

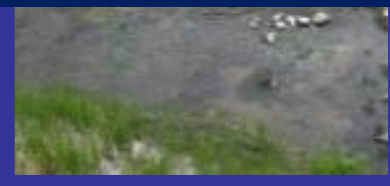
# Assessment of soil ecosystem services through an expert-based approach

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Department for Soil Health and Plant Nutrition

**Water regulation and purification**



**Climate regulation**



**Biodiversity**



**Primary productivity**



**Nutrient cycling**



# DEMANDS ON OUR LAND

I want to grow my milk output  
by 50%



# DEMANDS ON OUR LAND

We will provide clean drinking water

Ionad Cóireála Uisce  
Charraig Mhacaire Rois  
Carrickmacross  
Water Treatment Plant



DEMANDS ON OUR LAND

# Nations Unies

## Conférence sur les Changements Climatiques 2015

COP21/CMP11

### Paris France

We need to sequester carbon

PRESIDENT

SECRETAIRE

# DEMANDS ON OUR LAND

Protect the home of  
biodiversity



# DEMANDS ON OUR LAND

We need to find a home for our waste...



# WHAT CAN OUR LAND SUPPLY?

All soils / land perform all functions...

...but different parts of the land(scape) are better at delivering different functions



ENVIRONMENTAL SCIENCE & POLICY 38 (2014) 4  
Available online at [www.sciencedirect.com](http://www.sciencedirect.com)  
**ScienceDirect**  
journal homepage: [www.elsevier.com/locate/ees](http://www.elsevier.com/locate/ees)



## Functional land management: A framework for managing soil-based ecosystem services for the sustainable intensification of agriculture<sup>☆</sup>

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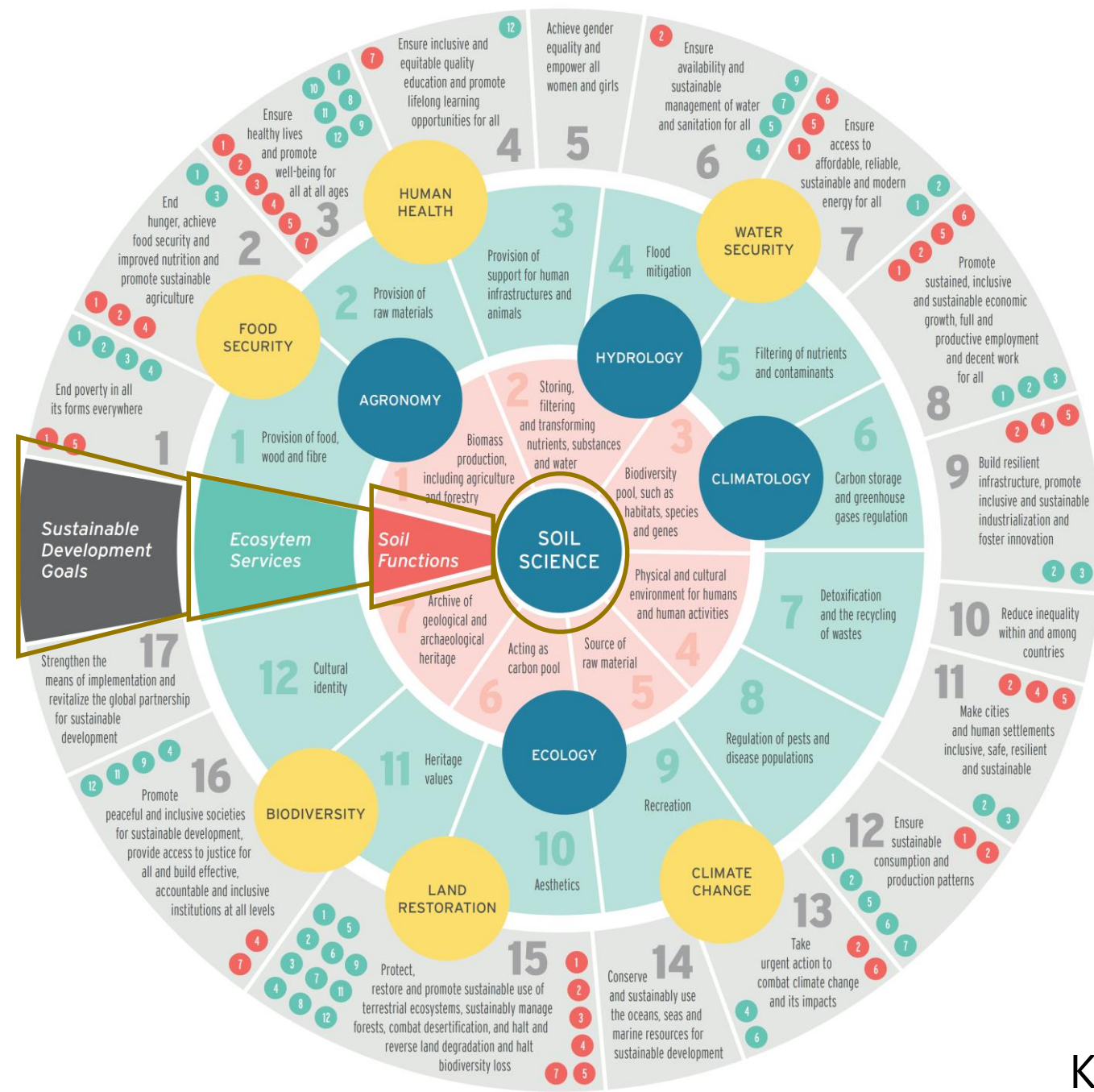
<sup>d</sup>Teagasc – Spatial Analysis Unit, Ashtown, Ireland





