VIRGINIA SERRA

LINCOLN UNIVERSITY DAIRY FARM (LUDF) – 20 YEARS OF SUCCESSFUL ON-FARM DEMONSTRATION

LUDF has been one of the most successful demonstration farms in New Zealand, leading the way in on-farm demonstration of highly profitable/ low-footprint dairy production systems. This article provides an overview of this success, including a summary of the key changes over time and how these have impacted on the farm's profit and environmental footprint.

About the farm

LUDF is a 160 ha milking platform owned by Lincoln University and managed by the South Island Dairying Development Centre (SIDDC) *(see Figure 1)*. It is a former university sheep farm converted to dairy in 2001. The farm is fully irrigated from ground water with a spray irrigation system, including two centre pivots (118.3 ha), small hand-shifted lateral sprinklers (32.2 ha) and k-lines (9.9 ha). It has a range of soils that represent most of the common soil types in Canterbury. The average PAW (profile available water) of the soils is 112 mm, ranging from 96 mm to 144 mm.

It is a well set-up farm with a good layout, but unlike many other farms in the region LUDF has no in-shed feeding system or any other feeding facilities. Effluent is distributed through pot spray applicators via a separate line underneath the pivot in the North Block. A 300,000 litre enviro saucer was built in 2011 and the Cleartech Effluent Treatment System was established recently to recycle water and reduce environmental impact.

Leading the way

LUDF has developed an impressive following among farmers and rural professionals. It has hosted well-attended field days and received thousands of visitors over the years. In 2001 when LUDF was established, irrigated dairy farming in Canterbury was still relatively new. LUDF has led the way in applying relevant and well-researched principles of successful pastoral dairying to irrigated systems in Canterbury. The farm also led the way in managing reproductive performance without induced calving before it was compulsory to do so.

After 10 years of a well-run production system, the environmental footprint from dairy farms became a key challenge, especially in Canterbury. It was then that LUDF led the way again in demonstrating high profit/low-footprint dairy systems. Since then several adjustments and fine-tuning of the 'new production system' have occurred, and no doubt LUDF will continue to evolve to adapt to future challenges and opportunities.

The original system – 2003/04 to 2009/10

Two seasons after its conversion, LUDF was well settled into the production system that would successfully run for the next seven years. It was based on a few well-implemented key decision rules that saw the farm achieving consistent high performance. It was a simple system with one herd, 24-hour grazing, low and consistent

Table 1: 2003/04 to 2009/10 seasons

	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	AVERAGE
kg liveweight/ha	1,960	1,960	1,960	1,974	2,058	2,107	1,941	**1,994**
Cows/ha	4.0	4.0	4.0	4.2	4.3	4.3	4.1	**4.1**
kg MS/ha	1,684	1,719	1,772	1,703	1,741	1,634	1,710	**1,709**
kg MS/cow	422	426	440	404	410	383	415	**414**
Imported suppl. fed (kg DM/cow)	304	277	320	235	407	338	262	**306**
Imported suppl. fed (kg DM/ha)	1,213	1,117	1,291	945	1,715	1,437	1,119	**1,263**
Pasture eaten (t DM/ha)*	15.3	16.1	15.3	16.4	17.9	17.2	16.2	**16.3**
kg N applied over 160 ha	200	200	187	187	164	200	185	**189**

**As estimated on DairyNZ's DairyBase*

Table 2: 2009/10 to 2013/14 seasons

	2009/10	2010/11	2011/12	2012/13	2013/14	AVERAGE
kg liveweight/ha	1,941	1,914	1,860	1,878	1,872	**1,893**
Cows/ha	4.1	4.2	3.95	3.94	3.9	**4.0**
kg MS/ha	1,710	1,638	1,861	1,878	1,725	**1,762**
kg MS/cow	415	392	471	477	440	**439**
Imported suppl. fed (kg DM/cow)	262	463	359	434	507	**405**
Imported suppl. fed (kg DM/ha)	1,119	1,911	1,500	1,714	1,996	**1,648**
Pasture eaten (kg DM/ha)	16.2	16.9	17.3	16.8	14.9	**16.4**
kg N applied/ha (over 160 ha)	185	260	340	350	250	**277**
Drainage mm/yr (Overseer)	333	333	333	333	na	**na**
Purchased N surplus (kg N/ha)	116	193	242	259	na	**na**

