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BAUXITE HYDROLOGY UPDATE

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This newsheet provides an informal update of hydrological research related to bauxite mining in the northern jarrah forest.

GENERAL RESEARCH PLANNING

The main activities in research planning have been meetings of the bauxite Synthesis Group and the bauxite subcommittee of the Research Steering Committee on Land Use and Water Supply. A field research trip was also organised for members of the Research Coordinating Committee and Research Steering Committee. The main outcomes of the above meetings are described below.

A working group was set up to establish a clear methodology for evaluating the interaction of bauxite mining and dieback disease. The main problems to be addressed are the requirements for vegetation monitoring, the measurement of water use changes as a result of the disease and pre-emptive management measures, and the prediction of dieback-mining effects at a regional scale.

A second working group was formed to consider and plan regional predictive modelling of the effects of mining and dieback disease on water resources. The tasks facing the group are to define required model outputs, consider a range of modelling strategies and define model data inputs.

The need for a second hillslope study in the high rainfall zone where mining is currently taking place was agreed. Minesite, Hillslope and Dieback Working Groups will collaborate on site selection.

General agreement was reached on the necessity of a small catchment trial mining experiment in the intermediate rainfall zone. However the location of this site is still under review, both from the point of view of Alcoa's future mining directions and the representativeness of the experimental catchments. Until a location is decided, a number of small catchments will be monitored for rainfall and runoff and their characteristics investigated further.

A schedule of research has been planned for the Mount Saddleback paired catchment study. Due to the low degree of similarity of these catchments to the bulk of the northern jarrah forest, emphasis will be given to monitoring rather than detailed hydrologic process studies.

JARRAH DIEBACK : EFFECT OF SITE ON SUSCEPTIBILITY OF JARRAH TO PHYTOPHTHORA CINNAMOMI

Over the last two summers a series of experiments have been conducted which have shown that the growth rate of P. cinnamomi in jarrah is affected by the water status of the trees. The amount of water available to the trees in part determines how much damage the fungus can do. This has led to the comparison of the susceptibility of trees on a number of sites in both the low (800 mm) and high (1100 mm) rainfall zones. Mean pre-dawn water potentials of trees on different Havel site types and in different localities vary significantly.

Summary of data

1. Phloem relative water contents (RWC) below 85% stopped or limited fungal growth. Lesion extension (necrotic tissue associated with fungal invasion) ceased in trees with low RWC's (e.g. in Feb., March, & April) although temperatures were highly favourable for fungal growth. Similar relationships (fungal growth vs RWC) were found for trees inoculated in the field and for stem blocks taken from single trees left to dry to develop a range of water deficits.
2. Water potentials of phloem pieces were determined with a Wescor psychrometer and the relationship between RWC was related linearly to water potential over the range 75 - 100% RWC corresponding to water potentials of - 1.5 to 0 MPa respectively.
3. Mean pre-dawn leaf water potentials on selected sites in late summer varied between - 0.67 ± 0.06 MPa and - 2.5 ± 0.1 MPa. (see Table 1).

TABLE 1 Mean tree pre-dawn water potentials (MPa)

Site type	Jarrahdale (n)	Site type	Dwellingup (n)
Z	- 2.5 ± 0.1 (12)	S	- 0.67 ± 0.06 (8)
T	- 1.3 ± 0.2 (5)	S-T	- 1.43 ± 0.05 (8)
P	- 0.63 ± 0.04 (7)	P-S	- 2.2 ± 0.3 (8)

Means of sites within each division are significantly different (P < . 05)

4. Final lesion lengths in 50 trees, inoculated in January, were correlated with April pre-drawn water potentials.
5. Experiments over two summers have shown that trees at a P site type (Havel Classification) off Kinsella road suffered less water stress than those at other site types. Large pole-sized trees at this site also continued wood production into summer. This was up to 3 months after wood production had stopped at all other sites.

Implications

Joe Havel stated years ago that P site types were of the highest disease impact type (P sites have Allocasuarina fraserana, Grevillea wilsonii, Adenanthos barbigera present). The suggestion now is that they are "wet" sites and jarrah's resistance to the fungus is overwhelmed due to prolonged periods of rapid fungal growth in the trees (i.e. most of summer). Additional P sites and also other 'fertile', well drained and upland-laterite sites are being compared this summer.

The association of disease with high soil moisture availability in the past has been attributed to production and dispersal of zoospores. Plant water status has now been identified as a major factor affecting susceptibility of jarrah to invasion by the fungus. This helps explain why 'dieback' is worst after years of heavy summer rain and least in low rainfall areas.

