NZ LANDCARE TRUST

CASE STUDY

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

Marlborough

Case study by:

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The purpose of this study was

- To model options to improve profitability and reduce nutrient losses, irrigation use and greenhouse gas emissions (GHG) 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 animal production and use of feed energy intakes (farm grown or bought in feeds) to calculate best economic profit. In this instance it provided a series of actual farm options that reduce N leaching and GHG. These were extended further as "what if" questions were investigated on the farm along with discussion on how and why the model had produced these.
- To determine nutrient losses and greenhouse gas emissions from both the milking platform and the milking platform + trees, and explore the possibility of using the forest to reduce overall nutrient losses per hectare and to use carbon sequestration from the forest enterprise to offset the dairy farm emissions, and explore the possibility of producing carbon neutral milk.

OVERVIEW

The data supplied for this analysis came from a Farmax simulation of the 2016/17 year for the farm using Dairybase information and data supplied in discussion with the farmer and discussions on aspects of the farm system the farmer wished to retain. The E2M modelled the existing farm (Run 1) and then used optimisation to model 5 alternative farm systems around herd number, calving date, levels of bought in feed, reduced use of nitrogen, the use of different pasture mixes and summer crops to reduce reliance on irrigation. The amount of inputs such as bought in feeds, 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.

- In Run 2 the model considered feeding the cows better by varying cow number between 360 and 394 cows with area of irrigation, nitrogen inputs, the forage system and grazing off all fixed. The model chose to reduce cow numbers from 394 to 360 cows, thereby feeding the cows better with pasture and buying 47T less PKE **(5 % increase in profit, reduction of 4% reduction in nitrate leaching and 5% in GHG).**
- In Run 3 the model was allowed to further reduce cows down to 345, the cows were fed better and MS/cow increased by 25 kg, fertility improved, replacement rate dropped and 70T less PKE was purchased **(11 % increase in profit, reduction of 5% in nitrate leaching and 7 % in GHG).**
- In Run 4 a 6 ha summer crop was introduced instead of a grass to grass renewal, 345 cows were run and 132T less PKE and 33T less maize silage were bought and the same MS/cow was maintained **(16 % increase in profit, reduction of 5% in nitrate leaching and 7% in GHG).**
- In Run 5 the summer crop was retained and the model selected 10 ha plantain and 10 ha of chicory and chose to reduce the area irrigated **(20 % increase in profit, reduction of 5% in nitrate leaching and 7 % in GHG).**
- In Run 6 the model was free to choose cow numbers, along with optimal nitrogen application for the fully irrigated farm and also use alternative forages. Cow numbers were reduced to 330 cows, reduced N use from 120 to 85 kg N/ha and no PKE or maize silage was purchased **(29% increase in profit, 13% reduction in nitrate leaching and 18% reduction in GHG emissions).**
- Impacts of MS price were also examined.
- The base farm system would require 58, 112 or 261 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 45, 87, 203 ha for the farm system with the lowest GHG emissions. The farm currently has 30 ha of native bush, 71ha of Pinus radiata and 22ha of mixed bush and Pinus Radiata forestry.

FARM OVERVIEW 2016/17

Table 1. Production Key Performance indicators

Dairybase production figures (dairybase bench mark)	
Milking platform (eff ha)	108
Runoff block(ha)	50
Forestry (ha)	71.3
Regenerating bush (ha)	29.8
Bush/forestry (ha)	22.5
Milking platform	
Est Pasture and crop eaten (T/ha/year)	11.5 (10.8)
Imported supplements (tDM/ha)	2.4 (2.0)
Imported supplements eaten (kgDM/cow)	669
Breed Type	JxF
Herd Size	390
Cows (no./ effective ha)	3.6 (2.8)
Comparative stocking rate (kg LWT/tDM)	80.6
Production per cow (kg MS/cow)	333 (389)
Production (MS/ha)	1203 (1087)
10 day peak kg/cow	1.55 (1.91)
Planned start of calving	30 Jul
6 week in calf rate (%)	69
Empty rate (%)	14%
Replacement rate (%)	22%

Dairy Base Economic KPI (DairyNZ Westland, Tasman)	
Milking platform operating expenses ($/MS)	5.07 (4.01)
Operating expenses ($/ha)	6097
Operating profit ($/cow)	543
Operating profit ($/ha)	1959

