Land-use effects on soil quality of agricultural systems in the Central Andes of Bolivia

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Outline of the presentation

1. Introduction

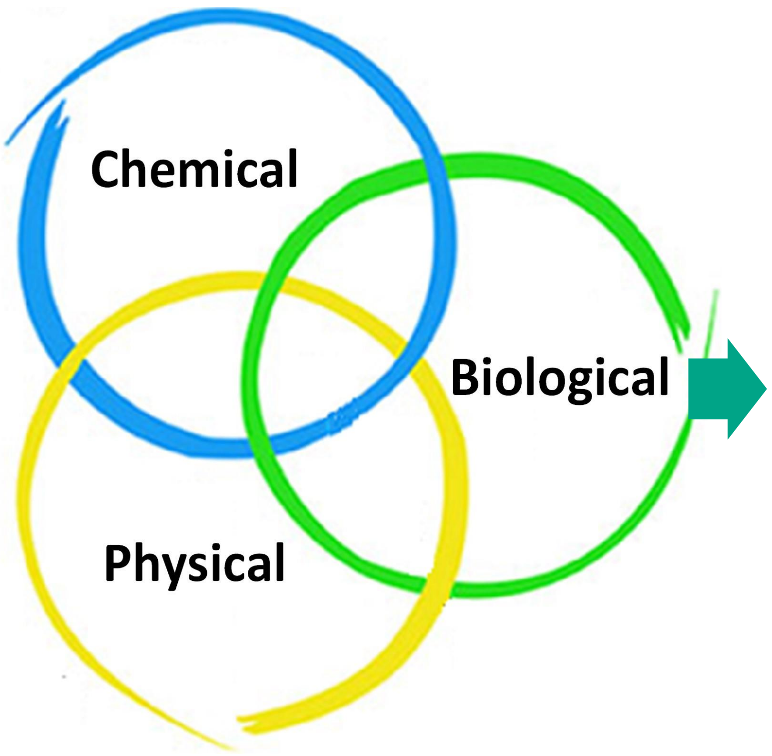
2. Study area

3. Methods, results and discussion

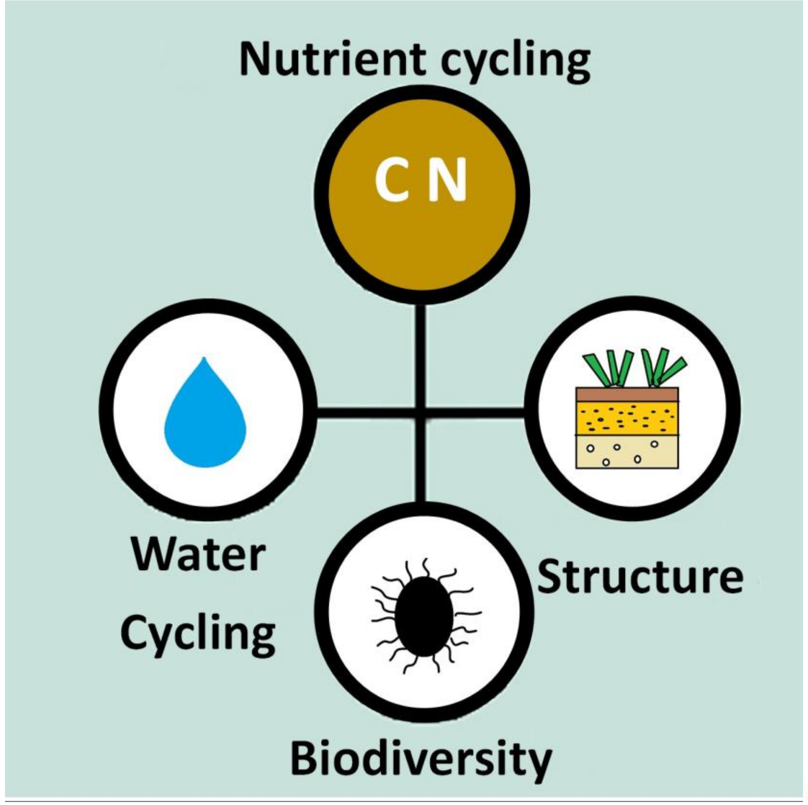
- **- Soil chemical variables as indicators of soil quality**
- **- Soil physical variables as indicators of soil quality**
- **- Ammonia oxidizers as indicators of soil quality**
- **- Effects of fertilization on soil quality and plant development**

4. Conclusions

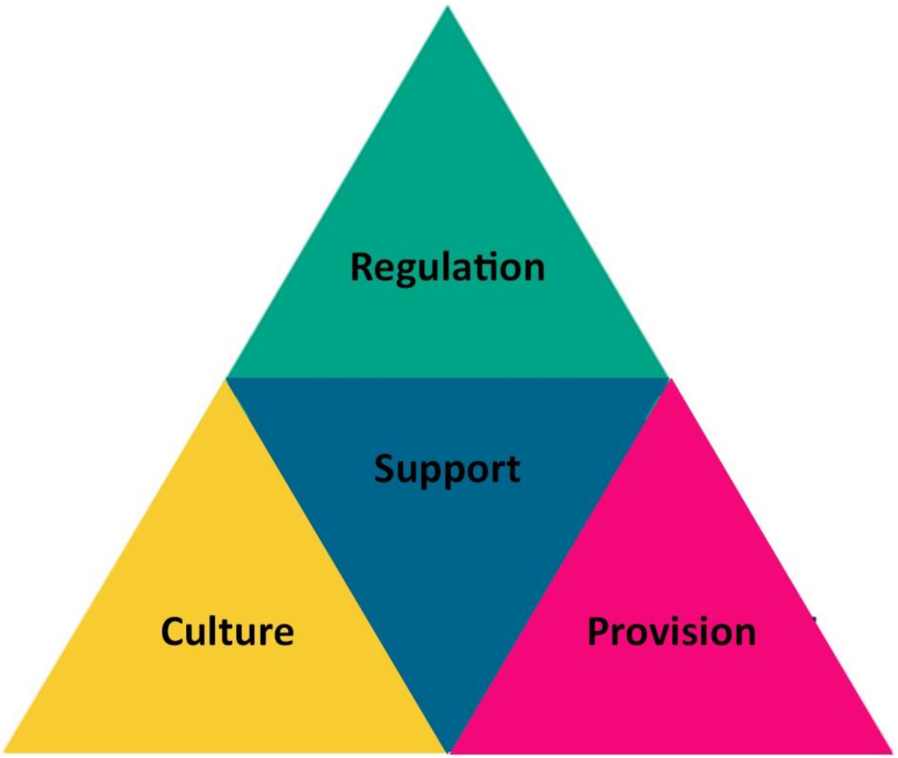
1. Introduction



Soil functions



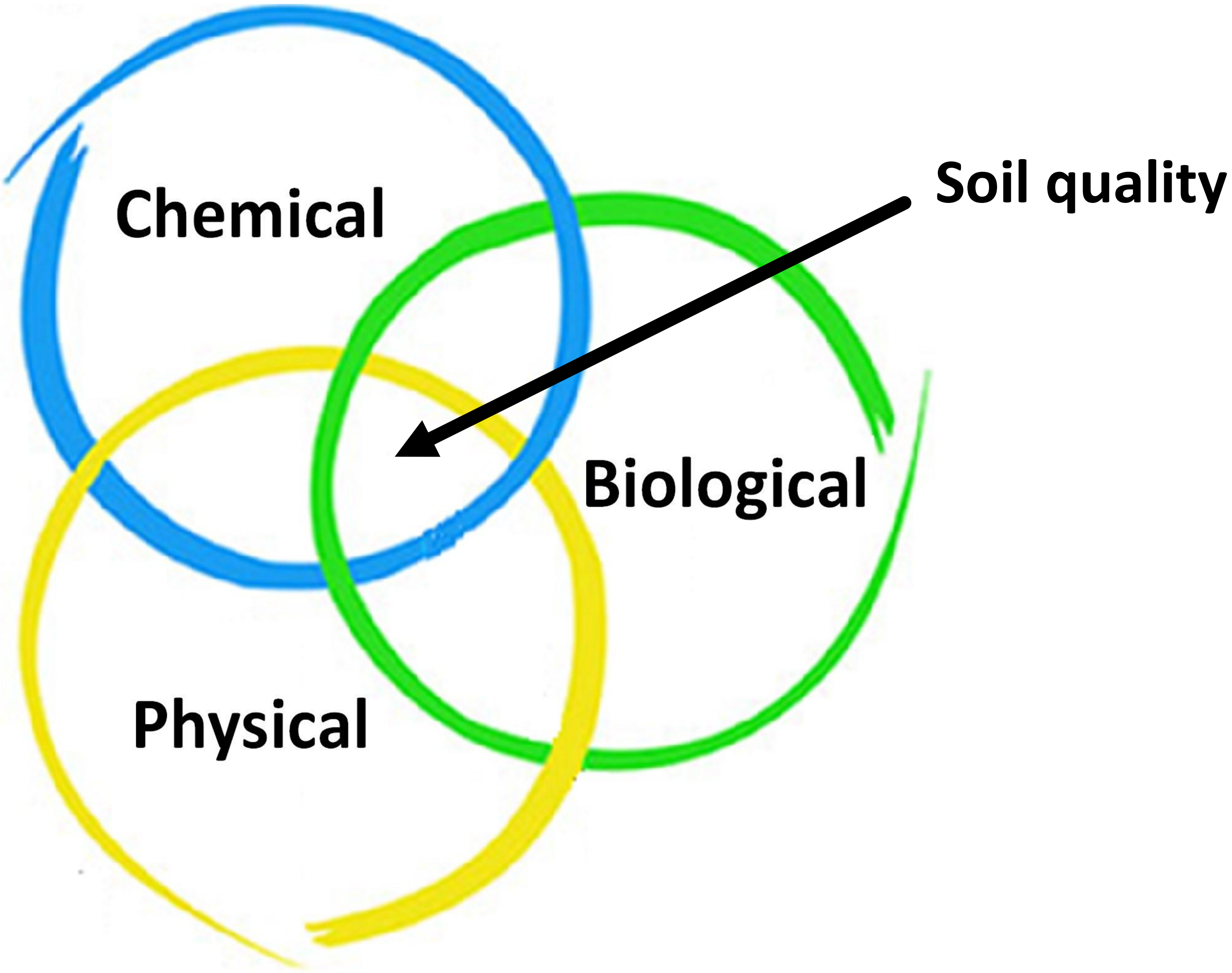
Ecosystem services



Soil quality:

"The capacity of a soil to function, to sustain biological productivity while maintaining environmental quality and promoting animal and human health"

(Doran and Parkin, 1994)

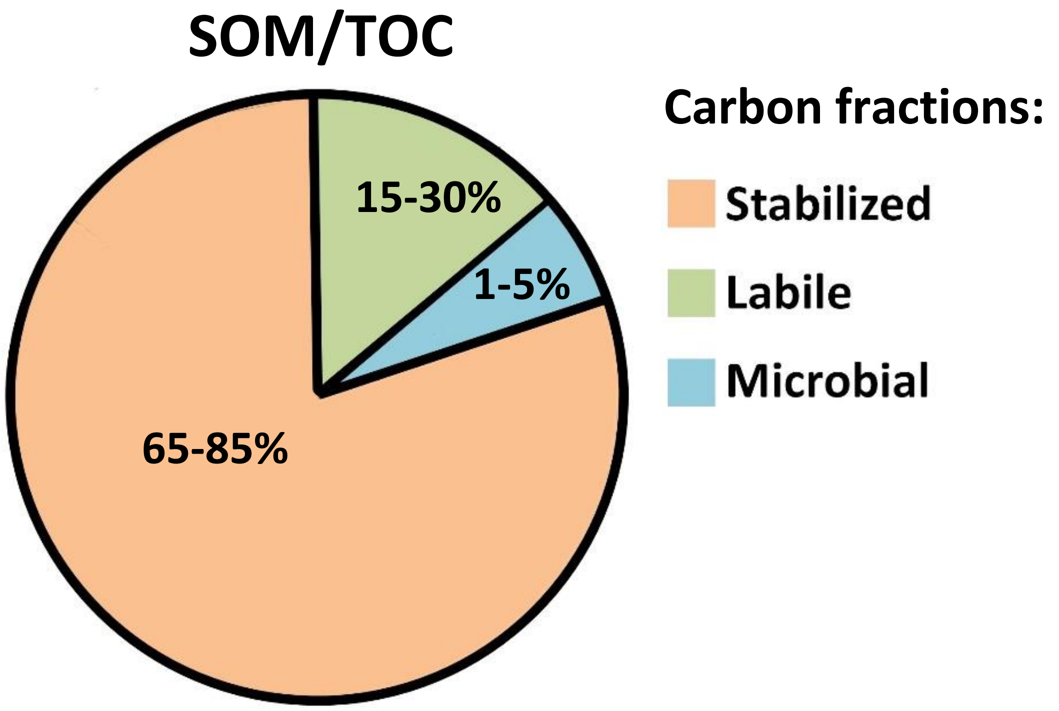

Soil quality
Chemical
Biological
Physical

Chemical characterisitics

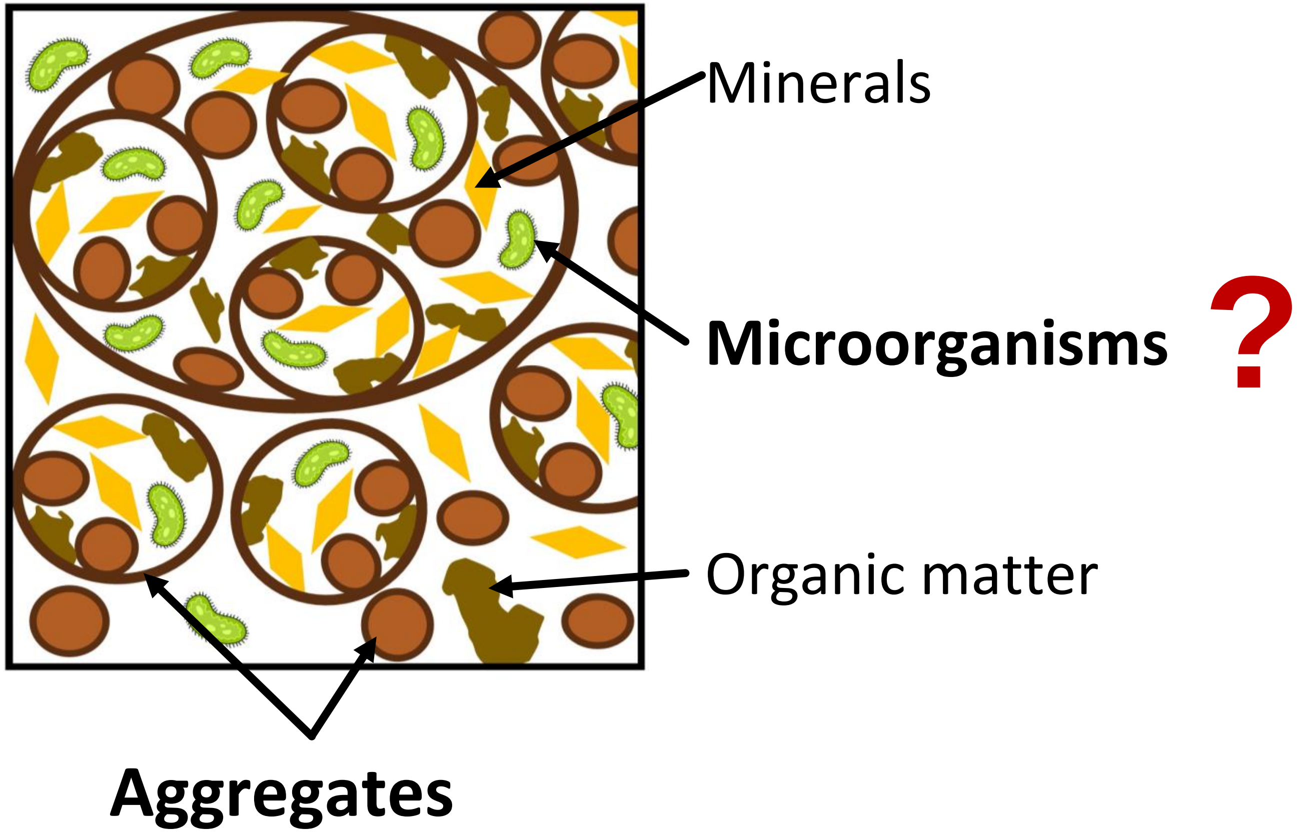
pH
C N fractions
Cations
Electrical conductivity
Nutrient contents

