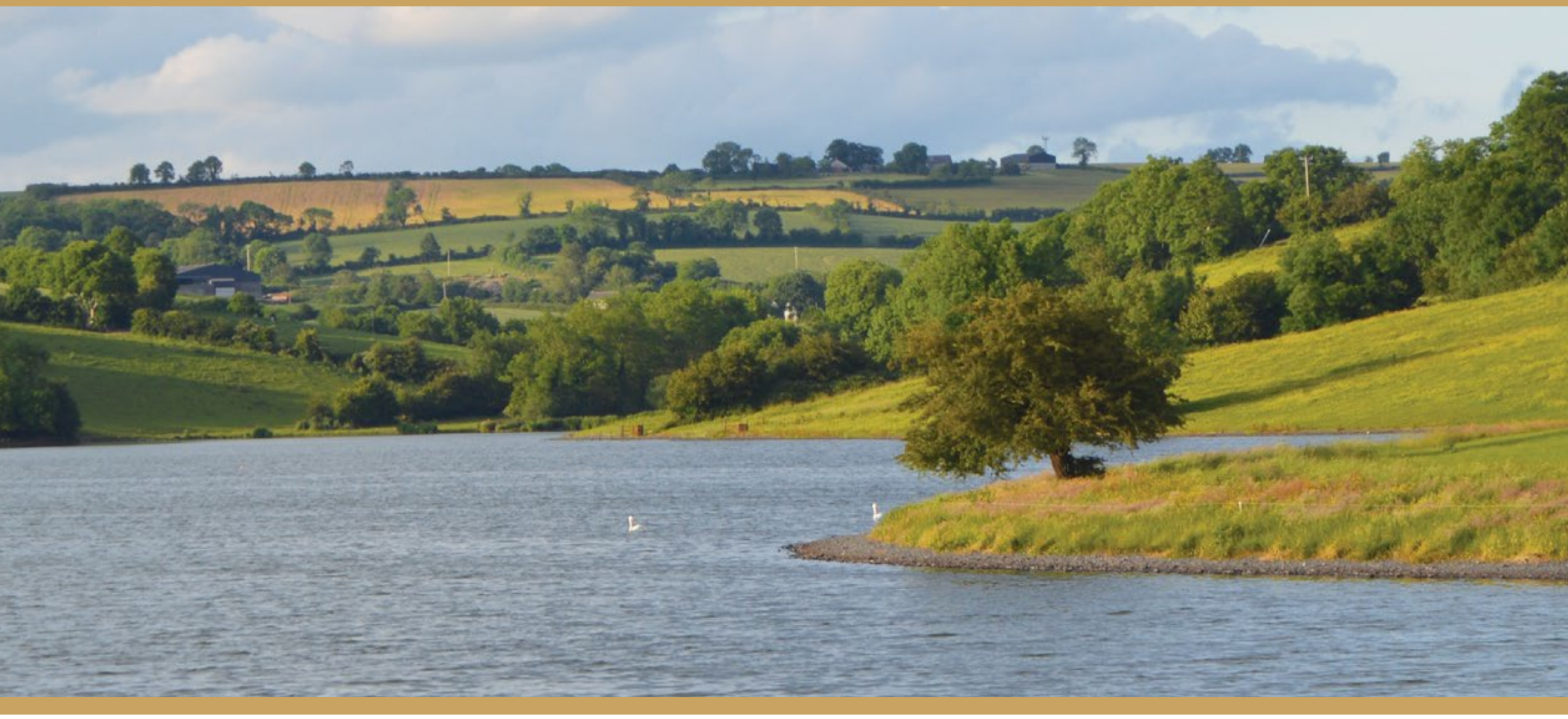
Booklet 32

Project D-29-06

A comparison of four intensive grassland based systems of milk production



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RESEARCH TEAM

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Agri-Food and Biosciences Institute

SUMMARY

This experiment was conducted at the Agri-Food and Biosciences Institute (AFBI), Hillsborough. Four milk production systems were examined over three successive lactations, with each system involving 20 cows.

The systems examined were '**Year-round housing**' (Holstein cows housed throughout the entire lactation), '**Conventional**' (Holstein cows housed during the winter, and grazing during the summer), and two '**Spring Calving**' systems. One of these Spring calving system involved Holstein cows and the other Jersey x Holstein crossbred cows.

All systems were designed to have high stocking rates (greater than 1.8 cows per ha) so that all would require a derogation under the Nitrates Action Programme in Northern Ireland.

Total concentrate intakes over the full lactation were 3.5, 2.5 and 0.85 tonnes with the Year-round-housing, Conventional and Spring calving systems, respectively.

Cows on the Year-round-housing system lost less body condition than cows on any other system, and started to gain body condition by approximately week-16 of lactation. These cows completed the lactation with a higher body condition score (2.7) and a higher live-weight than cows on any other system.

Full lactation milk yields were 9330, 8440, 6460 and 6450 kg with the Year-round-housing, Conventional and Spring calving Holstein and Spring calving crossbred systems, respectively.

The Holstein cows on the Spring calving system produced 400 kg more milk than the Jersey crossbred cows, but their milk had a lower fat and protein content. Fat + protein yield did not differ between these two cow genotypes.

'Milk from forage' values were 1470, 2890, 4660 and 4190 kg for the Year-round-housing, Conventional and Spring calving Holstein and Spring calving crossbred systems, respectively.

Somatic cell counts tended to be higher in the systems which involved longer periods of housing (Year-round-housing and Conventional). Somatic cell count was not reduced by crossbreeding.

System had little effect on the fertility of the Holstein cows. However, there was a general trend for crossbred cows to have improved fertility compared to Holstein cows, with this likely due to hybrid vigour.

Incidences of mastitis and lameness were highest with Holstein cows on the Year-round-housing and Conventional systems, with this likely due to the longer housing periods with these systems.

Crossbred cows had improved hoof health compared to Holstein cows. In general, crossbreeding with Jersey sires improves hoof health.

Phosphorus balances were 5.4, 0.6, -5.7 and -5.1 kg phosphorus per ha for Year-round-housing, Conventional, Spring-calving (Holstein) and Spring-calving (Jersey x Holstein), respectively. The latter three systems are not sustainable in the long term, with recent AFBI research indicating that an annual phosphorus surplus of approximately 5.0 kg phosphorus per ha is required to be sustainable. This demonstrates the need for farmers, especially those operating lower concentrate input systems, to undertake soil tests on a regular basis, and to apply inorganic (fertiliser) P when required, so as to maintain soil indexes at the agronomic optimum.

All systems had similar carbon footprints. This highlights that very different systems, if managed efficiently, can operate with a similar carbon footprint.

Net margin per litre was maximised with the spring calving systems. However, when net margin per cow was examined, the Conventional system was most profitable when milk price was 27 pence per litre, or higher. At a milk price of 22 pence per litre the Spring Calving systems tended to be more profitable.

The Spring calving system involving Jersey crossbred cows was more profitable than the Spring calving system involving Holstein cows (£39/cow/year).

As part of an associated research programme, three small scale experiments were undertaken to examine strategies by which to reduce P losses from applied slurry, and from the soil.

- The first experiment was designed to examine the effect of slurry spreading technique on phosphorus losses in runoff. The results highlighted that soluble phosphorus concentrations in runoff were reduced by 37% and 47%, respectively, when slurry was applied using either Injection or Trailing shoe, compared to splash plate.

- The second experiment examined phosphorus losses when slurry was applied to a sward on the same day that herbage was harvested, or either 10 or 20 days after herbage had been harvested. Soluble phosphorus concentrations in runoff were reduced by approximately 60% when slurry was applied to a sward at either 10 or 20 days after herbage had been harvested.

- There is a risk of soil phosphorus being lost when fields are trampled by grazing livestock. The third experiment examined the impact of grazing intensity in the spring on phosphorus losses in surface runoff. The results demonstrate that when grazing is well managed, the risk of phosphorus being lost from the soil surface is small. However, when grazing resulted in moderate soil damage, the risk of phosphorus loss increased significantly.

The outcomes of this entire research programme have demonstrated that when well managed, nutrient losses from intensive milk production systems can be small. These positive outcomes were presented to the European Commission, and helped Northern Ireland secure a renewal of the Nitrates Directive Derogation for a further four years (from January 2015).

BACKGROUND

The Nitrates Action Programme for Northern Ireland restricts stocking rates to the equivalent of 170 kg manure nitrogen per hectare (1.87 cows per hectare). However, as stocking rates on many farms are higher than this, Northern Ireland made a successful application to the European Commission in 2007 to allow farmers who operate predominantly grassland-based systems (greater than 80% grassland) to operate at higher stocking rates (up to 250 kg manure nitrogen per hectare, or 2.74 cows per hectare). In granting this 'derogation' the EU Commission required research to be conducted to demonstrate that nutrient losses from these more intensive systems were not excessive. To address this issue, four very different milk production systems were examined over a three year period. The performance of cows on these systems, together with some of the nutrient loss data recorded, is described in this booklet. A full copy of the report is available on the AgriSearch website.

