agronomy

Perspective

An Overview of Permanent Grassland Grazing Management Practices and the Impacts on Principal Soil Quality Indicators

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Citation: Milazzo, F.; Francksen, R.M.; Abdalla, M.; Ravetto Enri, S.; Zavattaro, L.; Pittarello, M.; Hejduk, S.; Newell-Price, P.; Schils, R.L.M.; Smith, P.; et al. An Overview of Permanent Grassland Grazing Management Practices and the Impacts on Principal Soil Quality Indicators. *Agronomy* **2023**, *13*, 1366. https://doi.org/10.3390/agronomy13051366

Academic Editor: Fujiang Hou

Received: 28 April 2023
Revised: 9 May 2023
Accepted: 10 May 2023
Published: 12 May 2023

Abstract: Grasslands are at risk of degradation due to unsustainable management practices and climate change. Here, we review the principal soil quality indicators (SQIs) to evaluate the sustainability of different grassland management practices globally. We discuss the importance of SQI assessment and the Soil Quality Minimum Dataset (MDS) specifically in the context of grasslands. We then review two potential solutions, the first of which is adopting grazing management, whereby sustainable grazing management plans (GMPs) offer great potential. The other solution is the development and adoption of novel grassland species, which may improve either drought resistance or infiltration rates, erosion and flooding. Sustainable grassland soil management can promote ecosystem service delivery and improve the resilience of the entire grassland ecosystem to anthropogenic change.

Keywords: soil quality indicators; grazing management; ecosystem services; permanent grasslands; management practices

1. Introduction

Grasslands cover more than 30% of total cultivated land in Europe and 69% globally [1,2] and are generally recognized for their role in soil erosion control and ecological multifunctionality [3,4]. Grasslands are experiencing degradation due to desertification and intensive grazing [5]. Grazing plays an essential role in grassland preservation, and well-managed grazing can promote soil quality, biodiversity and other related ecosystem services [6]. Grazing affects the nitrogen cycle [7], soil organic carbon (SOC) [8], soil water content [9], bulk density [10] and soil biodiversity [11]. However, overgrazing can also promote several soil degradation processes affecting entire grassland ecosystems [12]. Overgrazing compacts soil and triggers a series of subsequent issues related to the increase in bulk density, such as soil loss, runoff and flooding [13,14]. Moreover, soil compaction leads to depletion of SOC and total nitrogen, affecting the soil microbiota [15]. For these reasons, it is important to consider appropriate livestock densities to avoid these negative effects of overgrazing. However, the definition of heavy or light grazing at the European level may be too broad to assist farmers in their grazing decision making. For instance, Klipple and Bement [16] define grazing density based on the ability of grass species to maintain themselves as forage for grazing animals. Optimum grazing density is usually defined in terms of grass biomass production with the aim of a balance between carrying capacity and animal requirements. Research has shown that grass-growing capacity varies with climate, grass species, animal type and soil type. Milazzo et al. [14] highlighted the importance of protecting permanent grassland from the various erosive phenomena that threaten these ecosystems Europe-wide. In particular, they described that unsustainable grazing management, which depletes soil quality, promotes erosion and flooding phenomena. Therefore, it is challenging to establish grazing limits in practice, and it might be necessary to consider other soil quality indicators (SQIs) that can alert to soil degradation. In other words, to make adequate management decisions on grazing densities or practices that promote soil health, it is necessary to include SQIs that can assist farmers in establishing objective limits to grazing densities or other corrective measures. Several studies discuss the advantages and disadvantages of grazing, synthesizing a large volume of scientific evidence, often providing a qualitative assessment of different grazing practices [17]. They generally focus on the comparison between different types of grazing management, i.e., short-duration grazing [18], continuous vs. rotational grazing [19] or holistic vs. continuous grazing [20], and usually evaluate the impacts of practices on grass productivity [17] but not on soil properties.

Possibly the most important threat to grasslands is climate change, which threatens grasslands globally by exposing soils to prolonged droughts, making them prone to water erosion [21–23]. Heatwaves also endanger global grassland productivity [24], particularly in semi-arid and arid climates, where irregular and high-intensity precipitation is enhances flooding and erosion [23]. Liu et al. [25] assessed grassland degradation worldwide, asserting that more than 45% of grassland areas have experienced degradation processes resulting from human activities and climate change. Moreover, they stated that anthropogenic activities are more dominant in North America and Europe, while the Asian region is more affected by climate change. In the Chinese Loess Plateau, human activities and climate change contributed to 42% and 58%, respectively, of the total grassland degradation [22]. Several studies have explored the need to breed and select new drought-resistant grassland species to preserve the grassland provisional service [26,27]. However, in the global context of climate change and reduced water availability for grassland, breeding of new drought-resistant grassland species can reduce yield gaps and bare soil conditions and control soil degradation processes.

