Challenge 7 : How to recognize, quantify and map soil functionality?

Philippe Lagacherie, Henri Lechevallier, Alexandre M.J.-C Wadoux

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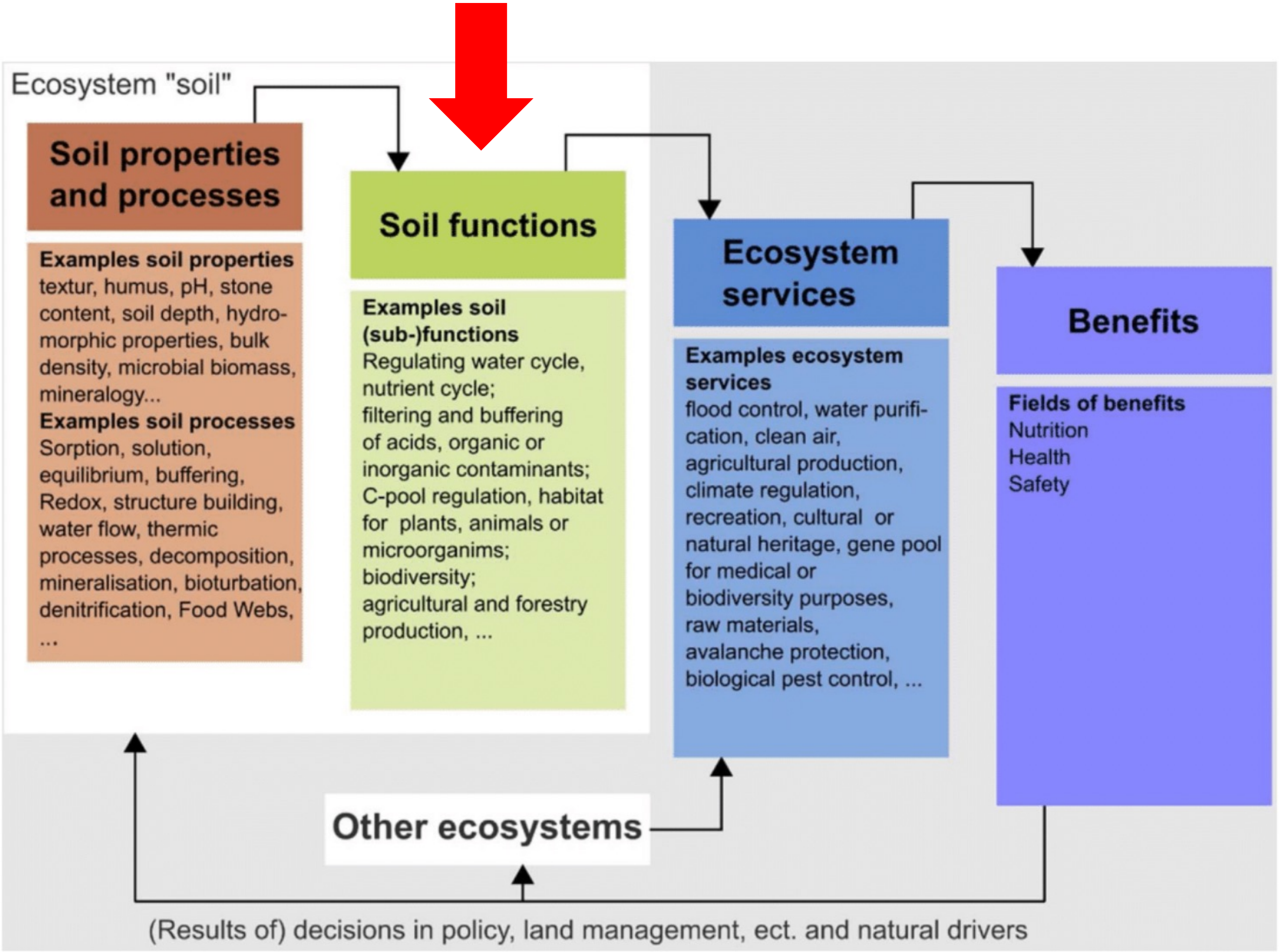
LISAH, INRAE, Montpellier, France

Users are interested in soil functions for their decision making



Greiner et al, 2017

Soil function attract more and more attention…

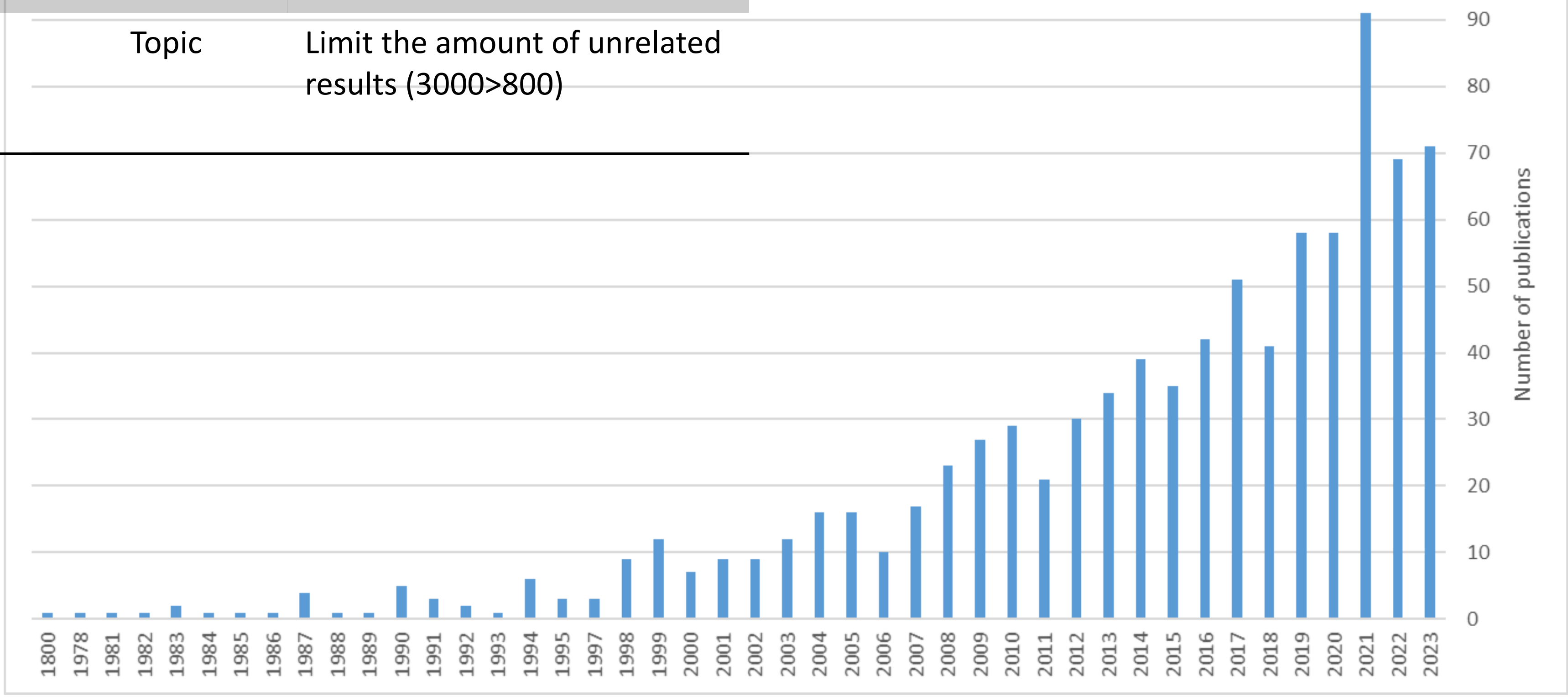
Search query (Web of Science, 3/08/23)

