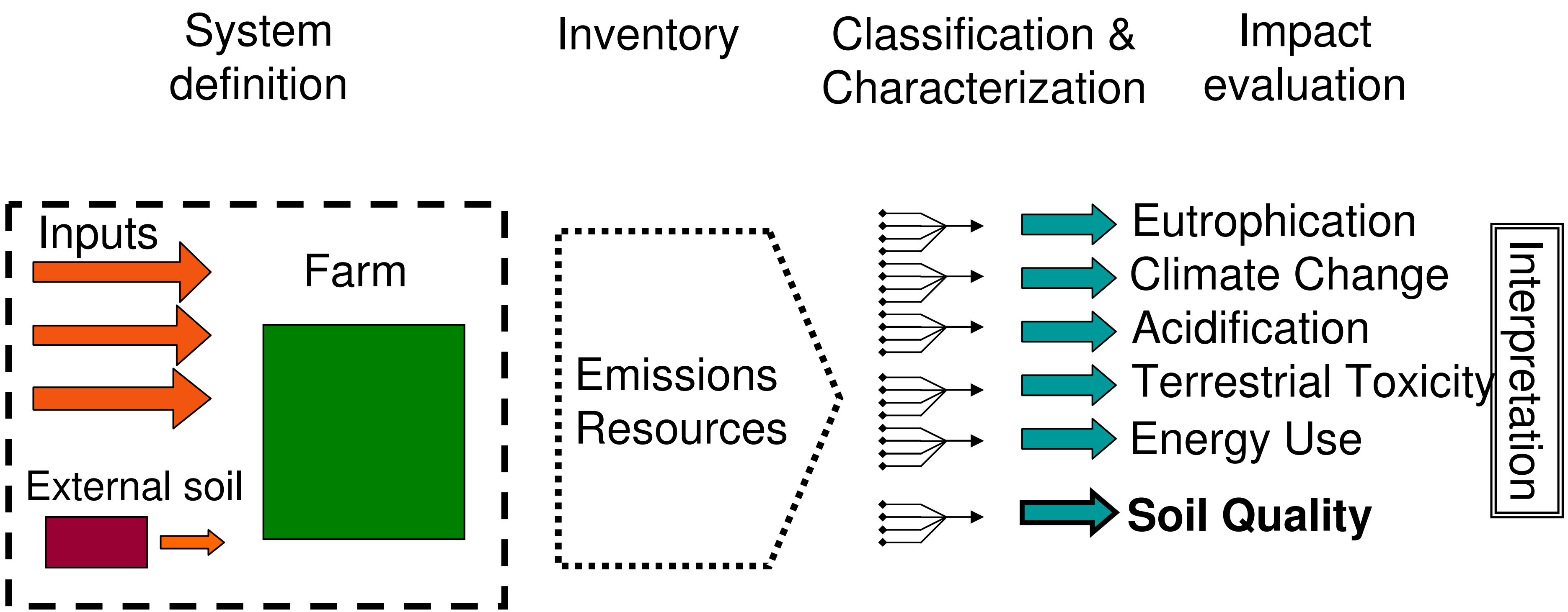
Global scale

Taking into account spatial and temporal variability in a life-cycle perspective

Inclusion of soil-quality impacts caused by certain environmental interventions of upstream processes, regardless of geographic location

