Economic and contaminant loss impacts on farm and orchard systems of mitigation bundles to address sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui Water Management Areas

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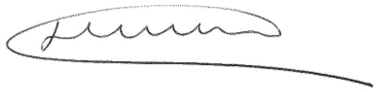
Prepared by:	Lee Matheson BApplSc (Hons), MNZIPIM (Reg.) ASNM Agribusiness Advisor Managing Director, Perrin Ag Consultants Ltd	
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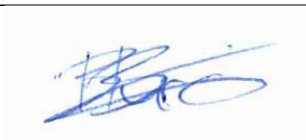
	Byron Bird BAgrSc, MNZIPIM, CNMA Agribusiness Consultant, , Perrin Ag Consultants Ltd	
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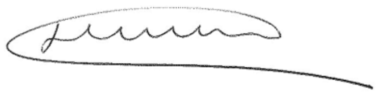
	Lee Matheson BApplSc (Hons), MNZIPIM (Reg.) ASNM Agribusiness Advisor Managing Director, Perrin Ag Consultants Ltd	
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Executive summary

The purpose of this report is to present an assessment of the farm/orchard-gate economic impact of applying a range of mitigation practices to reduce losses of nitrogen, phosphorus, *E. coli* and sediment. The effectiveness of these practices in reducing losses of nitrogen, phosphorus and agricultural greenhouse gas emissions across various land uses, as estimated in OVERSEER, is also presented. The aim of this study is to support freshwater planning for the Rangitāiki and Kaituna-Pongakawa-Waitahanui Water Management Areas (WMAs), as part of the Bay of Plenty Regional Council's Plan Change 12 process.

There is a separate bio-physical catchment model (eSOURCE) developed to support this process, which estimates contaminant losses and resulting water quality outcomes in a greater level of detail. The contaminant losses reported in this document will not be used directly in the bio-physical model, although they may help to determine the level of effectiveness of different mitigation practices.

Following on from the evaluation of mitigation practices and preliminary bundling work, baseline (M0) system models were created from which to assess the economic impact of implementing the mitigations on representative farm and orchard systems in the Kaituna-Pongakawa-Waitahanui and Rangitāiki WMAs. The modelled systems comprised six pastoral dairy farm, four pastoral sheep, beef & deer farm, a single arable farm system and two kiwifruit (green & gold) systems. Two forestry systems were also modelled, but primarily to establish a basis for the impact of their adoption by landowners as a partial mitigation practice on suitable land.

The pastoral and arable systems were all modelled in Farmax Pro[1] software to generate status quo production models, while the permanent crop systems (kiwifruit and forestry) were modelled in Excel. Revenue and expense assumptions used to reflect medium term expectations for the relevant sectors. All of the analysed farm and orchard systems were modelled in OVERSEER 6.3.0[2] to estimate baseline N, P and biological greenhouse gas emissions (methane and nitrous oxide).

With the cost analysis of mitigation of sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui WMAs primarily focussed on the "cost" [to profit] of applying mitigations *within* land use sectors, operating profit was determined as being the best KPI to utilise.

For this analysis, earnings before interest and tax (EBIT) was chosen as the preferred measure to allow consistency in the calculation of profitability between the pastoral, arable and permanent cropping land uses. In all instances, the cost of all the labour necessary within the land uses was accounted for by way of direct wages or salaries or as contracted inputs. All farm and orchard systems were assumed to be at status quo (with no impact on profitability via changes in feed or livestock inventory) and land rental (if any) was considered a finance cost and excluded.

The originally proposed mitigation bundles M1 through M3 had been refined via the community and stakeholder consultation process but underwent some slight further refinement as a result of preliminary modelling.

Sequential Farmax (and Excel) and OVERSEER models were then created to represent implementation of the mitigations in each bundle (if applicable to the farm system) in line with

[1] http://www.farmax.co.nz/
[2] https://www.overseer.org.nz/

standardized modelling protocols. At each modelling step, the farm models were adjusted to ensure the farm and orchard systems remained feasible. Any efficiency gains in the farm/orchard systems were limited to those created by the mitigations themselves, rather than via an improvement in farm management capability. Where a mitigation was not applicable for a given farm system, then it was not considered.

The outputs (physical and financial) from the farm systems from each sequential change were recorded to allow abatement curves of the mitigations to be created and to calculate the aggregated cost of each mitigation bundle when applied to each farm system.

When applied to the dairy farm systems, the bundles resulted in economic impacts broadly in line with cost expectations. For the non-dairy pastoral farm systems, some reallocation of mitigations to bundles is required due to the fact that some mitigations were not economically feasible.

As modelled, most of the proposed individual mitigations had relatively modest impacts on annual farm system profitability when considered as isolated practices. However, there were some key mitigation practices that had significant impacts on farm system profitability. This was similarly observed for N, P and GHG losses (as estimated by OVERSEER) albeit often for different practices.

For the dairy farm systems, the most-costly mitigations were:

- Development of stand-off pad infrastructure;
- Wetland developments;
- Creation of lined effluent storage;
- Substitution of autumn N fertiliser with supplementary feeds; and
- Reducing feed imported in the autumn.

On average, full adoption of the mitigation bundles (M1 through M3) on the dairy farm systems modelled reduced N losses by 44%, P losses by 21% and GHG losses by 17% - all for a reduction in profitability by 35%.

For the drystock farm systems, the most-costly mitigations were:

- Conversion of steep land to forestry (incorporating a conservative assumption on forestry revenues but excluding carbon);
- Wetland development;
- Elimination of N fertiliser that supported capital (breeding) livestock;
- Incorporation of low N forages into the farm system; and
- Gorse management.

Full adoption of the mitigation bundles (M1 through M3) on the drystock farm systems modelled reduced N losses between 14% and 35%, P losses between 0% and 38% and GHG losses between 8% and 34%. Profitability reduces between 53% and 183% from the current profits. Compared to dairy farm systems, the sheep, beef and deer farms are substantially affected by bundle implementation, particularly in the Kaituna-Pongakawa-Waitahanui WMA.

However, a special comment regarding the use of forestry as a mitigation is warranted here. The efficacy of forestry as a mitigation on steeper soils is more dependent on the "income" from the forested area rather than the cost of afforestation itself. While we are cognisant that we have used a very low annual "income" of $200/ha to represent the annual income stream from forestry over time, it is clear that using a figure closer to the equivalent annuity associated with forestry land use (see Appendix 5 and Appendix 6) has a significant impact on lowering the cost of mitigation.

Forestry has an opportunity to be a cost-effective tool for improving water quality where a longer-term view of returns can be made. Of course, the challenge of addressing land-owner's concerns about "how do I get enough income to live off if I change land use away from livestock farming to forestry?" is very real and not one that will easily be resolved.

For the arable farm system, the costliest mitigation was reducing N fertiliser inputs (which resulted in significant yield loss). For the orchards, converting the pasture into the vine canopies added significant per hectare costs, which are associated with mechanical pasture control beneath the vines.

Some of the mitigation, in addition to the impacts on farm operating profitability, had initial capital costs. For example, the net capital cost to fully implement through to M3 was in the vicinity of $369,000 ($3,000/ha) for non-irrigated dairy farms, $636,000 ($5,400/ha) for irrigated dairy farms and $394,000 for the sheep, beef and deer farms (c. $1,000/ha). In contrast, the capital costs of implantation were low for the arable and kiwifruit models, which are assessed at $14,000 ($350/ha) and $3,000 ($750/ha) respectively.

Some amendments to the mitigations in the bundles are probably warranted based on the analysis, as is more work on addressing the contrast and tensions between the cashflow impacts and the potential longer-term value uplift from using partial land-use change to forestry as a mitigation.

Table 1 overleaf summarises the results of the analysis for the different farming/growing systems and mitigation bundles.

Table 1: Summary of the cumulative impact of the mitigation bundles to the analysed farm and orchard systems

Land use	System	EBIT ($/ha/year)				N loss (kg/ha/year)				P loss (kg/ha/year)			
		Base	M1	M2	M3	Base	M1	M2	M3	Base	M1	M2	M3
Dairy	Lower KPW	1,983	1,970	1,852	1,506	51	38	31	23	3.4	2.8	2.7	2.6
	Mid KPW	1,413	1,328	1,287	843	54	40	40	32	1.4	1.3	1.3	1.2
	Upper KPW	1,115	933	922	529	68	49	55	30	4.0	3.4	3.2	3.1
	Lower Rangitāiki	2,582	2,490	2,462	1,958	67	49	49	36	1.2	1.1	1.1	1.0
	Mid-Upper Rangitāiki (irrigated)	2,121	2,118	2,026	1,489	62	49	48	35	1.1	1.0	0.9	0.9
	Mid-Upper Rangitāiki (unirrigated)	1,689	1,679	1,579	1,075	53	40	39	30	0.9	0.7	0.7	0.7
Drystock	KPW Dairy Support	421	310	96	10	28	28	22	18	2.0	1.8	1.2	1.2
	KPW Sheep & Beef	133	26	- 75	- 112	25	25	19	17	2.7	2.2	1.7	1.7
	Rangitāiki Sheep & Beef	219	138	112	90	36	35	33	31	1.0	0.94	0.91	0.9
	Rangitāiki Deer	229	148	126	64	25	25	24	22	1.2	1.1	1.1	1.1
Arable	KPW Maize	2,345	2,192	1,383	1,298	63	57	63	59	2.4	2.2	2.4	2.3
Kiwifruit	Gold	78,400	76,533	76,495		23	21	21		0.5	0.5	0.5	
	Green	19,500	17,608	17,570		19	18	16		0.5	0.5	0.5	
Forestry	Pinus radiata	530				2.5				0.1			
	Mānuka	130				3				0.1			

N and P loss figures as assessed by OVERSEER v6.3.0

1 Overview

A list of 42 rural land use management and land use change mitigations had been evaluated for their effectiveness and cost to the farm or orchard system in order to develop mitigation bundles for use in evaluating the cost of improving water quality in the Kaituna-Pongakawa-Waitahanui and Rangitāiki WMAs.

As reported in an earlier document (1A milestone v1.3 report), a cumulative three-layer framework, was developed to bundle the mitigations. However, in this case, bundles were primarily determined based on cost at the farm gate, filtered for effectiveness at reducing contaminant losses. These mitigation strategy bundles, designed to be applied cumulatively to farm and orchard systems, are:

(i) M1: low barrier to adoption; primarily defined by being of low cost (equivalent to less than 10% of Earnings Before Interest and Tax [EBIT]) with at least a low effectiveness for reducing contaminant/s in comparison to other bundles;

(ii) M2: moderate barrier to adoption; primarily defined by direct costs and/or reduced revenue equivalent to more than 10% but less than 25% of EBIT with a medium effectiveness for the targeted contaminant/s in contrast to M1 and M3;

(iii) M3: high barrier to adoption, primarily defined by significant reductions in pre-mitigation profitability (i.e. reduction in >25% of EBIT) and high effectiveness at contaminant reduction than the other mitigation bundles.

Total land use change mitigations were considered as a separate bundle (M4) and excluded from consideration. Existing current (baseline) practices were considered as M0.

The original bundles were evaluated at community group and separate industry meetings. The final list of bundles was compiled by the project management team for modelling the farm economic impact for the ten pastoral, two horticultural and one arable farm economic models developed for the two water management areas of interest.

In reaching these final bundles, it is important to highlight a number of the long list of specific mitigations that were invariably excluded from this analysis due to a lack of sufficient data of their impact on contaminant load to water. However, these mitigations have some promise with regards to cost-effectively lowering the loss of N, P, sediment and/or bacteria to water from our farm and orchard systems. These included:

- the “Spikey’ technology;
- introduction of dung beetles to pastoral systems.

The final bundles for each of the land use types are presented in Table 2 through Table 5 below.

Table 2: Dairy farm system mitigation bundles

Bundle	Order	Mitigation
M0		Full stock exclusion from all waterways greater than 1m wide at any point adjacent to dairy farm (including drains) and wetlands
		[Paddock rotation and responsible break-feeding, some level of effluent management, current irrigation practice]
		Complete protection of gully heads
M1	1	Placement of feeding equipment
	2	Timing of effluent application in line with soil moisture levels (assumes sufficient storage)
	3	Reduced tillage practices
	4	Improved nutrient budgeting and maintenance of optimal Olsen P
	5	Laneway run-off diversion
	6	Grow maize on effluent blocks (if already growing maize)
	7	*Elimination of summer cropping*
	8	Reductions in seasonal stocking rate
	9	Efficient fertiliser use technology
	10	Efficient irrigation practices (soil moisture monitoring)
	11	Use of plant growth regulators [to replace N]
	12	Adoption of low N leaching forages
	13	Relocation of troughs
	14	Slow release phosphorus fertiliser RPR
	15	Reduce autumn N application - replace with appropriate low(er) N feed
	16	3m average vegetated and managed buffer around rivers, streams, lakes and wetlands subject to the Dairy Accord; 1m around drains; 5m average buffer on slopes between 8 and 16 degrees, 10m average buffer on slopes above 16 degrees
M2	1	Increase effluent application area
	2	Develop a detention bund
	3	Controlled grazing with stand-off pads (16 hours per day on pad in autumn), if they already have a stand-off pand
	4	Installing variable rate irrigators on existing pivot irrigators
	5	Reduce imported autumn supplement fed by 20%
	6	Reducing fertiliser N use (to 100kg N/ha)
	7	Full stock exclusion from permanently flowing waterbodies less than 1m wide (REC Order 2 and above) and average 2m vegetated and managed buffer; 3m average buffer on slopes between 8 and 16 degrees, 7m average buffer on slopes above 16 degrees
M3	1	Afforestation of erosion prone land (e.g. >26 degrees)
	2	Stock excluded from REC Order 1 watercourses less than 1m wide and 1m wide average vegetated buffer
	3	Impervious effluent storage and sufficient capacity to comply with soil moisture guidelines and low rate effluent application
	4	Restricted grazing in covered stand-off pad, with use extended to winter as well
	5	Put in standoff pad if they haven't got one and use for 16 hours per day in autumn
	6	Switching from manual (e.g. K-line) to pivot irrigators with variable rate irrigators – irrigated dairy farms with manual irrigation systems only
	7	Creation of new wetlands
	8	Reducing stocking rates down by 0.3 cows/ha

Table 3: Drystock farm system mitigation bundles

Bundle	Order	Mitigation
M1	1	Improved nutrient budgeting and maintenance of optimal Olsen P
	2	Efficient fertiliser use technology
	3	Stock class management within landscape
	4	Adopt M1 arable cultivation practices for winter cropping
	5	Laneway run-off diversion
	6	Relocation of troughs
	7	Appropriate gate, track and race placement, design (where possible)
	8	Targeted space planting of poles
	9	Slow release phosphorus fertiliser RPR
	10	Adoption of low N leaching forages
	11	Full stock exclusion from all waterbodies greater than 1m wide at any point adjacent to farm (including drains) and wetlands. 2m average vegetated and managed buffer around rivers, streams, lakes and wetlands; 1m around drains; 3m average buffer on slopes greater than 8 degrees; 5m average buffer on slopes greater than 16 degrees.
M2	1	Eliminate N that supports capital livestock
	2	Detention bunds
	3	Complete protection of gully heads
	4	Management of gorse
	5	Whole paddock space planting of poles
	6	Full stock exclusion from permanently flowing waterbodies less than 1m wide (REC Order 2 and above) and 1m average vegetated and managed buffer; 2m average buffer on slopes greater than 8 degrees, 3m average buffer on slopes greater than 16 degrees [with associated stock water reticulation, if any].
	7	Convert steep land (e.g. LUC class 7-8, >26 degrees) into forestry/mānuka and fenced
	8	Changing stock ratios to reflect lower N leaching potential
M3	1	Full stock exclusion from REC Order 1 watercourses less than 1m wide and 1m wide average vegetated buffer.
	2	Creation of new wetlands
	3	Eliminate N that supports trading livestock

Table 4: Arable farm system mitigation bundles

Bundle	Order	Mitigation
M1	1	Grass or planted buffer strips
	2	Complete protection of existing wetlands
	3	Maintain optimal Olsen P
	4	Efficient fertiliser use and technology
	5	Cover crops between cultivation cycles
	6	Manage risk from contouring
	7	Reduced tillage practices
M2	1	Use of silt fencing
	2	Complete protection of gully heads -N/A
	3	Reducing fertiliser N use
	4	Strip tillage
M3	1	Creation of new wetlands
	2	Sediment traps

Table 5: Kiwifruit orchard system mitigation bundles

Bundle	Order	Mitigation
M1	1	Complete protection of existing wetlands
	2	Maintain optimal Olsen P
	3	Laneway run-off diversion
	4	Efficient fertiliser use and technology
	5	Efficient irrigation practices (soil moisture monitoring, not following fertiliser application)
	6	Grass swards under canopy, minimise bare ground and vegetated buffers around waterways.
M2	1	Detention bunds in gullies (assuming gullies occur in kiwifruit properties, perhaps mid KPW?)

It is important to note that not all of the mitigation practices in each bundle apply to every farming/growing system for the various land uses. Table 6 below shows which practices apply each farming/growing system.

Table 6: Application of mitigation practices to the farm and orchard models

		Dairy						Drystock				**Arable**	Kiwifruit	
		Lower KPW	Mid KPW	Upper KPW	Lower Rangitāiki	Mid-Upper Rangitāiki (irrigated)	Mid-Upper Rangitāiki (unirrigated)	KPW Dairy Support	KPW Sheep & Beef	Rangitāiki Sheep & Beef	Rangitāiki Deer		Gold	Green
M1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓
	3	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	✗	✓	✓
	4	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓
	5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓
	6	✗	✗	✗	✗	✗	✗	✓	✓	✓	✓	✗	✓	✓
	7	Excluded						✓	✓	✓	✗	✓		
	8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	10	✗	✗	✗	✗	✓	✗	✓	✓	✓	✓			
	11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	12	✓	✓	✓	✓	✓	✓							
	13	✓	✓	✓	✓	✓	✓							
	14	✓	✓	✓	✓	✓	✓							
	15	✓	✓	✓	✓	✓	✓							
	16	✓	✓	✓	✓	✓	✓							
M2	1	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗		
	3	✓	✗	✗	✗	✗	✗	✓	✓	✗	✗	✓		
	4	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	Excl.		
	5	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗			
	6	✓	✗	✗	✗	✗	✗	✓	✓	✓	✓			
	7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗			
	8							✗	✓	✓	✗			
M3	1	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓		
	2	✗	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓		
	3	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓			
	4	✓	✗	✗	✗	✗	✗							
	5	✗	✓	✓	✓	✓	✓							
	6	✗	✗	✗	✗	✓	✗							
	7	✓	✓	✓	✓	✓	✓							
	8	✓	✓	✓	✓	✓	✓							

2 Methodology

2.1 Description of economic and physical analysis modelling

Baseline (M0) system models were created for the six pastoral dairy, four pastoral sheep, beef and deer and a single arable representative farms, two kiwifruit orchards and two forestry systems in Farmax and/or Excel and OVERSEER 6.3.0 software.

Sequential Farmax and OVERSEER models were created to represent implementation of the mitigations in each bundle (if applicable to the farm system) in line with the modelling protocols outlined in Appendix 8 to Appendix 11. In cases where the economic impact of the mitigation was unable to be modelled in Farmax (i.e. capital expenditure), Excel models were used.

2.1.1 Farm system modelling

The pastoral and arable systems were modelled in Farmax Pro software to generate status quo production models. The financial modelling capability within the Farmax software was utilised to generate the financial outputs, with revenue and expense assumptions used to reflect medium term expectations for the relevant sectors.

2.1.2 Orchard and forestry modelling

The permanent crop systems (kiwifruit and forestry) were financially modelled in Excel. The P. radiata and mānuka modelling was undertaken to assist the analysis of when forestry was applied as a mitigation practice for the pastoral land uses. No mitigation modelling on forestry practices themselves (with regard to lowering impacts on water quality) was undertaken.

2.1.3 OVERSEER modelling

All of the analysed pastoral and arable farm and horticultural systems were modelled in OVERSEER 6.3.0 to estimate baseline N, P and biological greenhouse gas emissions (methane and nitrous oxide).

All of the systems were modelled according to the OVERSEER Best Practice Data Entry Standards (with the exception of constructed wetlands) and the additional requirements of the Bay of Plenty Regional Council. Geophysical inputs (climate data and soil type) were generated based on GPS coordinates for each farm systems, utilising the climate station tool in OVERSEER and S-map soil data.

Constructed wetlands were modelled in OVERSEER using the Wetland model, which is currently under review. This is a departure from the recently released OVERSEER 6.3.0 data input standards, which recommends wetland areas are input as Riparian blocks. The use of the Wetland model in this analysis (and associated input assumptions as presented in Appendix 8 to Appendix 10) generates greater estimate in reductions of N losses to water than from the Riparian model.

2.1.4 Mitigation bundle modelling

Mitigations were applied sequentially i.e. mitigation M1.1 was applied to the M0 model, then renamed and saved as M1.1. The M1.2 mitigation was then applied to the M1.1 model, renamed, saved and so on. At each step, the farm models were adjusted to ensure agronomic feasibility in line with a static management capability horizon. Where a mitigation was not applicable for a given farm system, then it was missed out.

The impact of capital expenditure associated with mitigations was accounted for by the adjustment to calculated EBIT the corresponding opportunity cost of capital and increases to depreciation (for infrastructure assets). Where capital in livestock was realized through reductions in stocking rate, the capital benefit of this was also accounted for. The economic value of mitigation options was accounted for as the change from the economic value without the mitigation option (i.e. the net change in economic value from the baseline situation with introducing mitigation option). This reflects the economic benefits (e.g. forestry) and costs of mitigations.

The modelled outputs (physical and financial) from the farm systems from each sequential change were recorded to allow abatement curves of the mitigations to be created and to calculate the aggregated cost of each mitigation bundle when applied to each farm system. These are the following:

- Physical production (i.e. kg MS, kg saleable product)
- N fertilizer inputs
- N losses to water
- Biological greenhouse gas emissions
- P losses to water
- Percentage change in operating profit
- Capital movements

2.2 Limitations of the approach

While OVERSEER is generally accepted as a reliable indicator of N and biological greenhouse gas emissions from pastoral and arable systems, P loss estimates from OVERSEER don't account for the spatial connectivity of critical source areas in the way that other models can and estimates of sediment and *E. coli* loss are absent in the model.

As a result, the analysis undertaken for this report likely underestimates the impact that mitigations could have on P losses and is unable to quantify the impact that any of the mitigations have on sediment and bacterial losses. Estimates of sediment and bacterial losses are expected to be derived from the BOPRC's concurrent study to this on bio-physical catchment modelling (eSOURCE).

OVERSEER estimates of N losses from horticultural production are potentially less reliable than those estimated from the pastoral and arable systems due to more limited due to the extremely limited amount of direct measurement of N losses to water from orchards (Benge & Clothier 2016), the results of this singular study being described as highly variable (New Zealand Kiwifruit Book 2017). In the interests of consistency, we have reported on these nonetheless recognising that estimates of N losses from kiwifruit orchards using SPASMO (Soil Plant Atmosphere System Model) are not dissimilar to those generated from OVERSEER (Benge & Clothier 2016, McIntosh 2009). However, we note that "a new Zespri-funded project being undertaken by Plant & Food Research has just commenced to measure N losses from orchards and to eco-verify kiwifruit practices". It is also important to note that there is general acceptance that kiwifruit will have a significantly lower N loss footprint to water than dairying.

2.3 Choice of financial KPIs

The choice of the financial KPIs to model in farm or property scale analyses such as these is often contentious, and the preferred measure tends to vary depending on the desired use of the output. Typical KPIs used include:

- Gross margin
- Operating profit
- Net profit before tax
- Net present value
- Internal rate of return
- Return on assets

Each is described briefly below.

2.3.1 Gross margin

Gross margin is the total revenue of an enterprise less its variable (direct) costs and reflects a given enterprise's contribution to a business's fixed costs and profits (Kay & Edwards, 1994). It is a useful measure to assess the relative profitability of a given enterprise to another within a business and typically utilised when considering how a business can maximise profit.

2.3.2 Operating profit

Operating profit is a measure of business profitability, independent of ownership or funding. It comprises both cash and non-cash elements (i.e. to account for gradual loss in value of assets used to generate profit) and provides a measure of how much profit a given business generates to meet financing costs, taxation, capital investment and returns to owners outside of that earned from participation in the operations of the business.

Earnings before interest and tax ("EBIT") tends to be the standard measure of enterprise performance. However, economic farm surplus ("EFS"), which also includes the value of unpaid labour and changes in feed inventory on hand, has tended to be the preferred measure in assessing the profitability of New Zealand farm businesses. This has been due to the dominance of owner-operator businesses where owners tend to take their reward for labour out of tax-paid business profit as opposed it being a wage or salary that forms part of operating expenses. As a result, the true cost of running a farm business would be underestimated using a conventional accounting approach.

Operating profit is a useful measure to assess how the relative profitability of a business, irrespective of how it's financed, might change because of changes to its operating systems. This could be useful when evaluating different management systems for a dairy farm or when looking at how a kiwi fruit orchard's profit is impacted by applying mitigations to reduce the risk of PSA.

2.3.3 Net profit before tax

Net profit before tax ("NPBT") is operating profit adjusted for financing costs (interest). This measure considers an individual business' financing requirements and represents the profit available to meet taxation, capital investment and returns on an owner's equity.

NPBT is a key metric for assessing how system change might affect an individual business' financial position. However, as NPBT is heavily influenced by the extent of any debt equity utilised by the business, it is not a useful measure for assessing the underlying profitability of a farming system.

2.3.4 Net present value and internal rate of return

Net present value is the sum of the present values for each year's net cash flow for the term of an investment, less the initial cost of the investment, at an assumed interest rate. An investment with a positive NPV indicates a rate of return higher than the assumed interest rate.

Internal rate of return ("IRR") is the interest rate at which the NPV of an investment is zero i.e. the implied return of the investment.

These metrics are useful for evaluating the relative returns between different businesses over time, particularly those with significant differences in the timing of cashflows (such as between pastoral farming and forestry).

2.3.5 Return on assets

Return on assets ("RoA") is operating profit divided by the total value of all the assets employed in a business.

It is a key metric for assessing the relative [status quo] profitability of investments between business types with similar temporality of revenue and expenses (i.e. between sheep & beef farms and dairy farms) and within business of the same type (i.e. between System 1 and System 5 dairy farms).

2.3.6 Choice of KPI for this analysis

With the cost analysis of mitigation of sediment and other freshwater contaminants in the Rangitāiki and Kaituna-Pongakawa-Waitahanui WMAs primarily focussed on the "cost" [to profit] of applying mitigations *within* land use sectors, then operating profit is the best KPI to utilise.

On this analysis, EBIT was chosen as the preferred measure to allow consistency in the calculation of profitability between the pastoral, arable and permanent cropping land uses. In all instances, the cost of all the labour necessary within the land uses was accounted for by way of direct wages or salaries or as contracted inputs. All farm and orchard systems were assumed to be at status quo (with no impact on profitability via changes in feed or livestock inventory) and land rental (if any) was considered a finance cost and excluded.

Discounted cashflow analysis (utilising a discount rate of 5%) was used to estimate profitability of the forestry land uses considered in the wider study, but as alluded to above, is not able to be directly compared with the annual per hectare profitability estimates derived from pastoral agriculture or established permanent horticulture.

2.4 Variations to proposed mitigation bundles

During the modelling process, a number of changes were made to the mitigation sequencing and a number of the mitigations themselves. These are briefly described in the next subsections.

2.4.1 Excluding the "Elimination of summer cropping (Dairy M1.7)"

The recent version of OVERSEER (6.3.0) is now generating N losses from fodder crop blocks (that rotate within pastoral blocks) on pumice and allophanic soils that are significantly lower than those estimated in earlier versions of OVERSEER. The Chicory fodder crops modelled in a number of the dairy farm models are generating only 8kg N/ha of loss, which is intuitively incorrect. As a result, when the chicory crops are eliminated, N losses to water as estimated by the OVERSEER version actually increase, which is counter-intuitive and would confound the outputs. Accordingly, it was decided to exclude this mitigation from the current analysis. We expect OVERSEER to be in a position to verify the validity of these outputs before the end of the year.

2.4.2 Changing the order of Dairy M3.2 and M3.3

Due to the relative capital cost and environmental impact of the mitigations, it was decided to move the priority of the exclusion of stock from waterways that are less than 1m wide and River Environment Classification (REC) Order 1 (now M3.2) ahead of the installation of lined effluent storage and the installation of low rate effluent application spreaders (now M3.3).

2.4.3 Revising the N fertiliser mitigations (Drystock M2.1 and M3.3)

Preliminary modelling of the farm systems required a re-think of these mitigation protocols. In the end, the reality was that while the analysis suggested that reducing numbers of capital (breeding) livestock in response to reductions in N fertiliser was likely to be profitable, this crude analysis overlooks the reality that breeding systems tend to have feed demand curves that best match feed supply. As a result, the reduced ability to harvest "free" spring and summer pasture with the demand derived from lactating ewes and cows can have a great impact on the farm system than might initially be suspected. Autumn N tended to support livestock numbers used to take advantage of spring surplus, while spring N tends to be used tactically to overcome early spring feed deficits and allow faster weight gain in growing livestock (but also potentially inadvertently "feed" surpluses).

As a result, it was decided to redefine M2.1 to "Elimination of N fertiliser applications used to accelerate liveweight gain" and M3.3 to "Elimination of N fertiliser used to support capital livestock".

2.4.4 Incorporating the reticulation of stock water in place of surface water bodies (Drystock M2.5) within the various stock exclusion mitigations

The exclusion of livestock from the three levels of surface water bodies in each of the three drystock mitigation bundles would have a commensurate requirement to provide reticulated stock water in paddocks where the relevant water body provided drinking water. The author's experience in the subject WMAs has formed the view that that there will be little reliance on natural water course for stock water and as such, no allowance has been made for reticulation costs. Should evidence to the contrary come forward, a cost assumption for this could be easily introduced into the analysis.

2.4.5 Excluding "Reductions in seasonal stocking rate (Drystock M2.5)"

After further reflection on this mitigation (lowering stocking rates during the season through early culling or grazing stock off-farm), it was decided this was moderately impractical to implement and hence model in most of the dry stock systems. This is because most culling actions occur as soon as is practicable on breeding properties and actively "exporting" nutrient loss to other catchments through the contract grazing of lower priority/higher N loss livestock is unlikely to be a sustainable activity given an assumption that the capacity of other catchments to assimilate increased loads of N is likely to be limited. As a result, this mitigation was excluded from the study, which is in line with both the approach increasingly adopted in analyses of this type and feedback from the community groups.

2.4.6 Excluding "Reducing stocking rate (Drystock M3.4)"

Given the assumption made within the models that farm management couldn't be "improved" to generate operational efficiencies, reducing stocking rate in drystock systems essentially requires a commensurate reduction in the pastoral area to ensure the farm system stays economically viable. This due to other management options to lower feed supply (i.e. reducing N fertiliser, reduce imported feed) having already been applied. As this is therefore essentially a land use change option and it was the last sequential mitigation to be applied, it was decided to exclude it from the bundle.