		OR	OR	OR	Search in	?
AND	Soil				Title	Object of study
AND	*function*	‘’ecosystem services’’	Health	Quality	Title	Related terms
AND	Eval*	Quanti*	Assess*		Title	Focus on evaluation
AND	*function*	Service			Topic	Limit the amount of unrelated results (3000>800)

750 papers

Expert-based selection by cursory reading

16 case studies on soil evaluation
15 soil evaluation tools



A large diversity of targeted quantities

abilities

(relative) soil quality within a given context

Soil condition

capacity to perform functions (water purification and regulation, the primary productivity function)

soil functions' performance trade-offs between the soil functions under current conditions"

potential contribution of soil to ecosystem services

performance of ecosystem services

most probable changes in soil quality indicators

long-term soil quality local yield potential

degre of functionnal performance

spatially explicit evaluation of current levels of soil functionality

ecosystem services

Soil quality index

Potential Multifunctionnality

To evaluate soils

supply of soil functions

soil quality

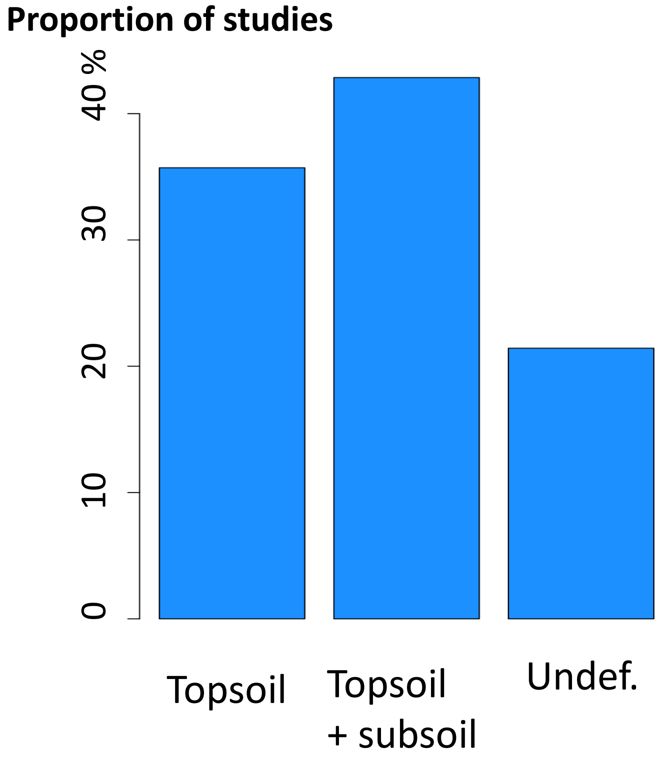
soil health indicators

soil performances

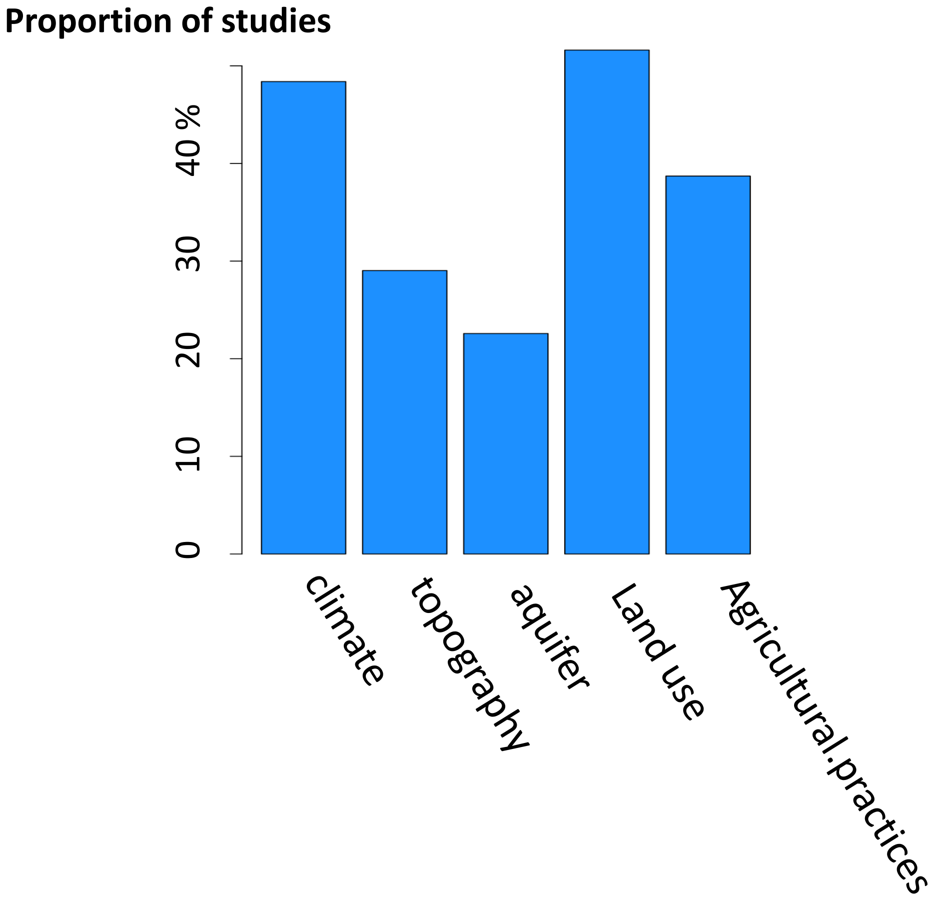
- **That could be classified into three distinct concepts…**
  - **Fulfilment level of a function** observed or modelled at a given period and at a given location (context)
  - **Capacity** to satisfy a function in any context
  - **Potential** to satisfy a function in any context (based on perennial soil properties only)