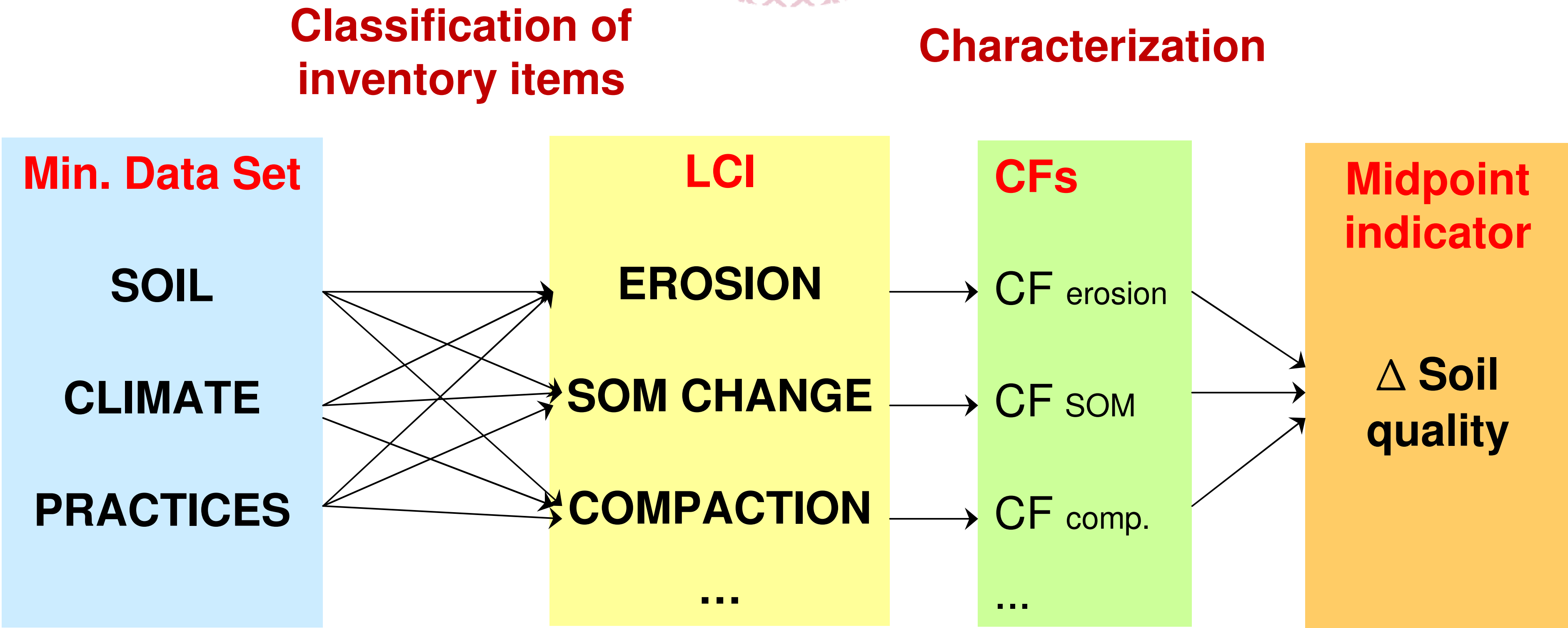
Unresolved issue in Life Cycle Assessment

Life Cycle Assessment



From Geier (1999)

Method



Site-specific soil and climate characteristics will influence impacts of agricultural practices (environmental interventions).

Units of inventory items

LCI in relation to the FU = *kg of maize produced*

LCI in relation to the FU = *hectare*

Erosion

kg of soil / yr / kg maize

kg of soil / yr / ha

Compaction

to be defined

- Number of passes
- Machine type
- Soil humidity
- Susceptibility to comp.

SOM Change

kg C / yr / kg maize

kg C / yr / ha

Salinization

to be defined

Impact estimates via simulation

EROSION:

Revised Universal Soil Loss Equation, version 2 (RUSLE2)

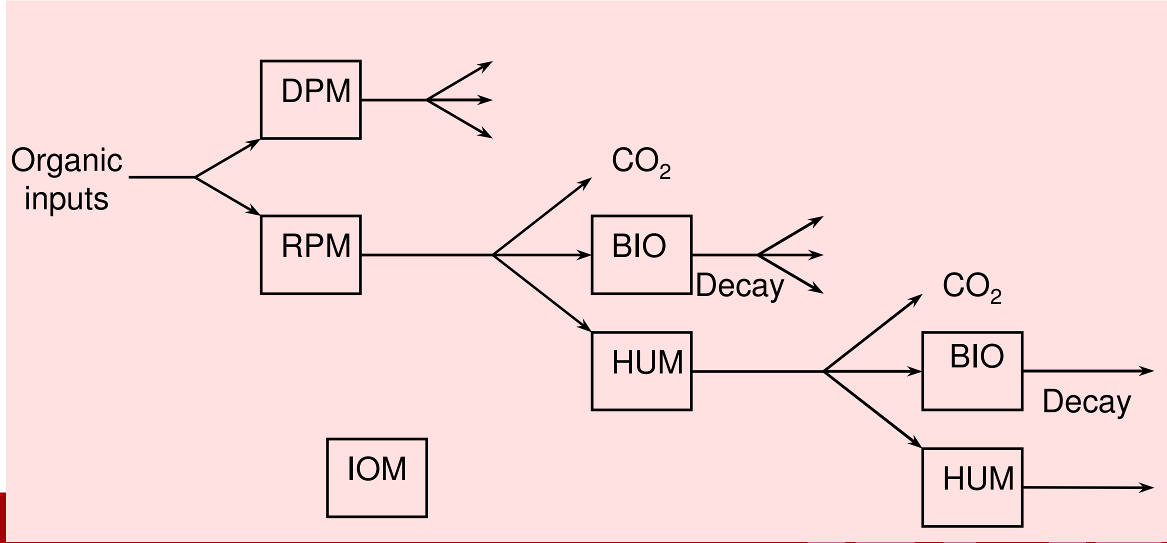
$$A = R \times K \times LS \times C \times P$$

