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OVERCOMING THE SHORTAGE OF FUELWOOD AND POLES THROUGH FORESTRY RESEARCH: ESTIMATES OF BENEFITS FROM THREE COMPLETED ACIAR FORESTRY PROJECTS[1] IN AFRICA AND THAILAND[2]

Godfrey Lubulwa[3], David Gwaze[4], Jeanette Clarke[5],
Patrick Milimo[6] and Jackson Mulatya[7]

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[1] The three projects are :
- PN8320–8331: Australian hardwoods for fuelwood and agroforestry – Phase I
- PN8808–8809: Australian hardwoods for fuelwood and agroforestry – Phase II, and
- PN8357:Management of nitrogen fixation by casuarina for fuelwood and agroforestry.

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[3] Senior Economist, Economic Evaluation Unit, Australian Centre for International Agricultural Research (ACIAR)

[4] Manager, Research and Development, Forest Research Centre, Zimbabwe Forest Commission, Harare.

[5] Research Scientist, Forest Research Centre, Zimbabwe Forest Commission, Harare.

[6] Formerly Head, Dryland Silviculture Division, Kenya Forestry Research Institute, Nairobi, Kenya.

[7] Head, Arid and Semi-Arid Lands, Kenya Forestry Research Institute, Nairobi, Kenya.

CONTENTS

ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
CARE	
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
DANIDA	Danish International Development Agency
FAO	Food and Agriculture Organization of the United Nations
FINNIDA	Finnish International Development Agency
ICRAF	International Centre for Research in Agroforestry
IRR	internal rate of return
KEFRI	Kenya Forest Research Institute
NORAD	Norwegian Agency for Development
NPV	net present value
SADC	South African Development Community

1. INTRODUCTION

1.1 Background

This paper describes a completed project assessment of three ACIAR funded projects:

- PN8320–8331: Australian hardwoods for fuelwood and agroforestry – Phase I
- PN8808–8809: Australian hardwoods for fuelwood and agroforestry – Phase II, and
- PN837: Management of nitrogen fixation by casuarinas for fuelwood and agroforestry.

ACIAR project PN8320–8331 and ACIAR project PN8808–8809 involved collaborative research between the following organisations:

- CSIRO Division of Forestry, Canberra, Australia;
- Forest Research Branch, Queensland Department of Forestry;
- Zimbabwe Forestry Commission, Harare, Zimbabwe;
- Kenya Forestry Research Institute, Muguga, Kenya; and
- Royal Forestry Department, Bangkok, Thailand.

ACIAR project PN8357 involved collaborative research between the following organisations:

- CSIRO Division of Forestry, Canberra, Australia;
- CSIRO Division of Soils, Waite Road, Glen Osmond, South Australia;
- CSIRO Division of Soils, Aitkenvale, Queensland;
- Zimbabwe Forestry Commission, Harare, Zimbabwe; and
- Royal Forestry Department, Bangkok, Thailand.

ACIAR project PN8320–8331 was the first project in the ACIAR forestry research program, and ACIAR project PN8808–8809 was its replacement. The evaluation of projects PN8320–8831 and PN8808–8809 poses problems because they were overview core projects from which arose other projects in the ACIAR forestry research program between 1983 and 1994. White et al. (1991) in reference to the breadth of the research agenda under these two projects notes:

> The projects PN8808 and 8809 under review are replacements of the earlier projects PN8320 and 8831. Their overall objective was to explore the domestication and use of lesser known Australian flora. It is a broad spectrum of research and innately will take some time to come to a satisfactory conclusion. Commendable progress has been achieved with commercial potential.

Turnbull (1986) notes that the ACIAR forestry program started with the aim of exploiting more fully the potential of Australian trees and shrubs for domestic fuel and agroforestry in developing countries. The three projects discussed in this paper had a focus on social or community forestry and examined a broader range of tree species than those used for industrial monocultures. Turnbull (1986) listed the following as characteristics considered desirable in selecting species for use in community or social forestry:

- capability to provide products and services to households, where products include:
  - – poles, posts and fuelwood;
  - – windbreaks and shade;

  - fodder;
  - living fences; and
  - soil improvements.
- adaptability, making for ease of establishment and maintenance;
- ability to grow in extreme environments including arid and humid tropical zones, infertile soils, heavy clays, saline, highly alkaline or waterlogged sites or exposed coastal situations;
- ability to fix atmospheric nitrogen;
- a capacity for rapid growth, appropriate for cultivation in areas experiencing severe fuelwood shortage or where there is serious soil erosion;
- an ability to coppice; and
- good burning properties.

The projects concentrated on species of casuarinas, acacias and eucalypts which were suitable for fuelwood for individual family needs rather than for cultivation in larger plantations. The casuarinas and acacias were of interest because:

- they are nitrogen fixing;
- they can tolerate infertile sites; and
- they can produce a range of wood products—firewood, charcoal, building poles, tannins, fodder, and honey.

The eucalypt species were of interest because:

- they are fast growing; and
- they have the ability to coppice, thus helping farmers to avoid replanting expenses.

1.2 The projects and their objectives

This suite of projects was designed to address the acute shortage of fuelwood in many developing countries. Shortages of fuelwood depress living standards and commonly have serious indirect consequences. These include: adverse changes in catchment hydrology and accelerated erosion may follow denudation; food production may be reduced if animal manure and other wastes are burnt as substitutes for fuelwood, further reducing the amount of natural fertiliser available to the soil. For example, Stewart (1986) notes that:

> More than half the districts in communal lands in Zimbabwe had deficits of fuelwood and construction wood at the start of the 1980s. The situation has continued to deteriorate, and it is estimated that in the communal areas, at least 5% of households use dung as fuel, and around half use crop residues as a minor cooking fuel. The availability of poles is even more critical than fuelwood supply. In a survey of selected communal areas, nearly two thirds of people interviewed reported that poles were difficult to find and many were travelling more than 10 kilometres from the household to obtain construction wood.

FAO (1981) concluded that, in 1980, 55 million people in Africa faced acute fuelwood scarcity and 146 million people faced a fuelwood deficit, and that by 2000 these numbers would have increased to 88 and 447 million, respectively.

The objectives of the three projects are given in Appendix A. This paper describes an evaluation of the impact of research results from these two umbrella projects and PN8357. All the projects were reviewed before completion. Evans et al. (1987) reviewed PN8320–8331, Roughley and Cromer (1987) reviewed PN8357 and White et al. (1991) reviewed PN8808–8809. The main conclusions of the reviewers are summarised in Table 1.

1.3 The scope of the paper

Section 2 discusses the estimation of the social welfare impacts of ACIAR projects PN8320–8331, PN8808–8809 and PN8357. The approach used is that of McKenney et al. (1993, 1994) and Davis et al. (1994). Thomas and Bright (1990) argued that economic evaluations of agro-forestry projects should take into account the negative and positive interactions between trees and agricultural activities. These interactions are likely to occur in the areas which were targeted by ACIAR projects PN8320–8331, PN8808–8809 and PN8357.

While these impacts occur, the projects were not designed to measure them explicitly and thus there are no estimates of their likely magnitudes. For example, on the negative side, agricultural output may decline as a result of tree growth and its associated increase in shading, reduction in soil nutrients and water availability to other crops and through increased root competition. However, a number of the species introduced under this project are nitrogen fixing and may increase soil fertility and yields of other crops in the farming system.

If the ACIAR projects succeed in increasing the supply of fuelwood in sub-Saharan communal lands, then the practice of using livestock dung and crop residues for fuel is likely to stop. This is likely to lead to an increase in soil fertility as livestock dung and crop residues are used to fertilise the soil rather than as a fuel.

Agricultural livestock productivity may be increased as a result of shelter or shade effects. Trees may prolong pasture productivity within a season due to a reduction in land drying by wind or direct sunlight.

Section 2 discusses the approach used in incorporating the more important of these interactions in the analysis.

Section 3 presents the results on the rate of return analysis. Section 4 discusses the impacts of the project on scientific knowledge, and section 5 impacts on human capacity building. Section 6 makes some concluding remarks.

Table 1. Main conclusions of project reviews.

Project number	Reviewers	Conclusions of reviewers
PN8357	Roughley and Cromer (1987)	The objectives of the project were too ambitious. Despite being unable to satisfy all the objectives important findings were made. A major achievement was the development of techniques to isolate *Frankia* strains from nodules. The project highlighted that using isolates is the only way to achieve reproducible results in this research. Substantial field responses to inoculation with *Frankia* were demonstrated at sites in Australia and Zimbabwe and these trials emphasised the importance of adequate levels of phosphorus if the *Frankia* are to function effectively. Some progress was made in producing *Frankia* inoculants in liquid cultures using chemically defined media but further work is required to scale these up to commercial use.
PN8320–8331	Evans et al. (1987)	Species elimination trials were planted over three seasons (1984/85, 1985/86, 1986/87). some 100 Australian species were trialed and around 12 of these from the genera *Acacia*, *Eucalyptus*, *Casuarina* and *Grevillea* performed well enough to justify more thorough evaluation. These trials showed the potential of nitrogen-fixing exotics, most with fast growth relative to indigenous species, for afforestation in communal lands. Seed provided by the project was used to raise seedlings planted in trials to test the natural resistance of 37 species to subterranean termite attack. The results show that *Acacia* species have high resistance compared to species of *Eucalyptus*. The implications of this finding extend beyond Zimbabwe. The project showed that the lesser-known Australian shrubs and trees include species that have the necessary attributes of nitrogen fixation, production of fuelwood and rough poles, adaptability to infertile soils and dry sites, and possibly regeneration from coppice under correct management.
PN8808–8809	White et al. (1991)	The project identified promising species in relation to *Acacia*, *Eucalyptus*, and to a lesser extent *Casuarina* and with one *Grevillea* species with potential in Africa. In Australia, the project had potential for impact on the *Eucalyptus* leaf oil industry, the essences industry, the fast growth short rotation bulk or cabinet timber industry, the bark extractives and tannins industry, the honey and edible fungi industries and the seed sales sector. In Zimbabwe, the project identified tree species which had the potential to increase, on short rotation cropping, the supply of house building poles and wattle and daub sticks. The project also has the potential to impact on 60% of households in the subsistence sector by increasing the supply of fuelwood and thereby reducing the time required to collect firewood. There is potential to impact on the honey industry through the increased availability of pollen and nectar supply species. In Kenya, the project identified tree species which had the potential to increase, on short rotation cropping, the supply of house building poles and wattle and daub sticks. The project also has the potential to impact on 60% of households in the subsistence sector by increasing the supply of fuelwood and thereby reducing the time required to collect firewood from natural forests. The project has high potential for reducing stress on the natural forest and hence environmental conservation which is a prime aim of the Kenya Government. There is potential to impact on the honey industry through the increased availability of pollen and nectar supply species. In Thailand, the project is likely to increase the supply of house timbers and fuelwood. *Acacia* species and provenances are likely to provide pulp, sawn timber and veneering industry inputs. The nitrogen-fixing attributes of these species are likely to lead to improved soil management. The use of *Acacia* species in degraded lands would be supportive of government policies of redevelopment of the forest cover. The combination of *Acacia* and *Eucalyptus* species is likely to improve the potential for the widespread village honey industry.
Other major outputs		Climatic interpolation surfaces were developed for the whole of Africa with data from over 1000 meteorological stations. Dr Trevor Booth's mapping program can assess conditions at over 10 000 locations. Given any species climatic requirements the mapping program can indicate suitable growth areas.