- This farm is managed by the farmer and his wife and is jointly owned in a family trust. This farm has been owned by the same family since 1861. The farm is located just out of Blenheim in the Tuamarina River catchment.
- The farmer's goals are to run a OAD milking system, manage succession, encourage family into the farm and have a good lifestyle over profit.
- The milking platform is 108 ha, the runoff has 13.6 ha of pastoral land, 30 ha of native bush, 71ha of Pinus radiata and 22ha of mixed bush and forestry.
- The farm has an annual rainfall of 1370mm/yr and is on well drained Brown soils. The farm irrigates with K lines on 78 ha of flat and has 33 ha of non-irrigated rolling hill. The irrigation water is only restricted 1 year in 10. The costs of irrigation used in the model was over 4 months $534/ha (labour, power, additional nitrogen) to produce 3800 kgDM/ha additional feed.
- The 390 cows JxF (450 kg LWT) are milked once a day all year round through a 28 side herringbone shed. In 2016/17 the cows were milked for 282 days. They struggle to keep mastitis low with the OAD milking. The replacement rate is 22%, empty rate 14%, 6-week in calf rate is 69% and start of calving is 30 July.
- The farm often has suboptimal low pasture covers and grazing residuals. The cows are fed 2 kg/day of palm kernel (PKE) throughout lactation. In spring before mating the cows are fed maize silage at 2.5 kg/cow/day and then again in April/May and in the autumn the cows also get 2.2 kg/cow/day of baleage. The baleage is made on the runoff as is 10 tonne of hay (fed in late pregnancy). No supplements are made on the milking platform. Cows are grazed off for 65 days in winter and then return to the runoff staggered by calving date where they calve and then walk the short distance to the milking platform.
- Pasture renewal on the milking platform is grass to grass. On the runoff a 5 ha rape crop is grown for the calves and 6 ha of maize silage.
- The milking platform receives 120 kgN/ha/year (<16kg kgN/ha/application). The average Olsen P in indicator paddocks is 41 (29-57).

For full whole farm assessment Link to NZ Landcare Trust website.

Table 2: Environmental Key Performance Indicators

Environmental KPI	Milking platform	Milking platform + Trees
Total N-loss (kgN)	9418	9418
N surplus (kg N/ha/yr)	251	114
N leached (kg N/ha/yr)	85	40
N loss to drainage (ppm)	7.6	7.6
N conversion efficiency	25	25
Total GHG (tCO2e) (CH4+N2O)	1353	1353
GHG (tCO2e/ha) (CH4+N2O)	12.2	5.5
Efficiency (CO2e/kgMS)	10.4	10.4

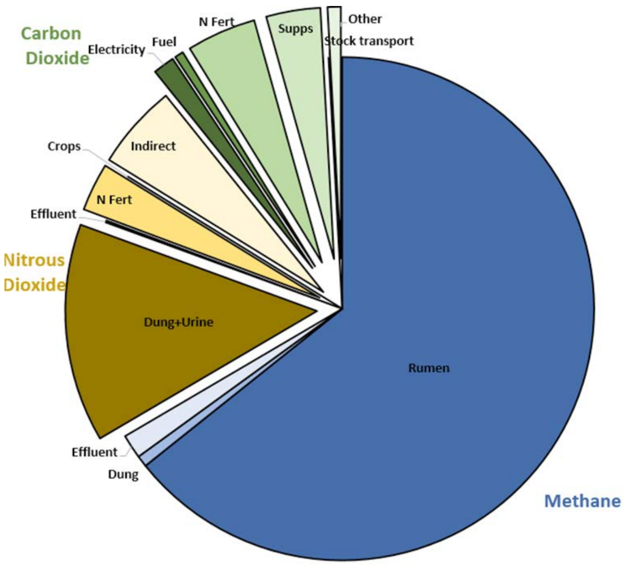

Figure 1. Break down of greenhouse gas emissions from the farm.

