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Modelling earthworm ecological category distribution reveals their habitat, land-use and environmental preferences.

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Background

- Growing interest in “green agriculture”
- Lack of understanding, how earthworms can contribute to soil fertility recovery across different land use practices
- Integrating “abiotic” and “biotic” soil sciences

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Species ecology considered: 18 modeled earthworm species and ecological categories across Germany

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EPIGEIC=6

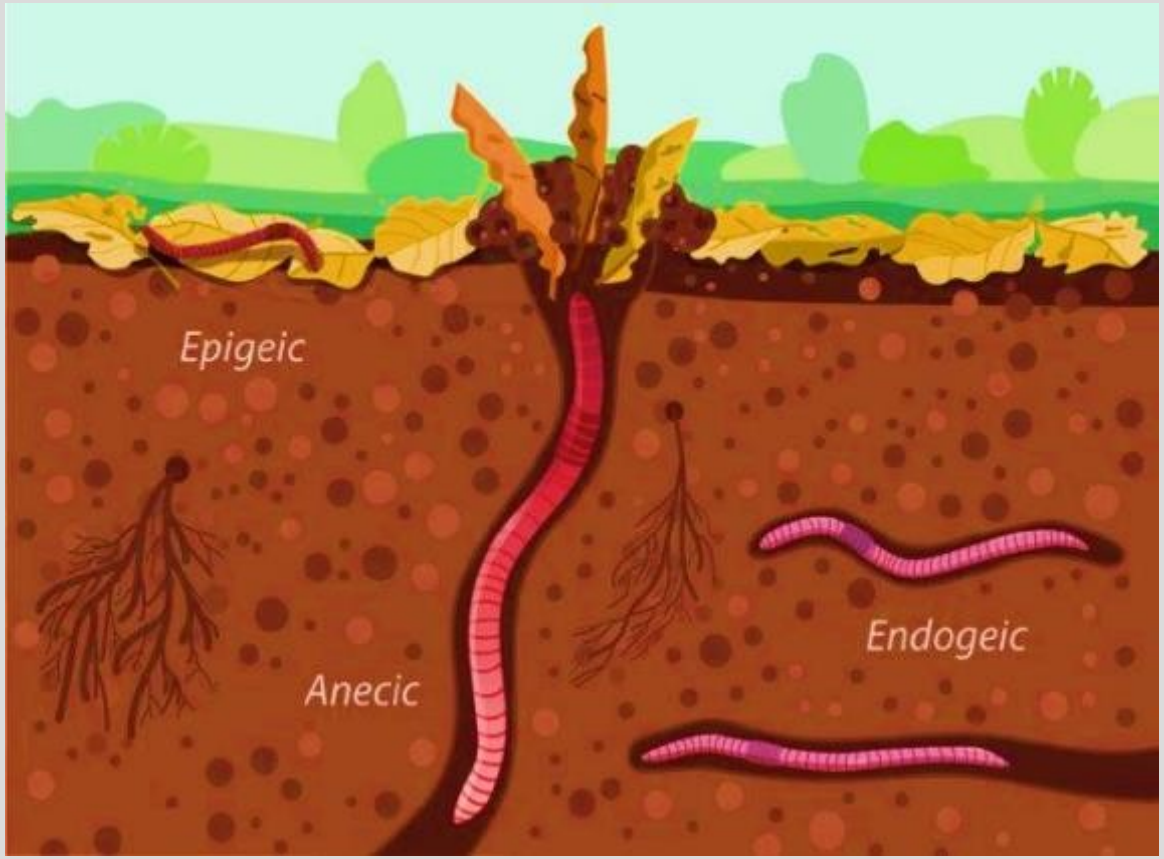
- Lumbricus castaneus (Savigny, 1826)
- Lumbricus rubellus Hoffmeister, 1843
- Dendrobaena attemsi (Michaelsen, 1903)
- Dendrobaena octaedra (Savigny, 1826)
- Dendrodrilus rubidus (Savigny, 1826)
- Eiseniella tetraedra (Savigny, 1826)

ENDOGEIC=9

- Aporrectodea caliginosa (Savigny, 1826)
- Aporrectodea rosea (Savigny, 1826)
- Octolasion tyrtaeum (Savigny, 1826)
- Allolobophora chlorotica (Savigny, 1826)
- Aporrectodea icterica (Savigny, 1826)
- Octolasion cyaneum (Savigny, 1826)
- Aporrectodea handlirschi (Rosa, 1897)
- Aporrectodea limicola (Michaelsen, 1890)
- Proctodrilus antipae (Michaelsen, 1891)

ANECIC/Epi-anecic=3

- **Aporrectodea longa (Ude, 1885)**
- **Lumbricus terrestris (Linnaeus, 1758)**
- Lumbricus polyphemus (Fitzinger, 1833)
- Lumbricus badensis Michaelsen, 1907



Research by Gabriel Salako

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WorkFlow & Automation

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edaphobase

1. Biological data

Filter and downlaoad 18 selected species data

Extract in to ecological group: Endogeic, Anecic & epianecic & Epigeic

Source: Edaphobase > 20,000 occ. data & > 1000 sites

2. Environmental data

Collect and extract environmental data

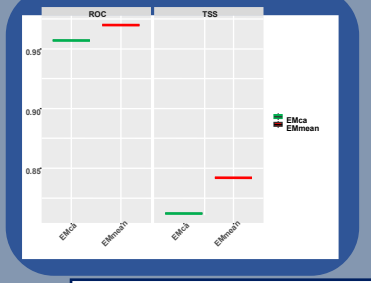
Climate, soil variables & habitat/land-use
Source: multiple

3. Model fitting (ML)

Model Fitting ML Algorithms= (Ensemble, RF, SEM, JSDM)
Model = species data ~climate + soil + habitat

