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A conceptual framework for the analysis of engineered biodiverse pastures

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ABSTRACT

Sown biodiverse permanent pastures rich in legumes (SBPPRL) were developed in Portugal in the 1960s and 1970s as a strategy to increase grassland productivity by sowing mixtures of up to 20 species/cultivars of legumes and grasses. Compared to semi-natural pastures, the resulting engineered system provides higher yields of better quality pasture, significantly increasing sustainable stocking rates, with multiple environmental co-benefits. Here, we propose a conceptual framework for the sustainability assessment of SBPPRL and apply it with existing data. Our objective is to inquire if this system is an example of sustainable intensification of livestock production, i.e., an economic and ecological win–win solution that can answer many of the causes for ecosystem degradation in semi-arid and sub-humid climate zones, such as in the Mediterranean basin. We build on experimental results from previous studies, which suggest that SBPPRL replenish soil organic matter pools and improve soil structure. The high increase in stable soil organic matter acts as a carbon sink, turning the system into an optimum tool for climate change mitigation and adaptation. Portugal made use of this fact by supporting the expansion of SBPPRL areas and abating the corresponding carbon from Kyoto Protocol emissions calculations. We resorted to the literature to evaluate other environmental effects due to the absence of data specifically for SBPPRL. Surface water runoff decreases and pirophyte shrub vegetation is eliminated or much reduced. Nitrogen accumulates in stable forms in the soil after being fixed by *Rhizobium*/legume symbiotic associations. Legumes depend on phosphorus fertilization; as such the nitrogen cycle in SBPPRL relies on a potentially non-renewable resource (required during the first years after installation of the pasture), which may be a potential limiting factor in the future. The effects on wild biodiversity are unclear. The methodology laid out in this article provides an innovative framework to assess these effects as additional experimental data becomes available.

1. Introduction

The system of engineered pastures henceforth designated as "Sown Biodiverse Permanent Pastures Rich in Legumes" (SBPPRL) uses biodiversity as a lever for productivity. Its development started in the second half of the 1960s when Portuguese agronomists, namely David Crespo, began noticing that fertilization alone was insufficient to reach satisfactory levels of grass productivity and animal feed quality. After tests conducted at his family's property "Herdade dos Esquerdos" (in Vaiamonte, Portugal, as depicted in Fig. 1), Crespo advocated that the introduction of species and varieties originated from the Mediterranean either absent or in lower proportions in spontaneous grasslands (as, for example, species/varieties of legumes) establishes a functioning ecosystem with complementary ecological niches and improves production (Crespo, 1975). He created the first SBPPRL seed mixtures. According to Fertiprado (http://www.fertiprado.pt), the major Portuguese company preparing seed mixtures, 94,260 hectares of rainfed SBPPRL were installed in Portugal between 1990 and 2008. During this period, there has

Abbreviations: DM, dry matter; PCF, Portuguese Carbon Fund; SBPPRL, sown biodiverse permanent pastures rich in legumes; SNP, semi-natural pastures.

