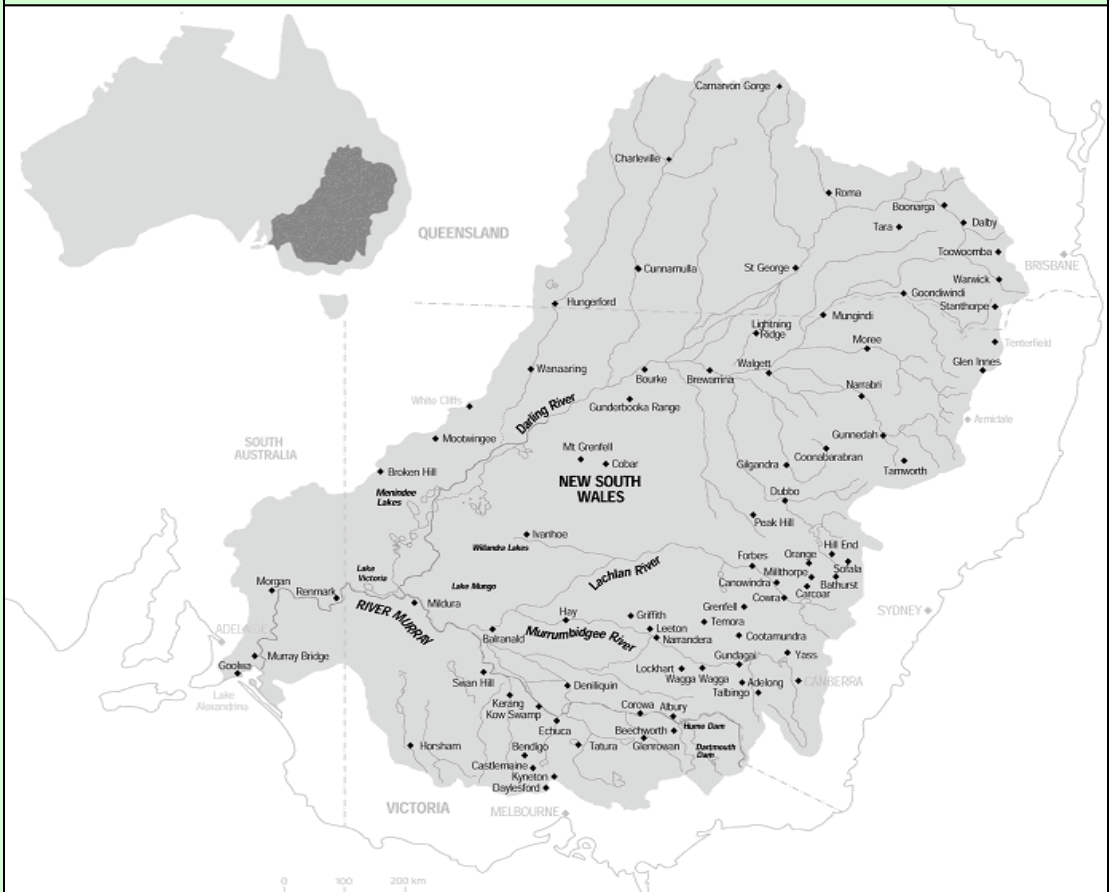
Risk & Sustainable Management Group

Murray Darling Program Working Paper: 4/M04

Research supported by an Australian Research Council Federation Fellowship
http://www.arc.gov.au/grant_programs/discovery_federation.htm

Optimal Timber Utilisation Strategies for Wik People on Cape York Peninsula

Tyron Venn



Schools of Economics and Political Science
University of Queensland
Brisbane, 4072
rsmg@uq.edu.au

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Optimal Timber Utilisation Strategies for Wik People on Cape York Peninsula

Tyron Venn[1]

1. School of Economics, The University of Queensland, Qld 4072, Australia.

A forestry industry based on the native Darwin stringybark forests of Cape York Peninsula has been identified as a potential generator of employment and income for Wik people. Information appropriate for examining potential Wik timber utilisation strategies is scarce, necessitating primary data collection activities in north Queensland. A mixed-integer, single-period goal program is developed to produce a suite of 'optimal' timber utilisation strategies from the perspective of Wik people. Optimal forestry strategies predicted by the goal programming model are financially viable and suggest, in general, that relatively low-technology forestry activities are likely to best satisfy Wik forestry objectives

1. INTRODUCTION

Wik, Wik-Way and Kugu peoples (referred to here as the Wik people) living in Aurukun Shire, Cape York Peninsula (CYP), aspire to be economically independent and self-reliant (Balkanu Cape York Development Corporation c1999) – a vision shared by the Queensland and Federal Governments (CYRAG 1997, Department of the Premier and Cabinet 2000). The High Court's *Wik judgement* in 1996, confirming the existence of native title on pastoral leases on Cape York Peninsula, and the granting in October 2000 of native title over a portion of the Wik land claim, have been major steps toward fulfilment of this vision. However, Wik people remain dependant on government welfare, including the Community Development Employment Program (CDEP) for income. The *Cape York Partnerships Plan* has committed the Queensland government to developing a strategy to drive a regional economy on CYP, which builds on the strengths of the region – its people, culture, history and extensive range of natural resources.

Balkanu Cape York Development Corporation (Balkanu) representatives of Wik people have identified the native forest timber resources in and adjacent to Aurukun Shire as one potential engine with which to drive the elders' vision of economic independence. Balkanu defined a study region on the western coast of CYP covering about 841,500 ha, approximately 30% of the Wik native title claim area, which is highlighted in Figure 1. It was suggested to the author that a large financial grant could become available from government to establish a Wik timber industry and, therefore, a range of forestry opportunities should be evaluated, including large-scale, high-technology operations. Representatives of Wik people are particularly interested in exploring the potential for manufacture of high-value dried and dressed finished products, including strip flooring and furniture, which are regarded as 'respectable' forestry activities that could raise the pride and self-esteem of Wik people. Wik elders have expressed particular interest in opportunities to export woodchips.