It may now be possible to rate the 'performance' of jarrah and understorey species in terms of their water relations and use different summer "stress" levels as criteria for predicting disease impact. The water relations of jarrah, marri and understorey species are currently being compared at a range of sites.

ALCOA'S RESEARCH

Evapotranspiration

Alcoa's priority one field project for the 85/86 summer has been the ventilated chamber study of evapotranspiration in a rehabilitated mine pit. Six trees have been instrumented, three E.resinifera and three E.wandoo. A two week monitoring run was completed in December and it is planned to do at least one run every month until the end of season. Ian Foster of CSIRO has been undertaking a number of experiments at the site to determine the impact the chamber may be having on the trees' ability to transpire at its normal rate. His report should be available in June.

These direct measurements of evapotranspiration are being backed up by below ground estimates of soil moisture changes using the neutron probe. This site is particularly suitable for neutron probe work as the profile is only around six metres deep.

Soil Moisture Measurement and Modelling

The soil samples and data from the 14 rubber packer neutron probe tubes that were installed this summer have been analysed. The results failed to give a satisfactory calibration curve. It is now felt that the problem may lie in the laboratory techniques used to determine soil moisture content, so thermo-gravimetrics will be done on samples from three additional holes to determine the amount of water that is chemically bound.

Paul Raper is undertaking 10 weeks work experience with Alcoa. This is being funded by a Neville Stanly Studentship. He is fitting an upgraded version of Barry Carbon's model called Flux to tensiometer data from the research minepit SP06. The work is progressing despite the heavy computer resources required to make runs.

Meteorology

Ray Steedman and Associates were employed to assess the accuracy of the above canopy meteorology station installed by Alcoa. They concluded that its quality of record would be equal to that from a more expensive conventional station.

CATCHMENT STUDIES

The construction of gauging stations for the proposed trial mining catchment (Yarragil North) and the adjacent control catchment (Yarragil East) has been completed. Both of these stations were commissioned in July 1985. Further upgrading of the existing gauging station on Yarragil 6C will be undertaken during the summer of 1985/86. The gauging station on Yarragil 4X will also be upgraded at the same time.

Processing of rainfall and saltfall data collected from the Yarragil 6C during the winter of 1985 has commenced. The application of an analysis of covariance to this data will provide guidelines on permanent rainfall and saltfall gauge network designs for the Yarragil catchments.

A draft document describing a small catchment research methodology for the Bauxite Catchment Research Group has been revised. Copies of the revised draft have been circulated among Group members for comment prior to publication. A draft of a document describing an overall research strategy for the Group is in preparation.

Work on the application of statistical parameter estimation techniques and uncertainty analysis to a simple rainfall-runoff model has been completed. A report describing this work is in preparation. Upon completion of the report, an evaluation of the performance of a small number of quasi-distributed and fully-distributed models of the complete land phase of the hydrological cycle will be initiated. This evaluation will permit the identification of an appropriate small catchment modelling approach and areas for further model development.

HILLSLOPE PROCESSES STUDIES

A comprehensive progress report of the Hillslope Processes Group study at Del Park has been completed. The report details the installation and operation of instrumentation and presents a preliminary analysis of 1984 data. A number of recommendations are made for the future development of the project. These include improved techniques for installation and calibration of neutron access tubes, and for measurement of soil water potential (at depth), evapotranspiration and salinity components; improved analysis of interception and groundwater recharge; and the development/application of groundwater and soil-plant-atmosphere water movement models. In addition to the progress report, routine monitoring, maintenance and data processing has continued. A system for measuring undisturbed soil hydraulic properties has also been developed and is undergoing testing.

LEAF AREA MEASUREMENT STUDIES

Work on estimating jarrah forest leaf area has been progressing on three different scales:

- i. individual tree leaf area,
- ii. stand leaf area, and
- iii. catchment leaf area.

1. Individual tree leaf area

A number of relationships between tree leaf area and specific dimensions of the tree have been found. Some of these are listed below (also see Fig. 1). Sapwood area (which has received a lot of attention in the literature as a very good predictor of leaf area) performed relatively poorly. However, some of the other relationships based on tree and crown dimensions were quite good. The tree measurements required to estimate tree leaf area are likely to be less time consuming than those for sapwood area, with about 100 trees/day being a reasonable target for a two man team. The inclusion of a subjective or objective measure of crown density is likely to improve the precision of these relationships.

