Litterfall nitrogen and phosphorus fluxes in two Tasmanian *Eucalyptus nitens* plantations

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Abstract

Knowledge of N and P fluxes in litterfall is essential to understanding N and P cycling in plantations. Rates of litterfall and N and P concentrations were measured for one year in two Eucalyptus nitens *plantations of ages three and ten years. Measurements were in unfertilised treatments at both sites and in a fertilised treatment at the three-year-old site. Sampling positions within and between rows were compared in the younger plantation. For annual rates of litterfall and concentrations of N and P, leaves were ranked much greater than bark which was approximately equal to branches. Daily rates of litterfall and litter N and P fluxes were highest during February–March and lowest during September to November. Conversely, concentrations of N and P in leaf litter were highest during July to September and lowest during January to May. Annual litterfall and N and P fluxes were unaffected (*$P < 0.05$*) by fertiliser, sampling position or plantation age. However, fluxes in litterfall ranked higher in N-fertilised treatments than in unfertilised treatments and in within-row regions than in between-row regions of a three-year-old plantation. The average rate of litterfall was 5.1 Mg/ha/yr, the N flux was 52 kg/ha/yr, and the P flux was 2.6 kg/ha/yr. Absolute values and patterns of N and P fluxes in litterfall of* E. nitens *plantations in Tasmania were similar to those already reported for other* Eucalyptus *plantations and native forests.*

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Introduction

Expansion of Australia's 389 000 ha hardwood plantation estate, of which 101 800 ha (26%) are established in Tasmania, is being promoted by both the Federal Government and the forest industry. Hardwood afforestation in Australia exceeds 84 600 ha / yr, including 16 500 ha / yr in Tasmania (Australia, Forest Taskforce 1995; Ministerial Council on Forestry, Fisheries and Aquaculture *et al.* 1997; Australian Bureau of Statistics 2001; National Forest Inventory 2000), predominantly as *Eucalyptus globulus* and *E. nitens* grown for pulp and paper production. The productivity of *Eucalyptus* plantations in Tasmania and interstate is commonly limited by low availability of N and P (Bennett *et al.* 1997; Cromer 1996). Hence, the return of N and P to the forest floor via litter may significantly affect the need for, and be affected by, fertilisation. Knowledge of N and P cycling in litter will be useful to guide fertility management of *Eucalyptus* plantations.

Despite numerous studies of litterfall in *Eucalyptus* native forests, there have been no published studies of litterfall N or P in *Eucalyptus nitens* plantations or in other *Eucalyptus* plantations grown in Tasmania, and there have been few studies of litterfall in *Eucalyptus* plantations of any species grown in Australia. Hence, most of the data available for litterfall in *Eucalyptus* species comes from native forests.

The amounts of N and P returned to the forest floor in litter annually from Australian native forests cover a wide range. Adams and Attiwill (1991) and O'Connell *et al.* (1978) reported a range of 9–85 kg / ha / yr of N, and Lee and Correll (1978) and Turner and Lambert (1983) report a range of 0.3–2.7 kg / ha / yr of P in *Eucalyptus* forest litterfall. Fertilisation increased the fluxes (rate of flow) in litterfall mass, N and P in a *Eucalyptus* plantation and native forest (O'Connell and Grove 1993; Pereira *et al.* 1994). For example, *Eucalyptus diversicolor* regrowth forests of Western Australia returned 3.7–4.5 Mg / ha / yr of litter, containing 25.3–30.8 kg / ha / yr of N and 0.82–1.02 kg / ha / yr of P when unfertilised and 4.7–5.7 Mg / ha / yr of litter, 36.7–42.3 kg / ha / yr of N and 1.45–2.42 kg / ha / yr of P when fertilised (O'Connell and Grove 1993). Rates of litterfall in *Eucalyptus* plantations are likely to be higher than in native forests due to the encouragement of high growth rates by the use of weed control and fertiliser. Rates of soil net N mineralisation (0–10 cm depth) at five Tasmanian *E. nitens* plantations were in the range 13–188 kg / ha / yr (Moroni 2002). Hence, fluxes of N and P in litterfall could be a significant component of nutrient cycling and knowledge of these rates is essential to understanding N and P cycling in plantations.

