Production potential of grassland and fodder crops in high-output systems in the Low Countries in north western Europe and how to deal with limiting factors

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Abstract

The farming community currently growing fodder crops and grassland in areas with intensive dairy production in the EU is confronted with opportunities and threats related to (1) characteristics of cropping systems, (2) scientific and technological developments, (3) tightening of regulations, (4) scarcity of land and restricted freedom of use of the land, (5) changing climate and (6) changes in consumer attitudes and behaviour. Using highly productive varieties in appropriate crop rotations, and applying good agricultural practices, offers opportunities for reducing environmental impacts hence proactively preventing further strengthening of the regulations. The scarcity of land in densely populated areas and ongoing restrictions on the freedom to use the land are confronting intensive dairy farmers with problems for which technical solutions may not bring relief. The decreasing consumption of animal products in the developed world may change land use in the future.

Keywords: cropping systems, grassland, silage maize, regulations, land-use change

Introduction and scope of the paper

This text focuses on intensive dairy production systems in the Low Countries, in the coastal region in north-western Europe, where both herbage and forage crops (with a focus on silage maize) are used in animal rations. The area dedicated to grass or to silage maize is closely related to regulations regarding fertilisation: while regulations in the Netherlands are favouring grassland, this is not the case in Belgium. We report on optimising crop production within a context of regulations that continue to limit inputs by addressing the questions: 'How to enhance efficiency, nutrient-use efficiency and eco-efficiency in forage crop production?' Several technical and managerial options that influence the course of the production curve of grasses and silage maize are considered. Production curves can be taken to a higher level or their slope can change, e.g. by plant breeding and by good agronomic practices (Figure 1). Improved efficiencies result in reduced use of inputs, in producing more with equal amounts of inputs, or in producing with reduced levels of emissions. Legumes are mentioned here only briefly, as they have been addressed in recent EGF meetings. Potential effects of climate change and consumers' attitudes are intertwined where appropriate. No economic considerations are made.

Cropping systems: monocropping versus crop rotation

Intensive dairy farms in the lowlands of north-western Europe are predominantly dependent on two crops: grass and a cereal as an energy-supplying crop. Silage maize is the most important energy provider wherever the climate is favourable for its cultivation. The ratio of maize to grass silage in the rations supplied on farms with high milk production in the northern part of Belgium (Flanders) is about 60/40 from October to the end of April, whereas the ratio of silage maize to grass (grazed + conserved) is about 50/50 from May until the end of September. The high interest in silage maize is related to the high energy content of the crop, which has substantially increased during the past decades. Indeed, compared to varieties grown around the year 2000, the newest varieties have a starch content in the dry matter (DM) that is about 20% higher, varying between 35 and 40% of the dry matter (data extracted from the Belgian Variety Catalogue Trials).

Silage maize is grown in a very tight crop rotation or in monocropping on many farms, which provides a very convenient cropping system in terms of economy and labour organisation (Van Eekeren *et al.*, 2008). Until recently many intensive dairy farms only had two crops: grass and silage maize, the latter frequently grown in monocropping. Nutrient regulations are tending to move the actual production away from the potential production. Given the shape of production functions, crops consequently become more sensitive to fluctuating environmental conditions and it is no longer an option to mimic or to restore bad agricultural practices by using extra inputs (Hanegraaf *et al.,* 2009; Nevens and Reheul, 2003; Smith *et al.*, 2007). There are more reasons to reconsider the cropping system. Simple repetitive agricultural practices such as monocropping favour weeds closely related to the crop (Murphy and Lemerle, 2006). The stable environment allows easy adaptation of the weeds to the control strategies (Harker, 2013). Maize monocropping entailed flora and weed shifts from broad-leaved weeds to panicoid grasses and favoured the development of herbicide-resistant biotypes of several weed species, e.g. the dicot species *Chenopodium album* and *Solanum nigrum* which became resistant to atrazine in the mid-1980s. Maize weed flora shifted from an easily controllable, species-rich well-balanced flora to a less easily controllable, unstable species-poor flora dominated by panicoid grasses in the years after 2010. Panicoid species such as *Echinochloa crus-galli, E. muricata, Digitaria ischaemum, D. sanguinalis, D. aequiglumis*, *Setaria viridis, S. verticillata, S. faberi, S. pumila, Panicum dichotomiflorum, P. schinzii and P. capillare* are currently spreading quickly within Belgian maize fields or are forming growing naturalized populations outside the fields (Groom, 2011; Hoste and Verloove, 2011; Van Landuyt *et al.*, 2006). According to Claerhout *et al.* (2015) weed populations from maize monocropping systems were consistently less sensitive (up to 14%) to foliar-applied maize herbicides than populations from cropping systems with maize in crop rotation.

