Suburban development and change in vegetation nutritional status

MARCIA J. LAMBERT  
JOHN TURNER  
Forestry Commission of NSW, PO Box 100, Beecroft, NSW 2119, Australia

Abstract
In a study of species presence/absence and soil properties in bushland around northern Sydney, Clements (1983) found that species groupings were related to total soil phosphorus. This report presents analysis of foliage nutrient concentrations in species within these groupings. The highest concentrations of phosphorus, calcium, magnesium and potassium occurred in the suburban/disturbed group. The lowest overall concentrations were found in foliage from species in the dry sclerophyll communities. Mean foliage phosphorus was 0.099%, 0.125% and 0.042% for wet sclerophyll, disturbed and dry sclerophyll groups, respectively. Exotic species, particularly in disturbed environments, had the highest foliage nutrient concentrations. Results presented here showed that foliage nutrient concentrations are consistent with definitions of these groups on the basis of total soil phosphorus. These changes are considered to be important for management and conservation of bushland areas around Sydney.

Introduction
Changes in vegetation as a result of suburban development of the northern Sydney region were reported by Clements (1983). Bushland sites in the northern suburbs of Sydney were compared with relatively unaffected areas in the Brisbane Waters, Ku-ring-gai Chase and Royal National Parks. Higher phosphorus levels were detected in soils of suburban sites compared with those from similar parent materials in non-suburban areas. The analysis of vegetation revealed three major clusters of species, based on hierarchical agglomerative clustering. The major species clusters were: (1) elements associated with wet sclerophyll or rainforest margins; (2) those related to the activities of man; and (3) species associated with dry sclerophyll forests and heaths. The first main cluster was considered to be related to nutrient-rich soils, the third cluster was related to nutrient-poor soils, whereas the presence of the second cluster was restricted to suburban sites. Clements (1983) concluded that a major effect of suburban development on bushland is to increase soil total phosphorus levels, thereby decreasing the abundance of species that occur naturally on low nutrient soils, and increasing the abundance of species adapted to high nutrient soils.

The present authors have analysed foliage samples for a variety of purposes from many of the species reported by Clements (1983) and they are summarized here. These were not taken from the same sites as Clements (1983) but from similar general geographical areas. There were fewer than five samples for most species and so a mean is reported for each species without error terms. The information is presented to give a basis for testing the hypothesis of a relationship between suburban disturbance and soil nutritional status and, hence, plant nutritional status. This becomes of critical importance for both the maintenance of existing vegetation or the amelioration of damaged sites. Non-parametric testing of between species groups (Sokal & Rohlf 1969) was carried out, specifically the Mann-Whitney tests.

Methods
Foliage samples for nutrient analysis were green foliage collected in winter; the first fully expanded leaves were sampled from species where there were obvious differences between young and old leaves. The method of foliage sampling was the same as that used in other studies within New South Wales (Braithwaite et
194 M.J. Lambert and J. Turner

al. 1983; Lambert et al. 1983; Lambert & Turner 1983). Samples were oven-dried at 70°C within 16 h of collection. They were then ground, dry-ashed and analysed for phosphorus, aluminium; calcium, magnesium and potassium according to the procedures of Lambert (1983). Chloride was extracted separately and determined potentiometrically by titration (Lambert 1983). All samples were collected in the northern suburbs of Sydney on soils derived from either sandstone or shales.

Results and discussion

The species are listed within the three main groupings of Clements (1983) and the same order of species has been maintained (Table 1). Ten species were available from Group 1 from a total of 36, 10 from Group 2 from a total of 15, and 15 from Group 3 from a total of 61.

Mean foliage phosphorus for Group 1 species, which were considered to be in the wet sclerophyll Group mainly on nutrient-rich soils derived from shales, was 0.099% and ranged from 0.039% for Casuarina torulosa to 0.244% for Acacia longifolia. The soil mean total phosphorus reported for the Wianamatta andNarrabeen shales (Clements 1983) was 139 ± 64 p.p.m. The mean foliage phosphorus for Group 3 species was 0.042% (range; 0.029-0.063%) and was significantly lower than that for Group 1 species, which were associated with nutrient-poor soils. Soil mean total phosphorus for the associated Hawkesbury sandstone soils was 60 ± 33 p.p.m. (Clements 1983). Even accepting suburban contamination, a relationship between foliage and soil phosphorus concentrations does not seem unreasonable for these two groups. The mean foliage phosphorus concentration for Group 2 was 0.125% with a range from 0.077% to 0.191%. Based on the Mann-Whitney test, both Groups 1 and 2 were higher than Group 3, but were not different from each other.

