Growing confidence in forestry's future Research Programme

SCION FORESTS ▪ PRODUCTS ▪ INNOVATION

Date: June 2019
Reference: GCFF TN-026

Technical Note

Preliminary economic outcomes of the GCFF mid-rotation fertiliser trials.

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Summary: Data from a national series of mid-rotation fertiliser trials were used to predict potential gains that could be achieved at the end of the rotation. Relative to the untreated controls, positive gains from applying fertiliser were found. For example, an increased stumpage of up to $5476 ha^{-1} was predicted for the site-specific treatment at Tairua Forest. The overall internal rate of return (IRR) of forest operations incorporating fertiliser treatments was predicted to increase by up to 0.23% at a 28-year harvest age. Net present value (NPV) of the urea treatment peaked at age 26 years, and there appeared to be approximately a three-year reduction in the economic rotation age compared with the untreated control treatment. The NPV analysis indicates that the site-specific approach has economic merit based on value gains in the larger pruned log grades. Based on this trial series, if forest growers determine fertiliser recommendations from soil analyses they can be confident that 80% of mid-rotation sites will show a positive increase in NPV. It should be noted that these results are based on measurements up to two years post fertiliser application, but economic gains from the fertiliser treatments are expected to continue to develop and provide additional value to growers.

Introduction

Forest growers are seeking to enhance the range of economically viable options available to increase stand productivity. The use of mineral fertilisers is currently one of the only practical operations that forest growers can use to change productivity within a rotation period.

For many years forest growers have been targeting nutrient deficient sites with applications of granular fertiliser products containing elements such as boron, phosphorus or nitrogen. However, better management practices and therefore nutrient retention over time has often meant that fertiliser responses are no longer obtained when based on historical prescriptions. Understanding crop requirements and building biomass-based nutrient pools is now key to increasing site nutrient resources and productivity over multiple rotations.

Forest growers require evidence of improved economic outcomes and an understanding of the potential risks and rewards before committing to new nutrient management strategies. Providing this evidence will encourage forest growers to undertake more intensive nutrition monitoring and to seek further opportunities for fertiliser use and profitable gains.

Methods

A series of mid-rotation fertiliser trials was established at nine sites, over a two-year period beginning in 2016. Operational stands ranging from Northland to Otago (Table 1 & 2) were treated with a range of fertiliser products (Table 3). Details of the trial design is provided in a previous Tech Note (TN-017). The “recipe” for the site-specific fertiliser treatments was based on an initial set ofsoil samples taken from each per site (*n*=5). The key nutrients determined to be limiting growth were supplied in operationally practical quantities (no more than 1.2 T ha^{-1} of blended product) in November of either 2016 or 2017 to multiple

supported by forestgrowers commodity levy

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This programme is also funded by Scion and the Ministry of Business, Innovation and Employment, New Zealand.

treatment areas representing a total of 1.25 hectares per site.

Tree growth was measured prior to treatment and then annually for up to a maximum of two growing seasons post treatment application. Data from five replicate plots per treatment were used to predict a range of future growth and economic outcomes based on a comparison with untreated controls ('do nothing'). Simulations were made using Forecaster (West *et. al*. 2013) following (, a similar approach taken in other forestry economic analyses (e.g. Watt *et. al.* 2017 and Dash *et. al*. 2018).

Average costs (Table 4) and log prices[1] (Table 5) representing the mean values across the nine sites were used to predict a trial series perspective of the economic responses based on current costs and benefits. Analysis of the data obtained from the simulations was carried out in the R statistical modelling system.

