MULGA: A BIOCLIMATIC ANALYSIS

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ABSTRACT

The distribution of mulga (A. aneura) *is examined in relation to selected environmental parameters at both continental and regional level. Simulated water balances indicate that both summer (November-April) and winter (May-October) rainfall are necessary to maintain the preferred positive, but low, evapotranspiration ratios.* A. aneura *is conspicuously absent from the semi-arid regions with a regular summer or winter drought.*

A numerical classification of arid and semi-arid climatic stations based on a set of derived indices for light, thermal and water regimes together with a resultant growth index is presented. Three major bioclimatic zones result: (1) a northern arid sector; (2) a southern arid sector; (3) a more humid sector in the east, centering on the Maranoa district of south-west Queensland.

An analysis of mulga distribution in relation to environmental parameters is based on survey data for this eastern sector of the mulga zone.

INTRODUCTION

Apart from the economic importance of mulga (*Acacia aneura*) as a browse shrub and drought fodder its successful adaptation to the arid inland of Australia is of considerable eco-physiological interest. Our objective is to evaluate the macroclimatic environment of *A. aneura* to provide a frame of reference for further, more detailed studies, and, perhaps, to generate some working hypotheses. This analysis is based on the present known distribution pattern of *A. aneura*, accepting that this pattern may reflect both past and present climates. The interaction of climate with other environmental factors is emphasised in relation to mulga distribution.

DISTRIBUTION

The most extensive stands of *A. aneura* occur within the Acacia shrubland formation (Moore and Perry 1970). Following the terminology of Specht (1970) the most widespread mulga communities occur as tall shrublands (shrubs, usually multistemmed, 2-8 m tall and with projective foliage cover of 10-30%) or, more rarely, as tall open shrublands. In the most favourable environments and particularly in the east, mulga occurs as a tree, forming low-open forests or even open-forests (trees > 10 m tall and with projective foliage cover within the range of 30 to 70%).

Significant gaps in the distribution pattern shown in Figure 1 are a reflection of soil constraints. On saline and sodic soils *A. aneura* is normally replaced by low shrubland (*Atriplex/Kochia*) or, in less arid areas, by other *Acacia* species.

BIOCLIMATIC ANALYSIS

The influence of weather and climate on ecesis of *A. aneura* can be analysed at a number of levels. Limited climatic and ecophysiological data available have necessitated effort at the continental and regional scale.

Continental Bioclimate

The present distribution pattern of the major stands of *A. aneura* provides a basis for analysis of the macroclimatic environment. The indicated occurrence of

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A. aneura well beyond the present major formations (Fig. 1) may well reflect previous extensions of the arid zone during the Pleistocene, or locally favourable combinations of climate, terrain and soil, and efficient seed dispersal.