- Effluent is stored in two unlined storage ponds and spread over 75% of the farm through the irrigation. But this is being changed to a Tasman tank. Most of the waterways have been riparian planted but there is more scope for shading the river.
- This farm has high nitrate leaching in some areas of the farm because of the stocking rate, irrigation and the supplementary feed that is bought in to the farm. The highest leaching blocks are the irrigated and effluent blocks which are leaching 106 kgN/ha/yr (8.5 ppm N in drainage) compared to the non-irrigated rolling block of 31 kgN/ha (5.6 ppm N in drainage). The leaching and N in drainage values are similar to other irrigated farms in the same area. However, including the tree blocks (2 kg leached N/ha) owned by the farmer, reduced per ha leaching of the overall farm to 40 kgN/ha.
- The high stocking rate and associated large amount of supplements being bought onto the farm are impacting on nitrate leaching and GHG. The impact of the supplements can be seen in the very high surplus N/ha for the farm. However, this farmer also has hill country surrounding the farm which he has converted from sheep and beef to forestry and regenerating bush in the same catchment which when included as part of the farm area, reduces the nitrate leaching and GHG emissions per ha by 53%.
- The milking platform produces 12.2 T/ha of GHG emissions mostly as methane from the rumen and nitrous dioxide from dung and urine on the paddocks (see Figure 2) which are driven by stocking rate. On the farm 77% of GHG come from methane, 7% from nitrous dioxide and 16% from carbon dioxide from fuel. As the fuel already contains an emissions tax it is normally discarded in calculating a farms GHG emissions. At the current rate of $25/tCO2e the full liability of these emissions (N2O+CH4) would be $34,000/year. Of these farming emissions 92% are methane (CH4) with most coming from the rumen of stock and much lesser amounts from effluent and dung. Nitrous oxide composes 7%, mostly from dung and urine.

ECONOMIC MODELLING

The objective 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 and even hopefully improve profitability. The farm was modelled using the Enviro-Economic Model (E2M). Marginal analysis forms the basis of this model. Each additional individual input cost (e.g. kgDM or kg N) is compared to the extra income generated (e.g. increase MS income). A continual "feedback loop" ensures many resource combinations are examined within the model before an optimal profit solution is reached. Inputs can be constrained (fixed e.g. cow number, N leaching) while others can be allowed to vary. The E2M can calculate the least cost combination when N leaching is constrained though this approach wasn't used in this modelling. The model used $6/kgMS for the analysis.

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 6 new runs. The farmer posed certain "non-negotiable limits" to changes in the farm system (eg keep OAD milking). The model made no changes to the level of nitrogen use for runs 1-6. The model did choose to change variables such as cow number (and therefore replacement number), calving date, bought in feed, changed pasture renewal system, and introduced alternative pasture species with the goal of improving profit.

The MS price will affect the Marginal Cost:Marginal Income relationship. At higher MS price the E2M model may choose to include more expensive inputs such as BIF and run more cows at higher MS prices. However when a farmer faces a nitrate leaching or GHG limit then increasing the number of cows may not be possible when MS price increases.

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; it is lowest for natives and highest for exotic hardwoods; pine trees are intermediate. The carbon sequestered is the difference between the carbon stocks from one-time point to another (normally 5 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 at 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 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 rather than large blocks in the catchment at one time. It is also beneficial to grow trees that sequester good rates of CO_2 but have more extended harvest intervals.

RESULTS

E2M modelling

See table for results

Run 1: Base farm.

Inputs were constrained to reproduce the farm. Nitrogen application was assumed to be 120 kgN/ha (20 kgN/ha Aug, Sept, Oct, Nov, Dec, Jan on whole farm 120kgN/ha). 67 ha irrigated in all runs. The base farm was the milking platform and it included grazing costs of $8/wk weaners; $12 heifers; $23 mature/head per week plus transport and feed produced on the runoff was purchased at fair value ($0.25c/kgDM for hay/baleage, and $0.28c/kgDM for maize silage). The base farm used 67 ha of irrigation and assumed this produced an additional 3000 kgDM from November to March.

Run 2. Cow number and calving date.

Fixed: irrigation, nitrogen inputs 120 kg/ha, forage system, grazing-off stock.

Varied: herd number between 360 and 394 cows; calving date to better match basic feed grown with cow demand; BiF up to maximum of base farm.

Model response: Cow number reduced to 360 cows; cows ate more grass in spring; calving date was delayed by a week; MS/cow increased by 10kgMS/cow simply by having more mature cows and less heifers; bought 47 Tonne less PKE. Dry rate reduced, and replacement rate from 22 to 20%

5 % increase in profit, reduction of 4% reduction in nitrate leaching and 5% in GHG

Run 3. Cow number and improve feeding of heifers.

Fixed: irrigation, nitrogen inputs 120 kg/ha, forage system, grazing-off stock.

Varied: cow number between 345 and 394, MS/cow, BiF up to maximum of base farm, feeding of cows.

Model response: Cow number was reduced to 345; pasture covers and pasture growth rates in spring increased; heifers were separated from main herd and fed better; replacement rate dropped from base level of 22% to 20%; increased proportion of mature cows in the herd; reduced rearing and grazing costs; bought 70 T less PKE; increase MS/cow by 25 kg.

11 % increase in profit, reduction of 5% in nitrate leaching and 7 % in GHG

Run 4. Summer crop and grazing-off.

