Cross-taxon congruence of soil biodiversity in *Pinus nigra* plantations two years after a selective silvicultural treatment

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

Compagnia delle Foreste

Unione dei Comuni del Pratomagno

Unione dei Comuni Amiata Val d'Orcia

SelPiBio Life

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LIFE13 BIO/IT/000282

EGU European Geosciences Union

SelPiBioLife (LIFE13 BIO/IT/000282)

The main purpose of the project is to evaluate the effects of a selective thinning on soil biodiversity in young black pine stands.

http://www.selpibio.eu/

Background:Black pine Stands in Appennine

Black pine stands have been established throughout the Apennines after the Second World War with the purpose of re-establishing forest cover in marginal and eroded soils.

Today the key functions are the protection against soil erosion and the hydrological regulation of catchments.

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Today: management of black pine stands

In order to guarantee the multifunctional and sustainable role of these stands, it is necessary to establish and realize a series of silvicultural treatments finalized to:

- increase the overall mechanical stability of the stand:
- regulate the mixing species;
- increase production value of the stand

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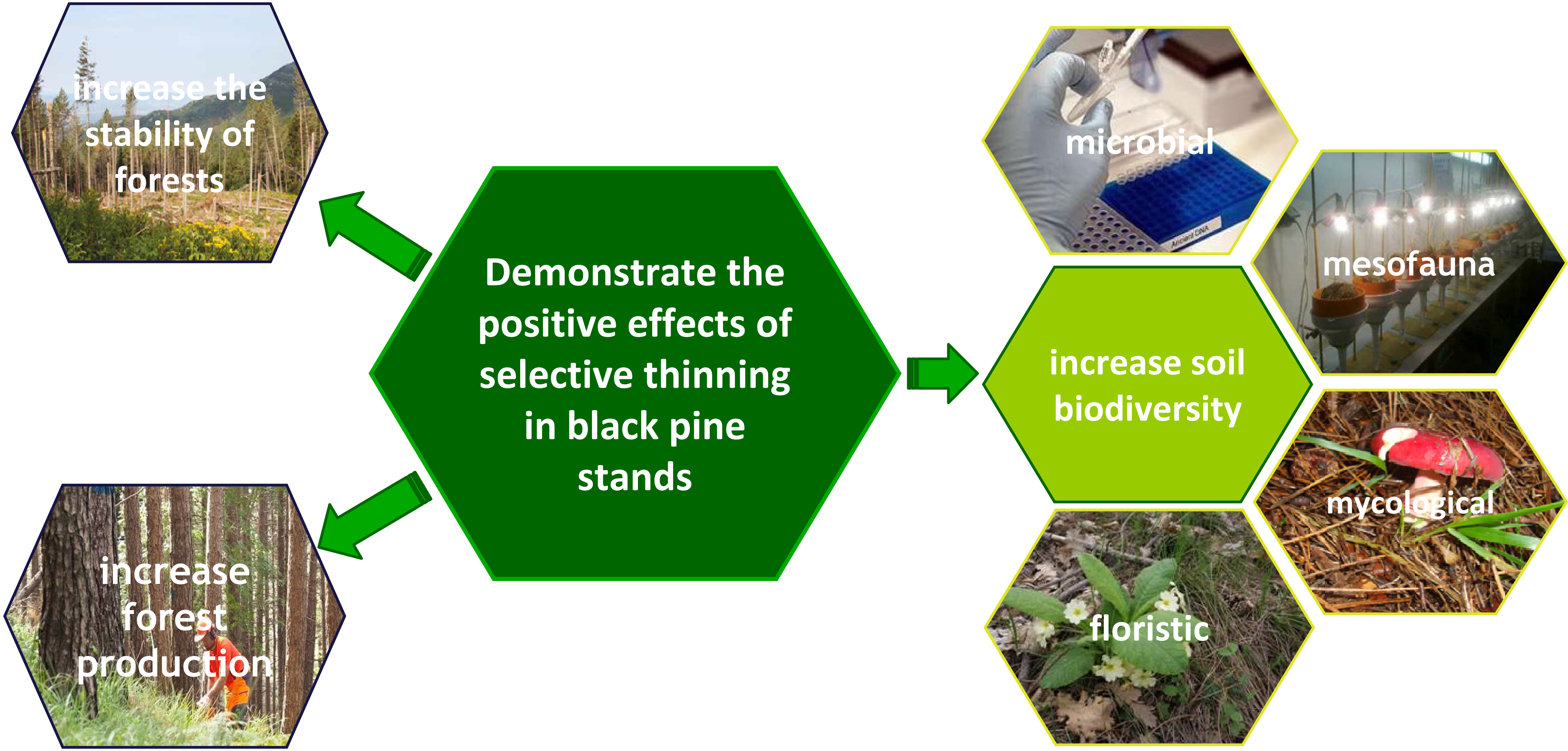
SelPiBio*Life*: objectives



Demonstrate the positive effects of selective thinning in black pine stands

increase the stability of forests

increase forest production

increase soil biodiversity

microbial

mesofauna

mycological

floristic

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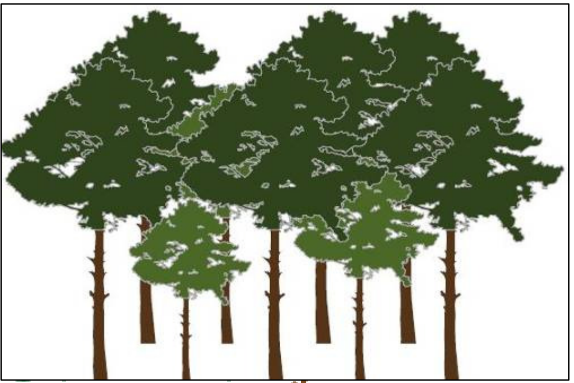
SelPiBioLife research hypotheses: 3 silvicultural treatments

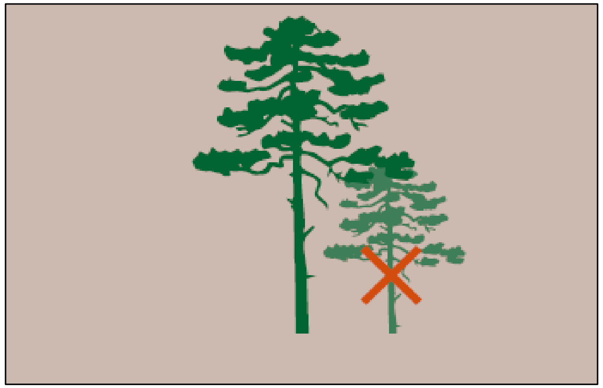
control

No intervention is realized



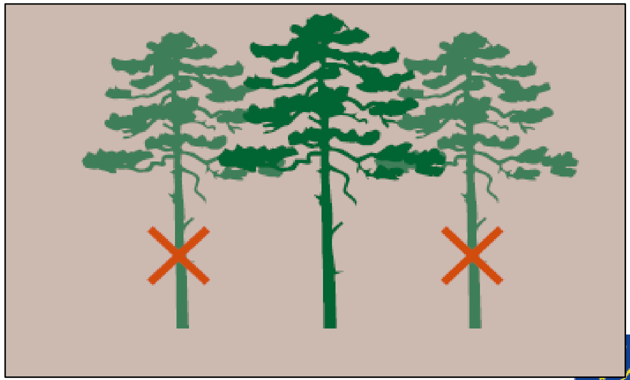
traditional

Dominated trees are removed. No significant effect on canopy cover.



selective

Selection of 100 candidate trees per hectare and removal of direct competitors.



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The selective thinning

The selective thinning is conceptually based on the identification of the dominant plants and the removing of the plants around. This approach provides the following results:

1. Enhance the pine succession and increase the economic value of the product
2. Enhance the pine dendrometric stability
3. Reduce the canopy cover and enhances the rate of light, water and temperature at the soil level

The global effect is an increasing of the functionality of the ecosystem and of the soil biodiversity

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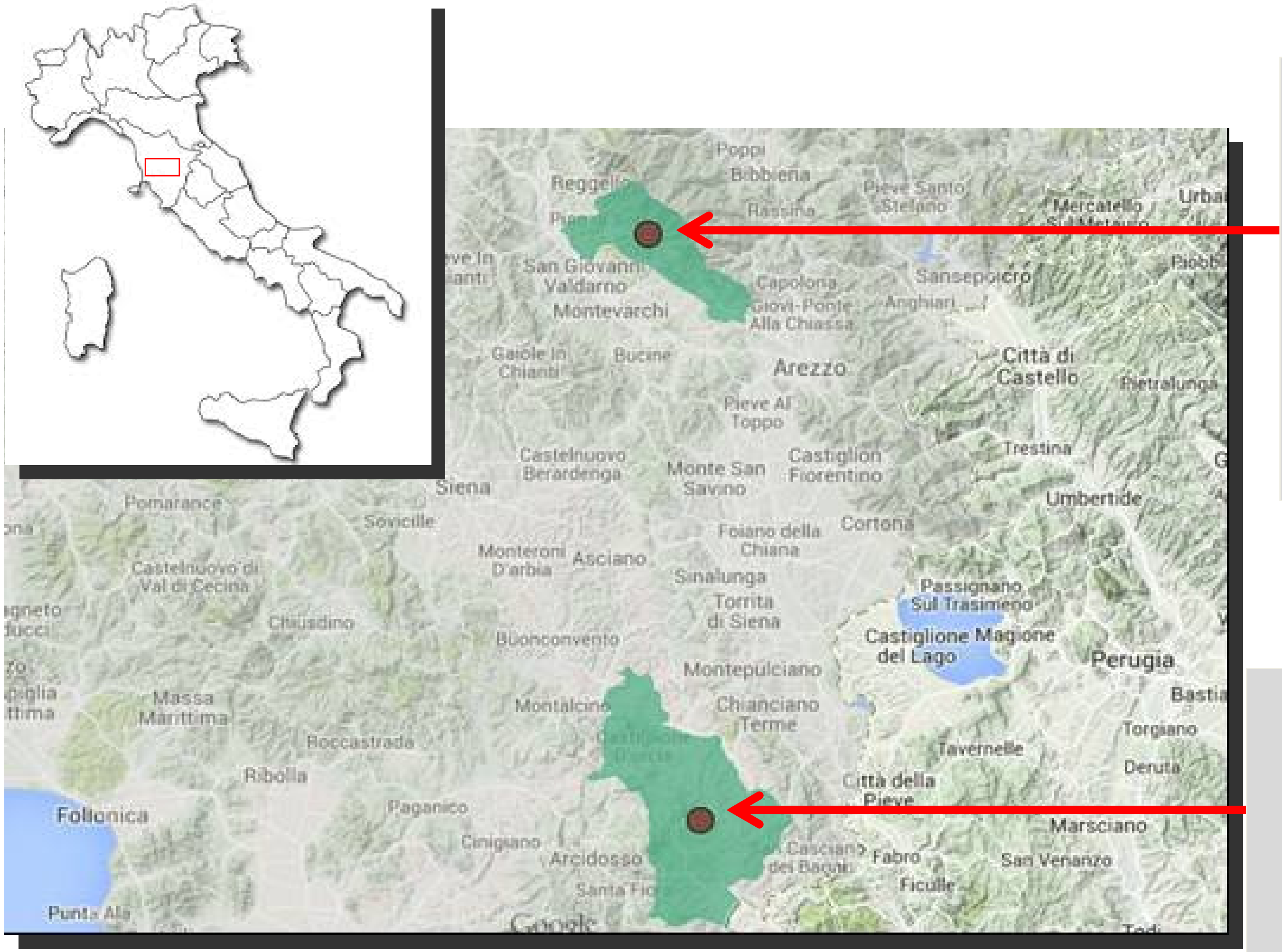
No thinning

Traditional thinning

Selective thinning

Monitoring areas

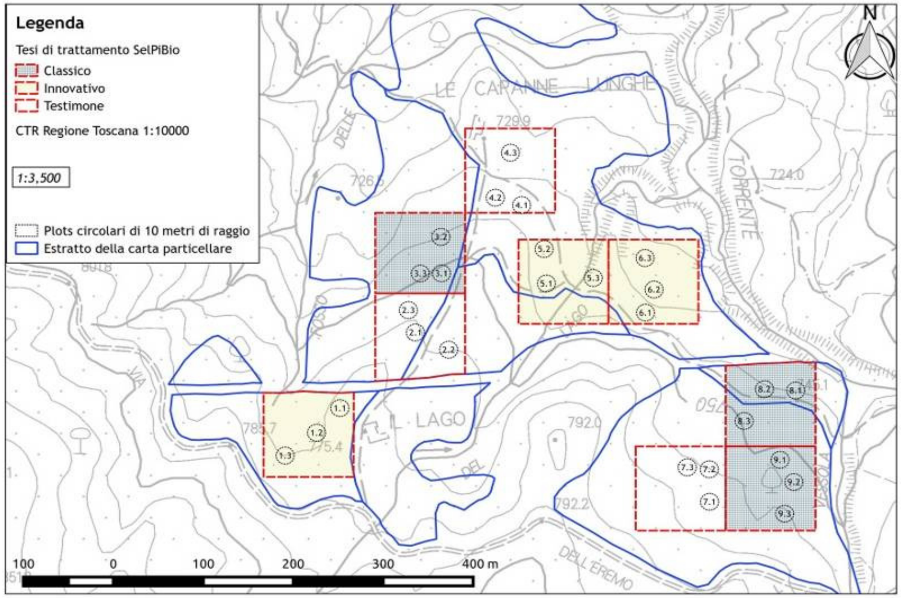


“Pratomagno-Valdarno”- «Pian della cucina» Municipality: Loro Ciuffenna (AR)
PRATOMAGNO

