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Soil inoculation improves ecosystem function of degraded grasslands

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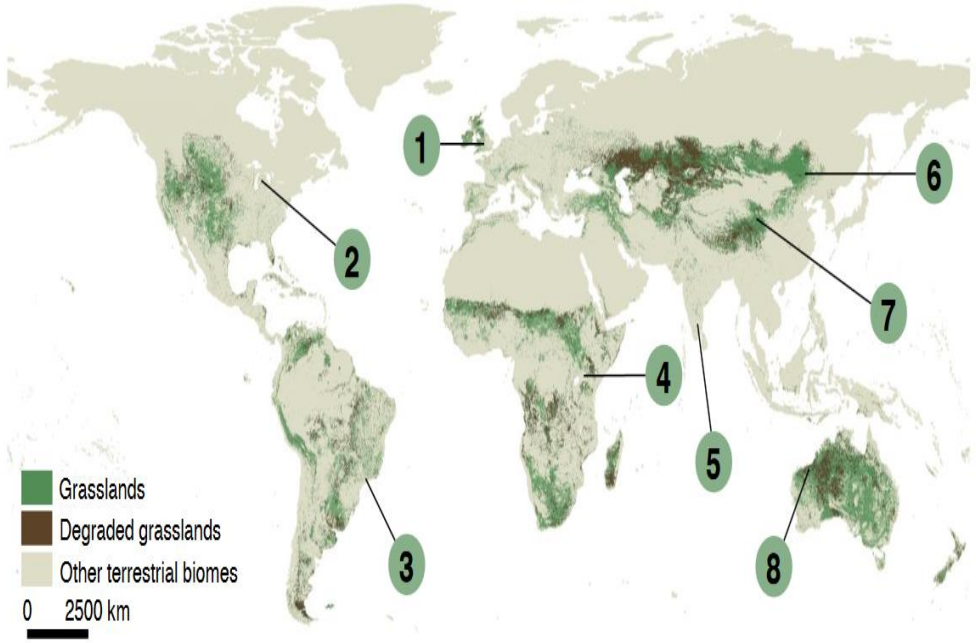
IAE

Background

Status of grassland degradation and measures for restoration

Global grassland degradation



(Bardget et al., 2021 *NREE*)

Measures to restore degraded grasslands

Replanting

Enclosure

Restoration of grasslands

Fertilization

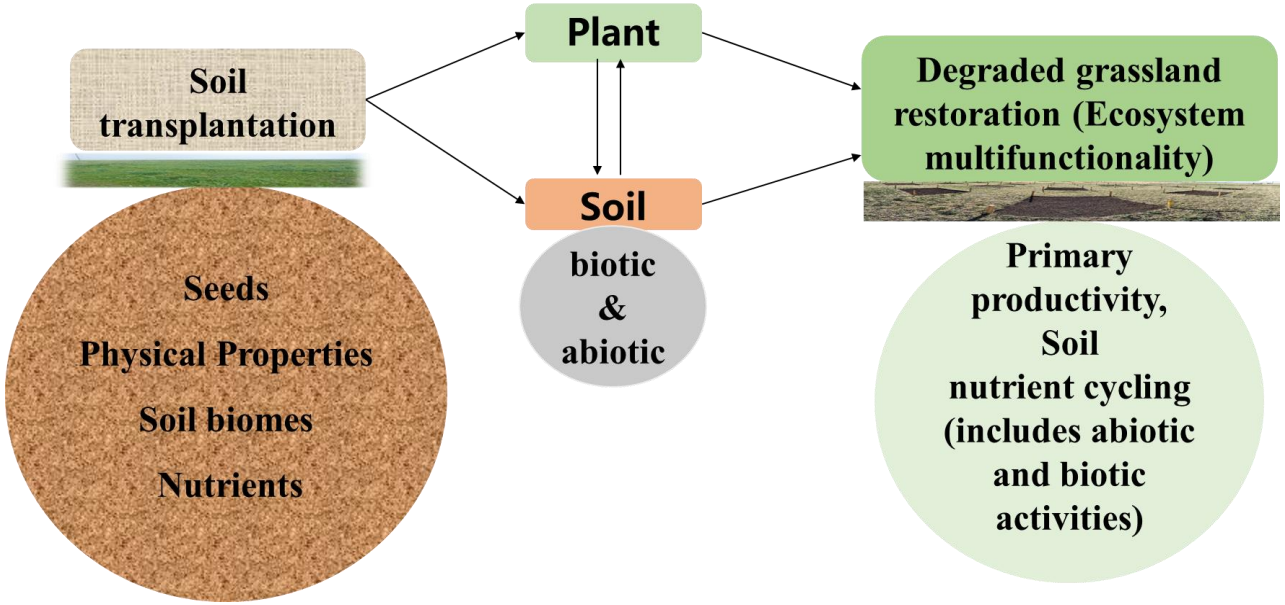
Artificial reconstruction

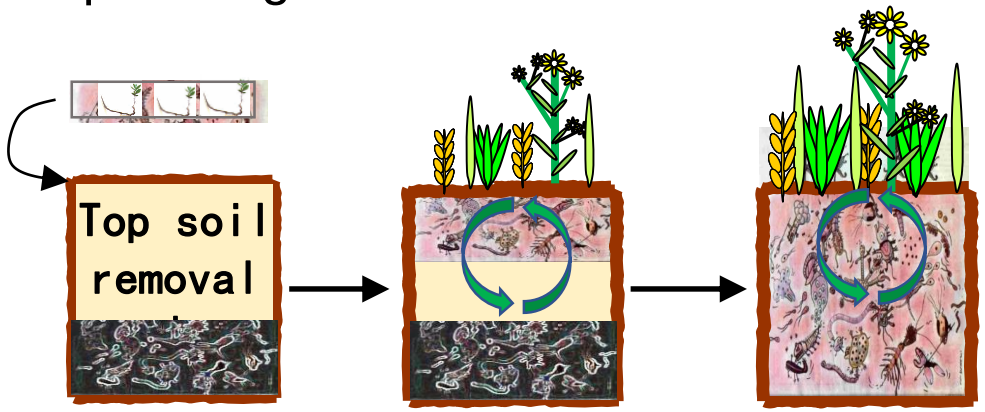
(http://grassland.china.com.cn)

Background

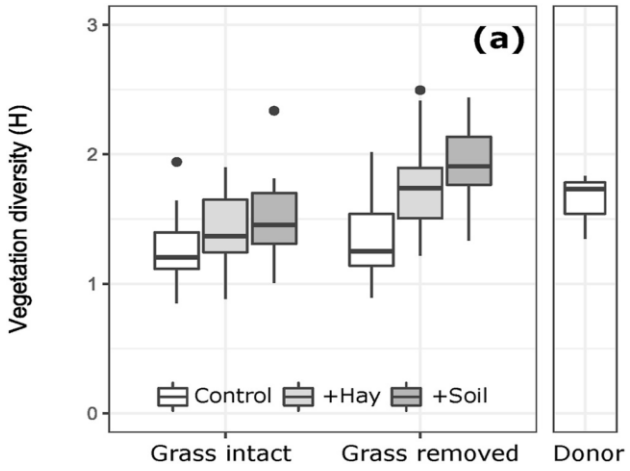
Soil transplantation

Soil transplantation: Transporting soil from a donor area and spreading this soil over another area.