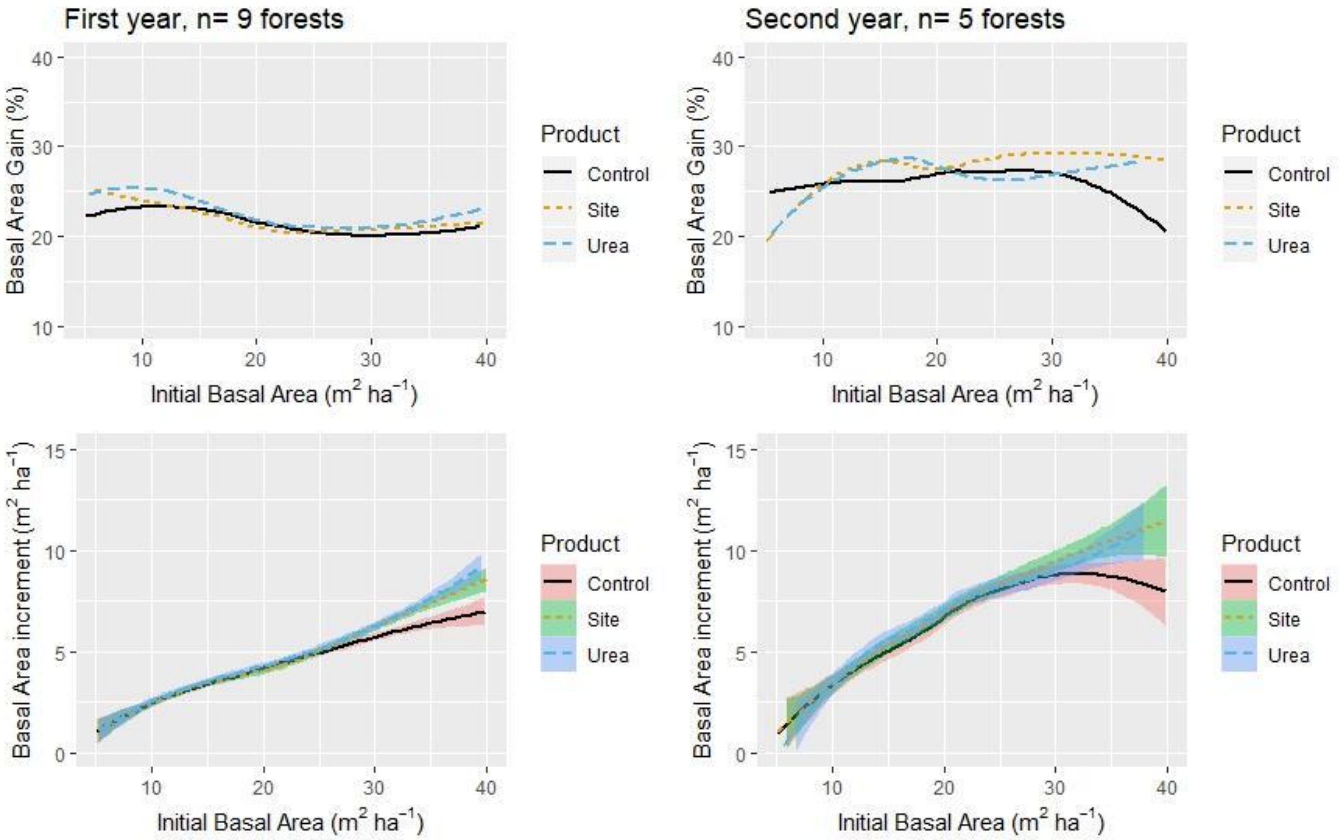

Figure 1. Relationships between basal area (gain or increment) and initial basal area at time of treatment. The left-hand graphs represent results from nine trials, one year after fertiliser application and the right-hand-column represents the five sites with data from two growing seasons post fertiliser application. Site = site-specific treatments, Urea = 200kg N ha^{-1}.

[1] Log prices are based on the February 2019 AgriHQ prices with average distance and cartage considered

Results and Discussion

Positive effects of fertiliser treatments on stumpage, log grade and NPV were found. Although some effects were not statisically significant, they appear to be increasing with time. Detrimental changes in growth trajectories, possibly due to poor crop health and/or unfavorable climatic conditions, were predicted at least three sites, based on the repeated measurements made in the untreated controls. Fertiliser applications have potentially improved the conditions at two of these three sites based on the growth responses.