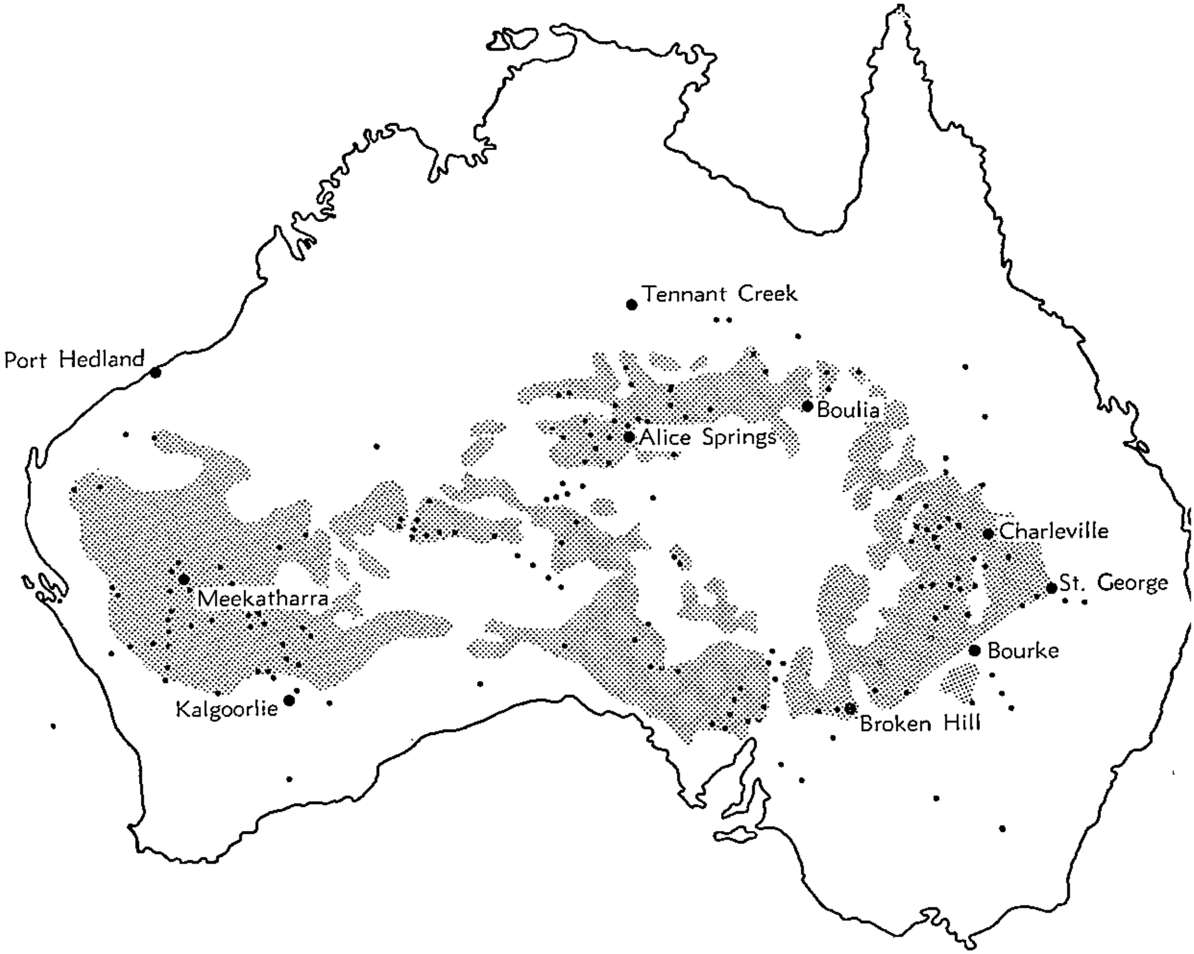

FIGURE 1
Distribution of *A. aneura* after Moore and Perry 1970; Specht 1970; Williams 1955; J. Carnahan personal comm. Stippling indicates major occurrences. Point records are from herbarium specimens and reliable observations (Hall, Specht and Eardley 1964).

(i) *Solar radiation*

In a mid latitude environment dominated by cT (continental Tropical) air masses, with clear skies, solar radiation is high throughout the year. For more than six months of the year daily receipts exceed 500 cal cm^{-2}. Mid winter values do not fall below 300 cal cm^{-2} day^{-1} except for a narrow band in the extreme southern part of the mulga distribution where these approach 250 cal cm^{-2} day^{-1}. Light energy is not a major limiting factor.

(ii) *Temperature*

Occupying land around the arid interior of the continent, *A. aneura* is exposed to the greatest diurnal and seasonal temperature ranges experienced anywhere in Australia.

The entire mulga zone experiences highest weekly mean maximum temperatures > 32°C, with large tracts > 36°C and lesser areas > 38°C. Heatwaves—prolonged periods with successive daily maxima exceeding 38°C—can be expected in most years.

Frosts—screen minimum temperatures less than 0°C—occur throughout the entire mulga zone, the duration of the frost period and its frequency of occurrence being greater in the south. The lowest weekly mean minimum temperatures everywhere exceed 4°C and for the larger part of the mulga zone range between 5° and 7°C. It is possible that low winter temperatures restrict distribution in the east, where lowest weekly minimum temperatures fall below 4°C.

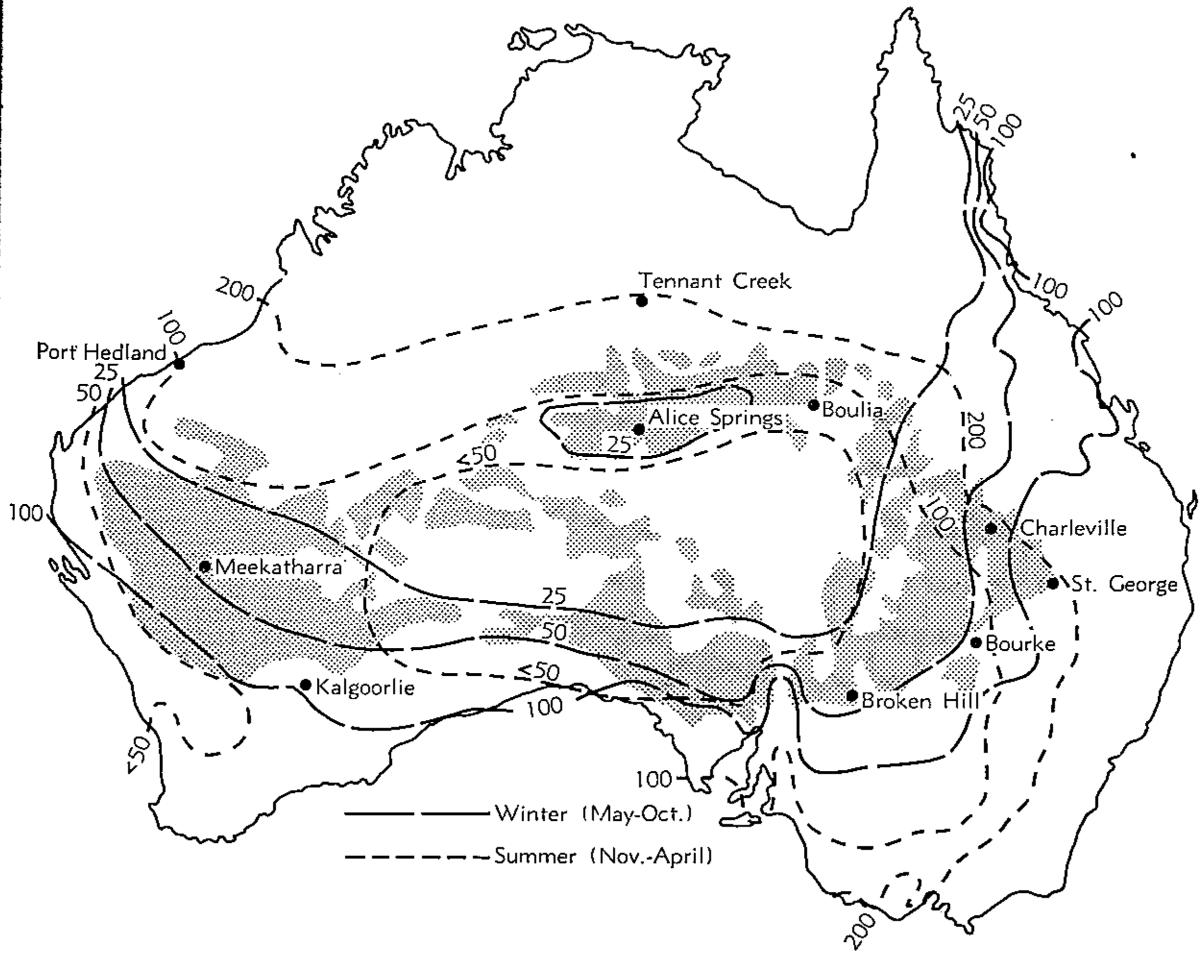

FIGURE 2
Summer (Nov.-Apr.) and winter (May-Oct.) rainfall equalled or exceeded 8 years in 10.

