# EIP-AGRI Focus Group – Grazing for carbon

## Mini-paper – *Guidelines*

### Authors

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## Introduction

Many different types of grazing systems exist in Europe ranging from simple to complex and involving a range of sward types ranging from single species swards to multispecies swards. In addition grazing systems occur across a range of soil types and climatic conditions. Grazing guidelines and grazing management systems have been developed in many regions and countries across Europe and those guidelines and systems vary widely in terms of complexity and adaptability. Adopting good grazing management practices through the use of appropriate guidelines can optimise production, as well as ecosystem services, including C sequestration, from grazing land. Soil C content is influenced by grazing management. In some regions (mainly in Northern Europe) soil C content is quite high and there is limited capacity to increase it and so maintaining soil C in those regions is a priority, while in other regions (mainly in Southern Europe) soil C content is low, and often declining, and therefore there is capacity to increase soil C content. In grazing systems soil C content has important roles to play including soil structure, sward productivity, nutrient use efficiency, and of course sequestering c in soil is very important in terms of mitigating greenhouse gas emissions.

This paper will outline issues around grazing management guidelines currently in existence across Europe such as grazing infrastructure, production, regrowth intervals, grazing management tools and guidelines, non-grazing season management, sward persistency; it will identify issues around grazing management to optimise production and soil C; and it will provide potential solutions to issues. It will provide suggestions for further development and research, as well as strategies and steps to improve the implementation of Grazing Guidelines for Carbon. Ideas for future Operational Groups and research-to-practice requirements will also be identified.

## Grazing infrastructure

Developing farm infrastructure can be costly; therefore developing simple guidelines to allow farmers utilise their existing infrastructure more effectively would be beneficial.

Farm infrastructure has a large effect on the management of grassland and in optimising production from grassland. The level of infrastructure required depends on the enterprise with more infrastructures necessary on dairy farms where there is twice daily movement of livestock.

Farm roadways allow stock to be easily and safely moved around the farm. The road ways should be of high quality to minimise the risk of lameness on farm. Multiple entrance/exit points combined with temporary fencing allow paddock size to be altered, or strip grazing to be implemented, and minimise soil damage around paddock entrances.

There are a range of fence types available including natural hedge row boundary fencing, sheep wire fencing, barbed wire fencing and electric fencing. Location will, to a certain extent, dictate the choice of fencing most appropriate to meet requirements.

Water supply for grazing livestock must be adequate for the herd requirements. Shared water sources and allowing livestock to drink directly from rivers and streams are not desirable due to the risk of contamination and associated health risks for livestock and humans, as well as fish and other river and stream inhabitants. In field and paddocks, trough size and water pressure are important considerations. Multiple water points allow flexibility in paddock size and use of temporary fencing.

Soil drainage can offer increased usage of wetter soils. Land drainage can have a negative effect on soil C storage, and so should only be considered when all other areas of the farm are fully productive. That is when soil fertility is correct and the most appropriate grassland species available for that region are established. After that, if additional herbage is require land drainage can be considered. There are many types of land drainage systems available, and some are more suitable to a particular area than others.

Livestock require shelter during adverse weather conditions such as heavy rainfall or high temperatures, which can be relevant for some climate zones in Europe. Options include natural landscape elements, e.g. groups of trees, or artificial infrastructure. The latter can reduce the economic benefits of grazing. The design of paddocks is more complicated if shelter is required. On the other hand, landscape elements are an agro-forestry measure and store carbon.

In planning farm infrastructure, consideration must be made of the potential requirement to protect grazing livestock from large carnivores which is an issue in some European landscapes. Additionally, protection from attacks by dogs and the spreading of diseases such as *Neospora caninum* may be necessary, though is somewhat difficult.

Ensuring farms are stock proof can also minimise the risk of humans being attacked by grazing livestock which is an issue in some European landscapes. In areas where it is not possible to erect physical fences, such as common grazing areas, the erection of warning signs can help reduce the risk of humans being attacked by grazing livestock.

At a legislative level, reviewing land and urban planning/distribution to group the farm area close to the farm could be useful so that farms are less fragmented. This is currently practiced in France and involves exchanging fields/land between farms so that paddocks are not spread over large areas.