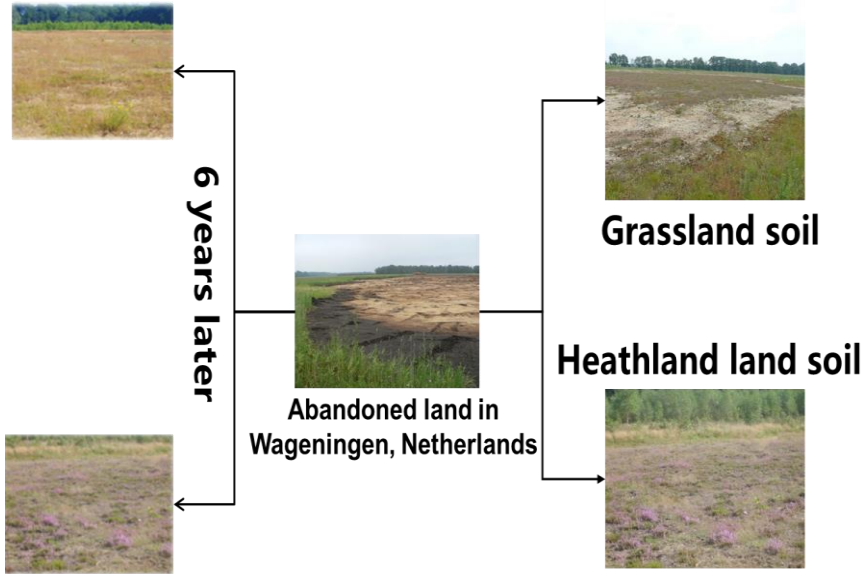




(Grman et al., 2020 *Restoration Ecology*)



(Emsens et al., 2022 *SBB*)

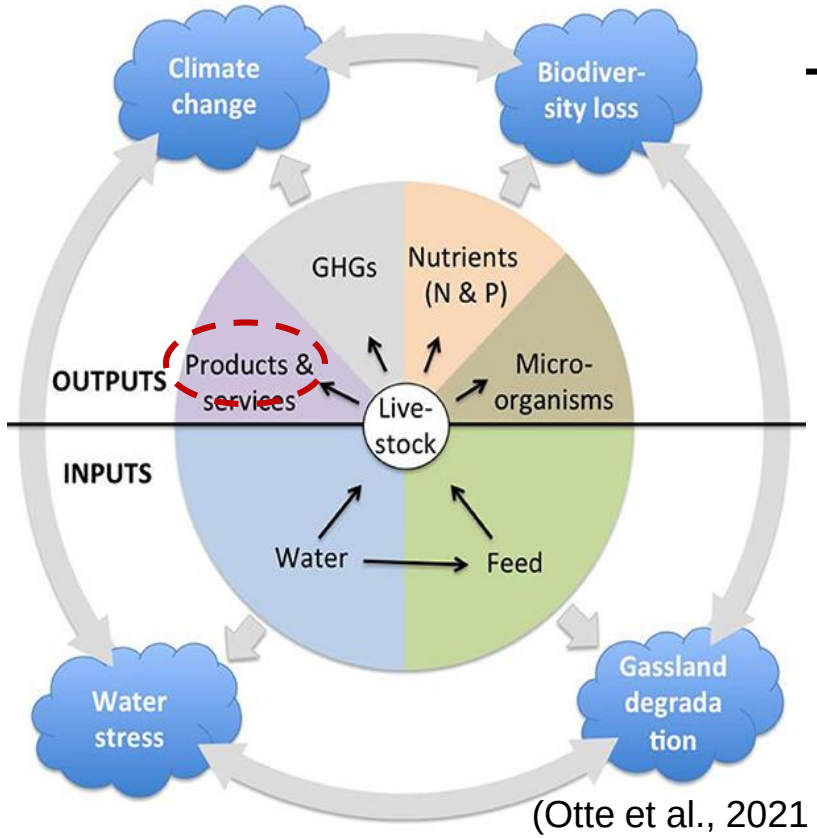


(Wubs et al., 2016 *Nature Plants*)

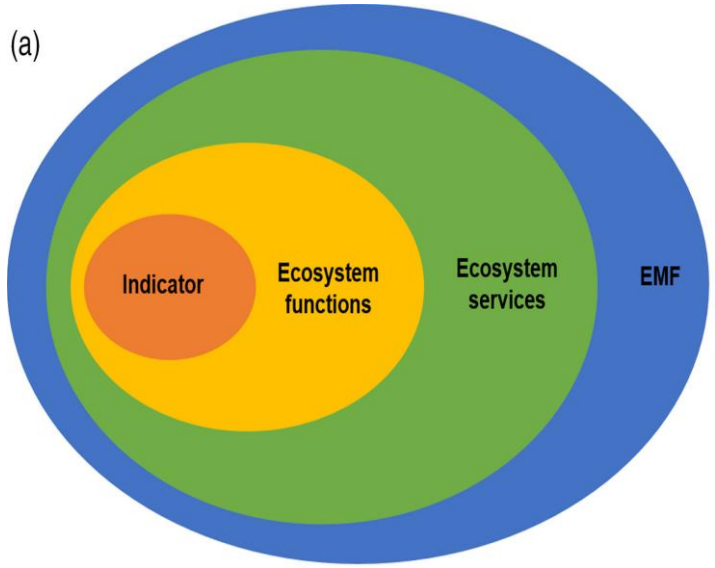
https://nioo.knaw.nl/en/soiltransplantation

Background

Assessment of degraded grassland restoration (Ecosystem multifunctionality)

