Future systems: growing sustainably

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Summary

- The sustainable intensification of Irish pasture-based dairy systems is achievable, but requires improved management practices and additional technology adoption on dairy farms.
- Future systems will continue to rely primarily on efficient ruminants fed on highly productive pastures. Substantial additional gains in both farm profitability and environmental efficiency can be achieved.
- The incorporation of white clover into grassland swards coupled with the use of protected urea fertilisers and low emissions slurry application methods can further enhance the sustainability of dairy systems.

Introduction

The stellar performance of the Irish dairy sector over the last five years has been unparalleled, both in terms of other indigenous sectors of the Irish economy or other international dairy industries. At the core of this success story are 18,000 family-owned dairy farms, producing approximately 7.6 billion litres of milk and supporting 60,000 jobs across the rural economy. Economic activity in the sector produces a far greater multiplier effect than other traded sectors. Every €1 of additional dairy exports corresponds to an additional €0.90 spend in the wider domestic economy. The unique nutritional quality and character of pasture-fed dairy products has been a cornerstone of the growing demand for Irish dairy products in 110 premium markets worldwide. The value of Irish dairy exports exceeded €4 billion for the first time in 2018, and accounted for 30% of total food and drink exports. With current production running 15 to 20% ahead of 2018, total production is expected to exceed 8 billion litres for the first time in 2019, resulting in additional jobs, investment and export earnings.

This success has been achieved against a backdrop of increased global pressures to realign increasing food demand with more environmentally efficient production systems to meet climate change targets. The concept of sustainable intensification has recently been developed to increase *productivity* (as distinct from increasing *volume of production*), while reducing environmental impacts. This means increasing yields per unit of inputs (including nutrients, water, energy, capital and land) as well as per unit of undesirable outputs (such as gaseous emissions, nutrient leakage or biodiversity loss). Globally, grassland is the most important agroecosystem; it is capable of efficiently feeding ruminants with human inedible feeds, increasing soil carbon (C) storage and maintaining high quality biodiversity. However, the competition for land use from arable food and fuel production is reaching unprecedented levels, and many international studies report increasing land degradation, biodiversity loss, food security risks and water scarcity arising from climate change. Increasing public awareness of the impacts of agriculture on land use and climate change highlight the need for greater efficiency and sustainability in all aspects of agricultural production across the globe. On-farm production systems are at the centre of many of the challenges we face, and need to adapt to these changing circumstances. This paper sets out both the challenges faced by the Irish dairy industry, and thereafter, describes the targets for future Irish dairy production systems including new research technologies that will assist farmers to realise these targets.

Why should Irish dairy farmers be concerned with sustainability?

In the context of an expanding, export-dependent agri-food sector, the sustainability of Ireland's dairy industry is now very much in focus. Customers, both at home and abroad, have become more engaged in the provenance, nutritive value and sustainability credentials of the food they consume. The business case for improving the environmental performance of dairy farms is compelling, as efficiencies gained also enhance the economic performance of a farm. At farm level, environmental sustainability comes down to minimising the amount of resources used (e.g., nutrients, electricity, feed, water, etc.) to produce each kg of output. Indicators of sustainable intensification are essential to verify the comparative advantage of Irish pasture-based food production systems. Even under current regulations, Irish agriculture faces significant environmental constraints in terms of water quality, ammonia (NH_3) and greenhouse gas (GHG) emissions and biodiversity loss which may result in EU fines (NH_3) and the necessity for Ireland to purchase credits (GHG's) for exceeding target levels in the future. There is a national ceiling on NH_3 emissions; as agriculture produces more than 90% of total NH_3 emissions, this is a de facto ceiling for agriculture. In comparison with intensive agriculture in other countries, Irish farming is not particularly intensive. Nevertheless, the EPA estimates that agriculture, principally cattle, contributed approximately a third of Ireland's GHG's in 2017, whereas the corresponding average for the EU was just over 10%. As Ireland has recently declared a national climate emergency, the Irish government is currently formulating targets for each sector to achieve a low carbon, climate-resilient and environmentally sustainable economy by 2050. As part of this national plan, agriculture (and land-use including forestry) will be required to reduce total emissions without compromising our capacity for sustainable food production. Irish dairy farmers need to be aware of, and proactive in, adapting dairy production systems to these new requirements.

