34. Improved pasture management

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1. Description of the practice

Grazing systems and related pasture management have different forms, ranging from simple to complex systems and involving single species swards to multispecies swards that occur across a range of soil types and climatic conditions. Grazing animals mostly refer to grazing herbivores, both domestic and wild, that feed mainly or only on vegetation. Pastures refer to areas fenced or with other barriers that are devoted to the production of forage primarily for grazing. Optimisation of soil C by grazing management is mainly associated with biomass production, involving grass regrowth intervals, non-grazing season management and sward persistency. These changes in biomass production are achieved by stocking methods that define how, when, what and how much animals graze (Allen *et al.*, 2011). Grazing strategies aim to allocate nutrition uptake among varying classes of livestock (i.e. creep grazing), improve efficiency of forage use (i.e. frontal grazing, mixed grazing), reduce negative effects on soils or plants (rotational grazing, deferred grazing), and extend seasons (i.e. sequence grazing). Accordingly, grazing (land) management refers to the manipulation of the soil–plant–animal complex in pursuit of a desired result. Grazing management may be extensive, meaning that a relatively large areas per animal is used at a relatively low level of labour or intensive, which is defined by relative increase of stocking rates, grazing pressure and forage. Importantly, rotational grazing is defined by repeated periods of grazing and rest among a number of paddocks throughout the time when grazing is allowed[20], and contrasts with continuous grazing where animals have unrestricted and uninterrupted access throughout the time grazing is allowed (Allen *et al.*, 2011). Irrespective of grazing management, defoliation affects photosynthesis and subsequent C allocation to root and shoot (Chen *et al.*, 2015, Zhou *et al.*, 2017), but also C and N returns to the pasture (25 to 40 percent of the intake, depending on the digestibility of diet), as well as the nature of remainders (e.g. litter, and ungrazed leaves and roots). So, timing and duration of grazing events, as well as their frequency and intensity play an important role on C sequestration through increase in biomass production by replacing aging or dead plant tissues with active photosynthetic younger plant tissues, and by recycling of N though animal ingestion and urine distribution (Tälle *et al.*, 2016). Accordingly, adapted good management practices (grazing strategies) may significantly influence soil function (Teague *et al.*, 2013; Hennessy *et al.*, 2018) and thereby C storage.

2. Range of applicability

Grasslands occupy up to half the earth's terrestrial surface (3.4 billion ha; FAO, 2015) and are often marginally productive compared to intensively managed agricultural areas. About 60 percent of the world′s agricultural land is covered by grazing systems. Distributed between arid, semi-arid and sub-humid, humid rainforest, and temperate and tropical highlands, grazing systems support about 360 million cattle and over 600 million sheep and goats. With regard to climate zones, grazing systems range from areas with verdant pastures in north western Europe or New Zealand, to humid areas, with ranch encroachment and deforestation of tropical forest (i.e. replacement of palatable species and by less palatable, herbaceous plants or bushes), as well as arid zones with extent of land degradation (e.g. moderately or severely degraded). In arid ecosystems, the periodicity of rain becomes the single most important factor affecting the quantity of feed available and excessive, prolonged grazing can leads to the disappearance of palatable species and degradation. In other areas (e.g. Kenya, western United States and Guinea) livestock improve soil and vegetation cover through biomass removal and dejections (i.e. nutrient recycling) while interacting with land, water, plant, and animal biodiversity. The way pasture systems are managed explains, to a large extent, their resilience. In arid rangelands, livestock is often moved in search of pasture according to season (e.g. after the wet season grazing animals are moved to "higher-potential" areas (e.g. valleys, mountain meadows). This continuous dis-equilibrium may conserve soil and vegetation in arid areas.

[20] Also see Factsheet No.35 "Grazing exclusion and rotational grazing"

Grazing practices, which vary in nature, frequency, and intensity of biomass removals (Allen *et al.*, 2011), affect soil structure and soil functions (Cui *et al.*, 2005) and thus, C cycling and C balance of grasslands. The environmental challenge is thus to identify pasture management which will maintain the positive and ease the negative effects of grazing.

