Food and Agriculture Organization of the United Nations

22-24 November 2022

# SOIL HEALTH ANALYSIS

Luis G. Wall

Laboratory of Soil Biochemistry and Biology
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University of Quilmes
Bernal, Argentina

6th Meeting of the Global Soil Laboratory Network (GLOSOLAN)

GLOSOLAN
GLOBAL SOIL LABORATORY NETWORK

GLOBAL SOIL PARTNERSHIP

- Our soil health understanding is a consequence of the experience accumulated after 14 years of studying soil responses to different managements, looking for soil biology activity regeneration, now named soil health and biofertility.

- The story began with no till-farmers questions about how to characterize monocropping and crop-rotation soils developing biological indexes.

- Then, it continued studying the effects of no-till agriculture intensification on soil properties, aimed at continuing developing soil biological indexes.

## 2008-2013 Crop Rotation vs. Monocropping

Wheat/soybean – Maize – Soybean —— *vs.* —— Soybean

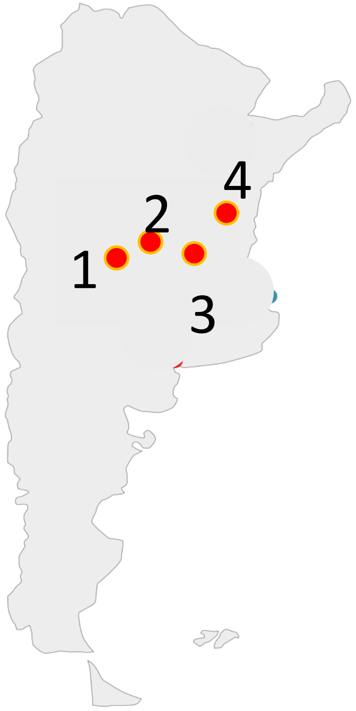
## 2014-2020 Intensification of Crop Rotation

Wheat/soybean – Maize – Soybean → Consociate Pasture

(reduction of fallow periods by cover crops and other winter crops)

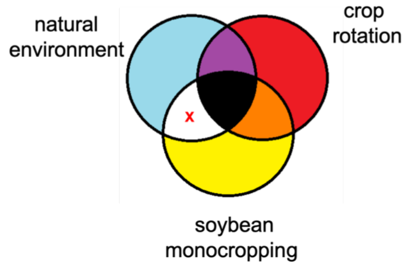
2008-2013

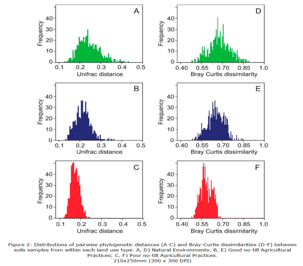
# MONOCROPPING *vs.* CROP ROTATION

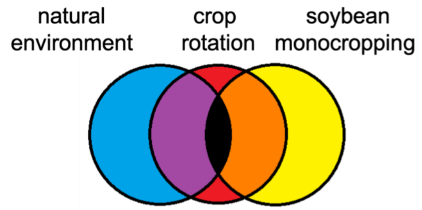


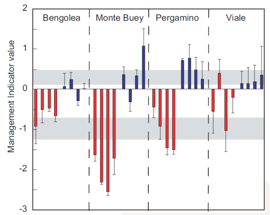

**BIOMARKERS**
of soil management

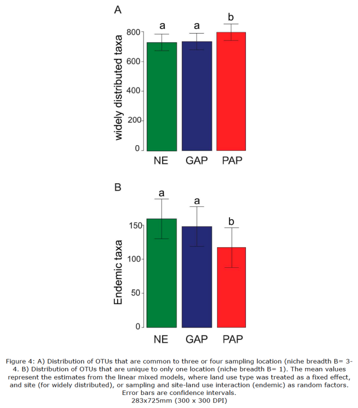
## Bacteria Microbiota
(soil DNA)