At one instant in time!

$$\text{Leaf area (m}^2\text{)} = 0.615 \times \text{Sapwood area (cm}^2\text{)} - 20.24$$
$$r^2 = 0.77 \quad \text{s.e.e.} = 16.8 \quad n = 15$$

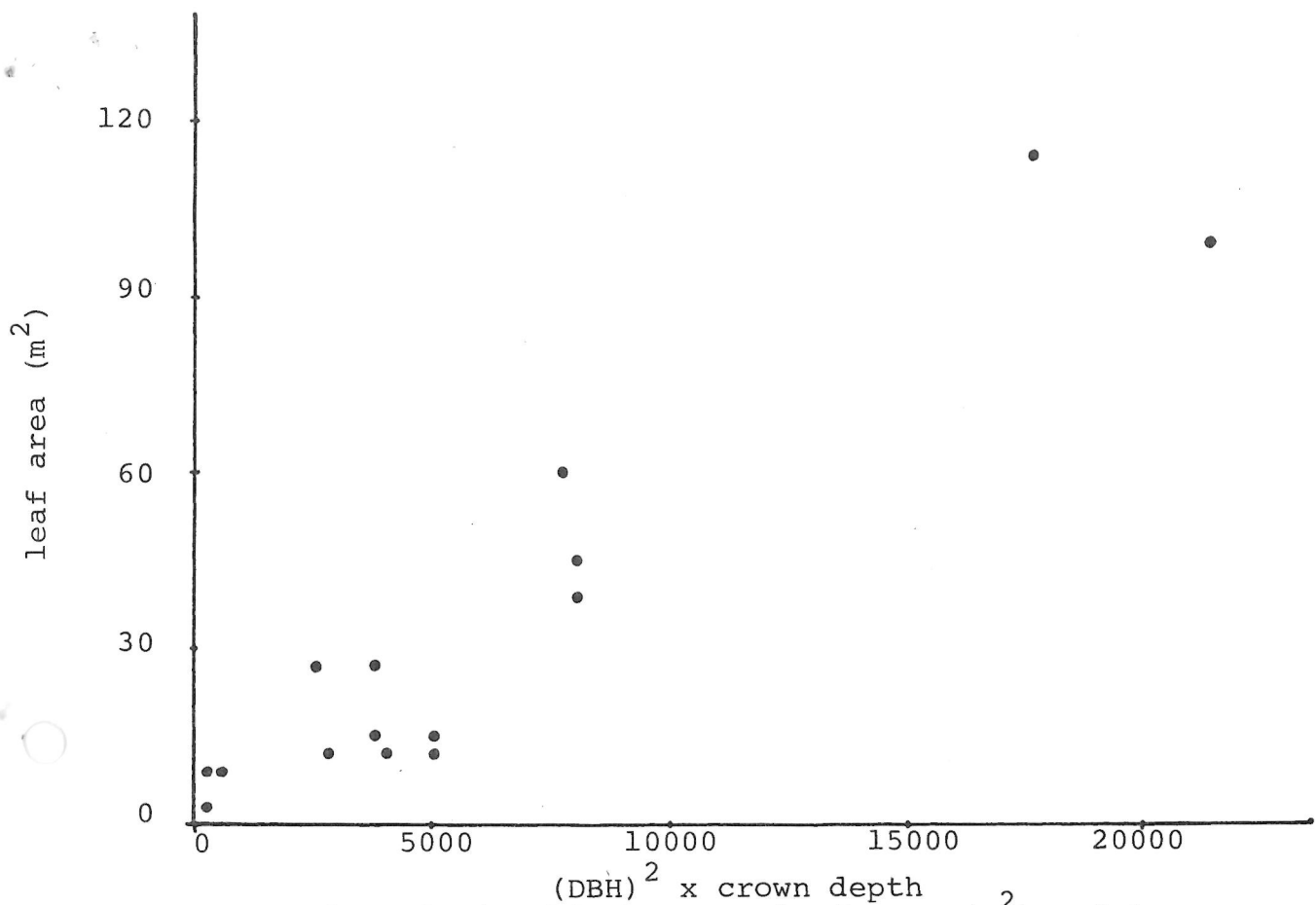


Figure 1 Relationship between leaf area (m²) and tree dimensions (DBH)² x crown depth for regrowth jarrah trees. $y = 0.00558 x + 0.47$ $r^2 = 0.88$ s.e.e. = 12.0