Fixed: irrigation, nitrogen inputs 120 kg/ha, MS 357 kg MS/cow.

Varied: Cow number between 345 and 394, BiF up to maximum of base farm, change pasture renewal on the irrigated milking platform from grass to grass to up to 6 ha of a summer turnip crop (9 T/ha), retain or graze off young stock.

Model response: Same 345 cow numbers were chosen; same increase in pasture cover, introduced 6 ha of turnip crop; bought 132T less PKE; bought 33 T less maize silage from the runoff. The higher residuals and better pasture covers and the associated improvement in quality were able to still maintain the same MS/hd production levels despite the removal of maize and PKE. The model still chose to graze off young stock.

16 % increase in profit, reduction of 5% in nitrate leaching and 7% in GHG

Run 5. Alternative forages and irrigation.

Fixed: Nitrogen inputs 120 kg/ha, 345 cows, 357 kgMS/cow.

Varied: BiF up to maximum base farm, up to 6 ha summer crop, pick two areas of up to 10 ha of either Plantain (13T/year, 3 year lifespan) and Chicory (11.5T/ha, 2 year lifespan) both with a winter dormant period. Establishment, maintenance and additional nitrogen costs of the swards were spread over the crop lifespan. The model was allowed to choose the area to irrigate.

Model response: 10 ha of plantain and 10 ha of chicory; no summer crop; 220 T less PKE was purchased. The maximum area it chose to irrigate was 40 ha.

Note: Stock are grazed out and so the farm is not dependent on winter growth so dormant period of alternative forages has less impact.

20 % increase in profit, reduction of 5% in nitrate leaching and 7 % in GHG

Run 6. Optimise Nitrogen applications.

Fixed: 362 kgMS/cow, irrigation.

Varied: Cow numbers; alternative forages; change the amount and timing of nitrogen applications and BiF up to maximum of base farm.

Model response: 330 cows; 7ha of chicory; reduction and change in timing of N use; 20kgN/ha Aug and Sept on all land; 12-13kgN/ha Oct, Nov and 20kgN/ha Dec, Jan, Feb on irrigated land only (overall 85 kg N/ha); no PKE or maize silage bought.

29% increase in profit, 13% reduction in nitrate leaching and 18% reduction in GHG emissions.

Impact of MS Price for Run 6 and 7.

A change in MS price can change the marginal cost to return relationships. We explored these changes in Run 6 and 7.

Run 6a, 7a. Fixed. As per final model Run 6 and 7. Varied MS price $6, $7, $8/kgMS.

Run 6b, 7b: Rerun again with same fixed and variable parameters as Run 6, Run 7 but with $7 and $8/kgMS. Limited N to 85kgN/ha.

Model response

Run 6b $7/kgMS. E2M milked 341 cows; bought 58 T of maize silage, 15 T PKE, 44T baleage and 14T hay; and brought back in 10+10 ha Plantain and Chicory.

Run 6b $8/kgMS. E2M milked 386 cows; bought in 110 maize silage; 200 T PKE, 44T baleage and 14T hay; brought back in 10+10 ha Plantain and Chicory.

Run 7b $7/kgMS the E2M milked 353 cows, 140,000 BiF.

Run 7b $8/kgMS E2M milked 395 cow; 370,000 kg BiF used.

Table 4. Impact of milk solids price on profit per ha

Profit $/ha	$6/kgMS	$7/kgMS	$8/kgMS
Run 6a (only changing MS price)	3546	4803	5802
Run 6b. Allowing more BiF, but limit of 85 kgN/ha	3546	4655	5882
Run 7b. Allowing more BiF, but limit of 85 kgN/ha	3802	4918	6173

An increased MS price makes more BiF a more profitable option. But when a limit on Nitrogen use is imposed there is relatively small effect on overall profitability by purchasing more BiF.

