EFFECTS OF TREE KILLING AND LIVESTOCK IN A POPLAR BOX (EUCALYPTUS POPULNEA) WOODLAND ON GROUND LAYER VEGETATION AND SOME SURFACE SOIL PROPERTIES

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Abstract

Land development in poplar box woodlands commonly involves the killing of trees to increase grass production for domestic livestock. The effects of this development were investigated using a stratified sampling technique whereby samples were taken at equispaced points along transects between pairs of trees. Measurements were obtained in four poplar box systems which represented a factorial combination of the treatments of killing trees and grazing by livestock. The variables measured characterized physical properties of the soil surface, chemical properties of the top 10 cm of soil, leaf and twig litter, and the density and biomass of grasses and forbs. There were marked gradients away from trees for all variables except available phosphorus. Both the gradients and the mean levels were used to evaluate the effects of trees and livestock in the woodland.

Grazing increased the amount of bare soil, surface soil salinity and available phosphorus and decreased water infiltration and herbage biomass. Killing trees changed the relative abundance of grass and leaf litter and increased grass density, herbage biomass, available nitrogen, soil compaction and water infiltration. Some the deleterious changes arising from livestock were reversed by tree killing but others were enhanced. It is concluded that there is unused potential for herbage production in the cleared grazing land but continuous management input would be required to sustain increased production because of the deleterious changes caused by livestock.

Introduction

Tree densities are commonly reduced in poplar box (Eucalyptus populnea) woodlands of S.E. Queensland to increase grass and animal production (Moore 1969, 1970). Virtually all trees must be killed to achieve maximum grass production (Walker et al. 1972), however, in grazed woodlands, it has been observed that grasses are often denser under the trees than in the spaces between the tree canopies. There is evidence too that an introduced grass, *Cenchrus ciliaris*, has a higher biomass under poplar box trees than in the space between the canopies, a result interpreted as a response by grass to higher soil phosphorus directly below the canopy (Ebersohn & Lucas 1965; Christie 1975). These seemingly conflicting observations indicate that grass density and production are not dependant on a single factor but are related to the interaction between trees and livestock.

The measurement of differences using random sampling with conventional plot experimentation is difficult within woodlands, because of spatial heterogeneity. This paper describes spatial heterogeneity in some surface soil properties and ground layer vegetation within poplar box woodlands subject to different treatments but relates the apparent variability to tree position using a sampling system based on transects between pairs of trees. The stratification of sampling was based on the premise that vegetation modifies the environment and, as trees are the largest and oldest biological units in woodlands, there will be spatial patterns related to tree position. The basis for some of the observed patterns is discussed, and differences are interpreted in terms of the applied treatments of the killing of trees and grazing by domestic livestock.

Methods

A number of experimental areas established 7 years previously at the Wycanna Woodland Experiment Centre (see Tunstall et al. 1981), Talwood, south west Queensland were sampled in March 1975. The natural vegetation is predominantly poplar box shrub woodland (Beeston et al. 1980) and the soil a solodic (Webb et al. 1980). The annual rainfall averages 500 mm and, while summer dominant, contains a significant winter component. The trees in the experimental plots were either alive (intact) or had been killed by basal injection with picloram so that the surface soil was undisturbed and the dead trunks remained standing. The plots were either grazed by sheep or livestock were excluded, giving a 2 x 2 factorial combination of treatments. The plot representing the trees not killed-grazed system was part of a 1230 ha paddock subject to normal station management. This plot was adjacent to the main experimental area and was 2 km distant from the closest watering point.

Measurements were obtained at these sites using a sampling system based on pairs of trees. An individual tree was selected at random and its pair then located such that any point along the line between the two trees was closer to either of the sample trees than to any other in the community. The second tree was not necessarily the nearest neighbour of the first. For this study a minimum distance between tree pairs was fixed at 9 m to provide the separation of crowns necessary to observe canopy related patterns. Twelve pairs of trees were selected in the intact, grazed system and six pairs in each of the other three systems. Sampling was within 12 quadrats, each 1 x 0.75 m, evenly spaced along each transect (total 360 quadrats).