grazing residuals (seven clicks on the rising plate meter or 1480 kg DM/ha using the winter formula), and a focus on simple and replicable systems. Young stock were grazed off the milking platform as were cows over winter. The physical productivity of the farm during this period is summarised in *Table 1*.

There was no pre-grazing mowing during this period and grass silage was cut to control pasture surpluses. Nitrogen (N) was applied after each grazing with clear decision rules about when to start and stop applications. The cornerstone of this production system was to grow as much pasture as possible, and then optimise its management to harvest as much high-quality pasture (ME) as possible.

Wind of change

With time, other top-performing Canterbury farmers started to catch up and pass LUDF on performance. The profitability comparison of LUDF with other high-performing dairy farms that started in 2010 identified areas for improvement. At this time, the Canterbury Land and Water Regional Plan (LWRP) process started with clear indications that N in waterways was an issue and that N leaching from dairy farms was a contributing factor.

The spread of the clover root weevil in Selwyn in the early 2010s decimated clover on many local farms, including LUDF, prompting an increase in N fertiliser use from around 189 kg N/ha (average from 2003/04 to 2009/10 seasons as presented in *Table 1*) to 250-350 kg N/ha (from 2010/11 to 2013/14 seasons as presented on *Table 2*). Eco-N was used during this period to reduce the risk of N leaching until it was removed from the market in 2013. Reproductive performance (without inductions) and maintaining cow condition throughout the season, especially for younger animals, were other challenges that the farm was facing. LUDF had demonstrated how to run a successful and profitable production system for nearly 10 years, so it was a good time to demonstrate a different system that could address the challenges mentioned above.

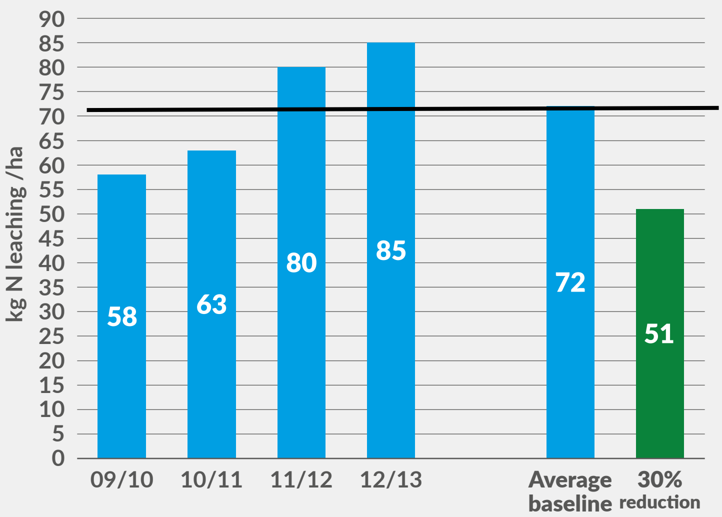

Figure 1: Estimated N leaching

High input/high output system – 2009/10 to 2013/14

LUDF is in the nutrient allocation zone of Selwyn Te-Waihora under Plan Change 1 (PC1) of the LWRP. Under this plan, from the 2017/18 season the farm is required to operate at or below its baseline N leaching figure based on the farming system between the 2009/10 to 2012/13 seasons, assuming industry agreed good management practices (gmps), and especially modified for PC1 and referred to as 'little gmp'. From 2022, dairy farms will have to operate 30% below the gmp baseline. All the Overseer modeling presented in this article was conducted by Ravensdown Environmental using OverseerFM v.6.3.2.