2. THE ESTIMATION OF THE SOCIAL WELFARE IMPACTS OF ACIAR PROJECTS PN8320–8331, PN8808–8809 AND PN8357

2.1 The research evaluation model

The impact of the ACIAR projects is likely to come from their influence on the social costs of producing forest products in the project collaborating countries. They are likely to impact on a number of functions of trees and shrubs in agroforestry (Boland 1986) including the following:

- Fuelwood: The most important function of trees and shrubs in the countries where the projects were based is as a source of fuelwood. This may be limited in the case where new species are introduced to a communal area because the new species may have different physical, silvicultural and environmental properties from those of trees households are used to. The qualities of a tree which make for good fuelwood include thornlessness, small stem diameter, low moisture content with minimal non-toxic smoke, rapid growth, disease and pest resistance and ability to coppice.
- Round wood as poles and posts for home building, for use as rafters in house construction, house walls and roof support and for fencing. For this function, trees must produce straight, durable, light wood, high strength to diameter ratio, with resistance to termites and other wood borers.
- Soil improvement. The preferred tree is a tree capable of atmospheric nitrogen fixation and an ability to return nitrogen to the soil through root decomposition or leaf fall.
- Soil protection or erosion control, where the basic idea is to prevent soil movement by root-binding the soil, preventing direct impact of raindrops or by increasing percolation of water through the soil. For this function the preferred tree is fast growing with spreading crowns and a vigorous root system with soil binding properties.
- Shade for humans and for livestock.
- Windbreaks. The ideal tree in this case is bushy and capable of withstanding strong wind (hot or cold) or the effects of salt-laden winds in coastal areas or wind-borne sand in desert areas.
- Fodder, as a source of emergency fodder for livestock during periods of drought. In this case trees should have palatable leaves which are nutritious and digestible.
- Live fences, where these are fences constructed using trees or shrubs. For this function trees must be with prickles or spines, have non-edible leaves, fast-growing, capable of growing under adverse conditions, close together and require minimal maintenance.

The paper focuses on two forestry commodities which were addressed by ACIAR projects PN8320–8331, PN8808–8809 and PN8357, namely:

- fuelwood—which FAO (1989) defines to include wood in the rough from trunks and branches of trees to be used as fuel for purposes such as cooking, heating or power production ; and
- other industrial round wood—which FAO (1989) defines to include round wood used for tanning, distillation, match blocks, gazogenes, poles, piling, posts, and pitprops.

In addition, some account is taken of the implications of the projects for soil fertility, soil erosion, off-site impacts and carbon sequestration.

This paper uses a traded good model (see, for example, McKenney et al. 1993, 1994; Davis et al. 1994) which recognises 70 regions of the world where fuelwood and other industrial round wood are produced. The model estimates the impact of the projects on consumers of fuelwood and other industrial round wood and the impact on producers of these two forestry commodities.

The ACIAR projects, if successful, are likely to change the cost of producing fuelwood and other industrial round wood in sub-Saharan Africa. This change in the cost of production for the two forest products is likely to impact on the prices of forest products in the countries that collaborated in the projects and on the world market prices of the two products. The impact on producers and consumers is measured by the change in producer and consumer surplus, respectively. These two terms are given by the following equations:

The change in producer surplus (PS_{ht}) in country h at time t:

$$\Delta PS_{ht} = (P^*_{fht} - P_{fht})\, Q_{fht} + 0.5[(P^*_{fht} - P_{fht})\, (Q^*_{fht} - Q_{fht})] \tag{1}$$

with $Q_{fht} = X_{it}Q_{fht}$,X_{it} the adoption rate for the technology in country *h* at time *t* and the * denoting after research equilibrium values for the different variables.

The change in consumer surplus (CS_{ht}) in country h at time t:

$$\Delta CS_{ht} = (P_{rht} - P^*_{rht})\, Q_{rht} + 0.5[(P_{rht} - P^*_{rht})\, (Q^*_{rdh} - Q_{rdht})] \tag{2}$$

The different variables are defined as follows:

$$Q_{fht} = a_{ht} + b_{ht}P_{fht} \tag{3}$$

where:
$Q_{fht}$is the quantity of a forestry commodity produced in country *h*; $P_{fht}$is the price of the forestry commodity in country *h*; and a_{ht} and b_{ht} are the intercept and slope of the supply curve in country *h*.

Retail demand:

$$Q_{rdht} = c_{ht} - d_{ht}P_{rht} \tag{4}$$

where:
$Q_{rdht}$is the quantity of a forestry commodity consumed in country *h*; $P_{rht}$is the retail price of the forestry commodity in country *h*; and c_{ht} and d_{ht} are the intercept and slope of the demand curve in country *h*.

In a linear model such as this, if estimates of the supply and demand elasticities are available, the following relationships hold:

$$b_{ht} = \varepsilon_{sh}\, Q_{fht}/P_{fht} \tag{5}$$

$$a_{ht} = (1 - \varepsilon_{sh})Q_{fht} \tag{6}$$

$$d_{ht} = -\varepsilon_{dh}\, Q_{rht}\, /P_{rht} \tag{7}$$

$$c_{ht} = (1 - \varepsilon_{dh})Q_{rht} \tag{8}$$

where:

ε_{sh} is the farm level supply elasticity in country *h*; and ε_{dh} is the retail level demand elasticity. If the country is a net exporter, the retail-to-world price linkage is:

$$P_{rht} = P_{wt} - z_h \tag{9}$$

where:
P_{wt} is the 'world market' price at time *t*; z_h is the transport cost from country *h* to the world market before research.

The excess supply from this exporting country *h* is given as:

$$Q_{esht} = Q_{rsht} - Q_{rdht} \tag{10}$$

If the country is a net importer, the retail-to-world price linkage is:

$$P_{rjt} = P_{wt} + z_{jt} \tag{11}$$

where:

P_{wt} is the 'world market' price at time *t*; and z_j is the transport cost to country *j* from the world market before research.

The excess supply from this importing country *j* is given as:

$$Q_{esjt} = Q_{rdjt} - \mathrm{Q}_{\mathrm{rsjt}} \tag{12}$$

The world market equilibrium 'before research' is given by solving the following:

$$\sum_{h=1}^{n} Qesht = \sum_{j=n+1}^{\mathrm{N}} Qedjt \tag{13}$$

where there are *h* = 1 ... n exporting countries and *j* = N – n importing countries.

The equilibrium world price associated with the system of equations (1) – (13) is given by the following equation (see Davis et al. 1987):

$$P_{wt} = -\frac{\sum (a_{it} - c_{it})}{\sum (b_{it} + d_{it})} + \frac{\Sigma(b_{ht} + d_{ht})\mathrm{Z}_h - \Sigma(b_{jt} + d_{jt})\mathrm{Z}_j}{\Sigma(b_{it} + d_{it})} \tag{14}$$

The domestic equilibrium values of P_{rht}, Q_{sht}, Q_{dht} and P_{fht} can be found by substituting this world price into the appropriate equation.

2.2 Estimating the impact of research

The expected impacts of ACIAR projects PN8320–8331, PN8808–8809 and PN8357 are:

- provision of fuelwood and construction timber to people living on communal peasant farms;
- reduced pressure on indigenous forests in communal lands; and
- rehabilitation of degraded land.

Agricultural research in ACIAR projects PN8320–8331, PN8808–8809 and PN8357 was designed to change the unit cost of producing fuelwood and other industrial round wood products in sub-Saharan Africa. The success of these projects is likely to lead to shifts in the farm level supply curves for these two commodities.

Let k_{hh} be the change in the unit cost of producing a commodity in country *h* due to the research undertaken in country *h*, and Δk_{ih} is the spillover effect of this research to country *i*.

The technologies resulting from agricultural research under ACIAR projects PN8320–8331, PN8808–8809 and PN8357 can be represented as leading to a change in farm level unit cost of production for fuelwood and other industrial round wood. This is equivalent to a parallel shift in the farm level supply function.

The 'after research' world equilibrium price is found by substituting these changes in the appropriate equations and solving for the equivalent of equation (13) which gives:

$$P^*_{wt} = -\frac{\sum(a_{it} - c_{it})}{\sum(b_{it} + d_{it})} + \frac{\Sigma(b_{ht} + d_{ht})Z_h - \Sigma(b_{jt} + d_{jt})Z_h}{\Sigma(b_{it} + d_{it})} + \frac{\sum b_{it}k_i}{\Sigma(b_{it} + d_{it})} \tag{15}$$

Again, these can be substituted into the appropriate equations to find the 'after research' domestic equilibrium values of P^*_{rht}, Q^*_{sht}, Q^*_{dht} and P^*_{fht}. The values denoted by the asterisk are the equilibrium values for prices and quantities after research.

To estimate the welfare impacts in equations (1) and (2) for a given country and year, it is necessary to obtain the following:

- the level of production and consumption before and after research, for the forest products affected by research;
- the prices of, and the elasticities of demand and supply for, the forest products affected by research;
- the level of adoption of the technologies developed during the research project; and
- the cost of producing fuelwood and other round wood before and after research.

The following subsections discuss the estimation of each of these variables.

2.2.1 The level of production of the forest products affected by research

The before-research levels of production of fuelwood and other industrial round wood were obtained from FAO (1994). The after-research level of production is estimated as indicated in section 2.1. Tables 2 and 3 show the production levels, consumption levels and estimates of selected parameters for fuelwood (non-coniferous) and for other industrial round wood, respectively. Zimbabwe is a non-trader in fuelwood, whereas Kenya and Thailand are net importers (Table 2). All three countries that collaborated in ACIAR projects PN8320–8331, PN8808–8809 and PN8357 are net importers of round wood (Table 3).

Table 4 indicates the Australian tree species which were found promising in the various countries under ACIAR projects PN8320–8331, PN8808–8809 and PN8357.

Table 2. Average production and consumption levels (m^3) of nonconiferous fuelwood for 1988 to 1990, and selected parameters used in economic evaluation.