The plant variables measured were the per cent cover of grasses, forbs, shrubs and litter in the categories of grass leaf, other leaves and twigs, grass and forb density and the biomass of herbage (mainly grass), twigs, and litter other than twigs. The soil variables measured were surface hardness, per cent bare soil, specific conductivity (salinity), pH, available nitrogen and phosphorus, total nitrogen, organic carbon, microrelief and depth of water penetration following a single rainfall event. Sampling was carried out in dry conditions which ensured comparability of data collected over the 2-week sampling by eliminating short term fluctuations. The cover of each component was estimated from colour transparencies taken vertically. Any dead organic matter other than twigs was classed as 'litter'; 'grass litter' was any dead material of grasses and 'leaf litter' the remaining dead organic material composed mainly of leaves from poplar box trees. 'Twigs' were any woody material. Soil for chemical determinations was obtained by bulking 4 x 10 cm depth cores taken from the corners of the quadrats. Specific conductivity and pH were determined on 1:5 soil, water suspensions. Soil surface hardness was estimated by averaging 20 penetrometer determinations per quadrat. Depth of water penetration was measured by pushing a metal rod down to the wetting front following rainfall of low intensity (approximately 20 mm in 24 hours). The accuracy of the measure was confirmed using soil pits. Surface microrelief was determined by taking levels along the transects and subtracting the general topographic slope from these measurements.

The results are presented in terms of distance from a single tree to aid interpretation. Positions 1 to 6 are only relative but they approximate the distance in metres from the tree. Positions 1, 2 and 3 were usually under a tree canopy. The data on cover estimates for grass, shrub, forb and twig litter were not analysed in detail because their low contribution resulted in numerous zero values.

Results

Figures illustrating changes away from trees of available phosphorus, herbage biomass, surface soil hardness, organic carbon, litter cover and depth of water penetration in the different systems have been presented elsewhere (Tunstall & Webb 1981). As further illustration of the form of the data, similar figures are presented here for pH, microrelief, bare soil and grass density (Fig. 1). Soil pH decreased away from trees but there was little difference between systems. Soil height likewise decreased away from trees but there were differences between systems associated with the killing of trees. The results for grass density and bare soil illustrate differences between systems of both mean levels and gradients relative to trees.

The results have been summarized in terms of treatment effects on the mean levels of the variables (Table 1) and the gradients away from trees (Table 2) with significance levels based on the variance between treatments. This experiment was of unreplicated plot design and so the observed differences could not, on statistical grounds, be attributed to treatment effects. However, if one assumes that the variation between transects provides a reasonable estimate of the variation between plots, then this can be used to assess the significance of differences between treatments. The validity of this assumption was investigated by comparing the results for the two plots in the trees intact, grazed system. There were no significant differences between the blocks, despite a difference in tree density.

The killing of trees resulted in a decrease in the mean level of leaf litter cover and forb density and an increase in percent bare soil, grass density, herbage and twig litter biomass, available nitrogen, surface soil hardness and depth of water penetration (Table 1). Grazing by livestock reduced the cover and biomass of leaf litter, herbage biomass and the depth of water penetration and increased the per cent bare soil, forb density, surface soil hardness and levels of salt, available nitrogen and available phosphorus in the surface soil (Table 1). Treatment interactions that can be readily interpreted are the low cover and biomass of leaf litter in the grazed, killed system (no live trees and few shrubs), the low density of grasses in the grazed, trees not killed system, the low density of forbs in the trees killed, ungrazed system (forbs suppressed by grasses and shrubs) and a high degree of soil compaction in the trees killed, grazed system (increased grazing resulting from the increase in herbage production following the killing of trees (Walker et al. 1972) and increased exposure of the soil to rain and radiation.

The gradients away from trees have been described using linear regression coefficients for either untransformed or log transformed data (Table 2). Assuming no gradient in the absence of trees, the overall mean gradient indicates an effect attributable to trees. Only for available phosphorus was there no overall gradient away from trees. All other variables excepting available nitrogen, per cent bare soil and surface soil hardness generally decreased with distance from trees.

The killing of trees resulted in a decrease in the gradient away from trees of total nitrogen, organic carbon, microrelief and depth of water penetration. Grazing by livestock increased the gradient away from trees of per cent bare soil, forb density, herbage biomass, available phosphorus, organic carbon, total nitrogen and depth of water penetration. The treatment interactions most readily interpreted are the increase in the gradient in grass density away from trees in the intact, grazed system (the observation on which the experiment was initiated) and the associated high level of available nitrogen between tree canopies, and the amelioration of soil compaction in the trees killed, ungrazed system following the growth of grasses and shrubs (see Tunstall et al. 1981).

