BIOCLIM - a bioclimate analysis and prediction system

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Summary

BIOCLIM can be used to map the distribution of any entity, including pest species, and provide climate analyses and predicted Australian distributions specific for that entity. In the case of pest species, this facilitates focusing of suppression efforts on areas where the species is most likely to spread rapidly or areas where there is a high predicted probability of finding additional populations of the species. BIOCLIM also has the capacity to predict alterations in the potential distribution of a species brought about by climate change.

Introduction

BIOCLIM, conceptually developed by Henry Nix (see Nix 1986), is probably best regarded as a generic method, there being several versions running on a variety of computers around the country. These versions differ mainly with respect to the number of climate parameters used.

The BIOCLIM System

Climate Surfaces

The 'core' of BIOCLIM is the climate surfaces, used to produce site-specific estimates of monthly temperature and precipitation for sites anywhere in Australia (with the exception of offshore islands), regardless of altitude or location with respect to meteorological stations. These surfaces comprise one nationwide surface for both mean maximum and minimum temperatures and 19 regional surfaces for mean monthly precipitation, for each month.

Australia-wide monthly mean minimum and maximum temperature surfaces were fitted to measured data from 901 meteorological stations. Estimates of the mean true error, averaged over the data points used, were less than 0.5°C for every month of the year for both maximum and minimum temperatures.

Nineteen regional monthly precipitation surfaces were fitted to data from a total of approximately 11,000 stations, for the period 1901- 1975 and with a minimum length of record of five years. Estimates of the mean true error at the data points varied among the surfaces but, with the exception of some months at the beginning and end of the wet season in northern Australia, all mean errors were either less than 10mm or less than 10% of the monthly mean. Some localized deficiencies in the surfaces could be expected to occur in areas where steep or complex climatic gradients are poorly sampled by the meteorological network.

Climate profile

The climate estimates for individual sites at which an entity has been recorded can be aggregated into a 'climate profile', specific for that entity. Monthly temperature and precipitation estimates, obtained for each site as a function of latitude, longitude and elevation of that site, provide the values for 16 climate parameters (Table 1), indicative of mean, seasonal and extreme values of the climate. For each parameter, values from all the sites in each data set are ranked into numerical order and the minimum, 5 percentile, 95 percentile and maximum values determined. These, collectively, constitute the climate profile.

For potential pest species from outside Australia or where the Australian distribution is currently very limited, climate profiles can be collected by hand from whatever data can be assembled or estimated and subsequently used for prediction purposes. The potential geographic implications of 'what if' scenarios can also be explored by changing the parameter values in an existing profile.

Predicted distributions

These are based on the similarity of climates at points on a geographical grid to the climate profile. The most widely-used grid is a 0.5-degree latitude-longitude grid of Australia, but regional finer-scale grids have been developed for particular projects, for example a 0.1-degree grid of southeastern Australia. Special purpose, including irregular or even random grids, could also be used.

Altitudes at each point on the prediction grid need to be estimated, either from topographic maps or from a digital elevation model, and climate values estimated for each point, as described above.

The climate values for each grid point are compared with the climate profile to determine if the climate is apparently suitable for the entity. A number of selection criteria can be used to generate varying levels of prediction. Symbols allocated to the various predicted categories can then be plotted, along with the original data points.

The above description of the BIOCLIM system implies a linear sequence of steps which are not readily amenable to user control. For most users, this has not been an unreasonable constraint. Options, however, do provide access to outputs at various steps in the total procedure, giving specialist users the opportunity to explore alternative methodologies (Nix 1986). Some of the assumptions and limitations inherent in BIOCLIM have been discussed by Nix (1986).

Applications of BIOCLIM

BIOCLIM has been applied to numerous animal and plant species, with useful results in virtually all cases. Published examples include native grasses (Prendergast and Hattersley 1985), temperate rainforest tree species (Busby 1986, 1988, Gibson 1986, Hill *et al.* (1988), mammals (Busby 1988), and skeleton weed (Panetta and Dodd 1987). The most comprehensive application of BIOCLIM to date has been to all 77 species of snakes in the family Elapidae (Longmore 1986). In all these, and numerous other unpublished analyses, BIOCLIM has proved remarkably successful in predicting species distributions and in highlighting the most probable climatic limiting factor(s).

