Possibilities and constraints for grazing in high output dairy systems

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Abstract

In temperate and oceanic regions, grazed grass is the lowest cost feed available for milk production. In other regions, grazed grass is less important but can contribute to the diet of livestock. Within high output systems the interaction between the animal and sward is challenging for a host of reasons, including intake and milk production potential, substitution, grass allowance, quality, etc., which often means that grass utilisation and quality are compromised. Adaptation of grazing management and implementation of a range of grazing strategies can provide possibilities to increase the proportion of grazed grass in the diet of dairy cows in high output systems. As Europe transitions to a non-milk quota situation, increasing scale, or herd size, will probably lead to a trend towards a reduction in grazing, and may lead to a loss of the benefits of grazing. Therefore, strategies are required to increase the level of grazed grass in the diet of dairy cows on high output farms through the integration of grassland measurement and budgeting within everyday grassland management practices. There is a growing body of literature describing the benefits of grazing from an economic, environmental, animal welfare and overall social dimension. However, there are fewer reviews highlighting the constraints and difficulties to maintaining a high level of grass utilisation and good grazing performance in high output systems. The objective of this review is to present a balanced overview of the possibilities and the constraints for grazing in dairy systems in the future.

Keywords: grazing, dairy system, grassland managements, low-cost feed

Introduction

Global population growth to circa 9 billion by 2050 (UN Population Division, 2012) will result in an increased requirement for food globally, and specifically an increased requirement for meat and milk products, largely driven by the increased wealth of populations in developing countries. Increased food production must take place in a sustainable manner to minimise the environmental consequences. Grass, the feed for grazing livestock is, unlike concentrate feed for livestock, not suitable for human consumption. Furthermore, in many regions grassland occupies land area that is not suitable for growing crops which can be used to provide feedstuffs for humans. Agricultural reforms, increased demand for feed, drought and environmental considerations may indicate that self-sufficient farming using local or on-farm resources such as grazed grass will become more important in the future (e.g. Hofstetter *et al.*, 2014). Increased legislative pressures (e.g. Common Agricultural Policy reform, Kyoto Protocol, Gothenburg Protocol, EU Nitrate Directive) mean that in Europe increased milk production must be achieved in an economically and environmentally sustainable manner. Dillon *et al.* (2005) and Shalloo (2009) have shown that key drivers of profitability at farm level in temperate regions are associated with increased grass utilisation. In other regions, grazed grass is less important but can contribute to the diet of livestock during periods when there is optimum grass growth. While there are clear benefits to including grazing in dairy production systems, generally in Europe the contribution of grazed grass to dairy cow diets is declining, particularly as production systems intensify (Van den Pol-van Dasselaar *et al.*, 2008). There are a variety of reasons for this decline including increasing stock numbers per farm, declining availability of labour, shortage of summer feed supply, changing calving patterns, high genetic-merit cows, land fragmentation, etc. Overall, in high output systems there are many possibilities for and constraints to grazing. Possibilities include the adaptation of grazing management and implementation of a range of grazing strategies to provide opportunities to increase the proportion of grazed grass in the diet of dairy cows. Maximising the utilisation of grazed grass in all systems will have benefits including economic sustainability and animal welfare. There are also many constraints to grazing in high output systems which can broadly be divided into two: infrastructural and cultural. Infrastructural constraints include farm fragmentation, facilities, demand for milk and mechanisation. Cultural constraints include perceived importance of high milk yield per cow, grassland management skills, access to alternative forages, EU and local government policy, milk price and market. In this paper we aim to explore the possibilities and constraints for grazing in high output systems and demonstrate that grazing can have a positive role in those systems.

Definition of high-output systems and grass-based systems

High output can be high output per cow or high output per hectare (ha). Legislation, including previous EU milk quotas, and restrictions on nitrogen (N) and phosphorus (P) use have resulted in many farmers opting for high output per cow. Maximising profit from the farm is the farmer's ultimate goal, therefore considering output from the total farm unit may be the most appropriate measure of productivity. In high output systems the focus must be on output per ha (or per farm) rather than output on an individual cow basis. Focussing on high output per ha (or farm) ensures maximum use of the resources available on farm. In a meta-analysis, McCarthy *et al.* (2011) found that as stocking rate increased on dairy farms, milk output per cow decreased by approximately 8% but milk output per hectare increased by about 20%. For the purposes of this paper, high output is considered to be on a per hectare basis.