Canonical variate analysis was applied to each variable and the significance of differences between systems estimated using Mahalanobis's distances. Each of the plant variables - grass litter cover, leaf litter cover and herbage biomass discriminates between all systems at the 95 confidence level. Together, soil organic carbon and available nitrogen likewise discriminate between the systems. Of the possible comparisons 60, 40 and 30 were significantly different at the 95, 99 and 99.9 probability levels, respectively.

The ordinations obtained for the 21 variables using the canonical variate analysis were compared using the 'proscrustes rotation' technique. The analysis groups variables which vary similarly within and between systems, however, associated variables may be inversely related. The first axis of the ordination (Fig. 2), which accounts for approximately 55 of the variance, reflects differences in water penetration and surface soil compaction associated with grazing. Soil compaction was associated with a reduction in both water penetration and the cover of forbs and an increase in grass density and surface soil salinity. The second axis of the ordination, which accounts for approximately 50 of the remaining variance, mainly relates to the effects of killing trees on the ground vegetation. Litter was mainly derived from grasses where trees had been killed and from poplar box where trees were alive; forb density was inversely related to grass cover and to litter biomass.

The relationships between soil compaction and grass density, available nitrogen and herbage biomass and total nitrogen and organic carbon (Fig. 2) accord with expectation. The inverse correlation between twig biomass and per cent bare soil and their association with microrelief accords with the initial observation that twigs and branches produce a distribution of ground cover related to the position of trees.

Discussion

The results accord with the initial observation, but there is some uncertainty in the significance of specific treatment effects because of the assumption that the variance between transects equals that between plots. The higher general slope in the grazed, intact system than in the other plots (approx. 1 and 0.5 respectively) may have contributed to the lower infiltration of water into this system, however the results for other variables, such as soil pH, indicate a close similarity between sites. Also, the results on surface soil hardness and water penetration are equivalent to those obtained previously (Tunstall & Walker 1975) and results for the two plots in the trees killed, grazed system were the same, indicating little error in the assumption of equal within and between plots variance.

The marked gradient in available phosphorus away from poplar box trees noted by Ebersohn and Lucas (1965) was not observed here. These data indicate a general increase in available phosphorus and higher levels remote from trees with grazing, a result similar to the finding of Webb and Dowling (pers. comm.) that on such solodic soils the level of available phosphorus increases where clearing is combined with grazing and/or cropping. Given dry conditions in these systems, the levels of available phosphorus and nitrogen appear to reflect lack of uptake as well as rate of mineralisation.

Grazing resulted in an increase in bare soil and surface soil salinity and a decrease in water penetration and herbage biomass, changes that would generally result in reduced herbage production. Grazing was also associated with an increase in available phosphorus, a change which could reflect a reduction in plant growth. The killing of trees produced the obvious change in the relative abundance of grass and leaf litter but it also resulted in increases in grass density, herbage biomass, available nitrogen, soil compaction and depth of water penetration. Apart from soil compaction, these changes would usually result in an increase in herbage production. However, soil compaction was greater where tree killing was combined with grazing than elsewhere and many of the grass species which persist on the compacted soils are small in size; while they stabilise the soil surface they contribute little to production.

Changes in these systems that could be regarded as deleterious are therefore mainly due to livestock. With some variables the effects of livestock were lessened by the killing of trees but for others they were enhanced. The loss of water and occurrence of unused available phosphorus and nitrogen in 'improved' grazing land (trees killed, grazed system) indicates a potential for an increase in herbage production. This could be achieved through amelioration of the soil compaction and introduction of more productive species. However, an increase in herbage production is usually associated with an increase in grazing, thus reversion of an improved system to a degraded condition would be expected in the absence of strict control of grazing or repeated soil amelioration.

The technique of stratified random sampling within woodlands provided a high degree of resolution of differences between the woodland systems. However in the trees killed, not grazed system, where the largest living life form had changed from tree to shrub, there was frequently little gradient away from trees and the variance was high because the sampling procedure was not designed to reveal gradients at the smaller scale of pattern. Also, the results do not provide area based, estimates and so for some purposes the techniques would be inefficient. However, random sampling, whilst convenient in providing area based estimates, has limited value in woodland experimental studies where gradients such as with soil pH result in large errors being associated with means; treatment effects are masked by within plot 'variation'.