Country/ Region	Production 1988–1990 ('000 Average)	Consumption 1988–1990 ('000 Average)	Trade status	Elasticity supply	Elasticity demand
Bangladesh	29272	30061	Netimporter	0.6	0.4
Bhutan	1226	1254	Netimporter	0.6	0.4
India	226434	231148	Netimporter	0.6	0.4
Nepal	16975	17391	Netimporter	0.6	0.4
Pakistan	22029	22762	Netimporter	0.6	0.4
Sri Lanka	8241	8345	Netimporter	0.6	0.4
Burma	17417	17785	Netimporter	0.6	0.4
Indonesia	137627	140247	Netimporter	0.6	0.4
Kampuchea	5229	5366	Netimporter	0.6	0.4
Laos, PDR	3037	3129	Netimporter	0.6	0.4
Malaysia	6159	6319	Netimporter	0.6	0.4
Philippines	32615	33412	Netimporter	0.6	0.4
Thailand	30446	30879	Netimporter	0.6	0.4
Vietnam	23638	24154	Netimporter	0.6	0.4
China	0	0	Nontrader	0.6	0.4
Mongolia	135	135	Nontrader	0.6	0.4
Fiji	37	37	Nontrader	0.6	0.4
PNG	5533	5533	Nontrader	0.6	0.4
Samoa	70	70	Nontrader	0.6	0.4
Solomon Islands	137	138	Netimporter	0.6	0.4
Tonga	0	0	Nontrader	0.6	0.4
Vanuatu	24	24	Nontrader	0.6	0.4
South Pacific—other	0	0	Nontrader	0.6	0.4
Ethiopa	35591	36608	Netimporter	0.6	0.4
Kenya	20833	21594	Netimporter	0.6	0.4
Malawi	7491	7763	Netimporter	0.6	0.4
Mozambique	14422	14422	Nontrader	0.6	0.4
Tanzania	30112	31242	Netimporter	0.6	0.4
Uganda	11846	12293	Netimporter	0.6	0.4

Table 2. (Cont'd) Average production and consumption levels (m^3) of nonconiferous fuelwood for 1988 to 1990, and selected parameters used in economic evaluation.

Country/ Region	Production 1988–1990 ('000 Average)	Consumption 1988–1990 ('000 Average)	Trade status	Elasticity supply	Elasticity demand
Zambia	5878	6047	Netimporter	0.6	0.4
Zimbabwe	6260	6260	Nontrader	0.6	0.4
Zaire	32199	33244	Netimporter	0.6	0.4
Ivory Coast	8197	8514	Netimporter	0.6	0.4
Ghana	12830	12247	Netexporter	0.6	0.4
Nigeria	87958	90907	Netimporter	0.6	0.4
Cameroon	9758	10090	Netimporter	0.6	0.4
Angola	4345	4465	Netimporter	0.6	0.4
Madagascar	7062	7292	Netimporter	0.6	0.4
Sudan	6142	6320	Netimporter	0.6	0.4
Africa–2	28479	29304	Netimporter	0.6	0.4
Africa–3	14392	14727	Netimporter	0.6	0.4
Africa–4	7980	8129	Netimporter	0.6	0.4
Africa–5	9741	9790	Netimporter	0.6	0.4
Africa–6	2413	2477	Netimporter	0.6	0.4
Africa–7	49	43	Netexporter	0.6	0.4
Turkey	5517	5388	Netexporter	0.6	0.4
Egypt	2095	2144	Netimporter	0.6	0.4
Africa–1	3803	3882	Netimporter	0.6	0.4
WA/NA Other	5646	5802	Netimporter	0.6	0.42
Brazil	133161	135839	Netimporter	0.8	0.8
Colombia	13250	13507	Netimporter	0.6	0.4
Peru	7249	7000	Netexporter	0.6	0.4
Venezuela	740	759	Netimporter	0.6	0.4
Bolivia	1211	1245	Netimporter	0.6	0.4
Ecuador	4140	4140	Nontrader	0.6	0.4
Mexico	10096	10313	Netimporter	0.6	0.4
Argentina	3000	3000	Nontrader	0.6	0.4
Chile	5382	5470	Netimporter	0.6	0.4
Paraguay	4082	4082	Nontrader	0.6	0.4
Uruguay	2346	2351	Netimporter	0.6	0.4
Latin America 1	23543	23973	Netimporter	0.6	0.4
Latin America 2	232	232	Nontrader	0.6	0.4
Asia-Developed	3347	3347	Netexporter	0.8	0.8
Australia	2100	2100	Nontrader	0.8	0.8
Canada	5077	5077	Nontrader	0.8	0.8
USA	74933	72033	Netexporter	0.8	0.8

Table 2. (Cont'd) Average production and consumption levels (m^3) of nonconiferous fuelwood for 1988 to 1990, and selected parameters used in economic evaluation.

Country/ Region	Production 1988–1990 ('000 Average)	Consumption 1988–1990 ('000 Average)	Trade status	Elasticity supply	Elasticity demand
USSR	28400	28400	Nontrader	0.8	0.8
Japan	187	104	Netexporter	0.8	0.8
Developed 1-2	26319	24986	Netexporter	0.8	0.8
Developed 3-4	15848	15134	Netexporter	0.8	0.8
Total	**1311966**	**133227**			
Source: FAO (1994)					

Table 3. Average production and consumption levels ('000 m^3) of other nonconiferous industrial wood and selected parameters used in economic evaluation.

Country/ Region	Production 1988 to 1990	Consumption 1988 to 1990	Trade Status	Elasticity Supply	Elasticity Demand
Bangladesh	337	346	Netimporter	0.3	0.8
Bhutan	38	38	Nontrader	0.3	0.8
India	4764	4863	Netimporter	0.3	0.8
Nepal	0	0	Nontrader	0.3	0.8
Pakistan	379	391	Netimporter	0.3	0.8
Sri Lanka	527	533	Netimporter	0.3	0.8
Burma	1224	1250	Netimporter	0.3	0.8
Indonesia	2809	2862	Netimporter	0.3	0.8
Kampuchea	457	515	Netimporter	0.3	0.8
Laos, PDR	100	103	Netimporter	0.3	0.8
Malaysia	674	692	Netimporter	0.3	0.8
Philippines	2443	2503	Netimporter	0.3	0.8
Thailand	2570	2606	Netimporter	0.3	0.8
Vietnam	1775	1814	Netimporter	0.3	0.8
China	0	0	Nontrader	0.3	0.8
Mongolia	0	0	Nontrader	0.3	0.8
Fiji	3	4	Netimporter	0.3	0.8
PNG	0	0	Nontrader	0.3	0.8
Samoa	3	3	Nontrader	0.3	0.8
Solomon Islands	0	0	Nontrader	0.3	0.8
Tonga	0	0	Nontrader	0.3	0.8
Vanuatu	0	0	Nontrader	0.3	0.8
South Pacific—other	1	1	Nontrader	0.3	0.8
Ethiopa	1693	1693	Nontrader	0.3	0.8
Kenya	915	947	Netimporter	0.3	0.8
Malawi	310	321	Netimporter	0.3	0.8
Mozambique	942	967	Netimporter	0.3	0.8
Tanzania	1526	1575	Netimporter	0.3	0.8
Uganda	1817	1886	Netimporter	0.3	0.8
Zambia	467	485	Netimporter	0.3	0.8

Table 3. (Cont'd) Average production and consumption levels ('000 m^3) of other nonconiferous industrial wood and selected parameters used in economic evaluation.

Country/ Region	Production 1988 to 1990	Consumption 1988 to 1990	Trade Status	Elasticity Supply	Elasticity Demand
Zimbabwe	962	993	Netimporter	0.3	0.8
Zaire	2384	2462	Netimporter	0.3	0.8
Ivory Coast	729	757	Netimporter	0.3	0.8
Ghana	381	381	Nontrader	0.3	0.8
Nigeria	2279	2279	Nontrader	0.3	0.8
Cameroon	771	797	Netimporter	0.3	0.8
Angola	820	843	Netimporter	0.3	0.8
Madagascar	339	339	Nontrader	0.3	0.8
Sudan	2046	2105	Netimporter	0.3	0.8
Africa–2	2222	2285	Netimporter	0.3	0.8
Africa–3	1158	1190	Netimporter	0.3	0.8
Africa–4	540	557	Netimporter	0.3	0.8
Africa–5	251	252	Netimporter	0.3	0.8
Africa–6	159	162	Netimporter	0.3	0.8
Africa–7	7	6	Netexporter	0.3	0.8
Turkey	1630	1630	Nontrader	0.3	0.8
Egypt	102	104	Netimporter	0.3	0.8
Africa–1	648	669	Netimporter	0.3	0.8
WA/NA Other	4714	4744	Netimporter	0.3	0.8
Brazil	5586	5698	Netimporter	0.3	0.9
Colombia	408	408	Nontrader	0.3	0.8
Peru	88	88	Nontrader	0.3	0.8
Venezuela	26	26	Nontrader	0.3	0.8
Bolivia	13	13	Nontrader	0.3	0.8
Ecuador	95	95	Nontrader	0.3	0.8
Mexico	164	145	Netexporter	0.3	0.8
Argentina	340	340	Nontrader	0.3	0.8
Chile	553	553	Nontrader	0.3	0.8
Paraguay	414	414	Nontrader	0.3	0.8
Uruguay	44	44	Netexporter	0.3	0.8
Latin America 1	913	942	Netimporter	0.3	0.8
Latin America 2	109	105	Netexporter	0.3	0.8
Asia-Developed	769	620	Netexporter	0.3	0.9
Australia	605	615	Netimporter	0.3	0.9
Canada	2450	2433	Netexporter	0.3	0.9
USA	14222	14067	Netexporter	0.3	0.9
USSR	95400	95400	Nontrader	0.3	0.9
Japan	702	626	Netexporter	0.3	0.9
Developed1–2	15217	15105	Netexporter	0.3	0.9
Developed3–4	10785	8933	Netexporter	0.3	0.9
WORLD TOTAL	**196818**	**195621**			

Source: FAO (1994)

Table 4. Species which performed best when tested in projects 8808 and 8809 (denoted by x)[a].

Species	Australia: dry	Australia: moist	Kenya: dryland with black soils	Kenya: dryland with red soils	Kenya: coast	Zimbabwe	Thailand: moist	Other use[b]
Acacia ampliceps			Promising	x				
Acacia aneura			x					
Acacia aulacocarpa							x	x-P&P,tan
Acacia auriculiformis				x	Promising	Promising	Promising	x-P&P,tan, fungi
Acacia brassii				x				
Acacia cincinnata							x	x-P&P,
Acacia cowleana				x				x-food
Acacia crassicarpa					Promising	x	Promising	x-P&P,
Acacia cretata	x							
Acacia glaucocarpa		x						x-P&P,tan
Acacia holosericea	x	x		Promising		Promising		x-food
Acacia hylonoma		x						x-P&P,tan
Acacia leptocarpa				x			Promising	
Acacia mangium							x	x-P&P,
Acacia melanoxylon		x						x-P&P,tan
Acacia monticola								x-honey,
Acacia neriifolia		Promising						x-P&P,tan
Acacia oraria						x		
Acacia pellita				x				
Acacia plectocarpa				x				
Acacia salicina	x		Promising					
Acacia simsii								x-fodder
Acacia storei						x-moister end		
Acacia tumida								x-food
Araucaria cunninghamii					x			
Casuarina equisitifolia					x			
Eremophila bignonflora			Promising					x-wb
Eucalyptus argillacea			Promising					

Table 4. (Cont'd) Species which performed best when tested in projects 8808 and 8809 (denoted by x)[a].