# WHAT CAN OUR LAND SUPPLY?





# PRIMARY PRODUCTIVITY

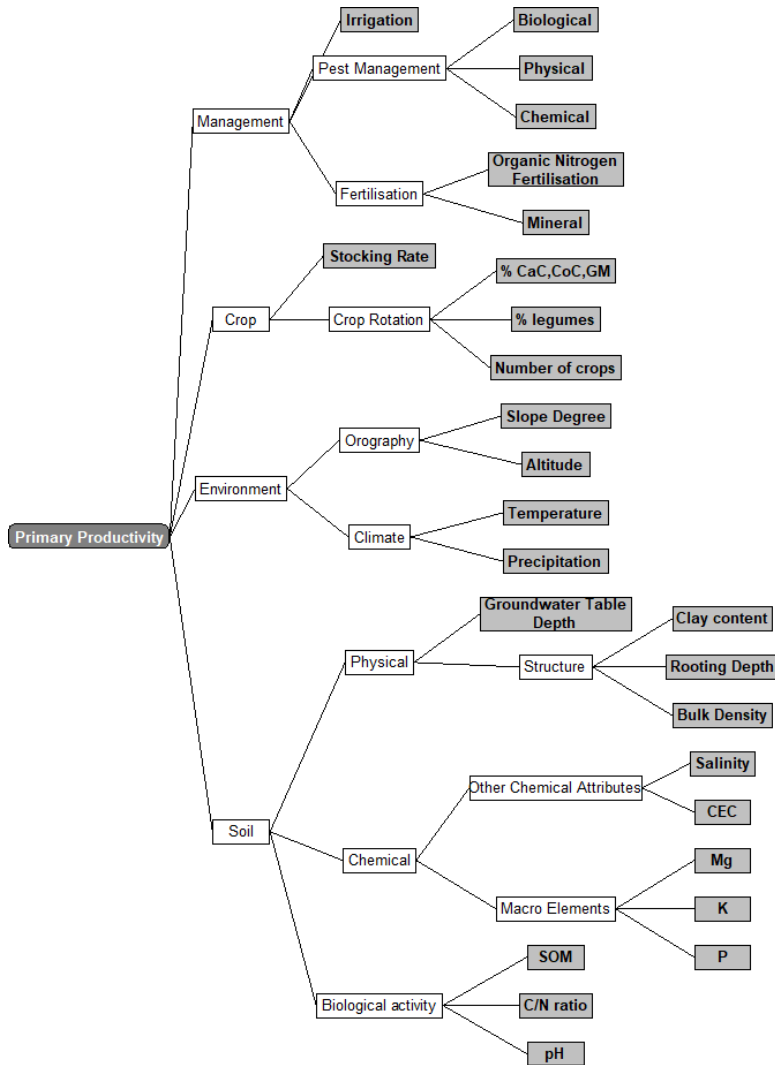
## Definition



- The capacity of a soil to produce plant biomass for human use, providing food, feed, fiber and fuel within natural or managed ecosystem boundaries

# PRIMARY PRODUCTIVITY

## Decision modelling

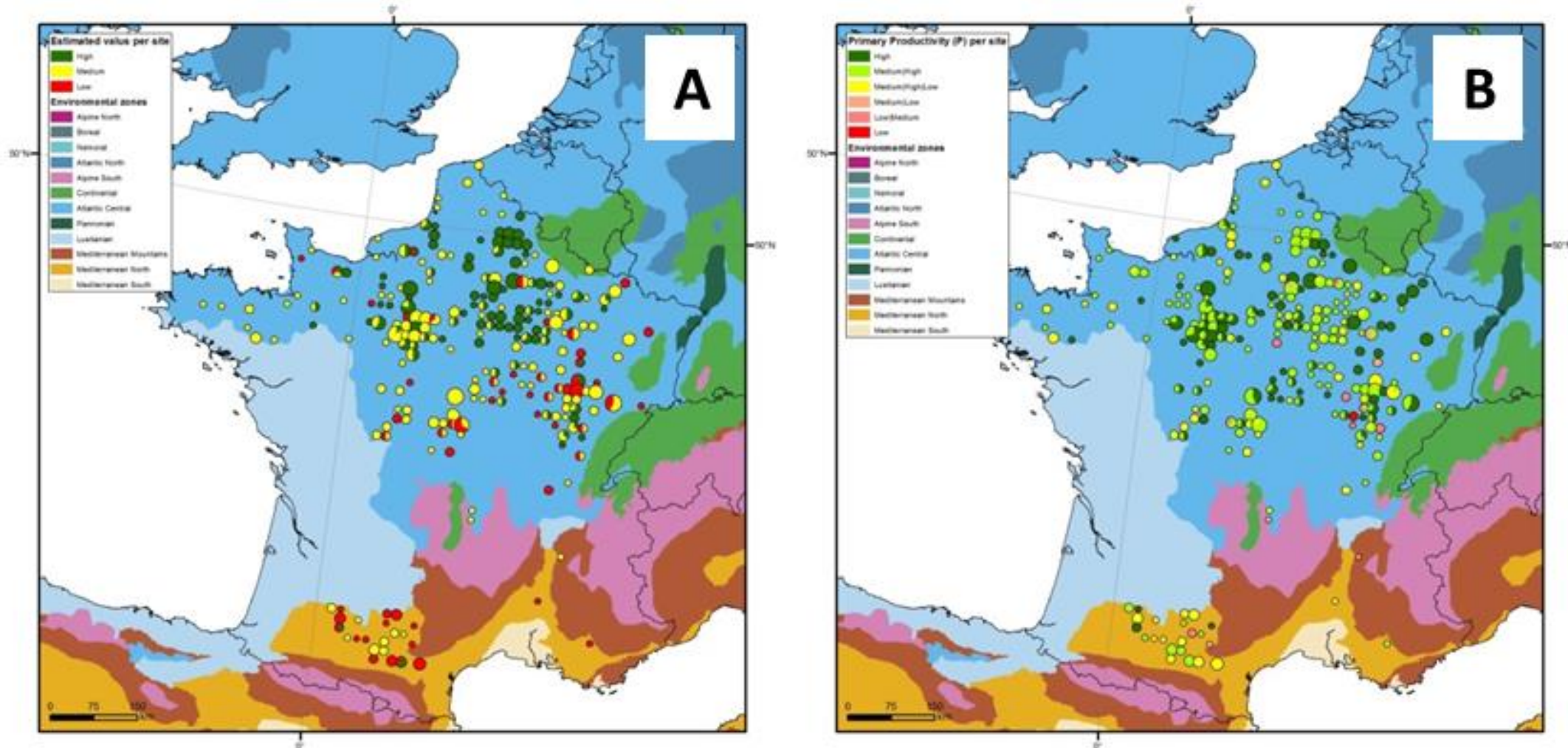


Attribute	Glob.norm.
Primary Productivity	22
Soil	22
Biological activity	7
pH	3
C/N ratio	1
SOM	2
Chemical	7
Macro Elements	3
P	2
K	1
Mg	1
Other Chemical Attributes	4
CEC	1
Salinity	3
Physical	8
Structure	4
Bulk Density	2
Rooting Depth	1
Clay content	1
Groundwater Table Depth	4
Environment	30
Climate	15
Precipitation	10
Temperature	5
Orography	15
Altitude	6
Slope Degree	9
Crop	20
Crop Rotation	15
Number of crops	6
% legumes	5
% CaC, CoC, GM	4
Stocking Rate	5
Management	28
Fertilisation	12
Mineral	6
Organic Nitrogen Fertilisation	6
Pest Management	6
Chemical	2
Physical	2
Biological	2
Irrigation	10

