Economic and environmental sustainability of rice-based rotations in Uruguay

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Introduction

Rice is an important crop worldwide but has a high carbon footprint relative to other cereals, particularly under monocropping. While integrated crop-pasture systems may have advantages (e.g. soil quality and reduced inputs), rotations with a higher frequency of annual grain production may increase economic returns and be more attractive to farmers. The potential for different rice-based crop rotations to optimize economic profitability and environmental quality has been poorly studied, particularly involving multiple sustainability indicators.

Objectives

Evaluate the sustainability of three rice-based rotations at the system level in terms of economics, productivity, carbon footprint, and energy and nitrogen use using seven years of data from a long-term experiment established in 2012 in Uruguay.

Material and Methods

Figure 1. Location of experiment in Uruguay and aerial picture of the long-term experiment with different rice-based rotation systems.

Treatments evaluated:

Year	1		2		3		4		5		6	
ROTATION	S-S	F-W	S-S	F-W	S-S	F-W	S-S	F-W	S-S	F-W	S-S	F-W
1) continuous rice (CR)	Rice	cc	Rice	cc	Rice	cc	Rice	cc	Rice	cc	Rice	cc
6) rice-soybean (R-S)	Rice	cc	Soybean	cc	Rice	cc	Soybean	cc	Rice	cc	Soybean	cc
4) rice-long pasture (R-PP)	Rice1	cc	Rice2	Permanent Pasture							Rice1	cc

cc= cover crop

Indicators evaluated:

- ✓ Energy Yield: GJ ha^{-1} yr^{-1} (including total grain and beef production depending on rotation)
- ✓ Greenhouse gas (GHG) emissions (management activities and field CH_4 and N_2O emissions): kg CO eq ha^{-1} yr^{-1} based on IPPC, 2006.
- ✓ Energy Use: MJ ha^{-1} yr^{-1}
- ✓ Nitrogen Use: kg N ha^{-1} yr^{-1}
- ✓ Economics: Income, Costs, and Gross Margin: USD ha^{-1} yr^{-1}

Sustainability Index:

Energy Yield, Total GHG, Energy Use, Income, Costs and Gross Margin were normalized to calculate a composite Sustainability Index. All variables were expressed so that higher values (closer to 1) were better.

More is better: $\frac{Yi - Ymin}{Ymax - Ymin}$ Less is better: $\frac{Ymax - Yi}{Ymax - Ymin}$

(Mutyasira et al., 2018)

Results

CR: continuous rice, R-S: rice-soybean, R–PP: rice-pasture

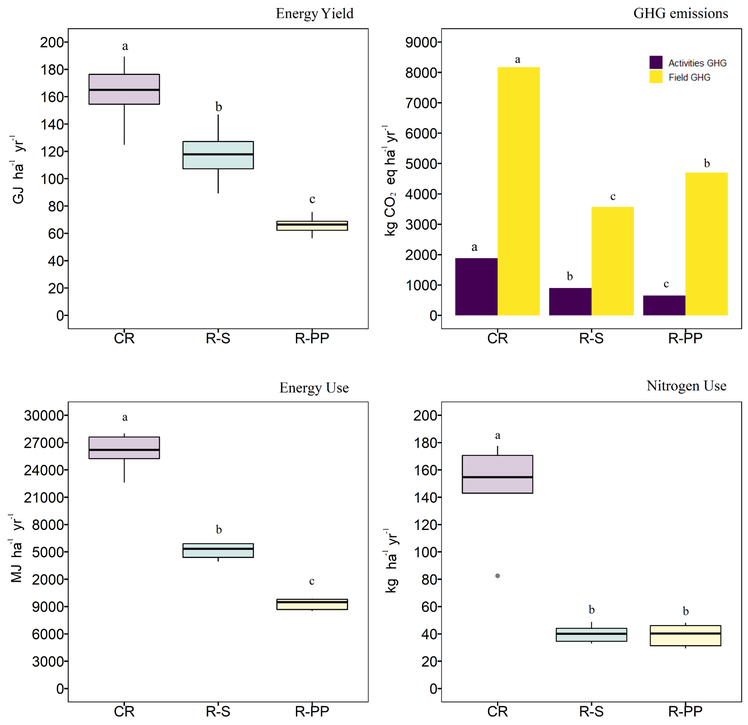

Figure 2. Energy Yield, GHG emissions, Energy use, and Nitrogen Use in three rotation systems. Different lowercase letters are significantly different between treatments at p≤0.05 by Fisher test.

