Source: Heinrich I, Gärtner H, Monbaron M, Schleser G (eds.) (2006) TRACE - Tree Rings in Archaeology, Climatology and Ecology, Vol. 4: Proceedings of the DENDROSYMPOSIUM 2005, April 21st – 23rd 2005, Fribourg, Switzerland. Schriften des Forschungszentrums Jülich, Reihe Umwelt Vol. 61, p. 300 – 307.

Higher nutrient-levels in tree rings of *Eucalyptus grandis* following a wildfire

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Introduction

Wet sclerophyll forest describes a narrow band of vegetation which, in northeast Queensland, occurs on the western edge of the rainforest above 600m. These forests grow in areas of high rainfall where rainforest would normally proliferate but the use of fire prevents the rainforest from invading. Scientists have documented a 50% loss of this forest type during the previous 50 years and many are worried that a complete take-over by rainforest could lead to the extinction of certain plant and animal species. With new evidence that rainforests are invading the wet sclerophyll forests at an alarming rate, scientists are assessing the impact of rainforest invasion on the wet sclerophyll flora and fauna.

The wet sclerophyll forest (WSF) of Far North Queensland describes a narrow band of vegetation stretching as a long narrow band on the northern tablelands 50 km inland parallel to the coast between Townsville and Cooktown adjacent to the western margin of the upland tropical rainforests above 600 m (Tracey and Webb 1975, Tracey 1982, Harrington and Sanderson 1994). These forests grow in areas of high rainfall where rainforest would normally proliferate but the use of fire by aboriginal people has prevented the rainforest from invading. Approximately 50% loss of this forest type during the previous 50 years have been documented (Harrington et al. 2000) which is of major concern to the local management authorities as the WSF has been part of the UNESCO World Heritage property Wet Tropics of Queensland since 1988. The cessation of aboriginal burning practices and an increase of non-aboriginal land use by the end of the 19th century paved the way for the invasion of rainforest into the WSF (Fautz 1984, Kohen 1995). Fire is also a vital part of the tall sclerophyll forests in the southern subtropical to temperate climate zones of Australia, which are in many aspects similar to the tropical WSF (Ashton and Martin 1996a, 1996b). Chambers and Attiwill (1994) ascribed the ash-bed effect in *Eucalyptus regnans* F. Muell. forests mainly to an increase in the availability of nitrogen and phosphorus.

Eucalypts, the dominant species in the WSF, possess a mobile sapwood pool, whereby nutrients are added through nutrient uptake and subsequently drawn on to maintain growth. At the sapwood-heartwood boundary nutrients are re-translocated into the living cells. In this way, nutrients, which would otherwise soon become a limiting growth factor, are recycled. This seems to be one of the main reasons for the adaptation of eucalypts to poor soils (Banks 1982). According to this concept of eucalypts adapted to growing on nutrient-poor soils, trees experiencing a post-fire ash-bed effect would not only exhibit a higher nutrient level in the tree ring after the fire but in the whole sapwood usually consisting of several tree rings. More nutrients become available, and for a period of time when more nutrients are present the tree would not re-translocate nutrients as effectively as without the ash-bed effect and as a consequence an unusually high level of nutrients would remain in the dead cells of the most recently built heartwood ring. Thus the ash-bed effect, according to this "sapwood displacement effect" (Banks 1982), would not be detected in the tree ring directly formed in the year after the fire but in the heartwood cells created at that time. The extent of the displacement depends on the number of sapwood tree rings, which vary within and between species.

In his PhD thesis, Banks (1982) showed an increased ring width following a fire, and that this growth flush lasted five or more years in eucalypts. Chemical analysis of nutrient levels in pre- and post-fire tree-rings sometimes resulted in higher levels of some of the nutrients examined. He hypothesised that nutrient uptake associated with the ash-bed effect could be one of the factors involved. It has been demonstrated several times that the ash-bed effect only lasts approximately one year, and the nutrient level returns to pre-fire conditions quickly (Renbuss et al. 1973, Grove et al. 1986, Adams and Attiwill 1991a,b, Ashton and Martin 1996a, Attiwill et al. 1996).

Since fire may be a key factor for the expansion of rainforest into the WSF, Unwin et al. (1985), Stocker and Unwin (1986), Ash (1988), Unwin (1989), Harrington and Sanderson (1994) and Harrington et al. (2000) emphasise the need for more studies on the historical fire regime in that area. Furthermore, effective long-term management of tropical rainforests should always include the nearby sclerophyll forests as part of the whole ecological system (Janzen 1988). Therefore, the current study aimed to test a method useful for identification and dating of past fires by chemically analysing core samples of *Eucalyptus grandis* W. Hill ex Maiden (rose gum) for nutritional elements.