Sandén et al., 2019  
*Frontiers in Environmental Science*

# COMPARING MODEL WITH EXPERT JUDGEMENT

A case study of nearly 400 sites in France



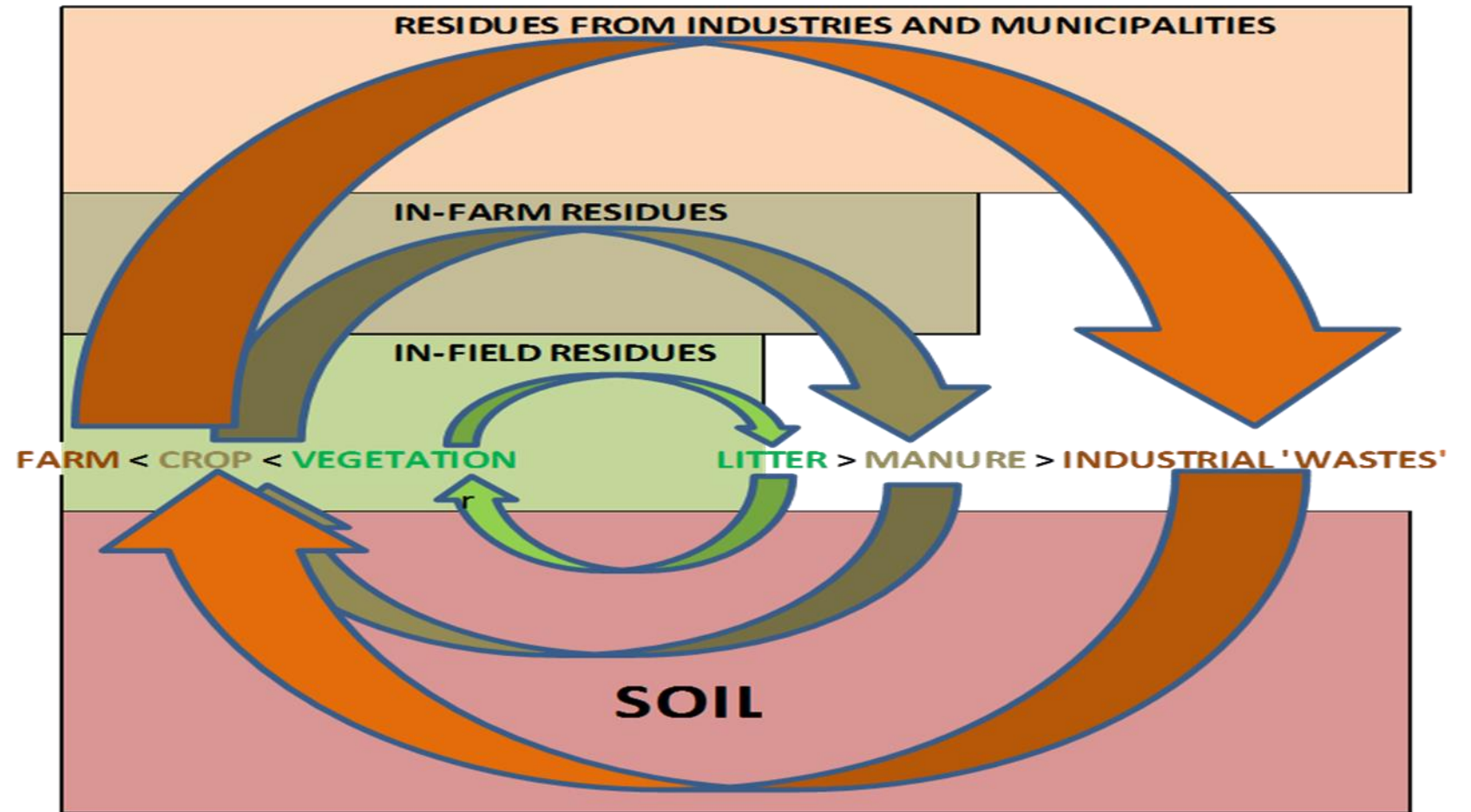
# NUTRIENT CYCLING

## Definition



- The capacity of a soil to receive plant nutrients in the form of by-products, to provide nutrients from intrinsic resources or to support the acquisition of nutrients from air or water, and to effectively carry over these nutrients into harvested crops.

