Leibniz Centre for Agricultural Landscape Research (ZALF)

Soil as a sustainable resource for the bioeconomy: in Germany

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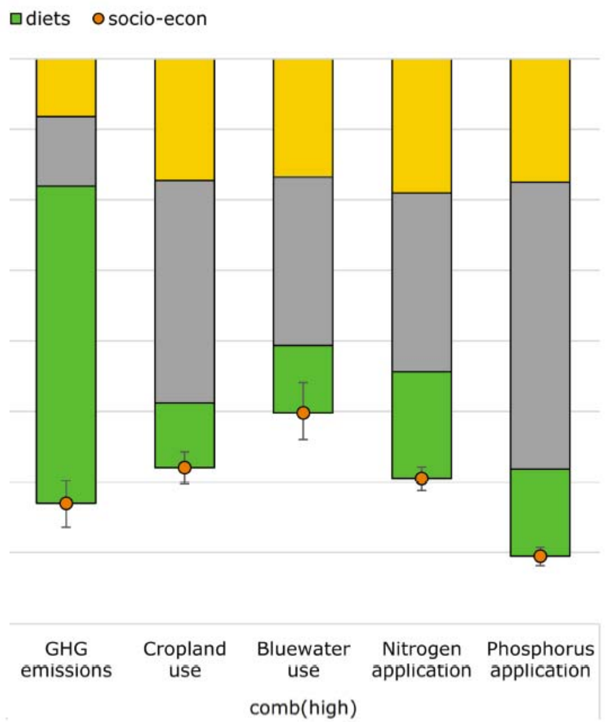
How to reduce the environmental impact of the food system?

Global simulations

Yellow: Waste reduction
Grey: Management progress
Green: Dietary changes



Springmann et al., Nature 2018


Farmers:
„Healthy soils are the best insurance against the impacts of climate change“
Water storage
Yield stability
Nutrient cycling
biodiversiry

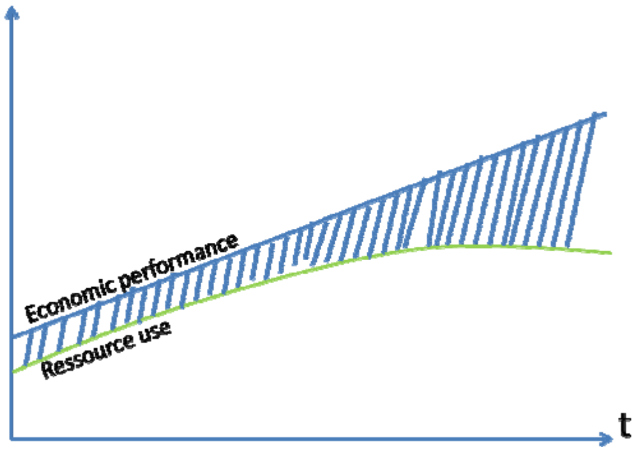
Bioeconomy Strategy

Increase production

+

Bioeconomy Strategy

Increase production



Reduce recourse use

Soil Multifunctionality: more than just production

Soil Functions

Biomass production

Habitat for biological activity

Filtering and storage of water

Carbon sequestration

Storage and recycling of nutrients

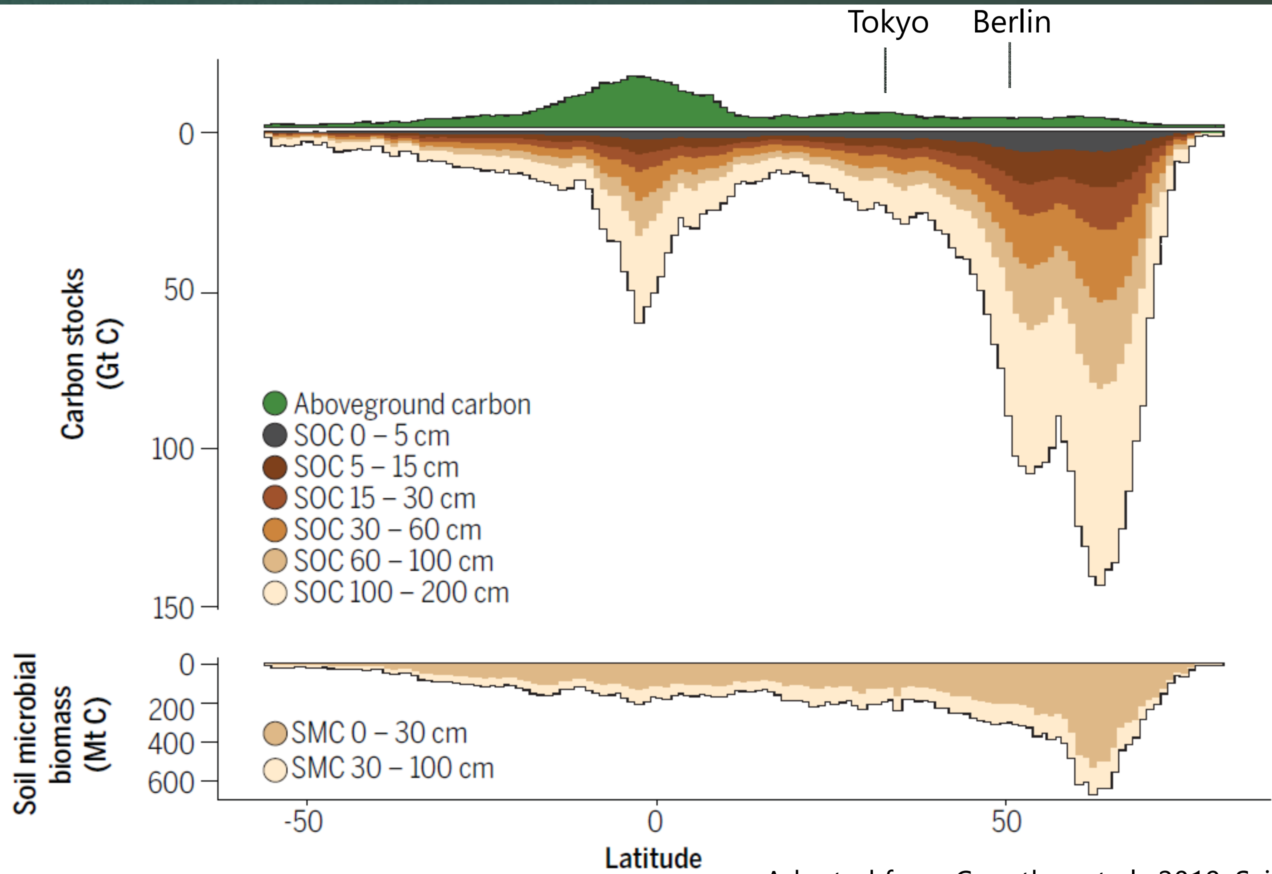
Soil management: what the farmers can do on the ground