2.4.7 Excluding "Strip tillage (Arable M2.4)"

There is limited data in a New Zealand context of the impact strip tillage will have on both the cost of cropping and the impact on reduced contaminants to water. OVERSEER currently has no further options beyond "minimum tillage" for its cropping model, so no further reductions in N loss to water will be generated in that model. As to the cost of strip tillage, there is some anecdotal evidence that such techniques can lower cultivation costs. However, these aren't quantified. As such, the decision to exclude this mitigation was made, but recognising that it, like some other "edge of field" and emerging mitigations are worthy of investigation as they could have great potential to reduce contaminant load to water from agricultural activities.

3 Dairy farm systems

3.1 Methodology

Six dairy farm systems were modelled. The chosen farm variants and their primary parameters were based on the work of Green et al (2017), which had utilised input from BOPRC land management personnel and DairyNZ staff. The adjustments in farm variants and their parameters were made after consultation with community stakeholders and industry representatives.

The farms were all modelled as long-term feasible models in Farmax Dairy Pro software, utilising base pasture production curves (derived from cage cuts) that were subsequently adjusted to better reflect observed regional parameters. Stocking rates were based on regional dairy statistics, again slightly modified based on input from local industry experts. Operating profit (earnings before interest and tax) utilised a $6.00/kg MS milk price, with operating expenses (including an arms' length adjustment for [unpaid] wages of management) based on the latest published DairyNZ Economic Survey data (Dairy NZ 2018) for the Bay of Plenty region. All grazing was assumed to be sourced externally, with all young stock assumed grazed off the farm area from weaning until returning as in-calf heifers. Effluent areas were initially assumed at a minimum of 4 ha per 100 cows and then adjusted to ensure N applied in dairy effluent was less than 150kg N/ha/year. Maintenance fertiliser and nitrogen expenditure was based on modelled requirements. The key parameters of the six farm systems are each described briefly below and then summarised in Table 13. The baseline economic output for the dairy farm systems is presented in Appendix 1. All analysis currently excludes the [financial] impact of Fonterra supplier shares (if any).

The impact of having to account for biological greenhouse gas ("BGHG") emissions has currently been excluded from this analysis. But we note that at a $25/t CO_2 price, the financial impact of having to pay for 10% of BGHGs would reduce EBIT from between $19 to $38/ha/year across the analysed dairy farms. Full offset at $25/t CO_2 price might reduce EBIT by $196 to $386/ha/year, being up to 20% of operating profit.

3.2 Kaituna-Pongakawa-Waitahanui dairy farms

3.2.1 Lower KPW dairy (System 3)

This model is designed to be representative of the higher stocked dairy farms on the coastal flats of the KPW catchment. Comprising of gley and organic soils with open drain systems, this 122 ha farm calves down 390 cows (3.2 cows/ha), peak milking 374 cows (3.1 cows/ha) and producing 1,062 kg MS/ha. No silage is made on farm and 50% of the milking herd are grazed off for six weeks. Palm kernel expeller is fed to cows in early and late lactation. Annual N fertiliser usage averages 173 kg N/ha. A stand-off area (comprised of an inert base) was assumed to be used by all cows on farm for an average of 3 days per month during the winter and early spring to protect soil from pugging. Operating profit is calculated at $1,983/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 50.7 kg N/ha/year and 3.4kg P/ha/year respectively and biological greenhouse gas (BGHG) emissions estimated at 15.4 t CO_2e/ha/year. Table 7 shows the sensitivity of operating profit to milk and urea prices for the Lower KPW dairy model.

Table 7: Sensitivity of operating profit to milk and urea prices for the Lower KPW dairy model

Urea price ($/t)	Milk price ($/kg MS) 4.50	5.00	5.50	6.00	6.50	7.00
500	413	944	1,475	2,006	2,538	3,069
564	390	921	1,452	**1,983**	2,514	3,045
600	376	907	1,438	1,969	2,500	3,031
700	339	870	1,401	1,932	2,463	2,994
800	302	833	1,364	1,895	2,426	2,957

3.2.2 Mid KPW dairy (System 3)

Representative of the farms on higher ground but less than 100m above sea level, the Mid KPW dairy model comprises 122ha of pumice soil, calving down 304 cows to peak milk 290. Milk production is 837kg MS/ha, but all cows are wintered on. With improved drainage, 3ha of maize silage is grown on-farm to help extend lactation in autumn. Palm kernel is fed to cows in both shoulders of the season and 19.2ha of grass silage is cut in late December and subsequently fed to dry cows over winter. N fertiliser use applied to pasture averages 131kg N/ha/year. Operating profit is calculated at $1,413/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 53.8kg N/ha/year and 1.4 kg P/ha/year respectively and biological greenhouse gas (BGHG) emissions estimated at 8.1 t $CO2_e$/ha/year. Table 8 shows the sensitivity of operating profit to milk and urea prices for the Mid KPW dairy model.

Table 8: Sensitivity of operating profit to milk and urea prices for the Mid KPW dairy model

Urea price ($/t)	Milk price ($/kg MS) 4.50	5.00	5.50	6.00	6.50	7.00
500	175	594	1,013	1,431	1,850	2,268
564	157	576	994	**1,413**	1,831	2,250
600	147	566	984	1,403	1,821	2,240
700	118	537	956	1,374	1,793	2,211
800	90	509	927	1,346	1,764	2,183

3.2.3 Upper KPW dairy (System 3)

The 122ha Upper KPW model is similar to the mid KPW model, but the farm system reflects lower pasture growth potential, both from the increased altitude but also from the steeper contour. A summer chicory crop is utilised to buffer poorer summer growth rates and lower pasture quality and palm kernel expeller is used to feed milkers in the shoulders of the season. Lower winter pasture growth rates are buffered with 50% of dry cows grazed off for six weeks. N fertiliser use averages 123kg N/ha/year. Milk production is 805kg MS/ha. Operating profit is calculated at $1,115/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 68.1 kg N/ha/year and 4.0 kg P/ha/year respectively and BGHG emissions estimated at 7.9 t CO_2e/ha/year. Table 9 shows the sensitivity of operating profit to milk and urea prices for the Upper KPW dairy model.

Table 9: Sensitivity of operating profit to milk and urea prices for the Upper KPW dairy model

	Milk price ($/kg MS)					
Urea price ($/t)	4.50	5.00	5.50	6.00	6.50	7.00
500	- 76	326	729	1,131	1,534	1,936
564	- 93	310	712	**1,115**	1,517	1,920
600	- 102	300	703	1,105	1,508	1,910
700	- 128	274	677	1,079	1,482	1,884
800	- 154	248	651	1,053	1,456	1,858

3.3 Rangitāiki dairy farms

3.3.1 Lower Rangitāiki dairy (System 2)

The 117ha Rangitāiki dairy model is designed to be representative of the non-irrigated dairy farms in the lower Rangitāiki plains, with 30% of the farm area comprising gley soils. High pasture growth potentially results in average production of 1,035 kg MS/ha from 330 cows calved down. Only small amount of maize silage needs to be imported into the farm system in autumn to extend lactation and all cows are wintered on. N fertiliser use is 120 kg N/ha, with surplus pasture harvested in February that is subsequently fed to dry cows over winter. Operating profit is calculated at $2,582/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 67.4 kg N/ha/year and 1.2 kg P/ha/year respectively and biological greenhouse gas (GHG) emission estimated at 9.9 t CO_2e/ha/year. Table 10 shows the sensitivity of operating profit to milk and urea prices for the Lower Rangitāiki irrigated dairy model.

Table 10: Sensitivity of operating profit to milk and urea prices for the Lower Rangitāiki irrigated dairy model

	Milk price ($/kg MS)					
Urea price ($/t)	4.50	5.00	5.50	6.00	6.50	7.00
500	1,046	1,564	2,081	2,599	3,116	3,634
564	1,030	1,547	2,065	**2,582**	3,100	3,617
600	1,020	1,538	2,055	2,573	3,090	3,608
700	994	1,512	2,029	2,547	3,064	3,582
800	968	1,486	2,003	2,521	3,038	3,556

3.3.2 Mid Rangitāiki dairy (System 2)

Modelled to represent an unirrigated dairy farm in the Galatea valley, this 117ha farm system produces 954kg MS/ha from 315 cows to calve down. The low winter growth rates require 75% of the herd to be grazed off over winter (7 weeks) and calving date is assumed to be later than the other farm models. Summer chicory (5.2ha) and maize crops (3.5ha) are grown on the farm each year, with the maize fed to milkers both in the autumn and again in the spring. Palm kernel expeller (PKE) is used to supplement milkers in early lactation and late summer and a small amount of surplus pasture is harvested as silage to feed dry cows over autumn and winter. A total of 118kg

N/ha is applied to pasture. Operating profit is calculated at $1,689/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 53.1 kg N/ha/year and 0.9 kg P/ha/year respectively and BGHG emissions estimated at 8.6 t CO_2e /ha/year. Table 11 shows the sensitivity of operating profit to milk and urea prices for the Mid Rangitāiki dairy model.

Table 11: Sensitivity of operating profit to milk and urea prices for the Mid Rangitāiki dairy model

		Milk price ($/kg MS)					
		4.50	5.00	5.50	6.00	6.50	7.00
Urea price ($/t)	500	274	751	1,228	1,705	2,182	2,659
	564	257	734	1,211	**1,689**	2,166	2,643
	600	248	725	1,202	1,679	2,156	2,633
	700	223	700	1,177	1,654	2,131	2,608
	800	197	674	1,151	1,628	2,105	2,582

3.3.3 Mid Rangitāiki irrigated dairy (System 2)

Modelled off a partially (50%) irrigated (K line) dairy farm in the Galatea valley, this 117ha farm system produces 1,072 kg MS/ha from 315 cows to calve down. The low winter growth rates require 50% of the herd to be grazed off over winter (7 weeks) and calving date is assumed to be later than the other farm models. Summer chicory (5.2 ha) and maize crops (3.7 ha) are grown on the un-irrigated portion of the farm each year, with the maize fed to milkers both in the autumn and again in the spring. PKE is used to supplement milkers in early lactation and silage harvested off the irrigated portion of the farm fed to dry cows over autumn and winter. A total of 132 kg N/ha is applied to pasture. Operating profit is calculated at $2,121/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 61.7 kg N/ha/year and 1.1 kg P/ha/year respectively and biological greenhouse gas (GHG) emissions estimated at 9.5t CO_2e/ha/year. Table 12 shows the sensitivity of operating profit to milk and urea prices for the Mid Rangitāiki irrigated dairy model.

Table 12: Sensitivity of operating profit to milk and urea prices for the Mid Rangitāiki irrigated dairy model

		Milk price ($/kg MS)					
		4.50	5.00	5.50	6.00	6.50	7.00
Urea price ($/t)	500	531	1,067	1,603	2,139	2,675	3,210
	564	513	1,049	1,585	**2,121**	2,656	3,192
	600	503	1,039	1,575	2,110	2,646	3,182
	700	474	1,010	1,546	2,082	2,618	3,153
	800	446	982	1,518	2,053	2,589	3,125

Table 13: Base parameters for the five dairy farm systems modelled

Model name	Lower KPW	Mid KPW	Upper KPW	Lower Rangitaiki	Mid Rangitaiki	Mid Rangitaiki irrigated
System	3	3	3	2	2	2
Effective area (ha)	122	122	122	117	117	117
No. cows (to calve)	390	304	304	330	315	315
Cows peak milked	374	290	290	316	301	301
Stocking rate (SR; cows ha^{-1})	3.1	2.4	2.4	2.7	2.6	2.6
Comparative stocking rate	85	84.1	87.4	82.6	83.6	84
Pasture yield (t DM ha^{-1})	14.2	11.3	10.4	15.6	12.7	13.4
Pasture consumed (t DM ha^{-1})	11.9	9	8.5	12.1	9.6	10
Imported feed/total feed (%)	16%	13%	14%	3%	8%	7%
Annual milk solids production (kg)	129,569	102,122	98,215	121,102	111,627	125,376
MS (kg cow^{-1})	346	352	339	383	371	417
MS (kg ha^{-1})	1,062	837	805	1,035	954	1,072
MS (as a % of liveweight; LW)	83.6	84.9	80.2	91.7	88	98.3
Feed conversion efficiency (kg DM eaten kg MS $produced^{-1}$)	13	12.8	13.1	12.3	12.5	11.2
Financial indicators						
Operating profit (\$ ha^{-1})	1,983	1,413	1,115	2,582	1,689	2,121
Area receiving effluent (% total)	16%	13%	13%	16%	15%	17%
Area irrigated (% total)	-	-	-	-	-	50%
Fertiliser inputs applied to pasture						
N (kg ha^{-1})	173	131	123	120	118	132
P (kg ha^{-1})	45	37	35	50	44	50
Average soil Olsen P (mg L^{-1})	32	31	30	32	45	45
Stand-off pad in use	Yes	No	No	No	No	No
Environmental losses						
N (kg ha^{-1})	50.7	53.8	68.1	67.4	53.1	61.7
P (kg ha^{-1})	3.4	1.4	4.0	1.2	0.9	1.1
Biological GHG (t CO_2e ha^{-1})	15.4	8.1	8.0	9.8	8.6	9.5

4 Non-dairy pastoral and arable systems

4.1 Methodology

Three sheep & beef farms were modelled in Farmax Pro, two for the KPW WMA and a single model for the Rangitāiki catchment. As noted in Green et al (2017), sheep & beef farming in the Rangitāiki catchment is dominated by Landcorp's Rangitāiki Station, with Lochinver Station and Landcorp's Goudies Station also having land in the Upper Rangitāiki catchment. While it is important to recognise the modelled farm system is unlikely to be representative of the smaller family operations that still occur in the catchment, it is difficult to ignore the specifics of this farm system given the scale of this operation. The partial integration of this property's deer operation with its cattle operation makes the specific modelling of this system to align with the parameters of the APSIM model impossible. As a result a representative Rangitāiki farm system with a low sheep:cattle ratio has been modelled to complement the exclusive Rangitāiki deer system (see below). While only a single KPW S+B model, comprising dairy support, had been proposed, a second farm system model was subsequently developed, comprising a breeding ewe flock and breeding cows, in addition to dairy heifer grazing.

The size of the modelled farms was informed by the annual Beef + Lamb New Zealand Economic Service Sheep & Beef Farm Survey (Beef & Lamb NZ 2018), with general parameters for the Class 3, 4 and 5 survey farms providing base physical and economic parameters for the Rangitāiki S+B (Class 3), KPW S+B and Rangitāiki D (Class 4) and KPW DS (Class 5) models respectively. Maintenance fertiliser and nitrogen expenditure were based on modelled requirements.

Operating profit was defined as earnings before interest and tax and included an adjustment for the market value of all labour (paid and unpaid) in the farm system, based off the FTE parameters in the B+L NZ survey. Income was assessed using base schedule relationships in Farmax Pro, with the sheep schedule set at \$5.50 (per kg carcass weight), prime bull \$5.50, prime steer \$5.55 and venison at \$8.00. Wool was set at a base price of \$3.40/kg greasy and velvet at \$100/kg. Grazing rates per head per week were set at \$6.50 for calves, \$9.00 for yearlings and \$25 for cows.

As with the dairy farm models, the impact of having to account for BGHG emissions has currently been excluded from this analysis. However, we note that at a \$25/t CO_2 price, the financial impact of having to pay for 10% of BGHGs would reduce EBIT from between \$9 to \$11/ha/year. However, full offset at \$25/t CO_2 might reduce EBIT by as much as 80% of assessed operating profit, depending on the farm system.

4.2 Sheep & beef farms

4.2.1 KPW Dairy Support (DS)

This 234ha property has an average slope of 12.6 degrees, comprising 22 ha of flats, 155 ha of rolling land, 52 ha of easy country and 5 ha of steep land. It's assumed this farm operation grazes 445 dairy heifer replacements from 4 months of age through to 21 months of age and winters 334 cows on pasture and silage for 8 weeks. N use is limited to 30 kg N/ha to 120 ha in the autumn to build up covers ahead of the grazing dairy cows arriving in late May.

Operating profit was estimated at $421/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 28.2 kg N/ha/year and 2 kg P/ha/year respectively and BGHG emissions estimated at 4.4t CO_2e/ha/year.

Table 14: Sensitivity of operating profit to grazing and urea prices for the KPW dairy support model

	Yearling heifer grazing price ($/head/week)					
Urea price ($/t)	8.00	8.50	9.00	9.50	10.00	10.50
500	216	319	423	527	629	733
564	214	317	**421**	525	627	731
600	213	315	420	524	626	730
700	210	312	416	520	623	727
800	207	309	413	517	620	724

4.2.2 KPW Sheep + Beef (S+ B)

This is a 324ha farm, with a similar area of flats, but a greater proportion of steeper land (16.4 degrees) to the KPW dairy support model below. The farm runs a flock of 1,250 MA ewes and 540 ewe hogget replacements. Lambing at 128%, all non-replacement lambs are finished before the start of winter at an average carcass weight of 17.3 kg, including 700 trade lambs purchased in December. The cattle policy comprises 50 Hereford x Friesian breeding cows, mated to a terminal sire and with all progeny sold store at weaning. Replacement in-calf cows are bought in the autumn. In addition to the breeding cows, 300 dairy heifer replacements are contract grazed from 4 months of age to 21 months of age. N fertiliser is applied at 30kg N/ha to the 94a of flats and rolling country in the autumn.

Table 15: Sensitivity of operating profit to lamb and beef prices for the KPW S+B model

	Lamb price ($/kg cwt)					
Beef price ($/kg cwt)	4.50	5.00	5.50	6.00	6.50	7.00
4.50	-131	-82	-32	18	68	118
5.00	-53	-3	47	96	146	196
5.55	33	83	**133**	183	233	282
6.00	104	154	203	253	303	353
6.50	182	232	282	332	382	431

Operating profit was estimated at $133/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 25.1kg N/ha/year and 2.7kg P/ha/year respectively and biological greenhouse gas (BGHG) emissions estimated at 4.3t CO_2e/ha/year.

4.2.3 Rangitāiki Sheep + Beef (S+B)

The Rangitāiki sheep & beef model is a 584 ha farm system, with a low (35%) sheep component and a diverse cattle policy; an Angus breeding cow herd (all male progeny finished, non-replacement heifers sold store at weaning), additional yearling steers purchased and finished, a bull beef operation and a dairy heifer grazing operation. The breeding ewe flock lambs at 135%, with all non-replacement lambs finished to a carcass weight of 17.2kg by May each year. The bulls are purchased as 100kg weaner calve each spring and all taken through two winters and slaughtered in late spring/early summer at 308kg carcass weight. Steers are killed at an average carcass weight of 320kg. Winter crops (4% of the farm area) are sown each year and 92 ha of surplus pasture is harvested in early summer for winter feed and a further 84 ha is sold as standing silage. Over 80% of the farm receives an N application of 30 kg N/ha; 40% in the spring and 60% in the autumn.

Table 16: Sensitivity of operating profit to lamb and beef prices for the Rangitāiki S+B model

Beef price ($/kg cwt)	Lamb price ($/kg cwt) 4.50	5.00	5.50	6.00	6.50	7.00
4.50	-22	7	36	65	94	124
5.00	65	94	123	152	182	211
5.55	161	190	**219**	248	277	307
6.00	239	268	297	327	356	385
6.50	326	355	385	414	443	472

Operating profit is estimated at $219/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 36.1kg N/ha/year and 1kg P/ha/ year respectively and BGHG emissions estimated at 3.8t CO_2e/ha/year.

4.3 Deer farm

4.3.1 Rangitāiki Deer (D)

The modelled deer farm is a breeding-finishing system modelled off that of Rangitāiki Station. At an assumed size of 324ha, the farm system winters 874 Ma and R2 hinds, fawning at 90% and 75% respectively. All non-replacement progeny is finished before their second winter, with the stags and hinds finished to 55kg and 54kg carcass weight respectively. As with the Rangitāiki sheep & beef model, 4% of the farm area is sown into winter crop and the 50% of the farm area gets an application of N fertiliser in the spring, with the other 50% receiving an autumn application. Approximately 500 trade lambs (28kg liveweight) are purchased in each year and sold in Jan/Feb. Surplus pasture (48ha) is conserved for use in the winter and a further 40ha of standing silage sold to third parties.

Table 17: Sensitivity of operating profit to venison and urea prices for the Rangitāiki Deer model

Urea price ($/t)	Venison price ($/kg cwt) 7.00	7.50	8.00	8.50	8.00	9.50
500	93	164	234	305	234	446
564	88	158	**229**	299	229	440
600	85	155	226	296	226	437
700	76	147	217	288	217	429
800	68	138	209	279	209	420

Operating profit was estimated at $229/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 61.7kg N/ha/year and 1.1kg P/ha/year respectively and biological greenhouse gas (GHG) emissions estimated at 9.5t CO_2e/ha/ ear.

4.4 Arable farm

4.4.1 KPW Arable

A single variant arable model was developed, based around a 40ha maize silage production system (yielding 20 tDM/ha sold for $0.26/kg DM harvested [excl. freight]), with the maize followed by an annual ryegrass crop that is able to support 300 dairy cows contract grazed for eight weeks and then used to produce 300 wrapped bales of silage before being re-sown into maize again. Total N fertiliser applied is 290kg N/ha, but despite this amount of N, we note that the OVERSEER nutrient budget still indicates a loss of N from the organic/plant pool of 242kg N/ha, which suggests these applications will be insufficient to maintain productivity in the long term.

Table 18: Sensitivity of operating profit to maize silage and urea prices for KPW Arable model

Urea price ($/t)	Maize silage price ($/t DM) 200	220	240	260	280	300
500	1,186	1,586	1,986	2,386	2,786	3,186
564	1,145	1,545	1,945	**2,345**	2,745	3,145
600	1,123	1,523	1,923	2,323	2,723	3,123
700	1,060	1,460	1,860	2,260	2,660	3,060
800	997	1,397	1,797	2,197	2,597	2,997

Operating profit was estimated at $2,345/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 62.7kg N/ha/year and 2.4kg P/ha/year respectively and biological greenhouse gas (GHG) emissions estimated at 3.1t CO_2e/ha/year.

Table 19: Base parameters for the five dry stock and arable farm systems modelled

Model	KPW DS	KPW S+B	Rangitaiki S+B	Rangitaiki D	KPW A
Effective area (ha)	234	324	584	324	40
Stocking rate (RSU ha^{-1})	12.8	12.9	11	10.5	6.7
Pasture yield (t DM ha^{-1})	9.4	8.8	7.69	7.7	9
Pasture consumed (t DM ha^{-1})	7.05	7.12	6.03	5.76	3.7
Number of livestock carried through winter (1 July)					
Breeding ewes	-	1,250	1,454	-	-
Total sheep	-	1,826	1,786	-	-
Breeding cows	-	50	67	-	-
Dairy heifers	445	300	276	-	-
Dairy cows	334			-	300
Total cattle	779	352	693		-
Hinds	-	-	-	874	-
Total deer	-	-	-	1,681	-
Animal production					
Meat (kg net carcass weight ha^{-1})	336	239	233	152	86
Wool and velvet (kg net wool /velvet ha^{-1})	-	38	22	0	-
Total (kg net product ha^{-1})	336	277	255	152	86
Feed conversion efficiency (kg DM eaten kg $product^{-1}$)	21	26	24	38	43
Animal reproduction					
Ewe efficiency index (%)	-	55%	55.7%	-	-
Cow efficiency index (%)	-	39.5%	39%	-	-
Hind efficiency index (%)	-	-	-	41%	-
Financial indicators					
Operating profit ($ ha^{-1})	421	133	219	229	2,345
Fertiliser inputs applied to farm area					
N (kg ha^{-1})	15	9	27	32	290
P (kg ha^{-1})	22	22	19	18	12
Soil Olsen P (mg L^{-1})	17	17	17	17	
Environmental losses					
N (kg ha^{-1})	28.2	25.1	36.1	25.2	62.7
P (kg ha^{-1})	2.0	2.7	1.0	1.2	2.4
Biological GHG (t CO_2e ha^{-1})	4.4	4.3	3.8	3.9	3.1

5 Kiwifruit

Two status quo kiwifruit models have been completed to date – a green (Haywards) and a gold (G3) model. Both are based on standard planting densities with 3.6m x 6m bays.

Operating profit was again defined as earnings before interest and tax and assumed arms' length/contract orchard management. The breakdown in operating costs were based off data from NZ Kiwifruit Growers Inc. (pers. comm) and adjusted based on recent ANZ data. Harvesting costs were separated out from the operating expenses and depreciation was calculated on the assumed orchard infrastructure and machinery investment over 20 years. The opportunity cost of any proprietary licence for G3 has been excluded from the EBIT estimates. Yields (as per the below) and a tray price of $5.50/tray for green and $9/tray for gold were used to calculate the orchard gate returns. Full breakdown is provided in Appendix 4 below.

Deurer et al (2011) note that 30% of BOP orchards are irrigated. To account for this in the model, we have assumed a typical irrigation practice of 20mm of irrigation water being applied every time the water stored in the top 2m of soil is less than just 75% of plant available water (PAW)(300mm applied between November and February) and then applying only 30% of this quantum. We recognise that where irrigation is used for frost protection such activity to mitigate late frosts occurring after nitrogenous fertiliser applications have commenced might result in drainage losses of N to water. However, this wasn't modelled, with the occurrence of this issue considered low.

We recognise that the status quo water and nutrient requirements of developing orchards will likely be different to those assumed, just as will the economic outputs and contaminant losses. However, considering the transition impact of land use change (say from converting dairy farms to kiwi fruit) was outside the scope of this work.

5.1 Green

The green kiwi fruit model is based on a Haywards orchard managed to 25 winter buds/m^2 and 55 flower buds/m^2. Yields are assumed to be 10,500 trays/ha on the basis of 43 class 1 fruit/m^2. A total of 110kg/ha of N fertiliser is applied in two applications of CAN (250kg/ha in Sep, 150kg/ha in Nov). Operating profit was estimated at $19,500/ha. N and P losses to water were assessed in OVERSEER 6.3.0 at 19kg N/ha/year and 0.5kg P/ha/year respectively and biological greenhouse gas (GHG) emissions estimated at 0.52t CO_2e/ha/year.

Table 20: Sensitivity of operating profit to OGR and yield for Green kiwifruit model

Yield (trays/ha)	OGR green kiwifruit ($/tray) 4.50	5.00	5.50	6.00	6.50	7.00
9,500	1,875	7,938	14,000	20,063	26,125	32,188
10,000	4,125	10,438	16,750	23,063	29,375	35,688
10,500	6,375	12,938	19,500	26,063	32,625	39,188
11,000	8,625	15,438	22,250	29,063	35,875	42,688
11,500	10,875	17,938	25,000	32,063	39,125	46,188

Table 21: Sensitivity of operating profit to OGR and labour costs for Green kiwifruit model

Labour costs ($/hour)	OGR green kiwifruit ($/tray) 4.50	5.00	5.50	6.00	6.50	7.00
17.5	9,845	16,407	22,970	29,532	36,095	42,657
20.0	8,110	14,673	21,235	27,798	34,360	40,923
22.5	6,375	12,938	19,500	26,063	32,625	39,188
25.0	4,640	11,203	17,765	24,328	30,890	37,453
27.5	2,906	9,468	16,031	22,593	29,156	35,718

5.2 Gold

The gold kiwi fruit model is based on a G3 orchard managed to 35 winter buds/m^2 and 70 flower buds/m^2. Yields are assumed to be 14,000 trays/ha on the basis of 70 class 1 fruit/m^2. A total of 120kg N/ha of N fertiliser is applied in two applications of CAN (300kg/ha in Sep, 150kg/ha in Oct). Operating profit was estimated at $78,400/ha (Table 22) and with labour costs of $22.5/hour (Table 21). N and P losses to water were assessed in OVERSEER 6.3.0 at 23kg N/ha/year and 0.5kg P/ha/year respectively and biological greenhouse gas (GHG) emissions estimated at 0.62t CO_2e/ha/year.

Table 22: Sensitivity of operating profit to OGR and yield for Gold kiwifruit model

Yield (trays/ha)	OGR gold kiwifruit ($/tray) 8.00	8.50	9.00	9.50	10.00	10.50
13,000	52,900	61,150	69,400	77,650	85,900	94,150
13,500	56,900	65,400	73,900	82,400	90,900	99,400
14,000	60,900	69,650	78,400	87,150	95,900	104,650
14,500	64,900	73,900	82,900	91,900	100,900	109,900
15,000	68,900	78,150	87,400	96,650	105,900	115,150

Table 23: Sensitivity of operating profit to OGR and labour costs for Gold kiwifruit model

Labour costs ($/hour)	OGR gold kiwifruit ($/tray) 8.00	8.50	9.00	9.50	10.00	10.50
17.5	64,869	73,619	82,369	91,119	99,869	108,619
20.0	62,884	71,634	80,384	89,134	97,884	106,634
22.5	60,900	69,650	78,400	87,150	95,900	104,650
25.0	58,915	67,665	76,415	85,165	93,915	102,665
27.5	56,930	65,680	74,430	83,180	91,930	100,680

6 Forestry

Two forestry models were considered – one a radiata plantation model and the other a mānuka plantation established for honey production. Unlike the farming and orchard models, the lack of annual cashflows for a pine forest make status quo profitability comparisons with the non-pastoral land uses on an annual EBIT basis impossible to achieve. A status quo planted mānuka model can be developed, but similar to an orchard situation, the initial lag in production and potentially a date at which plants will need to be renewed make a long-term investment analysis a better mechanism to compare the relative performance of mānuka as a land use. The models below in Appendix 5 and 6 are provided for completeness, not to allow a direct comparison with orchard or farm returns.

6.1 Pinus radiata

The radiata model is based on a 28-year non-pruned (framing) rotation under contract management. The base model excludes the financial impact of carbon, but 169 tCO_2 permanently sequestered would be available to sell on a one-off basis at year 10 (based on ETS sequestration profiles), assuming the forest was going to be replanted after harvest at year 28. Net stumpage at $43,490/ha and an establishment cost of $1,500/ha delivers an NPV of $6,827/ha (excluding land costs) at a discount rate of 5%. This would be equivalent to an annuity payment of $530/ha/year at the same discount rate over the same time frame.

The inclusion of the value of the sale of permanently sequestered carbon in the modelling increases the NPV of this model to $9,420/ha (excluding land costs); taking the equivalent annuity payment up to $630/ha/year.

The OVERSEER model estimates N losses to water at 2.5kg N/ha/year from exotic plantation forest and P losses at 0.1kg P/ha/year. These estimated nutrient losses are the average annual losses over the course of rotation.

6.2 Mānuka

The mānuka model is based on establishing mānuka trees at a cost of $2,000/ha and then a ground rent receivable for hives ($100/hive/year at a hive density of 1.5 hives/ha) plus a 10% share of any honey profits payable at the end of the season. Annual operating profit (EBIT) for the established stand is estimated at $130/ha, but this potentially being a ($20)/ha loss in a year where poor flowering result in negligible honey yields.

Mānuka will sequester carbon, but as a supposed permanent crop, the impact of the sale of this carbon within the ETS reporting periods after establishment are one-off permanent sales and impossible to capture in an annual operating profitability estimate. The quantum of the CO_2 sequestered by a managed mānuka stand will depend on the extent of biomass the stand will be permitted to accumulate.

