
In many parts of Africa woodlots of flooded gum are a familiar sight.

Matching trees to climate

A moment's reflection about the day's meals of a typical urban Australian reminds us that we are almost totally dependent upon plants and animals introduced into Australia during the last 201 years. We eat almost nothing that has not been introduced.

And despite the fact that people have been living on Australia's plants for more than 30 000 years, the macadamia stands out as the only edible Australian species that has been groomed for export. Yet other Australian plants, particularly our gum trees, are a familiar sight overseas. Although these Australian exports do not produce food, in many poor countries where firewood is in desperately short supply Australian trees planted for fuel are helping people cook the food they have. But, for every successful fuelwood plantation, there is a desperate need for hundreds more.

United Nations studies report that this lack of fuelwood has reached a crisis. In countries where most of the people depend on firewood as their chief source of fuel, natural forests and woodlands close to homes have been cut down and villagers now walk many kilometres to gather what they need to cook their food. Gathering a week's fuel is now an entire day's task for many African and Asian families.

The long-term solution for these families may well lie with alternative energy sources. But for most, stoves driven by solar power, biogas, or reticulated electricity are just a dream. The immediate practical solution is to grow more fuel closer to home, a practice that will also stop the destruction of woodlands and forests, which leads to widespread land degradation. Although some foresters argue that reforestation programs should use native vegetation, others contend that suitable local species grow too slowly to meet the huge demand and exotic species such as eucalypts should be used. The issues are complex (see the box on page 10), but going on the number of requests for seed it seems that Australian trees will continue to make a significant contribution to alleviating the fuelwood shortage.

The particular attraction of many of Australia's tree species lies in their adaptation to harsh environments. Every year CSIRO's Australian Tree Seed Centre in the Division of Forestry and Forest Products distributes thousands of seedlots for trial plantings. In 1986/87, it sent out 12 000 seedlots from 571 species. It's no easy task to select the trees for an overseas location from hundreds of species of eucalypts and other Australian natives, including acacias and casuarinas that can thrive on infertile soils through their ability to fix atmospheric nitrogen.

Field trials are essential, but, given the urgency of the problem and the time trees take to mature, foresters need to be confident that species chosen for trials are likely to succeed. Dr Trevor Booth at the Division of Forestry and Forest Products is one of a number of scientists developing ways to improve the selection process. Supported by funds from the Australian Centre for International Agricultural Research (ACIAR), he has been developing an approach to species selection that combines some fundamental ecological principles with computer technology.

First describe the niche -

As any high school biology student will tell us, a species continues to exist because its individuals survive long enough to reproduce. It exploits a spot that suits it in the ecosystem — its own ecological niche. If it is transferred elsewhere, its best chance of survival will often be in a niche with similar

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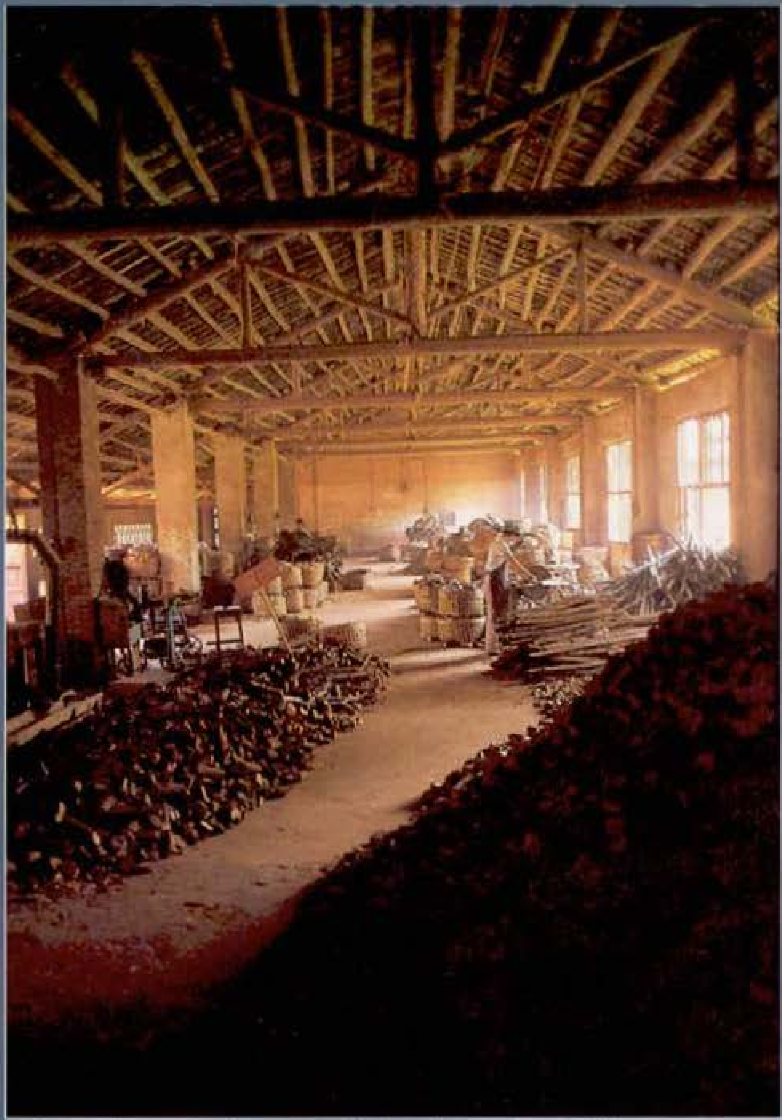
Searching for and collecting fuelwood is still a time-consuming chore for many African children.

