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Permanent Grassland

Increase resource efficiency to improve profitability and sustainability

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Introduction

Increasing resource efficiency in terms of profitability is of core relevance to the overall objective of the focus group. Maintaining permanent grasslands in Europe is also an important element in the Greening of the Common Agricultural Policy. The area of permanent grassland in Europe during recent years has declined. This is due to either: (i) abandonment of those areas that are unsuitable for cropping or other agricultural purposes, and where socio-economic factors combined with environmental and edaphic conditions seriously limit the profitable use for permanent grassland-based farming; or (ii) conversion of permanent grassland to maize, short-term leys or arable crops on those areas that are more easily cultivated or more accessible. These land-use changes impact on the provision of other ecosystem services from permanent grassland, notably its roles in C sequestration and biodiversity. Furthermore, permanent grasslands make important contributions to cultural heritage, including landscapes that benefit many people in terms of human well-being, and which also support other rural business including enterprises linked to recreation and tourism.

The focus of this mini paper is therefore on examining aspects of resource-use efficiency of permanent grassland in the context of profitable utilization, with further consideration of the trade-offs that need to be considered in order to deliver other ecosystem services, particularly C sequestration and biodiversity.

The definition of permanent grassland is that used by the International Forage and Grazing Terminology Committee: "Land on which vegetation is composed of perennial or self-seeding annual species which may persist indefinitely. It may include naturalized or cultivated species" (Allen et al., 2011).

The mini-paper addresses the need to identify the different levels at which resource efficiency of permanent grassland can be improved, and to consider where are there opportunities. Four levels are considered at which different opportunities can be identified: (i) Ensuring herbage production and quality, i.e. managing permanent grassland swards to produce adequate feed energy for livestock; (ii) Ensuring good efficiency of utilization of grassland herbage into livestock diets; (iii) Ensuring utilization by livestock leads to conversion to profitable livestock output; and (iv) Ensuring that resource efficiency also contributes to ecosystem services.

1) Herbage production

Dry matter yield and forage quality: managing permanent grassland to increase ME (metabolisable energy) value

Farmers using permanent grassland need to ensure that annual and seasonal herbage production is sufficient in quantity and quality to support livestock requirements without recourse to excessive supplementation. Within Europe, grassland production is highly variable depending on the soil, climate, management, nutrient and other inputs (e.g. irrigation) and botanical composition. On a per-ha basis this can range from below 2 t DM (e.g. on upland sites in NW Europe and on seasonally drought-affected rain-fed southern sites) to over 15-20 t DM of harvestable forage per year (e.g. sites on well-watered fertile soils in temperate zones like Ireland, western UK).

Improvements in grassland production in recent decades have been achieved largely by increasing nutrient inputs (especially N fertilisers). Excessive N use has led to other environmental problems. The focus now is to address the wider issue of improving the efficiency of use of inputs and of factors that affect plant growth. In particular, the timely provision of N and other plant nutrients; efficient use of rainfall and soil water; choice of forage species where changes in sward composition are possible; and maintaining soil quality by avoiding compaction, erosion, etc. The challenge for herbage production can be summed up in the following question: can we ensure that photosynthesis occurs at an optimum level (or one that is sustainable in terms of agricultural use, environmental objectives and socio-economic objectives) so that net herbage accumulation is appropriate to the requirements of the farmland situation? As the overall objectives also include carbon sequestration and biodiversity provision, the achievement of high levels of forage production may not be compatible with these and other ecosystem services. Similarly, low herbage production may result in low C sequestration and low-production swards are not always beneficial for biodiversity: there are still research challenges here.

