41st AARES CONFERENCE

20-25 JANUARY, 1997

CARBON SEQUESTRATION IN THE COMMUNITY RAINFOREST REFORESTATION PROGRAM (CRRP)

Jean-Claude Eono

UNIVERSITY OF QUEENSLAND AND CRC - TREM

Department of Economics, University of Queensland and the Cooperative Research Centre for Tropical rainforest Ecology amd Management.

CARBON SEQUESTRATION IN THE COMMUNITY RAINFOREST REFORESTATION PROGRAM (CRRP)

Jean-Claude Eono[1]
Department of Economics, University of Qld

ABSTRACT: *Non-market benefits of reforestation are many. A benefit of forests is their function as carbon sink. In effect, the costs of reducing greenhouse emissions through reduction in fuel usage from transport, industry and households may not be as efficient in reducing greenhouse emissions as reducing these emissions through a sink.*

This paper demonstrates that a social benefit such as reduction in CO_2 can justify tree planting. Trees planted under the Community Rainforest Reforestation Program over the three years 1993-1995 will absorb about 170,549 tonnes of CO_2. The direct financial cost of planting for this period was \$7.115m by Government Agencies. Given a \$5 per tonne of CO_2 sequestrated (1996 prices), the total social benefit over 35 years is approximately \$0.853m. While this benefit is important, in the 1992-1993 financial year alone, the amount of CO_2 emitted by all vehicles in the localities covered by the CRRP was approximately 398,000 tonnes of which cars contributing about 83,291 tonnes. We conclude that although the social benefits of carbon sequestration in the CRRP seem substantial in relation to the costs, to really encroach into the overall amount of CO_2 emitted in the region, reforestation in the CRRP must at least be equal to standard plantations of radiata pines (i.e. planting density) and more planting is required to cover cars emissions. Contributions to CO_2 emissions from other vehicle categories should be balanced by the industrial and transport sectors.

Introduction

The goal of this paper is to estimate the benefit of carbon sequestration in reforestation undertaken undertaken under the Community Rainforest reforestation Program (CRRP) in North Queensland. In the first section, a review of studies on carbon yield is undertaken. In the second section, an estimation of CO_2 sequestration for the CRRP is undertaken. In the third section, an estimation of CO_2 emission for vehicles (in particular, passenger cars) in the Local Government Areas under study is used to put the CRRP carbon benefit into perspective. It is concluded that although the CO_2 benefits derived from the CRRP appear substantial in relation to the program and are in addition to many other benefits, CRRP plantations (in their function as carbon sink) are not as efficient as standard radiata pine plantations.

---

[1] Jean-Claude Eono is Research Officer, Dept. of Economics, The University of Queensland, carrying out Ph.D. studies on a project supported by the Cooperative Research Centre in Tropical Rainforest Ecology and Management (CRC - TREM)

Estimate of carbon yield

Individual trees and stands of the same species can differ markedly in growth and yield patterns due to many factors, including differences in climate, environment, soil conditions and density of planting. Data on the amount of carbon contained in the different parts of a tree and in forest soils for the same species can also vary considerably depending on the source consulted. Barson and Gifford (1989) assessed the potential of tree planting in Australia as a CO_2 sink. They cite Booth (1989) who considers that a typical stem wood growth rate for *P. radiata* in Australia is 10 tonnes dry matter per hectare per year (a volume growth rate of 20 m^3 per hectare per year) equivalent to about 5 tonnes of carbon. Allowing for leaves, fine branches, roots and soil organic matter, Barson and Gifford (1989) assume an annual average carbon sequestration rate of 7.5 tonnes carbon per hectare over 40 years. This assumption implies that total biomass is 1.5 times above ground biomass or that about 67 percent of carbon is stored in the stem wood and the rest in leaves, roots, fine branches and soil organic matter. They used a value of 390 tonnes carbon per hectare as the asymptotic biomass.

Barson and Gifford (1989) note that these growth and yield assumptions may be generous for Australian conditions, as similar average rates of stem volume growth apply to New-Zealand state-owned forests at peak plantation growth rate.

The following table provides various estimates of carbon biomass:

Table 1: Estimate of carbon yield on pine plantations (Tonnes per hectare)

Barson and Gifford (1989) [a]	Lambert (1979) [b]	Grierson et al. (1991) [c]	Maclaren and Wakelin (1991) [d]	Boardman [e] (1995)
390	332	373	310	243

a Average quality P. radiata grown in NSW (30 years)
b Assuming peak plantation growth rate in New Zealand forests (40 years)
c Average for P. radiata grown in Victoria, include estimate of soil carbon content
d Estimate of tree components (excluding stem wood) applied to the stem wood of Boardman (1995)
e P. radiata site quality 3 grown in South Australia (35 years)

Source: BTCE estimates based on data from different sources.