3. Impact on soil organic carbon stocks

Grazing strategies have received increasing national and global interest as potential "climate-smart" pathways for sequestering C and improving soil health (e.g. Derner, Stanley and Chad, 2016). Grazing of grasslands can act either as potential sinks or source of C, ranging from -1.3 to more than 1 tC/ha/yr storing on average 0.26 ± 0.07 tC/ha/yr (mean of 11 literature references e.g. Conant *et al.*, 2017, Sandermann *et al.*, 2015, Abdalla *et al.*, 2017, Franzluebbers and Stuedemann 2009; Table 149). Carbon sequestration potential depends on climate, soil characteristics, vegetation (i.e. species composition, presence/absence of C_3 or C_4 grasses, etc.) and intensity of biomass removal, as well as animal stocking densities and the ingested amount of biomass produced. A comparison between grazing and mowing regimes shows that under comparable biomass exports grazing systems tend to sequester more C, in particular when moderately fertilised (Liu *et al.*, 2014), and in biodiverse pastures (Teixeira *et al.*, 2011).

Grazing intensity seems to increase SOC stocks under a medium warm climate (+7.6 percent), but decreases C sequestration potential under moist cool climate (-19.5 percent, Abdalla *et al.*, 2017). For dry wet and dry cool climates, grazing intensity may lead to C increase in soils when combined with low to medium grazing intensities (e.g. Byrnes *et al.*, 2018, Conant and Paustian, 2002). Overall, it appears that optimal use (biomass removed to biomass produced ratio) of grasslands has the potential to significantly increase C sequestration while reducing N losses. Several studies showed a low to moderate biomass removal (30 percent to 70 percent of biomass produced), indicating a potential to sequester 0.2 to 0.5 tC/ha/yr, whereas biomass removals of above 80 percent led to either no or some C losses. In light to moderate grazing systems, less biomass intake and lengthy growth period and reduced animal disturbance can promote photosynthetic activity (i.e. plant growth and increase pasture production, Hennessy et al., 2018), nutrient cycling through animal ingestion and distribution of urine (Chen *et al.*, 2015), resulting in increased soil C storage (Zhou *et al.*, 2017). Meta-analyses suggest that rotational grazing strategies (e.g. high-intensity, short-duration grazing) can improve SOC and bulk density over continuous grazing (Byrnes *et al.*, 2018). Grazing systems tend to sequester more C, particularly when fertilised (e.g. Franzluebbers and Stuedemann, 2009), than mowing regimes linked to the biomass removal differences.

Table 149. Evolution of SOC stocks with improved pasture management at 0-30 cm depth.

Location	Climate zone	Soil type	Additional C storage [range] (tC/ha/yr)	Duration (Years)	More information	Reference
Global	All	All	0.28	NA	Grassland management (i.e. grazing, fertilisation)	Conant, Paustian and Elliot (2001); Contant *et al.* 2017)
South-eastern Wyoming, United States of America	Semi-arid	Sandy loam (Ascalon)	Light: 0.2 Heavy: 0.7	12	Light (5-15% vegetation utilization rate) to high (35-45% utilisation) grazing at mixed grass prairie	Reeder and Schumann (2002)
North-eastern Colorado, United States of America		Sandy loam (Olney)	Light: 0.8 High: 0.9	12	Light (20-40% vegetation utilization rate) to high (60-75% utilisation) grazing at short grass steppe	Reeder and Schumann (2002)
Georgia, US	Humid sub-tropical	Kaolinitic, thermic Typic Kanhapludults (USDA), Acrisols (FAO)	Light: 0.4 High: 1.4	12	Light (maintain 3t/ha dry matter (DM) forage on site) to heavy (maintain 1.5 t DM/ha) grazing and fertilisation	Franzluebbers and Stuedemann (2009)
Mid-north of South Australia	Mediterranean	Rhodoxeral, Haplocalcid	Continuous: 0.06 [-0.35 - 0.74]; Rotational: 0.09 [-0.20 - 1.01]	15	Continuous *vs.* rotational grazing under light (<40% vegetation utilization rate) to high (>80% utilization rate) and fertilisation.	Sandermann *et al.* (2015)