This leads to an important question: are there ways in which high levels of herbage productivity can be met while at the same time ensuring provision of additional ecosystem services? One opportunity that can go some way to achieving environmentally sound herbage productivity is through the use of well-adapted multi-species swards (Huyghe et al., 2012). These include swards with nodulated legumes capable of fixing large amounts of symbiotic nitrogen and resulting in a sustainable increase of DM yields and quality (higher crude protein concentrations and increased, feed intake). Legume-based permanent grassland can also provide opportunities for improved root development and consequently improved soil structure, as well as reduced requirements for fertilizers, and also help reduce enteric methane emissions by using tannin-containing species (Piluzza et al., 2014). These outcomes can lead to net reductions in greenhouse gas emissions. Legume-based permanent grassland swards can also improve the biodiversity (relative to simple grass swards). The potential of legume-based grassland for livestock in Europe has recently been reviewed (Lüscher et al., 2014) as an outcome of four EU-FW7 projects (AnimalChange, MultiSward, LegumePlus and Legume Futures).

There are very strong arguments in favour of a greatly expanded use of legumes in permanent grassland swards, due primarily to the production benefits they confer in N fixation. There is, however, potential incompatibility between maintaining biodiversity and the use of legumes in situations when N fixation adversely affects plant communities and species whose conservation status demands low nutrient levels. On the other hand, these high conservation status grasslands also require agricultural utilization to prevent their loss from scrub invasion etc, thereby presenting a challenge of ensuring their survival in a sustainable way.

Opportunities to address resource use efficiency at the basic level of forage production might include the following:

(i) Obtaining improved information on soil nutrient status, soil characteristics (pH, texture, depth, drainage, salinity, etc.) and soil physical constraints (compaction, soil water, organic matter content). From this information, actions might be considered to overcome edaphic limitations to the plant-growth potential of productive species in the sward, notably legumes, whose adaptation to soil and climate conditions is of paramount importance for ensuring sward persistence and productivity.

(ii) Obtaining information on forage resources to determine the opportunities for improvement of species quality and growth potential appropriate to the site (e.g., specialist seed drills for oversowing legumes or other valued forage species, including species that might improve soil structure or utilize soil water; use of physical methods or low-impact herbicidal control of noxious weed species; periodic reseeding of areas especially where this enables the provision of adequate amounts of quality feed at periods of seasonal farm-level feed deficit). Furthermore, depending on the growth potential of the vegetation components, responses to fertilization could be small, however, with high potential environmental impact and high economic costs. Therefore, we should promote the use of legumes with high leaf area.

However, as noted above, there are instances of incompatibility of sward improvement with local agri-environmental requirements. For example, for Swedish permanent pastures (and also in other countries) the use of herbicides, reseeding and, in most areas, even fertilizing of permanent grassland is restricted under the terms of the environmental payments. These, mostly semi-natural, grasslands play an important role as fodder resource but they also provide farmers with opportunities to produce public goods and services (landscape and nature management). Thus, there is a difficult challenge. Increasing the herbage production by, for instance, fertilisers to get better resource efficiency (and better C-sequestration) will result in loss of the payments for preserving/enhancing biodiversity. Therefore, on these semi-natural grasslands and other permanent pastures, it is also necessary to increase resource efficiency in other ways, perhaps through grazing management.

2) Efficiency of utilization of herbage from permanent grassland (by increasing the proportion of ME from grass converted to Utilized ME [UME], i.e. utilised as ME for growth, lactation and maintenance).

Herbage growth can only translate into livestock production after it is grazed or harvested (by mowing) and fed to livestock. At this level we need to identify ways in which net herbage accumulation of permanent grassland swards can be utilized by grazing or mowing, and to minimize losses during feeding or that arise from senescence of unutilized herbage, but without compromising the future regrowth of the sward.

Seasonal herbage growth and accumulation in European permanent grassland does not usually match the seasonal demand of livestock. This can result in seasonal overgrazing (with environmental damage) or seasonal underutilization when herbage growth exceeds demand.

Weather-related inter-years variability in herbage growth can further increase this imbalance. Management options for improving seasonal utilization include strategic mowing of surplus forage for later feeding, or reducing/eliminating the use of other feedstuffs in ruminant diets when pasture herbage is in surplus.