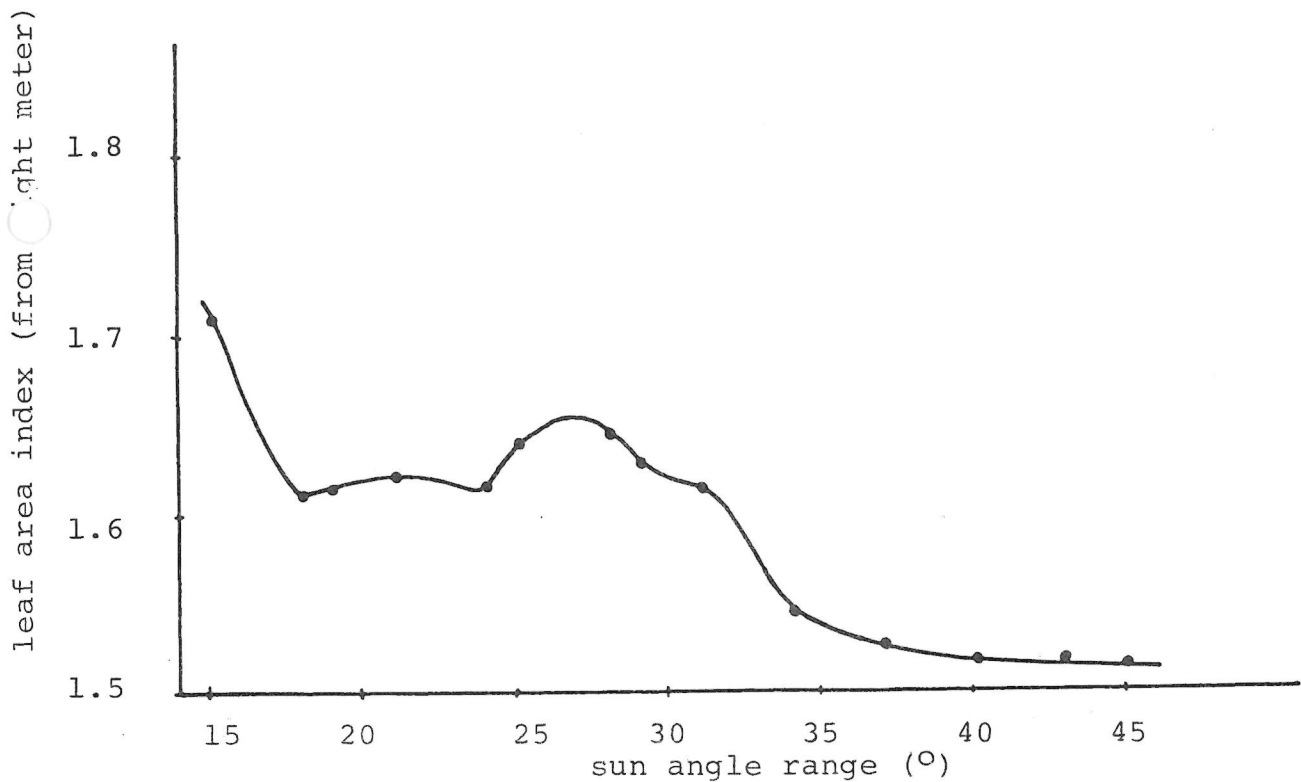


Figure 2 The effect of sun angle range on estimated leaf area index for a regrowth jarrah stand near Dwellingup. The angular ranges considered vary from a 15° winter minimum range (77° to 62° from the zenith) to a 45° summer maximum range (77° to 32° from the zenith).

Leaf area (m^2) = $0.183 \times (\text{crown depth} \times (\text{crown width})^2) - 2.41$
 $r^2 = 0.85$ s.e.e. = 14.9 n = 15

Leaf area (m^2) = $0.0622 \times (\text{DBH})^2 - 11.07$
 $r^2 = 0.84$ s.e.e. = 14.0 n = 15

Leaf area (m^2) = $0.00011 ((\text{DBH})^2 \times \text{crown depth} \times (\text{crown width})^2) + 11.75$
 $r^2 = 0.89$ s.e.e. = 12.4 n = 15

DBH is the tree diameter at breast height.

Whilst these relationships are promising we can expect them to be reliable only for that site at that particular time. Some of the factors that are likely to affect the relationships are the flowering and seeding cycle, season, climate, site quality, soil moisture regime of that site, and stand density.

2. Stand leaf area (using the light meter technique)

The initial assessment of the light meter technique was encouraging though not final in its conclusions. We consider this a preliminary examination.

64 one minute light penetration readings were taken over one seventh of a hectare, moving the area of measurement as the sun angle changed, to consistently view the selected canopy plot.

The probe angles ranged from 77° to 33° from the zenith. The plot contained 82 trees (77 jarrah and 5 marri). Of these 18 jarrah and 4 marri were destructively measured for leaf and wood area.

