Dynamique du microbiome des sols tropicaux en réponse à des apports de produits résiduaires organiques

cirad

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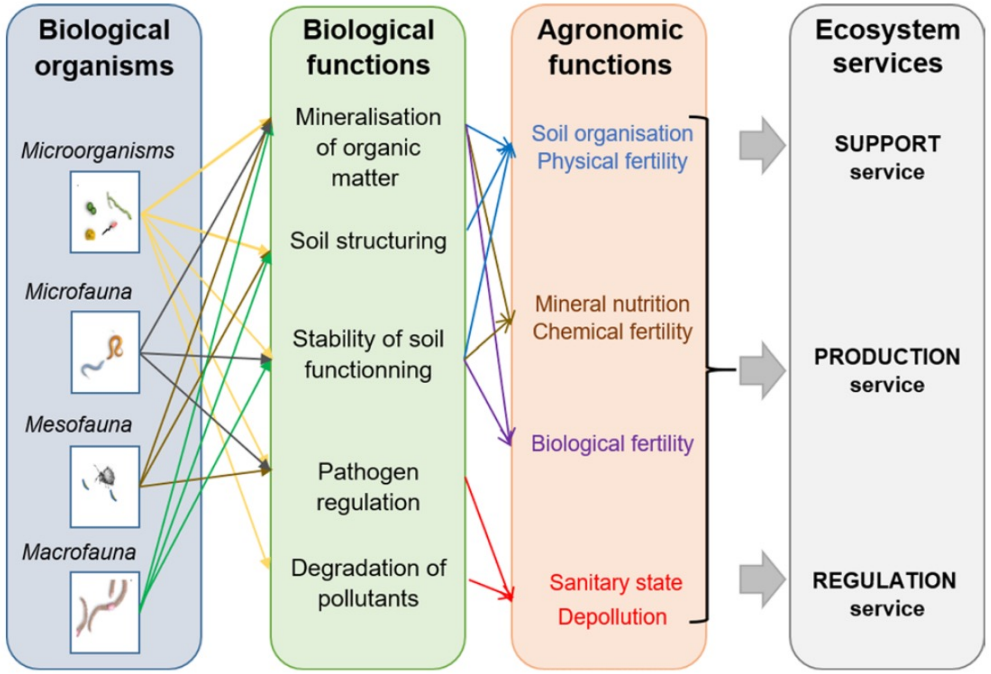
Intensification Ecologique des Sols Cultivés en Afrique de l'Ouest

Recyclage des PRO en agriculture – impacts sur les organismes du sol ?

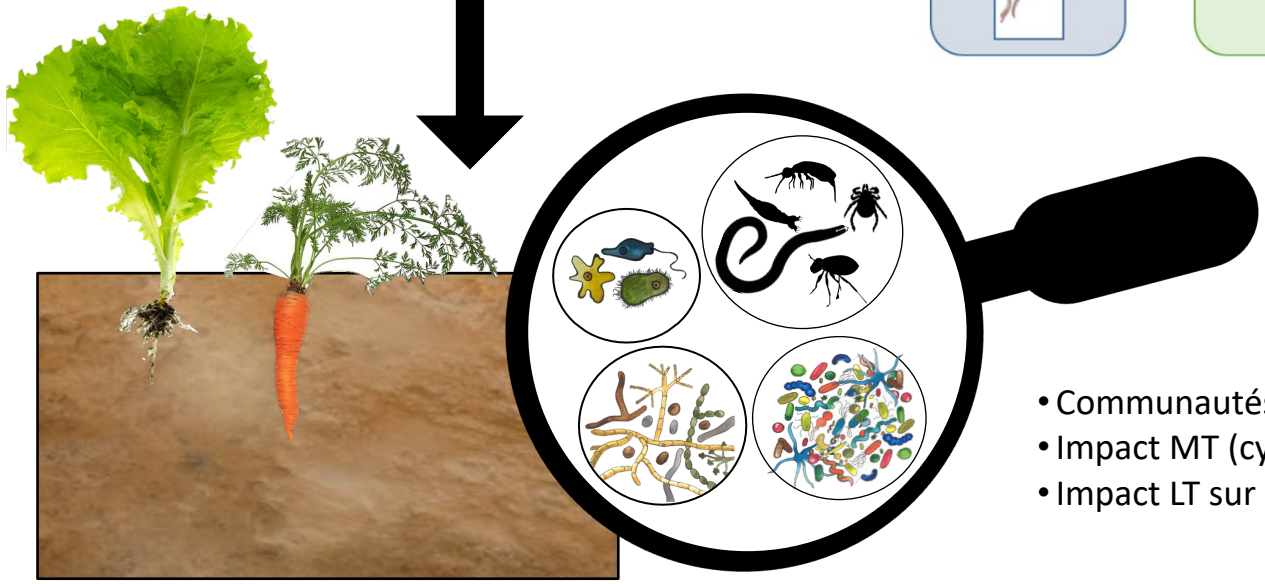
Boues de station d'épuration

Digestat de méthanisation

Litières de volaille

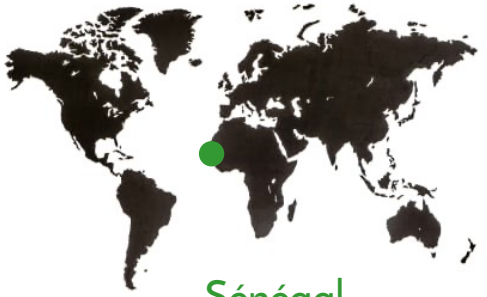


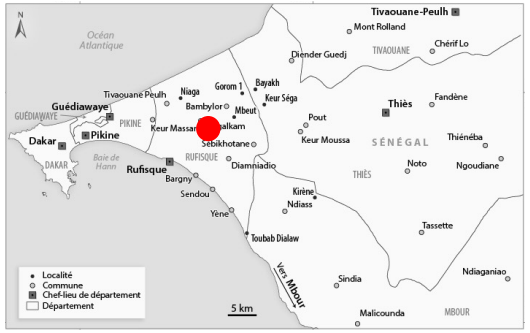
Christel et al., 2021, Envi. Chem. Letters



- Communautés des PRO et impact CT ?
- Impact MT (cycle de culture/saison) ?
- Impact LT sur les communautés du sol ?