The OVERSEER model estimates N losses to water at 3kg N/ha/year from native forest and P losses at 0.1kg P/ha/year.

7 Results and discussion of mitigation modelling

Key findings from the analysis of the farming systems are presented below.

7.1 Dairy farm systems

7.1.1 Summary of bundle implementation

On average, across the six representative dairy farm systems analysed, implementation of M1 lowered profitability by $64/ha, M2 by $65/ha and M3 by $448/ha. While the financial impact of implementing M3 was significant across all of the six models, the “cost” of M1 and M2 was variable. M1 actually had a higher cost than M2 for three of the farm systems, while for the other three M1 effectively had no impact on farm profitability.

Table 24: Change in annual dairy farm gate profitability ($/ha) from the implementation of mitigation bundles

	Lower KPW	Mid KPW	Upper KPW	Lower Rang	Mid Rang	Irrigated Rang	Average
M1	-13	-85	-182	-92	-10	-3	-64
M2	-118	-41	-11	-28	-100	-92	-65
M3	-346	-444	-393	-504	-454	-537	-446
Total	-476	-570	-587	-624	-564	-632	-576

The financial impact of implementing M1 tended to be heavily influenced by one main factor - the capacity of the farm to generate savings in fertiliser inputs as a result of proper nutrient budgeting and mining excessive soil P reserves;

All the farm models assumed baseline fertiliser applications determined by the historical “rules of thumb”[3] that discussion with local farmers and practitioners and the author’s own observations of this practice in the field suggest are still in common use. This is as opposed to nutrient requirements being formally assessed using a nutrient budget to balance for production and nutrient coming in from other sources (i.e. feed) and for soil type [which would be best practice]. Our professional experience and anecdotal observations would suggest that (i) the quality of soil testing is often variable (due to poor technique), (ii) it hasn’t been historical practice to make recommendations based on nutrient budgets, (iii) many farms still have soil P levels well above those required to optimise pasture production and (iv) P fertiliser applications regularly exceed those needed to maintain soil test levels. While we are not aware of any independent data to support an assertion that such mismatched fertiliser applications would be observed across all farms, we feel this assumption to be appropriate for use in this analysis, given our common observance of this and that it does serve to both (a) highlight the potential financial benefit of accurate nutrient budgeting and (b) the influence it could have on the “cost” of the M1 bundle.

[3] Like those presented in Morton & Roberts (1993)

Table 25: Relative changes in annual dairy farm gate profitability and water and atmospheric contaminants as measured in OVERSEER 6.3.0 from the implementation of mitigation

Lower KPW				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-1%	-26%	-17%	-9%
M2	-7%	-39%	-20%	-11%
M3	-24%	-54%	-25%	-23%

Mid KPW				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-6%	-25%	-9%	-4%
M2	-9%	-26%	-9%	-5%
M3	-41%	-41%	-15%	-17%

Upper KPW				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-16%	-18%	-16%	-4%
M2	-17%	-19%	-19%	-5%
M3	-53%	-38%	-23%	-17%

Lower Rang				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-4%	-27%	-12%	-5%
M2	-5%	-28%	-12%	-5%
M3	-25%	-46%	-16%	-15%

Mid Rang				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-1%	-24%	-17%	-4%
M2	-7%	-26%	-19%	-5%
M3	-35%	-43%	-25%	-15%

Irrigated Rang				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	0%	-21%	-13%	-4%
M2	-4%	-22%	-14%	-5%
M3	-31%	-44%	-21%	-15%

Average				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-5%	-23%	-14%	-5%
M2	-8%	-26%	-15%	-6%
M3	-35%	-44%	-21%	-17%

The aggregation of mitigations into bundles would probably also be enhanced by moving the substitution of autumn N fertiliser with imported feed into M2.

In general, reductions in N losses were achieved by M1 and M3, P loss reduction largely by M1 and BGHG emissions by M3. On average, full adoption of the mitigation bundles on the dairy farm systems modelled reduced N losses by 44%, P losses by 21% and BGHG losses by 17% - all for a reduction in profitability by 35%.

7.1.2 General observations

In general:

- The adoption of "proof of placement" fertiliser application technology on farm to reduce the coefficient of variance (CV) of spread and replacement of an early spring application of N fertiliser through the use of gibberellic acid in the preceding N application tended to be cost neutral result in reducing the nitrate leaching;
- The adoption of low solubility P fertiliser resulted in the single largest drop in farm P losses as modelled in OVERSEER, with wetland development, riparian buffers and afforestation (all reducing farm area) and reducing stocking rates and P losses;
- The substitution of autumn N fertiliser with imported supplementary feed (i.e. using maize silage to replace the pasture grown with fertiliser N) lowered losses, but always resulted in a reduction in profitability, such that it probably warrants inclusion of M2;
- All investment in stand-off and effluent infrastructure resulted in significant reductions in profitability when system intensity was held constant, but increasing/expanding the use of existing infrastructure (with a sunk cost) improved environmental performance for little negative financial cost;
- The exclusion of livestock from first-order (smaller) waterways generally had no negative productive impact (same production for slightly less area was almost always achieved), but could require significant capital investment;
- As modelled, the development of wetlands resulted in improved (reduced) N and P losses, but were expensive and generally required some reduction in stock numbers;
- Other than significant land use change, as modelled in OVERSEER, the adoption of low solubility P fertiliser provided a good mechanism to reduce P loss risk. A reduction in profitability was expected to occur because of the need for an initial capital application of slow-release reactive phosphate rock (RPR) fertiliser to counter the impact of 30% of the P content becoming available in any given year;
- Albeit the last mitigation applied, lowering stocking rate could improve [the already significantly reduced] farm profitability in some of the cases without assuming improvement in farm management capability. This suggests that there may be scope for some farm systems to reduce intensity (stocking rate and associated inputs) and actually experience minimal profitability loss. It is likely this could be achieved at earlier stages of the mitigation sequencing (i.e. optimising stocking rate after other significant mitigations).
- Improving the efficiency of irrigation, improved environmental performance (largely through a reduction in drainage) but the impact on profitability depended on the relative capital outlay;

- The impact of the bundles on BGHG emissions profiles of farms tended to correlate directly with reductions in N fertiliser usage (which lowered estimated N_2O emissions) and stock numbers (which lowers methane emissions). Introducing a stand-off pad (as modelled) typically increased emissions of both CH_4 and N_20, as result of the assumption of a carbon base (woodchip) for the stand-off area;
- The net capital cost (including capital released from livestock reductions) of implementing all three bundles averaged $369,000 for the unirrigated farms and $636,000 for the irrigated farm system. The opportunity cost of such capital (a discount rate of 5% was used) was accounted for in the change in profitability (as was any increase in depreciation associated with infrastructure).

7.1.3 Sensitivity analysis of bundle cost

The cost of implementing all the bundles was considered against a number of variables that might be expected to have some impact. Bundle cost was sensitised against the cost of a key input (N fertiliser), the prices for a key output (milk price), the cost of carbon and the extent to which farming might have to account for its biological emissions and the impact of council co-investment in the cost of fencing and planting riparian buffers and detention bund activities. The results are presented in Table 26 through Table 28.

Table 26: Cumulative average cost ($/ha) of implementing M1 - M3 with changes in milk and urea price

Urea price ($/t)	Milk price ($/kg MS) →	4.5	5	5.5	6	6.5	7
	500	-404	-465	-526	-588	-649	-710
	564	-392	-453	-514	**-576**	-637	-698
	600	-385	-446	-508	-569	-630	-691
	700	-366	-428	-489	-550	-611	-673
	800	-348	-409	-470	-531	-593	-654

Table 27: Cumulative average cost ($/ha) of implementing M1 - M3 with changes in carbon price and ETS accountability

Carbon price ($/t CO^{2}e)	% CO_2e emissions needing to be paid for →	0%	10%	20%	30%	40%	50%
	10	-576	-574	-572	-570	-569	-567
	21	**-576**	-572	-568	-565	-561	-557
	30	-576	-570	-565	-560	-555	-550
	40	-576	-569	-562	-555	-548	-541
	50	-576	-567	-558	-550	-541	-533

Table 28: Cumulative average cost ($/ha) of implementing M1 - M3 with changes in council funding

% funding for detention bunds	% funding for fencing and planting activities 0%	25%	50%	60%	70%	75%
0%	-584	**-576**	-567	-564	-560	-559
25%	-583	-574	-566	-563	-559	-557
50%	-582	-573	-565	-562	-558	-556
75%	-581	-572	-564	-560	-557	-555
100%	-580	-571	-563	-559	-556	-554

The following observations were made:

- As the price of product (i.e. milk) increased, the cost of bundle implementation increased. This is unsurprising as the quantity of farm output (kg MS) decreased as the mitigations were sequentially applied and the opportunity cost of lost production becomes greater as the price increased;
- As the price of an input (N fertiliser) increased, the cost of mitigation reduced. For an input like N fertiliser, which is heavily linked to one of the contaminants targeted by the mitigation bundles, lowering its use saves the farm system more at higher prices;
- As carbon price increased and the extent to which agriculture had to account for its emissions increased, the cost of the bundle implementation reduced, but not substantially. As modelled, the water quality mitigation bundles delivered a reduction in BGHG emissions to the six dairy farm systems between 15% and 23%, so this limited impact wasn't surprising. However, the impact was greater where the underlying BGHG footprint of the farm was higher and the mitigations had greater impact on lowering emissions. For example, assuming dairying had to account for 50% of their BGHG emissions, for the Lower KPW dairy farm (15 t CO_2e/ha/year) as carbon price increased to $50/t, the cost of bundle implementation reduced by 15% compared to the Upper KPW dairy farm (8 t CO_2e/ha/year), where costs only lowered by 5%;
- The impact of council co-investment [subsidy] for [the chosen] environmental works was quite low for the dairy farms modelled. Lifting the proportion of council funding for riparian fencing and planting from the assumed 25% level to 75% only reduced the average cost of bundle implementation by 3%. This reflects the generally limited scope of the riparian works needing to be implemented and the lower cost of the fencing needed to exclude dairy cattle from riparian areas compared with sheep, cattle and deer systems (see 7.2.3 below). Similarly, increased council funding for detention bund works had limited impact on cost (in the order of 1% reduction in bundle cost), again due to the limited component of the bundle that such works comprise.

The individual abatement curves for the six farm systems are presented below in Figure 1-Figure 12. On a nominal output basis, the change in profitability is charted on the left vertical axis and the change in environmental outputs is charted on the right vertical axis. The relative changes in outputs are graphed on a percentage basis against each other.

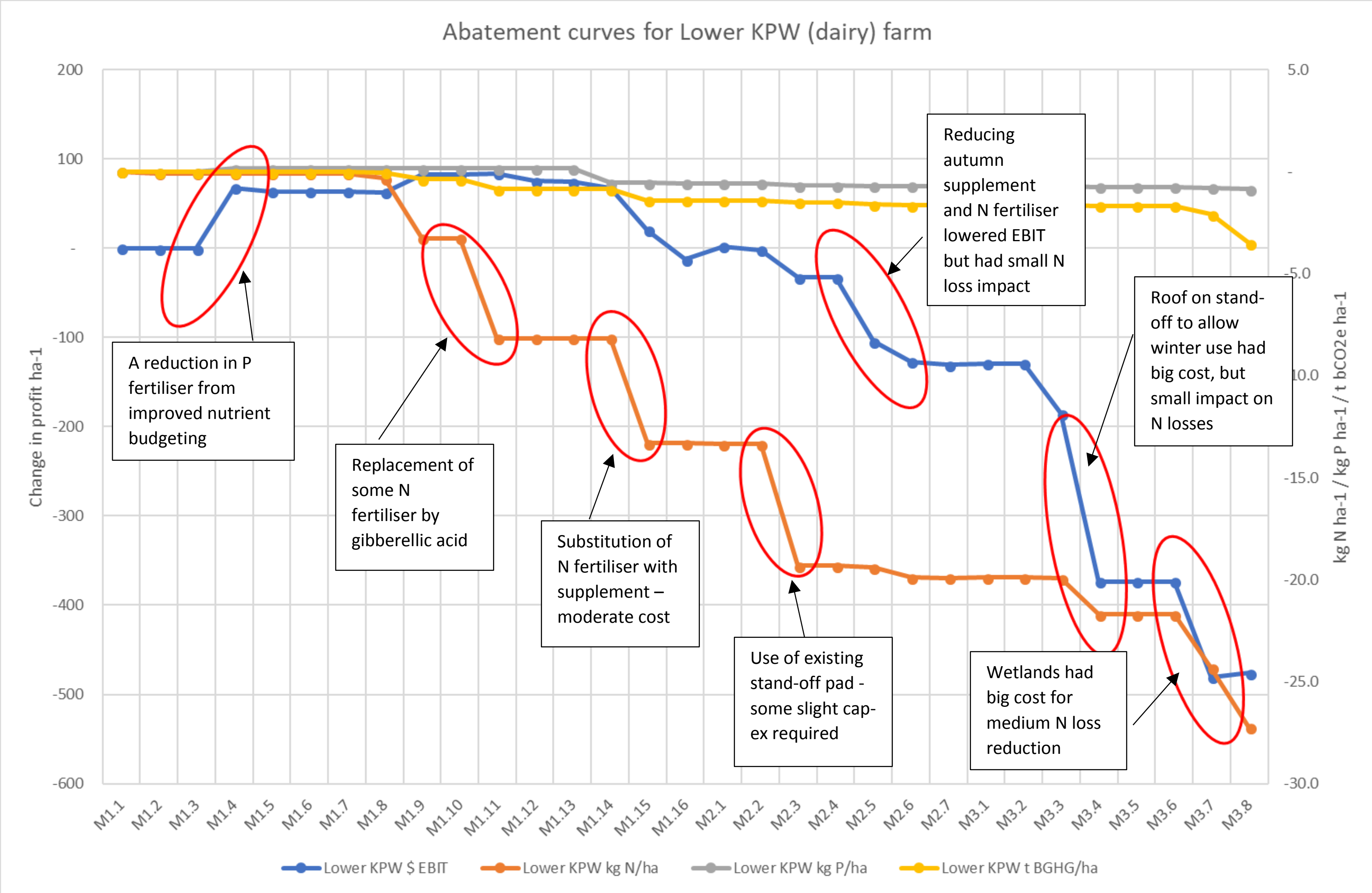

Figure 1: Sequential abatement curves for change in profit (LHS) and change in contaminant output (RHS) for the Lower KPW dairy farm system

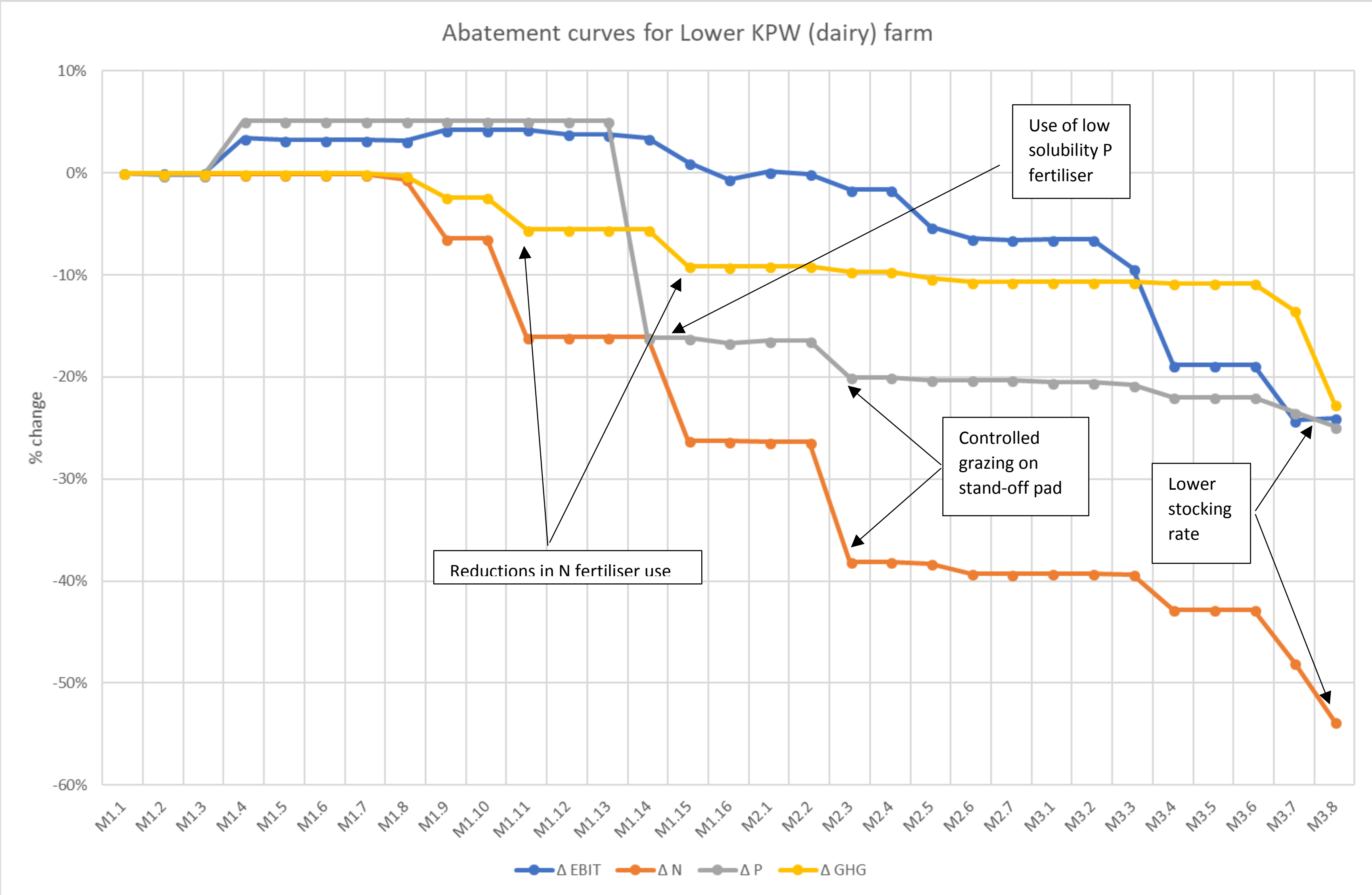

Figure 2: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Lower KPW dairy farm system

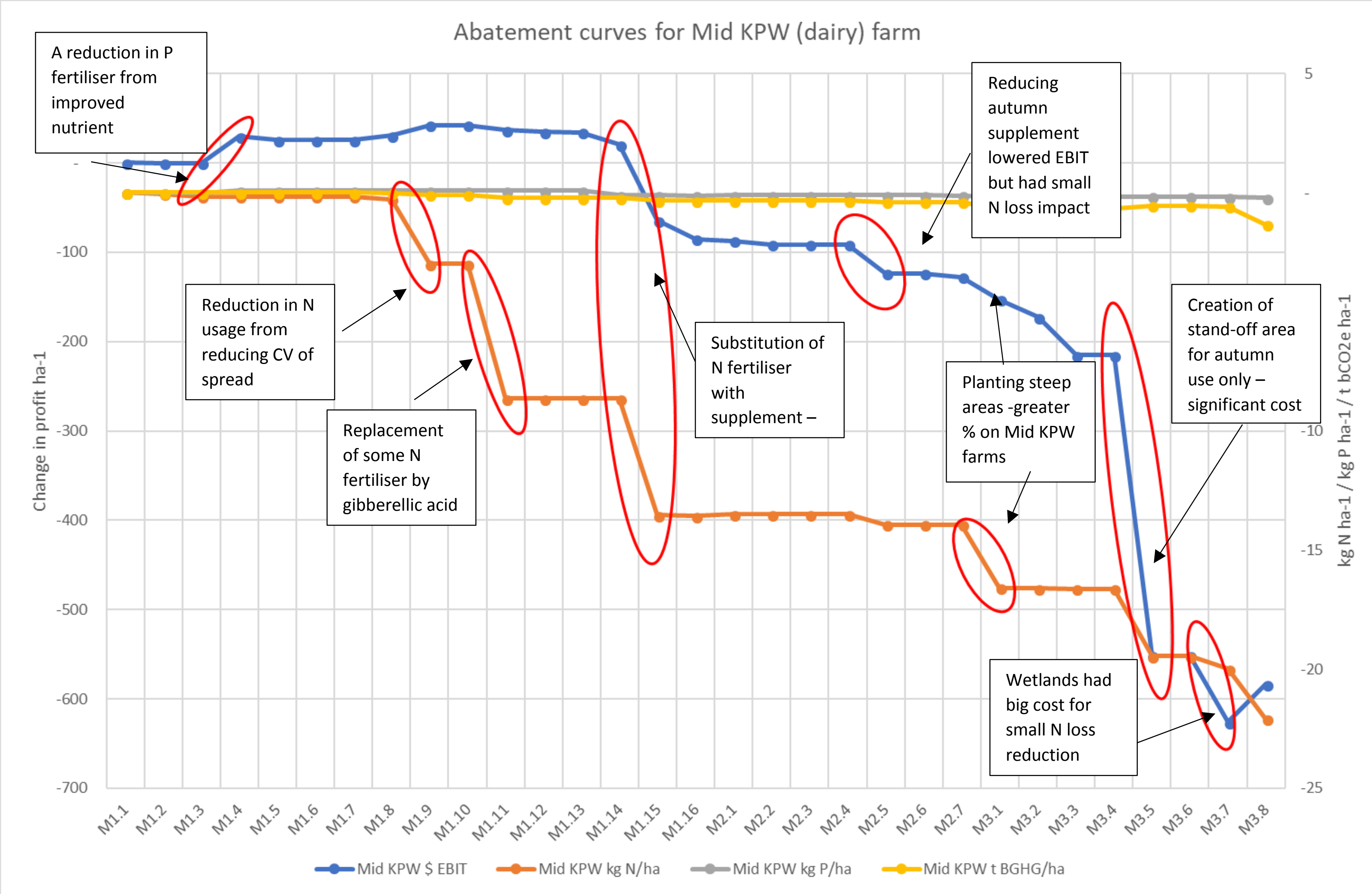

Figure 3: Sequential abatement curves for change in profit (LHS) and change in contaminant output (RHS) for the Mid KPW dairy farm system

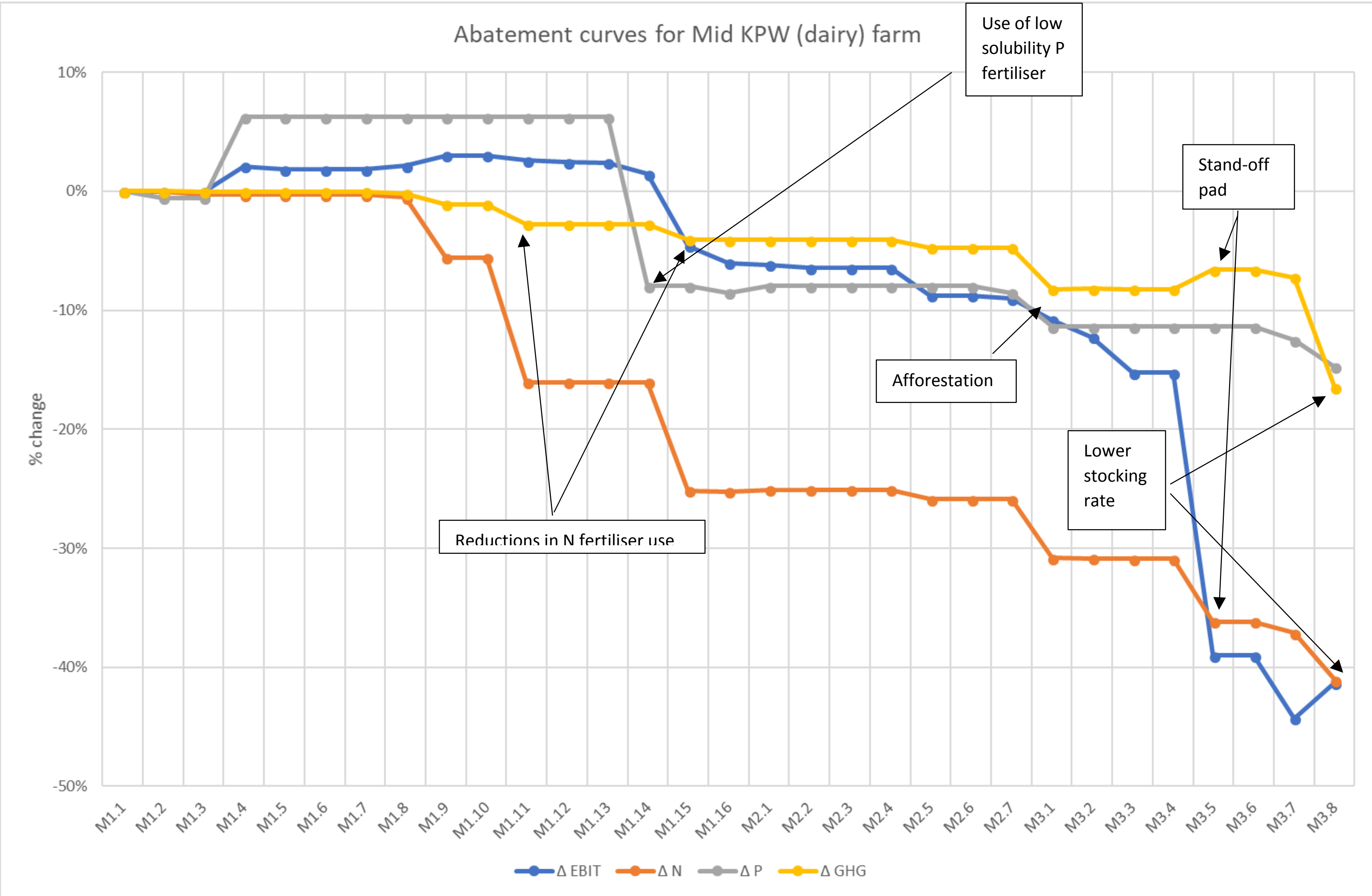

Figure 4: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Mid KPW dairy farm system

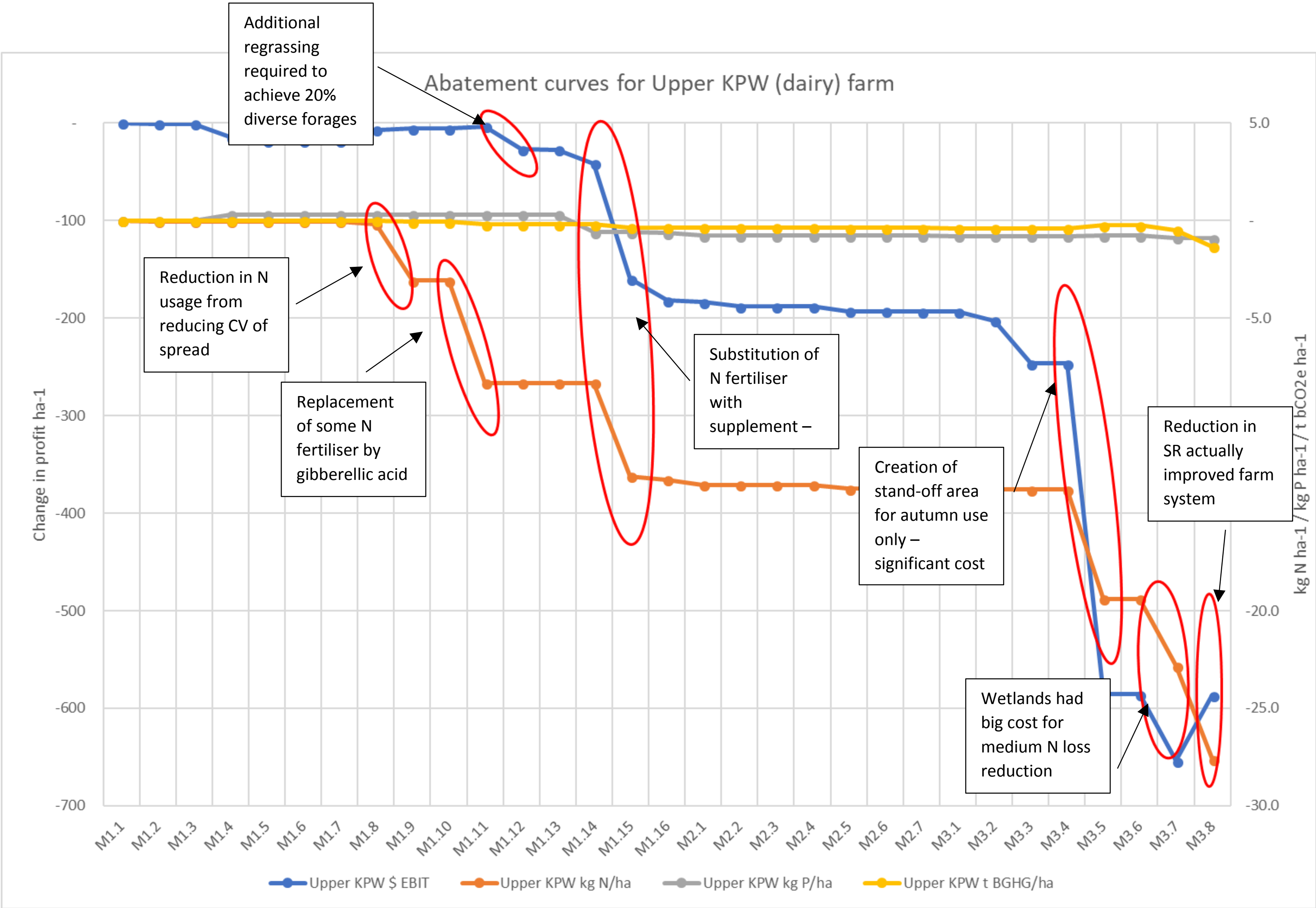

Figure 5: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the Upper KPW dairy farm system