From this data, regressions for leaf and wood area were determined. These were based on DBHOB (diameter at breast height over bark) and canopy dimensions.

Leaf area	wood area
$r^2 = 0.85$	$r^2 = 0.88$
s.e.e. = 12.0 m^2	s.e.e. = 1.6 m^2

Wood area was 17% of leaf area.

From these regressions total area index (i.e. projected wood and leaf area) and LAI were determined. These were TAI = 2.14 and LAI = 1.83.

The sunlight penetration measurements yielded a TAI of 1.52 with $\bar{\alpha} = 59.8$ ($\bar{\alpha}$ is mean leaf angle).

This TAI estimated from the regressions is accurate to $\pm 20\%$. The light meter has underestimated this calculated TAI by 26%. This underestimation is most likely due to discontinuities in the forest canopy. Dr Lang (CSIRO Division of Environmental Mechanics) is aware of this problem and is developing an improved instrument which caters better for these gaps.

The effect of restricting probe angle range was also investigated. This appears to be affected by the qualities of the leaf angle distribution and the spatial variation of LAI over the plot being measured i.e. the fit of the $K(\theta)$ versus θ line. It is therefore difficult to provide guidelines for probe angle range that apply for all canopy types.

As more use and assessment is made of this technique in various canopy types it is expected that a feeling for the appropriate probe angle range will develop.

Progressive limits to the probe angle range were applied for the data collected and the effect for this canopy type was tested. Decreasing the probe angle range increased the LAI. This increase is dramatic as the range decreases below 35° (Fig. 2). The maximum probe angle was 77° from the zenith. This indicated 35° minimum sun angle range would allow the technique to be applied over 7 months of the year.

3. Catchment scale (using multi-spectral scanning data)

Results from this work also look promising, but no ground truthing or validation has taken place.

The ratio of the reflectances of IR/R (a ratio that has been tested in non-forest situations to predict leaf area) shows the right sort of numbers for a series of test areas in and around Yarragil 4L:

i.	jarrah crown	2.02
ii.	unthinned forest	1.60
iii.	thinned forest	0.85
iv.	thinned forest (with cloud)	0.88
v.	swamp	0.77
vi.	thinned forest	1.01
vii.	unthinned forest	1.60
viii.	<u>E.saligna</u> plantation	1.74

However, the patterns of reflectance with wavelength did not follow those described in the literature.

An application to the Australian Water Research Advisory Council for a research grant to continue the development of these methods was rejected recently.

CONFERENCES

- o Bryson Bates attended the 1985 Hydrology and Water Resources Symposium held by the Institution of Engineers in Sydney. He presented a paper entitled 'Estimation of parameters and uncertainty in a runoff routing model'.
- o Nick Schofield visited the Institute of Hydrology, U.K. from 29th July to 2nd August and delivered two papers entitled 'A Study of Hillslope Hydrology in the Jarrah Forest of Western Australia' and 'An Approach to Modelling Hydrological Processes in the Jarrah Forest of Western Australia'. Discussions were held with the Soil Hydrology, Physical Processes, Evaporation Flux Studies and Hydrological Modelling Groups.
- o Nick Schofield visited the University of Leeds from 24-26th July and undertook discussions with Prof. M.J. Kirkby and other staff of the Geography Department specialising in hillslope hydrology.
- o Nick Schofield visited the CSIRO Divisions of Environmental Mechanics and Water and Land Resources, Canberra for the period 3-13th September. He communicated a paper entitled 'Ventilated Chambers' to the CSIRO Workshop on 'Atmospheric Transport Processes and Plant Canopies'.

RECENT PUBLICATIONS

Bartle, J.R. and Colquhoun, I.J. (in press). Ventilated Chambers. CSIRO Workshop on Atmospheric Transport Processes and Plant Canopies', Canberra.

Croton, J.T. (1985). Minepit monitoring methods and equipment. Alcoa of Australia internal report.

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Nichols, O.G., Carbon, B.A., Colquhoun, I.J., Croton, J.T. and Murray, N.J. (1985). Rehabilitation after bauxite mining in south-western Australia. Landscape Planning 12, 75-92.

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CONTRIBUTORS

General Research Planning (N. Schofield), Jarrah Dieback :
Effect of Site on Susceptibility of Jarrah to *Phytophthora*
cinnamomi (J. Tippett, S. Crombie, T. Hill), Alcoa's Research
(J. Croton), Catchment Studies (B. Bates), Hillslope Processes
Studies (N. Schofield), Leaf Area Measurement Studies
(K. Whitford and G. Stoneman).

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