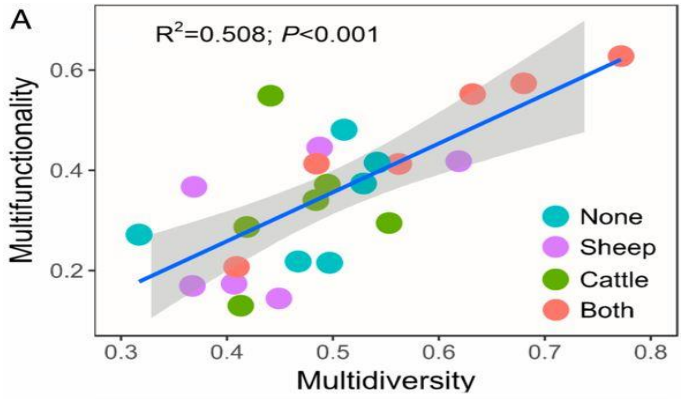


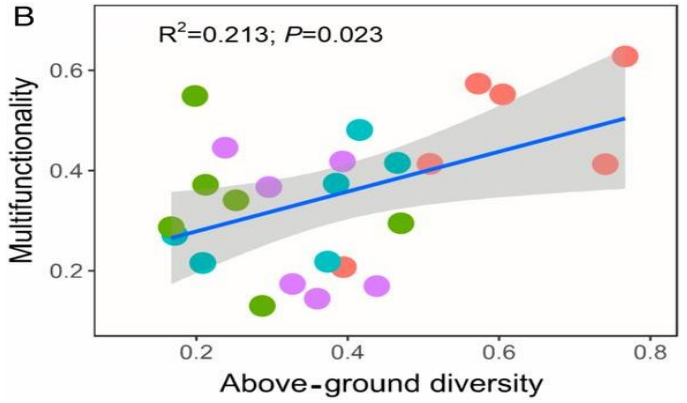
(Otte et al., 2021 *FIVS*)

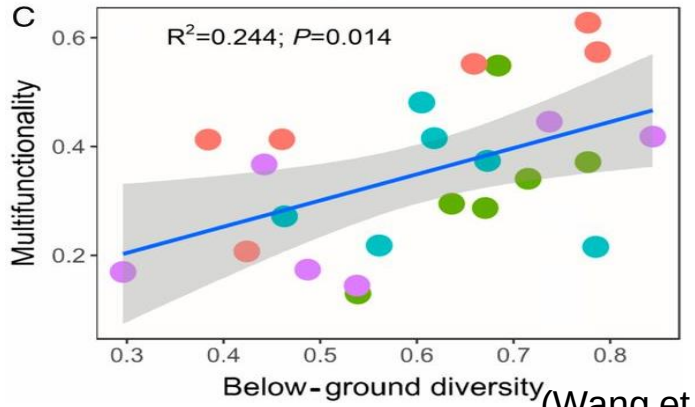


Ecosystem Multifunctionality (EMF):
The ability of ecosystems to simultaneously provide multiple functions and/or services.

(Garland et al., 2021 *Journal of Ecology*)







(Wang et al., 2019 *PNAS*)

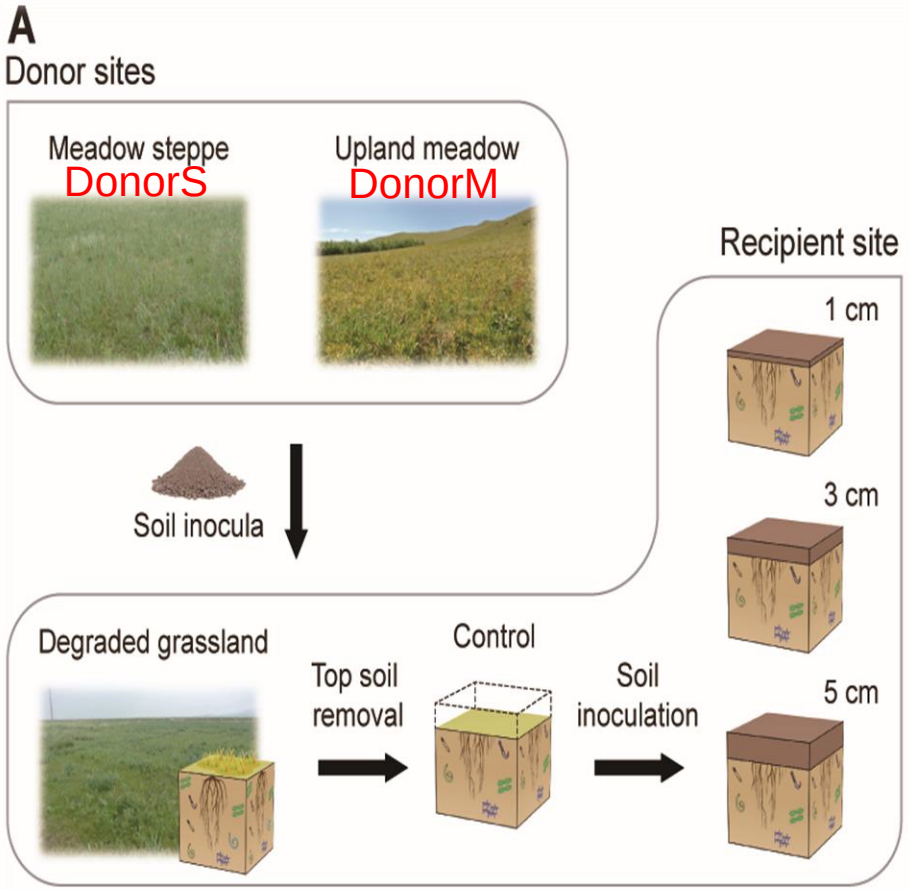
Hypothesis

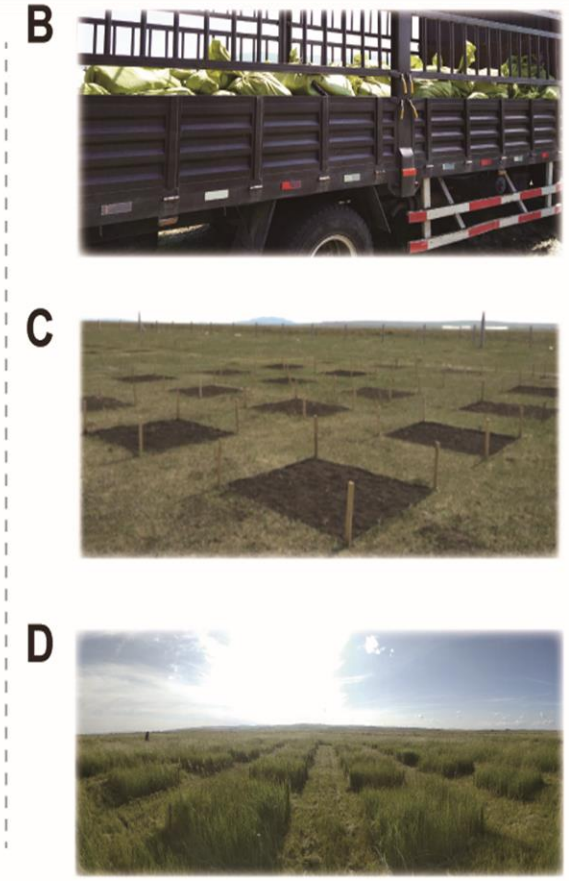
- Inoculation with the different donor grassland soils would steer soil microbiomes and plant communities towards the donor soil microbiomes and plant communities.

