

Woody overstorey impact on herbaceous understorey in *Eucalyptus* spp. communities in central Queensland

J. C. SCANLAN

Department of Primary Industries, PO Box 183, Charters Towers, Qld 4820, Australia

W. H. BURROWS

Department of Primary Industries, PO Box 6014, Rockhampton Mail Centre, Qld 4702, Australia

Abstract

Native pasture yield and species composition within naturally occurring *Eucalyptus* communities of central Queensland were studied. Within a site, herbaceous yield decreased as tree basal area increased with the greatest relative decrease at sites with low pasture production potential. Mitscherlich regressions between herbaceous yield and tree basal area ($Y = A + B \cdot e^{-kx}$) accounted for >80% of the observed variation at all sites. The absolute value of 'k' was greatest for those sites that had the lowest yield in the absence of trees.

Pasture composition in treeless plots varied widely among sites. However, the direction of species compositional change was similar for all sites except one subject to short-term inundation on a heavy clay soil. Grass tribes differed in their occurrence in areas of high tree basal area. Andropogoneae had lower actual yield and percentage composition (by dry weight) at high tree basal area, while Paniceae showed the reverse trend. Non-grass herbaceous plants made a greater contribution to pasture composition at higher tree basal area although actual dry matter yield remained relatively constant over a wide range of basal areas.

Introduction

Non-leguminous trees generally decrease herbaceous productivity within their projected canopy area and even beyond. This has been documented in Australia for *Eucalyptus crebra*

(Gillard 1979; Walker *et al.* 1986), for *Eucalyptus populnea* (Walker *et al.* 1972), for *Callitris columellaris* (Wells 1974), as well as for the leguminous *Acacia aneura* (Beale 1973). All except the first two studies were conducted in semi-arid native pasture areas.

Moisture competition is a major factor in this reduced pasture yield but it will only occur when both trees and grass are actively transpiring. Mott and Tothill (1984) suggest that moisture competition will be minimal in the tropics where the 'wet' season is rarely punctuated by dry spells and that it will be considerable in the subtropics where several dry periods are usually experienced during the growing season. This is supported by McCown *et al.* (1974) and McIvor (1981) who indicate that growth ceases towards the end of April in northern Queensland even though temperatures and soil moisture levels appear adequate for growth. Nutrient deficiencies are postulated as probable causes of growth cessation at the end of the 'wet' season (McIvor 1981).

Changes in species composition following tree thinning or removal have been rarely documented in native pasture systems. The most consistent change reported is that the increase in grass biomass following tree removal is greater than that for forbs (e.g. Miller *et al.* 1980; Ball *et al.* 1981; Clary & Jameson 1981).

Eucalyptus communities form extensive and economically important woodland systems in northern Australia (Mott & Tothill 1984) and an understanding of herbage production and composition is necessary for an understanding of animal productivity from these areas. The specific hypothesis tested was that areas with high tree basal area of *Eucalyptus* spp. in central Queensland have lower relative herbaceous biomass production and an altered species composition relative to areas with low tree basal area.

Method

Field sampling

Between-site variation may be sufficiently large to mask tree effects on pasture production in woodlands (Severson & Kranz 1976). Separation of this source of variation from tree density effects was achieved by examining different densities (plots) within the same site and comparing sites rather than plots from various sites.

A site was defined as an area of similar soil type, vegetation and slope (5–10 ha) within which various numbers of smaller plots were sampled. The actual plot size used varied from 0.04 to 0.36 ha with the smaller plots being necessary to obtain uniform areas with a high tree density.

The eight sites examined are described in Table 1. These sites were located within 100 km of Rockhampton, central Queensland in *Eucalyptus* communities in which the over-storey had not been treated by ring-barking or stem-injection with arboricide. The general climate is subtropical with an October–March rainfall comprising about 75% of annual rainfall, which varied from 750 to 950 mm across sites.