Reforestation in the CRRP is similar to a plantation whereby individual annual plantings involves trees of identical ages, but where the total plantation estate can be considered a forest of trees of mixed ages. It is further assumed that trees in this "plantation estate" is to be harvested at 35 years of age, with immediate replanting of the land.

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 and limited understanding of the growth process (Zeide 1993, Clutter et al 1993, Leech & Ferguson 1981). Zeide (1993) shows that all but the Weibull equation can be reduced to one of two basic growth functions, differing essentially in only the decline component. Because of its mathematical tractability, and the fact that it is used by a number of researchers, the Gompertz function was adopted in this study to describe the yield of a plantation estate over time. Its form may be expressed as:

$$V = Vme^{-be^{-kt}}$$

where V is the volume of biomass, Vm is the maximum or saturation level of / absorbed over the life of the plantation, t is time and b and k are constants.

When $t=0$, $V=V_0$, and $b=\ln(V_m / V_0)$ where V_0 is the volume of biomass in the seedlings.

Differentiating the function twice with respect to time and setting it equal to 0 (condition for the point of inflexion) yields:

$$k = (\ln b) / t_m$$

where t_m is the year of maximum growth (the age corresponding to point A in figure 1.

The asymptotic value of biomass (V_m) is obtained from average yield data. Biomass volumes are then converted to mass of carbon using conversion factors. The initial mass of carbon in the seedlings is assumed to be 0.05 tonnes per ha (Barson & Gifford, 1989). This would not differ with the tree species planted, however because of the lower density of trees in the CRRP. Vo is assumed to be 0.016 tonnes per ha..

Wood yield of a tree or identical aged stand is usually portrayed as sigmoidal functions as shown in figure 1a where initial exponential growth slows after reaching a maximum rate at a point of inflexion (A). The saturation level (C) which is reached asymptotically, represents the maximum biomass of the stand, after which growth continues but is matched by decomposition.

Figure 1b is a yield curve which shows the total number of what is being measured, or some attribute such as tree diameter or mass at different points in time. Yield curves for forests normally include any removals such as thinning that occur during the growth process (Vanclay 1994, p.106).

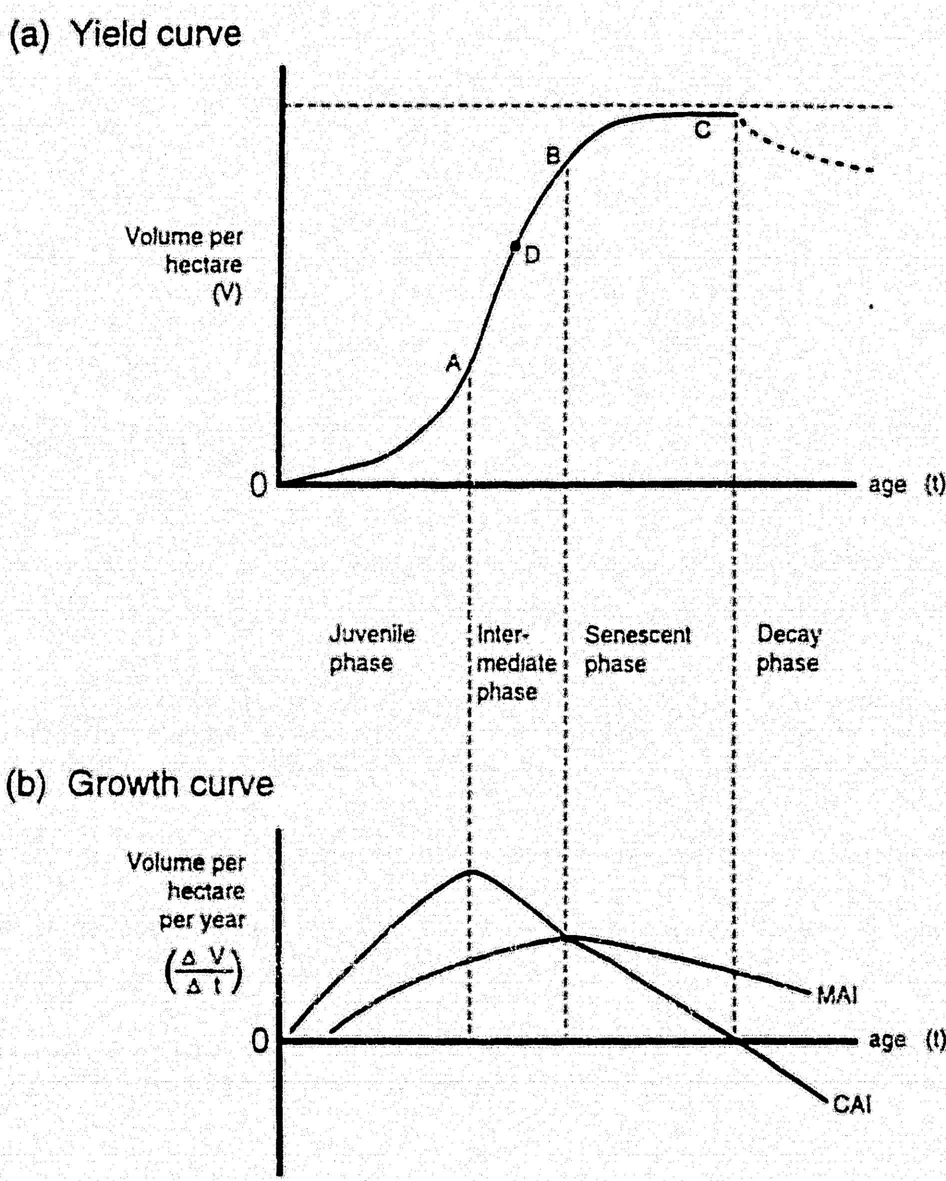
Yield curves for plantation forests are normally defined in terms of volume of wood (i.e. cubic meter of merchantable stemwood) per unit area (i.e. ha).

