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INTEGRATED RICE-PASTURE SYSTEMS SUSTAINABILITY IN URUGUAY[1]

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Abstract: Integrated rice-livestock systems were key for a sustained yield increase with decent resource-use efficiency and environmental indicators during 50 yrs. in Uruguay. The increased trends for intensification in cropping systems may prompt rice-livestock systems for decoupling and losing synergies. We summarize evidence about the sustainability of rice-livestock systems in Uruguay using indicators from farm data and a long-term experiment.
Key words: Crop-livestock; Agro-ecoefficiency; Environmental impact; productivity.

Introduction

Rice is cultivated in 165 Mha globally, being a basic food for people. The need to expand crop yield to address food security is critical, but there are concerns about the environmental footprint of intensification practices (Pittelkow et al., 2016). Unlike most of the world, rice in Uruguay is usually integrated with livestock rotating with perennial pastures (Castillo et al., 2021). Crops-livestock integration enhances yields, ecosystems services, resilience, economic results and climatic change adaptation (Carvalho et al., 2021). However, intensification and specialization processes in farming may push crop-livestock systems for decoupling and loss benefits. We hypothesized that rice-pasture systems increase productivity and resource-use efficiency, reduce environmental footprint, and improve economics compared with other systems. We reviewed evidence about the sustainability of rice-livestock systems in Uruguay.

Source of information

Some studies used field-level records from SAMAN rice mill farmers covering 40% of the annual Uruguayan seeded area (Tseng et al., 2021; Castillo et al., 2021). Other studies used a long-term experiment (LTE) fitted in 2012 in Uruguay on an Argialboll under a mesothermic humid climate. Briefly, the LTE assess 6 rice rotations (Macedo et al., 2021a): 1) Rice-Rice-Long Pasture of *Festuca arundinacea* and *Trifolium repens* (R-P_L); 2) Rice-Short Pasture of *Lolium multiflorum* and *Trifolium pratense* (R-P_S); 3) Rice-Soybean-Soybean-Rice-Pasture of *Festulolium spp*. and *Lotus corniculatus* (R-Sy-P); 4) Rice-Soybean-Rice-Sorghum (R-Sy-Sg); 5) Rice-Soybean (R-Sy); and, 6) Continuous Rice (CR). Ryegrass and *Trifolium alexandrinum* covers grown between cash crops in all systems. The LTE was a RCB with 3 synchronic reps and all rotation phases coexisting.

Results and Discussion

Rice actual yield in Uruguay (9.4 Mg ha^{-1}) represents up to 65% of the potential yield and 85% of the attainable yield (Carracelas et al., 2023). Integrated crop management allowed to simultaneously boost yields and attend environmental issues (Pittelkow et al., 2016). During 1993-2013, yield grew 38%, net energy yield raised 50%, water productivity improved 41%, and N use efficiency was sustained. Also, the yield-scaled C footprint fell 30%; pesticides contamination risk declined, but N potential losses grew 37%. The evaluation of the yield gap and various resource use efficiencies in 32 global rice cropping systems shown the indicators strength (Yuan et al., 2021). Top rice yield farmers had better ecoefficiency and environmental indicators than the average (Tseng et al., 2020). Although technology may raise 10% the yield ceiling, simultaneously increase yield, resource use efficiencies and environmental indicators (top 10%) in farms is a hard task with several synergies and tradeoffs (Tseng et al., 2021).

Rice yield after short and long pastures, sorghum and soybeans was 10, 14, 9 and 20% higher than CR (9460 kg ha^{-1}). The analysis of selected indicators shown R-P_L systems had lower costs and better economic results than CR and R-Sy (Macedo et al., 2022b). As R-Sy had the best multi-criteria index that integrates productivity, agro-eco-efficiency, environmental and economic indicators; the R-P_L was the most stable across four stability parameters used.

Rice in R-PL, or R-Sy had 33% and 26% higher energy return on investment (EROI) than CR (5.7 Mj Mj-1), respectively (Macedo et al., 2021a). Overall, CR system had 7% and 21% lower EROI than R-PL (6.1 Mj Mj-1) and R-Sy (7.2 Mj Mj-1), respectively.

The N balance in R-P_L was nearly zero (-6 kg N ha^{-1} yr^{-1}), but in CR was positive (45 kg N ha^{-1} yr^{-1}) and in R-Sy negative (-20 kg N ha^{-1} yr^{-1}) (Castillo et al., 2023). The N use efficiency in R-Sy, R-P_L and CR was 84, 54, and 48%, respectively. Rice-livestock country-level N balances were 3.5, 2.2 and 2.2 kg N ha^{-1} yr^{-1}, for rice, livestock, and the whole system, respectively (Castillo et al., 2021). While N use efficiency was 66, 13 and 23%, respectively.

Runoff nutrient losses during rice cropping were lower in R-P_L than in CR (Cantou et al., 2022). Although there was neutral to slightly positive balance of N and P in water and moderate rate of export, the initial flooding and the drainage prior harvest represented a risk.

Soil organic carbon sequestration was linked with pastures root biomass (Macedo et al., 2022a). The R-P_L system sequestered C (0.6 Mg ha^{-1} yr^{-1}). Other rotation systems maintain C levels, but those with soybeans trend to lose C in labile fractions (Macedo et al., 2021a).

Methane emissions peak at rice flowering (Fernández et al., 2022). Alternating soil wetting and drying cycles mitigated emissions but may reduce yield. Decoupling rice-pasture rotations to a more intensive system altered the methanogenic community structure and their methane emission potential (Pereira-Mora et al., 2023). Rotation affected N fixers and CH_4 consumers. However, no differences in emissions were found between rice in CR and R-P_L.

The ecotoxicology footprint of pesticides on soil and water was lower in R-P_L systems than in R-Sy or CR systems (Carrasco et al., 2023). Also, rice grain did not exceed pesticides residues limits in any rotation. A diversity of microorganisms and metabolic capacities in soil, water and plants were found (Ghiazza et al., 2023). Soil and rice roots microbial communities changed by flooding, cycle and rotation. Some predatory arthropods and earthworms population and biomass separated rotations, being lower in those with soybean and/or frequent flooding.

Final considerations

For rice in mesothermic humid climate, rotation systems with perennial pastures sustains crop yield and stability, improves ecoefficiency and minimizes environmental impacts.

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