The sampling techniques also provided information on the effects of trees in a woodland and these results illustrate the difficulties in defining the control or reference state in woodland studies. All variables except available phosphorus exhibited overall gradients relative to trees but seven years after the killing of trees the magnitude of the gradient had decreased with only total nitrogen, organic carbon, microrelief and water penetration. All plots had been grazed for at least 60 years prior to the experimentation. As the plots were sampled approximately 7 years after the treatments were applied or commenced, the grazed, intact woodland had been subject to the one treatment for the longest period; the treatment was in effect a release from grazing. It is probable that the treatment effects have been underestimated because of the short period of imposition of some of the treatments.

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Table 1. Mean levels of variables and significance of differences associated with treatment effects. Only significant effects presented.

Variable	Units	!	Overall Mean	Killing: Not Killed	Killing: Killed	Grazing: Grazed	Grazing: Not graz.	Grazed: Not killed	Grazed: Killed	Not grazed: Not killed	Not grazed: Killed
Ground cover											
Leaf litter	%	!	2.59	3.52	***1.19	3.17	***2.20	3.45	0.16	3.47	**2.41
Grass litter	%	!	1.54								
Bare soil	%	!	46.26	5.75	***35.52	37.60	***52.03				
Plant density											
Grass	Plants m^{-2}	!	2.53	2.16	***3.08			1.66	3.70	3.20	***2.53
Forbes	Plants m^{-2}	!	2.00	2.5	*1.79	1.43	***2.39	2.35	2.52	1.93	***0.86
Biomass											
Herbage	gm m^{-2}		3.76	3.21	**4.59	4.94	***2.98	2.00	4.69	5.26	**4.87
Leaf litter	gm m^{-2}		208.00			282.00	**159.00	195.00	87.00	215.00	349.00
Twig litter	gm m^{-2}	!	4.96	4.78	*5.22						
Surface soil											
pH		!	6.80			3.39	***3.82	3.96	3.54	3.26	**3.50
Salt content	µS cm^{-1}	!	3.65			0.82	***1.50	1.48	1.48	0.45	**1.25
Available N	ppm	!	1.23	1.09	*1.43	1.63	*1.7				
Available P	ppm	!	1.67								
Total N	ppm	!	4.69					4.75	4.60	4.5	**4.77
Organic C	ppm	!	4.86					4.93	4.75	4.74	**4.96
Hardness	N m^{-2}		47.40	41.5	***56.20	36.20	***54.8	45.00	71.30	38.20	***37.20
Relief	cm	!	2.04								
Water penetration	cm		22.85	20.21	***26.81	27.23	***19.93	16.37	25.74	26.44	*29.34

! Transformed by log (x + 1)

*, **, *** Significant at P, 0.05, 0.01 and 0.001 respectively.

Table 2. Linear regression coefficients describing variation associated with distance from tree. The actual slope coefficients for the treatments are derived by adding the overall mean slope to the coefficient given for each treatment. Only significant effects are presented.

			Overall	Killing		Grazing		Grazed		Not grazed	
Variable	Units	!	Mean	Not K.	Killed	Grazed	Not graz.	Not killed	Killed	Not killed	Killed
Ground cover											
Leaf litter	%	!	***-0.110					-0.102	0.110	0.106	***0.012
Grass litter	%	!	***-0.085					-0.053	0.008	0.107	*-0.009
Bare soil	%	!	***3.330			-2.430	***1.620				
Plant density											
Grass	Plants m^{-2}	!	*-0.038					-0.155	0.103	0.163	***0.044
Forbes	Plants m^{-2}	!	*-0.064			0.101	***0.067				
Biomass											
Herbage	gm m^{-2}		***-0.091			0.069	*-0.046				
Leaf litter	gm m^{-2}		***-29.800								
Twig litter	gm m^{-2}	!	***-0.152								
Surface soil											
pH		!	***-14.050					-1.1	1.6	2.9	*-2.3
Salt content	µS cm^{-1}	!	***-0.048			-0.035	*0.023				
Available N	ppm	!	*0.056					0.085	-0.035	-0.095	*-0.040
Available P	ppm	!	0.004			-0.013	*0.009				
Total N	ppm	!	***-0.028	-0.009	*0.013						
Organic C	ppm	!	***-0.027	-0.014	***0.021	0.015	*-0.010				
Hardness	N m^{-2}		***-0.515					0.082	-0.118	0.323	*-0.368
Relief	cm	!	***-0.242	-0.127	***0.191						
Water penetration	cm		***-0.850	-0.320	*0.480	0.84	***-0.56				

! Transformed by log (x + 1)

*, **, *** Significant at P, 0.05, 0.01 and 0.001 respectively.