A large diversity of representations of soil, contexts and functions

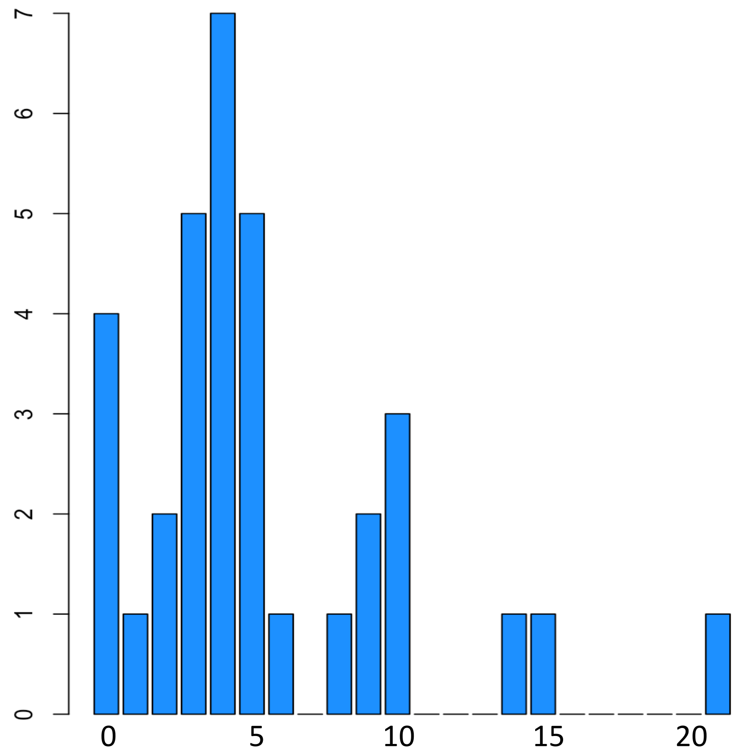
Considered soil depths



Considered contexts



Numbers of considered functions /ECS



Low diversity of quantification methods, …with limitations

- Most current methods
  - Decision trees and score functions fed by expert knowledge and/or literature harvesting (90 % of studies)
  - Agro-environmental models outputs (for level of fullfilment of individual functions)
  - Final aggregation into an unique indicator (60% of studies)

Low diversity of quantification methods, …with limitations

- Most current methods
  - Decision trees and score functions fed by expert knowledge and/or literature harvesting (90 % of studies)
  - Agro-environmental models outputs (for level of fullfilment of individual functions)
  - Final aggregation into an unique indicator (60% of studies)
- Some limitations
  - The embedded knowledges on soil functions are neither traceable nor revisable
  - Uncertainties are not considered (exception: *Vrebos et al, 2020*)

European Journal of Soil Science

SPECIAL ISSUE ARTICLE | Full Access

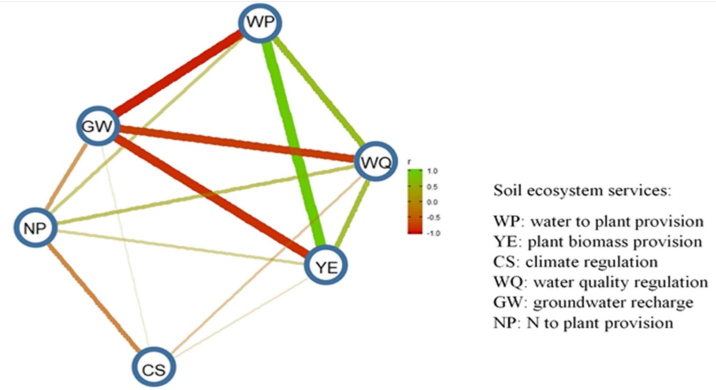
Spatial evaluation and trade-off analysis of soil functions through Bayesian networks

Dirk Vrebos, Arwyn Jones, Emanuele Lugato, Lilian O'Sullivan, Rogier Schulte, Jan Staes, Patrick Meire

First published: 23 August 2020 | https://doi.org/10.1111/ejss.13039 | Citations: 8

Services SFX pour INRAE

  - Weigthing, conflicts and trade-off between functions are rarely considered (Exceptions : *Vrebos et al, 2020, Ellili et al, 2021)*



- Diverse underlying concepts
- Diverse soil, functions and context representations
- Quantification methods with limitations

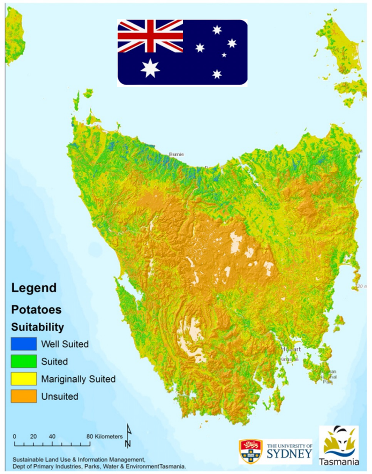
→

Lack of stabilized and consensual conceptual and methodological framework to adress soil functionnality

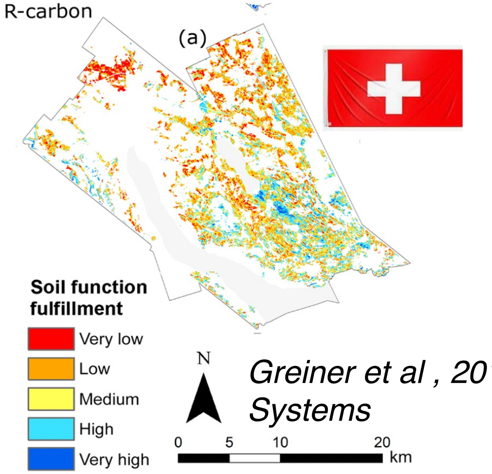
Soil function and multifunctionnality mapping

- Most of the 16 case studies on soil evaluation produced maps (70%)
- Most of the soil function maps are derived from conventional soil maps
- Still few studies using a DSM approach

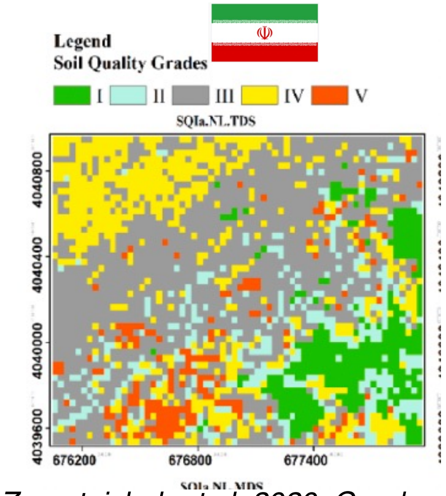
Digital Soil Mapping and Soil function/multifunctionnality mapping



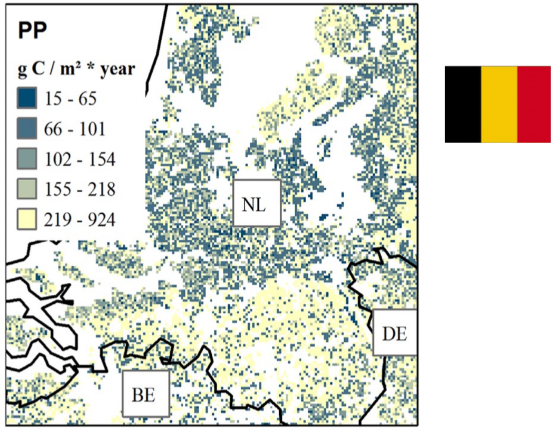
Kidd et al, 2015, Geoderma R.