Basal area responses

Based on the actual responses of individual tree-growth scaled to per hectare values across all sites, fertiliser appeared to increase the growth potential of the small trees and increase the productivity potential across sites compared with the untreated controls - a ‘do nothing’ approach (Fig. 1). These effects are indicated by the *basal area gain* of the fertiliser treatments below an *initial basal area* of 15 m^2/ha relative to the control trees (black solid line). An increase in productivity potential is shown by the maintenance of the slope of the basal area trend above 25 m^2/ha on the *initial basal area* axis, especially in the second year. Basal area is the best measure of fertiliser response because it incorporates diameter at breast height and an occupancy component (stems per hectare). Therefore, basal area incorporates a range of different regimes (stand age and stocking) employed at the different sites and can be used here to confidently predict tree growth trends. Using *basal area gain* (%)[2] the relative responses are dependent on tree size. A horizontal trend in *basal area gain* might be expected[3]. However, it is shown in Fig. 1 that fertiliser products have increased the basal area gain of the smaller and larger trees. This is a significant trend based on basal area increment, indicated by the unshaded gap between the modelled product lines above an *initial basal area* of approximately 25 m^2/ha. Based on a lesser number of sites in the second year, this trend remains consistent.

The data show that the average *basal area gain* increased during the second year by 1.2 percent across fertiliser treatments.

Predicted changes to log grades

Observations from previous unpublished reports indicated that higher value log grades were obtained at harvest from fertilised treatments. In this study, urea was also predicted to increase the volume of unpruned (S2) grades and the site-specific treatment increased the volume and value with an apparent shift of P2 grades to the larger diameter pruned P1 grades relative to untreated controls (Fig. 2). As the response of the different log grades varied with treatment, this justifies closer scrutiny in future cost-benefit analyses. This finding supports the hypothesis that urea increases the growth of the smaller trees, potentially making tree size distribution more consistent. Conversely, the site-specific treatment appears to be increasing the growth of the dominant trees and therefore the productivity potential of the sites.

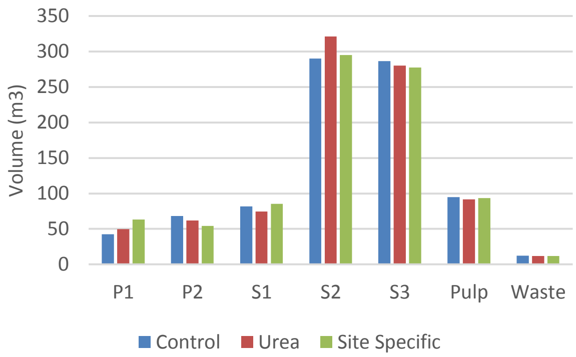

Figure 2. Predicted volumes of different log grades average across sites for Urea, Site-Specific and untreated control treatments at harvest age of 28.

Internal rate of return (IRR)

Internal rates of returns differed among sites, appearing to peak for most sites between the clear-fell ages of 18 to 25 years (Fig. 3a). Most sites had similar trends with the minor exceptions being Matahina and Kinleith, which indicated decreasing IRR from clear-fell ages 18 through to 32.

A better approach is to undertake analyses based on forest company actual costs and returns, however this is commercially sensitive information and not available for distribution. The trends indicate profitable returns and generally there are significant advantages for harvesting fertilised areas earlier than age 26 years.

[2] As supported elsewhere (eg. Littke et al 2014)

[3] Where larger trees provide larger gains.