In this paper, grass-based systems refer to systems where the diet of the dairy cow is mainly based on grazed grass, with grass silage the primary winter feed and also available for supplementing grazed grass during the grazing season.

Constraints to maximising grazed grass in the annual dairy cow feed budget

While this section of the paper deals with constraints, both real and perceived, to grazing in high output systems, it also includes some options to overcome or partially overcome some of those constraints.

Constraints: grass growth and quality

In European countries where grazed grass contributes to dairy cow diets there is a large variation in herbage production (Huyghe *et al.*, 2014) both within and between years (Hurtado-Uria *et al.*, 2013). Grass growth is influenced by many factors, some are within the farmers control (e.g. fertiliser application, grazing intensity, rotation length, etc.), and others are beyond the farmers control (e.g. temperature, rainfall, solar radiation, soil type, etc.). As a result of these factors grass availability is somewhat variable and difficult to forecast. A key issue for many is the lack of control over feed quality and availability associated with grazing (Dillon *et al.*, 2005). Consistency in feed supply and quality is desirable in high output systems. However, grass can still contribute to the feed budget when it is well managed and through the integration of buffer feeding and supplementation during periods of deficit it can be an extremely stable part of the overall cow diet. When available, grazed grass is a higher quality feed than grass silage for milk production. Management can be adapted to optimise grass supply and quality, and ensure it contributes significantly to the feed budget in high output systems.

Constraints: plant animal interaction

The key focus of grazing systems centres on the grass-animal interaction. It is at this level that the costs associated with grazed grass can increase or decrease dramatically depending on grass utilisation and animal performance. Within high output systems the interaction between the animal and the sward is challenging for a whole host of different reasons, including herbage dry matter intake (DMI) and milk production potential, substitution rate, grass allowance, etc., which often means that grass growth and utilisation are not optimised (Peyraud and Delagarde, 2011). In grass-based systems, the level of grazing intensity has a direct influence on grass utilised and grass quality, and ultimately performance per ha (McCarthy *et al.*, 2013; McMeekan and Walsh, 1963). The most limiting factor for milk production in grass-based systems is herbage DMI. The feed requirements of high genetic-merit cows cannot be met solely by grazed grass and so the quantity of other feed stuffs increases. Often, producers feel they have more control of the cows' diet when feeding total mixed ration (TMR) and purchased feed stuffs and they are not confident of the feed value of their grass. Kolver and Muller (1998) reported that grass-fed cows have lower feed efficiency than indoor-fed cows due to limited energy intake on grass. Kolver and Muller (1998) also found that high genetic-merit dairy cows produced less milk from grazed grass than when feed indoors on a TMR (29.6 and 44.1 kg milk cow^{-1} day^{-1}, respectively). Van Vuuren and Van den Pol-van Dasselaar (2006) calculated that when fed on a grass-only diet, the DMI can satisfy the maintenance requirements of the dairy cow and milk production of 22 to 28 kg cow^{-1} day^{-1}. Fluctuating grass supply and quality can affect animal performance, and this is something that generally does not appeal to farmers (Peyraud and Delagarde, 2011).

Constraints: cow type

Fertility is one of the main issues impacting on animal production and farm profit across Europe. In intensive grass-based ruminant production systems requiring seasonal calving good reproductive performance is essential (Shalloo *et al.*, 2014). There is strong evidence that animals selected based on high concentrate diets with little focus on fertility have poorer reproductive efficiency and cannot express full genetic potential for milk yield in a grass-based environment (Buckley *et al.*, 2005; Macdonald *et al.*, 2005; McCarthy *et al.*, 2007). Although high genetic-merit dairy cows cannot fully express their milk potential on grass-only diets, Buckley *et al.* (2000) found that cows could produce up to 7,000 kg milk cow^{-1} yr^{-1} on a well-managed grass-based system.