When collecting litter from younger plantations that have dense canopies within the rows and less dense canopies between

Table 1. Characteristics of the Basils and Basalt sites. Rainfall rates are long-term averages. NNM is net N mineralisation; AMN is anaerobically mineralisable N. These and other soil chemistries are for the 0–10 cm depth. (n.d. = not determined)

	Basils	Basalt
Previous vegetation	Eucalypt-myrtle	Eucalypt-myrtle
Planting dates	1993	1986
Ages examined (years)	3–4	10–11
Latitude	41°19'S	41°21'S
Longitude	145°39'E	145°51'E
Elevation (m)	550	580
Rainfall (mm / yr)	1800	1570
Daily soil temperature		
Jan_{min}–Jan_{max} (°C)	13–15	13–15
$July_{min}$–$July_{max}$ (°C)	2–6	2–6
Soil type[1]	Ferrosol	Ferrosol
Parent material	Basalt	Basalt
Surface texture	Clay-loam	Clay-loam
NNM (kg / ha / yr)[2]	70–91	n.d.
Total N (g / 100g)[2]	0.74	0.57
Total P (g / 100g)[2]	0.32	0.14
Total C (g / 100g)[2]	13.3	10.8
Hot KCl extractable N (mg / g)[2]	185	110
AMN (mg / g / week)[2]	155	130

[1] Isbell (1996)   [2] 0–10 cm depth, Moroni (2002)

the rows, more litter is likely to fall within rows than between rows. Hence, it may be necessary to sample litter from both intra- and inter-row regions of young plantations.

The objectives of the research reported here were to determine the seasonal patterns and annual rates of litterfall N and P in two *E. nitens* plantations (aged three years and ten years at the beginning of this study) in Tasmania on fertile sites; to examine the effect of N fertilisation on fluxes of litter-fall mass, N and P; and to examine the distribution of litterfall on the inter- and intra-row regions of the three-year-old plantation which was in the early phase of canopy closure. Results are discussed in the context of values reported for other *Eucalyptus* species grown in plantations and native forest.

Materials and methods

Site description

Two plantations growing on Ferrosols (Isbell 1996) were selected for study, one aged three years (Basils, 41°19'S, 145°39'E) and the other aged 10 years (Basalt, 41°21'S, 145°51'E). Soils at both sites had high concentrations of potentially mineralisable N, and Basils had high *in situ* rates of net N mineralisation (NNM, 70–91 kg / ha / yr, 0–10 cm depth, Moroni 2002); NNM had not been measured at Basalt. Site characteristics are summarised in Table 1. Both sites were ex-native forest and cleared of trees and shrubs, then strip cultivated (about 2.5 m ploughed and 1.5 m unploughed) before being planted with *E. nitens*. From each site, litter was collected from within randomly located control plots (250 m^2 approximate area, n = 3) that had not received any N fertiliser. At Basils, additional collections were made from randomly located fertilised plots (n = 3) that received 25 kg / ha of N at planting, 50 kg / ha of N at age one year and 100 kg / ha of N at age two years. Both treatments at Basils received 50 kg / ha of P at planting. Herbicides applied at both sites led to a low coverage of weeds, preventing litterfall from non-plantation species.

Litter collection

Litter was collected in ground traps that were 0.10 m high and 0.181 m^2 in area constructed from a 0.10 m wide sheet of galvanised iron riveted to form a ring that held fibreglass mesh 7 cm above the ground. At Basalt, four litter traps were placed randomly within each of the three unfertilised plots. At Basils, four traps were placed within each of the three fertilised and three unfertilised plots. Within plots, two litter traps were placed randomly within the rows and two between rows. In calculating fluxes per plot, between-row and within-row regions were assumed to each account for half of the total area. Litter was collected every five to eight weeks from both sites. Litter collected from each plot was bulked, except at Basils where within- and between-row samples remained separate, placed into brown paper bags and dried at 60°C for two days. The dried samples were then separated into leaves, loose bark, and branches (wood and bark), weighed, and subsampled for chemical analysis. Litter collections began in August 1996 at Basils and January 1997 at Basalt. Litter was collected over a 16-month period at Basils and a 12-month period at Basalt. Annual rates at Basils were estimated from the last 12 months of collections from this site, when collection times overlapped with those at Basalt.

