

The Rabbit Island Biosolids Project

Peter Wilks, Nelson Manager Pf Olsen Ltd
Hailong Wang, Scientist Scion Rotorua

Introduction

Biosolids from the Nelson regional wastewater treatment plant have been applied to a 1000-ha *Pinus radiata* plantation at Rabbit Island since 1996. Rabbit Island (Moturoa) is Crown Land that was vested to the Waimea County Council, now the Tasman District Council, in 1920 as a reserve. In addition to the plantation area, there is 300 hectares of recreation reserve.

The Island is very flat (maximum altitude 10m) and is made up of predominantly Tahunanui Sand soils with naturally low nutrient and organic levels. The lack of nitrogen in particular, greatly limits Radiata Pine growth. Organic material is almost absent from soil profiles due to previous burning practices for re-establishment. The soils are permeable and provide free root access to the shallow ground water levels which are between 2 and 4 meters below the surface. Annual rainfall is around 900mm.

The island is a very popular recreational asset with some of Nelsons finest beaches and is visited by around 150,000 people per year. Forestry activities are also very important and currently there is a sustainable cut of 20,000 tonnes per year which provides a significant source of income to the Tasman District Council to off-set rates.

Project Genesis

During the mid 1990's the Nelson Regional Sewage Business Unit (NRSBU) was required to re-apply for consents for discharge of wastewater to the Waimea Estuary, but realised that ongoing discharge to the estuary was not sustainable. In conjunction with the forest managers, PF Olsen Ltd, the idea was hatched to look at forest-based application of the waste water.

At the same time, the Bells Island treatment plant, located 800m across the estuary from Rabbit Island, was in need of a major upgrade as the organic load of the plant had reached 1.5 times the design capacity. The plant was subsequently upgraded in 1996 to allow the processing of effluent solids using a 2-stage ATAD process (auto thermophilic aerobic digestion). The treated biosolids is about 1-3% solids and has an average nitrogen content of 8-10% - well suited to spray application under pine trees.

The forest managers commissioned the then Forest Research Institute to carry out research into the operational viability of forest-based application of the biosolids. Fortunately at the time French researcher Jean Michel-Carnus was working at FRI and had considerable experience in such schemes overseas and was able to offer considerable guidance in the design of the eventual system used at Rabbit Island. Another leading pioneer in this field, Professor Dale Cole from the University of Washington, also provided valuable advice.

Scheme management

The Nelson Regional Sewage Business Unit (NRSBU) is a joint venture between Tasman District Council and Nelson City Council and oversees a wastewater scheme which serves a large part of Nelson city, Richmond, and Mapua. In 2008 the Wakapuaka treatment plant serving the northern part of Nelson, also joined the scheme. In addition to municipal waste water, the largest industrial

suppliers are Nelson Pine Industries, ENZA and the Alliance freezing works. The Bells Island plant treats sewage equivalent to a domestic population of 100,000. The application of bio-solids to forest areas on Rabbit Island has been undertaken since 1996 by Astro Environmental under contract to the NRSBU. Day to day supervision is the responsibility of the forest managers.

Overview of the current scheme

Waste water pumped to Bells Island is screened before entering aeration basins. Effluent then enters the clarifier where the solids are removed. The solids are passed through rotary drum thickeners before entering a two-stage ATAD (digesting and heating) process where the solids are stabilised and heated aerobically to around 60 degrees. At this temperature, viruses and other pathogens are effectively eliminated, and the biosolids achieve an 'Aa' rating under the NZ Biosolids Guidelines.

The bio-solids are then pumped across to holding tanks on Rabbit Island. Tankers transport the biosolids to



Tanker, known as maggot

the forest and are then connected to a high volume pump for delivery to a mobile, tracked spreader, affectionately known as the “maggot”. This machine has a built-in spray gun attachment that sprays up to 25m either side of the unit as it moves through the trees. A 100mm diameter rubber hose which connects it to the pump is automatically coiled in and out as it proceeds.

The bio-solids are applied throughout the year, although operations are kept away from recreational areas during the summer months. At present about 30,000m³ is applied, although the scheme has an annual capacity of up to 60,000m³.

