ESTIMATION OF COSTS AND BENEFITS OF THE COMMUNITY RAINFOREST REFORESTATION PROGRAM IN NORTH QUEENSLAND[1]

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This paper reports the experiences in a study designed to estimate the total economic value of a reforestation program in North Queensland. The Community Rainforest Reforestation Program was commenced in 1993, with stated objectives relating to timber production, protection of degraded land, improvement in water quality and workforce training. The various perceived cost and benefit contributions of this program have been identified with the aid of surveys of landholders and local government. Estimates have been derived of program costs and, where possible, of the level of benefits within identified categories. On the basis of this analysis, the CRRP appears to be marginally justifiable in economic terms. Within the resources available for the study, some program benefits could not be valued, including the 'social healing' value following the bitter local controversy over World Heritage listing, and the research value gained from growing a wide variety of species of high-quality tropical rainforest timbers in plantations.

1. INTRODUCTION

World Heritage listing of the Wet Tropics of Queensland rainforests in 1988 removed a substantial timber resource from production, and created considerable local hostility. Eleven local government authorities[2] (LGAs) subsequently secured approval and financial support from the Federal and State government to jointly

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[2] The 11 original LGAs participating in the CRRP are: Atherton, Johnstone, Douglas, Mareeba, Cardwell, Herberton, Cook, Hinchinbrook, Eacham, and Mulgrave and Cairns (merged in 1995). Three further LGAs participated in the program in 1995, viz. Mackay, Mirani and Whitsunday.

develop the Community Rainforest Reforestation Program (CRRP). This program had four goals, declared to be of equal importance, *viz*. developing a private plantation timber resource; arresting degradation of land following inappropriate clearing; improving water quality in rivers and streams; and training of a workforce to support rainforest plantation establishment (CRRP Management Committee, 1993).

Planting of mainly native hardwood tree species under the CRRP commenced in 1993. Initially, landholders were required to prepare and fence the site only, and government met all seedling and planting costs, as well as some subsequent maintenance. In 1995, a fee was introduced for participation, on a per hectare basis, but below the real cost. The area planted under this program totalled 1,142ha between 1992-93 and 1994-95 (CRRP Committee, 1995). After 1995, the program was contracted, and currently involves support for forestry extension but not tree planting.

The CRRP has been a unique experiment in growing native rainforest tree species, many of which have outstanding quality timber for furniture purposes. Prior to the program, little was known about the establishment requirements or growth performance of most of the species planted. It was clear that in addition to the value of timber produced, the CRRP would have a number of non-wood benefits, and a research project was developed with the aim of estimating the total economic value (TEV) and benefit-cost performance of the program.[3] Project findings would provide feedback to the governments involved on the desirability of this program, and guidance for future forestry support programs.

This paper discusses the research methodology and the findings of the economic evaluation of the CRRP. The next section discusses results of the surveys of local government authorities and of landholders designed to assess which benefits of the CRRP were most important to them. Section 3 reports on estimation of program costs, while Section 4 discusses estimation of program benefits. Section 5 presents findings on overall economic performance, and examines the sensitivity of performance in relation to a number of key parameters. An overall assessment of the evaluation is provided in Section 6. In Section 7, some policy implications for future tree planting programs are presented. Section 8 provides concluding comments.

2. PROGRAM BENEFITS AND THE ECONOMIC MODEL

While market costs and benefits (i.e. program costs and timber revenue) for the CRRP could be clearly identified, the nature of non-timber benefits was more difficult to identify. To adopt the TEV approach, a 'long list' of potential CRRP benefits was drawn up, from discussions with people involved in the program and from literature search. Measures were then taken to identify the most important benefit categories, including surveys of LGAs and landholders.

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[3] Total economic value in the case of farm forestry has been defined to include use value (direct, indirect and option value) and non-use value (bequest and existence value) (Harrison, 2000).

A questionnaire was developed to identify what benefits local government expected to gain from the program. Executive officers of 10 of the 14 local governments in the CRRP area agreed to be interviewed, and ranked potential benefits in order of importance as in Table 1. LGAs appeared to place greatest priority on commercial benefits – such as timber production, employment, attractiveness of the area for ecotourism, and business establishment – and a relatively low ranking on environmental benefits.

TABLE 1

RANKING OF POTENTIAL BENEFITS OF THE CRRP BY LOCAL GOVERNMENTS

Benefit category	Number of mentions	Mean rank
Sustainable supply of timber for future generation	10	3.2
Increased employment prospects in the shire	9	3.4
Community cohesion through employment scheme	5	4.4
Ecotourism	4	4.4
Establishment of other businesses relying on timber	6	4.5
Improvement of water quality	5	5.0
Increased awareness of environmental issues	8	5.1
Increase land values and bank credit rating to landholder	4	5.5
Decreasing the greenhouse effect	2	5.5
Education of landholders in forestry	8	6.1
Improvement of soil	4	6.3
Establishment of nurseries (large suppliers of seedlings)	6	6.8
Decreasing costs of pollution and sedimentation in water streams (i.e. anti-pollution devices not required)	3	7.0
Increase in revenue from fishing	2	7.0
Research benefits of the scheme (mix. spec. plant.)	8	7.1
Future decrease of timber imports (reduce national deficit)	9	7.5
Potential emergence of small businesses	7	8.1
Increase biodiversity	3	9.3

A postal survey was conducted of CRRP members to determine their ranking on prospective program benefits, with 48 responses obtained from 100 questionnaires (a one in four sample). As indicated in Table 2, landholders tended to place greatest priority on environmental benefits – such as wildlife habitat, water quality in streams, noise attenuation and farm beautification – rather than commercial benefits. This is consistent with findings of surveys of farm forestry in the farming community at large in North Queensland (Broome 1993; Emtage *et al.* 2001).