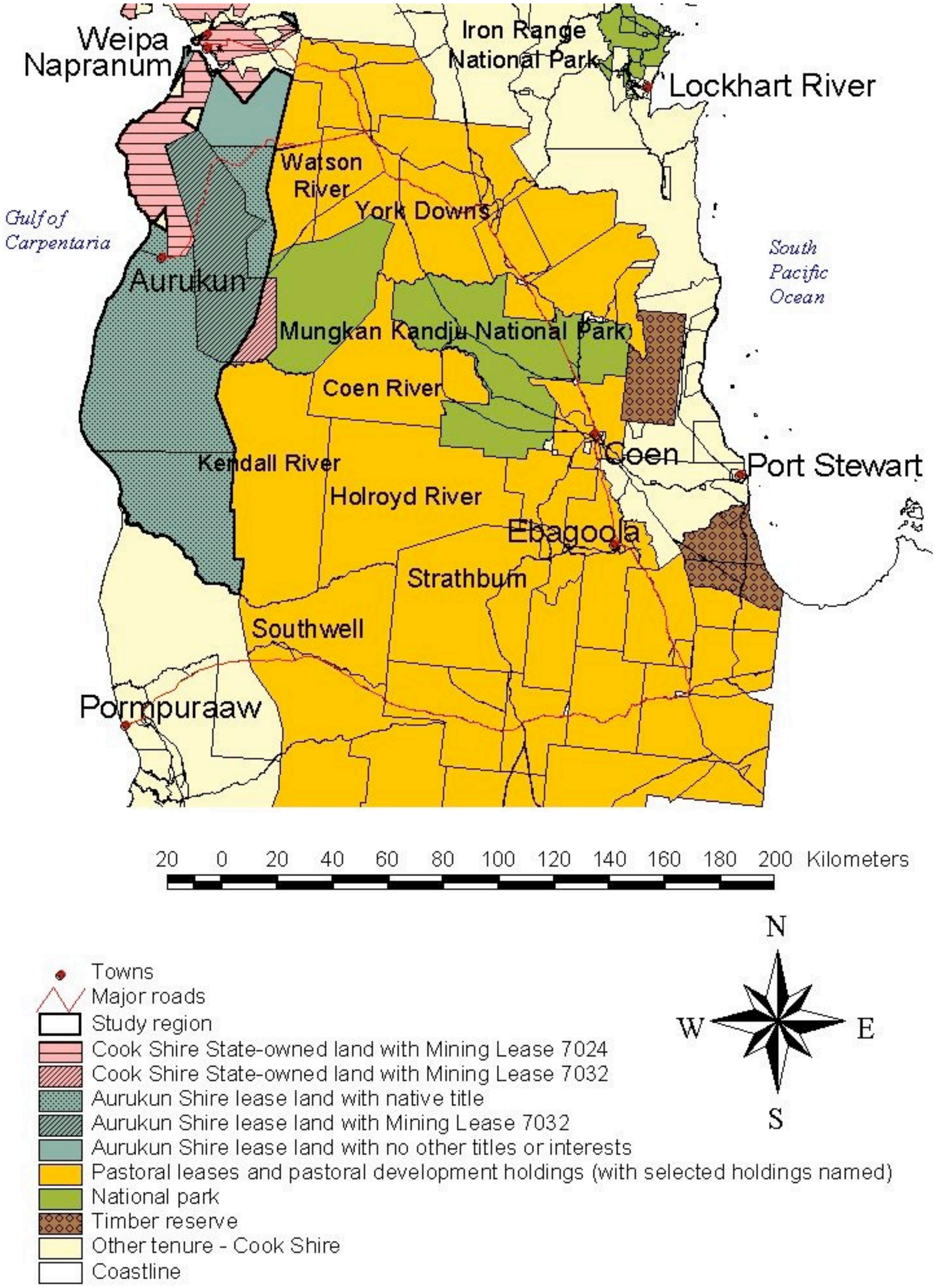
The author has been asked to assess the financial feasibility of a Wik forestry industry and provide information to support Wik decision-making about what types of forestry activities are likely to be appropriate given the timber resources available to industry and the socio-economic environment of the region. The paper describes the collection of forestry information relevant to the study region and a mixed-integer goal program that has been developed to support Wik decision-making processes about potential native forest forestry operations on their traditional lands. Optimal timber utilisation strategies from the private perspective of Wik people are presented and discussed. Concluding comments follow.

2. COLLECTION OF INFORMATION TO SUPPORT WIK FORESTRY DECISION-MAKING

Supporting the forestry decision-making of Wik people requires a wide variety of information about the region and its resources, including:

- wood properties of timber species, total and harvestable area of native forests with commercially valuable stands of timber, and harvestable volumes of merchantable timber;
- potential timber processing opportunities;

Figure 1. Central Cape York Peninsula highlighting the study region and its land tenure-title combinations



- markets for timbers;
- property rights regimes covering the timber resources; and
- the forestry objectives of Wik people.

2.1 Timber Resources of the Study Region

The Queensland Department of Primary Industries - Forestry (DPI Forestry) considers the native forests on CYP to be the largest remaining native forest resource in Queensland with potential to make a major contribution to future timber supplies (Wannan 1995). While the Peninsula has extensive areas of rainforest and *Melaleuca* forests, it is the 1.7 M ha of tall (canopy height ≥ 30 m) *Eucalyptus tetrodonta* (Darwin stringybark) forests outside of National Parks that are regarded by DPI Forestry as being of interest for commercial sawmilling operations (Wannan 1995). Analyses in ArcView geographic information system (GIS) software of spatial data provided by the Queensland Department of Natural Resources and Mines (DNR&M) indicate that the study region contains about 0.42 M ha of this resource. In addition, there are 0.16 M ha of shorter (canopy height < 30 m) Darwin stringybark forest types in the study region that may contain timbers in commercially attractive qualities and quantities.

The timber species of commercial importance in Darwin stringybark forests are Darwin stringybark, Melville Island bloodwood (*Corymbia nesophila*) and Cooktown ironwood (*Erythrophleum chlorostachys*). These species each have high density, high natural durability and aesthetically pleasing timbers, which are suitable for a wide range of internal and external uses (Bootle 1983, Smith *et al.* 1991, Hopewell 2001, Annandale *et al.* 2002). Nevertheless, little effort has been directed toward quantifying and qualifying the timber resource on CYP (Annandale and Taylor 2000). The only published estimate of sawlog volumes in Darwin stringybark forests on CYP suggests that standing volume of merchantable timber is in the vicinity of 2 m^3/ha (Wannan 1995). However, the *Wannan report* has been criticised by DPI Forestry as an overly simplistic analysis. Anecdotal information suggests that merchantable 'compulsory sawlog'[1] volumes were estimated at between 6 m^3/ha and 10 m^3/ha on the site of the

[1] DPI Forestry defines a compulsory sawlog to be a log with a minimum small-end diameter of 30 cm, greater than or equal to 2.4 m in length and with little defect (Department of Primary Industries Forest

Scherger Air Force Base near Weipa (Davis 2001). Forestry operations during 2000 in Darwin stringybark forests at the Lily Vale pastoral lease on the east coast of CYP reportedly yielded an average of 6 m^3/ha of Darwin stringybark logs (Davis 2001).

The scarcity and uncertainty of information about the standing timber resource in Darwin stringybark forests of the study region presented major difficulties in assessing forestry opportunities for Wik people. A two-stage, stratified point-sampling timber inventory in the study region was undertaken. The forests were stratified into five types on the basis of floristics, structure and previous management. Plots were distributed among the five forest types on the basis of total area of the forest type and probable volume of merchantable timber. Plots were located by a combination subjective and systematic plot location techniques in ArcView in the office. A global positioning system was used to find the plot sites in the field. Within each point-sweep, sample trees were identified by species, had their diameter at breast height and crown break, and total height measured. A Method of Assessment of Recoverable Volume by Log types (MARVL) approach was adopted to assess the timber quality of sample trees, whereby each sample tree was ocularly divided into sections of uniform quality commencing at the butt. Log quality codes were assigned to each log section and heights where log quality changed were measured. In total, 220 point-sweeps were conducted and 1,782 sample trees measured.