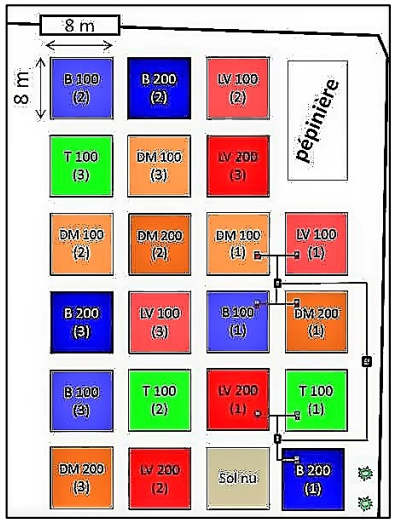
Activités réalisées





Site expérimental SOEREO PRO Sangalkam (depuis 2016)

- **4 traitements échantillonnés :**
  - **Témoin (M)** – fertilisation minérale (10:10:20 N:P:K)
  - **Boues de STEP méthanisées (SS)**
  - **Digestat de méthanisation de bouse de vache (D)**
  - **Litières de volailles (PL)**
- **Maraichage (tomates, laitues carottes)**



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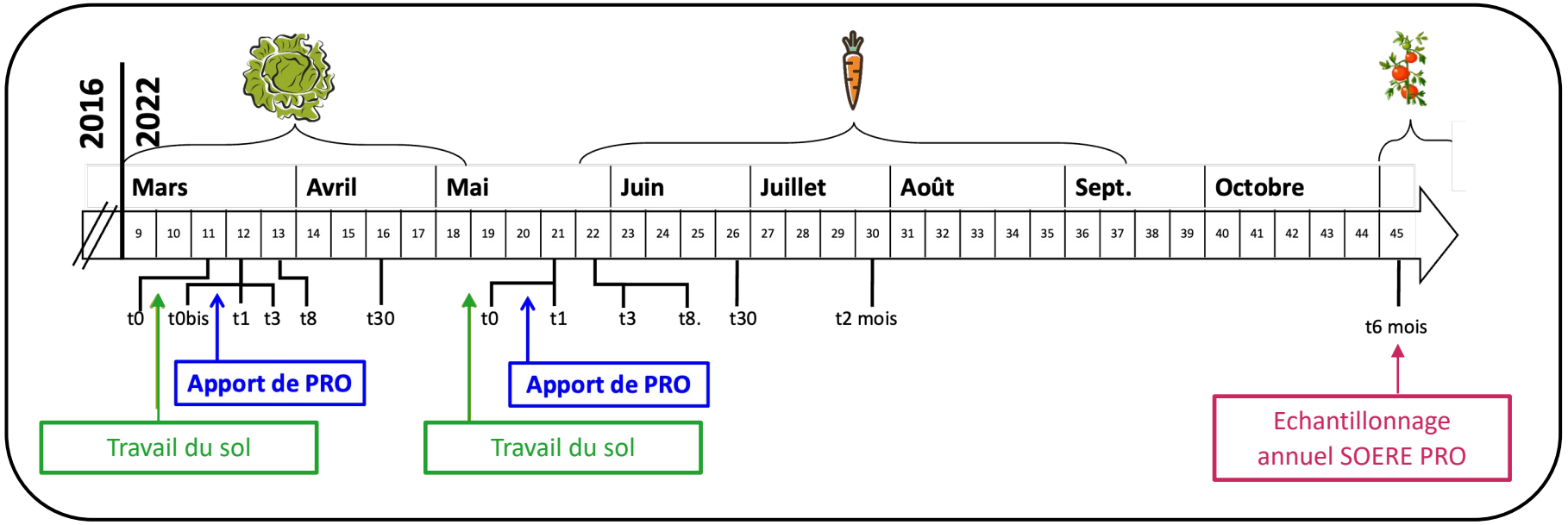
Activités réalisées



A chaque pas de temps:

- pH et humidité
- PLFA
- Extraction ADN et metabarcoding

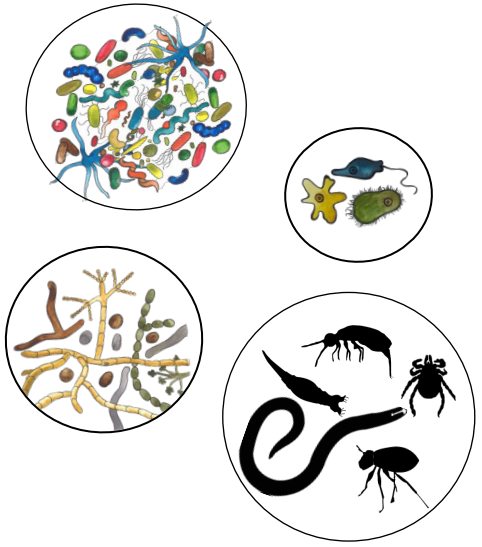
Mesures supplémentaires à t6 mois

- Propriétés physicochimiques

Bactéries et archées - 16S (région V4)

Champignons - ITS 1

”Universal eukaryote” - 18S (V9)