Species	Australia: dry	Australia: moist	Kenya: dryland with black soils	Kenya: dryland with red soils	Kenya: coast	Zimbabwe	Thailand: moist	Other use[b]
Eucalyptus argophloia	x		Promising			x		
Eucalyptus bakeri								x-oil
Eucalyptus brownii								x-oil
Eucalyptus cambageana	x							
Eucalyptus camaldulensis		x	Promising	x		Promising		x-oil,
Eucalyptus citriodora		x						
Eucalyptus globulus								x-oil,
Eucalyptus grandis					Promising			
Eucalyptus intertexta			x					
Eucalyptus melanophloia	x		Promising					
Eucalyptus microtheca	x			x		x		
Eucalyptus propinqua						x		
Eucalyptus punctata						Promising		
Eucalyptus raveretiana	x					x		
Eucalyptus stageriana								x-oil
Eucalyptus tereticornis					Promising			
Eucalyptus urophylla					Promising		Promising	
Grevillea pteridifolia				Promising		x		x-wb,honey,fl
Grevillea robusta								x-agro,
Leptosperum flavescens								x-oil
Melaleuca leucadendra								x-oil
Melia volkensii				x				
Sesbania formosa				x				

[a] These are species identified as promising by Dr Doug Boland (ICRAF/CSIRO Forestry)

[b] P&P = pulp and paper, fl = flowers, tan = tannins, wb = windbreaks, oil = oil and essence, honey = honey and nectar, agro = agroforestry, food = human food

2.2.2 The prices of, and the elasticities of demand and supply for the products

The prices of fuelwood and other industrial round wood are estimated from Dewees (1992) and Campbell et al. (1991). They are based on a fuelwood price of $Zimbabwe 28/t, a construction timber price of $Z 28, and an exchange rate of $AU1 = $Z6.47.

The elasticities of demand and supply in Tables 2 and 3 are obtained from ACIAR's Economic Evaluation Unit database.

2.2.3 The level of adoption of the technologies developed in the projects

The adoption of results from the ACIAR projects has been facilitated by other organisations operating on forestry projects in the collaborating countries. For example, at the same time as the two projects funded by ACIAR (PN8320–8331 and PN8808–8809), the following other projects were taking place:

- In Zimbabwe, an Australian forestry support program started in 1982. It was funded by the Australian Development Assistance Bureau (now AusAID) and included training of Zimbabwe students in Australia, provision of seed, seed collecting trips to Australia, supply of equipment, and provision of technical forestry expertise by Australian scientists. By mid-1985 this program had been redefined to take into account a request by the Zimbabwe Government to focus on rural afforestation in denuded communal lands (ACIAR 1986). The revised program included a posting at the Forest Research Centre in Harare for an Australian scientist to establish field trials of tree species likely to be of value to communal forestry.
- In Kenya, the Embu–Meru–Isiolo project funded by Overseas Development Assistance was started in 1983 with the main objective of generating information needed to guide forestry extension in the semi-arid parts of the three districts. This project included a number of species and provenance trials involving the lesser known species of *Acacia* and *Casuarina* which were part of ACIAR projects PN8320–8331 and PN8808–8809 (KEFRI 1992).
- In Kenya, the nitrogen fixation project funded through European Economic Community assistance started in 1989 with the objective of selecting effective nitrogen-fixing trees for the dryland areas (KEFRI 1992).
- The Bura Fuelwood project in Kenya funded by the Finnish International Development Agency (1984–1993) whose major achievement has been the identification and selection of *Prosopis juliflora* as a fuelwood species both for rainfed and irrigated conditions, and the development of biomass and volume functions for selected tree species (KEFRI 1992).
- Other rural afforestation projects in various parts of Kenya including: Turkana funded by NORAD; South Nyanza and Taita Taveta funded by DANIDA; Garissa funded by FINNIDA; Kakamega and Kisii funded by Dutch Beijer Institute; and Siaya by CARE Kenya (Wamugunda 1989).

However, because these other projects were taking place at the same time as the ACIAR projects it is difficult to credit adoption of specific Australian tree and shrub species to particular agencies. Thus, the attribution of benefits from the adoption in Africa of Australian lesser-known species to funding agency has to be done with caution.

In Zimbabwe the adoption of Australian tree species introduced during ACIAR projects PN8320–8331, PN8808–8809 and PN8357 is summarised in the following schema:

Total land area of Zimbabwe of 39.1 million ha

Commercial farming sector PLUS National parks demarcated for forestry activity = 30% of land area

Communal lands = 70% of land area

Australian tree species used in communal lands	Percent of species used in the area
1. *Eucalyptus camaldulensis*	80%
2. Other eucalyptus species (including *E. grandis* and *E. tereticornis*)	15%
Other species	5%
Total	100%
Share of species introduced during PN8320–8331, PN8808–8809 and PN8357	5% or less

In Kenya the adoption of Australian tree species introduced during ACIAR projects PN8320–8331, PN8808–8809 and PN8357 is summarised in the following schema:

Total land area of Kenya of 58.3 million ha

Rest of land area in Kenya = 20% of land area

Arid and semi-arid lands (see Wainaina 1992) = 80% of land area

Australian tree species used in the area	Percent of species used in the area
1. *Grevillea robusta*	
2. *Eucalyptus camaldulensis*	
3. Other eucalyptus species (including *E. grandis* and *E. tereticornis*)	
Total	100%
Share of species introduced during PN8320–8331, PN8808–8809 and PN8357	5% or less

Spillovers from the ACIAR projects PN8320–8331, PN8808–8809 and PN8357 to other African countries are likely to be significant, as tabulated below. While the paper notes the potential for spillovers to other regions in Africa, it does not explicitly include these spillovers in the rate of return analysis for the projects

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COUNTRY	Weight (g) of Australian tree seeds received[a]	COUNTRY	Weight (g) of Australian tree seeds received[a]
Angola	70	Malawi	14285
Botswana	5686	Mali	7229
Benin	13436	Mauritania	1854
Botswana	5686	Morocco	12668
Burundi	4185	Mozambique	6837
Burkina Faso	739	Namibia	3636
Cape Verde Island	5701	Niger	23873
Central African Republic	300	Nigeria	15012
Chad	911	Rwanda	14760
Congo	13205	Senegal	6730
Cameroon	4515	Sierra Leone	5251
Djibouti	520	Somalia	5159
Egypt	10760	South Africa	61068
Ethiopia	80687	Sudan	10538
Gambia	1160	Swaziland	2166
Ghana	5317	Tanzania	25089
Guinea	5080	Togo	2330
Guinea-Bissau	355	Tunisia	4672
Ivory Coast	440	Uganda	8341
Kenya	166734	Zaire	5905
Lesotho	8273	Zambia	9049
Liberia	1390	Zimbabwe	134693
Libya	2735		

[a] Weight of Australian tree seeds sent to the country from the CSIRO Tree Seed Centre in Canberra over the period 1981–95. Most of the seeds were of *Acacia* and *Eucalyptus* tree species.

Source: Dr Tim Vercoe, CSIRO Tree Seed Centre, September 1995.

2.2.4 The before-research cost of producing forest products

It is estimated that before research, wood consumption is 0.8 m^3/person/year (KEFRI 1992) or about 6.5 m^3/household (Campbell et al. 1991). The before-research cost of producing fuelwood and other round wood in sub-Saharan Africa should reflect not just the private cost of production, but also any environmental costs attributable to production using the before-research technology. The approach adopted is that proposed by Pearce and Warford (1993) who suggest that the marginal opportunity cost (MOC) of production should be estimated using the following equation:

$$MOC = MC + MEC + MUC \qquad (16)$$

where:

MC is the marginal cost of harvesting the forest products; $MEC$is marginal externality costs which are approximated by the value of any environmental damage arising from the use of a resource; and MUC is the marginal user cost and is equal to the value of future benefits forgone as a result of using one unit of the resource today. User costs exist if the resource is thought of as exhaustible rather than renewable. An equation for estimating the marginal user cost is (see Pearce and Turner 1989):

$$MUC = (P_b - C)/(1 + r)^T \tag{17}$$

where:

P_b is the price of the substitute technology. The alternatives to fuelwood are livestock dung and crop residues while the alternative to other industrial round wood (poles) from natural forests is assumed to be commercially produced round wood; C is the cost of harvesting forest products; r is the discount rate; and T is the time at which fuelwood is exhausted.

The following subsections discuss the influence of each of the above elements in the determination of the before-research cost of producing forest products.

The marginal cost of harvesting forest products

This is given by the price of forest products discussed earlier. Where wood is collected from communal forests at no charge, the price of forest products covers no more than the cost of labour expended in gathering the products from the forest.

Marginal externality costs due to the use of a resource/deforestation in communal areas

The marginal externality costs of before-research production of forest products are approximated by the value of any environmental damage arising from the use of a resource. The marginal externality cost of deforestation includes the following elements (Bradley and McNamara 1993):

- loss of soil fertility;
- increased soil erosion;
- off-site impacts of woodland exploitation on water flow and sediment transport affecting water quality for drinking or irrigation;
- reduction in carbon sequestration capacity leading to increased emission of greenhouse gases; and
- loss of biodiversity benefits which include genetic diversity, species diversity and eco-syste diversity (Bojo 1993).

This paper includes the first four effects in the computation of the marginal externality cost of forest use. The last impact is not included because the remaining dry forest woodlands in Zimbabwe are relatively low in species count, and not high priority objects for projects seeking to protect biodiversity (Bojo 1993).

Estimates of the costs associated with the first three impacts are derived using Pearce and Warford (1993, p113) as a benchmark. Pearce and Warford (1993) indicate that, for rural households in Haiti, the loss of soil fertility per unit of fuelwood used is equal to 1.08 times the market price of fuelwood, the cost of increased soil erosion is about 2.43 times the market price of fuelwood and the cost of off-site impacts is about 0.54 times the market price of fuelwood. These relationships are assumed to hold for both fuelwood and other industrial round wood. However, these estimates are derived from relationships estimated originally for Haiti. Bojo (1993) notes that there is no analysis available that can attach real numbers to these variables. However, leaving them out of the analysis would grossly understate the true before-research cost of producing forest products. Section 3 of the paper undertakes a series of sensitivity analyses of this part of the cost estimate. One of the sensitivity analyses assumes that these costs are zero; another sensitivity analysis assumes that while they are not zero, they are lower than those based on the Haiti study and are about 76% of those derived using Haiti as a reference. This lower estimate is based on estimates by Campbell et al. (1991).