An economic model of farm forestry has been developed taking this information into account. The model is composed of six sub-models designed to estimate (1) plantation establishment, maintenance, harvesting and management costs, (2) timber revenue, (3) carbon sequestration benefits, (4) water quality improvement and savings in water treatment costs, (5) economic flow-on benefits, and (6) other benefits (education, training and 'conservation'). These benefit categories chosen for estimation were based on importance ratings of stakeholders, and ability to make estimates of them given the time, budget and data availability limitations of the study.

TABLE 2

RANKING BY CRRP MEMBERS OF PRIVATE BENEFITS OF THE PROGRAM

Benefit category	Mean score	Rank by mean score	Frequency of mentions in top five benefits	Rank by frequency of mentions in top five
Improvement of soil nutrients	4.0	4	14	8
Improving water quality in watercourses and storages	4.1	5	23	2
Protecting wildlife habitat	3.9	3	28	1
Decreasing sedimentation in watercourses and storage	4.6	8	19	6
Complementing superannuation or pension	5.7	14	13	9
Increasing land values and bank credit rating	5.8	15	11	10
Developing small businesses relying on secondary forest products	6.2	16	8	12
Learning new skills in forestry	4.3	7	7	13
Legacy for children	4.6	9	21	3
Increasing pasture output	7.4	19	1	18
Increasing output of crops	7.8	20	1	18
Decreasing fertilisers input	6.6	17	1	18
Increasing milk yield	0.0	21	0	21
Shade for cattle	4.8	6	5	15
Windbreak	5.7	13	9	11
Establishing a plantation for logging	4.6	10	20	4
Decrease the impact of drought	7.1	18	4	17
Farm beautification	5.0	11	20	4
Buffer zone (e.g. to attenuate noise)	3.4	1	6	14
Arresting soil erosion	5.2	12	17	7
Others	3.7	2	5	15

Since the CRRP is a one-off program, some of the species planted have very long rotations, and whether landholders will replant after final harvest is uncertain, the net present value over a 50-year planning horizon was chosen as a performance criterion. The NPV takes account of both timber production and non-wood forest benefits (NWFBs):

$$NPV = -E + \sum \frac{RW(1-i)^t}{(1+r)^t} + \sum \frac{BNW}{(1+r)^t} - \sum \frac{C}{(1+r)^t} \quad (1)$$

where

NPV is the net present value of wood and non-wood benefits ($/ha);
E are the establishment costs ($/ha);
RW_t is revenues from timber timber sales in year t (t = 20, 30, 40 and 50) ($/ha);
BNWt are non-wood forest benefits ($/ha);
C_t are annual recurrent and non-recurrent costs ($/ha);
r is the real discount rate expressed as a decimal value; and
i is the real annual increase in stumpage value expressed as a decimal value.

The time base for discounting is 1 July 1993 (approximating the commencement of the program), and NPVs are adjusted to 1 July 2001.

3. PROGRAM COSTS

A distinction may be made between plantation costs and program management (including training) costs. The former have been estimated for plantations established during the first three years of operation of the CRRP, and include plantation establishment costs and post-planting and harvesting costs. Plantation establishment costs include those reported in CRRP annual reports (CRRP Management Committee, various years), and costs of inputs provided by landholders (e.g. for vegetation removal, ploughing or ripping and fencing) and time spent by Department of Primary Industries officers diverted from their normal duties to administer the program and to train LEAP participants. The costs of landholders time and machinery used including diesel to prepare the land for planting was estimated at $265/ha. Table 3 summarises initial costs (E in formula 1). The first two rows represent DPI costs, the third row landholder costs, and the remainder program costs.

TABLE 3

INITIAL COSTS FOR PLANTATION ESTABLISHMENT, 1992-93 TO 1994-95 ($M)

Activity	Year			
	1992-93	1993-94	1994-95	1992-95
Planning and management	0.33	0.29	0.19	1.01
Extension activities and support	0.02	0.14	0.20	0.36
Site preparation and cultivation	0.07	0.12	0.12	0.30
Cover crop establishment	0.02	0.04	0.04	0.10
Pre-plant weed control	0.02	0.04	0.04	0.11
Cost of plants	0.18	0.49	0.39	1.07
Planting and refilling	0.17	0.28	0.28	0.74
Post plant weed control	0.14	0.24	0.24	0.62
Fertiliser	0.02	0.04	0.04	0.09
Fencing	0.14	0.24	0.25	0.63
Total costs for the CRRP	1.12	1.92	1.78	4.81
Average cost ($/ha)	4,205	4,388	4055	4,216

Source: CRRP Management Committee (various years).