Utilising good farm infrastructure can minimise the effects of livestock on the soil by ensuring they do not congregate in one spot in a paddock or overgraze swards, and allow for rest periods between grazings. This will allow swards to recover between grazing, increase herbage production and minimise the requirement for sward renewal which may have negative impacts on soil C content.

## Regrowth intervals/rest periods

Rotation length depends on a range of factors including time of year/weather conditions, feed demand, sward species and grazing system. Rotation length can also be considered as the length of the rest period between defoliation events. Adequate levels of recovery between two defoliation events generally requires elongation of the apical meristem and a minimum number of leaves, some species may need to set seed, establish a desired structure (i.e. such as roots, which represent an important C input and thus to C sequestration), establish seedlings or some other measure of growth/regrowth (Fig. 1).

Because of the inherent variability of precipitation in grassland environments, achieving an adequate rest period (i.e recovery between defoliations) requires adaptive management that includes variable recovery

periods that may be a full growing season or more in some years, depending on weather, different levels of defoliation according to the season, and timing of defoliation and fertilisation.

The ideal rotation length allows the sward to regrow and renew following defoliation but should not be so long that a deterioration in sward structure occurs.

The rotation duration can be adjusted with the leaf stage of the perennial ryegrass. The optimal time to graze perennial ryegrass pastures is between the 2- and 3-leaf stage. Grazing too late (after the 3-leaf stage) increases the rotation duration but has no benefits and in fact reduces pasture quality because of senescence of the oldest leaf. However, grazing beyond the 3-leaf stage can be used as a strategy to carry over pasture from spring to summer deficit periods. Grazing before the 2-leaf stage reduces pasture growth and yield. It can sometimes be necessary to graze before the 2-leaf stage when there is some bare ground because of shadow from the canopy or to reduce spring growth rate. It should happen more than once a year so that pasture remains persistent.


Fig. 1. Above and belowground biomass development after repeated defoliation to simulated grazing pressure (Eyles et al., 2015)

## Production

Most grasslands are subject to marked seasonality of biomass production. Where annual cycles of temperature or rainfall impose cycles of plant growth and phenology that result in cycles of food abundance and quality. Information on the nutritive value of forage by phenological stages helps to choose suitable grazing times and stocking rates to achieve higher animal performance without damage to vegetation. Information on forage quality is also necessary to optimise ration composition with respect to maximal production, minimal excretion of indigested material and minimal costs. Factors that affect forage quality include species composition, leaf-to-stem ratio (such as newly emerged leaves), stage of growth, soil agents, climate, harvesting, diseases, and pests. 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) (Fig. 2), making forage quality predictable.  An application of decision rules based on climate, sward composition, herbage quality and mass targets are thus helpful to define grazing periods. Forage quality has further a significant effect on enteric fermentation, where poor forage quality increases $CH_4$ production of ruminants.

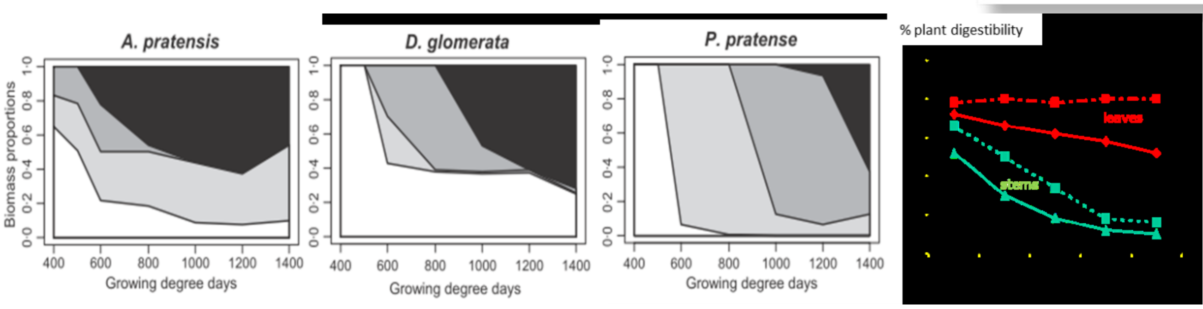



Fig. 2. Tiller biomass distribution among the four development phases during the course of the experiment for grass populations of Alopecurus pratensis, Dactylis glomerata and Phleum pratense, for four development phases: vegetative (white), elongation (light grey), floral development (dark grey) and seed development (black) (Rossignol et al., 2014); and plant digestibility in standing herbage mass, for dicots and grass leaves (red symbol) and stems (green) (adapted from Duru et al., 2008).