These results extend the work of Clements (1983) in that overall phosphorus concentrations of species on disturbed sites are higher (P < 0.1) than on undisturbed sites; and wet sclerophyll sites are higher than dry sclerophyll sites. However, it would appear to not be a phosphorus effect alone. While many of the soils derived from Hawkesbury sandstone have very low phosphorus concentrations, they are also low in other elements important for plant nutrition, and the suburban environment has also either enriched and/or increased the availability of these elements. For example, foliage calcium was 0.39%, 0.50% and 1.46% for the dry sclerophyll, wet sclerophyll and disturbed sites, respectively, the last figure being significantly higher than the other two. Potassium was 0.62%, 0.95% and 1.70%, respectively, for the same sites, this difference also being significant. That is, species on disturbed sites have a higher uptake of both calcium and potassium. Aluminium, which may be expected to be more available on disturbed sites, is slightly higher in foliage from Group 1 and appears to be closely related to genera, such as the aluminium-accumulating genus Ceratopetalum (Webb 1954; Turner & Kelly 1981). No significant effects were found for chloride concentration.

Foliage analyses were available for four species within the unnumbered group of Clements (1983) and these appeared to have similar analyses to Group 3, possibly representing remnants which did not respond to changed nutrient availability in an area (Table 1). Some other species not reported in Clements (1983) were also available (Table 2). Most of these matched the wet or dry sclerophyll pattern and are reported for interest. However, foliage from Grevillea robusta and Phytalacca octandra are considerably higher in nutrients and relate to species from disturbed sites which were similar to those from which they were sampled.

A major problem with both soil and foliage nutrient concentration data when attempting to compare sites and species is that actual availabilities or requirements for nutrients are not known. Thus, an undisturbed and a disturbed site may both have similar soil total phosphorus but disturbance (physical disturbance or change in drainage due to building construction further upslope) would alter organic matter decomposition and hence phosphorus availability. Further, a slow-growing plant with high phosphorus requirements may take up from the soil the same quantity of phosphorus as a faster-growing plant with low phosphorus requirements. Although only relative indices of nutrient uptake or requirement were measured, it appears that disturbance leads to changed

Results and discussion

The species are listed within the three main groupings of Clements (1983) and the same order of species has been maintained (Table 1). Ten species were available from Group 1 from a total of 36, 10 from Group 2 from a total of 15, and 15 from Group 3 from a total of 61.

Mean foliage phosphorus for Group 1 species, which were considered to be in the wet sclerophyll Group mainly on nutrient-rich soils derived from shales, was 0.099% and ranged from 0.039% for Casuarina torulosa to 0.244% for Acacia longifolia. The soil mean total phosphorus reported for the Wianamatta and Narrabeen shales (Clements 1983) was 139 ± 64 p.p.m. The mean foliage phosphorus for Group 3 species was 0.042% (range; 0.029-0.063%) and was significantly lower than that for Group 1 species, which were associated with nutrient-poor soils. Soil mean total phosphorus for the associated Hawkesbury sandstone soils was 60 ± 33 p.p.m. (Clements 1983). Even accepting suburban contamination, a relationship between foliage and soil phosphorus concentrations does not seem unreasonable for these two groups. The mean foliage phosphorus concentration for Group 2 was 0.125% with a range from 0.077% to 0.191%. Based on the Mann-Whitney test, both Groups 1 and 2 were higher than Group 3, but were not different from each other.

These results extend the work of Clements (1983) in that overall phosphorus concentrations of species on disturbed sites are higher (P < 0.1) than on undisturbed sites; and wet sclerophyll sites are higher than dry sclerophyll sites. However, it would appear to not be a phosphorus effect alone. While many of the soils derived from Hawkesbury sandstone have very low phosphorus concentrations, they are also low in other elements important for plant nutrition, and the suburban environment has also either enriched and/or increased the availability of these elements. For example, foliage calcium was 0.39%, 0.50% and 1.46% for the dry sclerophyll, wet sclerophyll and disturbed sites, respectively, the last figure being significantly higher than the other two. Potassium was 0.62%, 0.95% and 1.70%, respectively, for the same sites, this difference also being significant. That is, species on disturbed sites have a higher uptake of both calcium and potassium. Aluminium, which may be expected to be more available on disturbed sites, is slightly higher in foliage from Group 1 and appears to be closely related to genera, such as the aluminium-accumulating genus Ceratopetalum (Webb 1954; Turner & Kelly 1981). No significant effects were found for chloride concentration.

