“Soil futures - emerging drivers and needs of soil management and soil services”

Katharina Heming

EJP Soil Science Days 2024

EJP soil – biggest achievements from AB perspective

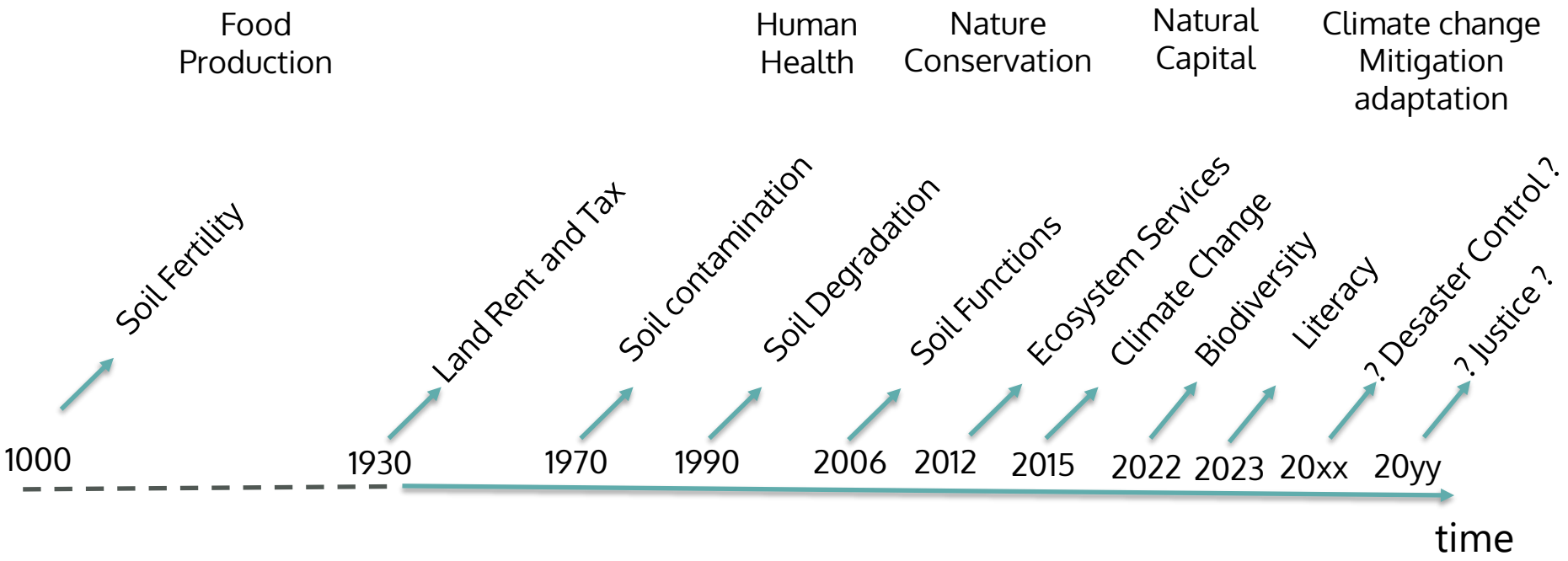
So much, and:

- Agricultural management – soil interaction
- Socio-economic perspectives; stakeholder involvement
- Ontology – common language – hamonisation of concepts and methods
- Data management – shared knowledge network
- Early career network
- Soil enthusiasm

…. and much more

Emerging discourses on soil systems

Why is soil perceived as relevant?



Soil in socio-economic system

External Conditions Drivers

Climate factors

Soil Management

Site Conditions

Soil as a natural ressource

Soil Functions

Services

Food / Fibre

Energy

Ecosystem Services

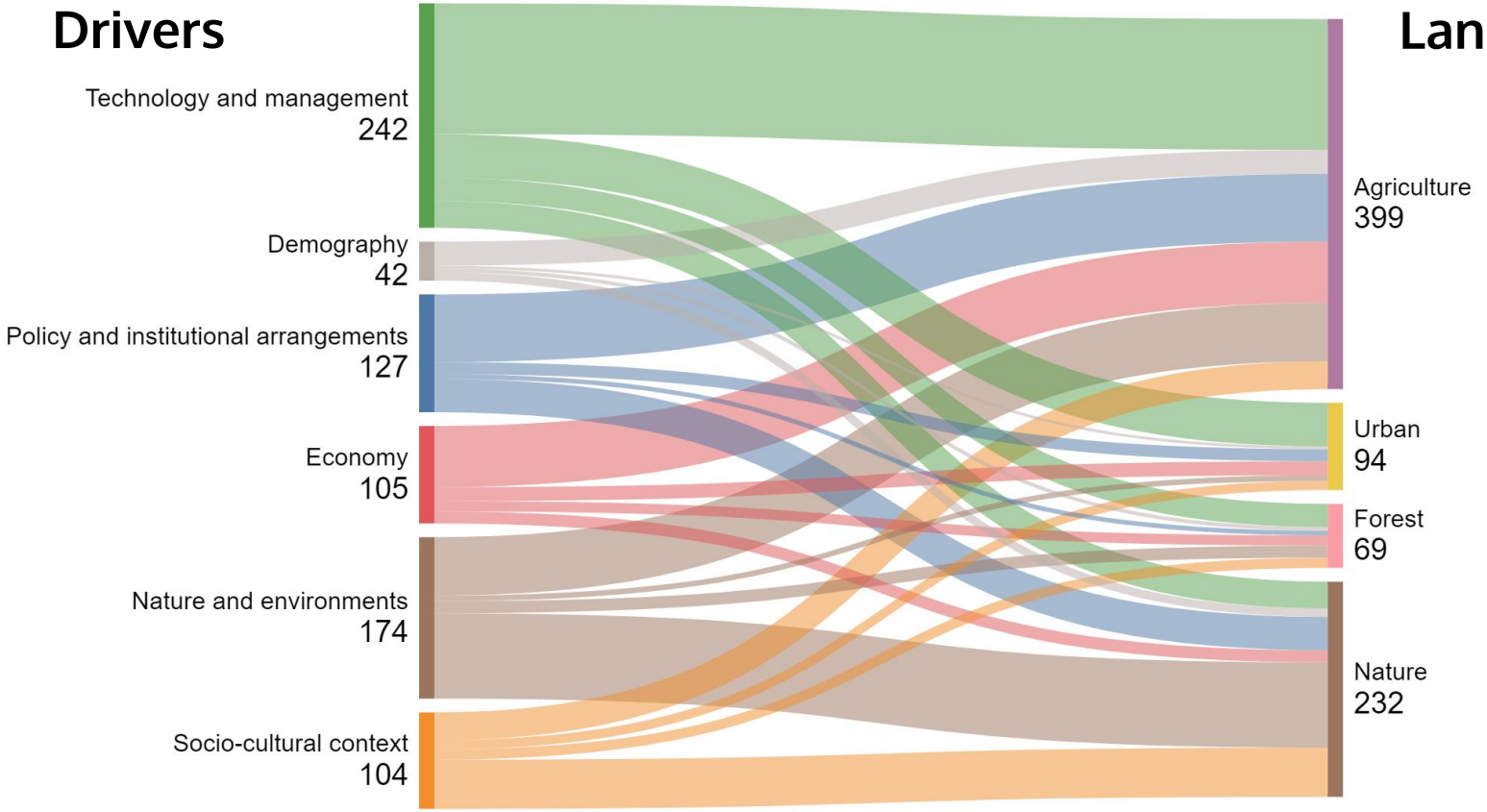
Climate Change Mitigation

Adaptation

Ressource Use Efficiency

Desaster Control

Europe:
external drivers for agricultural, urban, forest, nature land use



Soils for Europe

Chowdhury et al., SOLO D3.1, 2024

Agriculture: drivers of technologies and practices affecting soil health objectives