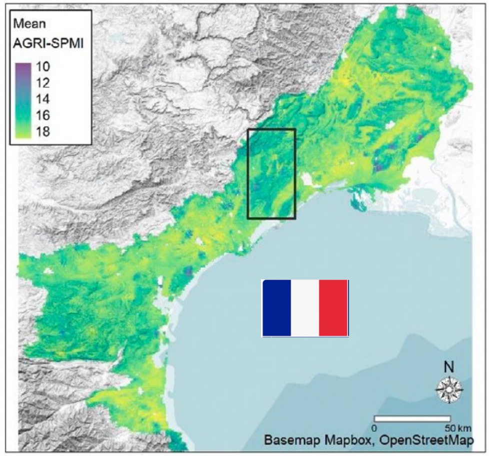
Greiner et al , 2018, Soil Systems



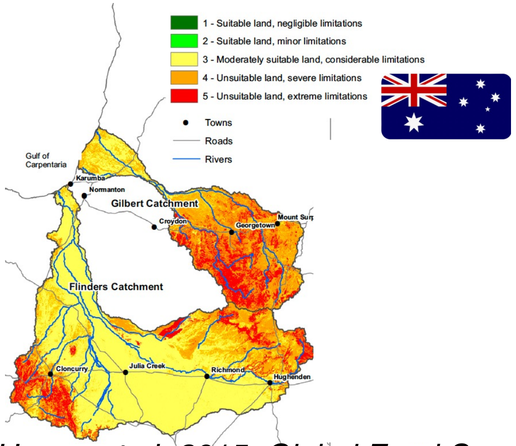
Zeraatpisheh et al, 2020, Geoderma



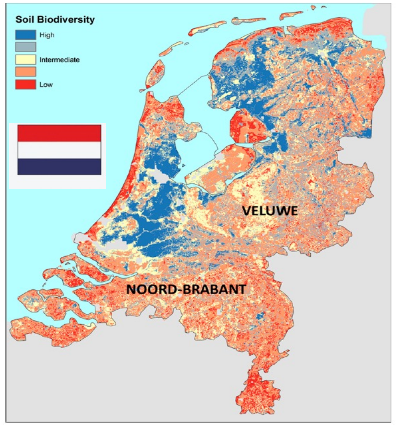
Vrebos et al, 2020, EJSS



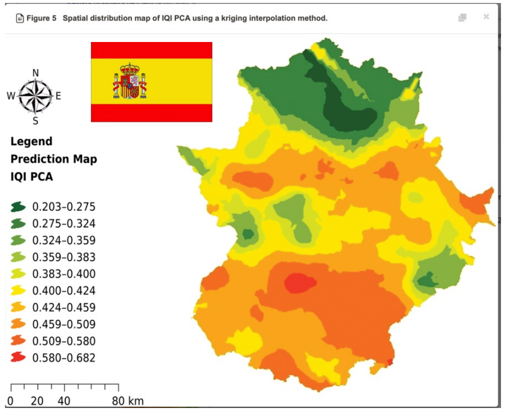
Angelini et al , 2022, EJSS



Harms et al, 2015, Global Food Security

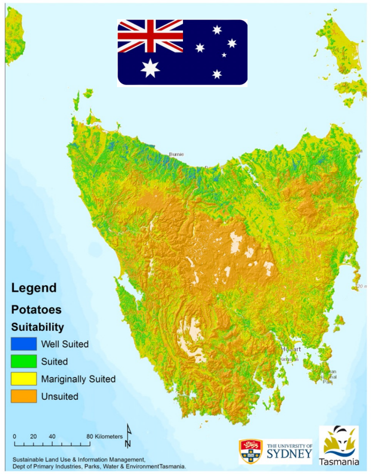


Rutgers et al , 2019, Soil Systems



Fernadez et al , 2020, Rev. Bras. Ciènc. Solo

Digital Soil Mapping and Soil function/multifunctionnality mapping



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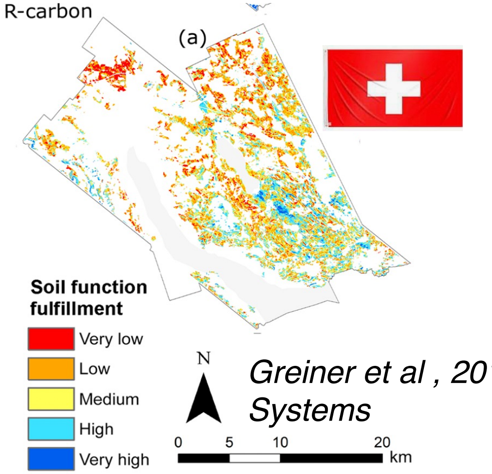
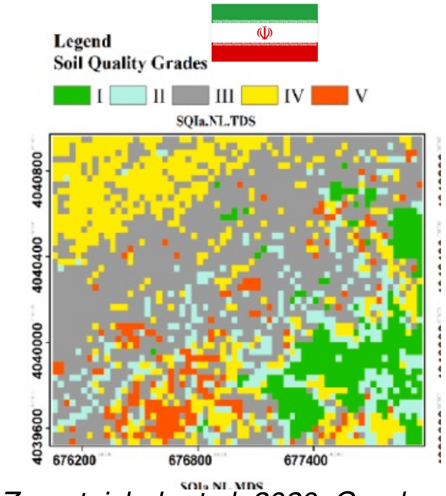
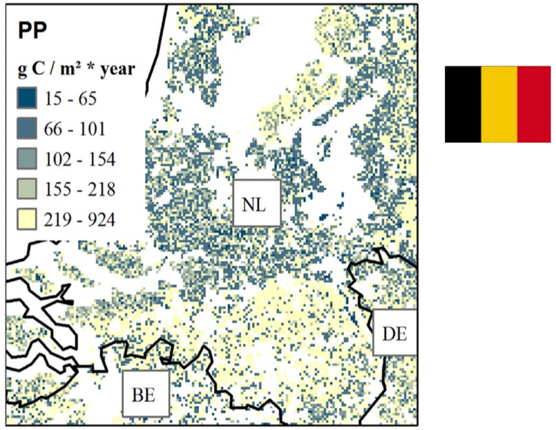


