Ecology and Management of the World's Savannas

Edited by:
J.C. Tothill and J.J. Mott
CSIRO, Division of Tropical Crops and Pastures
306 Carmody Road, St. Lucia 4067, Queensland, Australia

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PREDICTION OF TREE AND SHRUB POPULATION CHANGES IN A SEMI-ARID WOODLAND

W.H. Burrows, I.F. Beale, R.G. Silcock, A.J. Pressland
Charleville Pastoral Laboratory, Department of Primary Industries, P.O. Box 282, Charleville 4470, Queensland, Australia.

SUMMARY

Woody plant populations have been monitored on a 16 km vegetation transect in south-west Queensland's mulga (*Acacia aneura*) lands since 1965. Data from a subset of 9 km have been subjected to numerical classification which defines vegetation groups for transition matrix simulation of future changes in tree and shrub density. Records from 5 km of the transect not included in the initial analyses were used to test the reliability of the predictions, after superimposing the original classifications on the latter data set. Predicted changes in species populations are in agreement with documented trends for similar vegetation types in this environment.

INTRODUCTION

Semi-arid savannas, wherever they occur, have generally been overgrazed and encroached on by bush (Walker, Ludwig, Holling and Peterman, 1981). Since increasing tree or shrub density has a strong depressant effect on associated grass and forb yield (Jameson, 1967; Walker, Moore and Robertson, 1972; Beale, 1973) the dynamics of trees and shrubs in savanna communities are of considerable interest to the applied ecologist and range manager.

The 'Humeburn' and 'Tobermory' transects (Burrows and Beale, 1969) are permanently positioned in mulga (*Acacia aneura*) dominated communities of south-west Queensland and meet all of Austin's (1981) requirements for the study of vegetation dynamics. This paper describes how data collected on one section of the Humeburn transect is used to predict future population changes on it.

METHODS

Transect description and recording

The eastern section of the Humeburn transect is 16 km long. Position (within 0.2 m^2) and species of all woody plants have been recorded in 1965, 1969, 1972 and 1979 in a belt located 1 m either side of the transect centre line (see Burrows and Beale (1969) for further details). The transect covers a vegetation catena along a north-south axis. An escarpment (c. 36 m above zero datum level established at the commencement peg) is situated 10 km along the transect and provides a convenient division between similar mulga communities to the north and south.

Data analysis

The procedure followed is a modification and extension of that adopted by Austin (1980) and Austin and Belbin (1981). Data for the first 9 km of transect (Site A — commencing at the southern most peg) were divided into 180 quadrats, each 50 m × 2 m, and plant counts obtained in 1965, 1972 and 1979 were pooled to give species density data for a total of 540 quadrat records. These data were then subjected to the divisive polythetic classification program POLYDIV (Williams and Lance, 1975) and twelve 'community groups' were recognised. The change in groups to which particular quadrats were assigned (between each recording time) was used to establish transition matrices for these communities for 1965-1972 and 1972- 1979 respectively. The density of all species in each defined community group is provided by the POLYDIV output. Group frequency is defined as the percentage of the transect occupied by quadrats representative of the particular group.

Drought conditions prevailed in the 1965-1971 period with a mean annual rainfall for Cunnamulla (the nearest long term meteorological station to Humeburn) of 323 mm. By contrast in the years 1972-78 above average rainfall was received and the annual mean for Cunnamulla was 460 mm. On this basis seven year moving averages for Cunnamulla rainfall were determined for records from 1880 to 1978. Those seven year averages > 393 mm (the mean for 1965-1971 and 1972-1978 inclusive) were adjudged 'wet' (W) and those <392 mm were adjudged 'dry' (D). This resulted in a sequence, WWDDDDDDDWWDDW, for the 98 years of rainfall records from which a Markov-type probability matrix for the likelihood of 'wet' and 'dry' periods occurring was derived. These probabilities were used in Monte Carlo simulations of future wet and dry cycles.