Soils for SOLO Europe

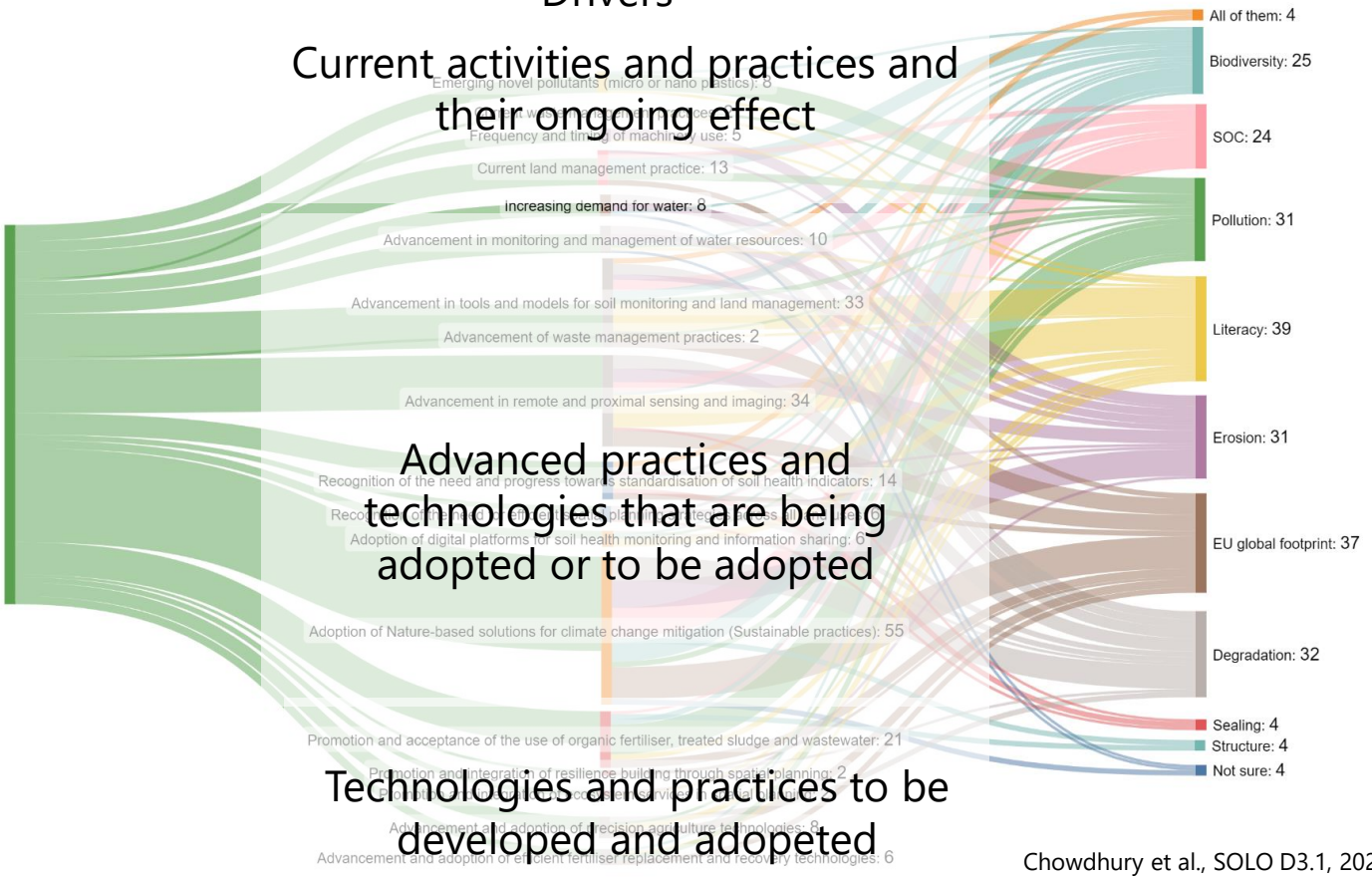
Drivers

Current activities and practices and their ongoing effect

Agriculture
141

Advanced practices and technologies that are being adopted or to be adopted

Technologies and practices to be developed and adopeted



Soil health objectives

Chowdhury et al., SOLO D3.1, 2024

Foresight

Barriers of today, opportunities for tomorrow?

Emerging drivers of soil management

Multiple Drivers

- Demand / Product prices
- Factor costs
- Policies
- Education and training
- Research and Development

Socio-economic

- Available agricultural land
- Soil degradation
- Climate change
- Natural resources (water, P)

