30. Conservation of permanent grassland

Mohammad I. Khalil[1], Cláudia M.d.S. Cordovil[2], Rosa Francaviglia[3], Beverley Henry[4], Katja Klumpp[5], Peter Koncz[6], Mireia Llorente[7], Beata E. Madari[8], Muñoz-Rojas Miriam[9,10], Nerger Rainer[11]

(Co-authors in alphabetical order)

[1]School of Applied Sciences & Technology, Prudence College Dublin, Dublin 22 and School of Biology & Environmental Science, University College Dublin, Dublin 4, Ireland

[2]University of Lisbon, School of Agriculture, Forest Research Center, Lisboa, Portugal

[3]Council for Agricultural Research and Economics, Research Centre for Agriculture and Environment (CREA-AA), Rome, Italy.

[4]Science and Engineering Faculty, Queensland University of Technology, Brisbane, Australia

[5]Grassland Ecosystem Research, INRA, Clermont-Ferrand, France

[6]Duna-Ipoly National Park Directorate, Budapest, Hungary and MTA-SZIE Plant Ecology Research Group, Gödöllő, Hungary

[7]Forest Department. University of Extremadura, Plasencia Campus. Spain

[8]Embrapa Rice and Beans, Santo Antônio de Goiás, GO, Brazil

[9]UNSW Sydney, School of Biological, Earth and Environmental Sciences, Sydney NSW, Australia

[10]The University of Western Australia, School of Biological Sciences, Crawley, WA, Australia

[11]Soil & More Impacts GmbH, German office, Hamburg, Germany

1. Description of the practice

Grasslands represent important ecosystems, providing key services to human livelihoods by producing fodder for animals, food production, the regulation of nutrients and water and the sequestration of carbon (C) in soils (Byrnes *et al.*, 2018). Permanent grasslands are defined as land being used for several consecutive years (normally 5 years or more) to grow grass or other herbaceous fodder, forage or energy crops, either through cultivation (sown/reseeded) or naturally (native/autochthone, self-seeded). Due to conversion to arable land for the production of food and animal feed crops, grasslands have declined worldwide during the last century (Queiroz *et al.*, 2014). For example, over 90 percent of the semi-natural grasslands (i.e. grassland of natural origin, under minimum human influence vegetation dominated by grasses) in northern Europe have been lost because of agricultural intensification, abandonment, afforestation, societal changes and development pressure (Peyraud and Peeters, 2016). As permanent grasslands often contain large soil C stocks, because of higher belowground C inputs than croplands and year-round plant cover, management (e.g. reseeding after 5 years) and related soil and environmental factors could induce soil C losses faster than gains, making efforts to protect and conserve these grasslands of high priority (Smith, 2014). Likewise, in the case of temporary grasslands including arable ley, periodic/frequent tillage for re-sowing results in large losses of SOC (between 20 percent and 60 percent of C stored in surface soils (Franzluebbers, Swchik and Taboada, 2014). Even these short-term grasslands, which lay in between crops and permanent grasslands, have the potential for soil C accrual (Johnston *et al.*, 2017). Therefore, conservation of permanent grasslands should be a global goal in order to protect existing soil C storage and to accrue more C in soils with high potential for C sequestration (e.g. Minasny *et al.*, 2017).

2. Range of applicability

This sub-section is devoted to the conservation of managed "permanent grassland" (native and non-native) referring also to the "protection of native grassland". Permanent grasslands have declined considerably since the 1930s (e.g. Bullock *et al.,* 2011). In North America, 80 percent of the central grasslands has been converted to cropland (Foley *et al.,* 2005). Similarly, more than 43 million hectares of the Eurasian steppe have been converted into cropland. As for Europe, temporary sown grasslands have become more important in the Northern countries (i.e. 35 percent of agricultural area in Sweden, 28 percent in Finland and 24 percent in Estonia and Norway) and in several Eastern countries (*circa* 20 percent in Poland, Hungary, Bulgaria; Peyraud and Peeters, 2016. The area under low productive poor permanent grasslands (rangeland) has only decreased marginally between 1990 and 2007 (from 13.2 to 11.5 million ha for eight countries; Belgium, Denmark, France, Ireland, Luxemburg, Spain, Netherlands, United-Kingdom) (Peyraud and Peeters, 2016). The conversion of permanent grasslands to arable land have led to losses of large amounts of SOC (-36 ± 5 percent, Poeplau *et al.*, 2011) due to enhanced soil organic matter decomposition due to soil disturbance, reduced C inputs from plant material (i.e. litter, roots) and increased erosion (see also 3.4 Conversion of grassland to cropland).