Table 2 presents key parameters for the period between 2009/10 and 2013/14. This period is important because the first four years represent the baseline period (2009/10 to 2012/13) and from 2010/11 to 2013/14 represent the transition period towards 'precision dairying'. During this period, the farm achieved higher production per cow with higher supplement and N fertiliser use.

As shown in *Figure 1*, the average N leaching for the baseline period for LUDF was estimated at 72 kg N/ha/year, but significant changes occurred over these four years. Looking at N leaching in a simple way there are two key aspects to consider: drainage and N surplus.

The higher the drainage, the higher the risk that N will be leached into groundwater. Similarly, the higher the N surplus (N in inputs minus N in outputs), the higher the risk of N leaching.

Drainage (estimated by Overseer) remained unchanged during the baseline period at 333 mm/ha *(Table 2)* as the irrigation system and management was modelled the same over these four years. Therefore, the main reason behind the increase in N leaching during the baseline period was explained by the increase in N use (from 185 in 2009/10 to 350 kg N/ha in 2012/13) and supplement fed (from 262 to 434 kg DM/cow). As mentioned earlier, clover root weevil was a key driver behind the increase in N fertiliser.

The temporary suspension of Eco-N (DCD) in 2013 required a change in farm practice. As described in Pellow (2017) in early 2014, it became apparent that the farm would exceed the 2009/13 N leaching baseline for the 2013/14 season. Measures were taken in late lactation to stay below the baseline, including drying-off all cows in early autumn. It is estimated that these short-term reactionary responses cost the farm about $84,000. This experience prompted LUDF to seek alternative management strategies that would ensure N leaching would not be above the baseline and on target to achieve the required reduction.

Nil-infrastructure/low-input system – 2014/15 to 2018/19

From the 2014/15 season, LUDF adopted and scaled up the 'Nil-Infrastructure/low-input' farm system emerging from the Pastoral 21 (P21) research programme. This research was jointly funded by the Ministry of Business, Innovation and Employment, DairyNZ, Fonterra, Beef + Lamb New Zealand and the Dairy Companies Association of New Zealand.

This move was a further step to exploring systems with lower environmental footprint and higher efficiency. The changes have been well described by Pellow in 2017 and Chapman in 2017. The physical productivity of the farm during this period is summarised in *Table 3*.

Table 3: 2014/15 to 2018/19 seasons

	2014/15	2015/16	2016/17	2017/18	2018/19	AVERAGE
kg liveweight/ha	1,680	1,724	1,700	1,680	1,656	**1,688**
Cows/ha	3.5	3.5	3.5	3.5	3.4	**3.5**
kg MS/ha	1,742	1,812	1,789	1,571	1,733	**1,729**
kg MS/cow	498	522	517	451	504	**498**
Imported suppl. fed (kg DM/cow)	302	134	397	444	22	**260**
Imported supp. fed (kg DM/ha)	1,186	468	1,377	1,538	76	**929**
Pasture eaten (kg DM/ha)	15.7	16.6	16.0	16.2	16.5	**16.2**
kg N applied/ha (over 160 ha)	143	179	173	178	148	**164**