The application of bio-solids is strictly controlled as the composition of the bio-solids varies with the season and nitrogen concentrations can range from 6% to 15% of the dry solids. The bio-solids are independently analysed every 2 weeks for bacteria, pH, heavy metals and nutrients, and the application rate per hectare is then set based on the principal limiting factors, being the nitrogen concentration. Applications of either 300 or 450kg/ha of Nitrogen every 3 years are permitted depending on stand age.

Effect on tree growth

An experimental research trial was established within the plantation in 1997 to investigate the effects of biosolids applications on tree growth, nutrition, and the ecosystem. The trial has been monitored annually since it was established. Scion, under the direction of Dr Hailong Wang, analyses the data and provide an annual report on progress. In addition, several wood quality assessments of density, stiffness, and sonics have also been carried out, including some testing as part of the Wood Quality Initiative programme.

The trial site was established in a stand of *P. radiata* planted in 1991. Biosolids was first applied to the trial in 1997 and has been applied every 3 years since. There are three application rates: 0 (control), 300 (standard) and 600 kg N/ha (high), and three stocking density treatments as subplots of 300, 450 and 600 stems/ha. In total there are 36 plots and the trial site covers 4.0ha.

To monitor groundwater quality 8 piezometers have been installed up and downstream of the trial. Soil samples are taken annually to monitor changes in nutritional status and metal concentrations.

Effect of biosolids loading rate on volume response

The most recent measurement data, collected in 2008, confirms that stem volume has continued to show significant increases where biosolids has been applied (Figure 1). In 2008 at age 17, the stem volume of the High treatment (382 m³/ha) was 38% greater than the Control (276 m³/ha), and that of the Standard treatment (356 m³/ha)

was 29% greater than the Control, indicating a substantial gain in productivity, as shown in Figure 1.

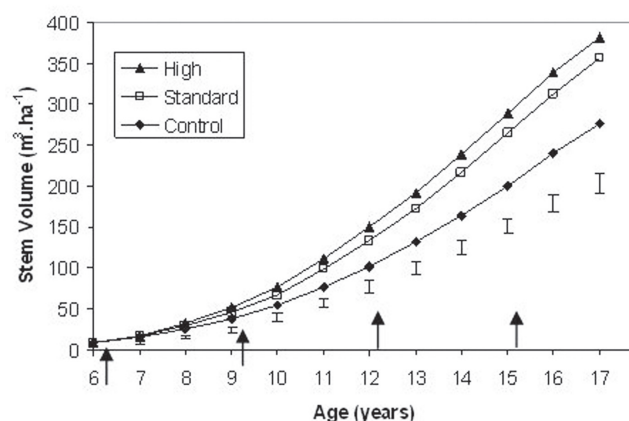


Figure 1. Effect of biosolids application on stem volume since the initial biosolids application at age 6 years. The arrows show when biosolids treatments were applied.

Until 2008, current stem volume increments in both the Standard and the High rate treatments were always significantly greater than in the Control (Figure 2). However, in the 2007-2008 growth year, although the volume increment in the Standard treatment remained significantly higher than the Control, the volume increment in the High treatment was not significantly greater. However this reflects the natural trend driven by the sigmoidal nature of the growth curve.

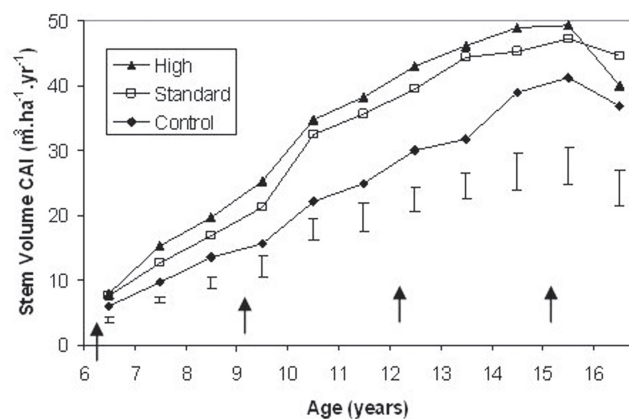


Figure 2. Effect of biosolids loading on stem volume current annual increments (CAI) since the initial biosolids application at age 6 years. The arrows show when biosolids treatments were applied.