To facilitate the extraction of timber volume information from the timber inventory in the study region statistically sound and biologically realistic biological volume, taper over bark and diameter under bark models to crown break have been developed for Darwin stringybark from 42 destructively sampled trees. A lack of financial resources prevented the development of volume, taper over bark and diameter under bark models for Melville Island bloodwood and Cooktown ironwood. The Darwin stringybark models have been accepted as proxy models for Melville Island bloodwood. Smalian’s formula has been adopted to estimate the volume of Cooktown ironwood, and a constant rate of diameter taper is assumed for logs of this species between DBH and crown break.

Service (1994), *Hardwood Log Classification Guidelines*, Department of Primary Industries Forest Service, Brisbane.

Together, the taper and volume functions and timber inventory data can provide estimates of merchantable volume per hectare by forest type for any log specification. Table 1 presents the volume of 'compulsory sawlog' volume by species and forest type for the study region. However, tables of forestry data are unlikely to be well understood by Wik people, so pictorial representations of inventoried Darwin stringybark forests have been generated with Stand Visualization System software (developed by McGaughey 1997). These visualisations can be configured to convey the same information as can be found in a stand table arising from a forestry inventory.

Table 1. Under bark 'compulsory sawlog' volume per hectare by forest type in the study region

Forest type	Harvestable forest area (1000s ha) [a]	Mean compulsory sawlog volume under bark by species (m^3/ha)			
		DSK [b]	MBW [b]	CKI [b]	Total
1	334	4.67 (0.18)	1.69 (0.06)	0.40 (0.04)	6.75 (0.17)
2	148	0.00 (0.00)	0.80 (0.34)	0.00 (0.00)	0.80 (0.34)
3	64	0.26 (0.04)	3.44 (0.21)	0.04 (0.01)	3.74 (0.22)
4	0.2	0.00 (0.00)	0.99 (0.57)	0.00 (0.00)	0.99 (0.57)
5	1.6	2.68 (1.18)	0.80 (0.57)	0.00 (0.00)	3.48 (0.61)

Notes: Standard errors of volume estimates are in parentheses.

a. Harvestable forest area is the area of forest that can be harvested in accordance with the Code of Practice for Native Forest Timber Production from Crown lands (e.g. excludes forests in watercourse protection zones and on steep slopes).

b. DSK = Darwin stringybark; MBW = Melville Island bloodwood; CKI = Cooktown ironwood.

2.2 Potential Forestry Activities for Wik People

Discussions were held with Wik elders, representatives of Wik people, DPI-Forestry officers and managers of private forestry industries in Queensland to identify a range of appropriate forestry activities for the native forest resources of the study region. Recent research by CSIRO has indicated that the dominant commercial timber species of Darwin stringybark forests are unsuitable for pulp or reconstituted wood product manufacture with current technology (Clark 2003), so these possibilities are not considered. Table 2 lists the 25 forestry activities that have been examined for potential inclusion in a Wik forestry industry. The table also lists production capacities, variable costs and levels of employment generated for each activity, which have been derived from several published and anecdotal private industry sources, but modified to account for the cultural setting of Aurukun. In particular, it is assumed full-time employees in Aurukun work five hours per day, five days per week, 48 weeks per year, and that the hourly productivity of their labour is 70% of the private industry level.

2.3 North Queensland Timber Markets and Wik Forestry Industry Opportunities

A lack of information about timber markets for Darwin stringybark, Melville Island bloodwood and Cooktown ironwood led to the undertaking of a timber market survey in north Queensland, which is detailed in Venn (in press). Unstructured telephone and in-person discussions were held with 46 north Queensland sawmillers, furniture manufacturers and other users of timber, local governments, and government agencies. Potential market prices and quantities demanded for 13 product types, including electricity poles, structural timbers and strip flooring, have been estimated for Darwin stringybark and Cooktown ironwood. Cooktown ironwood is anticipated to achieve market prices higher than Darwin stringybark in appearance applications. Few interviewees were willing to comment on the market potential of Melville Island bloodwood. Several indicated that this species is inferior to Darwin stringybark and Cooktown ironwood, largely because of the prevalence of loose gum veins, which result in low usable sawnwood recovery (e.g. see Annandale *et al*. 2002).

Table 2. Wik forestry activities examined and selected characteristics

Activity	Capital cost ($ M)	Annual production capacity [a]	Total variable costs ($/m^3) [b]	Employment generated (CAFTEs)	Maximum number of activity [c]
Forest management for Wik industry	0.075		d	≥ 3	na
Forest management for 'outsider' industry	0.055		d	3	1
Harvesting (1 cutting crew)	0.075	0 to 3,000 m^3 of log	22.9	0 to 2	10
Harvesting (2 cutting crews)	0.110	0 to 6,000 m^3 of log	18.8	0 to 3	10
Hauling logs to Aurukun town or Weipa	0.150	0 to 6,000 m^3 of log	0.35 e	0 to 1	na
Portable sawmilling on-country	0.039	0 to 325 m^3 of log	135.1	0 to 1.5	5
Transporting GOS timber to Aurukun town from portable sawmills	0.070	0 to 1,625 m^3 of log	0.35 e	0.2 per p-sawmill on country	1
Portable sawmilling in Aurukun town	0.024	0 to 600 m^3 of log	164.8	0 to 4	1
Fixed-site sawmilling 1	1.200	425 to 2,200 m^3 of log	171.8	3 to 15	1
Fixed-site sawmilling 2	2.000	2,200 to 4,400 m^3 of log	142.5	12 to 23	1
Fixed-site sawmilling 3	3.800	4,400 to 11,000 m^3 of log	103.7	16 to 41	1
Fixed-site sawmilling 4	4.800	11,000 to 20,000 m^3 of log	71.1	25 to 45	1
Chemical treatment of poles	0.500	0 to 2,880 m^3 of log	45.1	0 to 1.5	1
Soak chemical treatment of sawntimber	0.005	0 to 140 m^3 green-off-saw	42.4	0 to 0.16	10
Vacuum chemical treatment of sawntimber 1	0.260	0 to 1,680 m^3 green-off-saw	33.5	0 to 1	1
Vacuum chemical treatment of sawntimber 2	0.500	0 to 2,880 m^3 green-off-saw	34.0	0 to 1.5	1
Vacuum chemical treatment of sawntimber 3	0.600	0 to 5,760 m^3 green-off-saw	29.5	0 to 1.5	1
Air-drying sawntimber	0.064 / 1,000 m^2	A: 1,255 m^3 / 1,000 m^2 of shed space S: 1,560 m^3 / 1,000 m^2 of shed space	70.7 64.0	0 to 1.4 / 1,000 m^3 sawntimber	100 (4,000 m^2 shed area)
Solar kiln drying sawntimber	0.035	A: 0 to 130 m^3 S: 0 to 65 m^3	115.1 161.8	0 to 3.3 / 1,000 m^3 sawntimber	10
Combination gas and solar kiln drying sawntimber 1	0.065	A: 0 to 198 m^3 S: 0 to 109 m^3	113.4 146.0	0 to 2.3 / 1,000 m^3 sawntimber	10
Combination gas and solar kiln drying sawntimber 2	0.110	A: 0 to 590 m^3 S: 0 to 326 m^3	99.1 121.6	0 to 1.1 / 1,000 m^3 sawntimber	10
Combination gas and solar kiln drying sawntimber 3	0.165	A: 0 to 985 m^3 S: 0 to 543 m^3	94.5 115.4	0 to 0.83 / 1,000 m^3 sawntimber	10
Strip flooring manufacture 1	0.9	0 to 1,050 m^3 appearance boards	205.3	0 to 6	1
Strip flooring manufacture 2	1.1	0 to 3,940 m^3 appearance boards	169.7	0 to 6	1
Small-scale furniture manufacture [f]	0.6	0 to 90 dining table and chair kits	4,520 g	0 to 6	1