The costs associated with carbon sequestration are derived from Bojo (1993) who assumed an average hectare of woodland with 42 tonnes of biomass, a carbon content of approximately half the amount of the biomass and estimated that the willingness to pay for the preservation of a hectare of woodland (purely from a carbon sequestration point of view) would be at least US$63 a hectare. This converts to $AU2.14 per cubic metre (assuming an exchange rate of $AU1 = $US0.70).

The marginal user cost—a result of using one unit of a forest resource today

The marginal user cost is equal to the value of future benefits forgone as a result of using one unit of the resource today. User costs exist if the resource is thought of as exhaustible rather than renewable. Equation (17) is used to estimate the marginal user cost (see Pearce and Turner 1989).

The substitutes for fuelwood from communal forests include burning of livestock dung and the use of crop residues. The economic value of alternatives to 1 cubic metre of fuelwood and 1 cubic metre of other industrial round wood are as follows:

Substitute commodity to fuelwood	**Price per cubic metre[a] $AU**	**Source**
Livestock dung	48	Munasinghe (1993)
Crop residues	9	Munasinghe (1993)
Weighted average cost of substitute technology	19	After Munasinghe (1993) where 25% use livestock dung and 75% use crop residues

[a] These estimates are based on estimates in Munasinghe (1993) for Lesotho where prices are estimated to be 100.61 Lesotho Maloti (a unit of currency) for livestock dung and 18.54 Maloti for crop residues. These are converted to Australian dollars assuming that $US1 = 3 Maloti and $A1 = $US0.7.

In the base case analysis a weighted average cost of the substitute is computed on the assumption that 25% of households are likely to substitute cow dung for fuelwood and 75% are likely to substitute crop residues for fuelwood. In the case of other industrial round wood it is assumed that a substitute to products sourced from communal lands is likely to be timber commercially produced either locally or imported. The average import parity price corresponding to production from Zimbabwe sawmills was about $AU150 per cubic metre (Easton 1993).

Years left before communal forests are exhausted, assuming before-research practices

In order to estimate the marginal user cost of communal forests it is necessary to estimate the number of years left before communal forests are exhausted. These estimates are crude approximations based on literature reviewed by Bradley and Dewees (1993), who conclude as follows:

> According to these sources (Banks, 1981, Fuller, 1981, and Speece, 1982), annual losses amounted to 1.5 percent of the total woodland area. The Food and Agriculture Organisation of the United Nations estimated that in 1963, 60 percent of what were then Tribal Trust Lands were wooded, although other estimates put the proportion at 30 percent in 1978. If correct, these two estimates, made fifteen years apart, would suggest a greater annual rate of decrease.

The proportion of forest cover left and the rate of forest clearance are used to estimate the number of years left before communal forests are exhausted, assuming that the before-research practices with respect to forest clearing are continued into the future. Table 5 summarises the before-research costs of producing fuelwood and other industrial round wood.

Table 5. The before research costs of producing fuelwood and other industrial round wood.

Costs: $AU/m^3	**Average annual cost $AU per cubic metre Fuelwood**	**Average annual cost $AU per cubic metre Other industrial round wood**
Labour for collecting	4.33	8.81
Soil fertility costs	4.68	9.51
Soil erosion costs	10.52	21.41
Off-site impacts (e.g. sedimentation)	2.34	4.76
Carbon sequestration costs	2.14	2.14
Cost of substitute technology—not included in the total but used to estimate MUC	19[a]	32.07[b]
Marginal user cost (MUC)	3.15[c]	4.99[d]
Total cost of forest products before research	27.15	51.62

[a] This estimate is based on the assumption that as fuelwood is depleted from the communal forests, households in the communal areas use more livestock dung and crop residues as a source of fuel sources The weighted average cost of $19 for the alternative technology for fuelwood is estimated on the lines suggested by Pearce and Warford (1993) assuming an 8% rate of interest and a time horizon of 20 years. It is also assumed that 25% of households use livestock dung and 75% of households use crop residues as substitutes for fuelwood from communal forests.

[b] This estimate is based on the assumption that as other industrial round wood is depleted from the communal forests, households in the communal areas increase their use of commercially produced timber. The weighted average cost of $32.07 for the alternative technology for other industrial round wood is estimated that the price of timber is about $Zimbabwe 110 (Crockford and Bgoni, 1993). The marginal user cost is estimated on the lines suggested by Pearce and Warford (1993) assuming an 8% rate of interest and a time horizon of 20 years.

[c] The marginal user cost for fuelwood is low compared with that for other industrial round wood and is partly dependent on the differential between the cost of substitute technologies for the two commodities. This differential in user costs also reflects the impression gathered from the literature that fuelwood collection for domestic purposes is not a significant factor in woodland clearance. For example, Bradley and Dewees (1993) point out that dead wood is usually collected for fuel, principally because it is easier to harvest, lighter to carry, and can be burnt immediately. Bradley and Dewees (1993) report that over 80% of households surveyed reported that they met most of their fuelwood requirements by collecting dead wood. They also reported a study by McGregor (1991) who found that fuelwood collection tended to be opportunistic, often collected on the way home from fields or gardens, or from around the home from brushwood fencing or other wooden structures. The conclusion from these studies is that collection of fuelwood for domestic use rarely leads to woodland clearance (Bradley and Dewees 1993, p.98).

[d] Other industrial round wood for use as poles for house construction and as fuel for brickburning has a higher marginal user cost. Bradley and Dewees (1993) note that brickburning requires wet wood so that bricks bake slowly and steadily. Thus, brickmaking requires felling of trees and is a significant factor in woodland depletion.. Bradley and Dewees (1993) also note that the harvesting of construction timber occurs almost entirely as a result of felling standing trees.

2.2.5 The after-research cost of producing forest products

This section discusses the estimation of the after-research costs for the production of fuelwood and other industrial round wood. The analysis is based on the requirements for growing a tree which produces a cubic metre of wood product in 6 years.

Table 6 shows the estimated physical requirements for the production of a tree in the semi-arid parts of Kenya.

Table 6. After-research physical inputs in the production of fuelwood and other industrial round wood.

	Year										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Planting materials per hectare (number)	100	10	10								
2. Labour for site preparation—person-day(s) staking, spacing, strip or spot clear	1	0	0	0	0	0	0	0	0	0	0
3. Ground preparation—person-day(s) strip ploughing, ridging, pitting, terracing, micro catchment	1	0	0	0	0	0	0	0	0	0	0
4. Watering (number of litres per tree per year)	12000	5200	520								
5. Labour for watering—person-day(s) a year	12	6	1.2								
6. Weeding and slashing—person-day(s)	10	10	10								
7. Protection from animals— person-day(s)equivalents	40		30		30						
8. Pest and disease control — labour in person-day(s)	1	1	1	1	1	1	1	1	1	1	1
9. Transport—person-day(s) equivalents	3										
10. Management input—person-day(s)	1	1	1	1	1	1	1	1	1	1	1

The values in the table were arrived at as follows:

Planting materials

Planting materials are estimated on the assumption that the carrying capacity in the semi-arid regions targeted by the projects may be low. Spacing is assumed to be 10 × 10 m based on KEFRI (1992). That assumption determines the number of planting materials required in the initial year. It is assumed that 10% of the planting materials planted in years 1 and 2 may need replacing.

Labour for site and ground preparation

Two days are reserved for this activity. However, if the tree planting requires the construction of micro-catchments, more labour resources are required. For example, a person-day is required for every 16 micro-catchments, implying 5 person-days for the 100 trees assumed in the papers.

Water

The amount of water required is based on information from KEFRI (1992) which states that watering is repeated every 2 weeks during the first 3 months of planting, at 7-week intervals during the rest of the first year, and then at 10-week intervals. In this paper it is assumed that watering is not necessary beyond the establishment phase; that is, from year 3 onwards. Each tree takes about 10 litres each time it is watered.

Labour for watering

From the watering schedule in KEFRI (1992), trees would need watering about 12 times in the first year and about 6 times in the second year. Each watering session is assumed to require one person-day.

Weeding and slashing

Weeding and slashing is required only during the establishment phase.

Protection from livestock damage

As a general rule, the higher the number of livestock in a homestead, the lower the tree seedling survival rate. This item covers the cost of constructing fences from thorny branches to discourage livestock from attacking tree seedlings, or growing a live hedge around the trees. Most of this cost is labour. In some cases, farmers could purchase wire mesh which would protect the seedlings for up to 2 years. However, in the communal areas which were targeted by the ACIAR projects the use of wire mesh to protect trees is generally restricted to fruit trees.

Management input for pest and disease control

The successful growing of lesser-known Australian tree species in sub-Saharan Africa and Thailand is assumed to require the equivalent of two person-days a year to monitor tree growth and control pests and disease. This cost component is represented by the symbol M_a.

Transport

The nursery growing tree seedlings for use in the communal areas is likely to be some distance away. The 3 person-days in Table 6 are used to approximate the transport costs from the nursery to farms in the communal areas—this is equivalent to 3 person-days for a rural worker on a monthly wage of $AU33 a month.

Establishment costs

In year t, $t = 0,1,2$; the establishment cost is the sum of the costs incurred in that year. These costs are converted into annual flows as follows. First, the costs are compounded to the start of production. Let E_t be the establishment cost incurred in year t. Furthermore, let E_{ct} be the compounded establishment cost in year t. Then E_{ct} is given by the following equation:

$$E_{ct} = E_t (1 + r)^{[t^* - t]} \tag{18}$$

where:
r is the compounding factor; and t^* is the year in which the smallholder first gets either fuelwood or poles from a wood plot. In the case of fuelwood $t^* = 6$. In the case of poles $t^* = 8$. Trees have to be grown for longer periods before they can produce adequate size poles.

Let A_{ea} be the amortised value, over the life of a tree, of the compounded establishment after-research costs. The amortised value of the establishment costs is estimated using the following equation.

$$A_e = [\Sigma_\tau E_{ct}(1 + r)]^T r/\{[(1 + r)^T - 1] \qquad (19)$$

where:
r is the rate of interest, $\Sigma_\tau E_{ct}$is the total compounded establishment cost; t is equal to 0, .., t* T is the productive life of a tree, assumed to be about 15 years

Maintenance costs

Maintenance costs are assumed to be incurred from the time trees are fully established—that is from year 3 onwards. Let M_t be the maintenance cost incurred in year t. Furthermore, let M_{t*} be the compounded value in year $t*$ of maintenance costs over the 15-year life of a tree. Then M_{t*} is given by the following equation:

$$M_{t*} = \Sigma_\tau\{M_t(1 + r)^{[t* - t]}\} \qquad (20)$$

where:
t =t*,..., T

Let A_{ma} be the annuity of the after-research compounded maintenance costs. This annuity is given by the following equation:

$$A_{ma} = [\Sigma_\tau M_t*(1 + r)]^T r/\{[(1 + r)^T - 1] \qquad (21)$$

Fixed costs: land

In the analysis it is assumed that the annual rental value, R_a, of a hectare of land used for fuelwood or other industrial round wood production by smallholders is about $AU3.10, based on estimates by Bojo (1993). The rental value of land is not affected by research.