As the daily growth rates of the pastures are subject to considerable variation (from 0 to >150 kg DM/ha/day) and pasture quality is also quite variable with growth stage, a good combination of grazing with forage conservation is a major concern in all animal production systems aiming to increase resource efficiency and profitability. However, there is a large range of options for such a combination, depending on the growing pattern of the pastures, the periods of abundance or scarcity, the evolution of herbage quality, etc. For example, in Mediterranean rain-fed permanent pastures, grazing may be extended throughout the year, conserved forage being obtained from annual forage crops specially grown for that purpose, or from irrigated permanent pastures; in both cases through a single cut in mid spring, in order to maximize yield x quality. Conserved forage can be part of planned annual feed budgeting, but also can provide an 'insurance' during periods of insufficient pasture yield and/or quality, and can thereby assure a more efficient utilization of the available resources by the animals.

At a farm and landscape scale an important issue is the utilization of areas of permanent grassland that are of low feed value (often of high biodiversity value). The 'two-pasture system' was developed for hill land in Scotland, based on the simple concept of using areas of highly improved forage in conjunction with low feed value forage resources (Eadie, 1978; Maxwell et al., 1984). Similarly, the 'forage chain' approach of Mediterranean grasslands is based on using areas of sown *Lolium multiflorum* and *Medicago sativa* to overcome the dry-season feed deficit of natural grazing areas (Cosentino et al., 2014b).

The 'two-pasture system' differs from what might be termed 'mixed-sward' availability. The two-pasture system consists of alternating, changing from one sward type to the other according to the nutrient demands of the livestock. In the second system the animals have the opportunity to graze any component of the vegetation at any time, and therefore they have greater opportunities for diet selection and attending to their physiological and self-medication needs at any moment. Under Mediterranean conditions, where vegetation regrowth is much slower, an adaptation of the two-pasture system could be more appropriate because the vegetation components will usually need longer periods for regrowth.

There is an important trade off between growth and utilization: the grass crop must be harvested repeatedly or a large proportion of the accumulated herbage can be expected to senesce and become unavailable. However, in order to maintain a grass sward that achieves maximum light interception and maximum photosynthesis only a small proportion of leaves can be harvested at any time (Parsons and Chapman, 2000). Grazing management remains a compromise between maximizing individual animal production and achieving efficient sward utilization. Sward height guidelines can be related to eating rate, grazing time and total intake, in sheep (Penning et al., 1991) and also in cattle (Mayne et al., 2000) and may be used as a management method to improve grassland efficiency under grazing.

Adjusting stocking rates to the average growth potential of a pasture may represent a key issue for improving the efficiency of pasture utilization. On sheep-grazed grassland, maximisation of the efficiency of herbage utilization needs to take account of two main factors: the type of flock and the stocking rate (grazing pressure). The components of the

flock should be selected in relation to the available biomass from the different vegetation components because of the differences in grazing behaviour and diet selection (Celaya et al., 2013).

3) Efficiency of utilization by livestock that leads to conversion of utilized ME into profitable output.

This is the pivotal stage in terms of efficiency of resource use from permanent grassland into economic output (as opposed to feed energy as discussed above). In animal systems the resource inefficiencies are slow carcass growth and, in female cattle /sheep, periods of non-lactation when they are consuming feed just for maintenance (e.g., Laidlaw and Sebek, 2012). There is an important need to consider the following: improvements in livestock growth rates, using less fodder/kg product, and ensuring lower calf/lamb mortality. Particularly important here is the need to reduce the proportion of UME that contributes to animal maintenance (this also has implications for GHG emissions when expressed per unit of livestock product). Thus, the following measures are relevant in this context:

- (i) use of high sugar forages to support utilization of the crude protein content of legumes in the rumen,
- (ii) strategic use of other protein sources to support forage from permanent grassland of low feed value,
- (iii) use of forage species in permanent grassland swards that can lead to animal health benefits and higher protein utilization [e.g. plants containing condensed tannins, like lotus and sainfoin (Frutos et al, 2007; Osoro et al., 2007; Celaya et al., 2008; Piluzza et al., 2014).],
- (iv) adapting livestock systems that minimise the numbers of single-suckling cows (and where appropriate, single lambs),
- (v) reducing the period when dairy cows are not in lactation (by improved oestrus determination),
- (vi) reducing losses of animals or animal products due to disease, parasitism or predation.