At higher stocking rates, competition has led to significantly smaller diameter trees. However, the higher stocked plots have significantly greater per hectare BA and volume than the lower stocked plots. There is a slight interaction between stocking and biosolids loading. Only treatments at the higher stockings have been boosted significantly in volume growth by the High loading, while at the lower stockings, trees receiving both High and Standard loadings have similar growth rates.

Table 1. Effect of biosolids on concentrations of the foliage nutrients in March 2008*.

Treatment	N		P		K		Ca		Mg		Zn		Cu		B		Fe		Mn	
	%										mg kg ⁻¹									
Control	1.16	b	0.14	a	0.83	a	0.16	a	0.14	A	28	a	3.3	a	29	a	32	a	231	A
Standard	1.28	ab	0.13	a	0.79	a	0.14	a	0.16	Ab	30	a	3.1	a	28	a	34	ab	152	B
High	1.39	a	0.12	a	0.76	a	0.15	a	0.17	B	29	a	2.9	a	26	a	38	b	134	B
*Values within a column followed by the same letter do not differ significantly (p=0.05).																				

Tree nutrition

Foliage sampling and analysis is carried out annually, and the 2008 results are shown in Table 1. This shows that biosolids application has had little effect on concentrations of elements other than nitrogen. Generally, foliar concentrations of all nutrients except nitrogen are in the “satisfactory” range of tree nutrition and indicate that none of these nutrients are limiting tree growth (Will 1985).

Foliar analysis has consistently shown that natural soil nitrogen supply is not satisfactory, with foliar nitrogen concentration of the Control treatment remaining consistently well below 1.5% N (Figure 3), a threshold value below which *P. radiata* may benefit from nitrogen fertiliser (Will 1985).

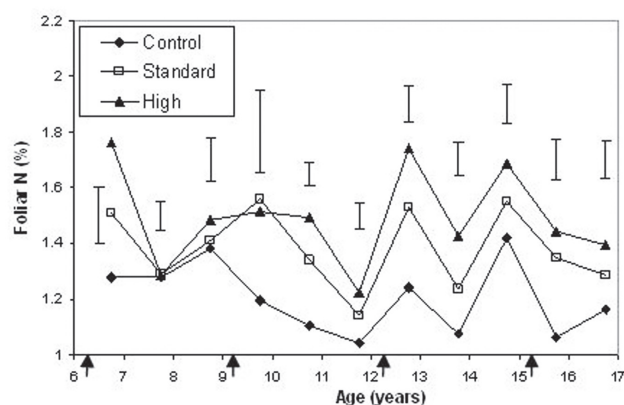


Figure 3. Effect of biosolids application on concentrations of nitrogen in foliage. Arrows indicate time of biosolids application.

Successive applications of biosolids have always produced a response in foliar N concentration in the subsequent assessment when compared with Control trees.

Effects on wood quality

Effect on density:

Mean densities by ring were obtained from densitometry data in 2005 at age 14. This analysis showed that in the

most recent growth ring the Control had a basic density of 415kg/m³, with the standard treatment 5% lower, and the high treatment 9% lower than the control (Wang et al. 2006). These results and those of the previous growth rings are shown in the graph below.

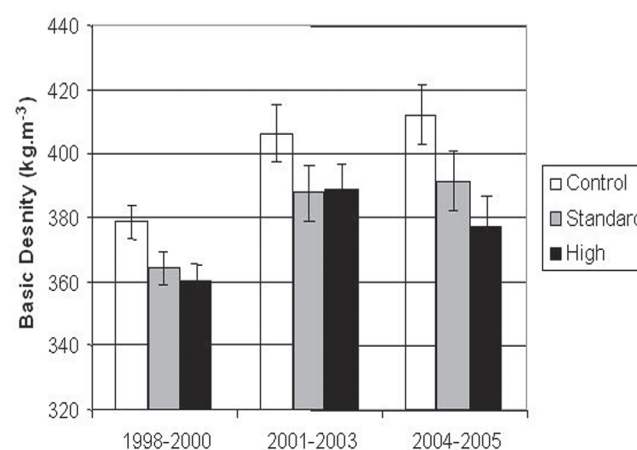


Figure 4

Effect on acoustics:

Sampling for stiffness of standing trees and some felled stems was carried out in 2006. The standard treatment was lower in stiffness by 13% compared to the control and the high treatment 18% lower than the control.

