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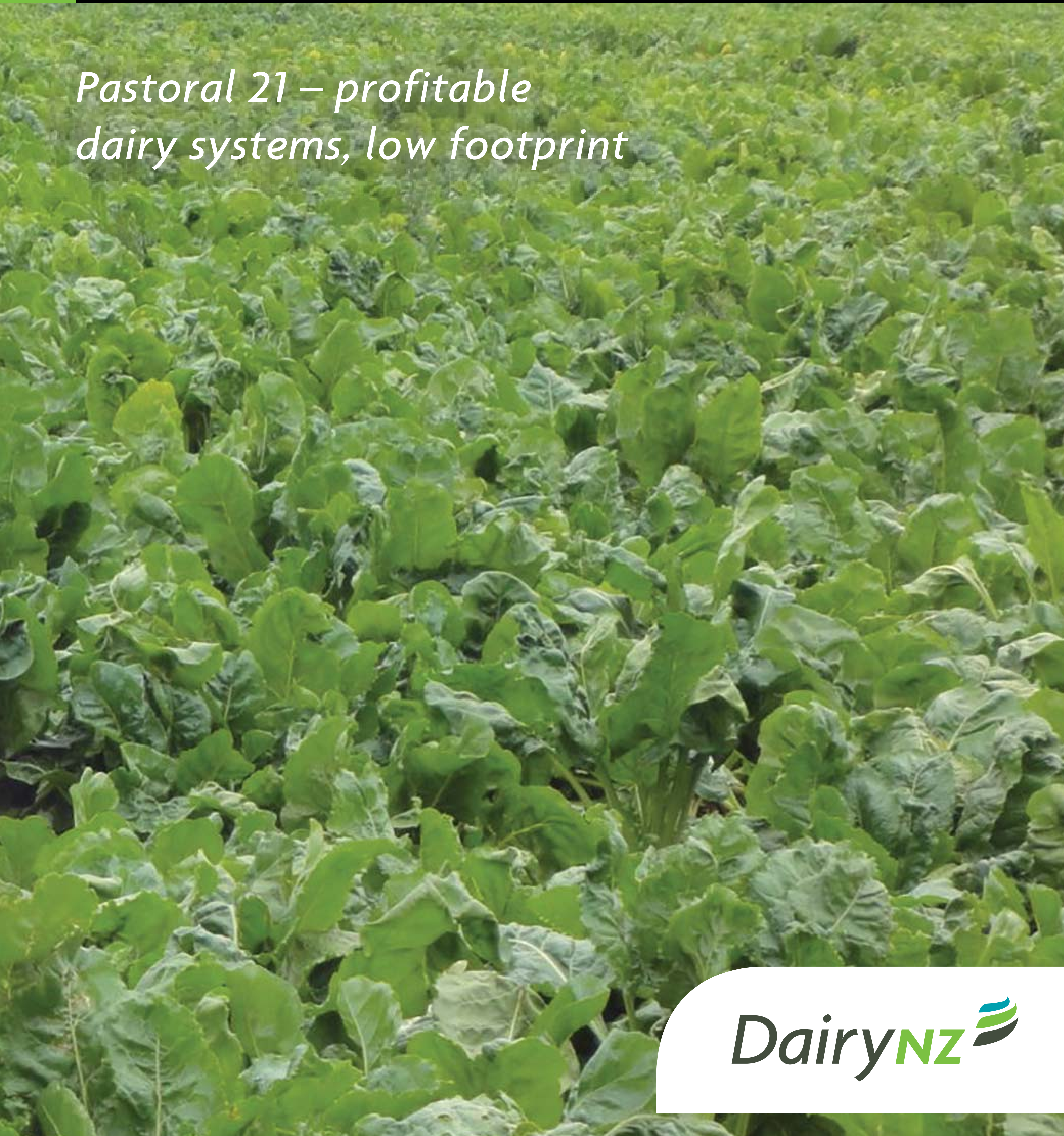

## Pastoral 21 – profitable dairy systems, low footprint

DairyNZ

OFF-PADDOCK SYSTEMS | FORAGE CROPS | MAXIMISING PASTURE

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# Pastoral 21 trial seeks profitable, low nutrient loss systems

**This issue of the *Technical Series* focuses on the Pastoral 21 (P21) programme, which is researching profitable dairy systems with a low nutrient footprint.**

Rollout of the Government's National Policy Statement for Freshwater Management via regional council planning processes could substantially impact land use and dairy farming practices throughout the country.

For farmers, the most difficult challenge is dealing with the loss of nutrients from land. For nitrogen (N), the loss is caused by nitrate leaching in drainage water below the effective rooting depth of pastures or crops. Once the nitrate has escaped the plant roots, it will accumulate in groundwater and freshwater bodies.

In some situations, phosphorus (P) can also move into surface drainage channels then into creeks and streams, if sediment (which the P is physically attached to) moves in surface runoff water.

The scenarios described above are bound by several threads.

- The more nutrients brought onto the farm, the greater the risk of nutrients being released into the environment. This is particularly true for N[1], as demonstrated by the Resource Efficient Dairying (RED) trial in the Waikato[2], which was the first attempt to relate changes in farm system intensification to nutrient losses.
- A strong focus on growing and grazing pasture is essential for future success. The efficient use of pasture binds all system elements together: water use, nutrient requirements, milk production, profit and environmental outcomes.

The four P21 projects profiled in this *Technical Series* were established in 2011/12 to test regionally-tailored options that reduce overall nutrient losses and can be applied to dairy farms. There are three targets – to reduce nutrient loss and maintain (or lift) production and profit. The studies are in the Waikato, Canterbury, Manawatu and South Otago.