Soils and Sustainable Development

- Food Security (Goal 2)
  - population: > 9 billion in 2050
  - Increasing meat consumption
- Energy security (Goal 7)
  - Bioenergy
- Sustainable production (Goal 12)
  - Resource use efficiency
  - Circularity of production
- Climate Change (Goal 13)
  - Mitigation with the natural Carbon Pool
  - Adaptation through soil water storage
- Terrestrial ecosystems (Goal 15)
  - belowground Biodiversity
  - Soil health

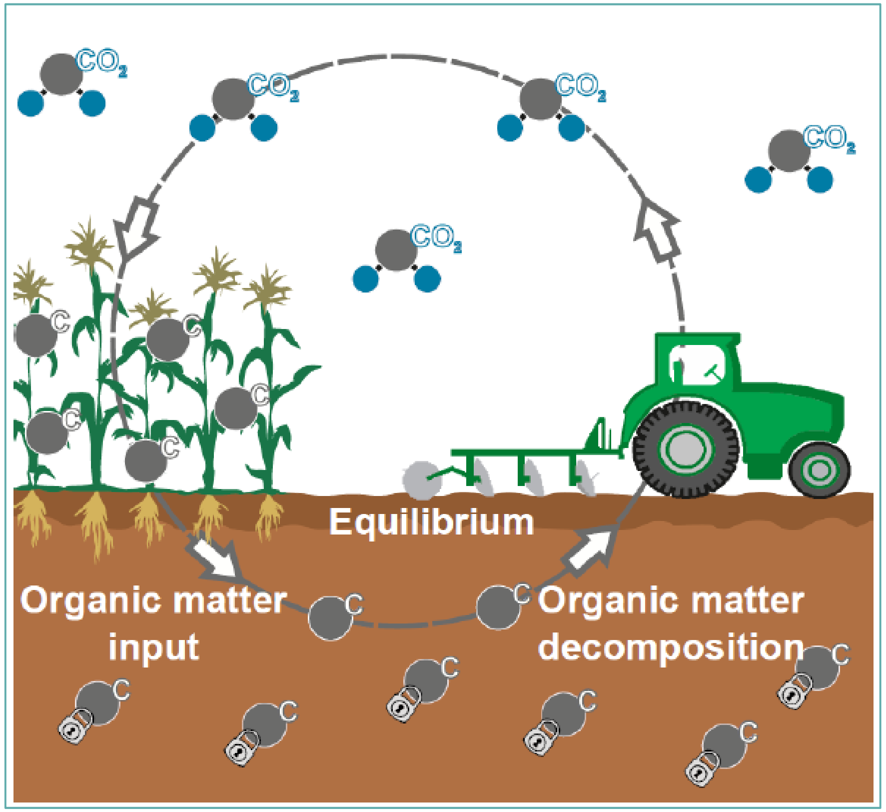
Globale Carbon Stocks

~1500 Gt **Soil**
~750 Gt Atmosphere
~560 Gt Vegetation



Adapted from Crowther et al., 2019. Science

Soil carbon cycle



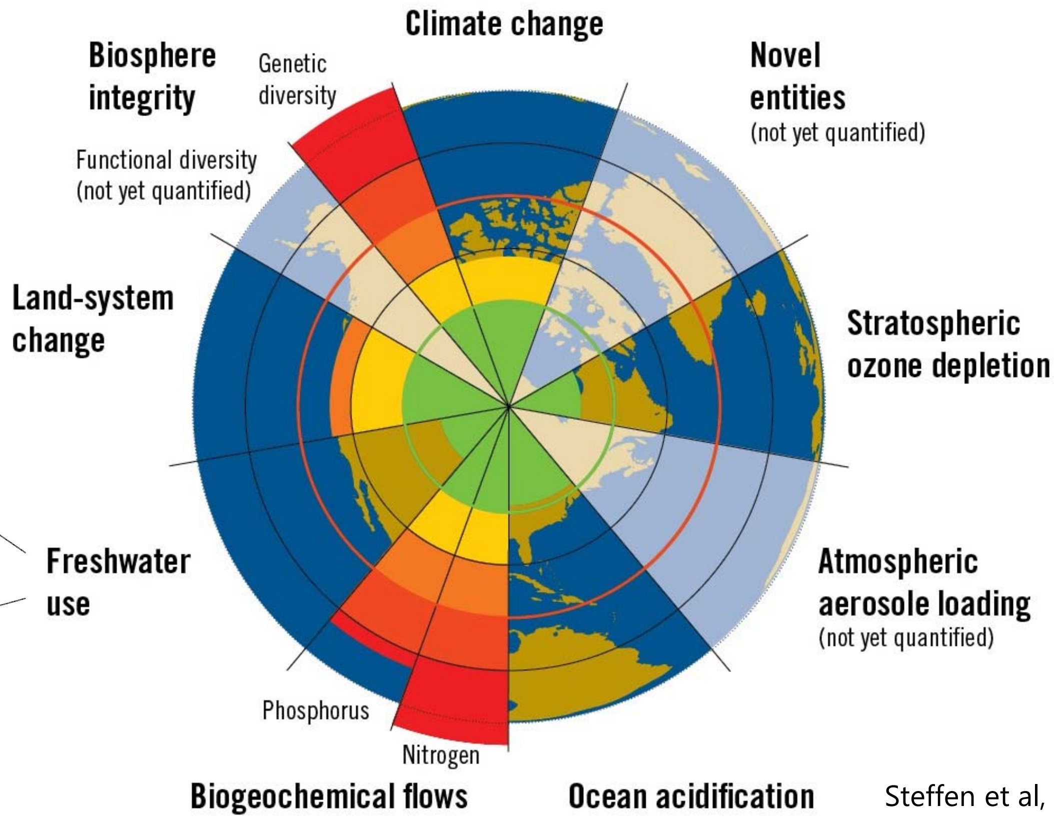