«Madonna delle Querce» - «Il Lago» Municipality: Castiglione d’Orcia (SI)
AMIATA

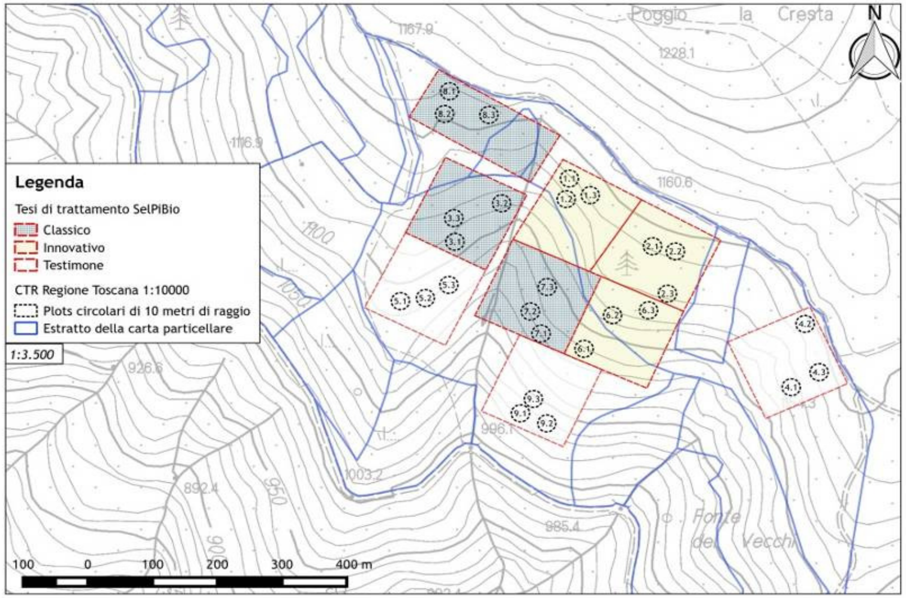
Brief description of the areas

Amiata



- Altitude: about 800 m a.s.l.
- Exposition: North-North-West
- Average slope: 3-6%.
- Vegetation: high
- pH : 6,9
- Total organic carbon (TOC): 1,73%

Pratomagno



- Altitude: about 1100 m a.s.l.
- Exposition: South- West
- Average slope: 20-25%
- Vegetation: low
- pH : 5,5
- Total organic carbon (TOC): 1,76%

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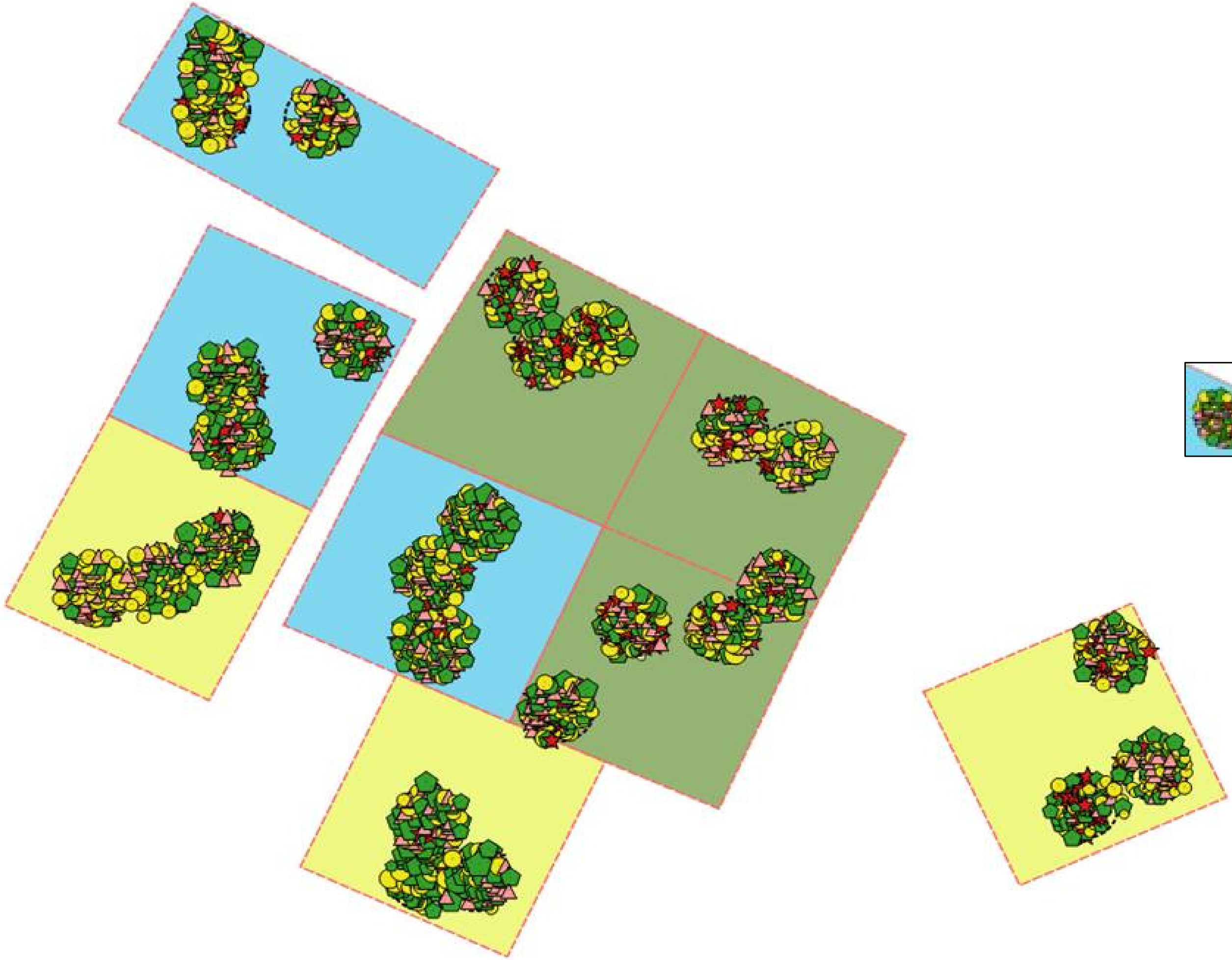
Experimental scheme



9 areas (1ha each) for each experimental site, with 3 replicates of each silvicultural thesis

3 *plots* (10 m diameter – 314 mq) for each area were selcted for sampling and three thesis applied

- ✓ **selective thinning**
- ✓ **traditional thinning**
- ✓ **control**

A total of 27 *plots* for each site

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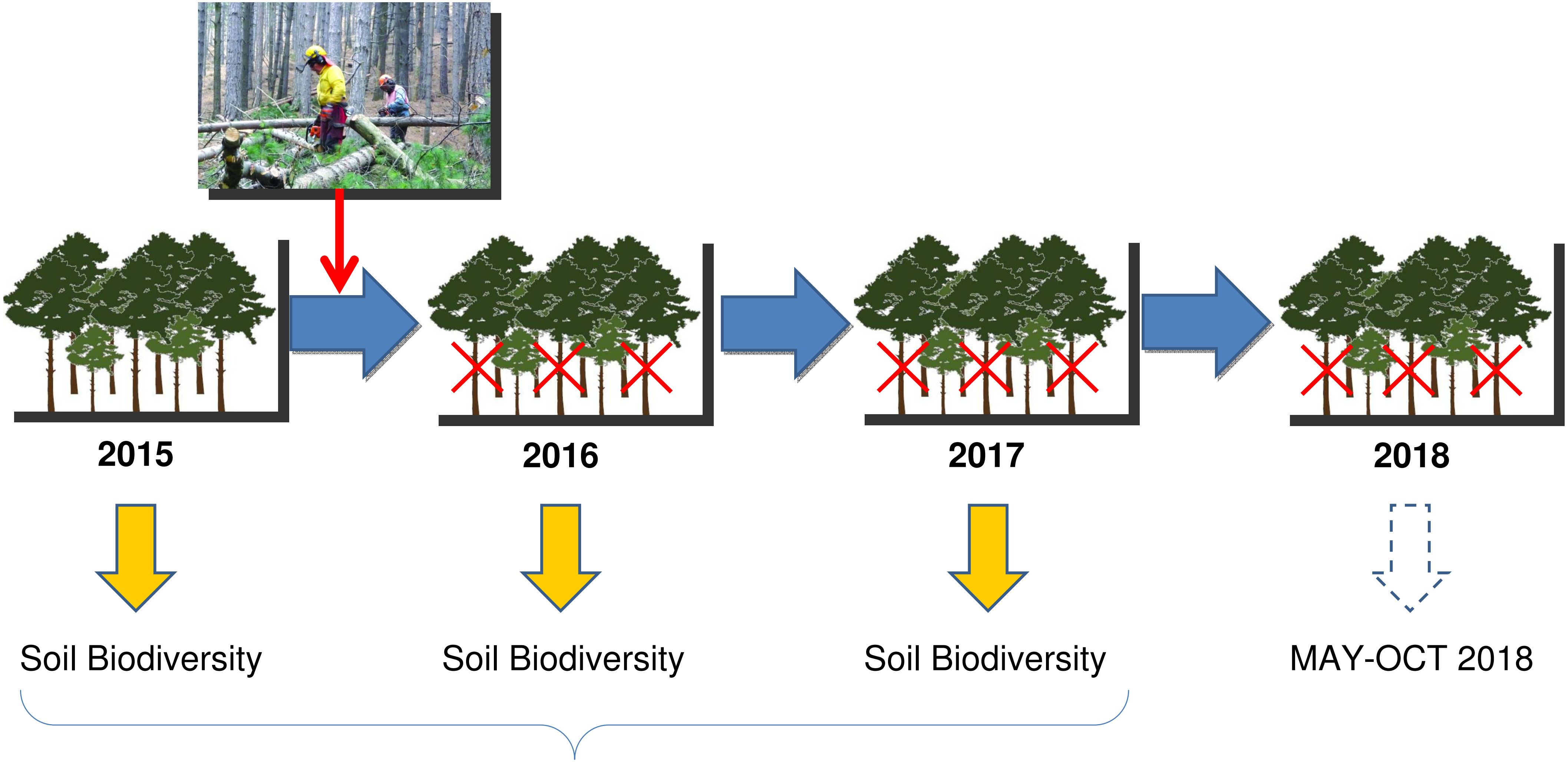
Soil sampling


2015

2016

2017

2018

Soil Biodiversity

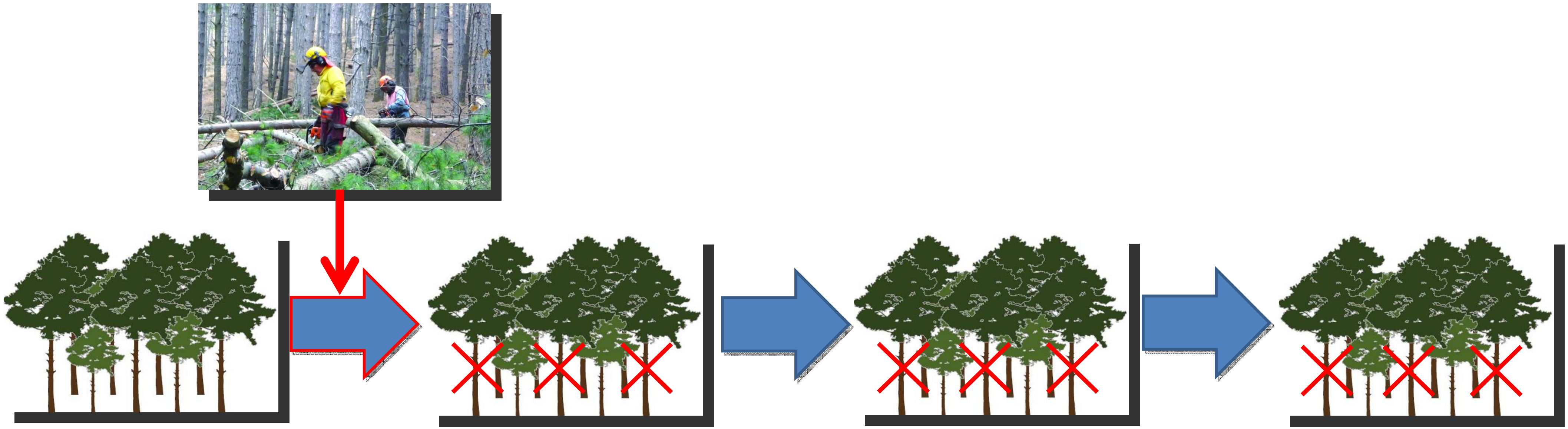
Soil Biodiversity

Soil Biodiversity

MAY-OCT 2018

http://www.selpibio.eu/

Soil sampling



Soil Biodiversity → **CROSS-TAXON CONGRUENCE**

Soil Biodiversity → **MICROBIAL DIVERSITY**

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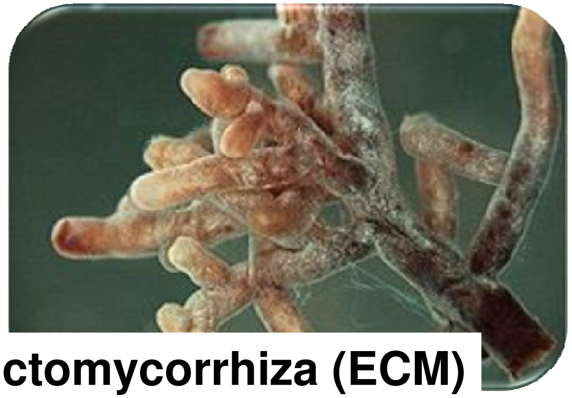
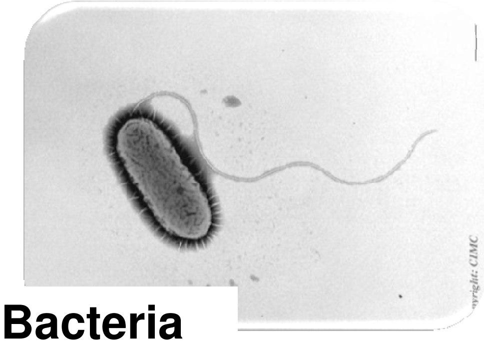
Assessment of soil biodiversity


Plants


Macro-fungi


Ectomycorrhiza (ECM)


Bacteria

**"SOIL"
BIODIVERSITY**


Carabids


Micro-fungi


Nematodes


Microarthropods

1. Cross-taxon congruence analysis (before treatments)

The immense variety of soil organisms plays a fundamental role in ecological processes, interacting with one another and with above-ground biodiversity in a complex and intricate network of biological activity. Thus, in order to explore the **ecological linkages** between aboveground and belowground biota affecting the ecosystem functioning in artificial black pine forests, a cross-taxon congruence analysis has been carried out before any silvicultural operations (baseline).