(iii) *Precipitation*

The major portion of the mulga zone has a mean annual precipitation < 250 mm. The eastern sector has somewhat higher rainfall, approaching 500 mm. Average values are rather gross bioclimatic indices in arid environments.

The generally arid character of inland Australia reflects the dominating role of the mid-latitude high-pressure belt. Characteristically anticyclonic cells bring dry, stable conditions and hinder the inflow of moist air masses from the south, east and north. In winter, these cells track to the north allowing inflow of cool (and cold) moist air masses from the Southern Ocean. In summer, these cells track to the south permitting inflow of warm, moist, unstable air masses from the north and east. The rainfall distribution patterns in the mulga zone reflect the ebb and flow of these moist air masses. Cyclonic disturbances occasionally bring very heavy rainfall, usually in late summer or autumn and more rarely in winter.

In order to examine summer and winter seasonal influences separately, rainfall probabilities have been calculated using a standard 50 year period (November 1915 to October 1965). Throughout all but the more favoured eastern sector both summer and winter seasonal values are less than 100 mm in 8 years in 10 (Fig. 2).

(iv) *Evaporation*

Annual evaporation totals, derived from the standard Australian sunken tank, are high, ranging from about 1800 mm to more than 2500 mm. Mid-winter values range from 15 to 25 mm a week and mid summer values everywhere exceed 60 mm a week.

(v) *The water balance*

The water regime of plant communities is a complex function of terrain, soil, plant and climatic factors. For the purposes of intra continent comparison, certain assumptions have been made. These are that mulga communities never achieve full soil cover and that the potential evapotranspiration rate with water freely available will not exceed $0.8E_0$ (tank evaporation). This maximum rate is reduced exponentially as the ratio of soil water storage plus current rainfall to the assumed maximum soil water store in the root zone declines. Furthermore, a medium textured soil with an available water storage of 100 mm was assumed. Obviously, at any given location, differences in soil depth, texture and structure can materially alter the outcome of the water balance. Possibly the single most important source of variation within the arid zone is redistribution of rainfall through runoff and run on. It would be desirable to incorporate such functional relationships in any detailed water balance study.

From the water balance, mean summer and winter moisture indices (ratios of estimated actual to potential evapotranspiration (E_a/E_t) after Fitzpatrick and Nix 1970) show that *A. aneura* is restricted to those arid areas where both mean summer and winter seasonal moisture indices average less than 0.4 (Fig. 3). A major portion of the range has summer and winter values averaging less than 0.2. The most extensive areas of mulga in the pastoral zones of the Murchison in W.A. and western N.S.W. and S.W. Queensland have winter seasonal values ranging from 0.2 to 0.4.

Substituting water balance output for the P/E ratios of Farmer, Everist and Moule (1947), the percentage deviation from equal summer/winter moisture index (E_a/E_t) values was computed. The buffering effects of soil-water storage produce a shift southwards of the equal summer/winter moisture index line compared with the P/E ratio line.

The data indicate that mulga is confined to the more arid sectors of a zone delineated by a percentage deviation of not more than 75% from the equal summer/winter moisture index line. The most extensive stands of mulga occur between zero and the —75% deviation lines. The boundaries between mulga and other formations are relatively sharp along the 75% deviation lines but in the east, where the zero and ± 50% lines extend into more humid zones, boundaries are more transitional. Thus, in the Maranoa region of S.W. Queensland mulga occurs in association with eucalypts, in particular E. *populnea.*