## Grass measurement and management tools/measurement of biomass

A range of grassland measurement tools and decision support systems (DSS) are available across Europe, and indeed worldwide. Tools vary in complexity, but regardless, they help to increase farmer confidence around grazing management decisions. They can provide information around biomass yield, grazing intensity and identify poorly performing paddocks.

Grassland measurement tools include:

- Manual Platemeter, e.g. Jenquip (www. http://jenquip.co.nz/categories/pasture-measurement)
- Electronic platemeter, e.g. Jenqip (http://jenquip.co.nz/categories/pasture-measurement), Grasshopper (www.truenorthtechnologies.ie)
- Rapid platemeter e.g. http://jenquip.co.nz/products/rapid-platemeters
- Cut and weigh systems, e.g. quadrate and shears (https://www.grasstecgroup.com/agri-services/product-category/grass-measuring-tools/)
- Sward stick e.g. http://jenquip.co.nz/products/automated-sward-stick
- Sward ruler e.g. https://www.youtube.com/watch?v=eNcn-YqQV0E;
- Wellie markers
- Visual assessment of herbage mass on farm is another tool used by grassland farmers (O'Donovan et al., 2002a). It involves visually assessing the herbage mass on each paddock as you walk through it.
- Leaf stage to maximise pasture performance is an effective indicator to know when the paddock is ready to graze. (https://www.dairynz.co.nz/feed/pasture-management/assessing-and-allocating-pasture/leaf-stage/)

Other decision support tools allow the farm to utilise the measurements of biomass to make informed decision around grazing management. Such tools include spring rotation planner, grass wedge and autumn rotation planner (www.teagasc.ie).

Grass growth or biomass production modelling is also a useful tool, although these are usually used by researchers and/or advisors rather than farmers. The GrassGro model (Barrett et al., 2005) is used to provide a prediction of grass growth for the coming week on grass only and grass clover swards in Northern Ireland via GrassCheck (http://www.agrisearch.org/grasscheck).

In recent years there is increased interest in using decision support systems (DSSs) in grassland management. Examples of grassland DSSs include the Grass Wedge (Teagasc, 2009), Herb'aVenir (Defrance et al., 2005), Pâtur'Plan (Delaby et al., 2015), PastureBase Ireland (Teagasc, 2017a), DairyNZ Pasture Growth Forecaster Tool (DairyNZ, 2017). These facilitate grassland management and allow the anticipation of the availability of grass for grazing.

Some countries have very clear guidelines on grassland measurement, e.g. Ireland via www.teagasc.ie, while in other countries the information is not so clear or accessible. In general grassland management tools can be adapted and modified to suit different countries or regions. For example the grass wedge was developed in New Zealand, adapted for use in Ireland and further adapted for use in the Netherlands.

Grazing management guidelines for diverse swards or multispecies swards are less well defined compared to perennial ryegrass swards. Developing suitable grazing management guidelines could optimise herbage production, and contribute to increased C sequestration through appropriate sward management.

In Eastern Europe, a variety of best grassland management practices are available (Barcsák, 2004, Vinczeffy, 1993), especially in terms of conservation and restoration points, which also support high productivity (Török et al., 2016, Prach et al., 2016). Koncz et al. (2017) showed that extensive grassland management via grazing could be sink for C in this region, provided that there is enough precipitation to support high production. Further investigations of the C sequestration potential of grasslands in Eastern Europe are required.

## Managing grazing in the non-grass growing season

In most regions grass or biomass production varies within and between years. Within Europe there are periods of the year where there is little or no growth. Depending on the region this could be during winter when soil temperatures are low (soil temperature <$5^0$C) and solar radiation is low and soil is covered by frost and snow, or it might be during summer when temperatures are high and there is little or no rainfall. In regions where grazed herbage comprises some or all of livestock diets during the non-grass growing season it might be possible to carry over some grass from the growing season. For example, Hennessy et al. (2006) showed that by closing swards in early to mid-autumn, herbage mass can be accumulated for grazing in the winter period. In Ireland, the 60:40 rule is used in autumn to allow livestock graze until late November and also ensure there is grass available for grazing in early February.