? ~

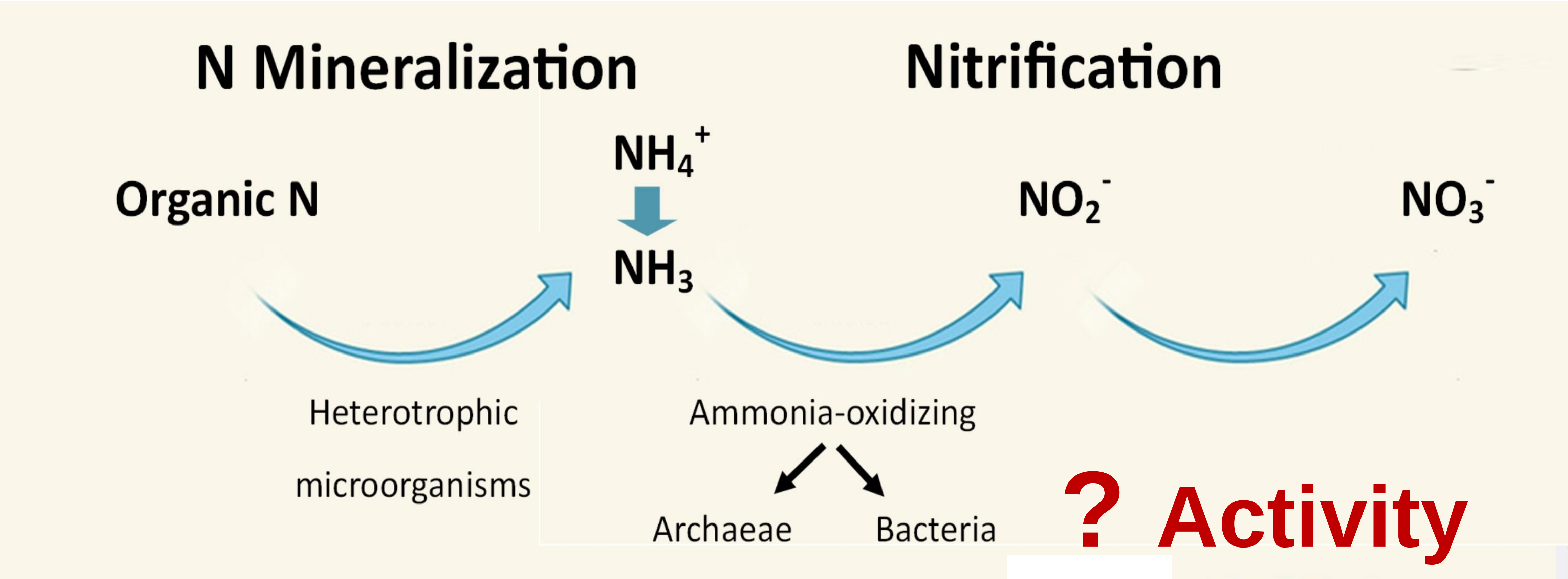
Microbial processes:
C Respiration
N mineralization



Physical characteristics

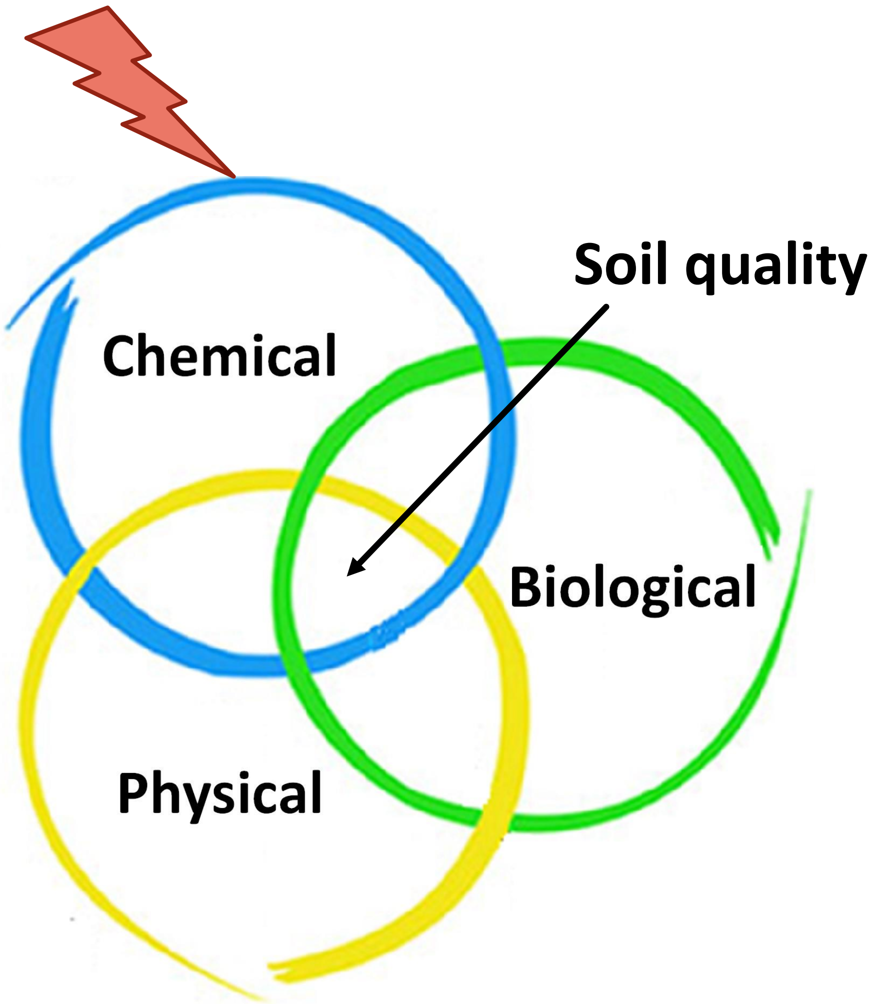


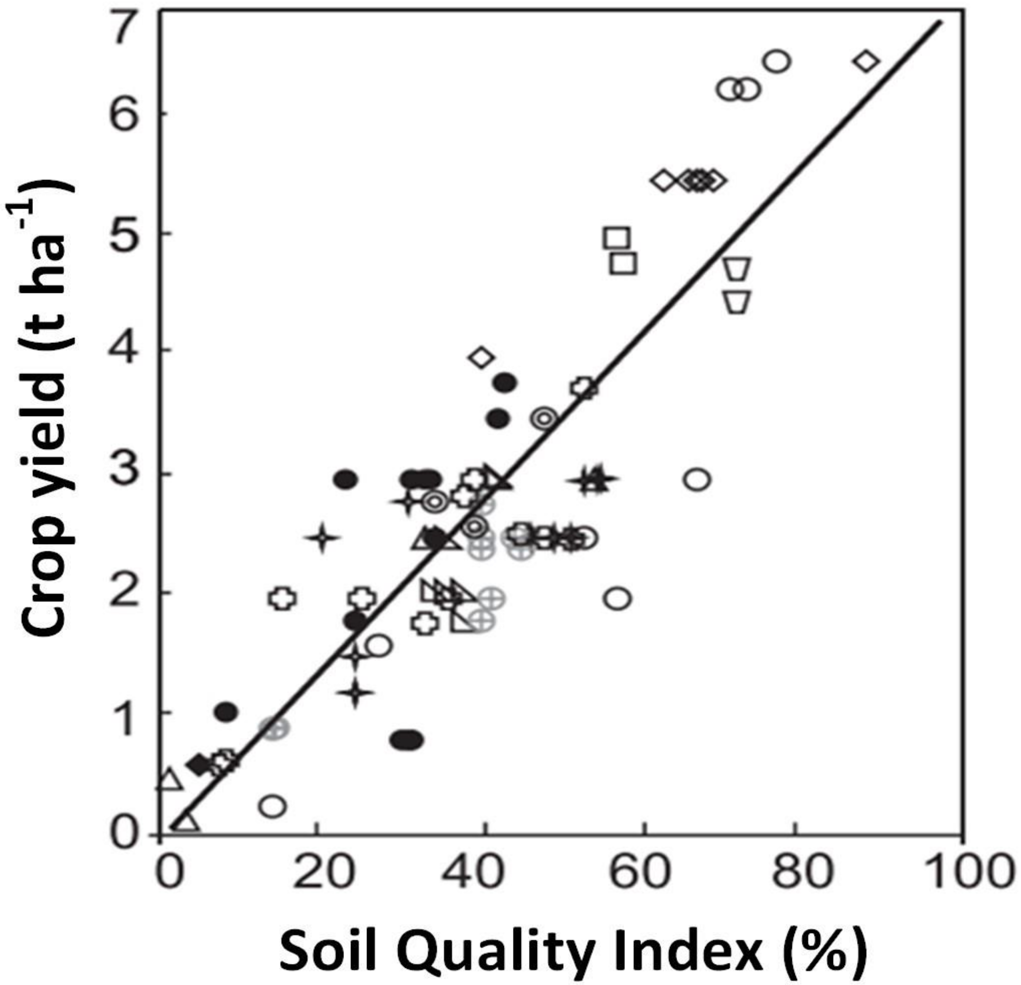
Microbial processes



~ Chemical variables
(pH, N fractions, cations, SOM)

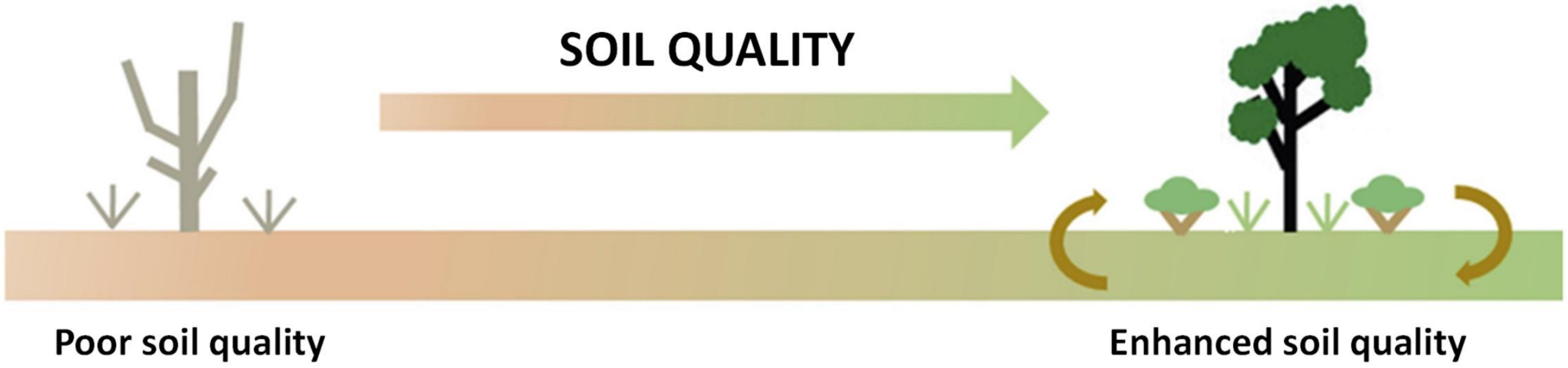
Land use change





Mueller et al. 2013

Management



Long-term food production

Organic amendments

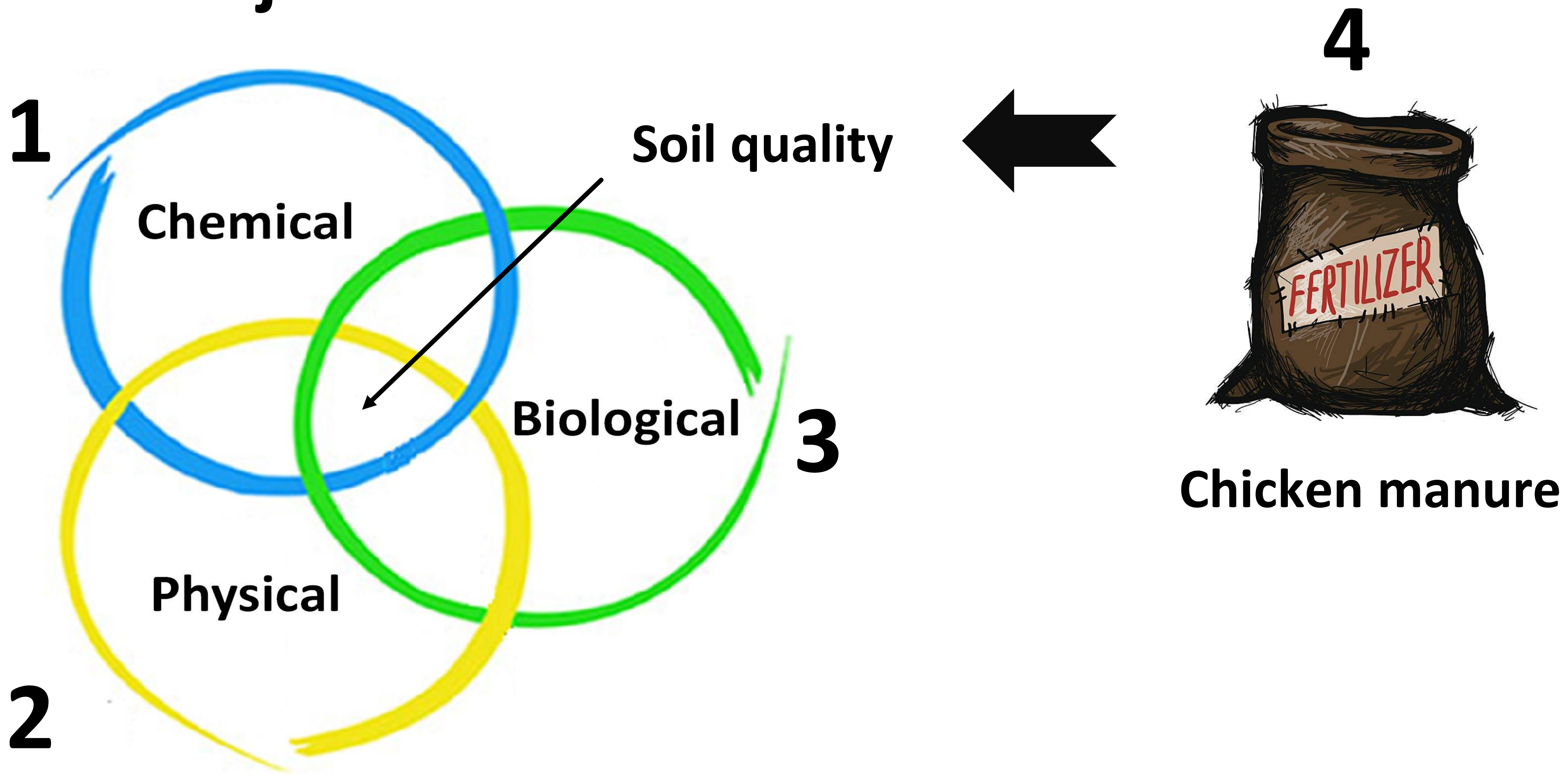
Agricultural systems in the Andean region