What are the important sustainability metrics?

The environmental metrics that are of most concern in Ireland include air quality, water quality, energy use and biodiversity. Air quality measures of foremost importance include both GHG and NH_3 emissions, both per hectare and per kg of fat and protein corrected milk (FPCM). At the farm scale, N and P surplus (defined as the excess of N and P inputs in feeds and fertilisers less N and P exports in milk) and N and P use efficiency (defined as the amount of milk N and P produced relative to total N and P inputs) are commonly used as overall measures of the efficiency of nutrient use to minimise nutrient loss to water. Energy efficiency is measured as kiloWatt hours per 1,000 litres of milk sold (kWh/1,000 L). Biodiversity is measured in terms of the proportion of farming area with hedgerows and high value ecosystems. Although Irish pasture-based dairy systems have been widely heralded for our lower intensity of food production, the rapid expansion in the sector has increased total agricultural contributions across each of the metrics. The increase in Irish dairy production over the past five years has been possible due to a 26% increase in the size of the national dairy herd, from 1.1 to 1.4 million dairy cows. Using data compiled through its national farm survey, the recently published Teagasc National Farm Survey 2017 Sustainability Report report tracked the performance of Irish farms in terms of environmental sustainability and sets out the challenge for a growing dairy industry. The report highlighted that farm level GHG and NH_3 emissions efficiency (per unit of product produced) has been improving, and Ireland is among the lowest in terms of emissions intensity when compared against international dairy industries. The recent expansion in animal numbers and area per farm, however, has resulted in increasing total emissions and stable nutrient surpluses on Irish farms (Figure 1 and 2).

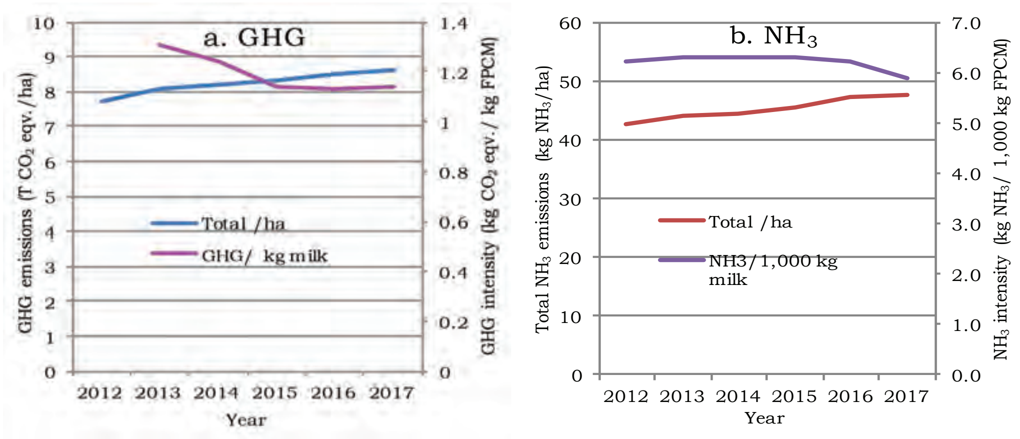

Figure 1. *Recent trends in a) Green House Gas (GHG) and b) Ammonia (NH_3) emissions on Irish dairy farms (Teagasc National Farm Survey Sustainability Report, 2017)*

So how does Ireland compare with other countries?