OWP properties

< <

	N	C	C/N	P	K	Zn	Cu	Cr	Pb	Cd	Ni
	%	%		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Sewage Sludge (SS)	1.6	16	10	7784	1391	598	169	71	53	3	28
Digestates (D)	1.4	23	17	4804	14254	101	18	11	8	2	8
Poultry litter (PL)	2.3	22	11	8759	9651	232	37	31	18	2	10

Soil properties

	M100	D100	SS100	PL100	
pH H2O	5.53 a	6.22 b	6.91 c	7.1 c	*
C org (g/kg)	5.35 a	5.1 a	10.06 b	6 a	*
C tot (g/kg)	6.22 a	5.76 a	11.31 b	7.06 ab	*
N tot (g/kg)	0.55 a	0.46 a	1.06 b	0.59 a	*
N-NO3 (mg/kg)	5.46	4.28	7.73	6.78	ns
N-NH4 (mg/kg)	2.23	1.05	1.68	1.33	ns
C/N	11.31	12.49	11.05	12.17	ns
P tot (mg/kg)	710.2	216.59	423.68	325.44	ns
P assim (mg/kg)	80.55	19.28	36.86	33.43	ns
CEC (méq%)	8.87	7.5	10.67	7.38	ns
Na éch (méq%)	0.11	0.09	0.12	0.1	ns
Mg éch (méq%)	1.91	2.06	2.1	1.84	ns
K éch (méq%)	0.61 ab	0.5 a	0.77 b	0.58 a	*
Ca éch (méq%)	5.07	4.01	8.64	6.47	ns

← pH increase in soil fertilized with OWP

← C and N increase in soil fertilized with SS

Sequencing results

ADNID laboratoire du Groupe QUALTECH

→ **Frogs pipeline**

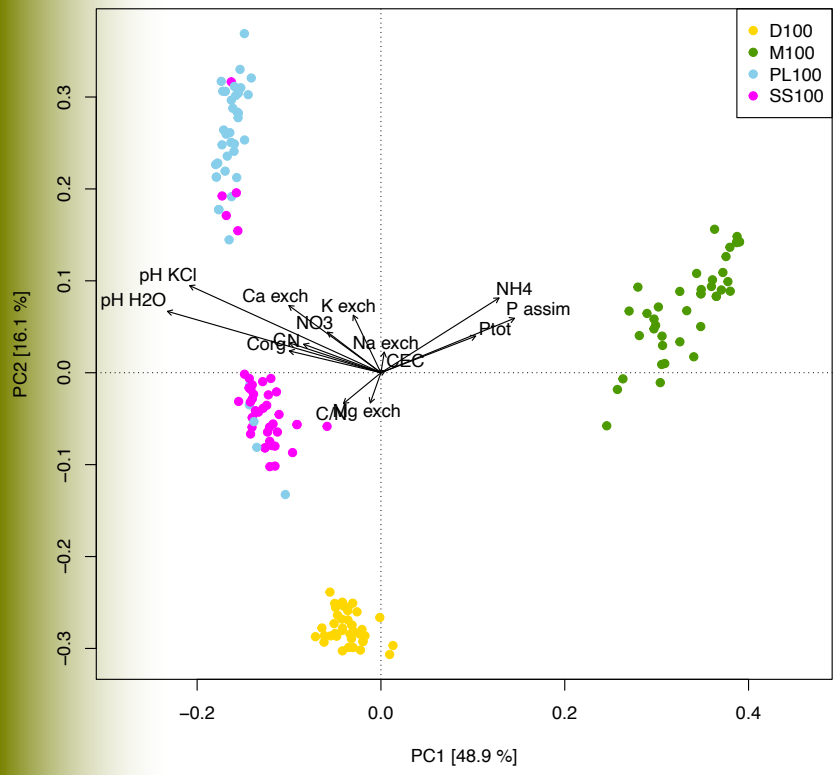
- Nb of sequences
  - 16S : 4 384 182
  - ITS : 2 802 700
  - 18S : 2 092 137
- Nb of taxa/OTU
  - 16S : 87 705
  - ITS : 10 156
  - 18S : 24 143
- Percentage of taxa with <10 reads
  - 16S : 70 %
  - ITS : 62%
  - 18S : 46%

Pre-treatment

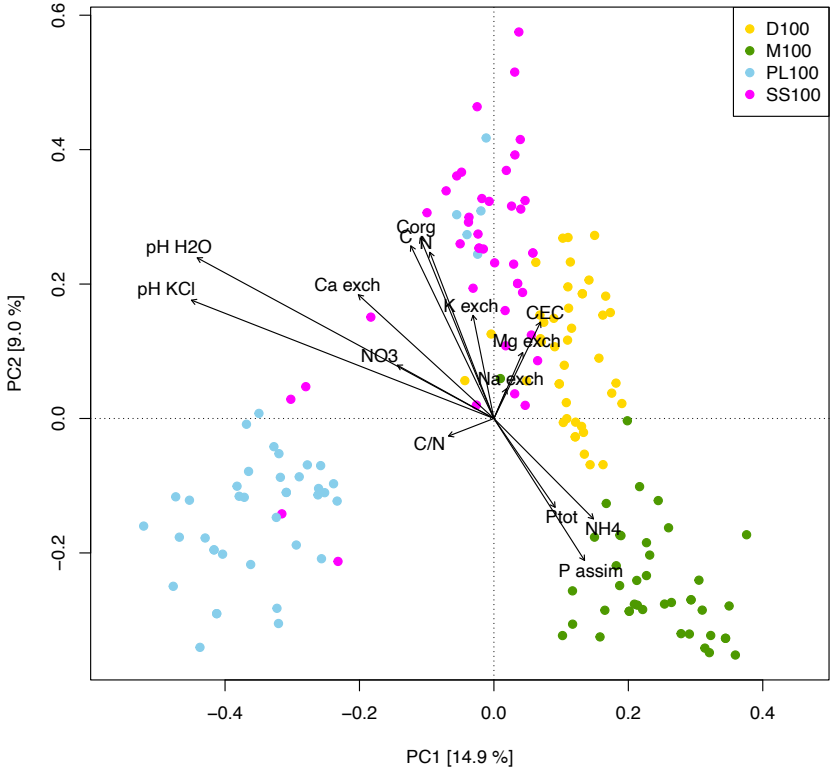
- Remove OTUs without a kingdom-level annotation, the chloroplasts and mitocondria
- Check of the sequencing deptn and removal of samples with too low nb of reads (1 for 16S and ITS, 12 for 18S)
- Rarefy to even depth (12047 – 16S, 6750 – ITS, 4979 – 18S