To determine future stand composition the initial frequencies of each of the twelve POLYDIV groups were sequentially multiplied by the transition matrix corresponding to the rainfall sequence simulation. As an example, the actural 1979 community group frequency (%) is given in matrix terms by:

WDX_0 where D = transition matrix 1965-1972
W = transition matrix 1972-1979
X_0 = community group frequency (%) for 1965

Plant density was determined by overall summing of species densities in each group defined by POLYDIV, multiplied by the predicted percentage frequency for that group in any particular year. Densities were expressed as mean number of plants ha^{-1} occurring over the 9 km transect sample.

Ten simulations of projected species densities for seven year intervals from 1965-2063 were carried out and means for each species determined. Verification of the appropriateness of the method was obtained by comparing predicted species densities for 1972 and 1979 with actual densities recorded. For an independent check of the validity of the method we used the following procedure:

ALICOM (a computer routine, available on the CSIRO TAXON library, which superimposes previously defined POLYDIV generated group structures onto new data sets — D. Ross pers. comm.) was run with the 1965 data collected from the last 5 km section of the transect (Site B), located north of the escarpment. These data were not used in any previous computations. The resulting community group frequency vector was then multiplied by the D and W transition matrices and species densities for 1972 and 1979 determined as before. These results were compared with actual densities recorded in 1972 and 1979.

RESULTS AND DISCUSSION

Model testing

Testing species regeneration (or succession) models for tree and shrub communities is particularly challenging, since the phenomena they predict may take years or even generations to observe in nature (Shugart and West, 1980). No statistical test is sufficiently rigorous to make conclusive statements about the correctness of such models. Nevertheless, verification, validation and application procedures suited to model testing are described by Shugart and West (1980) and Shugart, West and Emanuel (1981). We have followed these steps in examining the utility of the Humeburn predictions.

Table 1. Observed (O) and predicted (P) relative densities for woody species on the Humeburn transect. Site A = comparisons for data on which the predictions are based. Site B = comparisons for data which are independent of the prediction model. See text for details. Species with initial (1965) plant densities < 10 ha^{-1} are not included. The *Acacia aneura* (< 5 cm stem diameter class) is presented separately to the main table as the data includes seedlings with pinnate leaves still present.

	Relative Density (%)									
	1965	1972		1979		1965	1972		1979	
	O	O	P*	O	P*	O	O	P	O	P
	Site A					Site B				
Species										
Acacia aneura (5-10 cm)**	1.4	1.4	1.3	1.2	1.2	0.0	0.1	0.0	0.1	0.0
Acacia aneura (> 10 cm)**	2.3	1.9	2.0	2.3	1.9	1.6	1.4	1.7	2.1	2.0
Acacia cambagei	0.7	1.4	1.3	1.4	2.0	0.6	0.4	2.4	0.6	2.1
Cassia spp.	0.6	0.6	0.7	1.4	0.9	0.6	3.6	1.8	3.8	0.8
Dodonaea adenophora	3.2	2.6	3.0	4.8	3.3	0.3	3.3	1.3	4.9	2.3
Eremophila bowmanii	1.4	1.5	1.8	3.1	2.1	0.2	0.1	2.2	0.4	4.2
Eremophila gilesii	85.2	84.5	83.8	78.7	81.7	90.9	81.2	75.0	70.5	73.4
Eremophila glabra	0.7	1.2	1.2	1.6	1.7	0.5	0.2	2.1	0.6	2.0
Eremophila mitchellii	3.4	4.0	4.0	4.6	4.3	4.8	9.5	12.7	15.9	11.5
Eucalyptus populnea	0.8	0.9	0.9	0.9	0.8	0.5	0.3	0.8	1.1	1.7
Total density (plants ha^{-1})	1670	1748	1712	1547	1698	4158	3226	1728	2527	1501
Acacia aneura (< 5 cm)** (plants ha^{-1})	601	686	876	1649	1012	692	626	756	1192	1264

* Predictions based on mean values for 10 simulation runs

** Stem diameter classes measured 30 cm above ground level

Comparison of observed and predicted values (Table 1) suggests that our model gives generally consistent and reliable results. However the time span of actual observations (14 years) is still well below the generation time of trees such as *Acacia aneura* and *Eucalyptus populnea*, although it does approach that of many *Eremophila* species. Anderson (1966) notes some of the problems that can arise where the time span covered by transition matrices varies from the life expectancy of individuals.