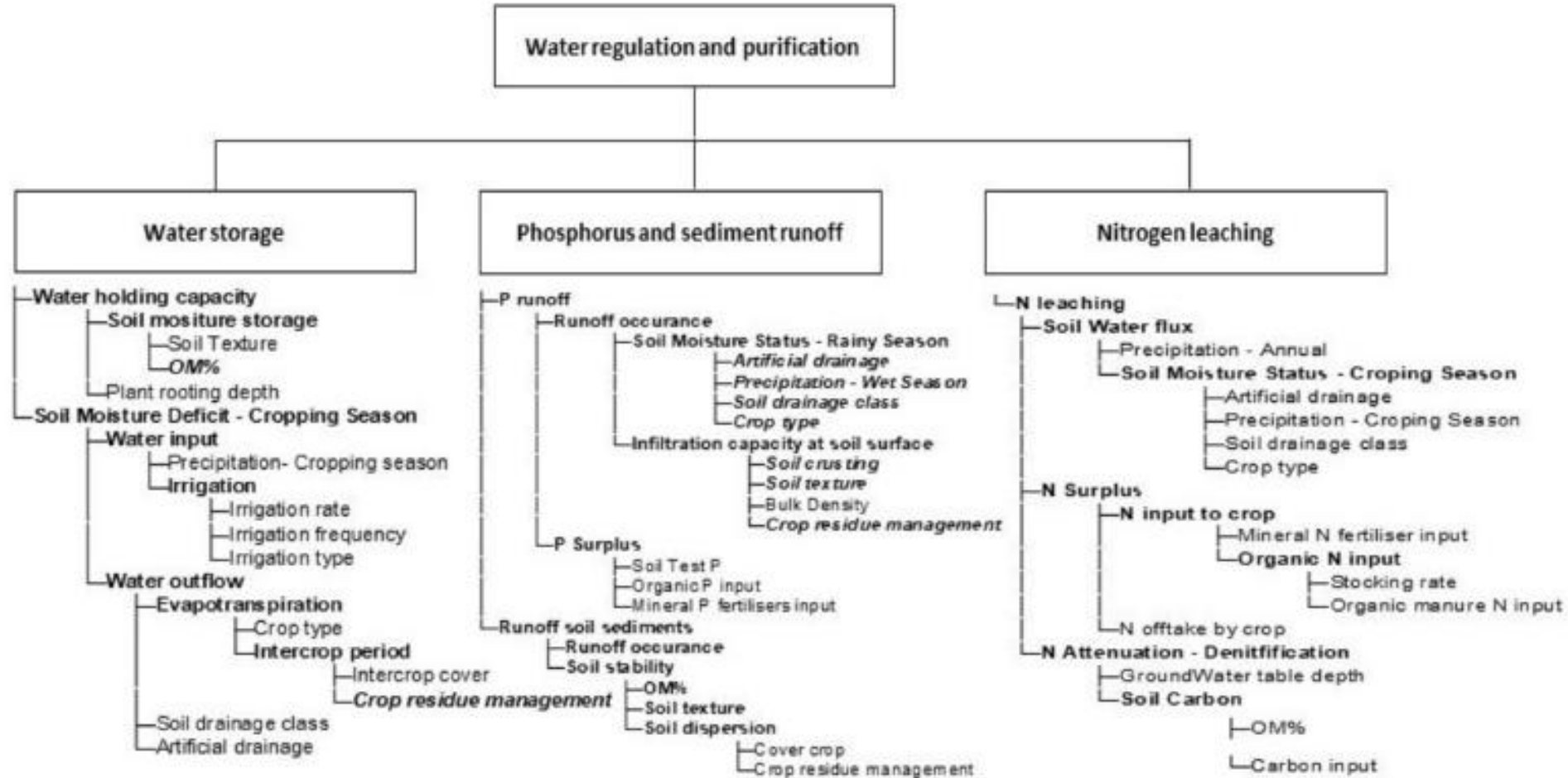
# NUTRIENT CYCLING



- The capacity of the soil to remove harmful compounds and the capacity of the soil to receive, store and conduct water for subsequent use and to prevent droughts, flooding and erosion.



