NZ LANDCARE TRUST

CASE STUDY

FINDING A WIN-WIN FOR BOTH THE FARMER, AND THE ENVIRONMENT.

Takaka

Case study by:

A.J. Litherland (NZ Landcare Trust), B. Riddler (E2M modelling), M. Langford (Fonterra), M Shadwick (DairyNZ)

For further information contact:
e. annette.litherland@landcare.org.nz
p. 027 724 4445

The purpose of this study was

- To model options looking to reduce nutrient losses, irrigation use and greenhouse gas emissions from the dairy farm without impacting on farm profitability.
- To model the farm using the Enviro-Economic Model (E2M). This full farm systems approach combines prediction of animal production from feed energy intakes (farm grown or bought in feeds) and optimises to calculate the best economic profit. In this instance it provided a series of actual farm options to reduce N leaching and greenhouse gas emissions (GHG) and to improve profit. These were extended further as "what if" questions were investigated which stimulated discussions and better understanding of the farm system.
- To determine nutrient losses and GHG emissions from both the milking platform and the whole farm. To explore the possibility of using the runoff and trees to reduce nutrient losses per ha by dilution by forestry, and use carbon sequestration from the forestry, to offset the dairy farm emissions in order to explore the practically of producing carbon neutral milk in Golden Bay.

Fonterra

DairyNZ
Profitability. Sustainability. Competitiveness.

OVERVIEW

The data supplied for this analysis came from a Farmax simulation of the 2016/17 year for the farm (Run 1) using Dairybase information and data supplied in discussion with the farmer. There were also discussions regarding aspects of the farm system they wished to retain. The E2M optimisation model then considered four alternative farm systems that reduced nitrogen use, used different pasture mixes to reduce reliance on irrigation and the use of the runoff block versus a self-contained system. The amount of inputs, such as brought in feeds (BiF), supplements harvested, areas of summer crops, cow stocking rate and per cow production level were varied by the model based on the energy feed supply and economic optimisation.

From the farmer:

"Initially we became involved in this project to look at ways to reduce nitrate leaching, our farming footprint and to increase our environmental awareness. The amount of data and time taken for the project was far more than expected and we would have questioned our involvement had we known what was required. While the project has come up with some good discussion points, I question the practicality of the model outcomes."

Run 2

In the second run, we looked at optimal N use with 412 kgMS/hd and 114 ha irrigated being fixed. The model chose to reduce cow numbers by 60, bought less pellets, reduced summer crop and reduced N use by 59% **(3% increase profit, reduction N leaching by 25%, GHG by 11%).**

Run 3

In the third run, cow numbers were reduced by 90 cows, bought less feeds, made more silage, grazed more stock at home and reduced N by 74% and area irrigated **(5% increase in profit, reduction N leaching 35%, GHG 18%).**

Run 4

In the fourth run, we introduced more drought tolerant species, increased per cow production, consumed less pellets, used less nitrogen, made more of own feed on farm and reduced grazing off **(17% increase in profit, reduction N leaching 32%, GHG 26%).**

Run 5

In the fifth run, we introduced runoff as part of the system and growing all own feed and being self-sufficient in grazing **(27% increase in profit, reduced N leaching by 10%, GHG 9%).**

The base farm system would require 80, 154 or 359 ha of exotic hardwood, pine or native plantings to offset its GHG (CH_4+N_2O) and produce carbon neutral milk for the base farm and 65, 126, 295 ha for the farm system with the lowest GHG emissions. The farm currently has 75 ha of forestry land.

FARM OVERVIEW 2016/17

Table 1. Production Key Performance indicators

Dairybase production figures (bench mark Top of the South)	
Milking platform (eff ha)	165
Milking platform trees (ha)	21.9
Runoff (ha)	82
Forestry on runoff (ha)	53.1
Est Pasture and crop eaten (/ ha/year)	13.3 grown (10.7) eaten
Imported supplements (tDM/ha)	2.1
Imported supplements eaten (tDM/cow)	0.641
Breed Type	Ayr. bred towards JxF
Herd Size	554
Cows (no./ effective ha)	3.3 (2.7)
Production per cow (kg MS/cow)	416 (389)
Production (MS/ha)	1380 (1067)
10 day peak kg/cow	2.06 (1.93)
Planned start of calving	5 Aug
6 week in calf rate (%)	64
Empty rate (%)	9%
Replacement rate (%)	22%