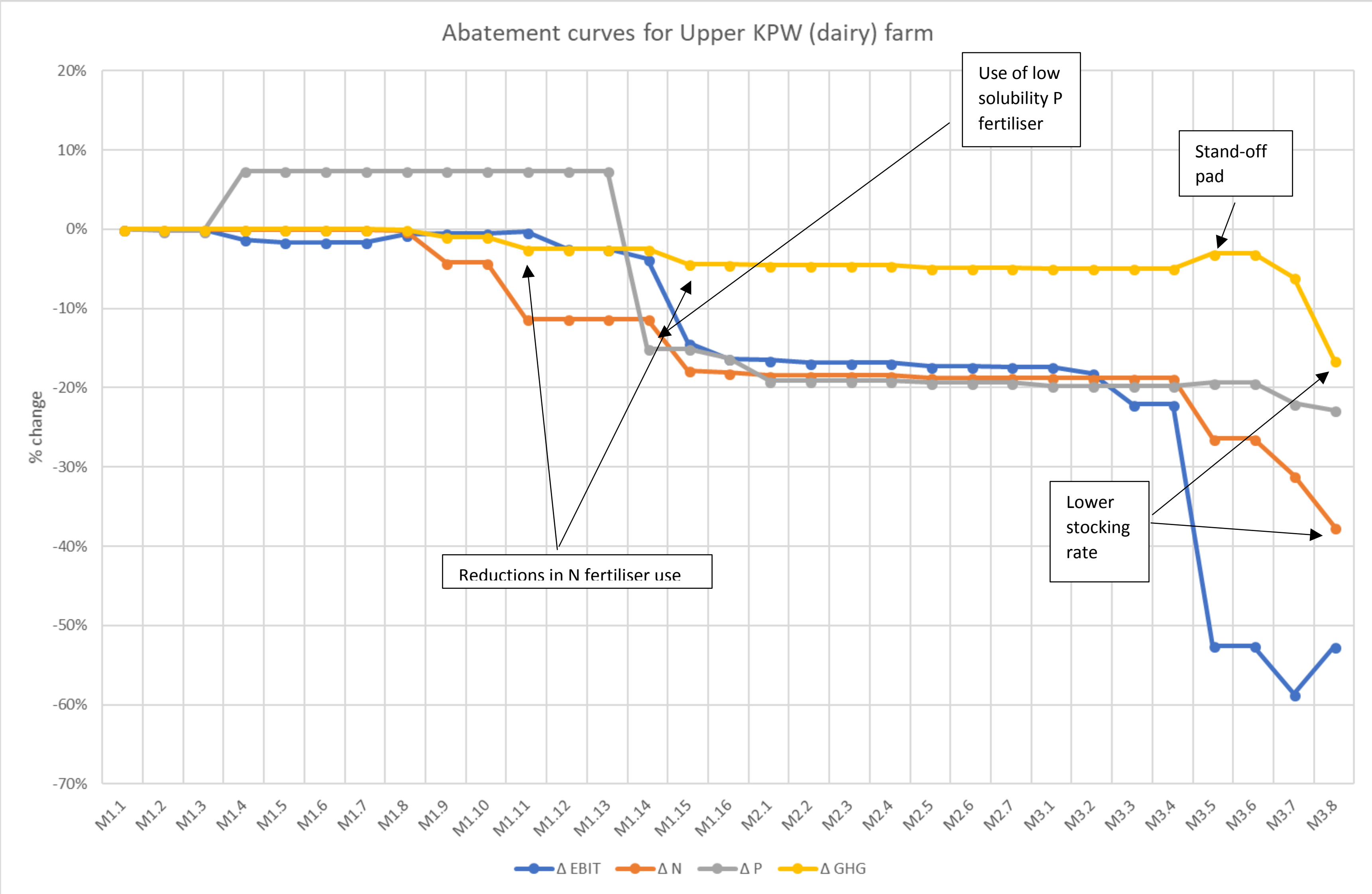

Figure 6: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Upper KPW dairy farm system

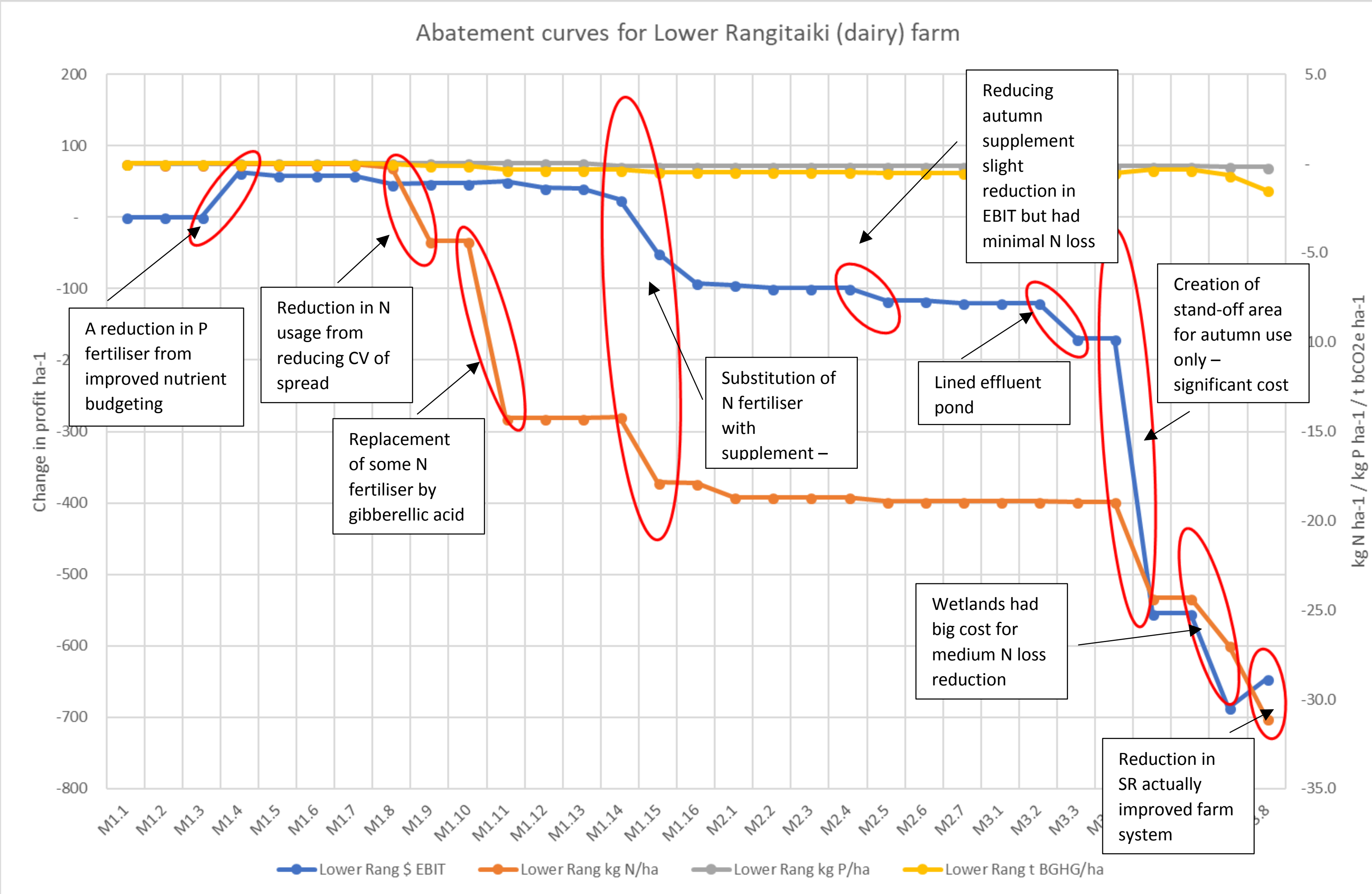

Figure 7: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the Lower Rangitāiki dairy farm system

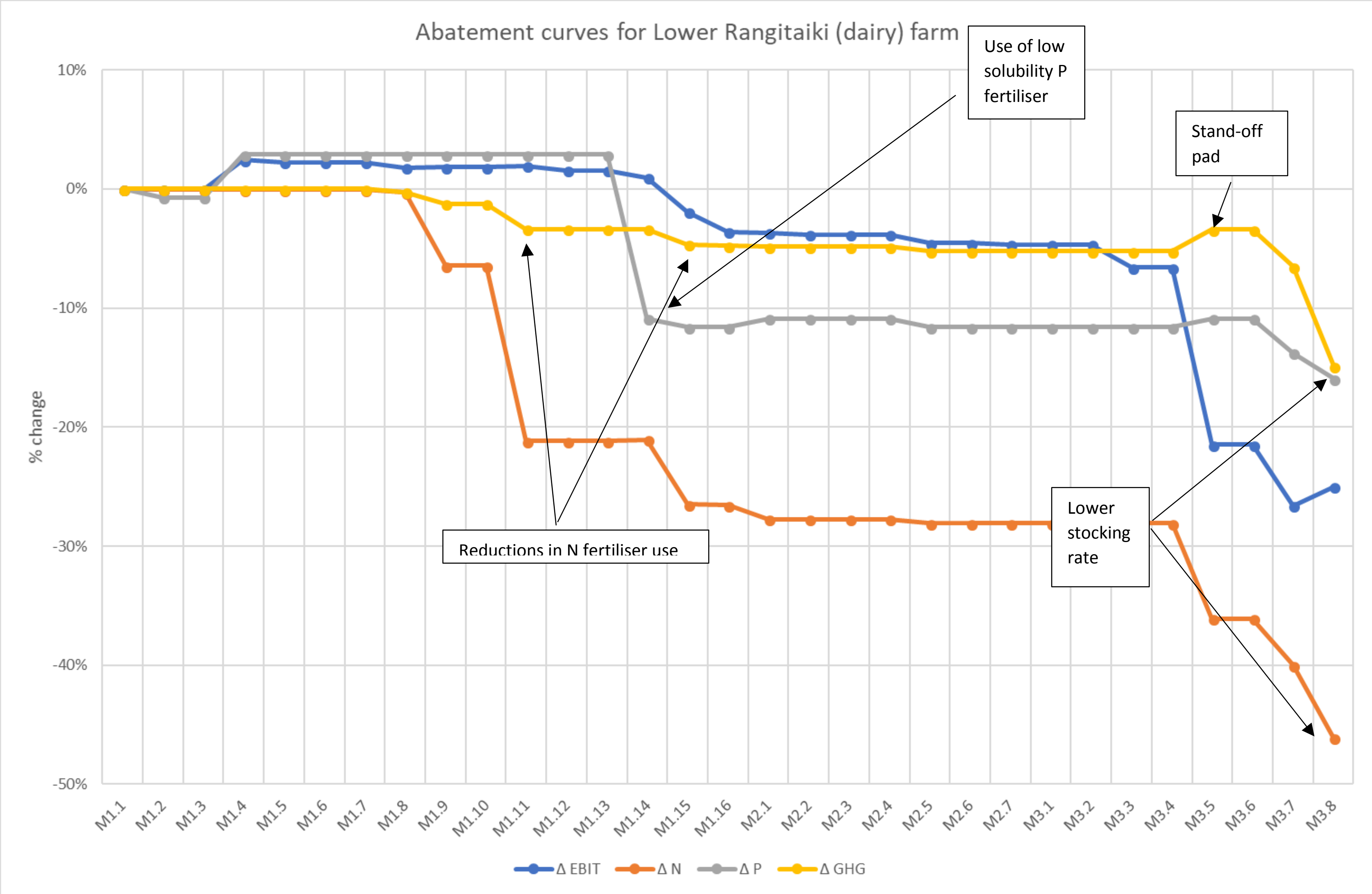

Figure 8: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Lower Rangitāiki dairy farm system

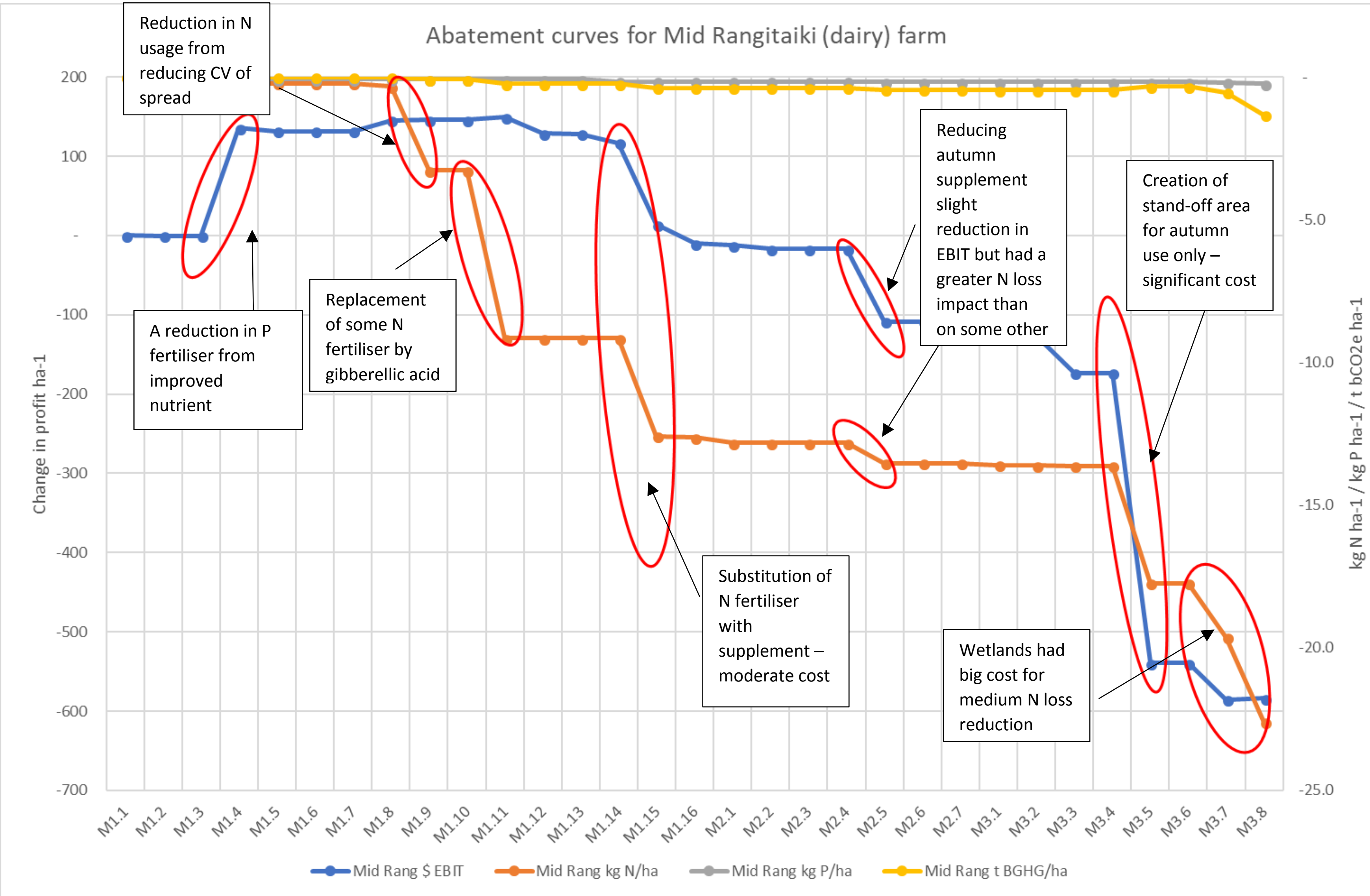

Figure 9: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the Mid Rangitāiki dairy farm system

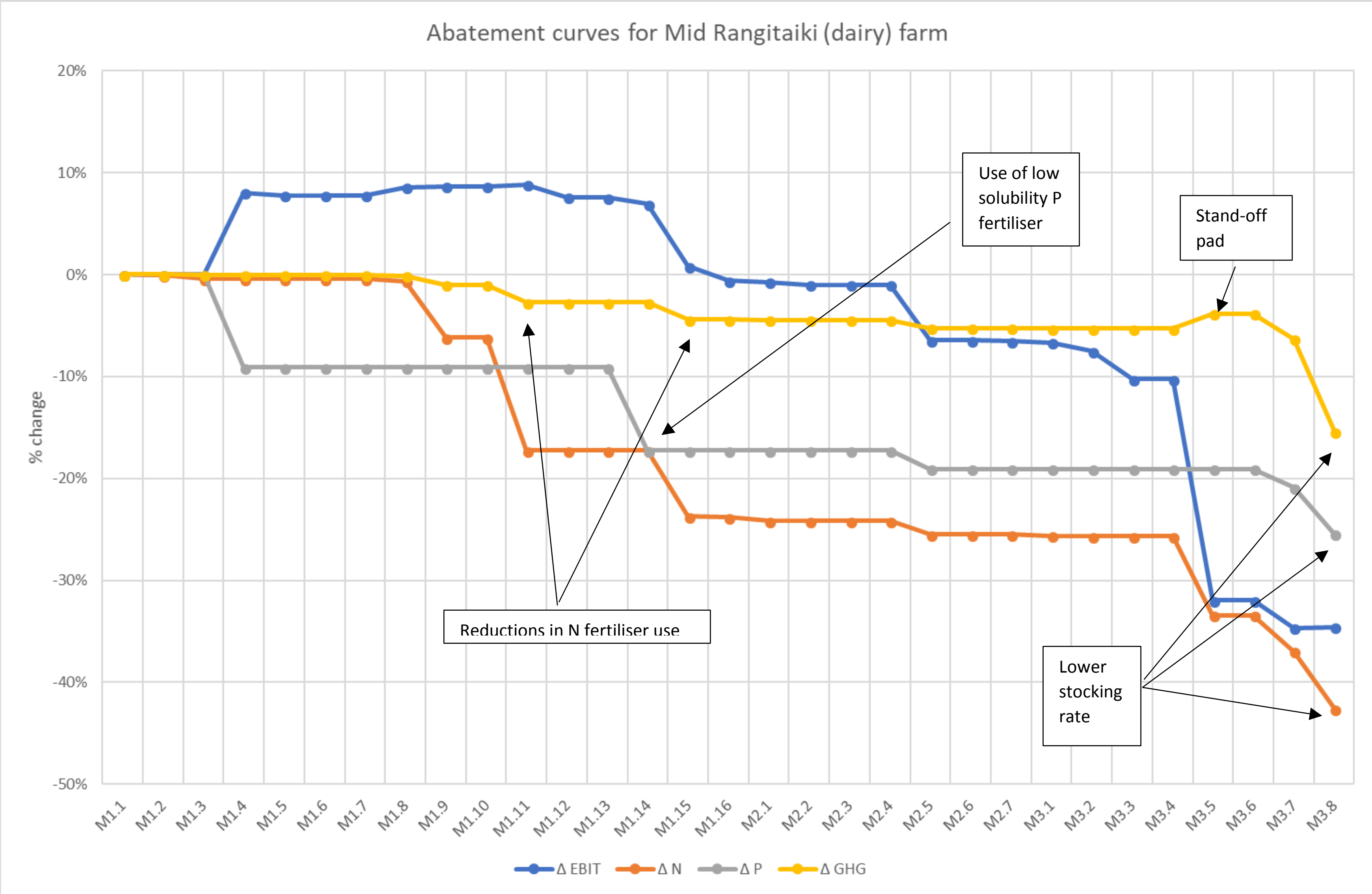

Figure 10: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Mid Rangitāiki dairy farm system

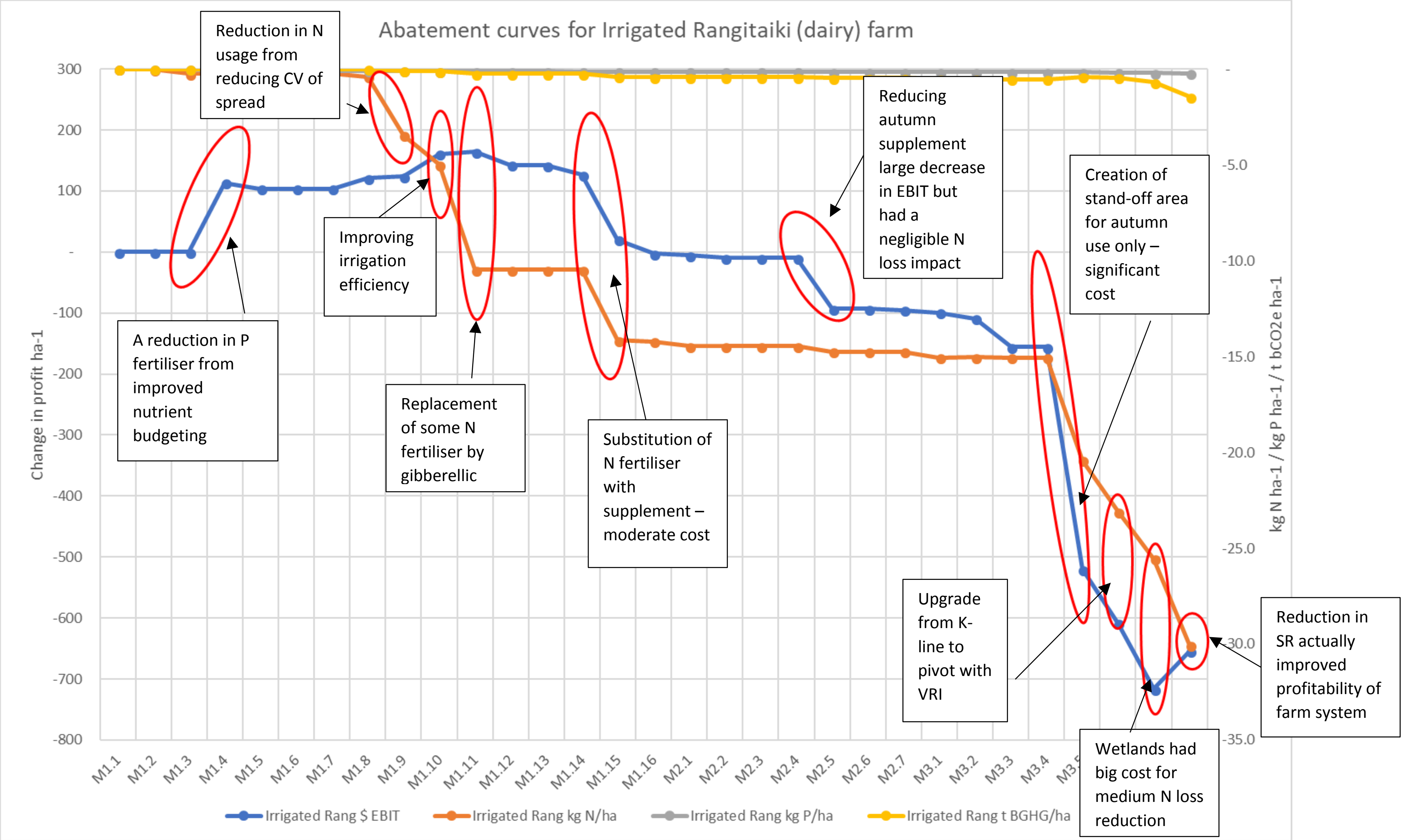

Figure 11: Sequential abatement curves for change in $ profit (LHS) and change in contaminant output (RHS) for the Irrigated Rangitāiki dairy farm system

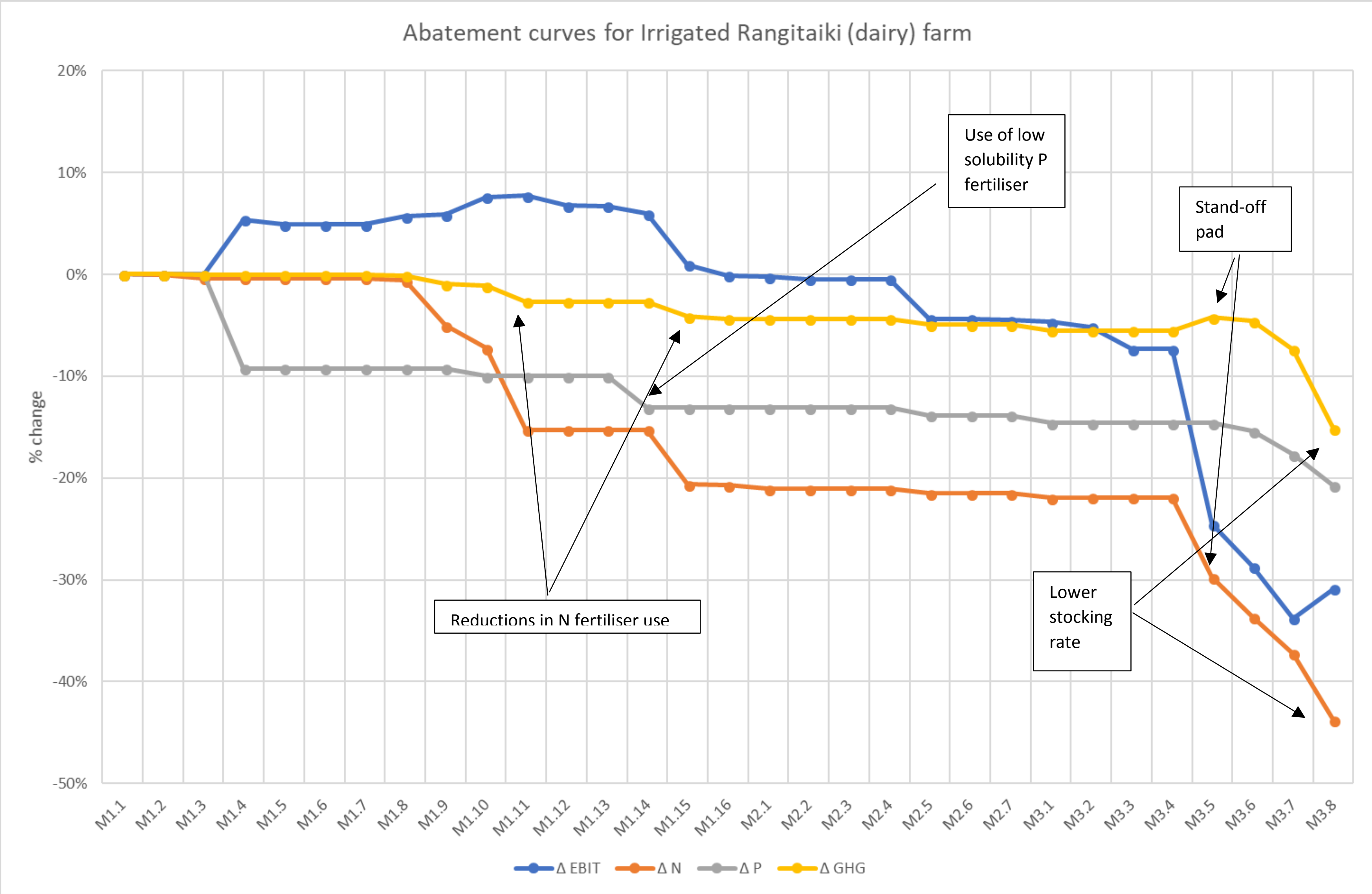

Figure 12: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Irrigated Rangitāiki dairy farm system

7.2 Drystock farm systems

7.2.1 Summary of bundles

On average across the four drystock farm systems analysed, implementation of M1 lowered profitability by $95/ha, M2 by $80/ha and M3 by $51/ha. While the overall financial impact of implementing the full bundle across the farm systems was significant, this was more so for the systems in the Kaituna-Pongakawa-Waitahanui WMA, particularly for the KPW sheep and beef farm system that was essentially unprofitable after M1 had been implemented. Unlike the dairy farm systems, where the mitigation sequencing and the aggregation into bundles resulted in bundles with economic outcomes in line with expectations, those for the dry stock systems performed quite differently, with the financial impact of applying the mitigation differing from our expectations. This suggests a review of the bundling will be required and/or that a strict mitigation bundling approach to any measures designed to improve water quality will be more challenging for drystock farm systems.

Table 29: Change in annual drystock farm gate profitability ($/ha) from the implementation of mitigation bundles

	KPW DS	KPW S+B	Rangitaiki S+B	Rangitaiki Deer	Average
M1	-111	-107	-81	-81	-95
M2	-214	-101	-26	20	-80
M3	-86	-37	-22	-62	-52
Total	-411	-244	-129	-122	-227

The financial impact of implementing M1 tended to be heavily influenced by one main factor - the incorporation of low N forages into the farm system – modelled here as the development of diverse swards to comprise at least 20% of the pasture. At this scale this imposed significant costs on the farm system that were not recouped through productivity gains. Excluding this mitigation would have seen the cost of M1 reduce to an average reduction in profit of $41/ha.

The inclusion of afforestation of steep land within the M2 bundle for the dry stock systems (versus M3 for the dairy farm systems) had the greatest impact on the cost of the M2 bundle for the KPW farms. For the Rangitāiki deer model, the apparent use of unprofitable N fertiliser in spring had a large positive impact on the “cost” of M2 implementation.

The variation in bundle impact for these farms is likely to be greater than for the dairy farms, which exhibited greater homogeneity in system parameters.

The bundle aggregation could potentially be enhanced for the drystock systems by moving low N forages into M2 and afforestation into M3. We’d recommend this approach be considered.

As can be seen from Table 30 overleaf, the percentage reductions in farm system profitability outstrip the reduction in the three “contaminants” estimated by OVERSEER, being N, P and biological greenhouse gas emissions (CH_4 and N_20). Full adoption of the mitigation bundles on the drystock farm systems modelled reduced N losses by 14%-35%, P losses by 0%-38% and BGHG emissions by 8%-34%% - all for a reduction in profitability ranging between 53% and 183% of existing profits.

Table 30: Relative changes in annual drystock farm gate profitability and water and atmospheric contaminants as measured in OVERSEER 6.3.0 from the implementation of mitigation

KPW DS				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-20%	-1%	-12%	0%
M2	-66%	-22%	-38%	-25%
M3	-83%	-35%	-38%	-34%

KPW S+B				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-81%	-1%	-18%	-1%
M2	-156%	-25%	-38%	-22%
M3	-184%	-31%	-38%	-25%

Rangitaiki S+B				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-37%	-2%	-6%	-1%
M2	-49%	-8%	-9%	-6%
M3	-59%	-14%	-10%	-9%

Rangitaiki Deer				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-35%	-2%	-9%	0%
M2	-27%	-4%	-9%	-2%
M3	-53%	-14%	-10%	-8%

7.2.2 General observations

In general:

- The elimination of N fertiliser that was deemed to support capital livestock lowered overall profitability in each of the three times it was implemented, even though crude marginal analysis would suggest this not to be the case. Part of the reason for this is the stickiness of some farm costs, primarily labour and fixed overheads;
- Other than significant land use change, as modelled in OVERSEER, the adoption of low solubility P fertiliser provided a good mechanism to reduce P loss risk. A reduction in profitability was expected to occur because of the need for an initial capital application of the RPR to counter the impact of only 30% of the P content becoming available in any given year;
- In the absence of any carbon liability, planting the steep land (as modelled) typically resulted in a reduction in profitability, particularly for the higher value pastoral land uses (dairy support). This is again due to the stickiness of fixed costs and labour, the conservative approach taken to account for longer term tree income and the difference between the breakdown of contour in our study and that derived by the GIS analysis of the BOPRC. As suggested in earlier reports, comparing livestock enterprises with forestry using annual

profit measures is also fraught with problems and we really need a discounted cashflow approach to adequately analyse this. We suspect the approach necessitated in this analysis undervalues the longer-term value of forestry as a mitigation on steeper pastoral land.

- The integration of sufficient low N forages in the farm system (a minimum area of 20%) was a significant cost to these farm systems where limited re-grassing was assumed to occur. The often-limited areas within these drystock farms that could be successfully re-sown into diverse swards provide some logistical challenges and it is likely these areas would already have the highest performing pastures on the farm, limiting any productive gain from these pastures. As a result, there was a cost of $691/ha over 10% of the farm area that delivered no "measurable" improvement in environmental performance;
- Wetland development at a nominal 3% of farm area required significant capital expenditure and the associated cost of capital represented a significant proportion of farm profit;
- Where the exclusion of livestock from waterways was required, the financial impact was greater where sheep (7 wire fencing) or deer (1800mm netting fencing) had to be excluded;
- As modelled, gorse management on steeper land can be expensive. The cost could be defrayed by a reclamation of effective grazing area, but this wasn't modelled. In practice this can be hard to achieve from large but scattered stands as a result of long-term suppression of clover growth after 2-4-D or metsulfuron applications and the ongoing challenge of regrowth in these areas.
- Improving cropping practices for winter cropping, while having a slight negative impact in profit had the potential to deliver moderate improvements in environmental outputs, despite the often-low area of the farm this related to.
- Increasing sheep to cattle ratios lowered N losses, but lowered profitability as well. This directly relates to the relative profitability of the sheep and cattle systems modelled;
- The net capital cost (including capital released from livestock reductions) of implementing all three bundles averaged $394,000 for these farms (a range of $835/ha to $1,297/ha). The opportunity cost of such capital was accounted for in the change in profitability (as was any increase in depreciation associated with infrastructure). The majority of these costs were associated with riparian fencing and planting, capital RPR fertiliser and then afforestation costs.