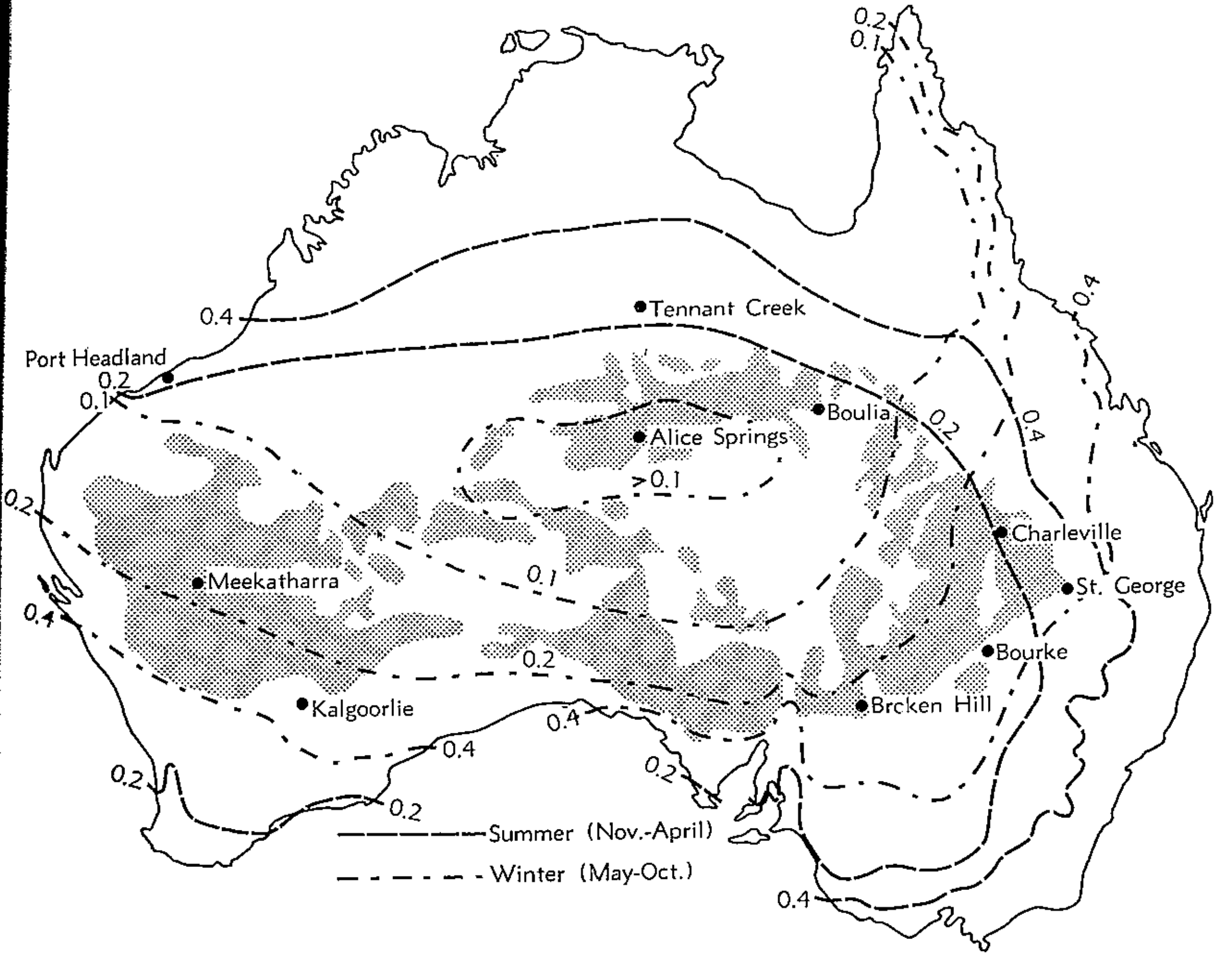

FIGURE 3
Mean summer (Nov.-Apr.) and winter (May-Oct.) moisture indices (E_a/E_t).

Classification of Bioclimate

Insufficient growth, phenological and meteorological data were available for a rigorous analysis of mulga bioclimate. Limited evidence (Everist 1949; Hall, Specht and Eardley 1964) suggests that mulga shoot growth is greatly restricted during winter, even when the water regime is favourable. In addition, the relatively high optimum temperatures for seed germination (29-30°C) indicate a thermal growth response of the tropical legume pattern (see Fitzpatrick and Nix 1970). With this pattern, dry matter production is at a maximum around 30°C and with upper and lower thresholds for growth at about 38°C and 10°C respectively.