At any point in time the average stock of carbon sequestered per ha in a plantation estate that accords with this yield function is given by:

$$V_m \frac{\int_{t=0}^{t_n} e^{-be^{-kt}}\, dt}{t_n}$$

where tn is the rotation period between successive harvest

Figure 1: Yield and Growth Curves



A = INFLECTION POINT $\left(\frac{d^2V}{dt^2} = 0\right)$

B = OPTIMAL HARVESTING AGE IN TERMS OF PHYSICAL PRODUCT (YIELD)

C = MAXIMUM BIOLOGICAL YIELD $\left(\frac{dV}{dt} = 0\right)$

MAI = MEAN ANNUAL INCREMENT

CAI = CURRENT ANNUAL INCREMENT

Source BTCE.

Carbon sequestrated in the CRRP from 1993 to 1995

The Community Rainforest Reforestation Program (CRRP) is a three-level joint government program in North Queensland which addresses the issues of conservation, employment and future source of high quality timber. It provides landholders with the opportunity to plant native or exotic rainforests trees at minimal private costs on land which is degraded or not used. These plantations are complementary to existing Government plantations.

The CRRP is designed to achieve four interrelated objectives, viz. develop a private plantation timber resource; arrest degradation of land following extensive inappropriate clearing; improve water quality in rivers and streams; and train a workforce to support rainforest plantation establishment (CRRP Management Committee, 1993).

The CRRP involves the following shires:

Cardwell	Mirani	Mareeba	Atherton
Hinchinbrook	Eacham	Douglas	Cook
Thuringowa	Mackay	Mulgrave/Cairns	Johnstone
White Sundays	Herberton		

The area and number of trees planted is shown in the table 2:

Table 2: Number of trees and area planted in the CRRP

Year planted	Area (ha)	Number of trees	Density
1992-93	266.20	168,063	631
1993-94	436.81	298,848	684
1994-95	439.24	341,420	777
Total	1,142.25	808,331	709

Source: CRRP Annual reports

Of species planted, 43.15% are Eucalypts (353,183 trees over 531 ha). The average mean annual increment (MAI)over all the species planted is 7.90m^3/ha/yr. Many species have no known mean annual increment. This MAI would be very conservative given that the MAI used by the studies cited for radiata pines assume an MAI of 20m^3.

Using this average MAI, after 35 years, the total volume of biomass would be 315,832m^3 above ground and 63,166 m^3 underground (20% of above ground biomass). Given that the trees species are hardwood, a density of .5 tonnes of biomass was used instead of .44 tonnes of biomass per m3 (Turner, 1990). The amount of carbon sequestrated varies in studies between 40 and 50% of the total biomass (Boardman). An amount of 45% is assumed here.

Table 3. Estimation of carbon sequestration in the CRRP over 35 years.