Materials and methods

The study site is located on a northern slope of Mt. Haig, (145° 36' E, 17° 06' N), Atherton Tablelands, altitude 1200m asl. An almost pure stand of *E. grandis* with a shrub-layer consisting of sclerophyll plants and young rainforest-trees had developed adjacent to rainforest (Harrington and Sanderson 1994). A controlled intensive fire burned the site in October 1996 killing the rainforest undergrowth. After the fire, only a grass layer consisting mainly of *Themeda triandra* Forssk., and some tussock sedges, for example *Gahnia aspera* (R.Br.) Spreng. and *Gahnia sieberiana* Kunth developed. Because large parts of the wet tropics in Far North Queensland are listed in the World Heritage cutting trees for cross sections was not an option but only two core samples per tree were extracted from 20 *E. grandis* stems at breast height. All tree size-classes ranging from 20 to 105 cm were included in the collection. The surface of each core was cut with a knife instead of using sand paper creating a smooth surface with visible rings but without contamination from dust particles. The samples were placed on holding devices without gluing them and the rings marked on the holder. The cores were oven-dried at 60°C for five days, cut at the boundary of each ring, ground to <0.2 mm and chemically analysed for phosphorus (P) and nitrogen (N). Since eleven of the trees sampled did not supply enough ground material only nine *E. grandis* core samples were analysed. The single digestion method of Anderson and Ingram (1989) was used. Nitrogen was determined colorimetrically by the salicylate-hypochlorite method of Baethgen and Alley (1989), and phosphorus by an adaptation of Murphy and Riley`s (1967) single solution method (Anderson and Ingram 1989).

Results

The samples exhibited relatively distinct tree rings in the parts formed in recent years. The wood is diffuse to semi ring porous with vessels decreasing in size towards the end of the growing season. In some years a small vessel free zone appears as a dark band within two tree rings probably marking an unusually dry season. Wedging rings and kino veins, large resin ducts caused by stress such as fire and drought, are typical features of this species. While wedging rings often hindered the identification of annual rings, kino veins were used as markers to identify event years and hence occasionally helped during the visual crossdating procedure.

Table 1: Nitrogen- and Phosphorus-levels in tree rings of E. grandis formed before (1996) and after the fire (1997)

Tree	**Size**	**N (µg/g)**		**P (µg/g)**	
No	**dbh**	**1996**	**1997**	**1996**	**1997**
1	80cm	714.7	802.8	19.5	21.6
2	25cm	1045	1636	30.1	52
3	30cm	847	2184	19.7	40.5
4	50cm	1033.1	2932.2	50.6	79
5	100cm	567.7	1576.2	30	73.6
6	25cm	401.9	1272.2	40.4	42
7	60cm	797.4	915.2	25.3	47
8	30cm	647.6	726.5	23.7	31.3
9	40cm	622.6	980.3	21	22

Only the tree rings before and after the fire event located within the sapwood were analysed because their boundaries were most distinct in these outer parts of the samples. In table 1 the results of the chemical analysis are presented. For each tree nitrogen (N) and phosphorus (P) concentrations are presented for the year before and after the fire. All trees show an increase in both, N and P levels in the 1997 tree ring, the year after the fire with some trees exhibiting a near threefold increase in N (trees 3, 4, 5 and 6) but less distinct for the P-levels. No specific trends regarding age and size of the trees are recognisable.

Discussion and conclusions

As noticed in other studies (Bamber et al. 1969, Mucha 1979, Banks 1982, Brookhouse 1997, Smith 1997) the usage of disc samples is desirable when tree-ring analysis of Eucalypts is conducted. This was confirmed in this study with core samples unable to pick up false rings due to wedging ring patterns. However, these features can be detected in disc samples and then avoided by choosing the most appropriate radii. For the current study this problem was circumvented by examining only the most recent rings but for further investigations of longer periods cross sections are indispensable.

The results indicate that *E. grandis* has experienced an ash-bed effect directly after an intense fire. In the years before the 1996 fire a dense understorey consisting of sclerophyll and rainforest species had developed on the relatively fertile Mt Haig study site. Under those circumstances there would be an increase in soil fertility due to an increase in nitrogen fixing understorey plants, a change of the litterfall composition, a wetter micro-climate and a higher decomposition rate (O`Connell et al. 1981). Under the exclusion of fire the invasion of rainforest species into the site, according to Webb (1969), would also be an indication of the increased fertility of the soil.