Soil quality is defined as the ability of soil to perform ecosystem functions [28]. It is a broad concept that is not limited to the biological, physical and chemical soil properties but also involves productivity and animal and human health [29]. The concept of soil quality was introduced in 1977 by Warketin and Flacher [30] to respond to increasing stakeholder concerns about soil resources and to evaluate land use decisions made in the institutional context. Interest in soil quality increased in response to a publication by Council et al. [31], and academia began to focus on critical soil function identification and a common soil quality assessment framework [29]. Since then, soil quality has attracted increased attention with respect to monitoring land management, sustainable development and ecosystem restoration through the evaluation of soil quality indicators (SQIs) [32,33]. However, due to the wide variety of soils, climate, land uses and management systems, it is challenging to standardize SQI benchmarks for a universal assessment. There are two problems that can be identified: (1) there is no universally accepted set of optimum SQIs that should be considered, and (2) there is no ideal or exact index value that can universally standardize soil quality assessment. However, using a framework that prioritizes soil quality goals and evaluate the management operation to achieve those specific soil functions can help [28]. Indeed, the periodic estimation of SQIs can guide farmers in management decisions, and even on inherently "poor" soils, positive effects can be achieved if compared to an initial measurement or to an appropriate local benchmark. In this sense, it is important to select an appropriate SQI, weighing cost and benefits and considering local conditions and objectives [28].

In this study, we aim to provide a global perspective on grassland soil quality assessment and management, applying the lessons with relevance to mitigate soil grassland degradation in Europe and UK. First, we review the importance of SQIs for sustainable grazing management methods to avoid land degradation risk. Secondly, we present an overview of new drought-resistant grass species that improve soil quality and reduce soil loss.

2. Soil Quality Indicators for Grassland

SQIs are defined as measurable physical, chemical and biological attributes that relate to functional soil processes and can be used to evaluate SQ status and that are sensitive to changes in management [34] (Table 1). These attributes are commonly soil properties, although in a wider sense, non-soil properties can also indirectly inform on soil quality, for example, yield, surface vegetation cover, or the presence of erosion features. The latter are often easier and faster for farmers and landowners to assess. Commonly used chemical indicators include organic/total carbon and nitrogen, extractable phosphorus and potassium, pH, electrical conductivity and cation exchange capacity. Biological indicators include microbial respiration rates, microbial biomass, nitrogen mineralisation rates, macrofauna (often earthworms), nematodes, microbial community composition and enzymatic activity. Physical indicators include soil bulk density, structure, texture, aggregate stability, porosity, water storage, hydraulic conductivity and infiltration [33]. In relation to soil erodibility and flood risk reduction, the physical indicators are the most directly relevant because they influence rainfall–runoff dynamics and water storage capacity, which sustains and regulates river flows and therefore contributes to stream flow buffering [35]. Nevertheless, many of the chemical and biological SQIs play important indirect roles through their influence on soil physical properties. For instance, soil structure and aggregate stability are both related to SOC, which, in turn, depends on a range of biological soil properties [36,37]. As such, many of these SQIs are inter-related, and while physical properties are likely to have the biggest direct impact on soil erosion and flood risk, chemical and biological SQIs could serve as useful proxies to assess management. Bünemann et al. [38] showed that the most commonly used physical SQIs are water-holding capacity, water content, bulk density and texture. Several studies have assessed the soil hydraulic properties of grasslands in comparison with those of cropland soils. Abdalla et al. [39] reviewed overall soil loss and SOC loss under different land uses and found a remarkable protection capacity of grassland when compared to orchards, croplands and forests. While total rainfall and slope were found to be the key drivers of soil erosion, high soil surface cover, SOC and clay content all limited soil loss. Several studies accompanied SQI observations with measurements of SOC and quality due to its strong link with soil physical properties. Ghimire et al. [40] in the USA, among others, showed that SOC, microbial biomass and total nitrogen—the most commonly used SQIs [38]—were all higher under permanent grasslands compared to croplands, owing, in large part, to the lower degree of soil disturbance in permanent grasslands. Lehtinen et al. [41] analysed the distribution of soil aggregates and assessed the quality, quantity and distribution of soil organic matter (SOM) in two unimproved and four improved (two organic and two conventional) grasslands in subarctic Iceland. They found a higher macroaggregate stability in association with organic farming practice compared with conventional farming due to higher organic inputs. However, few attempts have been made to relate grassland species composition to soil erodibility and SOC content and stock. Enri et al. [42] highlighted the importance of grassland species composition in affecting SOC stock in alpine pastures, while topographic attributes were found to have negligible effects. Root characteristics are also important for increasing SOC stock, as well as determining the capacity of grasslands to resist erosion. Horrocks et al. [43] demonstrated a strong effect of forage species and variety on aggregate stability, friability and SOC in grasslands in a tropical environment in Colombia. These studies demonstrate the importance of vegetation type influencing SQIs. While physical indicators provide a direct link to the ability of a grassland to reduce erosion, a large and increasing number of studies now emphasises the vital role of biological indicators with respect to soil health and quality [33].