A: annual loss
R: rainfall run-off erosivity factor
K: soil erodibility
LS: topographic factor
C: cover-management factor
P: supporting-practices factor

SOM CHANGE:

RothC, version 26.3

RPM: resistant plant material
DPM: decomposable plant material
BIO: microbial biomass
HUM: humified organic matter
IOM: inert organic matter



Minimum Data Set

EROSION (RUSLE2) SOM (RothC) COMPACTION	Soil	➡Soil Texture: % clay - % loam - % sand ➡ Slope length and steepness ➡ % rock cover (hyp=0) ➡ Organic Matter Content ➡ Soil depth ➡ Density
	Climate	➡ Mean monthly temperatures ➡ Monthly precipitation ➡ Monthly evapotranspiration
	Practices	➡ Crops / soil cover ➡ Type of operation / machines ➡ Yield (dry matter) ➡ Quantity of residues ➡ Amount of manure applied

Data availability

Measured | Simulated with local or regional model | Simulated with universal model RUSLE – Roth C

Preference – Precision

LCI (erosion; SOM…)

Measured | local or regional data | National scale data

Preference – Precision

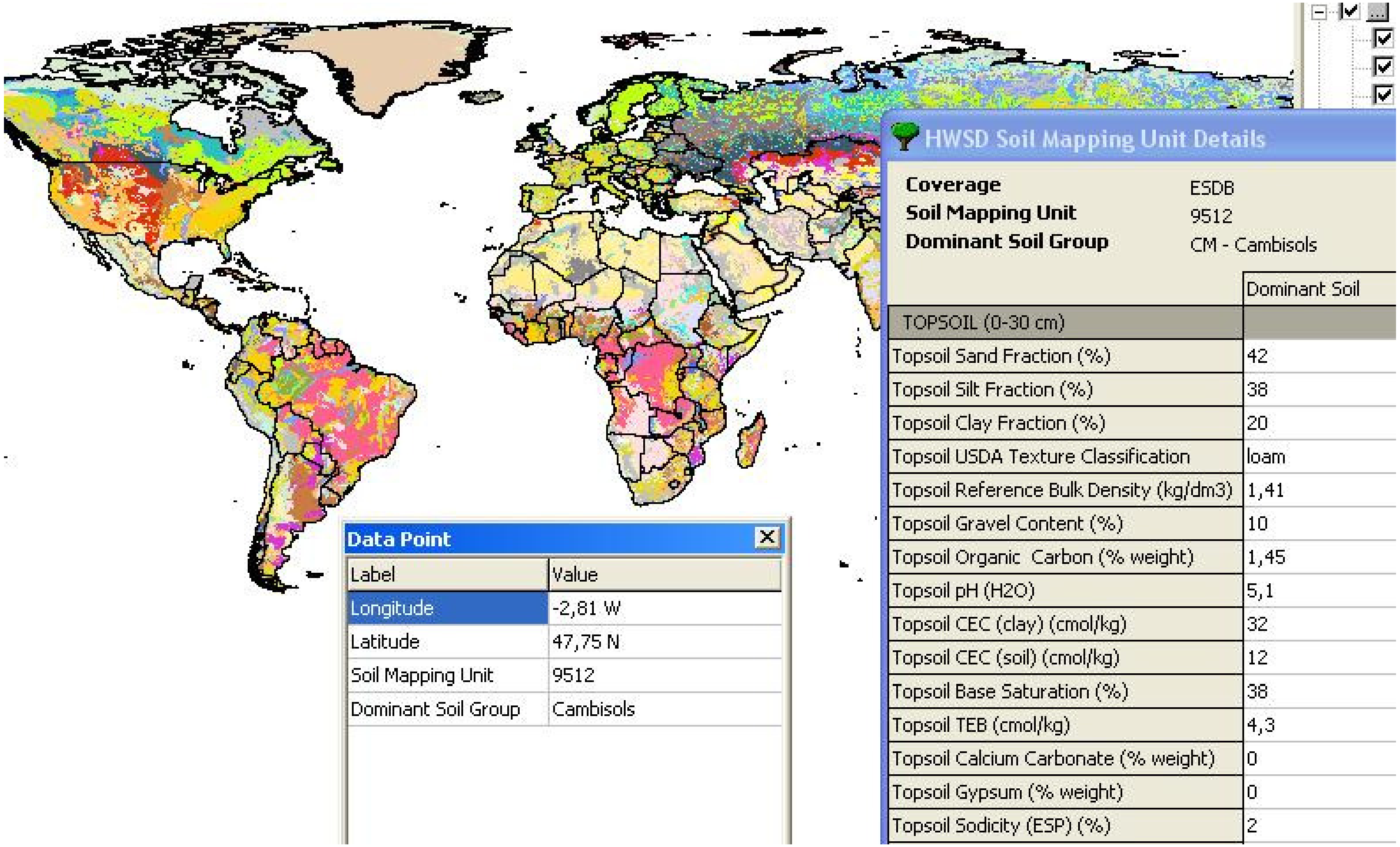
MDS (soil, climate, practices)