Barlow et al., 2007; Keith et al., 2012

Predictive factors

1) Taxa
2) Soil physic-chemical properties: soil texture, total C and N, SOM, pH, CEC
3) Geographical coordinates
4) Topographic factors: aspect (sessagesimal degrees), elevation (m), flow direction of water, slope (percentage), Topographic Position Index (TPI), x and y geographical coordinates expressed as metric units in ETRS89/UTM 32N reference system (EPSG 25832)
5) Dendrometric parameters: number of trees/ha, basal area/ha, average diameter at breast height, average height of the stand, dominant height, Clark and Evans Index (Clark and Evans, 1954), and Photosyntetic Active Radiation on the ground (PAR).

All environmental parameters obtained at plot level were aggregated at sector level using average method.

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Cross-taxon congruence among taxa

Mantel tests were used to perform pairwise cross-taxon correlation analysis among taxa, using Bray-Curtis dissimilarity matrices.
Similarly, Mantel correlation was calculated between each taxon and the Euclidean environmental distance matrix obtained by all predictors (soil, spatial-topographic, dendrometric variables).

Taxa	**Arthropods**	**Bacteria**	**Carabids**	**ECM**	**Macrofungi**	**Microfungi**	**Nematodes**	**Plants**	**Environment**
Arthropods	-								
Bacteria	0.391**	-							
Carabids	0.065	0.416**	-						
ECM	0.269**	0.592***	0.252*	-					
Macrofungi	0.326**	0.683***	0.343**	0.284**	-				
Microfungi	0.316**	0.876***	0.380**	0.552***	0.672***	-			
Nematodes	0.142	0.091	0.118	0.129	0.136	0.050	-		
Plants	0.344**	0.787***	0.325*	0.5401***	0.513***	0.740***	-0.020	-	
Environment	0.394**	0.966***	0.451**	0.615***	0.692***	0.875***	0.110*	0.838***	-

In general, the distribution pattern of almost all the groups analysed showed highly supported inter-group congruence, while nematoda were not significantly correlated with other taxa

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Cross-taxon congruence among taxa

Partial Mantel tests were used to evaluate if a significant taxa concordance remained after the conditional effect of the environment variables was removed.

Taxa	Arthropods	Bacteria	Carabids	ECM	Macrofungi	Microfungi	Nematodes	Plants
Arthropods	-							
Bacteria	0.047	-						
Carabids	-0.137	-0.086	-					
ECM	0.038	-0.009	-0.036	-				
Macrofungi	0.081	0.080	0.048	-0.247	-			
Microfungi	-0.063	**0.245****	-0.034	0.036	**0.192***	-		
Nematodes	0.108	-0.057	0.077	0.080	0.085	-0.094	-	
Plants	0.027	-0.158	-0.107	0.057	-0.170	0.027	-0.207	-

Resuts showed that only bacteria and macrofungi maintained a moderate and significant (*r* = 0.24; p<0.01; r = 0.19 p<0.05, respectively) correlation with **microfungi**, independent of environmental factors.

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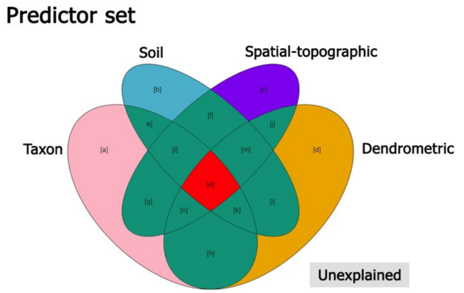
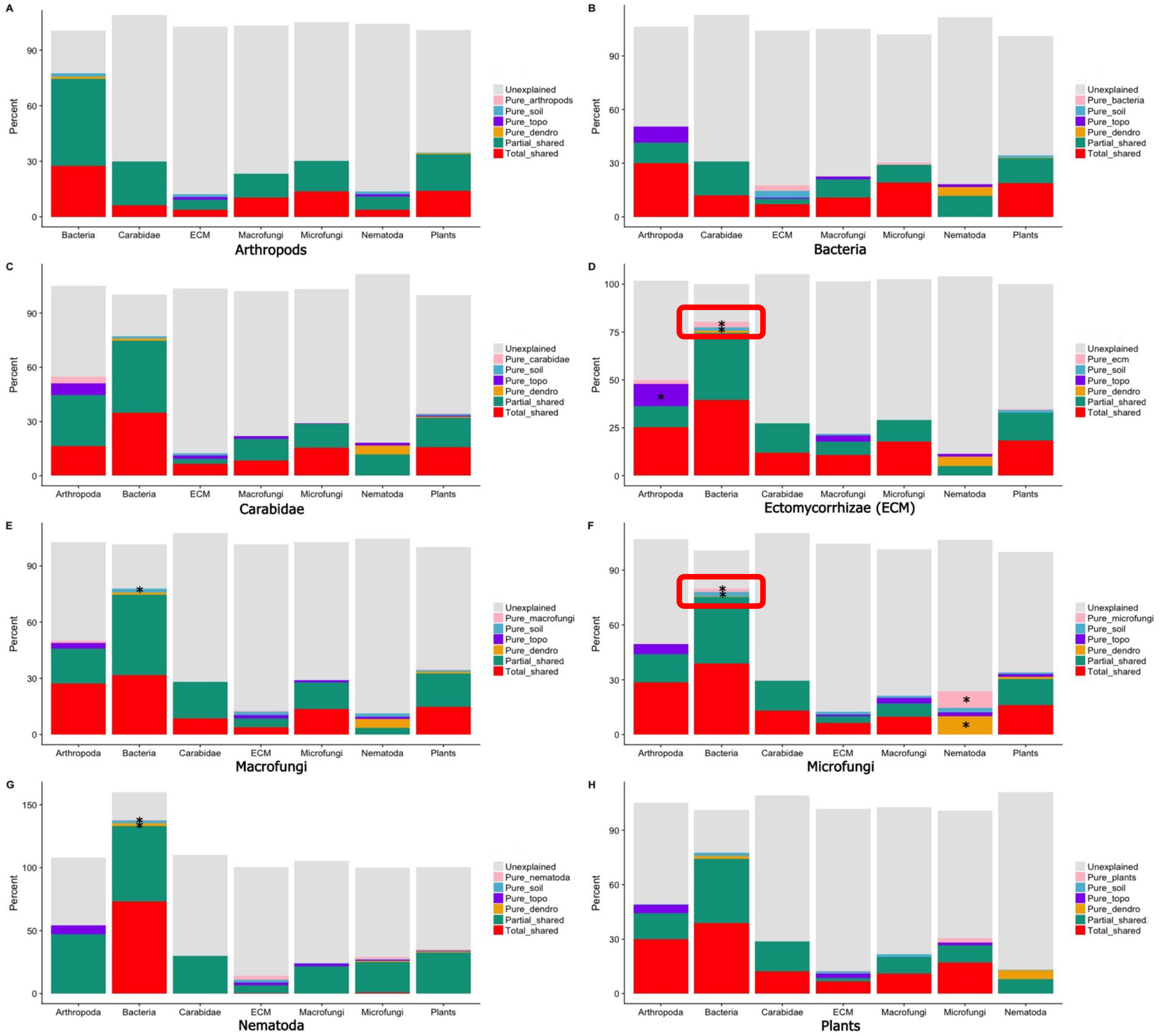


Cross-taxon congruence between soil taxa and variation partitioning

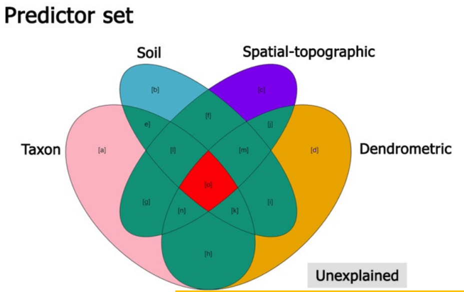


Redundancy analysis (RDA) with variation partitioning (Borcard et al., 1992) was applied to quantify the proportion of variation in each biological group that could be explained by another taxon as well as by the environmental predictor sets. Pure or combined effect of another predictor is reported as barchart:

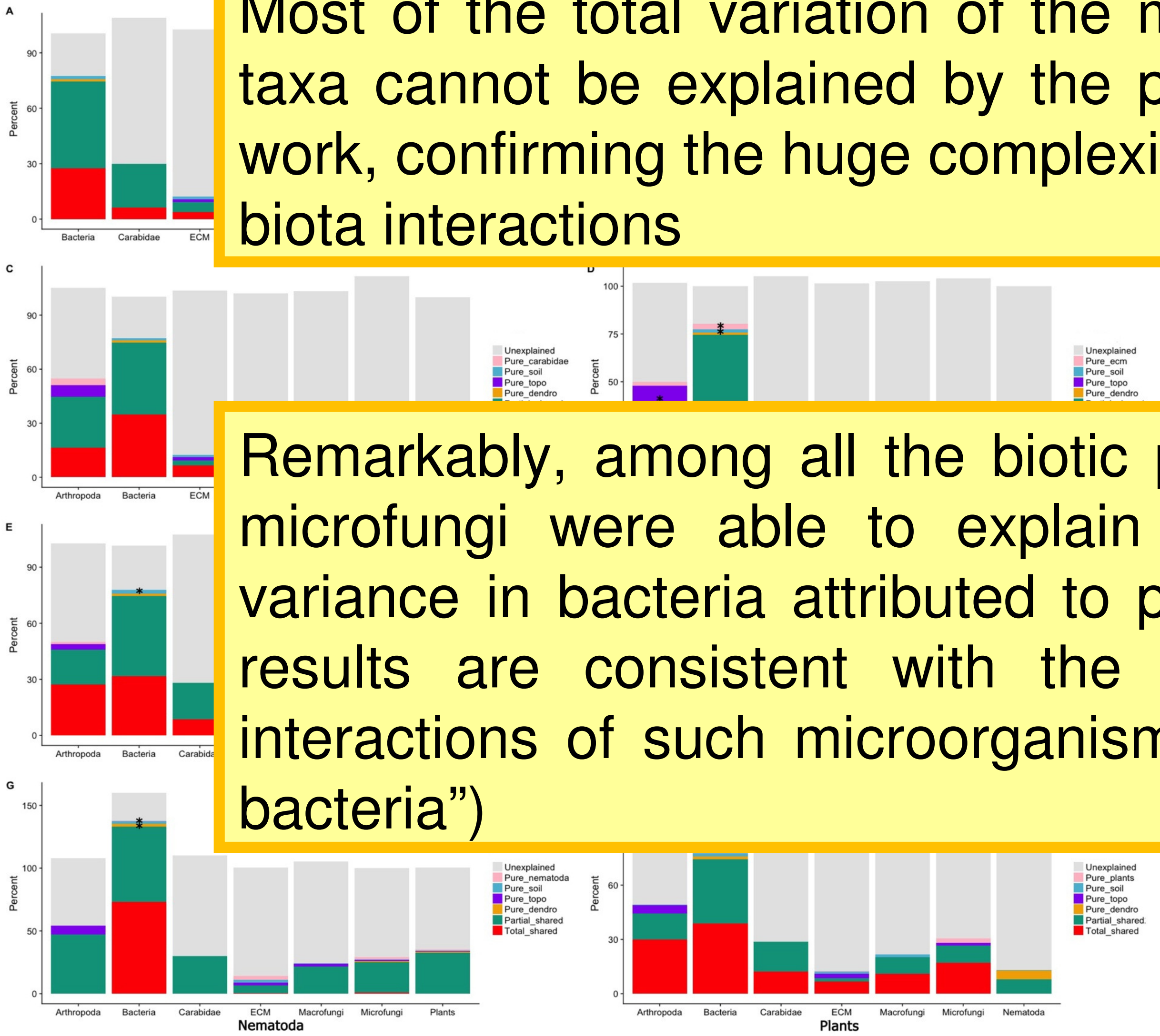
- Most of the variance is unexplained
- Considering the “pure_taxon” fraction, only ECM and microfungi were able to explain a significant degree of variance in bacteria

The pure taxon effect reflects the cross-taxon congruence between pairs of taxa not associated with any environmental predictor and hence related purely to proxies of potential biotic interactions.

Cross-taxon congruence between soil taxa and variation partitioning



Most of the total variation of the majority of the dependent taxa cannot be explained by the predictors selected in this work, confirming the huge complexity of natural environment-biota interactions



Remarkably, among all the biotic predictors only ECM and microfungi were able to explain a significant degree of variance in bacteria attributed to pure taxon effects. These results are consistent with the ecological linkages and interactions of such microorganisms (i.e. "mycorriza helper bacteria”)

Redundancy analysis (RDA) with … d et al., … ntify the … biological … ained by … by the environmental predictor sets. Pure or combined effect of another predictor is reported as barchart:

… lained … fraction, … e able to … variance

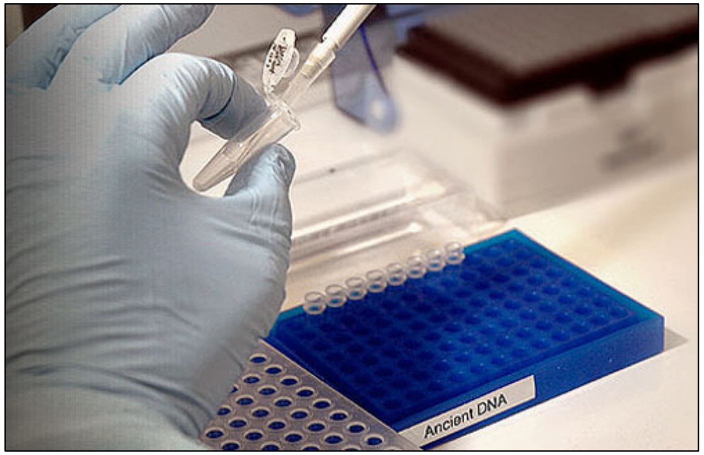
… he cross-taxon congruence between pairs of taxa not associated with environmental-spatial predictors and hence related purely to proxies of potential biotic interactions.