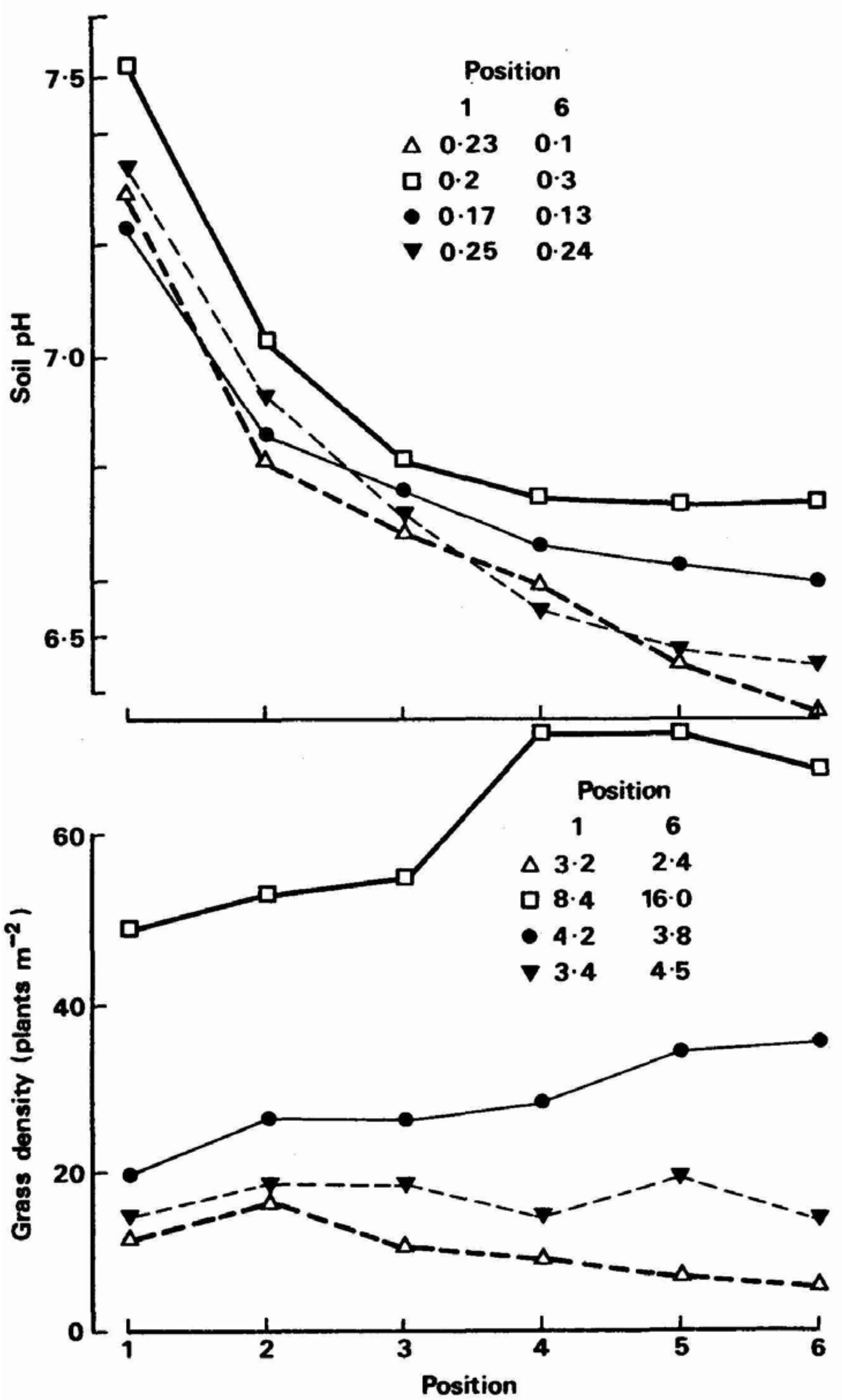

Fig. 1a Changes in surface soil pH and grass density relative to tree position in four poplar box systems. Position 1 is adjacent to trees. The 95% confidence limits are given for positions 1 and 6.