Discrepancies between observed and predicted populations for the independent data set (Table 1, Site B) can largely be attributed to differing proportions of ridge and creek frontage between Sites A and B. Seventy three per cent of Site A is occupied by red earth, Gn 2.12, soils (Northcote, 1965) compared with fifty four per cent for the same soil type on Site B. The model tends to overestimate actual densities of species which establish best on ridge habitats (e.g. *Eremophila bowmanii*) and underestimate those which favour frontages (e.g. *Cassia* spp.). This can be ascribed to the model being based on Site A data which has more ridge topography than Site B.

An underestimate of the total density of *E. gilesii* populations in the independent data set resulted from a severe infestation of the wingless grasshopper (*Monistria* spp. — see Allsopp,1978) in 1978/79. This insect killed out large sections of *E. gilesii* on Site A with consequent effects on transition probabilities, but apparently had not infested the population on Site B.

[Note: the POLYDIV community group composition and 'Wet' and 'Dry' transition matrices used in these data analyses are omitted because of space limitations — these listings are available from the senior author on request].

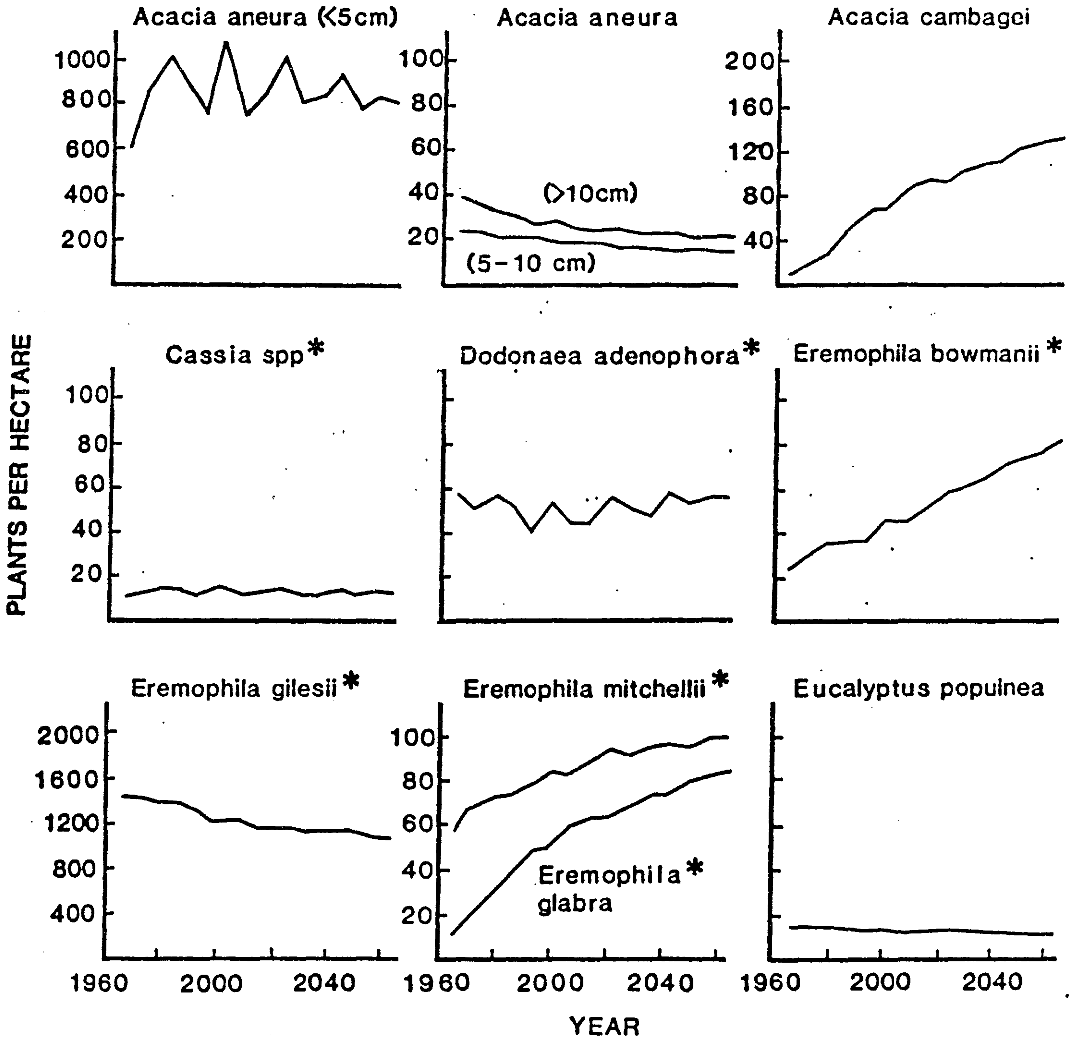

Figure 1. Population projections for woody vegetation on the Humeburn transect. Species with densities < 10 ha^{-1} in 1965 are not depicted. Those species marked with an asterisk are regarded as woody weeds. The *Acacia aneura* size classes are stem diameters measured 30 cm above ground level with seedlings included in the < 5 cm class. Note the different scales on the Y-axes.

Predicted populations

The most notable feature of simulated species densities on the transect (Figure 1) is that no dramatic changes in total woody plant populations are anticipated over the 100 year projections. This contrasts with observations of greatly increased shrub density in the Cobar area (Anon., 1969) and the recent rapid shrub invasions documented by Booth and Barker (1981) in the Wanaaring district of New South Wales. Both of these reports refer to land forms with deeper soils and less rainfall runoff than that experienced at Humeburn.