The findings of this research programme have now been presented to the European Commission, and based on these and other evidence, Northern Ireland has now had its 'Derogation' renewed (from 1 January 2015) for a further four years. This is excellent news for intensive livestock farmers. This research programme comprised two main parts.

Part 1: A comparison of four intensive grassland based systems of milk production.

Part 2: Strategies to reduce phosphorus losses from grassland based dairy systems.

PART 1
A comparison of four intensive grassland based systems of milk production.

INTRODUCTION
A wide range of milk production systems are practiced on Northern Ireland dairy farms. For example, systems differ in terms of calving season (Autumn, Spring and 'all year'), annual concentrate inputs (0.5 – 4.0 tonnes per cow) and milk outputs (4,500 – 12,000 litres per cow), stocking rates (1.0 – 3.5 cows per ha) and overall management regime (totally housed, housed by night during the summer, full time grazing). In addition, while the Holstein-Friesian is the predominant dairy cow breed within Northern Ireland, alternative breeds, and the use of crossbreeding, have been adopted on some farms. The first part of this project was conducted at the Agri-Food and Biosciences Institute (AFBI), Hillsborough, and involved a comparison of four different grassland-based milk production systems.

THE EXPERIMENT
Twenty cows were managed on one of four milk production systems over three successive years. An overview of these systems is presented in Table 1.

The 'Year-round-housing' system involved winter calving Holstein cows. These were housed throughout the entire lactation and offered a mixed ration comprising grass silage, maize silage and concentrates. Concentrate levels were approximately 13 kg/cow/day for the first 180 days of the lactation, and 9 kg/cow/day for the remainder of the lactation.

The 'Conventional' system also involved winter calving Holstein cows. These were housed during the winter and offered the same diet as cows on the Year-round-housing system. Cows on this system started grazing in early April and were offered 4.0 – 5.0 kg concentrate/day throughout the summer grazing season.

The remaining two systems were lower input 'Spring Calving' systems. One of these systems involved spring calving Holstein cows and the other spring calving Jersey x Holstein crossbred cows. Cows on these two systems were offered grass silage plus 6.0 kg concentrate/cow/day from calving until turnout, with turnout being as early as possible each year. During the grazing period these cows were supplemented with 1.0 kg concentrate/cow/day.

Each system was designed to operate at a high stocking rate, namely a stocking rate which would require a derogation from the Nitrates Directive Action Programme. In addition, each system was managed to minimise nitrogen and phosphorus loss to the environment. Cows on all systems were milked twice daily.

Table 1 Overview of the main components of each of the four systems examined

	Year-round-Housing	Conventional	Spring Calving	
Cow type	Holstein	Holstein	Holstein	Jersey x Holstein
Calving season	October - April	October - April	January - April	January - April
System overview	All year housing	Winter housing, summer grazing	High reliance on grazed grass	High reliance on grazed grass
Concentrate intake (t per lactation)	3.5	2.5	0.85	0.85

MAIN FINDINGS

Intakes

Total lactation dry matter intakes were highest with the Year-round-housing system (6.4 t) and lowest with the spring calving systems (4.5 t) (Figure 1).

Total concentrate intakes (DM basis) over the full lactation were 3.08 t with the Year-round-housing system, 2.18 t with the Conventional system and 0.74 t with the spring calving systems (3.5, 2.5 and 0.85 t fresh basis, respectively).

Grass silage intakes were greatest with the Year-round-housing system (as these cows were housed throughout year), and lowest with the Spring calving systems (due to their shorter housing period). Maize silage was not offered to cows on the Spring calving systems.

Grass intakes were highest with the Spring calving systems as cows on these systems had a long grazing period and were offered only a small amount of concentrate while grazing.

Holstein and Jersey crossbred cows on the spring calving system had similar intakes, with this demonstrating the high intake capacity of the smaller crossbred cows.

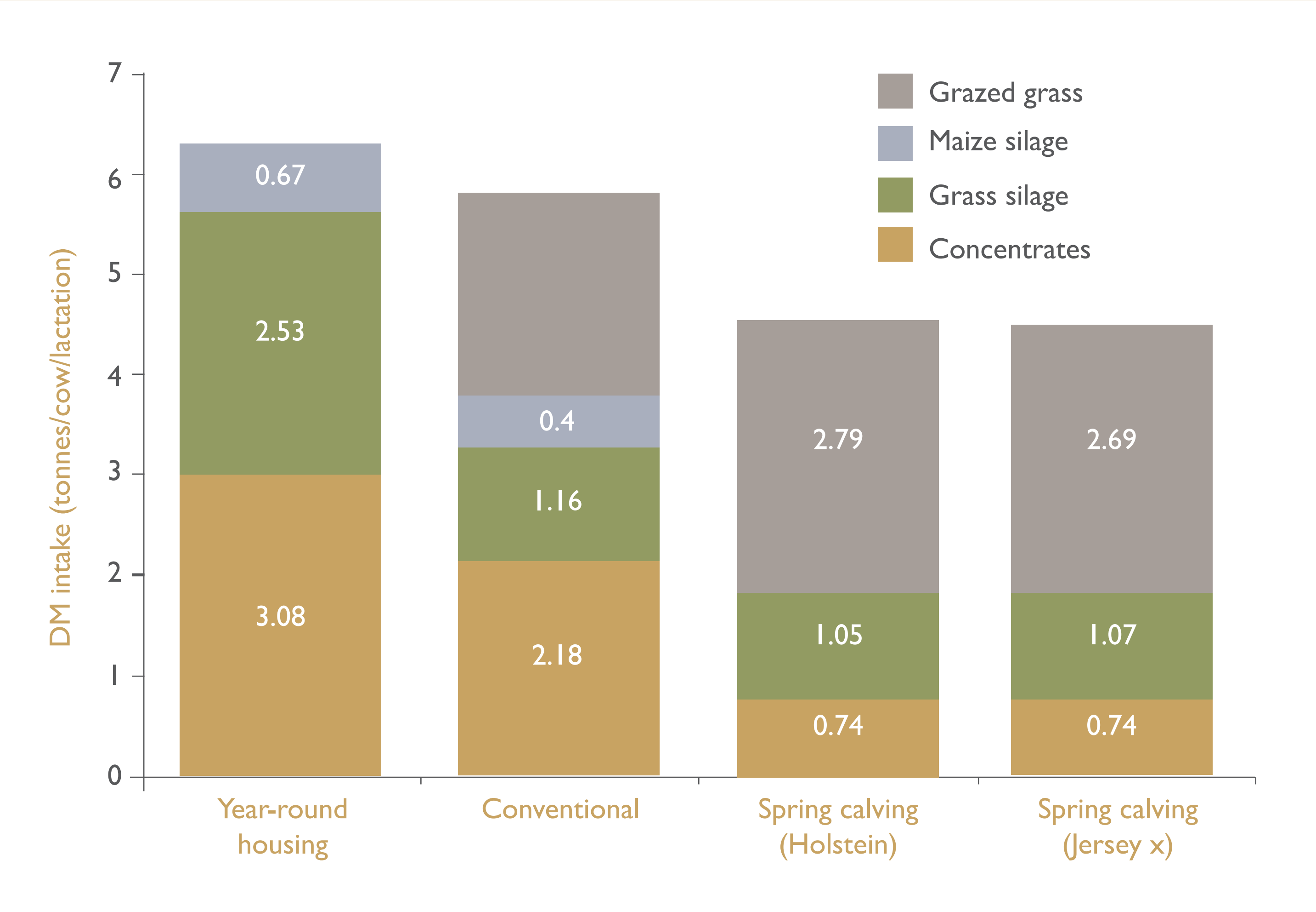

Figure 1 Intakes of each dietary component with each of the four systems

Body tissue changes

Changes in body condition score (1 – 5 scale) and live-weight of cows on each of the four systems during the course of the lactation is presented in Figures 2 and 3, respectively.

Cows on the Year-round-housing system lost less body condition than cows on any other system, and started to gain body condition by approximately week-16 of lactation. These cows completed the lactation with a higher body condition score (2.7) and a higher live-weight than cows on any other system.

Cows on the Spring calving systems had the greatest loss of body condition and completed the lactation thinner than cows on any other system. There was no difference in body condition change between the Holstein and cross-bred cows on this system.

Cows on the Year-round-housing system began gaining live-weight at approximately week-7 post calving, and continued to gain live-weight until drying-off. Cows on the Conventional system began to lose live-weight following turnout, and finished the lactation with a lower live-weight than those on the Year-round-housing system.

Holstein cows on the Spring calving system were approximately 60 kg heavier than the Jersey crossbred cows on this system. Nevertheless, the Holstein and Jersey crossbred cows on this system lost similar amounts of live-weight in early lactation and gained similar amounts of live-weight in late lactation.