The before- and after- research cost per unit (U)

The before-research and after-research unit costs are tabulated below, giving the impacts of the projects on unit costs for fuelwood and other industrial round wood.

Fuelwood	**Before research**	**After research**	**Change**	**Percent change**
Estimated cost of production per hectare	Collect from communal forest	$AU64.37	Not applicable	Not applicable
Yield in m^3/ha/year – low	0.8 (KEFRI 1992, p18)	5.0[a]	4.2	525%
Yield in m^3/ha/year – high	3.0 (KEFRI 1992, p18)	10[a]	7.0	233%
Unit cost of production/m^3 – low	$AU27.15[b]	$AU12.87[c]	$AU14.28	53%
Unit cost of production/m^3 – high	$AU27.15[b]	$AU6.44[c]	$AU20.72	76%

[a] Dr John Fryer, ACIAR, pers. comm., September 1995. These estimates are consistent with estimates from the trials (see Mitchell 1989) where yield estimates of wood volume from the more promising species range from 4.5 to 9.2 m^3/ha;

[b] Before-research unit costs are the costs of collecting forest products from communal woodlands;

[c] The after research costs are estimated using equations 16–21.

Other industrial round wood	**Before research**	**After research**	**Change**	**Percent change**
Estimated cost of production per hectare	Collect from communal forest	$AU64.37	Not applicable	Not applicable
Yield in m^3/ha/year – low	0.8 (KEFRI 1992, p18)	5.0[a]	4.2	525%
Yield in m^3/ha/year – high	3.0 (KEFRI 1992, p18)	10[a]	7.0	233%
Unit cost of production/m^3 – low	$AU51.62[b]	$AU15.75[c]	$AU35.88	69%
Unit cost of production/m^3 –high	$AU51.62[b]	$AU7.88[c]	$AU43.74	85%

[a] Dr John Fryer, ACIAR, pers. comm., September 1995. These estimates are consistent with estimates from the trials (see Boland 1989a) where yield estimates of wood volume from the more promising species range from 4.5 to 9.2 m^3/ha

[b] Before-research unit costs are the costs of collecting forest products from communal woodlands.

[c] The after research costs are estimated using equations 16–21.

$$U_a = [A_{ea} + A_{ma} + R_a + M_a]/Q_a \qquad (22)$$

where:
the subscript *a* refers to after-research values.

The difference between U_b, the production cost per cubic metre of forest product before research and U_a, the cost of production per cubic metre of forest product after research, gives the cost reduction due to research under the ACIAR projects.

Table 7 shows after-research cost estimates for the two products in more detail. The difference between the costs for fuelwood and other industrial round wood results from different rotation lengths. For fuelwood it assumed that the rotation length is 6 years, whereas for poles it is 10 years.

The changes in unit costs are used in the estimation of benefits to producers and consumers using a traded commodity model discussed earlier.

3. RESULTS

This section discusses the preliminary estimates of the potential benefits of ACIAR projects PN8357, PN8320–8331 and PN8808–8809. In subsection 3.1 the base case results are discussed. The base case is based on the data in Tables 2–7. The cost reductions achieved by the research projects assumes that the lesser-known Australian tree and shrub species achieve a yield of 5 cubic metres of forest product per hectare (see Table 7).

Under these assumptions, it is estimated that ACIAR projects PN8357, PN8320–8331 and PN8808–8809 are likely to generate over a 30-year time horizon, net present values of about $AU27.3 million distributed as follows:

- Thailand is estimated to gain by $AU20 million;
- Kenya is estimated to gain by $AU4.7 million;
- Zimbabwe is estimated to gain by $AU5.5 million; and
- the rest of the world is estimated to gain by about $AU0.1 million.

Alternatively, the research costs of $AU3.2 million jointly incurred by ACIAR, and the Australian, Thailand, Kenya and Zimbabwean collaborating institutions can be considered as an investment. This investment is estimated to yield a rate of return of about 27% over 30 years.

This result depends on the current estimates of:

- the before-research costs of producing fuelwood and other industrial round wood by collecting from the communal forests:
- the yield of forest product per hectare achievable with the lesser-known Australian tree and shrub species;
- the ceiling adoption rates assumed in the base case.

3.1 Effect on base-case results of changes in estimates of the before-research costs of production

In the base case it was assumed that the collection of fuelwood and other industrial round wood from communal forests is associated with soil fertility costs, soil erosion costs, costs of off-site impacts and carbon sequestration costs. Bojo (1993) suggests that these costs may be 70% of those in the base case. In this section a sensitivity analysis is undertaken where the soil fertility costs, soil erosion costs, costs of off-site impacts and carbon sequestration costs given in Table 5 are reduced by 30%.

Reducing these costs by 30% reduces the before-research cost of producing fuelwood and other industrial round wood from $AU27 and $AU51/m^3, respectively, to $AU21 and $AU40/m^3.

This in turn reduces the net present value of the ACIAR projects from $AU27.3 to $AU16.7 million and the internal rate of return from 27 to 22.8%.

If it is assumed that soil fertility costs, soil erosion costs and costs of off-site impacts are zero, then the research undertaken under the ACIAR projects would have yielded no return.

Table 7. After-research costs for the production of fuelwood and other industrial round wood in the communal areas.

	Cost per unit Kenya shs	Cost per unit $AU	Year										
			0	1	2	3	4	5	6	7	8	9	10
1. Planting materials per hectare (number)	$15	$0.43	$43	$4	$4	$0	$0	$0	$0	$0	$0	$0	$0
2. Labour for site preparation (person-days—staking, spacing, strip or spot clear)	$33	$1	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3. Ground preparation (person-days—strip ploughing, ridging, pitting, terracing, micro catchment)	$33	$1	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4. Watering (number of litres per tree per year)	$0	$0	$86	$37	$4	$4	$0	$0	$0	$0	$0	$0	$0
5. Labour for watering (person-days a year)	$33	$1	$11	$6	$1	$1	$0	$0	$0	$0	$0	$0	$0
6. Weeding and slashing (person-days)	$33	$1	$10	$10	$10	$0	$0	$0	$0	$0	$0	$0	$0
7. Protection from animals (person-days equivalents)	$33	$1	$38	$29	$29	$0	$0	$0	$0	$0	$0	$0	$0
8. Pest and disease control – labour in person-days	$33	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
9. Transport (person-days equivalents)	$33	$1	$3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
10. Management input (person-days)	$33	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1	$1
11. Fixed factors –land		$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4	$4
Total Establishment Costs			$198	$91	$53								
Compounded Establishment Costs-fuelwood	Fuelwood		$314	$133	$72	$0	$0	$0	$0	$0	$0	$0	$0
Total compounded establishment cost -fuelwood	Fuelwood								$520				$520
Compounded Establishment Costs-other industrial round wood	Other industrial round wood		$366	$156	$84	$0	$0	$0	$0	$0	$0	$0	$0
Total compound establishment cost -other industrial round wood	Other industrial round wood												$606
Total maintenance costs						$10	$6	$6	$6	$6	$6	$6	$6
Compounded maintenance costs to start of production-fw	Fuelwood					$13	$7	$6	$6				
Total compounded maintenance costs-fw	Fuelwood								$31				
Compounded maintenance costs to start of production-oirw	Other industrial round wood					$18	$9	$8	$8	$7	$7	$7	$6

Table 7. (Cont'd) After-research costs for the production of fuelwood and other industrial round wood in the communal areas.

	Cost per unit Kenya shs	**Cost per unit $AU**						**Year**					
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Total compounded maintenance costs-oirw	Other industrial round wood												$69
Annuity of the establishment costs-fw	Fuelwood		$61	$61	$61	$61	$61	$61	$61				
Annuity of the compounded maintenance costs -fw	Fuelwood		$4	$4	$4	$4	$4	$4	$4				
Annuity of the establishment costs-oirw	Other industrial round wood		$71	$71	$71	$71	$71	$71	$71				
Annuity of the compounded maintenance costs -oirw	Other industrial round wood		$8	$8	$8	$8	$8	$8	$8				
Annual per hectare cost (sum of the two annuities)-fuelwood			$64	$64	$64	$64	$64	$64	$64				
Annual per hectare cost (sum of the two annuities)-oirw			$79	$79	$79	$79	$79	$79	$79				
			Low	High									
Output /ha - fuelwood			5.00	10.00									
Output /ha - oirw			5.00	10.00									
Unit cost per cubic metre after research-fuelwood			$13	$6									
Unit cost per cubic metre after research-other industrial round wood			$16	$8									
Cost saving per cubic metre-fuelwood	Fuelwood		$14	$21									
Cost saving per cubic metre- other industrial round wood	Other industrial round wood		$36	$44									
Change % Fuelwood			53%	76%									
Change % Other Industrial round wood			69%	85%									

3.2 The yield of forest product/ha of the lesser-known Australian tree and shrub species

The base case estimates are based on a low yield of lesser-known Australian tree and shrub species of 5 m^3/ha in Thailand, Kenya and Zimbabwe. In communal areas in Kenya and Zimbabwe, a common practice is to plant a mixture of tree species. The low yield is consistent with estimates of average yields over a range of species of lesser-known Australian trees and shrubs.

It may be possible, however, to obtain higher yields up to about 10 m^3/ha (Dr John Fryer, ACIAR, pers. comm., September 1995). If this is achieved, the results change as follows. An increase in yield from 5 to 10 m^3/ha is equivalent to increasing the cost savings due to research from about $AU14/$m^3$ to $AU21/$m^3$ for fuelwood and, in the case of other industrial round wood, from $AU36/$m^3$ to $AU44/$m^3$. These changes in turn impact on the base case estimates as follows.

If, instead of a yield of 5 m^3/ha, householders can achieve a forest products yield of 10 m^3/ha, then the net present value of the ACIAR projects would increase from $AU27.3 million to about $AU36 million and the internal rate of return would increase from 27 to about 29%.

3.3 The impact on base case results of changes in ceiling adoption rates

In the base case the ceiling adoption level is assumed to be 5% because it is unlikely that the lesser known Australian tree and shrub species will have as high levels of adoptions as those observed for the more known Australian species (for example, *Eucalyptus camaldulensis* and *Grevillea robusta*) which were introduced in sub-Saharan Africa much earlier.