Furthermore, crop rotation offers opportunities to fight some expanding pests (such as different species of soil nematodes and western corn rootworm, *Diabrotica virgifera virgifera*). It allows a more sustainable soil management (Lal, 2008, 2009), in particular a better management of soil organic matter and of nutrient dynamics (Kayser *et al.*, 2008; 2010; Spiertz, 2010; Thorup-Kristensen, 2006; Thorup-Kristensen *et al.*, 2012). The crop diversification topic within the greening of the Common Agricultural Policy (CAP) (2014-2020) may be considered as an incentive to focus on the value of crop rotations, although several scholars consider the new CAP as likely to be far too weak to result in any long-term provision of ecosystem services (Pe'er *et al.*, 2014).

Nevens and Reheul (2002b) compared silage maize grown in a 3-year rotation cycle (in the sequence of fodder beet, maize, faba bean and also in a sequence of fodder beet, maize, maize) with maize grown in monocropping during a period of over 10 years on a soil classified as silt loam (USDA soil texture classification) in Belgium. Crops were grown either on arable land continuously cropped with annual crops or in a ley-arable system (3 years grassland followed by 3 years arable land) and fertilised at different N levels. When grown on arable land continuously cropped with annual crops, maize in rotation outyielded maize in monocropping significantly in 80% of cases. The yield bonus (both DM yield and N-yield) was not significant at 180 kg N ha^{-1}, but was approximately 25% (and significant) at 75 kg N ha^{-1}. The effect on DM-yield of the crop rotation was marginal in the ley arable system (Figure 1).

The nitrogen dynamics in crop rotations and in ley-arable systems are modelled in Vertès and Mary (2007) and experimentally quantified in (1) Vertès *et al.* (2007), (2) Nevens (2003) and Bommelé (2007), reporting data from sandy loam soils in Belgium, and (3) more recently in Verloop (2013) reporting data

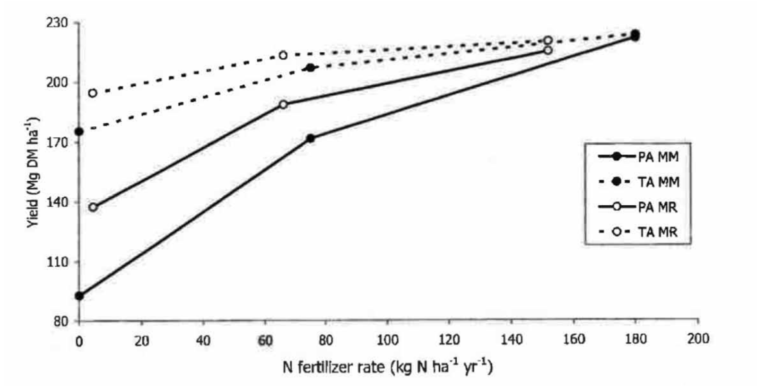

Figure 1. Yield of silage maize in relationship to nitrogen fertilisation. MM: maize in monocropping, MR: maize in crop rotation; PA: arable land continuously cropped with annual crops; TA: ley-arable system (3 years arable followed by 3 years ley or *vice versa*).

from sandy soils on the experimental farm The Marke in the Netherlands. The latter found no evidence for enhanced nitrate leaching due to the rotation of grass with silage maize compared to permanent cultivation, provided N fertilisation to the crops in the arable phase is adjusted. On the sandy loam soils in Belgium, the opening crop after the break-up of grassland did not need any N to produce a full yield. If maize was the opening crop, a cover crop was necessary to take up the residual mineralised N.