Foliage analyses were available for four species within the unnumbered group of Clements (1983) and these appeared to have similar analyses to Group 3, possibly representing remnants which did not respond to changed nutrient availability in an area (Table 1). Some other species not reported in Clements (1983) were also available (Table 2). Most of these matched the wet or dry sclerophyll pattern and are reported for interest. However, foliage from Grevillea robusta and Phytalacca octandra are considerably higher in nutrients and relate to species from disturbed sites which were similar to those from which they were sampled.

A major problem with both soil and foliage nutrient concentration data when attempting to compare sites and species is that actual availabilities or requirements for nutrients are not known. Thus, an undisturbed and a disturbed site may both have similar soil total phosphorus but disturbance (physical disturbance or change in drainage due to building construction further upslope) would alter organic matter decomposition and hence phosphorus availability. Further, a slow-growing plant with high phosphorus requirements may take up from the soil the same quantity of phosphorus as a faster-growing plant with low phosphorus requirements. Although only relative indices of nutrient uptake or requirement were measured, it appears that disturbance leads to changed...
nutritional conditions allowing weeds with higher nutrient requirements to become established.

Although no species was sampled from two or more of the groups, some genera were. *Ceratopetalum apetalum* (Group 1) was higher in phosphorus and calcium than *C. gummi-ferum* (Group 3) but the differences were not

TABLE 1. Foliage analyses of various species sampled in the northern suburbs of Sydney

| Species | Soil parent material | P | Al | Ca | Mg | K | Cl |
|---------|----------------------|---|----|----|----|----|----|
| Group 1 (wet sclerophyll) | | | | | | | |
| *Ceratopetalum apetalum* D. Don | Shale | 0.053 | 1.041† | 1.246 | 0.299 | 0.481 | 0.174 |
| *Acmena smithii* (Poir.) Merrill et Perry | Shale | 0.063 | 0.010 | 0.596 | 0.225 | 0.828 | 0.230 |
| *Angophora floribunda* (Sm.) Sweet | Sandstone | 0.057 | 0.013 | 0.490 | 0.154 | 0.969 | 0.336 |
| *Pteridium esculentum* (Forst. f.) Cockayne | Shale | 0.180 | 0.010 | 0.225 | 0.212 | 1.992 | 0.376 |
| *Casuaria tenuis* Ait. | Shale | 0.039 | 0.003 | 0.415 | 0.154 | 0.640 | 0.648 |
| *Persoonia linearis* Ander. | Sandstone | 0.100 | 0.024 | 0.267 | 0.226 | 0.558 | 0.223 |
| *Acacia longifolia* (Andrews) Willd. | Shale | 0.244 | 0.017 | 0.317 | 0.372 | 2.090 | 0.240 |
| *Elaeocarpus reticulatus* Sm. | Shale | 0.057 | 0.017 | 0.537 | 0.048 | 0.636 | 0.038 |
| *C. littoralis* Salisb. | Shale | 0.109 | 0.016 | 0.686 | 0.161 | 0.610 | 0.608 |
| *Imperata cylindrica* (L.) Beauv. | Shale | 0.084 | 0.014 | 0.220 | 0.167 | 0.710 | 0.271 |
| Mean | | 0.099 | 0.014 | 0.500 | 0.202 | 0.950 | 0.314 |

| Group 2 (disturbed) | | | | | | | |
| *Cinnamomum camphora* (L.) Nees* | Shale | 0.103 | 0.041 | 2.829 | 0.353 | 1.430 | 0.026 |
| *Lingustrum lucidum* Ait.* | Shale | 0.125 | 0.019 | 0.673 | 0.529 | 1.325 | — |
| *L. sinense* Lour.* | Colluvium | 0.123 | 0.021 | 1.331 | 0.414 | 1.265 | 0.475 |
| *Pittosporum undulatum* Vent. | Sandstone | 0.084 | 0.030 | 1.175 | 0.206 | 1.769 | 0.286 |
| *Ochna serrulata* (Hochst.) Walp.* | Sandstone | 0.095 | 0.012 | 1.467 | 0.186 | 0.723 | 0.124 |
| *P. revolutum* Ait. | Sandstone | 0.077 | 0.021 | 0.589 | 0.470 | 2.455 | 0.349 |
| *Omalanthus populifolius* Grahm. | Shale | 0.180 | 0.023 | 1.435 | 0.463 | 1.806 | 0.815 |
| *Tradescantia albiflora* Kunth* | Shale | 0.188 | 0.024 | 1.677 | 0.449 | 2.370 | 1.106 |
| *Rubus vulgaris* Weike et Nees.* | Shale | 0.191 | 0.038 | 1.155 | 0.484 | 1.165 | — |
| *Lantana camara* L.* | Shale | 0.088 | 0.037 | 2.290 | 0.448 | 2.710 | 0.762 |
| Mean | | 0.125 | 0.027 | 1.462 | 0.400 | 1.702 | 0.493 |