Beta diversity

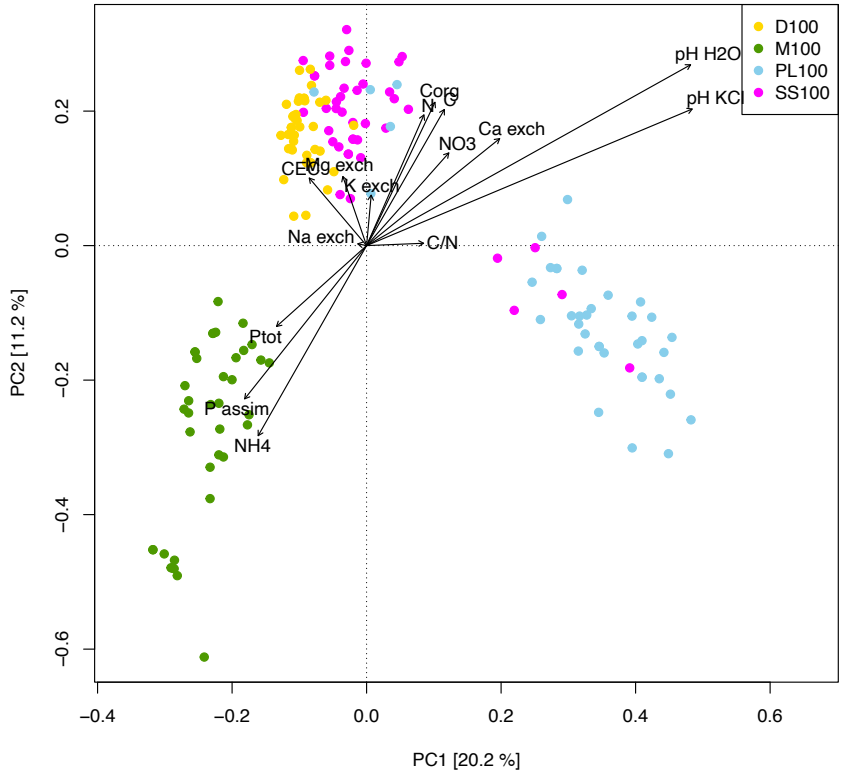
PCA – Bacteria



PCA - Fungi



PCA - Eukaryotes



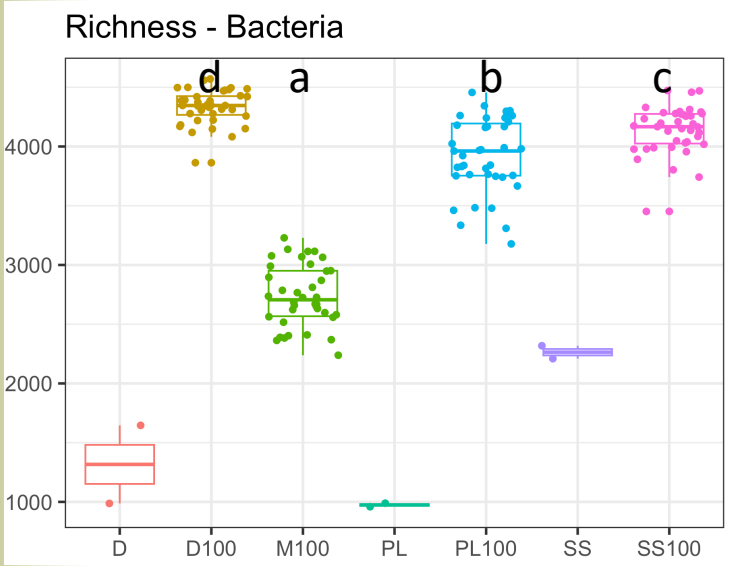
Permanova (adonis2, Vegan)

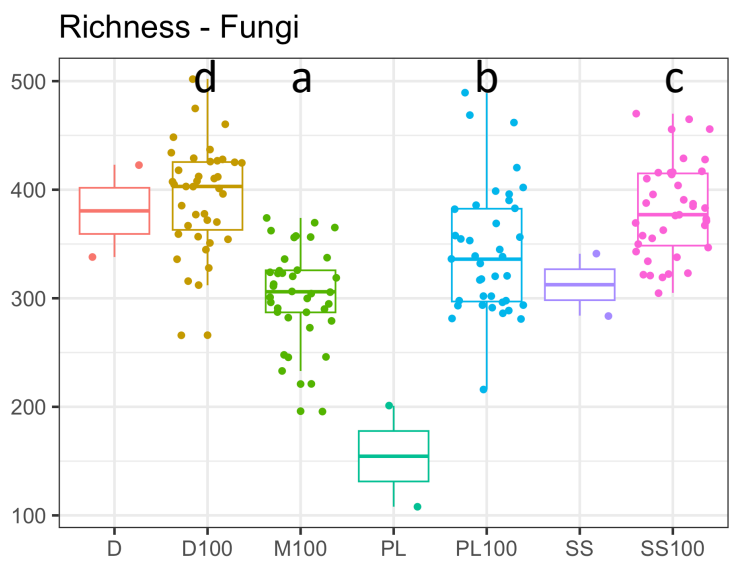
	Df	SumOfSqs	R2	F	Pr(>F)	
Treatments	3	9.7991	0.74606	184.2248	0.001 ***	75 %
Time	8	0.5027	0.03828	3.5443	0.001 ***	4 %
Plant	1	0.0931	0.00709	5.2525	0.001 ***	<1 %
Residual	154	2.7305	0.20789			
Total	166	13.1344	1			