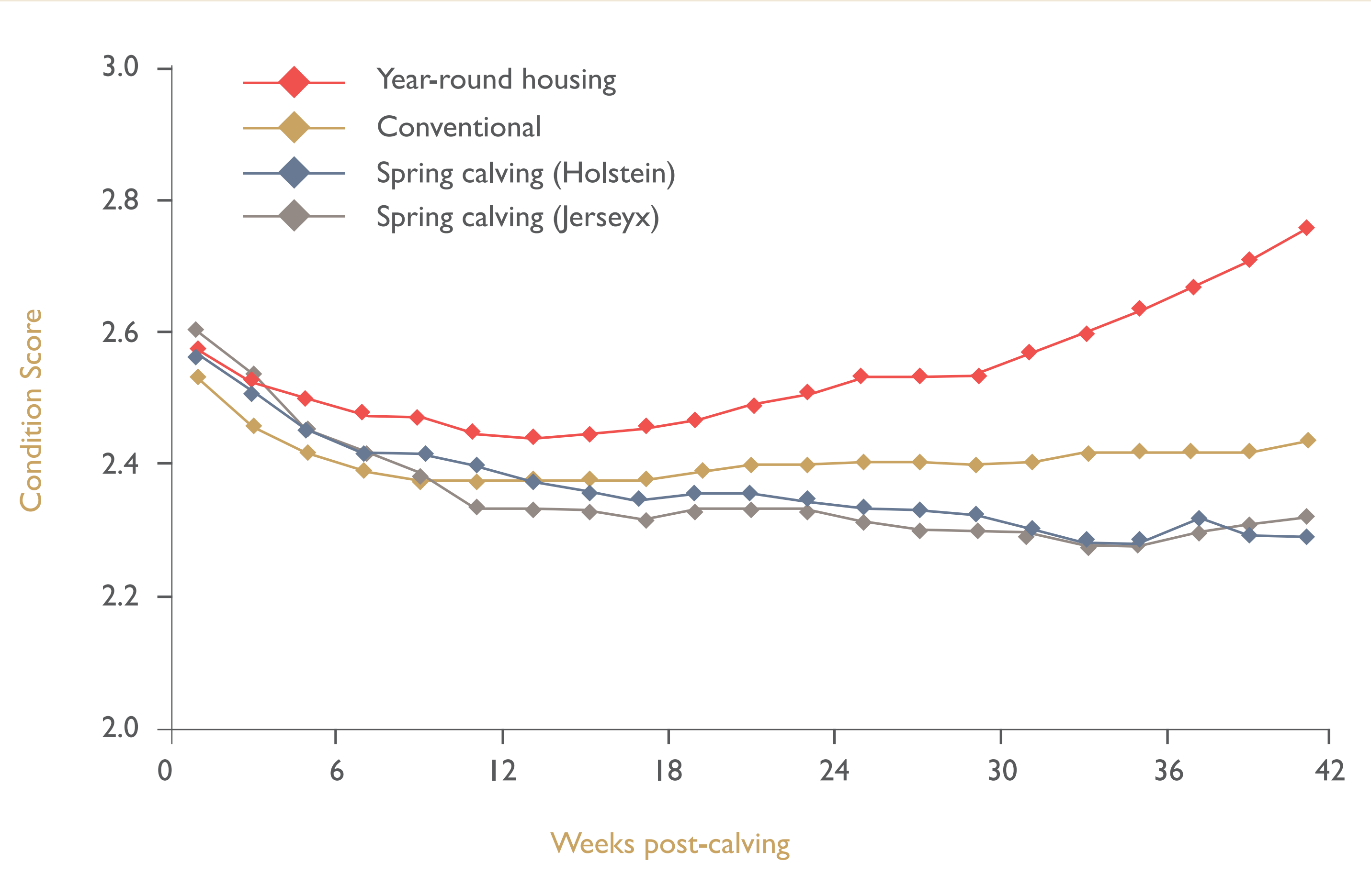

Figure 2 Effect of system on condition score changes throughout the lactation

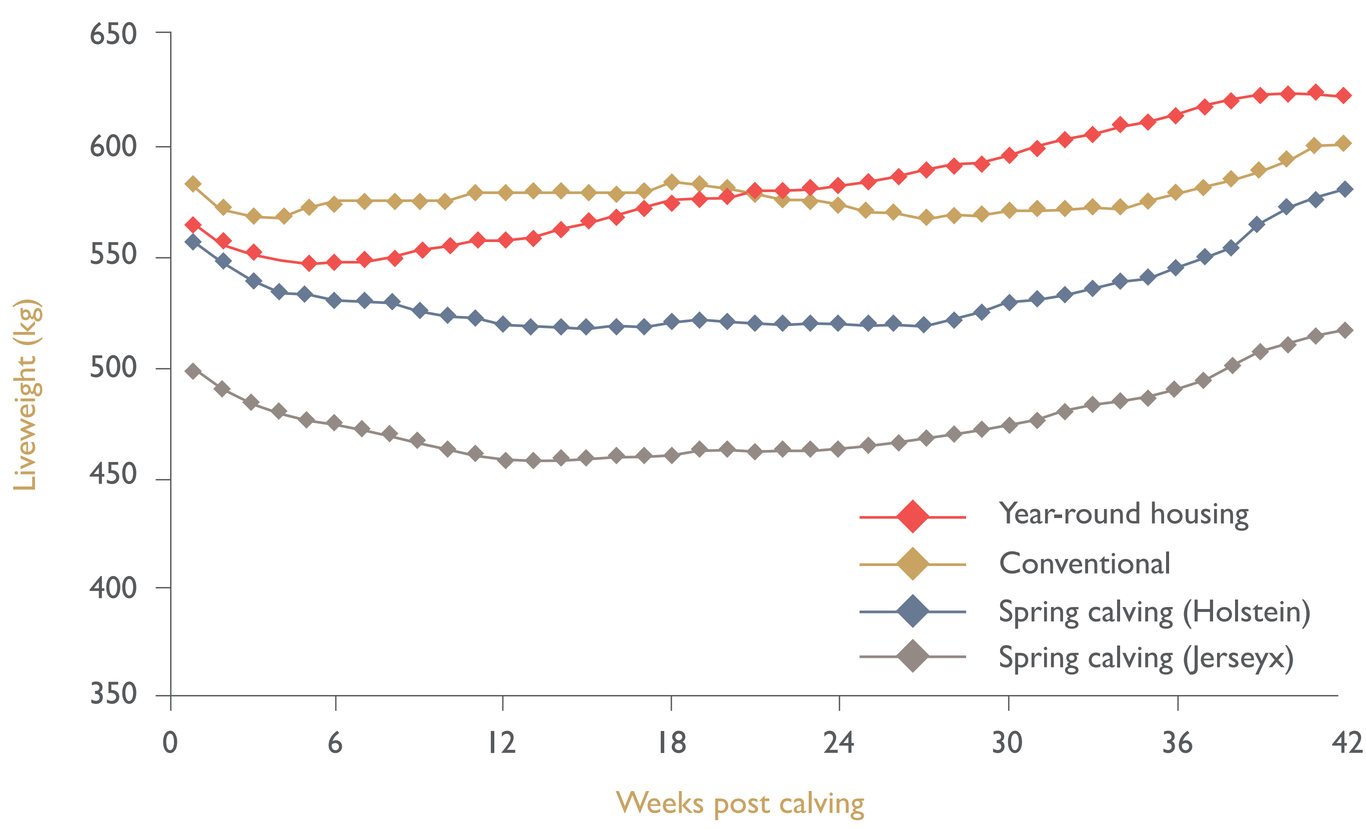

Figure 3 Effect of system on live-weight changes throughout the lactation

Milk production
Full lactation cow performance data is summarised in Table 2.

As expected, milk output was highest with the Year-round-housing system. However, cows on the Year-round-housing system produced only 900 kg more milk than those on the Conventional system, despite an additional tonne of concentrates being offered (a milk yield response of 0.86 kg milk per kg concentrate).

Holstein cows on all systems produced milk with a high fat and protein content, a reflection of the sire selection programmes that have been in place at Hillsborough during the last decade. The high milk fat content with the Year-round-housing system is due to the greater proportion of silage in the diet with this system, with forage fibre a key driver of milk fat production.

The Holstein cows on the Spring calving system produced 400 kg more milk than the Jersey crossbred cows. However, the Jersey crossbred cows produced milk with a higher fat and protein content than the Holstein cows. The overall effect was that fat + protein yield did not differ between these two cow genotypes. This agrees with the findings of previous comparisons of Holstein and Jersey x Holstein crossbred cows undertaken at Hillsborough (AgriSearch Booklet Number 24).

'Milk from forage' values were lowest with the Year-round-housing system and highest with the Spring calving systems. This highlights that milk from forage values of over 4500 kg are possible with grass based systems.

Concentrate feed rates over the full lactation decreased from 0.38 kg concentrate/kg milk with the Year-round housing system to 0.13 kg concentrate/kg milk with the Spring Calving Holstein system.

Somatic cell counts tended to be higher in the systems which involved longer periods of housing (Year-round-housing and Conventional). That somatic cell counts were not reduced with the crossbred cows in not unexpected. Hybrid vigour is known to have little effect on somatic cell counts.