Although there are few studies that make international comparisons across countries, there are an increasing number of studies that investigate the greenhouse gas (GHG) emissions associated with individual farming systems, or which make comparisons between systems (for example, grass-fed versus feedlot or conventional versus organic systems). The comparison of different industries is also complicated by the various methodologies employed. In terms of emissions, some sources are based on activity-based emissions, which only consider emissions which are directly associated with the within farm activity, whereas an alternative approach, called a life cycle assessment (LCA), not only includes direct emissions from animals, but also emissions of feed and fertilisers both within and outside the country in addition to C sequestration rates related to feed production (including grassland and grazing). Teagasc research has shown that, including total emissions using LCA, the C efficiency of grazing is superior more typical confinement dairy systems.

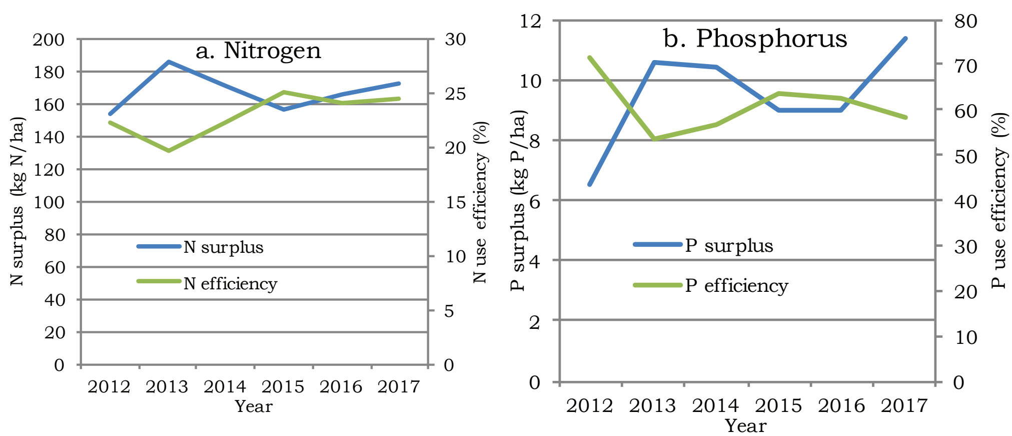

Figure 2. *Recent trends in a) Nitrogen (N) and b) Phosphorus (P) surplus and use efficiency on Irish dairy farms (Teagasc National Farm Survey Sustainability Report, 2017)*

The EU Commission's Joint Research Centre (JRC) report on EU emissions was published in 2010 based on 2004 data and shows that Ireland (, together with Austria,) is the most C-efficient producer of milk in the EU at approximately 1 kg CO_2 eq./kg milk (Figure 3). The results observed are similar to those reported for pasture-based systems in New Zealand (Basset-Mens *et al.*, 2009) and well below comparable estimates from more intensive confinement systems in other EU countries (Cederberg and Mattsson, 2000; Thomassen *et al.*, 2008).

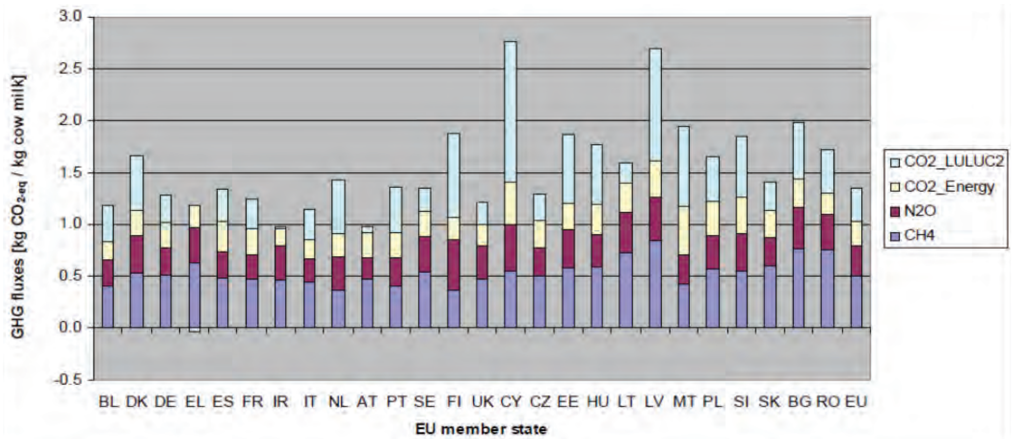

Figure 3. *European Union Joint Research Centre report on EU emissions from dairy production in various member states (EU JRC, 2010; Ireland: IR)*