Suppose that these adoption rates are not achieved due to some other undesirable aspect of the lesser-known Australian species. For example, some of the burning characteristics of Australian trees species have been reported to be inferior to those of firewood traditionally used in Kenya, Zimbabwe and Thailand (Boland, 1989, Editor). In this sensitivity analysis it is assumed that at most only 1%[1] adoption[2] is achieved with the lesser-known Australian tree and shrub species.

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[1] This is an estimate that Dr A. Mushaka (Forest Research Commission, Harare) gave of adoption levels of Australian lesser-known tree species in Zimbabwe. Dr Mushaka's estimate was based on his 4 years (1991-1995) as a Zimbabwe Forest Commission extension officer. His work involved visiting nurseries that supply planting materials to smallholders and advising nursery owners on best practices for the species held in nurseries. The impression he got from his visits was that the lesser-known Australian tree species were not very common. The lack of planting materials in the nurseries supplying smallholders was reflected in low adoption levels.

[2] Methods (for example, farm level surveys or sample surveys of nurseries in Kenya and Zimbabwe) that are capable of giving better estimates of adoption levels were too expensive to use in this study. However, in the case of Kenya, better information on adoption is likely to be generated by the Dryland Applied Research and Extension project currently under way and funded by the Overseas Development Administration (ODA) in the United Kingdom. The ODA-funded project is revisiting the Embu-Meru-Islo districts in Kenya to quantitavely establish adoption levels for the different tree species introduced in a reforestation project which made use of ACIAR project planting materials in the 1980s.

Even at this low level of adoption preliminary estimates indicate that the ACIAR projects would generate a positive net present value of about $AU2 million over 30 years and an internal rate of return of 12%.

4. IMPACT ON SCIENTIFIC KNOWLEDGE

One measure of the impact of a project on scientific knowledge is the number of publications it generates. Using that measure, the three projects (PN8357, PN8320–8331 and PN8808–8809) have made a significant impact on knowledge of the lesser-known Australian tree and shrub species and on requirements for their domestication in harsher environments in sub-Saharan Africa and Southeast Asia. Appendix B lists over 200 papers and other publications generated by the projects.

5. IMPACTS ON HUMAN AND INSTITUTIONAL CAPACITY BUILDING

The formal impacts on human capacity building of projects PN8357, PN8320–8831, and PN8808–8809 are summarised in Appendix C. These impacts are long term, since most of the scientists whose skills were enhanced are still involved in forestry research in their respective countries. The numbers of individuals whose capacities were enhanced through workshops and by direct involvement in project work were greater than those involved in formal training.

6. CONCLUDING REMARKS

This paper has described an economic evaluation of the impact of three interrelated ACIAR projects (PN8357, PN8320–8831, and PN8808–8809). The economic evaluation has taken into account the direct cost of producing fuelwood and other industrial woods and the indirect cost associated with obtaining these products from communal forests. The indirect costs include soil fertility costs, soil erosion costs, costs of off-site impacts and carbon sequestration costs.

Under assumptions describing the base case scenario, it is estimated that ACIAR projects PN8357, PN8320–8331 and PN8808–8809 are likely to generate over a 30-year time horizon, net present values of about $AU27.3 million distributed as follows:

- Thailand is estimated to gain by $AU20 million;
- Kenya is estimated to gain by $AU4.7 million;
- Zimbabwe is estimated to gain by $AU5.5 million; and
- the rest of the world is estimated to gain by about $AU0.1 million.

The projects are likely to yield a rate of return of about 27% over 30 years. This result depends on the current estimates of:

- the before-research costs of producing fuelwood and other industrial round wood by collecting from the communal forests:
- the yield of forest product per hectare achievable with the lesser-known Australian tree and shrub species; and
- the ceiling adoption rates assumed in the base case.

Varying these assumptions changes the preliminary estimates. On the lower end of the spectrum of estimate is the estimate of NPV of $AU2 million and an IRR of 12% if the ceiling adoption level is assumed to be 1%. However if yields of 10 m^3/ha are achieved after research, then the NPV and IRR could be as high as $AU36 million and 29%, respectively.

In addition to these estimates of NPV and IRR, the projects made significant contributions to scientific knowledge and human capacity building.

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Table 8. Summary: the flow of benefits over time—fuelwood and other industrial round wood due to ACIAR project PN8320/8331, PN8808/8809 and PN8357 ($AU ’000, 1990).

		Thailand Adopter	Thailand Non-adopter	Kenya Adopter	Kenya Non-adopter	Zimbabwe	Zimbabwe Non- adopter	Australia	Rest of the world	Total benefits	Research costs	Net benefits
1	1983	$0	$0	$0	$0	$0	$0	$0	$0	$0	256.7830367	($257)
2	1984	$0	$0	$0	$0	$0	$0	$0	$0	$0	747.4019226	($747)
3	1985	$0	$0	$0	$0	$0	$0	$0	$0	$0	778.7418035	($779)
4	1986	$0	$0	$0	$0	$0	$0	$0	$0	$0	507.7654563	($508)
5	1987	$0	$0	$0	$0	$0	$0	$0	$0	$0	399.5045676	($400)
6	1988	$0	$0	$0	$0	$0	$0	$0	$0	$0	686.5957976	($687)
7	1989	$0	$0	$0	$0	$0	$0	$0	$0	$0	603.6479126	($604)
8	1990	$0	$0	$0	$0	$0	$0	$0	$0	$0	408.586373	($409)
9	1991	$0	$0	$0	$0	$0	$0	$0	$0	$0	119.718	($120)
10	1992	$0	$0	$0	$0	$0	$0	$0	$0	$0	0	($0)
11	1993	$0	$0	$0	$0	$0	$0	$0	$0	$0	0	($0)
12	1994	$2,000	$0	$349	$0	$557	$0.00	$0	$1	$2,907	0	$2907
13	1995	$3,117	$0	$619	$0	$862	$0.01	$0	$2	$4,599	0	$4599
14	1996	$4,313	$0	$952	$0	$1,184	$0.01	$0	$3	$6,451	0	$6451
15	1997	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
16	1998	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
17	1999	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
18	2000	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
19	2001	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
20	2002	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462

Table 8. (Cont'd) Summary: the flow of benefits over time—fuelwood and other industrial round wood due to ACIAR project PN8320/8331, PN8808/8809 and PN8357 ($AU '000, 1990).

		Thailand Adopter	**Thailand Non-adopter**	**Kenya Adopter**	**Kenya Non-adopter**	**Zimbabwe**	**Zimbabwe Non- adopter**	**Australia**	**Rest of the world**	**Total benefits**	**Research costs**	**Net benefits**
21	2003	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
22	2004	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
23	2005	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
24	2006	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
25	2007	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
26	2008	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
27	2009	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
28	2010	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
29	2011	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
30	2012	$5,587	$0	$1,348	$0	$1,523	$0.02	$0	$4	$8,462	0	$8462
		0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Discounted benefits		$20,246.44	$0.33	$4,751.73	$0.22	$5,530.45	$0.07	$0.00	$14.43	$30,543.67	$3,207.38	$27,336.29
NPV											NPV	$27,336.29
IRR											IRR	26.80%

a: Adjusted for inflation with a base year of 1990; NPV: Net present value; IRR: Internal rate of return

Table 9. Distribution of benefits by forest commodity (fuelwood and other industrial round wood[a]) and by country or region.

	Fuel wood Consumers	**Fuel wood Producers**	**Fuelwood Subtotal**	**OIRW Consumers**	**OIRW Producers**	**OIRW Subtotal**	**Total benefit**
Bangladesh	$1,713.69	($1,713.38)	$0.31	$8.01	($8.01)	$0.00	$0.31
Bhutan	$71.78	($71.76)	$0.01	$0.00	$0.00	$0.00	$0.01
India	$13,256.43	($13,254.02)	$2.41	$113.29	($113.28)	$0.00	$2.42
Nepal*	$993.81	($993.63)	$0.18	$0.00	$0.00	$0.00	$0.18
Pakistan	$1,289.69	($1,289.46)	$0.23	$9.01	($9.01)	$0.00	$0.24
Sri Lanka	$482.46	($482.38)	$0.09	$12.53	($12.52)	$0.00	$0.09
Burma	$1,019.65	($1,019.46)	$0.19	$29.12	($29.12)	$0.00	$0.19
Indonesia	$8,057.25	($8,055.78)	$1.47	$66.79	($66.79)	$0.00	$1.47
Kampuchea (Cambodia)	$306.15	($306.09)	$0.06	$10.87	($10.87)	$0.00	$0.06
Laos, PDR*	$177.82	($177.79)	$0.03	$2.38	($2.38)	$0.00	$0.03
Malaysia	$360.55	($360.49)	$0.07	$16.04	($16.04)	$0.00	$0.07
Philippines	$1,909.42	($1,909.07)	$0.35	$58.09	($58.09)	$0.00	$0.35
Thailand	$83.46	$4,013.74	$4,097.20	$58.25	$16,090.99	$16,149.24	$20,246.44
Thailand-nonadopter	$1,699.13	($1,698.80)	$0.32	$40.25	($40.25)	$0.00	$0.33
Vietnam	$1,383.89	($1,383.64)	$0.25	$0.00	$0.00	$0.00	$0.25
China	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Mongolia*	$0.00	$0.00	$0.00	$0.07	($0.07)	$0.00	$0.00
Fiji	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Papua New Guinea	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Samoa (Western)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Solomon Is.*	$8.00	($8.00)	$0.00	$0.00	$0.00	$0.00	$0.00
Tonga*	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Vanuatu / New Hebrides	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
South Pac-Other	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Ethiopia	$2,083.65	($2,083.27)	$0.38	$21.75	($21.75)	$0.00	$0.38
Kenya	$57.11	$2,746.41	$2,803.52	$7.03	$1,941.19	$1,948.22	$4,751.73

Table 9. (Cont'd) Distribution of benefits by forest commodity (fuelwood and other industrial round wood[a]) and by country or region.