Table 2 Effect of system on milk production over three full lactations

	Year-round-Housing	Conventional	Spring Calving	
			Holstein	Jersey x Holstein
Days in milk	326	317	303	302
Lactation milk yield (kg per cow)	9330	8440	6460	6050
Fat (%)	4.49	4.33	4.29	4.90
Protein (%)	3.46	3.49	3.36	3.63
Lactation fat + protein yield (kg per cow)	741	660	495	514
Milk from forage (kg)	1470	2890	4660	4180
Concentrate feed rate (kg concentrate/ kg milk)	0.38	0.30	0.13	0.14
Somatic cell count (000 cells per ml)	222	209	114	183

Fertility performance

Fertility performance is presented in Table 3. Within the systems involving Holstein cows, there was a general trend for cows on the Year-round-housing system to have poorer fertility than those on the Spring calving system. While overall conception rates at the end of the breeding season did not differ between systems, cows on the Year-round-housing and Conventional systems had a 6 – 7 month breeding season, compared to a 14-week breeding season for cows on the Spring calving systems.

There was a general trend for crossbred cows within the Spring calving system to have improved fertility compared to Holstein cows on any other system. This improvement in fertility with crossbreeding is likely due to hybrid vigour, and has been observed in previous studies at Hillsborough.

Table 3 Effect of system on cow fertility over three lactations

	Year-round-Housing	Conventional	Spring Calving	
			Holstein	Jersey x Holstein
Days to 1st observed heat	54	52	48	40
Conception to 1st service (%)	24	27	36	38
Conception to 1st and 2nd service (%)	41	45	53	68
Calving interval (days)	397	390	382	376

Health performance

There was a clear trend for Holstein cows on the Year-round-housing and Conventional systems to have an increased incidence of mastitis than Holstein cow on the Spring calving systems (Figure 4). This is likely due to the longer housing period with the Year-round-housing and Conventional systems, and the greater milk yields of cows on these systems. Cleanliness of cubicles and bedding, versus cleanliness of pasture and weather conditions during grazing, can all impact on the mastitis risk.

The trend towards a lower incidence of mastitis with the crossbred cows (even though somatic cell counts were not lower) compared to the Holstein cows, is likely due to hybrid vigour. Hybrid vigour has been shown to reduce mastitis incidence, while having little effect on somatic cell counts.

Hoof health problems are known to increase with increased duration of housing. In the current study there were trends for cows within the Year-round-housing and Conventional systems to have higher levels of lameness compared to those within the Spring calving systems, and this is likely to reflect the increased length of the housing periods and higher concentrate feed levels within these systems (Figure 5). While the exposure of the hoof to slurry within cubicle housing is likely to increase the risk of hoof health problems, poor quality cow tracks can also increase the risk of lameness within grazing systems.

Within the Spring calving systems, crossbred cows had improved hoof health compared to Holstein cows.
In general crossbreeding improves hoof health, and Jersey crossbred cows are known to have harder hooves.

Figure 4 Effect of system on the percentage of cows treated for one or more cases of mastitis

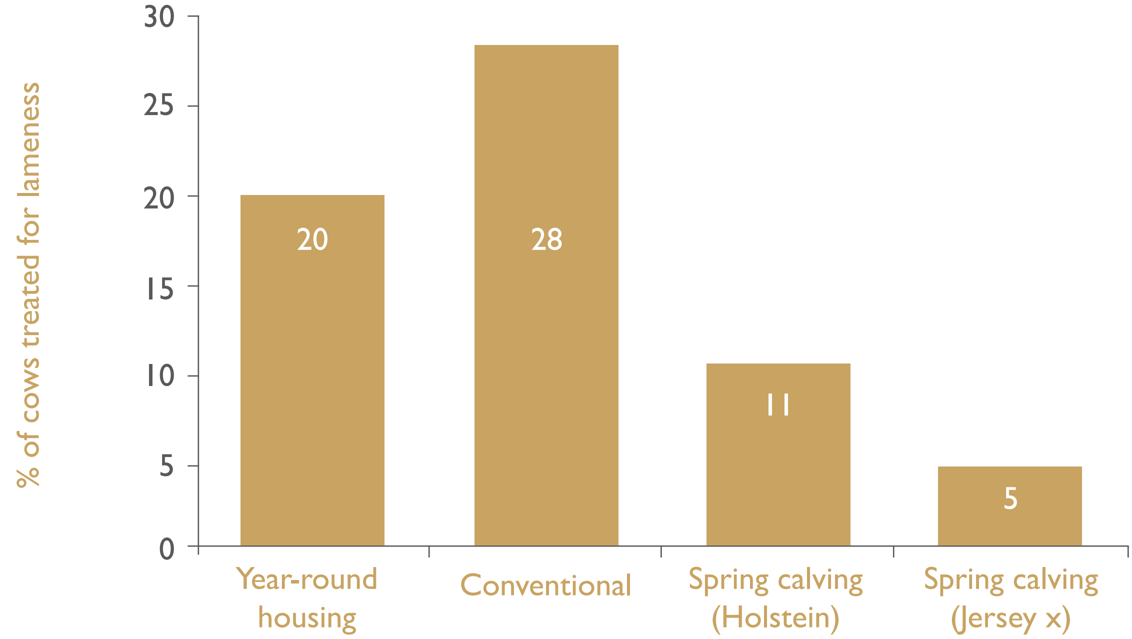

Figure 5 Effect of system on the percentage of cows treated for one or more cases of lameness

Stocking Rates

Average stocking rates during the grazing periods were 5.1 and 4.3 cows/ha with the Conventional and Spring calving systems, respectively.

Whole system stocking rates (including young-stock) are presented in Table 4. These were 2.5, 2.3, 2.4 and 2.4 for Year-round-housing, Conventional, Spring calving (Holstein) and Spring calving (Jersey x Holstein), respectively. Thus all four systems would require a derogation under the Northern Ireland Nitrates Directive Action Programme (a derogation is required when stocking rates are greater than 1.85 cows/ha, unless slurry is exported from the farm). These 'whole system' stocking rates were used when calculating whole farm phosphorus balances, greenhouse gas emissions and economic performance.

Table 4 Whole system stocking rates, including young stock

	Year-round-Housing	Conventional	Spring Calving	
			Holstein	Jersey x Holstein
Stocking rate (cows/ha)	2.5	2.3	2.4	2.4

Phosphorus balance

An objective of this experiment was to minimise phosphorus surpluses within each of the four systems. This was achieved by offering 'low' phosphorus concentrates (mean, 3.3 – 3.7 g P/kg fresh), and by not applying inorganic phosphorus fertiliser. The latter was justified by the high phosphorus status (index 3, or higher) of the soils within the study area.

Calculated phosphorus balances are presented in the first row of Table 5, with these being 5.4, 0.6, -5.7 and -5.1 kg P per ha for Year-round-housing, Conventional, Spring-calving (Holstein) and Spring-calving (Jersey x Holstein), respectively.

The positive phosphorus balance (5.4 kg P/ha) with the Year-round-housing system, despite no inorganic fertiliser phosphorus being used, is due to the large quantities of phosphorus being imported into the system in purchased concentrates. The phosphorus balance for the Year-round-housing system is likely to be sustainable in the longer term, provided slurry phosphorus is distributed across the entire grassland area of the farm.

Phosphorus balances within the other three systems are not sustainable in the long term. Indeed, the Spring-calving systems had a negative phosphorus balance (mean, -5.3 kg P/ha), which means that more phosphorus was removed from the farm in milk, calves sold and in cull cows, than was imported onto the farm in concentrate feed or fertiliser. This was reflected in the soil P status of the silage fields with these systems, which decreased over the three years of the experiment. Thus additional phosphorus will be required within these systems if they are to sustainable long term.

This was examined by modelling the impact of applying 20 kg P_2O_5/ha (8.8 kg P) to all grassland areas within each system. In this scenario (the second row in Table 5), the P balance with each system increased to 12.8, 8.7, 3.1 and 3.7 kg/ha for Year-round-housing, Conventional, Spring-Calving (Holstein) and Spring-calving (Jersey x Holstein) systems, respectively. Under this scenario the Year-round-housing system would have a phosphorus balance greater than the value of 10.0 kg/ha currently permitted for 'derogated farms' in Northern Ireland. This clearly demonstrates that with high concentrate input systems there is relatively little scope to apply additional P as inorganic fertiliser, thus highlighting the need to distribute slurry nutrients evenly across the entire land area. The relatively small surpluses with the Spring-calving systems suggest that these systems may still not be sustainable even at an application rate of 20 kg P_2O_5/ha.

Increasing the phosphorus application on all grassland within each system to 40 kg P_2O_5/ha (17.6 kg P) increases the phosphorus balance to 20.3, 16.8. 11.9 and 12.5 kg P/ha, for Year-round-housing, Conventional, Spring calving (Holstein) and Spring calving (Jersey x Holstein). At this level of P application, none of the systems would be able to meet the 10.0 kg P balance permissible for derogated dairy farms in Northern Ireland.