Another key issue for increasing the efficiency of resource utilization is the need to adjust as much as possible the variable nutritive requirements of the grazing animals during their respective reproductive/productive/maintenance cycles, to the herbage growth/quality patterns, both at grazing, and in combination with conserved forage or other available resources (e.g. crop stubbles, straw). The availability of feed and nutritive resources, as well as biodiversity requirements, should also be taken into account in planning the calving and lambing season, seasonal production of milk and meat; however, financial considerations at the farm level may further affect decision making, e.g. seasonal price differences in products.

4) Resource efficiency that contributes to carbon sequestration and biodiversity

Here we need to consider another important issue: how can improving resource-use efficiencies interact with additional objectives of ecosystem services, and how we address the need for trade offs?

Carbon sequestration

Soils and below-ground organic materials (roots, soil invertebrates etc) represent an important C pool that has potential to be increased, thereby offsetting atmospheric CO₂ increases. Maintaining permanent grassland contributes to increased C sequestration (conversely conversion of grassland to arable cultivation reduces soil C). Under cutting and grazing the amount of herbage that is utilized will affect the amount of below-ground growth and C sequestration. The following scenarios have been proposed: (i) *grazing will lead to increased soil C* when root biomass and other non-grazed plant residues and animal faeces are increased or when any decrease in plant residue inputs to the soil are offset by manure additions; (ii) conversely, *grazing will lead to reduced soil C* when it is sufficiently heavy to cause reduced plant biomass and C input to the soil, or when grazers select nutrient-rich plants that supply labile substrates to the soil, which in turn promote fast-cycling soil microbes leading to C loss (Bardgett and Wardle, 2010, pp 154-155).

Carbon sequestration in soils that support permanent grasslands is quite variable. Variation occurs not only according to the composition and yield of pastures, but also in relation to climate and soil conditions of the locality where they occur. Under Mediterranean conditions, higher yields of biomass produced by “biodiverse legume-rich sown permanent pastures”, when compared with natural pastures, can lead to higher levels of C sequestration, although the annual rate of C sequestration decreases when high levels of soil organic matter (SOM) are achieved. In those conditions it is difficult to find improved pastures with SOM exceeding 5% (this value being attained only after 25-30 years of pasture establishment in a soil having initially less than 1% SOM), but in temperate climates the % of SOM can reach much higher values. Normally, cut forages are much less efficient in promoting C sequestration in the soil than grazed pastures (see, e.g., Soussana et al., 2010; Laidlaw and Sebec, 2012)

Abandonment of permanent grassland might lead to short-term increased C sequestration in above-ground shrubby vegetation, but in the medium and long term this ungrazed accumulation can greatly increase the likelihood of wildfires and thus major C losses to the atmosphere. Moderate grazing pressures should therefore be maintained.

Biodiversity

Grassland biodiversity can be valued at a range of levels; for instance, at local levels even permanent grassland of quite moderate diversity can be important if surrounding land is species-poor or lacking in grassland species (e.g. intensive cropping, some forested land, or highly urbanised land). There are several categories of permanent grassland that are of particular biodiversity value, though these vary between European countries, with many having been designated as Biodiversity Action Plan priority habitats or as High Nature Value

(HNV) Farmland (Veen et al., 2009). Notable examples include: Mediterranean grasslands (which are a global biodiversity hotspot), and temperate grassland hay meadows. Improving the short-term economic profitability by changing the botanical composition and/or edaphic conditions is often at the expense of biodiversity and wider landscape values; therefore, there are trade offs that need to be considered.