# WATER REGULATION & PURIFICATION



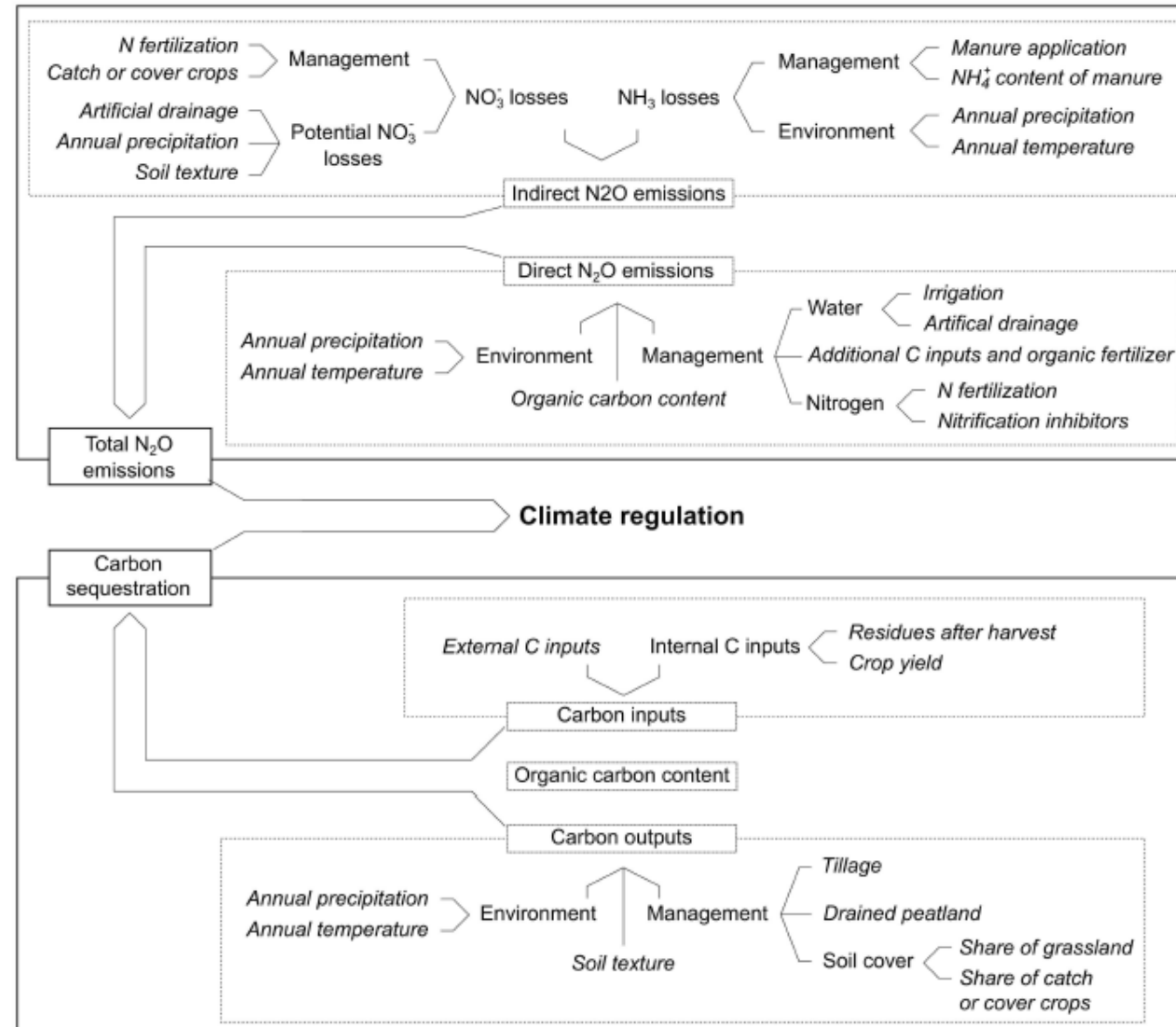
# CLIMATE REGULATION

## Definition



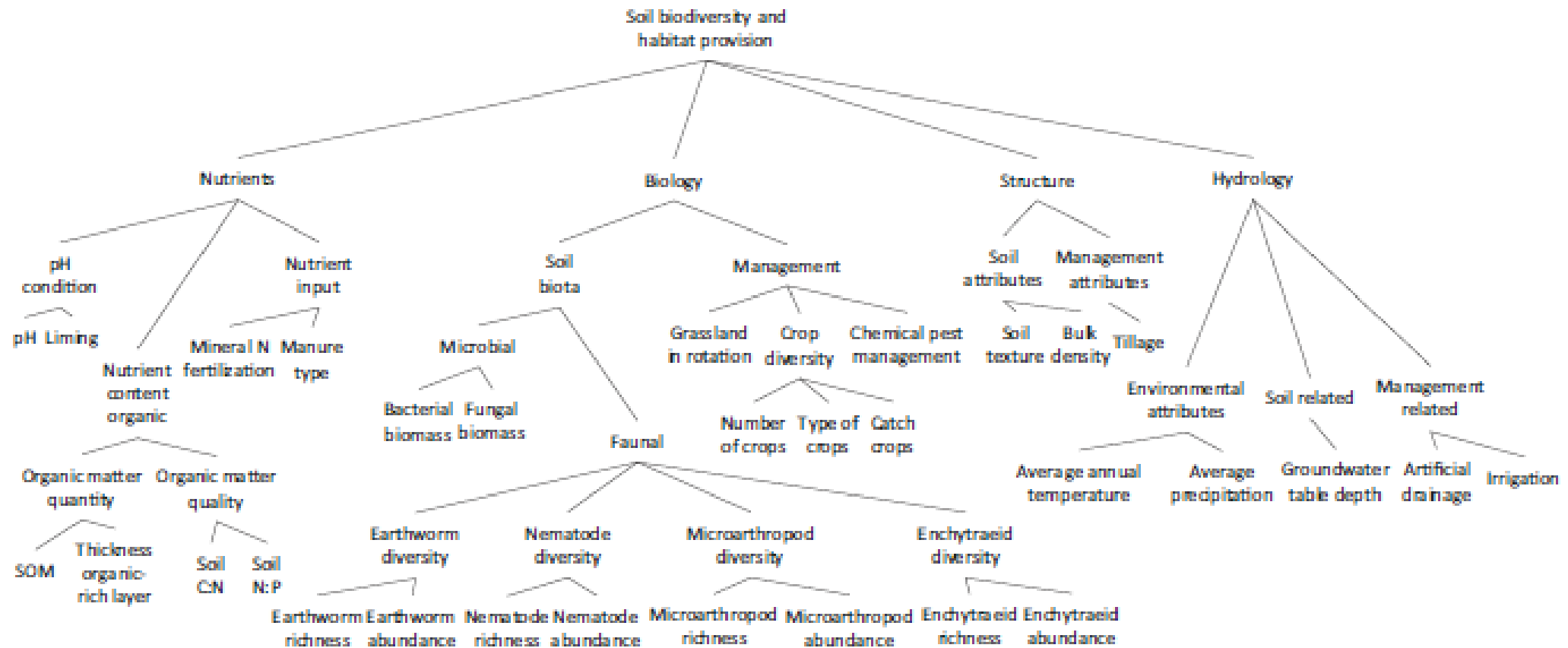
- The capacity of a soil to reduce the negative impact of increased greenhouse gas emissions on climate, among which its capacity to store carbon (C) and to minimize N<sub>2</sub>O emissions.

# CLIMATE REGULATION



- The multitude of soil organisms and processes, interacting in an ecosystem, providing society with a rich biodiversity source and contributing to a habitat for aboveground organisms.

# BIODIVERSITY & HABITAT PROVISIONING



**Water regulation and purification**



**Climate regulation**



**Biodiversity**



**Primary productivity**



**Nutrient cycling**



LOW  
MEDIUM  
HIGH

# SOIL NAVIGATOR

[www.soilnavigator.eu](http://www.soilnavigator.eu)



## SOIL NAVIGATOR

Home

Decision support system

Soil functions

Team

Publications

Tutorials

RUN



### EASY TO USE

A purposely designed interactive interface was created to grant users smooth access to what is a complex evidence based DSS.



### LONG-TERM OVERVIEW

Simultaneously assessing and improving five soil functions, simplifying the decision making process for long-term sustainability.

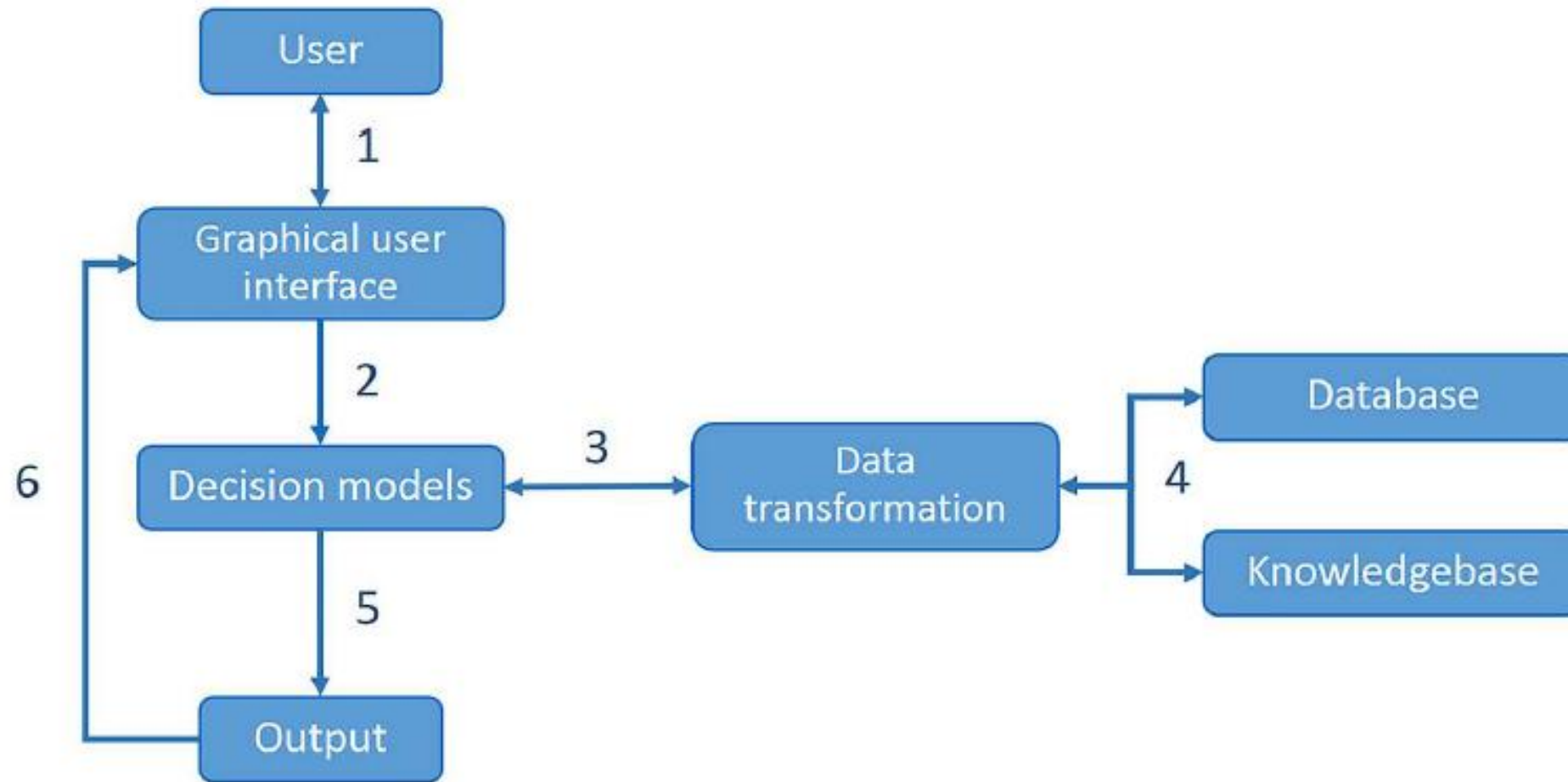


### VALUABLE OUTPUT

Evaluating the resulting supply of soil functions based on user preferences for the suggested management recommendations.