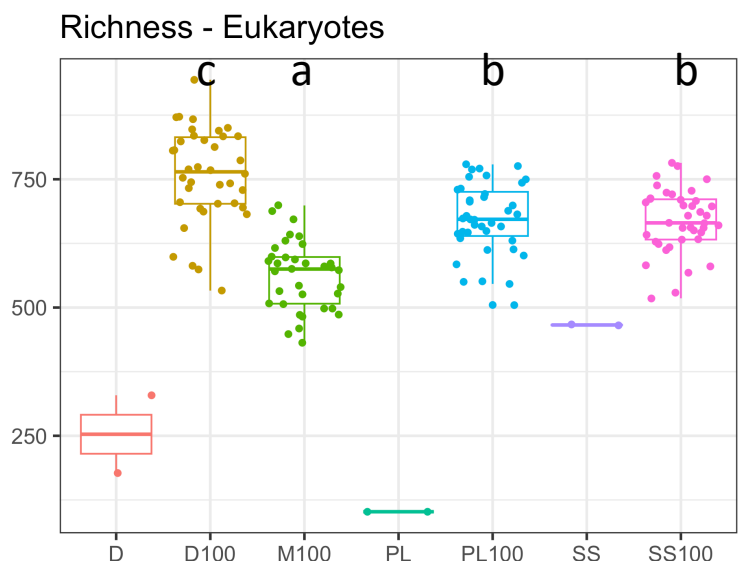
Df	SumOfSqs	R2	F	Pr(>F)	
3	6.9651	0.30206	28.5137	0.001 ***	30 %
8	2.7132	0.11766	4.1652	0.001 ***	12 %
1	0.7152	0.03102	8.7834	0.001 ***	3 %
154	12.5393	0.54379			
166	23.0591	1			

Df	SumOfSqs	R2	F	Pr(>F)	
3	5.5481	0.37887	36.0945	0.001 ***	38 %
8	1.3076	0.08929	3.1901	0.001 ***	9 %
1	0.2548	0.0174	4.9735	0.001 ***	2 %
145	7.4293	0.50733			
157	14.6438	1			

Alpha diversity - Richness







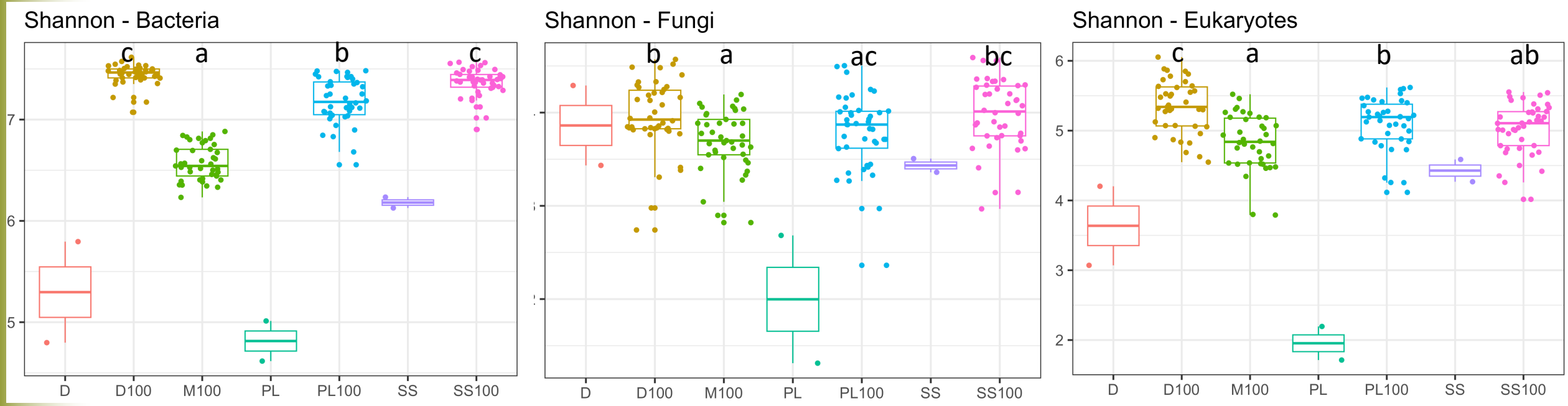
Glm (family = “poisson”)

→ Organic fertilization increases the richness in taxa for the three targets

→ Digestates yields the highest diversity

Digestates (D)
Soil + Digestates (D100)
Soil + Mineral fertilization (M100)
Poultry litter (PL)
Soil + Poultry litter (PL100)
Sewage Sludge (SS)
Soil + Sewage Sludge (SS100)

Alpha diversity - Shannon



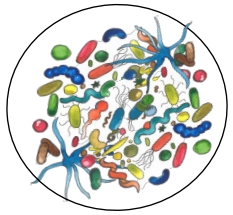
→ Provides information about both richness and evenness.
→ Shannon increase with biodiversity
→ H = 0 when there is only one species. H maximal when all species represented equally

→ Organic fertilization increases the diversity for the three targets
→ Digestates yields the highest diversity