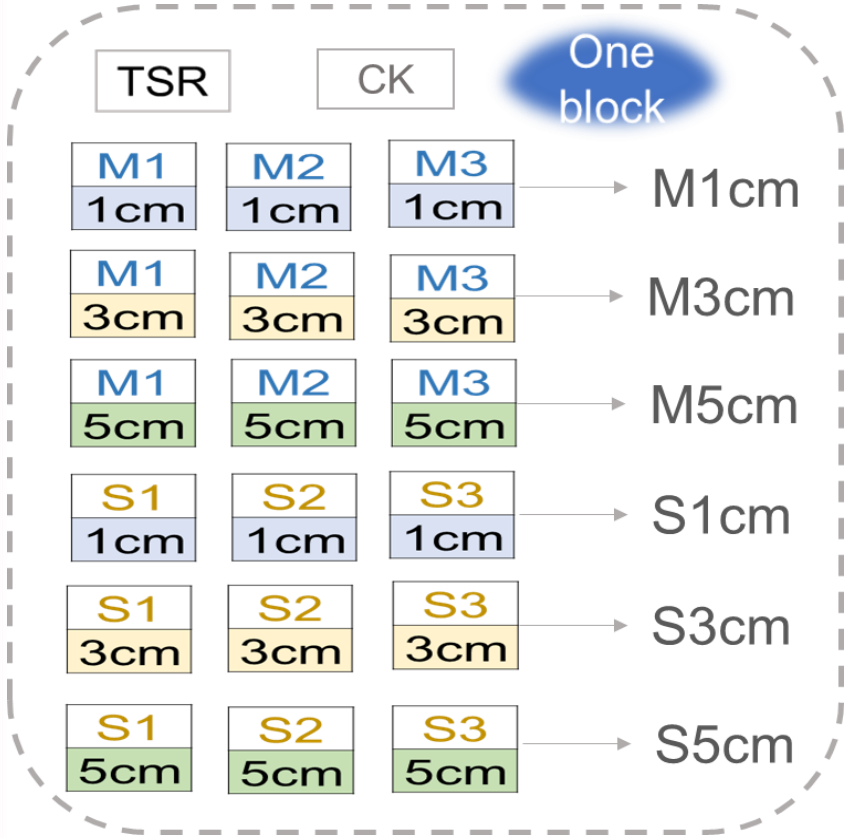
- Inoculation with upland meadow soil will lead to a better restoration (higher EMF) than meadow steppe through higher biodiversity in forest-steppe ecotone.

- The restoration of soil inoculation will be accelerated with increasing amounts of donor soil used to inoculate the field plots through higher biodiversity.

Experiment design







- 2 soil types(Meadow steppe-S, upland meadow-M); 3 replicates sites;
- 3 inoculum amounts (1 cm, 3 cm and 5 cm);
- 1 TSR (top soil removal and no inoculation);1 CK (no top soil removal and inoculation);
- 3 blocks (block1,block2,block3);
- A total of 60 plots were established in three blocks.

Analysis

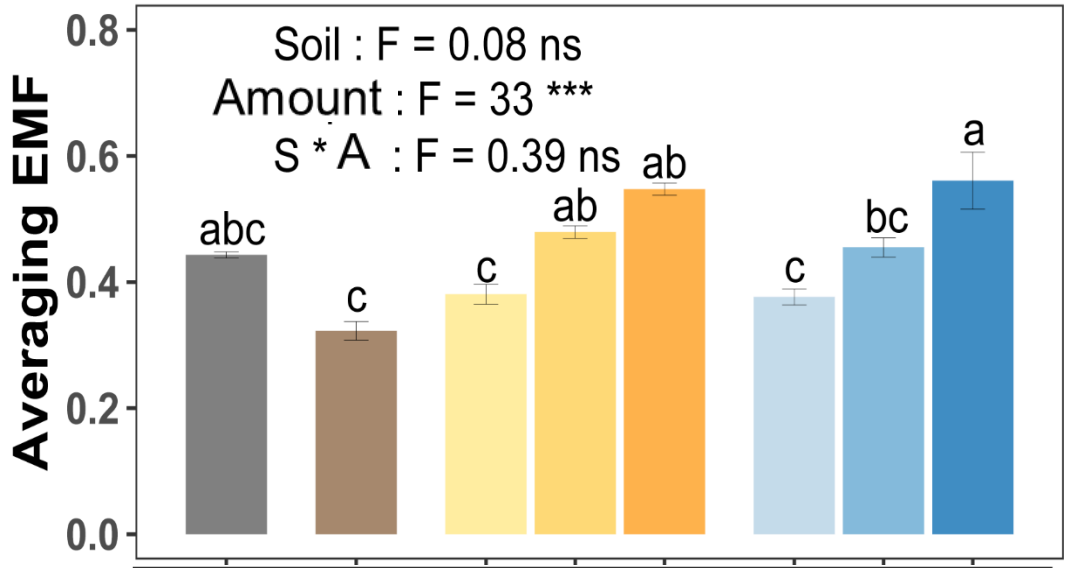
The indicators of ecosystem multifunctionality (EMF)

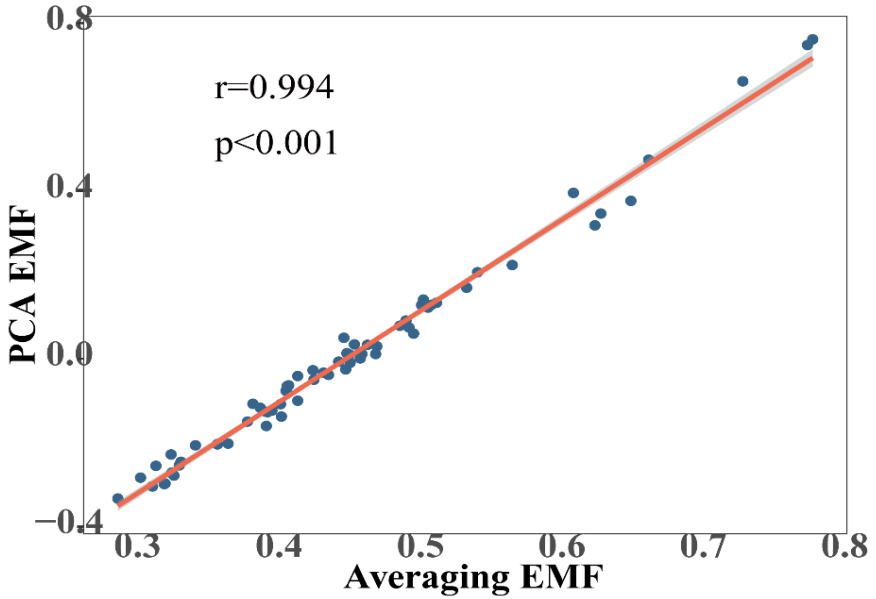
Indicators	Functions	Functional categories
Aboveground biomass **Root biomass**	Biomass of grass	Primary production
Soil organic carbon **Soil dissolved organic carbon**	Soil carbon storage capacity	Carbon cycling
Microbial biomass carbon	Microbial activity	
Soil respiration	Microbial activity	
Soil β-1,4-glucosidase	Enzyme activities	
Soil total nitrogen	Soil nitrogen storage capacity	Nitrogen cycling
Microbial biomass nitrogen	Microbial activity	
Nmin	Nitrogen cycling	
β-1,4-N-acetylglucosaminidase	Enzyme activities	
Soil total phosphorus **Soil available phosphorus**	Soil phosphorus storage capacity	Phosphorus cycling
Acid phosphatase	Enzyme activities	