	Fuel wood Consumers	**Fuel wood Producers**	**Fuelwood Subtotal**	**OIRW Consumers**	**OIRW Producers**	**OIRW Subtotal**	**Total benefit**
Kenya-nonadopter	$1,162.63	($1,162.41)	$0.22	$21.36	($21.35)	$0.00	$0.22
Malawi	$438.57	($438.49)	$0.08	$36.30	($36.30)	$0.00	$0.08
Mozambique*	$0.00	$0.00	$0.00	$43.21	($43.21)	$0.00	$0.00
Tanzania	$1,762.88	($1,762.56)	$0.32	$11.11	($11.11)	$0.00	$0.32
Uganda	$693.53	($693.41)	$0.13	$22.87	($22.87)	$0.00	$0.13
Zambia	$344.14	($344.08)	$0.06	$56.70	($56.70)	$0.00	$0.06
Zimbabwe	$478.75	$472.35	$951.10	$16.52	$4,562.84	$4,579.35	$5,530.45
Zimbabwe	$349.35	($349.29)	$0.07	$0.00	$0.00	$0.00	$0.07
Zaire	$1,885.07	($1,884.72)	$0.34	$0.00	$0.00	$0.00	$0.34
Ivory Coast	$479.91	($479.82)	$0.09	$18.34	($18.34)	$0.00	$0.09
Ghana	$751.12	($750.99)	$0.14	$19.51	($19.51)	$0.00	$0.14
Nigeria	$5,149.46	($5,148.52)	$0.94	$0.00	$0.00	$0.00	$0.94
Cameroon	$571.26	($571.15)	$0.10	$48.65	($48.65)	$0.00	$0.11
Angola*	$254.37	($254.33)	$0.05	$52.83	($52.83)	$0.00	$0.05
Madagascar	$413.42	($413.34)	$0.08	$27.55	($27.55)	$0.00	$0.08
Sudan*	$359.60	($359.53)	$0.07	$12.85	($12.85)	$0.00	$0.07
Africa-2	$1,667.30	($1,667.00)	$0.30	$5.97	($5.97)	$0.00	$0.30
Africa-3	$842.55	($842.40)	$0.15	$3.78	($3.78)	$0.00	$0.15
Africa-4	$467.16	($467.08)	$0.09	$0.16	($0.16)	$0.00	$0.09
Africa-5	$570.30	($570.20)	$0.10	$0.00	$0.00	$0.00	$0.10
Africa-6	$141.25	($141.22)	$0.03	$2.43	($2.43)	$0.00	$0.03
Africa-7	$2.86	($2.85)	$0.00	$15.41	($15.41)	$0.00	$0.00
Turkey	$322.99	($322.93)	$0.06	$112.10	($112.10)	$0.00	$0.06
Egypt, Arab	$122.65	($122.63)	$0.02	$132.84	($132.83)	$0.01	$0.03
Africa-1	$222.62	($222.58)	$0.04	$0.00	$0.00	$0.00	$0.04
WA/NA Other	$330.54	($330.48)	$0.06	$0.00	$0.00	$0.00	$0.06
Brazil	$7,796.36	($7,794.09)	$2.27	$0.00	$0.00	$0.00	$2.27

Table 9. (Cont'd) Distribution of benefits by forest commodity (fuelwood and other industrial round wood[a]) and by country or region.

	Fuel wood Consumers	**Fuel wood Producers**	**Fuelwood Subtotal**	**OIRW Consumers**	**OIRW Producers**	**OIRW Subtotal**	**Total benefit**
Colombia	$775.73	($775.59)	$0.14	$0.00	$0.00	$0.00	$0.14
Peru	$424.41	($424.33)	$0.08	$0.00	$0.00	$0.00	$0.08
Venezuela	$43.34	($43.33)	$0.01	$3.91	($3.91)	$0.00	$0.01
Bolivia	$70.92	($70.90)	$0.01	$0.00	$0.00	$0.00	$0.01
Ecuador	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Mexico	$591.06	($590.96)	$0.11	$0.00	$0.00	$0.00	$0.11
Argentina	$0.00	$0.00	$0.00	$1.05	($1.05)	$0.00	$0.00
Chile	$315.09	($315.03)	$0.06	$21.70	($21.70)	$0.00	$0.06
Paraguay	$0.00	$0.00	$0.00	$2.59	($2.59)	$0.00	$0.00
Uruguay	$137.36	($137.34)	$0.03	$18.28	($18.28)	$0.00	$0.03
Latin-America 1	$1,378.31	($1,378.06)	$0.25	$14.38	($14.38)	$0.00	$0.25
Latin-America 2	$0.00	$0.00	$0.00	$58.27	($58.26)	$0.00	$0.00
Asia-Developed	$195.96	($195.90)	$0.06	$338.23	($338.22)	$0.02	$0.07
Australia	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Canada	$0.00	$0.00	$0.00	$16.69	($16.69)	$0.00	$0.00
USA	$4,387.24	($4,385.96)	$1.28	$361.90	($361.88)	$0.02	$1.29
USSR	$0.00	$0.00	$0.00	$256.50	($256.48)	$0.01	$0.01
Japan	$10.97	($10.96)	$0.00	$4.46	($4.45)	$0.00	$0.00
Developed1-2	$1,540.97	($1,540.52)	$0.45	$625.92	($625.89)	$0.04	$0.49
Developed3-4	$927.88	($927.61)	$0.27	$376.89	($376.87)	$0.02	$0.29
World Total	$73,333.81	($65,467.11)	$7,866.71	$3,214.75	$19,462.21	$22,676.96	$30,543.67

[a] Other industrial round wood

Appendix A:
Objectives of ACIAR projects PN8320–8331, PN8808–8809 and PN8357

Projects PN8320–8331 had the following objectives:

- To specify potentially useful tree species from Australia’s unique genetic resources;
- To collect representative seed samples of these species;
- In co-operation with the Queensland Department of Forestry and other bodies, evaluate and characterise these species under a range of conditions in selected developing countries (initially sub-Saharan Africa) and in Australia;
- To assess in more detail the potential ecological adaptability of selected species;
- To select species for specific adaptation to stress environments including semi-arid, saline and calcareous conditions
- In cooperation with the Queensland Department of Forestry and other bodies, document the characteristics of selected species with special reference to propagation and to treatment and management in cultivation
- Encourage the adoption of this technology by close association with other cooperative forestry projects in developing countries
- Strengthen the capacity of researchers in collaborating institutions in the developing countries through a close association in research and through visits to Australia for ‘hands on’ research training.

Specifically, this was to be achieved by the acquisition and publication of information on:

- nursery techniques for germination and production of seedlings;
- survival and growth in the field;
- phenology and seed production;
- coppicing ability;
- ease of rooting cuttings and sets; and
- wood density.

The objectives of ACIAR project PN8808 were to explore the potential of lesser-known Australian tree species for forestry and agroforestry; where they grow best, and biological, silvicultural and utilisation characteristics.

Project activities under PN8808 included:

- The collection of tree seed and the establishment of species and provenance field trials;
- Supplementary research into species evaluation, leaf oils, fodder values, coppicing ability and vegetative reproduction;
- Research training; statistical design and analyses in Kenya and Thailand;
- Climatic matching predicting species performance;
- Field and glass house provenance screening trials;
- Management trials, coppicing, vegetative reproduction;
- Dry zone elimination trials in Zimbabwe and Kenya
- Screening for acid soils tolerance in Queensland;

- Workshops;
- Book publication *Trees for the Tropics*.

The objectives of ACIAR project PN8809 related principally to the continuing management and evaluation of the existing trials and with the addition of elimination trials for arid zone species, tests on nutritional effects on *Acacia* growth and form, and impact of tree species and spacings on pasture productivity. Specific objectives of project PN8809 were that The Queensland Department of Forestry:

- continue evaluation and characterisation of species biological and utilisation attributes in collaboration with CSIRO Division of Forestry and Forest Products, and other bodies where appropriate;
- implement new supplementary trials should promising new material become available;
- select and screen species potentially suited to establishment in semi-arid to arid environments to determine species more suitable for more intensive proving trials;
- determine if nutritional status affects stem form and growth habit of a selected number of species;
- evaluate pasture productivity in combination with a limited range of tree species at varying spacings and determine the attributes of the trees that are affecting pasture productivity;
- disseminate information generated in the trials through publications in international journals, conference proceedings, etc as appropriate;
- encourage the adoption of the technology through communication with relevant personnel, institutions, and projects in developing countries particularly through on-site visits and discussions of the trials.

The early major part of the project work, including the program on pastures and on acacia nutrition, was centred on Gympie, as a sub-humid, subtropical lowland site. Later the arid zone species elimination trials were established at Mareeba, Charters Towers and Longreach in a sequence of increasingly arid environments.

The objectives of ACIAR project PN8357 were:

- to select strains of *Frankia* of high effectiveness in nitrogen fixation for several species of *Casuarina*;
- to determine responses to inoculation in the field;
- to develop an inoculum technology for use in developing countries;
- to examine methods for estimating nitrogen fixed in the field;
- to examine soil factors affecting the amounts of nitrogen fixed in the field

Appendix B.
The impact of ACIAR projects PN8320–8331, PN8808–8809 and PN8357 on scientific knowledge

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Appendix C.
Impacts of the three projects on human and institutional capacity building

The capacity building impacts of the projects fall into two categories: postgraduate training and training in the methods for statistical analysis of forestry data.

C.1 Postgraduate training

As part of human capacity building under the ACIAR activities under PN8357, PN8320–8831, PN8808–8809 two African scientists were trained at postgraduate level, namely:

- Patrick Milimo for a PhD at Australian National University; and
- Miss Gicheru for a MSc at Australian National University.
- C.2 In 1990, biometricians from the CSIRO Biometrics Unit, Black Mountain conducted a workshop on the use of GENSTAT in the analysis of forestry data at Kenya Forestry Research Institute (KEFRI), Muguga. The following scientists attended the workshop.

Name of attendee	Highest university qualification at time of attendance	Position
1. Dr E. Williams	Ph.D.	CSIRO Biometrician and Course Instructor
2. Mrs M. Lubulwa	Post graduate Diploma in Statistics, ANU	CSIRO Experimental Scientist and Course Instructor
3. Kimondo, J.M.	M.Sc.	Workshop Convenor
4. Kamau, M.	B.Sc.	Officer in Charge, Gede
5. Kariuki, J.G.	B.Sc	Officer in Charge, Turbo
6. Ikisa, E.I.		Officer in Charge, Bungoma
7. Orondo, S.B.C.	B.Sc.	Officer in Charge, Londiani
8. Chege, F.	B.Sc.	Asals headquarters
9. Kamondo, B.M.	B.Sc	Seed Centre
10.Mwaghanga, F.	B.Sc.	Officer in Charge, Kibwezi
11. Ochieng, F.	B.Sc	Officer in Charge, lodwar
12. Chirchir, J.	M.Sc.	Embu
13. Gutheru		ACIAR Dryland Project, Nairobi
14. Mugendi	M.Sc	Agroforestry, Machakos
15. Kanja	B.Sc.	Agroforestry, Machakos
16. Kimiti	Biotechnology	Biotechnology
17. Omenda, T.O.	Silviculture	Silviculture
18. Obalia, P.O.	M.Sc.	Tree breeding
19. Owour, A.	B.Sc.	Entomology
20. Mwangi, L.M.	M.Sc.	Pathology
21. Chikamai, B.N.	M.Sc.	Forest products
22. Kaudia, A.	B.Sc.	Social forestry
23. Ongugo, P.	M.Sc.	Social forestry
24.Participant from Forest Research Centre Zimbabwe		

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