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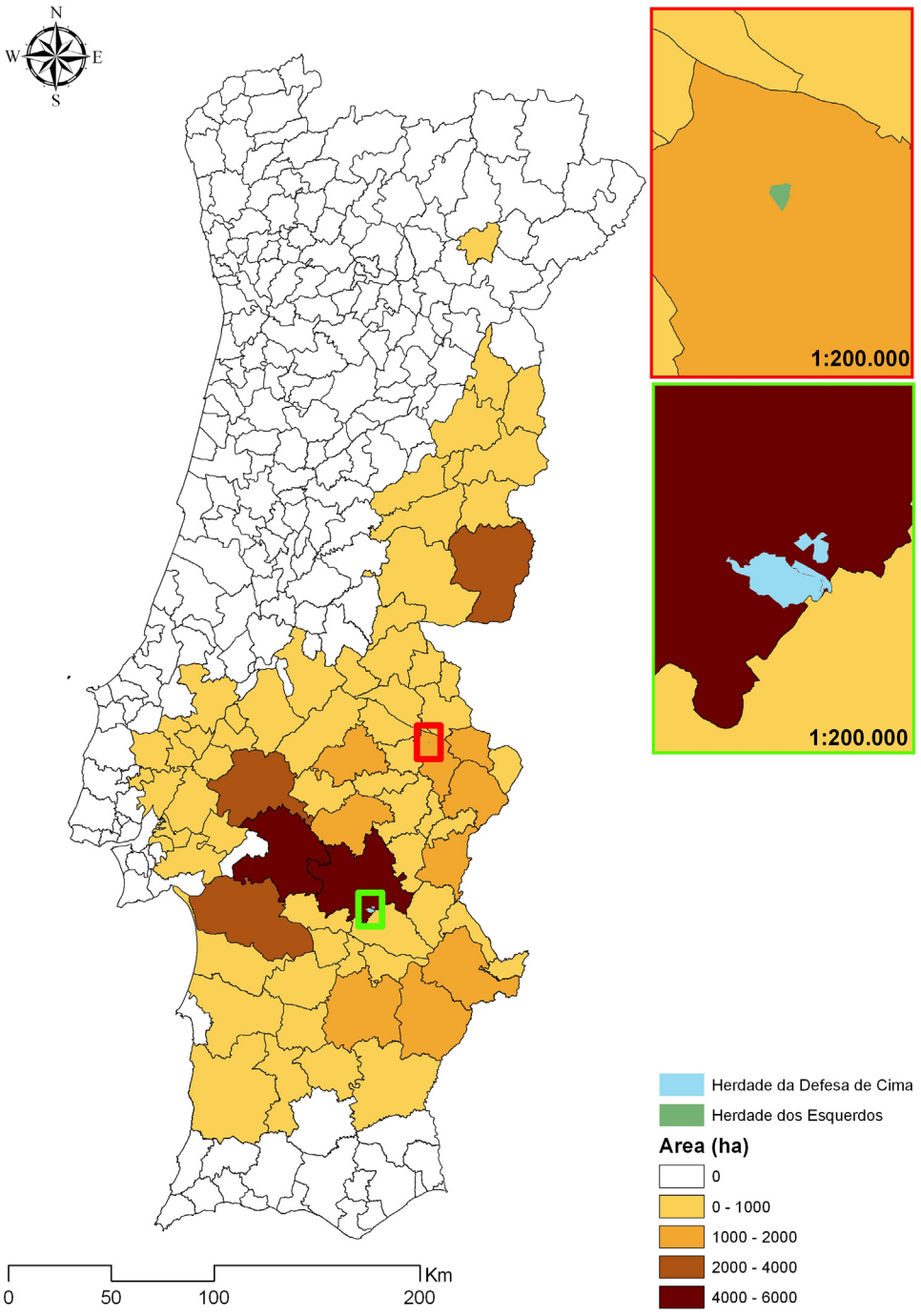

Fig. 1. Distribution of the area of sown biodiverse pastures rich in legumes sown in Portugal under support from the Portuguese Carbon Fund (2009–2013). The farm "Herdade dos Esquerdos" is shown in the upper right corner, and the farm "Herdade Defesa de Cima" immediately below.

been evidence of soil organic matter (SOM) increases in these grasslands. Since then the mechanisms for SOM accumulation and carbon sequestration in SBPPRL have been established (Teixeira et al., 2008; Teixeira et al., 2010Teixeira et al., 2011). Teixeira (2010) estimates that 3.5 million tons of CO_2 were sequestered in SBPPRL as soil carbon between 1996 and 2008. Because of this work, Portugal was one of only two countries, alongside Denmark, to choose the "Grassland Management" activity, in the framework of the voluntary land use land use change and forestry (LULUCF) activities under Article 3.4 of the Kyoto Protocol. Since 2008, The Portuguese Carbon Fund (PCF), a financial instrument created by the Portuguese Government to help the country comply with Kyoto targets, has been supporting the installation and maintenance of SBPPRL through a system of payments for carbon sequestration. Since then, the area has increased 48,491 ha (spread between 1095 farmers) distributed as shown in Fig. 1. SBPPRL now occupy an area of more than 4% of the country's agricultural land. Terraprima (http://terraprima.pt/), the company running the carbon sequestration project, estimates that SBPPRL are sequestering 1.54 million additional tons of CO_2 under PCF payment for the carbon sequestration service in the 2009–2014 timeframe.

Carbon sequestration in grassland soils has wide policy (Gerber et al., 2013; pp. 52–53, 88–89; Neely et al., 2009) and scientific (Lal, 2004) support but also many question marks regarding methodologies used for its assessment and the feasibility potential of concrete applications (Smith et al., 2007). The Grassland Carbon