Table 1. Published studies on the assessment of biological, chemical and physical SQIs in grassland and the related ecosystem services, such as provision of animal feed (p), water purification (w), biodiversity (b), climate regulation (c), and erosion and soil degradation processes (e).

Reference	Biological	Chemical	Physical	Country	Study Period	Ecosystem Service
[43]	Microbial community	SOC	Aggregate stability, friability	Colombia	1	p, e
[44]	Root growth, microbial biomass carbon, alkaline phosphatase, catalase	SOC, C/N, C/P, N/P	Water content	China	4	p
[45]		SOC, nutrient cycling index	Soil stability index, infiltration index	Iran	1	p
[46]		SOC, C/N	Bulk density, aggregate size distribution	Ireland	1	p
[47]			Structure, porosity, compaction, penetration resistance	Germany	1	p, e
[48]		N cycle, SOC,	Aggregate	Michigan	2	p, e
[49]		SOC, magnesium, C/N	Penetration resistance, aggregate size distribution	Ireland	1	p
[50]			Structure, compaction	England	1	e
[51]	Microbial activity, enzyme activity	SOC, N	Porosity, bulk density, texture	Ireland	1	b
[52]		pH, electrical conductivity, cation exchange capacity, P, N, nutrient availability	Bulk density, water-stable aggregates	Egypt	1	e
[53]		pH, extractable Al, P, SOC	Bulk density, porosity	Chile	2	p, e
[54]		SOC, C flux		Argentina, Uruguay, Brazil	4	c
[55]		SOC, N, K, P	Bulk density, soil water-holding capacity	China	5	e
[56]	Microbial biomass	SOC, N, P		India	1	b, w
[57]		SOC		Brazil	1	p
[58]		N, SOC	Water-stable aggregate, bulk density, texture	Georgia, USA	24	e
[59]		pH, electrical conductivity, SOC	Bulk density	China	1	p
[60]		pH, electrical conductivity, SOM, N, K, P	Bulk density	China	7	p
[61]		P, K, Mg, pH		Germany	5	p
[62]	Below-ground biomass	SOC		Argentina	1	p
[63]	Microbial biomass	N, C/N		France	1	b
[64]	Microbial diversity	pH, SOC, carbonate	Texture, bulk density	Italy	1 punctual analysis over a long period of observation	b
[65]	Microbial biomass	pH, SOC, total N, C/N, electrical conductivity		China	3	b
[66]	Microbial biomass	Total C, total N, total P, pH	Bulk density	China	1 punctual analysis over a long period of observation	b