a. Two annual production capacities are listed for all sawntimber drying activites. A is for appearance boards. S is for structural timber. Appearance timber is dried to 12% and structural timber to 20%.
b. Total variable costs are total labour and non-labour (e.g. equipment and machinery) operating expenses expressed in dollars per unit of annual production capacity. For example, strip flooring variable costs are $\$/m^3$ of appearance boards.
c. Maximum number of activity is the total number of times the particular activity may enter any given timber utilisation strategy.
d. Forest management does not directly produce timber products so it is not appropriate to report costs per unit of output. Variable forest management costs comprise the labour costs of forest managers (see Table 3), annual vehicle expenses of $6,240/vehicle and other expenses equivalent to 5% of total forest management labour costs.
e. Log and GOS timber haulage costs are expressed in $\$/m^3$ of log/km and $\$/m^3$ GOS/km respectively.
f. Owing to the high cost of freight for assembled furniture over large distances, it is assumed that furniture manufacturing in Aurukun would produce a product in 'kt' form, which could then be assembled closer to market.
g. 0.2 m^3 of appearance boards and 0.2 m^3 of structural boards are utilised in each dining table and chair kit.

2.4. Property Rights of Wik People to Timber in the Study Region

The size of a Wik forestry industry, its potential profitability and ability to raise capital will depend on factors such as: whether permits are necessary for commercial harvesting; whether royalties for harvested timber are payable to government; the regulations on timber harvesting; and the duration, exclusivity, transferability and divisibility of Wik peoples' rights to timber. However, the legal rights of Wik people to timber resources have not previously been analysed methodically. A comprehensive assessment has been made and the findings reported in Venn (2003).

On lands where Wik people have been granted native title, Wik people have rights to utilise timber resources that are commensurate with freehold title holders in Queensland. Subject to particular environmental and other legislation, and the forthcoming Code of Practice for Native Forest Timber Production on private lands, Wik people can harvest and process timber from this land without permit or paying royalties to the Queensland Government. Throughout the remainder of the study area, Wik people do not have the right to commercially utilise timber resources. DPI Forestry have indicated that it is highly likely a permit to facilitate commercial harvesting of timber would be issued upon receiving an application from Wik people. However, the Queensland Government has the power to charge royalties for timber harvested under such a permit. Harvesting would be subject to environmental and other legislation, the Code of Practice for Native Forest Timber Production from Crown lands, and agreement with the holders of mining leases that harvesting will not interfere with their rights and obligations.

There are several endangered, vulnerable and rare (EVR) species within the study area, including the red goshawk (*Erythrotriorchis radiatus*), which necessitates the retention of up to eight habitat and recruitment trees per hectare. Harvesting exclusion zones are required around watercourses and this will reduce the area of harvestable forest. The timber inventory data is suitable for identifying habitat trees and watercourse exclusion zones are estimated in ArcView.

2.5 Wik Forestry Objectives

Formal, structured discussions about the aspirations of Wik people and their forestry objectives had been planned; however, this approach was discouraged by other researchers working in Aurukun. Instead, informal discussions were held with Wik elders and non-indigenous managers in the Aurukun Shire Council about what Wik people would like to achieve through the establishment of a forestry enterprise. The majority of discussions with Wik elders were conducted on country while undertaking other activities including fishing, hunting, lighting forest fires to clean the country, checking the camping permits of tourists, harvesting timber for local consumption and performing forest inventory. These discussions revealed the following hierarchy of forestry goals in decreasing order of importance:

1. Maximise total employment generation;
2. Maximise employment generation on-country (i.e., outside of Aurukun town);
3. Maximise income generation;
4. Maximise forest area excluded from timber harvesting south of the Archer River; and
5. Maximise forest area excluded from timber harvesting north of the Archer River and outside of mining leases;

Goals 4 and 5 have a several purposes, but it was particularly emphasised that forests outside of mining leases may become important for other economic opportunities for Wik people, e.g. ecotourism.

3. A DECISION-SUPPORT TOOL FOR WIK FORESTRY DECISION-MAKING

The motivation for developing a decision-support tool is the generation of a suite of timber utilisation strategies that best satisfy the (private) forestry objectives of Wik people. Wik people have multiple, non-commensurate and conflicting forestry objectives. Multi-criteria analysis (MCA) techniques can accommodate these complexities and assist the decision-making processes of stakeholders and policy-makers. Venn and Harrison (2001) reviewed several MCA approaches and concluded that goal programming (GP) is particularly well-suited to provide decision-support to Wik people about forestry in the study region. Essentially, the aim in GP is to minimise unwanted deviations from aspiration levels[2] of management goals subject to resource and technical constraints.

A mixed integer, single-period GP model of forestry opportunities in the study region has been developed within the General Algebraic Modelling System (GAMS) mathematical programming software package to support the decision-making of Wik people. Important model parameters not described in the previous section are presented in Table 3.

Six capital budget constraints for a Wik forestry industry are considered, namely $0.25M, $0.5M, $1M, $2M, $5M and $10M. It is assumed in the analysis that these funds are obtained as grants from governments (Federal and State). Obtaining a $10 M grant to facilitate the purchase and development of forestry infrastructure, buildings, machinery and equipment may appear improbable. However, the Federal Government pays millions of dollars in welfare benefits (through CDEP and other pensions) to Wik people in Aurukun annually[3]. Viewed in this context, a multi-million dollar grant that creates private sector forestry employment and income for some Wik people, who

[2] The aspiration level represents a target performance level for a *variable* that is desired or acceptable to the decision makers.

[3] Reporting welfare payments in Australian indigenous communities is politically sensitive and the author had been criticised when trying to obtain current payments in Aurukun. Dale (1993) indicated that in the financial year 1988-89 the Federal Government paid $2.5M in CDEP wages to 233 recipients in Aurukun (excluding on-costs of administering CDEP and other welfare payments such as pensions for the elderly, disabled, and to single mothers). At the time of writing, there are still essentially no employment opportunities for Wik people in Aurukun that are not funded by the CDEP.

currently receive all of their income in the form of welfare benefits, may be a socio-economically rewarding investment for Wik people and Australian taxpayers generally.

Table 3. General parameters in the Wik Forestry GP Model

Parameter	Level
Planning period (years)	30
Discount rate (%)	7
Tax rate on corporate earnings (%)	30
Available labour (hours/CAFTE/yr)	1,200
Salary and on-costs of labour ($/CAFTE/yr)	22,810
Royalty on 'compulsory sawlogs' ($/m^3)	20
Royalty on 'optional sawlogs' ($/m^3)	10
Minimum harvest rotation on land tenure-title combinations without mining leases (years)	100
Minimum harvest rotation on land tenure-title combinations with mining leases (years)	30
Habitat tree retention requirements on land tenure-title combinations without mining leases (trees/ha)	8
Habitat tree retention requirements on land tenure-title combinations with mining leases (trees/ha)	5
Minimum timber volume harvested per hectare (m^3/ha)	2
Penalty cost for low intensity (≤ 4.5 m^3/ha) harvesting operations ($/ha)	20

Note: The penalty cost for low intensity harvesting (in $/m^3) decreases as the log volume harvested per hectare increases. Thus, the penalty for an operation harvesting 2 m^3/ha is $10/m^3, while for an operation harvesting 4 m^3/ha the penalty cost is $5/m^3.

