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AgriDENZ – An alliance for the climate – Dialogue on climate and agriculture between New Zealand and Germany

Global Forum for Food and Agriculture

Diálogo Agropecuario Uruguayo-Alemán

INIA – Instituto Nacional de Investigación Agropecuaria – Uruguay

Increasing soil carbon stock in temperate agriculture production systems

Best practices examples - Uruguay

Virginia Pravia – INIA Uruguay

bmel.de

Messe Berlin

Content

- Introduction:
  - Soil carbon in temperate agroecosystems
  - Natural ecosystem in the Region: The South American Pampas
- Agricultural management practies in Uruguay:
  - Policies for soil conservation: “sustainable soil/land use and management plan” (PUMRS-MGAP).
  - Soil carbon and agroecosystem models
  - LTE and SOC in agricultural systems
- Opportunities and Challenges for soil carbon sequestration in agricultural systems
- Final remarks

Introduction: Soil carbon in temperate agroecosystems of South America

- Agricultural intensification to sustain the global growing demand of food and energy increases pressure on natural resources.
- SOC is a key solution for climate change and food security provision
- **Is it possible to sequester carbon in the soil and maintain or increase productivity? For how long will it stay in the soil?**
- LAC Countries Committed to **Paris Agreement** on climate change (COP21)
- SOC sequestration is the main option to reduce GHG net emissions for countries of an agriculturally based economy
- A severe limitation is the dearth of local information on the response of SOC stocks to land management (e.g. fertilization or irrigation) and land use (e.g. Grassland conversion to cropland or forestland)
- A global challenge is to build solutions and tools for the design of sustainable production systems.

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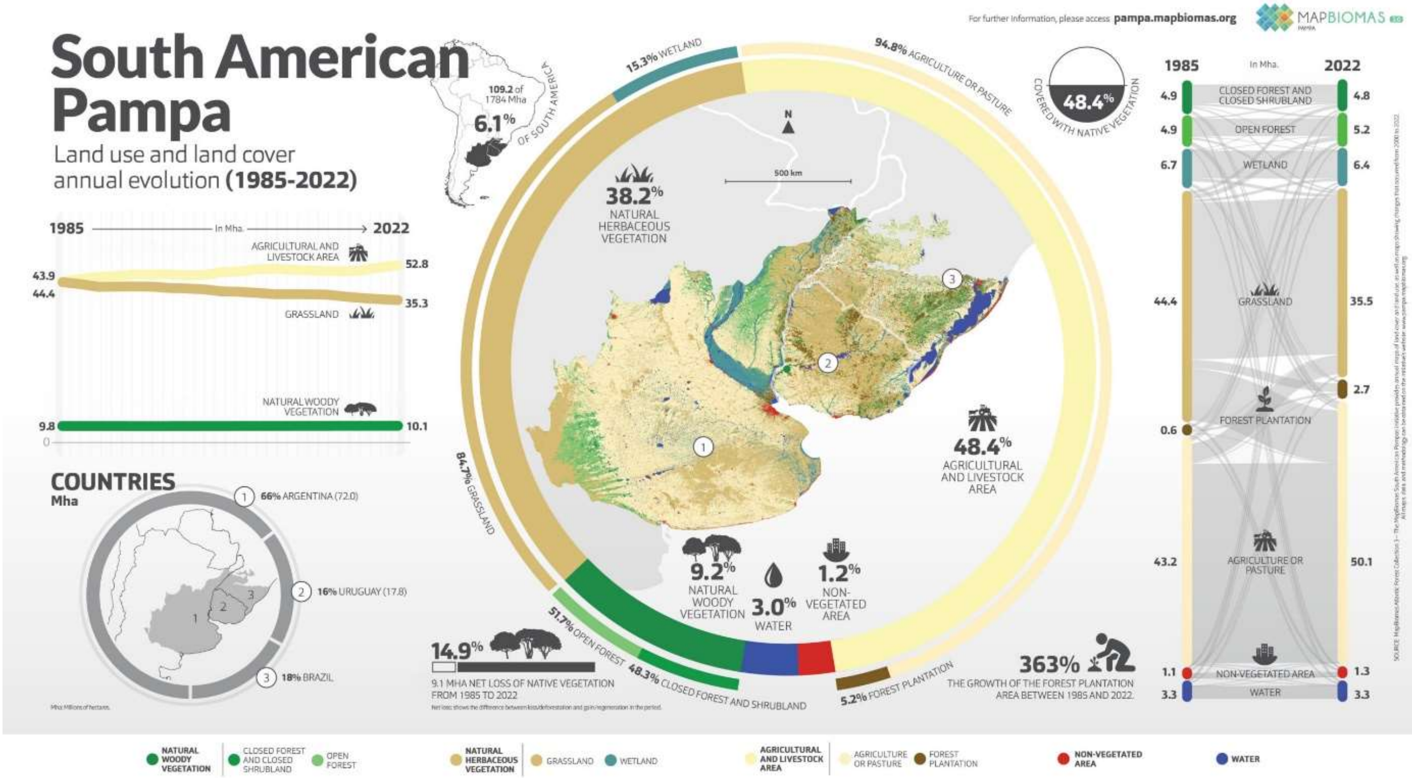
Introduction: Natural ecosystem in the Region