2. Assessment of microbial diversity two years after thinning

Microorganisms

SOIL

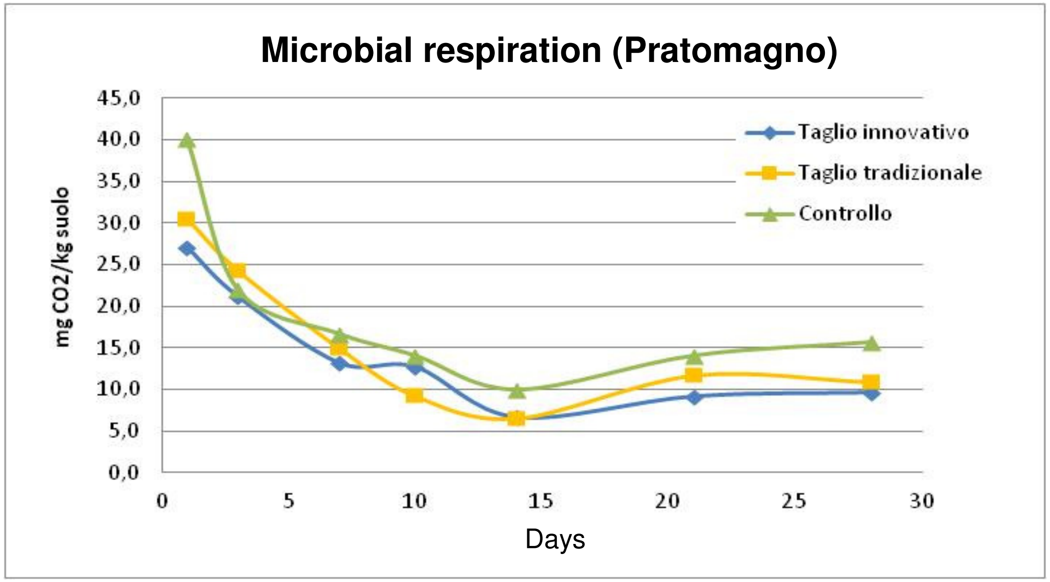
Analysis of the microbial community structure (Miseq, Illumina)

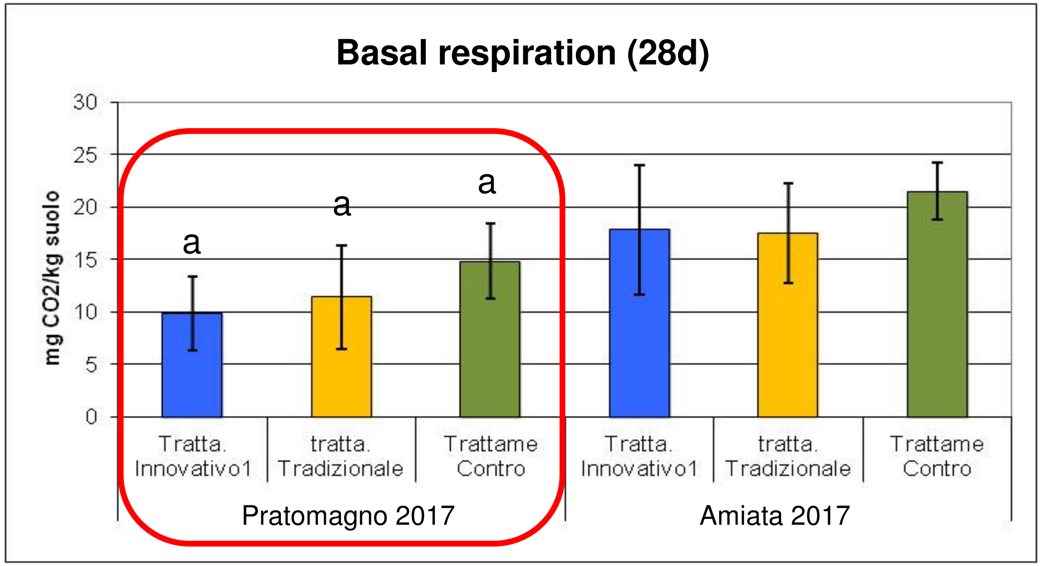


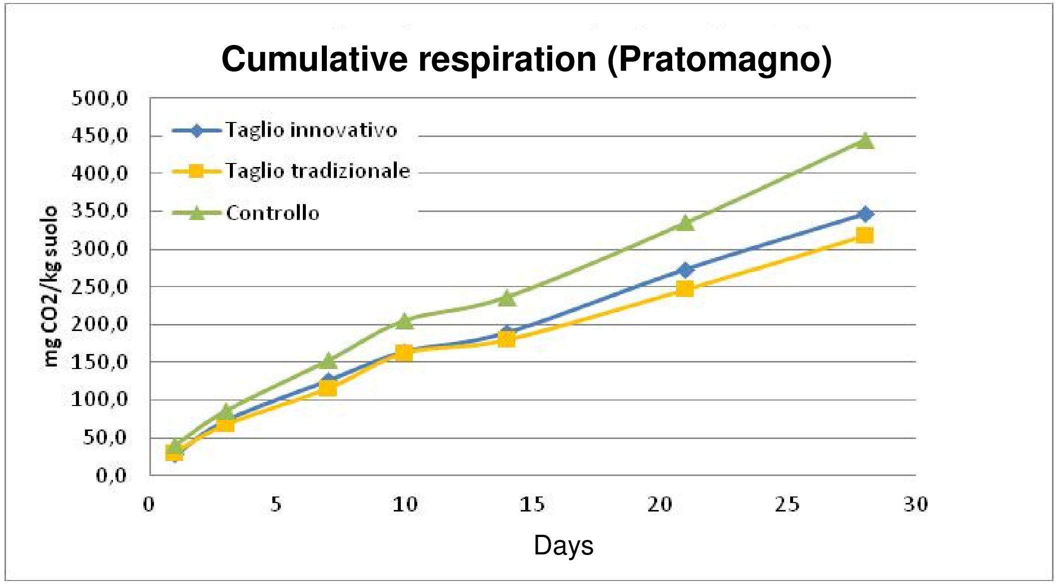
Soil microbial respiration (Alef, 1995)

Microbial C biomass (Vance et al., 1987)

Microbial respiration (Pratomagno)



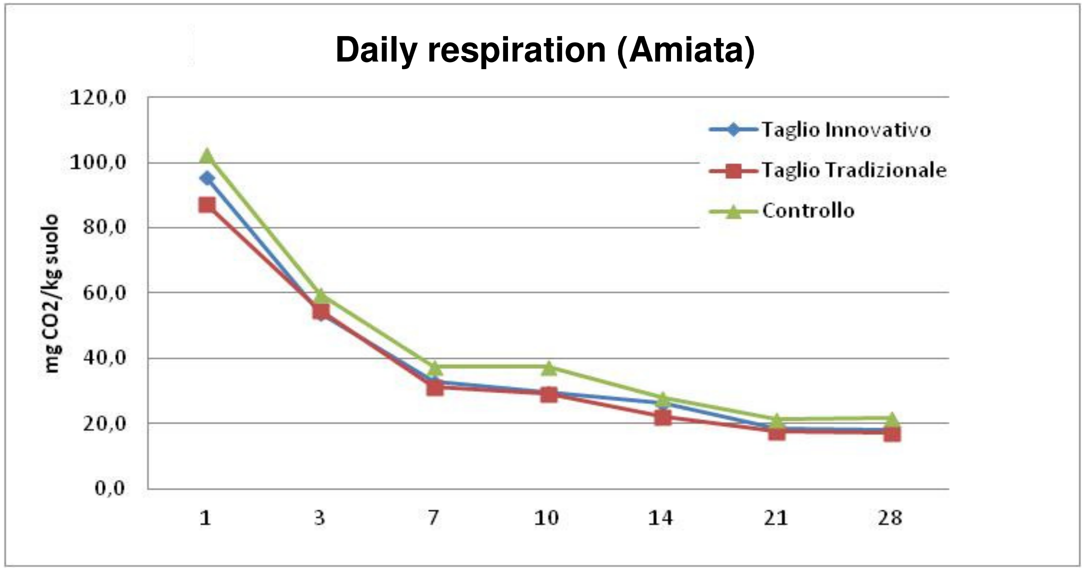


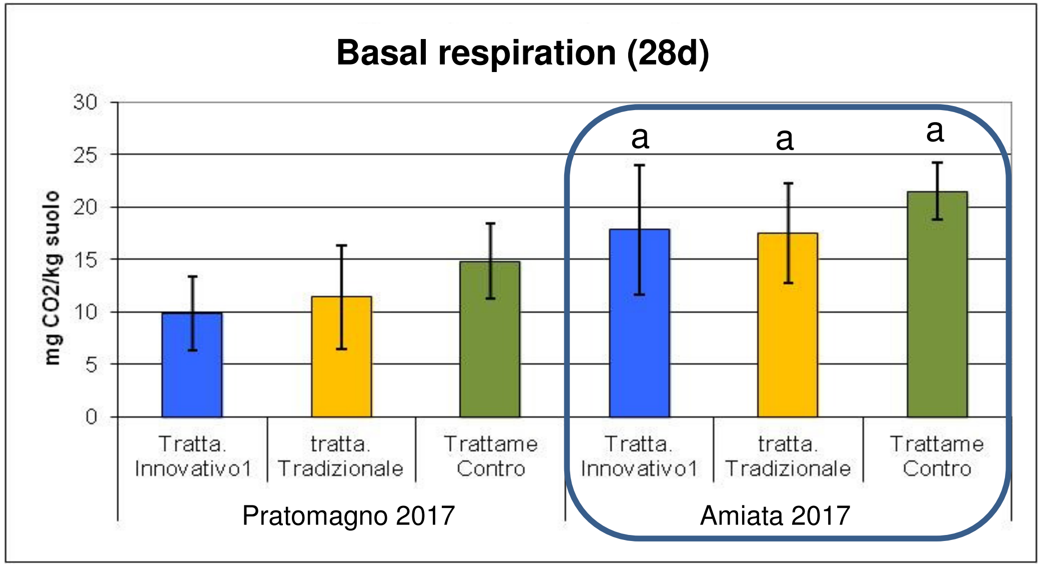


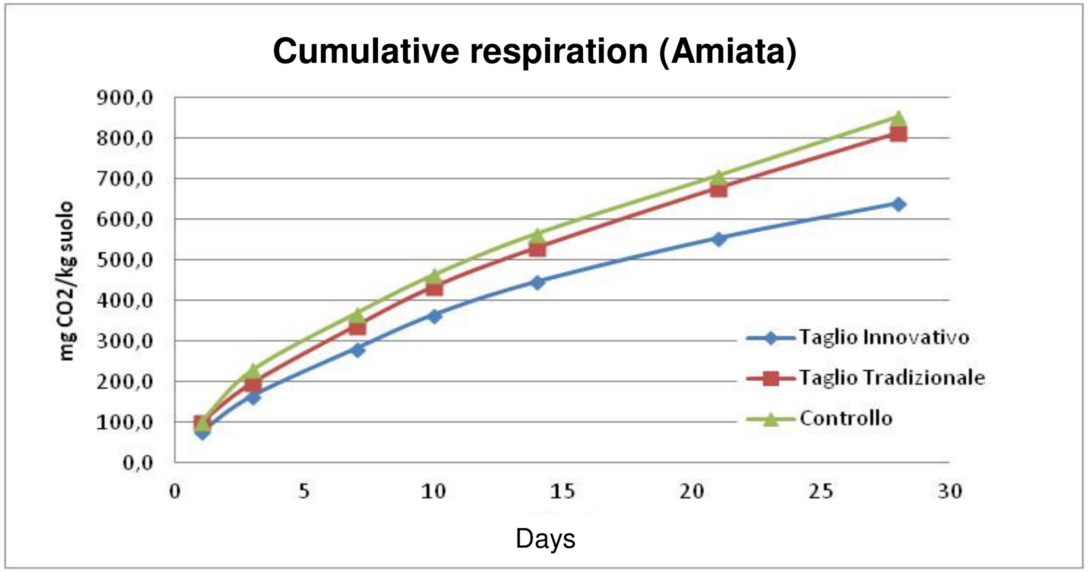
- In general, soils of AMIATA showed higher values than PRATOMAGNO (as observed in 2015 and 2016)

- Cumulative respiration resulted higher in the CTRL plots, as compared to treated plots (not significant)

Microbial respiration (Amiata)