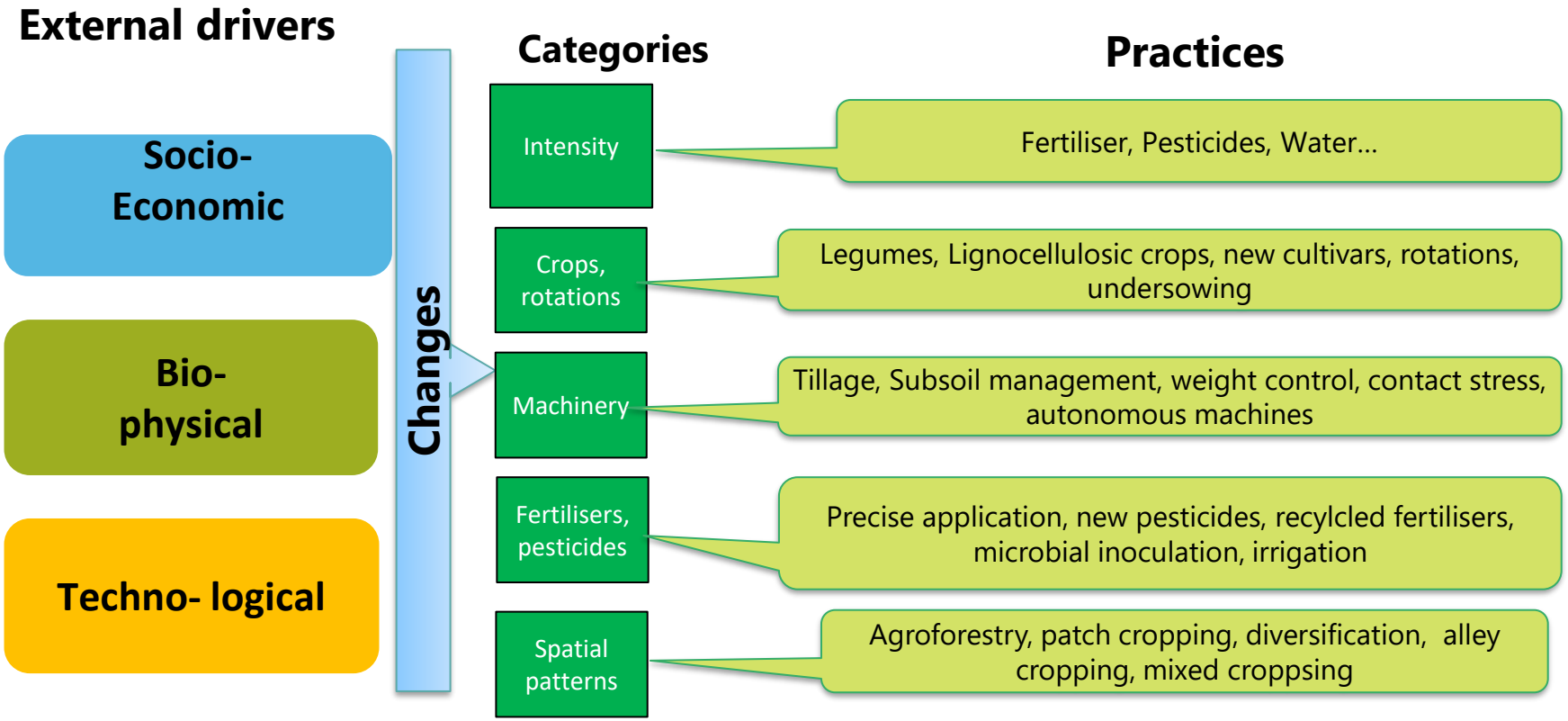
Biophysical

- Digitalization
- Data management
- Robotics
- Biomass technology

Techno-logical

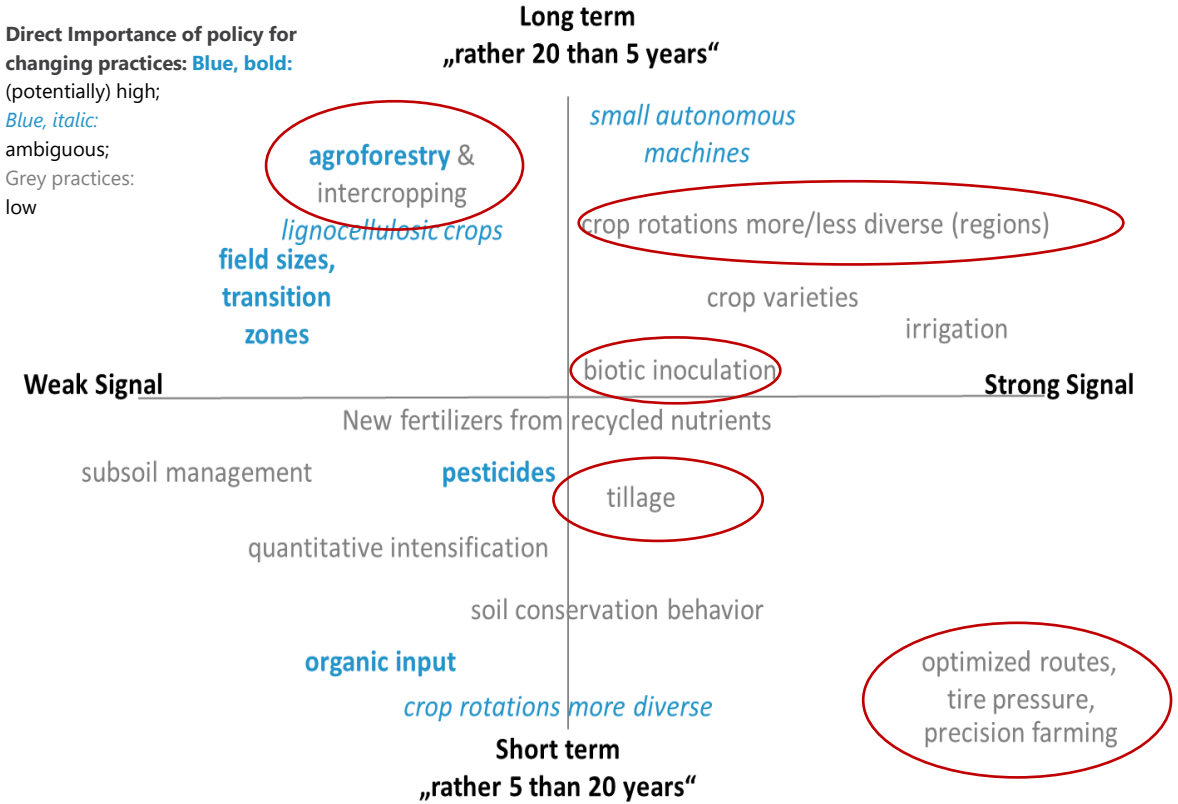
Techen & Helming 2017. Agronomy for Sustainable Development

Emerging drivers affecting agricultural practices



Techen & Helming 2017. Agronomy for Sustainable Development

Foresight on emerging soil management: signal strength and time frame



Techen & Helming 2019. BonaRes report

Trade-off of soil improving practices

Trade-offs

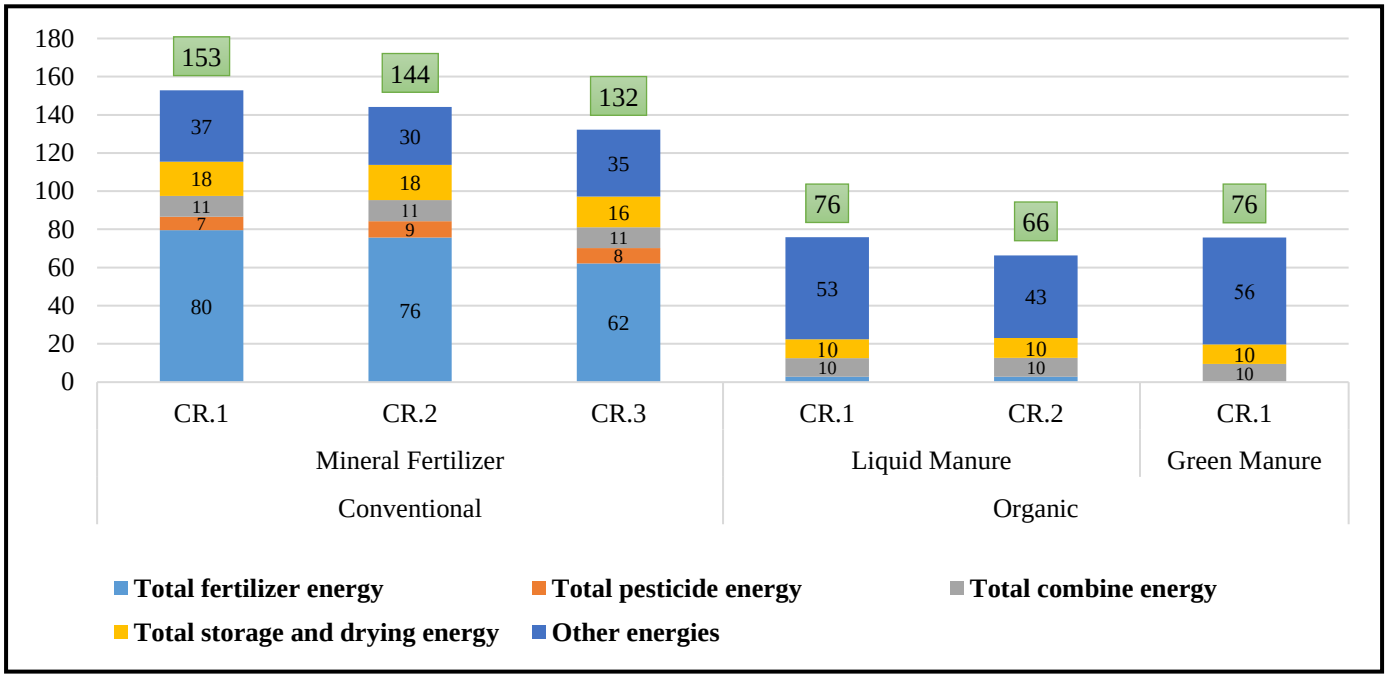
- Costs
- Systemic Changes

Landscape-elements	Organic Fertiliser	Crop Rotation	Soil-Cover	Reduced tillage	Wheel-pressure	Timing of Operations
						
Land competition	Arable Livestock Interaction	less Cash crops / Value Chains	Crop Rotation	Machines ::	Technology, Labour	Soil-Monitoring

Strauss et al., 2023. Agronomy for Sustainable Development

Energy consumption of different management practices

1000
MJ/ha



Rotation:
CR 1: wheat-barley
CR 2: wheat-barley-rape
CR 3: barley-wheat-rape-bean-wheat-rye

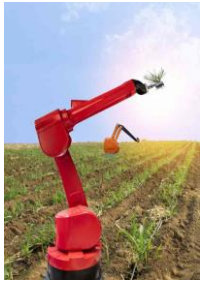
Aghabeygi et al., in review

Future Agriculture?
Uncertain, diverging visions

Agroecology

http://patrickwhitefield.co.uk/wp-content/uploads/2015/02/mulch-14-1024x682.jpg

High-tech large scale



https://www.techiexpert.com/wp-content/uploads/2019/09/IOT-in-Agriculture.jpg

https://www.thomasnet.com/insights/will-agricultural-ai-become-the-future-of-farming/

Busines as usual

K. Helming

Agroforestry

https://www.thuenen.de

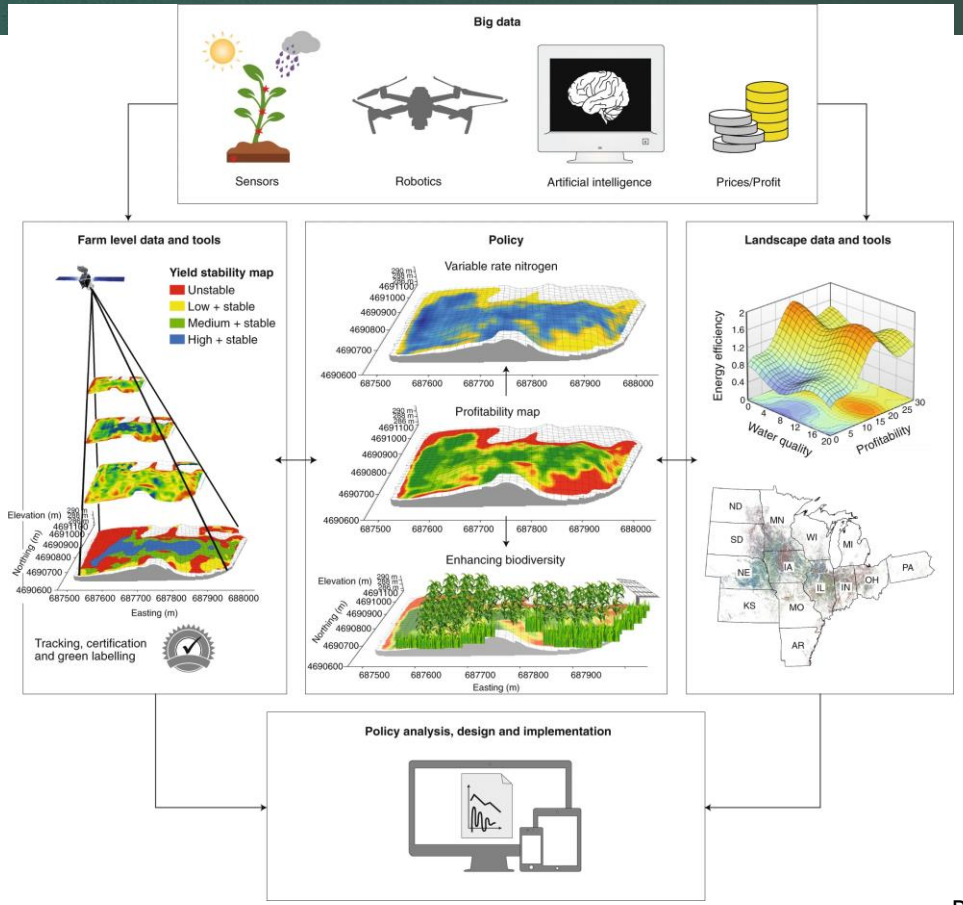
High Tech small scale

https://www.zalf.de

care farming

https://www.sustainweb.org/resources/images/food_growing/community_supported_agriculture.jpg