During the non-grazing season it is important to manage grazing so that swards are not destroyed by frost or ice or over-grazed when grazing still occurs as their thereby reducing their future productivity or reducing species content or density because swards may need to be resown. Cultivating swards to re-establish swards can result in disturbance of the soil and the soil organic matter resulting in C release and reducing the capacity for C storage.

Guidelines on the management of pastures between the growing seasons depend on the grazing system and the bio-physical production conditions include climate. In some European regions such as the Alps, the grazing season is limited to a period of about seven month. A pronounced winter period with low temperatures requires certain management in autumn to maintain pasture productivity. It includes maintaining plant height within a certain range to prevent frost damage and fungal infections. On extensive pastures with higher plant species richness, grazing can be unevenly distributed across the area. Some plants or plant parts may be refused by livestock due to unfavourable species composition. Typically for such sites, farmers mulch to control weeds and growth of herbaceous plants and trees. Mulching can sometimes be recommended even during the growing seasons for the same reason. In spring, harrowing of grassland shall activate biomass production and distribute dung patches.

## Stocking rate/carrying capacity

Traditionally, stocking rate is defined as the number of livestock units fed on a specific area of land during a defined period (McCarthy et al., 2011), e.g. number of livestock units on one hectare in a year. A livestock unit (LU), as defined by EuroStat, is a reference unit which facilitates the aggregation of livestock from various species and age as per convention, via the use of specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal (**http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Livestock_unit_(LSU))**. The reference unit used for the calculation of livestock units (=1 LU) is the grazing equivalent of one adult dairy cow producing 3000 kg of milk annually, without additional concentrate foodstuffs (EuroStat, 2017).

Another method of defining stocking rate is comparative stocking rate which is based on the carrying capacity of the farm defined by cow body weight, potential of the land to produce pasture, and the quantity of supplement purchased (kg of body weight/t of feed DM) (Macdonald et al., 2008). Because of the way it is calculated, comparative stocking rate allows the comparison on different systems (Macdonald et al., 2008) within and between countries.

Organic N loading is another form of stocking rate. The EU Nitrate Directive restricts stocking rate to 170 kg organic N/ha, though it is possible under country specific regulations, to increase this stocking rate through a derogation which individual countries have to apply to the EC for. The organic N loading is based on the N excreted by livestock and is calculated from the N content of the feed, the N content of the animal product (milk or meat or live weight gain) and N used for maintenance.

Defining the ideal stocking rate for a system depends on animal factors including the type of animal, genetic merit, body weight, intake capacity, physiological state, as well as the quantity of pasture production per hectare, N fertiliser applied, and the quantity of feed purchased into the system. Key to deciding stocking rate for grazing systems is the quantity of herbage produced on the farm or grazing platform, i.e., the area of the farm available for grazing. The stocking rate for a farm could be based on the total annual herbage production, or it could be based on a the herbage produced/available at the time of year when growth is low, for example, mid-summer in Mediterranean areas, winter in continental and maritime areas. Selecting the appropriate stocking rate requires consideration of the total quantity of herbage that the farm can grow annually, how much of that will be used for conserved forage (usually silage), how much supplement the farmer wants to feed, how much forage will be purchased, and how much of the diet will comprise grazed pasture. Depending on the management system, there may also be a requirement to produce winter forage from the grazing area. If there is, that requirement must be factored into calculating the stocking rate.

The carrying capacity is the amount of forage available for grazing animals based on total annual production; or how much forage a unit or piece of ground is able to produce on an average year. The carrying capacity is the maximum stocking rate possible, depending on livestock type/weight and nutrient requirements, that is consistent with maintaining or improving forage and other vegetation and related resources/processes (e.g. quality, C sequestration). This can vary from year to year on the same area due to changes in forage production.

## Out-wintering cattle on grassland

Out-wintering beef cattle has several potential advantages over housing, but these have to be very carefully weighed against possible concerns for soil and vegetation properties and for animal welfare. Out-wintering may have several benefits such as reduced feeding and bedding costs providing there is some grazing available, housing requirements, animal infection and GHG emissions related to manure storage and

spreading. However, out-wintering may be accompanied by loss of body weight (i.e. reduced intake) and excessive soil compaction and vegetation loss (cattle standing knee deep in mud for their forage is not acceptable) and related GHG emissions ($N_2O$ and $CH_4$ from soil) and nutrient leaching. Out-wintering thus requires proper planning and preparation for most eventualities.