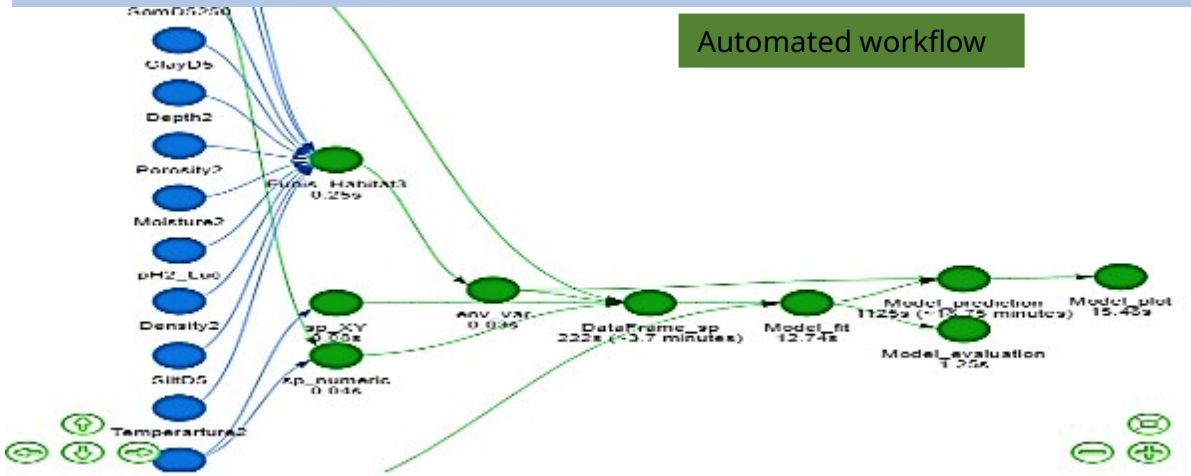
Fitted species-specific / community model

4. Model Evaluation

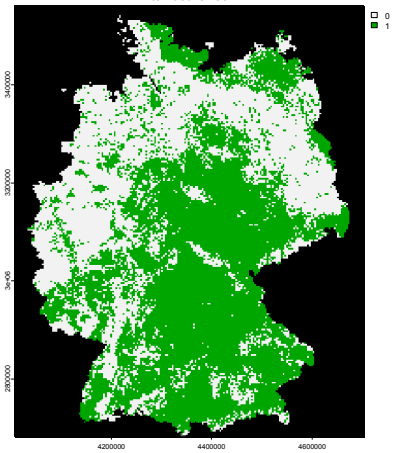


Ensemble committee average/mean: AUC/ROC, TSS

Automated workflow



5. Binary Prediction



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Predicted earthworm species & their spatial distribution histograms

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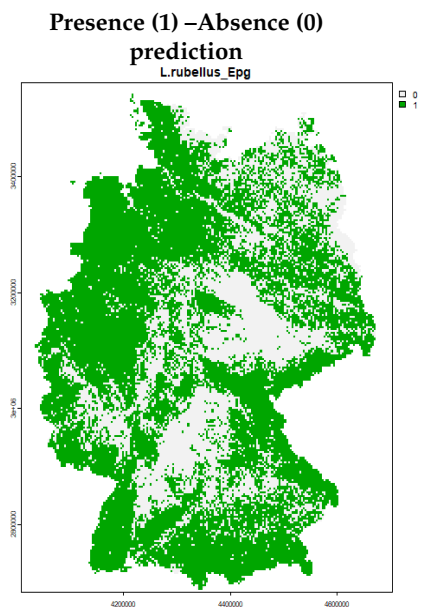
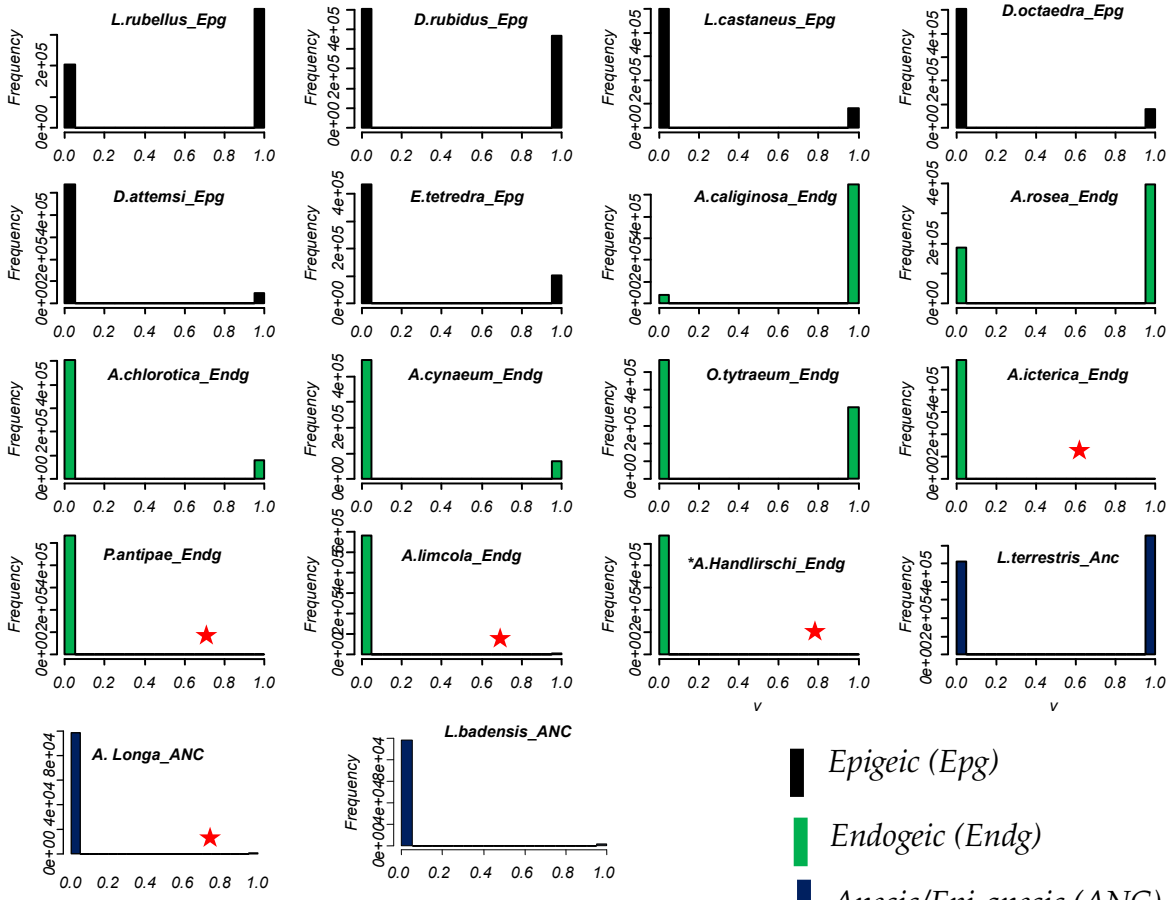