- Potato is the main crop
- Fallow periods have been shortened
- Chicken manure was incorporated
- Eucalyptus plantations were introduced

General objective

Assess the effects of potato, short fallow fields, eucalyptus plantations, and chicken manure fertilization on soil quality of agricultural systems of the Central Andes of Bolivia

Specific objectives



Specific objectives

- Assess the soil chemical characteristics and microbial process related to C and N cycling, and the suitability of labile C fractions as indicators of microbial processes.

- Evaluate the soil aggregates and their association with soil binding agents (minerals and C fractions) and microbial processes.

- Evaluate the activity and abundance of ammonia oxidizing archaea and bacteria, and their relationships with physicochemical variables.

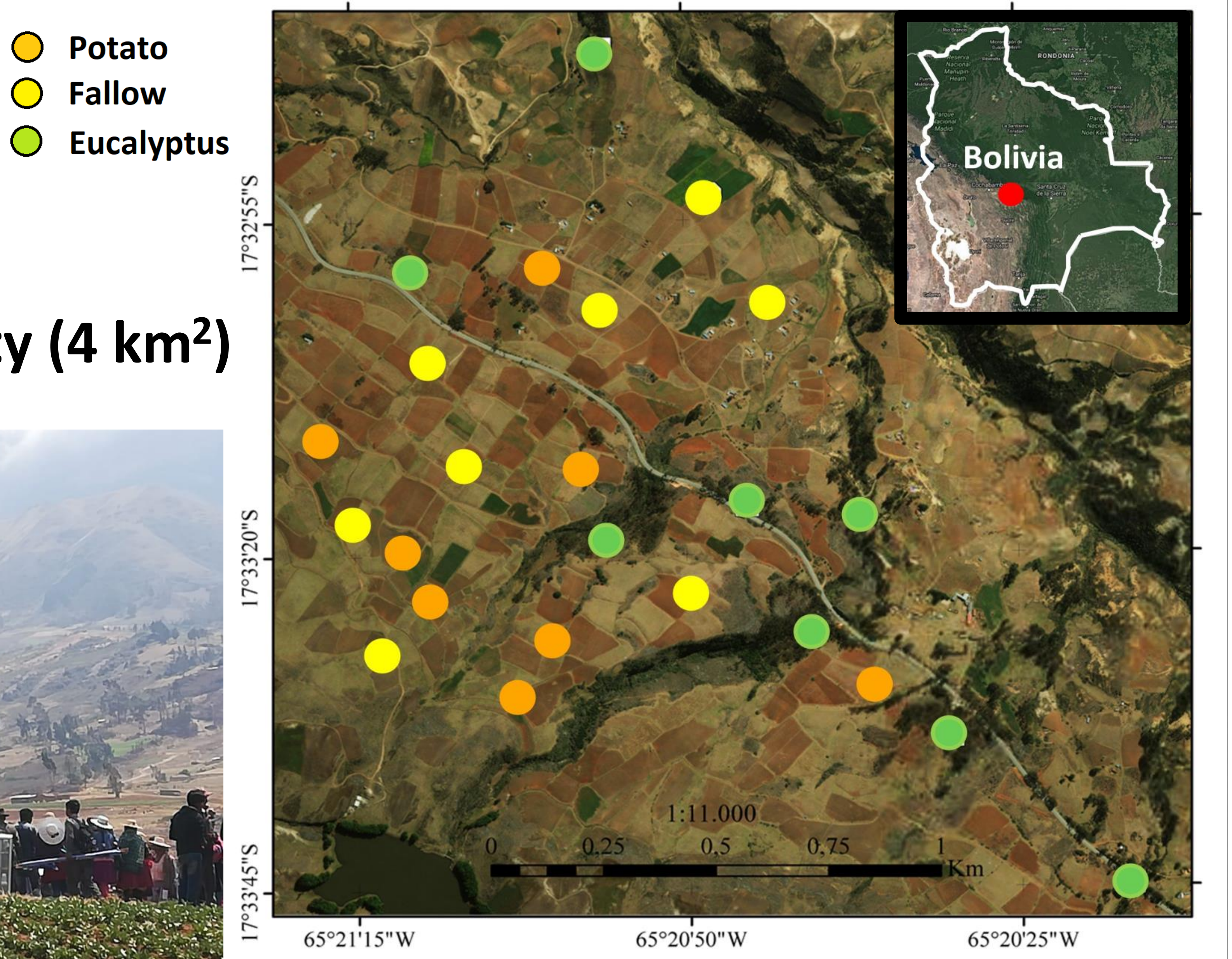
- Evaluate the effect of compost management on stability and maturity of chiken manure, and the effect of fertilization on soil quality and plant development.

2. Study area

Pocona

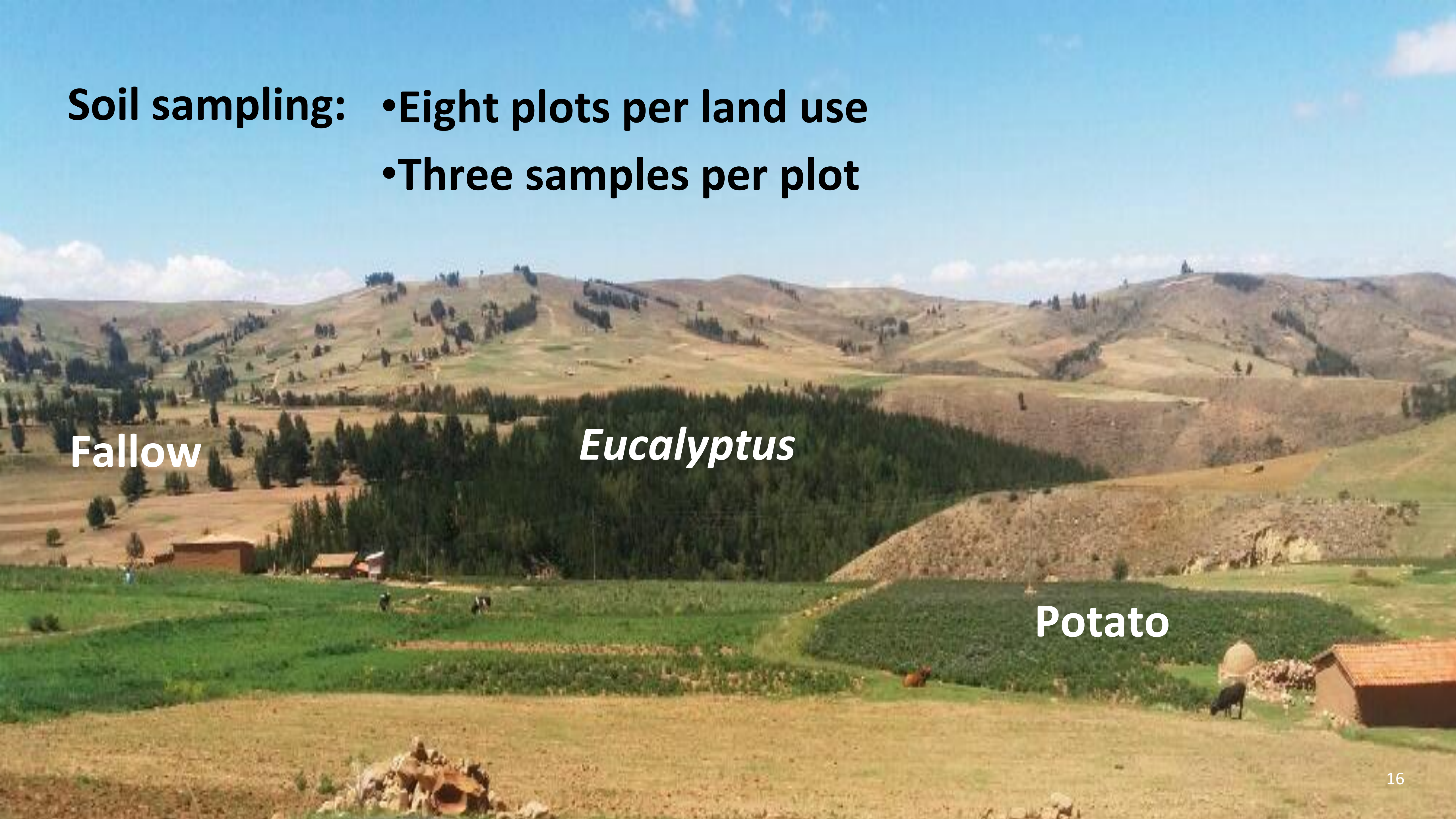
> 7000 farmers

Chullchunqani Community (4 km²)



Soil sampling:

- **Eight plots per land use**
- **Three samples per plot**



3. Methods, results and discussion

3.1 Soil chemical characteristics and their relationship with microbial processes

Methods

Chemical variables

pH

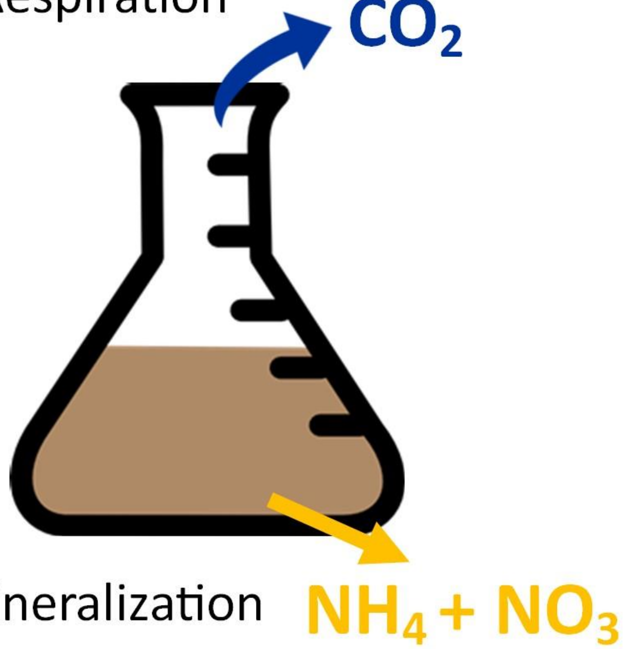
Cations

C fractions
- SOM – Total C
- Extractable C
- Microbial biomass

N fractions
- Total N
- Organic N
- Inorganic N

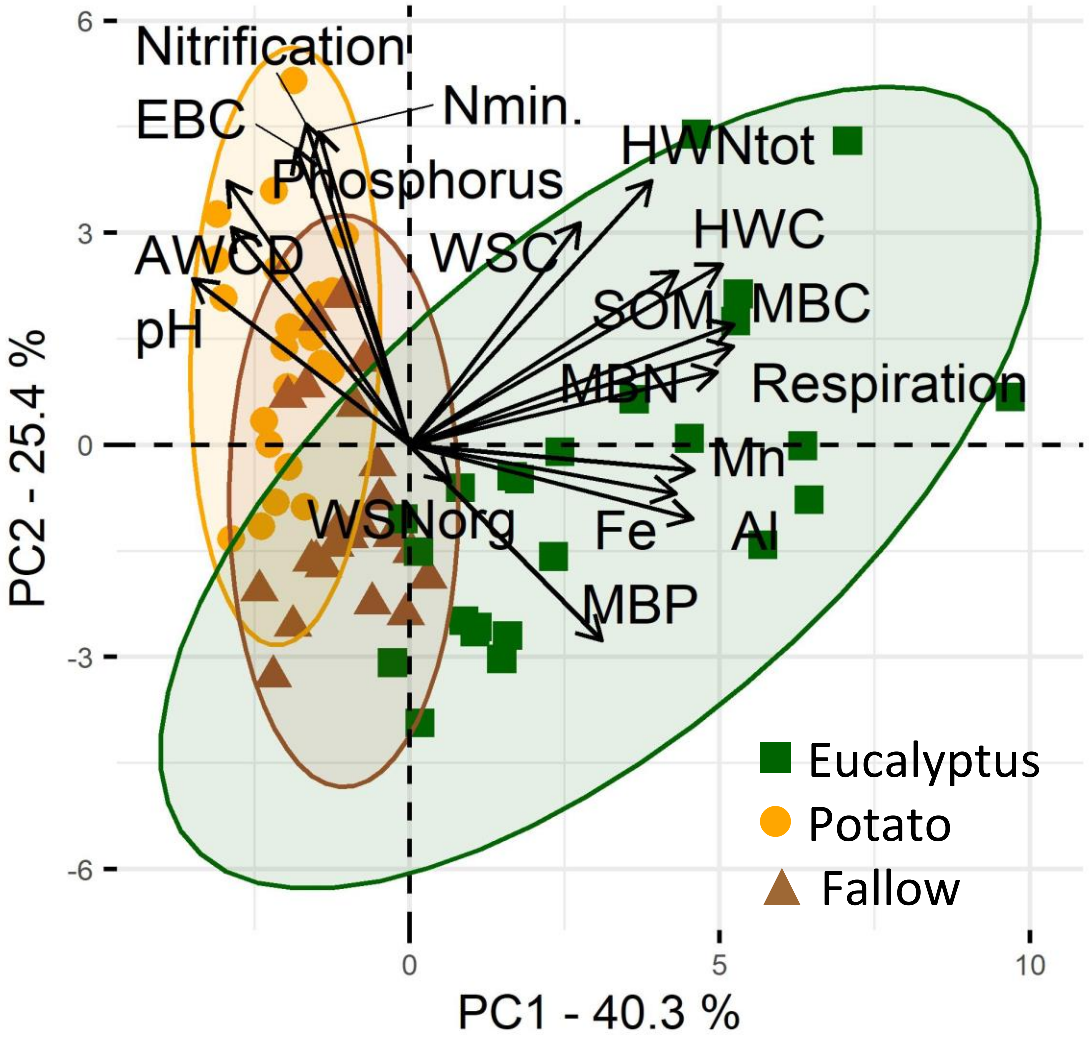
Microbial processes

Respiration

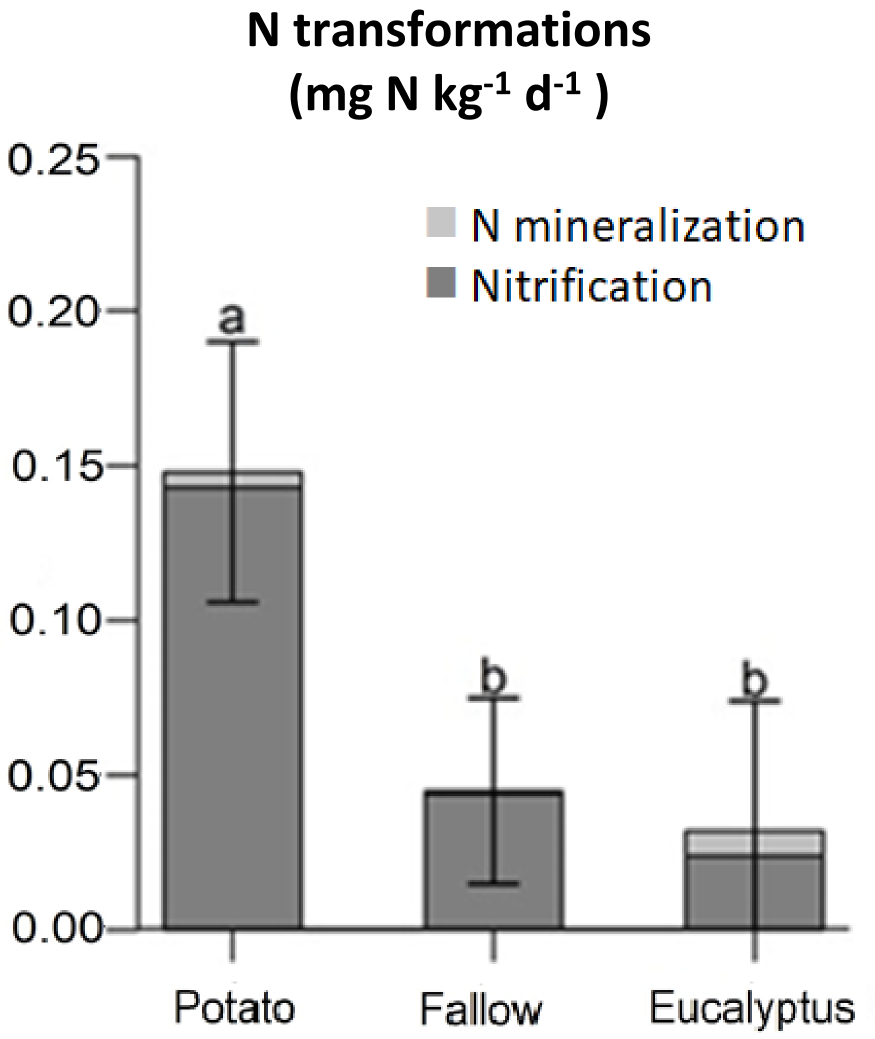


N Mineralization

Fallow and potato soils were similar for most soil variables and processes

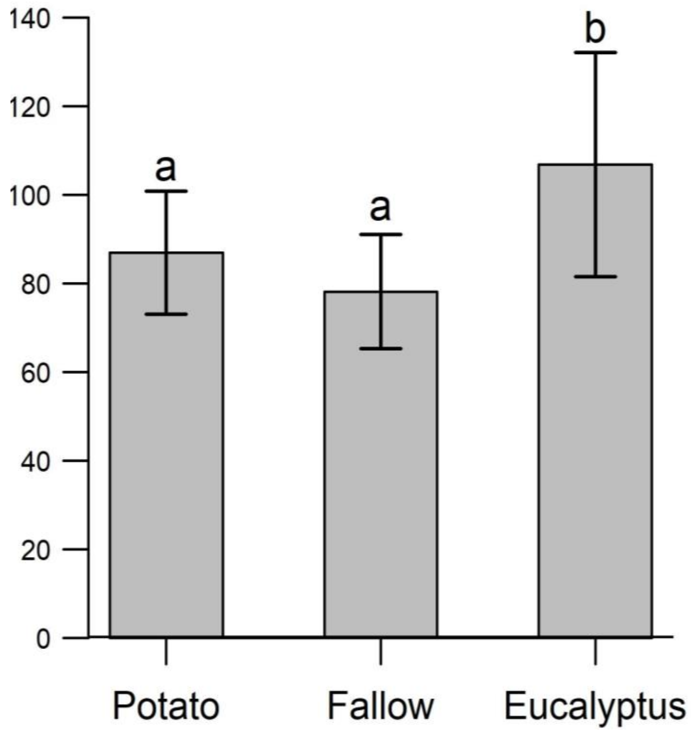


Fallow and eucalyptus plantations lead to a reduction of net N transformations

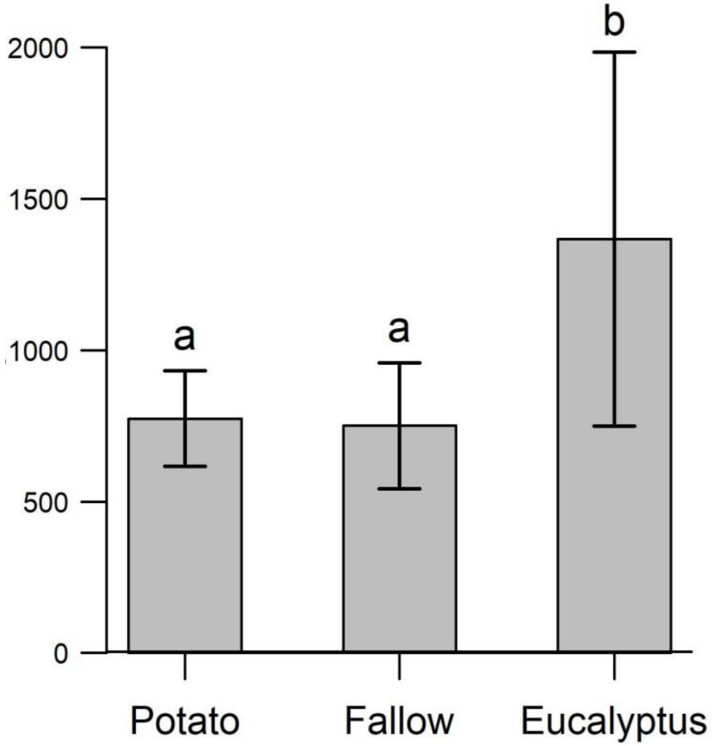


Eucalyptus increased C fractions and respiration potential

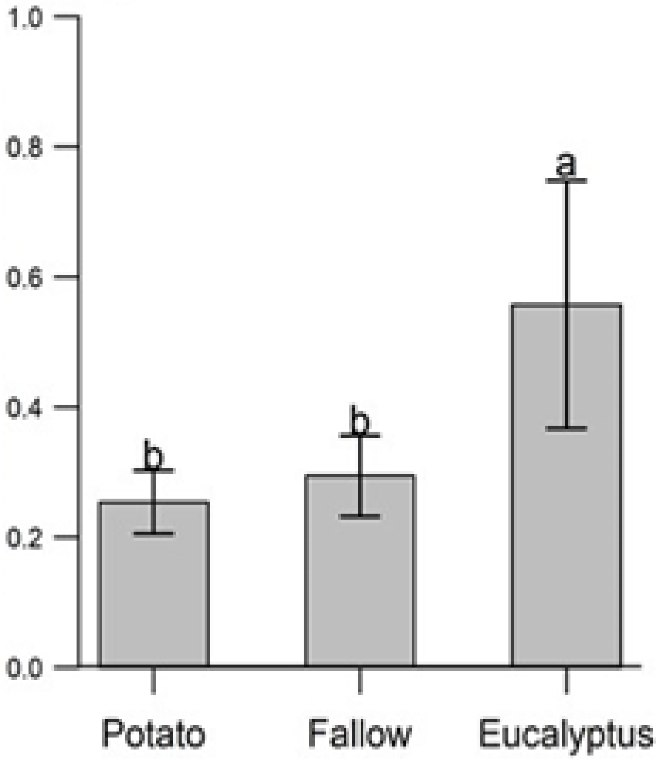
Soil organic matter ($g\ kg^{-1}$)



Hot water C ($mg\ kg^{-1}$)

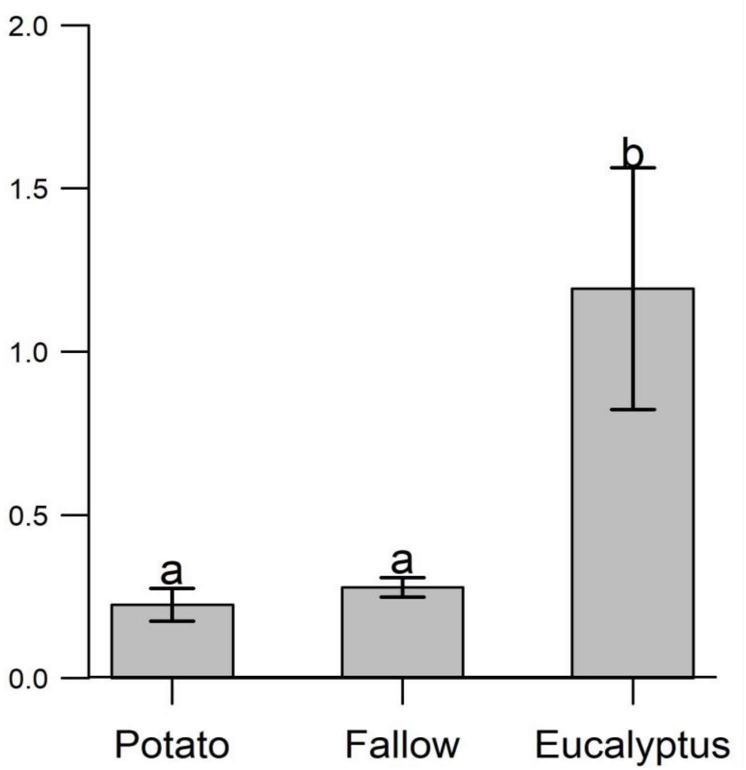


Respiration ($\mu g\ C\text{-}CO_2\ g^{-1}\ h^{-1}$)

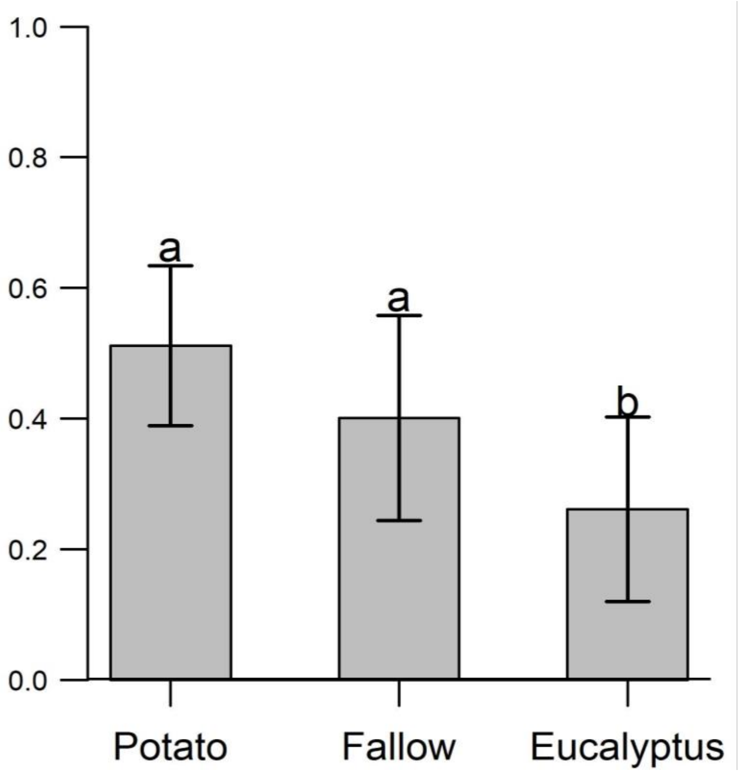


Under eucalyptus aluminum increased and metabolic diversity reduced

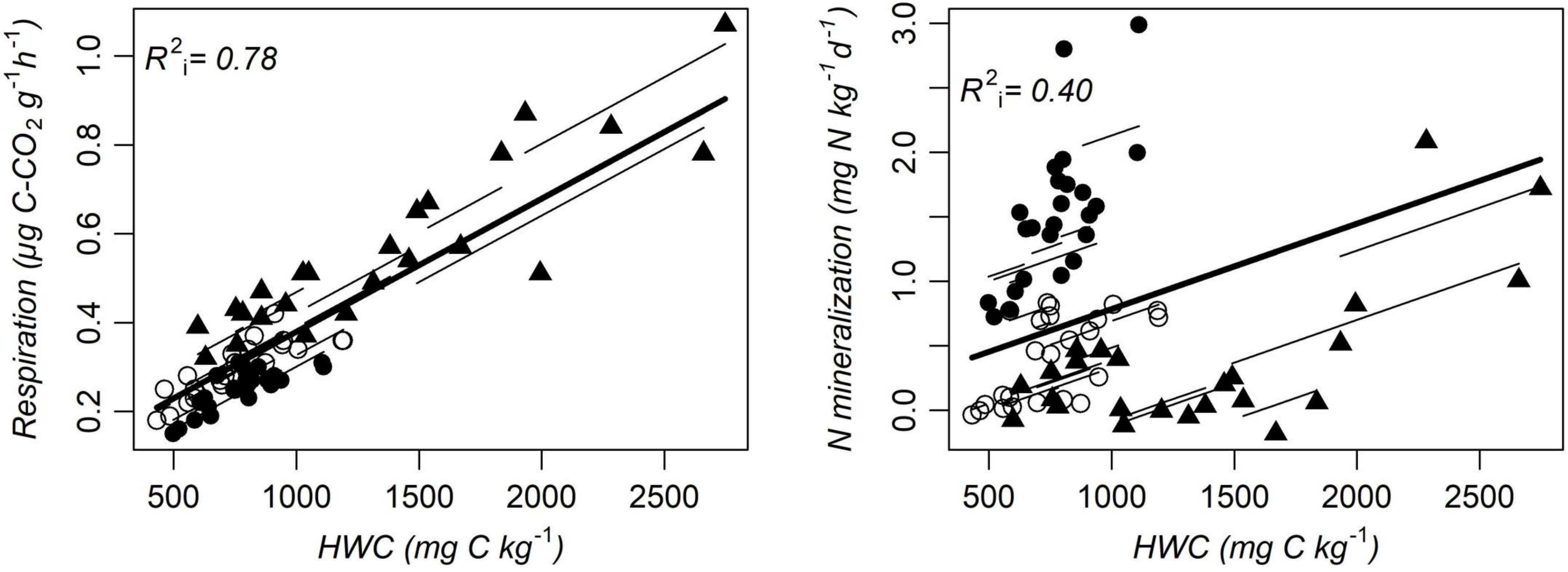
Exchangeable Al ($cmol\ kg^{-1}$)