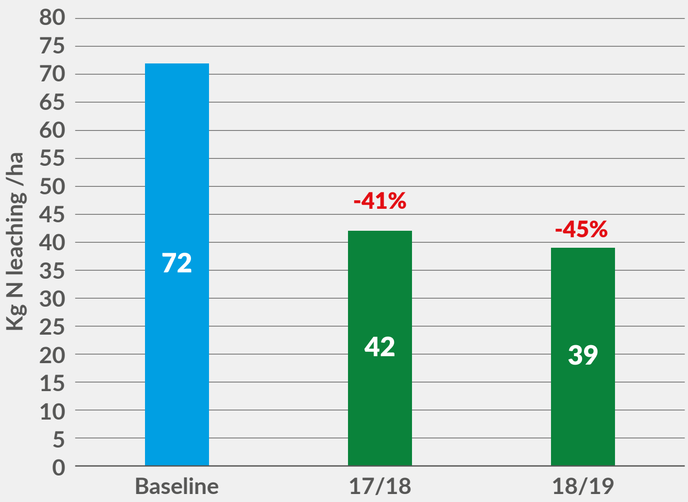

Figure 2: N loss reduction from baseline

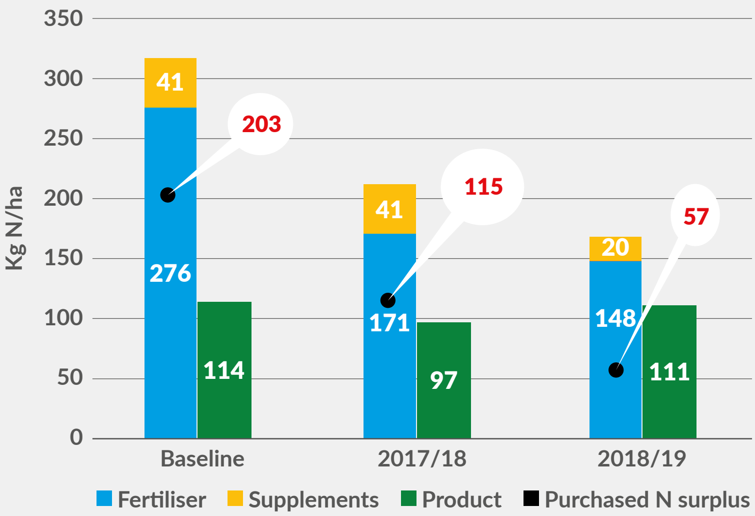

Figure 3: Purchased N surplus (kg N/ha)

During this period cows/ha (and kg LW/ha) was reduced by 12.5%. The focus on growing and harvesting pasture was still a key component of the system, but during this period more emphasis was placed on achieving high-performance per cow to compensate for the lower cow numbers. The key elements of this management included a split herd to preferentially feed young/light animals, pre-graze mowing and a more strategic use of N. The quality of the herd also improved because of the extra culling when moving to the lower stocking rate of the new system.

Environmental footprint

In the 2018/19 season, N leaching was 45% lower than during the baseline period *(Figure 2)*. This magnitude of N loss reduction exceeds the 30% reduction required by 2022, therefore LUDF has achieved compliance with Plan Change 1 and ahead of time. *Table 4* shows the estimated contribution of the key changes to the 45% reduction.

Table 4: Proportional contribution of changes to the reduction in N leaching

	CONTRIBUTION TO N LOSS REDUCTION
Soil moisture meters	14%
Irrigation system changes	14%
Effluent system change	2%
Farm systems change	15%
Total change	45%

Changes in the irrigation system and management

Changes in irrigation and management can explain 28% of the reduction from the baseline period. The key changes were: (a) improved decision rules around irrigation management with soil water meters (as the baseline was modelled without them); and (b) an increase in the area under pivot irrigation by 10.5 ha in the 2018/19 season. These changes improved the efficiency of irrigation with a lower volume of irrigation applied in the area irrigated by pivots and an overall reduction in drainage from 333 to 222 mm/ha/yr *(Table 5)*.

Changes in N surplus

The rest of the reduction is explained mainly by reductions in the farm N surplus resulting from the change in the production system. Farm systems changes explain approximately 15% of the reduction in N leaching compared to baseline. The main factors were: (a) a substantial reduction in N fertiliser use; (b) a reduction in supplements and therefore in N imported from that source; and (c) a reduction in herd size and feed demand, which resulted in less feed (and N) eaten per hectare. There was a small change in the effluent area from 34 ha to 39 ha in 2018/19, but this had only a minor effect on the modelled N leaching reduction (<2%).