3. Soil Quality Minimum Dataset (MDS) for Grazing Management Assessment

Grassland soil quality assessment cannot be defined by estimating single soil properties, and it would be impossible to use all soil properties to evaluate soil quality. Previous studies have attempted to create a minimum dataset (MDS) including a core set of soil characteristics to help to monitor soil quality, taking into account multiple physical, chemical and biological SQIs [44,67]. The selection of the soil properties to be analysed is an important process that can affect the quality and ease of monitoring. Indeed, the analysis of some physical and biochemical soil proprieties (i.e., hydraulic conductivity, soil water capacity and microbe biomass) can make soil status assessment cumbersome and complicated, as they require complicated and/or expensive laboratory procedures. Many SQIs are inter-related, so the analysis of one may be sufficient for the determination of others. For example, bulk density and hydraulic conductivity are inversely related, so measuring the former can give us an indication of whether the latter is increasing or decreasing. Rezaei et al. [45] studied the importance of the use of a soil quality MDS in a semi-arid grassland, taking into account time and economic costs. They compared two MDSs concerning the prediction of management goals of soil productivity and stability. The first, which did not take budget constraints into account, measured the physical properties of the soil and the landscape function analysis method that considers rangelands as landscape systems; the second considered only the measurement of soil physical properties. They found that the latter MDS optimally predicted pasture production underlying the relationships between soil physical properties and grassland growth. Askary and Holden [46] analysed soil quality in temperate grassland by measuring twenty-one indicators for the assessment of grassland management (including grazing), stating that only SOC, C/N ratio and bulk density were decisive in assessing the effect of management on soil quality. Complementary to laboratory analysis, several farmer tools kits have been developed to assess SQIs, providing an overall evaluation of the main grassland functions related to the delivery of soil ecosystem services. Ditzler and Tugel [68] developed the "*Soil Quality Test Kit Guide*", providing a simple field assessment for 11 SQIs. This tool is potentially applicable to all agriculture and agro-forestry systems and permits a three-level description of the main chemical, physical and biological SQIs. Nevertheless, visual soil assessment (VSA) is widely used and is known to be cost-effective and practical and to provide rapid results [69]. VSA provides reliable information about soil structure, the presence of telluric fauna, soil porosity, root development and soil colour. This information can be related to pH, bulk density and soil organic matter [70]. For example, the Visual Evaluation of Soil Structure (VESS) is a set of functional and reliable methods for assessing soil structural quality [47,71]. VESS mainly focuses on soil physical quality indicators that influence several soil functions, such as fertility, biological activity, root development and nutrient cycling [48]. However, it must be a support assessment method; it can be useful for the assessment of grazing management but not for biochemical proposes [49]. Despite the mentioned limitation, several authors have proven the reliability of VESS in grasslands. Newell-Price et al. [50] showed the applicability of the Peerlkamp method for bulk density assessment, while Cui et al. [53,72] used VESS to score bulk density, total carbon, nitrogen and microbial activity. To meet the needs of farmers to assess SQIs in the field and avoid time-consuming and expensive laboratory analysis, different high-tech solutions are available on the market, such as mobile apps and remote sensing. The SLAKES smart phone application developed by the University of Sydney assesses wet aggregate stability based on the slaking index of soil aggregates (inversely correlated with aggregate stability) in less than ten minutes [73]. Aggregate stability is related to microbial activity, OM and soil structure, and it is susceptible to management operations [74]. The SLAKES app is an easy, scientifically reliable method for quantifying soil quality that is available to non-scientists or groups with limited funding for soil analysis [75]. In addition, grassland SQIs can be monitored continuously using remote optical sensors, which provide useful information for the assessment of management and soil status [76]. The use of satellite information for grassland health and degradation assessment is becoming popular due to its extensible scalability. Xu et al. [77] reviewed remote methods for grassland health monitoring globally, collecting 1057 studies from Web of Science published between 1984 and 2015, observing that 70% were about vegetation status, of which 29% were about livestock management, 30% were about soil status and 25% were about the environmental system. As a matter of fact, with the newest remote sensing approaches, it is possible to retrieve several SQIs at field resolution, such as SOC, soil erosion, heavy grazing degradation, soil salinity and water logging [52,78].

4. Grazing Management to Improve Soil Quality

Sustainable grazing management practices aim to maintain or improve soil quality to prevent land degradation and increase biomass yield over time [46,79]. As such, grazing timing, grazing density, time between grazing events and livestock species are crucial considerations for the sustainable management of grasslands.

Grazing effects are species-specific (animal/plant) and vary with management types, bioclimatic regions and soil properties [80,81]. The interaction between climate and unsuitable farm management strategies can compromise the soil status and thereby promote flooding and erosion events [82,83]. Due to the main grassland purpose of providing livestock feed, grassland soils are subject to grazing pressures that promote soil quality degradation in the base of the grazing intensity [84]. Nevertheless, the definition of grazing intensity, in terms of heavy or light grazing, may be too broad to assist farmers in grazing decision making, as it varies depending on the base of grassland productivity and climate (Table 2). Klipple and Bement [16] define heavy density grazing as the degree of grazing that does not allow pasture species to maintain themselves, moderate grazing as the degree of grazing that allows grass species to maintain themselves but decreases their mix diversity and light grazing density as the degree of herbage utilization that permits palatable species to maximize their herbage capability. However, this definition takes into account fodder production as a reference and does not consider the effect on the soil quality. For instance, an increase in grazing intensity is generally related to a decrease in SOC, and conversely, light grazing intensities ameliorates increases in SOM and reduce soil erosion events [85,86]. Abdalla et al. [87] performed a meta-analysis on the effect of grazing intensity on SOC stock globally, highlighting a clear climate-dependent effect. They stated that in a dry, warm climate, the grazing effect negatively influences the SOC stock at all levels, except for light grazing, which increases SOC by almost 6%; in contrast, in moist climates, SOC was found to decline under grazing management of all intensities. Indeed, animal trampling compacts soil, destroying soil aggregates and altering the soil microbial community, boosting nitrogenous losses by denitrification, contributing to grassland degradation [55] (see Figure 1).