This issue highlights the major learnings and conclusions to date and indicates what farmers can expect to see emerging in the next few years.

Collectively, the P21 projects attempt to measure nutrient flows in different dairy farming systems across multiple regions which, as the article pg 9-11 explains, is technically very difficult. These findings are then related to farm management and profit, providing a platform for the sustainable development of dairying in New Zealand over the next two decades.

**dairynz.co.nz/p21**

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# Driving production, profit and environment in all-grazed systems

**Can farm systems achieve high profitability and high efficiency for conversion of inputs to milk from direct-grazed pasture and crop, while lowering the farm nutrient footprint?**

### Key findings

- Farm systems designed to achieve very high production efficiency with low inputs can deliver strong profits.
- Over three lactations, the estimated operating profit of low input-high efficiency systems in the Waikato and Canterbury has been similar to their counterpart high input systems.
- Interim results indicate substantial reductions in nitrogen (N) leaching losses from the lower input-high efficiency farm systems. Estimated N leaching losses have been reduced by 40-45%, compared with higher input systems run in parallel.
- Some of the N leaching reduction comes from reducing stocking rate and by lowering imported feed and fertiliser N inputs.
- Additional gains in the Waikato project came from standing animals off pasture for restricted periods in autumn.

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The above question is being addressed by two of the four Pastoral 21 (P21) projects, in the Waikato and Canterbury.

From this question, other queries arise around supplements, appropriate stocking rate, higher per cow milksolids (MS) yield, reduced replacement rates and greater pasture diversity.

Before the project started, computer modelling helped determine the best combination of system components. These are now being tested on-farm.

Started in June 2011, the Waikato project compares two farmlets, a current system and an alternative that may reflect future requirements to reduce nitrogen (N) leaching.

The 'Future' farmlet has very high breeding worth (BW) cows stocked at 2.6/ha, a low replacement rate and N fertiliser input less than 50 kg/ha. Cows on this farmlet can be offered grain at up to 3 kg DM/cow/day, to improve their energy intake when pasture growth or quality is low. ▶

In addition, Future farmlet cows are removed from pasture to a woodchip loafing pad (stand-off) for between 8-16 hours per day from March until June, to reduce urine deposits on pasture in the high risk period (when there is reduced N uptake in autumn/winter). Cows on the 'Current' farmlet (stocked at 3.2/ha) are only removed from pasture when soil conditions are very wet.

The Canterbury project started in October 2011 and compares two farming systems.

The 'high stocking rate efficient' system is based on a stocking rate of 5 high genetic merit cows/ha, with up to 400 kg N fertiliser per year, plus up to 800 kg DM/cow brought-in grain.

The 'low stocking rate efficient' system has a stocking rate of 3.5 high genetic merit cows/ha, up to 150 kg N/ha fertiliser and 40% of the farm in a diverse pasture mix of herbs (chicory and plantain) and legumes (red clover) plus perennial ryegrass and white clover.

The Canterbury project also measures nutrient losses from the wintering area on a support block.

The high stocked herd is wintered on fodder beet (which has a relatively low N content in the bulb), supplemented with pasture silage. The low stocked herd is wintered on a late-sown kale crop supplemented with green chop oat silage (from a catch crop sown immediately after the previous winter and harvested in late spring to 'mop-up' soil N left after the cows have returned to the milking platform).

**Table 1.** Pastoral 21 projects in the Waikato and Canterbury – description of farmlets, physical production, estimated operating profit and N leaching. All results are means of the first three lactations, unless otherwise noted.

| | Waikato | | Canterbury | |
|---|---|---|---|---|
| **Farmlet** | **Current** | **Future** | **Low stocked[4]** | **High stocked[5]** |
| **Stocking rate (cows/ha)** | 3.2 | 2.6 | 3.5 | 5.0 |
| **Cow genetic merit (BW, 2014)** | 129 | 199 | 158 | 140 |
| **Use of stand-off** | No | Yes | N/A | N/A |
| **Grain fed (kg/cow/yr)** | 0 | 267 | 94 | 580 |
| **N fertiliser on pasture (kg N/ha/yr)** | 137 | 46 | 158 | 311 |
| **Effluent applied (% of farm)** | 23 | 50 | N/A | N/A |
| **Effluent applied (kg N/ha/yr)** | 8 | 17 | N/A | N/A |
| **Pasture eaten (t DM/ha/yr)** | 14.3 | 13.0 | 14.8 | 16.9 |
| **Feed purchased (t DM/ha/yr)** | 1.4 | 1.3 | 0.34 | 4.95 |
| **MS produced (kg/cow/yr)** | 367 | 442 | 509 | 467 |
| **MS produced (kg/ha/yr)** | 1186 | 1158 | 1782 | 2337 |
| **Days in milk** | 239 | 260 | 269 | 258 |
| **Winter crop fed off-farm** | N/A | N/A | Kale | Fodder beet |
| **Estimated operating profit ($/ha/yr)[1]** | 4310 | 4083 | 5094 | 5368 |
| **N leaching (kg/ha/yr)** | 59[2] | 30[2] | 22[3] | 31[3] |

[1] Based on $7.40 and $6.75/kg MS in all three years for Waikato and Canterbury, respectively.

[2] Average of two years data from suction cup samplers.

[3] Average of three years data modelled in Overseer.

[4] Low stocking rate efficient.

[5] High stocking rate efficient.

## The Waikato story

The first three seasons have demonstrated that similar MS/ha can be produced from both systems, with similar estimated operating profit (table 1). The Future farmlet was about 5% less profitable than the Current farmlet, but both farms performed 20% better than the median for Waikato dairy farms.