- The Río de la Plata Grasslands (RPG) region is the largest area of the temperate humid and sub-humid grasslands biome in South America and one of the largest in the world.
- On fertile soils, generally suitable for agricultural development
- Undergoing an intense land cover change process.
- In 20 years, RPG region lost, at least, 2.4 million ha of grassland (9% of the remaining grassland area in 2001). (Baeza et al 2022)



https://pampa.mapbiomas.org/en/home-2/

The case of Uruguay in the Pampas and Campos Region

- Climax vegetation: Natural grassland C4 and C3
- Uruguay: Mostly low inputs systems (Livestock 76% of the land)
  - Land use:~65-70% grassland, 15% planted pastures
  - Integrated crop-pasture rotational systems
  - Intensification: Land Use Change 1 mill ha in 10 yr:
  - Cropland, forest, reduced sown pastures, intensified cropping sequences and livestock systems

- Consequences of this changes on the provision of ecosystem services, C and N cycling?.

- Can soils sequester carbon and for how long?

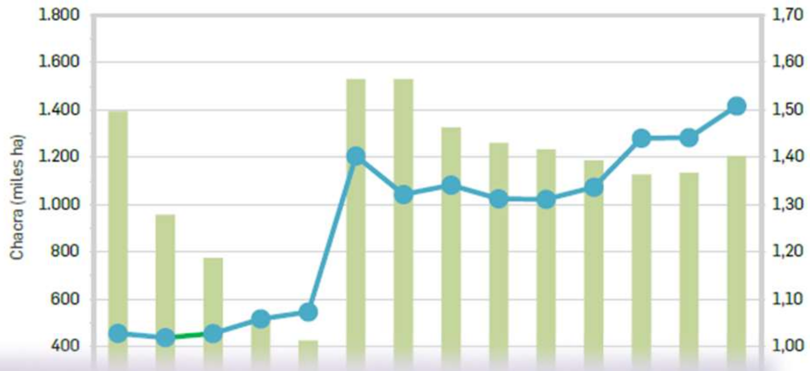


Image from:http://www.alianzadelpastizal.org/en/institucional/ibas/

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Policies for soil conservation in Uruguay (MGAP): Cropland area under Soil Use and Management Plans

- Current policies based on soil erosion estimated by USLE/RUSLE
  Wischmeier and Smith in 1978
- Factors determined at local run-off plots

UNITED NATIONS PARIS CLIMATE AGREEMENT SIGNING CEREMONY — 22 APRIL 2016

ORIENTAL REPUBLIC OF URUGUAY
Second Nationally Determined Contribution
to the Paris Agreement

5.1.1.3. Specific objectives for conservation and carbon stock enhancement in Land Use and Forestry.

Specific objectives for conservation and carbon stock enhancement in Land Use and Forestry: category 3.B Land presented net removals in the 1990 - 2019 NGHGIs.