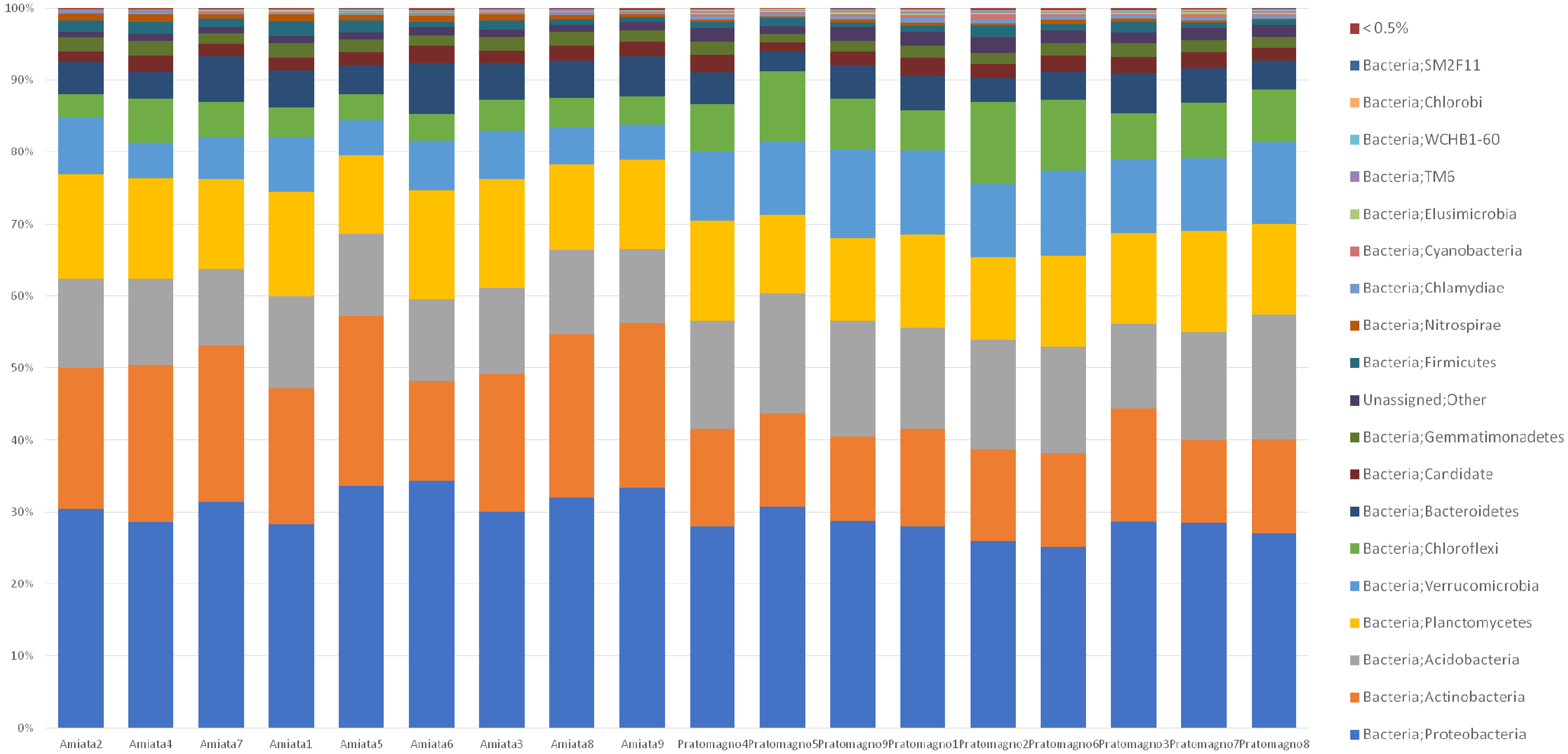




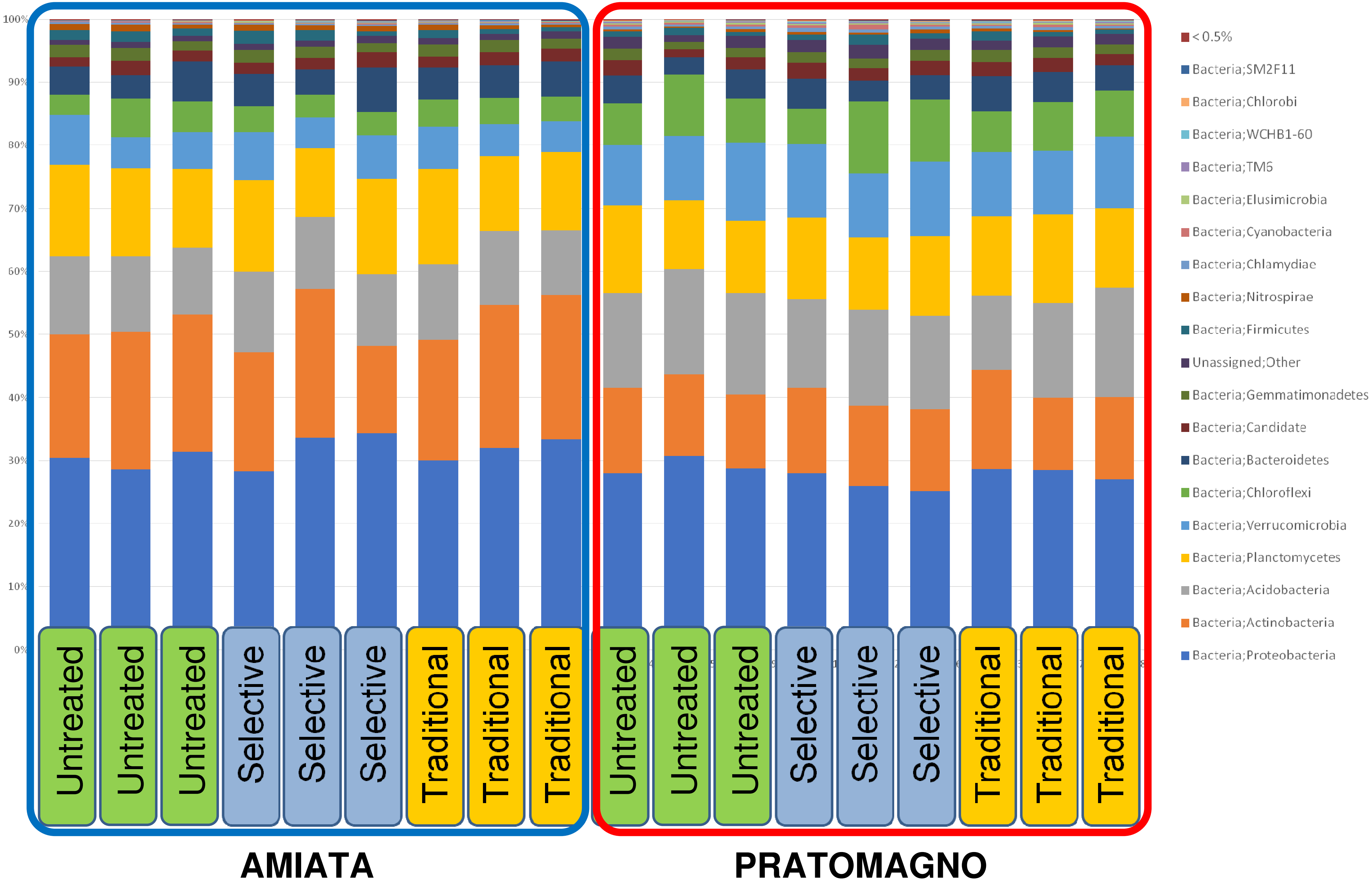
- In general, soils of AMIATA showed higher values than PRATOMAGNO (as observed in 2015 and 2016)

- Basal respiration of the three treatments did not show any significant difference. Samples of selective thinning provided the lowest Ccum values (not significant)

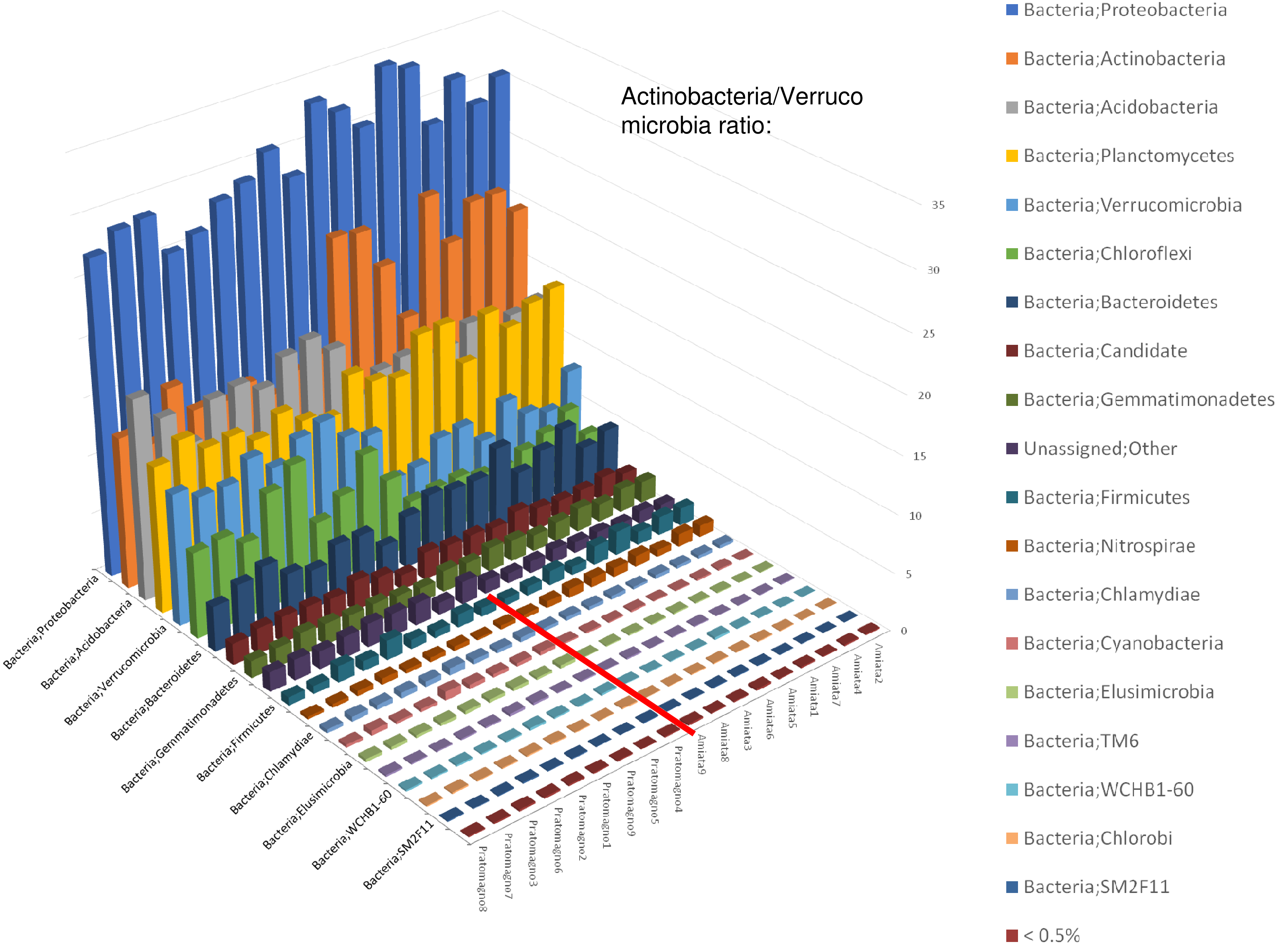
Bacterial diversity (Phyla)



Bacterial diversity (Phyla)

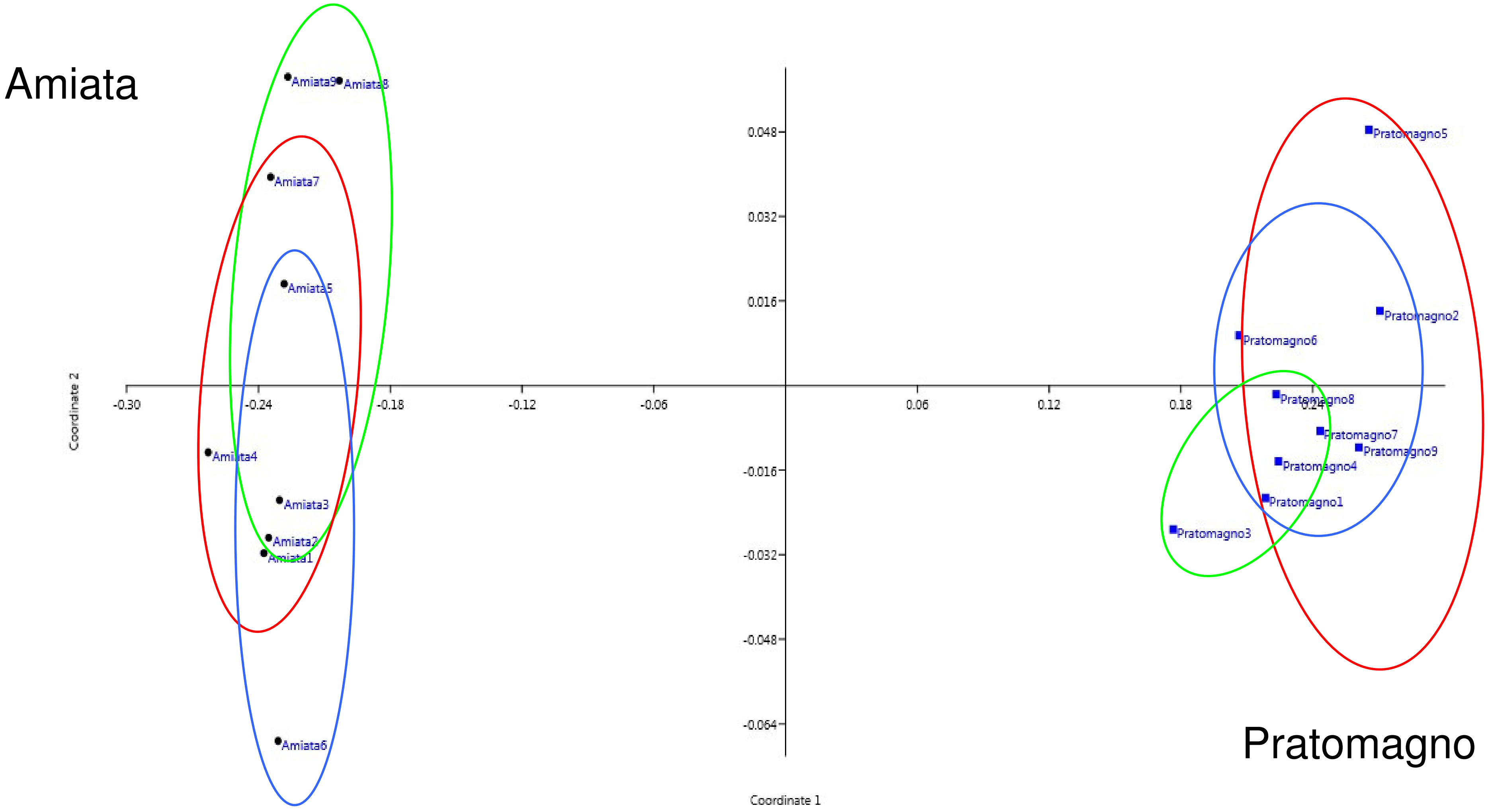


Relative abundances Bacterial diversity (Phyla)