Table 2. Overview of the classification of grazing intensity (LSU ha^{-1}) in different studies.

Country	Light Grazing (LSU ha^{-1})	Moderate Grazing (LSU ha^{-1})	Heavy Grazing (LSU ha^{-1})	Reference
China, Nanzhang County	0.16	1.75	2.58	[88]
China, Gansu Province	2.7	5.3	8.7	[89]
Ethiopia	0.48	1.44	2.4	[61]
Nebraska	2		4	[90]
North Dakota	1.04	2.16	3.52	[91]
Canada		1.92	3.84	[92]
Colorado	0.8	1.2	2	[93]
Iowa	0.9		3.52	[94]

A livestock unit (LSU) is the European stocking rate reference unit; one LSU is equal to one adult dairy cow producing 3000 kg of milk annually without additional concentrated foodstuffs.

Devi et al. [56] showed that moderate grazing intensity in subtropical grassland promotes an increase in the nutrient cycle and grassland sustainability. Franzluebbers et al. [57,58] stated that long-term light grazing in Southern Piedmont, USA, increases SOC, biological activity and soil quality. Many studies across all bioclimatic regions globally have stated that grazing intensity increases bulk density and pH, leading to higher denitrification processes and raising the soil erosion risk [59,95]. Jiao et al. [60] instead analysed the effect of different grazing management types, asserting that heavy grazing and no grazing management significantly increase bulk density compared to light and moderate grazing, underlining the positive effect of well-controlled grazing management. Heavy grazing is commonly recognised as the dominant factor that increases soil erosion and runoff generation in grassland [84,96]. For instance, heavy grazing can promote an increase in runoff generation by up to 117% compared with rotational light grazing, while the latter has a positive impact, reducing flood risk [97,98]. The choice of livestock breed is also important for farm productivity. New high-productive cattle breeds have different grazing behaviour and anatomic characteristics that impact grass composition and soil quality. Pauler et al. [61,99,100] observed the grazing behaviour of low-productivity cattle (Original Brauvieh) and high-productivity breed Angus × Holstein in the Swiss Alps, highlighting some significant differences in grassland impact. The Original Brauvieh, on average, is 100 kg lighter than the high-productivity breed and prefers to graze in flat areas close to the water point. Instead, the highly productive grazer roams long distances, selecting higher-quality forage, influencing the grassland species composition. Thus, grazing density and breed behaviour must be taken in consideration when selecting sustainable soil grazing strategies. However, the wide variability of grazing densities found in the literature shows that grazing density alone is not a good indicator of sustainability and must be completed by assessment of SQIs.

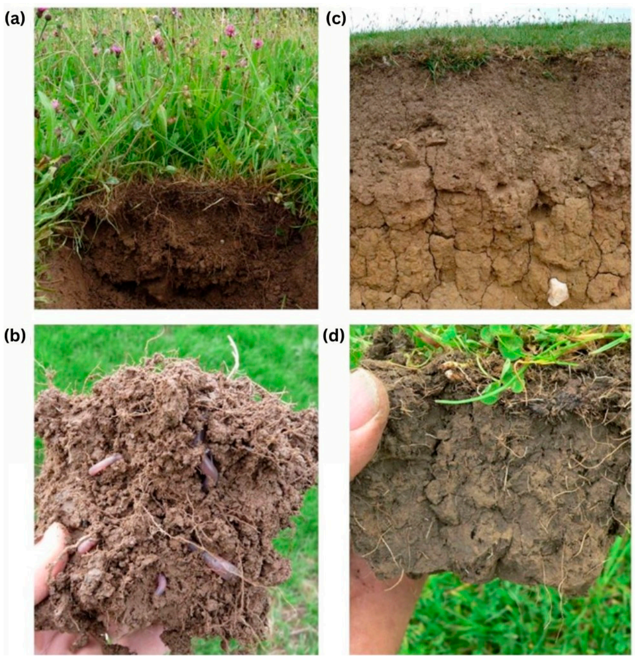

Figure 1. Non-compacted grassland soil vs. compacted soil (Northern England). (**a**) Zoomed image of non-compacted grassland soil; (**b**) zoomed image of the non-compacted soil layer; (**c**) zoom image of compacted grassland soil; (**d**) zoom image of the compacted grassland soil layer (R. Smith 2023).