Dairy Base Economic KPI (bench mark Top of the South)	
Milking platform operating expenses ($/MS)	4.03
Operating expenses ($/ha)	5567
Operating profit ($/ha)	3244

- This farm is managed by the owners and is jointly owned in a family trust. This farm has been owned by this family and farmed as a dairy farm for four generations. The farm is made up of 165 ha milking platform with 22 ha of Radiata pine trees planted 23 years ago and nearing harvest on the milking platform; 82 ha runoff block and 75 ha Radiata pine on the runoff. The farm is located in the Takaka Valley and bounds the Takaka River. This Golden Bay farm is in the highly sensitive Mt Arthur marble recharge zone feeding the Te Waikoropupū Springs. These springs have a pending water conservation order and an Advisory Group working on collective protocols for water use.
- This farm is in the top 10% of profitable dairy farms in the Top of the South. The farmer's goals are to be profit driven, maintain current high production but also to produce milk as cheaply as possible by being smart about expenditure and doing things where possible themselves (eg mowing, raking and carting baleage, spraying, and drilling). They want to achieve a good work - life balance and ultimately when the parents retire, employ more staff. They have been working each year on smaller projects to make the property more environmentally-friendly. These have included fencing and planting alongside creeks and adding bridges.
- The farm has an annual rainfall of 2020 mm/yr falling on recent or brown soils on river flats with some Pakihi soils. The rainfall often comes in deluges and the soils dry out rapidly in the absence of rain in summer and can pug easily during wet periods. A 114 ha of the milking platform is irrigated through three pivots and a K Line using water for 40 days per season from the Takaka River. The water is restricted in summer and is dependent on the Cobb dam releasing water. The Cobb dam releases water to make electricity when the spot price for electricity is high. The river periodically floods the lower reaches of the farm.

- The 554 cows are milked through a 50 bale rotary shed, with the main herd being milked twice a day while heifers and light cows go on OAD milking after Christmas. In 2016/17 the cows were milked for 258 days. Reproduction management is kept very simple. There is no metric checking, tail painting or CIDRs but KHMARS are used from the start of mating and mating lasts for 9 weeks. Both the BW and PW are low for the herd because they are coming from an Aryshire base and the herd has only just started being herd tested.
- The cows are fed pellets (often contain minerals) in the shed at rates of 1-3 kg/day throughout the milking year based on feed supply (cost $0.54/kgDM; utilisation 90%). Baleage is made and fed on the milking platform (spring and autumn) while hay is made and fed on the runoff. Cows are winter grazed for 6 weeks on the runoff and fed baleage and this is extended for late calving cows. The calves and heifers are grazed on the runoff all year round. There are also areas of bush and plantation forestry on the farm. There is a block of 50 ha of trees on the main farm that was planted in radiata pine at 1000 trees/ha in 2014, that will be thinned to 350 trees/ha and another 25ha of radiata pine that will be harvested in 2018/19. There are other forestry blocks that are jointly owned by the farmer and the neighbour.
- The milking platform receives 200 kgN/ha/year on the 116 ha of the non-effluent area in units less than 36 kgN/ha/application and approximately six applications per paddock per year. There is a big range in Olsen P and this is being addressed by whole farm paddock soil tests. Effluent is spread over 42 ha.

Table 2. Environmental KPI

Environmental KPI	Milking platform + 22 ha trees
Total N-loss (Tonne N)	18.9
N surplus (kg N/ha/yr)	268
N leached (kg N/ha/yr)	101
N in drainage ppm	7.38
N conversion efficiency	23%
Total GHG (tCO2e) (CH4+N2O)	2155
GHG (tCO2e/ha) (CH4+N2O)	11.5
Methane (tCO2e/ha)	8.6
N2O (tCO2e/ha)	2.9
Efficiency (CO2e/kgMS)	9.6