As a consequence of these changes, the whole farm purchased N surplus (N in fertiliser + N in imported feeds minus N in products) fell from 203 kg N/ha in the baseline period to 57 kg N/ha in 2018/19 *(Figure 3)*.

Table 5: Drainage (mm/ha/yr)

	2009/10–2012/13	2017/18	2018/19
Whole farm drainage mm/ha/yr	333	281	222
Average drainage/average PAW	2.95	2.5	2.0
Irrigation applied pivots (mm/ha/yr)	508	355	355
Area pivots (ha)	107.5	107.8	118.3

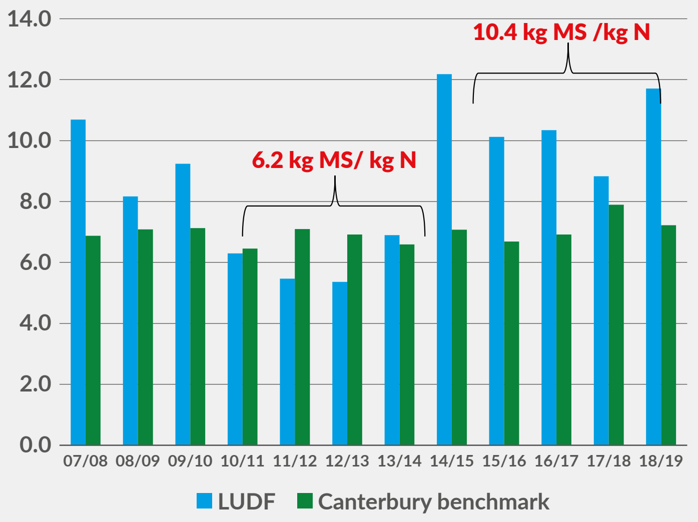

Figure 4: Kg MS produced/kg N fertiliser applied

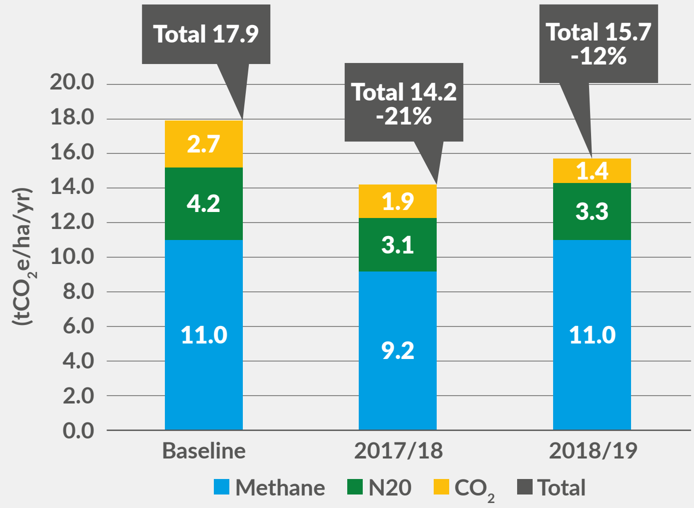

Figure 5: GHG emissions (t CO_2e/ha/yr)

This is substantially lower than what is commonly seen on Canterbury farms. Meanwhile, the overall N use efficiency of the farm (kg MS/kg N fertiliser applied) increased significantly compared with the baseline years (10.4 versus 6.2 kg MS/kg N fertiliser), a remarkable improvement in the overall system efficiency and a key step toward reducing the N footprint of the farm. This was achieved by halving N fertiliser input while 'losing' only ~40 kg MS/ha *(Tables 2 and 3)*. In doing so, LUDF went from similar or slightly below the Canterbury benchmark to markedly above it in N use efficiency *(Figure 4)*.

The reduction in N fertiliser was implemented using two main methods:

- Changing the frequency and amount of N applied at each event – contributing to 85% of the overall reduction in N applied
- Markedly reducing N fertiliser applied to the effluent areas – contributing to 15% of the reduction in total N applied.