Anderson and Holte (1981) suggest that forest and shrub communities may be exceptionally stable in the absence of external perturbations, while the present predictions tend to support Williams' (1968) contention that in Australia most plant communities have already adjusted to past and current animal management. Nevertheless our simulations indicate a slow but inexorable increase in the density of most woody weeds with a decline anticipated in the adult population of *Acacia aneura* (mulga), an important fodder tree (cf. Anon., 1969, Burrows 1973 a,b). These predictions, of necessity, assume that a similar style of management to that imposed on the land for sheep and cattle grazing in the 1965-1979 period will continue. This management includes the felling of mulga for drought feeding and we have no reason to doubt this assumption. Major perturbations such as fire, which did not take place during the initial 1965-1979 observation periods, are also assumed not to occur over the timescale of the predictions.

Transition matrices have been widely used to predict successional changes in vegetation in recent years (see Enright and Ogden (1979) and Van Hulst (1980) for detailed descriptions and criticisms). Austin and Belbin (1981) concluded from their studies of succession in a lawn that spatial heterogeneity is likely to be responsible for failures to predict future vegetation dynamics. They also suggest that the state of adjacent quadrats could be important in determining transition probabilities. We believe that the size of the Humeburn quadrats (100m^2), the sparse woody vegetation studied (leading to few 'edge effects') and the prior classification of the quadrats into like groups (on which the transitions are based) tend to negate Austin and Belbin's (1981) reservations about the methodology in this instance.

We have reached no conclusions about the successional status of the Humeburn community. Our interest lies simply in the population dynamics of the woody vegetation and their implications for continued pastoral use of the land. In the semi-arid environment of south-west Queensland cycles of drought and above average rainfall and common. Therefore it is intuitively sound to us that vegetation transitions are not constant in time (cf. Binkley, 1980). By combining transition matrices derived from observations in 'Wet' and 'Dry' cycles with the past probability of such events we believe we have increased our capacity to anticipate future vegetation trends.

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