Conservation Implications

Very useful for Identification of:
- rare or geographically restricted (red star) and
- large range/generalist species



★ ***Rare or geographic restricted species***

Epigeic (Epg)

Endogeic (Endg)

Anecic/Epi-anecic (ANC)

Salako et al; 2023
https://doi.org/10.1007/s10531-023-02608-9

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Earthworm species` distribution in habitat types

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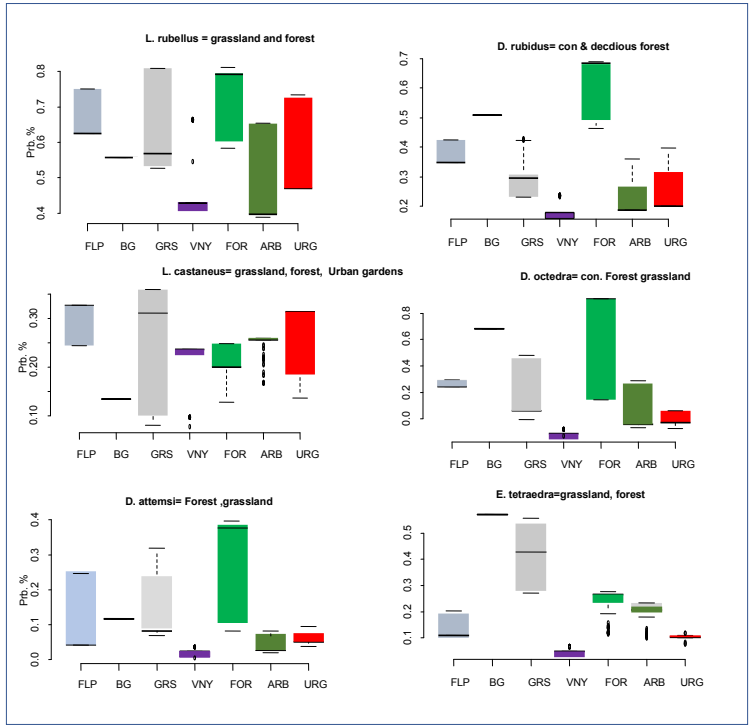
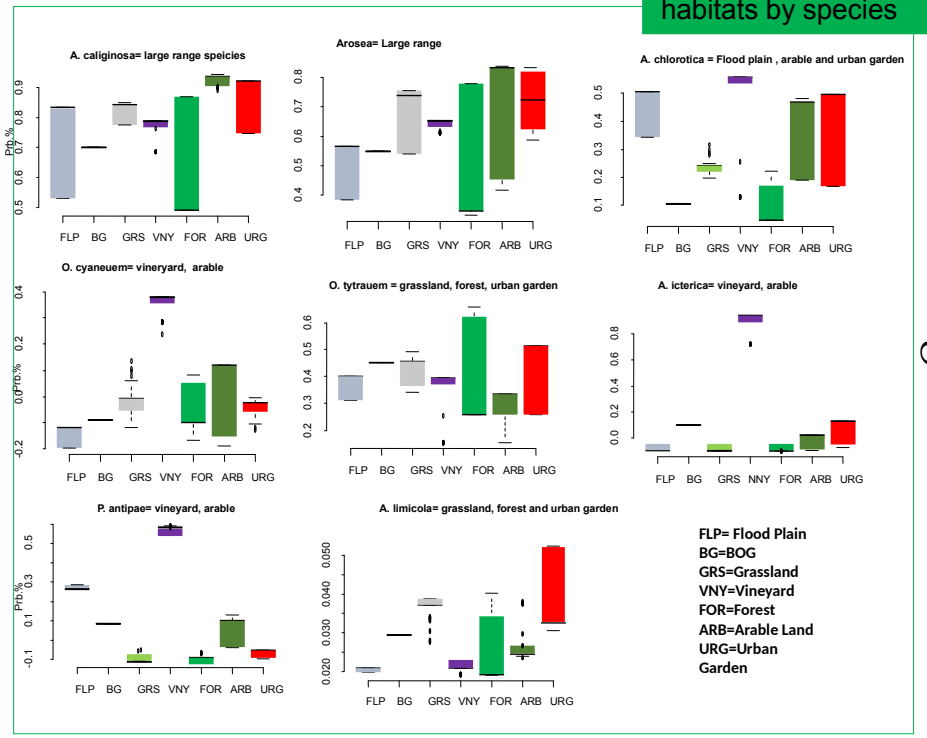
Conservation Implication:

Identification of suitable and prefered habitats by species

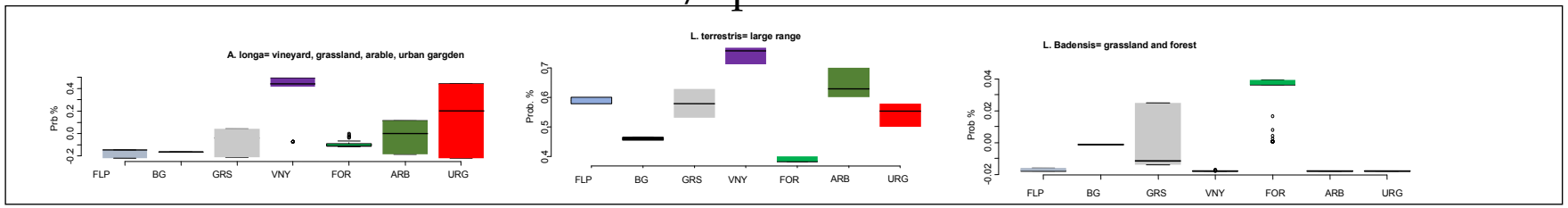
Epigeic



Endogeic



Anecic/Epi-aneicic



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Spatial Prediction of Community Biodiversity : Richness and Density

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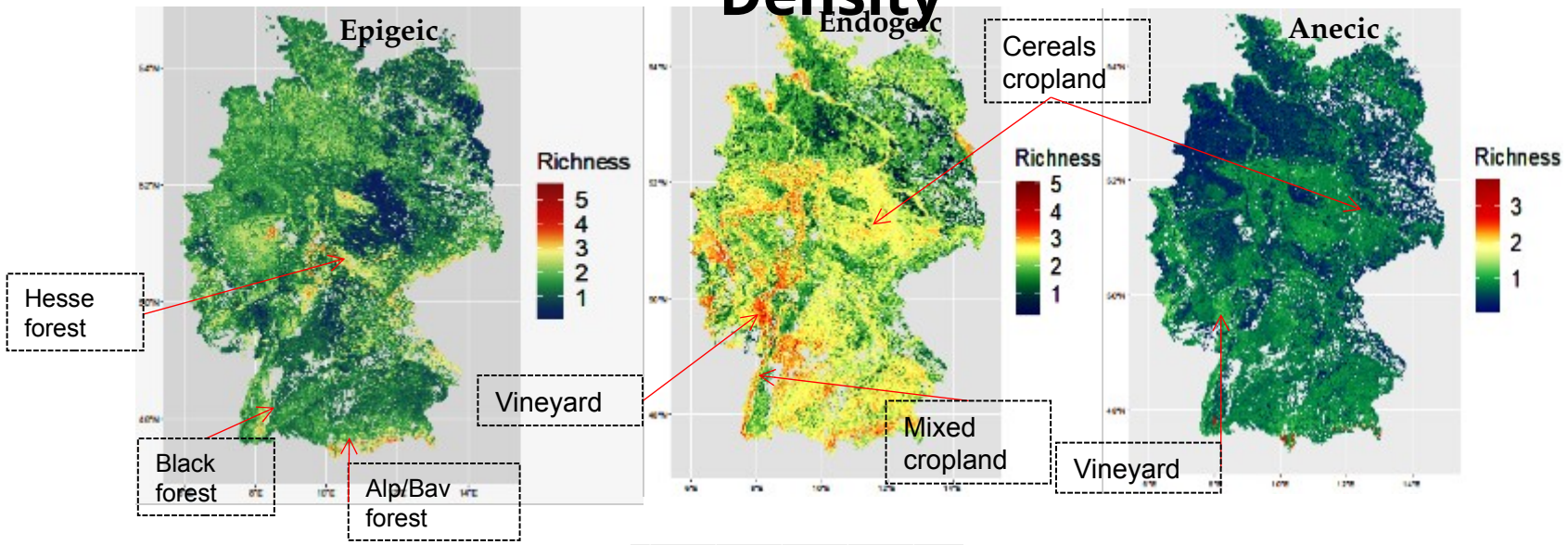