GHG	Carbon pool / Land Use Category	2030 Mitigation objectives Carbon stock conservation and enhancement*
CO_2	Living Biomass in Forest Lands	Maintain 100% of the native forest area of year 2012 (849,960 ha).
		Maintain 100% of the forest plantation effective area under management of year 2020 (1,053,693 ha).
		Maintain 100% of the shade and shelter forest plantations area of year 2018, including silvopastoral systems (88,348 ha).
	Soil Organic Carbon (SOC) in Grasslands, Peatlands and Croplands	Incorporation of good practices for natural grassland and breeding herds management in 1,500,000 ha of natural grassland
		Preserve 50% of the peatland area of year 2020 (4,756 ha)
		Maintain SOC levels in 30% of the cropland area under Soil Use and Management Plans in 2030 that have more than 30% of the rotation length with pasture
		Increase SOC levels on 15% of the cropland area under Soil Use and Management Plans in 2030 that have more than 60% of the rotation length with pasture

**The objective value for 2030, expressed in hectares, is shown in brackets.*

Next steps

The local calibration and validation of agroecosystem modeling tools explicitly considering soil C and N balances, or GHG emissions that can support current efforts on soil conservation policies and country reports.

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Agroecosystem simulation modeling

Adding efforts to current Policies for soil conservation in Uruguay (MGAP): Cropland area under Soil Use and Management Plans

Previous modeling Research focused on soil C and N cycling, but lacking GHG emissions

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Soil Science Society of America Journal

SOIL & WATER MANAGEMENT & CONSERVATION

Ecosystem dynamics of crop–pasture rotations in a fifty-year experiment in southern South America: Century model and results

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Abstract
The Century model was used to simulate soil C and N cycling and crop... tion dynamics in an ongoing field experiment in Uruguay (started in 19... model was calibrated using observed data from three treatments (crop or cro... rotations) and validated with a fourth treatment. The model correctly pre... impact of different treatments on microbial biomass, N mineralization, s... ration, and crop yields. The model and observed data show that soil resp... mineralization, soil C, and crop yields increase with increasing plant-derive...

Agricultural Systems 171 (2019) 13–22

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

ELSEVIER

Soil carbon saturation, productivity, and carbon and nitrogen cycling in crop-pasture rotations

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Agroecosystem Simulation modeling

Recent advances

- Developed a common database on observed data from three long-term experiments in Uruguay (LTE >20 yr) useful for modeling
- Select a gradient of intensification alternatives on land use and management including specific required data for model input from LTE treatments on crop and pasture rotations
- Expand previous local system simulations on Soil C and N stocks balance (Pravia et al 2019, Baethgen et al 2021) on LTE
- Evaluated C stocks and N_2O emissions using the Cycles agroecosystem model (Kemanian et al. 2024) https://github.com/PSUmodeling/Cycles/releases
- Simulating years of complete soil profile field data and N_2O emissions measurements
- Finally applied the model on three selected commercial farm fields of >10 yr of land use intensification to continuous cropping


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journal homepage: www.elsevier.com/locate/compag

ELSEVIER

The Cycles agroecosystem model: Fundamentals, testing, and applications

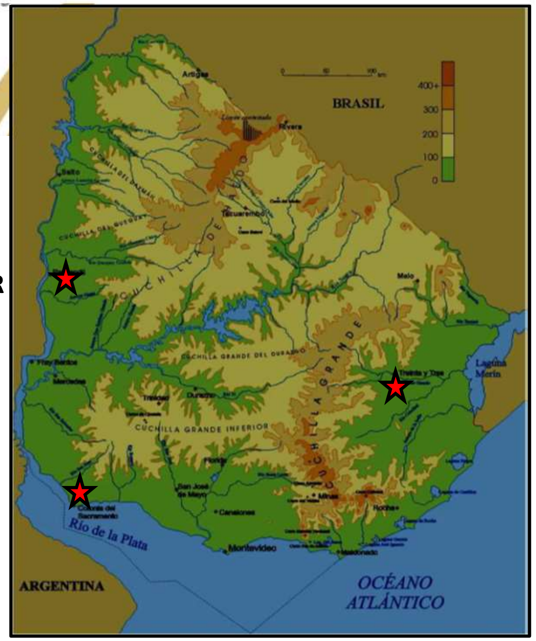
Armen R. Kemanian [a,*], Yuning Shi [a], Charles M. White [a], Felipe Montes [a], Claudio O. Stöckle [b], David R. Huggins [c], Maria Laura Cangiano [a,1], Giovani Stefani-Faé [a,2], Rachel K. Nydegger Rozum [a]