| Group 3 (dry sclerophyll) | | | | | | | |
| *Banksia spinulosa* Sm. | Sandstone | 0.039 | 0.281† | 0.276 | 0.130 | 0.279 | 0.520 |
| *Actinostachys minor* (Sm.) D.C. | Sandstone | 0.044 | 0.023 | 0.152 | 0.180 | 1.303 | 0.649 |
| *A. ulicifolia* (Salisb.) Court | Sandstone | 0.058 | 0.001 | 0.295 | 0.115 | 1.044 | 0.939 |
| *Banksia ericifolia* L. | Sandstone | 0.038 | 0.022 | 0.445 | 0.186 | 0.290 | 0.425 |
| *Casuarina distyla* Vent. | Sandstone | 0.034 | 0.012 | 0.543 | 0.152 | 0.760 | 0.602 |
| *Persoonia levis* (Cav.) Domin | Sandstone | 0.033 | 0.018 | 0.233 | 0.264 | 0.506 | 0.339 |
| *Banksia serrata* L. | Sandstone | 0.036 | 0.036 | 0.277 | 0.075 | 0.356 | 0.274 |
| *Ceratopetalum gummiferum* Sm. | Sandstone | 0.037 | 0.335† | 0.701 | 0.161 | 0.835 | — |
| *Eucalyptus gummifera* (Gaertn.) Hochr. | Sandstone | 0.041 | 0.018 | 0.441 | 0.229 | 0.390 | 0.093 |
| *Persoonia pinifolia* R. Br. | Sandstone | 0.046 | 0.019 | 0.398 | 0.142 | 0.445 | 0.399 |
| *Acacia suaveolens* Sm. Willd. | Sandstone | 0.045 | 0.005 | 0.402 | 0.315 | 0.855 | 1.919 |
| *E. haemastoma* Sm. | Sandstone | 0.046 | 0.014 | 0.381 | 0.190 | 0.330 | 0.074 |
| *Lomatia salicifolia* (Sm.) R. Br. | Sandstone | 0.029 | 0.029 | 0.618 | 0.159 | 0.469 | 0.132 |
| *A. linifolia* (Vent.) Willd. | Sandstone | 0.063 | 0.008 | 0.451 | 0.278 | 0.975 | 0.734 |
| *Angophora costata* (Gaertn.) Druce | Sandstone | 0.045 | 0.015 | 0.203 | 0.146 | 0.414 | 0.266 |
| Mean | | 0.042 | 0.017 | 0.388 | 0.181 | 0.616 | 0.526 |

| Unnumbered groups between 2/3 | | | | | | | |
| *Gahnia erythrocarpa* R. Br. | Sandstone | 0.025 | 0.007 | 0.044 | 0.050 | 0.982 | 0.494 |
| *Syncarpia glomulifera* (Sm.) Niedenzu | Shale | 0.062 | 0.013 | 0.393 | 0.109 | 0.724 | 0.332 |
| *E. sieberi* L. Johnson | Sandstone | 0.042 | 0.007 | 0.380 | 0.252 | 0.340 | 0.040 |
| *E. piperita* Sm. | Shale | 0.054 | 0.020 | 0.453 | 0.202 | 0.330 | 0.143 |

Mann-Whitney test

| Group 1 vs 2 | 65.5 | 89.0† | 93.5† | 89.0† | 84.0† | 52.0 |
| Group 2 vs 3 | 134.5† | 102.5 | 147.0† | 149.0† | 142.0† | 57.0 |
| Group 1 vs 3 | 137.5† | 121.5† | 89.0 | 90.0† | 105.0 | 96.0 |

*Exotic species. †Not included in mean. ‡Significant at 5% level. Groupings and order are as in Clements (1983).
large. Both were high in aluminium, this being noted as an aluminium-accumulating genus (Webb 1954). *Angophora* species were found in Group 1 and 3. *Angophora floribunda* (Group 1) was marginally higher in nutrients than *A. costata* (Group 3). *Acacia longifolia* (Group 1) was very much higher in phosphorus than the *Acacia* spp. in Group 3.