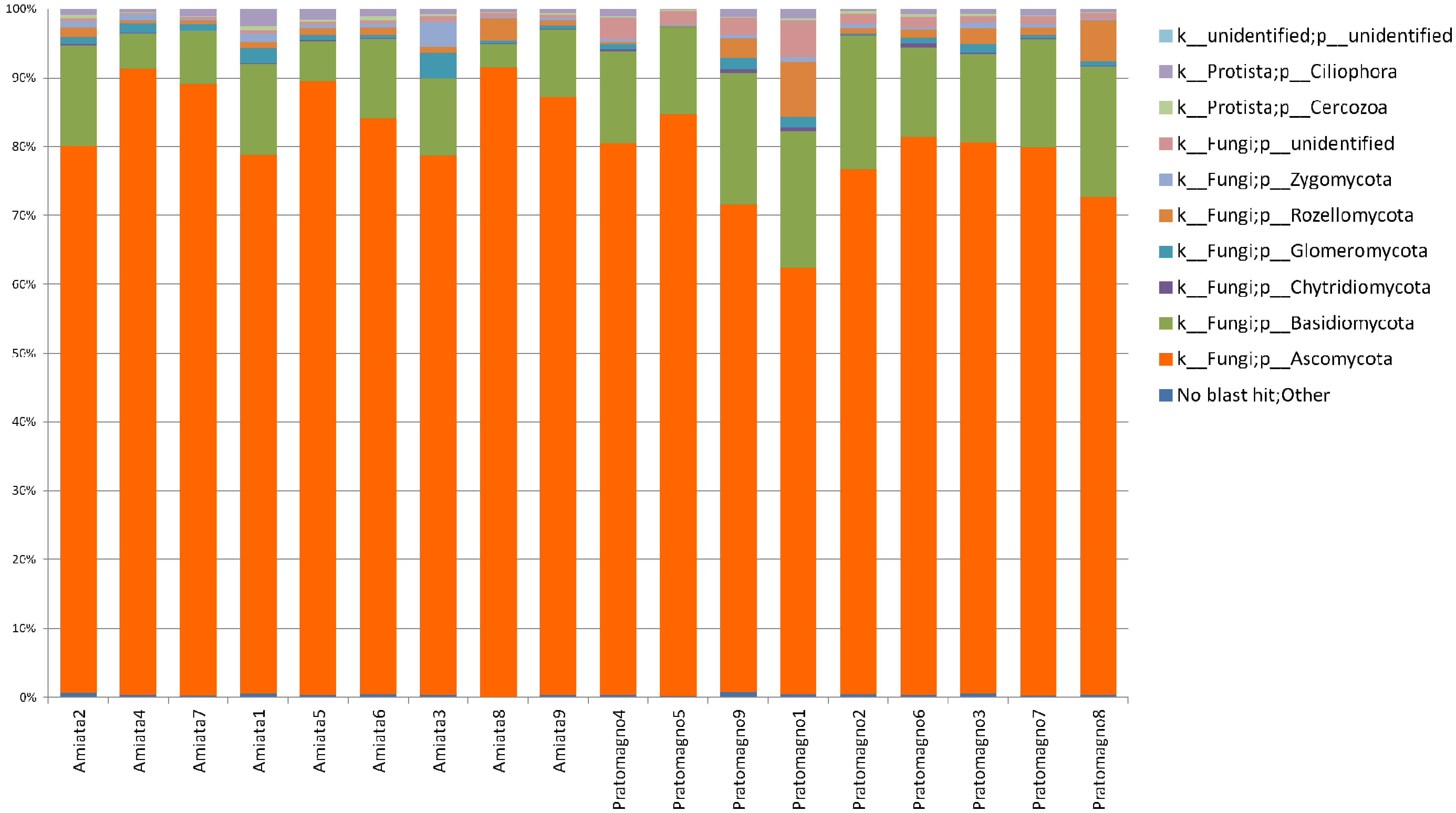
Actinobacteria/Verruco
microbia ratio:

NMDS analysis (Bacteria)

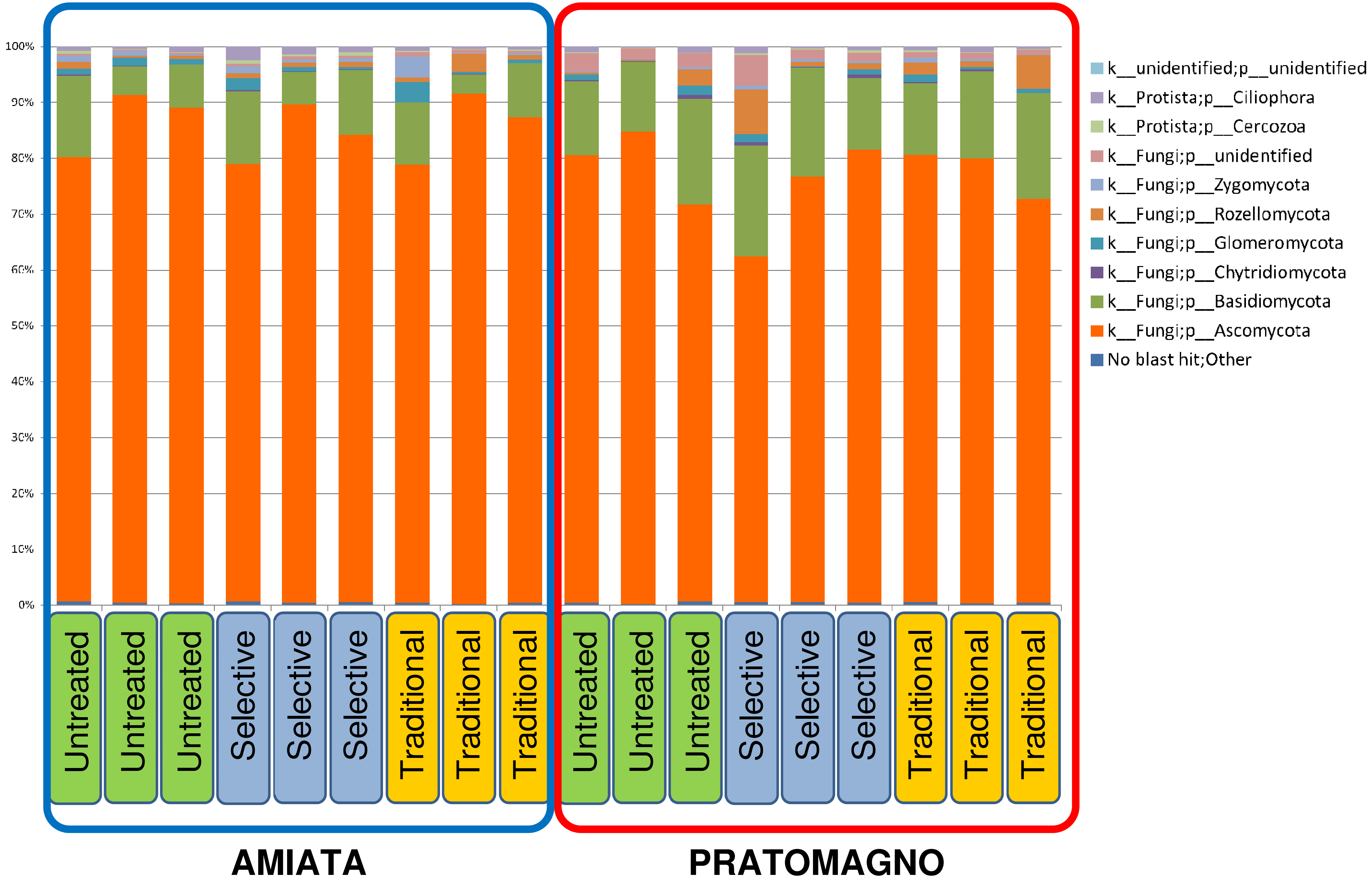


NMDS analysis (Non Metric Dimensional Scaling) of bacterial communities (Phyla) of AMIATA (1, 5, 6: selctive thinning (blu); 3,8,9: traditional (green); 2,4,7: control (red) and PRATOMAGNO (1,2,6: selective thinning (blu); 3,7,8: traditional (green); 4,5,9: control (red) in 2017.