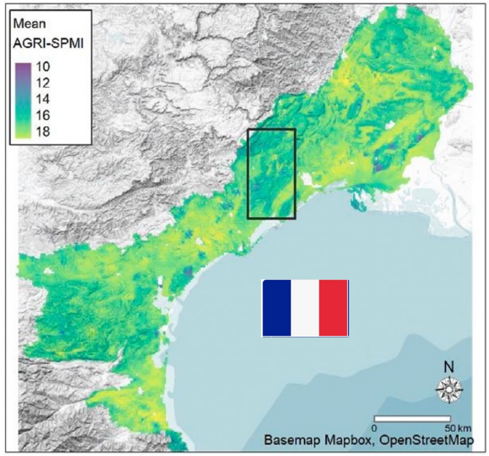
Greiner et al , 2018, Soil Systems



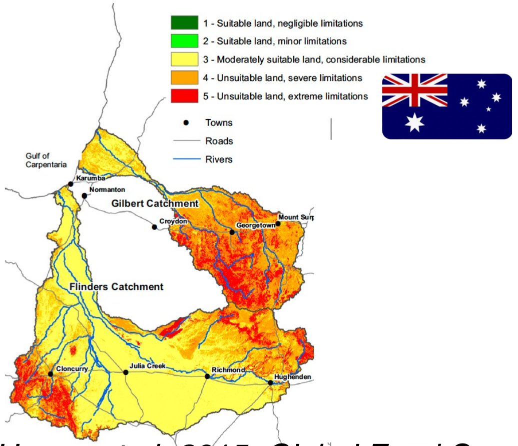
Zeraatpisheh et al, 2020, Geoderma



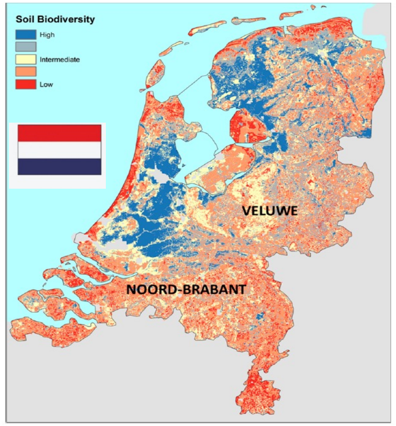
Vrebos et al, 2020, EJSS



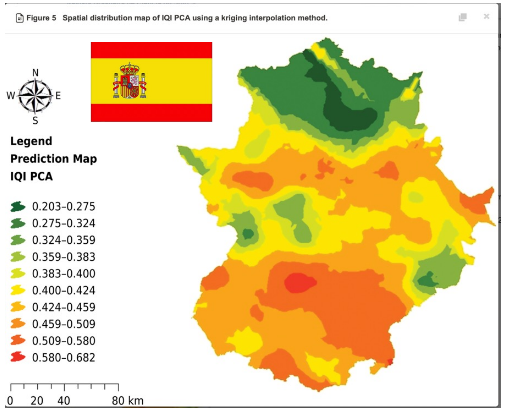
Angelini et al , 2022, EJSS



Harms et al, 2015, Global Food Security



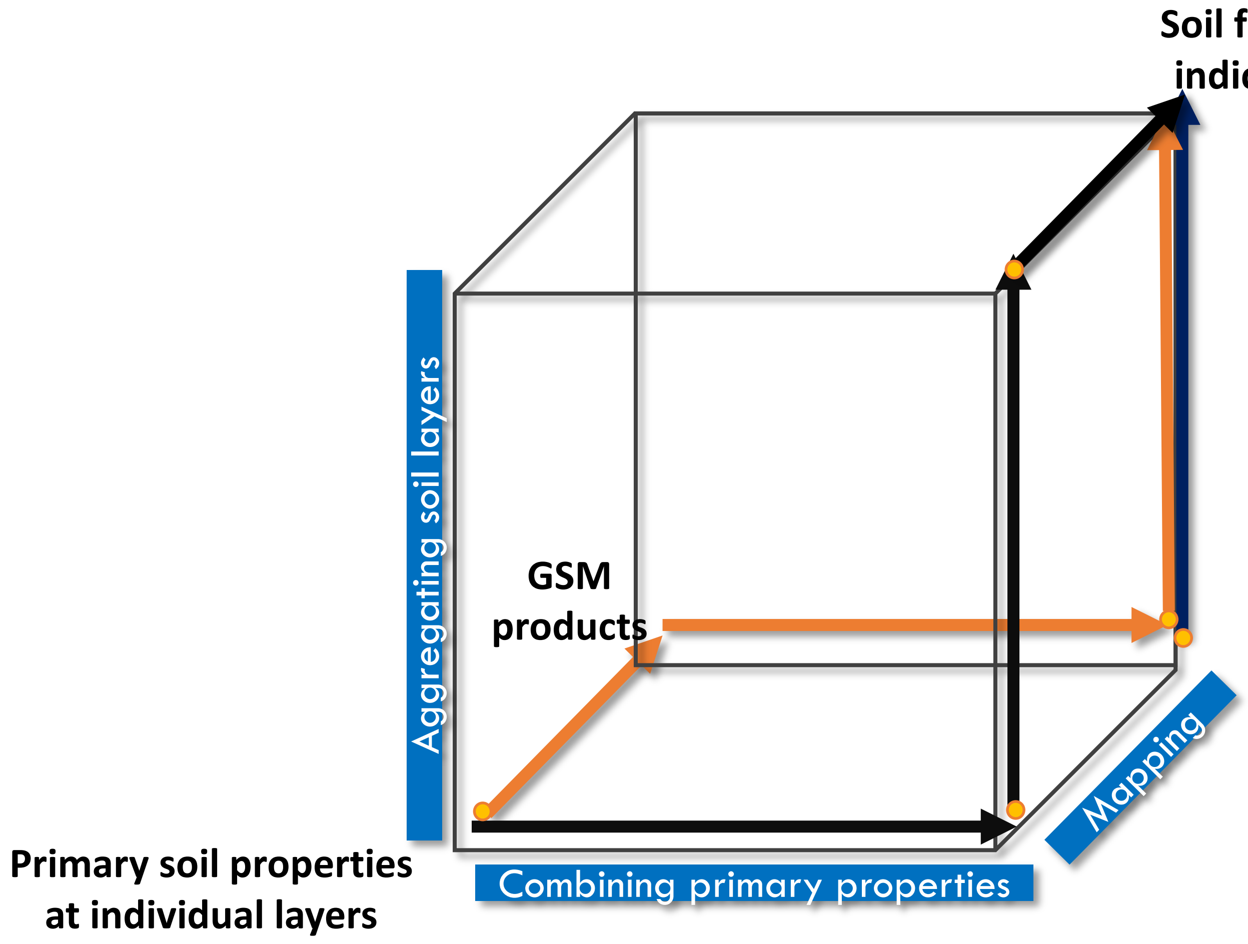
Rutgers et al , 2019, Soil Systems



Fernadez et al , 2020, Rev. Bras. Ciènc. Solo

→ **Digital Soil Mapping becomes multivariate !**