Location	Climate zone	Soil type	Additional C storage [range] (tC/ha/yr)	Duration (Years)	More information	Reference
UK, Northern Ireland	Tempe-rate	Brown clay-loam and gley	Light: -0.90 [-4.6 – 2.3]; Moderate: 0.88 [-1.01 – 3.55]; High: 0.58 [-3.85 – 3.24]	>20	Light (0.2 LU/ha) to high (2 LU/ha) livestock density, fertilisation, with different time span since reseeding events.	Carolan and Fornara (2016)
Temperate steppe, Guyuan County, China		Loamy sand	Light: 0.37 Moderate: 0.62 High: 0.12	-	Light (30% vegetation utilization rate) to high (64% utilization rate) by sheep grazing and fertilisation	Chen *et al.* (2015)
Eastern Cape, South Africa		Sandy loam (Aridosol)	Light: 0.093 High: 0.097	75	Light (0.8 sheep/ha) to high 1.2 sheep/ha) grazing by sheep	Talore *et al.* (2015)
East Africa (Burundi, Ethiopia, Kenya, Rwanda, United Republic of Tanzania and Uganda)	Various		Mean 1.07±0.26	NA	Review of different practices (enclosure, fencing, light and heavy grazing)	Tessema *et al.* (2020)
Portugal	Mediterranean	Various	0.71-1.91	42	Agrosilvopastoral systems/biodiverse pastures	Teixeira *et al.* (2011) ; Cordovil *et al.* (2020)

LU = Livestock Unit

4. Other benefits of the practice

4.1. Improvement of soil properties

Effects of grazing on soil properties are driven by plant tissue removal including defoliation, excretion (urine and dung deposits), but also by trampling. These exert mechanical pressure on soil pore space (Oenema *et al.*, 1997, van Klink *et al.*, 2015), and cause physical damage to the vegetation due to repeated passes of animals (Tate *et al.*, 2004). It implies that less intense management is thus a way to avoid soil degradation, in particular SOC depletion, and thereby attaining sustainable production. For instance, light to moderate grazing has been shown to significantly increase soil C and improve soil structure compared to heavy grazing (e.g. Reeder and Schuman 2002, Zhou *et al.*, 2017, Abdalla *et al.*, 2017, Byrnes *et al.*, 2018).

4.2. Minimization of threats to soil functions

Table 150. Soil threats

Soil threats	
Soil erosion	Depends on livestock density and frequency of use; carrying capacity should be respected to avoid degradation (i.e. low, moderate, and avoid high).
Nutrient imbalance and cycles	Grazing improves nutrient use and (re-) cycling under low and moderate livestock density and frequency of use, high animal density may lead to large nutrient inputs and decouple NPK Cycle (Rumpel *et al.*, 2014).
Soil biodiversity loss	Grazing fosters both above- and below-ground species diversity under moderate and low livestock density (Tälle *et al.*, 2016).
Soil compaction	Grazing animals lead to soil compaction under high livestock densities, whereas adapting to the carrying capacity prevents soil compaction (van Klink *et al.*, 2015).
Soil water management	High livestock densities and frequent grassland use decline water quality due to excess in animal dejections. Adapting pasture management to the carrying capacity prevents excess (Vertes *et al.*, 2012).

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

At low grazing intensities, animals may favour N recycling through ingestion and re-distribution of N via dejections (Soussana and Lemaire, 2014; Rumple *et al.*, 2015). Both promote net primary productivity of vegetation and thus increase litter production (Chen *et al.*, 2015; Zhou *et al.*, 2017). Too intense and frequent grazing decreases the number of living plants and produces less litter and that reduce C sequestration. In between these two extreme situations, several grazing systems may promote not only soil C but also improve grassland quality. For example, managed grasslands with high plant diversity enhance SOC at least in low to moderate input/output grasslands (Sebastià *et al.*, 2018). Light to moderate grazing enhanced SOC by increasing plant productivity, and recycling of N (e.g. Chen et al 2015). There is evidence that strategic management of grazing can positively affect production and might even reverse negative impacts of poorly managed grasslands through the enhancement of N cycling. For instance, under medium to high grazing pressure, fast-growing palatable species typical of nutrient-rich, managed grasslands show a high above-ground productivity and quality (lower C/N) promoting higher C inputs to soil and a rapid degradation by bacteria (Cotrufo *et al.*, 2013). Accordingly, grazing has the capacity to change vegetation by modifying plant community composition (presence of legumes in particular) (Zhou *et al.*, 2017) which play a key role in supplying aerial and root plant biomass into soil systems.