At six sites (E1 to E6), tree basal area was recorded and corresponding pasture yield and species composition determined. Tree basal area and total pasture yield only were recorded at the other two sites. Pasture sampling was carried out from 14 April to 7 May 1982, which coincided with the period of peak standing crop (end of summer growth period). All sites chosen were ungrazed or in areas known to be only lightly grazed by domestic stock.

Tree basal area was determined by recording every tree within the plot. Circumferences were measured at 30 cm above ground level in preference to ground level measurement to avoid problems with buttresses and in preference to waist height measurement to enable smaller stems to be measured. At three sites (E5, E7 and E8), basal area was determined using the Bitterlich stick method (Grosenbaugh 1952).

Basal area was chosen as the measure of potential tree influence, rather than tree density, since the former integrates stem size which can vary widely between individuals in natural eucalypt stands. Each 10 m² basal area corresponds to approximately 150 mature trees for the present study sites.

Herbaceous standing crop was visually estimated using a double sampling technique

TABLE 1. Location, soil type and slope, and the range of herbaceous standing crop and tree basal area of each *Eucalyptus* site in central Queensland

Site	Dominant tree species	Location	Soil type*	Slope (%)	No. plots	Basal area range (m ² ha ⁻¹)	Yield range [†] (kg ha ⁻¹)
E1	<i>E. melanophloia</i>	150°04'E 23°39'S	Ug5.13	2	6	0–30.2	2581–1129
E2	<i>E. fibrosa</i>	150°16'E 23°05'S	Db1.12	0	7	0–47.5	2308–692
E3	<i>E. populnea</i>	150°16'E 22°52'S	Dy3.32	0	10	0–27.7	1816–490
E4	<i>E. crebra</i>	150°18'E 22°52'S	Dy3.32	3	9	0–24.6	3351–648
E5	<i>E. crebra</i>	151°00'E 23°53'S	Dy3.42	5	7	0–28.1	2755–665
E6	<i>E. populnea</i>	150°38'E 23°38'S	Ug5.34	0	8	0–31.7	3050–823
E7	<i>E. crebra</i>	150°27'E 23°10'S	Dy3.32	1	7	0–25.3	1900–352
E8	<i>E. crebra</i>	150°26'E 23°10'S	Dy3.32	15	8	0–17.3	1450–170

*After Northcote (1974). †Yields corresponding to tree basal areas shown. (Yield is highest where tree basal area is lowest, hence range decreases.)

in which 50 quadrats were rated on a 0 to 5 scale. A further 12 quadrats were rated, cut, dried and weighed to provide a regression with which the ratings were converted to yield estimates. Botanical composition was determined using the dry-weight-rank technique suggested by 't Mannetje and Haydock (1963). This involves recording the three highest yielding species. The biomass is then allocated to species according to weighting factors determined by 't Mannetje and Haydock (1963). Together these techniques allow rapid estimation of yield of individual species and composition by percentage dry weight (Tothill *et al.* 1978).

Statistical analyses

The yield and pasture composition (by percentage dry weight) were determined using the BOTANAL subroutine within FORALL on the CSIRO CYBER 76 computer (Hargreaves & Kerr 1978). The non-linear regression analysis of pasture yield in relation to tree basal area was carried out using a maximum likelihood program (MLP on the CYBER 76). The Mitscherlich function (Richards 1969) was used in preference to the transition sigmoid curve suggested by Jameson (1967) and used by Walker *et al.* (1972). The chosen form was simpler to calculate and interpret, and required three parameters to be fitted to the data rather than five as in the case of the transition sigmoid curve. Good visual fits to the data and consistently high coefficients of determination were obtained.

Pasture composition data were analysed using the TAXON program available on the

CYBER 76 (Ross 1983). A principal co-ordinate analysis (PCOA) was used to examine the relationship among species compositions of all plots. The first and second vectors (after scaling by the eigen value of each vector) were used as axes to plot the position of all plots in two-dimensional space. The correlations between species frequency and vectors one and two were calculated using the BACRIV routine available in TAXON.

Grass species were combined into grass tribes and correlations between actual yield and percentage composition by weight and tree basal area were calculated by combining data for all sites.