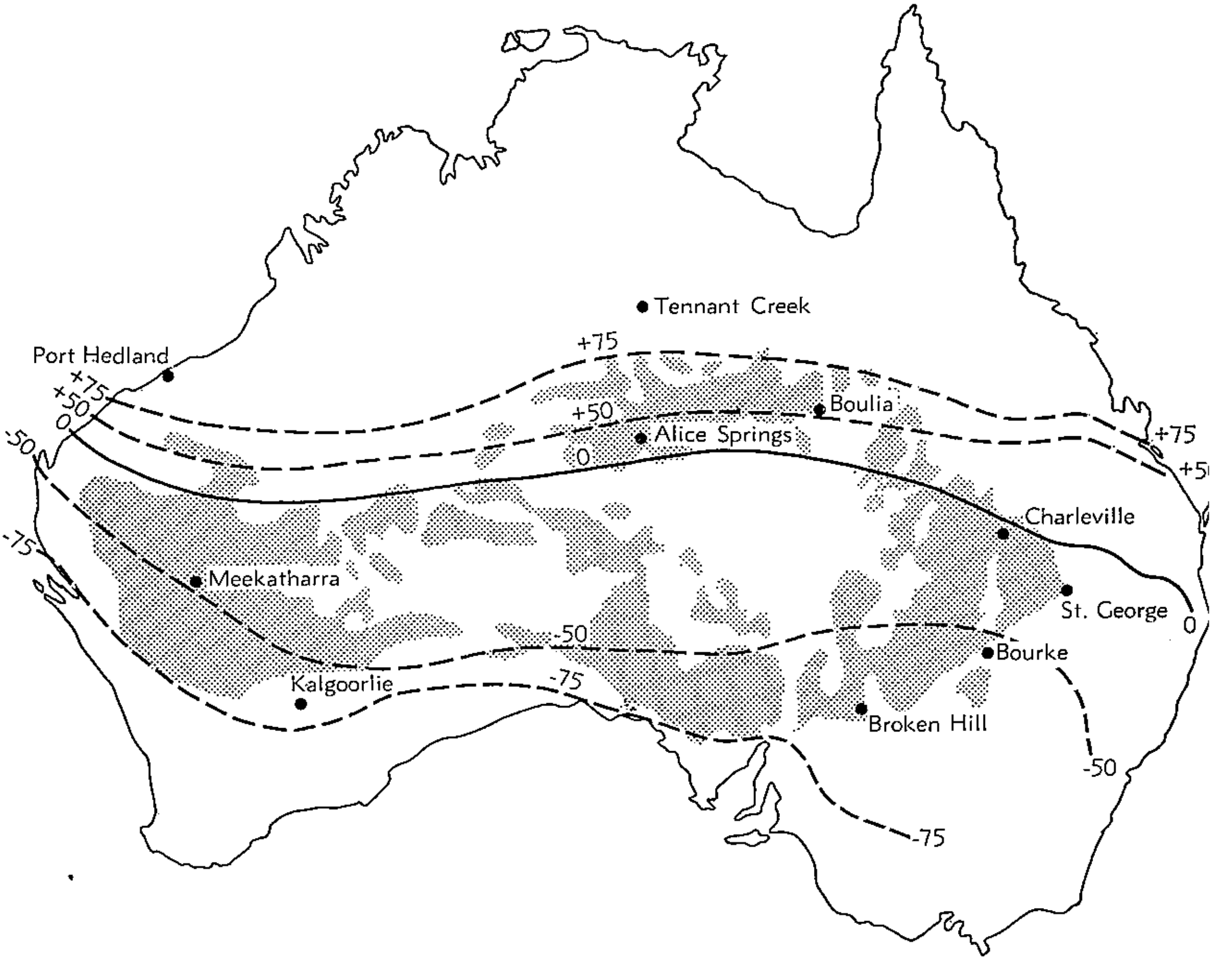

FIGURE 4
Percentage deviation from equal summer/winter moisture index values.

Light, thermal and moisture index values and a multi-factor growth index for the tropical legume response pattern are available. (Fitzpatrick and Nix 1970). These indices provide a transformation of climatic variables which takes the biological behaviour of species into account. A set of 13 values (i.e. at four week intervals throughout the year) for each of the four indices (light, thermal, moisture and growth) for 100 locations in and surrounding the mulga zone were used in a numerical classification to define a set of regional bioclimates relevant to *A. aneura*. The method is based on MULTCLAS developed by Lance and Williams (1967a, b; see also Williams and Lance 1968a, b) Stimson (1970), and Scott and Austin (1971). Examples of its use in bioclimatic classification are Russell and Moore (1970) and Nix (1972). The classification defines groups of climate stations having similar bioclimatic properties (Fig. 5). The first and second order boundaries (lines 1 and 2) divide the continent into three zones; a northern zone with a favourable summer season but completely dry winter; a central zone (more or less equivalent to the mulga zone) which has a marginal to fair growing season and low, but more continuous water

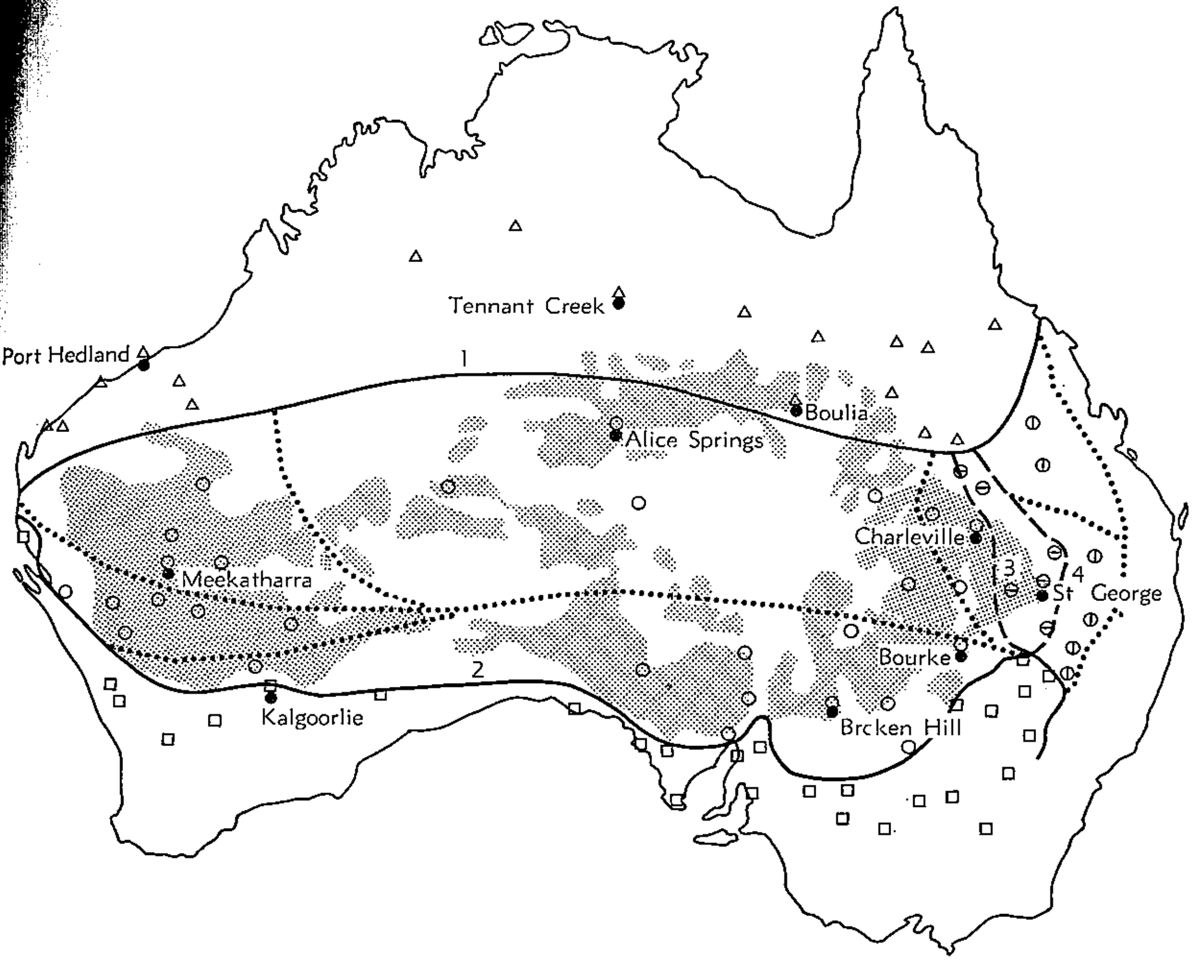

FIGURE 5
A numerical classification of bioclimatic variables relevant to mulga. Numbered lines are explained in the text. Symbols represent the different bioclimatic classification groups.

regimes due to summer and winter rain; a southern zone where thermal and moisture regimes are completely out of phase for plants with this thermal response pattern.