The animal required for efficient grass-based production systems must be robust and 'easy care', as well as being capable of high levels of performance from grazed pasture. Suitable breeds/strains are adapted to achieving a large intake of forage relative to their potential milk yield, are fertile and healthy; have good conformation to walk long distances and high survivability (Buckley *et al.*, 2005; Dillon *et al.*, 2007). Ideally for a grass-based system, dairy cows will calve early in spring every year and then immediately go to grass, thereby resulting in the best fit between grass supply and feed demand. Large differences in performance (especially in relation to fertility and survival) and overall farm profitability occur between divergent strains/breeds of dairy cows on a grass-based system when compared to a high concentrate system (Dillon *et al.*, 2007; McCarty *et al.*, 2007). Crossing the Holstein-Friesian with an alternative dairy breed sire (e.g. Normande in France, Jersey or Norwegian Red in Ireland) can provide producers with an alternative to increase overall animal performance by increasing herd health, fertility and milk value through hybrid vigour (Lopez-Villalobos, 1998; Prendiville *et al.,* 2011; Delaby *et al.*, 2014).

Constraints: grazing management skills

Specific skills are required for managing grass-based systems. These include cow breeding management, grassland management and feed budgeting skills. Cow breeding management is hugely important as grass-based systems are best suited to compact seasonal (spring) calving to match feed demand to grass supply. The breeding period must be short to achieve a compact calving pattern and heat detection and management of cow body-condition score at key times during the year (e.g. dry-off, calving, post-calving, breeding) are crucial to ensure a high submission rate and a high in-calf rate in a short breeding season (10-13 weeks). That said, seasonal-calving systems do not suit all situations in Europe, for example many north-western European grazing systems use year-round calving.

Grazing management is often perceived as complicated and uncertain. While that is partially true, it is certainly possible to manage grazing. For example, in some regions of Europe lack of rainfall in summer and high temperatures result in little or no summer grass growth, and this means that grazing is not possible. However, grazing in spring and autumn is still possible with good management. In some European countries grazing management skills have been lost to a large extent, primarily due to the increased emphasis on high-input systems. However, in regions of Europe where there is increased interest in grazing, existing technologies such as those mentioned above can be adapted. For example, Ireland adapted the spring rotation planner from New Zealand, and the Netherlands introduced the FarmWalk to more than 500 dairy farmers in 2014 and is aiming to introduce it to more than 1000 dairy farmers in 2015.

Constraints: technology

The role of technology in milk-production systems is increasing. The single greatest technological advance in milk-production systems is the automatic milking system (AMS) which automates the most labour-intensive aspect of the milk-production systems (O'Donovan *et al.*, 2008) and offers advantages in terms of lifestyle. Traditionally, the main markets for AMS have been in countries with high-yielding cows, high milk prices, high labour costs and indoor feeding systems (Lind *et al.*, 2000). In recent times, with technological advances and reduced equipment costs, there is an increasing trend in the use of AMS across Europe. However, generally as AMS increases, grazing decreases, and indoor feeding systems are common place (Van den Pol-van Dasselaar *et al.*, 2012). With the reduction or loss of grazing the benefits of grass in the dairy cow diet, as discussed later in this paper, are also lost. In New Zealand, Jago and Burke (2010) found that AMS can be successfully integrated with grazing and that the fundamental requirements of profitable grass-based systems do not have to be compromised through the introduction of AMS. Jago and Burke (2010) suggest that some compromise between production per cow and per ha might be required, i.e. production per cow might be reduced by introducing more cows to ensure maximum production per milking unit but production per ha will be increased. The FP7-funded AutoGrassMilk Project is examining the opportunities for incorporating AMS with grass-based systems in Europe. For some European countries, e.g. Sweden, Denmark and the Netherlands, that means introducing grazed grass to cows on the AMS and for others, such as Ireland, it means introducing the AMS to grass-based systems.