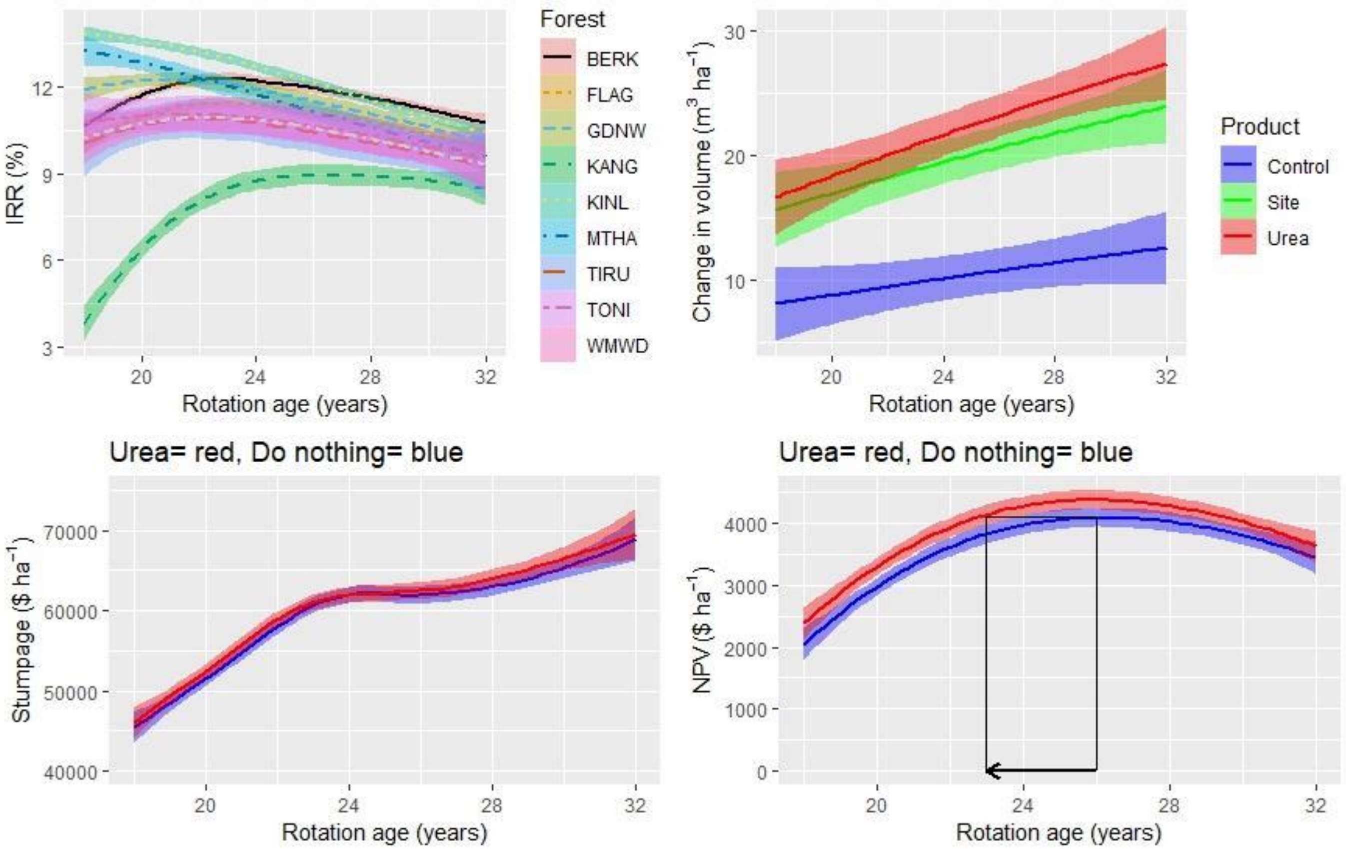

Figure 3a-d, clockwise from top left to bottom left are predicted IRR across sites, change in volume, net present value and stumpage. Untreated controls = Do nothing.

Change in volume

On average, both urea and site-specific treatments increased the predicted crop volume (Fig. 3b) by a significant amount before the stand reached 18 years of age. Treatment volume gains from fertiliser use based on post-treatment measurements were predicted to be maintained until harvest. The difference in the slopes of the predicted volume gains from fertiliser treatments compared to the control indicated that the fertiliser responses continued to build over time. Somewhat surprisingly, the urea treatment was projected to produce a greater volume gain than the site-specific treatment, but this did not produce greater economic returns, as discussed below.

Stumpage

The initial prediction of stumpage gain at a harvest age of 28 years based on the growth response one year after treatment was \$1,306 ha^{-1} for the site-specific treatment compared with \$1,608 ha^{-1} for the urea treatment. This result was not unexpected as urea is generally recognized to be more soluble than a range of other fertilisers. However, based on the five sites from which data over two growing seasons were available, the average predicted stumpage at clear-fell age 28 years for the site-specific treatment was \$2,443 ha^{-1}, considerably greater than the urea treatment (\$2,020 ha^{-1}). The maximum additional stumpage revenue of \$5476/ha was obtained at the Tairua Forest site. The reversal of the relative responses suggests a possible lag effect for the response to the site-specific treatment compared to conventional urea application of 435kg ha^{-1} (200kg ha^{-1} nitrogen). Further monitoring over the next two years will determine if this trend is confirmed.