## Maximising soil C sequestration

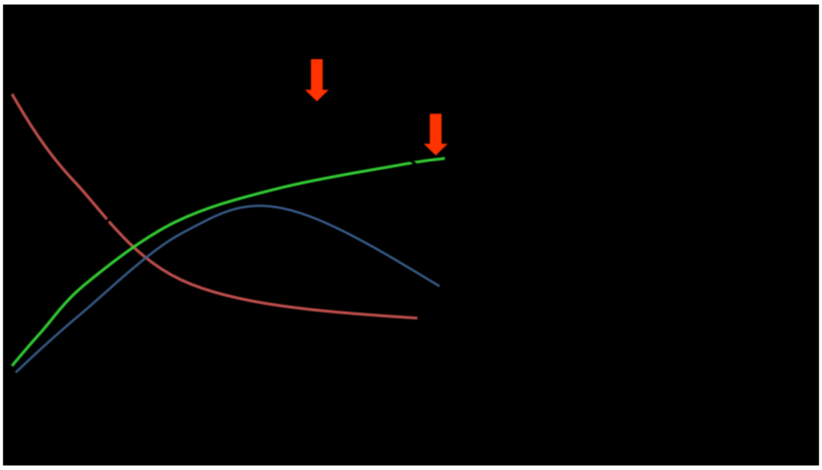
Grassland soils and associated vegetation are an important sink for C, particularly in the form of soil organic C (Peeters and Hopkins, 2010). Maximising grassland production or indeed animal production from grassland may not be ideal for maximum C sequestration. Reseeding grassland is an important means of increasing herbage production. However, cultivating soil to resow/reseed grassland is a source of C. Maintaining permenant grassland, especially on peat soils, and increasing the area of long-term grassland by minimising short term leys, maize and arable cropping can increase C sequestration.

The potential of soils to store C varies greatly and depends on their existing soil organic C store, C storage capacity and potential for C sequestration. Silvopasture and/or incorporating non-grass vegetation such as shrubs and trees in to pastureland can increase potential C storage (Peeters and Hopkins, 2010).

Grazing management should endeavour, where possible, to maintain existing soil organic C accumulations in permanent grasslands and wetlands by avoiding ploughing and drainage of these areas (Peeters and Hopkins, 2010). Necpalova et al. (2011) reported an annual C sequestration rate of 5.74 ton C/ha over a 9 year period on permanent grassland (grass and white clover swards) on a poorly drained gley (90%) and grey brown podzolic (10%) soil.

Soils that are building soil organic C stores are best placed to sequester C. Permanent grassland soils that are not cultivated, or are rarely cultivated are best placed to sequester C. Soils can increase soil organic C content by increasing soil organic matter content, slowing decomposition of soil organic matter and through additional photosynthesis by surface vegetation and transfer of this photosynthate to the soil (Powlson et al., 2011). Subsoils generally contain less C than topsoil and so the incorporation of deep rooted plants into grassland could transfer C via the roots to the subsoil. A balance between sequestration activities and agricultural production is important. In many cases incorporating organic C into the soil will result in benefits such as improved soil quality and hence crop yields (Smith et al., 2007).

Grazing management may also influence soil C content. In a comparison of rotational v’s continuous grazing, Banerjee et al. (2000) found no difference in soil C content between rotationally grazing and continuous grazing; but that experiment was over a relatively short period.



## Management for sward persistency for many years

A well-managed sward can be very persistent and remain productive for many years. In an ideal scenario, and for a variety of reasons, sward renewal would be kept to a minimum. It is expensive to reseed grassland. For example, Shalloo et al. (2011) reported that as sward persistency declines, reseeding is necessary and the more frequent the reseeding, the costlier it is. In addition, reseeding disturbs soil and can result in a release of C from the soil. Creighton et al. (2016) compared a conventional plough, till and sow reseeding method with a number of minimum cultivation methods (existing sward treated with glyphosate followed by three methods - Direct drill, Disc plus rotary power harrow, Power harrow only, and the application of diquat to suppress the existing sward followed by direct drilling) and with a control (old permanent pasture) and found that regardless of method, all reseeded swards produced similar or more herbage mass than the control in the year of reseeding, and produced more herbage mass than the control in the first full grass production year post reseeding.