The inclusion of fodder beet in the crop rotation was very favourable for the environment, since this crop depleted the soil very effectively resulting in residual mineral soil nitrogen of less than 50 kg N ha^{-1} in a soil profile of 0-90 cm irrespective of the applied N fertilization. Carlier and Verbruggen (1992) studied nitrogen balances on 61 Flemish dairy farms and concluded that the farms that produced fodder beet had by far the lowest nitrogen surplus at the farm level. Growing fodder beet continues to be a challenge, although some of the drawbacks are more manageable than in the past decades. The more frequent occurrence of mild winters in the Low Countries may facilitate conservation of the fresh beets. Co-ensiling of ground beets with silage maize may take away the concerns regarding storage as fresh beets over winter, but it requires a good match of the harvest of both crops. Performances of dairy cows fed with this forage stay at very high levels provided the proportion of fodder beet in the silage is approximately 25% (on a DM basis) and soil contamination is low (De Brabander *et al.,* 1989). The techniques used to clean sugar beets can be used to remove most of the soil. However, the prospects for growing fodder beet in a crop rotation may be hampered by the rapid spread of *Rhizoctonia solani*, which is infecting fodder and sugar beet as well as maize and ryegrasses (Heremans *et al.*, 2007). We observed very important losses during winter conservation of fodder beets, produced in a long-term field trial at the University of Gent with a 4-year crop rotation: fodder beet – silage maize – Brussels sprouts – potato followed by Italian ryegrass as a cover crop (D'hose *et al.*, 2012) and we concluded that without using a *Rhizoctonia*-resistant variety, growing fodder beet in this rotation has no further value. These observations are supported by many experiences from practice, indicating that losses during conservation are frequently unacceptably high without *Rhizoctonia*-resistant cultivars. Currently, there are only a few *Rhizoctonia solani*-resistant varieties of fodder beet available in Europe.

Borelli *et al.* (2014) reported results of several cropping systems over a 26-year period on a sandy-loam soil in the lowlands of the Po Valley of northern Italy. Silage maize was tested in rotation cycles of 3 and 6 years with Italian ryegrass, grain maize, winter barley and ley. Crops were managed (1) either following farmers' practices or (2) with 30% less mineral inputs and 25% less herbicide inputs. The most important conclusion of the experiment was that year-to-year variability was overwhelming compared to the effect of the treatments and that the effects of crop rotation and input were more pronounced in low-yielding years. They concluded that the rotation effect can compensate for a reduced input and that the adoption of rotation can be regarded as an insurance against low-yielding years; in other words, crop rotation improved yield stability: the longer the rotation, the better the yield stability, which is an important issue given climate change.

Nitrogen export and recovery

Nevens and Reheul (2002a,b) showed that N-export improved substantially in rotated maize (fodder beet, maize, maize) compared to maize in monocropping at equal N dressings. Rotated maize grown on permanent arable land with an N dressing of 180 kg ha^{-1} exported 7% more nitrogen than the maize in monocropping; at 75 kg ha^{-1} the bonus was 27%. In a ley-arable system, the surpluses were 5 and 7%, respectively.

Moreover, plant breeding may help to recover nutrients in different ways. Plant breeding continues to create silage maize varieties with a higher DM yield without the need for enhanced nutrient inputs. If the nutrient concentration does not decrease substantially, this must lead to a better nutrient productivity (DM yield per supplied quantity of nutrients) and smaller residues after harvest. Can we quantify this effect? Long-term analyses of the genetic progress in silage maize varieties show a more or less steady annual progress in DM yield of approximately 200 kg ha^{-1} during the period 1983-2012 (Laidig *et al.*, 2014; Piepho *et al.*, 2014; unpublished data of the analysis of the Belgian Variety Catalogue Trials). There are no signals that this progress is slowing down in forthcoming European varieties. According to silage maize breeders, there are no indications that these yield progresses come along with a dilution of nitrogen in the DM, but we have not found results of trials comparing old and new varieties at different N-levels. Analyses of maize silage in the Netherlands (BLGG, Wageningen) showed nearly constant total crude protein mean values in the period 2009-2011 and lower mean values in the period 2012-2014, but it is impossible to split genetic effects and non-genetic effects in these data. Nevens and Reheul (2002b) showed that nitrogen concentration in the DM increased with N fertilisation, and Wachendorf *et al.* (2006a) calculated this increase as 0.04 g (kg DM)$^{-1}$ per kg supplied N (within a range of 0-150 kg ha^{-1}). Barrière *et al.* (1997) found a negative correlation (r =-0.45) between N-content and biomass yield in 126 early hybrids in France. Experiences with grasses make us assume that the highest yielding varieties have a lower N concentration in the DM (although this decrease tends to become lower at high yield levels), but continue to have a higher N-yield (Figure 2). Trying to quantify this effect in silage maize, we come to the following speculative calculation. Assuming that varieties of a decade ago had a yield potential of 18 Mg DM ha^{-1} and current varieties have 20 Mg DM ha^{-1}, and also assuming an unchanged N concentration (1.2%), current varieties would export 24 kg N ha^{-1} more than varieties did a decade ago. If the actual N concentration is 5% points lower than before then the benefit would shrink to 12 kg ha^{-1}, and the benefit would disappear if the N concentration were to be 10% points less. So benefits