- There are stony loafing areas that are used particularly in spring. The effluent system was upgraded two years ago. Currently it has only two-day storage capacity but this is being extended with a Tasman storage tank (1115m3), and a solids separator and storage bunker have recently been installed. The effluent is currently spread over 42ha but the plan is to pump it via lines carried on the pivots and spread it over a greater area of the farm. The Takaka River is fenced with four to 20 metre riparian margins with fencing and planting taking place in July 2018.
- This farm has high nitrate leaching in some areas of the property because of the high rainfall, high nitrogen inputs, high stocking rate, the irrigation, soil type and the supplementary feed that is bought in to the farm. The highest leaching blocks are irrigated blocks on the recent soils The irrigated and effluent blocks are leaching between 107 to 143 kgN/ha/yr. The runoff leaches 27 kgN/ha and the pine trees on the milking platform are the lowest at 2 kg N/ha. The nitrate leaching for the overall farm was 101 kgN/ha/yr.

- In a high rainfall area, it is also important to consider the concentration of the N in drainage as it is high concentrations of N that cause issues in the waterways and the figure of 7.38ppm is lower than in Canterbury for example which has much lower N leaching per ha.
- On the farm 78% of GHG comes from methane, 10% from nitrous dioxide and 13% from carbon dioxide from fuel. As the fuel already contains an emissions tax it is normally discarded in calculating a farms GHG emissions and only methane and nitrous oxide are included. At the current rate of \$25/tCO_2e the full liability of these emissions (N_2O+CH_4) would be \$54,000 / year. Of these emissions 89% (in blue in figure below) are methane (CH_4) with most coming from the rumen of stock and much lesser amounts from effluent and dung. Nitrous oxide composes 11%, mostly from dung and urine.

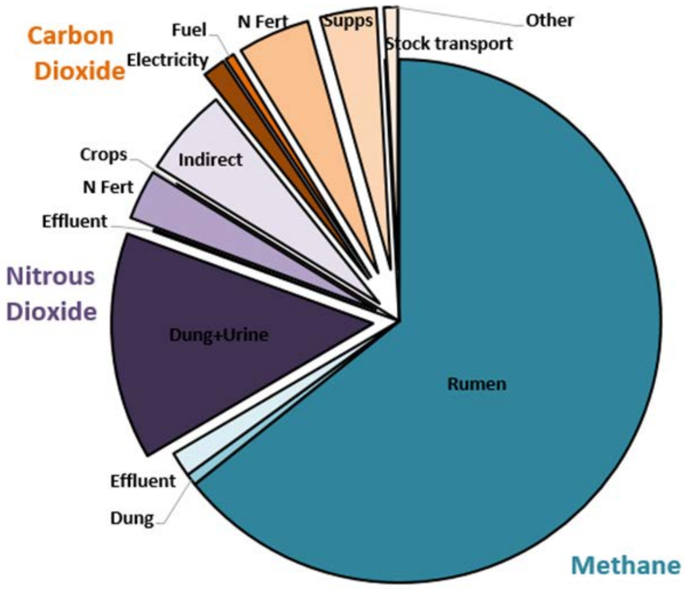

Figure 1. Break down of greenhouse gas emissions from the farm.

ECONOMIC MODELLING

E2M uses marginal cost/benefit relationships to drive its economic optimisation. Marginal analysis assesses the change in profit from each additional individual input (e.g. kgDM or kg N or BiF) by comparing the marginal cost with the marginal return (e.g. increase MS income). In the model inputs can be constrained (ie cow numbers, N leaching) while others can be allowed to vary. Then E2M calculates the least cost combination of varying inputs that gives the best economic outcome. For this analysis the model used MS price of \$6/kgMS.

To set up the base farm the model was constrained to the current inputs to reproduce a model of the current base system. Specific inputs were then allowed to vary over a series of 4 new runs. The farmer posed certain “non-negotiable limits” to changes in the farm system (eg still feed at least some pellets in the shed as they are an easy and effective way to add mineral supplements). Specific inputs were then allowed to vary over a series of four runs.

During the modelling process the constraint on milking cow numbers were relaxed which led to successive reductions in the number of cows milked but also allowed heifers to switch to twice a day milking when feed supplies allowed. When the model reduced cows it was because it was more profitable to do so. This improved the overall per cow production and reduced the area of irrigation and the need for hay and silage from the 82ha runoff area. This feed was instead fed directly to replacements and dry cows.