Analysis of drainage volumes and nitrate concentrations from 2012 and 2013 revealed significantly less N leaching on the Future farmlet compared with the Current farmlet (table 1).

These results are similar to modelling predictions before the project began[1] and are achieved in a small-scale, controlled system. The next steps are to identify which management interventions reduce N leaching the most and confirm (or otherwise) that the results can be scaled up to the commercial farm level.

### Modelling work

Actions to reduce N leaching on the Future farmlet can be grouped into two strategies: lowered inputs and standing cows off pasture for defined periods to capture urine.

Lowering inputs includes using less N fertiliser and reducing stocking rate, while making more use of cows with higher genetic merit, as they partition more feed into milk and less N is excreted in urine[2].

Urine patch models[3] capable of predicting N leaching, while considering urine patches and the relatively high leaching from these patches, were set-up to simulate the Current and Future farmlets (and to test the models) for 2013 (calendar year) using inputs described in table 1.

All simulations were run using Ruakura climate data for 2013 and parameters for a Horotiu silt-loam soil.

The models predicted higher N leaching compared with the measured values for both systems, but the relative difference between Current and Future was consistent with the values measured (table 2).

Obtaining close agreement between predicted and measured values for the two systems' N leaching losses is critical in interpreting the farmlet comparison's results.

From here, the models can help identify which mitigation measures (included in the Future system's design) are having the largest effect on nutrient losses. This is the next task for the modelling team, in both the Waikato and Canterbury projects.

**Table 2.** The measured and model-predicted N leaching for the 2013 calendar year for two farm systems (Current, Future) in the Waikato.

| | N leaching (kg N/ha per year) | | % change (Current to Future) |
|---|---|---|---|
| | Current | Future | |
| **Measured** | 67 | 38 | - 43 |
| **Predicted** | 80 | 52 | - 35 |

## Waikato summary

The total feed eaten on the Future farmlet was less per hectare (table 1), which could have resulted in less excretal N output.

However, removing cows from pasture for periods in autumn and winter would have also decreased the amount of urine deposited directly on the paddocks and decreased N leaching[4].

There were also differences in leaching between the two years. N leaching was greater in winter 2013 following a dry summer, despite less drainage that winter. Re-wetting soils after a drought causes a mineralisation flush[5] which could have contributed to N leaching.

Drought would also limit uptake of N from urine patches during the summer, possibly exacerbating N leaching. Despite these differences between years, the Future system was still effective in decreasing losses.

To conclude, using a combination of approaches (lower N inputs, a stand-off pad, higher BW cows) resulted in a N leaching reduction of 40-50% on the Future farmlet over the two winters measured.

The next step is to understand the roles of diet and standing-off in decreasing N leaching in the Future farmlet.

*A Waikato P21 study identified a combination of approaches which reduced N leaching.*

## Canterbury project

Averaged across the first three seasons, MS production for the low stocked herd was 9% higher per cow but 31% lower per hectare (milking platform only) compared with the high stocked herd (table 1).

The higher per hectare production in the high stocked herd was supported by an additional 143 kg N fertiliser/ha and an additional 4.6 t DM/ha of imported supplement, compared with the low stocked herd.

Despite higher milk income in the high stocked herd, the estimated operating profit was similar for both systems as a result of higher operating costs in the high stocked system, of which higher direct feed costs were one component.

Estimated N leaching (modelled using Overseer) was higher for the high stocked herd (31 kg N/ha) than the low stocked herd (22 kg N/ha), primarily due to the higher stocking rate and greater N inputs through fertiliser and feed.

### Canterbury comparison

The urine patch models[6] and Overseer predicted N leaching for the 2013 calendar year. Climate data from Lincoln weather station and soil parameters for a Templeton silt-loam were used.

The urine patch models predicted higher N leaching than Overseer (table 3). However, the relative difference between high stocked and low stocked herds predicted by both tools was similar (24% less leaching in the low stocked herd compared with high stocked).

**Table 3.** Predicted N leaching (kg N/ha/year, milking platform only) for high stocking rate efficient and low stocking rate efficient systems in Canterbury for the 2013 calendar year. Predictions are from two modelling tools, urine patch models and Overseer.

| Method | High stocked herd | Low stocked herd | |
|---|---|---|---|
| **Urine patch models** | 45 | 34 | kg N/ha/year |
| **Overseer** | 29 | 22 | kg N/ha/year |

## Conclusions

Many management combinations, including lower inputs and standing cows off pasture, can be implemented on commercial farms.

The combinations tested in the Waikato and Canterbury have so far delivered results very similar to those predicted from pre-experimental modelling. These strategies can effectively reduce N leaching losses, while retaining high levels of physical and financial performance when optimally managed.

In explaining the differences reported in table 2 (measured and predicted) and table 3 (urine patch models and Overseer), it is important to note that Overseer uses long-term annual averages (for example, for climate and pasture growth). The urine patch model uses actual information for each year and can be useful for identifying why measured reductions are seen. Therefore, differences between the two tools are to be expected.

The Waikato and Canterbury results have been achieved in controlled demonstration farmlets under a very high standard of management.

The next step will test how well they can be reproduced on commercial scale farms. This is happening at the 560-cow Lincoln University Dairy Farm (LUDF) this year, where a 'low input, low infrastructure' system similar to the low stocked herd is being implemented.