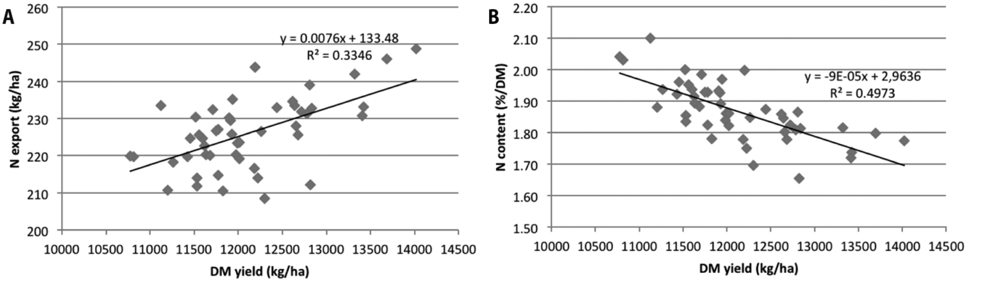

Figure 2. Relationship between N-content (A), N-export (B) and dry matter (DM) yield in 48 varieties and candivars of perennial ryegrass grown on a sandy loam soil in Belgium under a cutting regime; N-dressing: 260 kg ha^{-1} yr^{-1}. Data taken from the first year after the year of establishment.

are not miraculous but most probably non-negligible in soil nitrogen balances. The translation of this potential benefit into practice may be variable since Laidig *et al.* (2014) reported that only part of (if any) the genetic progress was capitalized in practice, proving that without good farming practices, genetic gains are not fully discounted. Or to turn it around: it takes good farming husbandry to benefit from breeding progress.

The role of catch crops is essential to reduce nutrient losses in all cropping systems. Cover crops need to be sown early in order to be effective. Schröder *et al.* (1996) and Schröder (1998) regressed the N-uptake by winter rye sown after the harvest of silage maize or Italian ryegrass undersown in the maize on the temperature sum (threshold 5 °C) starting from the sowing date (winter rye) or harvest of the maize. It took about 7 day×degrees to take up 1 kg N ha^{-1}, reflecting that in Dutch conditions a day in mid-September offers the opportunity to recover about 2 kg N ha^{-1}. Well-used cover crops can reduce the residual soil mineral nitrogen by approximately 50% (Schröder *et al.*, 1998; Wachendorf *et al.*, 2006). This means that late maturing silage maize varieties do not fit into good agro-environmental practices. Since the early maturing varieties may be as much as 5-10% less productive (e.g. Belgian Variety Catalogue Trials) a yield penalty can hardly be avoided by growing early varieties. However, early varieties usually allow (1) a harvest in better weather conditions causing less damage to soil structure and (2) an earlier installation of cover crops. Although it may be hard in the short term not to grow the most productive maize varieties, the proactive implementation of good agricultural practices (such as the tandem: early maturing maize followed by an effective cover crop) may avoid further tightening of the regulations, and which can be considered as an advantage in the long term.

At least two breeding companies in the EU are developing (non-GM) herbicide-tolerant varieties of *Lolium perenne* and *Festuca arundinacea*. The idea is to sow them simultaneously with the silage maize: applied herbicides suppress the early growth (thus minimizing the competition) and the grasses start to grow vigorously immediately after the maize harvest, provided they are not severely damaged by the harvesting machines. Undersowing takes away the need for soil tillage after the maize harvest and it eliminates the risk of not being able to timely install the cover crop. A trial at Gent University compared undersown tall fescue with Italian ryegrass installed immediately after the maize harvest (23 September) in 2014. The above-ground biomass of Italian ryegrass outyielded the above-ground biomass of undersown tall fescue at the end of February 2015. The very warm autumn of 2014 may have taken away the potential advantage of undersowing. There is a need for more research regarding the use of appropriate herbicides in order to find an equilibrium between suppressed early growth, competition with the silage maize and a quick recovery after the maize harvest.