5. Grazing Strategies for Grassland Soil Conservation

In mountain regions of Europe, ecoclimatic, topographic and vegetation characteristics of pastures can widely vary, even in small spatial ranges, affecting overall stocking rates and fine-scale livestock site use intensity [101]. In turn, animal excreta are heterogeneously distributed over pastures, consequently influencing soil features, nutrient availability, biocycling and, thus, plant species composition. Defining a numerical threshold of each grazing management intensity is becoming an important need to prevent grassland degradation and mitigate future soil loss and flooding hazard due to climate change. Therefore, the objective for sustainable grazing management should be to address the enhancement of grazing spatial distribution for a more homogeneous exploitation of pastures by livestock. When livestock are allowed to roam freely, they show a selective and spatially aggregated grazing pattern [102], which leads to the overgrazing of the most favourable areas (e.g., flat areas near water sources, etc.; Figure 2). A grazing management plan (GMP) is a tool that has been successfully adopted in the northwest Italian Alps [103,104] funded by the 2007–2014 EU Rural Development Program with the purpose of enhancing farm productivity and preserving plant and animal biodiversity, soil and landscape. To obtain a more even selection of available resources and reduce local overgrazing, a GMP defines grazing management practices aimed at balancing the animal stocking rate with the grassland carrying capacity [105]. This means that when considering forage productivity and quality, grazing occurs over an area for a defined time period without causing degradation of the grazing land. To accomplish this, pastures are subdivided in paddocks grazed in rotation so that livestock are induced to homogeneously exploit the available resources while limiting overgrazing as much as possible [102]. However, different studies comparing continuous and rotational grazing have found small differences between the two management regimes in terms of grass production, underlining the importance of stocking rate and climate condition as distinctive degradation drivers [106,107]. Virgilio et al. [17] performed a meta-analysis of the effect of grazing strategies on different indicators of rangeland sustainability, such as vegetation dynamics and soil quality. They found that multiple species grazing before complete destocking can ameliorate the vegetation composition of the grass layer. Rotational grazing has a minor impact on the vegetation status compared to continuous grazing, even if the impact of the latter is strictly related to livestock density. According to the authors, livestock density is the main factor affecting grass and soil degradation. Regardless of the grazing strategy, some measures can be applied to avoid grassland degradation, for example, attractive points such as drinking and feeding troughs and salt supplementations can be placed in underused areas (e.g., steep and shrub-encroached sites) to enhance livestock spatial distribution and reduce overgrazing in the most accessible sites [108]. Moreover, it is necessary to herd livestock into barns when the pasture soil is wet or saturated or, when possible, to reduce the length of the grazing period and to avoid rainy seasons. This minimizes soil disturbance and can represent other valuable solutions to avoid overgrazing [84].