Table 5. Output of analysis of E2M model for milking platform

	1 Base	2 Cow number and calving date	3 Cow number and improve feeding heifers	4 Summer crop and grazing off	5 Alternative forages and irrigation	6 Optimise Unrestrained cow number	7 Optimise Nitrogen applications
No. Cows	394	360	345	345	345	310	330
Total MS kgMS	130,730	124,100	123,325	123,325	123,325	110,000	119,430
Production per ha (kgMS/ha)	1210	1149	1142	1142	1142	1019	
Production per cow (kg MS/cow)	332	344	357	357	357	355	362
Baleage kgDM	44,000	44,000	44,000	44,000	44,000	43,000	43,000
Hay kgDM	10,500	10,500	10,500	10,500	10,500	0	10,500
PKE kgDM	200,000	153,000	123,300	67,800	18,000	0	0
Maize silage Runoff kgDM	110,000	110,000	110,000	76,730	110,000	0	0
Total BIF (kgDM)	369,000	317,500	288,800	232,300	149,225	43,000	53,500
DM eaten (tonne)	1,635	1,514	1,4870	1,484	1,458	1,320	1,400
R1yr graze off	Jan ->	Jan ->	Jan ->	Jan ->	Jan ->	All	All
Summer turnip crop (ha)	0	0	0	6	0	0	0
Plantain chicory ha	0	0	0	0	20	3 ha turnip	7ha chicory
R2yr graze off 12 months	All	All	All	All	All	All	All
Herd graze off 6-8 weeks	All	All	All	All	All	All	All
Total N-loss (kgN)	9418	9085	8975	8975	8975	8310	8199
N surplus (kg N/ha/yr)	251	238	231	226	212	207	202
N leached (kg N/ha/yr)	85	82	81	81	81	75	74
N conversion efficiency milking/ total farm	25/25	25/25	26/25	26/26	27/27	24/24	25/25
Total GHG (tCO2e) (CH4+N2O)	1865	1783	11748	1733	1712	1563	1553
GHG (tCO2e/ha) (CH4+N2O)	12.2	11.6	11.4	11.4	11.3	10.0	10.0
Efficiency (CO2e/ kgMS)	10.4	10.4	10.2	10.2	10.2	10.1	9.3
$Income	838,650	793,610	786,905	786,905	786,905	701,738	762,030
$Costs	514,930	454,845	428,305	410,925	397,275	311,655	343,810
$Surplus	323,720	338,770	358,600	375,980	389,630	390,010	418,220
$Surplus/cow	822	941	1039	1090	1129	1258	1267
$Surplus/ha	2943	3080	3260	3418	3542	3546	3802

CARBON SEQUESTRATION FROM TREES

The average carbon sequestration produced by different forestry strategies over specified time intervals were calculated and an average figure calculated for the specified analysis interval. This average figure was to calculate the area of trees needed to produce carbon neutral milk. The area was calculated for both total GHG (methane, nitrous oxide and carbon dioxide from burning fuel) and farming GHG (methane and nitrous oxide).

The farmers have 71 ha of Radiata pine and 52 ha of regenerating bush plus pines. The forestry is not staggered in its planting. If the farmers reduce their emissions as in Run 7 and for the next 35 years had a staggered pine tree block, coupled with top up sequestration from the native block, they could produce carbon neutral milk, covering both total or farming emissions for their farm. A staggered planted exotic hardwood block would only require 45 ha or 41 ha to meet total or farming emissions. Whether they should change the forestry strategy from a single pine block to staggered exotic hardwood blocks would require an analysis of forestry returns, an assessment of the proportion of the emissions (CH_4+N_2O, $34K 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 Trees Fund currently providing some of the costs of establishing trees.

The base farm system would require 58, 112 or 261 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 45, 87, 203 ha for the farm system with the lowest GHG emissions. The farm currently has 30 ha of native bush, 71ha of Pinus radiata and 22ha of mixed bush and forestry.

Table 6. Area of trees needed to produce carbon neutral milk to farm gate for farmers property for total tonne GHG (CH_4 + N_2O+ CO_2) or partial tonne GHG (CH_4 + N_2O) for the base farm or for Run7. The analysis period

			Hectares of trees (ha)			
			Base		Run 7	
Tree strategies	Analysis Interval	Carbon sequestration by trees GHG $tCO_2e/ha/yr$	Total CH_4+N_2O +CO_2	Farming CH_4+N_2O	Total CH_4+N_2O +CO_2	Farming CH_4+N_2O
Total GHG emissions from the farm (tonne)			1563	1353	1219	1109
Radiata pine (71 ha planting year 1, harvest at 27 years)	30 years	6	261	226	203	185
Radiata pine (equilibrium plant 4 blocks harvested and planted every 9 years, harvested 35 years)	35 years	14	112	97	87	79
Bush regenerating (53 ha, regenerated since 1990, no harvesting, 20 years)	20 years	3	521	451	406	370
Native (plant year 1, not harvested)	50 years	6	261	226	203	185
Exotic hardwood (plant year 1, not harvested)	35 years	20	78	68	61	55
Exotic hardwood (equilibrium, plant 4 equal blocks, block harvested and planted every 9 years, harvested 35 years)	35 years	27	58	50	45	41