Constraints: scale and fragmentation

As Europe transitions to a non-milk quota situation, increasing scale, or herd size, will probably lead to a trend towards a reduction in the overall levels of grazing, thus requiring very clear strategies to increase the levels of grazed grass in the diet of dairy cows through the integration of grassland measurement and budgeting within the everyday grassland-management practices at farm level. Fragmentation of farms is a huge issue across Europe in terms of grass-based milk production. In essence, the size of the block of land around the milking parlour, or within walking distance of the milking parlour, dictates the quantity of grazed grass available for the dairy cow herd. In general, maize, grass silage and other crops should be grown on blocks of land away from the milking parlour, and similarly young stock should be reared on outside land blocks.

Across northern Europe there is an increasing trend in the amalgamation of dairy farms. Usually cows are grouped together at one site to improve efficiencies around milking and labour use. Farmers also hope to achieve economies of scale and increased production efficiency. In some instances, when farms are adjacent to each other, the grazing area is increased for grazing herds. However, in many instances the amount of grazing ground is reduced for the amalgamated herd, resulting in reduced grazing and grazing-season length, as some of the land is not accessible for grazing. In those cases indoor feeding increases and sometimes zero grazing is practised – fresh grass harvested and fed indoors. The N-surplus also increases as grazing pressure on the available grazing land increases. This type of system results in more machinery, more time feeding and overall less efficiency.

Possibilities to increase grazed grass in the annual dairy cow feed budget

There are many possibilities for, and advantages to, grazing in high-output systems. It may be necessary to supplement grazed grass with other feed stuffs, but with strategic management, grazed grass can significantly contribute to the diet of dairy cows in high-output systems. Well managed grass has a high nutritive value and can meet feed requirements particularly in spring, summer and early autumn. Adaptation of grazing management can also allow grazed grass to make a significant contribution to dairy cow diets. Possibilities for grazing in high-output systems include economic, milk quality, environmental, animal welfare and labour-efficiency benefits.

Possibilities: economic and labour efficiency

Since the reduction in market support at EU level, European milk production is more exposed to the volatility of the world market. Milk price volatility will remain for the foreseeable future and is probably one of the biggest challenges for European dairy farmers. Economic efficiency is defined as maximising the returns from a fixed set of resources, e.g. land, labour and capital (McInerney, 2000). In dairy production systems, land is an important fixed resource. The farmer has a choice in terms of the production system he adapts based on land availability. For grazing, especially the land availability around the milking parlour, is particularly important. Many studies show that grazed grass is the lowest-cost feed for milk production (e.g. Dillon *et al.*, 2005; Finneran *et al.*, 2012). As grazed grass is a natural TMR (it contains fibre, protein, energy, minerals, etc.), incorporating grazed grass into dairy cow diets has the potential to significantly contribute to the economic sustainability of milk production systems and can reduce production costs; particularly around purchased feed and conserved forage, but not exclusively. 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). 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.* (2014b) showed that the economic benefit of grazing in the Netherlands depends on the fresh grass intake of grazing dairy cows (Figure 2). Grazing is financially attractive if the grass intake is higher than 600 kg DM cow^{-1} yr^{-1}. If the intake of fresh grass falls below this threshold, then grazing is less profitable than keeping the cows in the barn.

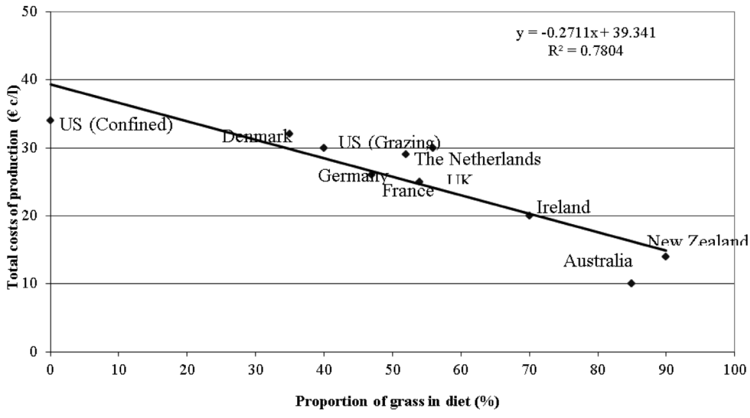

Figure 1. Relationship between total costs of production and proportion of grass in the diet of dairy cows (Dillon *et al.*, 2005).