N and P analysis

Tissue subsamples were ground to a fine powder, dried at 70°C for 24 h and cooled in a desiccator. Samples were then digested using an acid digestion method described by Lowther (1980). Solutions were analysed colorimetrically by flow injection analysis (Lachat Quikchem methods* 10-107-06-2E for N, and 10-15-01-1D for P).

* Methods are available on request from Lachat Instruments, 6645 West Mill Road, Milwaukee, WI 53218-1239, USA.

Statistical analysis

Means were compared using least significant difference (LSD) values where an analysis of variance (ANOVA) indicated a significant difference between means (*P* £ 0.05). A two-way ANOVA based on plots and groups was used to determine the significance of changes in rates of litterfall and N and P fluxes over time within sites. Groups comprised replicate observations of individual means to be compared (i.e. between sample dates within sites). Fluxes for individual periods within sites were compared on the common basis of daily rates. Differences between sites in annual rates of litterfall mass, N content and P content were compared by one-way ANOVA. Unfertilised replicates were used to compare litterfall between the three- and ten-year-old sites. Comparisons between fertilised and unfertilised treatments occurred at the three-year-old site only.

Results

There were no significant differences in litterfall (*P* = 0.34) between unfertilised and fertilised treatments at Basils, but average rates of litterfall were 18% higher in the fertilised treatment. Differences in litterfall in the between-row compared to the within-row areas were also not significant although 20% (*P* = 0.40) and 28% (*P* = 0.06) less litter fell between than within rows in fertilised and unfertilised treatments respectively (Table 2). More litter was collected between the rows than within rows at Basils at the fertilised and unfertilised treatments during 50% and 40% of the collection periods respectively. Between- and within-row data were averaged for subsequent analysis.

The rate of litterfall peaked in February–March at both sites (Figure 1), which coincided with low leaf litter N and P concentrations (Figure 2). Fluxes of N and P in leaf litter were highest during February–March at Basalt (Figure 3). There were less pronounced seasonal patterns in fluxes of N and P at Basils compared to Basalt, with lower fluxes from November to January at Basils (Figure 3).

As expected, concentrations of N were higher in leaf litter (0.9–1.3 g / 100g) than in branches (0.5–0.9 g / 100g) and bark (0.4–0.7 g / 100g) (Table 3). Likewise, concentrations of P were higher in leaf

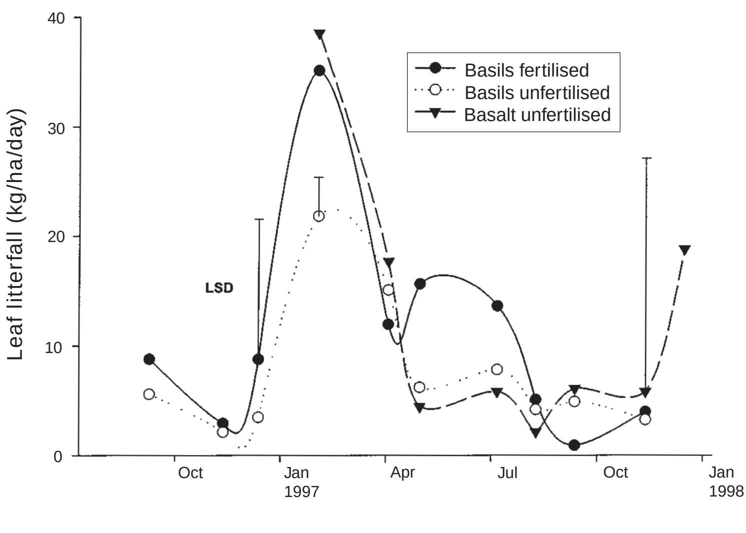

Figure 1. Temporal patterns of litterfall in E. nitens *at the Basils (fertilised and unfertilised) and Basalt sites. Bars are LSD (*P *< 0.05) for within-series comparison of means (*n *= 3). Data points are shown for the middle of each sampling period.*