3. Impacts on soil organic carbon stocks

Across pedo-climate zones, permanent grassland soils can act either as sinks or sources for atmospheric CO2 (Table 133, also see Minasny et al., 2017). Carbon sequestration potential largely depends on grassland types, soils and environmental factors, management practices (e.g. mowing and grazing) and intensity (Abdalla et al., 2018). These authors reported that managed grassland ecosystems act as potential sinks of C, storing on average 0.23 ± 0.05 tC/ha/yr in the 0-30 cm depth based on a global review and meta-analysis of 83 studies of extensive grazing, covering 164 sites across different countries and climatic zones. The observed range is, however, important (from -2.2 to >1 tC/ha/yr) due to the large panoply of permanent grasslands in terms of pedo-climatic zones, vegetation cover (e.g. species composition, C3 and C4 grasses) and management intensity and type. This is close to available long-term data (i.e. soil inventory data of Belgium, the United Kingdom of Great Britain and Northern Ireland, Canada and New Zealand) showing an average storage of 0.05 tC/ha/yr (e.g. Meersmans et al., 2011; Bellamy et al., 2005; Emett et al., 2010; Wang et al., 2014, Schipper et al., 2014, 2010). In contrast to temporary, permanent vegetation covers have the potential for sequestrating C for longer time and in deeper soil layers. After ploughing and sowing phase of temporary meadow, the C accumulation in the soil takes place primary in the surface layer (0-10 to 0-30 cm) and then spreads gradually towards deeper horizons (Franzluebbers et al., 2014). In addition, fertilisation has a beneficial effect on C sequestration in permanent grasslands (Conant et al., 2017; Eze, Palmer and Chapman, 2018; Khalil et al., 2020). There is a non-linear relationship between the amount of nitrogen and C storage, which depends on how the grasslands are used (Poepleau *et al.*, 2018).

Table 133. SOC sequestration in conserved grassland at 0-30 cm depth

Location	Climate zone	Soil type	Additional C storage [Range] (tC/ha/yr)	Duration (years)	More information	Reference
Global	Various	Various	0.47		Grasslands synthesis (i.e. native, permanent, temporary)	Conant *et al.* (2001, 2017)
			0.23		Managed grassland ecosystems	Abdalla *et al.* (2018)
Netherlands	North Atlantic Climatic	Various	0.41	20	National inventory permanent grassland (natural and › 5years age)	Hanegraaf *et al.*, (2009)
Spain	Mediterranean basin	Calcaric Cambisol	0.148	36	Soil sampling on permanent grassland (natural and ›5years age)	Marti-Roura, Casals and Romanya (2011)
Northern Ireland (UK)	Temperate	Clay loam, Silurian shale, greywacke	0.48	45	Analyses of permanent grassland (natural and › 5years age) under different amounts of organic fertilisation	Fornara *et al.* (2016, 2020)
Belgium		Various	0.16 [0.14; 0.17]	46	National inventory of permanent grassland (natural and › 5years age)	Meersmans *et al.* (2011)
United Kingdom of Great Britain and Northern Ireland			0.05 [-0.03; 0.14]	29		Wang *et al.* (2014)
Canada			0.20 [0.16; 0.24]	4-72		Wang *et al.* (2014)
New Zealand	Various		0.21 [-0.23; -0.20]	30	National inventory of permanent grassland (native, natural and › 5years age)	Schipper *et al.* (2014)
			-1.01 [-0.7; -1.3]	7	Analyses of permanent grassland (natural and › 5years age) under different grazing and fertiliser application	Skinner and Dell (2014)

4. Other benefits of the practice

4.1. Improvement of soil properties

Conservation of permanent grasslands avoids the process of ploughing which is intrinsically coupled with soil layer mixing, subsequent soil aeration, changes in soil temperate, and humidity, leading to the breakdown of soil aggregates and shifts towards more bacterial – dominated soil communities (Conant *et al.*, 2001). Whereas, sequestering C in grassland soils is a win-win situation since CO_2 is removed from the atmosphere, while increasing soil C results in many agronomic advantages including enhanced soil water retention that favours plant growth, soil health and biodiversity, increased availability of soil nutrients, improved soil structure and stability, decreased erosion and improved general soil functioning (Paustian *et al.*, 2019).