3.1 Expressing Wik Forestry Objectives as Goals with Preference Structures for Goal Programming

To transform Wik forestry objectives into goals for GP, aspiration levels must be determined for each objective. It was not possible to elicit specific aspiration levels for the set of forestry objectives identified from Wik elders. However, the candidate interpreted what had been discussed as a desire to employ as many 'young people' as possible, while generating as much income as possible and limiting harvesting outside of mining leases (particularly south of the Archer River) to as close to zero as possible. Aspiration levels for total employment, on-country employment and income generation goals have been obtained by transforming the Wik Forestry GP Model into a series of linear programming problems in which the performance level of each goal is maximised separately while ignoring all other goals. This identified the maximum feasible levels for each goal. The aspiration levels for harvesting exclusion areas south of the Archer River and outside of mining leases north of the Archer River have been set to the total forest area in each of these regions (implying zero area harvested).

Goals in the objective function of a GP are prioritised and weighted to reflect the preference structures of stakeholders and decision-makers. It has not been possible to collect Wik preference structure information in more detail than provided by the lexicographic ordering of objectives reported in Section 2.5. Although Wik preference structure information is scarce, it appears appropriate to examine several potential preference structures with lexicographic goal programming (LGP) and weighted goal programming (WGP) approaches.The preference structures implied in the LGP objective functions assume that no trade-offs are possible between the performance levels of goals of different priorities. That is, goals of higher priorities must be satisfied as fully as possible before lower priority goals are considered. The sequential linear method (Ignizio and Perlis 1979) is employed to solve the LGPs (i.e. goal deviational variables are minimised in a series of LPs beginning with the highest priority goal). In WGP, all goals have the same priority level. Trade-offs between the performance levels of goals are facilitated and the goal weights prescribe a preference structure in the rate at which these trade-offs can be made. Four objective functions have been specified, representing four different stakeholder preference structures:

1. LGP employment

$$\text{lexmin} \quad AllJobund^{(1)} + OCJobund^{(2)} + NPVund^{(3)} + HarvSAR^{(4)} + HarvNAR^{(5)}$$

2. LGP NPV

$$\text{lexmin} \quad AllJobund^{(2)} + OCJobund^{(3)} + NPVund^{(1)} + HarvSAR^{(4)} + HarvNAR^{(5)}$$

3. WGP absolute

$$\min \quad 0.13278\, AllJobund^{(1)} + 0.06639\, OCJobund^{(1)} + NPVund^{(1)} + 0.01328\, HarvSAR^{(1)} + 0.00133\, HarvNAR^{(1)}$$

4. WGP percentage

$$\min \quad AllJobund^{(1)} + OCJobund^{(1)} + NPVund^{(1)} + HarvSAR^{(1)} + HarvNAR^{(1)}$$

where lexmin is the lexicographic minimum (of an ordered vector) and superscripted numbers in parentheses indicate goal priority order;

AllJobsund is the negative deviation from the total employment aspiration level (CAFTEs);

OCJobsund is the negative deviation from the employment on-country aspiration level (CAFTEs);

NPVund is the negative deviation from the NPV aspiration level ($M);

HarvSAR is the negative deviation from the harvest exclusion zone south of the Archer River aspiration level (ha); and

HarvNAR is the negative deviation from the harvest exclusion zone outside of mining leases north of the Archer River aspiration level (ha).

The first two objective functions are LGP approaches to solving the GP model where maximising total employment and maximising NPV are the number one priorities, respectively. In the third objective function, the weights represent an attempt to convert the noncommensurate goal deviations into units of millions of dollars in present value terms. There is no research evidence on which to base precise estimates of weights for the objective function; however, it is not the absolute magnitude of these weights that is critical, but their relative orders of magnitude. The *AllJobsund* weight is the approximate annual income of a CDEP worker ($10,000) multiplied by the present value factor (*PVfactor*)[4]. On-country employment is preferred by Wik people to employment in town, so underachievement of on-country employment (*OCJobsund*) is additionally weighted by half the *AllJobsund* weight. Weights for *HarvSAR* and *HarvNAR* are $1,000/ha and $100/ha, respectively, multiplied by the *PVfactor*.

Objective functions 1 to 3 seek to minimise absolute prioritised or weighted deviations from goal aspiration levels. However, objective function 4 minimises the weighted percentage deviations from goal aspiration levels (where all weights equal 1). Therefore, the preference structure implied by this function is, for example, that a 1% underachievement of the aspiration level for harvesting exclusion area north of the Archer River is equivalent to a 1% underachievement in the NPV aspiration level.

[4] The *PVfactor* converts a constant annual cost or revenue over a specific planning period, at a particular discount rate, into a present value in units of millions of dollars. In this study the *PVfactor* is 1.3278×10^{-5} for a project with a 30-year life at a 7% discount rate.

4. OPTIMAL TIMBER UTILISATION POLICIES FOR WIK PEOPLE

The goal aspiration and performance levels for a total of 24 optimal timber utilisation strategies - one for each combination of capital budget constraint level and goal preference structure - are reported in Table 4. The information in Table 4 can also be presented graphically, as in Figure 2, which displays the relative goal performance levels, area of forest harvested, volume of logs harvested and output of finished products for the optimal timber utilisation strategies for a budget constraint of $2 M. The particular forestry activities associated with each optimal timber utilisation strategy can be summarised, as in Table 5 for a budget constraint of $2 M.

Predictably, higher budget constraint levels facilitate the establishment of optimal Wik forestry industries capable of generating higher levels of employment and net present value (NPV). However, the performance level columns highlight that this is often at the expense of a reduction in the area of the harvesting exclusion zones north and south of the Archer River. Sensitivity analyses have revealed that NPV is highly sensitive to several model parameters, especially sawntimber recovery rates and market prices. Consequently, the Wik Forestry GP Model is unstable for the preference relation implied by the LGP NPV objective function. However, the GP Model is robust against alternative parameter levels for the preference structures implied by the LGP employment, WGP absolute and WGP percentage objective functions.