Table 2. Rate of litterfall, and N and P fluxes in fertilised and unfertilised treatments of E. nitens *at the Basils site, within and between rows. Differences due to fertilisation or position were not significant (*P *< 0.05) for any variable. Standard errors are shown in brackets (*n *= 3).*

	Within rows		Between rows	
	Fertilised	Unfertilised	Fertilised	Unfertilised
Litterfall (kg / ha / yr)	5368 (779)	4763 (440)	4292 (830)	3419 (289)
N flux (kg / ha / yr)	65 (10)	59 (7)	56 (11)	44 5)
P flux (kg / ha / yr)	3.74 (0.29)	3.35 (0.36)	2.98 (0.56)	2.29 (0.24)

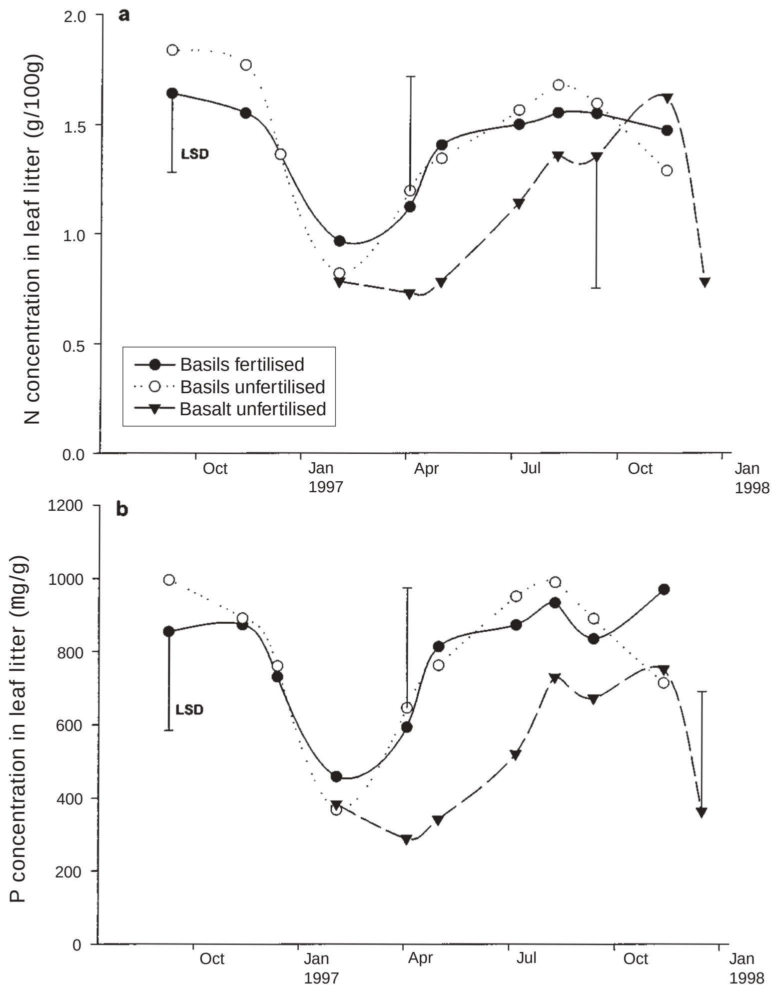

Figure 2. Temporal patterns in the N and P concentrations (a and b respectively) in leaf litter of E. nitens *at the Basils (fertilised and unfertilised) and Basalt sites. Bars are LSD (*P *< 0.05) for within-series comparison of means (*n *= 3). Data points are shown for the middle of each sampling period.*