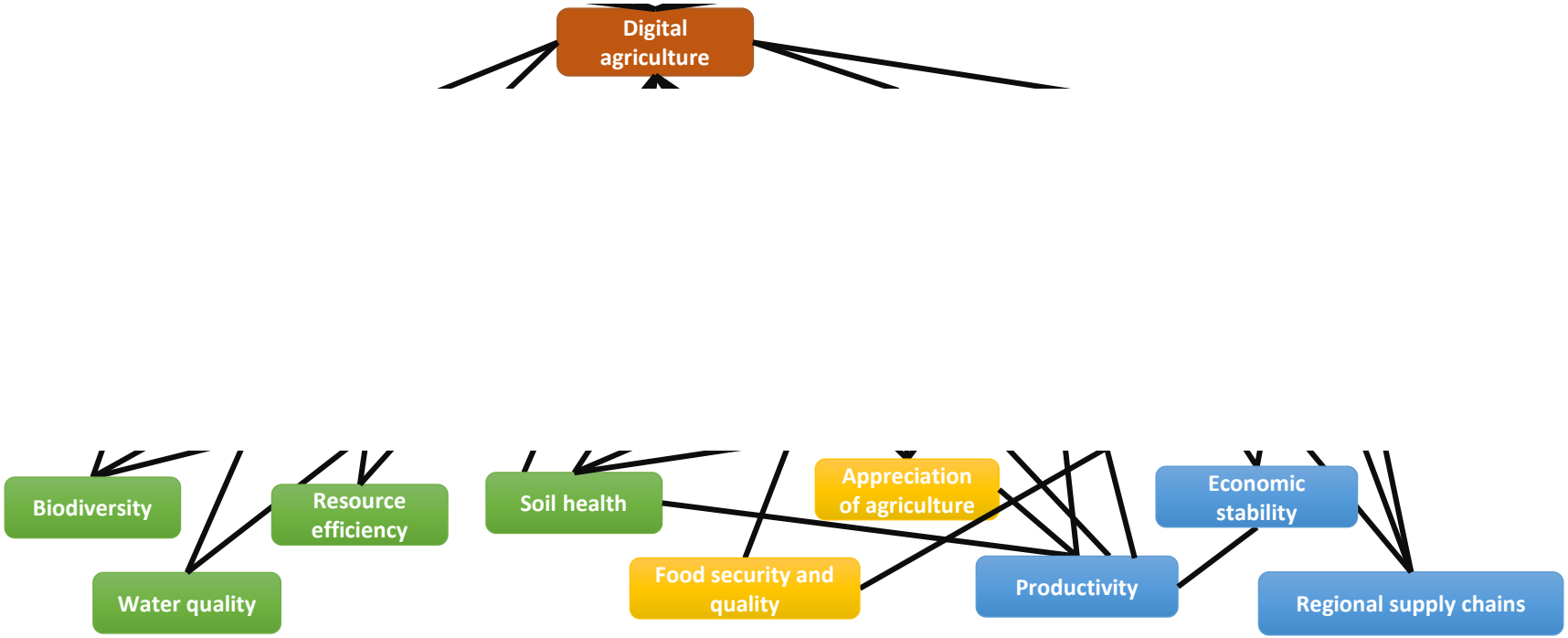
Digitalisation



1. Monitoring
2. Management
3. Communication

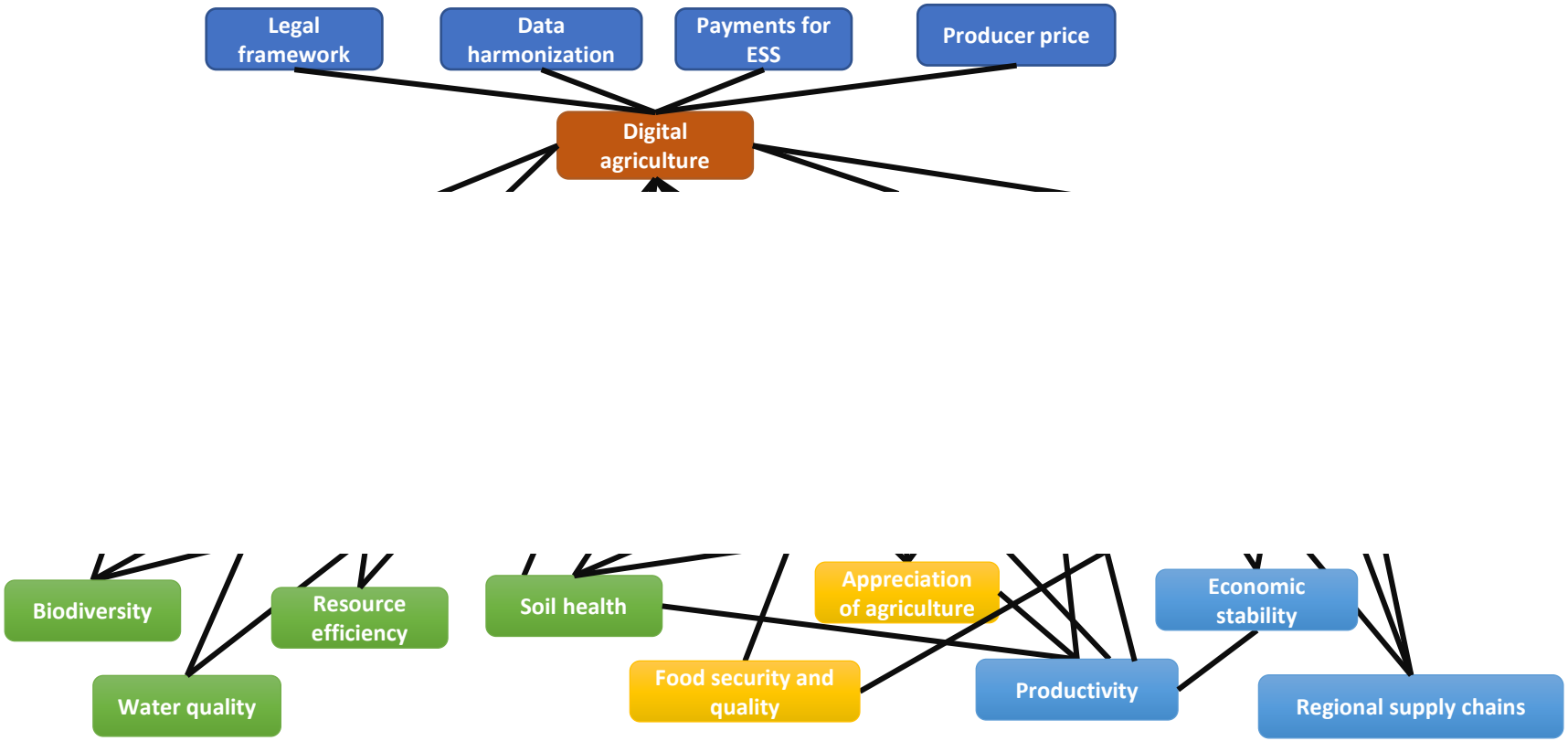
Basso & Antle, 2020. Nature Sustainability