Mean stumpage across the nine sites reached a plateau at just above \$60,000 ha^{-1} at a rotation age of 24 years. The gain in stumpage due to fertiliser use was, therefore, relatively small in the context of total stumpage. This is emphasized by the overlapping predicted trends (Fig. 3d). However, through analysis it was determined that there was a benefit to the net present value (NPV) of forest stands, which is discussed in more detail below.

Net Present Value

Our calculations are based on post establishment costs and the change in growth response after fertiliser treatment, but don't fully consider the cost of the fertiliser. NPV was significant and positively influenced by fertiliser treatments. This is indicated by the gap between the predicted values over the range of rotation ages (Fig. 3c). The urea treatment is shown for comparison with the untreated controls, and trends represent the average across all nine sites. The relative benefits equate to a maximum of a three-year reduction in rotation age for the same level of predicted NPV based on the current growth trends. This gain is equivalent to between 48-90 m^3 ha^{-1} of additional stem volume at harvest depending on site productivity of a fertilised stand that is harvested earlier.

Across sites, considering the retail cost of the fertiliser products as purchased for the field trials and estimated helicopter application rates, the site-specific treatment produced the best economic results at all sites with the exception of the Kaingaroa site (Fig. 4). The urea treatment provided positive significant gains at seven of the nine sites. The severe change in predicted NPV under "do nothing" treatment at Tairua Forest suggests that either there is a problem with the data or crop health as a result of phosphorus deficiency has a long-term detrimental effect on stand condition.