7.2.3 Sensitivity analysis of bundle cost

The cost of implementing all the bundles was considered against a number of variables that might be expected to have some impact for a number of the farm systems. Bundle cost was sensitised against the cost of a key input (N fertiliser), the prices for key outputs (beef, lamb and venison prices), the cost of carbon and the extent to which farming might have to account for its biological emissions, the impact of council co-investment in the cost of fencing and planting riparian buffers and detention bund activities and the cost of and annual income associated with commercial forestry as a partial land use change. The results are presented in Table 31 through Table 36.

Table 31: Cumulative cost ($/ha) of implementing M1 - M3 for Rang S+B with changes in lamb and beef price

Beef price ($/kg cwt)	Lamb price ($/kg cwt) 4.50	5.00	5.50	6.00	6.50	7.00
4.50	-113	-111	-108	-106	-104	-102
5.00	-122	-120	-118	-116	-114	-111
5.55	-133	-131	**-129**	-127	-124	-122
6.00	-142	-140	-137	-135	-133	-131
6.50	-152	-149	-147	-145	-143	-141

Table 32: Cumulative cost ($/ha) of implementing M1 - M3 for KPW DS with changes in N fertiliser and "beef" price[4]

Urea price ($/t)	Beef price ($/kg cwt) 4.94	5.24	5.55	5.86	6.17	6.48
500	-340	-376	-413	-450	-487	-524
564	-338	-374	**-411**	-448	-484	-522
600	-336	-373	-410	-447	-483	-520
700	-333	-370	-407	-444	-480	-517
800	-330	-366	-403	-440	-477	-514

Table 33: Cumulative cost ($/ha) of implementing M1 - M3 for Rang D with changes in N fertiliser and venison price

Urea price ($/t)	Venison price ($/kg cwt) 7.00	7.50	8.00	8.50	8.00	9.50
500	-118	-122	-126	-131	-126	-139
564	-114	-118	**-122**	-127	-122	-135
600	-111	-116	-120	-124	-120	-133
700	-105	-109	-114	-118	-114	-127
800	-99	-103	-107	-112	-107	-121

Table 34: Cumulative average cost ($/ha) of implementing M1 - M3 with changes in council funding

% funding for detention bunds	% funding for fencing and planting activities 0%	25%	50%	60%	70%	75%
0%	-236	**-225**	-215	-211	-206	-204
25%	-236	-225	-214	-210	-206	-204
50%	-235	-225	-214	-210	-205	-203
75%	-235	-224	-214	-209	-205	-203
100%	-235	-224	-213	-209	-205	-203

[4] With carcass weight equivalent a key output in the biophysical modelling used (Farmax), a change in beef price has been used here as a proxy for the changes in grazing prices that would ultimately affect the profitability of dairy support systems. The beef prices used here approximate to a range in heifer grazing rates of $8-$10.50/head/week (with calf and winter cow grazing prices relative to these)

Table 35: Cumulative cost ($/ha) of implementing M1 - M3 for KPW S+B with changes in carbon price and ETS accountability

Carbon price ($/t CO²e)	% CO_2e emissions needing to be paid for: 0%	10%	20%	30%	40%	50%
10	-244	-243	-242	-241	-240	-239
21	**-244**	-242	-240	-238	-235	-233
30	-244	-241	-238	-235	-232	-228
40	-244	-240	-236	-232	-227	-223
50	-244	-239	-234	-228	-223	-218

Table 36: Cumulative cost ($/ha) of implementing M1 - M3 for KPW S+B with changes in forestry income and cost of establishment

Establishment cost ($/ha)	Annual "income" from P. radiata forestry: 200	300	400	500	600	700
0	-229	-209	-189	-169	-149	-129
500	-234	-214	-194	-174	-154	-134
1000	-239	-219	-199	-179	-159	-139
1500	**-244**	-224	-204	-184	-164	-144
2000	-249	-229	-209	-189	-169	-149

The following observations were made:

- As the price of product (i.e. milk) increased, the impact on the cost of bundle implementation depended on impact of mitigation on production. Where implementation of the mitigation bundles resulted in reductions of output (as with lowered venison, beef or cattle liveweight production), then mitigation costs increased. This is unsurprising with the opportunity cost of lost production becoming greater as the price increased. However, where, as with the Rang S+B system the net output of a product (sheep meat) actually increased because of the mitigation framework, bundle cost decreased as product prices increased. (see Table 31);
- As the price of an input (N fertiliser) increased, the cost of mitigation reduced. For an input like N fertiliser, which is heavily linked to one of the contaminants targeted by the mitigation bundles, lowering its use saves the farm system more at higher prices (see Table 33);
- As carbon price increased and the extent to which agriculture had to account for its emissions increased, the cost of the bundle implementation reduced, but not substantially. As modelled, the water quality mitigation bundles delivered a reduction in biological greenhouse gas emissions to the four drystock systems between 8% and 34%. For the KPW sheep & beef model sensitised in this way (Table 35), the BGHG reduction was 25%, so a greater extent of impact than for the dairy farm models that averaged a 17% BGHG reduction wasn't surprising;

- The impact of council co-investment [subsidy] for [the chosen] environmental works was greater for the drystock farming systems than for the dairy farms. Lifting the proportion of council funding for riparian fencing and planting from the assumed 25% level to 75% reduced the average cost of bundle implementation by 10% (Table 34). This reflects the greater cost of the fencing needed to exclude sheep, beef cattle and deer from riparian areas compared with dairy farms and the fact that a higher degree of riparian fencing is already assumed to be in place on dairy farms as a result of the Dairy Water Accord. Increased council funding for detention bund works had limited impact on cost (in the order of <1% reduction in bundle cost), due primarily to the limited component of the bundle that such works comprise;
- The efficacy of forestry as a mitigation on steeper soils is more dependent on the “income” from the forested area rather than the cost of afforestation itself (Table 36). While we are cognisant that we have used a very low annual “income” of $200/ha to represent the annual income stream from forestry over time, it is clear that using a figure closer to the equivalent annuity associated with forestry land use, as per Appendix 5 and Appendix 6, has a significant impact on lowering the cost of mitigation (27% improvement) where moderate areas of tree planting is potentially required (65ha / 20% of farm area in the KPW S+B model). This is only a crude sensitivity analysis, given the cost of establishment has a significant impact on the returns from forestry given the time value of money, but it clearly illustrates the opportunity forestry has to be a cost-effective tool for improving water quality where a longer-term view of returns can be made. The challenge of addressing land-owner’s concerns about “how do I get enough income to live off if I change land use away from livestock farming to forestry?” is very real and not one that will easily be resolved.

The individual abatement curves for the four farm systems are presented below (Figure 13 - Figure 20). On a nominal output basis, the change in profitability is charted on the left vertical axis and the change in environmental outputs is charted on the right vertical axis. The relative changes in outputs are graphed on a percentage basis against each other.

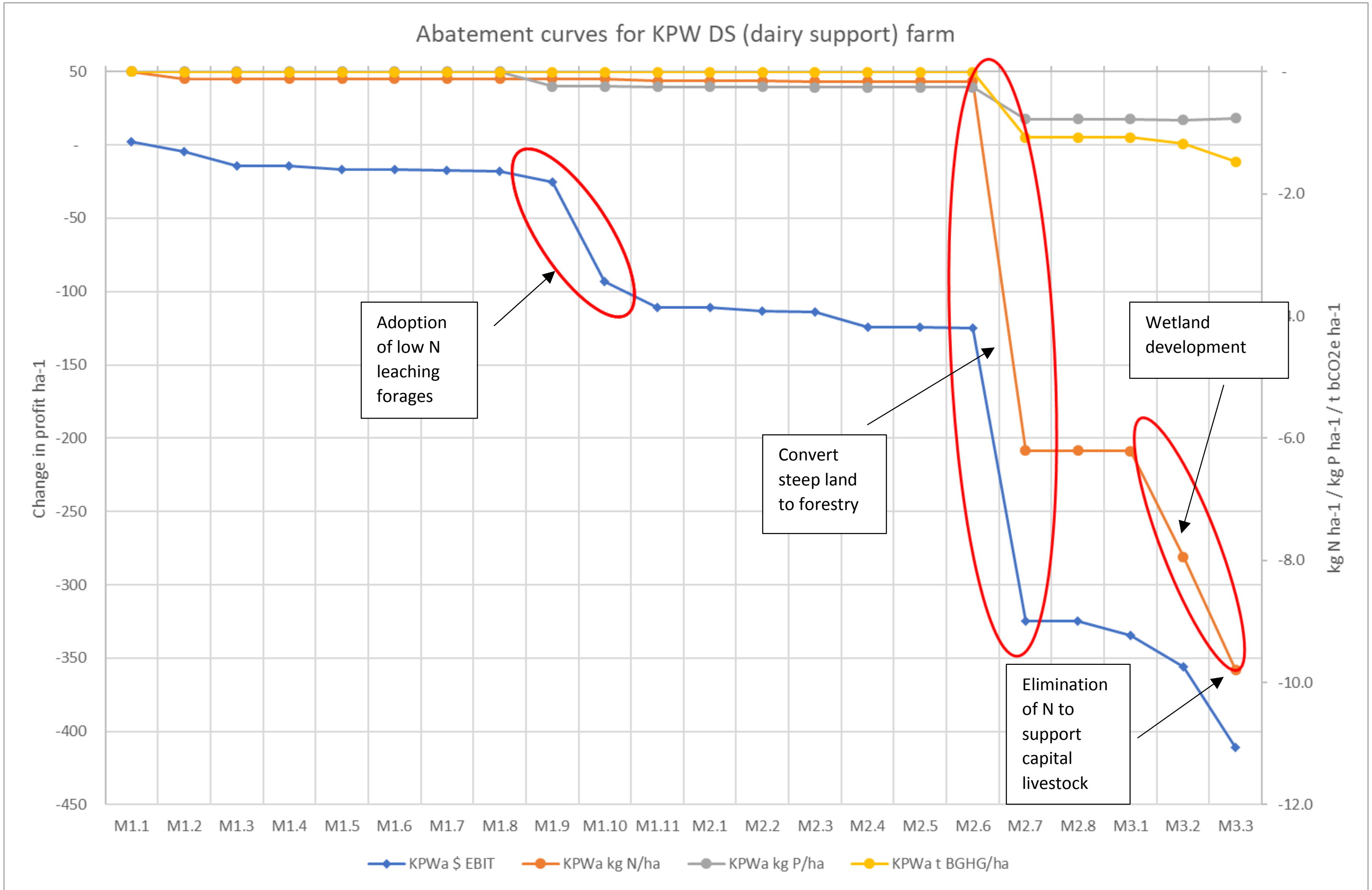

Figure 13: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the KPW dairy support farm system

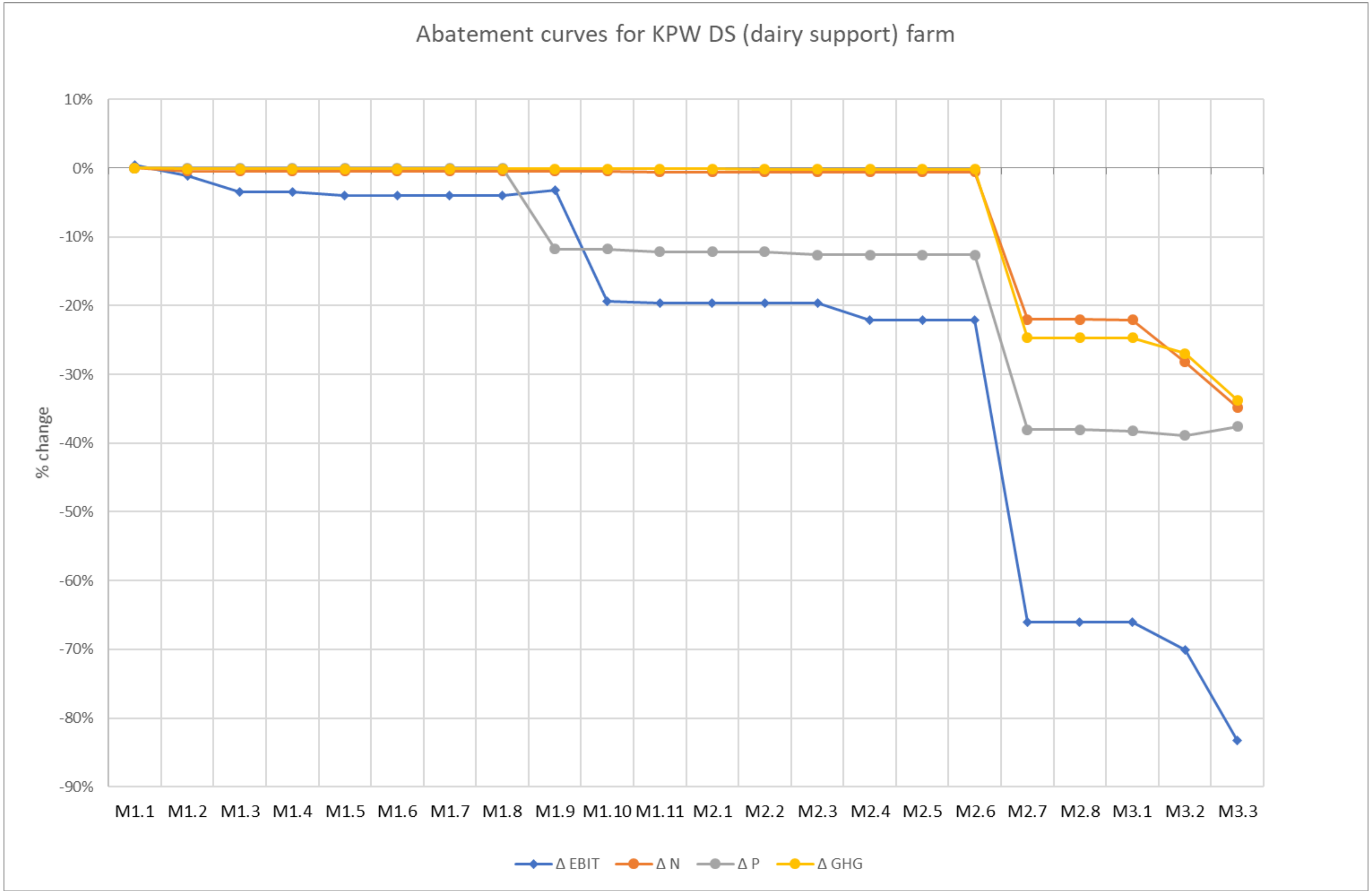

Figure 14: Sequential abatement curves for relative (%) change in profit and in contaminant output for the KPW dairy support farm system

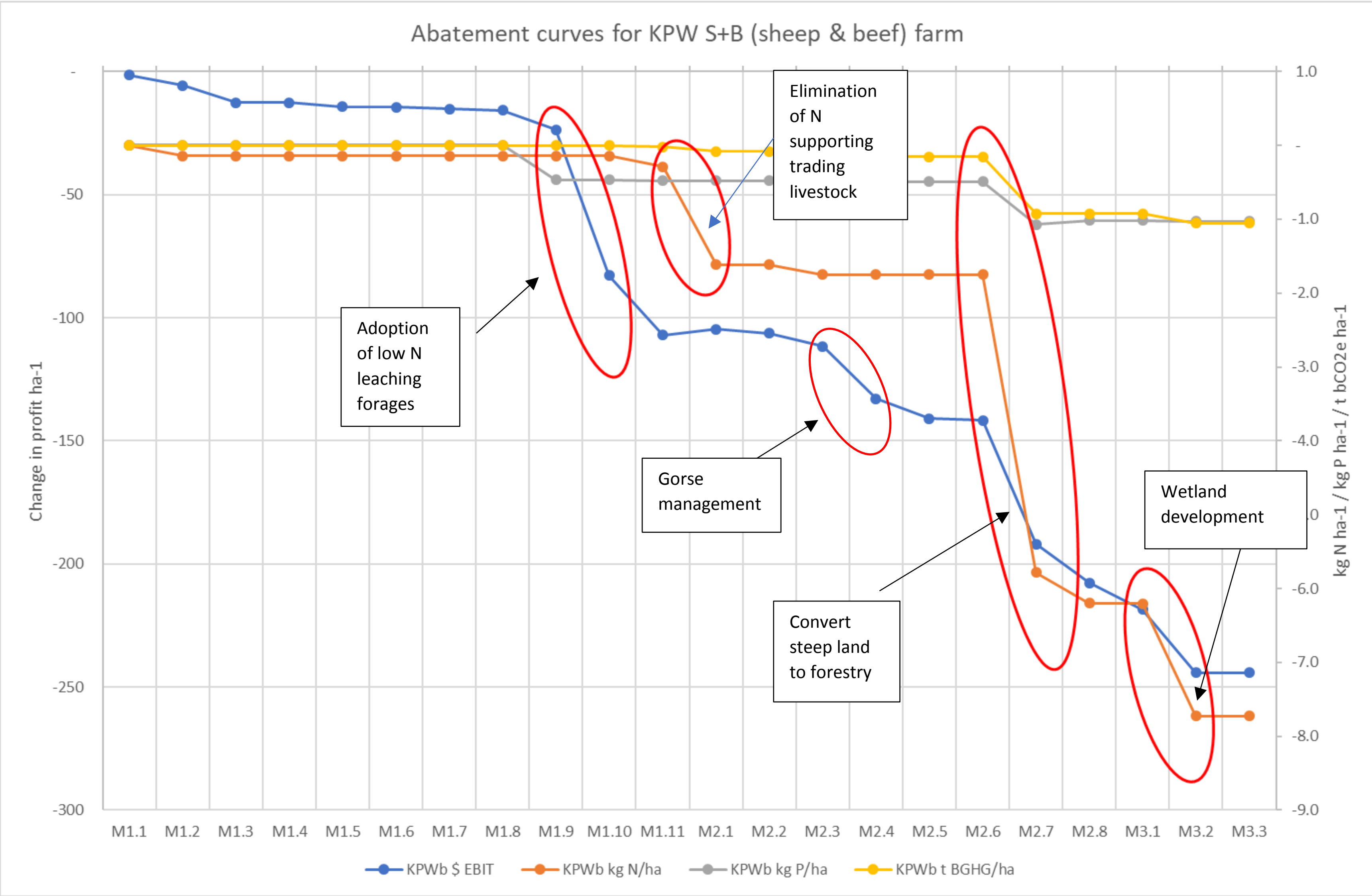

Figure 15: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the KPW sheep & beef farm system

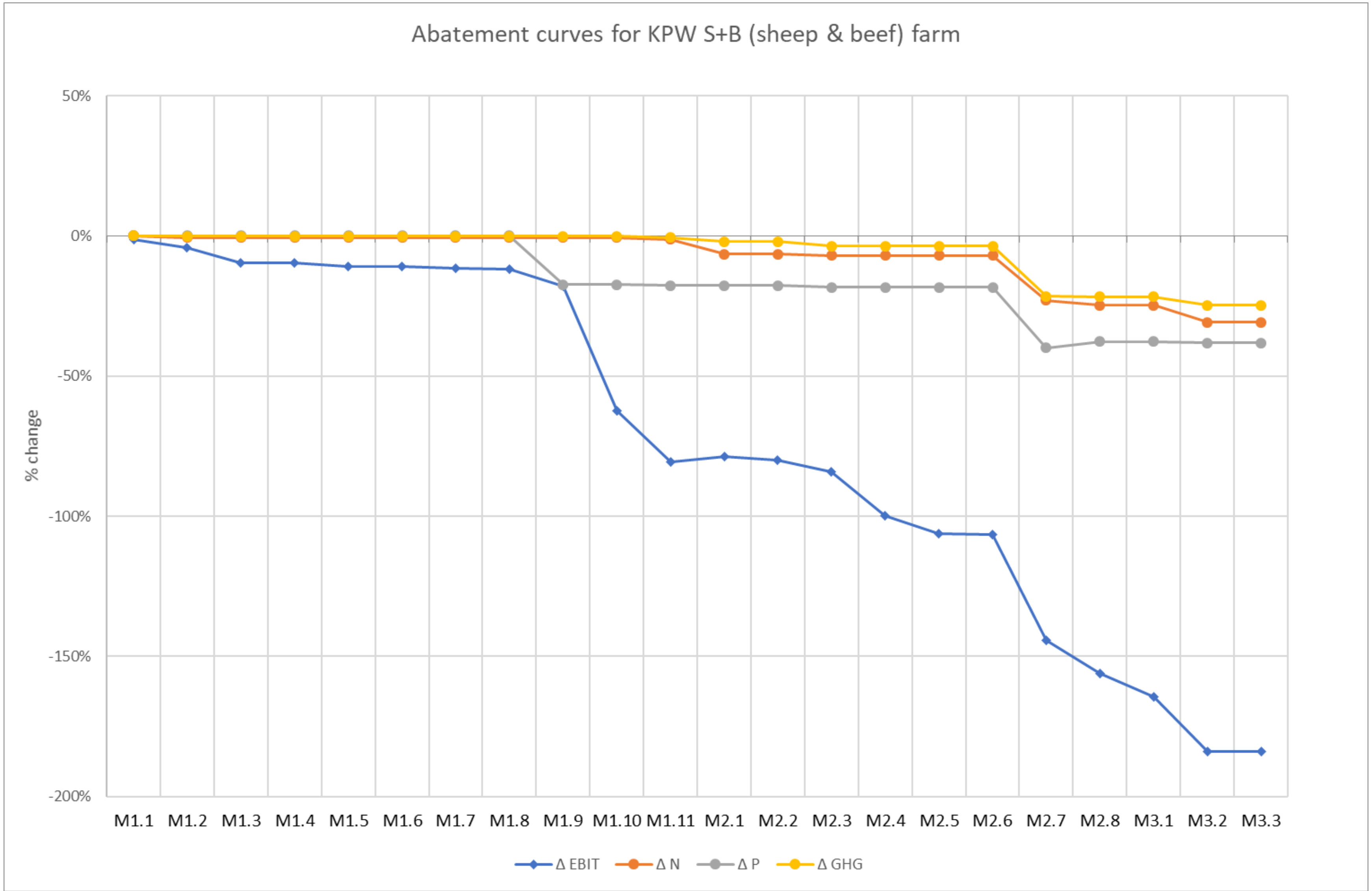

Figure 16: Sequential abatement curves for relative (%) change in profit and in contaminant output for the KPW sheep & beef farm system

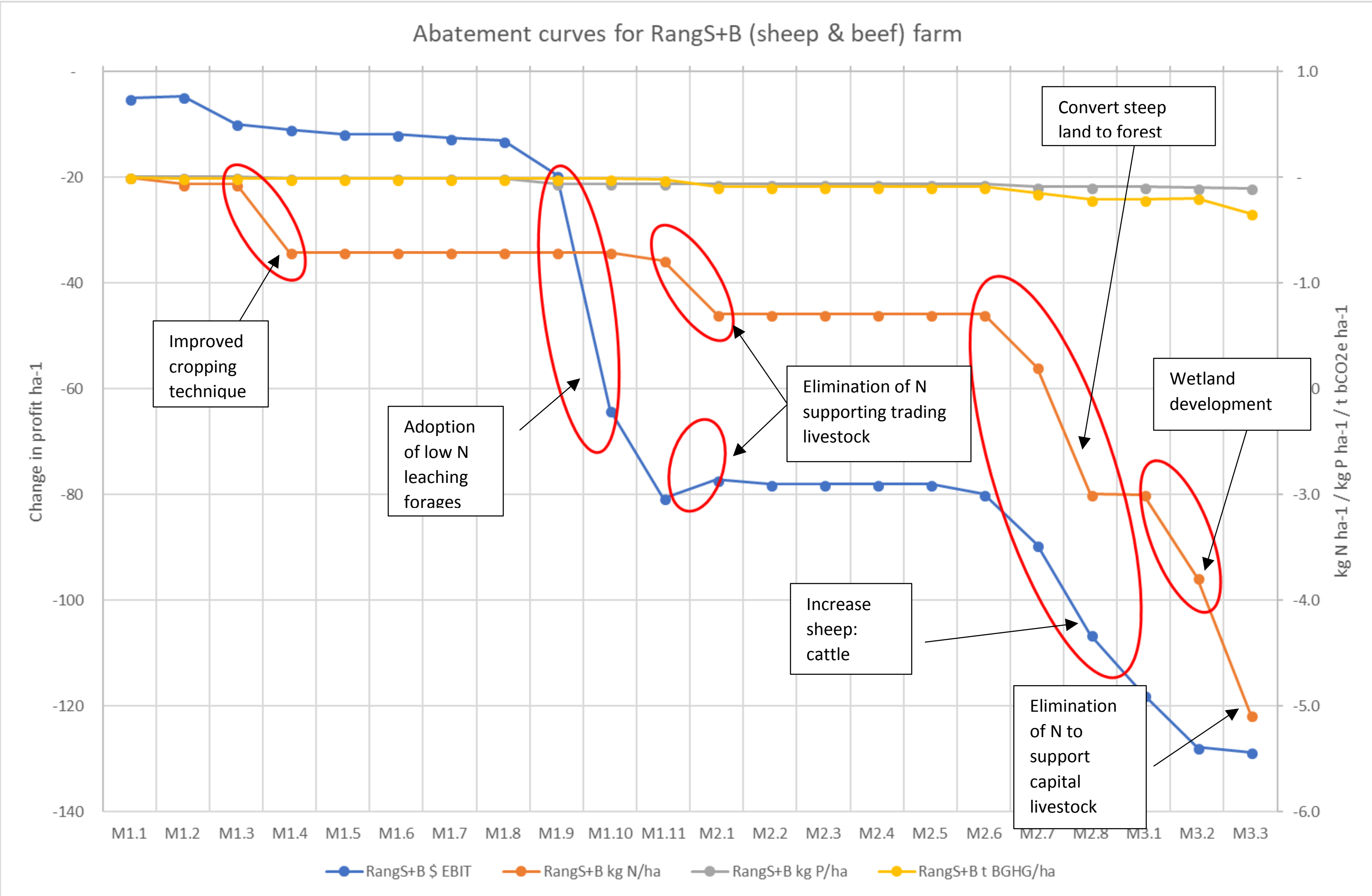

Figure 17: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the Rangitāiki sheep & beef farm system

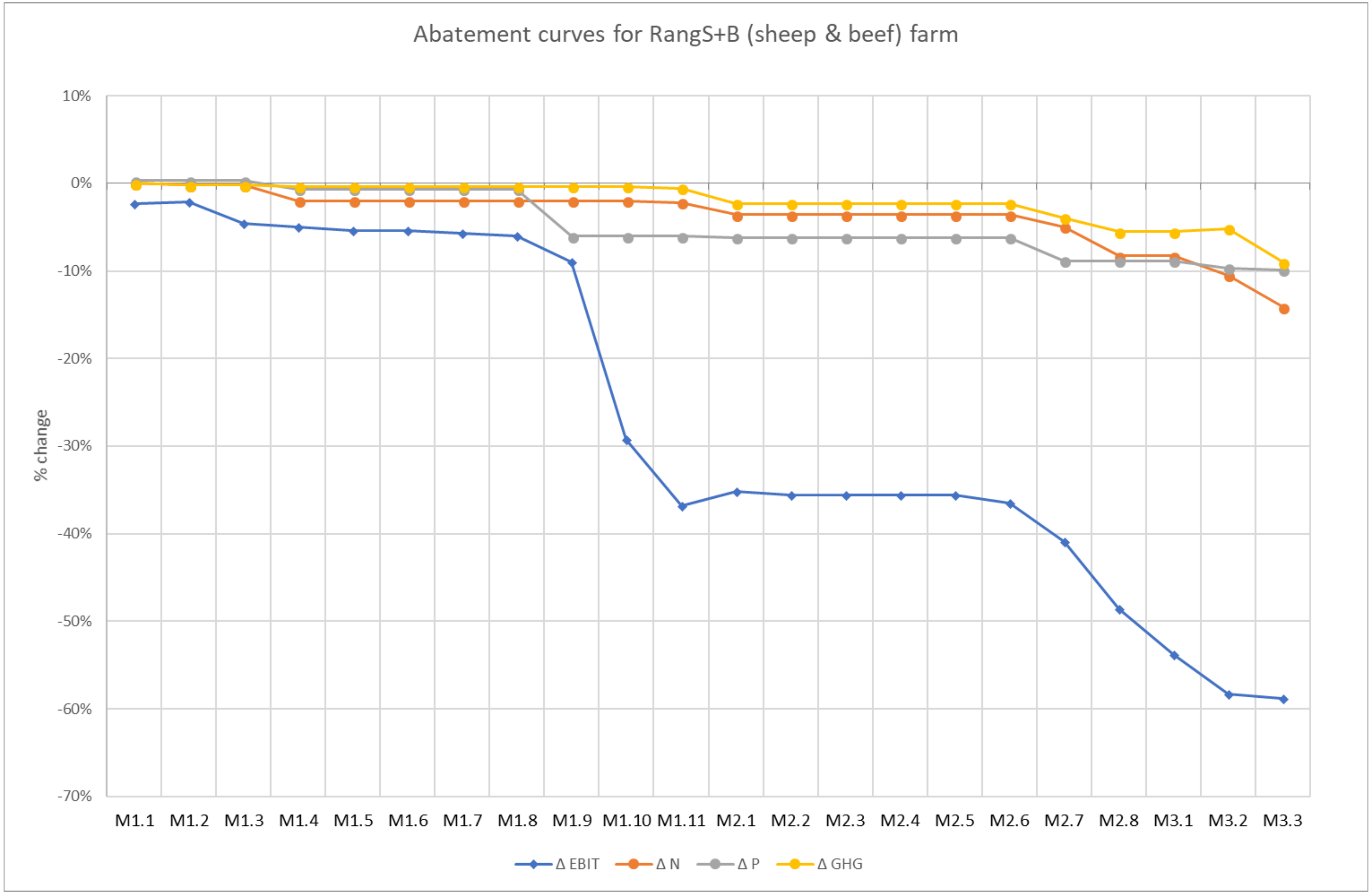

Figure 18: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Rangitāiki sheep & beef farm system