TABLE 4

RESEARCH, EDUCATION AND TRAINING COSTS, 1992-93 TO 1994-95

Cost item	Year of incurring cost			Total costs for
	1992-93	1993-94	1994-95	three years ($)
Training and education	20,829	135,619	101,039	257,487
Information system	14,140	105,102	143,827	263,069
Research and development	3,848	25,831	55,607	85,286
Extension and training	8,657	98,849	196,185	303,691
Conferences	456	9,765	8,403	18,624
Total costs ($)	47,930	375,166	505,061	928,157

TABLE 5

EXPENDITURES FOR THE FIRST THREE YEARS OF TREE PLANTING

Cost item	Expenditure by planting year ($M)			Total cost ($M)
	1992-93	1993-94	1994-95	1992-95
Plantation establishment (from Table 3)	1.12	1.92	1.78	4.81
Research, education and training (from Table 5)	0.05	0.38	0.51	0.93
Total year 0 outlays	1.17	2.29	2.29	5.75
Average cost ($/ha)	4,385	5,248	5,203	5,030

TABLE 6

POST PLANTING AND HARVESTING COSTS ($/HA)

Cost item	Year after planting	Cost
Post plant weed control	1	1,310
Post plant weed control	2	812
Post plant weed control	3	213
First prune(plus certification)	2	880
Second prune (plus certification)	4	649
Third prune (plus certification)	6	864
Thinning	8	501
First harvest marking and inventory	20	80
Second harvest marking and inventory	30	57
Third harvest marking and inventory	40	57
Fourth harvest marking and inventory	50	57
Total cost		5,480

Source: Based on Prydon (1997).

The CRRP had a formal training program that comprised over 25% of the total time involved by trainees (Sheperd, 1993), who were mainly recruited under the Federally funded Landcare and Environmental Action Program (LEAP). Also, there was an emphasis on provision of information, including development of a geographical information system (GIS), conferences, sponsorships and other education activities. These are not costs which can be allocated to timber production from a commercial perspective. They are more appropriately considered as investment in forestry research and education, which may lead to greater productivity in future forestry activities. Table 4 presents these costs for each of the three main planting years. Total initial or 'year 0' expenditures in the first three years are summarised in Table 5.

To these initial costs must be added post-planting costs (C) – including those for weed control, pruning and certification – and harvesting costs. These vary thoughout plantation age as indicated in Table 6, and have been included in the cost streams for the three main planting years. Except for the first three years of maintenance, annual costs are only applied to areas for which harvest is intended (928ha).

Some other (social) costs have no doubt arisen from the CRRP, e.g. where plantings provide a habitat for feral animals which damage cane crops. However, there will also be beneficial impacts, e.g. habitat for owls which will result in reduced rat damage to sugarcane crops. No allowance has been made for habitat value in this study. An allowance for the opportunity cost of land of $40/ha/year has been included, this low figure being due to the relatively degraded land used for plantations. The cost estimates by year are summarised in Table 7. Total economic costs of the program are estimated at $12M.

TABLE 7

AREAS OF COMMERCIAL TREE SPECIES PLANTED AND TIMBER VOLUMES LISTED BY TREE SPECIES GROUPING AND BY YEAR OF PLANTING

Species group	MAI (m^3)	Rotation length (year)	Area (ha) of trees planted by year and group			Volume of timber (m^3) by year of planting and by group		
			1992-93	1993-94	1994-95	1992-93	1993-94	1994-95
1	15	20	11.6	19.6	10.2	3,467	5,878	3,055
2	5	30	3.2	8.2	2.9	477	1,236	442
3	15	30	109.2	206.6	180.9	49,140	92,960	81,401
4	10	40	0.1	3.9	7.5	50	1,561	2,983
5	5	50	45.3	60.1	83.7	11,313	15,029	20,916
6	15	50	55.4	41.7	54.5	41,518	31,308	40,904
7	8	50	0.0	4.5	16.3	0	2,143	7,822
Total			224.7	344.6	356.0	105,966	150,115	157,524
Volume of timber produced per hectare (m^3)						472	436	443

4. PROGRAM BENEFITS

4.1 Estimation of revenue from timber production

In estimating the value of timber produced, it is assumed that 20% of trees will never be harvested, mostly in riparian areas[4], but also including areas of low timber quality and where small numbers of individual species have been planted in the program.[5] It is assumed that no planting will take place during staged harvesting of the various species – allowing the more valuable or slower-growing species to occupy more space – with a final clearfell in year 50. Staged harvesting is consistent with the harvest scheduling modelled for a Queensland Maple *(Flindersia brayleyana)* and Red Mahogany (*Eucalyptus pilularis)* stand by Herbohn and Harrison (2001).