Farmers perception of digitalised agriculture



MacPherson et al., in revision

Farmers perception of digitalised agriculture



MacPherson et al., in revision

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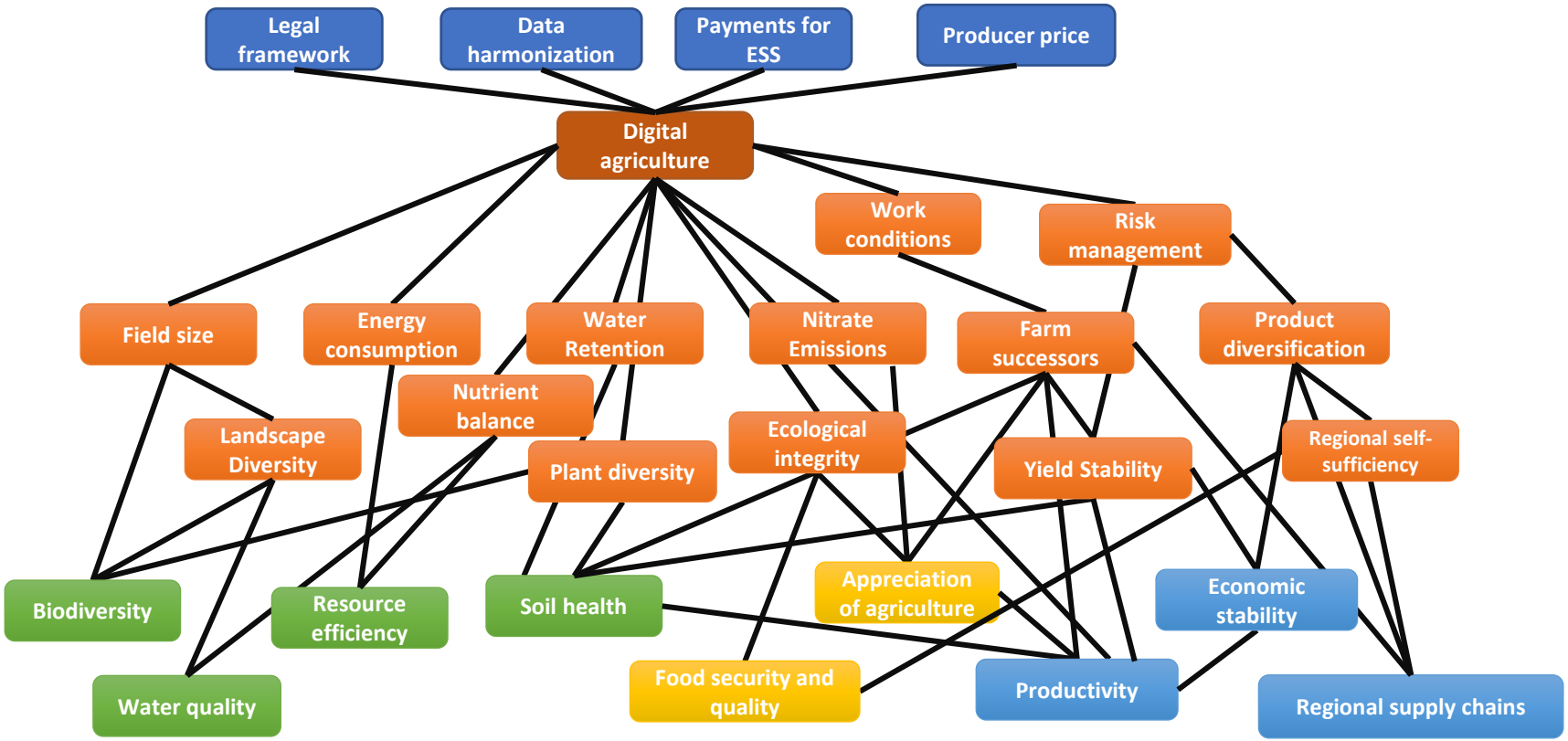
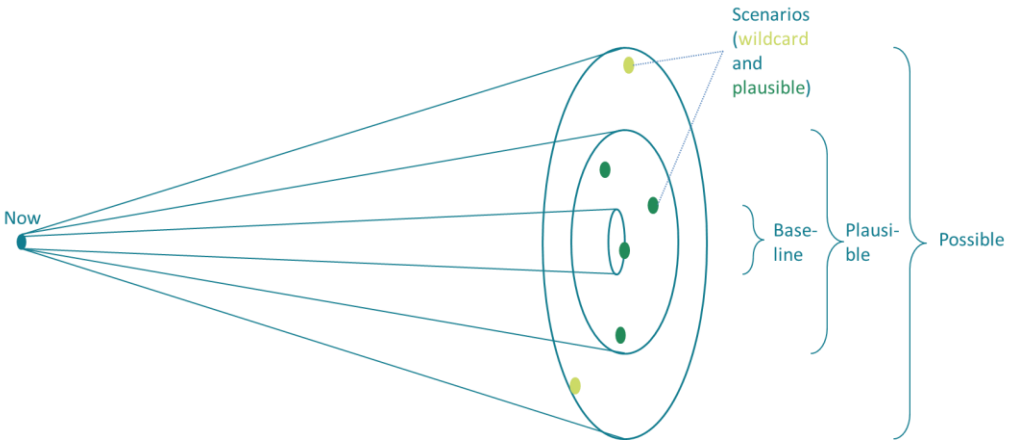


MacPherson et al., in revision

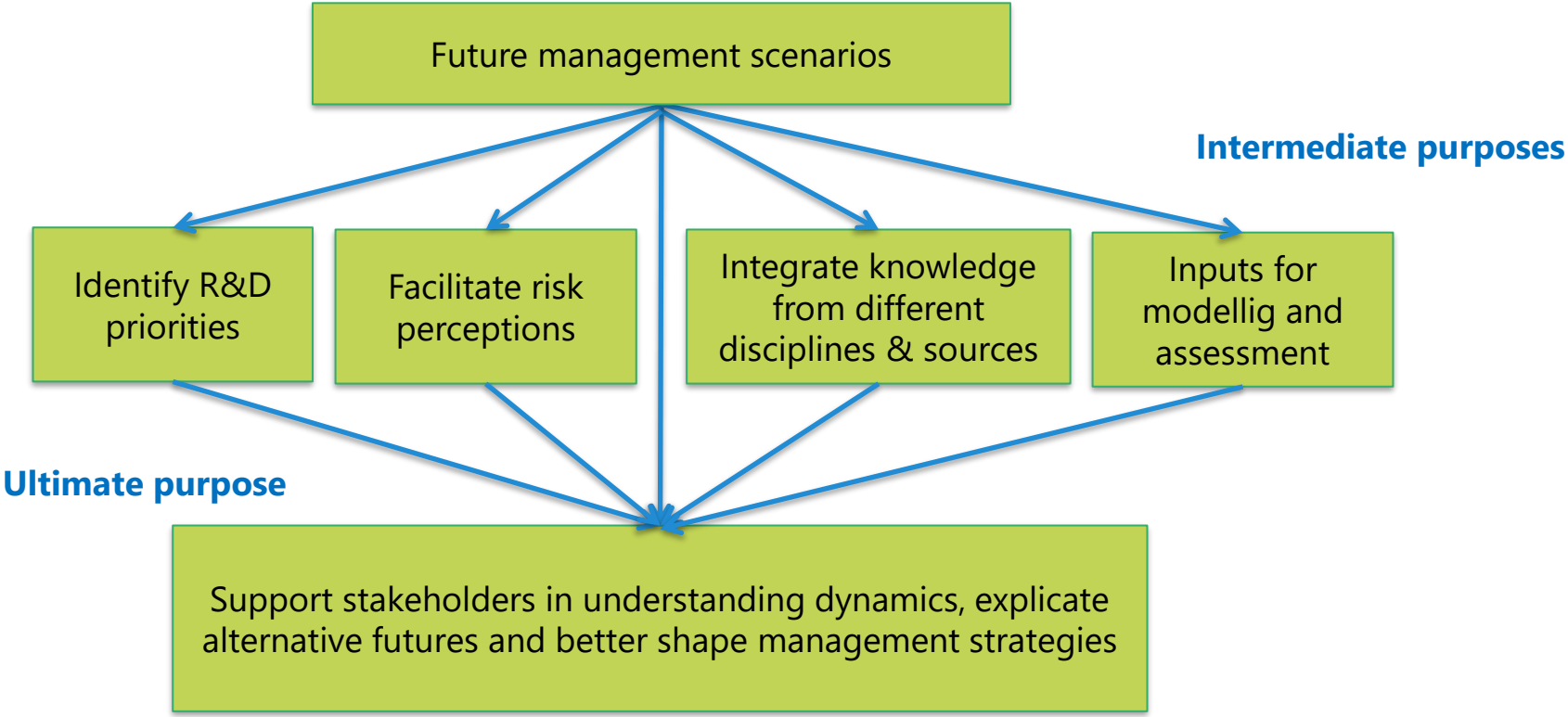
Scenarios

- Deal with uncertainties
- Future threats & challenges
- Windows of opportunity
- Solutions for tomorrow