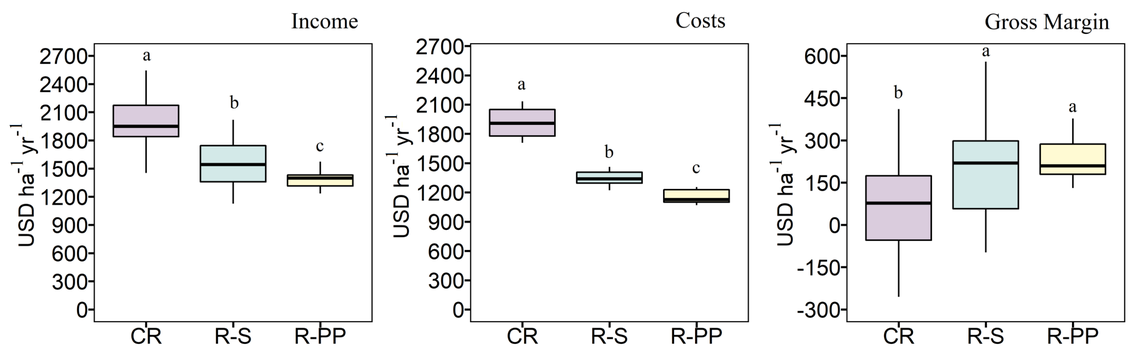

Figure 3. Income, Costs, and Gross Margin in three rotation systems. Different lowercase letters are significantly different between treatments at p≤0.05 by Fisher test.

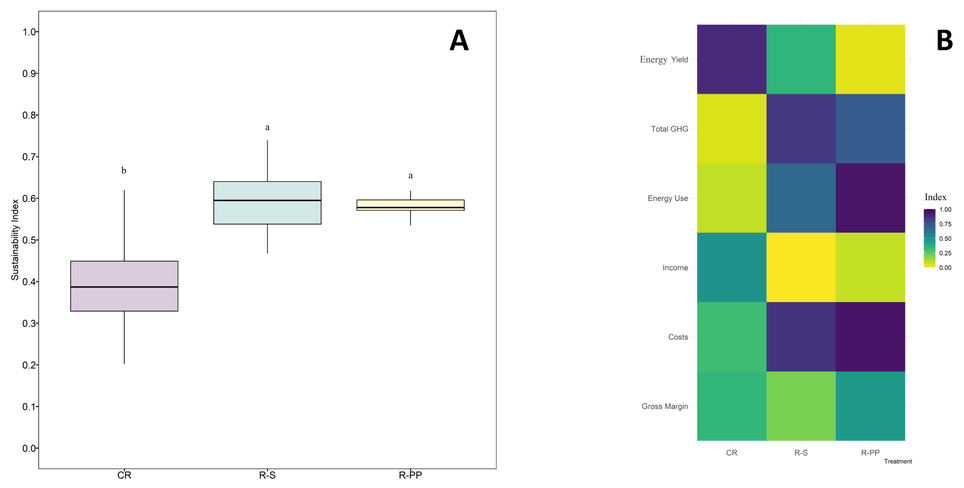

Figure 4. Sustainability Index (A) and Heat map (B) in three rice rotation systems. Different lowercase letters in A are significantly different between treatments at p≤0.05 by Fisher test.

Take home messages

- Continuous rice increased energy yield (total system productivity), but at the cost of higher GHG emissions and higher energy and N use.
- Continuous rice had higher costs, making it less profitable and leading to a lower sustainability index.
- Rice-soybean was similar to rice-pasture across indicators, but rice-pasture had lower variability for profits, potentially decreasing risk.

Results show perennial pastures are a key element of rice-based rotations in Uruguay. However, substitution with soybean could maintain economic and environmental sustainability of the system, at least for the timeframe evaluated in this study (7 yr).