LTE:

Paysandú
EEMAC- FAgro UdelaR
(established 1993)

Treinta y Tres
Palo a Pique UEPP-INIA
(established 1995)

Colonia,
INIA La Estanzuela
Rotaciones Viejas-RV
(established 1963)



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FMV_3_2020_1_162660
Proyecto de investigación aplicada Fondo Maria Viñas - 2020

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Ministerio de Ganadería, Agricultura y Pesca
DIRECCION GENERAL DE RECURSOS NATURALES

FACULTAD DE AGRONOMÍA

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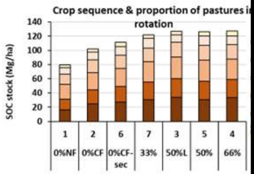
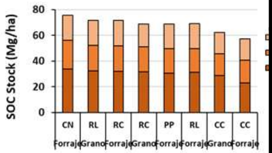
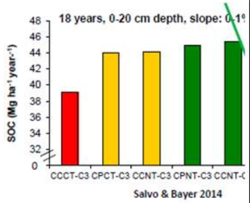
Long term experiments across the country

- Cover a gradient of SOC stocks as a result of intensification alternatives land use and management:
    - Tillage/no tillage
    - Monocultures
    - Grain cropping sequences
    - Integrated crop-pasture systems
    - Permanent Pasture







LTE	Treatament ID	Description
Colonia, INIA La Estanzuela Rotaciones Viejas-RV (established 1963)	CC_C4NoTill_F Continuous cropping (System 2)	Three-year annual crop rotation, including crops of: corn, barley, sorghum, wheat, and soybeans
	ROT_PC_NoTill: Crop-Pasture Rotation (System 5")	Six-year rotation: three years of the same cropping sequence as system 2, followed by three years of mixed white clover, lotus and fescue pastures. Rotation of 3 years of crops and 3 years of pastures
Treinta y Tres Palo a Pique UEPP-INIA (established 1995)	Continuous cropping (CC)	Two-year rotation of grain crops of soybeans and sorghum in summer and wheat crops in winter, or cover crops of oats or ryegrass
	Crop-Pasture Rotation (CP)	six-year rotation, including two years of grain crops in the same sequence as continuous cropping, followed by four years of fescue, white clover and lotus pastures.
	Permanent Pasture (PP)	sowing in cover of fescue, white clover and lotus, which is eventually renewed in the long term according to the persistence of the species of interest (every six years or more).
Paysandú EEMAC- FAgro UdelaR (established 1993)	CC_C3_Till	Continuous cropping under tillage with C3 photosynthesis species under tillage, where the sequences are mainly composed of wheat, barley and soybeans
	ROT-PC_Till	Crop rotation with pastures under tillage, where the CC_C3_Till sequence is rotated every three years by pastures of grasses and legumes for three years
	CC_C3_NoTill	Continuous cultivation with C3 photosynthesis species in direct sowing, in which the same rotation is carried out as in CC_C3_Till without tillage;
	ROT-PC_NoTill	Crop rotation with direct sowing pastures (, in which the same rotation as ROT-PC_Till is carried out without tillage;
	CC_C4_NoTill	Continuous cultivation with C4 photosynthesis species in direct seeding, similar to CC_C3_NoTill but replaces soybean or sunflower cultivation with C4 summer grasses (sorghum or corn);
	CC_Sb_NoTill	Soybean monoculture in direct sowing, this system was generated starting in 2006 from the CC_C3_No Till plot, where only soybeans are grown
Monoculture	CC_Mz_F	Corn monoculture with two years of Brassica carinata (one fertilized);
	CC_Mz_SF	Corn monoculture with two years of Brassica carinata (without fertilization);
	CC_Sb_F	Soybean monoculture with two years of Brassica carinata (one fertilized);
	CC_Sb_SF	Soybean monoculture with two years of Brassica carinata (without fertilization).