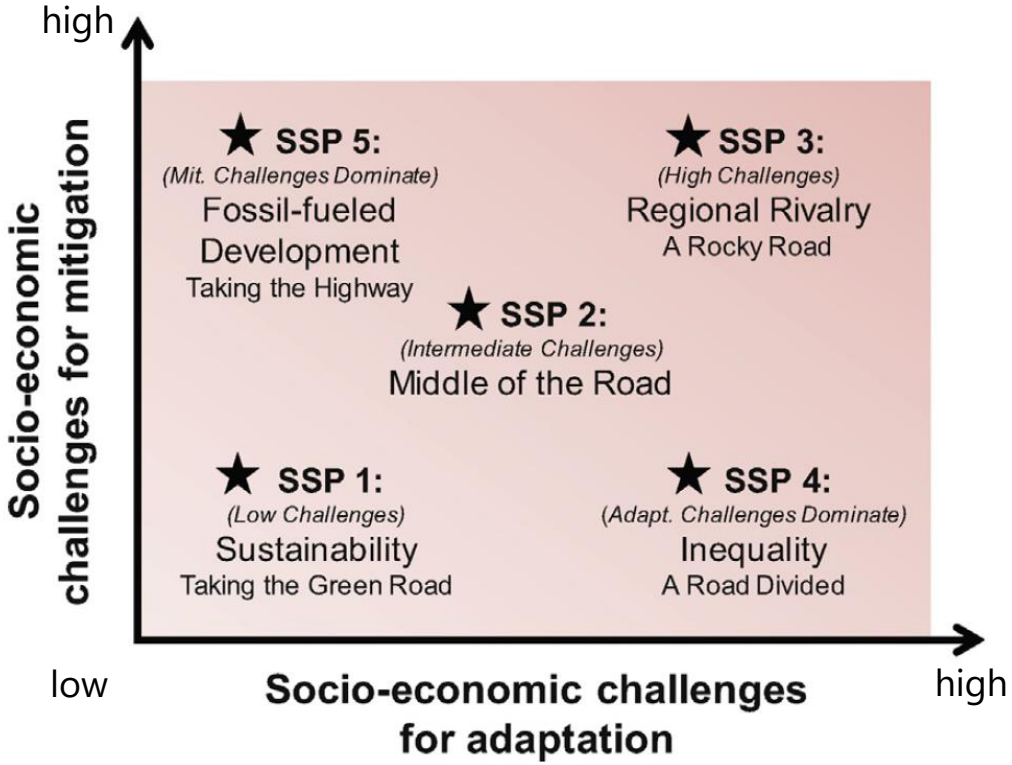


Agroecology
Digitalisation
Diversification
Transformation
Link to climate change

Why scenarios?



Shared Socioeconomic Pathways



- Developed in the climate change research community (O'Neill et al. 2017)
- „Pathways in the 21st century"
- Combining alternative futures of climate and society
- SSP storylines, including specifications for land use, SSP public data base at IIASA (modelling results)
- Used in combination with greenhouse gas emmission trajectories (RCPs)

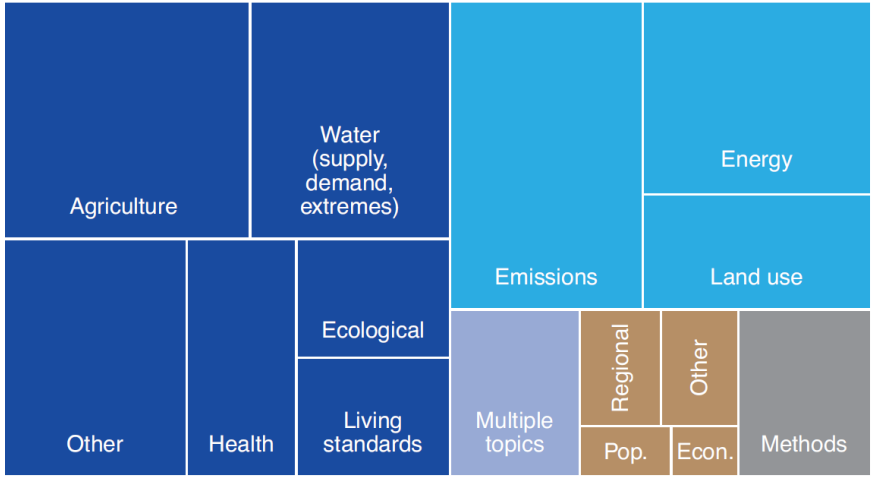
(O'Neill et al. 2017 in Global Environmental Change, doi: 10.1016/j.gloenvcha.2015.01.004)

Shared Socio-economic Pathways (SSP) scenario framework Adoption and experiences

- Widely adopted: used as framework in other settings
- Regional and sectoral specifications

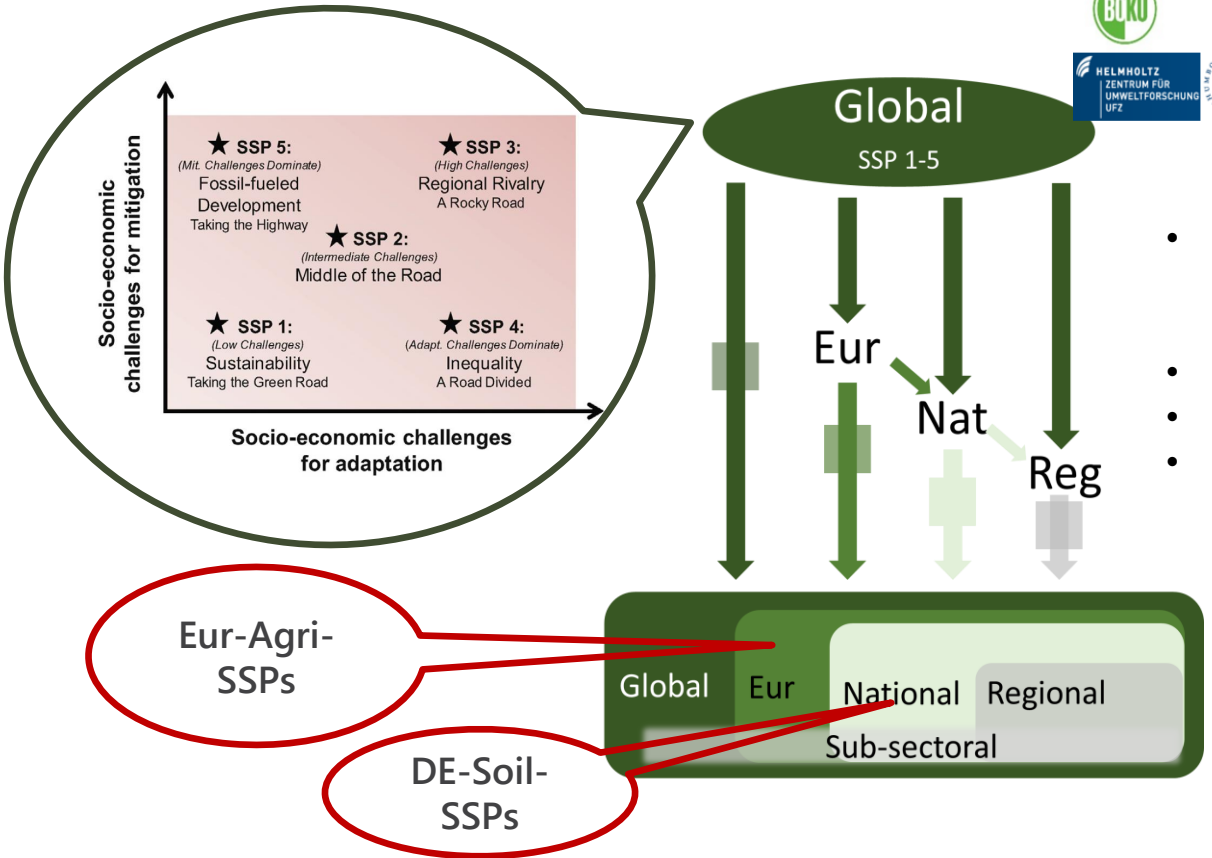
Pros:
- Consistency, Comparability, clarity
- Acceptance and visibility

Challenges:
- Applicability at regional and local scales
- Capture relevant perspectives and uncertainties
- Keep scenarios up to date
- Improve relevancy: capacity building, communication, accessibility, stakeholder involvements



(O'Neill et al. 2020 Nature Climate Change)

Eur-Agri-SSPs: Shared Socio-economic Pathways for European agriculture and food systems



- **Thematic:** alternative future developments of agriculture and food systems
- **Spatial scale:** Europe
- **Time scale:** 2050
- **Scenario type:** problem-focused, qualitative storylines, semi-quantitative specifications of plausible futures

Mitter, Techen, Helming et.al. 2019. J Env. Mangement

Mitter ,Techen, Helming, et al., 2020. Global environmental Change

Downscaling Eur-Agri SSPs to soil management in DE

Stakeholder Workshops for specifying SSP storyline elements for soil management

- Apply SSP protocol of Eur-Agri SSPs
- 5 online participatory scenario workshops, 2020/2021
  - 2 English workshops + outreach/international collaboration
  - 3 German workshops
- **90** participants from 6 stakeholder groups:
  - State/Policy
  - Civil societies
  - Agricultural associations
  - Enterprises
  - Farmers
  - Academia