Results

Yield

Significant curvilinear regressions ($P < 0.001$) between pasture yield and tree basal area were obtained for all sites (Table 2). Dry matter yield declined rapidly as tree basal area increased from 0 to $6 \text{ m}^2 \text{ ha}^{-1}$. At higher basal areas the relative decrease was less pronounced (Fig. 1).

Differences between curves (sites) were assessed by a regression of ' k ', the rate of decrease (Table 2), against site potential (Fig. 2). The significant regression ($P < 0.001$) between ' k ' and site potential indicated that the rate of decline of pasture yield with increasing tree basal area was greatest for those sites with the lowest site potential.

TABLE 2. Regression parameters for pasture yield (Y kg ha^{-1}) in relation to basal area of *Eucalyptus* spp. ($X \text{ m}^2 \text{ ha}^{-1}$), at each site in central Queensland, where $\text{Y} = A + B * e^{(-kX)}$

Site	A (s.e.m.)*	B (s.e.m.)*	k (s.e.m.)*	Coefficient of determination†
E1	1131 (320)	1549 (349)	0.1220 (0.0685)	0.85
E2	715 (103)	1680 (137)	0.0833 (0.0167)	0.97
E3	629 (105)	1310 (242)	0.2706 (0.0908)	0.84
E4	-59 (871)	3599 (810)	0.0715 (0.0345)	0.92
E5	463 (222)	2173 (215)	0.0854 (0.0189)	0.98
E6	463 (696)	2590 (625)	0.0588 (0.0330)	0.91
E7	90 (367)	2141 (342)	0.1806 (0.0351)	0.89
E8	151 (75)	1238 (133)	0.320 (0.0351)	0.93

*s.e.m. = Standard error of the mean.

†All values have $P < 0.001$.

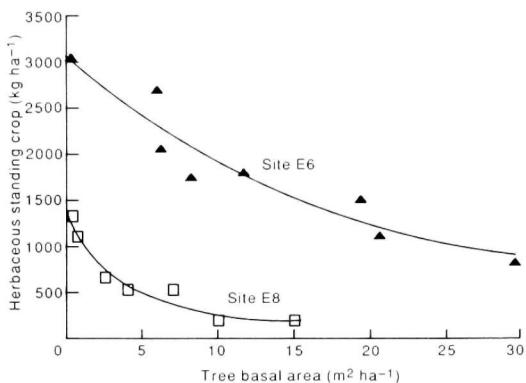


FIG. 1. Relationship between tree basal area and pasture standing crop for sites with high (E6) and low (E8) site production potential in *Eucalyptus* spp. woodlands of central Queensland. (Lines are fitted regression lines — see Tables 1 and 2 for more details.)

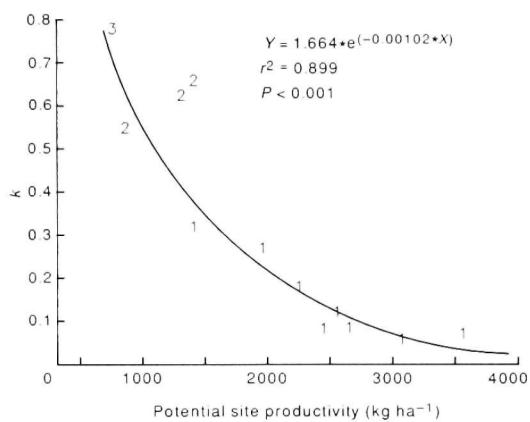


FIG. 2. Relationship between potential site productivity and the k value in the regression $Y = A + B * e^{-kX}$ (relating pasture yield Y to tree basal area X) from a range of communities. Data are from: 1, this study; 2, Beale (1973) — *Acacia aneura*; 3, Woods *et al.* (1982) — *Pinus tremuloides*.