Long Term Experiments and SOC in agricultural systems

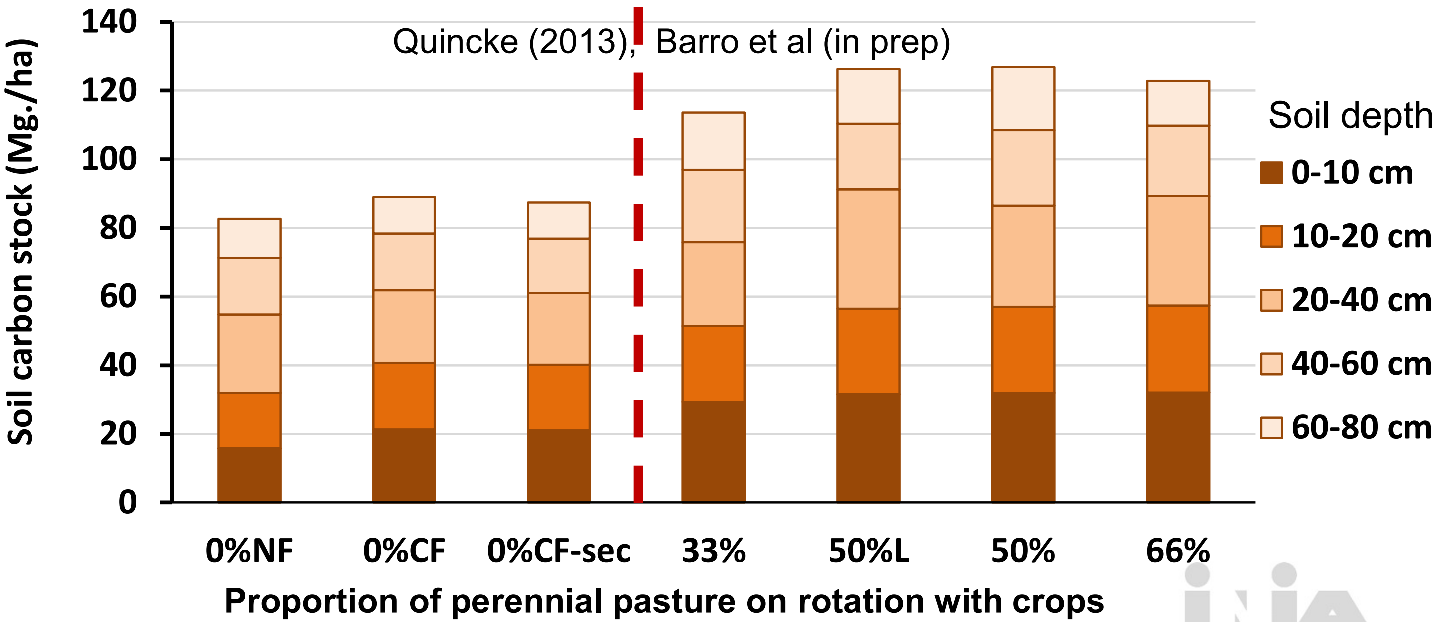
Cont Cropping (0% CF)

Rotation 3 yr crop-3yr pasture (50%)

Observed COS stocks– some lessons learned for in LTE Uruguay

LTE INIA La Estanzuela (since 1963):