A third order boundary (line 3) separates an eastern sector with more favourable water regimes from the remainder of the mulga zone. A fourth order boundary (line 4) separates this eastern mulga sector from a yet more humid sector dominated by Eucalypt woodlands and *Acacia harpophylla* open-forests. Lower order boundaries (dotted lines) indicate further bioclimatic subdivisions and analysis of these with respect to growth habit and phenetic variation would be of interest.

Regional Bioclimate

The more humid eastern sector of the mulga zone, identified by this analysis, is of particular interest. On the basis of size, density and community structural development it is the optimum environment for *A. aneura.* Fortunately, this bioclimatic

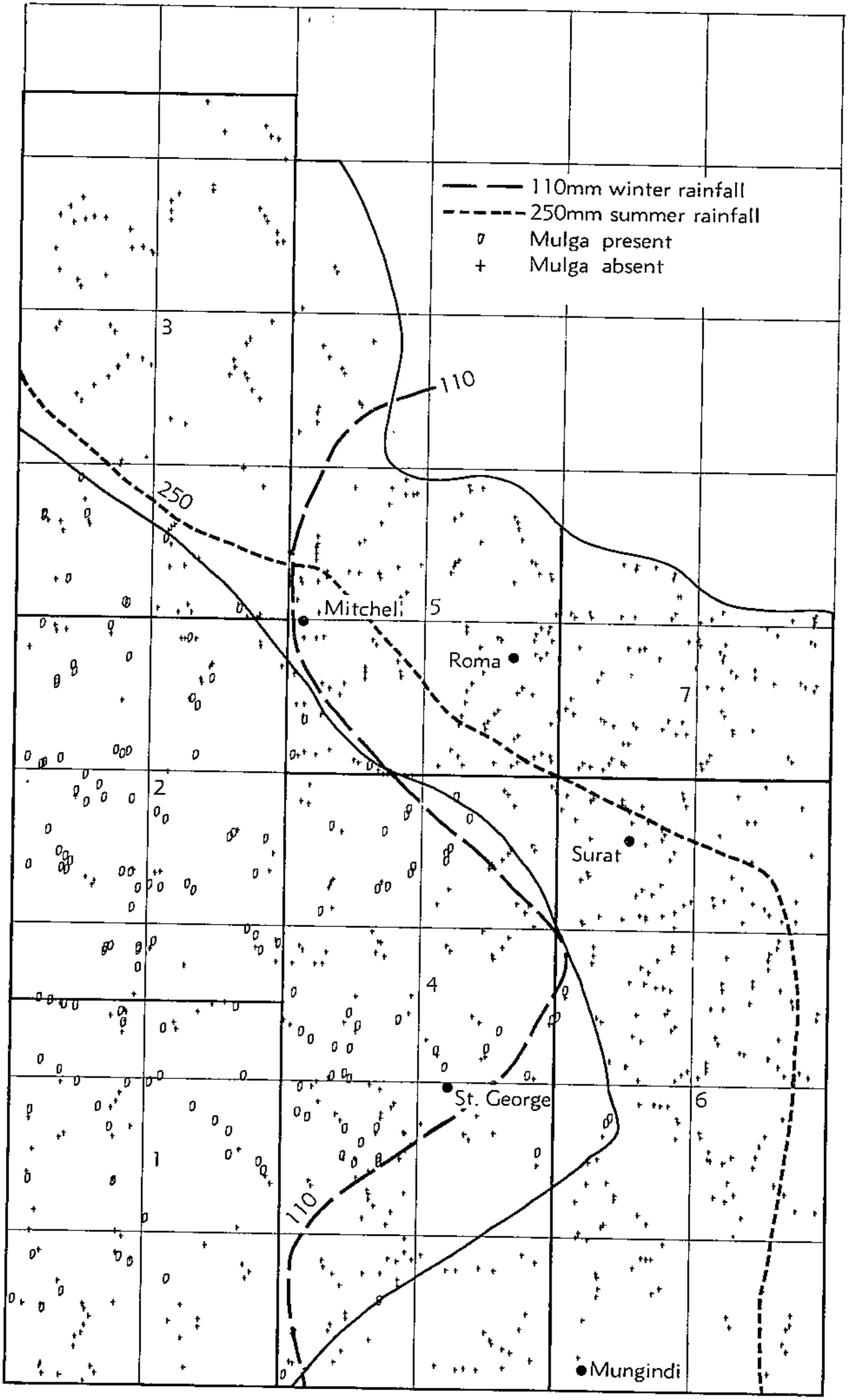

FIGURE 6
Distribution of *A. aneura* in seven geographic zones of the Balonne-Maranoa region from all sample sites.

optimum zone falls within the Balonne-Maranoa survey area (R. W. Galloway *et al.* in press). Data made available by these authors, for 911 sample sites, has allowed a more detailed analysis of this unique environment.