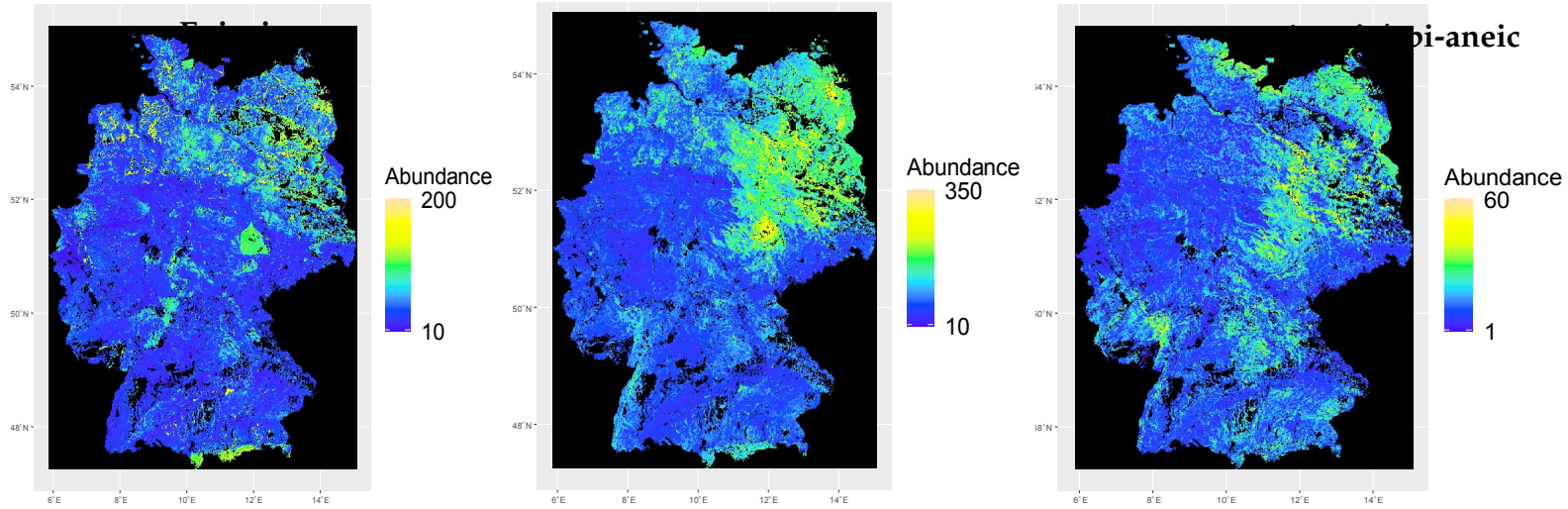

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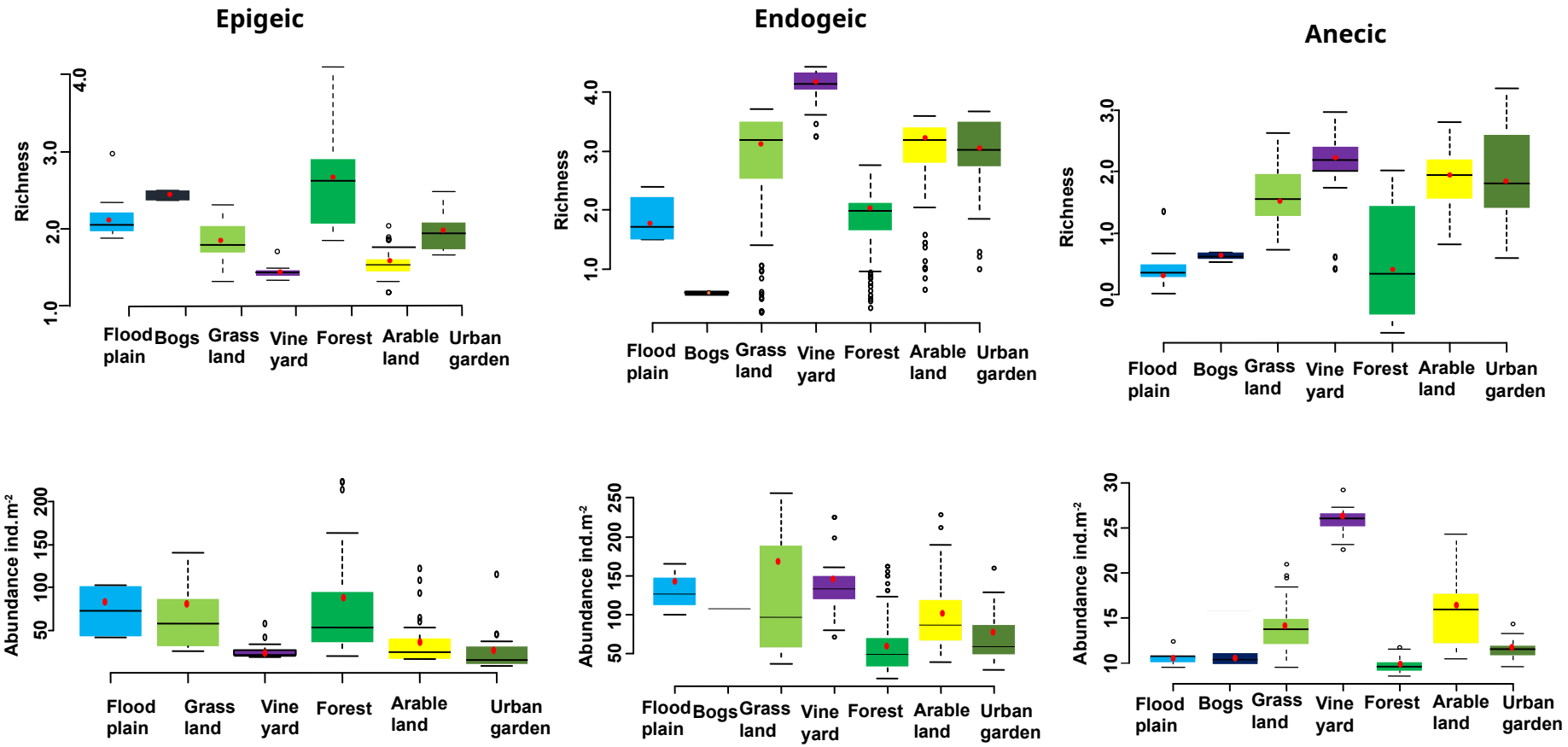
Community Biodiversity : Richness and Density in Habitat Types



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Which Habitats are different from others?