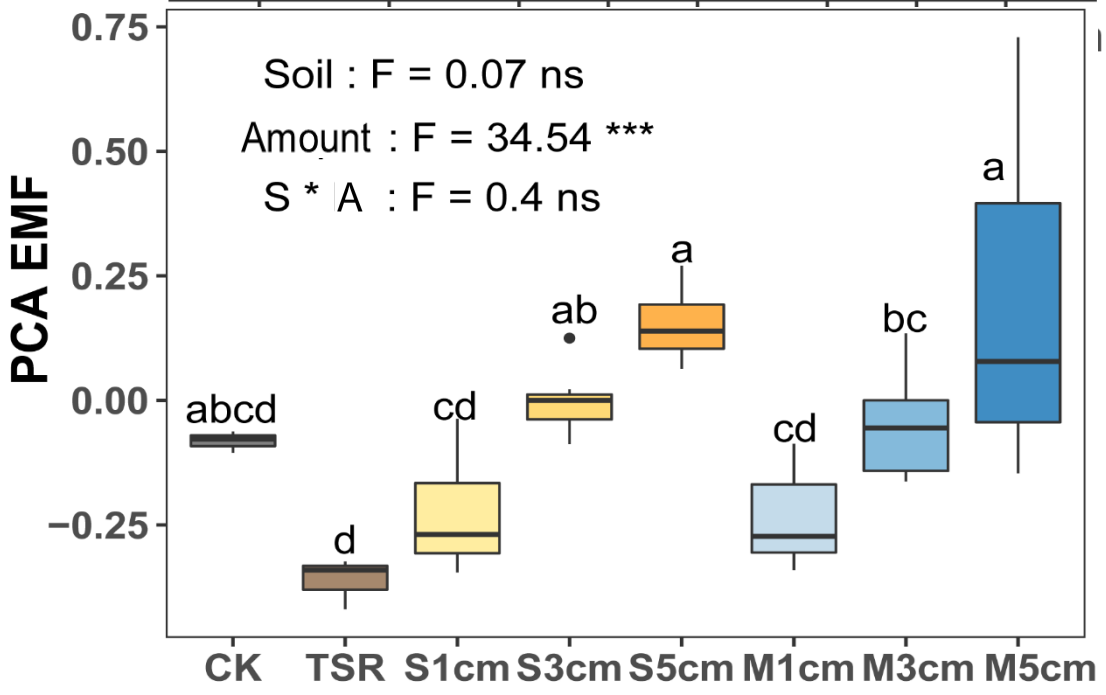
- ✓ **Normalized methods**: f(x) = [x − min(x)]/[max(x) − min(x)]
- ✓ **Averaging EMF**: $EMF = \frac{1}{N}\sum_{i}^{N} S_i$ (Byrnes et al., 2014 *MEE*) .
- ✓ **Multidimensional (PCA) EMF**: Use PCA analysis and calculate the composite score (Wagg et al., 2019 *NC*).