Tree stocking had little effect on either density or stiffness.

Environmental effects

Water

The ground water on Rabbit Island is analysed every 3 months for bacteria, pH, heavy metals and nutrients and the soils in selected application areas annually. After 13 years of applications there have been no significant increases in the levels of the major elements (e.g., phosphorus, nitrogen, etc.) or in the heavy metals such as lead, mercury and arsenic, with the exception of cadmium. The hills in Nelson to the east of Rabbit Island are known

to be high in natural cadmium and higher than desirable levels have been found in the ground water but this has not been attributed to any effect of the biosolids.

Soil

Soil analysis carried out in 2007 indicates that the High biosolids treatment has significantly increased concentrations of soil available P and organic carbon, but reduced soil pH (Wang and Kimberley 2009). The High treatment has also increased concentrations of copper, lead and zinc. However, these concentrations are considered as very low. The Standard treatment had no significant effect on soil quality.

Economic analysis

A recent report analysed the trial data to assess the economic costs and benefits of biosolids application (Kimberley and Wang *et al* 2009). The *P. radiata* 300 Index in the Radiata Pine Calculator was used to predict stem volume at harvest for each treatment, by projecting forward from the 2008 measurements.

Each unpruned log was then assigned into acoustic velocity classes: <3.0, 3.0-3.3, and >3.3km/s. This was performed by assuming that acoustic velocity is normally distributed with the Control treatment having a mean of 3.3km/s (based on the average of logs currently being harvested from unfertilised stands). For the Standard and High treatments the mean velocity was adjusted downwards by the percentage reductions observed in a June 2006 trial of log sonics using the HM300 'Hitman' tool.

The predicted stumpage was increased by 32% for the Standard loading, and 41% for the High loading (Figure 5). This increase arose from the greatly increased log volume and the greater average diameter of logs from biosolids treated trees. The volume of logs satisfying the most valuable pruned log grade specification increased by 48% and 57% for the Standard and High treatments respectively. Although a greater proportion of unpruned logs fell below the less than 3 km.s-1 acoustic velocity threshold in treated stands, in absolute terms, the volume (in m3) above this threshold was actually slightly greater for biosolids treated trees.

The predicted stumpages at age 30 are shown in Figure 5 below:

Conclusions

In general, biosolids application has been greatly beneficial to trees growing on Rabbit Island. Effectively they have transformed it from a low productivity to a high productivity forest site. The increased productivity has also had some negative influences on wood properties, which are only of minor importance for pruned logs but

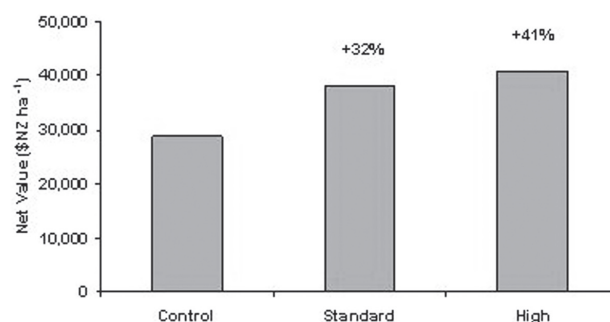


Figure 5

could have a negative effect on the value of structural logs. However, recent economic analysis shows that the predicted reduction in wood quality is more than offset by greater yields at time of harvest, and cost savings in fertilising.

The key factor for the successful utilisation of biosolids at Rabbit Island is an active collaboration between the forest owner, local authorities, researchers, and the community. On the right sites, there is potential for greater use of plantations for the management of bio-solids both to solve a waste problem and enhance forest economics.

Acknowledgements

The authors wishes to thank the Nelson Regional Sewerage Business Unit, Tasman District Council, NZ Foundation for Research Science and Technology for funding or in-kind support, FRST Envirolink, the MAF Sustainable Farming Fund, and all those who have contributed to the project over the years.

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