Δ Trees alive, grazed

□ Trees killed, grazed

● Trees alive, not grazed

▼ Trees killed, not grazed

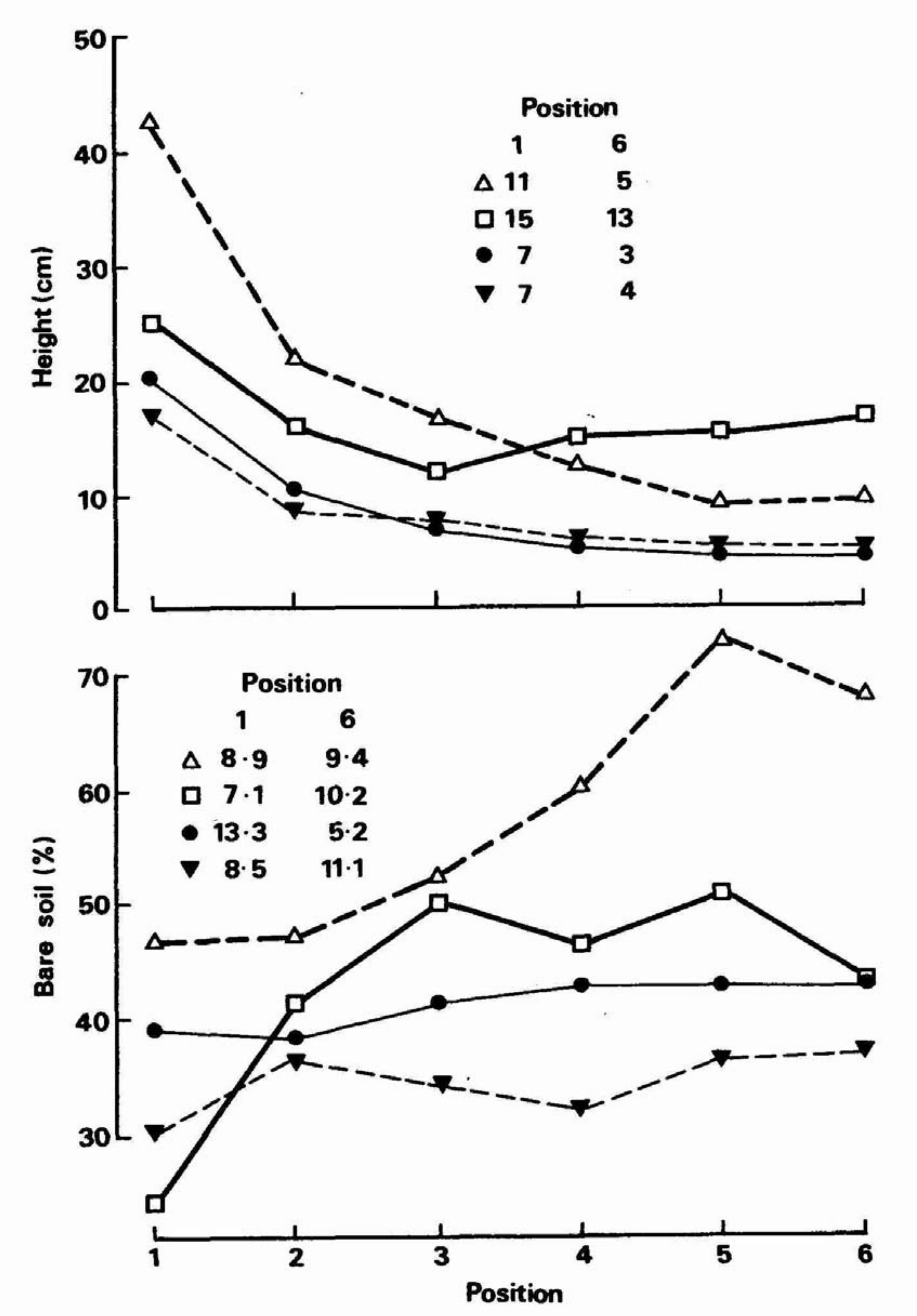

Fig. 1b Soil microrelief and changes in the amount of bare soil relative to tree position in four poplar box systems. Position 1 is adjacent to trees. The 95% confidence limits are given for positions 1 and 6.