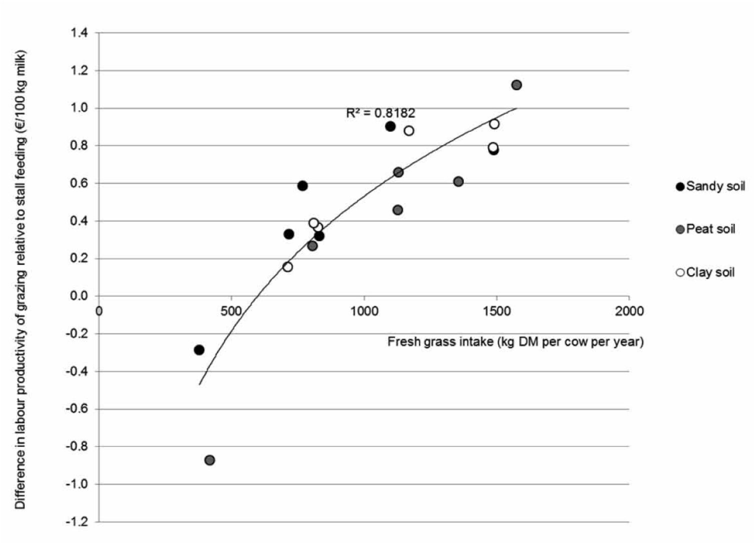

Figure 2. Income from grazing minus income with summer feeding (silage in the barn) relative to the quantity of fresh grass (kg dry matter (DM) intake per cow per year) for three soil types in the Netherlands as simulated by the whole farm model DairyWise. Positive numbers indicate an economic advantage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

Labour is a high cost in any dairy production system, and the availability of skilled labour is a concern for producers. There is a perception that grass-based systems are labour intensive. In fact, labour is different and differently spread across the year depending on the calving pattern and the reproductive season length. In countries where milk producers aim to take advantage of grass supply and where compact calving practised, the labour demand around calving and breeding tends to be concentrated into a short period of the year, generally spring and early summer. Hofstetter *et al.* (2014) reported that grass-fed dairy cows had significantly shorter calving intervals, empty time and time from calving to first service compared to cows fed indoors. Year-round calving, and therefore year-round breeding, is dominant in indoor feeding systems and also in part-time grazing situations in many north-western European countries. Geary *et al.* (2014) reported that spring-calving grass-based systems had higher net profit per farm than less-seasonal calving systems, due to lower labour demand. The effect of grazing on labour in year-round calving systems is highly variable. In theory, grazing leads to fewer labour hours, since the cows fetch their feed themselves and they transport the manure to the field. However, grazing dairy farmers sometimes report peaks in daily labour needed for fetching the cows to the milking parlour.

Other economic and labour efficiency advantages of grazing include reduced reseeding costs (reseeding of grass pastures is not necessary on an annual basis), reduced costs for mechanically harvesting of grass and spreading of slurry, and less feed storage and slurry storage costs.

Possibilities: environmental

One of the key challenges facing agriculture today centres on the requirement to reduce environmental losses and impacts. Many studies have been undertaken at country level examining the implications of different production systems on greenhouse gas (GHG) emissions (Casey and Holden, 2005; Schils *et al.*, 2005; O'Brien *et al.*, 2012), eutrophication (Basset-Mens *et al.*, 2009; Benoit and Simon, 2004; Benoit *et al.*, 1995; Briggs and Courtney, 1989) and biodiversity (Atkinson *et al.*, 2005; McMahon *et al.*, 2010; Nitsch *et al.*, 2012; Taube *et al.*, 2014). While all studies use different methodologies and are therefore difficult to compare directly, one key conclusion is evident across all: increasing resource-use efficiency is associated with increased environmental sustainability. Generally, grass-based systems are more resource efficient as they use home-grown feed stuffs and minimise the requirements for purchased feedstuffs and therefore the resources (area, energy, machinery) associated with those feedstuffs. Total consumption of non-renewable energy is reduced in grass-based systems compared to indoor systems (Le Gall *et al.*, 2009).

