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Grassland Crops as Drivers for the Improvement of Soil Fertility †

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Abstract: Managing soil fertility is vital for agriculture. However, modern farming excessively relies on mineral fertilizers, which lessens profit and endangers ecosystem health. Grasslands made up of Poaceae and Fabaceae, including woody species, offer feed for livestock, lowers farmers' economic risks, and conserve resources. Grassland crops can enhance soil fertility in a more sustainable way than mineral fertilization. To counter fertilizer-driven soil decline, permanent grasslands or crop rotations are effective. Also, grassland soils generally contain more nitrogen, potassium and organic matter and less phosphorus than cropland soils. They additionally enhance soil's physical and biological parameters, limiting erosion while elevating biodiversity. This work focuses on the benefits of grasslands towards crop production, reviewing their influence on soil fertility parameters that boost soil health.

Keywords: forages; grassland crops; pastures; soil fertility; soil health; sustainable agriculture

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1. Introduction

Modern agriculture faces several challenges in producing food to support an increasing world population, while also requiring rapidly adapting to climate change. Soil fertility is one of the key aspects of agricultural management. Nevertheless, enhancing crop yield has driven farmers to excessive utilization of inorganic fertilizers, with heavy damage to biodiversity and posing environmental and human health risks [1].

Agro-ecological practices can increase the sustainability of modern agriculture by adapting ecological principles and traditional practices, which minimizes the impact on the environment, boosts soil fertility, and contributes to the management of crop protection [2,3].

Soil fertility emerges from the interaction of biological, chemical, and physical processes [4]. Soil microbial and mesofauna communities are extremely relevant for plant nutrition and defense [5]. Arbuscular mycorrhizal fungi (AMF), plant growth-promoting rhizobacteria (PGPR), and beneficial nematodes are examples of important contributors to the enhancement of soil biological fertility [6–8]. Soil chemical fertility influences and is influenced by the other components and is related to the concentration of inorganic elements and their bioavailability. Key parameters in this context include the cation exchange capacity (CEC), soil organic matter (SOM) or content (SOC), ratios of macro- and micronutrients, and the pH that can influence their availability to plants [9]. Lastly, soil physical fertility relates to porosity, structure, and drainage that influence water availability and aeration [10].

Grasslands, encompassing both natural expanses and cultivated areas, predominantly comprise members of the Poaceae and Fabaceae families. These ecosystems stand as primary sources of sustenance for numerous livestock, underpinning global food security [11]. The use of pastures and forages has been associated with several ecosystem services that enhance the farm's long-term sustainability. These benefits include the promotion of soil fertility, carbon storage, water regulation, biodiversity, pollination, and pest control [12,13]. Hence, the use of these crops can be considered an agroecological measure that ensures sustainable food production.

In this study, a review of the beneficial role of grasslands on soil chemical fertility is presented comparing the effects of implementing croplands versus grasslands.

2. Bibliographic Sources

The research was performed using the Web of Science search engine (https://www.webofknowledge.com, last accessed on 1 July 2023), in all available databases, on published works from 2018 to 2023, using the topics "grassland crops" and "soil fertility". A total of 17 works were retrieved concerning soil chemical fertility parameters measured in croplands in comparison to grasslands (Figure 1). Works were mainly published in journals specialized in agriculture, environmental sciences, biodiversity conservation, plant sciences, and chemistry. These selected articles were cited 108 times; thus, the average number of citations per article is approximately 6.35.