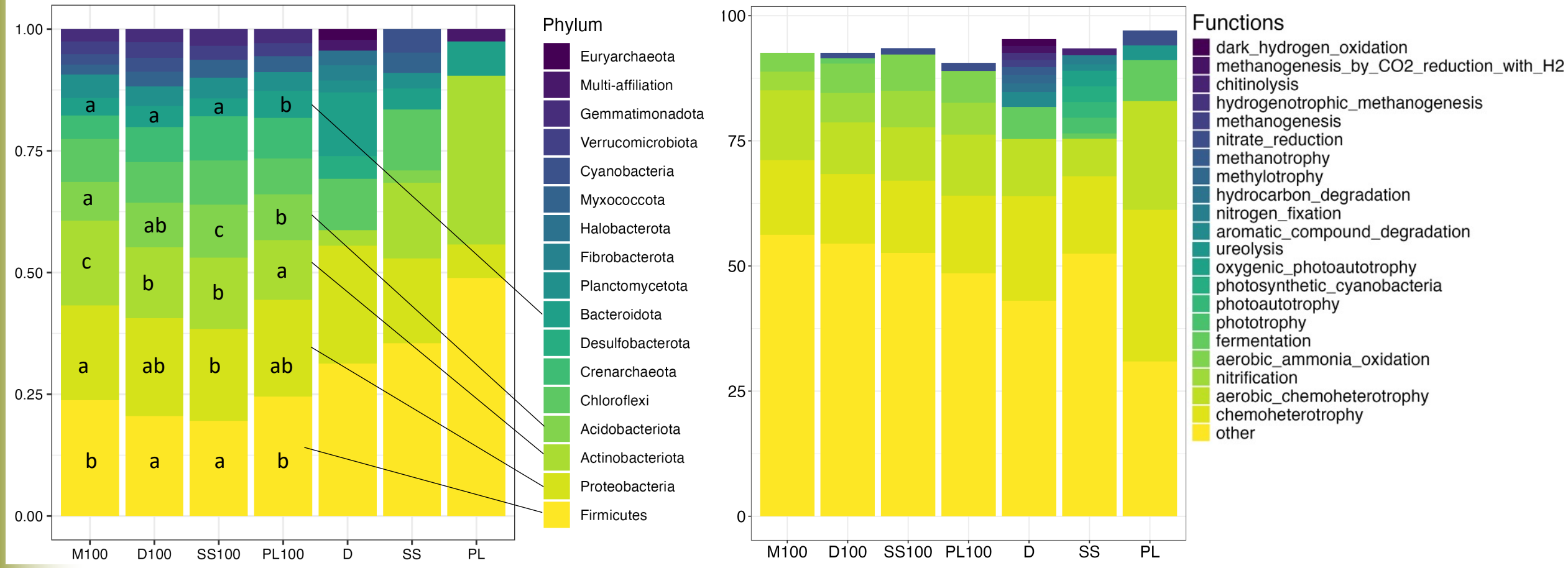
Digestates (D)
Soil + Digestates (D100)
Soil + Mineral fertilization (M100)
Poultry litter (PL)
Soil + Poultry litter (PL100)
Sewage Sludge (SS)
Soil + Sewage Sludge (SS100)