Different pasture combinations were then introduced to minimise the potential impact of dry spells and to allow the accumulation of higher covers without losing quality. The option chosen is a prairie grass and caucasian clover mix. Prairie Grass has better growth rates than ryegrass in most seasons and retains quality at pasture covers up to 4000kgDM/ha. This provides more feed storage flexibility and reduces the reliance on irrigation. It was assumed that prairie grass produced an extra 3000 kg/DM/ha annually than ryegrass (based on Manawatu data). Prairie grass seed heads are readily eaten by stock but care needs to be taken in grazing management especially during early establishment.

These changes improved profit by reducing costs faster than income was reduced. In runs two to four the runoff was initially considered a separate entity and the stock were grazed on runoff at commercial rates. Surplus pasture grown on the runoff was made into hay and silage and was "sold" to the dairy enterprise. In run five the 82ha "runoff" area was incorporated into the milking platform system but only as a non-milking animal area (replacements and dry cows). The inclusion of this into the milking platform would need the construction of a $200,000 bridge.

The outputs from these runs were then put into Overseer to calculate changes to nutrient losses and greenhouse gas emissions from the milking platform +22 ha of trees. We chose the option of using the generic rather than the farm specific calculation for nitrous oxide as it is known to overestimate nitrous oxide, especially under high rainfall.

A complication for a dairy farm is that it is not a self-contained system and has young stock and cows being grazed off and therefore their emissions are excluded while grazing off.

CARBON SEQUESTRATION FROM TREES

The carbon sequestration (carbon stock) was calculated from the ETS lookup tables. The initial analysis was based on the trees actually on the farm and then later analysis considered options better suited to offsetting carbon emissions. The ETS lookup tables (option used for most plantings of less than 100ha) assume the carbon accumulation based on age and for pine trees, age and region. There are large differences between the carbon stocks produced from different types of trees, and it is lowest for natives and highest for exotic hardwoods. The carbon sequestered is the difference between the carbon stocks from one-time point to another (normally five-yearly intervals in ETS). If the trees have been harvested during the time interval the amount of carbon sequestered will be negative. It is assumed that some carbon remains (in branches, stumps, roots etc) after harvesting but this disappears over 10 years after harvesting. So a single block of harvested trees over a given time analysis interval can give widely differing CO_2 sequestration depending on its growth harvest cycle in that time interval. From both a CO_2 point of view it is better to have staggered age blocks to give a more stable CO_2 pool to use as an offset for the milking platform emissions. To reduce the sediment loadings in our rivers and estuaries it is also beneficial to harvest smaller blocks at one time and also use trees that grow as much but have more extended harvest intervals.

RESULTS

E2M modelling

See table for results

Run 1: Base farm.

Inputs were constrained to reproduce the farm. 544 cows, 412 kg MS/cow. Nitrogen 200 kgN/ha. 11 ha summer crop. BiF 490T; The base farm was the milking platform + 22 ha of trees, young stock grazed off, herd winter grazed off and assumed costs ($8/wk weaners; $12 heifers; $23 mature/head per week plus transport). Feed produced on the runoff was purchased at fair value (0.25c/kgDM for hay/baleage). 15T of silage made on milking platform; irrigated area 114 ha. The cost of running (power, labour for the irrigation was $123/ha and it produced an additional 5000 kgDM/ha annually but there is no data collected on the farm to validate this assumption.

Run 2. Optimal N use.

Fixed. 412 kg MS/cow. 114 ha irrigated.

Varied. Cow number between 485 and 544 to better fit basic feed grown to animal demand, rate and timing of nitrogen, BiF not more than Base farm, summer crop up to 11 ha. Choose (or not) to graze off.

Model response. Reduced cow numbers by 60 to 485; 158T less pellets; summer crop reduced by 3ha; reduced use of nitrogen by 59%; grazed yearlings at home; all R2 grazed off and 240 cows were grazed off over winter.

3% increase in profit, reduced nitrate leaching by 25% and GHG by 11%

Run3. Optimal herd size and irrigation.

Fixed. 412 kg MS/cow.

Varied. Cow number to optimise profit, rate and timing of nitrogen, BiF not more than Base farm, summer crop up to 11 ha. Choose (or not) to graze off, area irrigated up to 114 ha.