Teagasc in Ireland have developed guidelines for reseeding/pasture renewal in the Pocket Manual for Reseeding (https://www.teagasc.ie/media/website/publications/2017/Reseeding-booklet.pdf).

## Grazing and society

In general, the societal acceptance of grazing is high. People associate grazing with animal welfare, attribute a higher quality to products resulting from grazing, and appreciate a landscape which includes grazing livestock. However, conflicts between competing interests can occur. For example, grazed livestock in alpine areas can be a danger to hikers. Grazing management guidelines to farmers shall include recommendations to manage potential conflict situations.

## Economics of grazing

Guidelines on grazing should include considerations of costs and benefits to farmers and should inform management decisions. Costs include variable and fixed costs such as for fencing, livestock transport, pasture maintenance, and livestock monitoring. Benefits from grazing include reduced housing, slurry storage and slurry application costs, reduced harvest costs and better animal health. In general, increasing production intensity increases the opportunity costs of grazing, i.e. reduced livestock yields compared to intensive indoor

feeding strategies. Some technologies, such as milking robots, may limit grazing opportunities. Grazing season length is also an important consideration when examining the cost-benefit of production systems.

Dillon et al. (2005) showed that total costs of production tend to increase as the proportion of grazed grass in the milk production system declines (Figure 1). The proportion of grazed grass in the diet of grazing livestock is influenced by the quantity of herbage that can be grown (influenced by species, soil type, fertiliser level, grazing management, weather conditions, etc.) and grazing season length. Shalloo (2009) showed that 44% of the variation in milk production costs in Ireland can be explained by the quantity of grass utilised by the dairy herd. Van den Pol-van Dasselaar et al. (2014) showed that the economic benefit of grazing in the Netherlands depends on the fresh grass intake of grazing dairy cows (Figure 2). Grazing was financially attractive if the grass intake was higher than 600 kg DM/cow/yr. This threshold can vary between years depending on milk price and variable costs. If the intake of fresh grass falls below this threshold, then grazing is less profitable than keeping the cows in the barn.