4.4. Mitigation of and adaptation to climate change

There are improved techniques to reduce livestock GHG emissions while increasing livestock productivity and resilience. Strategic grazing that sequesters C could contribute to trade-off/offsetting of GHGs emitted from the grassland systems. There is controversy on grass-fed ruminants that could mitigate livestock and agricultural GHG production. However, a reduction of emissions from manure storage (barn) and manure spreading, as well as the reduction in fertiliser use (i.e. urine and promotion of biological N fixing plants) was reported (Hirstov *et al.*, 2013). Strategic feeding (e.g. use of inhibitors, seaweed and balanced nutrition) could reduce enteric CH_4 and NH_3, in particular, substantially.

4.5. Socio-economic benefits

In many parts of the world, grazing grasslands under low to moderate livestock density are found to be sustainable in areas that are rich in flora and fauna. Ruminants fed by these grasslands are likely to produce tastier meat that is more nutritious and healthy feeds, which may be applied in organic farming and other quality farms (for example, PDO: protected designation of origin or PGI: protected geographical indication). In addition, diverse grassland systems grazed by ruminants often receive recognition as cultural landscapes to attract tourists and beautify areas.

4.6. Other benefits

Good grazing practices are a win-win situation since these allow a better coupling of C and N cycles within vegetation, soil organic matter and soil microbial biomass (Lemaire *et al.*, 2015), that favours plant growth, soil health and biodiversity. Environment-friendly grazing constitutes a compromise among biomass production, C sequestration and emissions (Soussana and Lemaire, 2014) and that may enhance product quality and revenues similar to increasing fertilization and cutting frequency (Schaub *et al.*, 2020).

5. Potential drawbacks to the practice

5.1. Tradeoffs with other threats to soil functions

Grazing affects grasslands via plant tissue removal (defoliation), excretion (urine and dung deposits), but also by trampling, which exerts mechanical pressure on soil pore space (Oenema *et al.*, 1997; Houlbrooke *et al.*, 2009), and causes physical damage to the vegetation where animals pass repeatedly (Tate *et al.*, 2004). There are "bad effects" (risk of erosion, leaching) of grassland management due to high animal density in combination with unfavourable climate conditions (i.e. dry and wet, respectively) and exposure (i.e. hilly lands). Accordingly, there are trade-offs between production (biomass and livestock) and environmental services such as C sequestration, soil health and water quality (Soussana and Lemaire, 2014).

Table 151. Soil threats

Soil threats	
Soil erosion	Livestock that exerts mechanical pressure and physical damage to soil and vegetation due to repeated/frequent passing (Houlbrooke *et al.*, 2009; Oenema *et al.*, 1997; Tate *et al.*, 2004; EIP-Agri, 2018).
Nutrient imbalance and cycles	Livestock promotes spatial heterogeneity in C-N-P pools through animal returns and grazing pattern (Bloor and Pottier, 2014).
Soil contamination/pollution	High livestock densities affect water quality under saturated conditions (Schils *et al.*, 2013).
Soil biodiversity loss	High livestock densities may lead to biodiversity losses (Zhou *et al.* 2017; van Klink *et al.*, 2015).
Soil compaction	High livestock densities lead to soil compaction (Oenema *et al.*, 1997; Tate *et al.*, 2004).
Soil water management	Moderate irrigation to pasture increases production and SOC in dry climates, whereas frequent irrigation decreases SOC and increases N losses though leaching (Mudge *et al.*, 2017; Vogeler *et al.*, 2019).

5.2. Increases in greenhouse gas emissions

There is evidence that grazing management strategies can affect N cycling, where intense livestock grazing and excreta inputs may lead to an increase in N_2O emissions and N losses from urine hotspots, which may become greater when grazed under saturated soil water conditions (Schils *et al.*, 2013). Rotational grazing events can cause the same but for a short term under high stock densities (e.g. more than 80 percent of biomass is removed by grazing). Likewise, animal diet either grass-fed and/or mixed (barn and occasional intense grazing) could lead to a decoupling of N, P and C cycles in grassland systems (see Rumple *et al.*, 2015). Similarly, grazing management has the capacity to modify enteric fermentation via changes in vegetation, plant community composition, presence of legumes, leaf-to-stem ratio, and thus forage quality. For example, forage digestibility declines with an increase of stem in biomass (i.e. reduction in leaf-to-stem ratio) and across growth stages (vegetative, bud, flower); poor forage quality increases enteric CH_4 emissions.