Analysis

Changes of Ecosystem multifunctionality





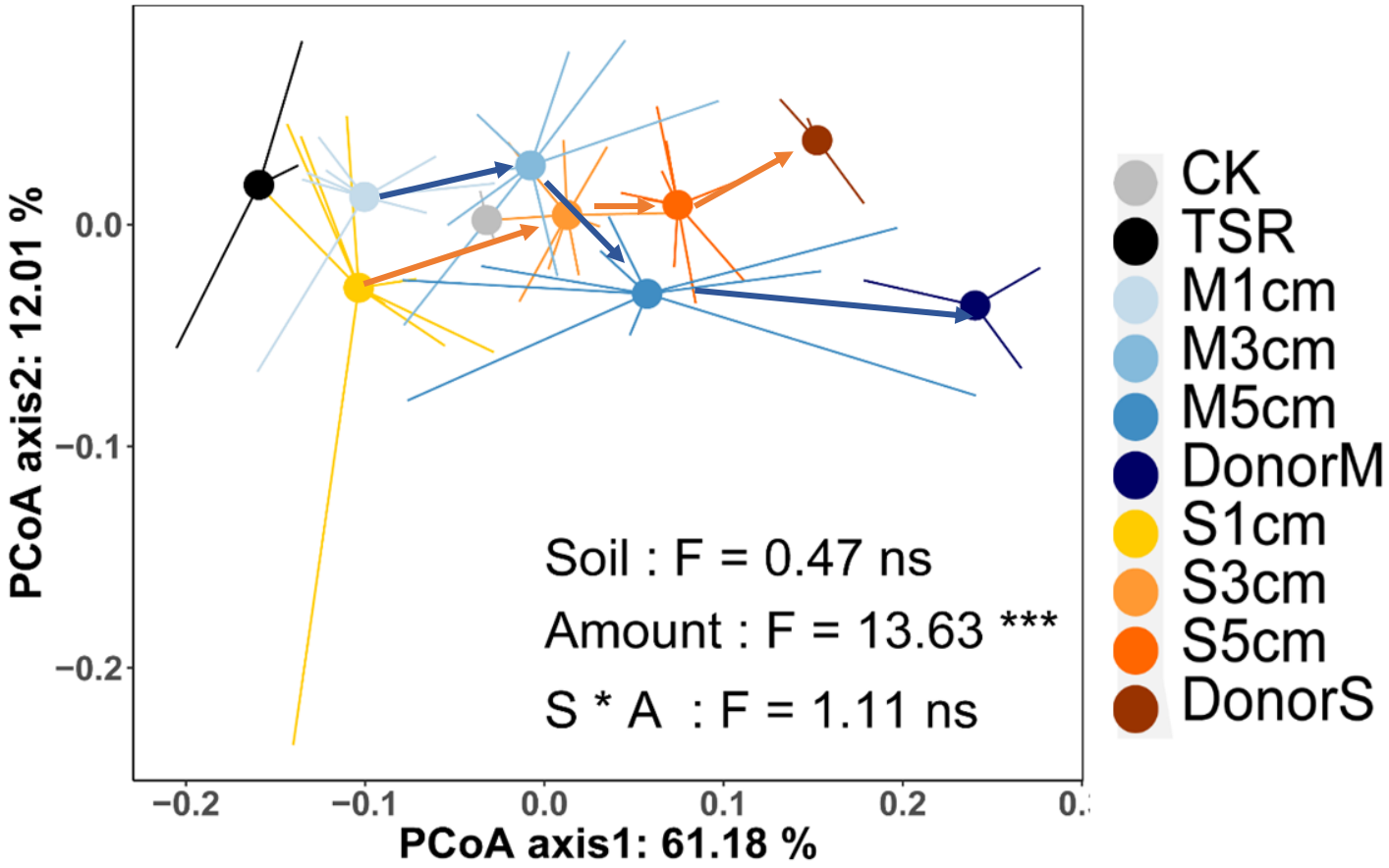


✓ Use averaging EMF in next analysis.

Analysis

Changes of ecosystem functions composition

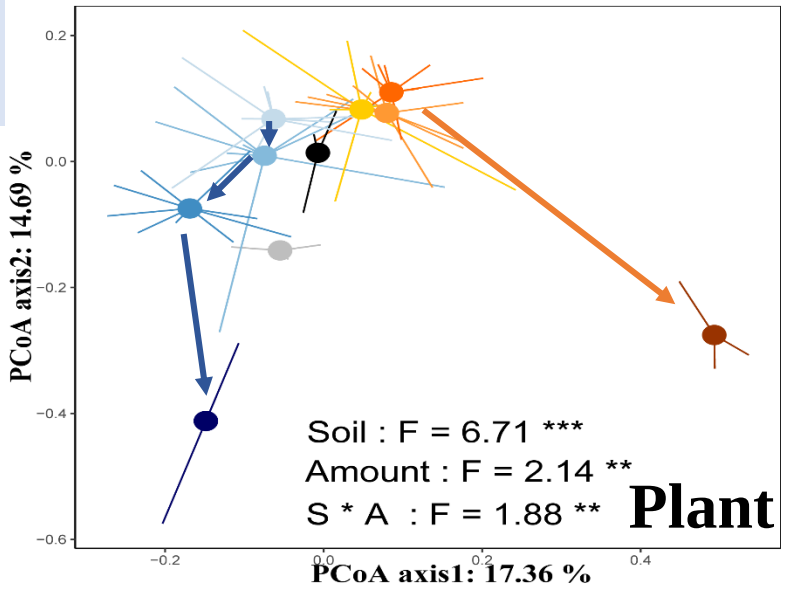
Principle coordinates analysis (PCoA)