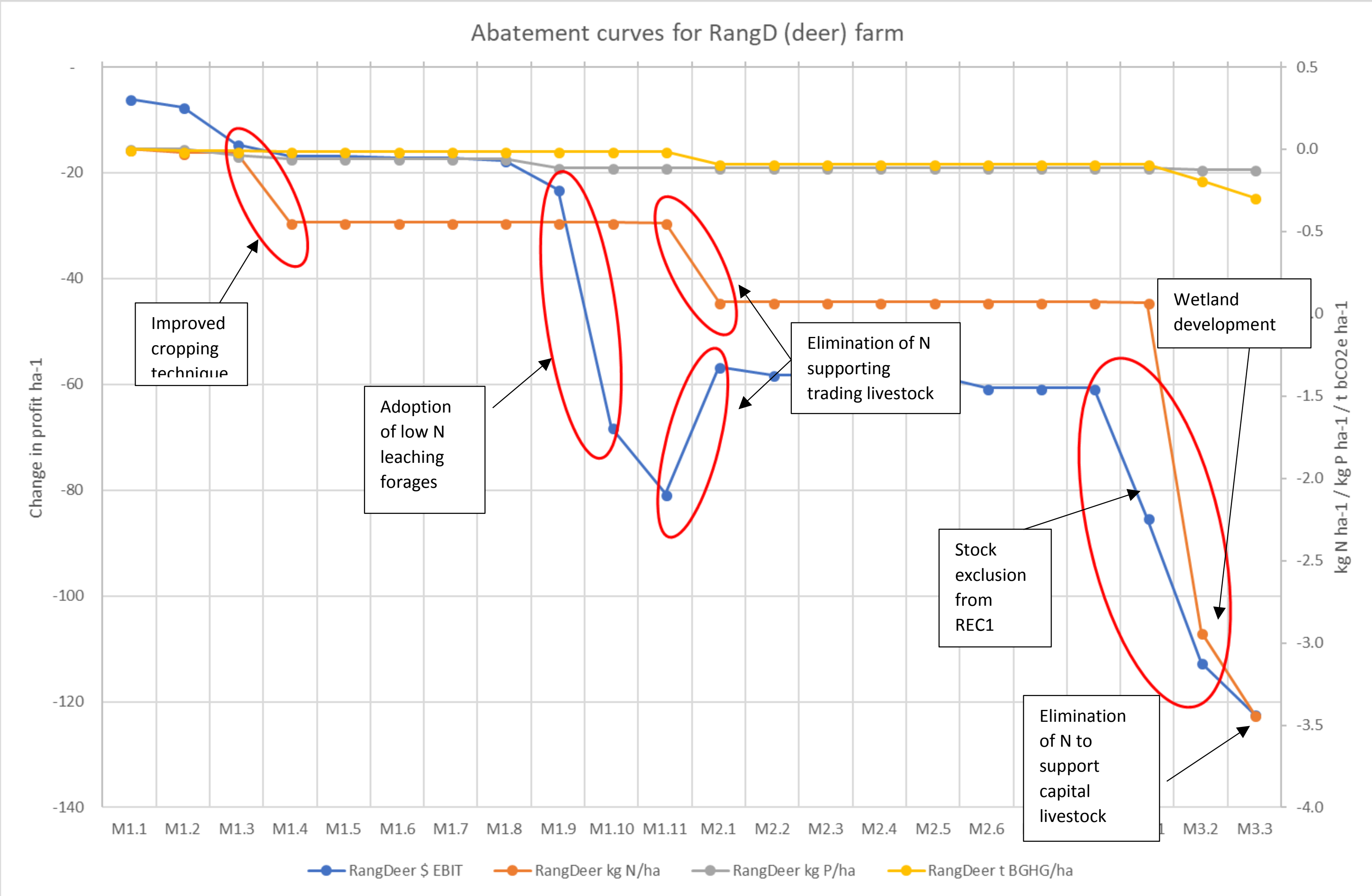

Figure 19: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the Rangitāiki deer farm system

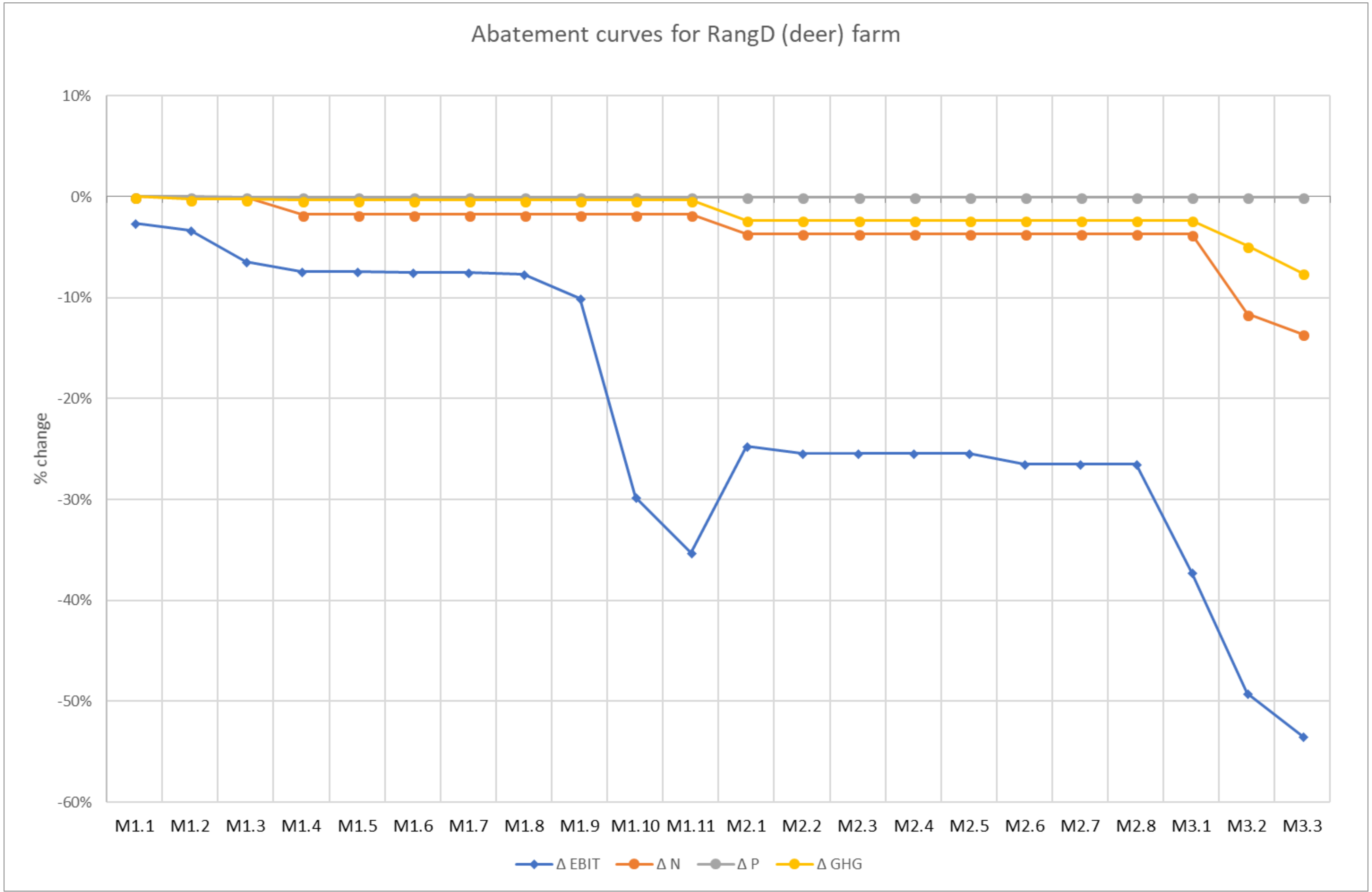

Figure 20: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Rangitāiki deer farm system

7.3 Arable farm systems

7.3.1 Summary of bundles

The implementation of M1 lowered the profitability of the KPW Arable farm system by $153/ha, M2 by $809/ha and M3 by a further $85/ha. The significant impact that reducing N fertiliser [by 15%] had on profitability and the fact that, as modelled, OVERSEER suggested N leaching would go up, makes the re-evaluation of this mitigation for the bundles highly recommended.

Table 37: Change in annual arable farm gate profitability ($/ha) from the implementation of each mitigation bundle (a) and relative cumulative changes in annual arable farm gate profitability and water and atmospheric contaminants as measured in OVERSEER 6.3.0 from the implementation of mitigations (b)

(a)

Bundle		KPW Arable
M1	-	153
M2	-	809
M3	-	85
Total	-	1,048

(b)

KPW arable				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-7%	-9%	-1%	-0.1%
M2	-41%	0%	-1%	-0.1%
M3	-45%	-7%	-4%	-0.2%

As can be seen from Table 37 (b) above, the percentage reductions in farm system profitability significantly outstrips the reduction in the three “contaminants” estimated by OVERSEER, being N, P and biological greenhouse gas emissions (CH_4 and N_20).

7.3.2 General observations

In general:

- Forgoing yield in lieu of reducing N losses accounted for 70% of the cost of the bundle implementation. Removing this from the bundles delivered bundles with similar implementation costs;
- As noted above, the OVERSEER modelling suggested removing N fertiliser from the model will increase N losses. This seems intuitively incorrect and follow-up with the OVERSEER team will be required.
- Compared with the pastoral farming systems and despite high N fertiliser usage, the application of the mitigation bundles had negligible impact on the biological GHG emissions profile of this farm system;
- Ten of the thirteen mitigations for the arable farm system were entirely designed to deal with reducing sediment losses. However, the sediment losses were not analysed in this study, as there is no possibility to estimate reductions in sediment losses with OVERSEER.

The biophysical modelling that is done in parallel with this analysis will be important to assess the impact on sediment losses from the bundles.

- The capital cost of implementing the bundles was low, at only $14,000 ($350/ha).

7.3.3 Sensitivity analysis of bundle cost

The cost of implementing all the bundles was considered against a few main variables that might be expected to have some impact for a number of the farm systems. Bundle cost was sensitised against the cost of a key input (N fertiliser), the prices for a key output (maize silage prices) and the cost of carbon and the extent to which farming might have to account for its biological emissions. The results are presented in Table 38 and Table 39 below.

Table 38: Cumulative cost ($/ha) of implementing M1 - M3 for KPW Arable with changes in N fertiliser and maize silage price

Urea price ($/t)	Maize silage price ($/t DM)					
	200	220	240	260	280	300
500	- 822	- 900	- 978	- 1,056	- 1,134	- 1,212
564	- 814	- 892	- 970	**- 1,048**	- 1,126	- 1,204
600	- 809	- 887	- 965	- 1,043	- 1,121	- 1,199
700	- 795	- 873	- 951	- 1,029	- 1,107	- 1,185
800	- 781	- 859	- 937	- 1,015	- 1,093	- 1,171

Table 39: Cumulative cost ($/ha) of implementing M1 - M3 for KPW Arable with changes in carbon price and ETS accountability

Carbon price ($/t CO^2e)	% CO_2e emissions needing to be paid for					
	0%	10%	20%	30%	40%	50%
10	- 1,048	- 1,047	- 1,047	- 1,047	- 1,047	- 1,046
21	- 1,048	- 1,047	- 1,046	**- 1,046**	- 1,045	- 1,045
30	- 1,048	- 1,047	- 1,046	- 1,045	- 1,045	- 1,044
40	- 1,048	- 1,047	- 1,046	- 1,045	- 1,044	- 1,043
50	- 1,048	- 1,046	- 1,045	- 1,044	- 1,043	- 1,041

The following observations were made:

- As with the dairy and drystock farm systems, as the price of the key product increased and the implementation of the mitigation bundles resulted in a reduction of output, then mitigation costs increased. Likewise, the converse was true for the cost of inputs whose use was reduced as a result of the mitigations;
- Unsurprisingly, with the bundles essentially having no impact on the arable farm models biological GHG profile (as estimated by OVERSEER), the cost of implementation was

essentially unchanged by potential changes to the carbon market or degree of farm system accountability under the ETS.

The individual abatement curves for the arable system is presented below in Figure 21 and Figure 22. On a nominal output basis, the change in profitability is charted on the left vertical axis and the change in environmental outputs charted on the right vertical axis. The relative changes in outputs are graphed on a percentage basis against each other

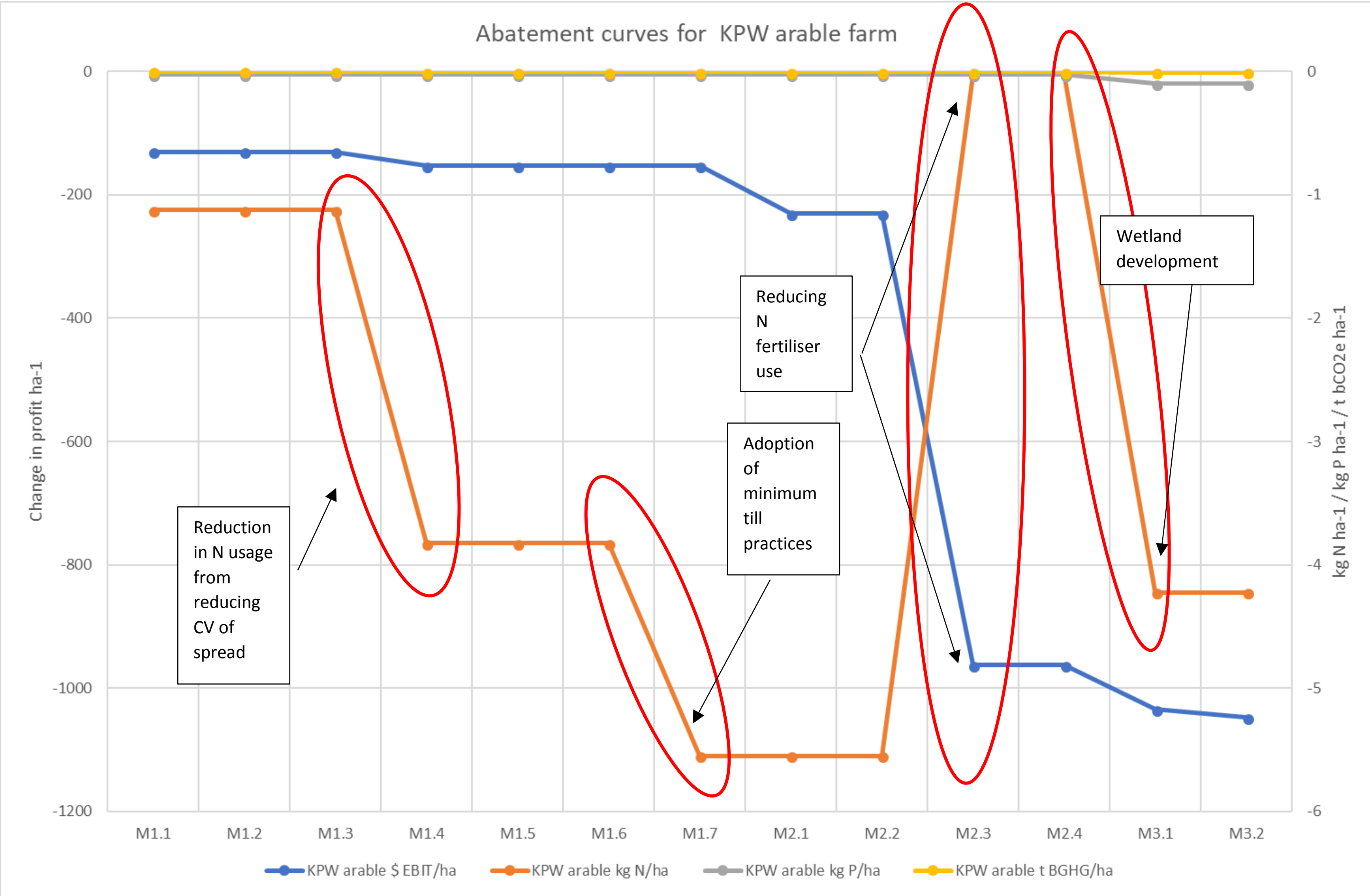

Figure 21: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the KPW arable farm system

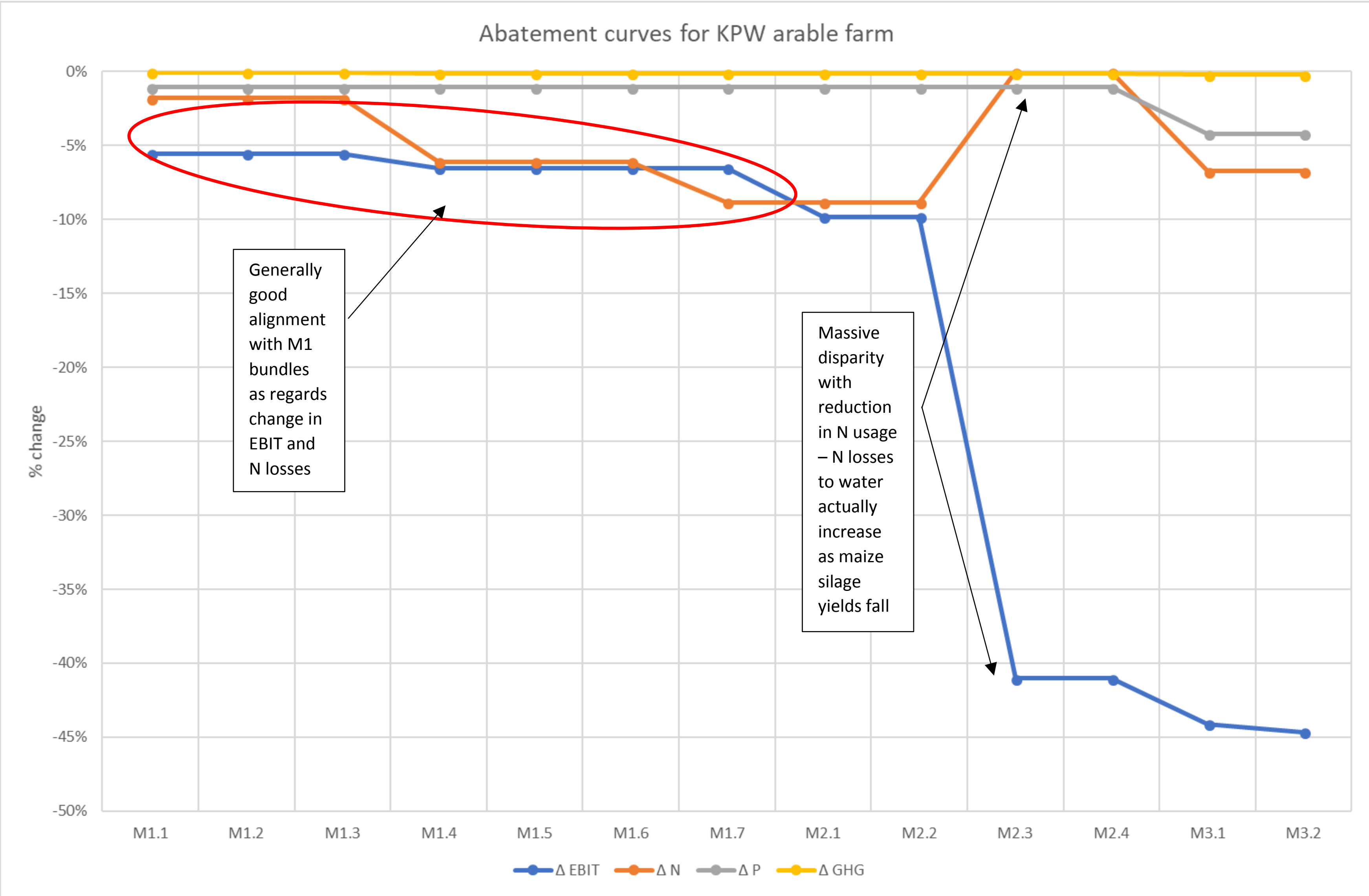

Figure 22: Sequential abatement curves for relative (%) change in profit and in contaminant output for the KPW arable farm system

7.4 Horticultural farm systems

7.4.1 Summary of bundles

Across the two kiwifruit orchard systems analysed, implementation of M1 lowered profitability by $1,892/ha and M2 by $38/ha (Table 40). While nominally high, the per hectare costs are low for the orchard systems as a percentage of total profitability and the overall level of contaminant losses are low.

The largest component of the M1 bundle cost was associated with managing the grass under the canopy, which was assumed to be done with regular mechanical removal. As a % of total returns, this was a more significant cost to green growers than for gold, which simply reflects the higher orchard gate returns currently experienced by gold growers.

Outside of this change, which ostensibly has negligible impact on N losses to water and would essentially have sediment capture benefits, the costs of implementing the mitigation bundles were minimal (Table 41).

Table 40: Change in annual kiwifruit orchard gate profitability ($/ha) from the implementation of each mitigation bundle

	Green	Gold	Average
M1	- 1,892	- 1,867	- 1,879
M2	- 38	- 38	- 38
Total	- 1,929	- 1,904	- 1,917

Table 41: Relative cumulative changes in annual kiwifruit orchard gate profitability and water and atmospheric contaminants as measured in OVERSEER 6.3.0 from the implementation of mitigations

Green				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-10%	-7%	0%	-2%
M2	-10%	-7%	0%	-2%

Gold				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-2%	-8%	0%	-1%
M2	-2%	-8%	0%	-1%

Average				
Bundle	Δ EBIT	Δ N	Δ P	Δ GHG
M1	-6%	-7%	0%	-1%
M2	-6%	-7%	0%	-1%

7.4.2 General observations

In general, notwithstanding the prevailing view that OVERSEER has limitations in modelling nutrient flows in orchard systems as well as those in pastoral farms due to a lack of empirical data:

- The greatest impact on N losses would appear to be associated with irrigated orchards improving water use efficiency, with its subsequent reductions in soil drainage;
- The suggested mitigation of post-harvest N applications is not recommended (Benge, J 2018, pers. comm) and as can be seen in the modelling potentially increases N losses to drainage. Having four split applications over spring would be a better option to improve efficiency of N fertiliser use, but OVERSEER can't currently model this accurately (i.e. it will treat two applications in the same month the same as a single application applying the same quantity of N fertiliser).
- It is important to note that the Psa (*Pseudomonas syringae pv actinidiae*) agrichemical control option called 'Kasumin' requires growers have to "mow" their orchards and be free of flowers before they are allowed to use this. Removing the herbicide option to control pasture would significantly impact on the ability to manage Psa.
- As might be expected, biological greenhouse gas emissions as modelled in OVERSEER were extremely low (<0.5t/ha) and are solely associated with the N fertiliser use in the orchards;
- The flat contour of the orchards assumed in the model (currently the default and only slope option in OVERSEER) reflect the low P risk, despite soil Olsen P levels >50ppm being assumed;
- The higher fruit yields of the gold vines than the green deliver improved N conversion efficiency;
- Capital costs of the full mitigation bundle implementation were estimated at $3,000 per orchard ($750/ha).

7.4.3 Sensitivity analysis of bundle cost

Because the yields and input quantities are essentially unchanged by the mitigation bundles applied to both kiwifruit models and the BGHG profile of orchards are so low, no sensitivity analysis has been deemed necessary to undertake.

The individual abatement curves for the two kiwifruit orchard systems are presented below in Figure 23 through Figure 26 below. On a nominal output basis, the change in profitability is charted on the left vertical axis and the change in environmental outputs charted on the right vertical axis. The relative changes in outputs are graphed on a percentage basis against each other.

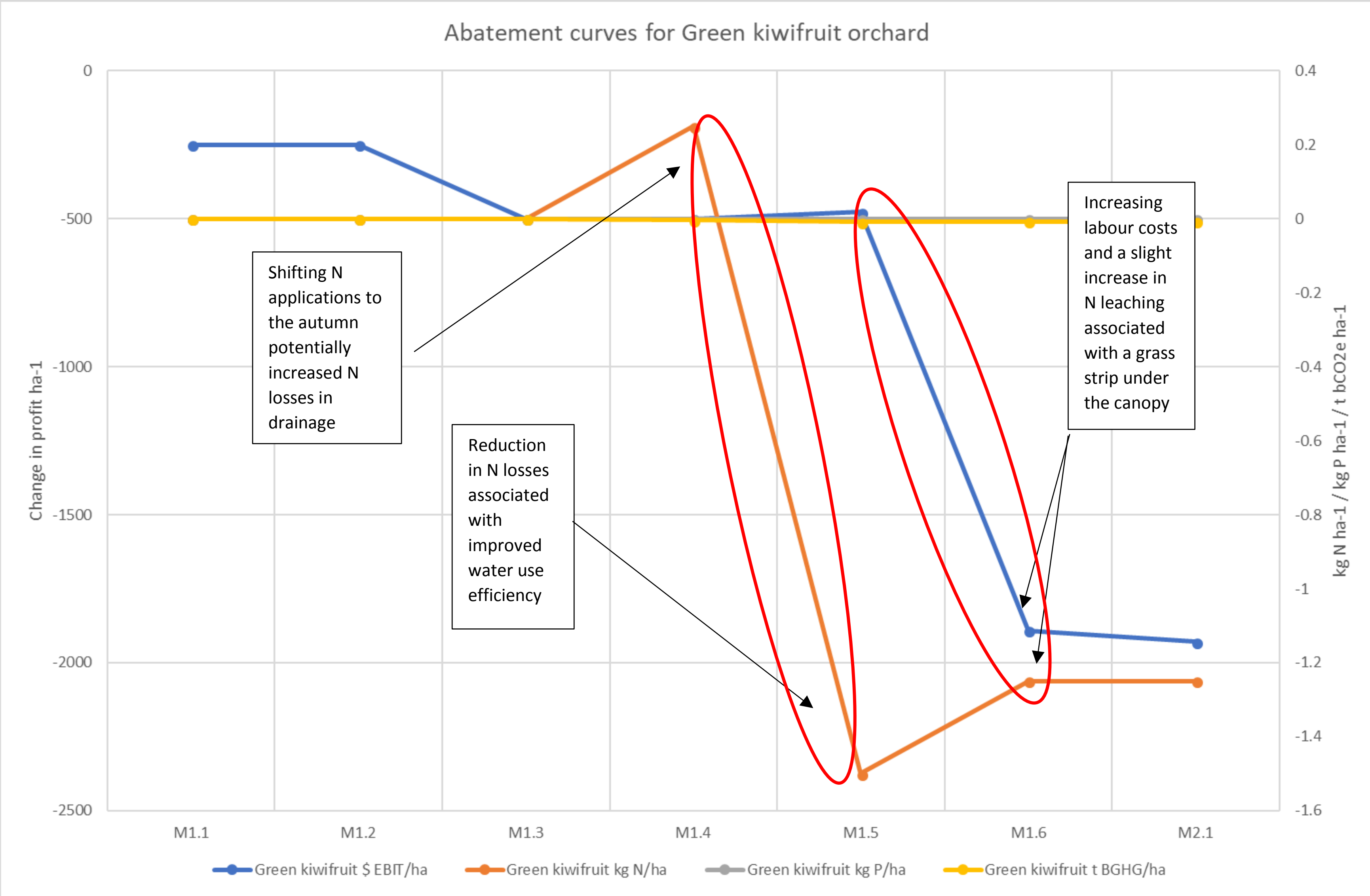

Figure 23: Sequential abatement curves for $ change in profit (LHS) and change in contaminant output (RHS) for the Green kiwifruit orchard system

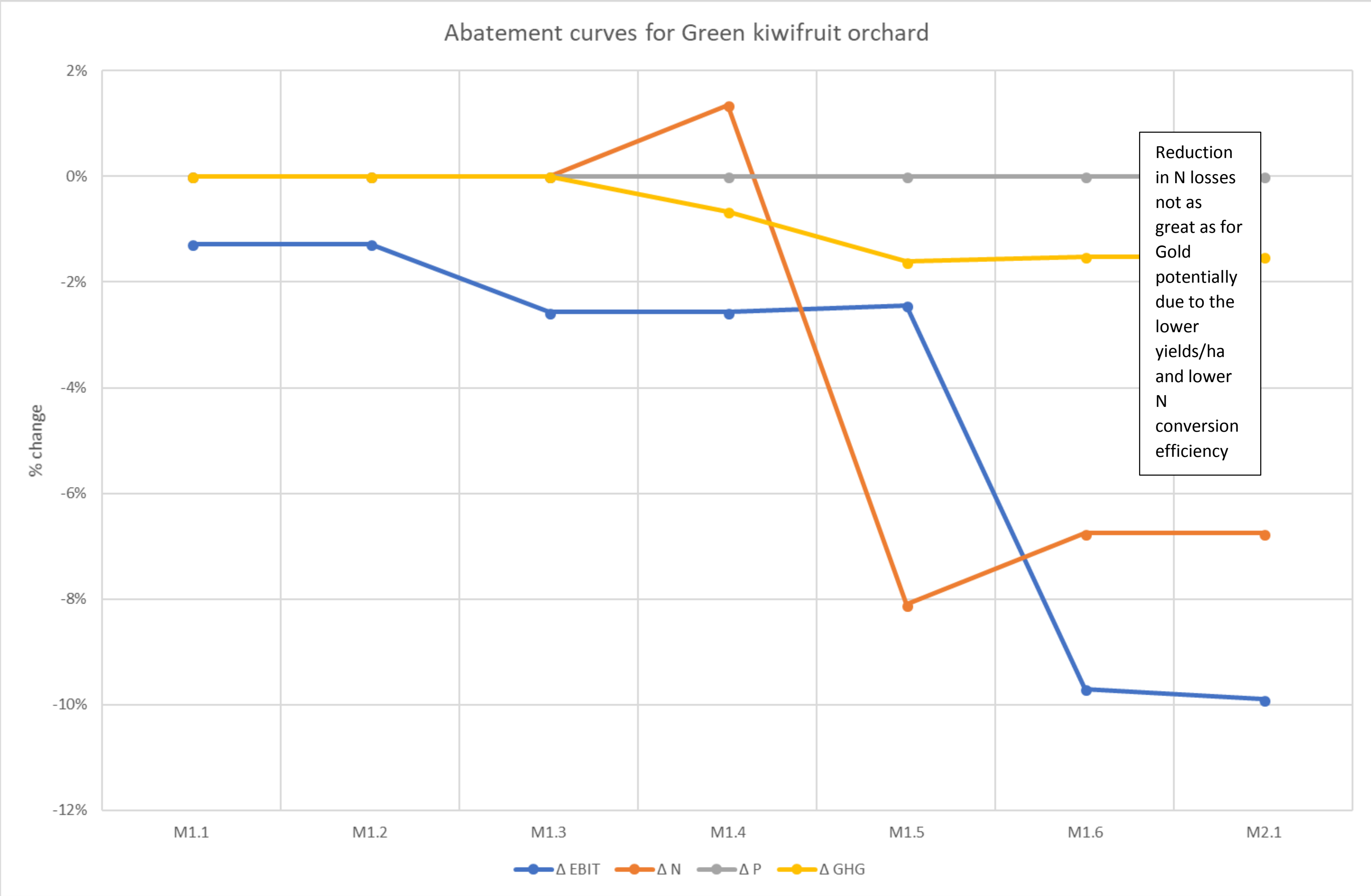

Figure 24: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Green kiwifruit orchard system