### Fast facts

- In the Waikato, using a combination of lower N inputs, a stand-off pad and higher BW cows resulted in a N leaching reduction of 40-50% on the Future farmlet over the two winters measured.
- Averaged across the first three seasons, MS production for Canterbury's low stocked herd was 9% higher per cow but 31% lower per hectare (milking platform only) compared with the high stocked herd. The high stocked herd's higher production was supported by an additional 143 kg N fertiliser/ha and an additional 4.6 t DM/ha of imported supplement, compared with the low stocked herd.

*Following P21's farmlet studies, the systems will be reproduced on commercial scale farms.*

# Can off-paddock farm systems balance profit with the environment?

**Pastoral 21 (P21) projects in the Manawatu and South Otago are investigating whether or not standing cows off-pasture can increase productivity and reduce impacts on water quality, while maximising pasture utilisation.**

The environmental footprint of dairying in both these regions is under scrutiny – particularly the levels of nitrate (N) leached and phosphorus, sediment and faecal contamination in runoff to rivers and streams.

Wintering non-lactating cows on crops also creates additional environmental impacts when treading reduces the soil's water absorption, leading to greater runoff of water and increased contaminant loss.

To decrease treading damage and improve supplement utilisation, some farmers are considering an off-paddock facility, ranging from a stand-off or feedpad to loose-housed and freestall barns.

However, little information exists about whether production and environmental benefits can be achieved through optimised management of off-paddock facilities on commercial farms.


**Dawn Dalley**, DairyNZ

Mike Hedley, Massey University; Ross Monaghan, AgResearch


Research teams at Massey University's No.4 Dairy Farm in Manawatu and at the Telford Farm Training Institute's dairy farm in South Otago have established farm-scale trials to address this information gap.

Investment in off-paddock facilities is a significant cost and full financials from these system trials will be produced as the work progresses. ▶

## Why go 'off-paddock?'

The capture, storage and low-rate re-application of urine and dung deposited during standing off periods has been proven to markedly reduce N leaching[1]. Plot scale research and modelling analysis has also indicated that taking cows off pasture during high-risk periods can reduce treading damage and increase pasture dry matter production[2].

However, results also indicate that standing off can compromise pasture utilisation, making it difficult to achieve consistent and even post-grazing residuals, unless carefully managed. While the risk is greatest when pasture growth rates are high, it can also occur at cooler times, such as in winter in the southern North Island.

The challenge for both projects is finding strategies for standing off that minimises treading damage, while maximising pasture utilisation and cow performance.

Dairy cows can eat their daily pasture dry matter intake in two periods of four-hourly grazing[3]. This provides the opportunity to stand cows off pasture when soils are wet, while still achieving a high pasture intake and limiting the need for additional supplementary feeding.

## Triggers for standing cows off

The decision to remove cows from pasture is based on soil wetness. Clay and silt loam textured soils at field capacity (i.e. a soil water deficit of 0 mm) is considered too wet to graze.

A water deficit of 1.5 mm (equivalent to one sunny day in winter, creating 1.5 mm of evaporation) should allow pasture to be grazed without treading damage. A further four days of winter sunshine will give a soil water deficit of 7 mm before a tractor-driven effluent tanker should apply effluent.

Analysis of 35 years of climate data indicates that at Massey University there are between 17 and 110 days per year wetter than the 1.5 mm grazing trigger. The worst-case scenario of 33 days continuously wet soils is when cows should ideally be stood-off, but clearly this can't happen in practice.

At Telford, low winter pasture growth rates and wet soils mean cows must be wintered off the milking platform on forage crops or in an off-paddock facility. Analysis of 20 years' climate data indicates that, on average, soils are too wet for safe grazing for a further 21 days per year outside the winter months.

To accommodate welfare needs, cows should be able to lie down for at least eight hours per day, which cannot be achieved on concrete feedpads.

These lying times are achievable in well-managed stand-off pads and loose-housed barns with woodchip, sawdust bedding[4] or slatted concrete[5], or in freestall barns with sand, rubber or foam mattresses[6].

## Telford results

At the Telford dairy farm, a 39 ha farmlet has 110 cows wintered in a loose-housed barn with woodchip bedding (the barn system[7]). Standing cows off is implemented in spring and autumn.

This herd's productivity and environmental footprint is also being compared with a 'standard' herd of 110 cows wintered on a support block's brassica crop. This farmlet is a 39 ha milking platform of identical soil type and topography.

*At Telford, 110 cows wintered in a loose-housed barn are being compared with a 'standard' herd wintered on a support block's brassica crop.*

At Telford, milksolids production per hectare was similar for both seasons (table 1). Expected peak milk production in the barn herd in 2012/13 was not achieved due to diet changes and extended periods in the barn through the wet spring.

The barn herd was offered less supplement during lactation, achieved more days in milk and more pasture silage was conserved on the barn system. However, failure to achieve consistent and even post-grazing residuals in early lactation, and a longer grazing rotation for most the season, led to a higher average pasture cover and often poorer quality pasture on offer.

Throughout spring, there was constant tension between protecting soils and pastures from damage and achieving high per cow production. Standing cows off during autumn was easier to integrate, as it occurred when the grazing rotation required lengthening and supplements were needed to fill pasture deficits.

Additional days in milk were achieved by standing cows off during autumn to protect pastures from damage, but this didn't translate into significantly more milk production.

Although the productivity responses at Telford have thus far been modest, barn use enabled the targeted 30% reductions in N, P and sediment losses to be achieved.

Much of this effect has been attained because the barn system does not require winter forage crop area, which has a higher nutrient (and sediment) loss risk.

## Massey results

At Massey, a freestall barn built to house 200 cows is being used for standing cows off a 73 ha milking platform (2.75 cow/ha). Annualised depreciation and interest costs of $200 and $300 per annum, respectively, are needed to cover the cost of the freestall barn and associated effluent infrastructure.