Table 4. Goal aspiration and performance levels for optimal timber utilisation strategies

Budget constraint ($M)	Goal	Aspiration level	Performance level by objective function			
			LGP employment	LGP NPV	WGP absolute	WGP percentage
0.25	G1 (CAFTEs)	6.8	6.8	5.1	5.1	6.8
	G2 (CAFTEs)	5.8	5.8	3.9	3.9	5.8
	G3 ($M)	-0.8	-1.1	-0.8	-0.9	-1.1
	G4 (ha/year)	1,975	1,975	1,975	1,975	1,829
	G5 (ha/year)	1,207	1,061	1,045	1,207	1,207
0.5	G1 (CAFTEs)	19.0	19.0	14.2	14.2	14.2
	G2 (CAFTEs)	12.1	11.6	11.6	11.6	11.6
	G3 ($M)	2.3	1.1	2.3	2.1	2.1
	G4 (ha/year)	1,975	1,613	1,614	1,975	1,975
	G5 (ha/year)	1,207	757	757	1,207	1,207
1	G1 (CAFTEs)	24.2	24.2	14.7	14.7	16.1
	G2 (CAFTEs)	13.2	11.6	11.4	11.4	13.2
	G3 ($M)	7.4	0.3	7.4	6.9	6.1
	G4 (ha/year)	1,975	1,612	1,399	1,975	1,975
	G5 (ha/year)	1,207	757	757	1,207	1,207
2	G1 (CAFTEs)	34.9	34.9	22.3	22.3	30.1
	G2 (CAFTEs)	15.2	14.2	13.6	13.6	15.2
	G3 ($M)	9.6	3.2	9.6	9.2	7.4
	G4 (ha/year)	1,975	1,399	1,399	1,975	1,975
	G5 (ha/year)	1,207	757	757	1,207	1,207
5	G1 (CAFTEs)	72.1	72.1	70.3	70.4	72.1
	G2 (CAFTEs)	23.8	23.8	20.3	20.3	22.3
	G3 ($M)	17.1	15.3	17.1	16.3	15.3
	G4 (ha/year)	1,975	1,399	1,399	1,975	1,975
	G5 (ha/year)	1,207	755	755	1,207	1,207
10	G1 (CAFTEs)	115.4	115.4	99.0	99.0	108.1
	G2 (CAFTEs)	36.7	36.7	29.7	29.7	36.7
	G3 ($M)	46.9	28.8	46.9	46.7	42.8
	G4 (ha/year)	1,975	787	1,859	1,975	1,975
	G5 (ha/year)	1,207	644	670	672	1,207

Notes: G1 is total employment goal; G2 is the employment on country goal; G3 is the NPV goal; G4 is the timber harvesting exclusion zone south of the Archer River goal; and G5 is the timber harvesting exclusion zone north of the Archer River and outside of mining leases goal.

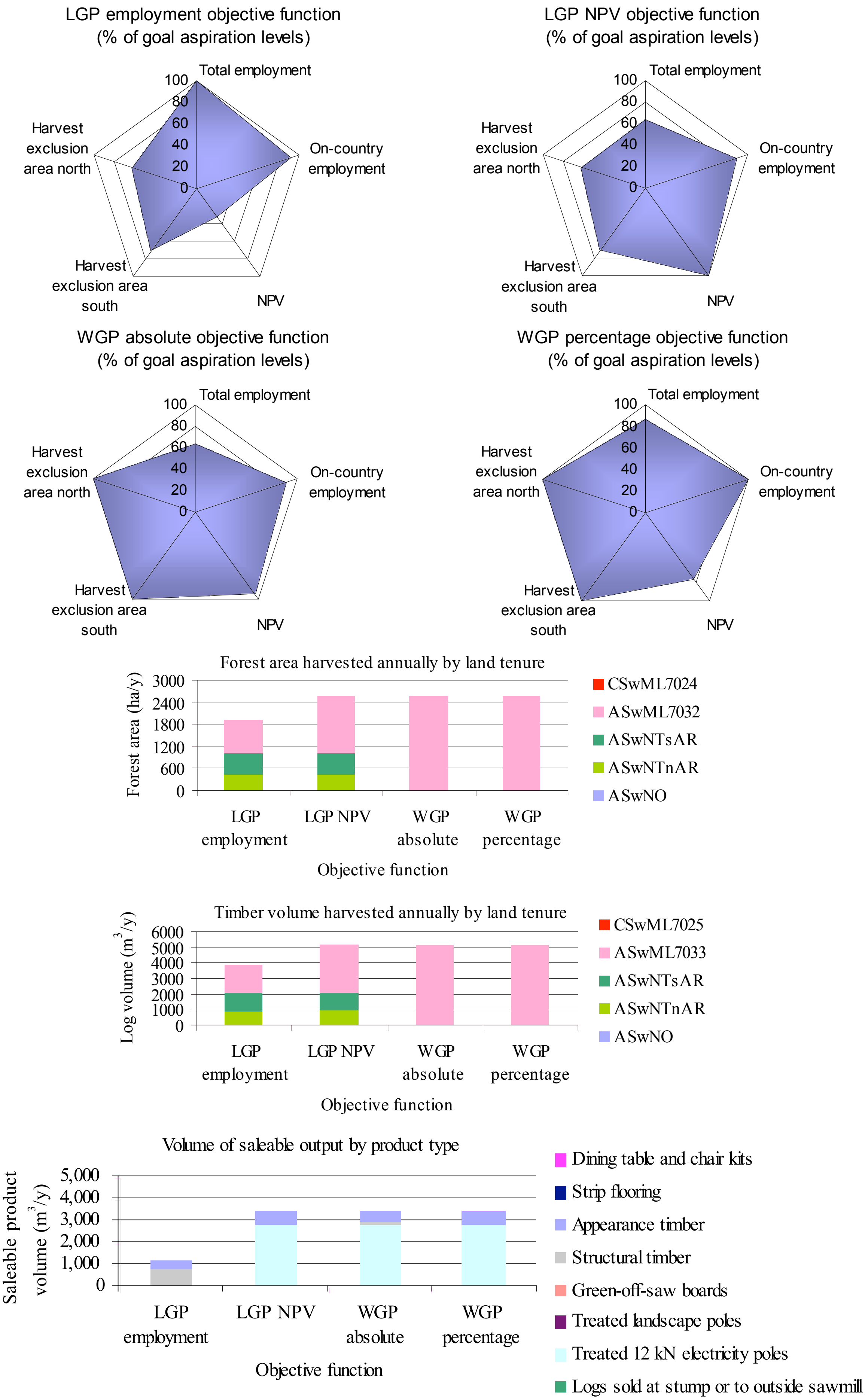


Figure 2. Relative goal performance levels, areas and volumes harvested, and output volume by product type for a $2M budget

Table 5. Optimal timber utilisation strategies for a $2M capital budget constraint

Forestry activity	Optimal timber utilisation strategies by implied goal preference structure			
	LGP employment	LGP NPV	WGP absolute	WGP percentage
Forest management	Yes	Yes	Yes	Yes
Oversee outsiders harvesting				
Timber harvesting	2 x 1 cutting team harvesting operations	1 x 2 cutting team harvesting operations	1 x 2 cutting team harvesting operations	2 x 1 cutting team harvesting operations
Portable sawmilling on country	5 portable sawmills	5 portable sawmills	5 portable sawmills	5 portable sawmills
Hauling logs to Aurukun town	1 haulage truck	1 haulage truck	1 haulage truck	1 haulage truck
Chemical treatment of electricity and landscape poles in town		Yes	Yes	Yes
Sawmilling in town	1 x 2,200 m^3 capacity sawmill	Portable sawmill	Portable sawmill	Portable sawmill
Chemical treatment of sawn timber in town	10 soak treating facilities	6 soak treating facilities	7 soak treating facilities	6 soak treating facilities
Seasoning of sawn timber in town	160 m^2 air drying shed, 4 solar kilns	680 m^2 air drying shed	680 m^2 air drying shed	680 m^2 air drying shed
Manufacturing strip flooring in town				
Manufacturing dining table and chair kits in town				Yes