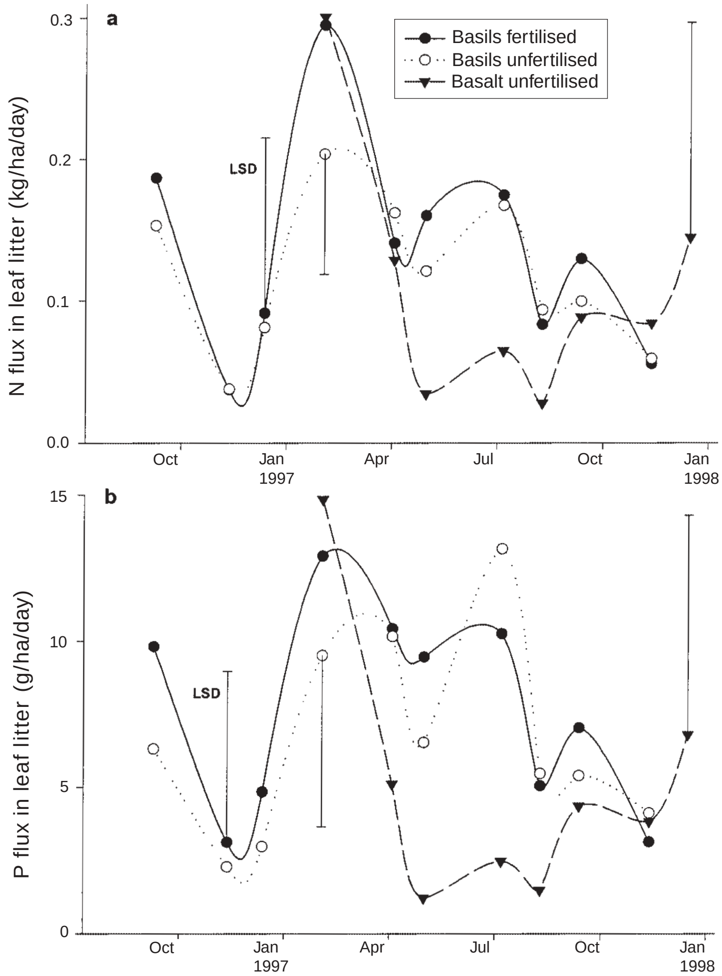

Figure 3. Temporal patterns of N and P fluxes (a and b respectively) in leaf litter of E. nitens *at the Basils (fertilised and unfertilised) and Basalt sites. Bars are LSD (*P *< 0.05) for within-series comparison of means (*n *= 3). Data points are shown for the middle of each sampling period.*

litter (410–680 mg / g) than in branches (220–440 mg / g) and bark (200–300 mg / g).

At Basils, an average of 4.46 Mg / ha / yr fell as litter, of which 98.3% was leaves, 1.2% bark and 0.4% twigs. More litter fell at Basalt (5.68 Mg / ha / yr), but this was significant only for the bark and branch fractions (Table 3).

Average fluxes at Basils were 56 kg / ha / yr of N and 3.1 kg / ha / yr of P. Leaves, bark, and branches contributed 99, 0.7 and 0.3% of the total N and P fluxes respectively (Table 3).

At Basalt, fluxes were 47 kg / ha / yr of N and 2.18 kg / ha / yr of P. Leaves, bark and branches contributed 92, 2.9 and 5.6% of the total N flux, respectively, and similar percentages of the total P flux (Table 3).

There were significant differences between sites for bark and branch falls (Basils < Basalt), leaf N and P concentrations (Basils > Basalt), and the amounts of N and P returned in bark litter (Basils < Basalt). At Basils, there was a significant difference between the fertiliser treatments for the amount of P returned in leaf litter (fertilised

Table 3. Eucalyptus nitens *litter mass, N and P fluxes and N and P concentrations at the Basils and Basalt sites. Standard errors are shown in brackets (*n *= 3). Letters denote significant differences (*P *< 0.05) between sites and treatments within tissue mass flux or nutrient concentration.*