Cows are wintered in the barn, graze pasture when soil conditions allow and are housed at night (February-June) to capture urine and dung, which is reapplied by tanker the next spring.

This herd's productivity and environmental footprint is also being compared with a 'standard' herd of 200 cows on 75 ha of identical soils (2.66 cows/ha), with 40% of the herd grazed off the milking platform in winter. Maize, pasture silage and meal are imported into both farmlets as required.

Both farms have 5-7% of the area renovated each year through the production of summer turnips. The goal for the housed system is to generate increased pasture growth from less treading

**Table 1.** Pastoral 21 project at Telford – description of farmlets, physical production, estimated operating profit and nitrogen, phosphorus and sediment loss for a 'standard' crop-based wintering farmlet and a 'barn' farmlet wintering cows indoors.

| | 'Standard' | | 'Barn' | |
|---|---|---|---|---|
| **Telford Farm Training Institute dairy farm** | **2012/13** | **2013/14** | **2012/13** | **2013/14** |
| **Stocking rate (cows/ha)** | 2.82 | 2.82 | 2.82 | 2.82 |
| **N fertiliser on pasture (kg N/ha/yr)[1]** | 109 | 111 | 74 | 63 |
| **Pasture grown (t DM/ha/yr)** | 13.0 | - | 14.4 | 12.9 |
| **Supplement made (kg DM/ha)[1]** | 671 | 470 | 1206 | 1584 |
| **Total supplement offered (kg DM/cow/yr)** | 563 | 497 | 445 | 387 |
| **MS produced (kg/cow)** | 323 | 353 | 327 | 361 |
| **MS produced (kg/ha)[1]** | 887 | 995 | 906 | 1017 |
| **Estimated operating profit ($/ha/yr)[2,3]** | 2030 | # | 1980 | # |
| **Predicted N loss (kg/ha/yr)[2]** | 25 | # | 13 | # |
| **Predicted P loss (kg/ha/yr)[2]** | 0.71[4] | # | 0.42 | # |
| **Sediment loss (kg/ha/yr)[2]** | 247[4] | # | 75 | # |

[1] Expressed per hectare of milking platform
[2] Expressed per hectare of whole farm area
[3] Based on $6.15/kg MS, does not include interest on borrowing or depreciation
[4] Does not include P and sediment losses in subsurface drainage from winter forage crop paddocks.
# Data still to be collated and performance calculated.
- Data not available due to infrequent farm walks during the season.

damage of wet soils and N boosted pasture from uniform slurry application, converting this to additional milksolids production and profit to pay the added depreciation and interest cost associated with this system.

At Massey, this is the first season with the fully completed freestall barn and effluent treatment system. Cows entered the barn in February 2014 to capture 50% of the late summer/autumn urine. Initial research effort has focused on acclimatising cows to spending nights in the barn and the first task was testing if bedding type assisted in training cows to use freestalls.

Cows had a choice of three bed types: sand, foam mattress and rubber wingflex mats. After one week, 74% of cows freely took up beds and 26% of cows lay in the laneways. Within the first three days, cows adopted sand beds the fastest.

The rate of foam and rubber mat use increased with the addition of sawdust after seven days and hay enticed those lying in the alley to move into the stalls. 7% of cows consistently lay in the alley. For the rising two-year-old heifers, hay was used from the outset of training and only 5% were not using freestall beds by day four.

## Conclusions

Integration of an off-paddock facility into a pasture-based dairy system requires careful planning and attention-to-detail with design and management, if the benefits of such infrastructure are to be realised.

Fully removing cows from paddock grazing during winter and for short periods in spring and autumn will reduce environmental impacts but further improvements in the productivity and profitability of such systems are required.

### Fast facts

- At Massey, 35 years of climate data indicated a worst-case scenario of 33 days' continuously wet soils when cows should ideally be stood-off.
- Although the productivity responses at Telford have been modest, barn use enabled the targeted 30% reductions in N, P and sediment losses to be achieved.

## Adapting to off-paddock systems

### Loose-housed barns

In loose-housed barns with woodchip bedding, implementing standing off has been challenging.

Reasons include: difficulty maintaining milk production; challenges producing sufficient high quality silage for early lactation cows; and difficulty consistently achieving target grazing residuals and pasture covers. Other reasons include issues managing cleanliness of the barn surface (to the standard required for lactating cows) and complicated decision-making for the farm team during busy periods.

### Freestall barns

A good transition plan is required to adapt cows to stalls:

- allow up to seven days of 24 hour housing for cows to acclimatise to stalls
- expect that up to 8% of older cows will not use stalls, even after six weeks
- sand bedding, although preferred by cows, is labour-intensive and requires a sophisticated effluent system to handle sand-laden manure
- construction should coincide with the non-lactating period so cows can be housed for 24 hours for at least a week, after initially allowing them to enter the barn for feeding only.

### Infrastructure

Good infrastructure and effluent management planning are required to deal with the large volumes of dung and urine produced when cows are housed. Road crossings, distance to suitable paddocks for effluent application and insufficient effluent infrastructure can restrict nutrients returning to where pasture silage has been harvested. Woodchip material used as bedding will likely require composting before applying to pastures and this requires capital infrastructure to avoid nutrient loss.