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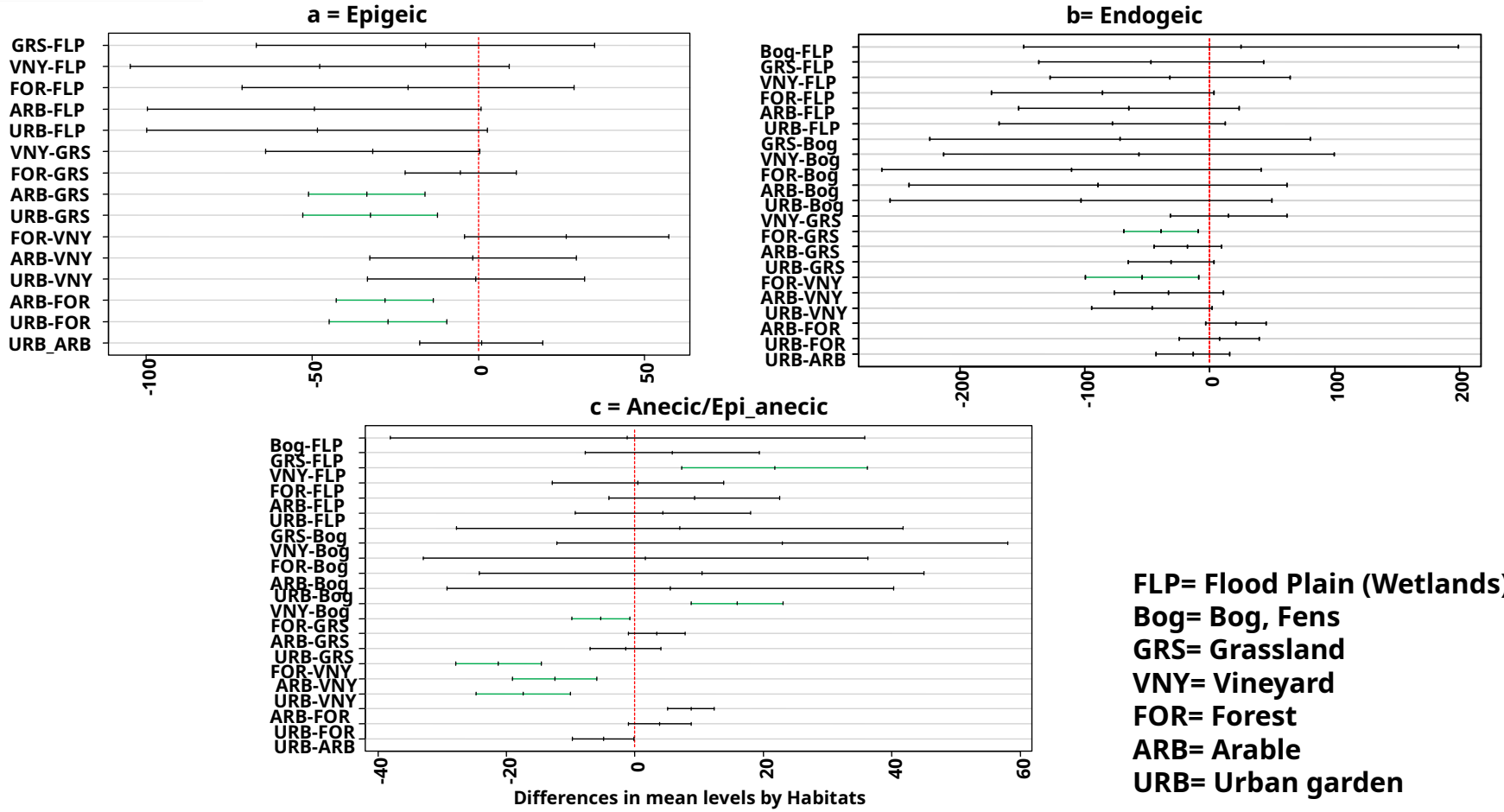

FLP= Flood Plain (Wetlands)
Bog= Bog, Fens
GRS= Grassland
VNY= Vineyard
FOR= Forest
ARB= Arable
URB= Urban garden

Green horizontal lines are statistically significant at 95% confidence level

a =Significant differences are predicted between forest on one hand, and arable and urban garden on the other
b = Significant difference are predicted between forest and grassland
c = Significant differences are predicted between mainly between vineyard on one hand, and forest, arable and grassland on the other hand
Flood plain and Bogs in comparisons to other habitats are predicted to have high variability or wide range (long horizontal lines) but not statistically significant

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Responses to environmental gradients: Anecics & Endogeics

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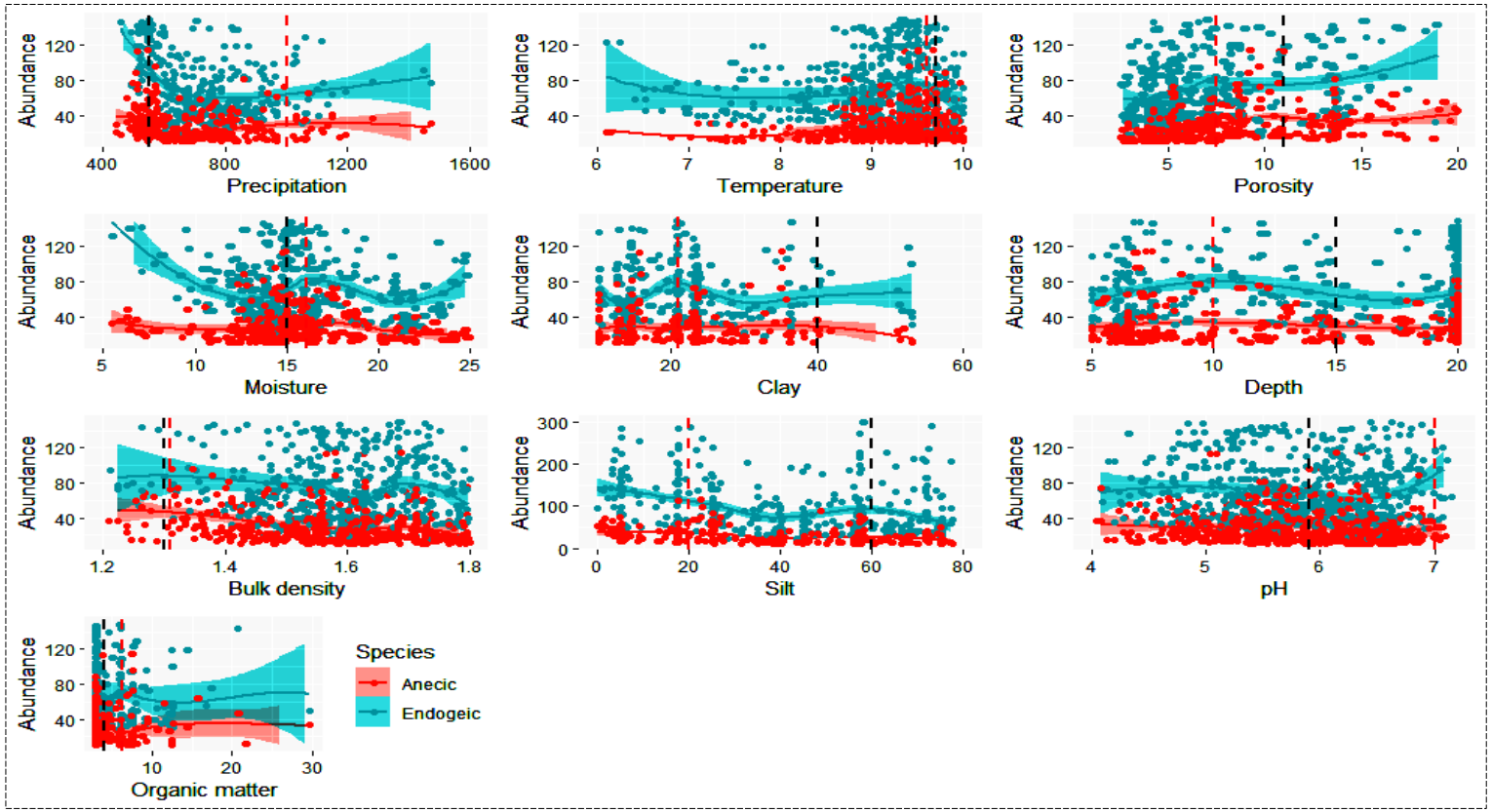