		Basils	
	Basalt	Fertilised	Unfertilised
Litterfall (kg / ha / yr)			
leaf	4869 (132)	4740 (563)	4030 (347)
bark	354 (8) a	62 (26) b	47 (20) b
branches	510 (206) a	27 (12) b	14 (2) b
total	**5733 (330)**	**4830 (581)**	**4091 (362)**
N concentration (g / 100g)[1]			
leaf	0.9 (0.1) a	1.3 (0.0) b	1.3 (0.1) b
bark	0.4 (0.1)	0.7 (0.1)	0.6 (0.1)
branches	0.5 (0.1)	0.9 (0.1)	0.8 (0.3)
N flux (kg / ha / yr)			
leaf	43 (2)	60 (6)	51 (6)
bark	1 (0.3) a	0.5 (0.2) b	0.3 (0.1) b
branches	3 (1)	0.2 (0.1)	0.1 (0.0)
total	**47 (2)**	**61 (6)**	**52 (5)**
P concentration (mg / g)[1]			
leaf	410 (17) a	680 (144) b	690 (17) b
bark	200 (35)	300 (46)	260 (12)
branches	220 (35)	440 (12)	350 (6)
P flux (kg / ha / yr)			
leaf	1.99 (0.09) a	3.32 (0.39) b	2.80 (0.29) a
bark	0.07 (0.01) a	0.02 (0.01) b	0.02 (0.01) b
branches	0.12 (0.06)	0.01 (0.01)	0.01 (0.00)
total	**2.18 (0.13)**	**3.36 (0.40)**	**2.82 (0.30)**

[1] Weighted for litter mass

> unfertilised). However, annual fluxes in total litterfall and litter N and P fluxes were not significantly different between Basils and Basalt or between fertilised and unfertilised treatments at Basils (Table 3).

Discussion

Fluxes of litter falling between rows were 20–28% less than those falling on the rows, but this difference was not significant ($P < 0.05$). However, canopy closure and lift had occurred by the end of the collection period, reducing the uneven distribution of canopy between intra- and inter-row regions and hence the likelihood of uneven distributions of litterfall between these regions. Thus, any uneven litter distribution is likely to be largely associated with the early stages of canopy closure.

Fertilised treatments had an average of 18% greater fluxes of litterfall mass, N and P than

Table 4. Concentration of N and P in leaf, bark and branch litter reported for Eucalyptus *forests and plantations. Locations and ages of cited studies are presented in Table 5, except for the study by O'Connell (1981), which was located in Western Australia in a 40-year-old stand. (n.a. = data not available)*

N concentration (g / 100g)			P concentration (mg / g)			Dominant species	Author
Leaf	Bark	Branch	Leaf	Bark	Branch		
***Eucalyptus* forests, mainland Australia**							
0.6–0.9	0.5	0.7	200–300	200	150	*E. regnans*	Ashton (1975)
0.5	0.4	n.a.	220	180	n.a.	*E. marginata*	Hatch (1955)
0.3–0.8	n.a.	0.3–0.4	150	n.a.	88	*E. obliqua/baxteri*	Lee and Correll (1978)
0.6–0.8	n.a.	n.a.	140–420	n.a.	n.a.	*E. diversicolor*	O'Connell and Grove (1993)
1.0–1.3	0.3	0.4	180–380	90	160	*E. diversicolor*	O'Connell and Menage (1982)
0.8	0.5	0.4	n.a.	n.a.	n.a.	*E. diversicolor*	O'Connell (1981)
0.7–1.5	0.4–0.7	0.4–0.7	251–857	124–267	124–267	*E. regnans*	Polglase and Attiwill (1992)
0.7–1.2	0.3–0.4	0.3–0.4	285–505	65–125	145–200	*E. grandis*	Turner and Lambert (1983)
***Eucalyptus* plantation, Western Australia**							
0.5–0.6	n.a.	n.a.	320–420	n.a.	n.a.	*E. globulus*	Hingston *et al.* (1995)
***Eucalyptus* plantation, New Zealand**							
0.6–1.3	n.a.	n.a.	500–750	n.a.	n.a.	*E. regnans*	Frederick *et al.* (1985)

unfertilised treatments but this was not significant in our experiment. O'Connell and Grove (1993) and Pereira *et al.* (1994) found N and P fertilisation increased fluxes in *Eucalyptus* litterfall mass, N and P when compared to unfertilised treatments. Hence, fertilisation is expected to increase these fluxes. The non-significant differences in litterfall between intra- and inter-row regions and between fertilised and unfertilised treatments are indicative of the high variability encountered and the need for greater replication in future studies.