TABLE 3. Species showing significant correlations with the primary and secondary vectors extracted from the principal co-ordinate analysis of species composition (% contribution to standing crop) in *Eucalyptus* spp. sites in central Queensland

Species	Vector 1		Vector 2	
	Correlation coefficient	Species	Correlation coefficient	
<i>Bothriochloa decipiens</i>	0.71	Sedge	0.75	
<i>Chrysopogon fallax</i>	0.69	<i>Paspalidium distans</i>	0.57	
<i>Panicum</i> spp.	0.69	<i>Cymbopogon refractus</i>	0.53	
<i>Eragrostis</i> spp.	0.47	<i>Bothriochloa decipiens</i>	0.47	
Native legumes	-0.53	<i>Eragrostis</i> spp.	0.45	
<i>Aristida</i> spp.	-0.53	Broad leaved weeds	0.40	
Other grasses	-0.63	<i>Themeda triandra</i>	-0.39	
		<i>Heteropogon contortus</i>	-0.62	

Composition

The tree basal area of each plot from each site was plotted individually against the first and second ordination axes extracted from the complete data set. All sites showed a consistent linearity with increasing basal area. The direction of change was similar for all sites except E6, which was a heavy clay site supporting *E. populnea* (Fig. 3) and was subject to short-term inundation.

The species correlations with vectors 1 and 2 from the ordination are shown in Table 3. As tree basal area increased, *Themeda triandra*

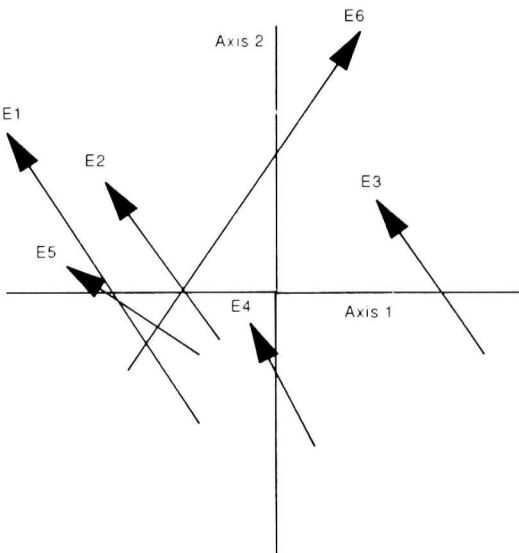


FIG. 3. Ordination of pasture species composition at each *Eucalyptus* spp. site studied in central Queensland. Arrows indicate the relative direction of increasing tree basal area (from treeless at origin of arrow to dense trees at head of arrow) when plot locations are replaced by their tree basal areas.

TABLE 4. Correlations between yield (actual or percentage of total dry matter) of major grass tribes and non-grasses and tree basal area for *Eucalyptus* spp. sites in central Queensland (data pooled across sites)

Grass tribe	Total dry matter yield	Composition (% of total dry matter)
Andropogoneae	-0.635**	-0.498**
Panicaceae	0.288*	0.443**
Aristideae	0.009 ns	0.133 ns
Eragrostideae	-0.351*	-0.128 ns
Chlorideae	-0.238 ns	-0.255 ns
Non-grasses	0.026 ns	0.496**

ns $P > 0.05$; * $0.05 > P > 0.01$; ** $P < 0.01$.

and *Heteropogon contortus* decreased with a concomitant increase in native legumes, broad leaved weeds, sedge, *Aristida*, *Paspalidium distans*, *Cymbopogon refractus*, *Bothriochloa decipiens* and *Eragrostis*.

The correlations between biomass in grass tribes and tree basal area are shown in Table 4. Both dry matter yield and contribution to total dry matter of Andropogonoid grasses decreased as tree basal area increased while Panicoid grasses exhibited the opposite relationship. Eragrostoid grass biomass showed a negative correlation with tree basal area but this was apparently in line with the overall decrease in total dry matter. Yield of non-grasses (broad leaved herbaceous plants and sedges) showed no correlation with tree basal area but comprised a greater component of the dry matter on offer at higher tree basal areas.