The various species with commercial timber value (over 140 species in total) have been classified into seven main groups based on growth rates and rotation length. It is assumed that the harvest age and growth rate (mean annual increment, MAI) is common within groups. These data (based on Keenan 1998 and Herbohn *et al.* 1999) are used to derive estimated timber turnoff (Table 7). Species group 1 includes *Grevilla robusta* and *Acacia mangium*; species group 2 includes the *Acacia* species except *Acacia mangium*; species group 3 which is the majority of trees planted includes all the Eucalypt species and *Elaeocarpus augustifolius*; species group 4 includes *Cedrela odorata*; species group 5 includes *Castanospermum australe*, the Flindersia species, *Nauclea orientalis*, *Tectona grandis* and *Elepharocarya involucrigeras*; species group 6 includes the Araucaria species and *Agathis robusta*; and species group 7 is *Paraserianthes toona*. The price of standing timber (or stumpage), was estimated at $30/m^3 at age 20, $50/m^3 at age 30, $148/m^3 at age 40 and $250/m^3 at age 50, based on Herbohn *et al.*, (1997) and DPI-Forestry (1997) (cited in Harrison and Herbohn, 1997). Revenue from logging and haulage is added (based on Stewart and Hanson, 1998), NRE, 2001), to obtain the mill-gate value of timber, or a price if landholders log and transport the timber themselves (e.g. as a cooperative). It was further assumed that the price of timber would increase in real terms at an annual rate of 0.3% following Sohngen *et al.* (1999).

4.2 Estimation of carbon sequestration benefits

Since CO_2 is the most important cause of global warming, the function of trees as a carbon sink is an important positive externality. In that carbon is not a traded product at the individual farm level, the benefit is a shared global rather than solely a national one. However, it seems appropriate to include a benefit for carbon sequestration in the analysis since Australia (along with other countries) can be

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4 Discussions with DPI forestry officers at commencement of the CRRP indicated an intention that about 80% of the planted area would be for timber production and 20% for permanent rainforest plantings.

5 Where fewer than 5,000 trees of any species was planted, it was assumed that the timber quantity would be insufficient for a commercial market to be found.

expected to face real costs in reducing net carbon emissions in the future, and is already doing so to some extent.

To estimate the annual uptake of carbon in a tree plantation, it is necessary to model biomass volume. There is a lack of consensus among foresters about the best form of a mathematical function to describe tree growth, possibly because of the lack of data on – and limited understanding of – the growth process (Leech and Ferguson 1981; Clutter *et al.*, 1993; Zeide 1993). Zeide (1993) showed that most tree growth equations can be reduced to one of two basic functional forms, differing essentially only in the decline component. The Gompertz function has been adopted in this study, expressed as (BTCE, 1996, p.30):

$$V_t = V_m e^{-be^{-kt}} \tag{2}$$

where V_t is the volume of biomass/ha in standing trees at time t, V_m is the maximum biomass volume over the life of the plantation, t is time expressed in years and b and k are constants. At planting (t=0), b = ln (Vm / V_0), where V_0 is the volume of CO_2 in the seedlings, k = ln b / t_m, t_m is the year at which the asymptotic mass is reached, and ln is the natural logarithm.

Equation (2) estimates the total biomass sequestered in stems, branches, leaves, roots and litter. The total volume of biomass is assumed to equal the useable timber volume plus branches and leaves volume estimated to be 50% of useable timber volume (estimated using the MAIs of Table 7), plus underground biomass estimated at 20% of above-ground biomass. To obtain from the biomass, the mass of carbon sequestered, the following assumptions are made: 45% of the biomass is carbon (following NGGIC, 1996, p. 22) and the carbon density is 0.44 tonnes /m^3 (following Turner 1990). Annual carbon mass increments are then estimated from the annual biomass increments for the seven species groups.

Offsetting carbon costs will occur in plantation establishment and maintenance, and in harvesting, transport and timber milling and processing, and some CO^2 will be released back into the atmosphere in decomposition of harvest residues, milling wastes and expended products. Carbon emissions from plantation machinery and log transport are estimated at 308t over 50 years[6]. The economic benefit from carbon sequestration, net of emissions, was then estimated by adopting a value of $23/tC sequestered (BTCE, 1996) accruing from the time of planting. The peak in

6 Carbon emissions occur when the land is being prepared and when logs are transported. The quantity of carbon emitted in land preparation in year 0 is estimated as Eo = DCEFH, where D the distance driven by a tractor or truck (km), C is the consumption of fuel (litres/100 km), E is the energy density of diesel (38.7 Mjoules/litre), F is the CO^2 emission factor (69.7 grams/Mjoules) and H is a conversion factor from CO^2 to carbon mass (H= 12/44). The mass of carbon released into the atmosphere to transport logs after each harvest is estimated as Eh = DTCEFH, where D = 100 km, T is the number of trips made by the trucks, C is diesel consumption (litres/100 km), and E, F and H are as above. Log trucking distance each way from harvest location to mill is assumed to average 50 km, and load capacity 26 tonnes of timber, which is equivalent to about 52 m^3 of timber, assuming a timber density of 0.5 t/m^3 (after BTCE, 1996, p. 37). The truck type to carry logs is 'rigid truck' with a consumption of diesel fuel of 26.5l/100km (after BTCE, 1996).

carbon sequestration is estimated at 22,256 t in year 2003, with total sequestration for the 1142 ha of 146,885t after all harvesting has been completed.[7]

4.3 Estimation of water quality benefits

It was not possible to derive independent estimates of water quality improvements for the CRRP; therefore, benefit-transfer methodology has been adopted to estimate the value of increased volume of water available and the saving in water treatment costs. Various studies (Alexandra 1992; Subramaniam 1995; Fahey and Jackson, 1995; Ferguson 1996) suggest strongly that an increased volume of water will become available for use following reforestation. The value of increased water yield due to the CRRP is estimated with reference to the predicted population in the North and Far North Queensland statistical divisions (SDs) over the next 50 years.