It is well accepted that there is a high N surplus in grazed grassland due to N fertiliser use, N fixation by legumes when present, and urine and faecal deposition by grazing livestock. However, permanent grassland acts as a store for N (Brogan, 1966; O'Connell *et al.*, 2003), lowering the risk of N loss to water. In long-term productive grassland soils there is usually net N mineralisation (Jarvis and Oenema, 2000). Recently, McCarthy *et al.* (in press) showed that increasing stocking rate, while keeping concentrate input and fertiliser N input constant, increased the N-use efficiency and reduced surplus N in grass-based milk production systems due to increased grass utilisation. Grassland has a high capacity to capture N, as grass is present year-round and grass is actively growing for a large part of the year (7 to 10 months). However, with very high stocking rates or in overgrazed situations, N losses can be high because faeces and urine are not evenly distributed over the field during grazing. This leads to more N leaching, more denitrification and more nitrous oxide emissions. Ammonia volatilisation, on the other hand, is less during grazing. Permanent grassland is ploughed infrequently, thereby minimising N loss from cultivation. Minimum tillage options for reseeding minimise soil disturbance and therefore minimise N and C loss (Del Prado *et al.,* 2014). Reseeding or renewing grassland ensures that there are productive species in the sward which are fast growing and can maximise N utilisation.

Wims *et al.* (2010) demonstrated that feeding lactating dairy cows on high quality low herbage mass swards can reduce CH_4 emissions per cow per day (282 g CH_4 cow^{-1} day^{-1}) and per kg milk solids (MS) produced (203 g CH_4 kg MS^{-1}) compared to cows grazing high herbage mass swards with lower quality (+21 g CH_4 cow^{-1} day^{-1} and +26 g CH_4 kg MS^{-1}) obtained through a higher regrowth period.

Grassland soils and associated vegetation are an important sink for C, particularly in the form of soil organic C (Peeters and Hopkins, 2010). Increasing the area of long-term grassland by reducing short term leys, arable crops and maize can increase C sequestration, as can maintaining existing permanent grassland, particularly on peat soils (Freibauer *et al.*, 2004).

Possibilities: milk quality and food safety

Animal nutrition affects the quality and nutritional value of dairy products (Downey and Doyle, 2007). The diet of ruminant animals can affect the taste and the chemical composition of the product produced (Hopkins and Holz, 2006). Coakley *et al.* (2007), Wyss *et al.* (2010) and Butler *et al.* (2011) all report increased levels of the unsaturated fatty acids, conjugated linoleic acids, vaccenic acid, and omega-3 fatty acids in milk from cows fed predominantly on grazed grass compared to other diets, including grass silage and concentrate-based diets. Unsaturated fatty acids are believed to be better for human health. Milk from cows on largely grass diets is higher in vitamins A and E than from other cow diets (Martin *et al.*, 2004). Milk processors are increasingly aware of the health benefits of grass-fed milk and use it as part of their marketing campaigns (e.g. http://www.kerrygold.com/advertising).

Food safety is of increasing concern as the food supply chain lengthens. As the length of the food chain increases, the sharing of knowledge, trust and understanding between farmers, processors, retailers and consumers declines and ultimately ceases. A large proportion of raw materials for animal feeds come from outside the EU. Maximising the quantity of grazed grass and home-produced grass silage or hay in the diet of dairy cows reduces the requirement for purchased feed.

European consumers have concerns about food quality and safety and tend to view grass-based milk production systems being as sustainable, safe and delivering high quality products and multiple ecosystem services (Van den Pol-van Dasselaar *et al.*, 2014a). They associate milk production with cows grazing in green fields. They consider these to be natural and local production systems. Citizens mention that they are prepared to pay for milk from grass-based production systems, but dairy companies often indicate that it is difficult to get the associated money from the market. In some European countries, such as the Netherlands, a so-called grazing premium is available to producers who allow their animals access to grazed grass.