*Integration of an off-paddock facility into a pasture-based dairy system requires careful planning.*

# Understanding the environmental footprint of farm systems

**Measuring losses of nitrogen (N) and phosphorus (P) in water is a large, technical challenge for the Pastoral 21 (P21) programme. So far the results strongly indicate reduced N and P loss from the alternative systems using lower stocking rates, crops and off-paddock systems.**

**Mark Shepherd**, AgResearch
Mike Hedley, Massey University; Keith Cameron, Grant Edwards, Hong Di, Lincoln University; Ross Monaghan, AgResearch

**Now, the project's priority is to add certainty to the findings so far and confirm the importance of farm system components on overall losses.**

The P21 programme's four farmlet studies compare regionally-typical farm systems against modified systems that aim to maintain productivity and profitability, while decreasing N and P losses to water.

The modified systems were developed using previous trial results and models that predict nutrient flows, animal performance and profit. These identified the most promising management options[1].

## Quantifying N and P losses

Production is ultimately measured by milk in the vat, whereas quantifying losses of N and P in water is less straight-forward. All measurement methods have pros and cons, and a range of approaches are used in the P21 programme.

Hydrologically-isolated plots (a site that captures any drainage and channels it through a single point for measurement) are a useful tool to measure paddock-scale losses of N (and P) through drains[2]. Drained, isolated plots form part of the grazing rotations at the Telford and Manawatu farmlets.

In free-draining soils, porous ceramic cups placed 60-70 cm into the soil can estimate N concentrations[3] in drainage water and leaching loads, when combined with a drainage estimate. ▶

## Key findings

- Interim results indicate substantial reductions in nitrogen (N) and phosphorus (P) losses from the alternative farm systems. Evidence is being gathered from each system. Since no method of measuring N and P is perfect, multiple methods are being used and data collated across each farm system.
- The major reductions in N leaching come from importing less N and decreasing urine deposits on paddocks in autumn/winter by using off-paddock facilities. These approaches are well-known, but the programme's strength comes from understanding the costs/benefits for the whole farm system by combining with productivity/profitability assessments.
- Better grazing management of winter forage crops can substantially reduce the loss of P and sediment in surface runoff. Strategic grazing and careful management of gullies and swales, that act as critical source areas (CSAs)[a], is particularly important on sloping land.
- The challenge remains for grazed winter forage crops and N leaching. The large amounts of urinary N deposited during crop grazing make leaching likely during the post-grazing period of bare soil. As N intake is already low by dairy cows grazing forage crops, there is limited opportunity for diet manipulation to reduce N intake.

However, the measurement area of an individual ceramic cup is small, so large numbers are required for a reliable estimate of N leaching from grazed paddocks[4]. This is the approach taken in the Waikato.

The stony Canterbury soils offer the greatest challenge. Here, lysimeters (columns of soil used for measuring drainage and N leaching, and are suited to free-draining soils) measure losses at the individual urine patch scale. This then requires estimates of urine coverage scaled up to the paddock.

Urine patch coverage is being measured by photographs of the urine-wetted area immediately after its deposit by cows and computer analysis calculates the actual area. Urine frequency and volume is also measured through devices on some cows, and urine N concentration is analysed on specific samples.

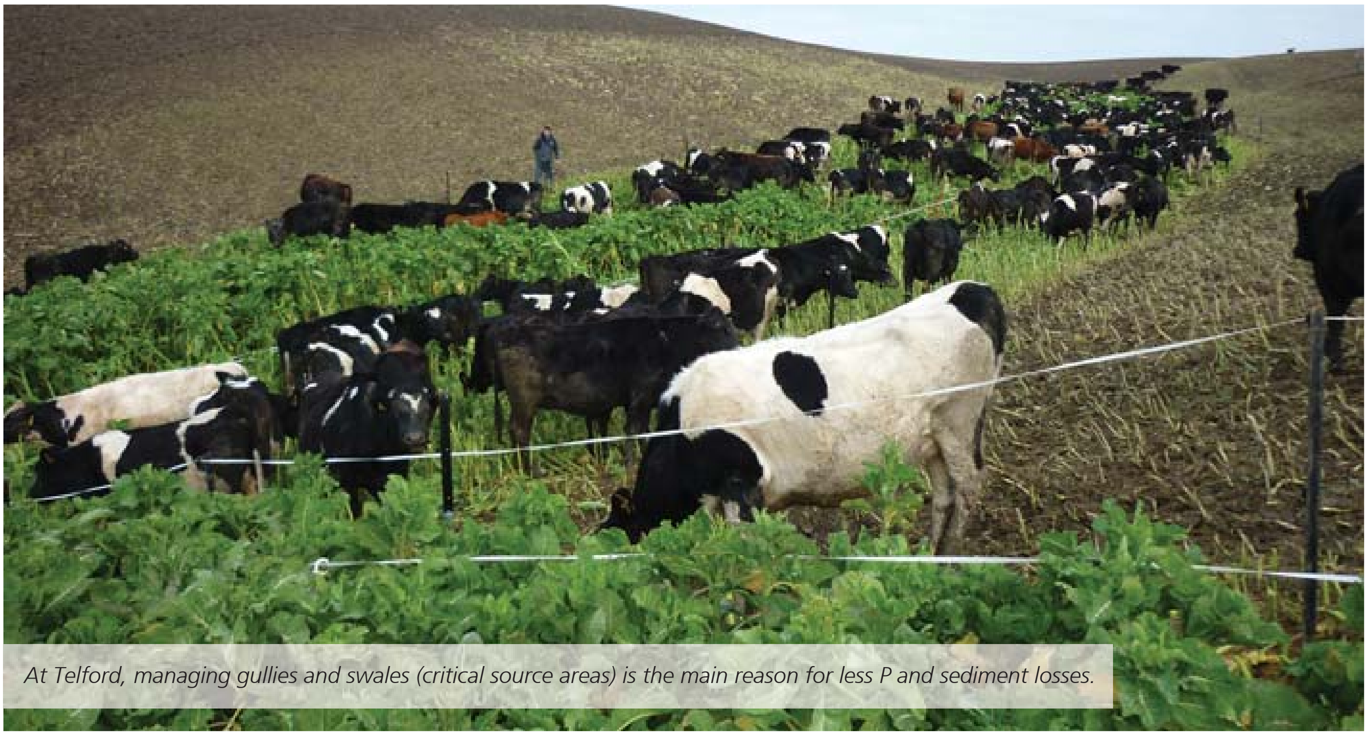
The use of porous cups to estimate N concentrations in drainage water and leaching loads is also being trialled in Canterbury this winter.