The performance level columns of Table 4 indicate that the preference structure implied by the objective function has a large effect on the optimal solution. The preference structure implied by the LGP employment objective function results in the generation of optimal timber utilisation policies with the highest level of employment for a particular budget constraint[5]. The LGP NPV preference structure generates the forestry strategy with the highest NPV level. Table 2 also highlights large trade-offs between employment generation and NPV when lexicographic preference structures are examined in the GP model. For example, at the $2 M budget constraint level, the LGP employment objective function generates an optimal timber utilisation policy that creates employment for 34.9 culturally appropriate full-time equivalents (CAFTEs) and returns a NPV of $3.2 M. However, the optimal policy generated by the LGP NPV objective function for the same budget constraint level creates employment for only 22.3 CAFTEs, but returns an NPV of $9.6 M. The large differences in employment and NPV performance levels between the LGP preference structures can be explained with reference to Table 5. The LGP employment strategy includes less cost-efficient harvesting operations and a 2,200 m^3/annum fixed-site sawmill, while the LGP NPV strategy employs cost-efficient harvesting operations and chemical treatment of poles instead of a 2,200 m^3/annum capacity sawmill.

The preference structures implied by the weighted goal programming (WGP) objective functions tend to predict optimal Wik forestry industries that provide goal performance levels in between the extreme levels of employment and NPV generated by the LGP objective functions. Generally, the WGP absolute objective function generates outcomes that are more directed towards NPV maximisation than the WGP percentage objective function. The latter produces forestry strategies that are more focussed on employment generation. For all scenarios, the two WGP objective functions also tend to generate optimal timber utilisation strategies that fully achieve or are closer to achieving the harvesting exclusion area aspiration levels than the two LGP objective functions.

---

[5] In some scenario and budget combinations, the preference structure implied by the WGP percentage objective function generates timber utilisation policies with more on-country employment than the LGP employment objective function; however, total employment generated by the latter always equals or exceeds the former.

4.1 Potential Timber Utilisation Startegy 'Winners'

Drawing upon knowledge acquired about the forestry aspirations of Wik people, the author has attempted to highlight a subset of forestry policies likely to best satisfy Wik forestry objectives. Overall, the preference relation implied by the WGP percentage objective function is judged most likely to be the closest aligned with the forestry objectives of Wik people. The strategies generated by this preference structure achieve a combination of high total and on-country employment levels, large harvesting exclusion areas for forests outside of mining leases and relatively high NPV levels. The forestry activities undertaken in these 'winning' optimal timber utilisation policies are presented in Table 6.

Wik elders aspire for their people to be economically independent. No optimal timber utilisation policy with a budget constraint of \$0.25 M generated a positive NPV, which indicates that the implementation of these forestry strategies would require on-going financial assistance. This is not a desirable outcome for Wik people and suggests that the minimum level of financial resources necessary to establish a successful timber industry in Aurukun Shire exceeds \$0.25 M.

5. INSIGHTS PROVIDED BY THE GP MODEL INTO THE OPTIMAL STRUCTURE OF WIK FORESTRY STRATEGIES

When employment generation is greatly more important than other forestry goals (e.g. when the GP model is solved with the LGP employment objective function), then '1 cutting team harvesting operations' best satisfy Wik goals. On the other hand, when NPV is more important than employment (e.g. when the GP model with the LGP NPV objective function), financially more efficient '2 cutting team harvesting operations' are more appropriate. The GP model's predictions suggest that, regardless of the actual forestry preference structure of Wik people, portable sawmills are likely to figure prominently in the optimal timber utilisation strategy. This is because portable sawmills can generate relatively high levels of on-country employment with relatively low log input volumes (small areas harvested) and low fixed costs.

Table 6. Optimal timber utilisation strategies for the preference relation implied by the WGP percentage objective function

Forestry activity	WGP percentage timber utilisation strategies by budget constraint level ($M)				
	0.5	1	2	5	10
Forest management	Yes	Yes	Yes	Yes	Yes
Timber harvesting	1 x 1 cutting team harvesting operations	1 x 2 cutting team harvesting operations	2 x 1 cutting team harvesting operations	3 x 1 cutting team + 1 x 2 cutting team harvesting operations	9 x 1 cutting team harvesting operations
Portable sawmilling on country	5 portable sawmills	5 portable sawmills	5 portable sawmills	5 portable sawmills	5 portable sawmills
Hauling logs to Aurukun town		1 haulage truck	1 haulage truck	2 haulage trucks	4 haulage trucks
Chemical treatment of electricity and landscape poles in town		Yes	Yes		Yes
Sawmilling in town			Portable sawmill	11,000 m^3 capacity sawmill	20,000 m^3 capacity sawmill
Chemical treatment of sawn timber in town	5 soak treating facilities		6 soak treating facilities	10 soak treating facilities	1 x 24 m^3 capacity vacuum pressure treatment facility
Seasoning of sawn timber in town	440 m^2 air drying shed	200 m^2 air drying shed	680 m^2 air drying shed	3,040 m^2 air drying shed	3,960 m^2 air drying shed, 1 solar kiln, 1 x 8m^3 and 7 x 24 m^3 capacity combination gas and solar kilns
Manufacturing strip flooring in town					3,940 m^3 capacity flooring plant
Manufacturing dining table and chair kits in town			Yes		

Note: There are no ‘winners’ at the $0.25 M budget constraint level.

Fixed-site sawmilling in town and chemical treatment of poles are predicted by the GP model to be the major timber output generating activities of a Wik forestry industry when the budget constraint is at least $1 M. Except for the preference structure implied by the LGP employment objective function, chemical treatment of poles is predicted to satisfy Wik forestry objectives better than fixed-site sawmilling for capital budget constraint levels of $1 M and $2 M. Wik objectives are better achieved by fixed-site sawmilling activities at the $5 M budget constraint level, while at the $10 M budget constraint level both types of activities are predicted to be undertaken to the fullest extent permissible in the model.

It is found that no optimal timber utilisation strategy includes sawntimber chemical treatment facilities that are capable of treating all the sawntimber predicted to be produced in the strategy. Consequently, a large proportion of harvested logs is forecast to be sawn such that all sapwood is removed. This indicates that the financial and employment generation benefits of chemically treating timber against lyctid susceptibility, which facilitates the legal the sale of timber with sapwood, are small in the study region. Vacuum pressure chemical treating of sawntimber is predicted only to be optimal in large-scale sawmilling strategies possible when the capital constraint is $10 M.

Kilns for seasoning sawntimber are rarely forecast by the GP model to feature in optimal timber utilisation strategies for Wik people. Air-drying is the optimal seasoning method due to the relatively low fixed and variable costs of this seasoning method in the study region compared with the other seasoning methods examined. Generally, kilns are only predicted in the optimal forestry policies for the preference structure implied by the LGP employment objective function[6] and where sawntimber production exceeds the maximum capacity of air-drying sheds, which can occur when the budget constraint is greater than or equal to $5 M (total area of air-drying sheds is constrained to less than or equal to 4,000 m^2).