From a water quality perspective, the quality of Irish groundwater and surface waters is among the best in Europe. Under the Water Framework Directive (WFD), the Environmental Protection Agency (EPA) reports show that overall levels of pollution remain relatively constant since the beginning of the 1990's. Some improvements have been made with the length of seriously polluted channel being reduced to just over 6 km in the 2013 to 2015, period compared with 17 km between 2010 and 2012 and 53 km between 2007 and 2009. The most recent report has however, highlighted a 3% decline in river water quality since 2015, with a decline in the number of pristine sites. The most recent report (EPA, 2018) also shows that nitrate and phosphate levels in rivers are relatively stable over time. In terms of relative agriculture pressures on water resources, the EU gross N and P balances provide an indication of the potential nutrient surpluses on agricultural land (kg N and P per ha per year) between countries over time.

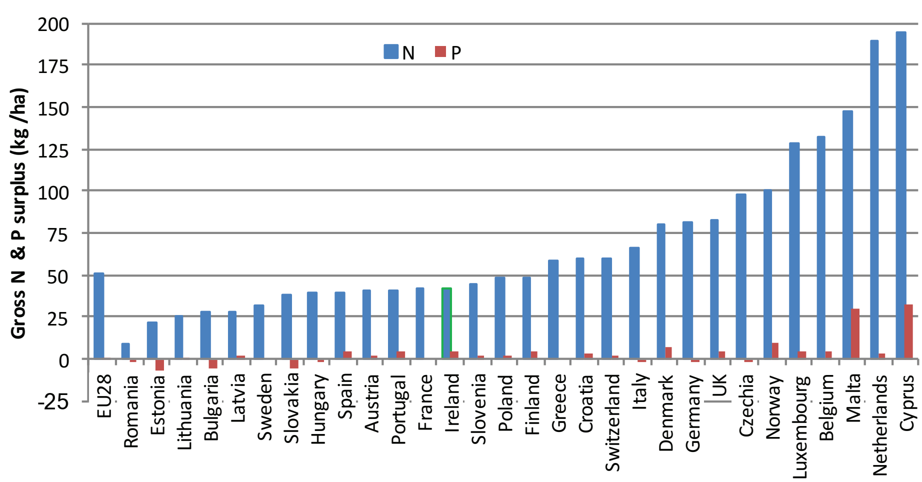

Figure 4. *Nitrogen (N) and Phosphorus (P) surplus for European Union countries in 2015 (Eurostat, 2019)*

The most recent analysis (2015) indicates that Ireland has a national N and P surplus of 42 kg of N and 5 kg P/ha respectively, which is below average for member states (Figure 4, Eurostat, 2019) and indicative of the comparatively extensive nature of Irish agriculture.

Beginning with the end in mind

Sustainability is not just confined to environmental considerations, but also encompasses the economic well-being of those involved in farming, the quality of food produced and the welfare of animals. There is a growing understanding of the role of pasture-based food production in efficiently converting human inedible grazed forage to high quality human edible nutrients with a low environmental footprint. In contrast, protein deficient confinement dairy systems use a large proportion of maize silage as the forage, which must be balanced by imported protein-rich feedstuffs. In effect, this outsources a considerable proportion of the environmental impacts to South America, where the expansion in soybean cultivation has been a major environmental concern. Permanent pastures also provide an important biological filter to reduce nutrient and chemical losses, conserve soils and store carbon, while also supporting high levels of biodiversity (particularly avifauna). In a European context, improving the efficiency of grazing production systems is recognised as the primary opportunity for sustainable intensification of food production for the future.