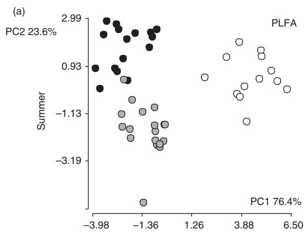



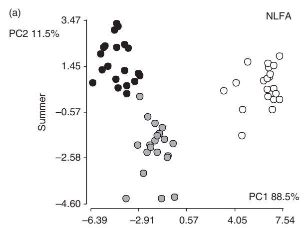

**LOSS of**
**β – BIODIVERSITY**

## Soil Lipidic Analysis

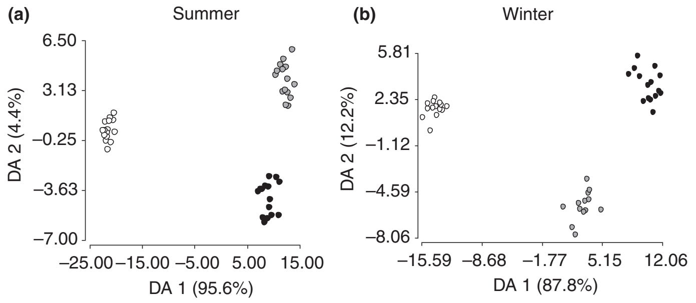
(PLFA)




(NLFA)




(WSFA)




**SOIL FATTY ACID SIGNATURE**
characterize soil use and management

OPEN ACCESS Freely available online
PLOS ONE

# Bacterial Indicator of Agricultural Management for Soil under No-Till Crop Production

**Eva L. M. Figuerola[1], Leandro D. Guerrero[1], Silvina M. Rosa[1], Leandro Simonetti[1], Matías E. Duval[2], Juan A. Galantini[2], José C. Bedano[3], Luis G. Wall[4], Leonardo Erijman[1,5]***

1 Instituto de Investigaciones en Ingeniería Genética y Biología Molecular (INGEBI-CONICET) Vuelta de Obligado 2490, Buenos Aires, Argentina, 2 CERZOS-CONICET Departamento de Agronomía, Universidad Nacional del Sur, Bahía Blanca, Argentina, 3 Departamento de Geología, Universidad Nacional de Río Cuarto, Río Cuarto, Córdoba, Argentina, 4 Departamento de Ciencia y Tecnología, Universidad Nacional de Quilmes, Roque Sáenz Peña 352, Bernal, Argentina, 5 Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Pabellón 2, Buenos Aires, Argentina

**Abstract**

The rise in the world demand for food poses a challenge to our ability to sustain soil fertility and sustainability. The increasing use of no-till agriculture, adopted in many areas of the world as an alternative to conventional farming, may contribute to reduce the erosion of soils and the increase in the soil carbon pool. However, the advantages of no-till agriculture are jeopardized when its use is linked to the expansion of crop monoculture. The aim of this study was to survey bacterial communities to find indicators of soil quality related to contrasting agriculture management in soils under no-till farming. Four sites in production agriculture, with different soil properties, situated across a west-east transect in the most productive region in the Argentinean pampas, were taken as the basis for replication. Working definitions of Good no-till Agricultural Practices (GAP) and Poor no-till Agricultural Practices (PAP) were adopted for two distinct scenarios in terms of crop rotation, fertilization, agrochemicals use and pest control. Non-cultivated soils nearby the agricultural sites were taken as additional control treatments. Tag-encoded pyrosequencing was used to deeply sample the 16S rRNA gene from bacteria residing in soils corresponding to the three treatments at the four locations. Although bacterial communities as a whole appeared to be structured chiefly by a marked biogeographic provincialism, the distribution of a few taxa was shaped as well by environmental conditions related to agricultural management practices. A statistically supported approach was used to define candidates for management-indicator organisms, subsequently validated using quantitative PCR. We suggest that the ratio between the normalized abundance of a selected group of bacteria within the GP1 group of the phylum Acidobacteria and the genus *Rubellimicrobium* of the Alphaproteobacteria may serve as a potential management-indicator to discriminate between sustainable *vs*. non-sustainable agricultural practices in the Pampa region.