# SOIL NAVIGATOR

Performance of soil functions and how to manage them





# SOIL NAVIGATOR

## Structural properties of the DEX models of the soil functions



What user needs to enter into the Soil Navigator

Soil function models	Total number of attributes	Number of aggregated attributes	Number of input attributes	Number of hierarchical levels	Number of integration rules
Primary productivity	42	16	25	4	294
Nutrient cycling	51	27	24	5	302
Climate regulation	540	21	19	5	301
Water regulation and purification	116	77	39	6	800
Biodiversity and habitat	55	24	31	5	612

Carbon sequestration	N <sub>2</sub> O emissions	Climate regulation
Low	High	Low
Low	Medium	Low
Low	Low	Medium
Medium	High	Low
Medium	Medium	Medium
Medium	Low	High
High	High	Medium
High	Medium	High
High	Low	High

Debeljak et al., 2019 *Frontiers in Environmental Science*  
 Van de Broek et al., 2019 *Frontiers in Environmental Science*

# SOIL NAVIGATOR

## Data entry



Soil Navigator

Scenario Germanydbog

**INPUT DATA**

SOIL

Soil physical properties +

Soil chemical properties and stoichiometry -

Soil pH  <4.5 pH-CaCl2     4.5-5.5 pH-CaCl2     5.5-6.0 pH-CaCl2  
 6.0-6.5 pH-CaCl2     6.5-7.5 pH-CaCl2     >7.5 pH-CaCl2

Cation exchange capacity  <10 cmol IE/kg     10-30 cmol IE/kg     >30 cmol IE/kg

Soil C:N ratio  <8     8-10     10-12  
 12-30     >30

Soil N:P ratio  <10     10-20     >20

Plant available P (Olsen P)  <10 mg/kg     10-30 mg/kg     30-50 mg/kg  
 50-70 mg/kg     70-100 mg/kg     >100 mg/kg

Plant available K  <80 mg/kg     80-160 mg/kg     >160 mg/kg

Plant available Mg  <50 mg/kg     50-100 mg/kg     >100 mg/kg

Salinity  <2 ECe dS/m     2-8 ECe dS/m     >8 ECe dS/m

Diagnostic soil horizons +

Soil biology +

Previous Next

Agroecosystem

Environment

Soil

Management

Input form

Dropdown

Radio buttons

Input value

Discrete

Numeric

Save & Update

Save as New

Proceed

Save

Next

Previous

# SOIL NAVIGATOR

## Assessment



Home / Soil Navigator

Soil Navigator

Scenario Germany4bog

### INITIAL ASSESSMENT & IMPORTANCE

An evaluation of the current status for the five soil functions: Primary Productivity, Nutrient Cycling, Habitat provision, Water Regulation and Climate Regulation is shown on the graphic to the right. Please specify your future demands by sliding the bars below to indicate your desired performance and priority for each of these five soil functions. Afterwards, please press "Optimize" to see the results. If needed to save the current preferences only, press "Save" button.

Soil Function	Current Status
Primary productivity	High
Water regulation	Good performance
Cycling of nutrients	Low
Climate regulation	Medium
Provision of biodiversity	Fair performance

Low Medium High

**Performance**

Very high  
High  
Medium  
Low  
Very low

Primary productivity

**Performance**

Very high  
High  
Medium  
Low  
Very low

Water regulation

**Performance**

Very high  
High  
Medium  
Low  
Very low

Cycling of nutrients

**Performance**

Very high  
High  
Medium  
Low  
Very low

Climate regulation

**Performance**

Very high  
High  
Medium  
Low  
Very low

Provision of biodiversity

Details +

Optimize  
Save  
Back

# SOIL NAVIGATOR

## Suggestions



Home / Soil Navigator

Soil Navigator

Scenario: Germany4bog

### EVALUATION REPORT

Following attributes need to be improved

**Share of legumes**  
identified in 1 soil function(s)

Attribute	Performance Level
Primary productivity	High
Water regulation	Good performance
Cycling of nutrients	Medium
Climate regulation	Medium
Provision of biodiversity	Poor performance

Strategy for improvement

Search indicators

**SHARE OF LEGUMES** ↑↑

Share of legumes requires drastic change (improve)  
Current value: Low

**Drastic change** improve

Details +

Back Re-evaluate

Re-evaluate  
Done  
Reset preferences  
Back

# YOUR TURN!

[www.soilnavigator.eu](http://www.soilnavigator.eu) – Archive – Taru\_test\_2023



- Lets divide into six groups
- Open the case, and save as new with a modified name