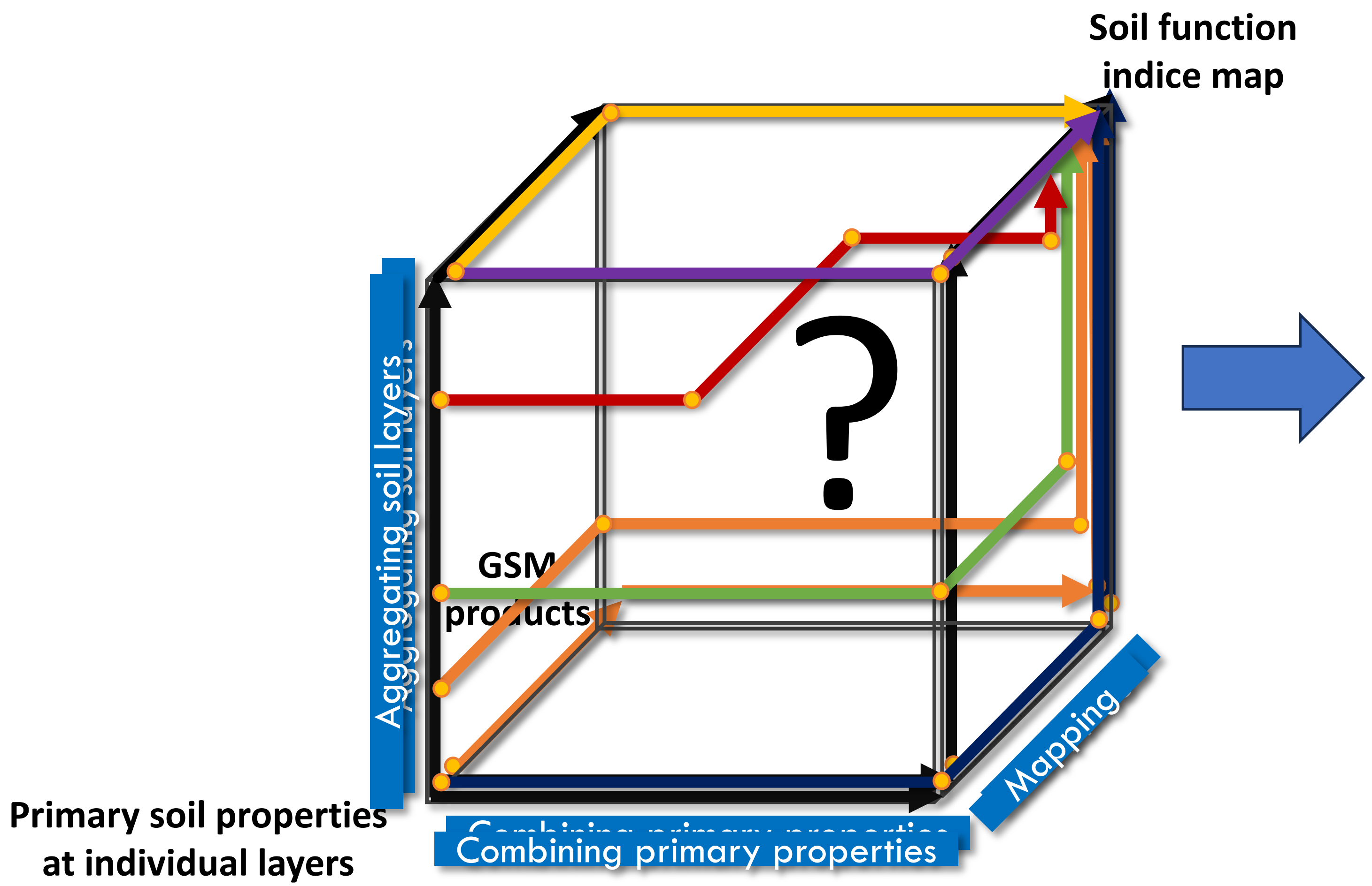
Different possible inference trajectories for multivariate DSM



« Mapping first » (most of the DSM applications)

« Calculating first » (*Rutger et al, 2019; Fernandez et al 2020*)

Different possible inference trajectories for multivariate DSM



- Do inference trajectories inpact DSM results ?
- If yes, how to select the best one ?

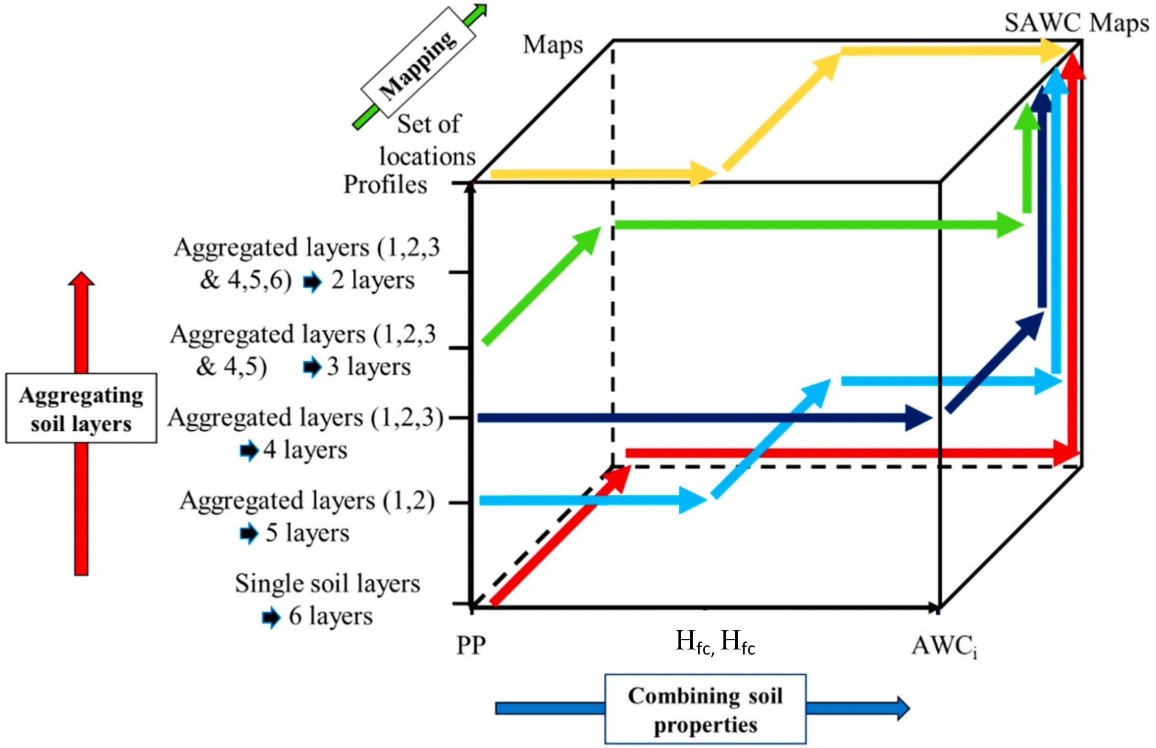
Example: mapping soil available water capacity *(Styc & Lagacherie, 2019)*