**Citation:** Figuerola ELM, Guerrero LD, Rosa SM, Simonetti L, Duval ME, et al. (2012) Bacterial Indicator of Agricultural Management for Soil under No-Till Crop Production. PLoS ONE 7(11): e51075. doi:10.1371/journal.pone.0051075

environmental microbiology
society for applied microbiology
Environmental Microbiology (2015) **17**(3), 678–688 doi:10.1111/1462-2920.12497

# Crop monoculture rather than agriculture reduces the spatial turnover of soil bacterial communities at a regional scale

**Eva L. M. Figuerola,[1] Leandro D. Guerrero,[1] Dominique Türkowsky,[1] Luis G. Wall[2] and Leonardo Erijman[1,3]***
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**Summary**

**The goal of this study was to investigate the spatial turnover of soil bacterial communities in response to environmental changes introduced by the practices of soybean monoculture or crop rotations, relative to of good agricultural practices, including crop rotation, may be critical for the long-term conservation of soil biodiversity.**

**Introduction**

No-till (also known as direct drilling and zero tillage) is an agricultural practice in which crop residues from previous harvesting are left on the soil surface, and the soil is not disturbed other than by the passage of the drill coulters. By reducing tillage, soil erosion is prevented, carbon storage is increased and available moisture is used more efficiently, making the soil management more sustainable (Díaz-Zorita *et al*., 2002; Derpsch *et al*., 2010). In Argentina, no-till presently dominates cropping practices, covering almost 26 million hectare, i.e. 75% of the total cultivated area (source: AAPRESID; www.aapresid.org.ar). On the basis of the associated gain

Soil Use and Management
*Soil Use and Management*, March 2015, **31,** 165–175 doi: 10.1111/sum.12165

# Crop rotation and seasonal effects on fatty acid profiles of neutral and phospholipids extracted from no-till agricultural soils

A. E. Ferrari[1], S. Ravnskov[2], J. Larsen[3], T. Tønnersen[2], R. A. Maronna[4] & L. G. Wall[1]
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**Abstract**

Analysis of phospholipids (PLFA) and neutral lipids fatty acids (NLFA) was used to characterize no-till productive agricultural soils associated with different crop rotation levels, replicated across a 400 km transect in the Argentinean pampas, during two sampling seasons, summer and winter. High rotation (HR) management consisted in maize–wheat–soybean intense rotation including cover crops. Low rotation (LR) management trend to soybean monocultures. Soils from nearby natural environments (NEs) were used as references. Fatty acids concentration in soils (nmol/g) decreased c.a. 50% from summer to winter differentially according to soil treatment being the smallest decrease in HR management 35%. Both PLFA and NLFA profiles showed strong potential to discriminate between different land uses. In winter samples, some rare or unknown fatty acids were relevant for

Soil Use and Management
*Soil Use and Management*, September 2018, **34**, 427–436 doi: 10.1111/sum.12440

# Crop rotation in no-till soils modifies the soil fatty acids signature

A. E. Ferrari[1], S. Ravnskov[2] & L. G. Wall[1]
[1]*Laboratorio de Bioquímica, Microbiología e Interacciones Biológicas en el Suelo, Departamento de Ciencia y Tecnología, Universidad Nacional de Quilmes, R. Sáenz Peña 352 B1876BXD Bernal, Buenos Aires, Argentina, and* [2]*Department of Agroecology, Faculty of Science and Technology, Flakkebjerg Research Centre, Aarhus University, Forsøgvej 1, Slagelse, DK-4200, Denmark*

**Abstract**

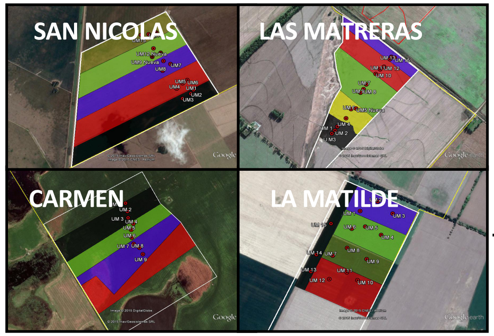
Analysis of whole-soil fatty acids (WSFA) was used to characterize no-till productive agricultural soils associated with different crop rotation managements on the Argentinean pampas, over two sampling seasons. Crop rotation (CR) treatment was compared with soybean monocropping (MC). Soils from nearby natural environments (NE) were used as reference treatments. The objective of this study was to characterize the soil lipid signature and seek putative markers of agricultural management. NE sites had greater concentration of total WSFA than agricultural sites, but no differences between CR and MC were identified. NE sites were characterized by straight chain and mono-unsaturated fatty acids, such as *16:1ω5c*, an established biomarker for arbuscular mycorrhiza. Comparing lipid profiles using multivariate methods allowed a comprehensive comparison among treatments. The CR and NE soil samples were more alike than those of MC, with several fatty acids in common. CR soils were associated with mixed, branched and hydroxylated fatty acids. MC profiles appeared to be enriched