A key feature of the change in fertiliser management was 2.4 fewer applications per year, and an average of 8 kg N/ha less N applied at each fertiliser spreading event (David Chapman, pers. comm.). The fewer applications per year was, in turn, facilitated by 1.7 fewer grazings per year reflecting a mean four-day increase in rotation length. The increase in rotation length resulted in an increase in leaf stage at grazing of ~0.3 leaves/grazing, which was estimated to have recouped about 1.1 t DM/ha of the expected reduction in pasture growth resulting from removing N fertiliser. This explains most, if not all, the 'buffering' of pasture yield reduction resulting from removing N fertiliser.

Having a high percentage of tetraploids in the pastures (95% of paddocks now have at least some component of tetraploids) has helped with the higher pre-grazing covers generated by the longer grazing rounds. Pre-grazing mowing has also been used to achieve the targeted residuals. It is important to mention that clover has returned to the pastures as it was before the clover root weevil outbreak.

There were also differences in the timing of N fertiliser applications with no N applied after the end of March. This can contribute to lower leaching not necessarily via direct leaching of N from fertiliser, but by having fewer grazing events into the late summer-autumn period where the N leaching risk of urinary N increases.

Stocking rate, dry matter intake and footprint

The total dry matter intake, estimated by Overseer, as an average for the last two seasons was 13% lower than during the baseline period. This difference reflects the lower demand per hectare driven by lower requirements from maintenance and milk production (reflected by lower liveweight/ha and lower MS production/ha). Less feed eaten translated into lower N excreted, from 787 kg N/ha to 652 kg N/ha.

As reported by Chapman et al. (2017), if we were accounting for the footprint of the whole business including wintering and young stock, the comparison would show an extra N loss reduction due to less dry matter intake consumed by fewer young stock and fewer cows over winter (about 122 t DM less feed eaten for the total farm operation). Carrying fewer cows over winter can have a significant impact because winter is a high-risk time of the year for N leaching. The caveat of this statement is to consider what would be the alternative use of land 'spared' by less animals and the alternative footprint compared with wintering or young stock grazing.

Greenhouse gas emissions (GHGs)

In light of the Zero Carbon Bill and possible commitments under He Waka Eke Noa it is important to note that GHG emissions, as an average for the 2017/2018 and 2018/19 seasons, were reduced by 16.5% from the baseline period *(see Figure 5)*. This was driven by the lower dry matter intake (as methane emissions are highly correlated to dry matter intake) and lower N surplus (as nitrous oxide is highly correlated to N surplus).

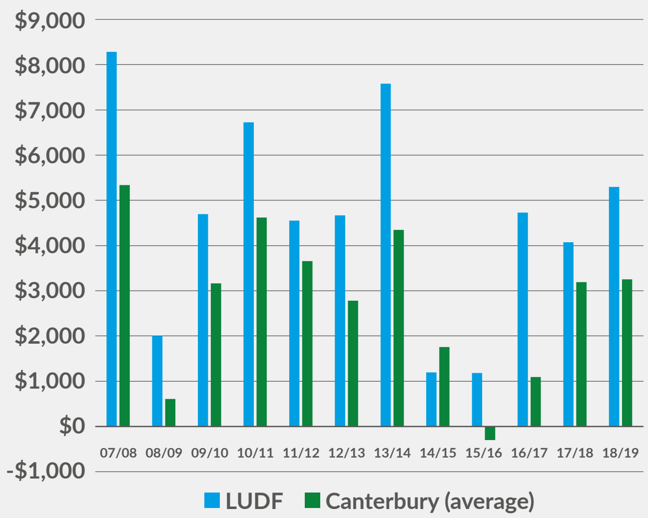

Figure 6: Operating profit ($/ha) LUDF and Canterbury benchmark

Changes in profit

Figure 6 compares operating profit per hectare for LUDF with the average Canterbury benchmark available on DairyBase. Except for the 2014/15 season LUDF achieved higher profit than the benchmarking group.