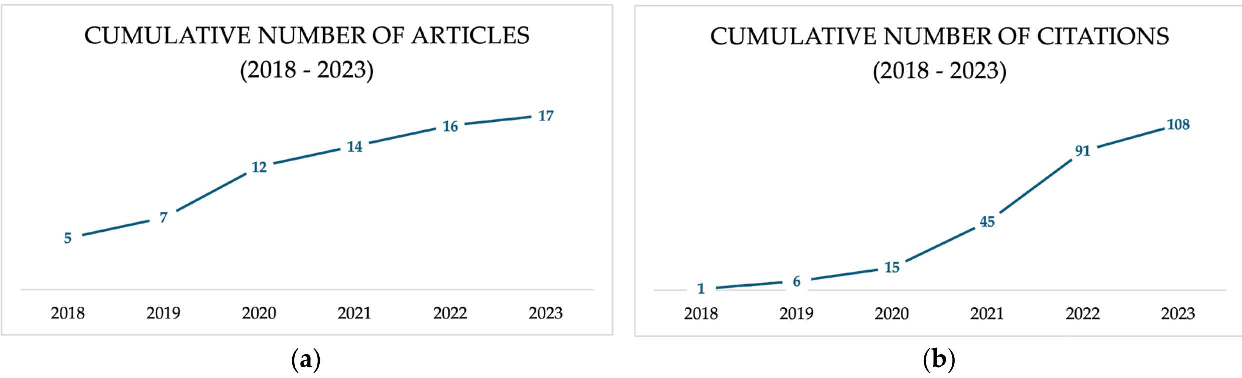

Figure 1. The cumulative number of published articles (**a**) and respective cumulative number of citations (**b**) between January 2018 and July 2023.

To assess the beneficial influence of grassland crops, when compared to croplands, on soil chemical fertility, a total of 10 parameters were considered. For this purpose, percentual relative differences of mean values were calculated following this formula:

$$\text{Relative Differences (\%)} = [(\text{GL-CL})/\text{GL}] \times 100 \quad (1)$$

where GL is the grassland mean value and CL is the cropland mean value.

3. The Influence of Grasslands on Soil Chemical Fertility

Differences between conventional crop fields and grasslands were reported for the selected soil chemical parameters. Several reports suggest a tendency for increased levels of soil organic carbon (SOC) or soil organic matter (SOM) through forage or pasture cultivation. Likewise, grassland soils frequently exhibited elevated nitrogen and potassium content, indicating improved nutrient conditions. Similarly, the C/N ratio tended to be slightly higher in pastures and forage soils, contributing to a slower and more sustained organic matter mineralization.

In contrast, cropland soils frequently showed elevated phosphorus concentrations, most likely due to the overuse of mineral-based fertilizers. This underscores the significance of careful phosphorus management to mitigate potential ecological implications.

Soils influenced by pastures and forages reportedly maintained pH values closer to neutrality when compared to croplands. This tendency can be partly explained by the pH buffering characteristics of soils with higher SOM. The complex interplay of organic compounds in the soil acts as a buffering system, stabilizing pH levels and mitigating abrupt fluctuations that could disrupt plant nutrient uptake (Table 1).

Table 1. Relative mean differences (%) of soil chemical fertility parameters reported for grassland and cropland species measured at specific soil depths.

Grassland vs. Cropland	Soil Depth (cm)	Mean Differences of Soil Chemical Fertility Parameters (%) [1]										Ref.
		SOM	SOC	C/N	TN	TP	TK	AN	AP	AK	pH	
Bluestem (*Dichanthium annulatum*) vs. Sorghum (*Sorghum bicolor*)	0–5 5–30	+139 +50		+18 +14	+106 +36							[14]
Feather grass (*Stipa purpurea*) and Fescue (*Festuca kryloviana*) vs. Oat (*Avena sativa*)	0–20		+45		+25	−13	+25	+56	+11	+56	−2	[15]
Grazing lands (sp. not referred) vs. Maize (*Zea mays*), Millet (*Pennisetum glaucum*), and Sesame (*Sesamum indicum*)	0–20	+107			+134				−1280	−55	−8	[16]
Reed grass (*Calamagrostis* spp.), Fescue (*Festuca* spp.), Meadow grass (*Poa* spp.), and Feather grass (*Stipa* spp.) vs. Maca (*Lepidium meyenii*)	0–30		−11	−2	−7		−35		−52		+2	[17]
Feather grass (*S. bungeana*) and Alfalfa (*Medicago sativa*) vs. Foxtail millet (*Setaria italica*) and Soybean (*Glycine max*)	0–10 10–20		+59 +47		+67 +34	+23 +14						[18]
Perennial ryegrass (*Lolium perenne*) and Red fescue (*F. rubra*) vs. Crop rotation (sp. not referred)	0–20	+54										[19]
Brachiaria (*Brachiaria brizantha*) vs. Cropland (sp. not referred)	0–10 10–20		−71 −79			+16 −3	+16 −88				+4 −3	[20]
Chomo grass (*B. humidicola*) vs. Bare land (sp. not referred) [4]	0–10 10–30		+13 +11		+16 +20						+6 +6	[21]
Alfalfa (*M. sativa*) and Tall wheatgrass (*Thinopyrum ponticum*) vs. Soybean (*G. max*), Sunflower (*Helianthus annuus*), Rye (*Secale cereale*), and Triticale (x *Triticosecale* Wittmack)	0–6 6–12 12–18	+25 +3 +6										[22]
Mown pasture (sp. not referred) vs. Potato (*Solanum tuberosum*)	0–30		+58 [2]									[23]
Guinea grass (*Megathyrsus maximus*), Sedge (*Cyperus* spp.), Waterleaf (*Talinum fruticosum*), and Paspalum (*Paspalum decumbens*) vs. Cassava (*Manihot esculenta*), Peanut (*Arachis hypogea*), Maize (*Z. mays*), and Cowpea (*Vigna unguiculata*)	0–30			+6	+2				−107		−2	[24]