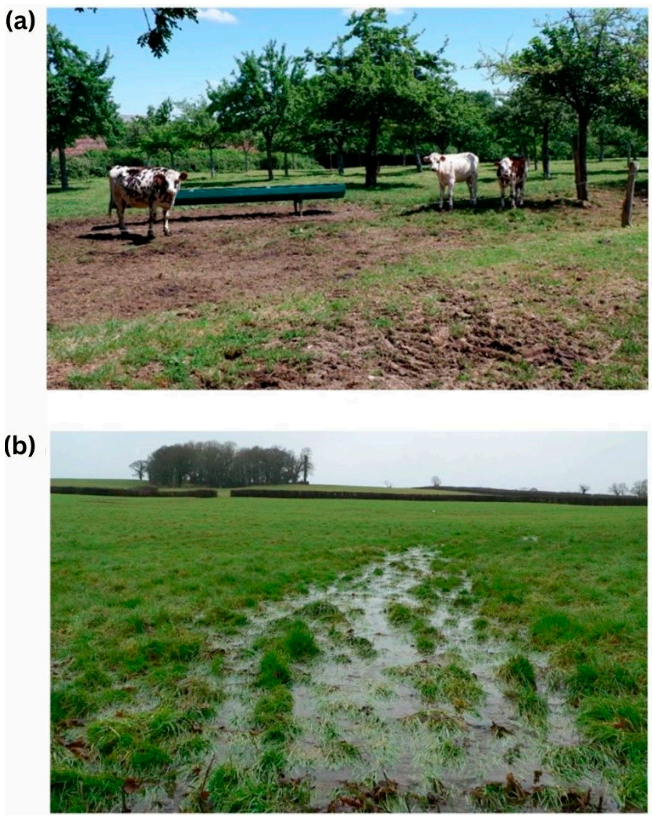

Figure 2. Grassland degradation due to overgrazing and trampling (**a**) near water sources of northern in France and (**b**) in a flat clay soil area of the United Kingdom.

6. New Grass Species for Grassland Soil Resilience

In addition to overgrazing, warmer and drier weather due to climate change is threatening grasslands by reducing grass diversity and productivity. Therefore, future experiments need to consider new management practices such as grass species resilience [109] not only to ensure productivity but also to preserve grassland soil. Grassland soil quality is strongly related to vegetation health; the reduction in some species may decrease the soil carbon stock [62]. Moreover, in degraded grassland, prolonged drought situations with high CO_2 emissions can deplete the soil microbial community and promote a shift of the telluric biodiversity, decreasing SOC stock and modifying biochemical cycles [63,110]. Furthermore, vegetation cover is a principal factor that influences soil erosion rates in grasslands. The capacity to resist erosion greatly depends on the traits of the specific grassland plant community [111–113]. Grassland species and varieties differ in their capacity to store water, stabilise soil with their root systems and increase SOM content, all of which are important factors in determining soil erosion rates [114,115]. As such, the establishment of new species and varieties into grassland communities can be an important technique for mitigating soil erosion. This can be achieved by increasing the functional diversity and species richness of grasslands or through the development of novel breeds or cultivars with desirable traits, which can then be incorporated into the grassland community. In areas experiencing severe soil erosion or where soil erosion rates are predicted to increase due to climate change and land use change, for example, semi-arid areas of southern Europe [116], establishment of grassland communities that ensure ecological stability is a key adaptation measure [113]. One way to increase ecological stability is through the promotion or establishment of greater plant functional diversity in the grassland community [117]. In many parts of the world, efforts to reduce soil erosion through establishment of new grassland species have not met expectations. Partly to blame for this result is the use of monocultures with a simple root structure, which are therefore inefficient at reducing soil erosion compared to areas with greater community functional diversity [118]. It is a common practice for species mixtures to be sown or encouraged on permanent grasslands to promote multifunctionality and encourage resilience to environmental stresses, including soil erosion [119]. Individual grassland plant traits are an important consideration when choosing species and mixtures that will deliver desired services such as a reduction in soil erosion. For example, below-ground biomass, organic matter contribution by roots and productivity are all important plant traits that can greatly affect the capacity of a grassland system to resist soil erosion due to trampling [111]. A meta-analysis of studies in which plant species diversity was manipulated found an overall positive effect of increasing plant diversity on below-ground biomass, which was considered a key indicator of erosion control [117]. In their investigation of grassland restoration efforts aimed at reducing soil erosion, Zhu et al. [118] showed that communities with a smaller root diameter and greater root tensile strength exerted the greatest control over soil erosion. Medicago sativa is a perennial legume that, as well as being a protein rich forage species, is planted for its ability to protect the soil from wind and water erosion through its deep roots that stabilise the soil structure [120]. The incorporation of M. sativa into species-rich grassland mixtures can simultaneously increase forage quality and reduce soil erosion and, as such, is an example of the ability to increase multifunctionality by establishing new species into the grassland community. Novel grassland varieties may extend the depth of subsoils and the range of soil biota by rooting deeper than traditionally used species, which can enhance protection against erosion [119]. Ahmed et al. [121] demonstrated a high genetic diversity of *Lolium perenne*, the major grass forage species in temperate regions and stated that this diversity could be exploited to breed new varieties that are adapted to and can mitigate against erosion risk. Furthermore, Marshall et al. [122] showed that hybridisation between *Trifolium repens* and *T. ambiguum* affected the root structure and density of offspring plants and that this could affect soil porosity and consequently impact erosion rates. Macleod et al. [112] hybridised perennial ryegrass (*Lolium perenne*) with a more stress-resistant meadow fescue (*Festuca pratensis*), developing a new cultivar called *xFestulolium loliaceum*. In a two-year experiment, they found that *L. perenne* 3 F. pratensis reduced surface runoff by 51% compared to the leading English nationally recommended *L. perenne* species. There have also been promising results from the breeding of grass species with deeper or more extensive root systems, e.g., Festulolium (ryegrass × fescue hybrid), which has a greater resource use efficiency (e.g., water), high biomass productivity and high contribution to SOC [123,124]. Grassland drought resistance is associated with deep-root water uptake [125]. For this reason, chicory (*Cichorium intybus* L.), which is a deep-rooted species (>2 m), is becoming widespread in temperate and continental climates. In Denmark, Rasmussen et al. [126] compared the subsoil uptake ability of *Cichorium intybus* L. with that of *Lolium perenne* L. and *Medicago lupulina* L., reporting that chicory benefits most from deep soil moisture (up to 2.3 m depth). In Pennsylvania, Skinner [127] introduced *Cichorium intybus* L. as a deep-rooted forb to a pasture mixture composed of orchardgrass (*Dactylis glomerata* L.), white clover (*Trifolium repens* L.) and perennial ryegrass (*Lolium perenne* L.), observing an increment of drought tolerance when chicory constituted more than 24% of pasture composition. Another promising grass species for the semi-arid and Mediterranean climate is tedera (*Bituminaria bituminosa* (L.) C.H. Stirton var. albomarginata). Tedera is an evergreen perennial legume that, due to its physiological properties, endures high water deficit in warm and windy areas [128–130]. Moreover, it regrows faster than lucerne after harvesting/grazing, reducing the bare soil condition and yield gap, representing a near-future alternative for the Mediterranean farmer to mitigate climate change effects [131]. Since soil erosion by water is one of the most widespread forms of soil degradation worldwide, the ability of these new varieties to reduce bare soil condition, store greater amounts of soil water and reduce runoff could have significant effects on soil erosion rates.