Wiesmeier et al., 2020

Planetary Boundaries: Green Water

Exceeding boundaries

Green Water:
- **Soil moisture**
- **Evaporation**
- **Terrestrial precipitation**

Blue Water:
- **Rivers**
- **Lakes**
- **Ground Water**



Wang-Erlandsson et al., 2022
Nature Reviews

Steffen et al, 2015 Science
Lade et al., 2019. Nature Sustainability

Soil degradation processes

Erosion (1)
20% soils

Biodiversity loss
Widespread

compaction (3)
36% Subsoils

salinization (1)
Ca. 3.8 Mio ha

sealing (1)
>275 ha/day

Loss of org. C (1)
45% of soils<2% OC

contamination (2)
ca. 3 Mio. sites

Numbers for EU-Europa:

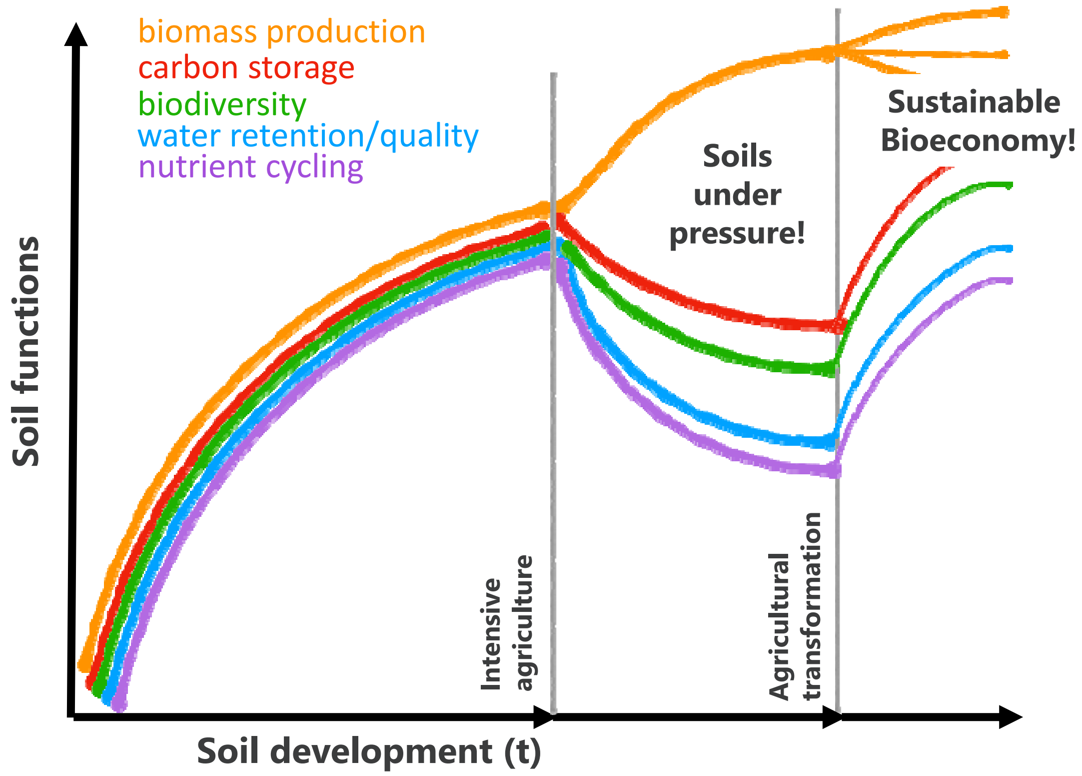
(1) Jones et al., 2012 EEA State of Environment Report