Δ Trees alive, grazed

□ Trees killed, grazed

● Trees alive, not grazed

▼ Trees killed, not grazed

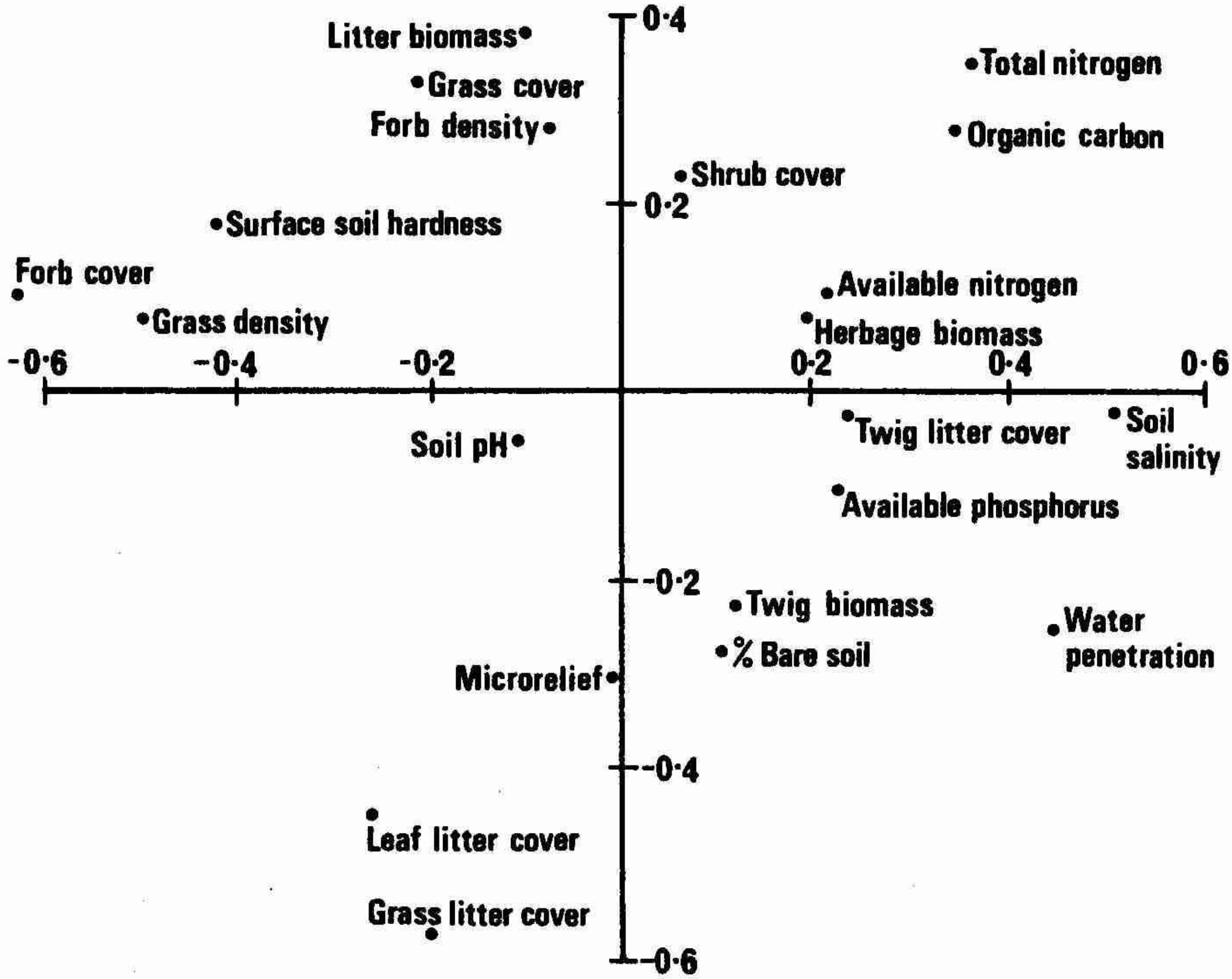

Fig. 2. Ordination obtained (first two vectors) from a 'procrustes rotation analysis' of the results of canonical variate analysis for each variable.