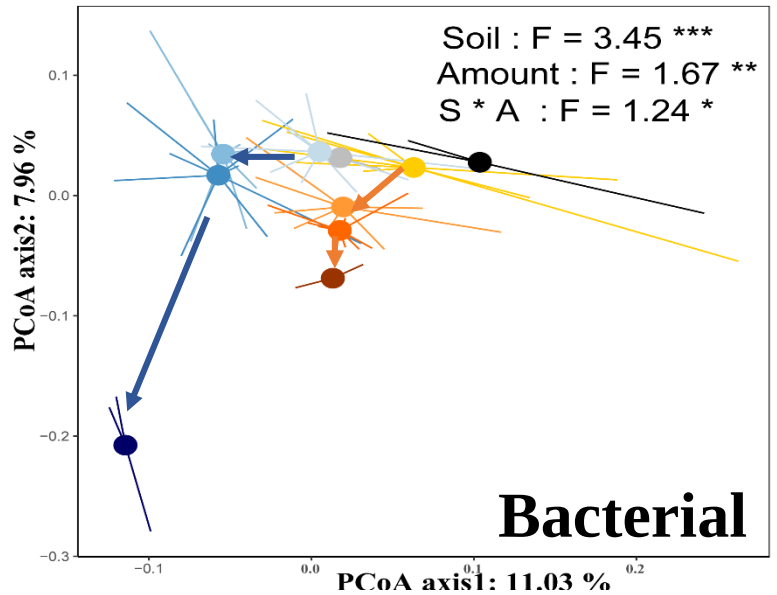


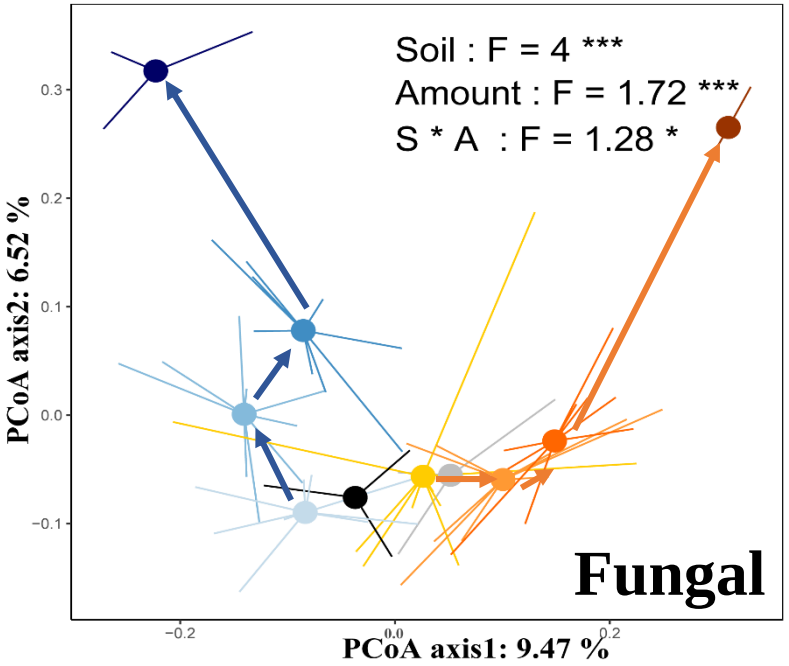
Analysis

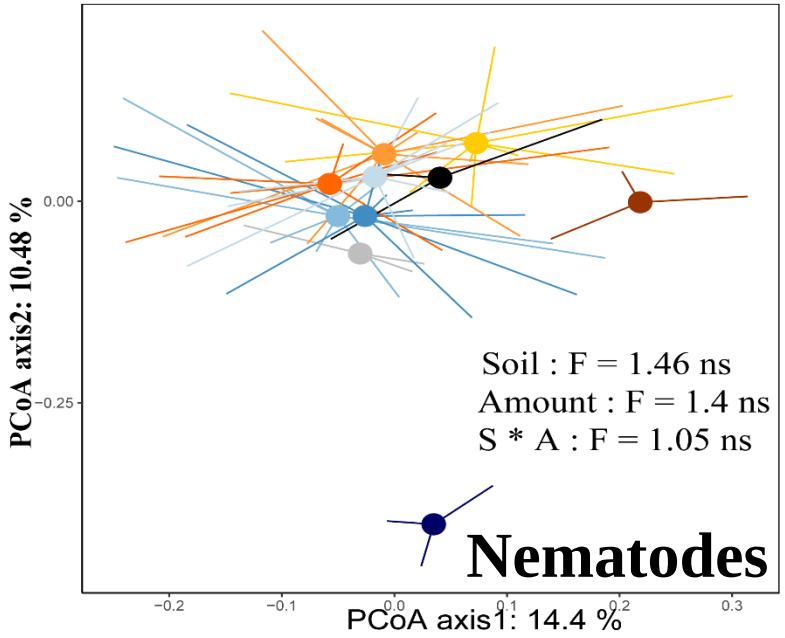
Principle coordinates analysis (PCoA)