# YOUR TURN!

[www.soilnavigator.eu](http://www.soilnavigator.eu) – Archive – Taru\_test\_2023



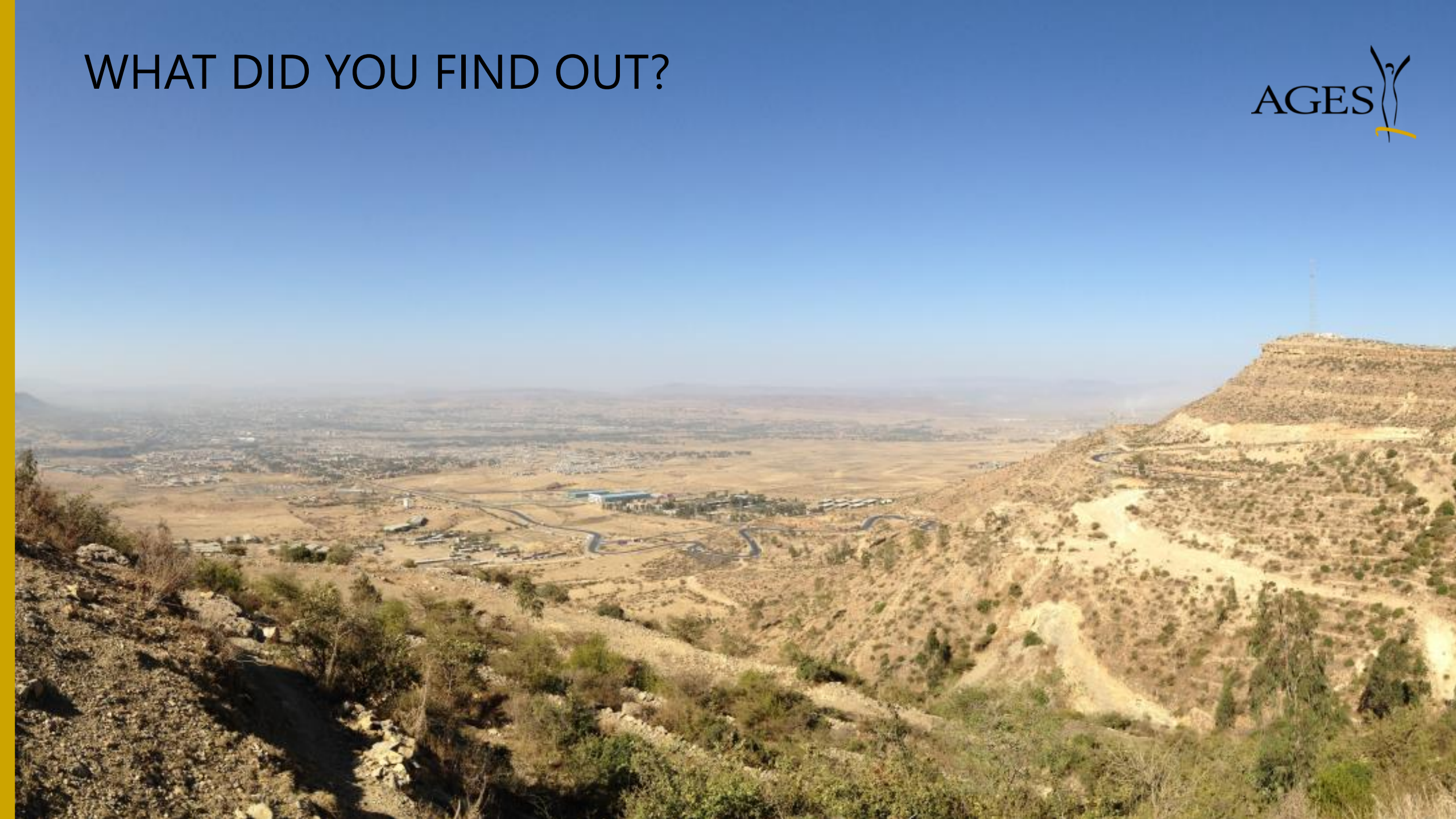
1. You are in a Danish cropland, with a role of being:
  - Farmers (group 1)
  - Policy makers (group 2)
  - Researchers (group 3)
  - Urban planners (group 4)
  - Citizens (group 5)
  - Mayors of municipalities (group 6)
2. Get your first soil functions assessment
3. Try to get four soil functions to medium and PP to high
4. Try to get all soil functions to high
5. Try to get 3/5 soil functions to high
6. Summarise your findings and prepare a short presentation

# GROUP PRESENTATIONS



- What kind of recommendations did you get?
- Was optimisation of all soil functions to high possible? If yes, why? If not, why?
- Which soil functions did you get to high (3/5)? Why these?
- What do the results mean in your role?
- How would you integrate soil functions assessments into your role?
- What would be required for you to include soil functions assessment into your daily work?
- What would you improve in the soil functions assessment?

WHAT DID YOU FIND OUT?





# LANDMARK SOIL SAMPLING - 2018

94 sites, 13 countries, 2 land uses and 5 environmental zones



Climatic zone	Number of grassland sites	Number of arable sites	Number of sites with calcic diagnostic	Number of sites with argic diagnostic
Alpine south	7	6	7	6
Atlantic	10	10	10	10
Continental	9	11	10	10
Mediterranean north	8	11	6	12
Pannonian	12	10	12	10

**Soil samples:** 0-25cm and 25-50cm, for biological analyses 0-15cm

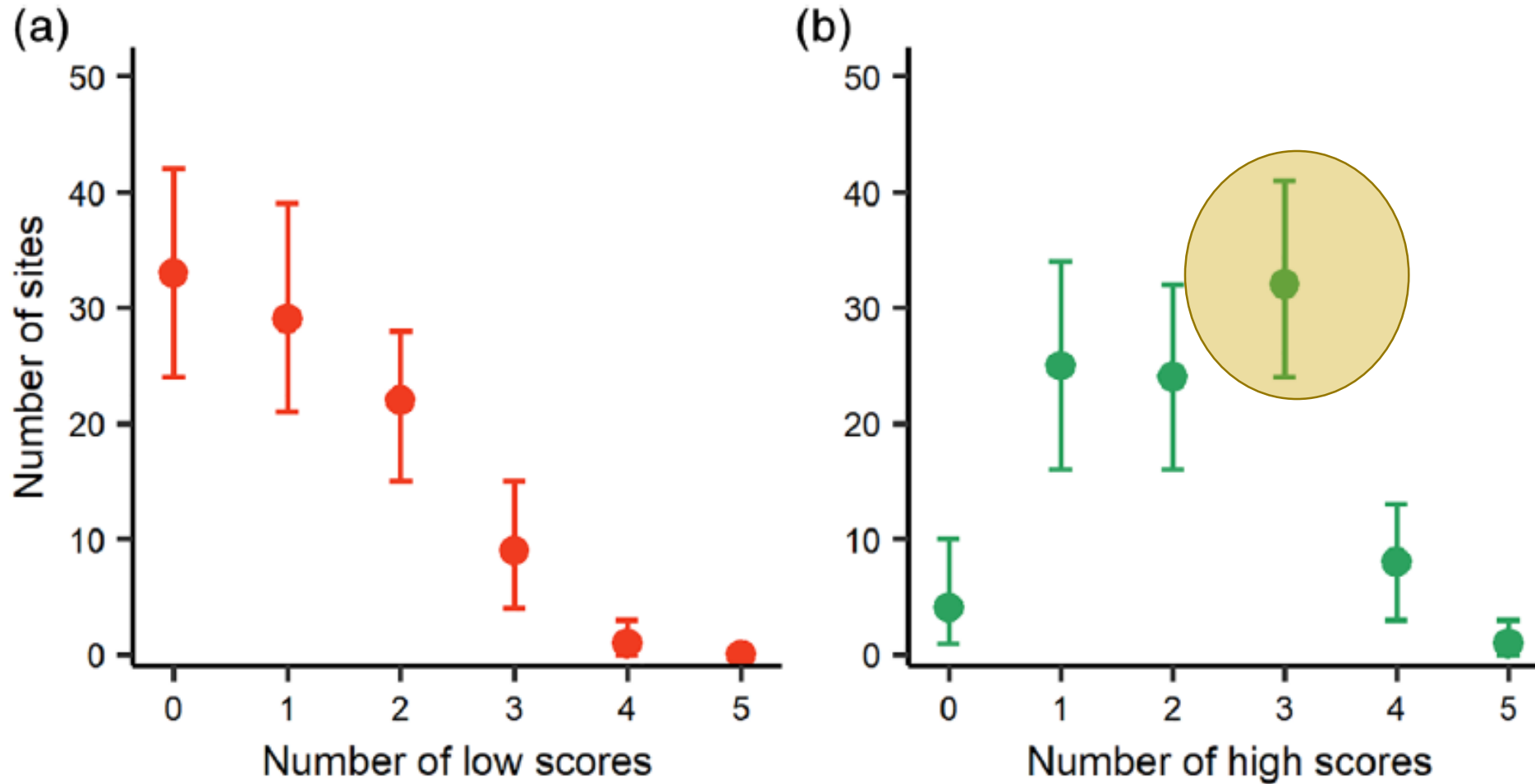
**Soil analyses:** soil texture, bulk density, soil moisture, pH, CEC, total and organic C&N, Mehlich-3 phosphorous, earthworm abundance, earthworm richness, nematode abundance, nematode richness, soil drainage class