Year	Total Stand volume over 35 years (m^3)	Underground biomass (m^3)	Carbon sequestrated (tonne) per ha over 35 years	Total Carbon sequestrated (tonne) over 35 years
2028	73604.30	14,720.90	153.00	40,727.79
2029	120777.97	24,155.59	151.56	66,201.35
2030	121449.86	24,289.97	151.54	66,564.62
Total	315832.13	63,166.46		170,549.37

The amount of carbon sequestration is well below the figures reported in the above studies, because in these studies the assumptions are for a planting density of 2,200 trees per hectare (BFCE,1996, p.35) and an MAI of about 20m^3. The total amount of carbon sequestrated over 35 years for reforestation amounts to 170,549 tonnes. If a 4t C/ha/y for above ground average annual increment of carbon for Eucalypts in plantations (National Greenhouse Gas Inventory Committee, 1994) was used, the total mass of carbon would be 159,915 tonnes plus 20% underground would be another 39,979 tonnes or a total carbon mass of 199,894 tonnes. The 4t C/ha/y applies to standard plantations where the density is more than double the CRRP planting density. If a carbon tax of $5 (1996 price) per tonne as was suggested in Australia was the price set for carbon, the social benefit of the first three years of tree planting in terms of carbon sequestration over 35 years is estimated at $852,746 (1996 price).

If the trees are logged at that time, and new seedlings planted, the amount of carbon released into the atmosphere will be minimum. One of the main use of the timber provided by the CRRP is for cabinet-making and maybe for poles. These products can have another 50 or more years of life (even 100 of years for very good quality furniture). Only some of the thinning maybe burnt or use for paper (average life time of one year or less). Because of the low density of the planting, there will be minimum thinning.

CO_2 Emissions From Vehicles In North-Queensland

To compare the results obtained for carbon sequestration, we provide an estimate of CO_2 emission by vehicles in the study area.

The figures for vehicle numbers were obtained from the Queensland Department of Transport. The list of abbreviation can be found in appendix 1.

The number of vehicles in each Local Government Authorities for the years 1993 is found in table 4 and is compiled from the sub-categories (a), (b), (c) and (d).

Table 4: Number of vehicles in the CRRP localities as at 30.06.1993

Vehicles No. District/type	(a) cars (a)	(b) LVC	(c) Rigid trucks	(d) articulated trucks	Total
Hinchinbrook	5,314	2,756	463	66	8,599
Thuringowa	14,213	4,836	515	97	19,661
Atherton	3,906	1,774	316	51	6,047
Cook	1,170	1,695	243	17	3,125
Douglas	2,626	1,253	135	37	4,051
Eacham	2,113	1,159	151	34	3,457
Herberton	1,586	1,038	136	32	2,792
Johnstone	6,732	3,150	352	88	10,322
Mareeba	6,006	3,135	415	65	9,621
Mulgrave	17,632	5,961	568	77	24,238
Cairns	22,623	7,434	891	139	31,087
Total	83,921	34,191	4185	703	123,000

(a) Categories CS, CSW, AMB, CH
(b) Categories U, P, UTL, UTT, UTU, UCA
(c) Categories T, TCC, TCM, TT, TTL, VAN, VPA,VRF, BCA
(d) Categories RTL, RTT, RRT, RBD

The estimation of total fuel consumed by vehicles was obtained by summing up of fuel consumption of each vehicle categories. These categories are cars, light vehicles, rigid trucks and articulated trucks. In each category, assumptions were made as to the type of fuel used, the mean age of the vehicles for which a deterioration factor (Table 6) is applied, the energy density and weight have been drawn from the BTCE study.

Table 5: CO_2 emission from vehicles in the CRRP localities in 1993

	Cars	LVC	Rigid Trucks	Articu. Trucks	Energy density (Mjoule/l.)	CO_2 Emission factors (g/Mj)
Av.km/year (s'000)	9.00	16.68	20.19	84.93		
Fuel (l/100km)	5.00	13.36	26.50	47.25		
Total fuel (s'000) 1993	37,764	76,193	22,391	28,211		
Fuel type						
Petrol	**.728**	**.728**	**.108**	**.001**	**34.2**	**66.0**
Diesel	**.198**	**.198**	**.857**	**.996**	**38.6**	**69.7**
LPG	**.074**	**.074**	**.036**	**.003**	**25.7**	**59.4**
CO_2emissions tonnes)					**Total**	
1993	86,438	174,399	58316	75,789	**396,935**	

Table 5 shows the total CO_2 emissions from vehicles in 1993 only. Emissions are almost three times the amount of CO_2 which will be absorbed over 35 years in the CRRP. Sequestration of CO_2 is twice the amount of emissions if only cars are considered. This is an important consideration. For example, the BFCE study was to provide an alternative tool to industry (transport of goods) to internalise the costs of CO_2 emission, thus excluding all cars. The CO_2 emissions by industries in North Queensland would be, under the BFCE assumptions 100% of categories (b), (c) and (d). Category (a) is therefore a proxy whereby it is assumed that the use of cars is only for individuals and their families for their own needs (Although a proportion would be for business use). From this assumption, we infer that this portion of carbon emission is generated by the community and the CRRP being a Community program, it becomes appropriate to compare CO_2 emissions from cars only with the results obtained from CO_2 sequestration in the CRRP.