Metabolic diversity of bacteria Index



The hot water extractable C was strongly related to respiration pontential and N mineralization



Potato **Fallow** **Eucalyptus**

3.2 Soil aggregates and their association with soil constituents and microbial processes

Methods

Wet Sieving

Megaaggregates: >2000 µm
Macroaggregates: 250-2000 µm
Microaggregates: 53-250 µm
Silt+clay: <53 µm

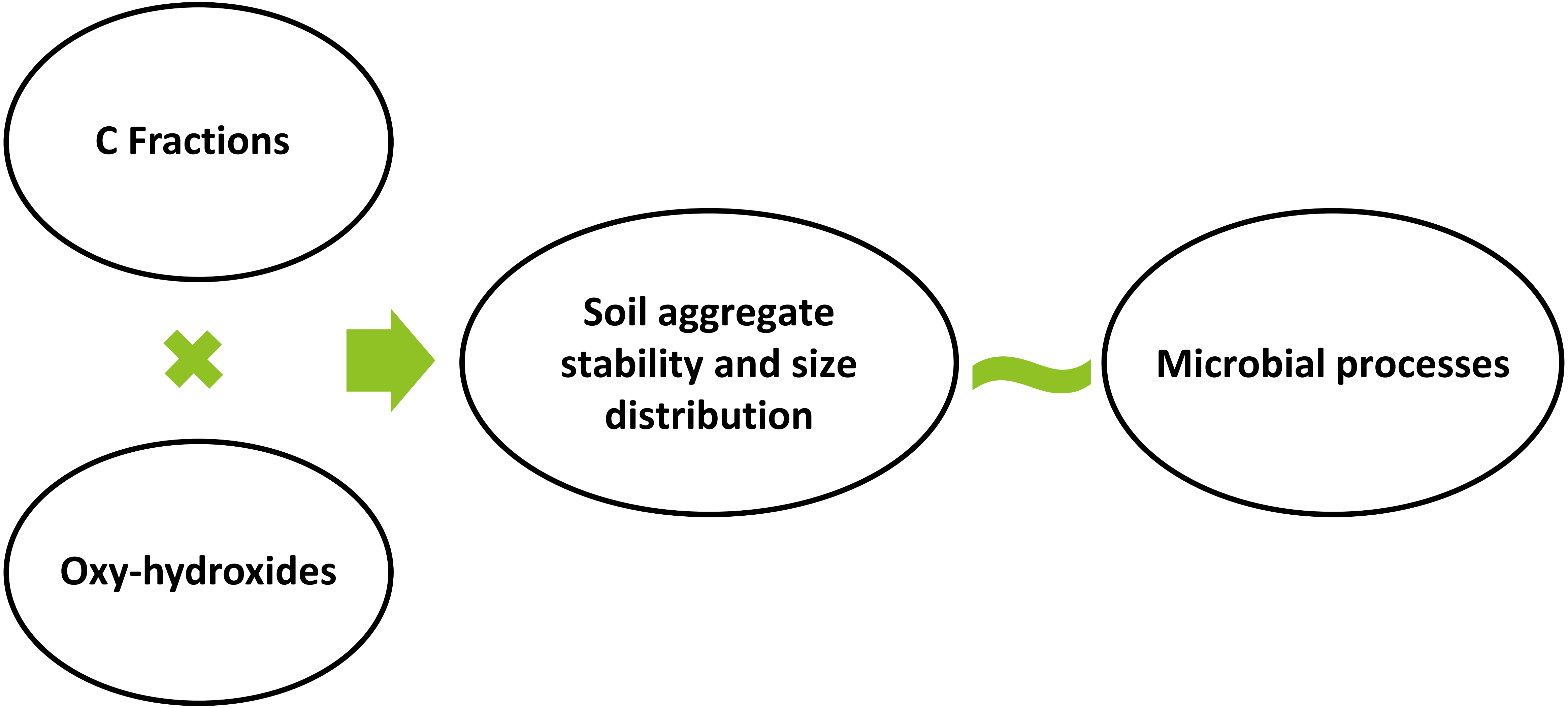
Oxy-hydroxides

Fe

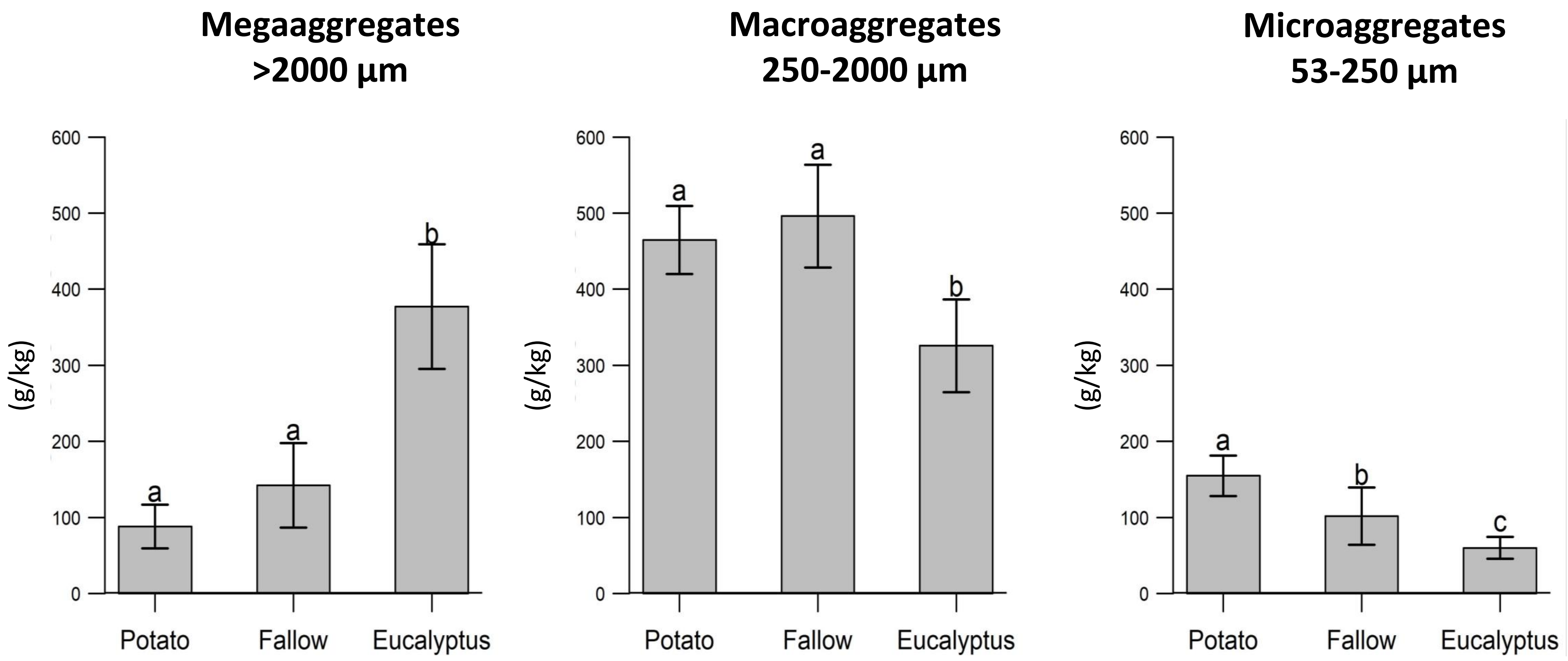
Mn

Al

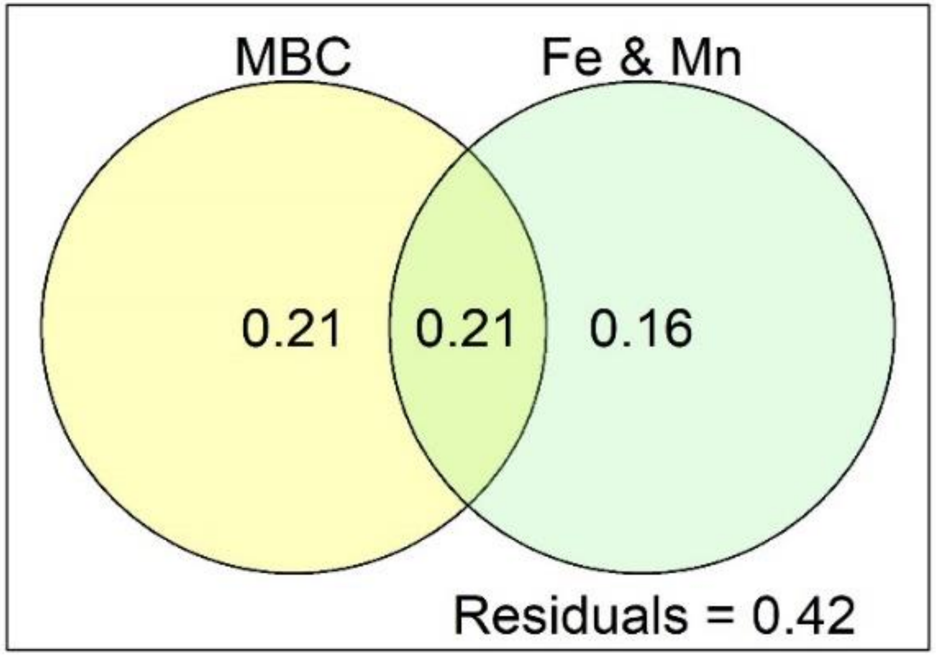
- Ditionithe
- Oxalate

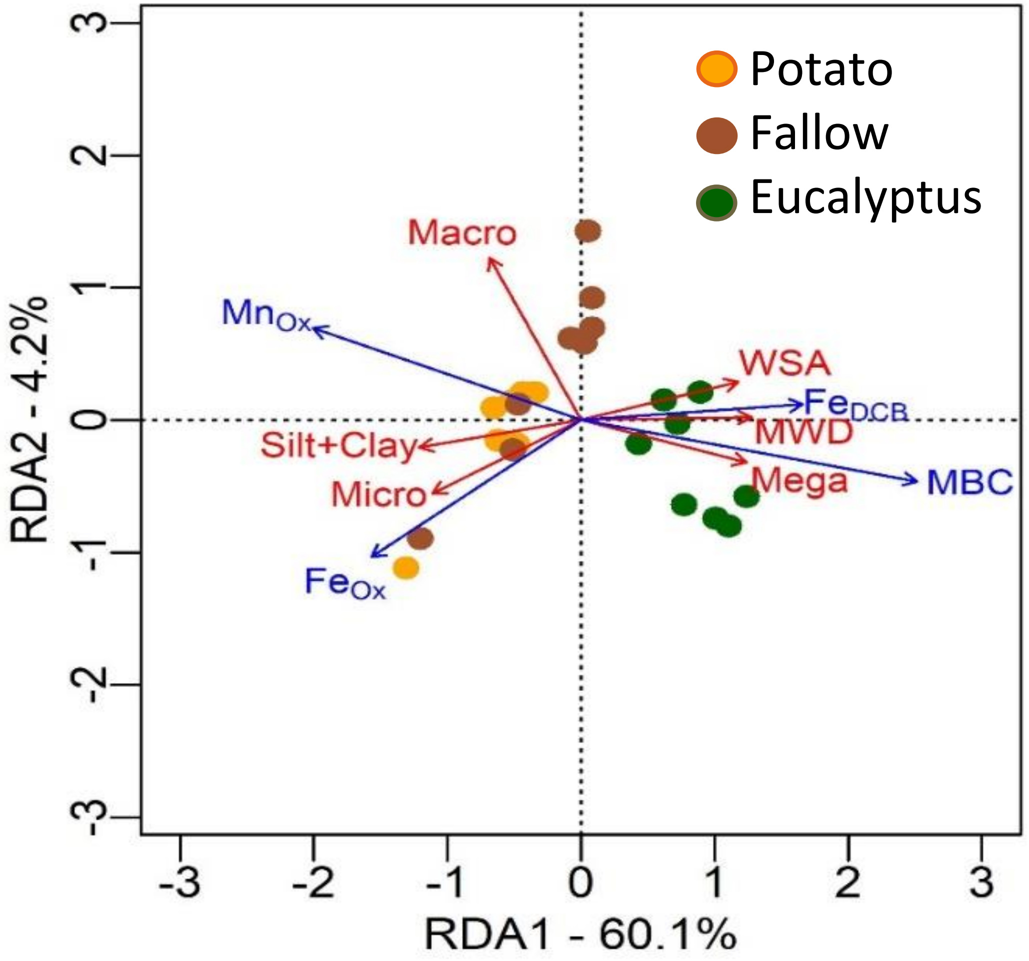

C Fractions
Oxy-hydroxides
Soil aggregate stability and size distribution
Microbial processes