Partial dependence and scatter plot of predicted mean abundance of anecic (red) and endogeic (blue), dotted lines are optimum along environmental gradient, y-axis =model fitted values of abundance (ind.m^{-2}), x-axis=environmental variable. Partial dependence plot was based on (RF) regression model.

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Densities along environmental gradients

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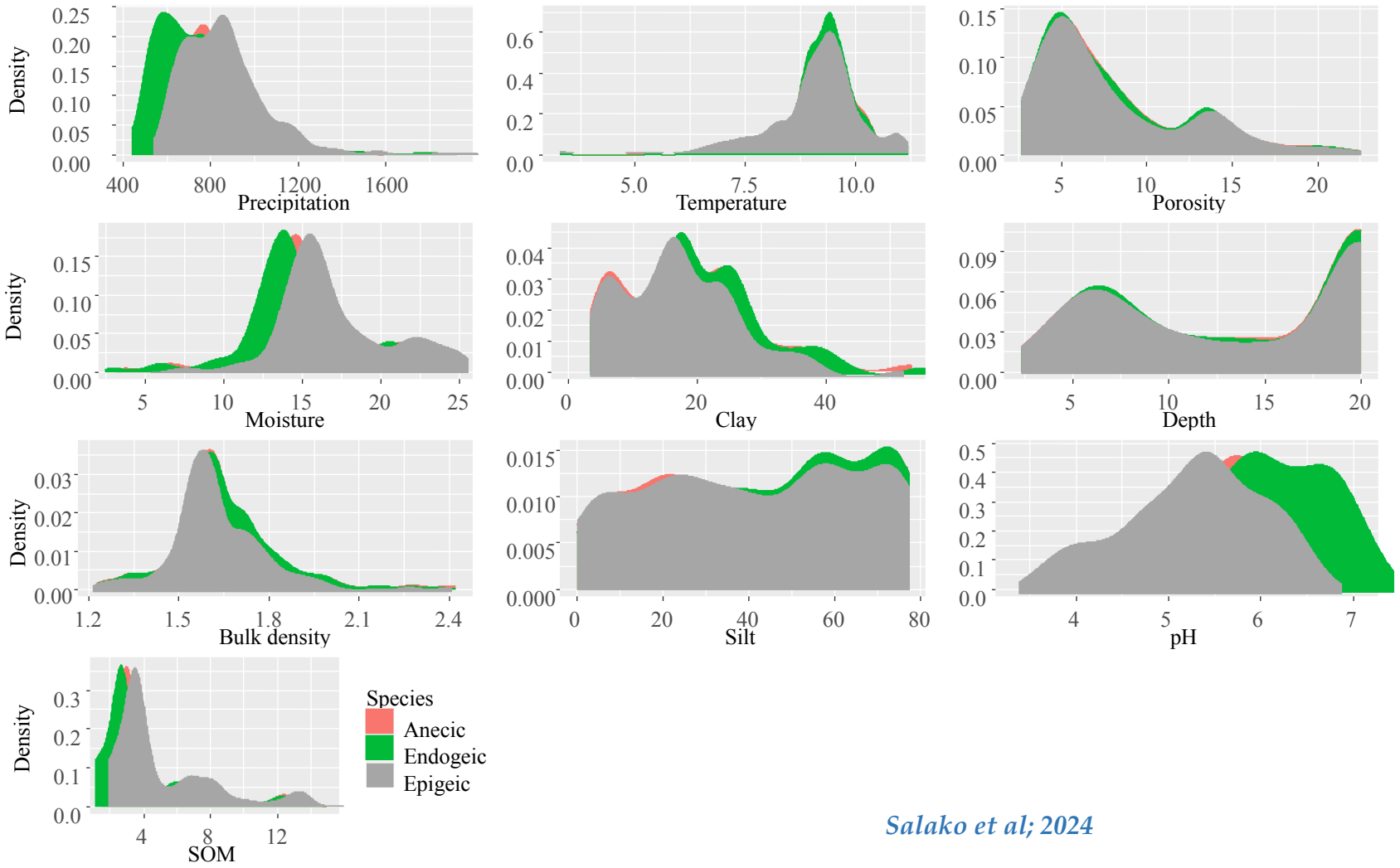

Salako et al; 2024

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Earthworm biodiversity information and optimum ranges

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S/N0	Type	Epigeic	Endogeic	Anecic/epi-anecic	Remarks
1	Dominant spp. composition	D. rubidus, D. octaedra, L.rubellus	A. caliginosa, A. chlorotica, A. rosea	L.terrestris A.longa	These species constitute >70% of relative density for their respective categories
2	Average spp. Richness (number)	2.0	3.5	1.2	
3	Average density (ind/m^{-2})	30- 80	120-150	5-30	Average density varies by habitat
4	Preferred Habitat	Forest, grassland & floodplain	Arable, vineyard & grassland	Grassland , vine yard and arable	Habitat approximately in order of preferences
		*Earthworm density optimum ranges			
5	Total annual precipitation (mm)	800-1000	500-800	500-600	Epigeic require higher amount of precipitation. The minimum threshold of precipitation for all categories=400 mm
6	Temperature (°c)	9.8-10	9.5-10	9.5-10	
7	Porosity (%)	5-10	5.0-20	10-20	Endogeic response much positively to increase soil porosity
8	Soil Moisture (%)	10-15	5.0-15	15-20	Epigeic require relatively more moisture contents than endogeic
9	Clay contents (%)	10-20	5.0-20	20-40	Both endogeic and anecic respond to higher clay contents
10	Silt contents (%)	20	20-40	60-65	
11	Soil Depth (cm)	0-5.0	5.0-15	15-20	Anecic density is high at deeper soil depth
12	Bulk density (g/cm3)	1.4-1.6	1.4-1.7	1.4-1.6	Bulk density > 1.6 decease earthworm density
13	pH ranges	3.5-5.5	5-7.0	5.5-6.5	Epigeic species could tolerate pH of < 4.5
14	SOM ranges (%)	3-5	2.5-3.0	2.5-3.0	Endogeic are found in