The eastern limit of mulga distribution has been derived from presence/absence data at all sample sites (Fig. 6). This boundary is closely related to the equal summer/winter moisture index line (see Fig. 4) in the north and to increasing summer and winter rainfall in the north and east. Thus, this optimal zone receives < 250 mm summer rainfall and < 110 mm winter rainfall in 8 years in 10. Presumably, competition from other species, particularly Eucalypts limits the extension of *A. aneura* to more mesic environments.

At this regional scale it is important to consider the species associated with *A. aneura* and the communities within which they occur. These communities can be recognised by various criteria. A numerical classification using presence/absence data and based primarily on overall similarity between the vegetation of different sites is available (Pedley and Austin, unpublished). This classification defined two major communities (P/Mulga/Ironbark and B/Mulga/Sandalwood) characterised by the presence of *A. aneura*; each of these could be further classified into three sub-groups.

Two other communities (A and E) replace P and B on similar sites in more humid areas to the east, beyond the geographical range of *A. aneura*. The association of *A. aneura* with massive earths and other soil types is shown in Table 1. *A. aneura* occurs predominantly on massive earths. However, it extends onto other soil types with increasing aridity in the west.

TABLE 1

Percentage of sites with A. aneura *in various geographical zone and soil type combinations from Balonne-Maranoa region.*

Number of observations shown in brackets

Geographical Zone	Massive Earths	Duplex Soils	Soil Type Clay Soils	Sandy Soils	Skeletal Soils
1	72.2% (36)	20.0% (15)	2.8% (35)	36.4% (11)	No samples
2	92% (50)	26.1% (23)	10.0% (10)	— (4)	66.7% (6)
4	56.4% (62)	9.4% (53)	— (55)	25.0% (18)	— (1)
3	35.7% (14)	3.2% (32)	— (30)	— (14)	50.0% (6)
5	14.3% (21)	— (40)	— (60)	— (9)	— (5)
6	5.6% (54)	— (71)	— (58)	— (4)	— (5)
7	— (11)	— (43)	— (22)	— (8)	— (5)

Climatic differentiation of communities occupying massive earth sites is clearly indicated, particularly in relation to the variants within each community (Fig. 7a, b). There is an east/west trend with types A and E replacing the variants of each type B and P. The community types defined by the numerical classification are geographically distinct, implying a sensitivity to the climatic gradient across the region.

A. aneura develops its highest biomass and approaches open forest structural formation in increasingly close association with *Eucalyptus populnea* towards the east until *E. populnea* replaces it entirely. Obviously, the moisture regime is a major determinant of structural and floristic differences.

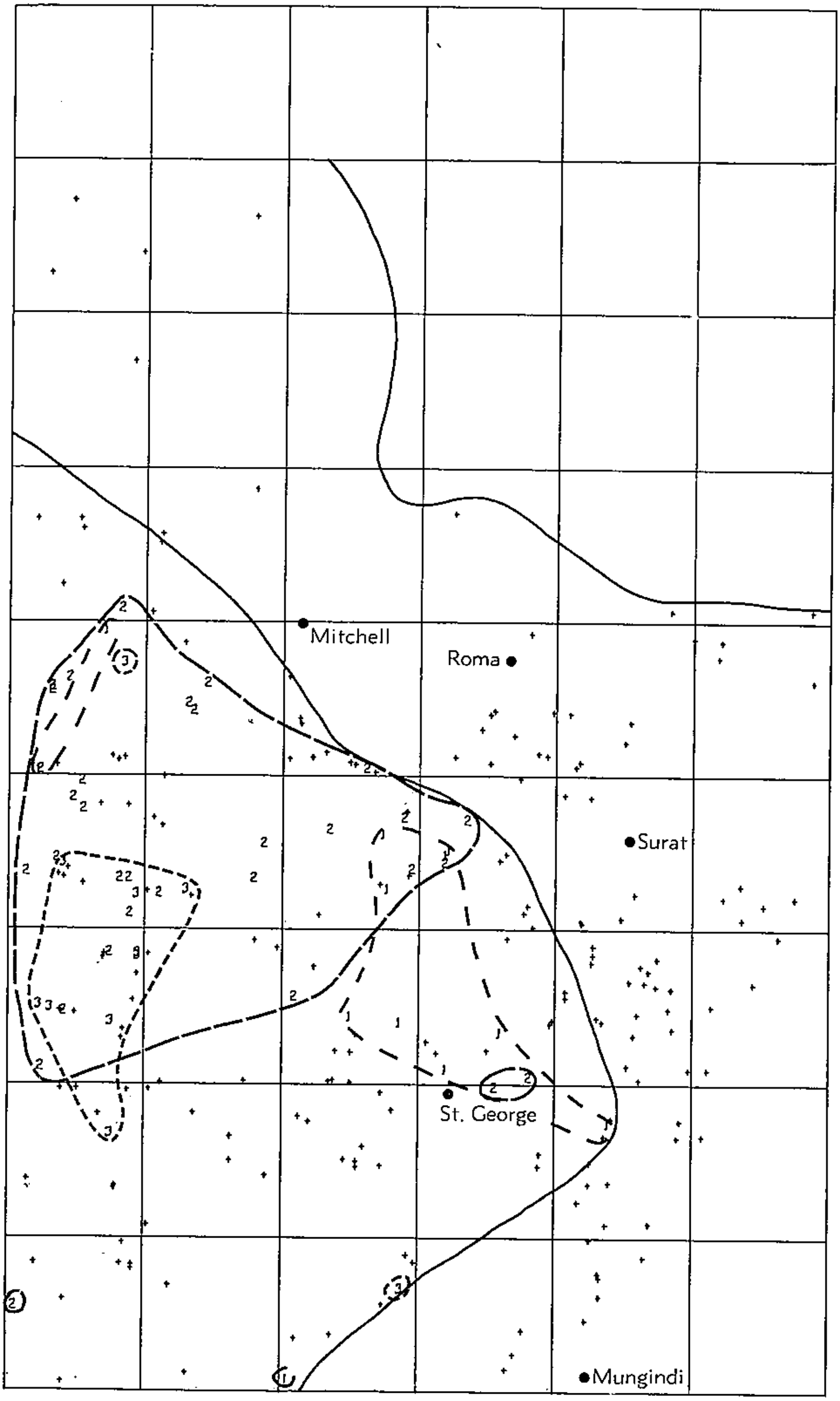

FIGURE 7a
Distribution in Balonne-Maranoa region of mulga/sandalwood community.
(numbers refer to discrete communities).