Apart from vegetation considerations, further work on urban disturbance and alteration of soil nutrient status and availability is necessary. This is particularly the case in the protection and/or maintenance of bushland areas. Enrichment will arise particularly in drainage lines from sullage, swimming pools, septic tanks or roading. This can be demonstrated from chemical analyses of the foliage of the weed species, *Ligustrum*, sampled from a relatively undisturbed area, adjacent to a septic tank and in a sullage area. The sample from a relatively undisturbed area was from a small bush with low vigour while the others were growing very vigorously. Phosphorus and calcium (Table 3) were much higher in foliage of *Ligustrum lucidum* in the disturbed areas, calcium was highest in the sullage area, and potassium was highest in the septic drainage area. The type of disturbance may potentially affect the type of invading or surviving species.

### References

Braithwaite L. W., Dudzinski M. L. & Turner J. (1983) Studies on the arboreal marsupial fauna of eucalypt forests being harvested for woodpulp at Eden, N.S.W. II. Relationship between the fauna density, richness and diversity, and measured variables of the habitat. *Aust. Wildl. Res.* 10, 231-47.

Clements A. (1983) Suburban development and resultant changes in the vegetation of the bushland of the northern Sydney region. *Aust. J. Ecol.* 8, 307-19.

Lambert M. J. (1983) Methods for chemical analysis. Forestry Commission NSW. Technical Paper No. 25, 3rd edn., 187 pp.

Lambert M. J. & Turner J. (1983) Soil nutrient-vegetation relationships in the Eden area, NSW. III. Foliage nutrient relationships with particular reference to *Eucalyptus* subgenera. *Aust. For. For. Res.* 13, 200-9.

Lambert M. J., Turner J. & Kelly J. (1983) Nutrient relationships of tree species in a New South Wales subtropical rainforest. *Aust. For. Res.* 13, 91-102.

Sokal R. R. & Rohlf F. J. (1969) *Biometry*. W. H. Freeman and Co, San Francisco.

Turner J. & Kelly J. (1981) Relationship between soil nutrients and vegetation in a north coast forest, New South Wales. *Aust. For. Res.* 11, 201-8.

Webb L. J. (1954) Aluminium accumulation in the Australian-New Guinea flora. *Aust. J. Bot.* 2, 176-96.

---

**TABLE 2. Species additional to those in Clements (1983)**

| Species                  | Soil parent material | P    | Al  | Ca  | Mg  | K    | Cl  |
|--------------------------|----------------------|------|-----|-----|-----|------|-----|
| *Lambertia formosa*      | Sandstone            | 0.029| 0.044| 0.231| 0.141| 0.366| 0.134|
| *Acacia botrycephala*    | Soapstone            | 0.069| 0.013| 0.792| 0.424| 0.250| 0.643|
| *Grevillea robusta*      | Soapstone            | 0.062| 0.016| 1.189| 0.133| 0.933| 0.315|
| *Phyllocladus oцинandra* | Soapstone            | 0.365| 0.037| 0.579| 1.034| 7.975| 0.735|
| *Macrozamia communis*    | Soapstone            | 0.110| 0.014| 0.520| 0.401| 1.010| 1.329|
| *Eucalyptus pilularis*   | Soapstone            | 0.048| 0.019| 0.373| 0.300| 0.320|       |
| *E. sieberi*             | Soapstone            | 0.045| 0.011| 0.380| 0.252| 0.340| 0.094|
| *E. radiata*             | Soapstone            | 0.080| 0.015| 0.413| 0.219| 0.427| 0.223|

* Exotic species.

---

**TABLE 3. *Ligustrum lucidum* sampled in close proximity but under different conditions**

| Species                                  | Percentage oven dry weight |
|------------------------------------------|---------------------------|
|                                          | P  | Al  | Ca  | Mg  | K  |
| Relatively undisturbed (see Table 1)     | 0.125 | 0.019 | 0.673 | 0.529 | 1.325 |
| Adjacent to septic tank overflow         | 0.267 | 0.015 | 0.870 | 0.289 | 2.125 |
| In sullage area                          | 0.264 | 0.016 | 1.236 | 0.432 | 1.580 |

(Final manuscript received July 1986)
This document is a scanned copy of a printed document. No warranty is given about the accuracy of the copy. Users should refer to the original published version of the material.