Discussion

Yield

Pasture yield was decreased by the presence of trees at all sites. The rate of decline in yield (as tree basal area increased) was least for sites with highest site potential. Consequently, the relative pasture yield reduction due to a given tree basal area was greater at sites with low site potential. This supports the observation that trees have a greater depressant effect on pasture yield in years of low rainfall and consequently lower potential pasture production (Ward & Cleghorn 1964; Du Toit 1968; Walker 1974; Clary 1975).

The decline in the absolute value of ' k ' as site potential increased (Fig. 2) reflects the greater

relative effect of tree basal area on pasture production at sites with low production potential. In the equation used here, A represents the yield supported under dense trees (as X increases, $B \cdot e^{-kX}$ approaches zero). As ' k ' in areas with low site production potential is relatively high, the yield approaches A much more quickly when site potential ($A + B$) is low. Data from Beale (1973) and Woods *et al.* (1982) also support this general relationship. The yield reduction caused by a specified level of tree basal area can therefore be predicted for eucalypt communities in this region, given site potential is known.

The reduced effect of trees on pasture production as site productivity increases is also evident from the relationship between site potential and the tree basal area at which herbaceous standing crop is 50% of that for open areas (BA_{50}). This approach allows data presented in a variety of forms to be used (Fig. 4). There is an increase in BA_{50} as site potential increases for all locations and for tree types as divergent as *Pinus*, *Eucalyptus* and *Acacia*. This general relationship is consistent with the conclusions drawn from Fig. 2.

Walker *et al.* (1986) reported a linear relationship between *E. crebra* tree biomass

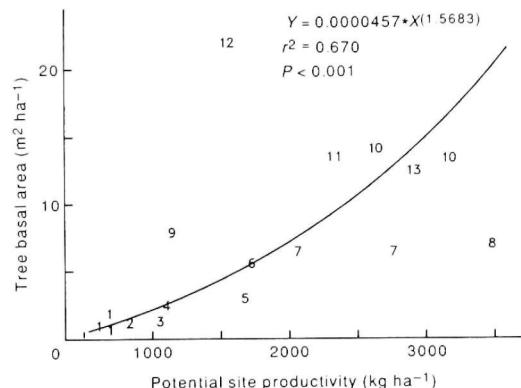


FIG. 4. Relationship between potential herbaceous standing crop in the absence of trees and the tree basal area that produces 50% reduction in that yield. Data are from: 1, Jameson (1967) — *Pinus ponderosa*/*P. edulis*; 2, Pearson (1965) — *Pinus ponderosa*; 3, Beale (1973) — *Acacia aneura*; 4, Clary (1975) — *Pinus ponderosa*; 5, Pase (1958) — *Pinus ponderosa*; 6, Severson & Kranz (1976) — *Pinus ponderosa*; 7, Grelen & Lohrey (1978) — *Pinus pulistris*; 8, Grelen *et al.* (1972) — *Pinus elliottii*; 9, Gaines *et al.* (1954) — *Pinus pulistris*; 10, Wolters (1981) — *Pinus pulistris*; 11, Woods *et al.* (1982) — *Pinus tremuloides*; 12, Clary (1974) — *Pinus elliottii*; 13, Walker *et al.* (1986) — *Eucalyptus crebra*.

Walker *et al.* (1986) reported a linear relationship between *E. crebra* tree biomass and herbage biomass, in contrast to the Mitscherlich function often fitted to such data. They explained this difference in terms of the higher rainfall (*sensu* higher site potential) at their site compared with other studies they reviewed. This is in keeping with the present observations that the Mitscherlich response curve flattens as site potential improves.

Composition

The ordination of plots within sites demonstrated distinct compositional differences between plots with different tree basal areas. Sites formed elongated groups when plotted against the first two vectors extracted from the data, although there was considerable overlap between sites (Fig. 3). The compositional change for the heavy clay soil site subjected to short-term inundation (E6) was quite different from those obtained from duplex soils or from shallow clay soils. This indicates that environmental conditions can override the effects of increasing tree density.