Soil structure improved under Eucalyptus plantations

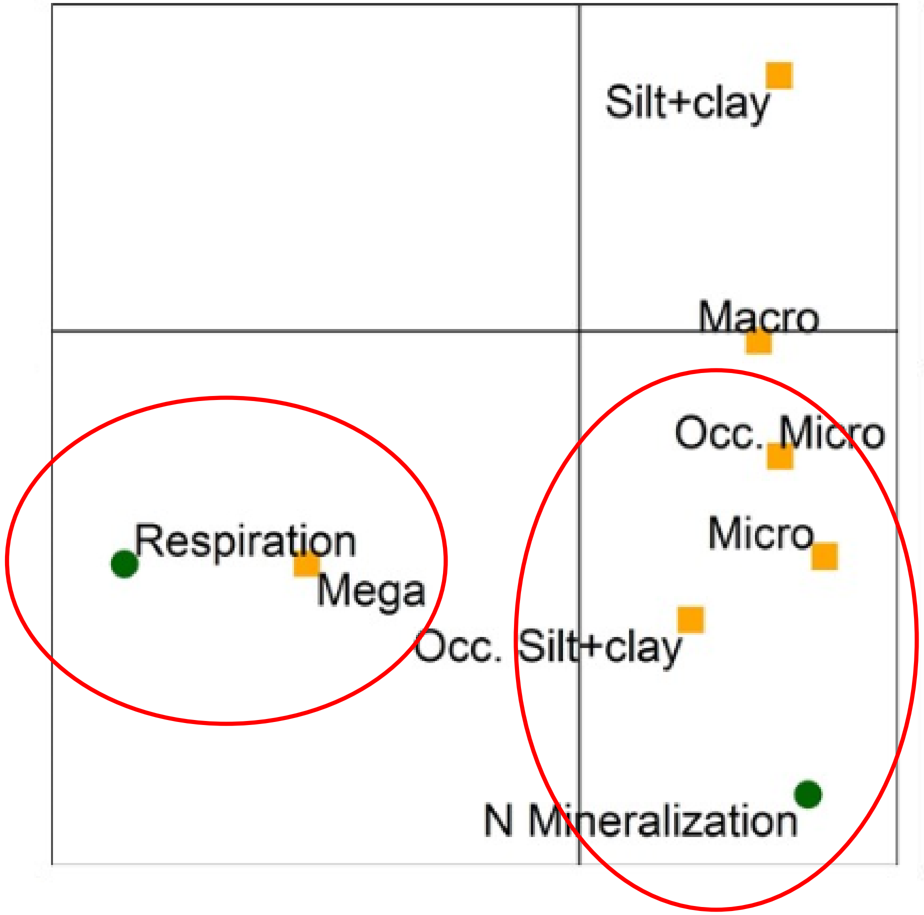


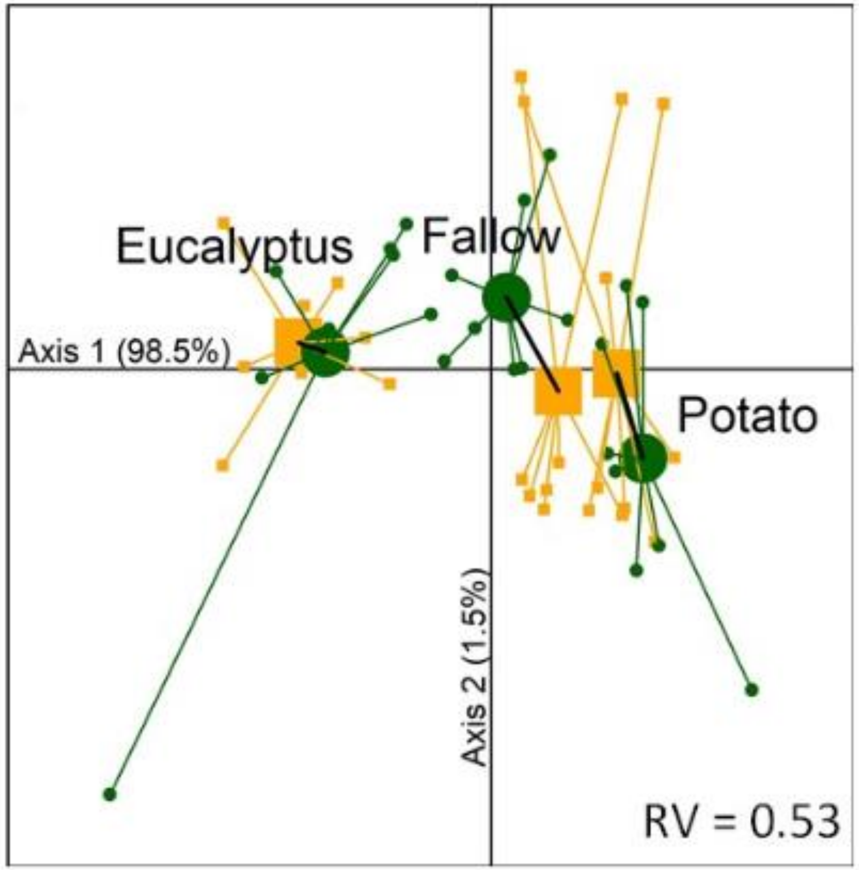
Aggregate stability and size distribution = Microbial Biomass C ✖ Fe, Mn