Core principles of efficient pasture-based grazing systems

Future pasture-based dairy systems will continue to be dependent on highly productive pastures combined with efficient ruminants (Table 1). Substantial additional gains in farm profitability can be achieved on most farms through refinement of Irish grazing systems. The greatest gains will come from increasing pasture production and utilisation followed by conversion to milk fat plus protein (milk solids; MS), and this will provide the primary avenue to improved environmental efficiency over the next two decades. Research modelling results indicate that for each 1 t DM/ha increase in pasture utilisation on dairy farms, GHG emission intensity is reduced by 4% and net farm profit is increased by €173/ha. Further improvements in pasture productivity can be realised by improving grazing management, reseeding unproductive swards and improving soil fertility to optimum levels. Optimising the soil pH to ≥ 6.3 through application of lime on acidic mineral grassland soils is vital to ensure efficient use of applied nutrients. Teagasc data indicates that a 10 day increase in grazing season length increases annual farm profitability by €30/cow, and reduced GHG emissions by 2% per annum. In addition, where soils are maintained within the optimum soil pH range, productive grass and clover persist for longer, resulting in reduced cultivation and increased C sequestration.

The selection of more efficient dairy cows is also of paramount importance. From an animal breeding standpoint, there are two key improvement goals: firstly, extend the lifespan of each animal and reduce the requirement for replacements; and secondly, to further increase individual animal performance from grazed pasture. Increasing herd Economic Breeding Index (EBI) by €10 per year increases annual farm profitability (by €20/cow/yr) and reduces GHG emissions by 2% per annum. In addition, selection of dairy cows that are capable of achieving large intakes of forage, relative to their size and genetic potential for milk production, increases feed efficiency and also reduces nutrient losses. Efficient grazing animals should produce in excess of 90% of bodyweight in annual milk solids production to increase N use efficiency. On that basis, dairy farmers should aggressively select on EBI and use milk recording to eliminate inefficient animals to further advance both the economic and environmental efficiency of Irish dairy herds.

Table 1. Performance indicators for current average, top performing and future dairy systems

	NFS1	Top 10%	Future target
Net profit (€/ha incl. full labour)	473	1,032	2,500
Dairy economic breeding Index (€)[2]	86	122	150
Herd maturity (No. calvings/cow)[2]	3.4	4.1	4.5+
Calving rate (% calved in 42 days)[2]	64	85	90
Optimum soil fertility (% farm area)	10	75	100
Fertiliser N (kg chemical N/ha)	180	250	150–250*
Grazing season length (No. days/cow)	235	265	280
Stocking rate (LU/ha)	2.1	2.3	2.8
Pasture utilised (t DM/ha)	7.3	9.6	13.0
Supplement (kg DM/cow)	1,050	910	500
Fat plus protein (kg sold/ ha)	825	1,021	1,350
Total GHG emissions (t CO_2 eq./ha)	9.2	13.9	12.6
GHG intensity (kg CO_2 eq./kg FPC milk)	1.14	1.00	0.71
Total ammonia emissions (kg NH_3 eq./ha)	46.9	65.1	46.2
Ammonia intensity (kg NH_3 eq./'000 kg FPC milk)	6.2	4.8	2.6
Nitrogen/phosphorus surplus (kg N or P/ha)	164/10	225/9	160/10
Nitrogen /phosphorus use efficiency (%)	25/62	26/70	35/85
Energy use (kWh/1,000L milk sold)	59	42	30
Biodiversity cover (% habitat area)	7	5–10	10+

[1]NFS: National Farm Survey (2015 to 2017), [2]ICBF (2018).
**Where an overall sward white clover content of 25% is achieved, chemical N can be reduced to 150 kg/ha*