Negi and Sharma (1996) have proposed two different eucalypt “ideotypes” regarding the efficiency of the re-translocation mechanism depending on the soil conditions. On fertile soils eucalypt species only partially re-translocate while on poor soils they possess a more efficient re-translocation mechanism. A similar suggestion comes from Keith (1997) who found a subgeneric difference in adaptation to soil nutrient concentrations and nutrient utilization. The two scenarios have been illustrated in figure 1. In one case there would be an opulent ash-bed uptake of nutrients on more fertile soils with a consequent waste of nutrients being not re-translocated from dying tissue such as old leaves and at the heartwood-sapwood boundary resulting in a reduced re-translocation of the nutrients from the heartwood to sapwood (Fig. 1, bottom).

In contrast, the other ideotype would occur on poor soils when the level of nutrients stored in the sapwood was not as high as in the first case. Those trees would not waste any nutrients but re-translocate most of them to ensure ongoing growth and survival in the harsh Australian environment (Fig. 1, top). Mulligan and Sands (1988) found that species adapted to low-nutrient soils had slower growth rates and stored as many nutrients as possible to enable longer survival on experimental soils with extremely low nutrient supplies.

The results presented here suggest that *E. grandis* at Mt. Haig, one of the fastest growing tropical Eucalypt species usually occurring on more fertile soils belongs to the bottom group in figure 1 because the nutrient levels in the tree-rings are higher in the year directly after the fire. It seems to have only a restricted ability to adapt to low nutrient supply or lost it gradually by adapting to more humid and fertile conditions. If *E. grandis* belonged to the ideotype growing on poor soils, one would expect little to no change of nutrient levels in the tree ring after the fire event.

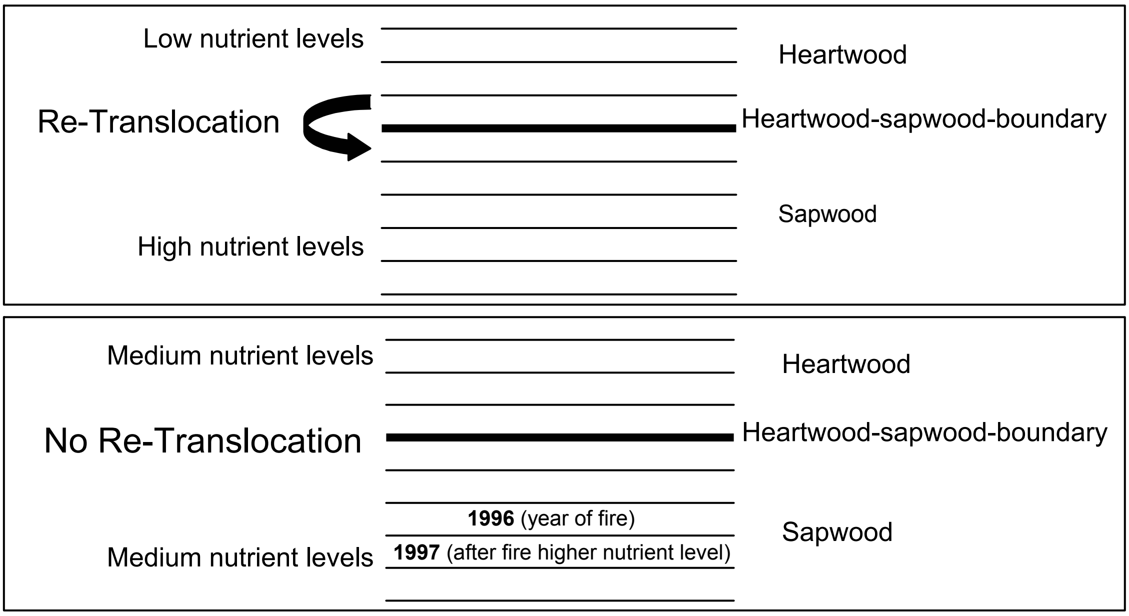

Figure 1. Diagram of the two potential types of nutrient distribution in eucalypts on a poor (top) and fertile soil (bottom)

Although this study was not able to fully examine the nutrient-level changes in the sapwood and heartwood of *E. grandis* it has indicated that on sites with soil types rich in nutrients, as is often the case in the ecotone wet sclerophyll forest between dry sclerophyll forests and rainforests, trees might not need to re-translocate the otherwise vital nutrients as strictly as on poor nutrient soil types. Dendropyrochronological ring studies have the potential to further investigate the fire regime of the wet sclerophyll forests of Far North Queensland where fire has always been a contentious point.