SOERE-PRO

Taxonomical and Functional assignation - Bacteria



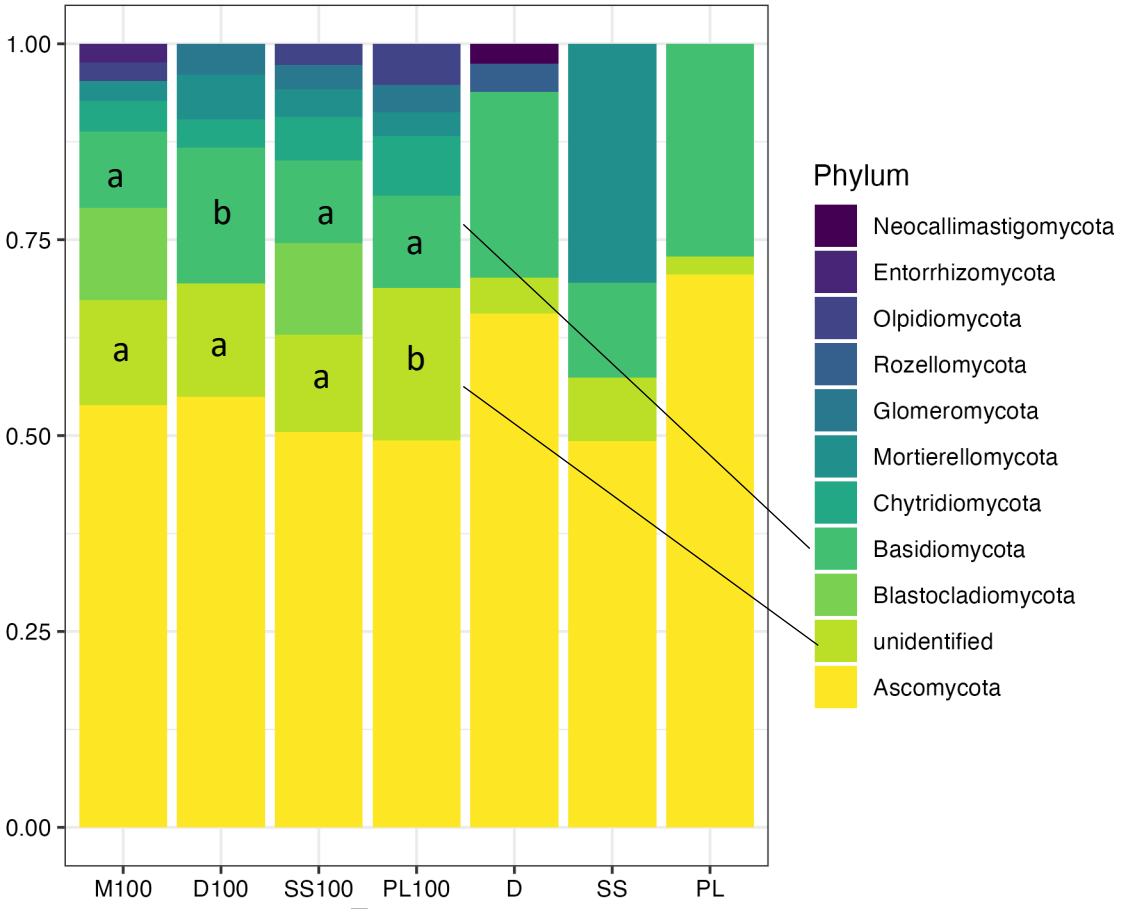
SILVA and Faprotax

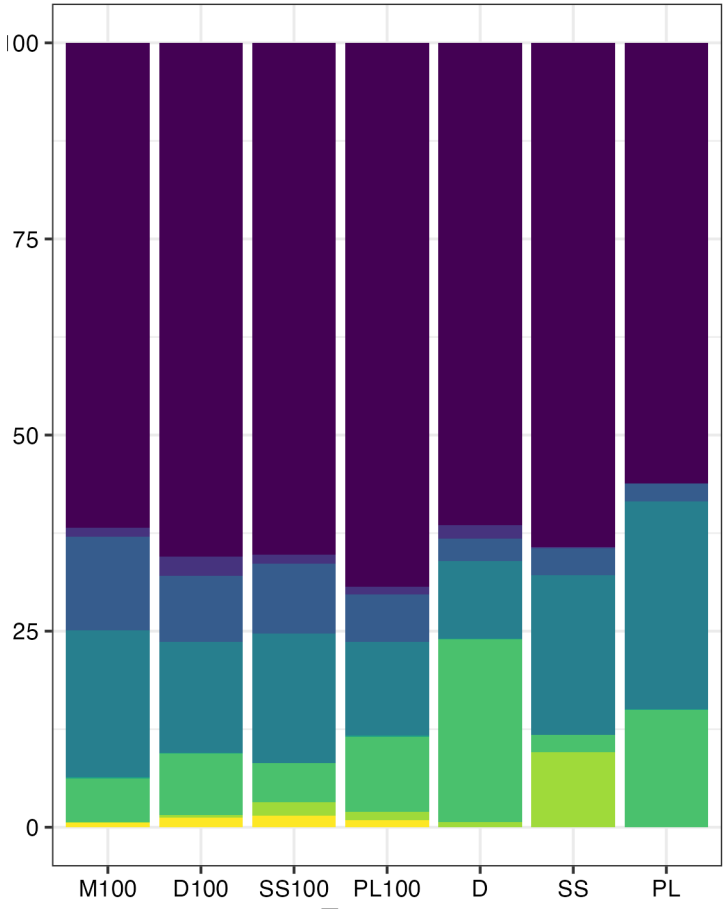


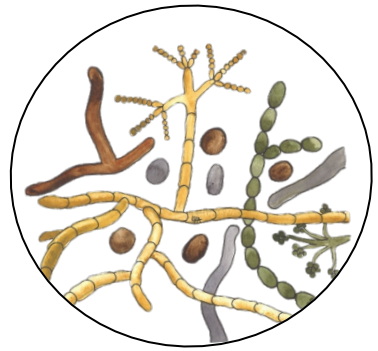
→**Firmicutes and Proteobacteria:** copiotrophic phyla known to prefer nutrient-rich environments and involved in the degradation of complex organic compounds
→**Actinobacteria** often described as having a copiotrophic lifestyle. Have been described abundant both in organically and inorganically fertilized soils
→**Acidobacteria and Bacteroidetes**: oligotrophic organisms adapted to nutrient-limited environments

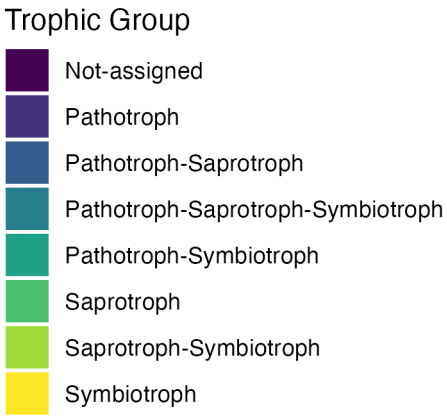
Taxonomical and Functional assignation - Fungi