Fuelwood plantations, like this one at Gozho school, Zimbabwe, provide a solution closer to home. Caring for these fast-growing eucalypts is part of the school's curriculum. The children gain valuable knowledge and experience, and the school earns a small income from the sale of poles and firewood to the local community.

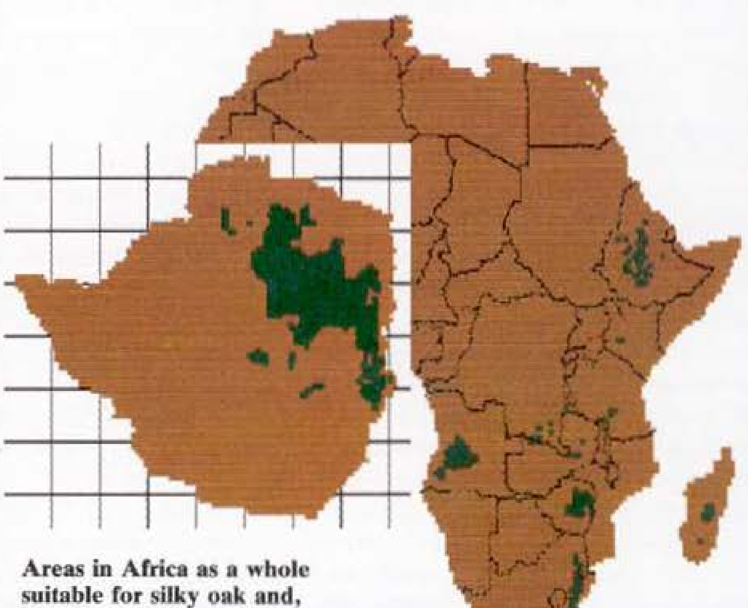


Wood is a valuable commodity here in southern China where eucalypt branches are turned into cotton-reels.

Matching sites for flooded gum...

The green areas have similar rainfall patterns and similar temperature regimes to those where flooded gum grows in Australia.

... and for silky oak



Areas in Africa as a whole suitable for silky oak and, in more detail, suitable areas in Zimbabwe.

Eucalypts abroad: saviours or sinners?

In the warmer parts of the world, the genus *Eucalyptus* has for years been a popular choice for introduction, making up about 40% of all plantations in the tropics. From Brazil to Ethiopia, India to China, its rapid growth and the wide range of conditions in which the various species can grow have endeared it to many. But lately some people have begun to strongly criticise its use.

Critics argue that eucalypts degrade the soil by reducing its fertility, that they lower the water table because of their high consumption of water, that they threaten ecological stability because they are often cultivated in large monocultural stands, and that they create 'ecological deserts' almost devoid of local fauna, particularly birds. In some countries, the dislike is so intense that people have pulled up plantations of young eucalypts.

The issue is hotly debated in development circles; are eucalypts a boon for the rural poor or an ecological disaster waiting to happen?

According to the authors of a United Nations Food and Agriculture Organisation (FAO) report — commissioned to provide an objective analysis of the available information on the ecological effects of eucalypts — the answer depends upon the circumstances. The report offers the following conclusions.