Focus on technology and environment


1. Population and urbanization*


2. Economy*


3. Policies and institutions*


4. Technology


5. Environment and natural resources

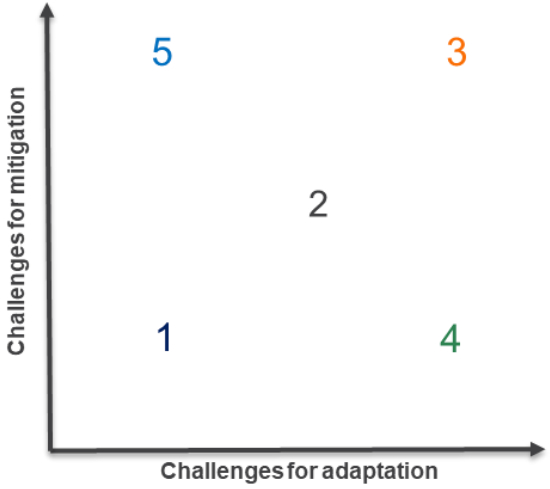
Bayer, Evgrafova, Arndt, Helming et al., in prep

Results: Environment and Natural Resources

Strong decrease	Tendency to decrease	Remains	Tendency to increase	Strong increase

Storyline elements			SMP1	SMP2	SMP3	SMP4	SMP5
	Soil management practices focusing on	Agricultural landscape diversity (i.e. field size and transition zones)					
		Integration of intercropping and agroforestry					
		Diversity of crop varieties					
		Diversity of crop rotations incl. cover crops and legumes					
		Subsoil management					
		Machinery weight and contact stresses					
		Intensity of tillage					
		Application of precision agricultural practices (e.g. plant- or site-specific)					
		Use of pesticides					
		Use of organic inputs, incl. inoculation and new fertilizers from recycled nutrients					
		Use of mineral inputs					
		Use of irrigation					
	Resource depletion induced by	Amount of agricultural land take (e.g. urban areas, streets etc.)					
		Amount of agricultural land transferred to nature conservation areas					
	Status of soil functions	Biomass production					
		Storage and recycling of nutrients					
		Filtering and storage of water					
		Habitat for biological activity/Biodiversity					
		Carbon sequestration					
	Occurrence of invasive species	Amount of weeds					
		Amount of pests					
		Number of diseases (soil-, water-, air-born)					
		Wildlife migration through the farms					
		Affecting cultural landscapes					

SMP1 – Sustainable path
SMP2 – Slow change path
SMP3 – Nationwide path
SMP4 – Divided path
SMP5 – High-tech path



Bayer, Evgrafova, Helming et al., in prep

German Soil Management Pathways (DE-SMPs):

BONARES
Centre for Soil Research

5: High-tech industrial soil management in a globalized environment

3: Soil management to sustain national food and energy security in a highly isolated environment

2: Slow changes in the current soil management practices

Challenges for mitigation

1: Sustainable soil management in a green and diverse environment

4: Soil management in unequal environments of large-scale industrial farms and local agro-food initiatives

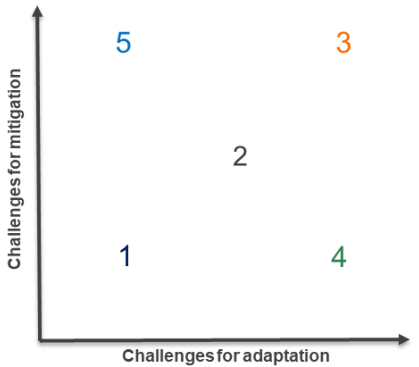
Challenges for adaptation

Bayer, Evgrafova, Arndt, Helming et al., in prep

Key messages from the Soil Management Pathways

- Socio-technical innovations and technology uptake are improving strongest in SSP1 (high-tec) and SSP5 (sustainable), but the implications for sustainable soil management are different across the SSPs
- Policies and international trade-regulations and standards determine in how far innovations only improve (economic) efficiency or also sustainability
- Diversification is key in SSP1 (sustainable): rotation, intercrops, agro-forestry, value chain diversification
- The food value chain, consumption and dietary choices strongly determine farmers room for manoeuvre on sustainable soil management
- Mixed message on de-globalisation: meeting national needs may increase production and put additional pressure on soil; but producing fodder protein may actually be of benefit for soil health

SMP1 – Sustainable path
SMP2 – Slow change path
SMP3 – Nationwide path
SMP4 – Divided path
SMP5 – High-tech path

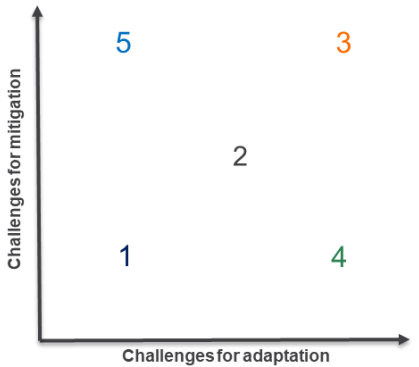


Bayer, Evgrafova, Arndt, Helming et al., in prep

Key messages from the Soil Management Pathways

- BAU (SMP2) was not a desired future;
- Sustainable path (SMP1) integrated technological with societal innovation and consumer cooperation
- High-tech path (SMP5) used technology for improving efficiency but mostly ignored diversification
- Divided path (SMP4) was often seen as representation of the current state
- Nationwide path (SMP3) scored worst on environmental health
- Diversification key point (integration of high-tech with biological methods)

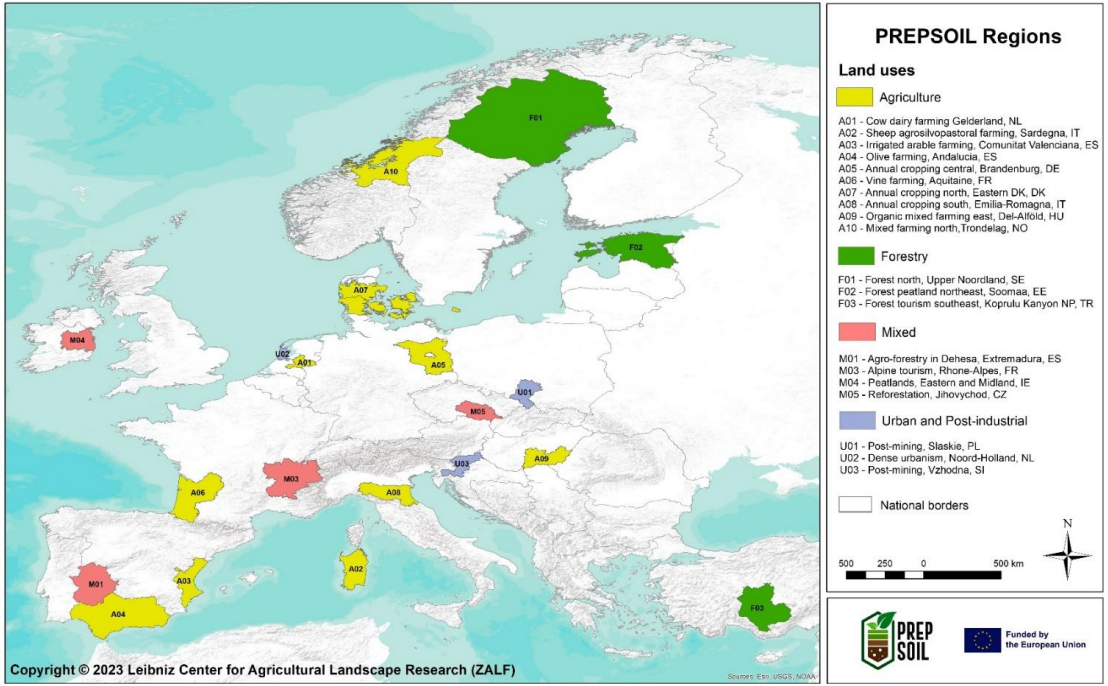
SMP1 – Sustainable path
SMP2 – Slow change path
SMP3 – Nationwide path
SMP4 – Divided path
SMP5 – High-tech path



Bayer, Evgrafova, Helming et al., in prep

Stakeholder based Soil Needs Assessment in Europe

Analysis in 20 European regions, alle land use types



PREPSOIL Regions

Land uses

Agriculture

A01 - Cow dairy farming Gelderland, NL
A02 - Sheep agrosilvopastoral farming, Sardegna, IT
A03 - Irrigated arable farming, Comunitat Valenciana, ES
A04 - Olive farming, Andalucia, ES
A05 - Annual cropping central, Brandenburg, DE
A06 - Vine farming, Aquitaine, FR
A07 - Annual cropping north, Eastern DK, DK
A08 - Annual cropping south, Emilia-Romagna, IT
A09 - Organic mixed farming east, Del-Alfold, HU
A10 - Mixed farming north,Trondelag, NO