2014-2020

# INTENSIFICATION of CROP ROTATION

## Development of biological indexes of soil management / health

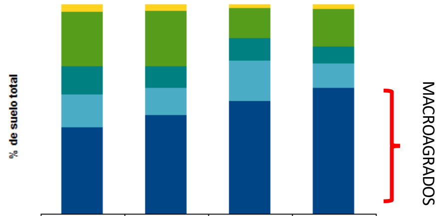
## ON-FARM STUDY




**CROP ROTATION INTENSIFICATION INDEX**

$$\frac{\text{days with plants}}{\text{total days of period}}$$

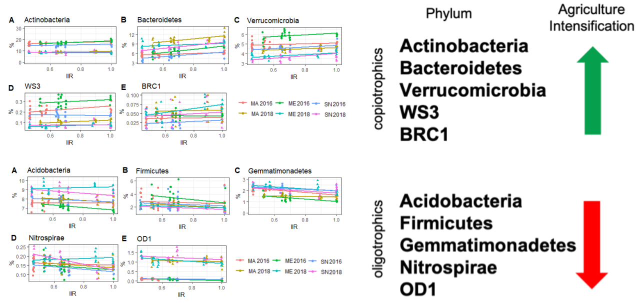
## AGGREGATES



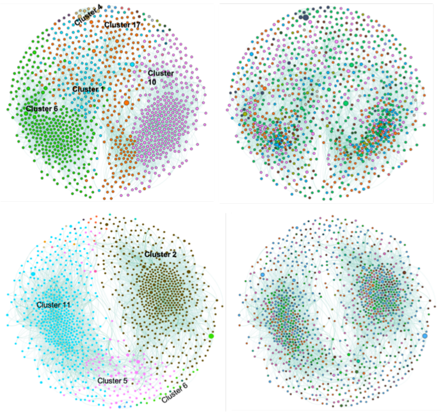

| | Tipica (Tr/Sj-Mz-Sj) | Intensiva (Tr/Sj-Vic/Mz) | Intensiva (Tr/Sj-Ar/Mz-Av/Sj) | Pastura |
|---|---|---|---|---|
| <2 | 4 | 3 | 2 | 2 |
| 20-2 | 26 | 26 | 15 | 18 |
| 63-20 | 13 | 10 | 11 | 8 |
| 250-63 | 15 | 13 | 19 | 12 |
| 2000-250 | 41 | 47 | 54 | 60 |

Submuestra

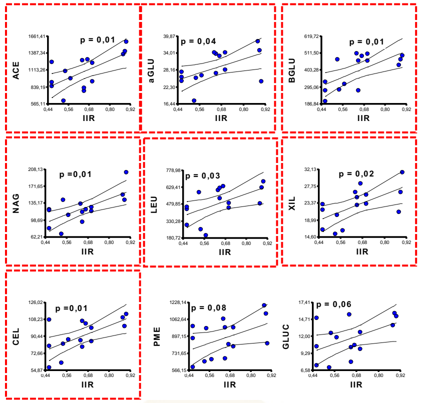
## MICROBIOTA (ADN)




