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Ecological intensification in Río de la Platagrasslands

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1 Introduction

Understanding existing agro-ecosystems in which food production is based on intensive internal resource use might provide inspiration for re-designing external input based systems. The livestock production systems in the *Río de la Plata Grasslands* (RPG) in southern South America represent a good example of such model. Animal production in this vast region, which includes parts of Brazil, Uruguay and Argentina, co-evolved with plant biodiversity on semi-natural grasslands that received negligible amounts of external inputs since the introduction of domesticated livestock in the 16th century (Soriano, 1992), constituting a feasible form of land-sharing. During the last 15 years, high prices of grains (mostly soybean and wheat) prompted conversion of grasslands to arable land (Paruelo *et al.*, 2006). Overgrazing due to high stocking rates on the remaining land caused loss of valuable grassland species (Overbeck *et al.*, 2007), low grassland and meat productivity (Carvalho & Batello, 2009) and negative environmental impacts on soils and climate due to erosion and losses of soil carbon and high greenhouse gas (GHG) emissions (Modernel *et al.*, 2013). This change in land use endangers the unique and 400 year old model of land sharing (Garnett *et al.*, 2013) in which meat production is sustained by natural grassland biodiversity. Two intensification strategies can be distinguished in the region. The first one (conventional intensification) proposes to increase meat yields through replacing natural grasslands by ley and feed crops (Cohn *et al.*, 2014). The second one(ecological intensification) proposes to increase meat yields by adjusting forage allowance[1] to animal energy requirements in time and space through smart use of species diversity (C3 and C4) in native grasslands (Soca *et al.*, 2008). The first strategy aims to intensify production to be able to save land and separate production and nature conservation areas (land sparing), while the second one aims to preserve the diversity of native grasslands while using them (land sharing)(Green *et al.*, 2005). In this paper, we analyse the ecosystem services provision of both intensification pathways, compared to the traditional system with low productivity.

2 Materials and Methods

Environmental indicators were calculated based on the production of one steer slaughtered at 500 kg. Farms that produce this animal can specialize, or combine three production activities: calving, growing and fattening. Specialized farms include three types: cow-calf (produce 150 kg calves), backgrounding (receives 150kg steers and sells them at 350 kg) and fattening (fattens steers from 350 to slaughter weight). Intensification strategies can differ depending on farm specialization.

The impact of the intensification process on the ES provision was estimated from a review of published studies in the region. Meat productivity and GHG emissions were estimates from nine farm case studies in Uruguay (Becoña *et al.*, 2014; Montossi, 2014; Picasso *et al.*, 2014). Calculations on the impact on biodiversity and carbon sequestration of current and ecollogically intensified systems was made from Brazilian experiments that evaluated the grazing pressure on natural grasslands on the soil carbon stock, considering 4% forage allowance (FA) as the traditional system and 12% FA for ecological intensification and crop-ley rotations for conventional intensification (Carvalho *et al.*, 2009; Conceição *et al.*, 2007; García Préchac *et al.*, 2004). Fossil energy reduction, pesticide use reduction, GHG emissions reduction, erosion risk reduction and water use efficiency were calculated using published farm data (Picasso *et al.*, 2014; Ran *et al.*, 2013). In order to standardize the different impact categories, the system with the most positive (or least negative) impact on an indicator was considered as the reference and set to 100%; the other systems were expressed as fractions of the reference.

3 Results and discussion

While conventional intensification would increase meat yields and reduce greenhouse gas emissions compared to the ecological intensification strategy, the also occurring negative environmental consequences question this option for the RPG farming systems (Table 1 and Fig. 1). Production cycles in conventionally intensified systems produce meat in less time than the other two, resulting in greater productivity per hectare.

Ecological intensification shows synergies among a number of indicators by improving meat productivity, biodiversity conservation, carbon sequestration, GHG emissions reduction and water use efficiency. The use of fossil fuels, pesticides and erosion risk is higher than in the traditional low productive system, but (sometimes substantially) lower

[1] *Weight of herbage per unit of animal live weight at a point in time (Allen et al., 2011).*

than under conventional intensification.

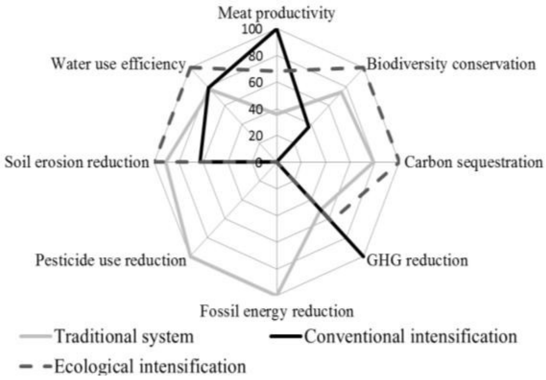

Figure 1. Impact of traditional, conventionally intensified and ecologically intensified livestock systems on the ecosystem services provided by natural grasslands in the RPG. Higher values (closer to 100) indicate better performance.

Table 1. Indicators and their values considered for each farming system.NG: Natural grasslands; L: Ley; GR: Grains.

Indicator	Traditional	Conventional intensification	Ecological intensification	Units
Diet composition (dry matter %)	100% NG	32% NG; 37% L; 31% GR	70% NG; 30% L	ha
Stocking rate	0.7	1.6	1.3	Livestock Units·ha^{-1}
Meat productivity	124	342	233	kg LW ha^{-1}yr^{-1}
Biodiversity conservation	2.6	1.3	3.5	No unit
Carbon sequestration	113	0	143	t C ha^{-1}yr^{-1}
GHG emissions reduction	20	10	16	kg CO_2 eq kg LW^{-1}
Fossil energy reduction	0.0	12.1	3.4	MJ kg LW^{-1}ha^{-1}
Pesticide use reduction	0.1	14.9	1.7	No unit
Soil erosion reduction	11	16	14	kg soil kg LW^{-1}
Water use efficiency	0.052	0.053	0.067	L kg LW^{-1} yr^{-1}

4 Conclusion

The evidence presented in this article shows that the RPG is a region where combining agriculture and conservation of biodiversity is possible (land sharing), but under threat of change from use as grassland to soybean. Given the long history of land sharing, preserving livestock production systems based on native grasslands is key to the maintenance of regional biodiversity and the associated array of ecosystem services. The unique combination of production and resource conservation under ecologically intensive methods of producing meat should be further investigated to understand its benefits and promote low-input technologies that are adapted to the specific farming conditions.

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