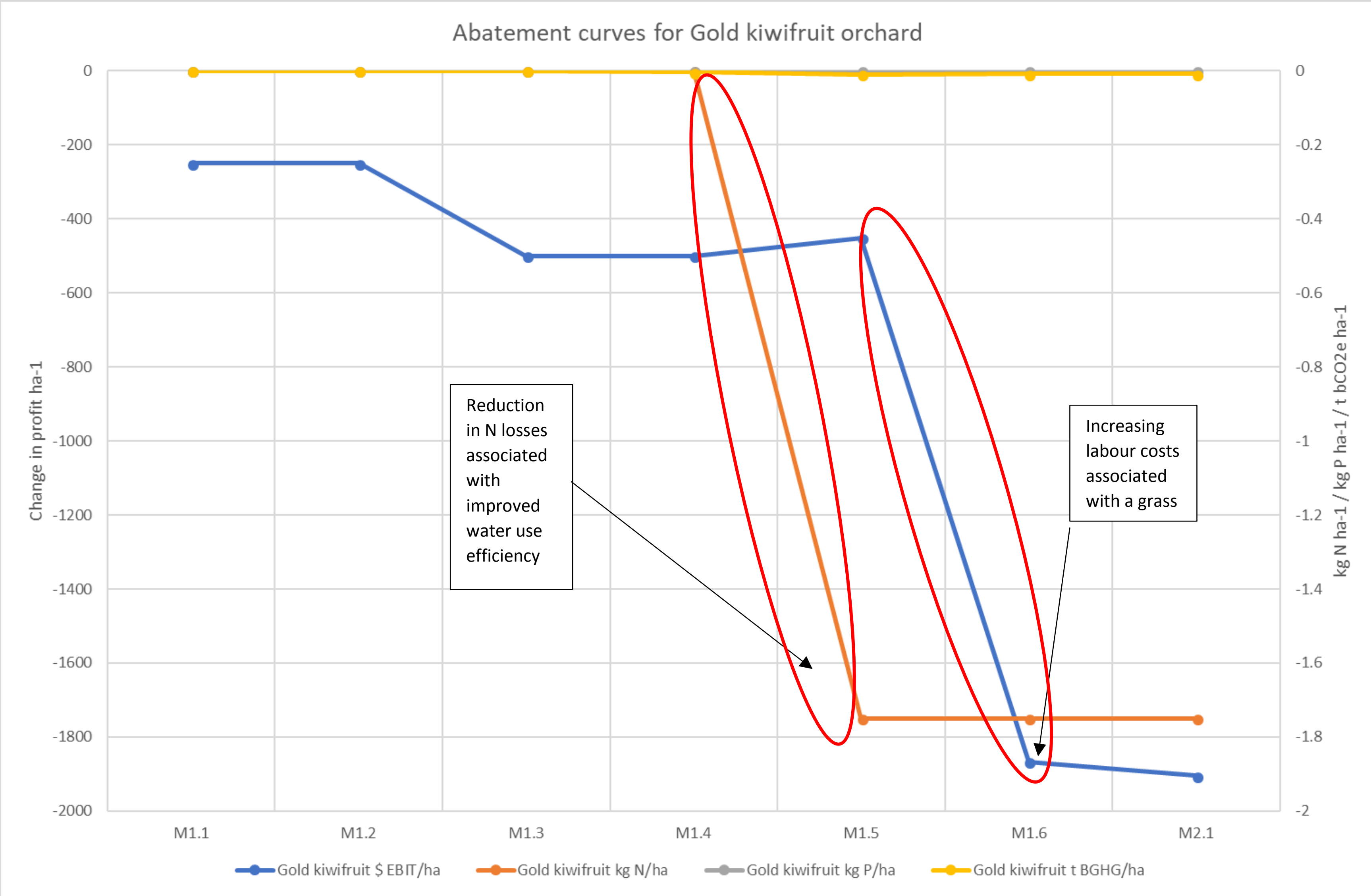

Figure 25: Sequential abatement curves for change in profit (LHS) and change in contaminant output (RHS) for the Gold kiwifruit orchard system

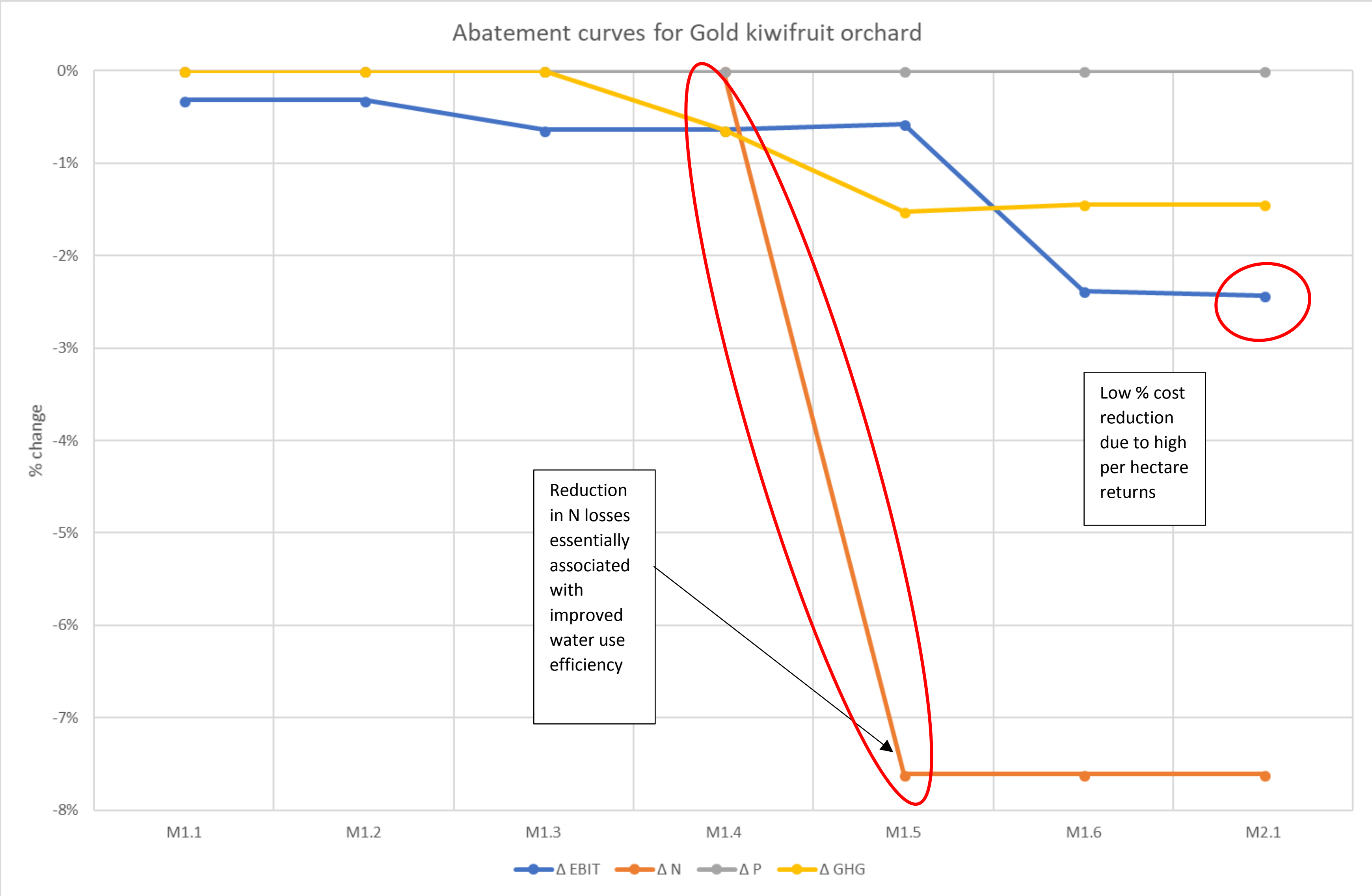

Figure 26: Sequential abatement curves for relative (%) change in profit and in contaminant output for the Gold kiwifruit orchard system

8 Conclusions

As modelled, most of the proposed individual mitigations had relatively modest impacts on annual farm system profitability, with significant impacts generated by key mitigation practices, which flowed through into the overall bundle cost. This was similarly observed for N, P and BGHG losses (as estimated by OVERSEER) albeit often for different practices.

For the dairy farm systems, the most-costly mitigations were:

- Development of stand-off pad infrastructure;
- Wetland developments;
- Creation of lined effluent storage;
- Substitution of autumn N fertiliser with supplementary feeds; and
- Reducing feed imported in the autumn.

On average, full adoption of the mitigation bundles on the dairy farm systems modelled reduced N losses by 44%, P losses by 21%, BGHG emissions by 17% and reduced profitability by 35% of current profit levels.

For the drystock farm systems, the most-costly mitigations were:

- Conversion of steep land to forestry;
- Wetland development;
- Elimination of N fertiliser that supported capital (breeding) livestock;
- Incorporation of low N forages into the farm system; and
- Gorse management.

Full adoption of the mitigation bundles on the dairy farm systems modelled reduced N losses by 14%-35%, P losses by 0%-38% and BGHG emissions by 8%-34%% - with a reduction in profitability ranging between 53% and 183% of existing profits. Compared to dairy farm systems, the sheep, beef and deer farms tended to be substantially affected by bundle implementation, particularly in the Kaituna-Pongakawa-Waitahanui WMA.

For the arable farm system, the costliest mitigation was reducing N fertiliser inputs (which resulted in significant yield loss) and for the orchards moving to having pasture under the vine canopies was judged to add significant per hectare cost associated with mowing the grass.

Apart from the profitability impacts of these mitigations, the net capital cost to fully implement M3 was in the vicinity of $369,000 ($3,000/ha) for non-irrigated dairy farms, $636,000 ($5,400/ha) for irrigated dairy farms and $394,000 for the sheep, beef and deer farms (c. $1,000/ha). In contrast, the capital costs of implantation we judged to be low for the arable and kiwifruit models at $14,000 ($350/ha) and $3,000 ($750/ha) respectively.

Some amendments to the mitigations in the bundles are probably warranted on the basis of the analysis, as is more work on addressing the contrast and tensions between the cashflow impacts and the potential longer-term value uplift from using partial land-use change to forestry as a mitigation.

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Appendix 1: Summary of model development

Landuse	APSIM	Refinements from Green et al.	Revised Perrin suggestions	Final models	Model name
Dairy	Dairy	Lower KPW (flat) dairy	Lower KPW (flat) dairy	Lower KPW (flat) dairy	Lower KPW
		Mid-Upper KPW (hill) dairy	Mid-Upper KPW (hill) dairy	Mid KPW	Mid KPW
				Upper KPW	Upper KPW
				Mid Rangitaki dairy	Mid Rangitaiki
	High intensity dairy	Rangitaiki (flat) dairy	Rangitaiki (flat) dairy	Lower Rangitaiki dairy	Lower Rangitaiki
			Rangitaiki (flat) irrigated dairy	Mid Rangitaiki irrigated dairy	Mid Rangitaiki irrigated
Sheep & Beef	Sheep & Beef	Sheep & Beef	Rangitaiki extensive breeding/finishing sheep cattle operation;	Rangitaiki extensive breeding/finishing sheep cattle operation;	Rangitaiki S+B
			Mid-Upper KPW dairy support	Mid-Upper KPW sheep & beef	KPW S+B
				Mid-Upper KPW dairy support	KPW DS
Kiwifruit	Kiwifruit	Green	Green	Green	Kiwi green
		Gold	Gold	Gold	Kiwi gold
		Organic	Organic		
Deer	Deer	Deer - venison operation	Rangitaiki breeding/finishing vension operation	Rangitaiki breeding/finishing vension operation	Rangitaiki D
Arable	Maize	Maize silage	Lower KPW maize silage and dairy support (winter cows)	Lower KPW maize silage and dairy support (winter cows)	KPW A
Vegetables	Vegetables	Te Teko vegetable rotation	Lower Rangitaiki vegetable rotation		
Forestry	Forestry	Radiata pine	Radiata pine	Radiata pine	Radiata pine
				Mānuka	Mānuka
Numbe of models	*7*	*10*	*12*	*15*	*15*

Appendix 2: Baseline dairy farm model profitability estimate

	Lower KPW	Mid KPW	Upper KPW	Lower Rangitaiki	Mid-Upper Rangitaiki	Mid-Upper Rangitaiki irrigated
	($)	($)	($)	($)	($)	($)
Income						
Milk sales	777,411	612,730	589,289	726,611	669,760	752,256
Net Livestock Sales	44,346	33,178	33,724	34,647	34,462	37,876
Contract Grazing	-	-	-	-	-	-
Change in Livestock Value	-	-	-	-	-	-
Total Revenue	821,757	645,908	623,013	761,258	704,222	790,132
Expenses						
Labour costs	136,884	106,140	106,140	115,656	110,166	110,166
Wages	86,768	67,280	67,280	73,312	69,832	69,832
Management Wage (assumir	50,116	38,860	38,860	42,344	40,334	40,334
Stock expenses						
Animal Health	33,461	26,048	25,941	28,148	27,051	27,051
Breeding	10,628	8,241	8,241	8,980	8,553	8,553
Farm Dairy	6,009	4,783	4,530	5,300	4,835	4,888
Electricity	16,082	12,470	12,470	13,588	12,943	12,943
Feed expenses						
Pasture Conserved	-	6,720	-	7,840	5,864	10,468
Feed Crop	-	8,400	11,250	-	16,300	16,860
Bought Feed	51,223	44,173	29,728	16,320	22,568	12,278
Calf Feed	2,335	1,829	1,817	1,877	1,871	1,871
Grazing	95,355	47,966	79,123	49,238	90,538	76,888
Other Farm Working						
Fertiliser (Excl. N)	32,940	26,840	25,620	35,451	34,866	34,047
Nitrogen	32,034	24,343	22,891	21,341	20,935	23,539
Irrigation	-	-	-	-	-	43,875
Regrassing	7,200	1,800	5,400	7,200	2,100	2,220
Weed & Pest Control	5,002	5,002	5,002	4,797	4,797	4,797
Vehicle Expenses	13,176	13,176	13,176	12,636	12,636	12,636
Fuel	8,418	8,418	8,418	8,073	8,073	8,073
R&M Land/Buildings	32,086	32,086	32,086	30,771	30,771	30,771
Freight & Cartage	8,228	6,380	6,380	6,952	6,622	6,622
Overheads						
Administration Expenses	18,300	18,300	18,300	17,550	17,550	17,550
Insurance	8,540	8,540	8,540	8,190	8,190	8,190
ACC Levies	4,514	4,514	4,514	4,329	4,329	4,329
Rates	18,178	18,178	18,178	17,433	17,433	17,433
Total Farm Working Expenses	540,593	434,347	447,745	421,670	468,991	496,048
Depreciation	39,284	39,284	39,284	37,674	37,674	45,981
Total Farm Expenses	579,877	473,631	487,029	459,344	506,665	542,029
Earnings before interest and tax	241,880	172,277	135,984	301,914	197,557	248,103
per ha	1,983	1,413	1,115	2,582	1,689	2,121

Appendix 3: Baseline dry stock and arable farm model profitability estimates

Land use	Sheep & beef			Deer	Arable
Model	KPW DS	KPW S+B	Rangitaiki S+B	Rangitaiki D	KPW A
	($)	($)	($)	($)	($)
Income					
Sheep					
Sales - Purchases	-	118,384	131,729	14,443	-
Wool	-	43,956	44,668	-	-
	-			-	-
Beef					
Sales - Purchases	-	20,626	248,483	-	-
Contract Grazing	339,661	150,908	162,422	-	48,000
Deer					
Sales - Purchases	-	-	-	331,549	-
Velvet	-	-	-	6,398	-
Crop & feed sales	-	-	26,928	12,800	230,500
Total Revenue	339,661	333,874	614,230	365,190	278,500
Expenses					
Labour (at arms length)	78,960	69,894	76,200	75,566	13,500
Stock					
Animal Health	-	11,208	11,594	9,169	-
Shearing	-	18,699	20,911	-	-
Velveting	-	-	-	977	-
Feed/Crop/Grazing					
Conservation	30,460	7,684	32,305	16,733	11,100
Forage Crops	-	-	21,600	11,700	144,000
Regrassing	-	-	14,400	7,800	-
Other Farm Working					
Fertiliser (Excl. N & Lime)	24,570	35,640	47,865	23,328	2,040
Nitrogen	5,472	4,284	22,348	14,791	-
Lime	2,160	2,991	5,390	2,991	369
Weed & Pest Control	4,898	6,781	12,223	6,781	837
Vehicle Expenses	7,200	9,969	17,970	9,969	1,231
Fuel	5,644	7,815	14,086	7,815	965
Repairs & Maintenance	29,809	43,072	63,596	33,942	2,677
Freight & Cartage	7,497	10,833	15,995	8,537	673
Electricity	3,869	5,590	8,253	4,405	347
Standing Charges					
Administration Expenses	9,112	12,617	22,741	12,617	1,558
Insurance	4,666	6,461	11,645	6,461	798
ACC Levies	2,015	2,903	5,182	3,141	344
Rates	11,115	15,390	27,740	15,390	1,900
Total Farm Working Expense	227,447	271,831	452,044	272,113	182,339
Depreciation	13,712	18,986	34,222	18,986	2,344
Total Farm Expenses	241,159	290,817	486,266	291,099	184,683
Earnings before interest and tax	98,502	43,057	127,964	74,091	93,817
per ha	421	133	219	229	2,345

Appendix 4: Baseline green and gold kiwifruit orchard model profitability estimates

Operating profit model	**Haywards**	**G3**
Proportion of potential yield	100%	100%
Trays/ha	10,500	14,000
		0
Orchard gate returns	57,750	126,000
less		-
Operating expenses	25,800	27,400
Operating surplus	31,950	98,600
less		-
Harvesting costs	4,200	6,700
Contract management	2,500	2,000
		-
EBITDA	25,250	89,900
less		-
Depreciation (20yrs)	5,750	11,500
		-
EBIT	**19,500**	**78,400**

Appendix 5: Baseline radiata pine forestry profitability (28 year unpruned regime)

AREA to be replanted (ha) 1 ha

	FORESTRY INVESTMENT - FRAMING MANAGEMENT REGIME												
	YEAR 1	**YEAR 2**	**YEAR 3**	**YEAR 4**	**YEAR 5**	**YEAR 6**	**YEAR 7**	**YEAR 8**	**YEAR 9**	**YEAR 10**	**YEAR 11**	**YEAR 12 - 27**	**YEAR 28**
Pre-plant release	$ 833												
Supply, plant and release	$ 667												
Releasing													
Survival and Releasing Assessment		$ 8											
Pruning							$ -						
Thinning								$ 874					
Management/Protection/Maintenance													
Mapping & Stand Records	$ 27	$ 2	$ 1	$ 1	$ 49	$ 10	$ 10	$ 10	$ 2	$ 2	$ 2	2	
Fire Levy & Water Points			$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	2	
Forest Health & Dothistroma Control			$ 4	$ 4	$ 22	$ 4	$ 4	$ 24	$ 4	$ 4	$ 4	4	
Pest & Weed Control	$ 18	$ 18	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	7	
Property Maintenance	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	5	
Road & Track Maintenance	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	5	
Insurance	$ 5	$ 10	$ 10	$ 10	$ 10	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	
Rates	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	
Management	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	7	
Total cost $ per Hectare	**$ 1,667**	**$ 155**	**$ 141**	**$ 141**	**$ 207**	**$ 156**	**$ 156**	**$ 1,050**	**$ 147**	**$ 147**	**$ 147**	**$ 147**	**$ -**
TOTAL COST	**$ 1,667**	**$ 155**	**$ 141**	**$ 141**	**$ 207**	**$ 156**	**$ 156**	**$ 1,050**	**$ 147**	**$ 147**	**$ 147**	**$ 147**	**$ -**
Estimated stumpage (net log revenue)/ha													**$ 43,494**
TOTAL INCOME	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$ 43,494**
CASHFLOW	-$ 1,667	-$ 155	-$ 141	-$ 141	-$ 207	-$ 156	-$ 156	-$ 1,050	-$ 147	-$ 147	-$ 147	-$ 147	$ 43,494
capital/lease for land	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL CASHFLOWS	**-$ 1,667**	-$ 155	-$ 141	-$ 141	-$ 207	-$ 156	-$ 156	-$ 1,050	-$ 147	-$ 147	-$ 147	-$ 147	$ 43,494

NPV	$6,827.15
discount rate	5.0%
internal rate of return	**9.71%**

NPV per ha	$6,827.15
Equivalent annuity over 28 years	$530.27

Appendix 6: Baseline radiata pine forestry profitability (28 year unpruned regime) incl. carbon

AREA to be replanted (ha) 1 ha

	FORESTRY INVESTMENT - FRAMING MANAGEMENT REGIME												
	YEAR 1	**YEAR 2**	**YEAR 3**	**YEAR 4**	**YEAR 5**	**YEAR 6**	**YEAR 7**	**YEAR 8**	**YEAR 9**	**YEAR 10**	**YEAR 11**	**YEAR 12 - 27**	**YEAR 28**
Pre-plant release	$ 833												
Supply, plant and release	$ 667												
Releasing													
Survival and Releasing Assessment		$ 8											
Pruning							$ -						
Thinning								$ 874					
Management/Protection/Maintenance													
Mapping & Stand Records	$ 27	$ 2	$ 1	$ 1	$ 49	$ 10	$ 10	$ 10	$ 2	$ 2	$ 2	2	
Fire Levy & Water Points			$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	$ 2	2	
Forest Health & Dothistroma Control			$ 4	$ 4	$ 22	$ 4	$ 4	$ 24	$ 4	$ 4	$ 4	4	
Pest & Weed Control	$ 18	$ 18	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	7	
Property Maintenance	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	5	
Road & Track Maintenance	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	5	
Insurance	$ 5	$ 10	$ 10	$ 10	$ 10	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	$ 15	
Rates	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	
Management	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	7	
Total cost $ per Hectare	**$ 1,667**	**$ 155**	**$ 141**	**$ 141**	**$ 207**	**$ 156**	**$ 156**	**$ 1,050**	**$ 147**	**$ 147**	**$ 147**	**$ 147**	**$ -**
TOTAL COST	**$ 1,667**	**$ 155**	**$ 141**	**$ 141**	**$ 207**	**$ 156**	**$ 156**	**$ 1,050**	**$ 147**	**$ 147**	**$ 147**	**$ 147**	**$ -**
Carbon transactions										169			
Carbon revenue $25 /t	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 4,225**	**$ -**	**$ -**	**$ -**
Estimated stumpage (net log revenue)/ha													**$ 43,494**
TOTAL INCOME	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ -**	**$ 4,225**	**$ -**	**$ -**	**$ 43,494**
CASHFLOW	-$ 1,667	-$ 155	-$ 141	-$ 141	-$ 207	-$ 156	-$ 156	-$ 1,050	-$ 147	$ 4,078	-$ 147	-$ 147	$ 43,494
capital/lease for land	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL CASHFLOWS	**-$ 1,667**	-$ 155	-$ 141	-$ 141	-$ 207	-$ 156	-$ 156	-$ 1,050	-$ 147	$ 4,078	-$ 147	-$ 147	$ 43,494

NPV	$9,420.93
discount rate	5.0%
internal rate of return	**12.60%**

NPV per ha	$9,420.93
Equivalent annuity over 28 years	$632.36

Appendix 7: Baseline Mānuka plantation profitability (third-party honey regime)

PLANTED MANUKA REGIME WITH HONEY INCOME STREAM

Area to plant 30.0 **ha**

Assumptions			
Income			**Notes**
Hives per ha	1.5	hives	
Rent paid for hives	$100	per hive	
Total honey profit ($/ha)	$1,500	per ha	Approx every 5 years there is a bad season with no honey yields
Profit share paid to owner	10%		
Carbon Price	$21.0	per t CO_2	Current carbon price
Expenses			
Planting Manuka	$2,000	per ha	
Spray release and stock replacement	$550	per ha	
Insurance	$30	per ha	
Rates	$40	per ha	
Manuka Plant Maintenance	$100	per ha	
Interest Rate	5%		

Income	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**SQ Year 5+**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**	**Year 13**	**Year 14**
Rent paid for hives				$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500
Share of profit				$4,500	$4,500	$4,500	$4,500	$4,500	$0	$4,500	$4,500	$4,500	$4,500	$0
Gross income	$0	$0	$0	$9,000	$9,000	$9,000	$9,000	$9,000	$4,500	$9,000	$9,000	$9,000	$9,000	$4,500
Operating Expenses														
Planting Manuka	$60,000													
Spray release and stock replacement		$16,500												
Manuka Plant Maintenance				$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000	$3,000
Insurance	$900	$900	$900	$900	$900	$900	$900	$900	$900	$900	$900	$900	$900	$900
Rates	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200	$1,200
Total Expenses	$62,100	$18,600	$2,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100	$5,100
Cash Surplus/Deficit	**-$62,100**	**-$18,600**	**-$2,100**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**-$600**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**-$600**
EBIT	**-$62,100**	**-$18,600**	**-$2,100**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**$3,900**	**-$600**	**$72,570**	**$2,640**	**$6,420**	**$6,420**	**$3,180**
per ha					**$130**									

Appendix 8: Dairy bundle modelling protocols

M1 mitigations

M1.2 Effluent applied in line with soil moisture levels

"Applications are actively managed box" ticked on the Effluent Block effluent tab in OVERSEER.

M1.3 Reduced tillage practices

Where conventional cultivation has been used, select "direct drill" in OVERSEER for forage brassicas or "minimum till" for cereal/vegetable crops instead. No cost savings are generated from this practice, as additional pest control is typically required when prior vegetation is only desiccated and not cultivated into the ground.

M1.4 Improved nutrient budgeting and maintenance of Olsen P

Reduce soil Olsen P levels to average of optimum range if above, to lower end of the range if below and on flat to rolling contour or leave on steeper land, adjust assumed fertiliser inputs to required P inputs as determined by "Maintenance nutrients" tab in Block reports in OVERSEER. Adjust fertiliser expenditure accordingly and add $500 annual cost for nutrient budgeting advice.

M1.5 Laneway run-off diversion

Assume a further $500/annum in Repairs and Maintenance (R&M) Tracks expenditure.

M1.6 Grow maize on effluent block

Ensure maize crop rotates through effluent block if it not already doing so. Potentially savings in N and P fertiliser in doing so.

M1.7 Elimination of summer cropping

Summer cropping eliminated, and feed substituted with no more than 3kg/cow/day of PKE, with associated feeding and capital costs if required. Regrassing of the same area is now assumed to occur as grass-to-grass renovation in the autumn.

NOTE: Excluded from the bundles until OVERSEER 6.3.0 N loss changes have been confirmed or otherwise.

M1.8 Reductions in seasonal stocking rate

Cull 10% of total culls in early Feb (if not already culling in that window) and a further 10% of culls in early March. Intakes of remaining cows increased to maintain total production (kg MS per peak cow milked).

M1.9 Efficient fertiliser use technology

Reduction in N fertiliser use with no loss of DM production due to improvements in the CV of spread on flat and rolling country. Additional $2,000 per annum cost for use of this technology and N fertiliser savings (Perrin Ag 2017). Modelled in Farmax with a reduction in quantity of 12%, but commensurate increase in assumed response rate.

M1.10 Efficient irrigation practices

Use of a simple tensiometer is assumed to deliver a 50% reduction in spring shoulder (November) water use with no production loss, with a commensurate reduction in water (and electricity) usage.

M1.11 Use of plant growth regulators [to replace N]

Assumed gibberellic acid (GA) applied to a single winter N application (on all flat and rolling land), with the additional DM response from the GA (14kg DM/kg N as per Boom et al 2016) utilised to reduce or eliminate the next subsequent N application. The cost of the GA was assumed at $38/ha - $8/ha for the product and $30/ha for contract application.

M1.12 Adoption of low N leaching forages

Assume 4kg plantain seed included in all permanent pasture seed mixes, adding $90.40+GST/ha (Source: PGGW) to the cost of regrassing. Assuming 10% of farm is re-grassed annually and with the plantain able to be considered persistent in the sward for two years, this should be sufficient to ensure 20% of the farm area might be considered to be sown in a “diverse pasture”. No farm productivity benefits have been assumed and the N loss impact as not yet modelled in OVERSEER.

M1.13 Relocation of troughs

Assumed relocation of troughs located in ephemeral flow paths at a cost of $360+GST (trough and fittings) and $120+GST per trough installation (Perrin Ag 2018b). Assume 5% of paddocks require one trough to be relocated, with an assumption of 60 paddocks per farm.

M1.14 Slow release RPR fertiliser

It is assumed a one-off capital application of RPR (3x maintenance) will be required to offset the lower availability, with RPR used normally thereafter. The quantity of 20% potash super phosphate assumed to be used has been replaced by a high P RPR, MOP and Sulphurgain Pure special mix to deliver identical nutrients.

M1.15 Reduce autumn N application

One autumn N application is replaced by the use of imported supplementary feed. PKE used for dry cow supplementation, up to 3kg/cow/day for milkers and then maize silage used for milking cows. If no PKE is currently being fed to dry cows, the capital impact of purchasing of trolleys has been accounted for. An increase in annual vehicle expenses (equivalent to 20% of the cost of the additional feed) is also included to account for the true cost of feeding out.

M1.16 3m average vegetated and managed buffer around rivers, streams, lakes and wetlands subject to the Dairy Accord; 1m around drains; 5m average buffer on slopes between 8 and 16 degrees, 10m average buffer on slopes above 16 degrees

GIS analysis provided by the Bay of Plenty Regional Council estimate the total length of fencing required to fence all Dairy Water Accord waterways for each geo-physical area modelled and the loss of pastoral area associated with increasing the buffer width. Fencing costs were modelled on a three-wire electric fence, with all posts and 50% of wire used in existing accord fencing assumed to be able to be re-used, but a higher per metre rate assumed for labour cost associated with the material recycling.

A native sedge vegetation option (see page 36 of the Dairy NZ Waterway Technical Notes, 2016) was assumed for the vegetation program (costed at an average of $20 per lineal metre of waterway planted, assuming both sides of the waterway were planted), with annual weed control costs of $130/ha retired (De Monchy 2018, pers. comm).

A subsidy of 25% from the BOPRC for all fencing and planting works has been assumed.

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

M2 mitigations

M2.1 Increase effluent application area

Effluent areas were increased in order to reduce the annual N application applied as dairy farm effluent (FDE) to 100kg N/ha. The cost of expanding the effluent area was costed at $705/ha, assuming one hydrant for every 4 hectares of new effluent area (Perrin Ag 2018b[5]). Maintenance P fertiliser applications were adjusted to reflect the change in effluent area, but N applications remained unchanged. It was assumed that the existing effluent pumps were of sufficient size to deliver effluent to the expanded area.

[5] Source: ABC Milking Ltd, FarmSource

M2.2 Develop a detention bund

A detention bund sufficient to detain a catchment of 40ha was assumed (approximately 4,800m^3 of storage), costing approximately $10,000+GST to install (Perrin Ag 2018b).

M2.3 Duration controlled grazing in autumn (assuming an existing stand-off pad)

A proportion of the milking herd will be stood-off for 16 hours per day during the autumn (March and April), subject to an allowance of 15m^2 per lactating cow. It has been assumed that effluent from the stand-off pad will be actively managed, with an associated additional labour cost (1.5 hours per day ($25/hour) for 61 days) and higher annual R&M costs ($1,000 per annum). It is also assumed that some capital upgrade to the stand-off area will be required to capture effluent from the pad and allow it to be actively managed within the effluent system - a $10,000+GST capital cost has been estimated.