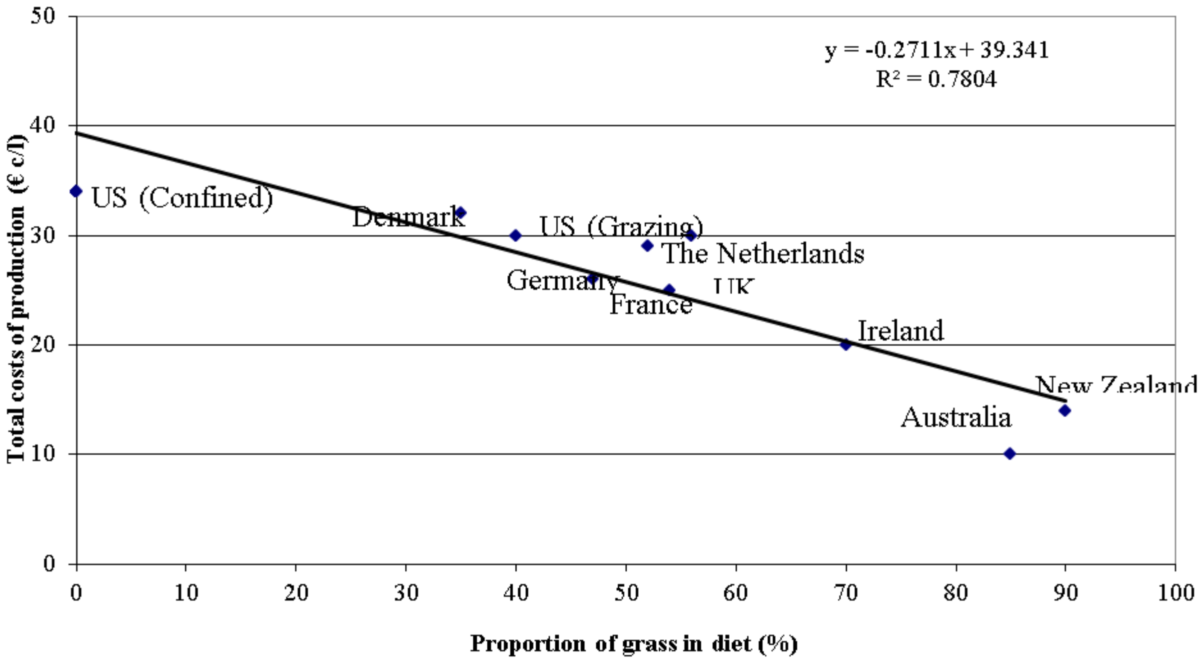



Figure 1. Relationship between total costs of production and proportion of grass in the dairy cow's diet. (Source: Dillon *et al.*, 2005).

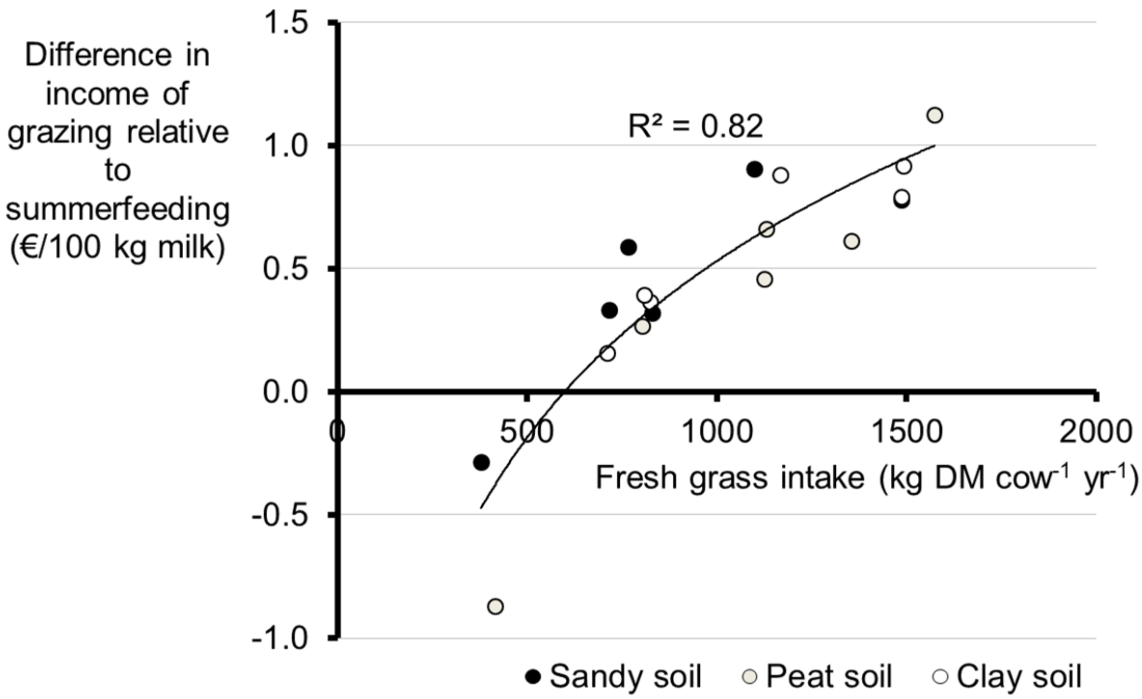



Figure 2. Income from grazing minus income with summer feeding (silage in the barn) relative to the quantity of fresh grass (kg DMI per cow per year) for three soil types in the Netherlands as simulated by the whole farm model DairyWise. Positive numbers indicate an economic advantage for grazing (Van den Pol-van Dasselaar *et al.*, 2014)

## Examples of projects

Amazing Grazing (the Netherlands) – www.amazinggrazing.eu The Amazing Grazing project is investigating and substantiating solutions to integrate grazing in future-focused dairy farms. Information is translated into knowledge, management tools and concrete grazing systems for use in practice. Amazing Grazing thus encourages the application and development of grazing in the Netherlands as part of modern professional practice, both now and in the future.