**Management practices:** fertilisers, crops, livestock, irrigation, artificial drainage, liming, pest and disease control

**Climate data:** provided by Agri4Cast team of JRC, daily meteorological data interpolated on a 25 \* 25 km grid

# 3/5 SOIL FUNCTIONS HIGH IN 30% OF SITES

Results of 92 European croplands and grasslands



# RELATIONSHIPS BETWEEN SOIL FUNCTIONS

## Local constraints and trade-offs



Land use	Climatic zone	Soil functions		$r_s$	$p$ -value
Grassland	Mediterranean north	PP	WR	-0.77	.02
Grassland	Mediterranean north	WR	BD	-0.75	.03
Grassland	Pannonian	NC	CR	0.61	.04
Grassland	Pannonian	CR	BD	0.69	.01
Arable	Alpine south	NC	WR	1.00	<.001
Arable	Atlantic	CR	BD	-0.72	.02
Arable	Continental	PP	CR	-0.72	.01
Arable	Continental	WR	CR	0.81	<.001
Arable	Pannonian	CR	BD	0.69	.03

# TAKE HOME MESSAGES



- Evaluating and monitoring multifunctionality is important for identifying and avoiding potential trade-offs
  - Importance of quality criteria for assessments (ÖNORM, ISO, etc.)
- Transition towards stimulating the delivery of other soil functions than primary production may benefit society more than the farmers in the short term
  - Importance of considering trade-offs with primary productivity that is the economic foundation for farmers and associated sectors in rural areas
  - Importance of inclusion of farmers' and stakeholders' knowledge, needs and willingness in the transition
- Soil organic matter plays a crucial role for soil functions
  - E.g. soil biodiversity and climate regulation both benefit from it

THANK YOU FOR YOUR ATTENTION!



# REFERENCES



- Debeljak, M., Trajanov, A., Kuzmanovski, V., Schröder, J., Sandén, T., Spiegel, H., . . . Henriksen, C. B. (2019). A Field-Scale Decision Support System for Assessment and Management of Soil Functions. *Frontiers in Environmental Science*, 7(115). doi:10.3389/fenvs.2019.00115
- Keesstra, S. D., Bouma, J., Wallinga, J., Tittonell, P., Smith, P., Cerdà, A., . . . Fresco, L. O. (2016). The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals. *SOIL*, 2(2), 111-128. doi:10.5194/soil-2-111-2016
- Sandén, T., Trajanov, A., Spiegel, H., Kuzmanovski, V., Saby, N. P. A., Picaud, C., . . . Debeljak, M. (2019). Development of an Agricultural Primary Productivity Decision Support Model: A Case Study in France. *Frontiers in Environmental Science*, 7(58). doi:10.3389/fenvs.2019.00058
- Schröder, J. J., Schulte, R. P. O., Creamer, R. E., Delgado, A., van Leeuwen, J., Lehtinen, T., . . . Wall, D. P. (2016). The elusive role of soil quality in nutrient cycling: a review. *Soil Use and Management*, 32(4), 476-486. doi:10.1111/sum.12288
- Schulte, R. P. O., Creamer, R. E., Donnellan, T., Farrelly, N., Fealy, R., O'Donoghue, C., & O'hUallachain, D. (2014). Functional land management: A framework for managing soil-based ecosystem services for the sustainable intensification of agriculture. *Environmental Science & Policy*, 38(0), 45-58. doi:http://dx.doi.org/10.1016/j.envsci.2013.10.002
- Van de Broek, M., Henriksen, C. B., Ghaley, B. B., Lugato, E., Kuzmanovski, V., Trajanov, A., . . . Six, J. (2019). Assessing the Climate Regulation Potential of Agricultural Soils Using a Decision Support Tool Adapted to Stakeholders' Needs and Possibilities. *Frontiers in Environmental Science*, 7(131). doi:10.3389/fenvs.2019.00131
- van Leeuwen, J. P., Creamer, R. E., Cluzeau, D., Debeljak, M., Gatti, F., Henriksen, C. B., . . . Rutgers, M. (2019). Modeling of Soil Functions for Assessing Soil Quality: Soil Biodiversity and Habitat Provisioning. *Frontiers in Environmental Science*, 7(113). doi:10.3389/fenvs.2019.00113
- Wall, D. P., Delgado, A., O'Sullivan, L., Creamer, R. E., Trajanov, A., Kuzmanovski, V., . . . Debeljak, M. (2020). A Decision Support Model for Assessing the Water Regulation and Purification Potential of Agricultural Soils Across Europe. *Frontiers in Sustainable Food Systems*, 4(115). doi:10.3389/fsufs.2020.00115
- Zwetsloot, M. J., van Leeuwen, J., Hemerik, L., Martens, H., Simó Josa, I., Van de Broek, M., . . . Creamer, R. E. (2021). Soil multifunctionality: Synergies and trade-offs across European climatic zones and land uses. *European Journal of Soil Science*, 72(4), 1640-1654. doi:https://doi.org/10.1111/ejss.13051

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