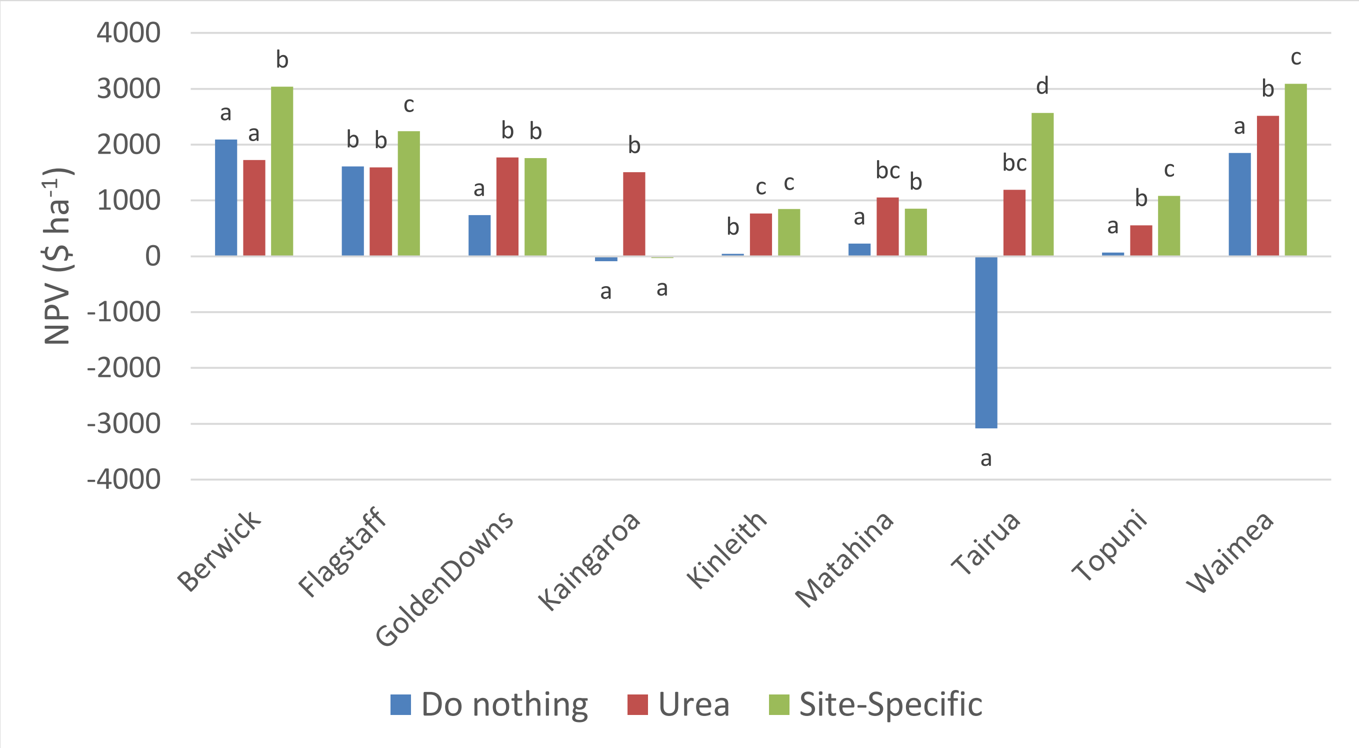

Figure 4. Net present value of future stumpage gains from applying fertiliser at mid-rotation. The analysis is based on the cost of fertiliser, the cost of application and the predicted gains in net harvest revenue. Letters indicate least square means comparison based on Tukey's differences within site, α < 0.05.

Next steps and implications

Additional growth data will be collected in July-Aug 2019, enabling the relationships between soil properties and predicted NPV to be investigated.

If growers base fertiliser use decisions on soil sample analyses as undertaken here, these findings suggest that they can be confident that ~80% of sites will respond profitably to both urea or the site-specific approach. By undertaking more fertiliser operations with annual growth monitoring, managers should be able to reliably improve the productivity of their sites.

Acknowledgements

Funding for this research came from the "Growing Confidence in Forestry's Future" research programme (C04X1306), which is jointly funded by the Ministry of Business Information and Employment (MBIE) and the Forest Growers Levy Trust, with the support of the NZ Forest Owners Association (FOA) and the NZ Farm Forestry Association (FFA). We would like to thank the field crews for collecting the data from these trials and those companies who hosted them.

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Table 1, Average stocking by forest and treatment

	BERK	FLAG	GDNW	KANG	KINL	MTHA	TIRU	TONI	WMWD
Control	515	495	485	340	535	515	456	995	610
Foliar N	465	425	510	375	510	515	613	1020	625
Foliar N + P + K	590	410	510	370	555	525	594	1050	530
Foliar P	565	535	485	350	550	575	613	1010	390
Site-Specific	460	420	540	325	490	560	513	1015	500
Urea	515	435	455	345	540	540	500	930	495

Table 2, Average soil characteristics, all nutrients are presented in units of ppm, except pH, which is the Logarithmic of H^+ concentration

Site	pH	Total C	Total N	K	Ca	P	Mg	Al	Mn	Fe	Zn	B	Cu
BERK	4.41	65590	3657	110.7	1344.5	14.7	103.3	1681.8	60.3	397.6	1.37	0.60	0.72
FLAG	4.50	52013	2551	112.0	395.5	12.9	156.6	1203.1	342.5	81.6	0.65	0.43	0.45
GDNW	4.86	35210	1733	124.9	514.9	21.3	126.7	1133.9	35.6	301.5	0.94	0.32	2.15
KANG	4.90	62768	2705	96.3	135.2	48.8	23.5	3461.1	13.0	221.2	1.72	0.44	2.50
KINL	5.15	69603	3396	187.3	372.4	11.1	63.0	1881.0	31.3	104.8	2.38	0.55	1.68
MTHA	5.91	30178	1787	104.2	756.2	10.1	189.3	1762.2	13.2	216.7	1.08	0.54	0.91
TIRU	5.38	47184	2296	111.5	318.2	9.0	131.9	3021.6	48.3	130.1	1.01	0.57	1.33
TONI	4.64	40735	1893	87.7	590.9	13.0	304.5	1263.0	149.0	340.9	0.90	0.49	0.80
WMWD	4.31	50801	1872	28.2	496.4	40.3	42.4	1907.2	1.8	86.4	0.67	0.44	2.62

Table 3, List of forest plant and thinning ages and corresponding Site-specific fertiliser products applied. Units of individual nutrients are kg ha^{-1}.