Crop –pasture rotations after 45 years with soil tillage



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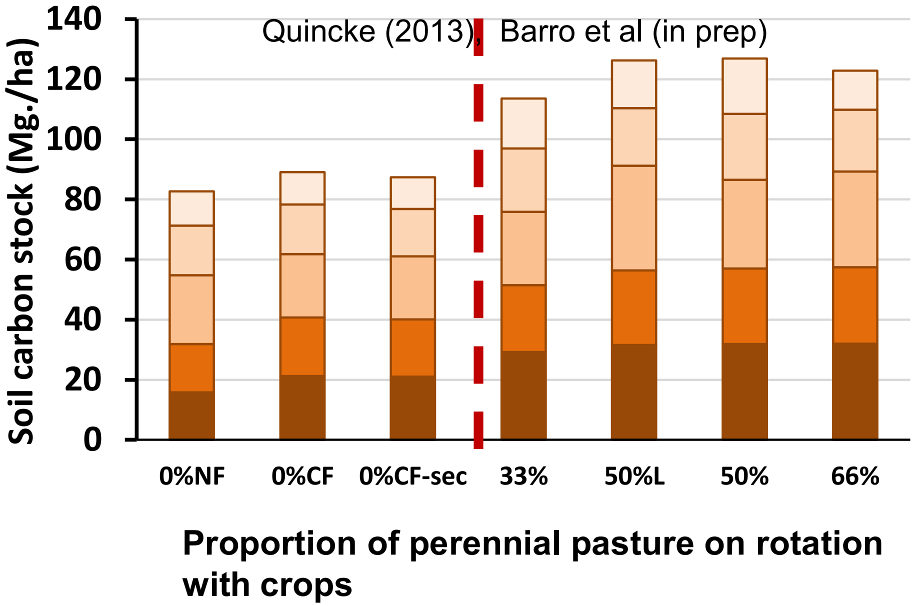
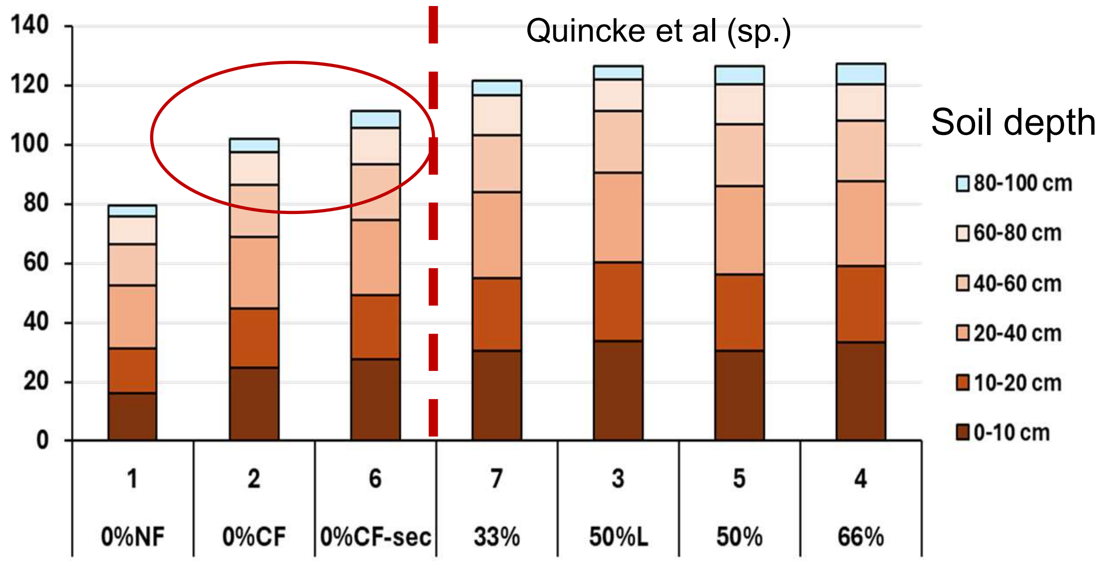
Long Term Experiments and SOC in agricultural systems