The population of 400 landholders in the CRRP as at June 1995 had on average planted 2.8 ha of trees. Given that 28% of the CRRP participants had trees planted along watercourses and water storages (Eono and Harrison, 1996), the total area of CRRP planting along watercourses and water storages would be 320 ha. With the increase water yield valued at $25.6/ha[8], the total benefit is $8,051 (about $7/ha/pa) per year, assumed to commence 30 years after planting.

Treatment costs provide a market value for improvement in water quality to potable standard. Water treatment costs for each LGA were obtained by telephone from persons in charge of water treatment, and savings from improved water quality estimated from decrease in treatment plant costs. These savings amounts to $9,937/year (about $8.7/ha) assumed to commence four years after planting. Further details of the estimation of water yield and quality benefits are provided by Eono and Harrison (2001).

4.4 Estimation of economic flow-on benefits

Reforestation will give rise to economic flow-on benefits to upstream industries, both at the time of plantation establishment and at harvest. Inter-industry input-output analysis provides a means of estimating these flow-on benefits, and income multipliers may be taken as an approximation to consumer surplus gains. Multipliers for a proposed farm forestry program in the Goulburn Valley have been derived by Todd *et al.* (1997), and these have been adapted in benefit transfer to CRRP plantings.[9]

The regional benefits were estimated from input-output multipliers taken as an approximation to economic surplus for NPV estimation. The total expenditure (estimated after all taxes, profits and downstream expenses) spent on the

7 The logic behind parameter estimates is further explained in Eono (2001).

8 Estimated by using an extra water yield of 3.7 Ml/ha (after Alexandra, 1992), and a price of $6.80/ML at Tinaroo Dam (DNR, 1997).

9 The multipliers used for the harvesting phase here actually correspond to those in the 'transitional I phase' which includes only harvesting in the Todd *et al.* (1997) study. Further, no steady phase is considered in the CRRP (harvesting and replanting) because no assumption of replanting is made.

establishment phase in upstream sectors was $1.1M. Also, an expenditure of $9.7M was estimated for the harvesting periods for haulage[10] (diesel, purchase of trucks, truck maintenance and repairs) and logging costs (portable mills purchase, protective clothing). The regional benefit flows-on are estimated at $1.14M for the establishment phase (1992-93 to 1994-95), using a multiplier of 1.0395 (Todd *et al.*, 1997, p. 130), and $3.75M, for the harvesting phase, using a multiplier of 0.3861 (Todd *et al.*, 1997, p. 138). These amounts have been apportioned by year of activity relative to the area planted and area harvested.

4.5 Estimation of education and training benefits

The workforce in the CRRP was mainly provided through a Commonwealth government Landcare and Environment Action Program (LEAP) labour market program implemented in 1992 for people between the ages of 15 and 20 years. Training time in this program consisted of 50% on-the job training and 50% at TAFE colleges. Participants received an allowance of $125 per week if under 18 and $150 per week otherwise. The CRRP as a labour force broker also received $3,930 from the Commonwealth for each participant trained.

In 1992-93, the program employed and trained 50 LEAP placements and 10 supervisors. In 1994, 220 LEAP placements, 17 Job Start placements, 17 General Forest Workers and 21 Field Supervisors were employed and trained (CRRP Committee, 1993-94). In 1995, 237 LEAP trainees and 27 older participants worked in the program (CRRP Committee, 1994-95). The training took an holistic approach including how to plant seedlings and communications skills, and instilled in the trainees a level of self-confidence which became an asset for subsequent employment.

It has not been possible given the resources available to this study to evaluate the private and social benefits of increased human capital arising from the involvement of LEAP trainees. Existence of the CRRP provided excellent field sites for on-the-job training. On the other hand, the trainees were not given continuing paid employment in the CRRP so benefits depended on them obtaining employment in other forestry programs or other employment areas. In the absence of better information, expenditure on training has been taken as an estimate of training and education benefits, and these are reported in Table 10. Because of the uncertainty surrounding education and training benefits, the economic evaluation has been performed both inclusive and exclusive of these estimates.

TABLE 10

BENEFITS OF TRAINING AND EDUCATION IN THE CRRP

Year	1992-93	1993-94	1994-95	1992-95
Training and education benefits ($)	20,829	135,619	101,039	257,487

10 Figures based on 8,890 trips averaging 100km per trip, a fuel consumption of 26.5l/100km and the purchase of 10 trucks to meet the extra demand (Eono, 2001).

4.6 Estimation of 'conservation' benefits

The CRRP has given rise to a number of conservation benefits (e.g. see Harrison, 2001). Inclusion of trees of no 'commercial' value reflects this conservation motive by landholders and government. These 'conservation' benefits are particularly difficult to quantify. The expedient adopted has been to estimate timber revenue foregone, i.e. the difference between what revenue would have been generated if only 'commercial' plantings had been undertaken and what it would be with the 20% of the planted area not being harvested. That is, the willingness to forego revenue is assumed to be a proxy for WTP for the private benefits gained. The exact nature of the benefits 'bought' cannot be determined, but may include benefits for future generations, streambank stabilisation, wildlife habitat, recreation benefits and spiritual and aesthetic values of plantations of native species. As indicated in Table 11, an estimated timber revenue of $13.4m is foregone, from which estimated values for improvement in water quality must be deducted to avoid double counting. This deduction amounts to $0.12M, and the total conservation benefit to $12.76M.