Annual rates of leaf litterfall did not differ significantly between the three- and ten-year-old plantations examined in this study, between *Eucalyptus regnans* plantations aged 4–11 years (Frederick *et al.* 1985), between native eucalypt forests dominated by *E. regnans* aged 5–250 years (Polglase and Attiwill 1992) and in many chronosequence studies in forests from around the world (Bray and Gorham 1964). This indicates that canopies were stable as soon as they had closed and that rates of turnover can remain constant within and between a range of forest types over long periods of time. The increase in woody litter with stand age observed in this study is expected to continue, which other studies have indicated can reach over 4000 kg / ha / yr (Frederick *et al.* 1985; Polglase and Attiwill 1992).

Leaf, bark and branch N and P concentrations and annual N and P fluxes encountered in this study were within the middle to upper range of concentrations (Table 4) and fluxes (Table 5) reported for *Eucalyptus* forests and plantations of various species, ages and locations, both internationally and within Australia. Within the study sites, litter nutrients were quickly recycled and made available for uptake, as there was little litter accumulation on the soil surface. Tables 4 and 5 present most of the published data for litterfall in *Eucalyptus*, indicating the need for further study of the contribution of litterfall fluxes to site nutrient cycles and fertility in plantations, especially domestically.

As observed in other studies, leaf litter contained large proportions of litter N flux (91–98%) and P flux (91–99%). In native forest, litter leaves contained 60–92% and 66–79% of the total litter N and P fluxes respectively (Adams and Attiwill 1991; Lee and Correll 1978; O'Connell and Menage 1982; O'Connell 1985; O'Connell and Grove 1993) and in plantations 91–100% and 80% of litter N and P respectively fell in leaf litter (George 1986; Pereira *et al.* 1994).

The seasonal patterns in litterfall were in general agreement with those found in other studies of *Eucalyptus*. More litter falls during the warmer months both in *Eucalyptus* plantations (Frederick *et al.* 1985; Madeira *et al.* 1995; Pereira *et al.* 1994) and native eucalypt forests (Adams and Attiwill 1991; Baker 1983; Lee and Correll 1978; O'Connell and Grove 1993; O'Connell and Menage 1982; Polglase and Attiwill 1992; Turnbull and Madden 1983). Higher leaf litter N and P concentrations in the colder months were also consistent with findings from other studies (e.g. Baker 1983; Frederick *et al.* 1985; Pereira *et al.* 1994; Polglase and Attiwill 1992; Van den Driessche and Webber 1977). Although there was some seasonality in bark litter-fall, and in its N and P content (bark fell predominantly from June to December, data not presented), these were minor compared to those in leaf litter.

Rates of litterfall and leaf litterfall are generally positively correlated with forest productivity (Adams and Attiwill 1986, 1991; Araujo *et al.* 1989; George and Varghese 1990; Madeira *et al.* 1995; Thomas 1992). The greatest separation of sites by litterfall flux is most likely to be observed during the period of greatest litter production. This occurred in February–March at both study sites, which suggests that rates of leaf litterfall in late summer are likely to be diagnostic for growth rates of *Eucalyptus* grown in temperate Australian environments.

The Basils and Basalt sites were considered fertile and moderately productive.