5.3. Conflict with other practice(s)

Pasture management including fertilisation has to take into consideration a compromise between biomass production to promote animal production and increasing C sequestration (Soussana and Lemaire, 2014) (i.e. intensity of biomass export, and C inputs to soil via litter and roots). Besides, promotion of animal production may lead to possible conflicts with (i) a life span extension of temporary grasslands in order to ensure forage quantity and quality, (ii) the introduction of annual legumes (e.g. clover and alfalfa) into temporary grasslands, leading to less complex grassland composition and (iii) the reduction of intensive systems to improve farm management towards a sustainable use of permanent and upland grassland areas.

6. Recommendations before implementing the practice

Carbon sequestration via grazing management needs to consider sustainable practices to preserve and improve present soil quality. Appropriate timing and duration of grazing could help achieve the goals for example by (i) identifying ideal period of rotation that allows the grassland to regrow and renew following defoliation and (ii) preventing grasslands from overgrazing that cause deterioration of pasture structure. Grazing events can be adjusted with the leaf stage of the perennial grass. The optimal time to graze perennial ryegrass pastures is between the 2- and 3-leaf stages because grazing before the 2-leaf stage reduces pasture growth and C inputs to soil. Both C storage and forage use reach an optimum beyond which C storage decreases (a threshold of ~ 0.5 to 0.7 for the ratio between biomass produced and biomass removed by grazing was reported (Klumpp and Graux, 2020). As for livestock, information on the nutritive value of forage across phenological stages help to select suitable grazing times and stocking rates, in order to achieve optimum animal performance without damaging vegetation, reducing C sequestration potential, and increasing soil N_2O and enteric CH_4 emissions (Hennessy *et al.*, 2018),

7. Potential barriers for adoption

Increasing demand for livestock products often results in competition for natural resources, and between food and feed, leading to a carbon-constrained economy, poor human health and a change in socio-cultural values. In general, intensification of livestock farming is accompanied by decreasing use of open range feeding and local resources, and increasing use of concentrated feeds, mainly feed grains. Therefore, it is necessary to consider the total agricultural systems. There are potential risks for ecosystem services and maintaining diverse grazing grasslands due to the numerous episodes of land degradation associated with drought and overgrazing. Other possible barriers that limit the adoption of the beneficial pasture management practices for example are natural degradation; scarce socio-economic evaluation; lack of training, skills, advisory services, supporting tools, inputs; and psychological reluctance in some instances.

Table 152. Potential barriers to adoption

Barrier	YES/NO	
Biophysical	Yes	Limits to sustainably manage grasslands due to competition between food and feed.
Cultural	Yes	Psychological and structural reluctance with regard to changes in practices, due to difficulties in separating local behaviour (e.g. farmer traditions) from practices.
Social	Yes	Social and cultural barriers are often related. Inherent identities which include, sense of identity, occupation, control, and status in the community, as well as social and cultural capital, influence on decisions to adopt climate-friendly practices (Gruère and Wreford, 2017).
Economic	Yes	There is reluctance to competition in food, feed and markets due to missing socio-economic evaluation, markets and labels.
Institutional	Yes	Lack of funding or programmes and networks to support skill development of ranchers.
Legal (Right to soil)	Yes	Paddocks may be far away from each other to apply sustainable grazing management.
Knowledge	Yes	Lack of training, skills, advisory services, supporting tools.
Other	Yes	Natural degradation

Photos of the practice

Photo 43. Example of different grazing management practices and intensities when grazed by sheep grazing (top), continuously grazing by cattle (middle) and strip-grazed by cattle (bottom).

Table 153. Related cases studies available in volumes 3 and 5

Title	Region	Duration of study (Years)	Volume	Case-study No.
Mitigation of SOC losses due to the conversion of dry forests to pastures in the plains of Venezuela (Bolivarian Republic of)	Latin America and the Caribbean	5 and 18	3	40

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