This emphasises the need for farmers, especially those operating lower concentrate input systems, to undertake soil tests on a regular basis, and to apply inorganic P when required, so as to maintain soil indexes at the agronomic optimum.

Table 5 Calculated phosphorus balances (kg phosphorus per ha per year) for each of the four systems at three different phosphorus fertiliser application levels

	Year-round-Housing	Conventional	Spring Calving	
			Holstein	Jersey x Holstein
No inorganic P fertiliser applied (actual situation in study)	5.4	0.6	-5.7	-5.1
If 20 kg P_2O_5/ha is applied to all grassland	12.8	8.7	3.1	3.7
If 40 kg P_2O_5/ha is applied to all grassland	20.3	16.8	11.9	12.5

Greenhouse gas footprint of the four systems

The temperature of the earth's atmosphere has increased during the last century, and this is now having an effect on global climate patterns. In addition, there is convincing evidence that climate change can be attributed in part to increasing concentrations of greenhouse gases within the earth's atmosphere.

Greenhouse gases are produced from many sources, some natural and others directly related to human activities, including agriculture. Within Northern Ireland approximately 26% of total greenhouse gas emissions are from agriculture, compared to only 9% within the UK as a whole, with this reflecting the importance of agriculture to the local economy. The main agricultural greenhouse gases are:

- **Carbon dioxide** - produced from burning fossil fuels such as diesel in tractors and coal during electricity generation.
- **Methane** - produced by bacteria in the rumen of the cow during digestion of food, and also produced at a slower rate by bacteria in slurry stores.
- **Nitrous oxide** - produced when bacteria break down nitrogen in the soil and in slurry stores.

The importance of greenhouse gases has increased in recent years as many governments are setting targets by which emissions should be reduced, while in addition, supermarkets are interested in being able to demonstrate that the products they sell are produced in an environmentally friendly manner. In addition, greenhouse gases represent a loss of both feed energy (as methane) and nitrogen from your farm. This costs you money. In general, low emissions are associated with more profitable production systems.

Total greenhouse gas emissions from a farm can be calculated using a greenhouse gas calculator, and in the case of a dairy farm, emissions are normally presented as emissions per kg of milk produced. This is normally referred to as the 'carbon-footprint', and is expressed in 'carbon-dioxide equivalents' (CO_2-e).

The AFBI Dairy Systems Greenhouse Calculator was used to calculate the carbon-footprint of each of the four systems (Figure 6). The range of carbon footprints across the four systems was relatively narrow (0.98 – 1.07 kg CO_2-e/kg energy corrected milk), thus demonstrating that all systems can operate with a similar carbon footprint, when managed efficiently.

However, data from commercial dairy farms in Northern Ireland indicate a much wider range of carbon-footprints, with footprints as high as 1.7 kg CO_2-e/kg energy corrected milk having been recorded. This clearly demonstrates the low efficiency which exists on some farms.

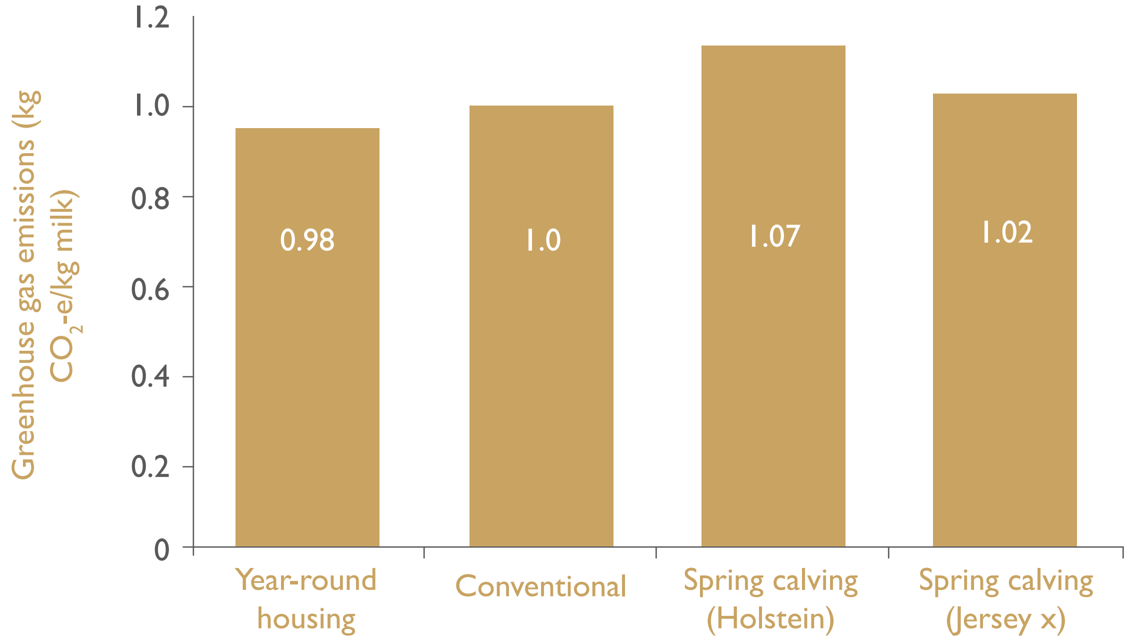

Figure 6 The carbon footprint of each of the four systems, without carbon sequestration (kg CO_2-e/kg energy corrected milk)

Financial performance of the four systems

It is now recognised that volatility in milk prices and input costs are likely to remain a permanent feature of dairy farming for the foreseeable future, and as such, optimum systems are those that are likely to be robust and resilient over a wide range of milk price/concentrate cost scenarios. Thus the net margin with each of the four systems was examined over a range of milk prices, namely 32, 27 and 22 pence per litre (adjusted for compositional bonuses).

Differences between breeds in replacement rates, stillbirth rates, and calves and cull cows sold have been included within the calculations. Feed costs for the 'milking herd' were based on actual feed inputs within the study, with costs for grass silage, maize silage and grazed grass assumed as £105, £115, £60/t DM, respectively (CAFRE Forage costs, 2013). The cost of all concentrates was assumed as £275/t fresh.

Fixed costs were obtained from CAFRE Benchmarking (average of 2012 and 2013) for herds identified as 'Fully Confined' and 'Conventional' (and producing at least 7500 litres/cow/year) and as 'Spring Calving'. These fixed costs included machinery depreciation and running costs, contractor costs, building depreciation, property charges, paid labour, conacre and finance, and miscellaneous charges. Across all farms within each of these three categories, mean fixed costs were £619, £536, £481 per cow, for Fully Confined, Conventional and Spring calving farms, respectively.

Irrespective of milk price, net margin per litre (Figure 7) was lowest with the Year-round-housing system and highest with the Spring calving systems. This reflects the lower concentrate inputs, and the increased reliance on grazed grass with the Spring calving systems. However, unless milk production is limited by milk quota, maximising margin per litre might not be a key objective.

Net margin per cow is presented in Figure 8. In general, the Conventional system was most profitable when milk price was 27 pence per litre, or higher, while at a milk price of 22 pence per litre the Spring Calving systems tended to be more profitable. This finding supports previous modelling work undertaken by AFBI which indicated that moderate input-moderate output autumn calving systems (approximately 8000 litres/cow/year), and high output Spring calving systems (approximately 7000 litres/cow/year) are the most robust systems for Northern Ireland. The system with the lowest net margin under all milk price scenarios was the Year-round-housing system. This high cost system is particularly susceptibility to low milk prices.

The Spring calving systems involving Jersey crossbred cows were more profitable that those involving Holstein cows (£39/cow/year). This supports the findings of previous comparisons of these two genotypes at Hillsborough.

Nevertheless, it must be recognised that the relative difference in net margin between each of the systems was 'relatively' small when compared to actual differences in net margin within similar systems in practice. This is due to the fact that all four systems operated at high levels of efficiency. The relatively narrow range of net margins across the four systems highlight that a range of systems can operate with similar net margins in Northern Ireland, provided high levels of technical efficiency are achieved within each system, with this in agreement with the findings of CAFRE benchmarking over many years.