P loss by drainage water movement is measured at Telford and Manawatu sites. Most P will be lost via surface runoff and this is a big focus of the Telford work, where runoff is collected at the bottom of two sub-catchments where winter forage crops are grazed.

## Regional approaches

The science team at each site uses a range of measurement techniques to gain evidence of improved environmental performance, not just measuring/estimating N leaching from the bottom of the root zone.

Work in the Waikato identified a lower percentage of N in feed, indicating the Waikato's Future farmlet herd is eating less N. This will decrease N leaching, although standing cows off



*At Telford, managing gullies and swales (critical source areas) is the main reason for less P and sediment losses.*

[a] Critical source areas (CSAs) are areas of enriched nutrient sources and hydrological activity that occur in small parts of a catchment or farm, but contribute a disproportionately large amount of nutrient to the environment.

pasture for periods in autumn/winter would further reduce urine on the paddocks and decrease N leaching. Further measurements of urinary N production are planned.

The Manawatu team has identified February to June as the critical period to minimise urine deposits to decrease N leaching. This is achieved by housing cows at night only, although the lack of grass in the severe 2014 autumn drought meant the cows could be housed for 24 hours.

Effluent collected from housing this winter was stored until August (2014), when soil water deficits of >7mm allowed the first slurry application (30 $m^3$/ha) to 16 ha by tanker. Four further applications are planned for 2014.

Two reapplication methods, trailing shoe and spray, are being tested for N use efficiency. Preliminary guidelines for timing the reapplication of slurry include a forecast soil temperature of above 10ºC for the week following application, to make sure grass growth can utilise the applied N.

Work at Telford on effluent and the bedding material management from the wintering barn has shown promise, with minimal losses of N and P through the drains when effluent is applied to the hydrologically-isolated plots.

Attention is also now turning to managing the autumn reseeding of pasture, identified as releasing large amounts of soil mineral N after cultivation.

In Canterbury, it has been identified that wintering on forage crops off the milking platform contributes a disproportionately high level of N leaching, compared with total farm footprint. Work is progressing to examine how catch crops, such as oats and barley, can be grown after kale and fodder beet to capture N before it is lost from the root zone to leaching.

## Early results

The target is to reduce N and P losses by 30-50%. In the Waikato, there was a significant difference in N leaching between the two farmlets in both 2012 and 2013 winters (see article pg 1-4).

Estimated losses were 22 and 50 kg N/ha in winter 2012, and 38 and 67 kg N/ha in 2013 in Future (low leaching) and 'Current' farmlets, respectively. The higher overall losses in 2013 may be due to the extreme summer drought of 2013. Large losses of N were also measured at this site after the 2008 drought.

Winter 2014 in Manawatu will be the first opportunity to test the new housing system's effects on N leaching. However, there is previous evidence that standing off (duration controlled grazing) can halve this site's N losses when compared with standard grazing practice.

Over three years, annual N leaching losses were 8-21 kg N/ha from standard grazing (a seven hour day graze, 12 hour night graze), while standing off (a four hour graze, day or night) reduced losses by 43-65%[5].

Water and soil sampling techniques indicate that the targeted 30% reductions in N, P and sediment losses were generally achieved in 2013 at Telford (2014 assessment still underway). Managing the grazing of forage crops to protect the critical source areas (gullies and swales) is the main reason for less P and sediment losses[6] (see photo).

For N, wintering cows off-paddock and restricting the duration of pasture grazing in autumn are the main strategies that have decreased the risk of N leaching.

In Canterbury, leaching losses under a range of urinary N deposit rates from cows grazing kale and fodder beet have been measured. The actual losses per hectare will be calculated once the urine patch coverage data is available.

The results to date show the urine N deposit rate from cows grazing kale and fodder beet is lower than from cows on grass. However, high stocking density in winter forage grazing will have a large effect on the N loss.

## Looking ahead

The overall approach is a combination of measurements, modelling and the collection of other corroborative data, all aimed at building an understanding of the farm system and how management interventions modify N and P cycling and losses.

This in-depth analysis is necessary for the industry and knowing the contributions of the farm system's component parts (e.g. the relative effects of diet versus standing cows off pasture) is critical in understanding these systems more fully.

Emphasis is also being placed on expressing results in terms of the entire area used to support the dairy systems under evaluation (e.g. including winter forage crop areas), not just the dairy platform.

The investigations will continue to ensure that (a) there is confidence in the assessments of environmental performance and (b) the industry is as fully informed as possible.

### Fast facts

- In the Waikato, there was a significant difference in N leaching. The estimated losses were 22 and 50 kg N/ha in winter 2012, and 38 and 67 kg N/ha in 2013 in Future (low leaching) and Current farmlets, respectively.
- In Canterbury, the results to date show the urine N deposit rate from cows grazing kale and fodder beet is lower than from cows on grass. However, high stocking density in winter forage grazing will have a large effect, increasing the N loss.