Although the dendrochronological part of the study has encountered similar problems (wedging and false rings) to those in Hickey et al. (1999) the construction of an approximate annual record of historical fire occurrences comparable to the results in Burrows et al. (1995) seems feasible. Future studies should also concentrate on sites with a known fire event in the more distant past to investigate whether the after-fire nutrient flush is also discernible in the heartwood. Furthermore, it is recommended to apply this method to other sites further south with a pronounced seasonal climate ensuring more reliable annual tree rings. Four instead of only two core samples per tree should be taken to obtain enough ground material for the chemical analysis. If possible, whole disc samples of the site should be used to ensure higher reliability during crossdating. Finally, it is recommended to expand the analysis of nutrients to other elements, *e.g.*, potassium and magnesium.

Acknowledgments

Technical support came from Steve Turton, Department of Tropical Environment Studies and Geography, James Cook University, Cairns Campus, Laurence May, Department of Natural Resources, Atherton and the Department of Geography, University of Bonn. The chemical analysis was carried out by Robert Congdon, School of Tropical Biology, James

Cook University, Townsville. I would also like to thank Graham Harrington, Keith (Sandy) Sanderson and Matt Bradford, CSIRO Tropical Forest Research Centre, Atherton for their help. This research was funded by the German Academic Exchange Service (DAAD) Bonn.

References

Adams, M.A., Attiwill, P.M. (1991a): Nutrient balance in forests of northern Tasmania. I. Atmospheric inputs and within stand cycles. *Forest Ecology Management 44*: 93-113.

Adams, M.A., Attiwill, P.M. (1991b): Nutrient balance in forests of northern Tasmania. II. Alteration of nutrient availability and soil water chemistry as a result of logging, slash-burning and fertilizer application. *Forest Ecology Management 44*: 115-131.

Anderson, S.E., Ingram, J.S.I. (1989): Tropical Soil Biology and Fertility: A Handbook of Methods. C.A.B. International, Aberystwyth.

Ash, J. (1988): The location and stability of rainforest boundaries in north-eastern Queensland, Australia. *Journal of Biogeography 15*: 619-630.

Ashton, D.H., Martin, D.G. (1996a): Changes in a spar-stage ecotonal forest of *Eucalyptus regnans, Eucalyptus obliqua* and *Eucalyptus cypellocarpa* following wildfire on the Hume Range in November 1982. *Australian Forestry 59*: 32-41.

Ashton, D.H., Martin, D.G. (1996b): Regeneration in a pole-stage forest of *Eucalyptus regnans* subjected to different fire intensities in 1982. *Australian Journal of Botany 44*: 393-410.

Attiwill, P.M., Polglase, P.J., Weston, C.J., Adams, M.A. (1996): Nutrient cycling in forests of south-eastern Australia. In: Attiwill, P.M., Adams, M.A. (Eds), Nutrition of Eucalypts, Collingwood: 191-227.

Baethgen, W.E., Alley, M.M. (1989): A manual colorimetric procedure for measuring ammonium nitrogen in soil and plant Kjeldahl digests. *Communications in Soil Science and Plant Analysis 20*: 961-969.

Bamber, R.K., Floyd, A.G., Humphreys, F.R. (1969): Wood properties of flooded gum. *Australian Forestry 33*: 3-12.

Banks, J.C.G. (1982): The use of dendrochronology in the interpretation of the dynamics of the Snow Gum Forest. Unpublished PhD-Thesis, Australian National University, Canberra.

Brookhouse, M.T. (1997): Identification and analysis of growth rings in *Eucalyptus obliqua* L`Hérit and *Eucalyptus cypellocarpa* L. Johnson. Unpublished Honours Thesis. Australian National University, Canberra.

Burrows, N.D., Ward, B., Robinson, A.D. (1995): Jarrah forest fire history from stem analysis and anthropological evidence. *Australian Forestry 58*: 7-16.

Chambers, D.P., Attiwill, P.M. (1994): The ash-bed effect in *Eucalyptus regnans* forest: chemical, physical and microbiological changes in soil after heating or partial sterilisation. *Australian Journal of Botany 42*: 739-749.