Table 5. Annual litterfall and N and P fluxes reported for Eucalyptus *forests and plantations. (n.a. = data not available)*

Litterfall (Mg / ha)	N flux (kg / ha)	P flux (kg / ha)	Dominant species	Source	Location[4]	Age (years)
***Eucalyptus* plantations, international**						
5.0	n.a.	n.a.	*E. camaldulensis*	Claudot (1956)	Morocco	n.a.
4.1–6.3	43.4–65.4	2.0–4.5	*E. regnans*	Frederick *et al.* (1985)	NZ	4–11
8.5	58	4.6	*E. globulus*	George and Varghese (1990)	India	10
3.4	69.6	1.6	*Eucalyptus* hybrid	George (1986)	India	5
***Eucalyptus* plantations, mainland Australia**						
1.5–5.7	n.a.	n.a.	*E. globulus*	Hingston *et al.* (1995)	WA	3–8
7.3–8.7	n.a.	n.a.	*E. grandis*	Turner (1986)	NSW	8–28
***Eucalyptus* forests, mainland Australia**						
7.0–9.9	43.5–57.6	1.3–1.9	*E. regnans*	Ashton (1975)	Vic	23–58
3.6	n.a.	1.0	*E. obliqua*	Attiwill (1968)	Vic	n.a.
3.1	n.a.	1.0	*E. obliqua*	Attiwill *et al.* (1978)	Vic	45–60
3.9–6.9	21.4–46.4	0.9–2.0	various[1]	Baker (1983)	Vic	19–90
n.a.	24.1–29.9	0.9–1.5	*E. obliqua*	Baker and Attiwill (1985)	Vic	80
2.3–3.4	10.3	0.6	*E. marginata*	Hatch (1955)	WA	36
2.1–2.7	9.8	0.3–0.4	various[2]	Lee and Correll (1978)	WA	2–40
4.9	n.a.	n.a.	*E. maculata*	McColl (1966)	NSW	n.a.
5.4	23.9	n.a.	*E. diversicolor*	O'Connell (1981)	WA	40
1.1–9.5	8.6–58.1	0.5–1.9	*E. diversicolor*	O'Connell and Menage (1982)	WA	2–40
n.a.	32.5–58.1	0.9–1.9	*E. diversicolor*	O'Connell (1985)	WA	2–40
3.7–5.7	25.3–51.2	0.8–2.4	*E. diversicolor*	O'Connell and Grove (1993)	WA	3–5
4.9–9.4	38.1–83.5	1.6–3.1	*E. regnans*	Polglase and Attiwill (1992)	Vic	5–250
5.9	n.a.	n.a.	*E. diversicolor*	Stoate (1958)	WA	n.a.
7.0	39.7	n.a.	*E. grandis*	Turner and Lambert (1981)	NSW	27
9.6	66.7	2.71	*E. grandis*	Turner and Lambert (1983)	NSW	25–29
6.5	41.2	1.4	*E. pilularis*	Webb *et al.* (1969)	NSW	n.a.
n.a	16.7–29.3	n.a	various[3]	Woods *et al.* (1981)	n.a.	> 20
***Eucalyptus* forests, Tasmania**						
3.5–5.3	8.5–32.1	0.3–2.1	various	Adams and Attiwill (1991)	Tas	80– > 200
4.8–5.6	n.a.	n.a.	*E. obliqua*	Turnbull and Madden (1983)	Tas	38–400

[1] *E. obliqua, E. regnans, E. sieberi*
[2] *E. obliqua, E. baxteri*
[3] *E. pauciflora, E. dives, E. dalrympleana, E. delegatensis*
[4] NSW = New South Wales, Tas = Tasmania, Vic = Victoria, WA = Western Australia, NZ = New Zealand

Concentrations of potentially mineralisable N at both sites, and *in situ* rates of NNM at the Basils site were high, and there had been little or no response in tree growth to applied N (Moroni 2001; G. Holz, pers. comm.). Average basal areas of 11 and 33 m^2 / ha at Basils (age five years) and Basalt (age 10 years), respectively, were in the mid range of basal areas reported for *E. nitens* plantations grown in Tasmania and New Zealand (Candy 1997). However, because these plantations were planted at elevations in excess of 500 m, low temperature is the most likely factor limiting growth. Rates of litterfall are generally positively correlated with forest productivity, and hence rates of litterfall at the Basils and Basalt sites were likely to be mid range of rates expected for *Eucalyptus* plantations grown in Tasmania.

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