(2) Panagos et al., 2003. J. Environ. Public Health

(3) Jones et al. 2003. Soil Tillage Research

Soil Mission Support

The mission of the agricultural tranformation

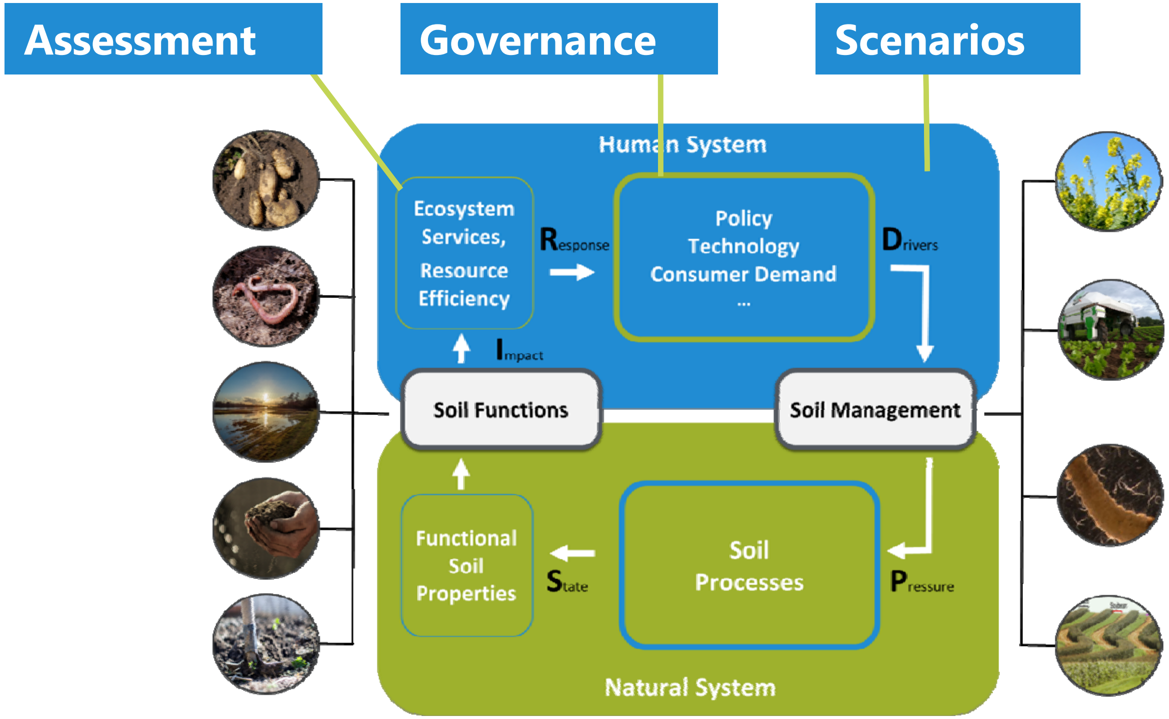


BONARES Centre for Soil Research

Sponsored by the Federal Ministry of Education and Research

Need for transformation

Systems Approach to agricultural transformation and soil health



Driver
Pressure
State
Impact
Response

Vogel et al., 2018. Soil
Helming et al., 2018 Land Degradation & Development

Drivers: Foresight on future 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)