M2.5 Reduce autumn supplement fed by 20%

Total imported feed fed from Mar through May is lowered by 20%. This is managed through drying cows off earlier than otherwise scheduled and using any pasture cover left to feed remaining milkers a higher pasture intake. Fuel and vehicle costs are reduced by 20% of the feed cost eliminated.

M2.6 Reducing fertiliser use

Annual N fertiliser usage to pasture is reduced to no more than 100kg N/ha. Autumn N will be eliminated ahead of spring N, with cows dried off to manage any feed deficit.

M2.7 Full stock exclusion from permanently flowing waterbodies less than 1m wide (REC Order 2 and above) and average 2m vegetated and managed buffer; 3m average buffer on slopes between 8 and 16 degrees, 7m average buffer on slopes above 16 degrees

GIS analysis provided by the Bay of Plenty Regional Council estimate the total length of fencing required to fence all permanently flowing waterways smaller than those mandated under the Dairy Water Accord, for each geo-physical area modelled and the loss of pastoral area associated with increasing the buffer width. Fencing costs were modelled on a new three-wire electric fence.

A native sedge vegetation option (see page 36 of the Dairy NZ Waterway Technical Notes, 2016) was assumed for the vegetation program (costed at an average of $20 per lineal metre of waterway planted, assuming both sides of the waterway were planted), with annual weed control costs of $130/ha retired (De Monchy 2018, pers. comm).

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

M3 mitigations

M3.1 Afforestation of erosion prone land

GIS analysis provided by the Bay of Plenty Regional Council estimate the loss of pastoral area associated with retiring steep land (>26 deg) determined as prone to erosion for each geo-physical area modelled.

Areas less than 2ha in size were assumed to require fencing off with a three-wire electric fence (assume 200m per hectare fenced off) and planted in mānuka or similar non-commercial native plant species ($2,500+GST/ha). Annual maintenance costs of $100/ha planted have been assumed (Perrin Ag, 2018b).

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

M3.2 Stock excluded from REC Order 1 watercourses less than 1m wide and 1m wide average vegetated buffer

GIS analysis provided by the Bay of Plenty Regional Council estimate the total length of fencing required to fence all ephemeral water courses (those likely to be considered by farmers as "wet all winter") for each geo-physical area modelled and the loss of pastoral area associated with increasing the buffer width. Fencing costs were modelled on a new three-wire electric fence.

A native sedge vegetation option (see page 36 of the Dairy NZ Waterway Technical Notes, 2016) was assumed for the vegetation program (costed at an average of $20 per lineal metre of waterway planted, assuming both sides of the waterway were planted), with annual weed control costs of $130/ha retired (De Monchy 2018, pers. comm).

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

NOTE: Was previously M3.3

M3.3 Impervious effluent storage with sufficient capacity to comply with soil moisture guidelines and low rate effluent application.

A lined effluent pond suitable to hold 90 days storage was estimated at a capital cost $175+GST per cow due to calve (Perrin Ag 2018b[6]), inclusive of low rate effluent application equipment. Depreciation rates were increased based on a 20-year lifespan for the pond. Once in place, the system allowed the "Low application method" option to be selected in the Block effluent tab in OVERSEER.

NOTE: Was previously M3.2

[6] Source: Seays Earthmovers

M3.4 Installation of roof to pre-existing stand-off area and extension of use for duration-controlled grazing to winter (May/June)

The cost to install a kitset plastic skinned shelter over an existing stand-off area is estimated at \$110+GST per square metre (Perrin Ag 2018b[7]). It has been assumed that extended use of the stand-off pad incurs an additional labour cost (1 hour per day (\$25/hour) for 61 days in May & June). Depreciation rates were increased based on a 20-year lifespan for the pond and the roof's prevention of water entering the effluent system will allow the assumption that the increased effluent storage in M3.2 is sufficient to manage the additional effluent. Once the cows are dry, an allowance of $5m^2$ per cow is deemed sufficient.

M3.5 Installation of stand-off pad and use for 16 hours per day in autumn

The cost to install a compliant stand-off area (carbon based) sufficiently large to stand-off all lactating cows ($15m^2$/cow) for 16 hours per day is estimated at a capital cost of \$720/cow, with an annual maintenance cost of \$60/cow (Perrin Ag 2018b). It has been assumed that effluent management from the stand-off pad will be actively managed, with an associated additional labour cost (1.5 hours per day (\$25/hour) for 61 days)

M3.6 Installation of a centre-pivot with VRI technology to replace K-line spray irrigation

A net \$4,600/ha cost to replace existing K line systems was assumed (Perrin Ag 2018b). Water (and irrigation costs) use reduced by 25% for no production loss and a labour saving of 2 hours per day for 135 days, but increase in depreciation.

M3.7 Creation of new wetlands

The creation of wetlands totalling 3% of farm landscape with a potential 100% reduction in nitrate nitrite nitrogen (NNN) from roughly 1/5th of the total farm area is assumed. The development cost has been estimated at \$3,000/ha (Perrin Ag 2018a).

The base farm system has then been proportionally scaled back to ensure feasibility was maintained in line with the average pasture cover track in the immediately preceding scenario.

Wetlands have been entered in OVERSEER on the basis of the following input parameters:

- Wetland condition: Artificial Type 1 - Flow path length to width ratio >5 (2 or more stage wetland[8], with even elongated channel or serpentine path created using internal bunds), well vegetated with good dispersion and even flow through the majority of wetland and minimal channelisation or dead-zones;
- Wetland type: Type A;
- Catchment area: 20% of total farm area;
- Catchment convergence: High convergence;

[7] Source: Redpath Shelters
[8] Where water "treatment" process of the wetland and separated into different steps

- Aquitard depth: 3-5m.

M3.8 Reduction in per hectare stocking rate

Stocking rate (defined as peak cow milked per hectare) is reduced by 0.3 cows/ha. The management capability horizon is held constant (which includes the assumed wages of management), requiring per cow production to remain static (no more than 10kg MS/cow/year increase) and the lower stocking rate managed by reductions in imported feed and fertiliser N usage. Maintenance P fertiliser inputs were then re-optimised based on any change in feed inputs, with adjustments made to expenses based on the savings in the reduction in feeding out. The capital impact of a reduction in cow numbers is also accounted for.

The per cow production horizon was allowed to increase for those farms with summer (January-February) growth rates in excess of 40kg DM/ha/day as it was considered an easy management decision to allow cow intakes of high quality pasture to increase. In practice this only applied to irrigated pasture and the Lower Rangitāiki dairy farm system.

Appendix 9: Drystock bundle modelling protocols

M1 mitigations

M1.1 Improved nutrient budgeting and maintenance of Olsen P

Reduce soil Olsen P levels to average of optimum range if above, leave if below, adjust assumed fertiliser inputs to required P inputs as determined by "Maintenance nutrients" tab in Block reports in OVERSEER. Adjust fertiliser expenditure accordingly and add $500 annual cost for nutrient budgeting advice.

M1.2 Efficient fertiliser use technology

Reduction in N fertiliser use with no loss of DM production due to improvements in the CV of spread on flat and rolling country. Additional $2,000 per annum cost for use of this technology and N fertiliser savings (Perrin Ag 2011). Modelled in Farmax with a reduction in quantity of 12%, but commensurate increase in assumed response rate.

M1.3 Stock class management within landscape

Ensuring stock classes are grazed on appropriate landscapes is expected to be largely achievable on most properties without significant infrastructure or stock class changes. We have assumed an increase in labour costs equivalent to one hour per day over the winter period to optimally manage livestock in this manner (91 days x 1 hour/day x $25/hour).

For deer operations, this is largely associated with addressing wallows and fence running. We have assumed a one-off capital investment in fencing etc. with a cost of capital equivalent to the labour costs inferred above.

M1.4 Adopt M1 arable cultivation practices for winter cropping

This mitigation incorporated all the applicable M1 mitigations in the arable model. For winter forage brassicas, this included:

- Use of direct drilling in lieu of conventional cultivation;
- Optimising P fertiliser in line with expected yield;
- Use of improved spreading techniques for N fertiliser application;
- Use of a cover crop between winter grazing and re-sowing into new grass;
- Use of a grass buffer strip at the edge of all cultivated areas;
- Improved cultivation techniques on areas of contour;

On average, this was assumed to deliver a net cost of $57/ha to the winter cropping activity for no loss in net DM production. For more information see Appendix 3 below.

M1.5 Laneway run-off diversion

Assume a further $500/annum in R&M Tracks expenditure. For deer farms it is assumed any laneway diversion will be accounted for in the capital works associated with M1.3 above.

M1.6 Relocation of troughs

Assumed relocation of troughs located in ephemeral flow paths at a cost of $360+GST (trough and fittings) and $120+GST per trough installation (Perrin Ag 2018b[9]). Assume 5% of paddocks require one trough to be relocated, with an assumption of an average paddock size of 6ha.

M1.7 Appropriate gate, track and race placement

Assumed relocation of gates and tracks located in ephemeral flow paths at a cost of $1,500+GST per relocation. Assume 5% of paddocks require one gateway to be relocated, with an assumption of an average paddock size of 6ha. For deer farms it is assumed any laneway and gate relocation will be accounted for in the capital works associated with M1.3 above.

M1.8 Targeted space planting of poles

The targeted planting of poles to areas within paddocks that presented the greatest risk of erosion has been assumed. Average density of these plantings has been assumed at 25 stems/ha (a capital cost of 500/ha) over 2% of the farm area. Pasture production on the planted area is assumed to be unaffected, given the loss of pasture from shading is assumed to be offset by the reduction in pasture loss from erosion events that have typically been occurring.

M1.9 Slow release RPR fertiliser

It is assumed a one-off capital application of RPR (3x maintenance) will be required to offset the lower availability, with RPR used normally thereafter. The quantity of Sulphurgain 15S assumed to be used has been replaced by a high P RPR and Sulphurgain Pure special mix to deliver identical nutrients.

M1.10 Adoption of low N leaching forages

Assume 4kg plantain seed included in all permanent pasture seed mixes, adding $90.40+GST/ha (Source: PGGW) to the cost of regrassing. We have assumed 10% of the farm is re-grassed annually (via under sowing or similar) and with the plantain able to be considered persistent in the sward for two years, this should be sufficient to ensure 20% of the farm area might be considered to be sown in a “diverse pasture”. No farm productivity benefits have been assumed and the N loss impact as not yet modelled in OVERSEER.

[9] Source: PGGW

M1.11 Full stock exclusion from all waterbodies greater than 1m wide at any point adjacent to farm (including drains) and wetlands. 2m average vegetated and managed buffer around rivers, streams, lakes and wetlands; 1m around drains; 3m average buffer on slopes greater than 8 degrees; 5m average buffer on slopes greater than 16 degrees

GIS analysis provided by the Bay of Plenty Regional Council estimate the total length of fencing required to fence all Dairy Accord waterways for each geo-physical area modelled and the loss of pastoral area associated with increasing the buffer width. Fencing costs were modelled on a three-wire electric fence for dairy support ($5/m erected), 7 wire for sheep ($14/m erected) and deer fencing for deer ($26/m erected).

A native sedge vegetation option (see page 36 of the Dairy NZ Waterway Technical Notes, 2016) was assumed for the vegetation program (costed at an average of $20 per lineal metre of waterway planted, assuming both sides of the waterway were planted), with annual weed control costs of $130/ha retired (De Monchy 2018, pers. comm).

A subsidy of 25% from the BOPRC for all fencing and planting works has been assumed.

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

<u>M2 mitigations</u>

M2.1 Elimination of N fertiliser applied to accelerate liveweight gain

Assuming a "standard" pasture dry matter response to applied fertiliser nitrogen of 10:1, N fertiliser applied at a cost of $699+GST/t urea[10] equates to a cost of $0.15/kg DM produced. Where the gross margins of a livestock enterprise are less than this, then at the margins N fertiliser applied to produce feed for these classes of livestock is unlikely to be profitable. In these instances, is likely to be more profitable to reduce livestock numbers. Where N fertiliser is applied to accelerate liveweight gains in growing (trading) livestock (as is often the case with spring N) it is typically more profitable to adjust down the numbers of capital livestock (with a lower gross margin) to allow targeted weight gains to occur.

M2.2 Develop a detention bund

A detention bund sufficient to detain a catchment of 40ha was assumed (approximately 4,800m^3 of storage), costing approximately $10,000+GST to install. (Perrin Ag 2018b).

M2.3 Complete protection of gully heads

[10] Source: Ballance AgriNutrients

It has been assumed that gully heads erosion potential exists associated with the easy and steep contoured areas of a farm. We have assumed that these areas will need to be retired or have other capital works put in place to manage gully head erosion, with the cost of such works equating to $1,650/ha for 2% of area of the steep and easy contoured proportion of the farm, with half of that area (1%) needing to be retired (modelled as a riparian area in OVERSEER).

M2.4 Management of gorse

An additional $30/ha in annual weed & pest expenditure has been assumed to be used specifically for accelerated gorse control on the easy and steep contoured land. No productivity improvements have been assumed.

M2.5 Whole paddock space planting of poles

This is considered an applicable mitigation for north-facing easy contoured hill slopes in sheep grazing systems susceptible to erosion, given the exclusion of whole paddocks in solely cattle farming or deer farming systems is considered too disruptive during the establishment phase. Planting at 50 stems/ha ($1,000/ha establishment cost, Perrin Ag 2018a) has been assumed. As these paddocks have a northerly aspect, pasture production is typically low over summer anyway, so the shading impact of the trees as they mature is expected to have limited impact on pasture production. Combined with the reduction in soil loss and positive impacts that shading will have on animal welfare, the net production impact on the farm system is considered negligible. We have assumed 25% of a farm's easy contoured land to be suitable for these purposes.

M2.6 Full stock exclusion from permanently flowing waterbodies less than 1m wide (REC Order 2 and above) and 1m average vegetated and managed buffer; 2m average buffer on slopes greater than 8 degrees, 3m average buffer on slopes greater than 16 degrees [with associated stock water reticulation, if any]GIS analysis provided by the Bay of Plenty Regional Council estimate the total length of fencing required to fence all permanently flowing waterways smaller than those mandated under the Dairy Accord, plus all seeps, for each geo-physical area modelled and the loss of pastoral area associated with increasing the buffer width. Fencing costs were modelled on a new three-wire electric fence.

A native sedge vegetation option (see page 36 of the Dairy NZ Waterway Technical Notes, 2016) was assumed for the vegetation program (costed at an average of $20 per lineal metre of waterway planted, assuming both sides of the waterway were planted), with annual weed control costs of $130/ha retired (De Monchy 2018, pers. comm).

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

M2.7 Afforestation of erosion prone land

GIS analysis provided by the Bay of Plenty Regional Council estimate the loss of pastoral area associated with retiring steep land (>26 deg) determined as prone to erosion for each geo-physical area modelled.

Areas less than 2ha in size were assumed to require fencing off with a suitable stock-exclusion fence (assume 200m per hectare fenced off) and planted in mānuka or similar non-commercial native plant species ($2,500+GST/ha). Annual maintenance costs of $100/ha planted have been assumed. Areas greater than 2ha are considered suitable for commercial production forestry, with an establishment cost of $1,500/ha. The annualised benefit of production forestry on such areas has been added to EBIT on the basis of a forestry right payment of $200/ha planted. We recognise that this is lower than the likely annual return overtime based on a discounted cashflow approach if the trees were owned, but was selected to be conservative. The impact of forestry if a higher annual income equivalency was used is explored in the discussion.

Areas for planting comprised all the steep blocks in the relevant Farmax models, with the balance taken from easy contoured land (not already in space planted poles). Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

M2.8 Changing stock ratios to reflect lower N leaching potential

Increasing the sheep: cattle ratio would be expected to lower N leaching. The sheep:cattle ratio is adjusted by 10%, to a maximum ratio of 60:40 sheep: cattle.

<u>M3 mitigations</u>

M3.1 Full stock exclusion from REC Order 1 watercourses less than 1m wide and 1m wide average vegetated buffer

GIS analysis provided by the Bay of Plenty Regional Council estimate the total length of fencing required to fence all waterways that are less than 1m wide and REC Order 1[11] for each geo-physical area modelled and the loss of pastoral area associated with increasing the buffer width. Fencing costs were modelled on a new three-wire electric fence.

A native sedge vegetation option (see page 36 of the Dairy NZ Waterway Technical Notes, 2016) was assumed for the vegetation program (costed at an average of $20 per lineal metre of waterway planted, assuming both sides of the waterway were planted), with annual weed control costs of $130/ha retired (De Monchy 2018, pers. comm).

Unless the loss of area delivered a deviation from the baseline average pasture cover track or resulted in the model becoming unfeasible in Farmax the farm system was left unchanged. Where required, the base farm system was proportionally scaled back to ensure feasibility was maintained.

[11] all ephemeral water courses (those likely to be considered by farmers as "wet all winter")

M3.2 Creation of new wetlands

The creation of wetlands totalling 3% of farm landscape with a potential 100% reduction in nitrate nitrite nitrogen (NNN) from roughly 1/5th of the total farm area is assumed. The development cost has been estimated at $3,000/ha (Perrin Ag 2018a).

The base farm system has then been proportionally scaled back to ensure feasibility was maintained in line with the average pasture cover track in the immediately preceding scenario.

Wetlands have been entered in OVERSEER on the basis of the following input parameters:

- Wetland condition: Artificial Type 1 - Flow path length to width ratio >5 (2 or more stage wetland[12], with even elongated channel or serpentine path created using internal bunds), well vegetated with good dispersion and even flow through the majority of wetland and minimal channelisation or dead-zones;
- Wetland type: Type A;
- Catchment area: 20% of total farm area;
- Catchment convergence: High convergence;
- Aquitard depth: 3-5m.

M3.3 Elimination of N applications to support capital livestock

Assuming a “standard” pasture dry matter response to applied fertiliser nitrogen of 10:1, N fertiliser applied at a cost of $699+GST/t urea[13] equates to a cost of $0.15/kg DM produced. Where the gross margins of a livestock enterprise are less than this, then N fertiliser applied to produce feed for these classes of livestock is unlikely to be profitable. In these instances, is likely to be more profitable to reduce livestock numbers. However, the reduced ability to harvest “free” spring and summer pasture with the feed demand derived from lactating ewes and cows can have a great impact on the farm system than might initially be suspected. Autumn N tends to support livestock numbers used to take advantage of spring surplus. Removing this “capital” N application was managed by a reduction in capital (breeding) stock numbers.

[12] Where water “treatment” process of the wetland and separated into different steps
[13] Source: Ballance AgriNutrients

Appendix 10: Arable bundle modelling protocols

M1 Mitigations

M1.1 Grass or planted buffer strips

Leaving an uncultivated 1m wide buffer strip along the edge of all crop areas, including ephemeral water courses is estimated to reduce effective crop area (and therefore yield) by up to 2%. Crop yields in Farmax are reduced by 2% and crop area in OVERSEER reduced by 2%. Animal liveweight gains or stock numbers are adjusted to accommodate lower feed availability.

M1.2 Complete protection of existing wetlands

It was assumed no wetlands existed within the boundaries of the arable farm systems model.

M1.3 Maintain optimal Olsen P and appropriate P fertiliser use

P fertiliser applications were adjusted to ensure the actual needs of any crop were being addressed, rather than the often-typical practice of applying capital levels of fertiliser “just to make sure”.

M1.4 Efficient fertiliser use technology

Reduction in N fertiliser use with no loss of DM production due to improvements in the CV of spread on flat and rolling country. Additional $2,000 per annum cost for use of this technology and N fertiliser savings (Perrin Ag 2017). Modelled in Farmax with a reduction in quantity of N fertiliser of 12%, but commensurate increase in assumed response rate.

M1.5 Cover crops between cultivation cycles

The sowing of a cover crop between crops is estimated to cost $82/ha. While not planted specifically for dry matter production, the use of a cover crop is assumed to offset any yield reductions because of the use of buffer strips (as per M 1.1 above) when following a brassica crop.

M1.6 Manage risk from contouring

The adoption of contour appropriate cultivation practices is assumed to add $50/ha to the total cost of cultivation. The use of alternating strip tillage isn’t applicable for brassica crops.

M1.7 Reduced tillage practices

Where conventional cultivation has been used, select “direct drill” in OVESEER for forage brassicas or “minimum till” for cereal/vegetable crops instead. No cost savings are generated from this practice, as additional pest control is typically required when prior vegetation is only desiccated and not cultivated into the ground.

M2 Mitigations

M2.1 Use of silt fencing

Assuming that 80% of soil losses come from only 20% of farm area, the use of a silt fence to capture run-off from the 20% most susceptible area of the arable block has been assumed. For the 40ha arable model, this assumes silt fencing is required for use on 8ha of land. The cost of silt fencing is estimated at an annual cost of $378/ha “fenced” (Perrin Ag 2018a).

M2.2 Complete protection of gully heads

It has been assumed that gully heads erosion potential exists associated with the easy and steep contoured areas of a farm. We have assumed that these areas will need to be retired or have other capital works put in place to manage gully head erosion, with the cost of such works equating to $1,650/ha for 2% of area of the steep and easy contoured proportion of the farm, with half of that area (1%) needing to be retired (modelled as a riparian area in OVERSEER).

M2.3 Reducing fertiliser N use

Fertiliser N applications for maize silage are typically in the order of 12kg N/ha applied per tonne DM of maize silage yield targeted for harvest. The maize silage crop model has assumed a total N application of 211kg N/ha as part of the maize silage rotation. As this equates to a rate of 10.55kg N/ha per tonne DM of silage harvest, we have assumed any reduction in N fertiliser will have a corresponding reduction in yield. In this analysis, N fertiliser use has been reduced by 15% (with a reduction in crop costs of $48/ha), with a 3 t DM/ha loss in silage yield.

M3 Mitigations

M3.1 Creation of new wetlands

The creation of wetlands totalling 3% of farm landscape with a potential 100% reduction in nitrate nitrite nitrogen (NNN) from roughly 1/5th of the total farm area is assumed. The development cost has been estimated at $3,000/ha (Perrin Ag 2018a).

The base farm system has then been proportionally scaled back to ensure feasibility was maintained in line with the average pasture cover track in the immediately preceding scenario.

Wetlands have been entered in OVERSEER on the basis of the following input parameters:

- Wetland condition: Artificial Type 1 - Flow path length to width ratio >5 (2 or more stage wetland[14], with even elongated channel or serpentine path created using internal bunds), well vegetated with good dispersion and even flow through the majority of wetland and minimal channelisation or dead-zones;
- Wetland type: Type A;
- Catchment area: 20% of total farm area;
- Catchment convergence: High convergence;
- Aquitard depth: 3-5m.

M3.1 Creation of a silt trap

Assuming that 80% of soil losses come from only 20% of farm area, the construction of a silt trap to capture run-off from the 20% most susceptible area of the arable block has been assumed. For the 40ha arable model, this assumes a silt trap is required to capture flow from 8ha of land. The cost of silt fencing is estimated at a one-off capital cost of $1,300 per hectare (Perrin Ag 2018a) - $10,400 of cap-ex for this model arable system.

[14] Where water "treatment" process of the wetland and separated into different steps

Appendix 11: Kiwifruit bundle modelling protocols

M1 Mitigations

M1.1 Complete protection of existing wetlands

A minimal cost of $250/year has been assumed to account for any weed control required to prevent weed incursion of already protected wet areas.

M1.2 Maintain optimal Olsen P

It is assumed that GAP practices that already result in optimal soil P levels are maintained under kiwifruit orchards.

M1.3 Laneway run-off diversion

Assume a further $250/annum in R&M Tracks expenditure.

M1.4 Efficient fertiliser use

Efficient fertiliser use is modelled here by splitting the calcium ammonium nitrate (CAN) applications across four application periods, rather than just two. This sees post-harvest applications in March and April as well as at bud break and flowering.

M1.5 Efficient irrigation practices

Duerer et al. (2011) define efficient irrigation management as an aliquot of 10 mm of irrigation water being applied every time that the water stored in the 0-2 m depth is less than 50% of the plant-available water (PAW; Tab. 1). This essentially results in a reduction in the volume of water applied of 75% (from 300mm per annum to 75mm per annum) for no loss of yield. Irrigation costs are reduced by 75% as well. It was assumed that orchards would have existing tensiometers available to monitor soil moisture levels.

M1.6 Use of grass swards under canopy and minimising bare ground

"Full pasture" selected as sward type on the General block tab in OVERSEER. This assumes herbicide desiccation of the pasture in the rows the vines are located doesn't occur. Without herbicide, in the absence of new/improved mowing technology growers would have to mechanically weed in rows, using a tool like a weed-eater. This would take a significant amount of time (days per orchard each time) and be a problem for a sector where labour shortage is already an issue. A few years ago, there were side-arm mowers to try and deal with this, but they didn't work well and would damage younger plants (Benge, J 2018). An additional $1,500 in labour and fuel costs per hectare is calculated as a result of needing to mechanically weed the inter-row ground at least six times per year, with a reduction of $85/ha in chemical and application costs from the discontinued herbicide applications.

M2.1 Develop a detention bund

A detention bund sufficient to detain a catchment of 4ha was assumed (approximately 480m^3 of storage), costing approximately $3,000+GST to install.

Appendix 12: Riparian areas, afforestation areas and fencing length estimates

BOPRC estimated the total areas to be retired, afforested and/or fenced under the mitigation bundles. These areas were then applied to the individual farm system models pro-rated for modelled farm area and system type. The original data and the proportionality assumed for the pastoral models is presented below.

		Area retired (hectares)					**Fencing required (km)**		
Farm system type	**Total Area**	**M1 (Riparian)**	**M2 (Riparian)**	**M2 (>25 degrees)**	**M3 (Riparian)**	**M3 (>25 degrees)**	**M1**	**M2**	**M3**
Lower KPW Dairy	11,085	80	8	NA	4	19	*432*	40	34
Mid KPW Dairy	10,212	72	14	NA	20	1,014	*246*	42	234
Upper KPW Dairy	7,061	101	3	NA	6	807	*163*	5	56
Lower Rangitāiki Dairy	3,919	19	2	NA	-	-	*148*	14	-
Mid-Upper Rangitāiki Dairy	19,826	127	10	NA	26	195	*534*	43	282
Sheep & Beef KPW (including Dairy Support)	16,840	103	2	3,488	16	NA	303	10	165
Sheep & Beef Rangitāiki	11,213	30	2	250	13	NA	139	17	134
Deer Rangitāiki	4,462	7	1	-	6	NA	33	7	63

Riparian areas and fencing lengths are based on Booker et al[15] estimates of wetted widths and GIS analysis. Afforestation areas are based on slope characterisation from the New Zealand Land Resources Inventory database.

[15] The dataset including these estimates is available from the Ministry for the Environment's Data Service at https://data.mfe.govt.nz/table/2536-natural-river-flow-statistics-predicted-for-all-river-reaches/data/ and the methodology is described in:
Booker, D.J. (2010) Predicting width in any river at any discharge. Earth Surface Processes and Landforms. 35, 828-841.
Booker, D.J., Hicks, D.M. (2013) Estimating wetted width and fish habitat areas across New Zealand's rivers. Report to Department of Conservation, CHC2013-075, 33pp.
Booker, D.J.; Woods, R.A. (2014) Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. Journal of Hydrology DOI: 10.1016/j.jhydrol.2013.11.007.

Farm system type	Total Area	Fencing length required (km)		
		M1	M2	M3
Lower KPW Dairy	122	4.749	0.440	0.374
Mid KPW Dairy	122	2.939	0.502	2.796
Upper KPW Dairy	122	2.808	0.086	0.968
Lower Rangitaiki Dairy	117	4.418	0.418	0.000
Mid-Upper Rangitaiki Dairy	117	3.151	0.254	1.664
Sheep & Beef KPW	324	5.830	0.192	3.165
KPW Dairy Support	234	4.210	0.139	2.286
Sheep & Beef Rangitāiki	584	7.239	0.885	6.979
Deer Rangitāiki	324	2.396	0.472	4.575

Farm system type	Additional area retired (hectares)					
	M1 (Riparian)	M2 (Riparian)	M2 (>25 degrees	Total M2	M3 (Riparian)	M3 (>25 degrees)
Lower KPW Dairy	0.88	0.09		0.09	0.04	0.18
Mid KPW Dairy	0.86	0.17		0.17	0.24	1.64
Upper KPW Dairy	1.75	0.04		0.04	0.10	0.58
Lower Rangitaiki Dairy	0.57	0.06		0.06	-	
Mid-Upper Rangitaiki Dairy	0.75	0.06		0.06	0.15	0.88
Sheep & Beef KPW	1.98	0.04	67.11		0.31	
KPW Dairy Support	1.43	0.03	48.47		0.22	
Sheep & Beef Rangitāiki	1.56	0.10	13.02		0.68	
Deer Rangitāiki	0.51	0.07	0.00		0.44	

Figure 27: BOPRC fencing length data as applied to the pastoral models utilised for this analysis

Appendix 13: Fencing costs[16]

per km for		3 wire electric			
0 hrs/km Blade fence line			$60.00	$0	
15 Strainers	No2 2.4m @		$37.40	$561	
15 Stays			$13.90	$209	
125 Posts	No2 &No2 1/2rounds @		$7.74	$968	
4.8 coils wire	650m @		$79.99	$388	
375 Insulators	for posts @		$0.45	$169	
45 Insulators	for strainers@		$2.09	$94	
0.24 Staples	25kg box @		$159.00	$38	
1 Gates	Steel @		$240.00	$240	
0 Gates	Elect.Tape @		$35.00	$0	
0.00 Electric fence unit			$2,049.00	$0	
		Materials		$2,666	$2.67
		Labour		$2,500	$2.50
		Total		**$5,166**	**$5.17 per m**

per km for		3 wire electric using existing materials			
0 hrs/km Blade fence line			$60.00	$0	
0 Strainers	No2 2.4m @		$37.40	$0	
0 Stays			$13.90	$0	
0 Posts	No2 &No2 1/2rounds @		$7.74	$0	
2.4 coils wire	650m @		$79.99	$194	
375 Insulators	for posts @		$0.45	$169	
45 Insulators	for strainers@		$2.09	$94	
0.24 Staples	25kg box @		$159.00	$38	
0 Gates	Steel @		$240.00	$0	
0 Gates	Elect.Tape @		$35.00	$0	
0.00 Electric fence unit			$2,049.00	$0	
		Materials		$495	$0.49
		Labour		$2,750	$2.75
		Total		**$3,245**	**$3.24 per m**

per km for		8 wire post & batten		1	electric
1.5 hrs/km Blade fence line			$90.00	$135	
25 Strainers	No2 2.4m @		$37.40	$935	
25 Stays			$13.90	$348	
3 Angles			$13.90	$42	
250 Posts	No2 @		$7.74	$1,935	
12.9 coils wire	650m @		$79.99	$1,034	
1000 battens			$1.84	$1,840	
275 Insulators	for posts and strainers @		$0.45	$124	
200 Permanent strainers	for strainers@		$3.59	$718	
0.64 Staples	25kg box @		$159.00	$102	
1 Gates	Steel @		$240.00	$240	
0 Gates x2 wire	Elect.Tape @		$35.00	$0	
0.03 Electric fence unit			$2,049.00	$57	
		Materials		$7,508	$7.50
		Labour		$6,500	$6.50
		Total		**$6,500**	**$14.00 per m**

[16] Source: PGGW