The only 'failure' of which I am aware is with the prediction for Koala in western New South Wales. In this region, the Koala is restricted to river red gum trees, themselves restricted to watercourses. The Koala's distribution is therefore limited by a habitat factor that is not directly related to climate, thus BIOCLIM was not a particularly useful tool in

Table 1. Climate profile parameters (BIOCLIM Version 2.0)

No.	Parameter	Unit
1	annual mean temperature	°C
2	minimum temperature of coolest month	°C
3	maximum temperature of warmest month	°C
4	annual temperature range (3 - 2)	°C
5	mean temperature of coolest quarter	°C
6	mean temperature of warmest quarter	°C
7	mean temperature of wettest quarter	°C
8	mean temperature of driest quarter	°C
9	annual mean precipitation	mm
10	precipitation of wettest month	mm
11	precipitation of driest month	mm
12	coefficient of variation of monthly precipitation	×
13	precipitation of wettest quarter	mm
14	precipitation of driest quarter	mm
15	precipitation of coolest quarter	mm
16	precipitation of warmest quarter	mm

that application.

Other applications have included intercontinental climatic analyses of eucalypt plantation success (Booth 1985, Booth *et al.* 1987), estimations of Tasmanian Holocene climates (Markgraf *et al.* 1986) and prediction of impacts on elements of the Australian flora and fauna of climate change due to the buildup of 'greenhouse' gasses (Busby 1988).

Discussion

The BIOCLIM system has proved to be a highly flexible and powerful tool for evaluating distributions on a variety of spatial, and even temporal, scales. It has the potential to be used in other application areas, but much of this potential remains to be realized.

A major feature of BIOCLIM is that most of its assumptions and procedures are explicit and its results are repeatable. Although there is limited scope for intervention in the standard BIOCLIM analysis, intermediate results are available at several stages for input into alternative analysis systems.

BIOCLIM had been originally established on the nation-wide CSIRONET computing system and thus was available to a wide variety of users. Recent changes to this network have severly restricted this access. Plans are currently being developed to make BIOCLIM available on the Environmental Resource Information Network (ERIN) system, but this will take some time. In the meantime, a rather rough PC version could be made available to users competent in FORTRAN and willing to take the challange. Write to me at the above address.

References

Booth, T.H. (1985). A new method for assisting species selection. *Commonwealth Forestry Review* 64, 241- 50.

Booth, T.H., Nix, H.A., Hutchinson, M.F. and Busby, J.R. (1987). Grid matching: a new method for homoclime analysis. *Agricultural and Forest Meteorology* 39, 241- 55.

Busby, J.R. (1986). A biogeoclimatic analysis of *Nothofagus cunninghamii* (Hook.) Oerst. in southeastern Australia. *Australian Journal of Ecology* 11, 1- 7.

Busby, J.R. (1988) Potential impacts of climate change on Australia's flora and fauna. *In* 'Greenhouse: Planning for Climate Change', ed G.I. Pearman, pp.387- 98 (CSIRO, Melbourne.)

Gibson, N. (1986). Huon Pine conservation and management. Wildlife Division Technical Report 86/3, National Parks and Wildlife Service Tasmania.

Hill, R.S., Read, J. and Busby, J.R. (1988). The temperature-dependence of photosynthesis of some Australian temperate rainforest trees and its biogeographical significance. *Journal of Biogeography* 15, 431- 49.

Longmore, R. (1986). 'Atlas of Elapid Snakes of Australia'. Australian Flora and Fauna Series Number 7 (Australian Government Publishing Service, Canberra.)

Markgraf, V., Bradbury, J.P. and Busby, J.R. (1986). Paleoclimates in southwestern Tasmania during the last 13,000 years. *Palaios* 1, 368- 80.

Nix, H.A. (1986). A biogeographic analysis of Australian elapid snakes. *In* 'Atlas of Elapid Snakes of Australia', ed R. Longmore, Australian Flora and Fauna Series Number 7 pp. 4-15 (Australian Government Publishing Service, Canberra.)

Panetta, F.D. and Dodd, J. (1987). Bioclimatic prediction of the potential distribution of skeleton weed *Chondrilla juncea* L. in Western Australia. *Journal of the Australian Institute of Agricultural Science* 53, 11- 6.

Prendergast, H.D.V. and Hattersley, P.W. (1985). Distribution and cytology of Australian *Neurachne* and its allies (Poaceae), a group containing C_3, C_4 and C_3- C_4 intermediate species. *Australian Journal of Botany* 33, 317- 36.