## Networks interactions



## ENZIMES




**β-Glycosidase**

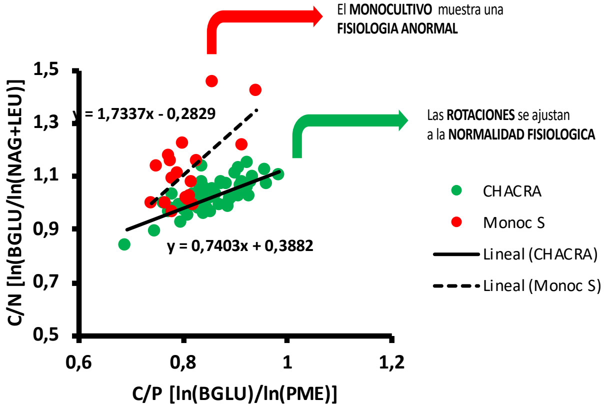
**Cellobiohydrolase**

**Chitinase**

**Leu-Peptidase**

**Phosphatase**

## as integral biological activity



agronomy
MDPI

*Article*

## The Diversification and Intensification of Crop Rotations under No-Till Promote Earthworm Abundance and Biomass

**María Pía Rodríguez [1,2,*], Anahí Domínguez [1,2], Melisa Moreira Ferroni [1], Luis Gabriel Wall [2,3] and José Camilo Bedano [1,2]**

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**Abstract:** The diversification and intensification of crop rotations (DICR) in no-till systems is a novel approach that aims to increase crop production, together with decreasing environmental impact. Our objective was to analyze the effect of different levels of DICR on the abundance, biomass, and species composition of earthworm communities in Argentinean Pampas. We studied three levels of DICR—typical rotation (TY), high intensification with grass (HG), and with legume (HL); along

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Applied Soil Ecology

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## Impact of diversification and intensification of crop rotation (DICR) in soil bacterial microbiota in on-farm study after four and seven years

Juan P. Frene [a], Eva Figuerola [b,c], Luciano A. Gabbarini [a], Leonardo Erijman [b,c], Luis G. Wall [a,*]

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[b] *Instituto de Investigaciones en Ingeniería Genética y Biología Molecular "Dr. Héctor N. Torres" (INGEBI, CONICET), C1428ADN, Buenos Aires, Argentina*
[c] *Departamento de Fisiología, Biología Molecular y Celular, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, C1428EGA Buenos Aires, Argentina*

A R T I C L E I N F O

*Keywords:*
Intensification agriculture
Crop diversity
Crop rotations
Soil microbiome

A B S T R A C T

No-till agricultural diversification and intensification of crop rotations (DICR) effects on soil biological properties were studied in an on-farm study. DICR stands for increasing soil cultivation period and consequent reduction of fallow times by using different winter and summer crops, including cover crops, in two and three-year rotation schemes. Five different levels of DICR were tested -typical local rotation, intermediate rotation, high intensification with grasses, high intensification with legumes, and a continuous multispecies pasture-, and replicated at three different agricultural farms situated in the Argentinean Pampa. The soils were analyzed at four and seven years after DICR started. The on-farm studies were established at each site in a plot of ca. fifty hectares with a typical local rotation history and evaluated after four and seven years of changes. The impact on prokaryotic soil communities was measured by 16S rRNA gene sequencing. Overall, the sustained DICR showed a progressive effect with reduced Bray-Curtis dissimilarities at second sampling. At the phylum level, Actinobacteria, Bacteroidetes, Verrucomicrobia, BCR1, and WS3 increased with the level of DICR while Acidobacteria, Firmicutes, Gemmatimonadetes, OD1, and TM7 showed the opposite trend. Selected taxa based on LEfSe detection were

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FEMS

*FEMS Microbiology Ecology*, 97, 2021, fiab025

doi: 10.1093/femsec/fiab025
Advance Access Publication Date: 11 February 2021
Research Article

RESEARCH ARTICLE

## Impacts of switching tillage to no-tillage and vice versa on soil structure, enzyme activities and prokaryotic community profiles in Argentinean semi-arid soils

Luciano A. Gabbarini[1,†], Eva Figuerola[2,3,†], Juan P. Frene[1,†], Natalia B. Robledo[1], Federico M. Ibarbalz[2,‡], Doreen Babin[4,§], Kornelia Smalla[4,¶], Leonardo Erijman[2,3] and Luis G. Wall[1,*,♯]

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frontiers in Soil Science

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## Agriculture by Irrigation Modifies Microbial Communities and Soil Functions Associated With Enhancing C Uptake of a Steppe Semi-Arid Soil in Northern Patagonia

*Juan P. Frene [1], Valeria Faggioli [2†], Julieta Covelli [1†], Dalila Reyna [1†], Luciano A. Gabbarini [1†], Patricio Sobrero [1], Alejandro Ferrari [1], Magalí Gutierrez [3] and Luis G. Wall [1*]*

