Nitrogen uptake in New Zealand Short Rotation Crops

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1. ABSTRACT

Short rotation energy forests offer a mechanism for nutrient capture in land treatment systems, with most interest in the uptake of nitrogen. The question is often asked as to how much nitrogen would a young close spaced forest capture. Because total biomass production is closely associated with nutrient uptake, especially in young stands, the *Eucalyptus* genus is usually considered because of its fast early growth when compared to radiata pine. To determine potential rates of nitrogen uptake, relevant studies in New Zealand and Australian literature were assessed. Studies were compared using one factor, the mean annual increment of nitrogen uptake, to account for differences in ages, species and site, etc.

Nitrogen uptake values range from 38 to 217 kg/ha/yr for effluent irrigated plantations and 30 to 83 kg/ha/yr for rain-fed plantations. The highest value of 217 kg/ha/yr is from a plantation with extremely high rates of effluent irrigation and is not considered typical of a "normal" treatment system and therefore must be treated with some caution.

There is little data on nitrogen uptake in very young stands (0 to 3 years old) in New Zealand or Australia. However, based on the literature reports for rain-fed plantations, and expected increase from effluent treated plantations combined with high stockings and younger rotations than used for conventional forestry, 100 kg/ha/yr of nitrogen uptake could be considered an estimate for a young eucalypt plantation (depending on site, growth rate, species, planting density, rotation and loading rates).

2. INTRODUCTION

Trees are often used as an instrument for nutrient removal (particularly nitrogen) from sites. Short rotation forests grown for bioenergy have been considered a mechanism for nutrient uptake, at times associated with land treatment systems. Short rotation can be regarded as a rotation length of less than 10 years, and generally closer to five years, utilising coppicing species planted at higher seedling densities than conventional forestry, hence the term energy forests for these closer spaced plantations designed to efficiently produce biomass.

Differences in nutrient uptake between species are usually associated with total biomass production. Eucalypt species that exhibit fast initial growth rates are often considered superior to species with slower rates of biomass production. However, with high initial planting densities pine is not far behind the biomass productivity of some hardwood species, but is less productive at younger ages, Madgwick and Oliver (1985).

This paper summarises the available literature from New Zealand and Australian where studies have examined the biomass production and/or nitrogen uptake of Eucalypt species growing in rain-fed plantations or wastewater irrigated plantations. The aim of the paper is to summarise our knowledge on potential nitrogen uptake rates in eucalypt plantations so that we may better predict nitrogen capture in short rotation eucalypt forests.

3. DISCUSSION

A range of one-off studies in New Zealand and Australia have documented nitrogen levels in stands, but these studies are from different sites, different ages and differing environmental conditions. Currently there is considerably more New Zealand information published on nitrogen uptake from rain-fed forestry plantations than from wastewater irrigated plantations. Few New Zealand studies have been conducted on eucalypt plantations including land treatment. It is therefore necessary to build a profile of relevant data for interpretation. To bring the data to a common level, the mean annual increment of nitrogen uptake per hectare has been calculated (Table 1). This is for all above ground components, however, some Australian data reported foliage levels only.

To remove all the nitrogen reported as uptake would mean total tree removal from the site. This may be practical or relevant depending on the destination of the material removed. For this reason short rotation energy forests offer a solution to utilising young eucalypt biomass as well as removing nutrients.

There is considerable variation in nitrogen uptake, depending on site, age, stocking and irrigation levels, with estimates ranging from 30 to 217 kg N/ha/yr. These values reflect a wide range of irrigation systems, some with effluent and others rain fed. Effluent streams also vary and more importantly loading rates vary considerably.

One of the most recent comprehensive studies in New Zealand is that of the Whiritoa land treatment scheme. A *Eucalyptus botryoides* plantation had received domestic effluent from the local sea-side community, with approximately 60 kg/ha/yr of nitrogen applied since establishment. The assessment at age 8 years estimated nitrogen uptake rates of 70 kg N/ha/yr at this low nutrient loading. The control plots were estimated to take up 64 kg N/ha/yr. The site is still continuing as a land treatment system with effluent applied over the coppicing stems.

Australian eucalypt land treatment data suggests levels of nitrogen uptake of the same magnitude (Table 1).