TABLE 11

ESTIMATED 'CONSERVATION' BENEFITS

Number of years after planting for benefit to accrue	Timber revenue ($/ha)	Proportion of total timber revenue (%)	Total conservation benefit ($M)	Conservation benefit ($/ha)
20	410	0.68	0.09	76
30	12,068	19.71	2.52	2,202
40	648	1.06	0.14	118
50	48,090	78.55	10.03	8,777
Total	61,217	100.00	12.76	11,174

The proportion of total conservation benefits estimated in Table 11 is assumed to be the same as the proportion of timber revenue foregone.

Notably, only the private conservation benefits would motivate permanent plantings, so external conservation benefits are not included in this estimate. Further, some conservation benefits would be gained from plantations which will be subject to harvesting. Hence the approach adopted here is likely to underestimate conservation benefits. Because of the uncertainty in these estimates, the economic evaluation has been performed both inclusive and exclusive of conservation benefits.

5. OVERALL PERFORMANCE ESTIMATES AND SENSITIVITY ANALYSIS

All of the estimates of value components have been integrated in Equation 1, and net present values derived as in Table 12, in terms of both 1993 and 2001 dollars. With regard to timing of program benefits, it is notable that carbon sequestration benefits occur particularly in the first 16 years of the rotation cycle while no timber benefits occur before the first 20 years of the rotation cycle.

If all the costs are attributed to timber production, and no other project benefits are considered, the NPV in 2001 dollars (7% discount rate) is estimated as a loss of \$6M and an economic internal rate of return of about 5%. When non-timber benefits are taken into account, the program is predicted to generate an NPV of minus \$0.87M, and an economic internal rate of return (EIRR) of 6.5%. This suggests that the program has been of marginal economic value. However, the estimate could be considered a lower bound, since some of the benefit estimates are conservative (particularly training and research benefits).

It is notable that the estimated timber benefits (\$4.9M, including \$3.4M direct benefits plus flows-on of \$1.5M) and non-wood benefits (\$4M, excluding flow-on benefit) are almost equal. Carbon sequestration benefits are the major component of the latter (\$2.9M), followed by conservation benefits of \$0.7M.

If conservation benefits and the training and education benefits are excluded from the economic analysis, because of the uncertainty attached to these values, the net present value of the program is minus \$1.8M [\$0.69M and \$0.25 M are subtracted from – \$0.87M] and the EIRR is 5.95%.

Sensitivity analysis has been conducted to provide some indication of the robustness of the estimated economic performance of the CRRP with respect to key parameters, specifically discount rate, harvest volume, price increase in timber, carbon sequestration value and initial timber prices. Unfavourable scenarios include a 2% increase in discount rate, a real annual timber price fall of 3% (an unlikely scenario), a 10% increase in cost levels, and a value of carbon sequestered of only \$3/t (a possibility) (Table 13). The NPV is most sensitive to the price of timber and discount rate and least sensitive to cost levels and the MAI. Notably, a change in MAI changes not only the timber benefit, but also the carbon benefit.

6. OVERALL ASSESSMENT OF THE EVALUATION

This study has provided a partial economic evaluation of the CRRP. It has not been possible to place values on some potentially important benefit categories, and in some cases where estimates have been made assumptions have been made on the basis of very limited information.

Recent evidence suggests that the area harvested may be less than the 80% assumed in this analysis. Sensitivity analysis was not conducted with respect to this parameter. The proportion which will be harvested is difficult to predict, since harvesting decisions may not be made until many years into the future. It could be that landholders state low harvest intentions because of current indecision and a desire to be seen as being 'environmentally correct'. Should a substantially lower proportion of the planted area be harvested, this could be due to landholders placing a greater private value on tree retention, because of low timber quality (e.g. due to low seedling quality, inherent poor tree form or lack of silvicultural treatments), or because markets for the timber turned out to be weak. At least in the former case, overall program benefits would probably be largely unaffected by this changed harvest proportion, and could even be increased (e.g. less leakage in carbon sequestration benefits).

TABLE 12

ECONOMIC BENEFITS AND COSTS OF THE CRRP ($M, 1993)