Aggregate stability and size distribution ~ Microbial processes



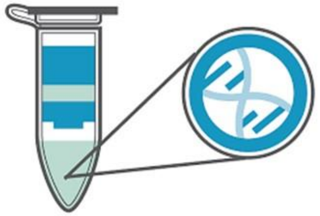


3.3 Ammonia oxidizers activity and abundance and their association with chemical variables

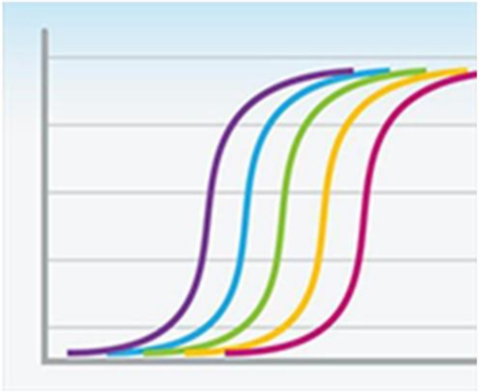
Methods

Abundance

DNA extraction

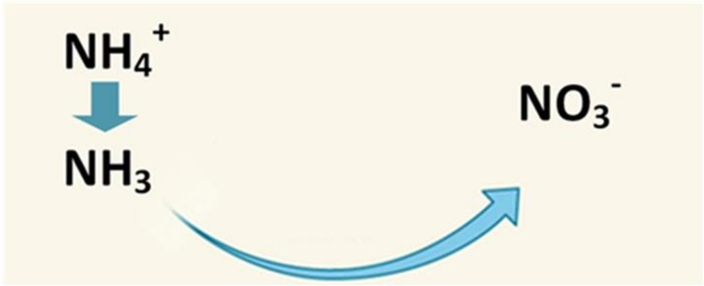


qPCR of *amoA* gene

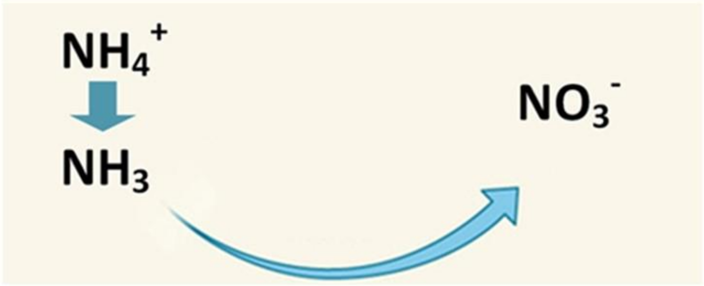


Activity

Total potential nitrification

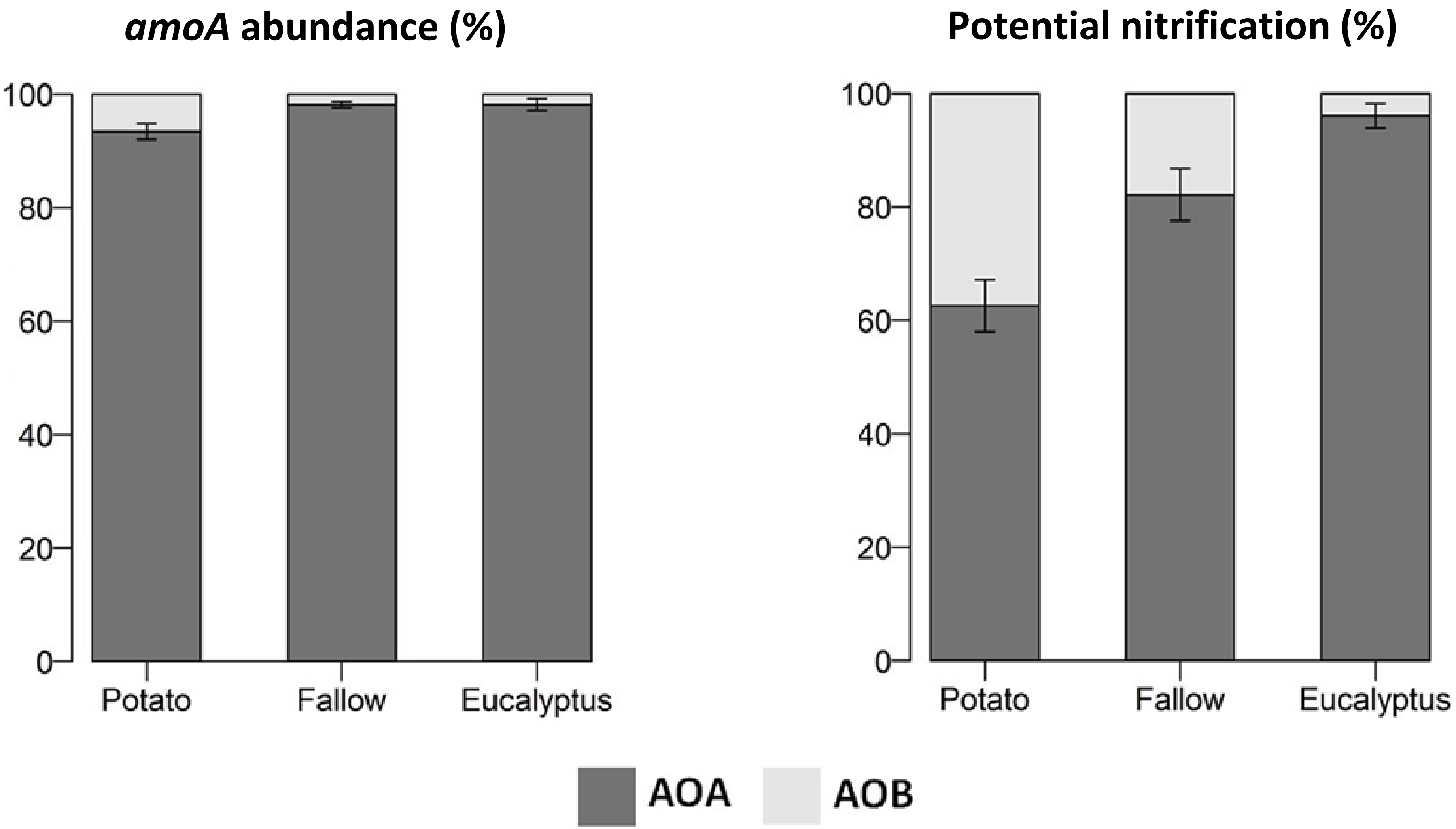


Archaea potential nitrification

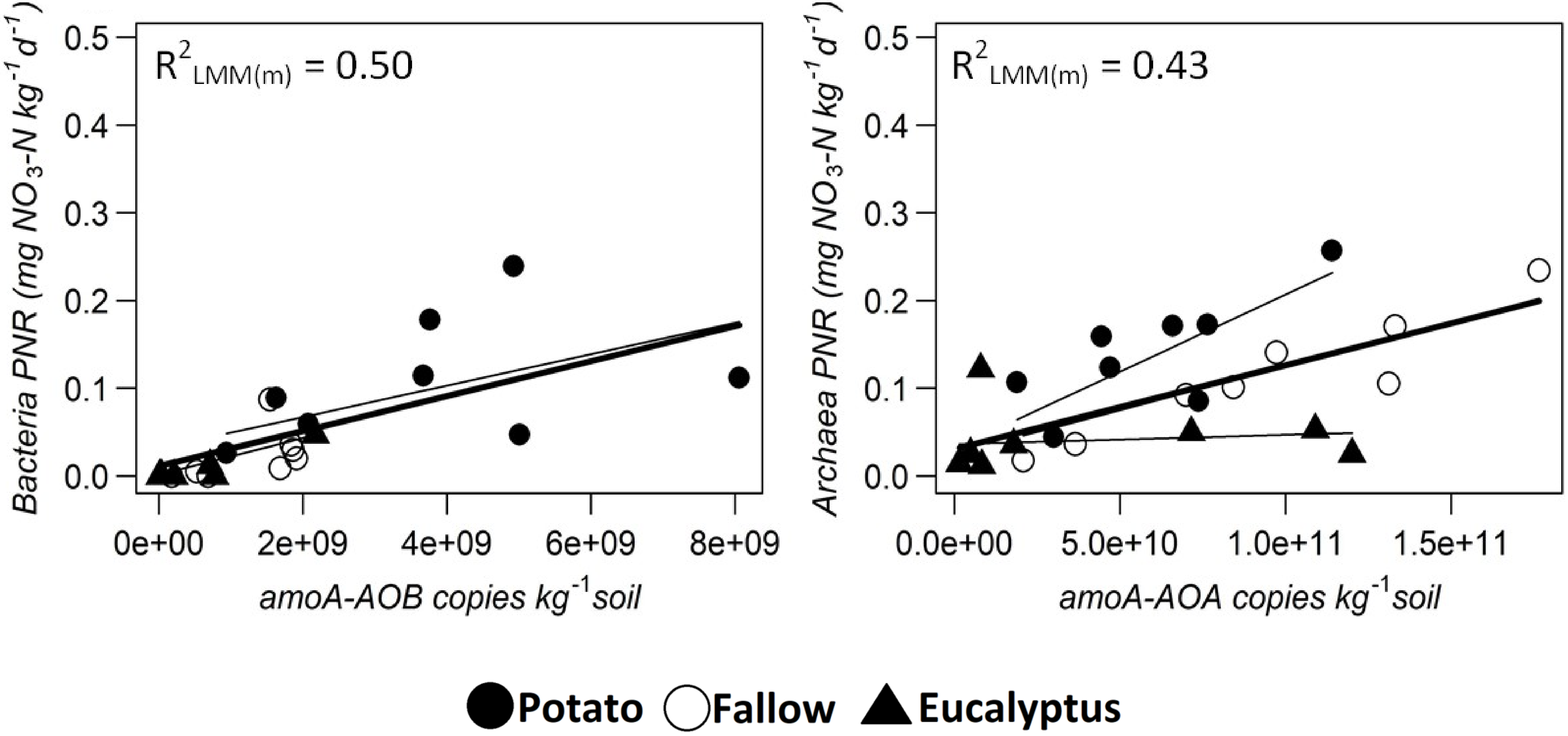


Bacterial inhibitor

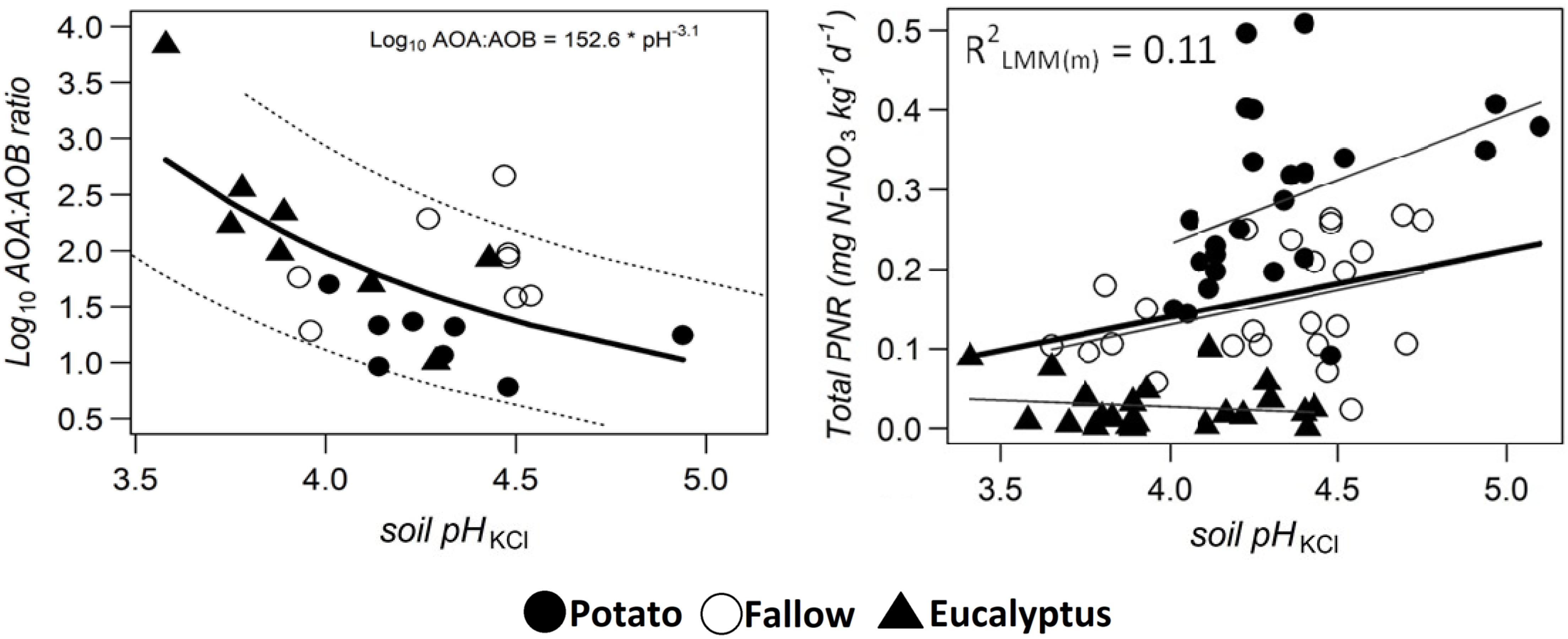
AOA abundance and activity dominated under the three land uses



Increase of the AOA and AOB abundances were associated with higher activity



Changes of AOA:AOB *amoA* ratio were correlated with soil pH



3.4 Effects of fertilization on soil quality and plant development

Methods

Chicken manure composting

9 Piles

Treatments:

0T No turning
4W Turning every 4 weeks
2W Turning every 2 weeks

Sampling dates: 2 9 16 23 31 37 45 53 58 65 72 89 107 122 136 150 days

Physico-chemical analyses

Subset: 2 23 45 65 107 150 days

Soil fertilization experiment

Methods

Soil fertilization experiment

2 23 45 65 107 150 days

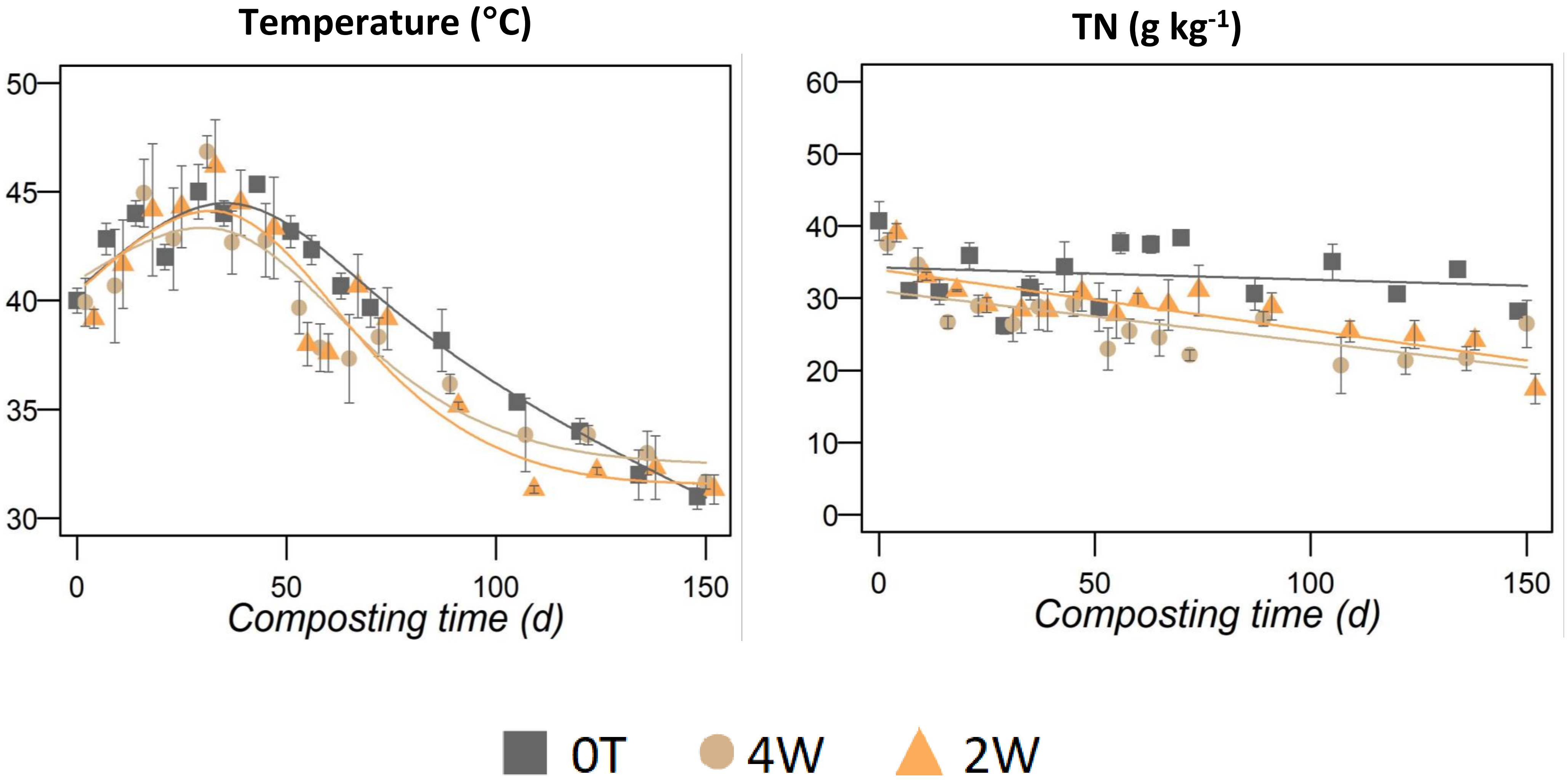
Fallow soil

\+ Compost (0T, 4W, 2W)

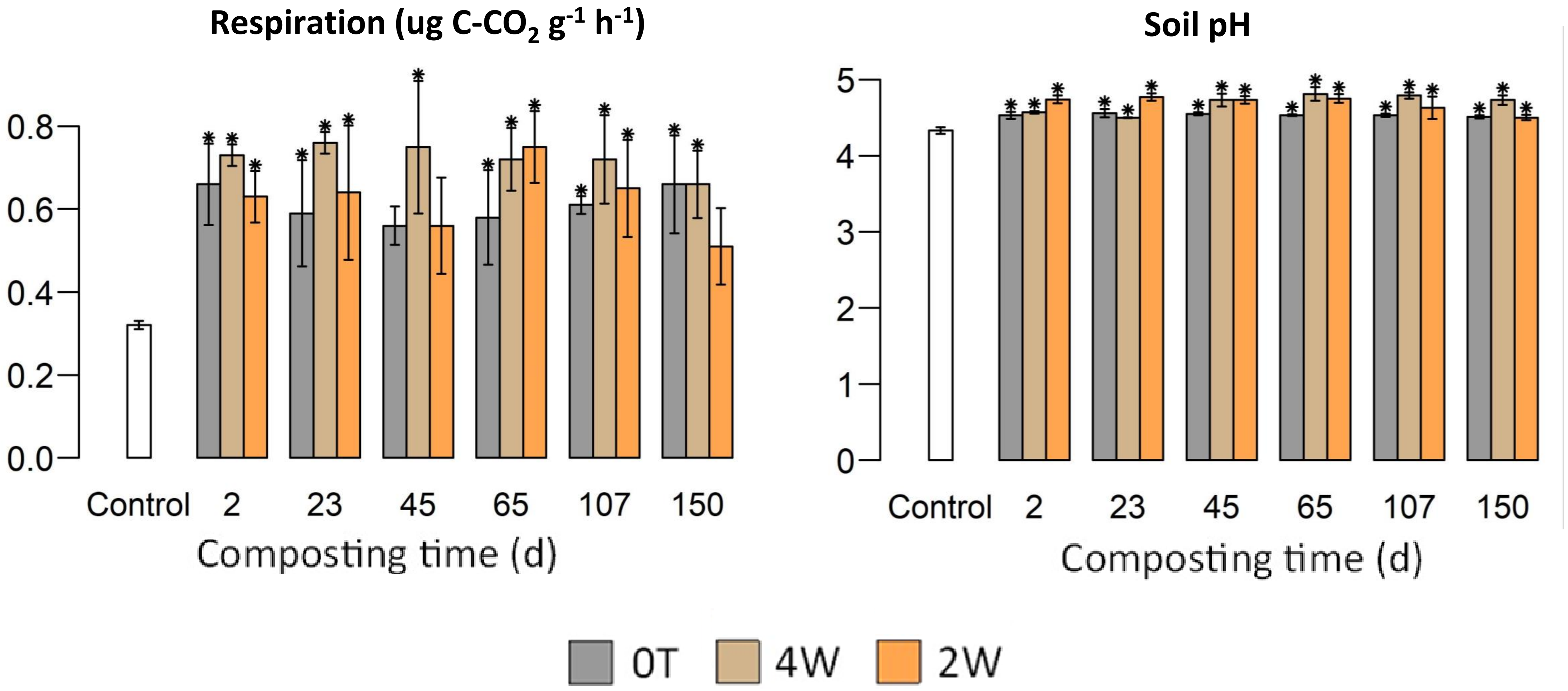
Avena sativa

- Soil physico-chemistry
- Plant development

Turning events accelerated composting process and promoted N loss

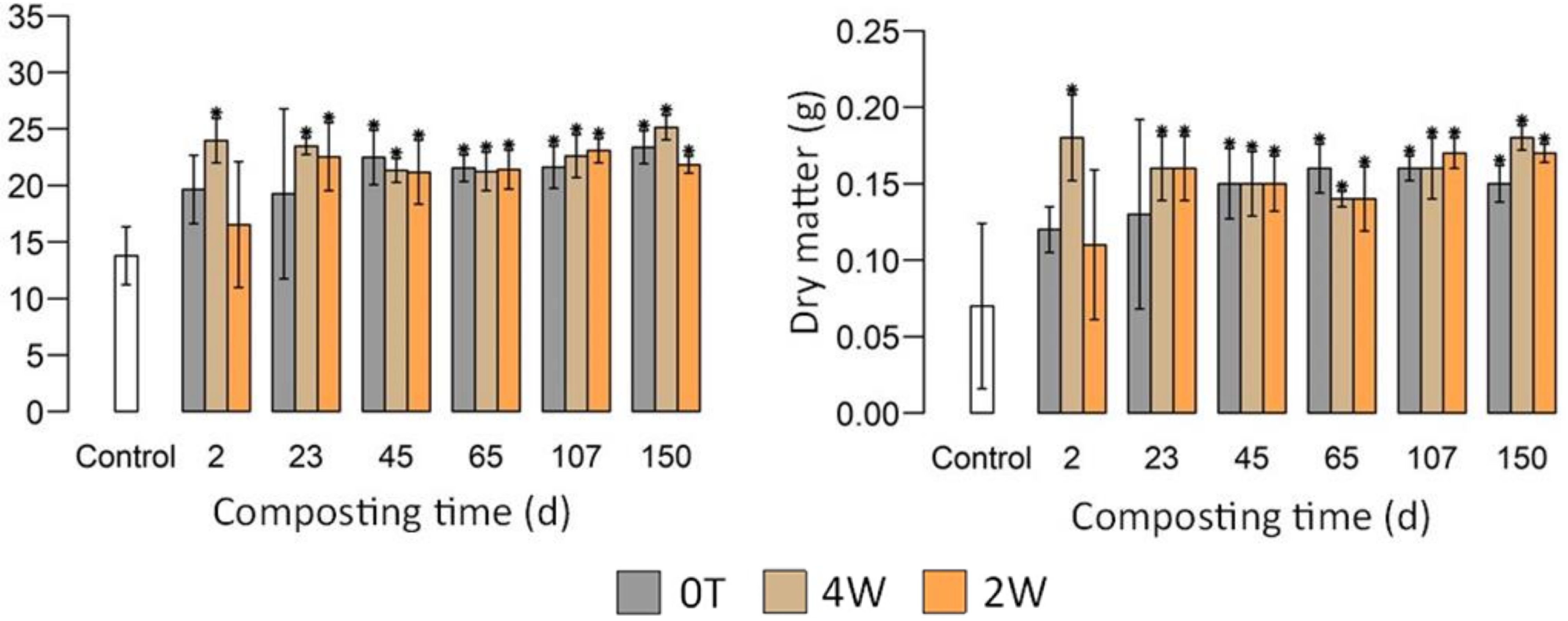


Manure increased labile C and N, respiration potential, and soil pH



Fertilization enhanced plant development

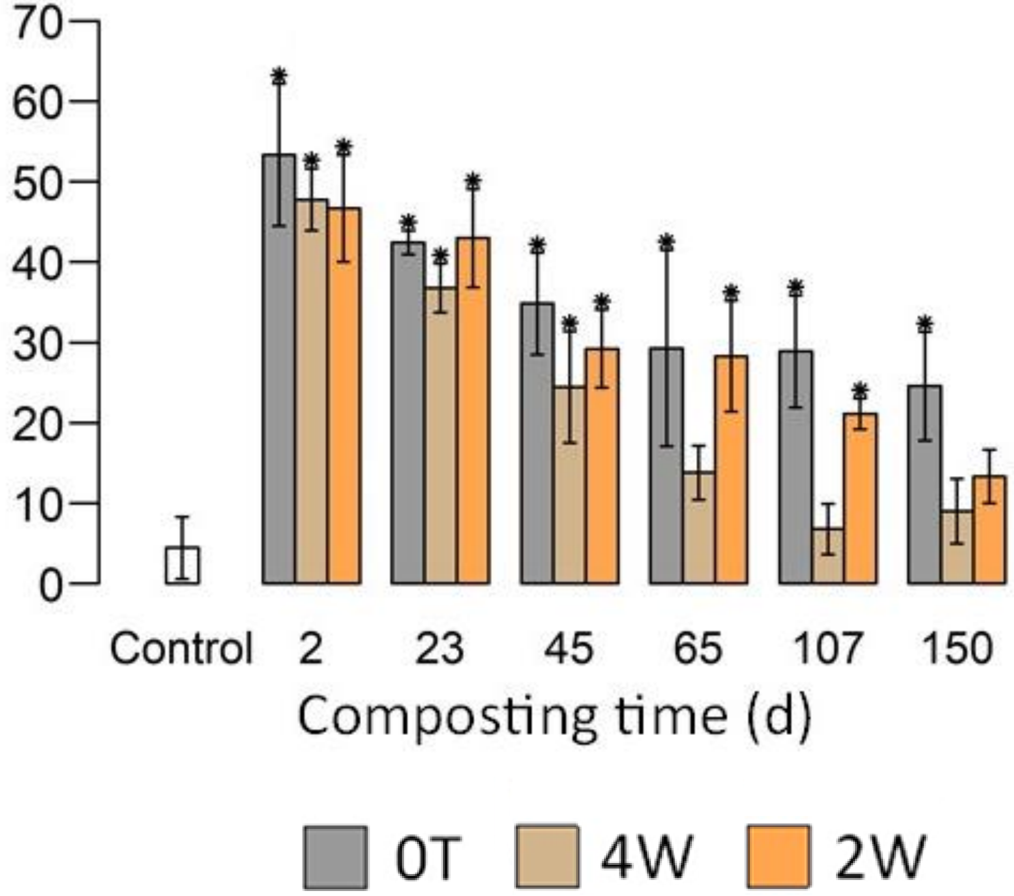
Shoot length (cm) **Biomass (g)**



Manure at early stages of decomposition increase the risk of negative effects on plants