Identifying the appropriate stocking rate (SR) is the key strategic decision for pasture-based dairy farms. This is generally defined as the number of animals allocated to an area of land (i.e., cows/ha). Although the beneficial impacts of SR on grazing system productivity have been widely reported, the impact of SR on environmental efficiency must also be considered. Previous studies have indicated that increased SR was associated with increased chemical fertiliser and supplementary feed importation, greater nutrient surpluses and reduced nutrient-use efficiency, resulting in increased losses to ground water and the general environment. Currently, the average Irish dairy farm has a SR of 2.1 livestock units (LU) per hectare. Hence, any increase in farm SR needs to occur without greater usage of chemical fertiliser, and without an increase in concentrate supplementation per cow. Based on improved grazing management and soil fertility, increasing overall farm SR will result in increased pasture utilisation and improved farm profitability and environmental efficiency in the future. As a component of the sustainable intensification of dairy production, improved management practices are required to maintain low levels of nutrient loss within more intensive pasture-based systems, including greater use of organic manures to replace chemical fertiliser, more strategic use of chemical N, reduced cultivation reseeding, improved nutrient budgeting, and, importantly, the preferential management of higher risk farm areas. Previous studies have also reported that the C footprint of milk production will be reduced by maximising the use of grazed pasture at an appropriate overall SR. The optimum SR for farms that produce different amounts of pasture and feed different amounts of supplement is defined in Table 2 below.

Table 2. Stocking rate (cows/ha) that optimises profit on farms growing different amounts of grass and feeding different amounts of supplement/cow				
	Grass grown, t DM/ha			
Kg supplement DM/cow	10	12	14	16
500	1.8	2.2	2.5	3.0
1,000	2.0	2.4	2.9	3.2

Farming for the future — new practices for intensive dairy farms

Irish dairy farmers have been enthusiastic innovators during the last decade, which has contributed greatly to improvements in productivity within the sector. The adoption of the following research practices on intensive dairy farms can further reduce both emissions and nutrient losses, and facilitate the achievement of the future industry targets as set out in Table 1 above.

Grass clover swards

Traditionally, white clover was included in perennial ryegrass mixtures to improve sward nutritive value and reduce N fertiliser use. The availability of cheap N fertiliser, however, reduced the variability in pasture production during spring and increased overall pasture production. This led to a reduction in the use of white clover, with declining levels reported in temperate grazing regions such as Western Europe and New Zealand. Managing grassland with less mineral N fertiliser inputs and with greater reliance on biological N fixation from clover can reduce costs, reduce GHG emissions (industrial synthesis of mineral N fertiliser is energy intensive) and increase the digestibility of herbage. Data was compiled from multiple studies to quantify the milk production response associated with the introduction of clover into perennial ryegrass swards. At a mean sward clover content of 32%, mean daily milk and milk solids yield per cow were increased by 1.4 and 0.12 kg/day, respectively, compared with grass only swards. The same studies indicated that there is potential to replace up to 100 kg fertiliser N/ha, while maintaining output and profitability on intensive dairy farms where white clover content exceeds 25% of the sward biomass. Ongoing analysis of trial results indicate that the combined animal performance gains and cost saving from reduced N fertiliser use in ryegrass plus white clover pastures could increase annual farm profitability by €450/ha, while also reducing GHG emissions by up to 10%.

There are however, challenges with the adoption of white clover on dairy farms. The use of white clover is not widespread (on derogation farms or on farms in general), and may be problematic on wetland soils. The yield stability of white clover in intensively managed pastures remains problematic and the limited range of clover friendly grassland herbicides and risk of bloat in grazing livestock have discouraged some farmers. While research has shown the possibilities for overcoming these obstacles through improved grazing management, over-sowing swards and the use of bloat prevention technologies, further work is required to increase the stability and persistency of white clover and more generally encourage greater adoption.

Low emissions slurry spreading (LESS)

Slurry is an important source of nutrients (N, P & K) and application to grassland must be properly timed to maximise the efficiency of nutrient capture and replenish soil fertility levels. The targeted application of slurry in spring, based on soil test results, will ensure the most efficient use of slurry nutrients for grass production and minimise potential NH_3 losses. Slurry N losses in the form of NH_3 emissions are potentially the largest loss of reactive N on Irish farms, with manure spreading responsible for a quarter of all NH_3 losses in Ireland. Using LESS methods, such as trailing shoe or band spreaders, has a large effect on N losses and increases slurry N value by 10%, thereby increasing pasture productivity and further reducing chemical N requirements.