Year	Costs	Timber benefit	Net timber benefit	Flow-on benefit	Carbon benefit	Water benefit	Conservation benefit	Training benefit	Total NWFB	Total Benefit	Net benefit flow
1993	1.13	0.00	-1.13	0.27	0.00	0.00	0.00	0.02	0.29	0.29	-0.84
1994	2.29	0.00	-2.14	0.44	0.01	0.00	0.00	0.14	0.58	0.58	-1.71
1995	2.81	0.00	-2.62	0.44	0.02	0.00	0.00	0.10	0.57	0.57	-2.24
1996	1.34	0.00	-1.26	0.00	0.06	0.00	0.00	0.00	0.06	0.06	-1.28
1997	0.95	0.00	-0.89	0.00	0.12	0.00	0.00	0.00	0.13	0.13	-0.82
1998	0.37	0.00	-0.34	0.00	0.21	0.01	0.00	0.00	0.22	0.22	-0.15
1999	0.46	0.00	-0.43	0.00	0.31	0.01	0.00	0.00	0.32	0.32	-0.15
2000	0.35	0.00	-0.33	0.00	0.39	0.01	0.00	0.00	0.40	0.40	0.05
2001	0.46	0.00	-0.43	0.00	0.46	0.01	0.00	0.00	0.47	0.47	0.01
2002	0.22	0.00	-0.21	0.00	0.50	0.01	0.00	0.00	0.51	0.51	0.29
2003	0.22	0.00	-0.21	0.00	0.51	0.01	0.00	0.00	0.52	0.52	0.30
2004	0.05	0.00	-0.04	0.00	0.50	0.01	0.00	0.00	0.51	0.51	0.47
2005	0.05	0.00	-0.04	0.00	0.48	0.01	0.00	0.00	0.49	0.49	0.44
2006	0.05	0.00	-0.04	0.00	0.44	0.01	0.00	0.00	0.45	0.45	0.41
2007	0.05	0.00	-0.04	0.00	0.41	0.01	0.00	0.00	0.42	0.42	0.37
2008	0.05	0.00	-0.04	0.00	0.37	0.01	0.00	0.00	0.38	0.38	0.33
2009	0.05	0.00	-0.04	0.00	0.33	0.01	0.00	0.00	0.34	0.34	0.29
2010	0.05	0.00	-0.04	0.00	0.29	0.01	0.00	0.00	0.30	0.30	0.26
2011	0.05	0.00	-0.04	0.00	0.26	0.01	0.00	0.00	0.27	0.27	0.22
2012	0.05	0.00	-0.04	0.00	0.23	0.01	0.00	0.00	0.24	0.24	0.19
2013	0.06	0.11	0.04	0.05	0.17	0.01	0.02	0.00	0.25	0.35	0.29
2014	0.07	0.19	0.11	0.08	0.12	0.01	0.03	0.00	0.25	0.44	0.36
2015	0.07	0.10	0.02	0.04	0.12	0.01	0.03	0.00	0.21	0.30	0.23
2016	0.05	0.00	-0.04	0.00	0.14	0.01	0.00	0.00	0.15	0.15	0.10
2017	0.05	0.00	-0.04	0.00	0.12	0.01	0.00	0.00	0.13	0.13	0.08
2018	0.05	0.00	-0.04	0.00	0.11	0.01	0.00	0.00	0.12	0.12	0.07
2019	0.05	0.00	-0.04	0.00	0.09	0.01	0.00	0.00	0.10	0.10	0.06
2020	0.05	0.00	-0.04	0.00	0.08	0.01	0.00	0.00	0.09	0.09	0.05
2021	0.05	0.00	-0.04	0.00	0.07	0.01	0.00	0.00	0.08	0.08	0.04

TABLE 12 (CONTD)

Year	Costs	Timber benefit	Net timber benefit	Flow-on benefit	Carbon benefit	Water benefit	Conservation benefit	Training benefit	Total NWFB	Total Benefit	Net benefit flow
2022	0.05	0.00	-0.04	0.00	0.06	0.01	0.00	0.00	0.07	0.07	0.03
2023	0.06	2.59	2.37	0.44	-0.46	0.01	0.59	0.00	0.57	3.17	3.11
2024	0.07	5.28	4.87	0.89	-0.94	0.01	0.96	0.00	0.93	6.21	6.15
2025	0.07	4.49	4.14	0.75	-0.81	0.02	0.97	0.00	0.92	5.41	5.35
2026	0.05	0.00	-0.04	0.00	0.04	0.02	0.00	0.00	0.06	0.06	0.01
2027	0.05	0.00	-0.04	0.00	0.03	0.02	0.00	0.00	0.05	0.05	0.01
2028	0.05	0.00	-0.04	0.00	0.03	0.02	0.00	0.00	0.05	0.05	0.00
2029	0.05	0.00	-0.04	0.00	0.03	0.02	0.00	0.00	0.05	0.05	0.00
2030	0.05	0.00	-0.04	0.00	0.02	0.02	0.00	0.00	0.04	0.04	0.00
2031	0.05	0.00	-0.04	0.00	0.02	0.02	0.00	0.00	0.04	0.04	-0.01
2032	0.05	0.00	-0.04	0.00	0.02	0.02	0.00	0.00	0.04	0.04	-0.01
2033	0.06	0.02	-0.04	0.00	0.02	0.02	0.03	0.00	0.07	0.08	0.03
2034	0.07	0.27	0.19	0.02	0.00	0.02	0.05	0.00	0.09	0.36	0.29
2035	0.07	0.50	0.41	0.03	-0.02	0.02	0.05	0.00	0.08	0.58	0.52
2036	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.01
2037	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.02
2038	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.02
2039	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.02
2040	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.02
2041	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.02
2042	0.05	0.00	-0.04	0.00	0.01	0.02	0.00	0.00	0.03	0.03	-0.02
2043	0.06	14.64	13.63	0.39	-0.55	0.02	2.34	0.00	2.20	16.84	16.78
2044	0.06	14.32	13.33	0.44	-0.48	0.02	3.83	0.00	3.81	18.13	18.07
2045	0.04	19.92	18.58	0.63	-0.64	0.02	3.86	0.00	3.86	23.78	23.74
PV (7%, 93$)	8.58	2.98	-5.30	1.32	2.58	0.11	0.61	0.22	4.84	7.82	-0.76
PV (7%, 01$)	9.79	3.40	-6.05	1.51	2.94	0.12	0.69	0.25	5.52	8.92	-0.87