SOIL. The effects of uncropped eucalypts on soil depend upon the state of the soil in which they are planted — beneficial on degraded sites, probably not so when replacing indigenous forest. Eucalypts planted on bare sites result in an accumulation and incorporation of organic matter. Cropping eucalypts on a short rotation, especially if the whole biomass is taken, leads to rapid depletion of the reserve of nutrients in the soil. This is a direct consequence of their rapid growth and would apply in much the same way to any other highly productive crop.

WATER. Eucalypts planted where no trees grew before reduce the water yield of catchments and lower water tables. Although other tree genera would probably produce comparable effects, evidence from the humid tropics suggests that young rapidly growing eucalypt plantations consume more water and do not reduce run-off after storms as well as natural forests. The strong surface roots of some eucalypts mean that they compete vigorously with ground vegetation and with neighbouring crops in situations where water is in short supply.

COMPETITION. The effects of eucalypts on ground vegetation depend upon climate and competition, for water in particular. Ground vegetation is less affected in wet conditions than in dry, when it may be greatly reduced leaving the soil bare and prone to erosion. It is axiomatic that numbers and diversity of animals are lower in exotic plantations than in natural forest. This applies to eucalypts grown as exotics.

The FAO report concludes that a universal statement about the favourability or otherwise of planting eucalypts would be inappropriate, as each case should be examined on its individual merits.

Dr John Turnbull, Principal Research Scientist in the Division of Forestry and Forest Products and currently seconded to ACIAR, agrees, but considers that the debate will continue for some time. 'In my view the negative ecological effects of eucalypts have been overstated in an effort to discredit tree-planting schemes which have resulted in what some see as undesirable social and economic consequences', he says. 'For example, in parts of India it is alleged that eucalypts ostensibly planted to supply fuelwood to the rural poor have been used instead as the raw material for rayon and pulp industries. Those who see this as a social injustice have vilified the eucalypt on ecological grounds rather than blaming the planners' decisions or the farmers who seek a higher financial return in selling their wood to the factories.

'Nevertheless, I believe that we should be investigating a range of species with different characteristics that are closely aligned with local needs and prevailing environmental conditions. The Australian aid agencies AIDAB and ACIAR are sensitive about promoting eucalypts to the exclusion of all other species, especially in agroforestry or social forestry. AIDAB through its "Seeds of Australian Trees for Developing Countries" project, and ACIAR, through its collaborative research programs in Zimbabwe, Kenya, China, Pakistan, Indonesia and Thailand, are seeking to maximise the benefits of using fast-growing species of many genera to solve local problems.

'The direct ecological effects of growing eucalypts? The FAO report summarises the effects quite well. All plants extract nutrients from the soil. If they are harvested and the biomass is removed, the soil is depleted and may need to be fertilised. This is a universal occurrence and applies to rice, sugar-cane, leucaena and other fast-growing trees like eucalypts. In practice, the rate at which this nutrient depletion occurs depends to a large extent on the type of soil and its physical structure. Soils which are inherently fertile can support high-yielding crops for many years without productivity declining. Others may be depleted very quickly.

'A similar comment can be made about the use of water. All plants require water to grow, and the faster they grow the more they need. Eucalypts are no exception. But the amount used by eucalypts per unit of biomass produced may in fact be lower than some other fast-growing trees. Eucalypts appear to be efficient water users.

'The anti-monoculture argument against eucalypts could logically be applied to a wide variety of other crops. While there are risks, particularly with regard to the potential spread of pests and diseases, these have not prevented numerous other plants being grown successfully as monocultures — many of which, through years of selective breeding, have a much lower degree of genetic diversity than a typical eucalypt crop.

'In contrast with many of the technical arguments, the criticism that eucalypts are intrinsically incapable of meeting some of the social objectives of most farm and community forestry programs has more validity. Indeed, some of the properties that make eucalypts attractive for foresters to grow are the very ones which reduce their wider social usefulness. For example, the fact that the leaves on many eucalypt species are not browsed by livestock is a major advantage in areas where protection from grazing animals is difficult. But it also means that eucalypt plantations do not increase local fodder supplies which may be a high priority for the rural poor. And unlike the leguminous acacias or casuarinas, eucalypts do not have the ability to fix atmospheric nitrogen so are less suitable as soil improvers.