Forestry

F01 - Forest north, Upper Noordland, SE
F02 - Forest peatland northeast, Soomaa, EE
F03 - Forest tourism southeast, Kopulu Kanyon NP, TR

Mixed

M01 - Agro-forestry in Dehesa, Extremadura, ES
M03 - Alpine tourism, Rhone-Alpes, FR
M04 - Peatlands, Eastern and Midland, IE
M05 - Reforestation, Jihovychod, CZ

Urban and Post-industrial

U01 - Post-mining, Slaskie, PL
U02 - Dense urbanism, Noord-Holland, NL
U03 - Post-mining, Vzhodna, SI

National borders

N

500 250 0 500 km

PREP SOIL

Funded by the European Union

Soil needs:

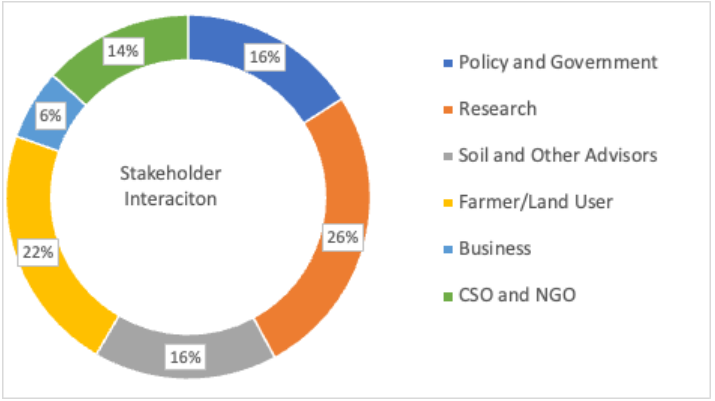
"what soil needs from humans to serve human needs"

PREPSOIL Deliverable D2.1

Stakeholder based Soil Needs Assessment in Europe

Stakeholder workshops

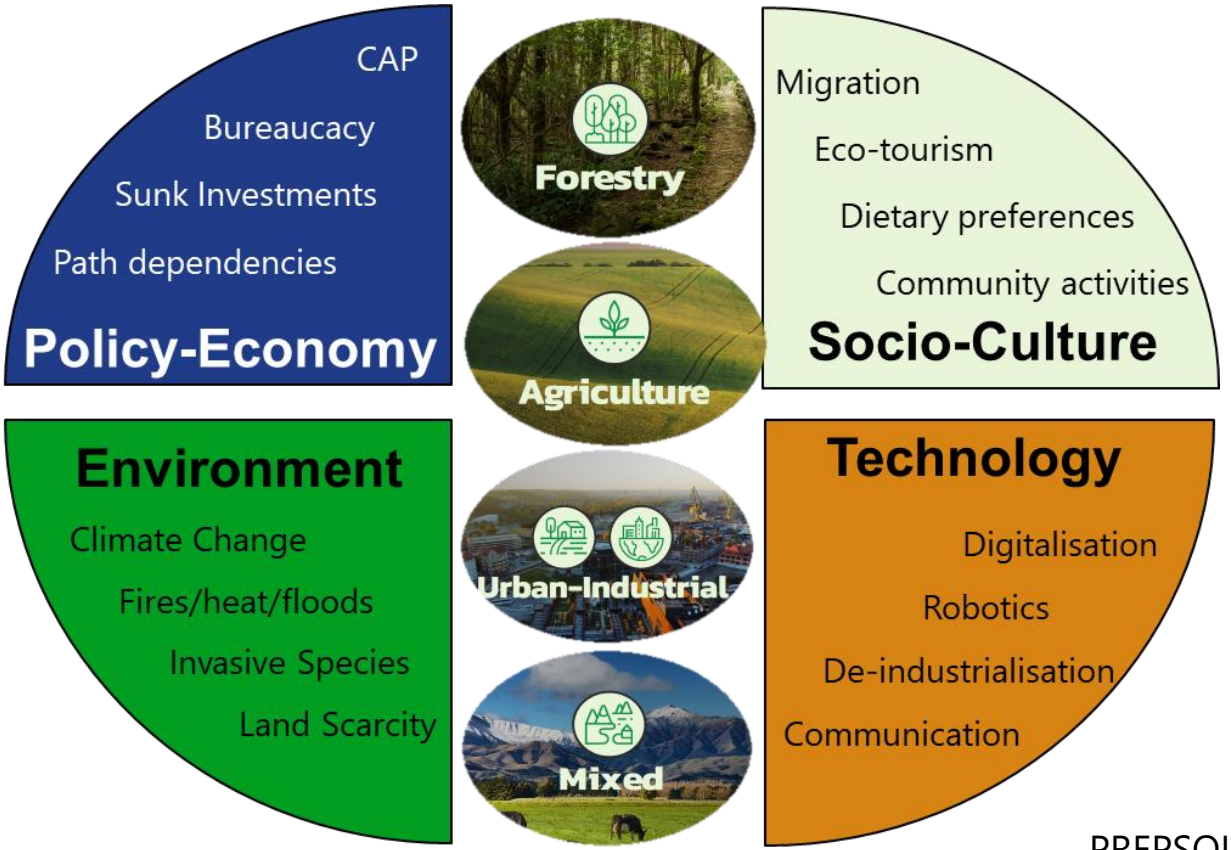
Stakeholder groups involved



> 500 individuals in total

PREPSOIL Deliverable D2.1

Drivers of soil management



Soil needs in Agriculture

Soil improving management solutions are available but barriers are high

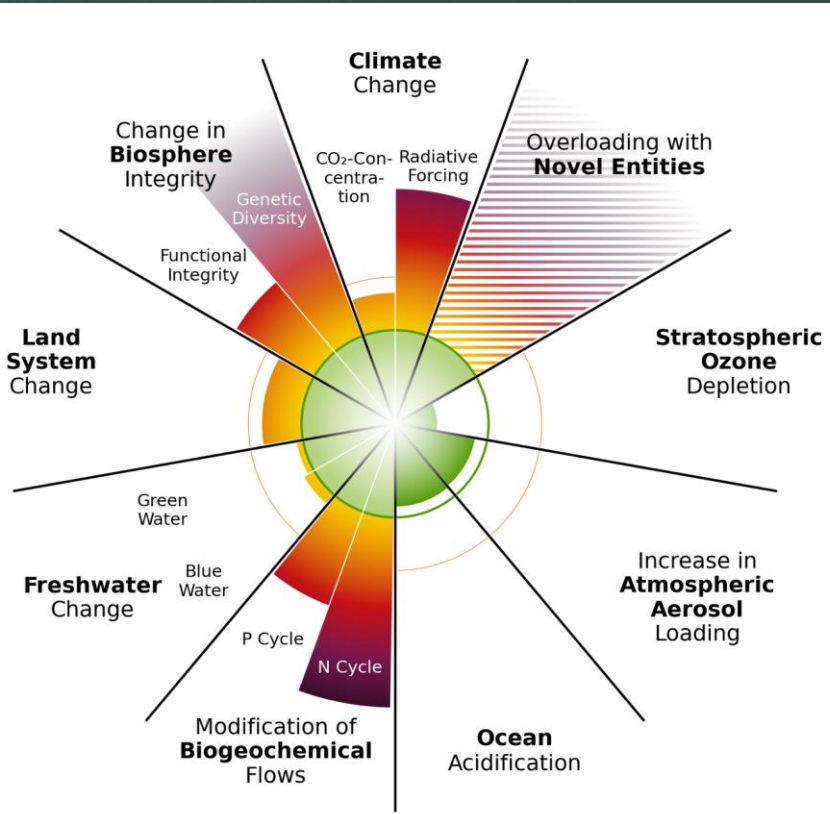
- Remove economic, policy and knowledge barriers to soil improving management
- Redirect policy (CAP) to support provision of ecosystem services alongside production
- Integrate agro-ecological principles with modern technologies in a systems aproach
- Acknowledge cultural identity, ownership, and a sense of belonging to an area.
- Engage consumers into the transformation
- Consider path dependencies and land use history

Conclusions

- Understanding **future** conditions helps to identify the **room for manoeuvre** for sustainable soil management
- Soil improving management requires **systemic changes** at the level of farming systems (and food system), not single interventions
- **Consumers** and **value chain** play important role in transformation, alongside technology and policy
- Solutions are **site specificities**, but do not get lost in details when communicating

Planetary boundaries: where is the soil?

Soil is more than SOC



Richardson et al., 2023, adapted
https://www.pik-potsdam.de/de/produkte/infothek/planetare-grenzen/planetare-grenzen

Thank you for your attention