The comparison of the operating profit per hectare of LUDF and the Canterbury benchmark signal that the profitability at LUDF has not been severely affected by the changes over the last five years. Another way of comparing the impact on profitability of the changes is to compare the changes in milk production and the potential changes in cost.

Over the last five seasons, milk production per hectare is only 2% below the previous five but it was produced by 80 less cows, with less N fertiliser (-113 kg N/ha/yr) and less imported supplements (-0.77 T DM/ha) *(Tables 2 and 3)*. Therefore, it is likely that similar output was produced with lower expenses including lower cow costs (e.g. animal health and breeding), lower N fertiliser and supplement costs, and less young stock and wintering grazing costs. Therefore, it can be expected that the system run over the last five years has the potential of higher profitability compared to the systems run previously.

Final thoughts

LUDF has arrived at a production system that has reduced N losses and GHG emissions, with a high level of productivity and potentially higher profit. The principles of the P21 research have been successfully implemented at LUDF over the last five years. This is a clear and valuable example of how P21 research can be scaled-up from farmlets to commercial businesses to help give farmers confidence. In this case, confidence that the industry can meet current and future environmental regulations while retaining high productivity and profitability.

LUDF has successfully transitioned to a lower-input system while maintaining a strong focus on monitoring and decision-making, and the tactical use of supplements and N. A range of adaptation tactics were used to mitigate the impacts of lower N inputs on feed supply from pasture, so that the overall system remained strongly pasture-based and costs of production were controlled. These included longer rotations and appropriate decision rules for supplement use and N fertiliser applications.

Further changes to the system have been modelled, including further improvements to the irrigation system in the areas not currently irrigated by pivots, as well as some alternative strategies for autumn management (culling strategy and supplement use). These options can reduce N loss further, but the magnitude of reduction will be smaller now that the 'big ticket items' have been addressed. In the future, further reductions in N loss could be achieved with a different pasture base (e.g. plantain and the adoption of 'low-N' cow genetics). Both of these options are being investigated now in R&D programmes with promising results.

In 2020, after nearly 20 seasons under its belt, LUDF continues to be a reference for dairy farmers in Canterbury and across the country, leading the way on profitable and low-footprint grazing production systems.

Acknowledgements

I would like to acknowledge Arron Hutton and Clare Buchanan (Ravensdown) for providing the Overseer modelling, David Chapman (DairyNZ) for the data and analysis of the impact of farm system changes on N leaching, and Ron Pellow and Peter Hancox and the farm team for implementing the changes over the last five years.

Further reading

Pellow, R. 2017. Applying Pastoral 21 Farmlet Research to a Whole Farm – Results From Lincoln University Dairy Farm. In *Science and Policy: Nutrient Management Challenges for the Next Generation.* L.D. Currie and M.J. Hedley (Eds). Occasional Report No. 30. Palmerston North, NZ: Fertilizer and Lime Research Centre, Massey University.

Chapman, D.F. et al. 2017. Nitrogen Leaching, Productivity and Profit of Irrigated Dairy System Using Either Low or High Inputs of Fertiliser and Feed. The Pastoral 21 Experience in Canterbury. In *Science and Policy: Nutrient Management Challenges for the Next Generation.* L.D. Currie and M.J. Hedley (Eds). Occasional Report No. 30. Palmerston North, NZ: Fertilizer and Lime Research Centre, Massey University.

Virginia Serra is the New Systems and Co-Development Team lead at DairyNZ and has been part of the LUDF Management Team during the 2009-2011 years and of the Business Advisory group from 2010 to 2017. She is currently leading the Hinds and Selwyn Project aiming at supporting farmers reduce their footprint while maintaining profit. Email: virginia.serra@dairynz.co.nz. J