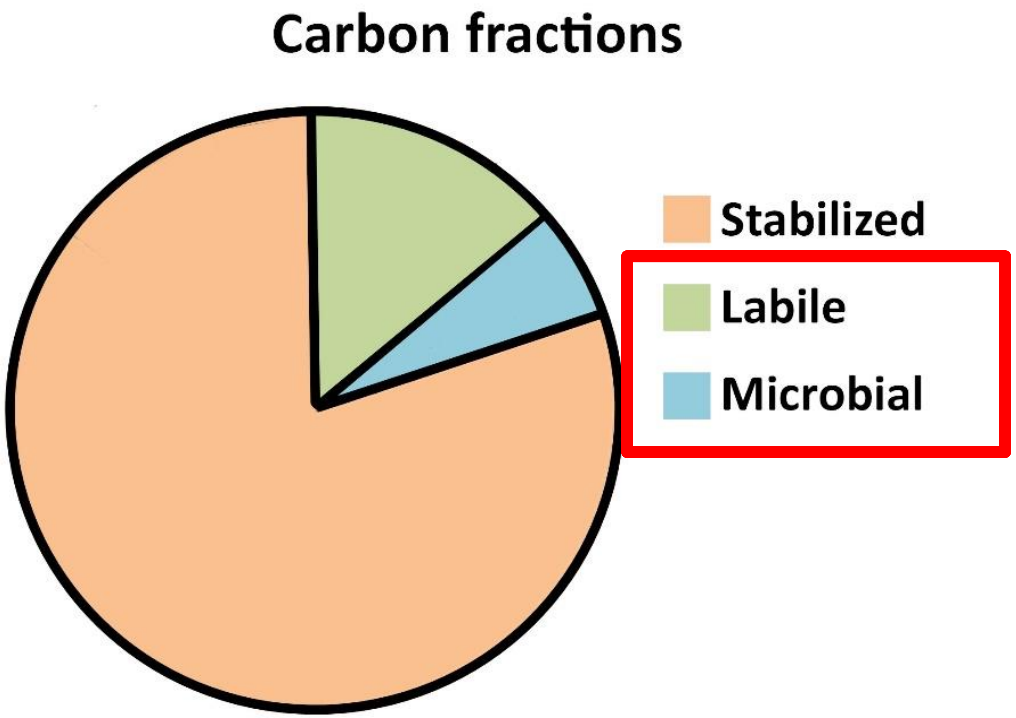
Seeds with root damage

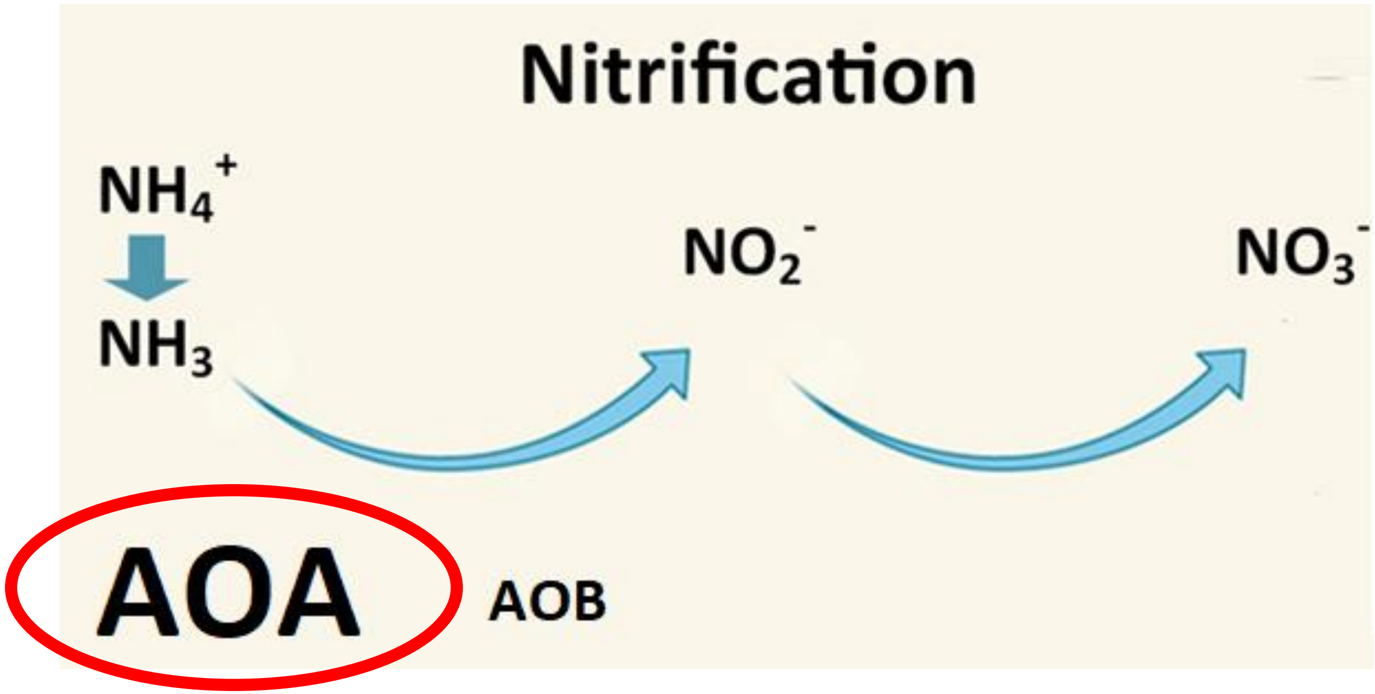
Root damage %



General Conclusions

- **Evaluation of the interaction between the soil chemical, physical and biological components contributed to understand how soil quality respond to land uses.**





Fallow

Fallowing soils did not have an effect on soil quality compared to cultivated fields

Eucalyptus

Eucalyptus reduced chemical and biological soil quality but improved soil physical quality compared with cultivated fields

Fertilization

Chicken manure improved soil chemical and biological quality for cultivation

Acknowledgements

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- Laboratory of plant and microbial ecology – ULg
- Laboratorio de Suelos y Aguas – UMSS
- Pocona Municipality
- Chullchunqani Community and Subcentral Huayapacha

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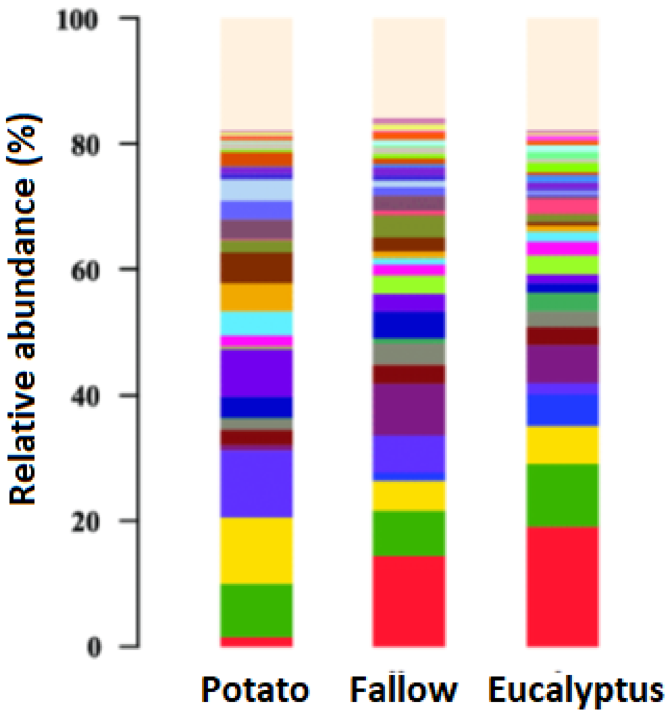
- Thanks to my family for their endless emotional support and encouragement.

Thanks for your attention

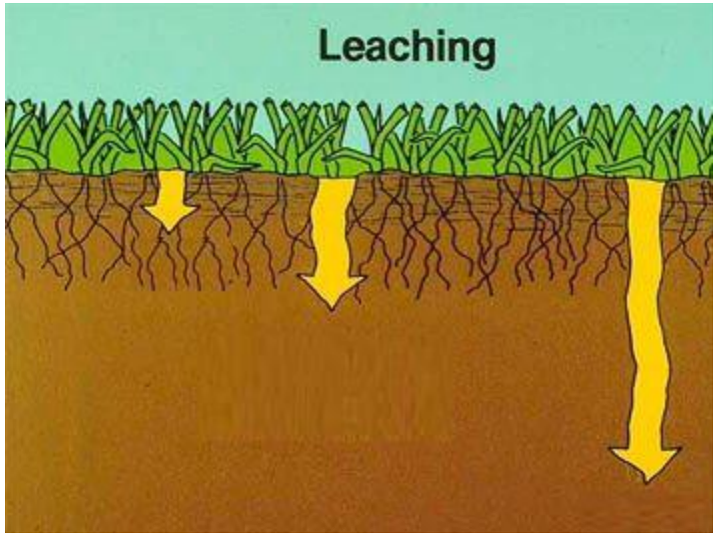
Backup information

Perspectives and future research

Microbial community structure



Nutrient balance



Mean values ± standard deviation of sand, silt, and clay fractions, water holding capacity (WHC). Different letters indicate significant differences between land uses (p-value <0.05, n=8, ANOVA and Tukey).

	Potato	Fallow	Eucalyptus
Sand (%)	21.80±4.84 a	22.85±4.29 a	34.08±9.64 a
Silt (%)	29.51±3.87 a	31.57±8.75 a	29.53±5.02 a
Clay (%)	48.69±5.88 a	45.57±11.30 a	36.38±6.26 a
WHC (%)	51.20±4.02 a	53.20±2.60 a	48.79±7.73 a

Chicken manure decomposition and fertilization experiment

Chicken manure decomposition: Nine manure piles were assigned to three turning frequency treatments and followed during 150 days:

T0: no turning
4W: turning every 4 weeks
2W: turning every 2 weeks

16 sampling dates

Fertilization experiment: 6 sampling dates were selected and used to assess the effect of manure on soil properties and plant development.

T0: no turning
4W: turning every 4 weeks
2W: turning every 2 weeks

Left: roots without rood damage. Right roots with signs of apparent damage in the form of tissue oranging. Different background color for A and B are presented to improve contrast and distinguish differences

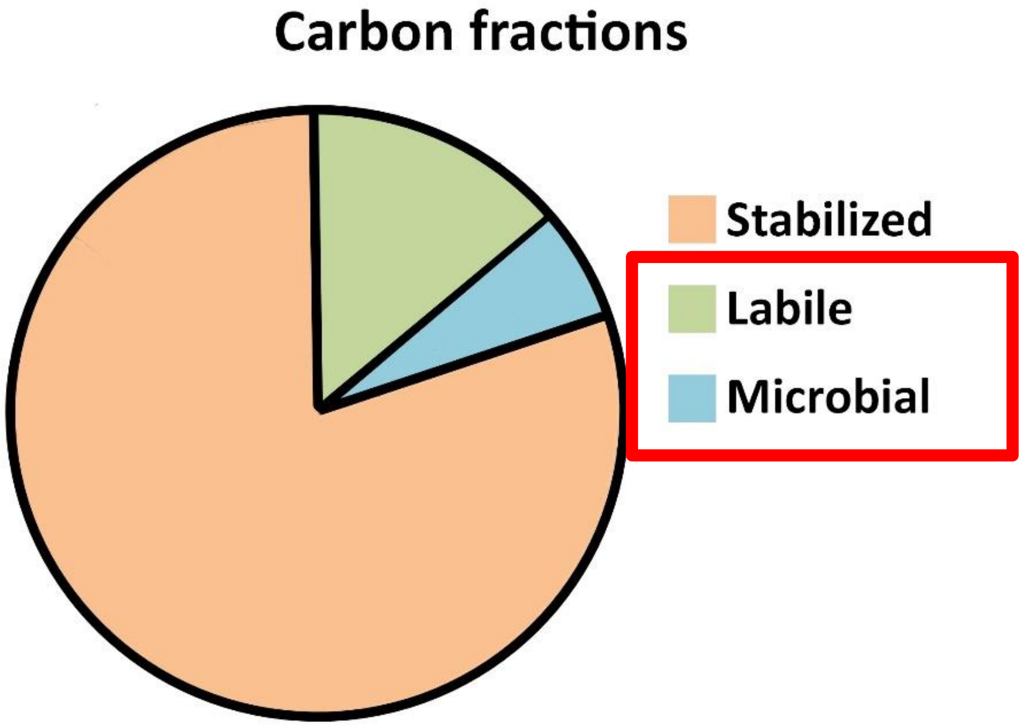
Manure piles stablishment






General Conclusions

- The labile hot water extractable C and microbial biomass are potential indicators of changes in soil processes related to C and N cycling, and to changes in aggregates formation, respectively.



General Conclusions

- **Evaluation of the interaction between the soil chemical, physical and biological components contributed to understand how soil quality respond to land uses.**

- **AOA dominated the three land uses studied and changes in the dominance are were associated to soil pH. Agricultural practices leading to changes in pH would thus determine changes in their contribution to nitrification.**