Soil thickness

Coarse fragment

PTF inputs: Clay, silt, sand

$$SAWC = \sum_{i=1}^{n} SLh_i * \left(\frac{100-st_i}{100}\right) * \left[\underbrace{\left(\sum_{j=1}^{n} \alpha_j PP_j + \varepsilon\right)}_{H_{fc}} - \underbrace{\left(\sum_{j=1}^{n} \alpha_j PP_j + \varepsilon\right)}_{H_{fc}}\right]$$



soil systems

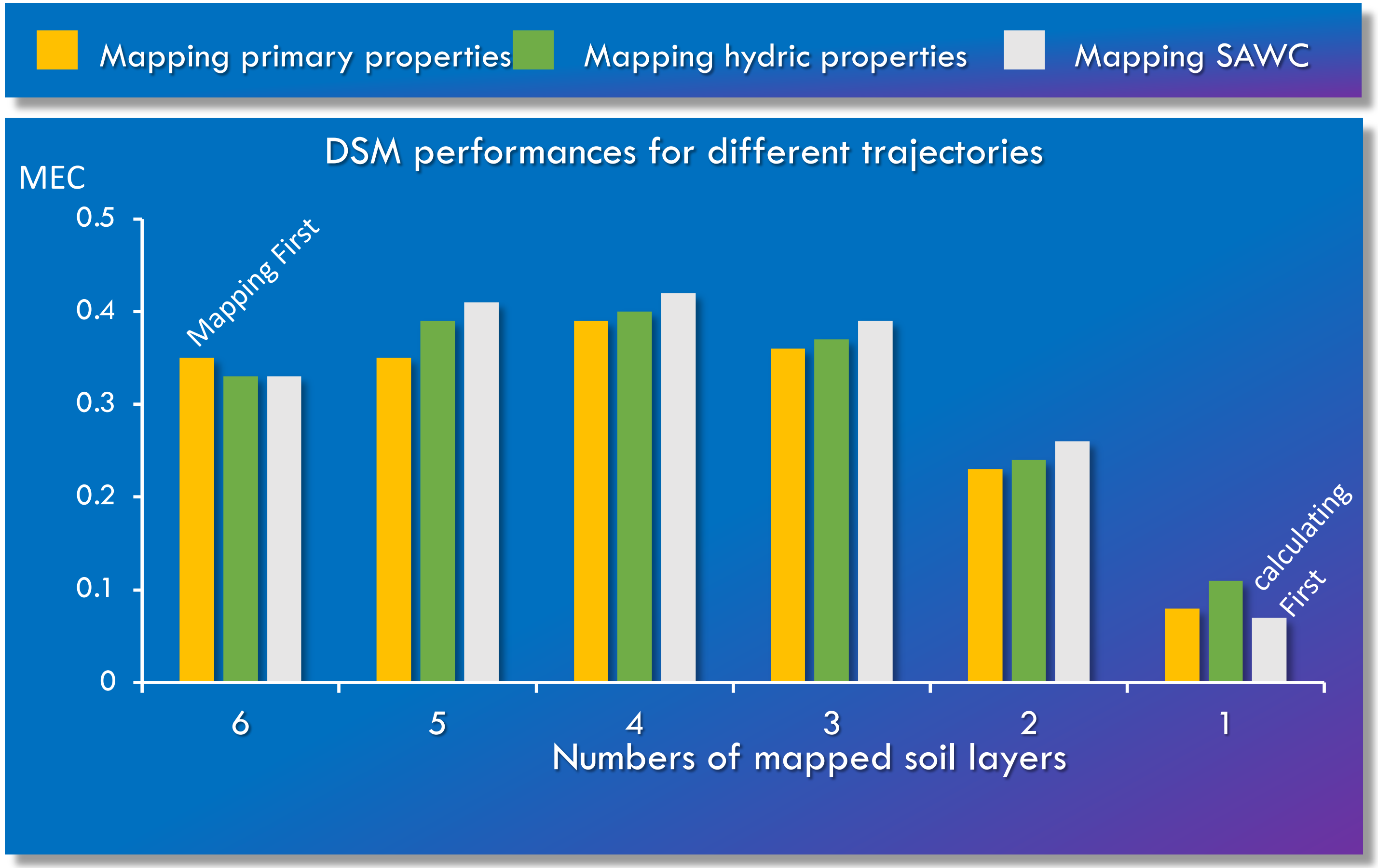
MDPI

Article

What is the Best Inference Trajectory for Mapping Soil Functions: An Example of Mapping Soil Available Water Capacity over Languedoc Roussillon (France)