Breaking-up of grassland

We are convinced that good grassland should be extremely well taken care of in order to keep it in good shape for as long as possible. Only if the botanical composition no longer allows high yields should break-up of the sward be considered. The newest CAP regulations have made it very difficult to break up permanent grassland. Keeping grassland in good condition is very much a management issue. The larger the herds, the more difficult it becomes to keep the grassland in good condition, either because of the heavy trampling by large groups of grazing animals or – as in case of zero grazing – the waning attention for any field activities. We have noticed during the past years that a high regional density of harvesting machines operated by professional contractors allows for quick harvests of cut grass during small windows of good weather conditions and we consider this as one of the best insurances for the persistence of productive grassland. If grassland should eventually be broken-up, it is common knowledge that spring-ploughing causes less N losses than autumn-ploughing (e.g. Schmeer, 2012) and that the older the sward, the greater its nitrogen fertilizer replacement value (NFRV). More data are provided in Nevens (2003) and Verloop (2013). We have commented in the previous section that an arable period is a good option to take advantage of the NFRV provided one takes care to ensure a near-permanent groundcover by using appropriate crops and cover crops. An underestimated problem is the potential for insect damage to the opening crop, resulting in the substantial loss of seedlings. The problem can be solved by the use of insecticides but there is a need for other options. Crops that compensate for the loss of individual plants, e.g. because the surviving plants produce extra tillers (as in the case of forage grasses and cereals) can limit the damage. Early maturing spring cereals with stiff straw allow a timely installation of a cruciferous cover crop guaranteeing a good uptake of residual nitrogen. Another option is to install annual or perennial ryegrass to be harvested as a forage in the autumn and the following spring. Kayser *et al.* (2008) ploughed up 9-year-old grassland in the spring at three locations in Germany and installed spring barley followed by yellow mustard during year 1 and silage maize in year 2, to be compared with silage maize grown during the first 2 years. The barley+cover crop reduced the soil mineral nitrogen by about 50%. Schmeer (2012) used a spring cereal as break crop in northern Germany before re-installing grassland and showed that this option reduced N leaching by 40% compared to autumn ploughing. Ansari *et al.* (2009) and Campos-Herrera and Guttiérez (2009) reported on new work regarding the use of pathogenic strains of entomopathogenic nematodes and fungi for wireworm control. The former concluded that the combined use of these biocontrol agents may prove synergistic in the control of wireworms and may offer a chemical-free approach to control this pest.

Renewing grassland offers, in theory, the opportunity to take advantage of progress in plant breeding. However, progress in grass and white clover breeding has been much smaller than in arable crops. Chaves *et al.* (2009), analysing the Belgian official variety trials in the period of 1966 to 2007, reported an annual genetic gain in DM yield of about 0.3% for both *Lolium perenne* and *Lolium multiflorum*, data that are close to the results of Laidig *et al.* (2014) based on the German official variety trials. The annual genetic progress in DM yield of white clover and red clover is similar (Annicchiarico *et al.,* 2014): about 0.5% per year. This means that in the short term no spectacular yield advances are to be expected owing to genetic progress, all the more because the capitalizing of the genetic gain of grass varieties in practice seems very inconsistent (Laidig *et al.*, 2014). In the absence of spectacular genetic gains, good agronomic practices can offer remarkable opportunities.

Reheul *et al.* (2007) and Bommelé (2007) reported substantial differences in DM yield between grassland sown after ploughed-down grassland and grassland sown on arable land. Grassland established on arable land significantly outyielded renewed grassland (means of N fertilizations of 100, 300 and 400 kg ha^{-1} yr^{-1}) during the first two years after the year of (spring) establishment. The DM yield bonus over a period of three years (the year of establishment was not included) was 10%; even at 400 kg N ha^{-1} yr^{-1} the bonus was still 5%. It was even 20% in 2003, a year with a very dry summer. In addition, the establishment of white clover was much better on arable land than in renewed grassland, most probably because of the high amounts of mineralized N after renewing: over a period of three years (year of establishment not included), white clover DM in the total DM yield was twice as high in grassland installed on arable land compared to renewed grassland (means over N rates of 0, 100, 300 and 400 kg ha^{-1}). All benefits started to fade away after the third year of establishment. Therefore, remarkable but partly unexploited benefits can be gained by installing grassland in arable land instead of resowing it. These data are valuable in the context of adaption to the effects of climate change, with a higher probability of dry summers in temperate Europe.