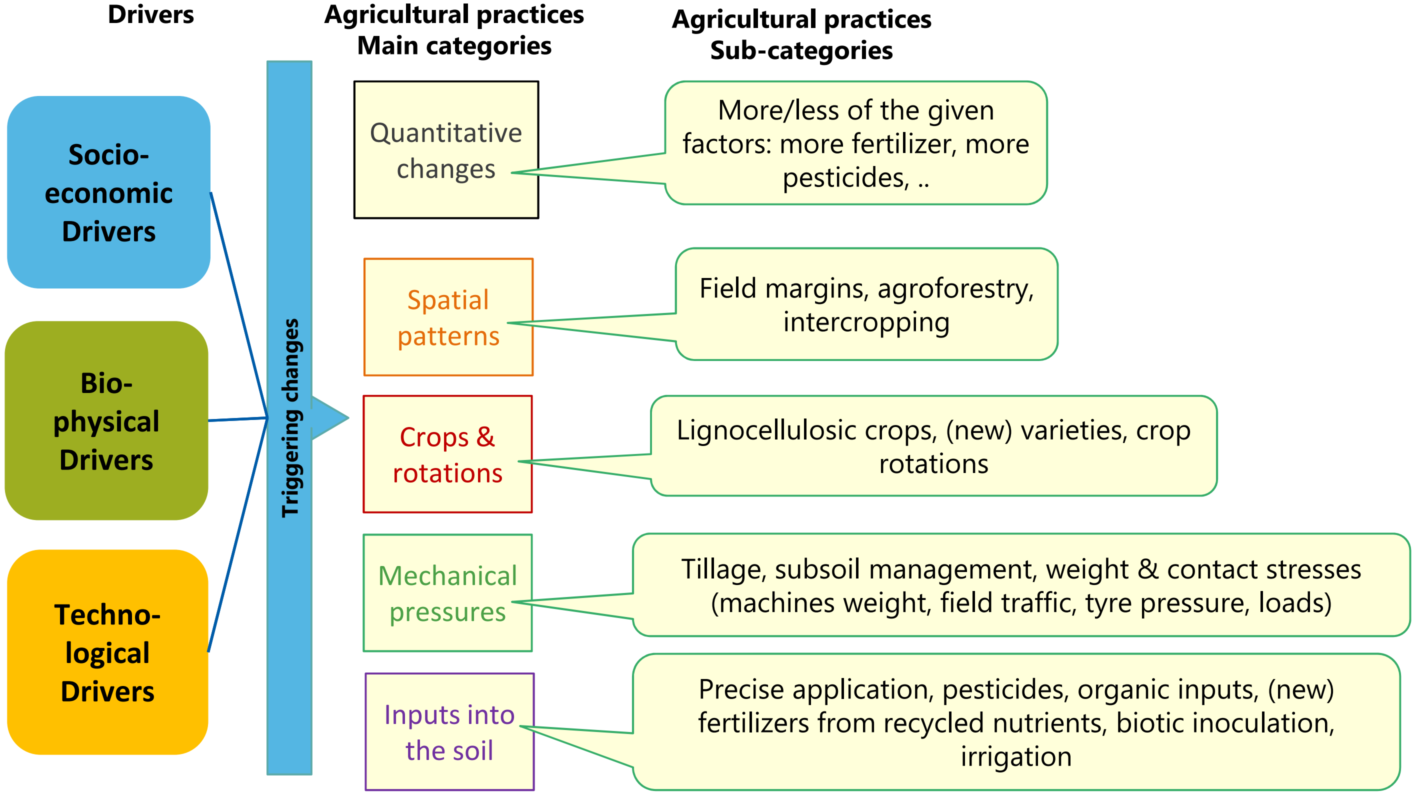
Biophysical

- Digitalization
- Data management
- Robotics
- Biomass technology

Techno-logical

Techen & Helming 2017. Agronomy for Sustainable Development

Foresight on emerging soil management practices and technologies



Techen & Helming 2017. Agron. Sust. Dev.

Socio-economic scenarios, climate change and soil management

- ✓ Opportunities and barriers for sustainable soil management solutions
- ✓ Impacts and feasibility of innovative solutions using participatory impact assessment

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

1: Sustainable soil management in a green and diverse environment

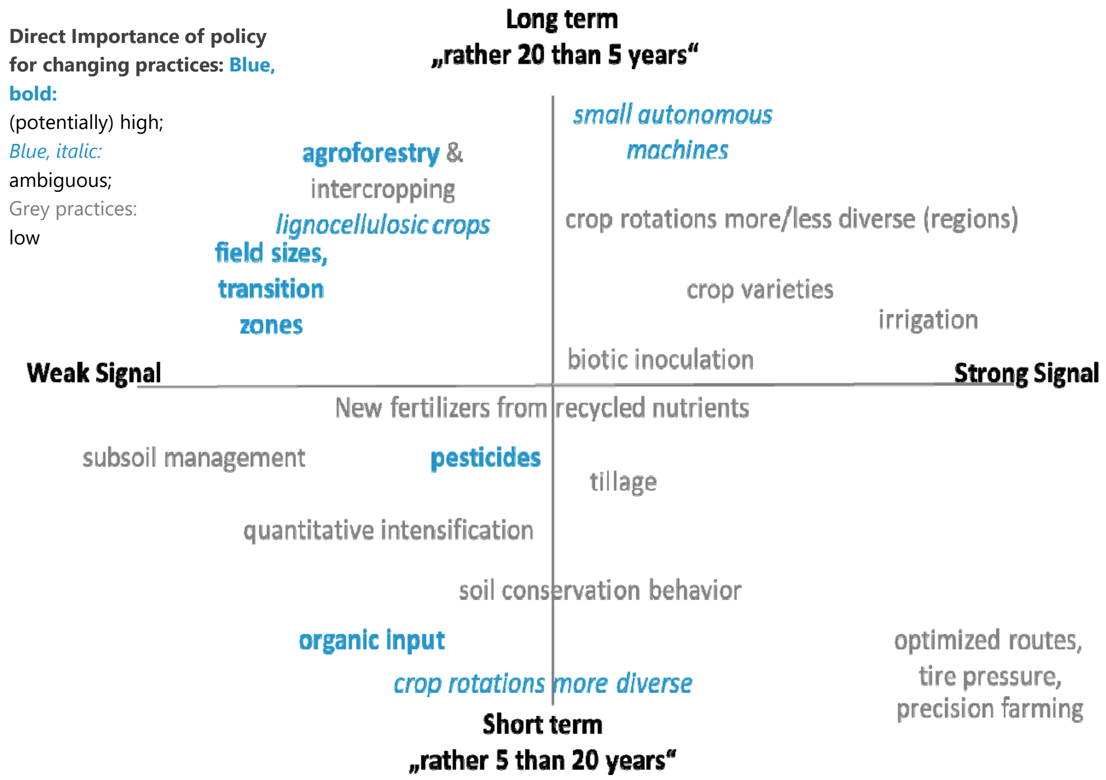
4: Soil management in unequal environments of large-scale industrial farms and local agro-food initiatives