Global scale

Fill inventory with data as site-specific and accurate as possible

If necessary, use low-resolution data available at a global scale

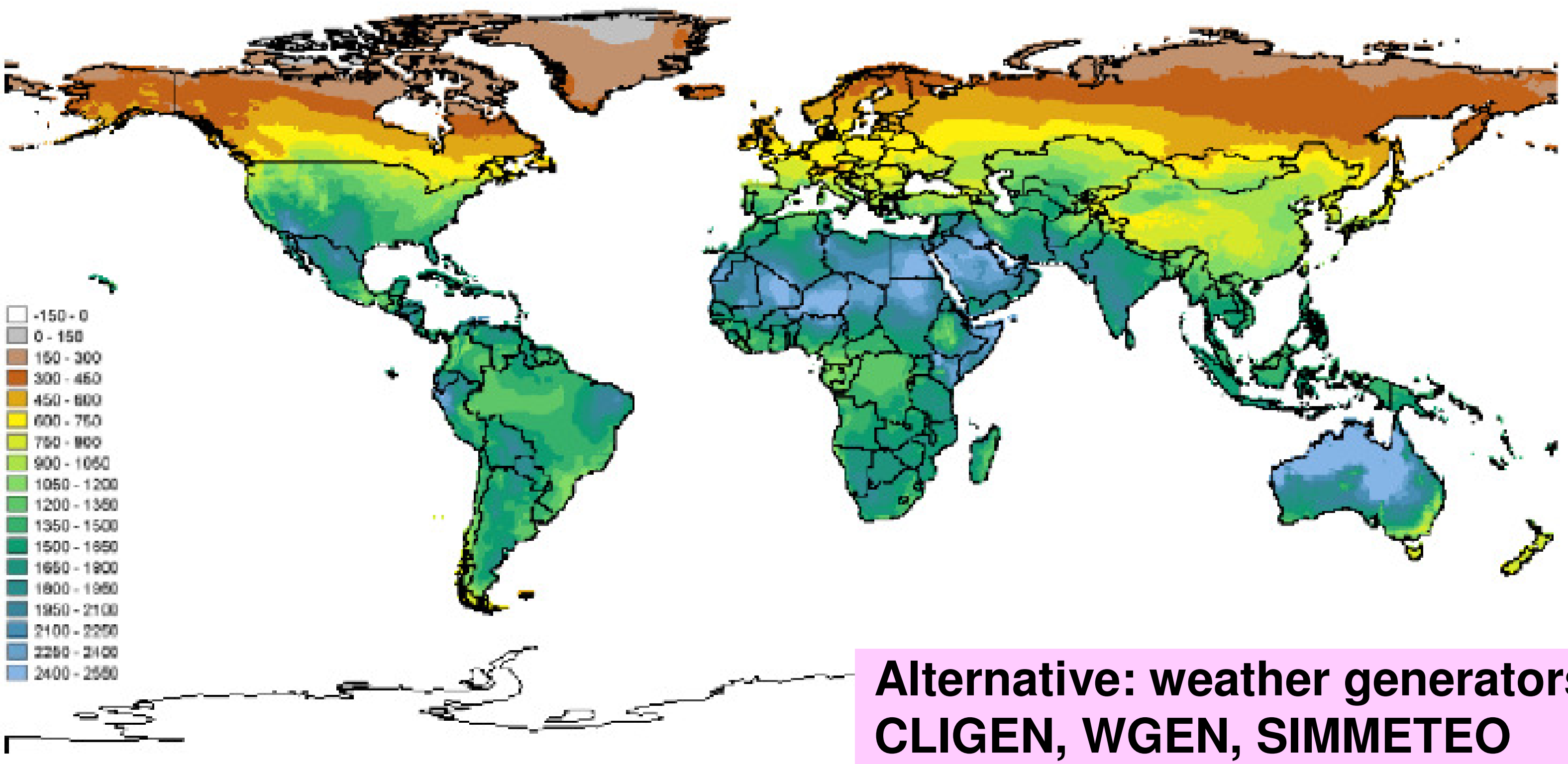
Some soil properties