The species composition of treeless plots is determined by site factors such as fertility, drainage, soil depth and rainfall. The presence of trees merely modifies this potential composition, with species composition likely to be more similar within plots at the same site than at a given level of tree basal area across sites.

The most consistent species change over all sites was the decrease in *Heteropogon contortus* in plots with moderate to high tree basal area. Most species favoured by high tree densities produce less dry matter or are less desirable from an animal production point of view compared with *Heteropogon contortus*. Exceptions in the latter case are native legumes and other broad leaved plants favoured by increasing tree densities (Table 3).

Johnson and Tothill (1985) noted that removal of the tree and shrub layers from the savanna vegetation of eastern Australia results not only in an increase in abundance of the existing graminoid flora, but also a significant modification of the flora leading to a change in dominance at the tribal level. These observations are supported by the data collected in this study (Table 4). The fact that Andropogonoid grasses are favoured by tree clearing relative to Panicoid species could be of some significance

in deriving stable pasture systems for these cleared woodlands. It is presently common for graziers to sow non-Andropogonoid exotic species (for example *Panicum*, *Chloris* and *Cenchrus*) into these derived systems but they either do not persist or commonly 'run-down'. More stable pastures, in the mid-term, should result from planting native or introduced Andropogonoid grasses such as species of *Bothriochloa*, *Dichanthium*, *Heteropogon* and *Themeda*.

Acknowledgements

The authors acknowledge the helpful suggestions and comments made by the late Dr P. C. Whiteman and the technical assistance of Mr G. W. Fossett. Financial support for this project was provided by the Australian Meat Research Committee (now Australian Meat and Livestock Research and Development Corporation).

References

- Ball M. J., Hunter D. H. & Swindel B. F. (1981) Understory biomass response to microsite and age of bedded slash pine plantations. *J. Rangel. Manage.* **34**, 38–42.
- Beale I. F. (1973) Tree density effects on yields of herbage and tree components in south west Queensland mulga (*Acacia aneura*) scrub. *Trop. Grassl.* **7**, 135–42.
- Clary W. P. (1974) Response of herbaceous vegetation to felling of alligator juniper. *J. Rangel. Manage.* **27**, 387–9.
- Clary W. P. (1975) Range management and its ecological basis in the ponderosa pine type of Arizona: The status of our knowledge. *USDA For. Ser. Res. Paper No. RM-158*.
- Clary W. P. & Jameson D. A. (1981) Herbage production and shrub removal in the pinyon-juniper type in Arizona. *J. Rangel. Manage.* **34**, 109–13.
- Du Toit P. F. (1968) A preliminary report on the effect of *Acacia karoo* competition on the composition and yield of sweet grassveld. *Proc. Grassl. Soc. Southern Afr.* **3**, 147–9.
- Gaines E. M., Campbell R. C. & Brassington J. J. (1954) Forage production on longleaf pine stands of southern Alabama. *Ecology* **35**, 59–62.
- Gillard P. (1979) Improvement of native pasture with Townsville stylo in the dry tropics of sub-coastal northern Queensland. *Aust. J. Exp. Agric. Anim. Hus.* **19**, 325–36.
- Grelan H. E. & Lohrey R. E. (1978) Herbage yield related to basal area and rainfall in a thinned longleaf plantation. *USDA For. Ser. Res. Note No. SO-232*.
- Grelan H. E., Whitaker L. B. & Lohrey R. E. (1972) Herbage response to pre-commercial thinning in direct-seeded slash pine. *J. Rangel. Manage.* **25**, 435–7.