Challenges for mitigation

Challenges for adaptation

Evgrafova et al.; in prep.

Emerging soil management technologies: signal strength and time frame

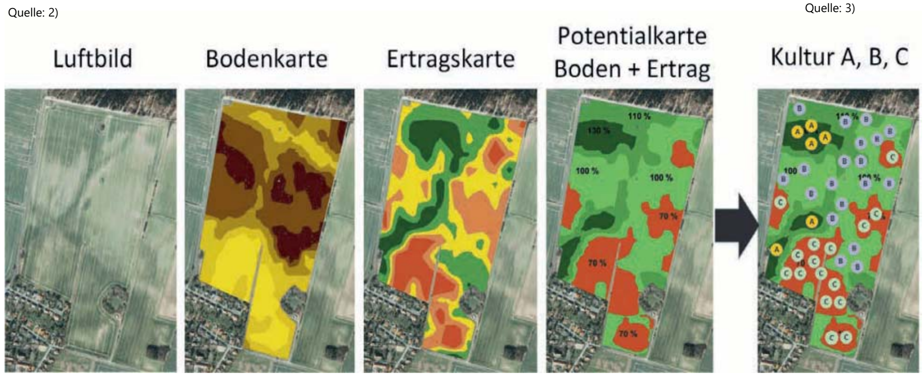


Techen & Helming 2017. Agronomy for Sustainable Development

Precision Farming and sensing: digitalization for improving soil health

Quelle: 2)

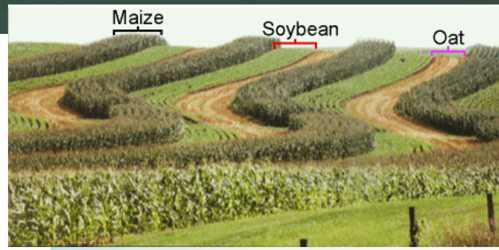
Quelle: 3)



Quelle: 1)

1) WEGENER, J. K., MINßEN, T.-F. & GAUS, C.-C. 2017. Developing new cropping systems - Which innovative techniques are required? Landtechnik, 72
2);3) Gandofer (LfL 2018).

Small autonomous machines: digitalization for improving soil health



Drivers: production costs, soil threats, technology, policy

Time frame for relevant spread: 15-20 years

Probability: very high for autonomous machines, high but uncertain for small autonomous machines

Impact: opportunities for smaller-scaled farming, intercropping, less weight stresses → positive impact on all soil functions possible, but details and other impacts unclear (e.g. resource efficiency)

Sources top to down:
http://otizvora.com/forum/index.php?topic=1116.15; Farm Journal Media; Ecorobotix autonomous robot weeder 2016; Herlitzius, TU Dresden, https://tu-dresden.de/ing/maschinenwesen/int/ressourcen/dateien/agrarsystemtechnik/forschung/Poster_AST_Maehdrescherkonzepte.pdf?lang=de