Fautz, B. (1984): Agrarlandschaften in Queensland. *Geographische Zeitschrift* 65. Beilage. Wiesbaden.

Florence, R.G. (1981): The biology of the eucalypt forest. In Pate, J.S., McComb, A.J. (Eds), The Biology of Australian Plants, University of Western Australia Press, Nedlands, 147-180.

Florence, R.G. (1982): The Australian Forests. In Jahn, G. (Ed), Handbook of Vegetation Science, Dr W Junk, The Hague, pp. 73-95.

Grove, T.S., O`Connell, A.M., Dimmock, G.M. (1986): Nutrient changes in surface soils after an intense fire in jarrah (*Eucalyptus marginata* Donn ex Sm.) forest. *Australian Journal of Ecology 11*: 303-317.

Harrington, G.N., Sanderson, K.D. (1994): Recent contraction of wet sclerophyll forest in the wet tropics of Queensland due to invasion by rainforest. *Pacific Conservation Biology 1*: 319-327.

Harrington, G.N., Thomas, M.R., Bradford, M.G., Sanderson, K.D., Irvine, A.K. (2000): Structure and plant species dominance in North Queensland wet sclerophyll forests. *Proceedings of the Royal Society of Queensland 109*: 59-74.

Hickey, J.E., Su, W., Rowe, P., Brown, M.J., Edwards, L. (1999): Fire history of the tall wet eucalypt forests of the Warra ecological research site, Tasmania. *Australian Forestry 62*: 66-71.

Janzen, D.J. (1988): Tropical dry forests: The most endangered major tropical ecosystem. In Wilson, E.O. (Ed), Biodiversity, Washington DC: 130-138.

Keith, H. (1997): Eucalypts: an introduction. In Williams, J.E., Woinarski, J.C.Z. (Eds), Eucalypt ecology – Individuals to ecosystems, Cambridge University Press, Cambridge: 1-15.

Kohen, J.L. (1995): Aboriginal environmental impacts. Sydney.

Mucha, S.B. (1979): Estimation of tree ages from growth rings of eucalypts in northern Australia*. Australian Forestry 42*: 13-16.

Mulligan, D.R., Sands, R. (1988): Dry matter, phosphorus and nitrogen partitioning in three *Eucalyptus* species grown under a nutrient deficit. *New Phytologist 109*: 21-28.

Murphy, J., Riley, J.P. (1967): A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta 27*: 31-36.

Negi, J.D.S., Sharma, S.C. (1996): Mineral nutrition and resource conservation in Eucalyptus plantations and other forest covers in India. In Attiwill, P.M., Adams, M.A. (Eds), Nutrition of Eucalypts, Collingwood: 399-325.

O`Connell, A.M., Grove, T.S., Lamb, D. (1981): The influence of fire on the nutrition of Australian forests*.* Proceedings of the Australian Forest Nutrition Workshop productivity in perpetuity. CSIRO, Melbourne, 277-289.

Renbuss, M.A., Chilvers, G.A., Pryor, L.D. (1973): Microbiology of an ashbed. *Proceedings of the Linnean Society of N.S.W. 97*: 302-311.

Smith, D. (1997): The relationship between ring-width and precipitation in subalpine *Eucalyptus pauciflora*. Unpublished Honours Thesis. Australian National University, Canberra.

Stocker, G.C., Unwin, G.L. (1986): Fire. In Clifford, H.T., Specht, R.L. (Eds), Tropical plant communities, St. Lucia: 91-103.

Tracey, J.G. (1982): The humid tropical region of North Queensland. CSIRO, Melbourne.

Tracey, J.G., Webb, L.J. (1975): Vegetation of the humid tropical region of North Queensland. (15 maps at 1:100,000 scale + key.) CSIRO Aust. Long Pocket Labs: Indooroopilly, QLD.

Unwin, G.L. (1989): Structure and composition of the abrupt rainforest boundary in the Herberton Highland, North Queensland. *Australian Journal Botany 37*: 413-428.

Unwin, G.L., Stocker, G.C., Sanderson, K.D. (1985): Fire and the forest ecotone in the Herberton highland, north Queensland. *Proceedings of the Ecological Society of Australia 13*: 215-224.

Webb, L.J. (1969): Edaphic differentiation of some forest types in eastern Australia. II. Soil chemical factors. *Journal of Ecology 57*: 817-830.