Model response: Cow numbers reduced to 450; 20T more silage made on milking platform in early summer; 74% reduction in N; 180 T less pellets; 120 T less baleage purchased, summer crop reduced by 5 ha; Grazed yearlings at home; all R2 grazed off and 210 cows were grazed off over winter; irrigation area reduced by 47 ha to 67 ha.

5% increase in profit, reduced nitrate leaching by 35% and GHG by 18%

Run 4. Alternate pasture sward.

Fixed. Cow number 450. Irrigation area 67 ha.

Varied. MS/cow, rate and timing of nitrogen, BiF not more than Base farm, summer crop up to 11 ha. Choose (or not) to graze off. Allow an option to use up to 47 ha of more dry-tolerant species such as Prairie Grass + Caucasian Clover (PG+C) that gives greater responses to nitrogen in areas of the farm no longer irrigated.

Model response: The heifers can now remain on TAD milking and improve their production to 275kgMS/heifer; cows less feed pinches, increase to 448 kg MS/cow; 95T baleage made on milking platform; 74% reduction in N; 140T less pellets, no baleage and hay purchased from runoff; no summer crop grown; all yearlings and R2 grazed on milking platform; 140 cows grazed off over winter.

17% increase in profit; reduced total nitrate leaching by 32%, GHG by 26%

Run 5. More alternate pasture sward, self-contained.

Fixed. 448 kgMS/cow. Include 72 ha of Prairie Grass +Caucasian Clover. 140 T of pellets; 67 ha irrigated. Runoff costs were assumed to be the same as the assumed grazing bill. New farm area 269 ha.

Varied. Cow number to optimise profit, rate and timing of nitrogen, BiF not more than Base farm, summer crop up to 11 ha. Choose (or not) to graze off, area irrigated. The runoff was introduced as part of self-contained system such that all stock and feed (except for base pellets non-negotiable applied by farmer) requirements are now sourced from the milking block and 82ha runoff. If this is on an area that provides access to the milking shed ($200,000 bridge required!), a store of standing feed can be maintained for flood events. The emphasis in Run 5 is to have a system where almost all the feed grown is harvested by the animal. This reduces costs and simplifies the system.

Model response. Cows reduced to 405; 160 T baleage made on milking platform; 80% reduction in N; no baleage made on runoff; no summer crop, all stock grazed at home; greater flexibility as to pasture covers with a greater area of Prairie grass mix (holds its quality better at higher covers). Pellets are retained (although the model would prefer to feed all pasture for economic reasons) as a means to give mineral supplements and as reward for cows into the shed to keep the milking operation flowing well.

Note that the emissions and nitrate leaching from the grazed off cows and young stock in the base farm are not included in the base farm data, so the reduction with Run 5 seems artificially small.

27% increase in profit, reduced total nitrate leaching by 10%, GHG by 9%

For further information on the E2M modelling

Outcomes of E2M modelling on Lincoln Dairy farm. (http://www.siddc.org.nz/assets/LUDF-Focus-Days/10-May-2012-.pdf)

Anderson, W.J; Ridler, B.J. 2017. The effect of dairy farm intensification on farm operation, economics and risk: a marginal analysis. Animal Production Science. 2017 pp. 1350-1356

Anderson, W.J.; Ridler, B.J. 2010: The profitability of herd performance and supplementation in pasture-based milk production with carbon-emission charges. Proceedings of the Australasian Dairy Science Symposium, 2010, Lincoln University.

Anderson, W.J.; Ridler, B.J. 2010b: The effect of increasing per cow production and changing herd structure on economic and environmental outcomes within a farm system using optimal resource allocation. Proceedings of the Australasian Dairy Science Symposium, 2010, Lincoln University, pp.215-221