Forest	Planted	Thinned	Thin age	Fertiliser application	Application rate Kg ha^{-1}	Product	C	N	K	Ca	P	Mg	S	Mn	Zn	B	Na
Berwick	2005	2015	10.67	2016	750	CaCO3	90			270							
Berwick	2005	2015	10.67	2016	260	K2SO4			117				143				
Berwick	2005	2015	10.67	2016	140	HPO4(NH4)2		25.2			28		2.8				
Flagstaff	2007	2017	10	2017	500	CaCO3	60			180							
Flagstaff	2007	2017	10	2017	300	K2SO4			135				165				
Flagstaff	2007	2017	10	2017	220	HPO4(NH4)2		39.6			44		4.4				
Flagstaff	2007	2017	10	2017	25	ZnSO4							5		10		
Golden Downs	2008	2017	9	2017	500	CaCO3	60			180							
Golden Downs	2008	2017	9	2017	400	K2SO4			180				220				
Golden Downs	2008	2017	9	2017	220	HPO4(NH4)2		39.6			44		4.4				
Golden Downs	2008	2017	9	2017	20	ZnSO4							4		8		
Kaingaroa	2002	2014	12.58	2016	250	CaCO3	30			90							
Kaingaroa	2002	2014	12.58	2016	20	MgO2SO3						6	4				
Kaingaroa	2002	2014	12.58	2016	10	ZnSO4							2		4		
Kinleith	2007	2015	8.38	2016	500	CaCO3	60			180							
Kinleith	2007	2015	8.38	2016	200	HPO4(NH4)2		36			40		4				
Kinleith	2007	2015	8.38	2016	20	MgO2SO3						6	4				
Matahina	2008	2016	8	2017	400	K2SO4			180				220				
Matahina	2008	2016	8	2017	128	HPO4(NH4)2		23.04			25.6		2.56				
Matahina	2008	2016	8	2017	60	MnSO4							38.4	21.6			
Matahina	2008	2016	8	2017	20	ZnSO4							4		8		
Tairua	2001/2	2014	13.42	2016	500	CaCO3	60			180							
Tairua	2001/2	2014	13.42	2016	250	PO4(NH4)2		45			50		5				
Tairua	2001/2	2014	13.42	2016	60	NaCaB5O9				9						12.6	5.4
Tairua	2001/2	2014	13.42	2016	20	ZnSO4							4		8		
Topuni	2010			2017	800	CaSO4				232			192				
Topuni	2010			2017	350	K2SO4			157.5				192.5				
Topuni	2010			2017	220	HPO4(NH4)2		39.6			44		4.4				
Topuni	2010			2017	25	ZnSO4							5		10		
Waimea	2005	2015	10.34	2016	500	CaCO3	60			180							
Waimea	2005	2015	10.34	2016	250	K2SO4			112.5				137.5				
Waimea	2005	2015	10.34	2016	90	MnSO4							57.6	32.4			
Waimea	2005	2015	10.34	2016	20	ZnSO4							4		8		

Table 4, List of activities and the average cost per units are shown.

Cost	Rate	Unit
Discount rate	7	%
Administration	80	\$ ha^{-1} yr^{-1}
Dothistroma spray	60	\$ ha^{-1}
Land rent	60	\$ ha^{-1} yr^{-1}
Planting	0.75	\$ $stem^{-1}$
QC	40	\$ ha^{-1}
Waste thin	400	\$ ha^{-1}
QC	45	\$ ha^{-1}
Prune 1	1.5	\$ $stem^{-1}$
QC	45	\$ ha^{-1}
Prune 2	1.95	\$ $stem^{-1}$
QC	45	\$ ha^{-1}
Prune 3	2.35	\$ $stem^{-1}$
QC	45	\$ ha^{-1}
Ground based harvesting	27	\$ m^{-3}
Roading	2000	\$ ha^{-1}
cartage	0.24	\$ m^{-3} km^{-1}
average distance for domestic	42.2	km
average distance for export	95	km
Management	5	\$ m^{-3}
Weights & levies	0.5	\$ m^{-3}
Machine transport	0.5	\$ m^{-3}
Pre-harvest inventory	100	\$ ha^{-1}

Table 5, Abbreviate log grade name, brief log grade description, defining small end diameter (SED) and minimum length specifications, and assigned Feb 2019 quarter AgriHQ value incorporating average cartage and travel.

Log Grade	Description	SED (mm)	Min length (m)	Value (\$ m^3)
P1	Large pruned, export peeler	400	3.9	160.7
P2	Medium pruned	300	4	146.9
S1	Export A grade, unpruned large	400	4	127.4
S2	Export A grade, unpruned medium	300	4	127.4
S3	Export A grade, unpruned small	100	4	114.9
Pulp	Residual logs	100	3.8	45.9
Waste	Short sections, everything else	<100	None	0