Nature based solutions to improve soil health and resource use efficiency

Soil tillage

moldboard

No till

Soil Cover

Crops and Rotations

Ramtillkraut/Phacelia

Lupine

Hemp

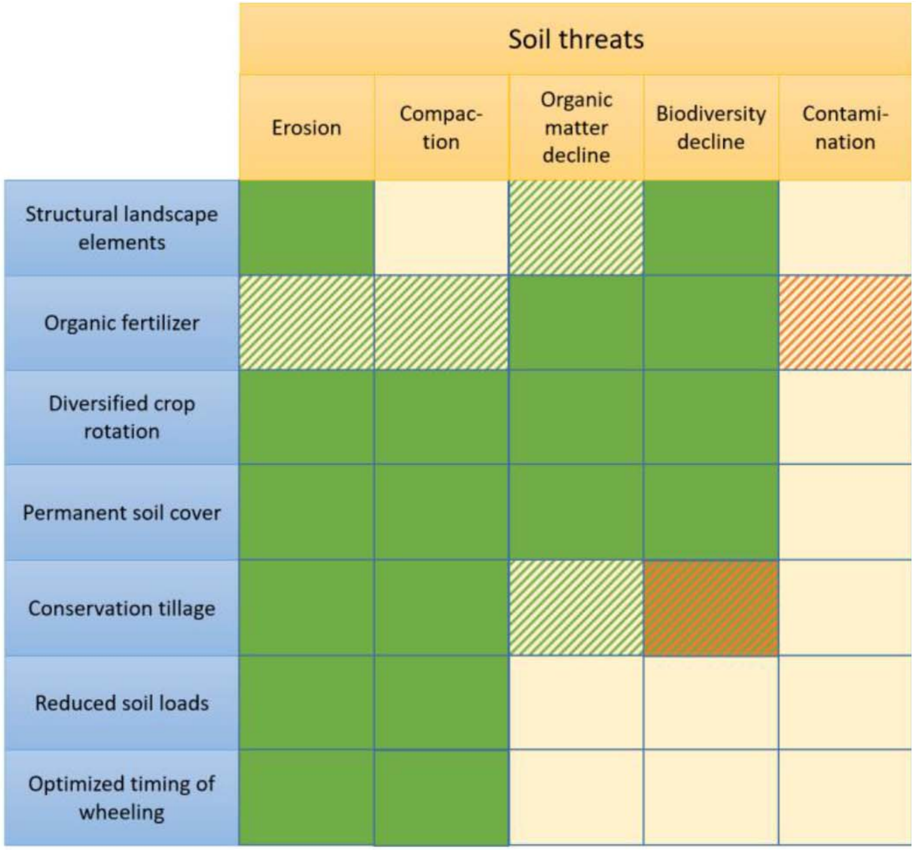
Diversification of crops and rotations

Legumes

Intercrops, cover crops

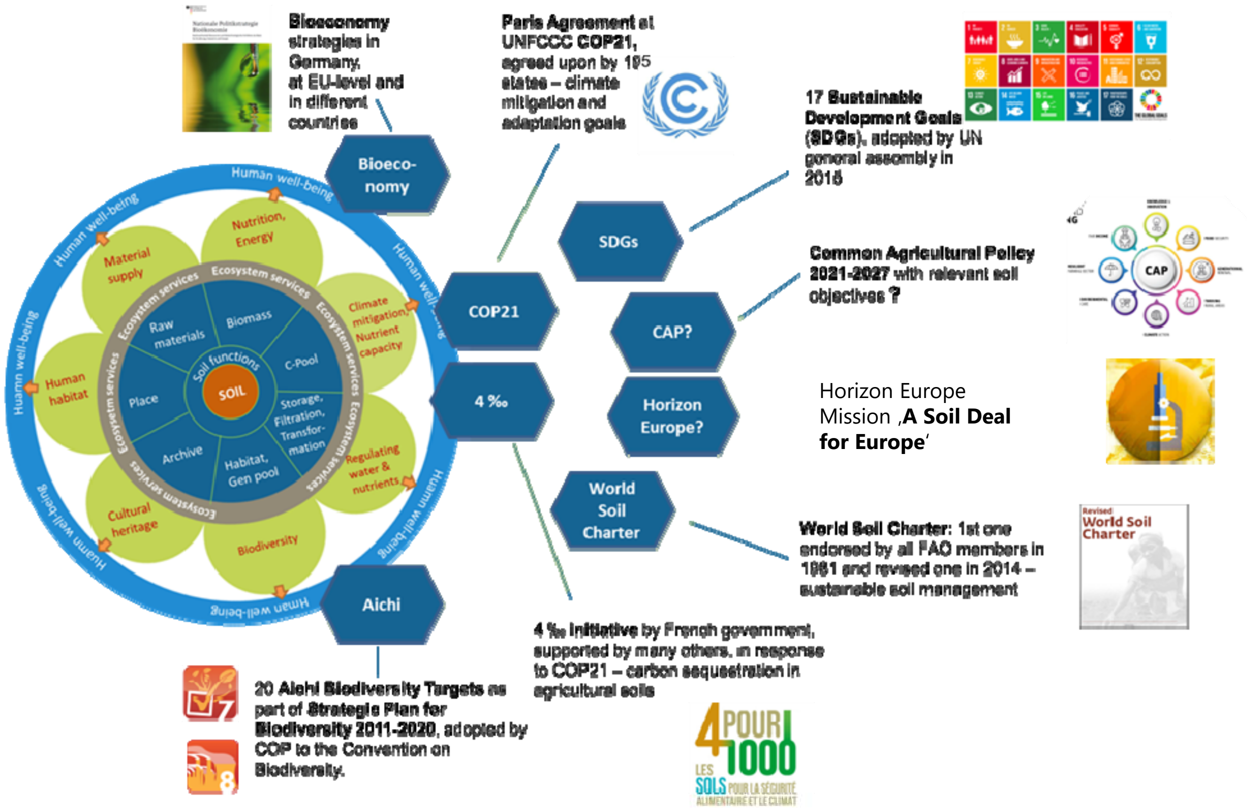
Organic fertilizers

Short list of Soil improving management practices



Strauss, Paul, Helming. Agronomy for Sustainable Development (under review)

Policy goals related to soil functions



Techen & Helming, 2019, BonaRes Series

Horizon Europe Mission ‚A Soil Deal for Europe"