In Mediterranean zones, biodiverse legume-rich sown (and otherwise improved) permanent pastures are very efficient in increasing pasture productivity and soil fertility, but simultaneously they can contribute to a range of ecosystem services including capacity to sequester atmospheric CO₂ in the soil, drought survival and soil erosion control (Cosentino et al., 2014b).

More widely, maintenance of HNV and other biodiverse grassland has been heavily supported over the past ca. 25 years through agri-environmental schemes. More recently, the assumption that biodiversity is necessarily synonymous with low economic value to the farmer has been questioned. In this regard, an additional aspect of efficiency is that of 'embedding' the intrinsic properties of the permanent grassland into the output through product valorisation. Sometimes termed 'eating biodiversity' (Buller, 2008) this can be an economically sustainable way of utilising the uniqueness of biodiverse permanent grassland to produce added-value products like meat, cheese and honey - thus raising the economic and social efficiency of these types of permanent grassland. Seed for habitat restoration is also another potentially important 'product' from biodiverse grasslands.

Farming systems: several potential outcomes can be considered:

- (i) to optimise animal production within the context of maintaining biodiversity and / or leading to improved C sequestration;
- (ii) to devise systems that deliver biodiversity benefits (and/ or improved C sequestration) within the context of maximum production
- (iii) to improve the valorisation of measures that affect C sequestration and biodiversity protection/ enhancement (noting that 'carbon trading' is already providing a currency for this).
- (iv) to identify problems that prevent farmers from taking up innovations for improved resource use efficiency (lack of knowledge, markets, infrastructure?).

These systems can be considered at a range of scales: within the landscape, within the farm, and for different sward types or grassland habitat classes. Outcomes need to consider the inputs and actions of stakeholders, timescales and methods of knowledge dissemination (new ICT tools, manuals, feedback from users, including farmer participation in research).

Research Projects

Effect of plant species differences on soil water retention (reduced run off) through improving soil structure (UK project SUREROOT).

FP7-266018 AnimalChange

FP7-245216 Legume Futures

FP7-244983 MultiSward

Eating Biodiversity: an investigation of the links between quality food production and biodiversity protection. <http://www.relu.ac.uk/news/Buller%20Policy%20&%20Practice%20Notes.pdf>

Innovative Actions

- 1) Increase the presence of well nodulated diverse legumes in permanent grasslands to sustainably improve pasture productivity and profitability. This is already a common practice in some Mediterranean zones but needs to be introduced in other European climatic zones and considerable research efforts are needed to find adequate productive and persistent legume species and cultivars and their respective Rhizobia adapted to the existing variable soil and climate conditions.
- 2) Another activity should look for plants containing condensed tannins or other beneficial animal health/nutritional elements, to be associated with legumes and grasses in order to increase the value of pastures in keeping productive healthy animals.
- 3) Taking into account that phosphorus (P) is a key element for legume growth, we need to take into account that many soils are poor in available P, and fertilizers containing this nutrient are of fossil, therefore non-renewable origin; and that there are various soil microorganisms which, in association with plants, may be able to solubilize P (e.g. Pseudomonas) and/or extend the plant rhizosphere (e.g. arbuscular Mycorrhiza). It would be a requirement to formulate some research activities about these microorganisms and their associations with plants, to promote the uptake by plants of the existing soil nutrients.

Other examples of challenges that could need innovative actions:

- Use of different (new?) systems of mixed grazing (to reach clean grazing, fewer parasites, better utilization and higher growth rates)
- Reducing losses by different kinds of carnivores
- Grazing practice for reduced parasite burden, especially on meadows
- Use of silvo-pastoral systems (production of meat, bioenergy, biodiversity on the same area)
- Reduction of labour needed by use of new technology for supervising of animals on large areas
- Reduction of poaching in a wetter climate
- Reduction of losses in live weight at turnout (from indoors to grazing)

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