4.2. Minimization of threats to soil functions

Table 134. Soil threats

Soil threats	
Soil erosion	Minimizes *surface* runoff via permanent vegetation cover and established root zone (Auerswald and Finer, 2018).
Nutrient imbalance and cycles	Species richness improves nutrient use and cycling (Cong *et al.*, 2014, De Deyn *et al.*, 2011).
Soil salinization and alkalinization	Depends on irrigation water quality and level.
Soil acidification	Depends on fertilizer type and level.
Soil biodiversity loss	Permanent (semi) natural vegetation has likely more diversity compared to sown grasslands.
Soil compaction	Not the practice *per se* but the management intensity (i.e. animal stocking rate), as permanent grasslands are more likely to be grazed than temporary sown grasslands.
Soil water management	Control on *water* runoff and water quality though permanent and settled vegetation cover.

4.3. Increases in production (e.g. food/fuel/feed/timber/fibre)

Permanent grasslands are often associated with low biomass yield and forage quality. Recent studies underline plant diversity as an important production factor and independent of management intensity (e.g. Binder *et al.*, 2018; also see Factsheet No.31/Volume 3 on Grassland diversification), because it enhances quality-adjusted yield and revenues similar to increasing fertilization and cutting frequency (Schaub *et al.*, 2020). It also appears that grasslands with complex flora allow higher C storage than with lower species diversity (Hungate *et al.*, 2017; Lange *et al.*, 2015). This storage increases with the specific richness of the meadow providing a higher root biomass, often having legumes (Cong *et al.*, 2014; Yang *et al.* 2019), attributing to the diversity of root systems (more or less dense and deep).

4.4. Mitigation of and adaptation to climate change

Permanent grasslands provide multiple services, and make an important contribution to climate change mitigation and adaptation. Conversion of permanent grasslands increases CO_2 and N_2O emissions due to soil disturbance through ploughing and the associated acceleration of decomposition processes, N and C availability, soil aeration and pH (i.e. Vellinga *et al.*, 2004; van Kessel *et al.*, 2012, also see Factsheet No.33/Volume 3 on Conversion of cropland to grassland). Likewise, permanent grasslands are more likely to experience low management intensities (e.g. rangelands, fertiliser inputs and animal density) than temporary sown grasslands. Low management intensities (also see Factsheets No. 34 to 36/Volume 3 on Grazing management) receive less fertiliser inputs and animal excreta resulting in less N_2O emissions but increase enteric CH_4 due to reduced forage digestibility (Archimède *et al.*, 2011). Permanent grasslands are often species rich, which contributes to the temporal stability of their services, as species-rich communities tend to perform better than any individual species (Mace, Norris and Fitter, 2012).

4.5. Socio-economic benefits

In many parts of the world, grasslands have received less agricultural improvement (fertilizing, weed killing, ploughing or re-seeding) to become ″unimproved″ grasslands (e.g. rangeland, lowlands) with a (wild-) plant diversity. Agricultural intensification has led to a replacement of original or semi-natural communities in sown monocultures of cultivated varieties of grasses and clovers. Accordingly, ″unimproved, natural″ grasslands are among the threatened types of habitats, and thus appropriate managements are encouraged through special incentives to landowners and involvement of wildlife conservation groups. These areas are often associated with eco-tourism (e.g. Schripke *et al.*, 2017). Likewise, flora and fauna-rich permanent grasslands and upland areas produce high quality foods/feeds, leading to rise in the number of organic farms and quality labels (PDO: protected designation of origin; PGI: protected geographical indication in the European Union).

4.6 Other benefits

Conservation of permanent grasslands, naturally or as a result of human activity (i.e. long-term sown grasslands) also provides services, such as cultural heritage landscapes (Puszta, Alpes), where we perceive "natural" vs. "cultural" landscapes (Peeters, 2009; Gibon, 2005).