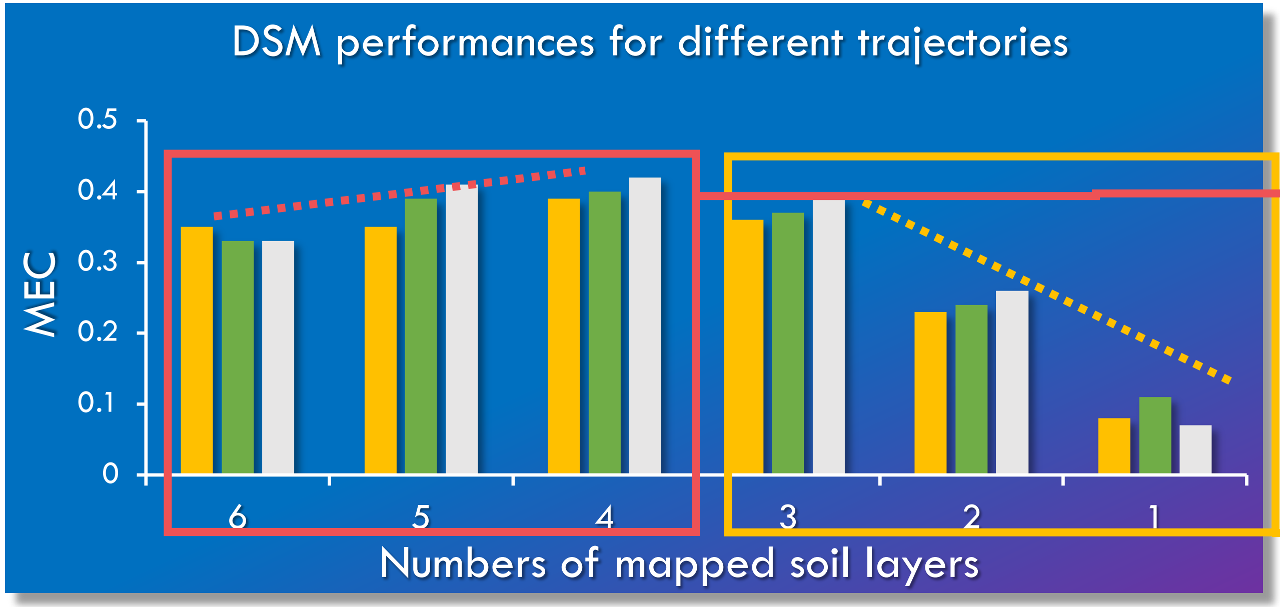
Quentin Styc [1,2,*] and Philippe Lagacherie [1]

Inference trajectories for mapping Soil Avalaible Capacity and DSM performances



- DSM performances vary following the inference trajectories
- The best Inference trajectory is neither « mapping first » nor « calculating first »

The role of correlations between basic soil properties



Average correlations of soil properties between soil layers

	0-5	5-15	15-30	30-60	60-100
5-15	0,99				
15-30	0,94	0,96			
30-60	0,78	0,79	0,87		
60-100	0,58	0,57	0,64	0,85	
100-200	0,4	0,41	0,46	0,58	0,78

→ The most correlated soil properties should be aggregated first before mapping

How to propagate uncertainty of soil function assessment and DSM ?

Few studies…

- DSM errors propagated to SAWC by using analytical formulae of error propagation *(Roman-Dobarco et al, 2019, Styc & Lagacherie, 2021)*

- DSM errors propagated to soil function fullfillments by using Monte Carlo simulations parametrized with estimated DSM uncertainties *(Greiner et al, 2018)*

- DSM errors propagated to a soil multifunctionnality index by using stochastic simulations of soil properties derived from linear models of coregionalisation *(Angelini et al, 2022)-*

- Soil function assessement uncertainties represented by a Bayesian Belief Network *(Vrebos et al, 2020)*

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Uncertainty assessment of *GlobalSoilMap* soil available water capacity products: A French case study

M. Román Dobarco, Hocine Bourennane, Dominique Arrouays, Nicolas P.A. Saby, Isabelle Cousin, Manuel P. Martin

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Uncertainty assessment of soil available water capacity using error propagation: A test in Languedoc-Roussillon

Styc Quentin[a,b], Lagacherie Philippe[a,*]
[a] LISAH, Univ Montpellier, INRAE, IRD, Montpellier SupAgro, Montpellier, France
[b] BRL Exploitation, Nîmes, France

SOIL, 4, 123–139, 2018
https://doi.org/10.5194/soil-4-123-2018

Uncertainty indication in soil function maps – transparent and easy-to-use information to support sustainable use of soil resources

Lucie Greiner[1], Madlene Nussbaum[2], Andreas Papritz[3], Stephan Zimmermann[4], Andreas Gubler[1], Adrienne Grêt-Regamey[5], and Armin Keller[1]

Received: 5 September 2022 | Revised: 10 January 2023 | Accepted: 30 January 2023
DOI: 10.1111/ejss.13345
ORIGINAL ARTICLE
European Journal of Soil Science WILEY

A multivariate approach for mapping a soil quality index and its uncertainty in southern France

M. E. Angelini[1,2] | G. B. M. Heuvelink[3,4] | P. Lagacherie[2]

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DOI: 10.1111/ejss.13039
SPECIAL ISSUE ARTICLE
European Journal of Soil Science WILEY

Spatial evaluation and trade-off analysis of soil functions through Bayesian networks

Dirk Vrebos[1] | Arwyn Jones[2] | Emanuele Lugato[2] | Lilian O'Sullivan[3] | Rogier Schulte[4] | Jan Staes[1] | Patrick Meire[1]

How to map the uncertainty associated with maps of soil functionnalities ?

	AFEP*	MCS**	SLMC***	BBN****
Account for DSM errors	✓	✓	✓	✗
Account for Soil Function assessment errors	✗	✗	✗	✓
Account for DSM error correlations	✓	✗	✓	✗
Applicable to all aggregated values	✗	✓	✓	✓

- ***AFEP**: using analytical formulae of error propagation (Roman-Dobarco et al, 2019, Styc & Lagacherie, 2021)
- ***MCS**: using Monte Carlo simulations parametrized with estimated DSM uncertainties (Greiner et al, 2018)
- ***SLMC**: using stochastic simulations of soil properties derived from linear models of coregionalisation (Angelini et al 2022)
- ***BBN**: using a Bayesian Belief Network (Vrebos et al, 2020)

Still room for further improvements

Proposed Agenda for future researches : soil functions and soil quality assessments

- Converge toward a well-admitted conceptual and methodological framework
  - Setting ontologies
  - Clarify the representations of soils and of their context (scenarios for evaluations)
  - Identifying adequate numeric tools to represent the complex knowledge on Soil functions (BBN ?)

- Develop traceable (numeric) approaches to collect relevant knowledges on soil functions
  - Harvesting knowledge from literature (traceable and reproductible meta-analysis)
  - Assessing fullfillments of soil function using process-based models and derived metamodels
  - Elicing local expert knowledges (participatory approaches)
  - Managing uncertainties and conflicts between different sources of knowledge about soil functions
  - Avoid mixing scientific decisions and policy ones

Proposed Agenda for future researches : Mapping soil functions and soil quality

- Develop Multivariate DSM approaches
  - Optimizing the inference trajectories → Spatial Soil Inference system
  - Combining, propagating and representing uncertainties for decision-making
  - Experimenting multivariate machine learning algorithms
- Develop new approaches for mapping time-variant soil properties
- Develop dynamic user interfaces to communicate complex map contents

As a conclusion

- The « Quantifying and mapping soil functionnality » challenge : a new horizon for the pedometricians
- The response should be collective (As the GlobalSoilMap project was)
- Potential users and neighbor scientific communities should be more involved than before