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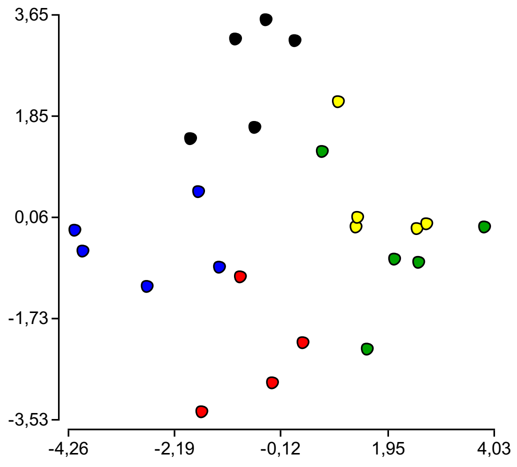
*Malak M. Tfaily, University of Arizona, United States*

The transformation of the semiarid steppe soil after 5 years of intensive irrigated agriculture in Northern Patagonia was analyzed in an on-farm study. The private grower venture used conservative practices, including no-till to maintain soil structure, high crop rotation and cover crops. To characterize steppe soil changes by irrigated agriculture, we analyzed the enzymatic activities involved in the biogeochemical cycles (carbon, nitrogen, phosphorus and sulfur), the whole soil fatty acids profile, the state of soil aggregation, and the bacterial and fungal microbiota through DNA sequencing methods.

## Whole soil fatty acids profiles (WSFA)

separation of soils with different managements and degrees of agricultural intensification.




These lipidic profiles show a remarkable dynamic of seasonal variation over time, which reflects its relationship with the dynamics of soil biology associated with agricultural management. ***It was impossible to find particular fatty acid biomarkers of soil health***, **but** …

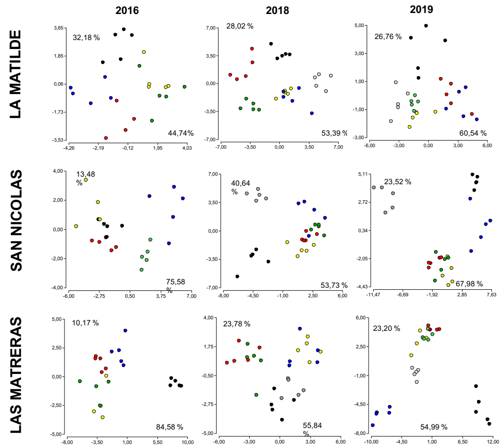
## *Soil lipidic signature - WSFA profile*

(aprox. 70 fatty acids signals after a Gas Chromatography)

(own developed algorithm)

## Soil Health Lipidic Index

(a number)



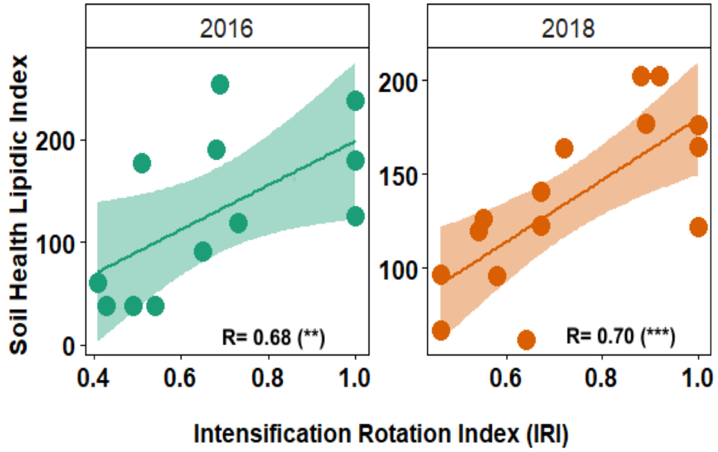

Degree of Intensification (d/d)

| Time (years of good managment) | (0.43) | | | (0.90) |
| --- | --- | --- | --- | --- |
| (4) | 60 | 91 | 119 | 126 |
| | 67 | | | |
| (8) | 141 | | | 195 |