Growing more drought-tolerant species is another option to cope with dry periods and climate change in general. *Dactylis glomerata* and *Festuca arundinacea* (tall fescue) are promising species in this respect (Pontes *et al.,* 2007). Cougnon *et al.* (2014) studied perennial ryegrass and tall fescue in Belgium either in a single-species sward (300 kg N ha^{-1} yr^{-1}) or mixed with white clover (165 kg N ha^{-1} yr^{-1}) under a cutting regime. Over a period of three years following the year of establishment, pure swards of tall fescue outyielded pure swards of perennial ryegrass by 23%; the difference between perennial ryegrass and tall fescue increased every year, and during dry spells differences were as high as 50% (Cougnon, 2013), most probably owing to the deeper rooting of tall fescue. Since N-content of the two species was not significantly different, tall fescue showed a net higher N-productivity than perennial ryegrass. A trial studied during 2011-2014 with both tall fescue, meadow fescue, perennial ryegrass, hybrid ryegrass and *Festulolium* confirmed the high DM yield, N-export (Figure 3), N-productivity and N-recovery of tall fescue compared to the other species (Table 1). Disadvantages of the species, compared to perennial ryegrass, are the lower digestibility of the organic matter (up to 7%-units less; Cougnon *et al.*, 2014), the slow establishment and the lower animal preference. Progress in breeding for these traits probably will come at the expense of DM yield. The lower animal preference tends to disappear when the forage is wilted and ensiled (Luten and Remmelink, 1984). The lower digestibility of the organic matter is less of a problem when farms are in need of rations with a high structural value or fibre content.

Access to land

The access to land is threatened in some areas by land use changes and the operational freedom is hampered by ever increasing regulations. Land is taken out of agriculture particularly in densely populated and peri-urban areas, both for urbanization, roads and industry, as well as for non-agricultural biological production (Poelmans, 2010). The scarcity of agricultural land is leading to increased competition between farmers for the available land, thus increasing land prices.

According to Poelmans (2010) built-up areas will occupy about 15% of the territory of Belgium, the Netherlands, the northern part of France, the western part of Germany and the south of UK by 2030;

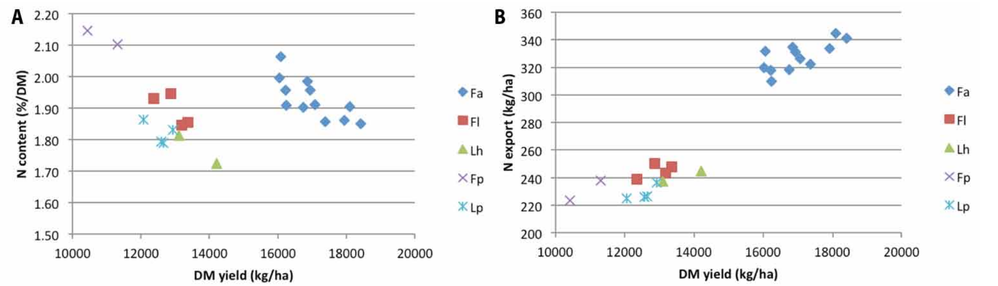

Figure 3. Relationship between N-content (A), N-export (B) and dry matter (DM) yield in five grass species grown on a sandy loam soil in Belgium. Field trial with cutting regime established in September 2011. Data taken from 2013; N-dressing: 300 kg ha^{-1} yr^{-1}. Fa: *Festuca arundinacea*, Fl: × *Festulolium*; Lh: *Lolium* × *hybridum*; Fp: *Festuca pratensis*, Lp: *Lolium perenne*.

Table 1. Dry matter (DM) yield (kg ha^{-1}), N-export (kg ha^{-1}), N-recovery (kg N exported (kg N supplied)$^{-1}$), nutrient-use efficiency (NUE) (kg DM (kg $N_{exported}$)$^{-1}$), N-productivity (kg DM (kg $N_{supplied}$)$^{-1}$) and N-content (%) for *Festuca arundinacea* (Fa), *Festulolium* (Fl) and *Lolium perenne*. Same trial as in Figure 3. Cumulative data of 10 cuts in the period 2012-2014. Standard deviations between brackets.

	300 kg N ha^{-1} yr^{-1}			190 kg N ha^{-1} yr^{-1}		
	Fa (n=12)	Fl (n=4)	Lp (n=4)	Fa (n=12)	Fl (n=4)	Lp (n=4)
DM yield	32,264 (1,333)	29,986 (1000)	28,812 (504)	25,740 (1,675)	25,465 (610)	23,282 (734)
N-export	612 (17.4)	540 (10.7)	506 (3.0)	462 (24.4)	417 (18.4)	378 (6.8)
N-recovery	1.02	0.9	0.84	1.22	1.10	0.99
NUE	53	56	57	56	61	62
N-productivity	54	50	48	68	67	61
N-content	1.90	1.80	1.76	1.79	1.64	1.62