5. Potential drawbacks to the practice

5.1. Tradeoffs with other threats to soil functions

Conserving permanent grasslands may lead to a decline forage productivity and related C inputs to soil (e.g. litter and exudates), especially in nutrient-poor areas and under low N input management practices. Improved management actions (i.e. amendments of N, P, K, and lime) enhance C inputs to soil but SOC densities/stocks may eventually reach an equilibrium state over time (e.g. Smith, 2014) or may not (Khalil *et al.*, 2020). Grasslands are highly sensitive to management and land use changes. Proper management to enhance and/or maintain SOC density/stocks to reduce atmospheric build-up of CO_2, improve soil quality and fertility, reduce compaction, erosion and nutrient loss for plant growth and prevent a vegetation conversion/land use change (e.g. grazing, species composition, and mineral nutrient availability) that would decrease the soil C is important.

5.2. Increases in greenhouse gas emissions

Many management practices (e.g. fertilization, liming and grazing) do lead to non- CO_2 emissions, in particular N_2O from soil particularly due to the amount and types of N additions via fertilisation and biological fixation (legumes) irrespective of grassland types. However, emissions due to soil disturbance can be important (Vellinga *et al.*, 2004; Merbold *et al.*, 2014).

5.3. Conflict with other practice(s)

Although grasslands have been identified for having high conservation values and support for food production, conflicts may arise in areas of intense livestock production and competition for feed. In this area, permanent grasslands have remained under-appreciated, even though there are growing concerns for specialising agricultural systems using grass-crop-rotations and their environmental impacts (O'Mara, 2012). Besides, conserving permanent grasslands may lead to a decline in forage productivity and forage quality over time, especially in nutrient poor areas and under low N input management practices.

5.4. Other conflicts

The conservation of grasslands associated with low management intensities induces changes in the plant community composition, and ecological succession that lead to an increased shrub abundance (Teixeira *et al.*, 2015). Even though, this may have positive effects on C storage, in some areas this increases the risk of fire, and that may require the application of "prescribed fire" to maintain grasslands. Accordingly, conservation might need some flexibility to incorporate management practices such as fire into grazing systems to maintain soil fertility, avoid encroachment, and restore herbaceous productivity (Teague *et al.*, 2010).

6. Recommendations before implementing the practice

Support of improved agronomical practices, sound complementary policies and good governance is imperative. Local public extension services, in collaboration with local product labels (e.g. PDO, organic farming, grass-fed) and identity markers (e.g. Buffalo mozzarella, Serrano Ham, Kerrygold Irish butter), are crucial for the introduction and success of grass-based farm practices, which allow the maintenance and improvement of permanent grasslands for livestock production. Moreover, tourism and landscape heritage may provide further encouragement to preserve permanent pastures. However, identity markers and product labels are at different scales of development being either easily quantifiable (e.g. food, dishes, livestock products) or not tangible such as pastoral practices, know-how and cultural landscapes. For developing countries, the conservation of soil fertility while avoiding over grazing is most crucial. The timely uses of decision tools for early warning may help compensate drought and non-drought periods, as well as avoid overgrazing of the rangeland resources. These tools, based on advanced crop and grazing models, and empirical relationships between weather, vegetation, regrowth, can predict drought and feed shortages for livestock several weeks before grazing period. This allows them to better prepare for the incoming feed shortages and nutritional crises in a timely manner by transhumance (e.g. Wilhite and Svoboda, 2000).

7. Potential barriers for adoption

Even though permanent grasslands support multiple ecosystem services and C sequestration, in areas where arable land competes with grasslands possible uncertainties in grassland productivity and related required vegetation modifications (e.g. reseeding, weed and shrub control) to maintain grasslands may be a barrier for preservation. Hence, analysis of incentives (e.g. subsidies, economic policy, environmental taxes and C markets) to sequester carbon may help motivate farmers in adopting "good management practices" (see Rocha Correa *et al.*, 2018).

Table 135. Potential barriers to adoption

Barrier	YES/NO	
Cultural/Social	Yes	Psychological reluctance with respect to new practices (Rocha Correa *et al.*, 2018).
Economic	Yes	Absence of socio-economic evaluation, markets, labels, subsidies, (Rocha Correa *et al.*, 2018).
Institutional	Yes	Missing skills.
Legal (Right to soil)	Yes	Paddocks are too distant from each other to apply sustainable grazing management.
Knowledge	Yes	Lack of training, skills, advisory services, supporting tools.
Other	Yes	Competition with other agricultural land use of economic interest.

Photos of the practice

Photo 39. Permanent grassland and land mosaic with permanent grassland field in France.

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