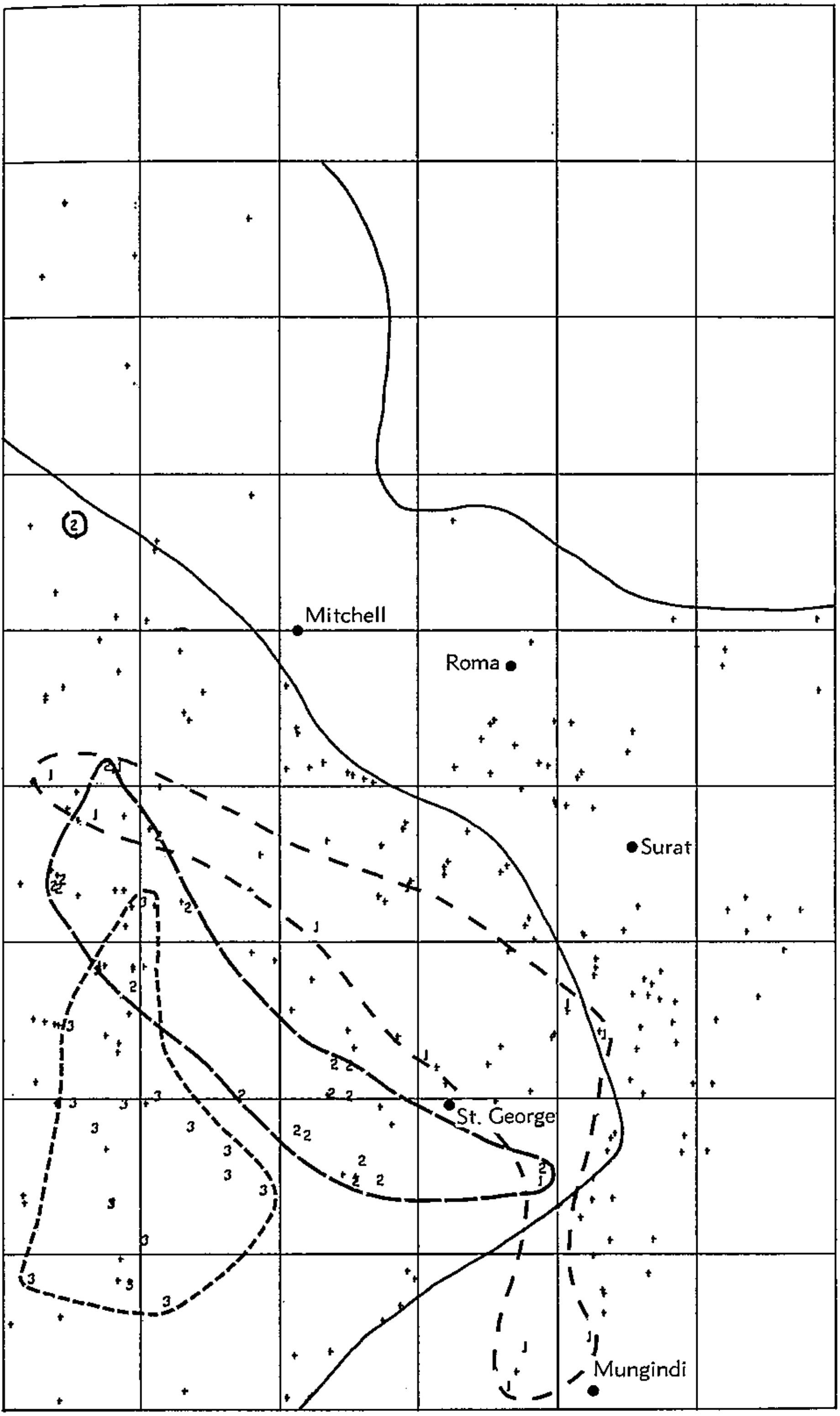

FIGURE 7b
Distiributlon in Balonne-Maranoa region of A(1) and E(2) communities.
(numbers refer to discrete communities).

DISCUSSION

The response of a species to climatic factors depends on the interaction of other environmental factors with climate, the physiological adaptations of the species and competition from other species present. At continental scale, the most significant bioclimatic variable is the water regime. *A. aneura* is adapted to environments where soil water regime is almost always limiting for growth, but where there is some probability of recharge at all seasons. Areas with regular seasonal drought appear unsuitable. The interaction of rainfall distribution and both surface and internal profile characteristics of cracking clay soils and solodics may produce soil water regimes unsuitable for *A. aneura*. On favoured soils in more mesic environments the role of competition from eucalypts remains to be defined.

At the regional level, the interaction of climate and soil type can be made more explicit, and its relationship to mulga communities demonstrated. Given quantitative data, such a regional analysis can be extended further to incorporate plant competitive factors (Austin 1972). However these types of analysis provide inferences or hypotheses about causal factors rather than proof.

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