It must also be noted that the ranking in net margin within the current study is impacted by many factors, and the margins can be relatively sensitive to changes in the assumptions made. Thus individual farmers, under different circumstances, and with different efficiencies from those within the current study, may have very different net margins from those determined

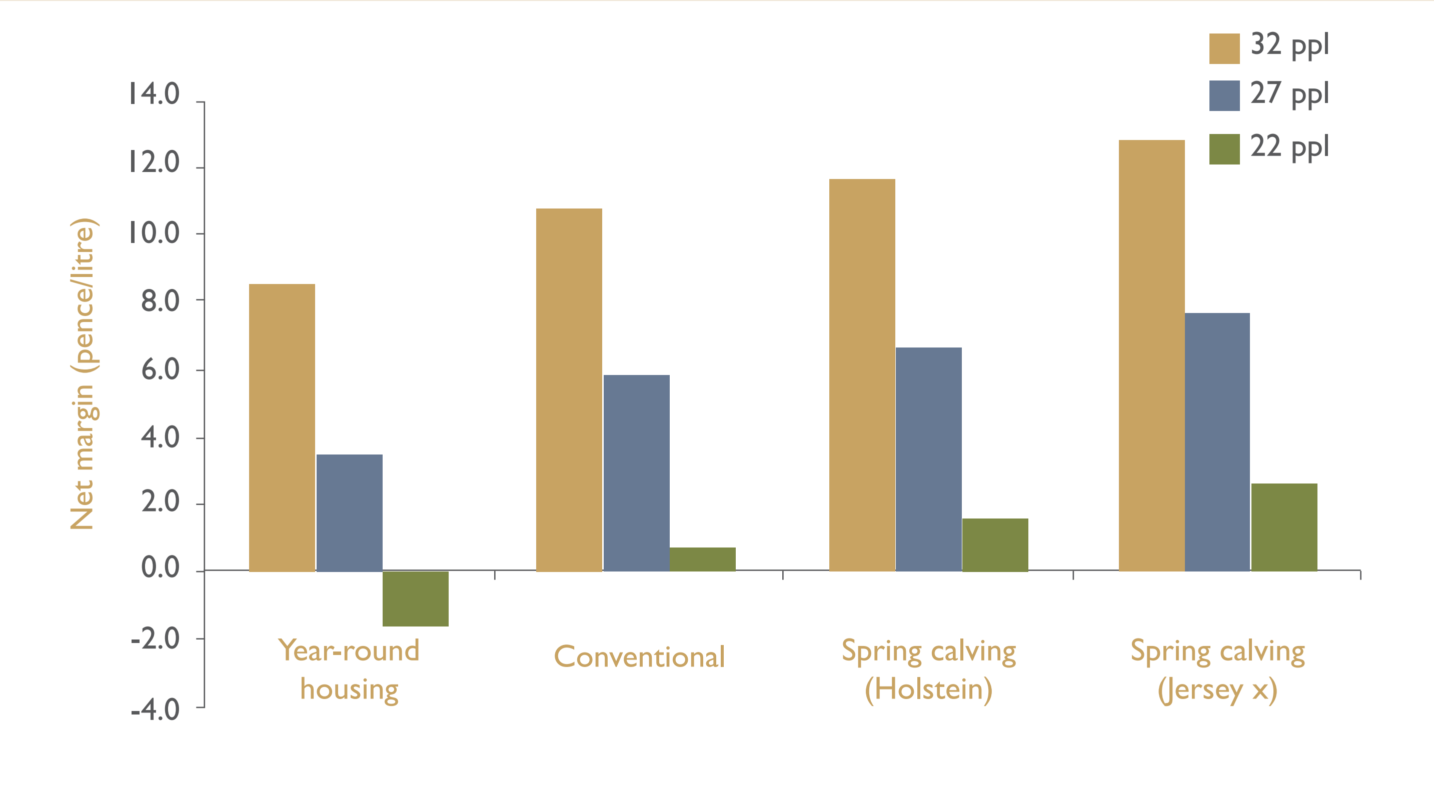

Figure 7 Effect of system on net margin per litre (pence) across a range of milk prices

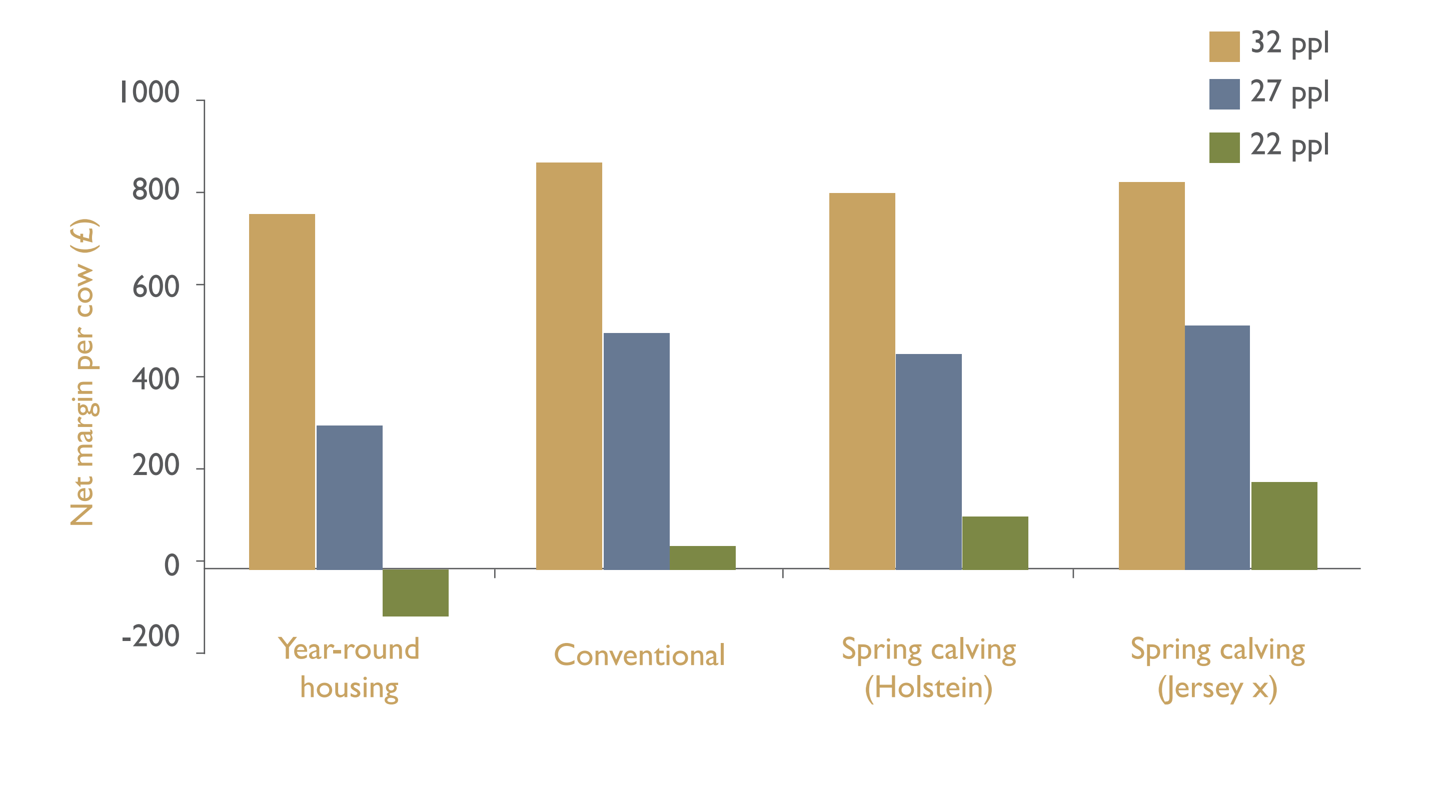

Figure 8 Effect of system on net margin per cow (£) across a range of milk prices

PART 2
Strategies to reduce phosphorus losses from grassland based dairy systems

INTRODUCTION
Eutrophication is the term used to describe the enrichment of rivers, lakes, estuaries and coastal waters with nutrients, especially nitrogen and phosphorus. Within Northern Ireland we have good water quality with respect to nitrogen, however many of our rivers and lakes are classified as 'eutrophic' due to their very high phosphorus levels. Recent research has demonstrated that a considerable percentage of phosphorus entering watercourses in Northern Ireland is of agricultural origin (from manures, fertilisers and soils). Phosphorus from agricultural land is mostly lost in 'surface runoff' (water running over the surface of the ground).

The high phosphorus levels in our rivers and lakes have created a significant problem for Northern Ireland in that we have not been able to meet the water quality standards required by the European Commission. As a result, the whole of Northern Ireland has been designated as a Nitrate Vulnerable Zone (NVZ), and this has already placed considerable restrictions on farming practices. If water quality within Northern Ireland does not continue to improve, the European Commission may force Northern Ireland farmers to adopt even more restrictive agricultural practices. Thus it is in all our interests to work towards improving water quality.

Algae bloom on eutrophic water

One of the first steps that can be taken to reduce phosphorus losses from livestock systems is to reduce the phosphorus content of the diet offered. A previous AgriSearch funded project (Booklet Number 18: Reducing Phosphorus levels in dairy cow diets) demonstrated that phosphorus levels in dairy cow diets can be reduced without having a detrimental effect on cow performance. Cows offered lower phosphorus diets will excrete less phosphorus in manure. However, manure will always contain some phosphorus, and consequently it is important that appropriate manure management practices are adopted to minimise the risk of phosphorus being lost to the environment.

Within this research programme four plot scale experiments (Experiments 1 – 3) were undertaken to examine strategies by which to reduce phosphorus losses from applied slurry, and from the soil. In each of these experiments a rainfall simulator was used to apply a precise quantity of 'rainfall' to small 'treatment' plots. The surface runoff from these plots was then collected in a tray which was inserted in the soil at the bottom of each plot, and analysed for concentrations of either 'soluble' phosphorus or 'particulate phosphorus'. Soluble phosphorus is the most polluting form of phosphorus as it is readily available to algae within rivers and lakes. Particulate phosphorus tends to be attached to soil particles, and is less polluting in the short term, but acts as a longer term source of phosphorus pollution.