Possibilities: animal welfare

There is a general perception that the welfare of grazing animals is better than that of housed animals or animals on intensive feed lots. Animal welfare includes the possibility to express natural behaviour and animal health. Grazing animals generally are not restricted in terms of space and have free access to exercise and for roaming. Allowing animals to graze outdoors in groups permits social contact and allows the selection of the hierarchy of the herd. In general, in grazing situations animals can express their natural behaviour better than in situations of indoor feeding. Grazing has advantages and disadvantages with respect to animal health, but in general the advantages are seen as more important. They mainly focus on claw health and udder health. Leaver *et al.* (1988) reported that the prevalence of lameness is low during the grazing period. Olmos *et al.* (2007) found that pasture-based dairy cows had reduced lameness and better locomotive ability and also had a greater opportunity for uninterrupted lying time compared to housed dairy cows. Benefits of grass-based systems in terms of lameness must be considered with caution as in certain circumstances, such as when cow tracks are not maintained in grass-based production systems, incidence of lameness can still be high (Lean *et al.*, 2008). Washburn *et al.* (2002) reported that there are several examples in the literature showing that access to pasture can improve aspects of cow health such as mastitis.

Possibilities: grazing management

Technologies such as the Grass Wedge (Teagasc, 2009), Herb'aVenir (Defrance *et al.*, 2005) or Pâtur'Plan (Delaby *et al.*, this volume) facilitate grassland management and allow the anticipation of the availability of grass for grazing. In the Netherlands, these technologies have been incorporated in the FarmWalks where 5-10% of the dairy farmers jointly learn about grazing management. Grassland management skills can be learned, but require regular practice and it can take time to be entirely comfortable with the measurements and trust the measurements. Grassland management tools such as the spring rotation planner, the grass wedge and autumn budgeting combined with a weekly farm cover measurement (www.teagasc.ie) provide the farmer with reliable information with which to make decisions around managing surpluses and deficits in grass supply, feeding, supplementation, and fertiliser. Farmer discussion groups can help farmers learn the required grassland management and budgeting skills through mentoring and peer support.

Every farm can incorporate grazed grass into the diet of dairy cows through different management strategies. For example, when there is limited land area available, or when soil or weather conditions are poor, restricted access to grazing can be practised (Pérez-Ramírez *et al.*, 2008; Kennedy *et al.*, 2009; Kennedy *et al.*, 2014). This management approach involves turning cows out to grass for a fixed period of time each day. Kennedy *et al.* (2009) showed that in spring, dairy cows achieved 90% of their daily grass DMI when provided with access to grass for three hours after morning and evening milking, and milk production was not reduced compared to cows that were fulltime grazing. Similarly in autumn, Kennedy *et al.* (2014) found no negative effects of restricted access to grass for cows in late lactation. In France, Pérez-Ramírez *et al.* (2008) reported that restricting access time to pasture reduced milk yield and composition in spring and early summer. Grass-clover swards offer benefits in terms of extending regrowth period, particularly in periods of low or no grass growth due to low rainfall and high temperature (Lüscher *et al.*, 2014). In areas with low summer growth, it is worth considering altering the calving pattern to match feed demand with grass growth. One possible strategy is to have two compact-calving periods, one in spring and one in autumn; this will allow the herd to maximise the amount of grass converted to milk (Delaby and Fiorelli, 2014).

New technologies are continuously being developed and new grassland Decision Support Tools (DSTs) such as the Grasshopper described by MacSweeney *et al.* (2014), cow sensors (Ipema *et al.*, 2014) and virtual fencing (MacSweeney *et al.*, 2014) will assist farmers in accurately allocating herbage to grazing dairy cows. These tools are also likely to increase farmers' confidence when it comes to grazing management and herbage allocation (Delaby *et al.*, this volume). The increase in accuracy and availability of precision technologies increases the potential integration of precision grazing into grass-based systems through the replacement of some of the skills required for optimised grazing management.

Conclusions

Although there are many constraints to grazing in Europe, there are many possibilities to overcome those constraints. Adapting existing grassland management tools from countries with grass-based milk production systems will help improve the management of grazing systems. New and evolving technologies will also have a role to play in incorporating grazing into high-output milk production systems. Adapting the herd in terms of breeding and calving period can also increase the role that grazed grass plays in the diet of dairy cows in high-output systems. Maximising the utilisation of grazed grass in all systems will increase the sustainability of high-output dairy systems.

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