Crop –pasture rotations after 45 years with soil tillage



After 57 years, **last 12 years under no tillage**



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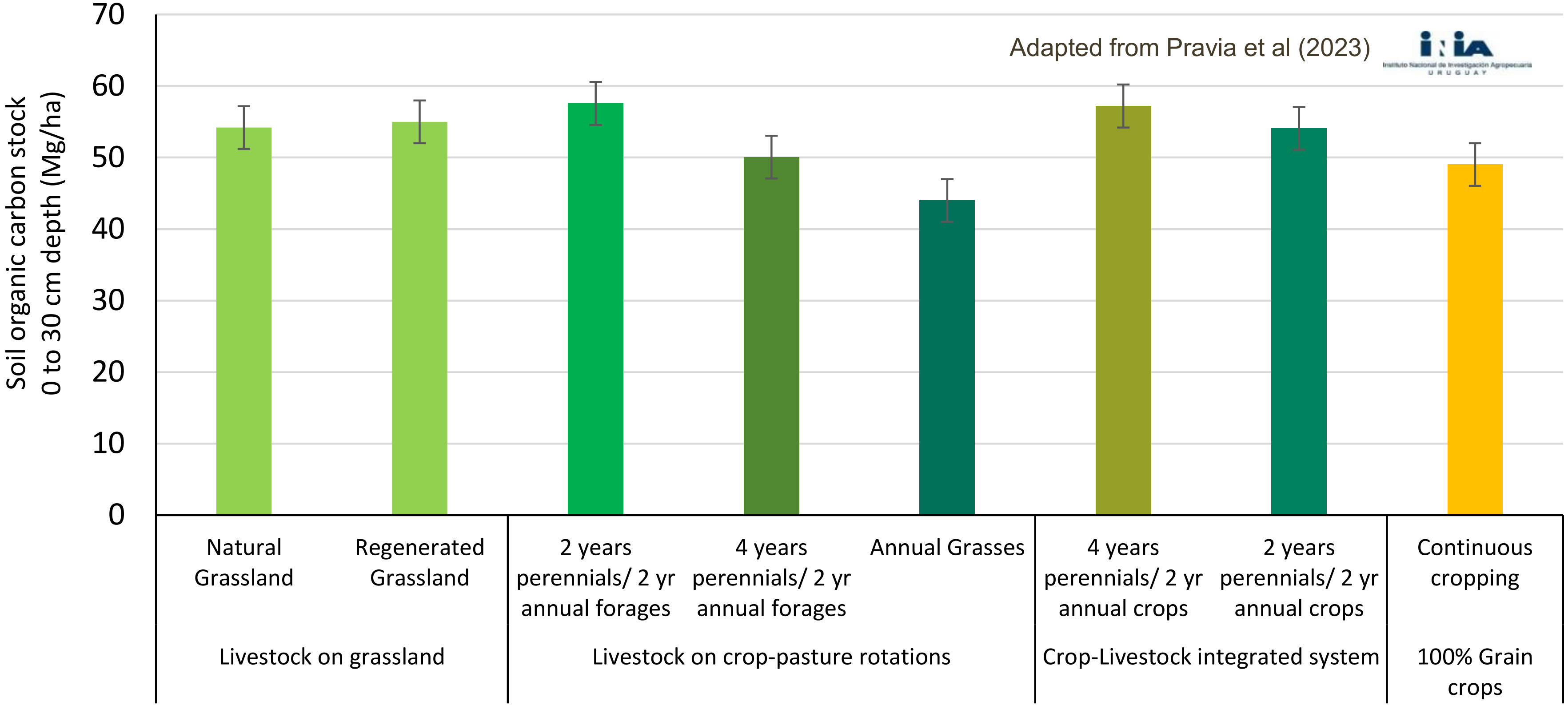
Long Term Experiments and SOC in agricultural systems

Observed COS stocks– some lessons learned for in LTE Uruguay

LTE: Unidad Experimental de Palo a Pique (since 1995)
land use change in livestock systems, intensification leveles and intregration with grain cropping

SOIL ORGANIC CARBON IN SOILS OF URUGUAY:

- After 20 years implementing alternative management pactices in livestock and cropping systems under no tillage (argiudols and argiaquolls)



Opportunities for carbon sequestration in integrated livestock-agricultural systems:

- The integration of agriculture and livestock with rotations of perennial pastures under no tillage allows maintaining carbon stock levels close to the original ones
- The effects of no tillage and rotation design have complementary effects
- Planting perennial species to recover degraded soils is an efficient carbon sequestration strategy (win-win) -> quantify profits
- Explore sequences that:

  - Maximize inputs (service crops, revalue perennial species) and

  - Reduce losses due to mineralization (fallow times, N contributions)

Final remarks

Maximizing the synergies in the biological processes that operate in the system, the use of management practices that tend to sequester carbon contributes to preserving soil health and making more efficient use of natural resources.

Scientific knowledge summarized in models can support informed farming decisions and governmental policies for a better design on agricultural systems

Aknowledgements

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