mostly areas with an important dairy farming. Bomans *et al.* (2011) concluded that about 5% of the total area of Flanders is taken up by 'horsification', representing nearly 70,000 ha, in order to feed at least 140,000 horses. Belgium had 485,000 dairy cows in 2012 (Statbel). At least half of these 70,000 ha was former agricultural land until quite recently. One third of the Flemish pasture land is used for horses. This area is very unevenly distributed over the territory: few horses in the western part of the region, where both dairy, arable crops and vegetable production are very important, and high numbers in the province of Antwerp, also a very important dairy area. According to Van der Windt *et al.* (2007) there were about 400,000 horses in the Netherlands (occupying approximately 200,000 ha with a very strong growth in the 1990s). There were about 1.44 million dairy cows in the Netherlands in 2006 (Eurostat). Therefore, in both Belgium and the Netherlands the number of horses is at least a quarter of the number of dairy cows. A similar 'horsification' trend is found in the peri-Berlin area in Germany (Zasada *et al.*, 2013) with both extensive and intensive (up to 52 horses per ha) holdings. Horse-keeping increases land prices and creates ambivalent environmental impacts. The extensively managed holdings may be beneficial for the environment, landscape and biodiversity while intensively managed holdings are characterized by overgrazing with high loads of nutrients and detrimental consequences for the visual landscape (Zasada *et al.*, 2013).

More challenges, threats and trade-offs in intensive dairy systems

The huge imports of protein into Europe are calling, at about every 10 years, for more home-grown proteins. In the past, grass has been considered as a protein crop but the restrictions on N input may put an end to this. It is common knowledge that both DM yield and N concentration drop with decreasing N supply (as can be deduced in Table 1). The current N input on grassland under a cutting regime is set on 300-320 kg ha^{-1} plant available N in Flanders and in the Netherlands (385 kg ha^{-1} on clay soils in the Netherlands). Bommelé (2007) calculated an average N yield of 374 kg N ha^{-1} during 2002-2005 for different types of grassland – both permanent and young grassland – managed under a cutting regime with a mineral N supply of 300 kg ha^{-1}. The corresponding average DM yield was 13,754 kg ha^{-1}, resulting in a N-content of 2.72% (crude protein content of 17%.) The N-content in Table 1 is much lower (probably owing to higher yields): on average about 1.80% at 300 kg N ha^{-1}. Tighter restrictions may further decrease the N yield and concentration, resulting in grass with rather low contents of crude protein (on average 11.3% protein at 300 kg N ha^{-1} and 10.5% crude protein at 190 kg N ha^{-1}: Table 1) and hence a growing need to supply more non-grass protein. If grass has to be considered as a protein crop, the use of sufficient nitrogen is crucial. There is ample organic N available on dairy farms but its use is limited to 170 kg ha^{-1} in Belgium and the Netherlands. In cases where derogation (coupled with a number of restrictions on land use, cover crops and mineral P-fertilisation) is allowed, up to 230-250 kg ha^{-1} slurry N is allowed. The derogation is crucial under the high-output system: without derogation, both grazing and on-farm nutrient recycling come under pressure. A good recycling allows more farm-produced protein (particularly with grass), thus restricting the import of non-farm protein.

Westhoek *et al.* (2011) provide an excellent overview of the protein puzzle. In line with the CAP reform 2014-2020 many member states are supporting protein crops from 2015 on. Protein crops fit into two parts of the new regulation: they can figure as a third crop and they are eligible in the frame of Ecological Focus Area. As a consequence, the fading production of peas, faba beans and lucerne may resume. The grain legumes all have at least one constant when grown in temperate areas: the yield stability cannot compete with the stability provided by grassland and silage maize. Recently new initiatives are being taken to breed and to grow soybeans in areas where this crop has never been considered before. Preliminary results clearly show that opportunities are limited in the short term in temperate climate regions of Europe. Current early-maturing types have a growing season that ends late in September, jeopardizing a safe harvest. Their yields in Belgium and the Netherlands are at about 2.5-3.0 Mg ha^{-1} (at 15% moisture). Since annual progress by breeding varies between 10 and 45 kg ha^{-1}, a combination of breeding efforts and good agronomic practices will be necessary to substantially increase yields in the mid- and long-term (J. Aper, soy breeder at ILVO). Combining silage maize with a protein crop is also a returning issue. Although the potential advantages of multispecies cropping systems are well known (e.g. Malézieux *et al.*, 2009) farmers' adoption has been extremely low so far in Europe. The KWS breeding company in Germany is putting a lot of effort in combining silage maize with *Phaseolus* beans with realistic perspectives. The eligibility of crop associations within the context of crop diversity of the CAP may help to implement this association in practice. Several European breeding companies and institutes are increasing breeding work with forage legumes: white and red clovers are the favourites in the lowlands and more attention is going to the development of varieties performing well in mixtures with grasses.