PasturBase Ireland (Ireland) – **www.pasturebaseireland.ie**

PastureBase Ireland is a grassland management decision support tool and a mechanism to capture background data on farms. PastureBase Ireland stores all grassland measurements in a common structure. This will allow the quantification of grass growth and DM production (total and seasonal) across different enterprises, grassland management systems, regions, and soil types using a common measurement protocol and methodology. The capture, through the database, of on-farm grassland measurements from research and commercial farms will provide valuable strategic data for the grassland industry.

Grass 10 (Ireland) - **https://www.teagasc.ie/crops/grassland/grass10/**

Grass 10 a multi-year campaign (2017-2020) to increase grass utilisation on Irish livestock farms (dairy, beef and sheep), with the objective of achieving 10 t grass DM/ha/year utilised and 10 grazings/paddock/year.

Project LIFE+PTD (France) Dynamic Rotational Grazing management – Pâturage Tournant Dynamique - https://www.life-ptd.com/

The goal of this LIFE project is to benchmark in French conditions a method of grazing management based on grass physiology. 120 farmers test this grazing management method on their farms. Over 5 years, different aspects are evaluated in order to assess the impact of this grazing management method on: 1) Carbon sequestration, earthworm population and soil structure and composition; 2) Energy use and greenhouse gas emissions; 3) Profitability and economic performance; 4) Animal performance (average daily gain or milk production); 5) Grassland production: herbage samples are taken before each grazing rotation to assess the annual yield and the feed quality. The feed quality is evaluated using NIRS.

## Proposal for potential operational groups

- Developing and evaluating sward renewal techniques that minimise soil disturbance while ensuring sward establishment/renewal
- Production and persistence of multispecies swards under grazing
- Adapting existing grazing management DST's in other regions
- Guidelines to preserve and manage natural and semi-natural guidelines using the best methods available, including traditional methods
- Incorporate C into existing grazing management guidelines, i.e. incorporate the benefits of C to provide the 'whole picture. This could involve developing a Framework Code similar to $NH_4$.

## Proposals for (research) needs from practice

- Development of grazing management guidelines for multispecies swards for different regions (soil types, weather conditions, sward composition) to ensure productive and persistent swards
- Development of guidelines for grazing that allow farmers to optimise animal production while maintaining or increasing soil carbon
- Determine the most appropriate sward renewal methods to minimise soil carbon loss
- Determine how important harrowing or mulching fields after/before grazing season is.
- Quantifying the persistence of grassland species (grasses, legumes, forbes) under varying levels of grazing intensity.
- Identifying the 'trade-off curve' for C sequestration in grazing systems, i.e. optimising both production and C storage in grazing systems.
- Identify if there are extra benefits to increasing soil C in Northern Europe compared to Southern Europe.
- Identify/List the components influencing soil C content in different regions, e.g. stocking ratye, level of production, regrowth interval, etc.
- Define the optimum time to graze, i.e. how does one identify the best time to graze – leaf stage, sward height, etc.

## Recommendations for further development

Current grazing guidelines do not consider the effects on soil C. For many parts of Europe, grazing is a hugely important component of ruminant production systems due to the many ecosystem services it provides, and

will continue to be so into the future. One ecosystem service that grazed grassland is in a position to support is C sequestration. Development of region specific grazing guidelines that optimise animal production performance and optimise C sequestration is a key area for further development. Developing an indirect indicator, or proxy, for C sequestration could be very useful for farmers to understand and measure C sequestration on their farms. Educating farmers, advisors, and the wider grassland industry in soil C management is a key development which must occur if the benefits of grazing, in terms of maintaining or increasing soil C content, are to be realised. The benefits of soil C in terms of soil quality, nutrient use efficiency, productivity, etc. must be highlighted if a change in mind-set is to occur. An obvious way of increasing stakeholder knowledge around soil C and its importance is to 'show and tell', i.e. demonstration.

## Conclusions

There is a wide range of grazing guidelines available across Europe. Some are quite simple to implement, while others are more complex. Tools can be adapted across regions using local knowledge to increase animal production and herbage production from grazed pasture. Current grazing guidelines have little or no consideration of the effects of management decisions on soil C. Grazing will continue to be an important part of ruminant production systems across Europe due to the many ecosystem services it provides. One ecosystem service that grazed grassland is in a position to support is C sequestration.

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