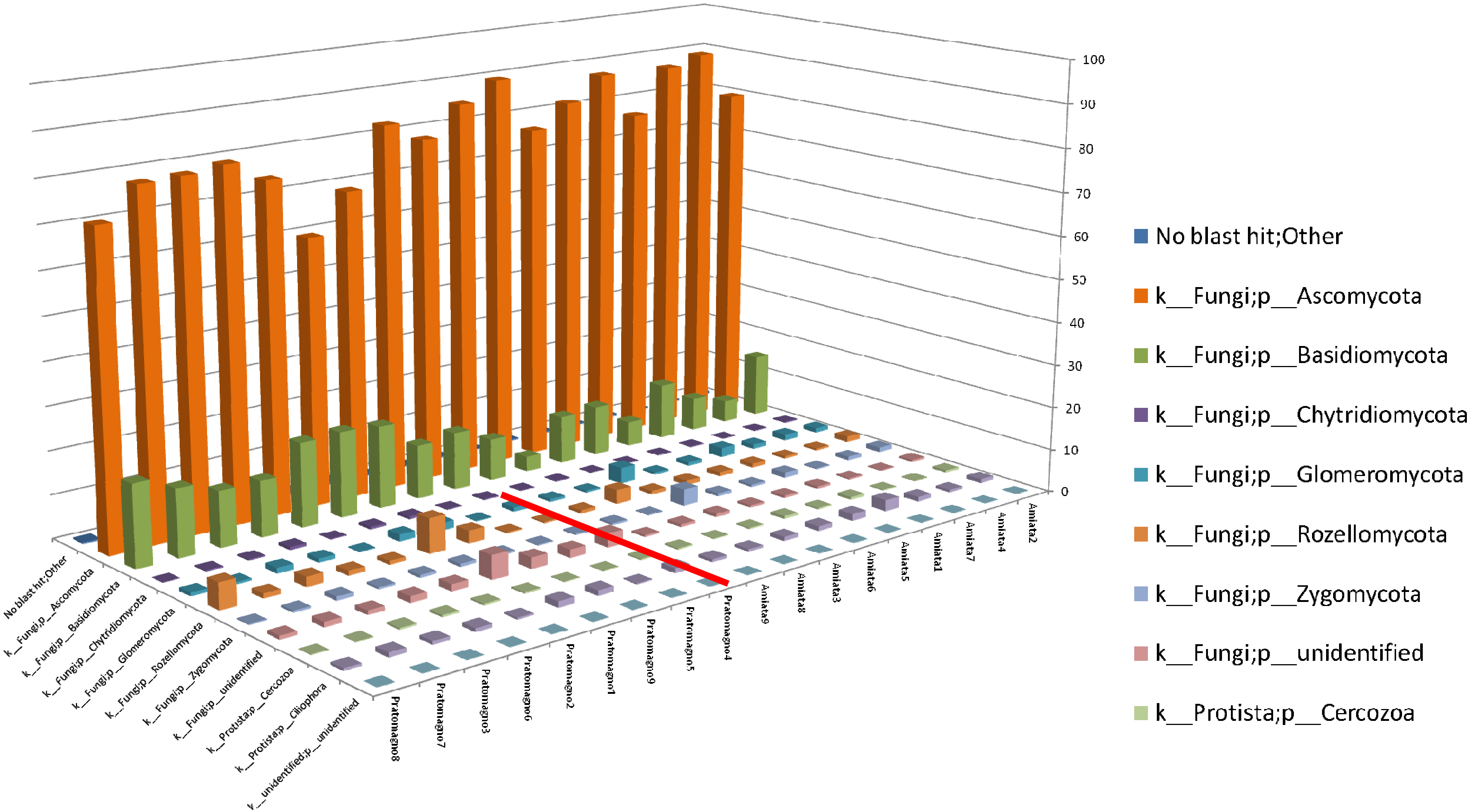
Fungal diversity



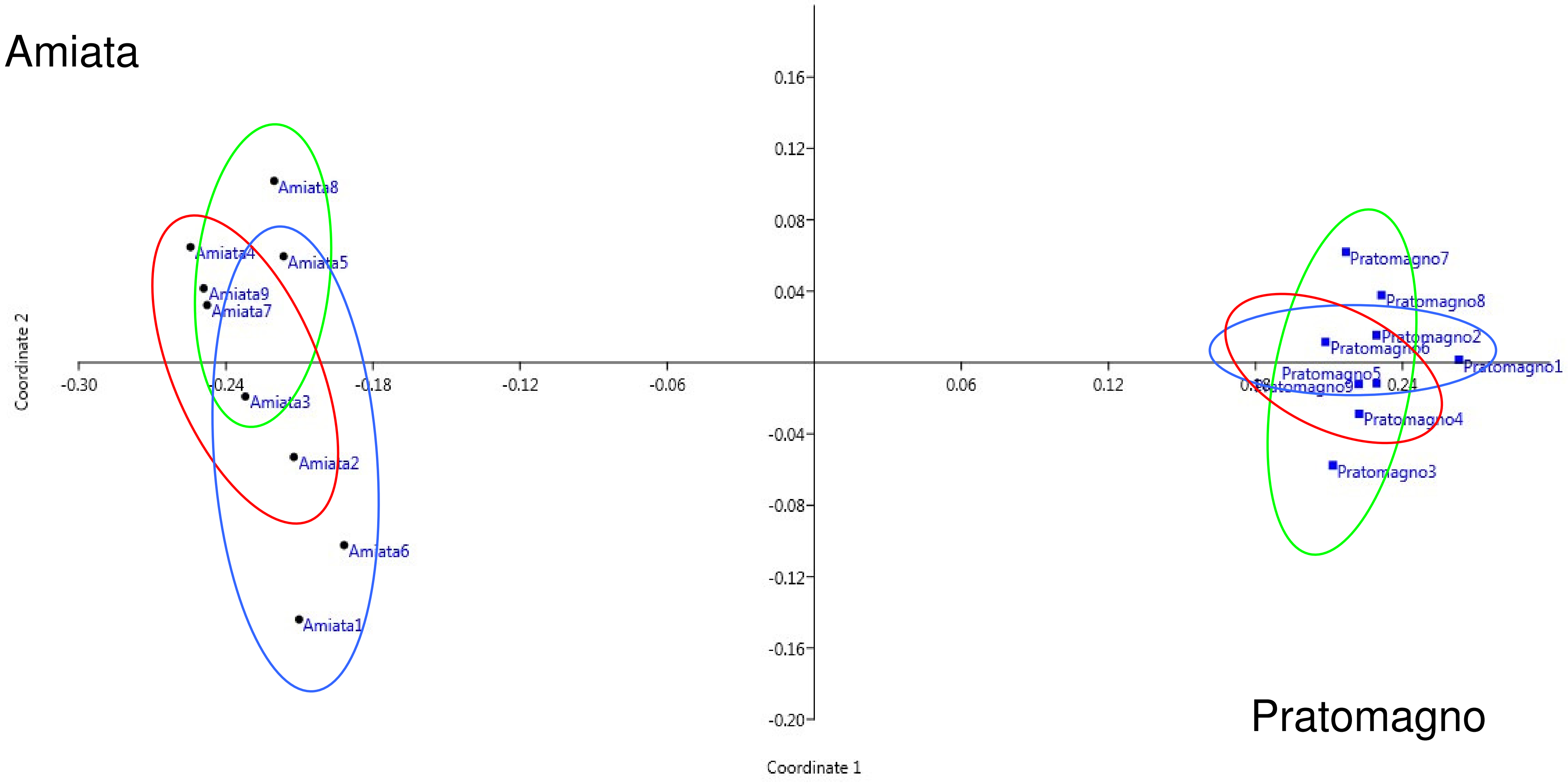
Fungal diversity



Fungal diversity



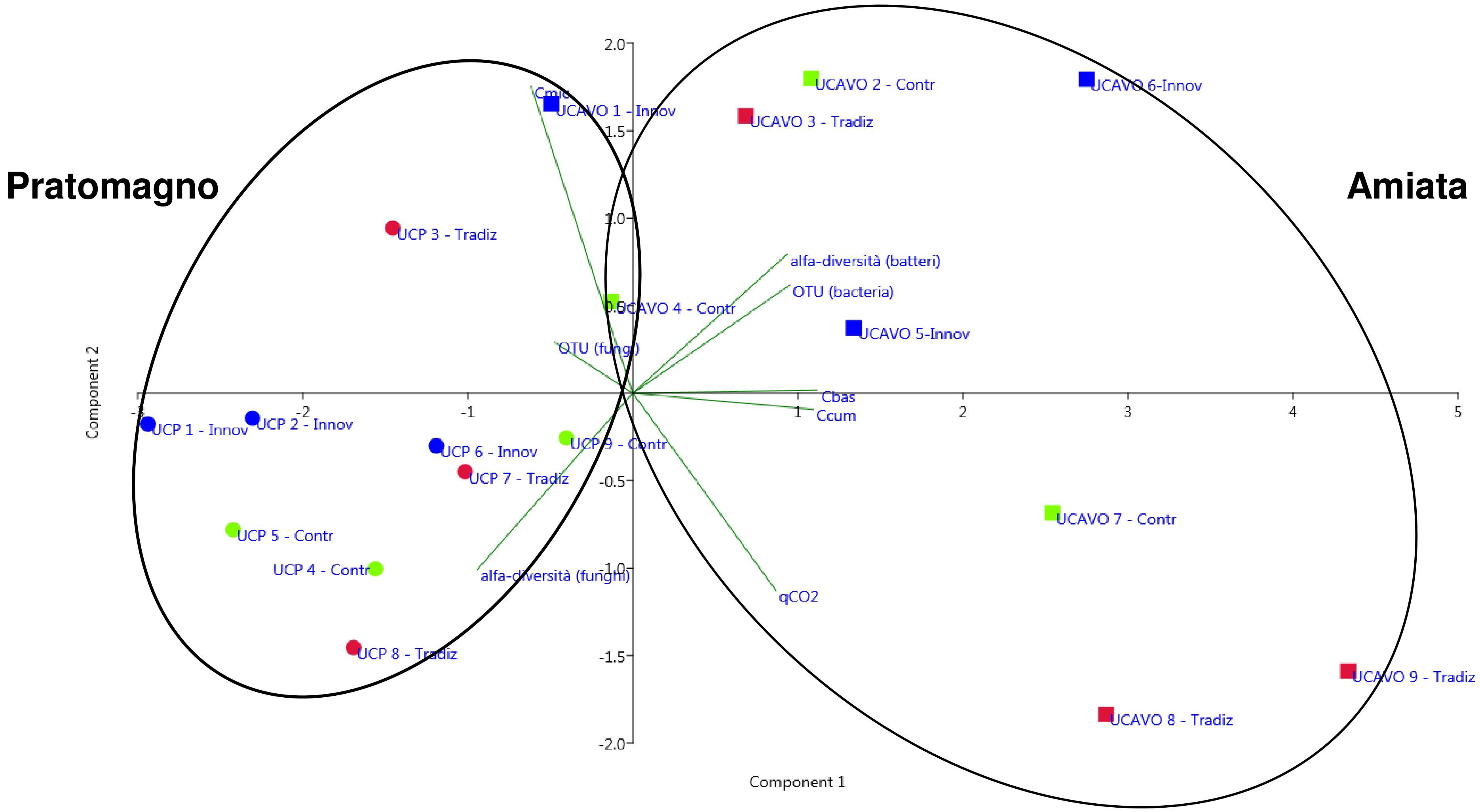
NMDS analysis (Fungi)

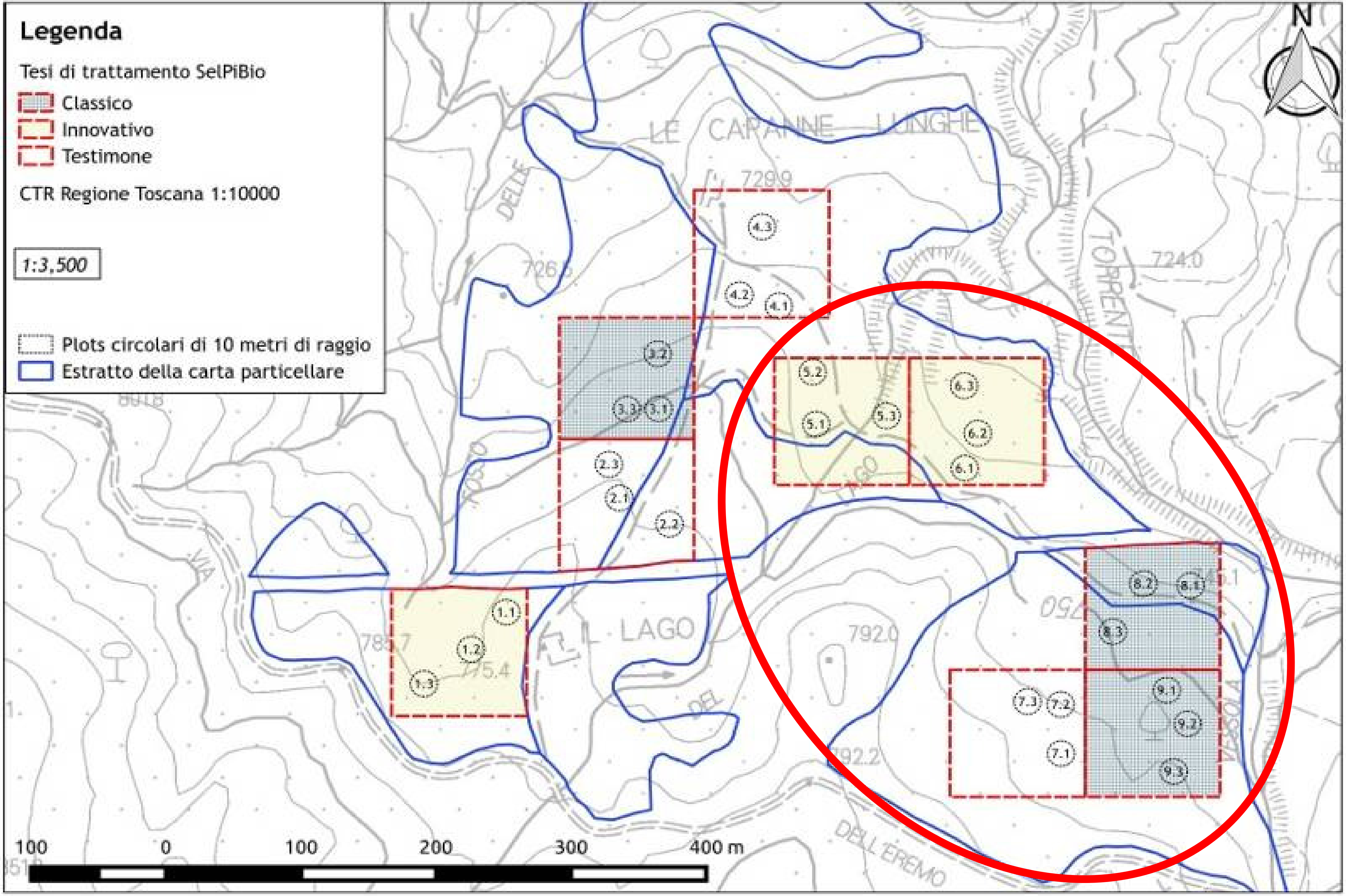


NMDS analysis (Non Metric Dimensional Scaling) of fungal communities (Phyla) of AMIATA (1, 5, 6: selctive thinning (blu); 3,8,9: traditional (green); 2,4,7: control (red) and PRATOMAGNO (1,2,6: selective thinning (blu); 3,7,8: traditional (green); 4,5,9: control (red) in 2017.

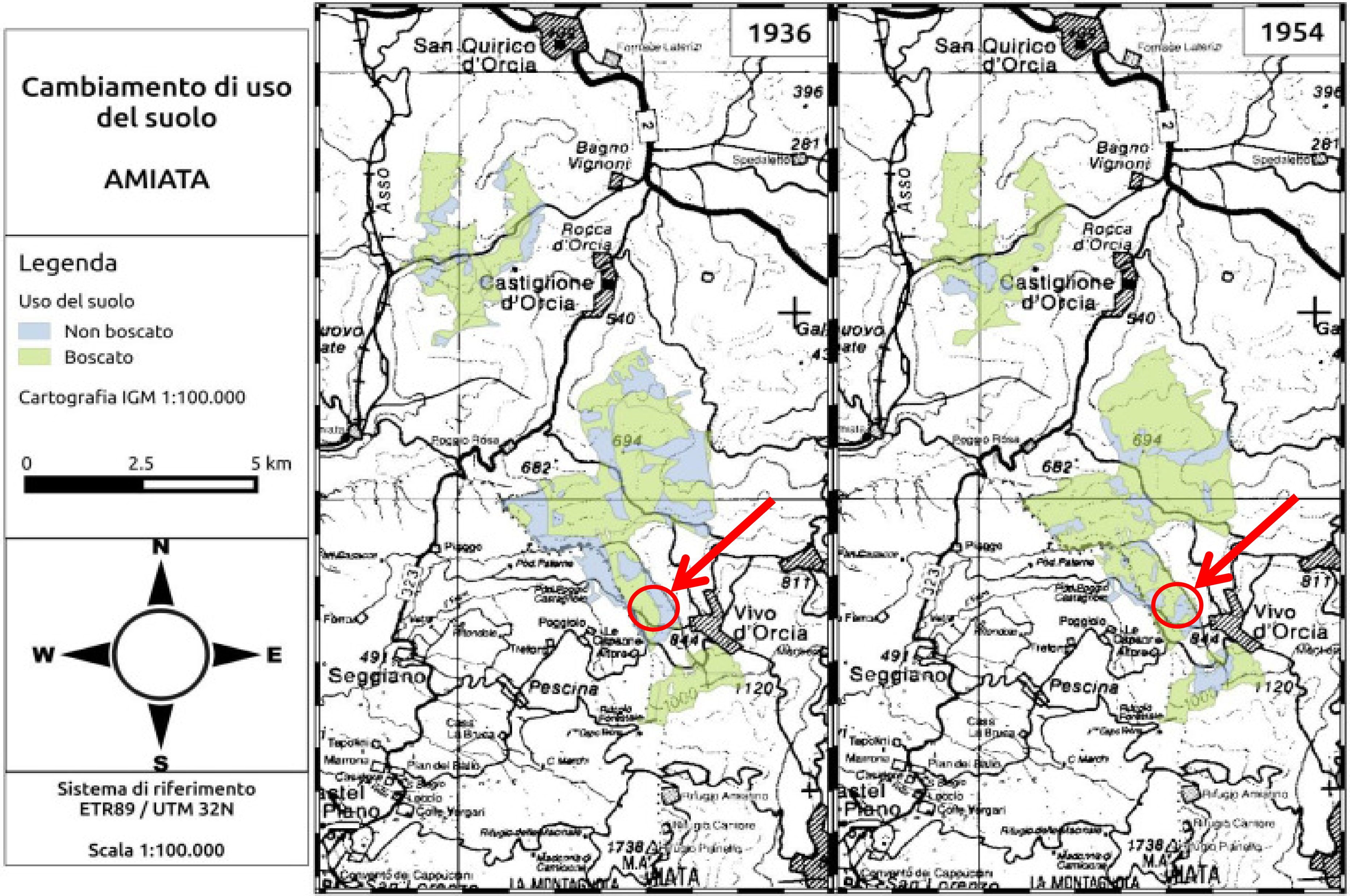
Principal Component Analysis (PCA)

PC	% variance
1	54,8 %
2	17,3 %

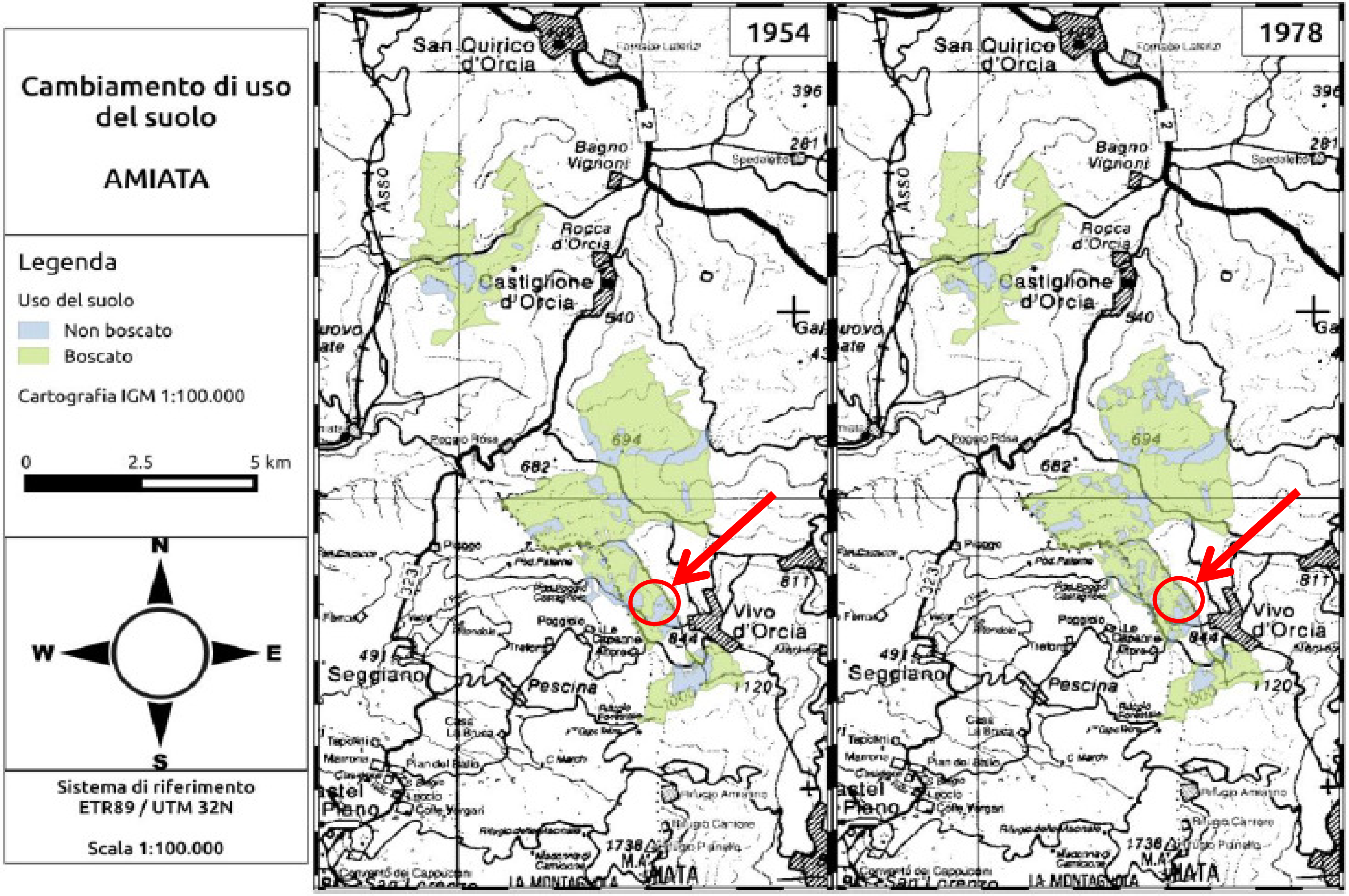



Legenda
Tesi di trattamento SelPiBio
▨ Classico
🟨 Innovativo
☐ Testimone
CTR Regione Toscana 1:10000
1:3,500
Plots circolari di 10 metri di raggio
Estratto della carta particellare
N
LE CAPANNE LUNGHE
IL LAGO
TORRENTE
DELL'EREMO
4.1
4.2
4.3
3.1
3.2
3.3
2.1
2.2
2.3
1.1
1.2
1.3
5.1
5.2
5.3
6.1
6.2
6.3
7.1
7.2
7.3
8.1
8.2
8.3
9.1
9.2
9.3
100 0 100 200 300 400 m