# Forage systems to reduce nitrate leaching

**There is potential for substantial growth in the economic value produced by New Zealand agriculture[1,2]. In the livestock industries, this growth will require increases in feed production for animals from grazed pastures, plus a greater contribution from forage crops, but within nutrient discharge limits set by regional councils.**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### Key findings

- Reducing the amount of nitrogen (N) excreted in animal urine and improving the efficiency of N uptake by plants will reduce the amount of N leached from soil.
- The `Forages For Reduced Nitrate Leaching' programme aims to develop pasture and crop solutions that reduce surplus N in animals' diets and/or increase N uptake by plants to reduce the N leaching footprint of dairy, sheep and beef, and mixed (arable plus livestock) farm businesses.
- Researchers and developers will work with leading farmers and industry representatives to develop options that can be readily integrated into farm systems.

Growth in both pastoral and cropping sectors must come within the nutrient discharge limits set by regional councils under the National Policy Statement for Freshwater Management.

The new DairyNZ-led programme 'Forages For Reduced Nitrate Leaching: a cross-sector approach' will address this challenge by providing new knowledge, tools and technologies for forage production that:

- reduce livestock urinary nitrogen (N) excretion
- sustain high levels of forage and animal production
- improve plants' N uptake efficiency to reduce reliance on N fertiliser and the amount of potentially leachable N
- maximise yield and N use efficiency in forage crop phases of arable crop rotations
- can be readily integrated into arable, beef/sheep, dairy or mixed-farming systems.

The programme is addressing three main areas, highlighted below.

### Benefits of alternative plant species in pastures

This work will focus on pasture species and pasture management options (irrigation, grazing and fertiliser) that can reduce N excretion from livestock and improve the uptake of N from soil.

Diverse pastures (including herbs such as chicory and plantain, and grass species other than standard perennial ryegrass) have been reported to reduce urinary N excretion[3,4] or increase the efficiency of plant uptake of soil N[5].

Pasture species now available to farmers will be systematically compared for yield, N content in the dry matter and N uptake. The effects of management on these processes will also be investigated before simulation models, animal studies and grazing experiments are used to develop options for testing at commercial farm scale (see below).

### Productive and N-efficient crop management

The production and urinary N excretion of animals grazing forage crops with high nutritive value, but relatively low N content in the dry matter, will be investigated. High yielding crop rotations will be developed to maximise N-use efficiency and minimise N losses.

Crop and effluent management systems will be developed to reduce N losses from continuous cropping, while reducing reliance on fertiliser N inputs.

For example, the use of manure (from dairy milking platforms and support blocks) to replace some fertiliser used on mixed-cropping farms[6] will be evaluated to gauge the potential for improving the N use efficiency of both enterprises.

### Improved N-use efficiency and reduced nitrate leaching losses

Farm systems that incorporate the best options for improving N-use efficiency and reducing N leaching (as identified in the first two research aims) will be developed in this part of the programme.

Farm system modelling will help identify potential risks and test how well the results hold in situations beyond those encountered in the research trials (for example, in different climatic zones and on different soil types). Ten leading farmers in Canterbury (representing dairy, beef and sheep, arable and mixed farm systems) will participate in the programme to co-develop, test and demonstrate successful options.

The farmers will also assist in developing communication material, decision support tools and extension of the results. The involvement of farmers, researchers, developers and farm consultants is an important point of difference for this programme.

It will create better opportunities to bring the knowledge of all participants to bear on the challenge and should substantially improve the chances of successful change occurring on-farm.

*Forages for Reduced Nitrate Leaching is a partnership between DairyNZ, AgResearch, Plant & Food Research, Lincoln University, Foundation for Arable Research and Landcare Research. The principal funder is the Ministry of Business, Innovation and Employment. All partners co-fund the programme.*

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# Science snapshots

## *DairyNZ levy funded or supported science*

### Immune response to *Streptococcus uberis* vaccination *(Wedlock et al.[1])*

- Results from this study suggest subcutaneous vaccination of cattle with *S. uberis* (mastitis-causing) proteins can induce antibody responses. This is positive, however more work should be done to determine if intramammary vaccination could provide better protection against mastitis.
- Protein extracts were prepared from three main strains of *S. uberis* that cause mastitis in New Zealand and were formulated into vaccines.
- Fifteen Holstein-Friesian x Jersey calves were vaccinated at six months of age and compared with a control group (n=5). Vaccinated calves produced a strong antibody response.
- Six cows were vaccinated at three and one week prior to dry off, and again at two to three weeks pre-calving. Antibody responses were apparent in blood and mammary gland secretions 10 days after dry-off and post-calving.

### Ryegrass seeding rate affects plant size but not necessarily persistence *(Lee et al.[3])*

- Results from this study show that sowing rate is a relatively minor issue for pasture persistence. Correct choice of cultivar and endophyte, and good implementation of weed control, seed bed preparation, soil fertility and grazing management are the main areas to focus on.
- This study tested the hypothesis that ryegrass plants established from high seeding rates will be smaller and less likely to survive the first summer.
- Four perennial ryegrass cultivars were sown in autumn 2011 in Northland, Waikato and Canterbury, at five seeding rates from 6-30 kg/ha, with five replicates.
- Plant size declined progressively as seeding rate increased. However, the relationship between plant size and survival was variable. Where hot, dry summers can kill plants (e.g. Waikato), a lower seeding rate (e.g. 18 kg/ha) may aid survival. In less stressful environments (e.g. under irrigation in Canterbury), survival of smaller plants may be similar to that of larger plants.
- Individual seedlings were selected in each plot and marked so that their survival and development could be monitored for one full year.

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**Science snapshots**

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