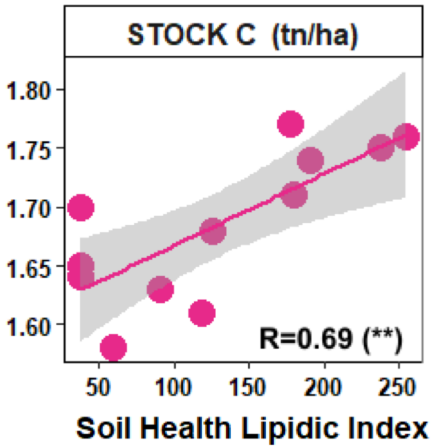
* Data for one particular farm

# Soil Health Lipidic Index
(a number that show good correlation with soil health facts)

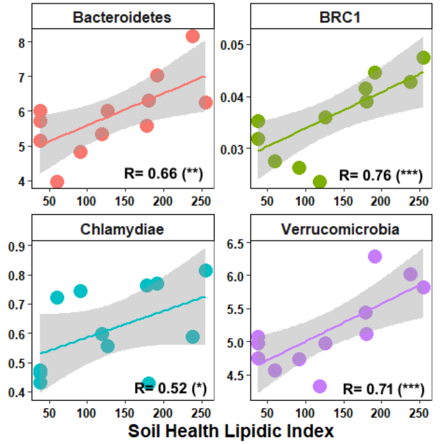
## management

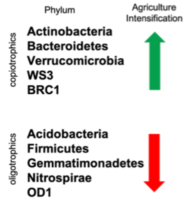


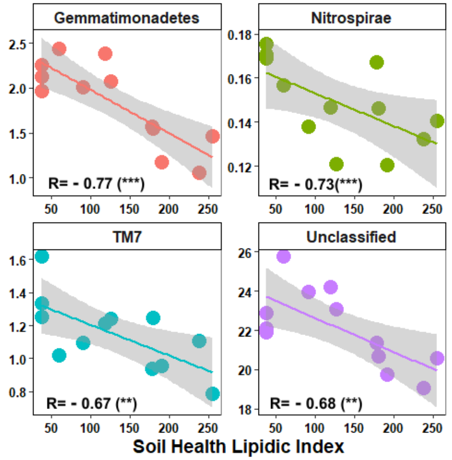

## soil C sequestration



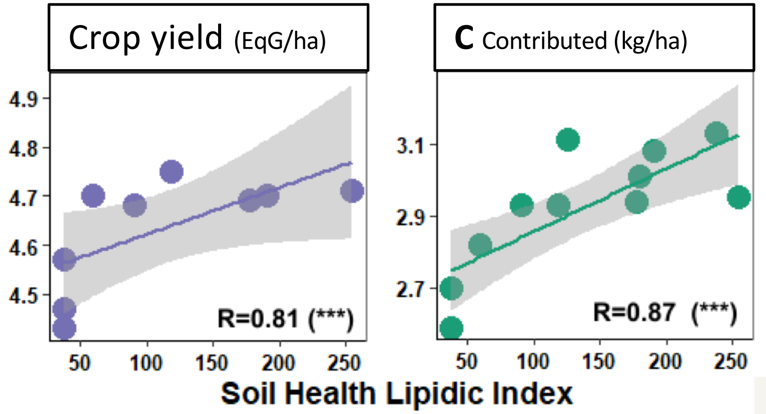

## soil microbiome
( *Bacteria* microbiota structure)



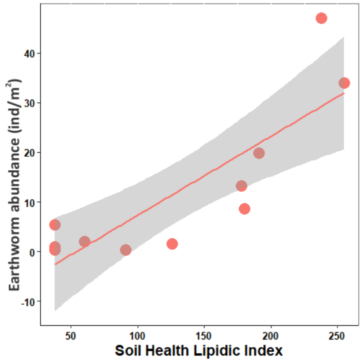




## productivity




## fauna
(earthwhorms)






GLOBAL SOIL PARTNERSHIP

Our soil health index is a consequence of the experience accumulated after 14 years of studying soil responses to different managements, looking for soil biology activity regeneration.

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Universidad Nacional de Quilmes

CONICET

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Photograaphy: Luis G. Wall



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