Protected urea fertiliser

There is a strong yield response from ryegrass swards to supplemental N addition, including from mineral fertilisers. Loss of N, via NH_3 and nitrous oxide (N_2O) emissions and N leaching, however, must be reduced. Recent studies have shown that protecting urea with a urease inhibitor reduces loss of NH_3 to the environment by 80%. Furthermore, protected urea reduces N_2O losses by 71% compared with ammonium nitrate, without compromising productivity. Results from several studies indicate that protecting 50 kg/ha of urea-N will save 6 kg N/ha, which can increase the value of grass growth by up to €40/ha per yr. Protected urea can also help reduce N losses to water by holding N in ammonium form, which is more stable in soil particularly during wet conditions.

Reducing concentrate crude protein content

On average, Irish dairy cows have a requirement for a diet with a Crude Protein (CP) content of 15 to 17%. In general, high quality grazed pasture has a CP content in excess of 18% during the grazing season. Therefore, grazed grass more than adequately meets animal requirements for crude protein. Several studies have been completed during the last 10 years showing no benefit from feeding rations with high CP content at pasture. Indeed, feeding high CP content concentrates during the grazing season provide excess CP to the dairy cow, who must then expend energy to excrete the excess N. From an environmental perspective, reducing concentrate CP content will reduce N surplus and loss to the environment. A 1% reduction in CP of dairy concentrates reduces N excretion by 1% and also results in a 5% reduction in GHG and NH_3 emissions. On that basis, using concentrates with a CP content of 12–14% is recommended when animals are at pasture.

Protecting biodiversity

Biodiversity is an important primary environmental indicator of sustainable agricultural systems. Although extensively managed farmland will always provide the highest quality ecosystems, improving biodiversity on intensively-managed farms can also play an important role in halting the decline of farmland biodiversity and maintaining soil C. Pasture-based farming systems are uniquely well positioned to support wildlife within the landscape; it is estimated that natural habitats constitute 12–14% of the area of grassland farms in Ireland. Greater efforts are required to improve both the area and quality of high biodiversity habitats. Examples include maintaining and managing existing habitats such as hedgerows and field margins, and the inclusion of watercourse buffer strips.

Energy and water efficiency

Although average electricity costs on Irish dairy farms are €5 per 1,000 litres of milk produced, large variation exists between farms (from €2.60 to €8.70). The main energy uses are for milk cooling (31%), milking (20%) and water heating (23%). Teagasc research suggests that it is possible to reduce on-farm electricity consumption, and related CO_2 emissions, by up to 60% and save over €2,500 (100 cow herd) by installing an effective milk pre-cooler (e.g. plate cooler), variable speed drives on the vacuum and milk pumps and solar photovoltaic systems.

Future opportunities - Methane reducing feed additives

Methane from the cow's digestive system is the main source of GHG/C emission from milk production. Numerous additives have been fed to cows to reduce methane emissions, but most are not effective or their effect weakens after a short period i.e. 8 weeks. Moreover, some additives have a negative effect on animal production or the environment (e.g., the ozone layer). New research in the USA and Europe, however, indicates that mixing the inhibitor 3-NOP (3-nitrooxypropanol) into the feed ration or feeding plant extracts (e.g., Mootral™) can persistently reduce cow methane by up to 30% without any significant adverse effects, and may improve cow productivity. These additives are likely to be required to meet long term (2050) emission and food targets, but further testing is required to determine if these additives reduce emissions in grazing dairy cows.

Conclusions

Improved efficiency in dairy systems is a significant challenge for the future. The world demand for food will increase further in the coming decades, but intensive milk production systems must become more sustainable with lower nutrient surpluses and increased emissions efficiency. Irish dairy farm systems can grow sustainably based on highly productive swards and genetically elite dairy cattle consuming a predominantly pasture diet. Considerable gains in both farm profitability and environmental efficiency can be achieved through incorporation of white clover into grassland swards coupled with the use of protected urea fertilisers and low emissions slurry application methods.

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