1 out of 5 missions in Horizon Europe

8 Objectives

1 Reduce land degradation relating to desertification

2 Conserve and increase soil organic carbon stocks

3 No net soil sealing and increase the reuse of urban soils

4 Reduce soil pollution and enhance restoration

5 Prevent erosion

6 Improve soil structure to enhance habitat quality

7 Reduce the EU global footprint on soil

Soil Mission Support

Voluntary carbon market / private carbon offset

- Interest by companies & civil society to offset their emissions
- Farmers could change their management to increase SOC stock
- They could be rewarded through „carbon certificates“

➡ Several certification schemes already exist

www.carbocert.de

Carbon Farming: Potential to mitigate climate change

- Nature based solution
- Soil based climate change mitigation
- "4 pour mille" Initative – increasing soil organic carbon
- Co-benefits: improved soil health, climate change adaptation


Biomass production


Storage and recycling of nutrients


Carbon sequestration

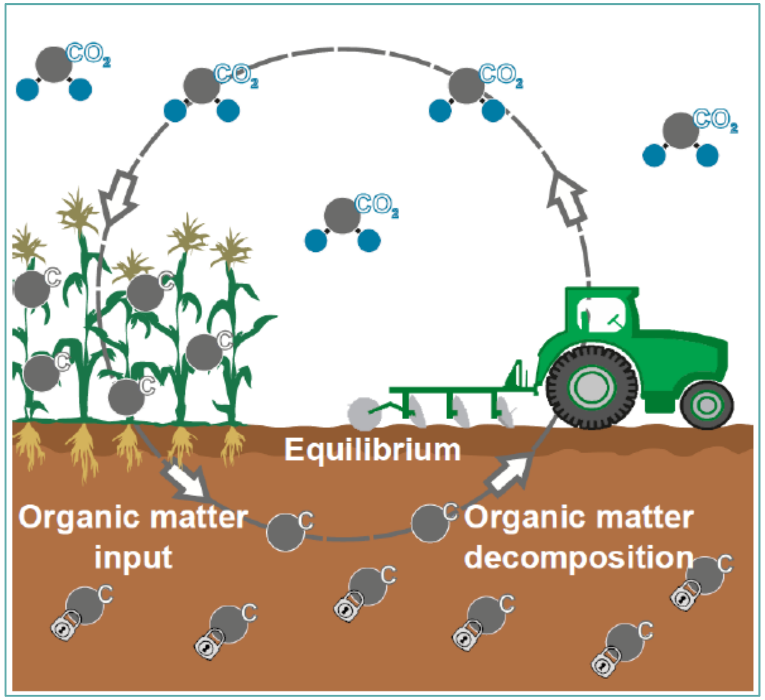

Habitat for biological activity


Filtering and storage of water

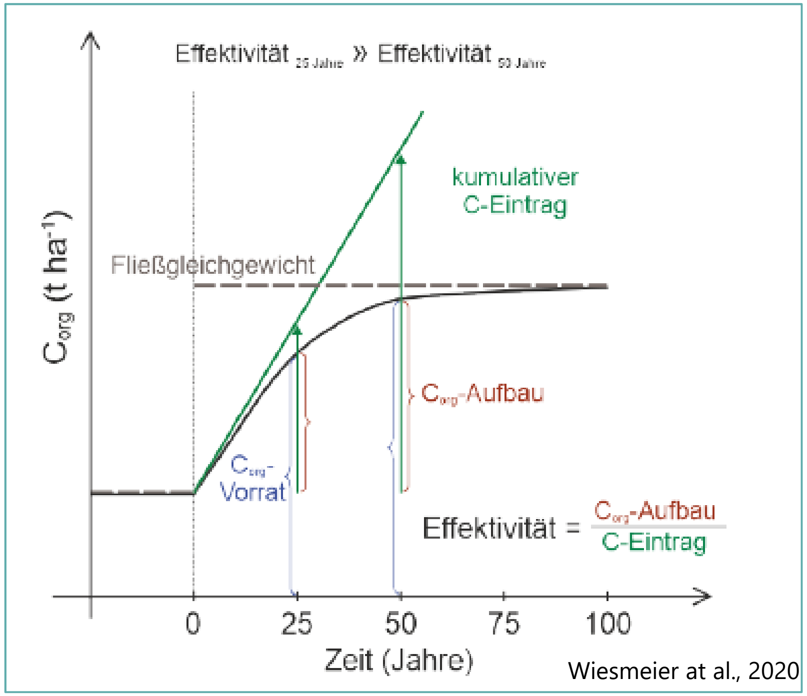
www.bonares.de

www.zalf.de

Soil Oganic Carbon increases – towards steady state



Requires management changes



Limited potential

Agricultural soil carbon certificate - challenges

- **System:** spatio-temporal heterogeneity, dynamic system towards steady state
- **Monitoring**: difficult, expensive
- **Permanence**: very difficult to guarantee
- **additionality**: risk double finance
- **Leakage**: concentrate ‚good' management on the certified fields
- **Fairness**: pioneers profit less
- **Synergies**: climate change adaptation, biodiversity, water storage, resource use efficiency

Paul et al., under review

Earthworms perspective on the future of the bioeconomy:

- Set the socioeconomic conditions enabling farmers to conduct soil health management
- Integrate high-tech with biological measures and societal innovations
- Diversify the management
- Reduce consumption and waste