For more information, please go to www.landcare.org.nz

Table 3. Results from E2M analysis

	1 Base farm	2 Optimal N use.	3 Optimal herd size and irrigation	4 Alternate pasture sward.	5 More alternate pasture sward, self-contained.
No. Cows	544	485	450	450	405
Total MS kgMS	223,500	200,000	184,700	201,740	181,400
Production per					
Production per cow (kg MS/cow)	412	412	410	448	448
Spring N Use	June July Aug Sept Oct Jan 35kgN/ha 116 ha	Jul Sept 35kgN/ha 116 ha	Jul Sept 35kgN/ha 116 ha	Jul Sept 35kgN/ha 116 ha	Aug Sept Dec 20kgN/ha 72ha
Autumn N Use	Jan Mar Apr 35kgN/ha 116 ha	Jan Mar Apr 20kgN/ha 116 ha	Jan Mar Apr 10kgN/ha 44 ha	Jan Mar Apr 10kgN/ha 44 ha	Jan Mar 20kgN/ha 72ha
Supplement milking area kgDM	15,000	35,000	95,000	160,000	15,000
Summer crop area (ha)	11	8	6	0	0
PG+ C (ha)	0	0	0	47	72
Pellets Buy	280,000	122,335	100,000	140,000	140,000
Total BIF	490,000	332,335	190,000	140,000	140,000
DM eaten (tonne)	2,456	2,200	2,043	2,145	2,355
R1yr graze off	All	0	0	All	0
R2yr graze off 12 months	All	All	All	All	0
Herd graze off 6-8 weeks	All	240	210	140	0
Total N-loss (T)	18.9	14.2	12.3	12.9	16.8
N surplus (kg N/ha/yr)	268	223	184	183	170
N leached (kg N/ha/yr)	101	76	66	69	63
N conversion efficiency	23%	25%	27%	29%	23%
Total GHG (tCO2e)	2155	1928	1767	1874	1947
GHG (tCO2e/ha)	11.5	10.3	9.5	10.0	7.3
GHG conversion efficiency (kg CO2e/ kgMS)	9.6	9.6	9.6	9.3	10.9
$Income	1,427,150	1,272,370	1,180,550	1,282,715	1,153,240
$costs	832,080	661,720	558,470	583,880	396,230
$Surplus	595,070	610,650	622,080	698,835	757,010
$/cow	1,094	1,259	1,382	1,553	1,869
Surplus ($/ha)	3,606	3,701	3,770	4,235	4,588

GHG greenhouse gas (CH_4+N_2O)

CARBON SEQUESTRATION FROM TREES

The average carbon sequestration produced by different forestry strategies over specified time intervals were calculated and average figures were calculated to give an indication of the area of trees needed to produce carbon neutral milk. The area was calculated for both total and farming GHG.

The farmers have 75 ha of forest as part of their farm but this is currently planted in blocks of pine which are not well staggered. If the farmers reduce their emissions as in Run three for example, they have sufficient forestry land to produce carbon neutral milk. Whether they should change the forest strategy to staggered exotic hardwoods would require an analysis of forest returns, an assessment of the proportion of the emissions (CH_4+N_2O, $54K for base farm) the farm maybe called on to pay (proposed 5% initially), the loss of income from ETS (the carbon credits would be held and not sold to claim carbon neutrality) and the possible premiums carbon neutral milk could receive. It is an ideal time to consider these strategies with the Billion Dollar Trees fund currently providing some of the costs for establishing trees. There are future changes to the ETS scheme which may change the analysis.

Table 4. Area of trees needed to produce carbon neutral milk to farm gate for farmer's property for total GHG ($CH_4 + N_2O + CO_2$) or partial GHG ($CH_4 + N_2O$) for the base farm or for Run3. The analysis period

			Hectares of trees (ha)			
			Base		Run 3	
	Analysis Interval	Carbon GHG tCO2e/ha/yr	CH4+N2O +CO2	CH4+N2O	CH4+N2O +CO2	CH4+N2O
			2415	2155	1934	1767
Pine (planting year 1, harvest at 20 years)	25 years	-2	NA	NA	NA	NA
Pine (4yr old pines, harvested 20- years)	25 years	5	483	431	387	353
Pine (plant 4 blocks harvested and planted every 9 years, harvested 35 years)	35 years	14	173	154	138	126
Exotic hardwood (plant year 1, not harvested)	35 years	22	110	98	88	80
Exotic hardwood (plant 4 blocks, harvested and planted every 9 years, trees harvested 35 years)	35 years	27	89	80	72	65
Native (plant year 1, not harvested)	50 years	6	403	359	322	295