'On the other hand, in China, Ethiopia and India I've seen small farmers use eucalypts for fuelwood, posts and poles, honey production, shade and shelter and eucalypt oil. These trees were clearly meeting the farmers' objectives. In some cases they provide the farmers with savings and security as well as contributing a cash income to their subsistence agriculture. Generalisations are fraught with danger!'

The ecological effects of *Eucalyptus*. M.E. D. Poore and C. Fries (eds). *Food and Agriculture Organisation Forestry Paper* No. 59, 1985.

Planning for climatic change

Australia 2030 AD: atmospheric CO_2 concentration doubled.

A rise of 2–4°C in the annual mean temperature, with the greatest warming in the south and in the winter. Daily maximum rainfall increased by 20–30% with some changes in the frequency distribution. Higher spring, summer, and autumn rainfall in regions influenced by the Australian monsoon season. Winters drier by 20% in those areas deriving rain from Australia's mid-latitude high and low pressure systems. Sea level risen by 20–140 cm. Tropical cyclones shift 200–400 km further south, reaching Brisbane and the Gold Coast, with possible changes in frequency and intensity. Snow line risen by 100 m per 1°C warming. Wind speed decreased by 20% north of 36°S but increased south of it.

This is the summary of a working scenario prepared by Dr Barrie Pittock of CSIRO's Division of Atmospheric Research and presented to the participants of the 1987 Australian National Conference on climatic change resulting from the changing composition of the atmosphere. Dr Pittock circulated the scenario prior to the conference, with the request that the participants use it as a basis for exploring the sensitivity of their sector to climatic changes of plausible magnitude, not as the basis of a firm prediction. Dr Pittock stressed that the scenario was merely a time slice through a changing and evolving situation. Warming is expected to continue beyond 2030 and, with it, sea-level rise.

A number of scientists used the scenario to examine what might happen to parts of Australia's natural environment. Many used computer models to help predict the effects of change. Among them, Dr John Busby of the Australian Biological Resources Study used BIOCLIM to assess the potential implication of climatic change on four entities: alpine vegetation, temperate rainforest, a rare mammal species (long-footed potoroo), and a common one (antilopine wallaroo).

In each case, Dr Busby selected a number of sites where the plants and animals were known to occur. He recorded the latitude, longitude, and elevation of each site and obtained an estimate of climate from computer-generated 'interpolation surfaces' prepared from meteorological data.

After adjusting the data in line with the scenario outlined above, he looked at the changes in distributions that would occur. He calculated that Australia's present alpine climate would virtually disappear,

Where the climate is suitable, and marginal, for temperate rainforest. The forest's actual distribution is confined to patches within the present suitable areas. The fact that some other areas may become suitable by the year 2030 does not mean rainforest will establish there. The climate may change that quickly; the rainforest certainly couldn't.

with a dramatic reduction in the area occupied by the present alpine flora and fauna. Some species at lower altitudes may be able to migrate to more suitable climates, but the island-like nature of most alpine communities makes migration difficult.

The outlook for the present temperate rainforest also seems uncertain. Dr Busby's calculations show that the rise in winter temperatures, while unlikely to cause a direct degradation of the rainforest, would make it climatically marginal.

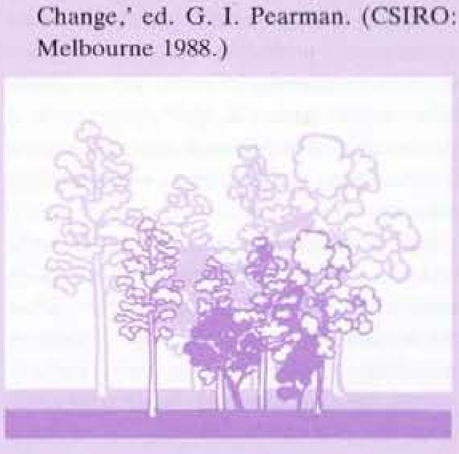
According to Dr Busby, the future of the long-footed potoroo (*Potorous longipes*), already rare and endangered, looks particularly grim. The animal presently lives predominantly in far-eastern Victoria, but as the the climate there changes, potentially 'suitable' habitats might not become available at other locations. In any case, no suitable migration corridors would be available. Survival of the species would probably depend upon active intervention by man.

The probable fate of the antilopine wallaroo (*Macropus antilopinus*), now found widely distributed along Australia's northern coast, is only marginally better. It is likely to become rare and endangered.