Unite and Funguild Database



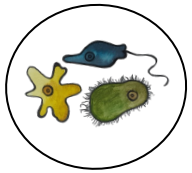


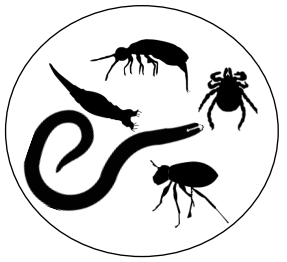




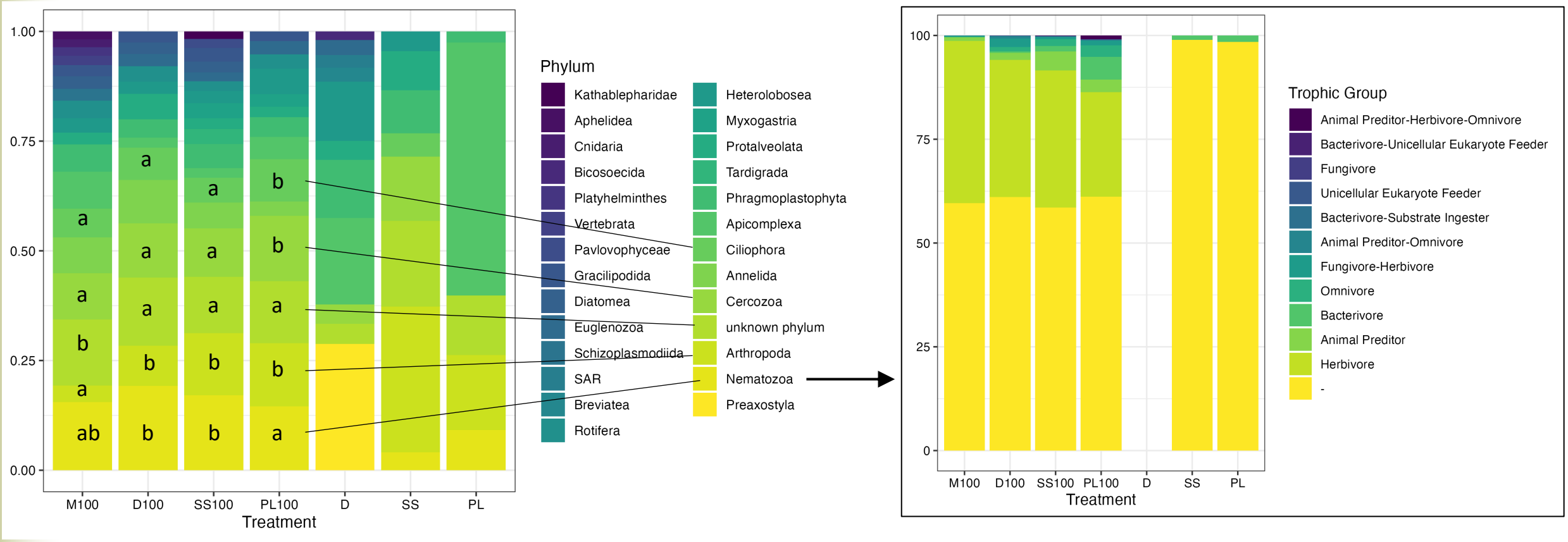
→ Application of OWP tend to increase Basidiomycota, one of the main soil decomposers and decrease Glomeromycota

Functional assignation - Eukaryotes





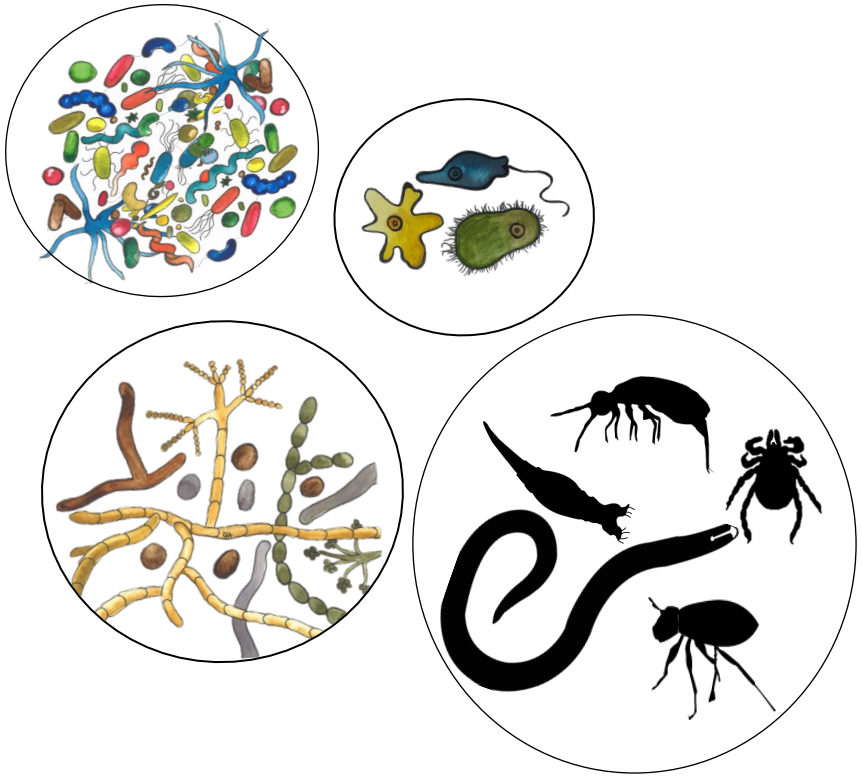
SILVA and funguild (pour les nématodes)



→ Nematozoa is the most abundant phylum. Increase in D and SS pots.
→ Nematode communities more diverse in OWP-treated soils

Next steps:

- Differential abundance testing (impact of treatment, time and crop on individual taxa)
- Indicator species analysis
- Link the taxa within the OWP and soil
- Co-occurrence network
- Check other functional assignations (Gratin?)



Conclusion

- Repeated use of organic fertiliser increase soil quality (increase of pH in all OWP treatments, increase SOM mainly in SS)
- Increase alpha diversity in all OWP treatments
- Long term fertilisation practices are the main drivers of soil communities
- Sensitivity to fertilization practice increase from fungi < eukaryotes < bacteria

Comparison with the results of other sites (loamy clay)

- **La Mare (Reunion Island)** : *Sadet-Bourgeteau et al., Frontiers in microbiology 2022.*
  → No differences in bacterial community composition between treatments (time was the main effect)
- **Colmar (France)** : *Sadet-Bourgeteau et al 2018 Applied soil ecology*
  → No impact of OWP on soil chemical characteristics or microbial communities' parameters. Rem : smaller amount of OWP applied than at quali agro
- **Quali Agro (France)** : *Sadet-Bourgeteau et al 2018 Applied soil ecology*
  → A 50% increase in microbial biomass was observed with OWP with the most stable organic matter contents.
  → More bacteroidetes and less Basidiomycota and Glomeromycota in OWP treated soils.
  → No effect on diversity indices (prokaryotes and fungi)

Thank you