There is an ongoing trend in the western world to consume less animal products, including dairy products; the opposite is occurring in developing countries (Westhoek *et al.*, 2011). Several drivers push consumers to consume less livestock products, e.g. the realisation that overconsumption of animal products is unhealthy, that livestock need large areas for feed production, and that livestock production has a large water footprint as indicated by Mekonnen and Hoekstra (2010, 2012). People get overwhelmed with water consumption values of up to 15,000 l kg^{-1} meat, but usually it is not mentioned that this includes the rainwater falling on crop and pasture land. As rain is falling on any land (be it cropped or not), this figure has no honest meaning in the absence of a comparison with other outputs of the land. If the downward trend of consumption of animal products in the EU continues, one can wonder what the consequences will be for dairy farming in the EU and for the associated crop production. Westhoek *et al.* (2011) studied several scenarios regarding decreases in consumption of animal products in the EU. Modelling showed that when consumption of livestock products decreases by one third, the grassland area in the EU would decrease by 4%. The model predicts a more extensive production system but farmers would only abandon grassland to a minor extent in order not to lose CAP subsidies. The area cultivated with arable crops would not decrease; on the contrary it would increase by 2 million ha compared to the reference (situation 2007) scenario, and biodiversity would suffer due to the loss of pasture land. Based on modelling, and making a lot of assumptions (e.g. permanent grassland stays as permanent grassland), Westhoek *et al.* (2014) concluded that if we halve our animal protein intake, 9.2 million ha of temporary grassland and 14.5 million ha of arable land would no longer be necessary to feed European livestock; this land would be used for cereal production or for perennial energy crops. N emissions would decrease by approximately 40%; greenhouse gases by approximately 40% if perennial energy crops are grown, and by approximately 20% in the case of cereal production.

Reidsma *et al.* (2006) quantified the impacts of land-use change on biodiversity in the EU. One of their striking statements is 'The ecosystem quality of intensively managed grassland corresponds to the situation between extensive (ecosystems quality of 25%) and intensive (ecosystems quality of 10%) cropland management' indicating that even intensively managed grassland is not too bad for biodiversity. Particularly because its value for ecosystem services, biodiversity conservation, landscape diversification and cultural or historical heritage, more and more grassland is confronted with strong restrictions for use and management. Danckaert *et al.* (2008) analysed the legal status of permanent grassland in Flanders and came to remarkable conclusions. About a quarter of the agricultural area of Flanders is covered by permanent grassland (approximately 150,000 ha). About 80% of this surface is situated in areas with at least one legal way of protection with corresponding restrictions for management and use. About 20% is historical permanent grassland and/or ecologically fragile grassland with a forthcoming absolute prohibition to plough the sward or to renew it. This may be good news for nature conservation but it substantially restricts the degrees of freedom for farming activities. If one has a high proportion of land affected by these limitations, surviving becomes very difficult. Owing to recent decisions regarding N emissions, farmers may lose their licence to produce when their farm is in the vicinity of a Natura 2000 area. According to Folke *et al.* (2014) cowsheds and fertilization activities are responsible for 50% and

45%, respectively, of the ammonia emissions in Dutch agriculture. It is clear that in these circumstances the fertilization of crops will be monitored very strictly and that future fertilization will have to be as emission-poor as possible and as tight as possible related to the crops' needs.

Conclusions

Intensive dairy systems are very closely linked with nutrient management and land use. The efficient use of nutrients will be crucial to maintain high crop yields. Good crop husbandry, well planned cropping systems and the best available agronomic practices, underpinned by plant breeding, are necessary to optimize yields in times of restrictions of nutrient use. The protein content in grass is declining and hence more non-grass protein will be needed in case restrictions become further strengthened. An important dilemma is whether or not to use home-grown protein or to use imported protein. The availability of land will be a crucial factor in this debate. Scarcity of land, the shrinking degrees of freedom to use it, and developments in the margins of, or outside the agricultural world, are calling for a continuous vigilance in order to safeguard intensive dairy systems.

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