Table 1. *Cont.*

Grassland vs. Cropland	Soil Depth (cm)	Mean Differences of Soil Chemical Fertility Parameters (%) [1]										Ref.
		SOM	SOC	C/N	TN	TP	TK	AN	AP	AK	pH	
Alfalfa (*M. sativa*), Sorghum (*S. bicolor*), Winter wheat (*Triticum aestivum*), Chickpea (*Cicer arietinum*), and Spring barley (*Hordeum vulgare*) vs. Winter wheat (*T. aestivum*), Chickpea (*C. arietinum*), and Spring barley (*H. vulgare*)	not referred	+60			+64 [3]	+62	+76					[25]
Perennial ryegrass (*L. perenne*) and Clover (*Trifolium* spp.) vs. Potato (*S. tuberosum*), Maize (*Z. mays*), and Winter wheat (*Triticum aestivum*)	0–30		+45		+43							[26]
Grassland (sp. not referred) vs. Rice (*Oryza sativa*), Maize (*Z. mays*), and Okra (*Abelmoschus esculentus*)	0–15 15–30 30–45	+46 +42 +13										[27]
Grassland (sp. not referred) vs. Cropland (sp. not referred)	0–50										−3 [5] −22	[28]
Blue grama (*Bouteloua gracilis*), Buffalo grass (*B. dactyloides*), and Little barley (*H. pusillum*) vs. Wheat (*T. aestivum*)	0–8 8–15 16–23 23–30		+67 +37 +37 +28								+2 +6 −1 0	[29]
Grassland (sp. not referred) vs. Cropland (sp. not referred)	0–30		+40		+32				−233		+8	[30]

[1] SOM—soil organic matter; SOC—soil organic carbon; C/N—carbon/nitrogen ratio; TN—total nitrogen (N); TP—total phosphorus (P); TK—total potassium (K); AN—available nitrogen; AP—available phosphorus; AK—available potassium. [2] The values concern average plant derived C_{org} inputs per year. [3] The values concern average total inputs of N, P, and K. [4] This land use concerns an area with very sparse vegetation with less than 5% ground cover. [5] The authors mention that the pH of both land-use types showed a bimodal distribution, with peaks at pH 6.1 and 7.3 (cropland) and pH 5.0 and 7.1 (grassland).

The beneficial role of grasslands in soil fertility is strongly connected to the agricultural practices used and the crops grown. In fact, the precise net impact of grasslands on the overall improvement of soil fertility may be undervalued due to the difficulty in adequately implementing control plots for diverse land uses with varying levels of mineral fertilizer application.

Generally, great focus has been given to the topsoil layer, given its crucial role in plant nutrition [9]. This soil layer is the most bioactive part of agricultural soils since beneficial microbial communities that can fix atmospheric N_2 and solubilize phosphorus are deeply dependent on the proximity to the plant's roots [31,32]. Furthermore, the impact of land use is prone to diminish with the increase in soil depth, putatively related to the volume explored by the root system of the crops. On the other hand, root architecture can substantially alter the depth of the soil layers that can be influenced [33]. Therefore, the traditional combination of grasses and legumes is a proficient approach for more comprehensive soil volume exploration, with the added benefit of enhancing rhizosphere microbial activity [34].

4. Conclusions

The study of the beneficial role of grasslands for soil fertility can reveal novel means to improve food sustainably. Several fertility parameters were found to be greater in pastures and forages than in croplands. Switching to an eco-friendlier crop production system supported by the integration of grasslands into sustainable agricultural practices may improve crop yields, soil health, and biodiversity and provide other benefits in the long term.

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