Rainfall simulator, showing tray inserted into the soil at the bottom of the plot to collect surface runoff

EXPERIMENT 1

Does slurry application technique affect phosphorus losses from applied slurry

Background: The adoption of trailing shoe and shallow injection slurry spreading systems have been shown to improved the utilisation of slurry nitrogen, and to increase herbage yields. However, little is known about the effect of slurry spreading technique on phosphorus losses in surface runoff. This experiment was conducted to compare phosphorus losses from slurry applied using different application methods.

Treatments: Cattle slurry was applied immediately after grass had been harvested, at a rate of 40 m^3/ha. Four treatments were examined, as follows:

- No slurry
- Slurry applied using a splash-plate
- Slurry applied using a trailing shoe
- Slurry applied using shallow injection

Two days after slurry was applied, 'simulated rainfall' was produced using a 'rainfall simulator', and surface runoff was collected and analysed for soluble phosphorus.

Results and Conclusions: Concentrations of soluble phosphorus in the runoff collected from these plots are presented in Figure 9. As expected, losses were higher from plots which were treated with slurry, than from the 'No slurry' treatment. When the three slurry spreading techniques are compared, soluble phosphorus concentrations in runoff from the Trailing shoe and Injection treatments were approximately 37% and 47% lower than from the Splash-plate treatment.

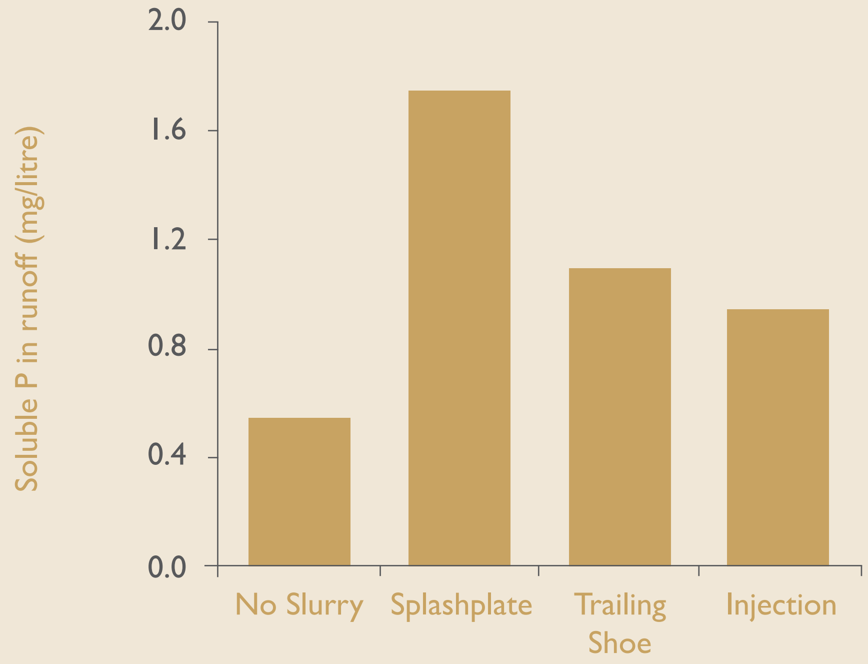

Figure 9 Effect of slurry spreading technique on soluble phosphorus concentrations in surface runoff

This study highlights that the use of either shallow injection or trailing shoe spreading systems can reduce the environmental impact of slurry spreading and help retain important nutrients within the soil system. This work is now being repeated on a field scale using farm machinery, to examine if the results are consistent with the findings from the small scale plots used in this experiment.

EXPERIMENT 2

The impact of herbage re-growth interval on phosphorus losses in runoff post slurry application

Background: One of the benefits of using a trailing shoe slurry application system is that slurry can be applied up to 2 - 3 weeks after silage has been harvested, without contaminating the re-growth herbage. Applying slurry to a field after the sward has partly re-grown (rather than to a silage stubble) may also reduce the risk of phosphorus being lost in runoff, as the growing sward may 'intercept' rainfall and reduce the amount of rain that comes into direct contact with slurry. This experiment was undertaken to examine phosphorus losses when slurry was applied after various periods of 're-growth'.

Treatments: Slurry was applied to grassland plots using a simulated trailing shoe technique. Three treatments were examined, with treatments differing in the re-growth interval since the plots had been harvested previously, as follows:

- Slurry applied on the day of silage harvest
- Slurry applied10 days after silage harvest
- Slurry applied 20 days after silage harvest

Zero Re-growth

10 Day Re-growth

20 Day Re-growth

Swards at time of slurry application

Two days after slurry was applied, 'simulated rainfall' was produced over the plots using a 'rainfall simulator'. Surface runoff was collected in trays, and the amount of 'soluble' phosphorus in runoff measured.

Results and Conclusions: Figure 10 clearly demonstrates that soluble phosphorus concentrations in runoff were reduced by approximately 60% when slurry was applied either 10 or 20-days after silage had been harvested. Allowing a grass sward to recover for between 10 to 20 days following harvest, before applying slurry using a trailing shoe, can be highly effective in reducing phosphorus losses in runoff. This is a simple technique that can be adopted to help reduce phosphorus losses to waterways.

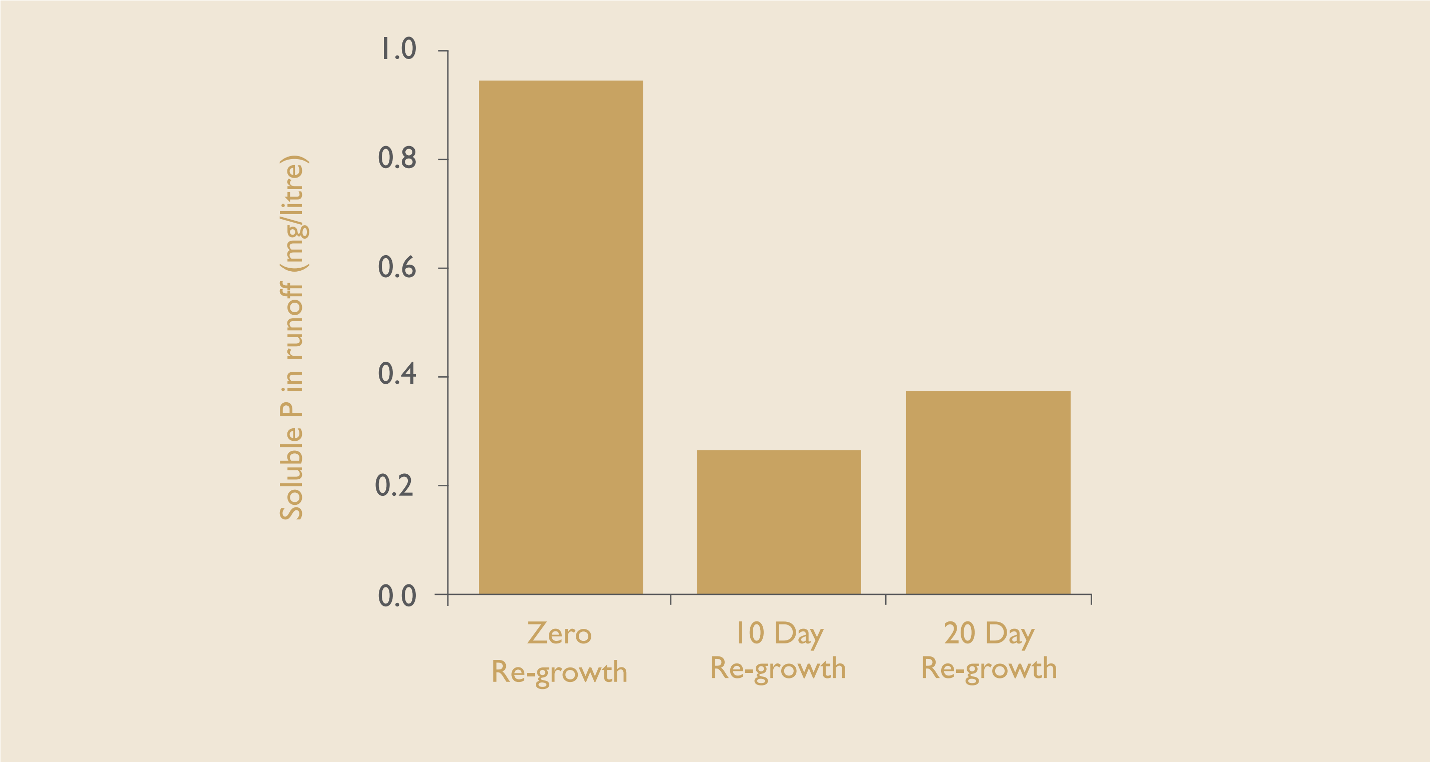

Figure 10 Effect of herbage re-growth interval on soluble phosphorus concentrations in runoff

Slurry Stores

EXPERIMENT 3

Managing early season grazing to reduce the risk of phosphorus losses in runoff

Background: Experiments 1 and 2 examined losses of 'soluble phosphorus' from slurry. However the soil itself is another potential source of phosphorus loss as considerable quantities of phosphorus can be stored within the top few centimetres of the soil on many intensive farms. It has been suggested that when the soil surface is damaged, either by grazing livestock or by heavy machinery, this soil phosphorus may be lost in surface runoff. Although properly managed grazing is thought to be 'low risk', when grazing is accompanied by trampling and soil damage, the risk of phosphorus being lost is likely to increase. This experiment was conducted to examine the impact of early season grazing by dairy cows on phosphorus losses in surface runoff.