- Grosenbaugh L. R. (1952) Plotless timber estimates — New, fast, easy. *J. For.* **50**, 32–7.
- Hargreaves J. N. G. & Kerr J. D. (1978) BOTANAL — A comprehensive sampling and computing procedure for estimating pasture yield and composition. II. Computational package. *CSIRO Trop. Agron. Tech. Mem. No. 9*.
- Jameson D. A. (1967) The relationship of tree overstory and herbaceous understorey vegetation. *J. Rangel. Manage.* **20**, 246–9.
- Johnson R. W. & Tothill J. C. (1985) Definition and broad geographic outline of savanna lands. In: *Ecology and Management of the World's Savannas* (eds J. C. Tothill and J. J. Mott) pp. 1–13. Australian Academy of Science, Canberra.
- 't Manneij L. & Haydock K. P. (1963) The dry-weight-rank method for botanical analysis of pasture. *J. Br. Grassl. Soc.* **18**, 268–75.
- McCown R. L., Gillard P. & Edye L. A. (1974) The annual variation in yield of pastures in the seasonally dry tropics of Queensland. *Aust. J. Exp. Agric. Anim. Hus.* **14**, 328–33.
- McIvor J. G. (1981) Seasonal changes in the growth, dry matter distribution and herbage quality of three native grasses in northern Queensland. *Aust. J. Exp. Agric. Anim. Hus.* **21**, 600–9.
- Miller R. F., Findley R. R. & Alderfer-Findley J. (1980) Changes in mountain big sagebrush habitat types following spray release. *J. Rangel. Manage.* **33**, 278–81.
- Mott J. J. & Tothill J. C. (1984) Tropical and sub-tropical woodlands. In: *Management of Australia's Rangelands* (eds G. N. Harrington, A. D. Wilson and M. D. Young) pp. 255–69. CSIRO, Melbourne.
- Northcote K. H. (1974) A factual key for the recognition of Australian soils. Rellim Technical Publications, Glenside, South Australia.
- Pase C. P. (1958) Herbage production and composition under immature ponderosa pine stands in the Black Hills. *J. Rangel. Manage.* **11**, 238–43.
- Pearson H. A. (1965) Studies of forage digestibility under ponderosa pine stands. *Proc. Soc. Amer. For.* pp. 71–3.
- Richards F. J. (1969) The quantitative analysis of plant growth. In: *Plant Physiology VA* (ed. F. C. Steward) pp. 1–76.
- Ross D. (1983) *TAXON Users' Manual. Edition P3B. CSIRONET Manual No. 6*. CSIRO, Canberra.
- Severson K. E. & Kranz J. J. (1976) Understory production not predictable from aspen basal area or density. *USDA For. Ser. Res. Note No. RM-314*.
- Tothill J. C., Hargreaves J. N. G. & Jones R. M. (1978) BOTANAL — A comprehensive sampling and computing procedure for estimating pasture yield and composition. I. Field sampling. *CSIRO Trop. Agron. Tech. Mem. No. 8*.
- Walker B. H. (1974) Ecological considerations in the management of semi-arid ecosystems in south-central Africa. *Proc. 1st Intern. Cong. Ecol.* pp. 124–29.
- Walker J., Moore R. M. & Robertson J. A. (1972) Herbage response to tree and shrub thinning in *Eucalyptus populnea* shrub woodlands. *Aust. J. Agric. Res.* **23**, 405–10.
- Walker J., Robertson J. A., Penridge L. K. & Sharpe P. J. H. (1986) Herbage response to tree thinning in a *Eucalyptus crebra* woodland. *Aust. J. Ecol.* **11**, 135–40.
- Ward H. K. & Cleghorn W. B. (1964) The effect of ringbarking trees in *Brachystegia* woodland on the yield of veld grasses. *Rhod. Agric. J.* **61**, 98–107.
- Wells K. F. (1974) Pasture and forest: the situation in north-western NSW. CSIRO Div. Land Use Res. Tech. Mem. No. 74/6.
- Wolters G. L. (1981) Timber thinning and prescribed burning as methods to increase herbage on grazed and protected longleaf pine ranges. *J. Rangel. Manage.* **34**, 494–7.
- Woods R. F., Betters D. R. & Mogren E. W. (1982) Understory herbage production as a function of Rocky Mountain aspen stand density. *J. Rangel. Manage.* **35**, 380–1.

(Final manuscript accepted January 1990)

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.