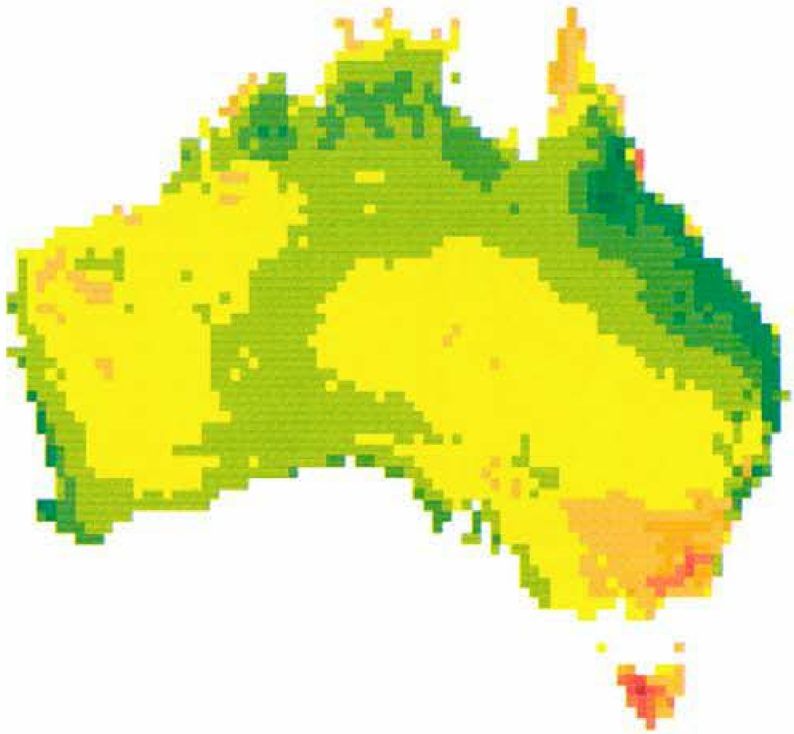
Dr Busby stresses that the primary assumption of the prediction system is that entities can only colonise and survive in areas with climates fitting their present profile. Although some may be able to adapt to changed climates it seems highly likely that, without man's decision to intervene, many animals and plants will become extinct.

Advance knowledge about the capacity of individual species to adapt will help us plan for the action we may need to take to prevent their extinction. Computer programs such as BIOCLIM help us predict some of the likely outcomes of change, but they become more useful if the models are validated by field trials that give practical information about species performance in different climatic environments. The success or failure of an Australian wattle growing near Harare may well provide us with a crucial preview of how it may respond to changing climatic conditions within its natural distribution. The climate analyses carried out by Dr Booth and his colleagues, covering hundreds of trials of Australian species in Africa and Asia, will be a valuable aid for Australia's future land managers.

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



Matching Harare's climate



The dark green areas show where the climate is most similar to Harare's; the red show where it is least so.

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attributes. However, in the absence of competition from other species it may also grow well in environments that differ somewhat from those in its natural distribution.

Niches are a simple enough theoretical concept, but in practice their complexity makes them difficult to define; in fact ecologists admit to the impossibility of measuring every environmental factor that determines a niche. But most would agree that a relatively small number of factors are most important.

Publications and data banks designed to help foresters select suitable species for trial generally use simple soil descriptions and climatic factors related to temperature and rainfall to describe a species niche. Soil conditions are important, but matching one country's soil types with another's poses considerable problems. In contrast, standard climatic measurements are available from many thousands of locations around the world. Finding climatically similar sites (homoclimes) is, therefore, a logical first consideration.

Unfortunately, though, all too often the location of a trial and the region from which trees are to be introduced lie far from meteorological stations. So foresters searching for homoclimes have had to make educated guesses — based on records from the nearest stations — in deriving climatic data for these sites.

To develop a more reliable method, Dr Booth has made use of climatic data-bases and interpolation programs developed by Professor Henry Nix and Dr Michael Hutchinson, of the Centre for Resource and Environmental Studies at the Australian National University.

Computer matching

Using data from about 1000 temperature-recording stations and more than 4000 recording rainfall, Dr Hutchinson, together with Dr John Busby of the Australian Biological Resources Study, has calculated 'interpolation surfaces' for Australia. Given the latitude, longitude, and elevation of any site, they can estimate mean monthly maximum and minimum temperature with an error usually well below 0·5°C and mean monthly rainfall with an error of less than 10% over most of the country. Using these surfaces Dr Busby estimated mean climatic conditions for 2795 points in a regular grid across Australia.