Treatments: Three treatments were examined, as follows:

- Un-grazed sward
- Well-managed grazing with minimal soil damage
- Grazing with moderate soil damage

Ungrazed sward

Well-managed grazing

Grazing with moderate soil damage

The experimental swards were grazed on 23rd February. With the well-managed grazing treatment, cows were removed after approximately 2 hours of grazing, while with the grazing plus moderate soil damage treatment, cows were removed after grazing for approximately 4 hours. Two days after grazing, 'simulated rainfall' was produced over the plots and surface runoff collected in trays and analysed for phosphorus.

Results and Conclusions: Early season grazing had no effect on the quantity of soluble phosphorus that was lost in surface runoff. With well managed grazing there was a small increased in the quantity of 'particulate phosphorus' lost in surface runoff (Figure 11). However, particulate phosphorus losses with the 'grazing plus moderate sward damage' treatment were increased by 50% compared to the un-grazed treatment.

The results of this study demonstrate that when grazing is well managed, the risk of phosphorus being lost from the top soil layer is not significantly increased. However, when grazing was accompanied with moderate soil damage the risk of phosphorus being lost increased significantly. Thus the advice is to 'tread carefully', especially in wet weather, to minimise sward damage and a loss in yield, and to minimise the risk of phosphorus loss.

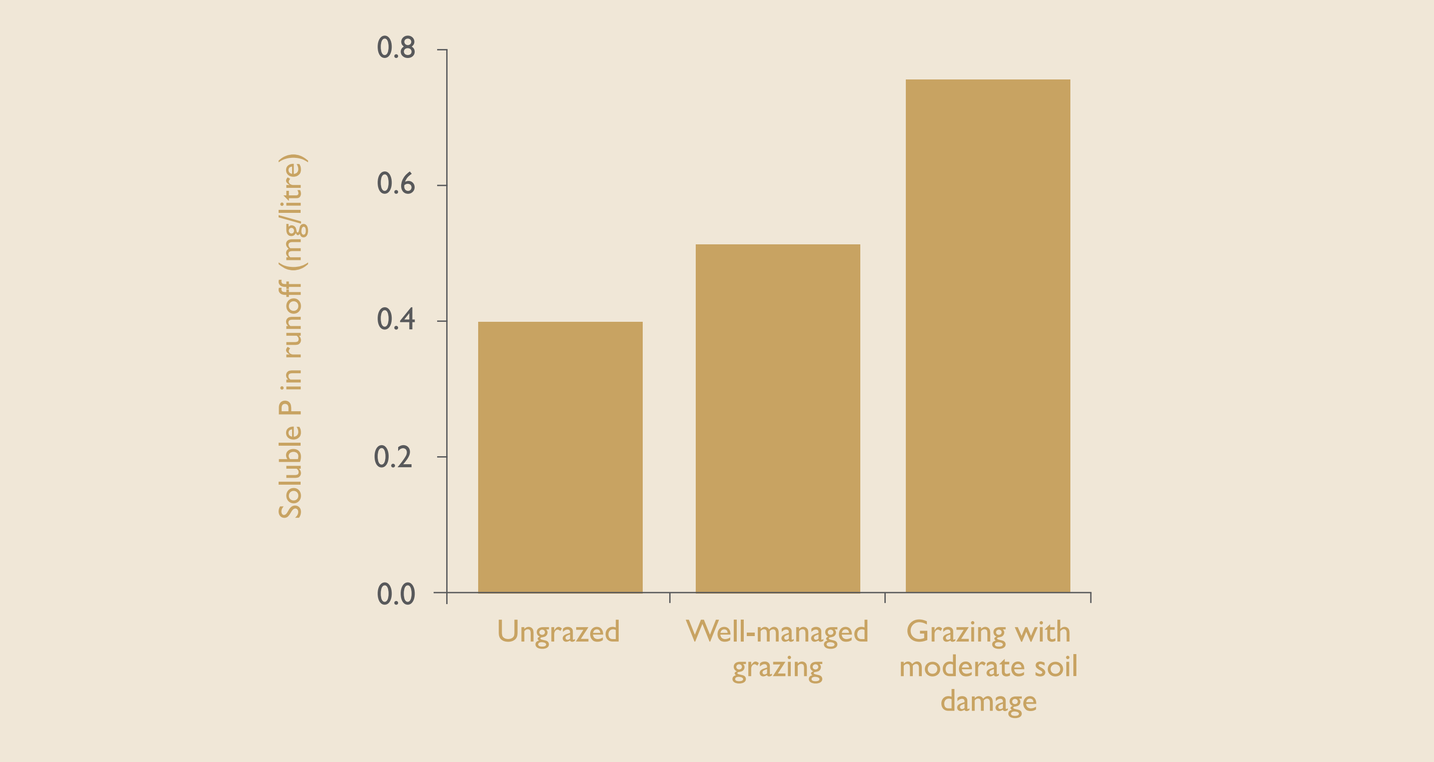

Figure 11 Effect of grazing intensity of particulate phosphorus concentrations in surface runoff

Well managed grazing in Spring reduces the risk of nutrients being lost to the environment

NOTES

AGRISEARCH BOOKLETS

1 SHEEP
The Effects of Genetics of Lowland Cross-Bred Ewes and Terminal Sires on Lamb Output and Carcass Quality
2 DAIRY
A Comparison of Four Grassland-Based Systems of Milk Production for Winter Calving High Genetic Merit Dairy Cows
3 DAIRY
Dairy Herd Fertility - Examination of Effects of Increasing Genetic Merit and other Herd Factors on Reproductive Performance
4 SHEEP
Developing Low Cost 'Natural-Care' Systems of Sheep Production
5 BEEF
An Examination of Factors affecting the Cleanliness of Housed Beef Cattle
6 BEEF
The Effects of Housing System on Performance, Behaviour and Welfare of Beef Cattle
7 DAIRY
Developing Improved Heifer Rearing Systems
8 BEEF
The Influence of Suckler Cow Genetics and Terminal Sire on Performance of the Suckler Herd
9 DAIRY/ BEEF
Reducing Organic Nitrogen Outputs from Dairy Cows and Beef Cattle in Nitrate Vulnerable Zones
10 DAIRY
The Effect of the Type of Dietary Supplement on the Performance of the Grazing Dairy Cow
11 DAIRY
Are International Dairy Sire Genetic Evaluations Relevant to Milk Production Systems in Northern Ireland?
12 DAIRY/ BEEF
Holstein Bull Beef
13 DAIRY
Effective Footbathing of Dairy Cows
14 DAIRY
Effects of Feeding Forage Maize and Whole Crop Silages on the Performance of Dairy Cows
18 DAIRY
Reducing Phosphorous Levels in Dairy Cow Diets
19 DAIRY
The Effect of Applying Slurry During the Grazing Season on Dairy Cow Performance
Contribution of Meat (Beef and Lamb) from Grass-Fed Ruminants to the Total Human Dietary Intake of Long Chain N-3 Polyunsaturated Fatty Acids.
21 BEEF
Maximising Returns from Beef Sourced from the Dairy Herd
22 DAIRY
A Comparison of the Performance of Holstein-Friesian and Norwegian Red cows on Northern Ireland Dairy Farms
23 DAIRY
The Effect of a Number of Novel Supplementation Strategies on Milk Production and Fertility of High Yielding Dairy Cows
24 DAIRY
A Comparison of the Performance of Holstein-Friesian and Jersey Crossbred Cows across a Range of Northern Ireland Production Systems
25 DAIRY
The Effect of Applying Cattle Slurry as the Sole Source of Nutrients over a Four Year Period on the Yield and Persistency of Seven Perennial Forage Crops
26 DAIRY
Grassland performance and its relationship with profitability on 10 Northern Ireland dairy farms
27 DAIRY
The Effect of offering concentrates during the dry period on dairy cow performance
28 DAIRY / BEEF
Prevalence of BVD in Northern Ireland Dairy and Suckler Herds
29 DAIRY
Developing improved concentrate feeding and grazing strategies for dairy cows
30 DAIRY
The effect of early lactation concentrate build-up strategies on dairy cow performance
31 FERTILITY
Developments in cow fertility research

Other Publications
BovIS User Guide (Carcass Benchmarking Application)
Diagnosis and Treatment of Lameness in Sheep
A comparison of confinement and grazing systems for diary cows

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