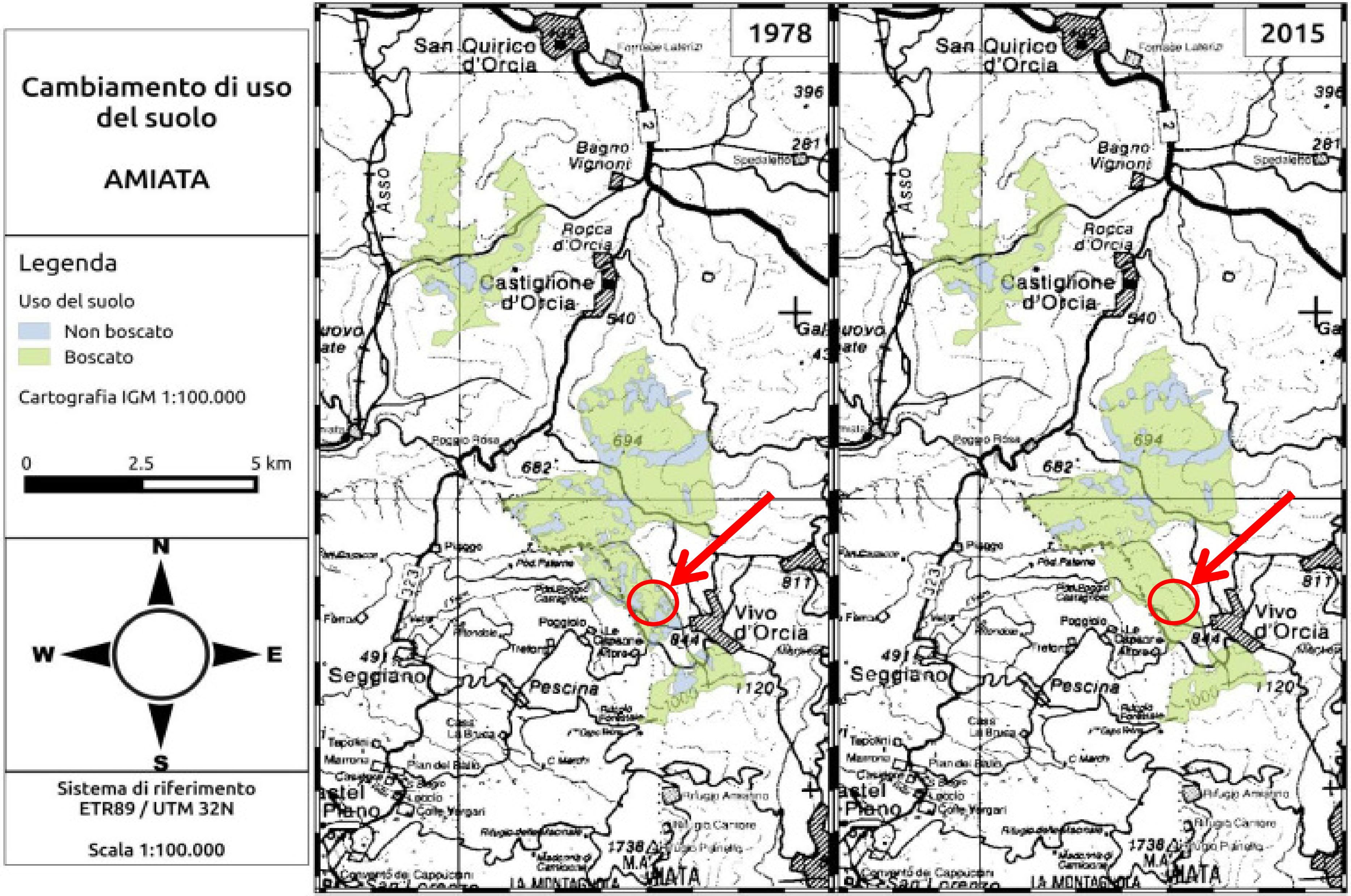
1936-1954: map of land use indicating the spatial distribution of forest (green) and grassland/meadow (blu). Red arrows indicate the area where plots 1-4 (green) and 5-9 (blu) were located



1954-1978: map of land use indicating the spatial distribution of forest (green) and grassland/meadow (blu). Red arrows indicate the area where plots 1-4 (green) and 5-9 (blu) were located



1978-2015: map of land use indicating the spatial distribution of forest (green) and grassland/meadow (blu). Red arrows indicate the area where plots 1-4 (green) and 5-9 (blu) were located



Principal Component Analysis (PCA)

PC	% variance
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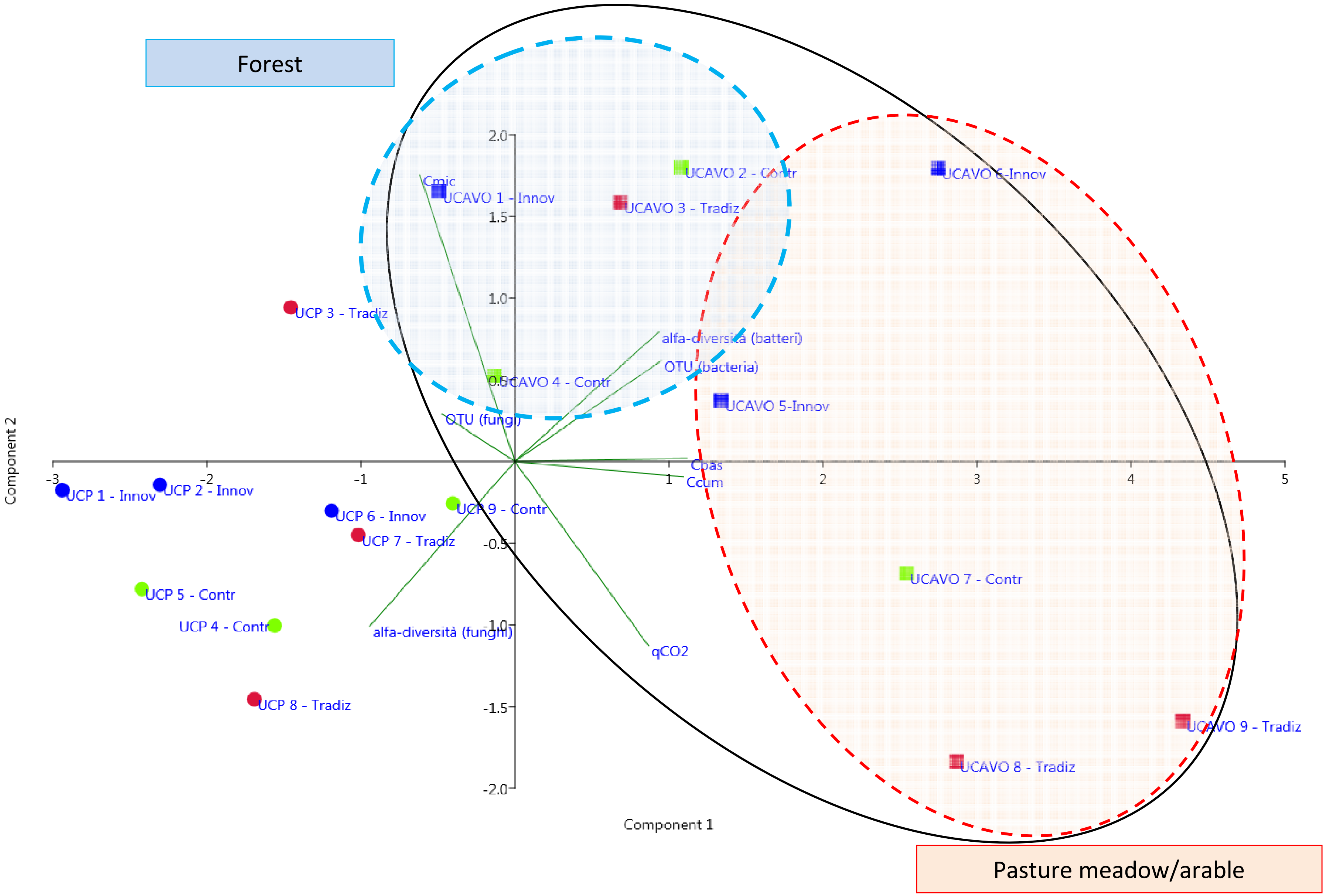
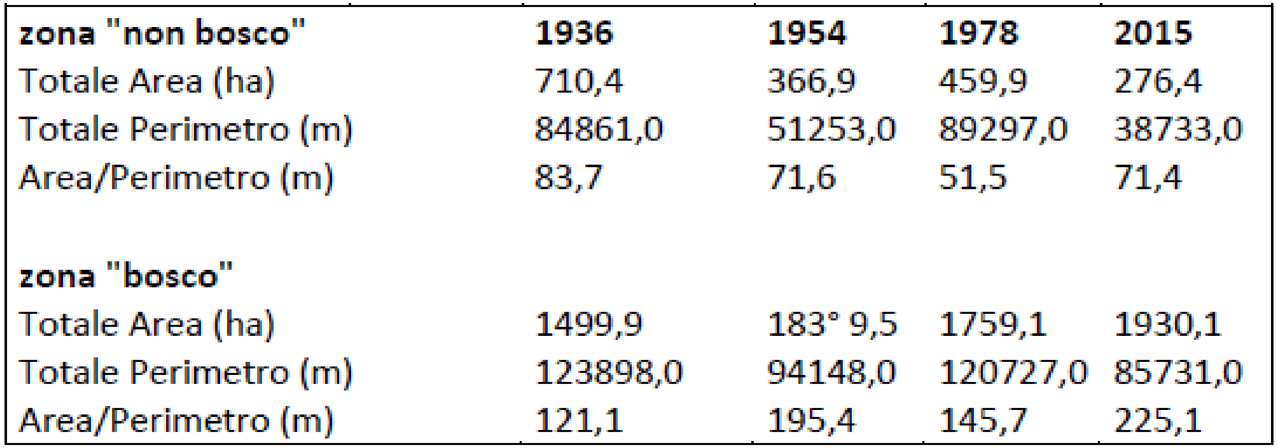
2	17,3 %



CONCLUSIONS

- Cross-taxon congruence analysis carried out before silvicultural treatment indicated that soil bacteria and microfungi and strictly correlated, regardless the environmental features
- Most of the total variation of the majority of the dependent taxa cannot be explained by the predictors selected in this work, confirming the huge complexity of natural environment-biota interactions
- Only ECM and microfungi were able to explain a significant degree of variance in bacteria attributed to pure taxon effects.
- After two years from thinning, soil microbial activity and community structure of the two experimental areas is significantly different. However, the thinning did not significantly affect neither microbial activity or diversity.
- Remarkably, PCA of microbial data of AMIATA clustered samples according with their different land use over the last decades….a legacy from the past?



zona "non bosco"	**1936**	**1954**	**1978**	**2015**
Totale Area (ha)	710,4	366,9	459,9	276,4
Totale Perimetro (m)	84861,0	51253,0	89297,0	38733,0
Area/Perimetro (m)	83,7	71,6	51,5	71,4
zona "bosco"				
Totale Area (ha)	1499,9	183° 9,5	1759,1	1930,1
Totale Perimetro (m)	123898,0	94148,0	120727,0	85731,0
Area/Perimetro (m)	121,1	195,4	145,7	225,1

Rispetto al 1936 i plot che erano completamente o parzialmente occupati dal bosco (cedui degradati a prevalenza quercina), sono:
1.1, 1.2, 1.3
2.1, 2.3
3.3
7.1
7.2
9.2
9.3

Plots ex-seminativi: 4, 5 ,6, 7, 8

PARTNERS

1. **CREA – VE (Dr.Paolo Cantiani – Coordinator): silvicultural management, Project Management**
2. **CREA – AA (Dr. Stefano Mocali, Drs. Isabella De Meo, Drs. Elisa Bianchetto, Drs. Silvia Landi,): silvicultural management, Microbial diversity,Floral diversity, Nematodes and arthropods**
3. **University of Siena (Drs. Elena Salerni): Fungal diversity**
4. **Compagnia delle Foreste (Dr. Paolo Mori, Drs. Silvia Bruschini): Dissemination**
5. **UCP (Stefano Samaden): silvicultural management**
6. **UCAVO (Piergiuseppe Montini) : silvicultural management**

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Thank you