Changes of bio-community composition





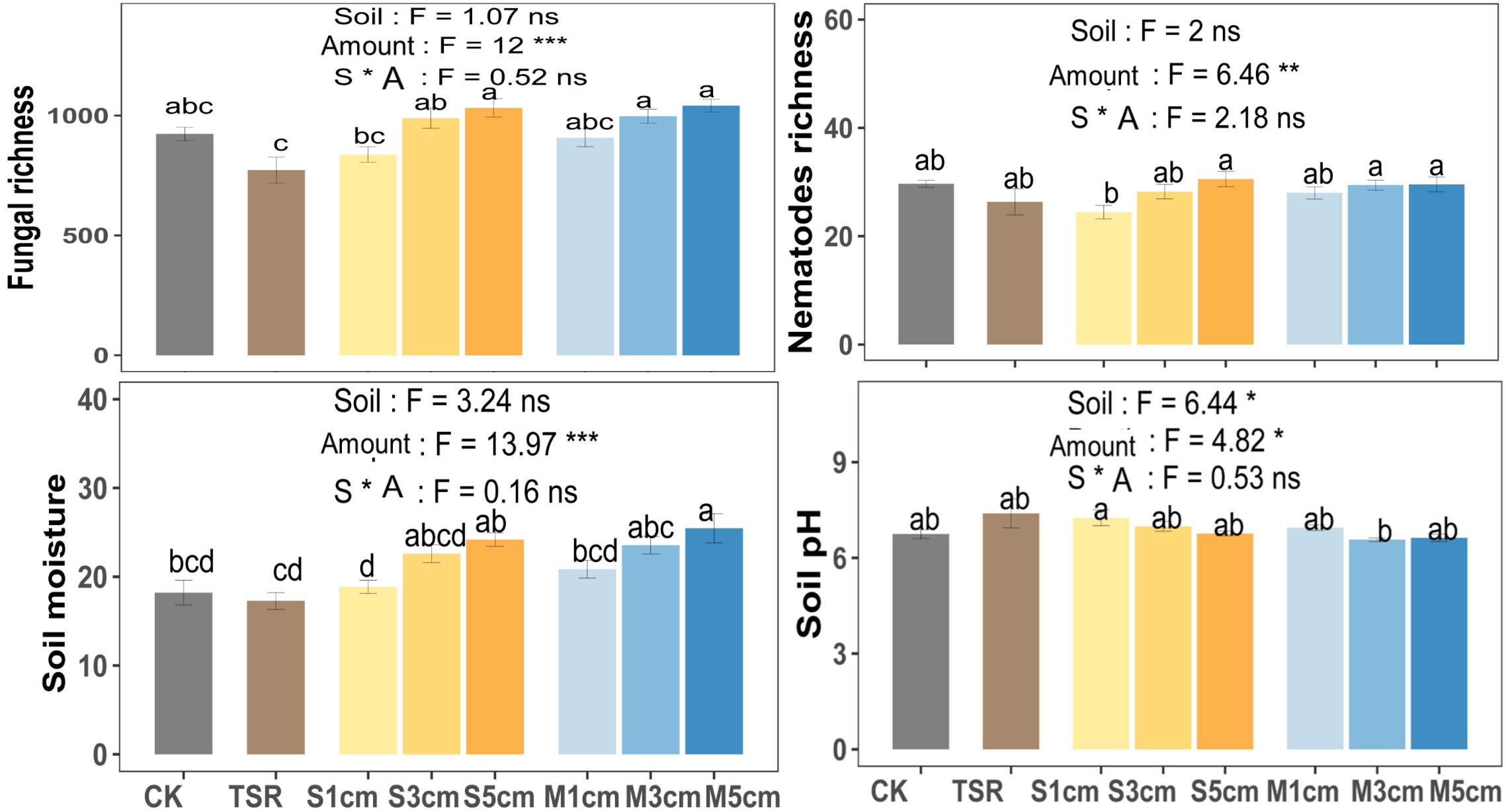




CK
TSR
M1cm
M3cm
M5cm
DonorM
S1cm
S3cm
S5cm
DonorS

Analysis

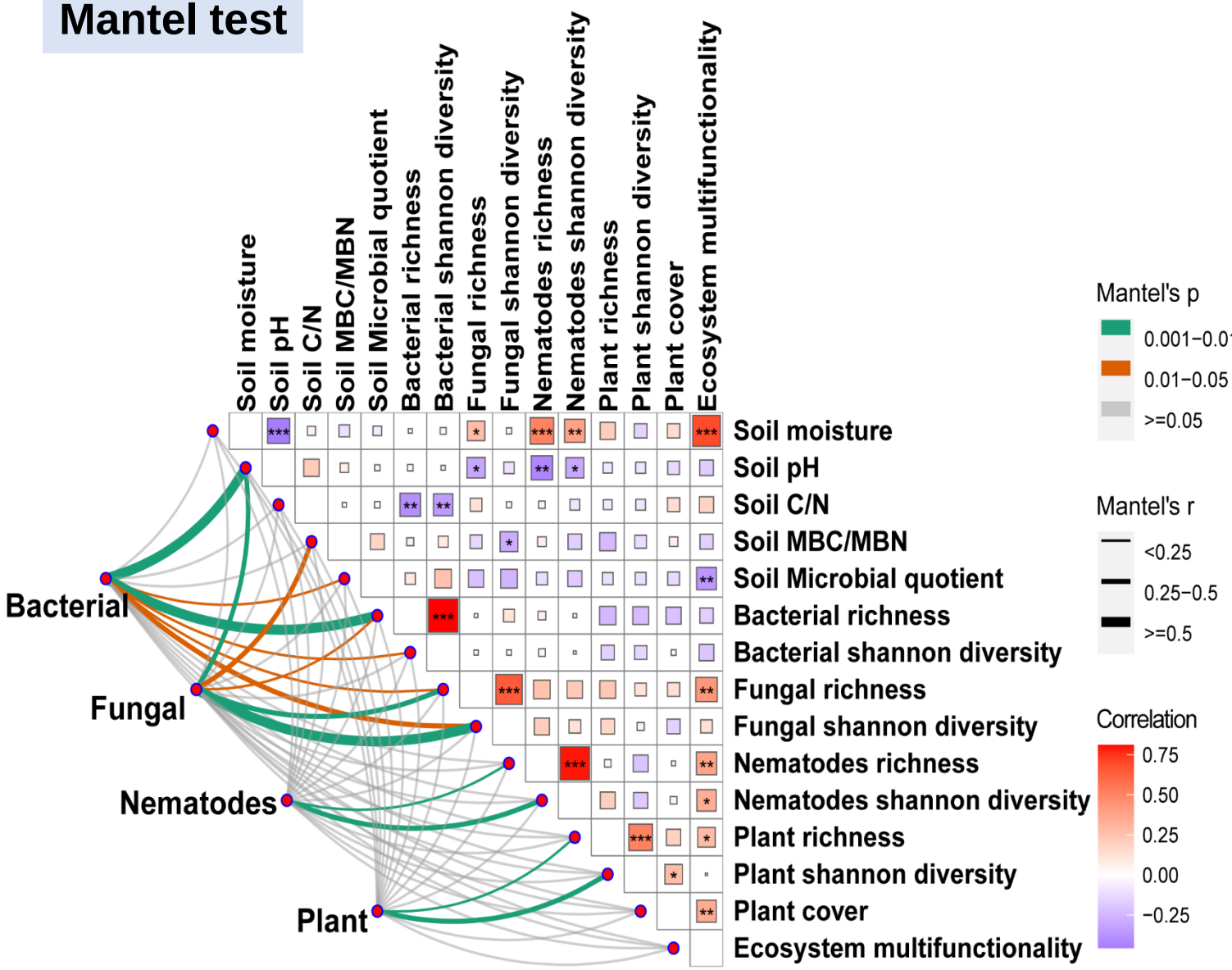
Biotic and abiotic factors significantly affected by soil transplantation



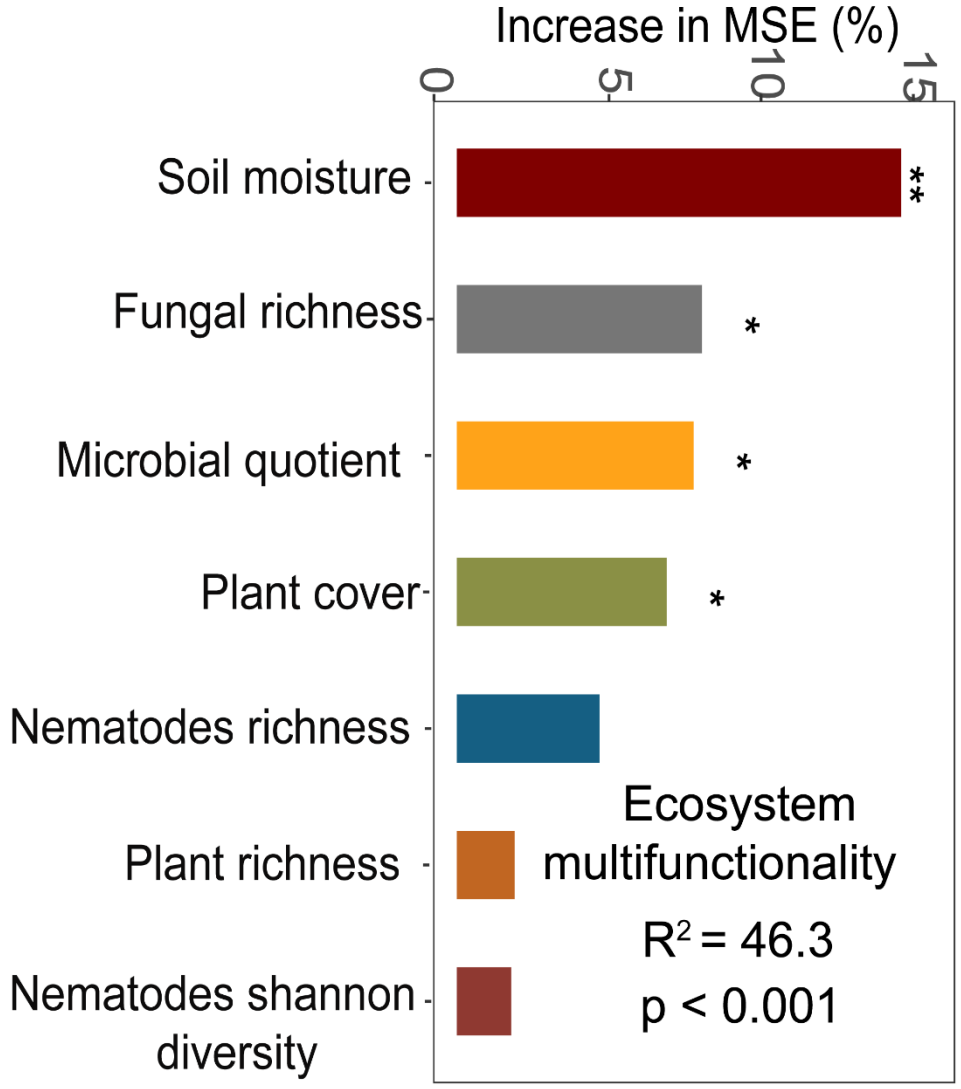
Analysis

Effect of abiotic and biotic factors on ecosystem multifunctionality

Mantel test



Random forest model



Summary

- Inoculation with soil communities that originate from different donor grasslands steers soil microbiomes as well as plant communities of the inoculated degraded grassland site into different directions.

- The changes in the soil and plant communities and the similarity to the donor sites increased with the amount of inoculum used.

- Soil inoculation can promote restoration of degraded ecosystems and the direction the ecosystem develops after inoculation depend on the amount of inoculum.

- Soil moisture, fungal richness, microbial quotient and plant cover are main factors influence the ecosystem multifunctionality.

Acknowledgments

Thanks for your attention!

Han *et al. Ecological Processes* (2020) 9:63
https://doi.org/10.1186/s13717-020-00256-3

Ecological Processes

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Effect of grassland degradation on soil quality and soil biotic community in a semi-arid temperate steppe

Xu Han[1,2†], Yuhui Li[1,2†], Xiaofang Du[1,2], Yingbin Li[1], Zhengwen Wang[1], Siwei Jiang[1] and Qi Li[1*]