Dr Booth uses these grid data as the basis for a microcomputer program called CLIMSIM, which finds homoclimes with other parts of the world. For example, the map above shows what sites in Australia have a climate similar to that of Harare, Zimbabwe. The dark green areas are most similar, the dark red ones are least so. Such maps can be correlated with maps showing the natural distribution of Australian species that have potential for fuelwood production. For Harare, the most climatically similar areas are in Australia's north-east and, in fact, many of the successful introductions of our natives planted close to Harare have come from there. These include flooded gum (*Eucalyptus grandis*), the forest red gum (*E. tereticornis*), and the river red gum (*E. camaldulensis*).

Matching climates like this and comparing them with species-distribution maps is a quick and very cheap way of identifying plants worth testing at a particular place overseas. However, as mentioned before, some species can succeed in conditions that differ from those of their natural distribution. To determine this adaptability Dr Booth and his colleagues devised methods of analysing the climatic requirements of particular species.

The basis of the approach is the Bioclimatic Prediction System developed by Professor Nix, Dr Busby, and Dr Hutchinson. They use a computer program (BIOCLIM) to manipulate data describing the distribution of a species in Australia and to produce information describing its range of climatic conditions. This provides a first indication of the species' climatic requirements. Dr Booth has used the BIOCLIM program to derive such knowledge for many Australian tree species.

In the second stage, Dr Booth uses results from trials outside Australia to improve that knowledge. For example, silky oak (*Grevillea robusta*)has been grown successfully at the International Council for Research in Agroforestry (ICRAF) research station at Machakos near Nairobi, Kenya, despite the fact that the region has a slightly lower mean annual rainfall and the coldest month is slightly warmer than silky oak's natural habitat in southern Queensland and northern New South Wales. Information like this is used to modify descriptions of a species' climatic requirements.

To assist the analysis of data from overseas trials, Dr Booth has developed climatic interpolation surfaces for Africa. He produced these using Dr Hutchinson's programs and climatic data collected by Professor Nix and his colleague Ms June McMahon, along with data gathered by the Food and Agriculture Organisation (FAO).

Finally, Dr Booth used these interpolation surfaces to develop a climatic data-base for Africa consisting of 10 187 locations in a regular grid across the continent. For

Poles from fast-growing young eucalypts make low-cost, durable construction material.

Acacia holosericea **— a tropical Australian species — is attracting great interest overseas. The leaves are unpalatable on the tree, but when allowed to dry are readily eaten by livestock.**

each location, it includes data for latitude, longitude, and the following climatic factors:

- mean annual rainfall (mm)
- rainfall regime (summer, winter, uniform, or two major rainy seasons)
- dry season length (months)
- mean maximum temperature of hottest month (°C)
- mean minimum temperature of coldest month (°C)
- mean annual temperature (°C)

Dr Booth has written a microcomputer program to produce maps showing where particular species would be likely to grow successfully. He can compare conditions at each location with details of a species' climatic requirements. For example, he used information for flooded gum from 107 locations within its natural distribution and 52 trials in 10 African countries to produce the map on page 9.

As good as the interpolation methods are, they depend for their success on the available meteorological data. For areas where particularly good data are available, Dr Booth can develop more detailed maps. For example, he has used Dr Hutchinson's programs to analyse data from 484 locations in Zimbabwe to produce a data-base of 4999 locations in a 5-minute (about 10-km) grid.

Dr Booth developed the climatic database for Africa because of the urgency of the continent's fuelwood crisis and the large number of requests that African countries are making for seed of Australian trees. The research is part of a broader ACIAR-funded co-operative program involving trials in Africa, Asia, and Australia that seek to identify promising species and define suitable environments for fuelwood crops.

While the climate-matching techniques are now providing a valuable preliminary sieve for selecting promising species and sites, Dr Booth is the first to warn against selecting species and provenances solely by using homoclimes. For example, soil conditions also need to be suitable, appropriate symbionts may need to be present (see *Ecos* 54), and pests can be a problem in some regions. To improve the quality of the information, he is integrating the results of his research with other databases, such as TREDAT, which is being developed by Mr Alan Brown of the Division of Forestry and Forest Products and the Queensland Department of Forestry. TREDAT can be consulted for information on various additional factors that influence the choice of a species, including the important issue of people's needs and preferences.

David Brett

More about the topic

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