7. Conclusions

In the context of climate change and increasing grassland degradation, it is essential to understand soil quality development for the resilience of grassland ecosystems. Herein, we showed the importance of using a variety of SQIs, including physical, chemical and biological indicators to achieve different international sustainability goals. Soil quality preservation and maintenance should be considered essential for environmental quality in general [132]. The application of sustainable management cannot be separated from careful monitoring of soil quality development. Indeed, the assessment of the reviewed SQIs is a reliable strategy for undertaking effective and sustainable management practices. However, efforts to assess soil quality qualitatively and quantitatively are not new, and the standardization of indicators remains an ambitious task. Therefore, due to the site-specific nature of soil quality, an SQI threshold should be selected according to the base of the soil function of interest. Thus, the development of an SQI assessment framework, given the limited availability of data, can support grassland managers in preserving soil quality. Despite the current limitation of standardization, there are several initiatives aiming to harmonize soil quality information (i.e., the Global Soil Partnership and the Global Soil Biodiversity Atlas) at different scales that can support management decisions. Sustainable grazing strategies can be implemented and adapted to promote soil quality and the related delivered ecosystem services, with the aim of overcoming climate change effects. Several grazing management plan programs have been designed and promoted by local authorities, aiming to improve the quality of the sward layer and to promote biomass production. However, the framework of reference indicators used by farmers generally does not include soil quality. Studies both at the European and regional levels should open new pathways for sustainable grazing management that promote soil quality and contribute to restoring degraded lands and combatting desertification. The testing of new drought-resistant grassland species with desirable traits for soil protection must be explored in different bioregions with the aim of improving grassland resilience in terms of soil protection, production and ecosystem service delivery.

Author Contributions: Conceptualization, F.M and T.V.; writing—original draft preparation, F.M. and R.M.F. All the authors contributed to data collected and reviewed previous drafts. All authors have read and agreed to the published version of the manuscript.

Funding: This research is funded by the European Union under the Horizon 2020 projects "Developing SUstainable PERmanent Grassland systems and policies (Super-G)", grant no. 774124 and "Transforming Unsustainable management of soils in key agricultural systems in EU and China. Developing an integrated platform of alternatives to reverse soil degradation" (TUdi), GA 101000224. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union (EU) or the European Research Council. Vanwalleghem and Milazzo also acknowledge additional financial support from the Spanish Ministry of Science and Innovation, the Spanish State Research Agency, and through the Severo Ochoa and María de Maeztu Program for Centers and Units of Excellence in R&D (Ref. CEX2019-000968-M).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to acknowledge Richard Smith for providing some important pictures.

Conflicts of Interest: The authors declare no conflict of interest.

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