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Perspectives

Refine exploration of complex species–environment interactions using structural equation model (SEM)

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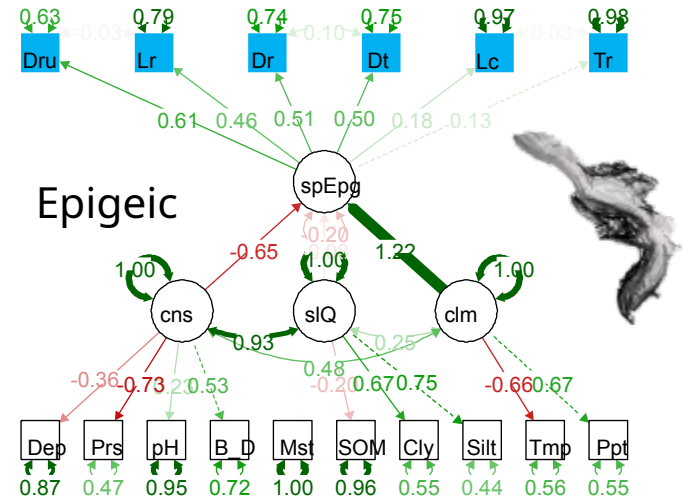
EPIGEIC
Tr=E. tetraedra
Lc= Lcastaneus
Dt= D. attemsi
Dr = D. octaedra
Lr= L. rubellus
Dru= D.rubidus

ENDOGEIC
Otn=O. tytrauem
Ict=A. Icterica
Pa=P. antipae
Acl=A.caliginosa
Acr= A.chlorotica
Ar= A. Rosea
Ah= A. handiirichi
Alm= A. limicola
Oc= O.cyaneum

ANECIC/EPI-ANECIC
Al= A.longa
Bd= L.badensis
Ltr= L.terrestris

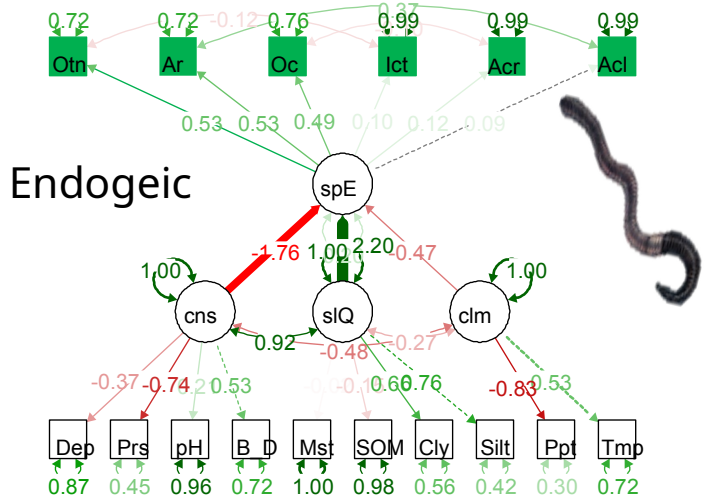
Climate (ppt) has higher predictive influence and causal effect on epigeic

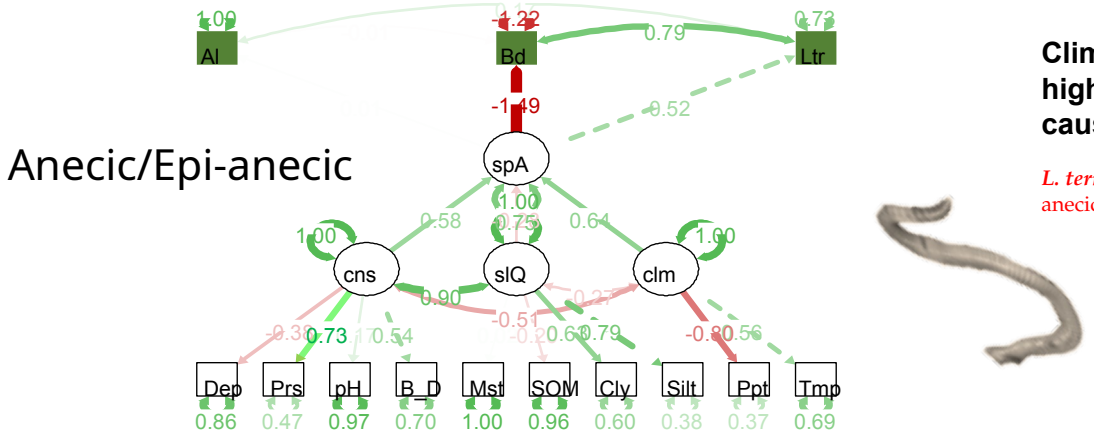
D. octaedra L. rubellus **D. *rubidus* are predictive of epigeic**



Soil quality (clay and silt) have greater predictive influence and causal effect on endogeic

***A. rosea, o.* tytrauem *and* O. cyaneum are the strong** contributors to the prediction of Endogeic survival surprisingly *A. Caliginosa* interestingly was low





Climate (temp) and constraints have higher predictive influence and causal effect on anecic/epianecic

L. terrestris is predictive of Anecic/epi-anecic category

Thank you!