Source: http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/

Climate data

Plate 2. Average annual reference evapotranspiration (Penman-Monteith)



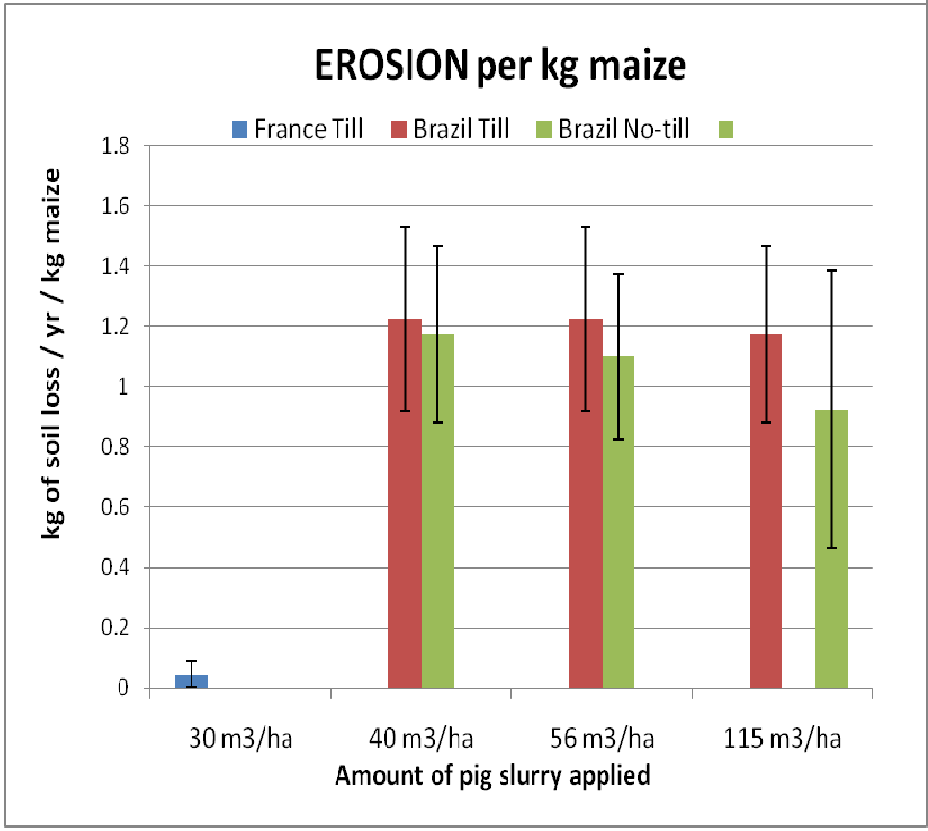
Alternative: weather generators CLIGEN, WGEN, SIMMETEO