Table 1. Mean Annual Increment of nitrogen capture in New Zealand and Australian eucalypt plantation studies

Species	Site	Age (years)	Irrigated (MAI) (kg N/ha/yr)	Rain-fed or Control (MAI) (kg N/ha/yr)	Reference
E. nitens	Rotoehu NZ	4		83	Madgwick, *et al*. 1981
E. fastigata	Rotoehu NZ	4		80	Madgwick, *et al*. 1981
E. botryoides	Whiritoa NZ	8	70	64	Gielen, *et al*. 1999
E. regnans	Tokoroa NZ	10		69	Frederick, *et al*. 1985a
E. camaldulensis	Woodonga (Aus)	4	66		Stewart, *et al*. 1988
E. grandis	Woodonga (Aus)	4	65		Stewart, *et al*. 1988
E. saligna	Woodonga (Aus)	4	60		Stewart, *et al*. 1988
E. globulus#	Bolivar (Aus)	5	59	51#	Boardman, *et al*. 1996
E. regnans	Tokoroa NZ	7		56	Frederick, *et al*. 1985a
E. regnans	Tokoroa NZ	4		55	Frederick, *et al*. 1985a
E. nitens	Kaingaroa NZ	5		49	Frederick, *et al*. 1984
E. regnans	Tokoroa NZ	8		43	Frederick, *et al*.. 1985b
E. occidentalis	Bolivar (Aus)	5	48	-	Boardman, *et al*. 1996
E. grandis#	Bolivar (Aus)	5	41	37#	Boardman, *et al*. 1996
E. regnans	Tokoroa NZ	13		40	Frederick, *et al*. 1985a
E. camaldulensis	Bolivar (Aus)	5	38	30#	Boardman, *et al*. 1996
E. saligna	Te Puke NZ	8		30	Frederick, *et al*. 1985c
E. globulus	Dannevirke NZ	3	217		Guo, *et al*. 1999
E. ovata	Dannevirke NZ	3	134		Guo, *et al*. 1999
E. botryoides	Dannevirke NZ	3	142		Guo, *et al*. 1999
*E. nitens**	Lysimeter-NZ	2.5	186		Roygard, 1999
*E. saligna**	Lysimeter-NZ	2.5	114		Roygard, 1999
E. maidenii	Bay of Plenty-NZ	1.0		110#	Nicholas unpublished
E. maidenii	Bay of Plenty-NZ	2.0	90#		Nicholas unpublished
E. maidenii	Bay of Plenty-NZ	3.0	66#		Nicholas unpublished

Foliage only

The Australian guidelines, (Myers *et al.,* 1999), suggest uptake rates of 79 kg/ha/yr for *E. grandis* at ages 0 to 2 years, peaking at 84 kg/ha/yr in years 2 to 4, declining to 17 kg/ha/yr by ages 12 to 16, and averaging 48 kg/ha/yr over a 16 year rotation.

Some New Zealand studies in rain-fed stands (Madgwick *et al*., 1981), have reported higher levels of nitrogen uptake than the Whiritoa example but have used much higher stand densities which can lead to very high establishment costs and high seedling mortality from competition. The study at Dannevirke, New Zealand has reported very high levels of nitrogen uptake: 217, 134 and 142 kg/ha/yr. Care is needed in interpreting data as a national average of nitrogen uptake from this site because nitrogen loadings were very high – in excess of 1,000 kg/ha/yr.

Parker and Thomsen (2000) suggested that nitrogen uptake rates of 600 kg/ha/yr have been recorded in New Zealand studies, but levels of this magnitude are not supported by the literature. The New Zealand guidelines for land utilisation of effluent (NZLTC 2000) suggest that nitrogen uptake rates of 200 kg/ha/yr are possible from young eucalypt stands, but this claim is not supported by the quoted reference of Barton *et al.* (1991), which was also reporting on the Dannevirke site.

Based on the literature reports for rain-fed plantations and expected increase from effluent treated plantations combined with high stockings and younger rotations than used for conventional forestry, 100 kg/ha/yr of nitrogen uptake could be considered an estimate for a young eucalypt plantation (depending on site, growth rate, species, planting density, rotation and loading rates).

However, others have suggested lower figures such as 75 kg/ha/yr (M. Tomer, pers comm.) Recognising that there are many factors that can influence nitrogen uptake, provided a correctly sited eucalypt stand is well established and well managed, the higher value of 100 kg/ha/yr appears possible. More data is required to determine the validity of this assumption.

Eucalypt species should be considered as an alternative to radiata pine for wastewater irrigation schemes in New Zealand because of their ability to uptake nutrients and water due to high rates of biomass accumulation in the early years. Using this biomass for energy production would utilise the biomass as a product and provide a means for early nutrient removal. However, eucalypt performance in some regions of New Zealand is not well understood. In particular, new insect threats may change options for the preferred species. There are also questions regarding the management of this genus that has the potential to offer so much for nitrogen capture in land treatment schemes.

4. CONCLUSIONS

From the published literature on nitrogen uptake in eucalypt stands, the data suggests that some eucalyptus species offer a reasonable level of nitrogen capture under New Zealand conditions with or without effluent irrigation, mostly because of high early biomass accumulation. It is considered that eucalypt species, if correctly sited and managed could have the ability to capture approximately 100 kg/ha/yr of nitrogen.

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