As a high capital cost activity, with sawmilling and kiln-drying as prerequisite activities, strip-flooring manufacture becomes financially feasible at a budget

[6] Kiln operation generates more employment than air-drying.

constraint of \$5 M; however, other forestry activities better satisfy Wik forestry objectives at this capital budget constraint level. Strip flooring enters the optimal timber utilisation strategy only at a budget constraint of \$10 M, when the combination of high-value output and high employment generation results in this activity being optimal for all preference structures examined.

Small-scale dining table and chair kit manufacturing is unlikely to best satisfy Wik forestry objectives. This is somewhat surprising given furniture manufacturing provides a low capital cost means for generating a relatively large number of jobs in town and produces high-value output. However, small-scale furniture manufacture is a low throughput activity, exacerbated in Aurukun by low labour productivity, such that production costs are high relative to finished product price. Chemical treatment of poles, which has a capital requirement similar to furniture manufacturing, is more financially lucrative and additional investment in sawmilling machinery is capable of to generating more jobs per dollar of capital invested than furniture manufacture.

In the interest of limiting the length of this paper, reporting of the GP model's predictions about the timber resources utilised in optimal forestry strategies has been omitted. However, some comments about their implications for forestry opportunities in Aurukun are warranted. First, except for large-scale forestry operations facilitated by capital budget constraints of \$5 M or \$10 M, it is optimal to confine timber harvesting to forest type 1, which has high standing volumes of merchantable timber compared with forest types 2 to 5. Second, timber utilisation strategies generated by the GP model indicate that harvesting Melville Island bloodwood is unlikely to be commercially attractive. Third, the optimal timber harvesting strategies generated by the GP model generally involve harvesting all merchantable Cooktown ironwood logs in a hectare and sufficient volume of high-quality Darwin stringybark logs (poles and 'compulsory sawlogs') to attain the minimum harvest allowed by the model of 2 m^3/ha before moving the harvesting operation into the next hectare of forest 'chasing' more Cooktown ironwood logs. An interesting exception to the harvest of Cooktown ironwood and high-quality Darwin stringybark logs occurs when employment generation is the highest priority goal (i.e. the LGP employment objective function). In that case, the harvest of low-quality logs is predicted to be optimal. Low-quality logs yield a lower percentage of sawntimber, meaning that a higher volume of logs are required to manufacture a particular volume of finished sawntimber products. This has the potential to generate more employment (while increasing operating costs) in forest management, timber harvesting, hauling and sawmilling than is possible when utilising high-quality logs.

6. CONCLUSION

A financially viable Wik forestry industry that satisfies Wik forestry objectives could be developed on CYP. However, optimal timber utilisation strategies for the study region only infrequently involve the production of dressed, finished products with high technology equipment and skilled labour, which some representatives of Wik people have advocated. On the contrary, the Wik Forestry GP model suggests relatively low-technology production methods (e.g. portable sawmilling, chemical treatment by soaking and air-drying) are likely to better satisfy Wik forestry objectives. A social analysis of privately optimal timber utilisation strategies for Wik people, which accounts for transfer payments, the social order and self-esteem benefits of ‘real economy’ employment in Aurukun and the costs of ecosystem services foregone through the selective harvesting of Darwin stringybark forests has been performed and is the subject of a forthcoming paper.

ACKNOWLEDGEMENTS

The author would like to thank the Rural Industries Research and Development Corporation, Cape York Partnerships (Queensland Department of State Development), the Australian Centre for International Agricultural Research and the Queensland Department of Natural Resources and Mines for funding for this research

REFERENCES

Annandale, M. and Taylor, D. (2000), ‘Draft project outline: developing a sustainable forest management system for the forests of Cape York Peninsula’, Queensland Forestry Research Institute, Atherton.

Annandale, M.G., McGavin, R.L. and Venn, T.J. (2002), 'Injinoo Sawmilling Project Phase 1: Small-Scale Timber Processing', Queensland Forestry Research Institute, Brisbane.

Balkanu Cape York Development Corporation (c1999), *Cape York*, http://balkanu.com.au/capeyork.htm, accessed 16 May 2000.

Bootle, K.R. (1983), *Wood in Australia: Types, Properties and Uses*, McGraw-Hill, Sydney.

Clark, N. (2003), Principal Experimental Scientist, Papermaking Systems, CSIRO Forestry and Forest Products, Clayton South (Victoria), personal communication.

CYRAG (Cape York Regional Advisory Group) (1997), *Cape York Peninsular Land Use Strategy - Our Land Our Future: A Strategy for Sustainable Land Use and Economic and Social Development*, Cape York Peninsular Land Use Strategy, Department of Local Government and Planning, Cairns, and Department of the Environment, Sport and Territories, Canberra.

Davis, A.G.W. (2001), Regional Sales Officer, DPI Forestry, Atherton, personal communication.

Department of Primary Industries Forest Service (1994), *Hardwood Log Classification Guidelines*, Department of Primary Industries Forest Service, Brisbane.

Department of the Premier and Cabinet (2000), *Cape York Partnerships: Some Practical Ideas*, Queensland Government, Brisbane.

Hopewell, G.P. (2001), 'Characteristics, Utilisation and Potential Markets for Cape York Peninsula Timbers', Queensland Forestry Research Institute, Brisbane.

Ignizio, J.P. and Perlis, J.H. (1979), 'Sequential linear goal programming: implementation via MPSX', *Computers and Operations Research*, **6**(3): 141-45.

McGaughey, R.J. (1997), 'Visualizing forest stand dynamics using the stand visualization system', in, *Proceedings of the 1997 ACSM/ASPRS Annual Convention and Exposition*, April 7-10, Seattle, WA, American Society for Photogrammetry and Remote Sensing, Vol. 4: 248-257.

Smith, W.J., Kynaston, W.T., Cause, M.L. and Grimmett, J.G. (1991), *Building Timbers: Properties and Recommendations for their Use in Queensland*, Queensland Forest Service, Brisbane.

Venn, T.J. and Harrison, S.R. (2001), 'Appropriate Multi-Criteria Decision Support Tools for Aiding Indigenous Decision-Makers in Aurukun Shire, Cape York

Peninsula', in F. Ghassemi, M. McAleer, L. Oxley and M. Scoccimarro (eds), *Integrating Models for Natural Resources Management Across Disciplines, Issues and Scales, Volume 3: Socio-economic Systems*, MODSIM 2001, international congress on modelling and simulation, 10-13 December 2001, The Australian National University, Canberra, Modelling and Simulation Society of Australia and New Zealand Inc., Canberra, pp. 1097-102.

Venn, T.J. (2003), 'Property rights of Wik people to timber resources on Cape York Peninsula, Australia', a paper presented at the International Association for the Study of Common Property (IASCP) Regional Workshop, Traditional Lands in the Pacific Region: Indigenous Common Property Resources in Convulsion or Cohesion, 7-9 September 2003, Brisbane, available on-line at http://www.indiana.edu/~iascp/pacific2003.html.

Venn, T.J. (in press), 'Potential markets for logs and sawn timber from the Darwin stringybark forests of Cape York Peninsula', in J. Suh, D. Smorfitt, J. Herbohn and S. Harrison (eds), *Marketing of Farm-Grown Timber in Tropical North Queensland*, monograph no. ?, Rainforest CRC, Cairns.