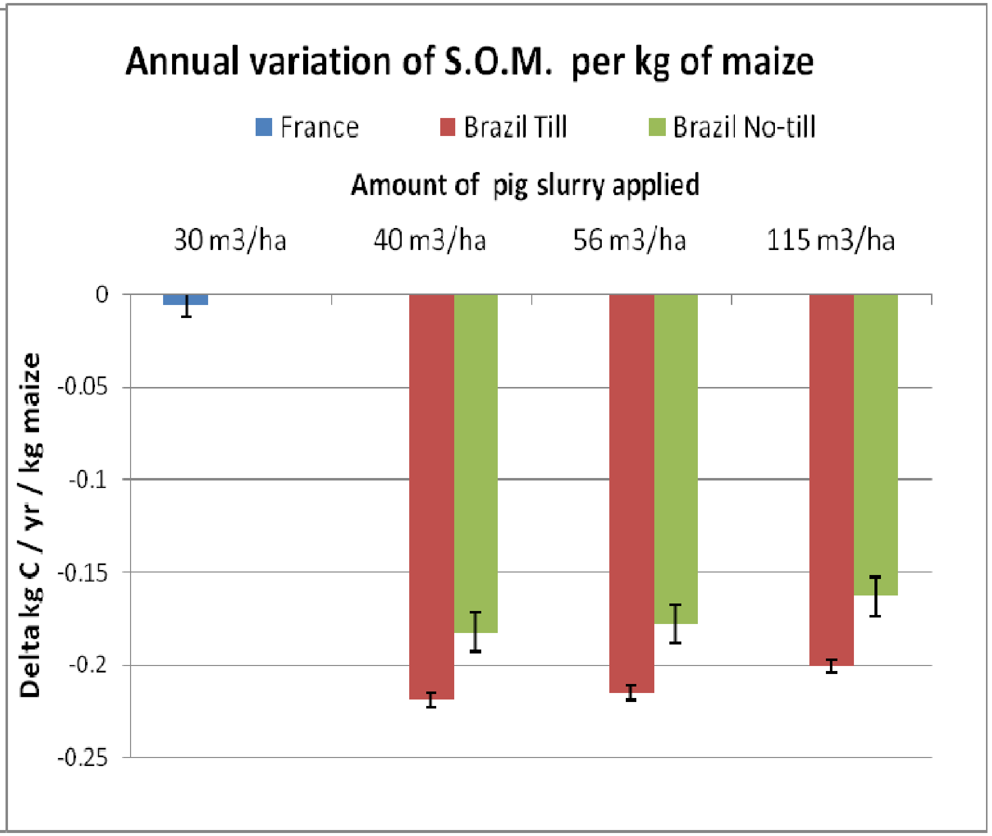
Source: FAO (Global Agro-Ecological Zones Assessment)
http://www.iiasa.ac.at/Research/LUC/GAEZ/

Case studied

FU: 1 kg of grain maize or hectare	FRANCE Brittany	BRAZIL Santa Catarina State
Soil classification (FAO)	Cambisol	Nitisol
Clay / Silt / Sand (%)	20 / 48 / 32	62 / 35 / 3
Organic matter (%)	4	3
Slope length (m)	100	100
Slope steepness %	4	4
Soil depth (cm)	30	30
Density (t/m^3)	1.23 (measured) (1.41 simul.)	1.16 (simulated)
Climate	Oceanic	Humid sub-tropical
Mean annual T (°C)	11	21
Mean annual precip. (mm)	1060	2200
ETP (mm)	656	1032
Pig slurry applied	30 m^3/ha	40 – 56 – 115 m^3/ha
Tillage practices	Tillage	Tillage / No tillage
Crop rotation	Maize– Maize	Maize - Maize