In terms of omitted benefit categories, landscape quality appears to have high values for property owners, and tree planting improves the landscape appearance for tourists relative to the previous degraded landscape. A survey of rural property valuers and real estate agents reported in Harrison *et al.* (2001) found that reforestation does lead to an increase in property value, although the expenditure on plantation establishment is not fully capitalized into land value. However, to include impact on land value would be to double count this asset value, to the extent that plantations are harvested and generate income. It is notable that 72% of the CRRP landholders surveyed perceived that tree plantings will increase the value of their properties, though most thought the increase would be less than 2%. In the local government authorities survey, 27% of respondents shared the view that tree plantations will increase the value of properties as well as assist landholders in obtaining bank loans. Other social benefits could be factored into the analysis, including increased knowledge about the silvicultural requirements and performance of rainforest species, training in silvicultural techniques, the increased planting outside the program due to the demonstration effect of successful stands, and the social healing brought about program following the acrimony arising from World Heritage listing of Wet Tropics rainforests.

7. DISCUSSION

This study has revealed that estimation of the overall economic performance of a publicly supported program with multiple environmental and social benefits is indeed a challenging task. There has been heavy reliance on benefit transfer methodology, and a large number of assumptions have been required. In interpreting overall estimates of economic performance, it must be recognized that some of the benefit estimates have been made with a high degree of uncertainty. Also, the surveys of LGAs and landholders indicate that a number of other private and social benefits have been generated by the program, hence the analysis underestimates overall economic performance of the CRRP.

Somewhat counter to expectations, the non-wood benefits of the mixed-species plantings under the CRRP appear to be no larger than the timber benefits. Nevertheless, the study suggests that overall program benefits justify government subsidisation of farm forestry in this particular program, given the estimated economic internal rate of return of 6.5% when only partial benefits are included and conservative assumptions are made. Given that there are economies of scale in production and marketing, presumably timber profitability could be increased by larger plots and use of a smaller number of more well recognized species, although this could reduce the non-wood benefits of the program. Surveys conducted in this study revealed that landholders are eager to plant more trees on their properties, so relatively small but well targeted assistance programs might promote further planting.

Regional flow-on benefits from reforestation are somewhat limited, because activity in the early years is limited to land preparation and tree planting and establishment, and flow-on benefits at the harvest stage must be heavily discounted. Also, the spatially dispersed nature of the plantings in 400 separate small plots

TABLE 13

PERFORMANCE SENSITIVITY TO CHANGES IN KEY PARAMETERS ($M, YEAR 2001 PRICES)

Parameter being changed	Change (%)	Total costs (C)	Timber revenue (T)	Cash-flow (A)	Flow-on benefit (F)	Non-wood forest benefits (NWB)				Total (NWB) (B)	Benefit-flow (A+F+B-C)	NPV
						Carbon	Water	Conservation	Training			
Baseline	7%	9.8	3.4	-6.0	1.5	2.9	0.1	0.7	0.3	4.0	8.9	-0.9
Discount rate	5%	8.6	8.9	0.2	1.3	2.6	0.1	0.6	0.2	3.5	13.7	5.1
	9%	9.1	1.6	-7.1	1.3	2.4	0.1	0.3	0.2	3.0	6.0	-3.1
Timber price	+3%	9.8	10.1	0.2	1.5	2.9	0.1	0.7	0.3	4.0	15.6	5.8
	-3%	9.8	1.0	-8.3	1.5	2.9	0.1	0.7	0.3	4.0	6.5	-3.3
All costs	+10%	10.8	3.7	-6.7	1.5	2.9	0.1	0.7	0.3	4.0	9.3	-1.5
	-10%	8.8	3.1	-5.4	1.5	2.9	0.1	0.7	0.3	4.0	8.5	-0.3
Carbon price	$3/t	9.8	3.4	-6.0	1.5	0.4	0.1	0.7	0.3	1.5	6.4	-3.4
	$50/t	9.8	3.4	-6.0	1.5	6.4	0.1	0.7	0.3	7.5	12.4	2.6
MAI	10%	9.8	3.7	-5.7	1.5	3.2	0.1	0.7	0.3	4.3	9.6	-0.2
	-10%	9.1	1.4	-7.2	1.3	2.2	0.1	0.3	0.2	2.8	5.6	-3.5

averaging about 3 ha in area over 14 local government areas could mitigate against flow-on benefits. Later stage processing could involve a configuration of many small and widely dispersed mills. On the other hand, processing of very high value cabinet timber could lead to high flow-on benefits.

The output of the economic model reveals the importance of including the benefits of carbon sequestration, which accounted for more than half of the estimated non-wood benefits. The increasing likelihood of payments to plantation owners for carbon sequestration offers the potential for an early cash inflow, while helping to achieve greenhouse gas reduction targets associated with international agreements.

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