Results – Erosion and S.O.M. change





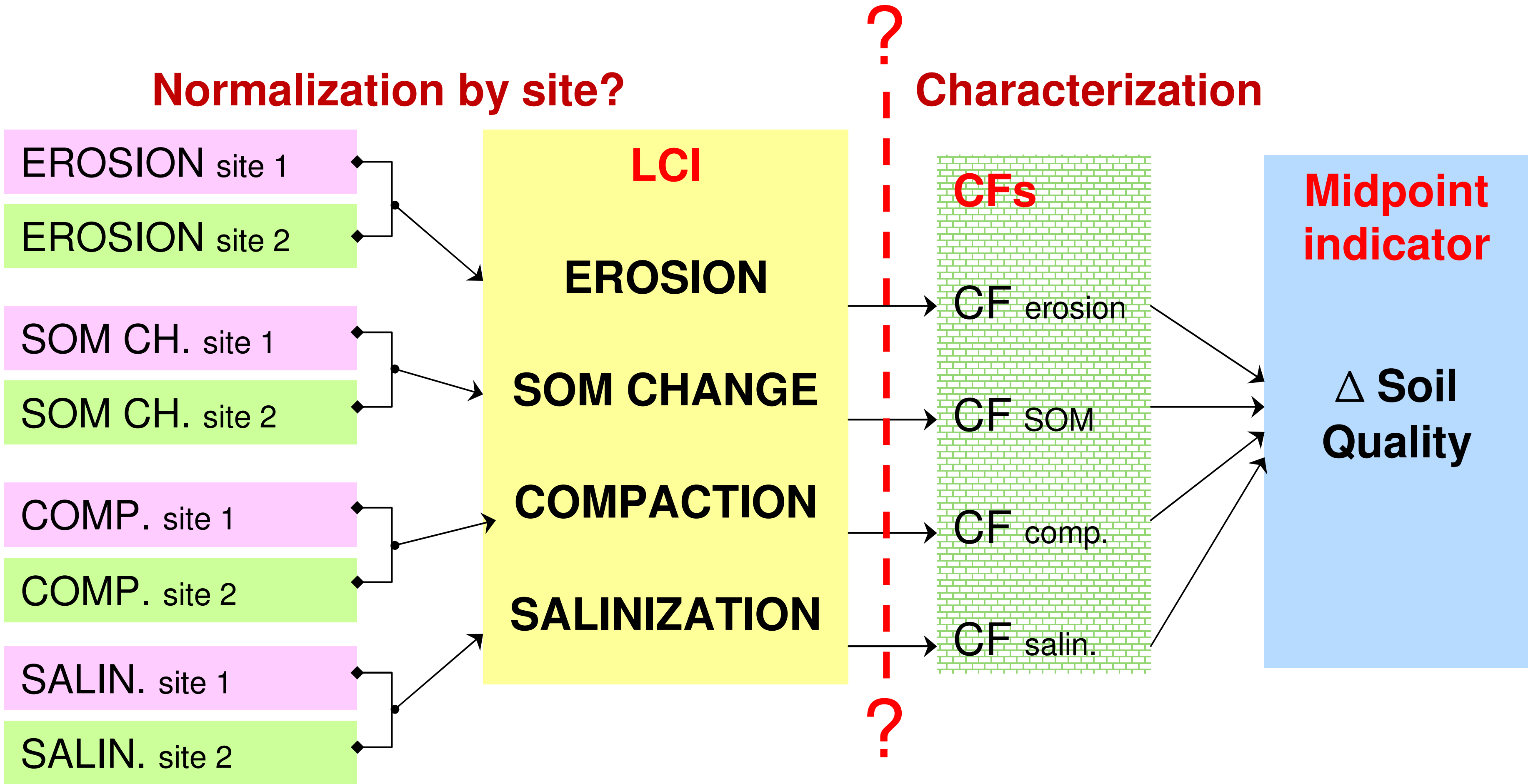
Sensitivity analysis

RUSLE2		t soil loss / ha / yr	
Variable	Variation	**Brittany**	**Brazil**
O.M.	+/- 20%	-0.1	-0.063
residue	+/- 20%	-0.1	-0.052
Rock Cover 1%	+/- 20%	-0.052	0
Rock Cover 5%	+/- 20%	-0.114	-0.143
Slope lenght	+/- 20%	0.2	0.125
Texture	+/- 10%	0.851	0.654
Texture	+/- 20%	0.819	0.737
Temperature	+/- 20%	1	0.64
Slope steepness	+/- 20%	1.04	1.125
Precipitation	+/- 20%	1.37	1.38

$$SensitivityIndex = \frac{\frac{O_h - O_l}{O_m}}{\frac{I_h - I_l}{I}}$$

Roth C		t C / ha	
Variable	Variation	**Brit**	**Braz**
Clay	+/- 20%	0.041	0.006
Precipitation	+/- 20%	-0.106	-0.265
ETP	+/- 20%	0.223	0.355
Temperature	+/- 20%	-0.404	-0.582
Meas. Tot. C (72)	+/- 20%	0.566	0.724
Meas. Tot. C (52.2)	+/- 20%	0.484	0.653
Residue	+/- 20%	0.444	0.353
Residue	+/- 50%	0.436	0.882

Multiple-site aggregation



Conclusions -Perspectives

- Choice of MDS according to impact selected in the inventory allows a methodological framework which can evolve continously
- Importance of taking into account all on-site and upstream agricultural soils

- What levels of precision for the data ?
- What about compaction and salinization ?
- Aggregation into midpoint indicator of soil quality ?


Thank you for
your attention