Conclusion

In this paper, the estimation of CO_2 sequestration in the CRRP plantings from 1993 to 1995 was undertaken. With an area of 1,142 ha planted over these three years and a density of 709 trees per hectare, the CO_2 sequestration has been estimated at about 170,549.37 tonnes over 35 years which is equal to a social benefit of $ 852,746. These results, although being substantial, need to be placed in perspective. In order to gain an appreciation of these results, an attempt was made to estimate the CO_2 emissions of vehicles in the study area. The results indicate that CO_2 emissions for the year 1992-93 alone is about 397Mt, this includes private cars (which were excluded from the BTCE study). The relatively poor result of the CRRP in terms of CO_2 absorption is caused by a management regime which is well below the standard plantations of radiata pine which were the basis of the BTCE study. These plantations have an original planting density of about 2,200 trees per hectare with thinning occurring after 5 years, 10 and 20 years. This thinning management is unlikely to occur in the CRRP as the density is already very low.

References

Barson, M. and Gifford R., (1989). *Carbon dioxide sinks: The potential role of tree planting in Australia,* in D.J. Swaine (ed.) Greenhouse and Energy, CSIRO, Melbourne.

Boardman, R., (1995). cited in BTCE (1996), Costs of Carbon Sequestration Through Afforestation: Greenhouse Gas emissions in Australian Transport, Working Paper 23, Department of Transport and regional Development, Canberra.

Bureau of Transport and Communications Economics (BTCE), (1996), *Trees and Greenhouse: Costs of sequestering Australian Transport Emissions,* Working Paper 23, AGPS, Canberra, ACT 2601.

Bureau of Transport and Communications Economics (BTCE), (1996), *Costs of reducing Greenhouse gas emissions from Australian road freight vehicles: An application of the BTCE Truckmod Model,* Working Paper 22, AGPS, Canberra, ACT 2601.

Clutter, J.L., J.C. Fortson, L.V. Pienaar, G.H. Brister, and R.L. Bailey, (1983), *Timber Management: A Quantitative Approach,* John Wiley & Sons, New York.

CRRP Management Committee (1993), "Community Rainforest Reforestation Program: Sowing the Seeds for a Future Wet Tropics Timber Industry", Queensland Department of Primary Industries Forest Service, Brisbane.

Grierson, P.F., Adams, M.A. & Attiwil P.M., Carbon Sequestration in Victoria's Forests, report commissioned by the State Electricity Commission, Victoria.

Lambert, M.J., (1995), cited in BTCE (1996), *Costs of reducing Greenhouse gas emissions from Australian road freight vehicles: An application of the BTCE Truckmod Model*, Working Paper 22, AGPS, Canberra, ACT 2601.

Leech, J.W., and L.S. Ferguson, (1981), Comparison of yield models for unthinned stands of radiata pines, *Australian Forest Research*, Vol.11, pp.231-245.

Maclaren, J.P., and Wakelin, S.J., (1991), *Forestry and Forest Products as a Carbon Sink in New Zealand*, Forest Research Institute Bulletin no. 162, New Zealand Ministry of Forestry.

National Greenhouse Gas Inventory Committee, (1994), Land Use Change and Forestry, Workbook for Carbon Dioxide from the Biosphere, Workbook 4.0, Department of the Environment, Sport and territories, AGPS Press, Canberra.

Turner, J. (1990), *Forestry, the Timber Industry and the Greenhouse Effect*, miscellaneous paper, State Forests of NSW, Research Division.

Vanclay, J.K., (1994), Modelling Forest Growth and Yield: Application to mixed Tropical Forests, CAB International, Wallingford, UK.

Zeide, B., (1993), "Analysis of growth equations", *Forest Science*, Vol.39, No.3, pp. 594-616.

Appendix 1.

Table 6 Deterioration factor for vehicle at end of year

Vehicle age	Deterioration factor
1	1.020
2	1.030
3	1.041
4	1.051
5	1.062
6	1.072
7	1.083
8	1.094
9	1.105
10	1.116
11	1.121
12	1.127
13	1.132
14	1.138
15	1.132
16	1.127
17	1.121
18	1.116
19	1.105
20	1.105
21-30	1.138
30+	1.200

Source: BTCE, 1996, p.72

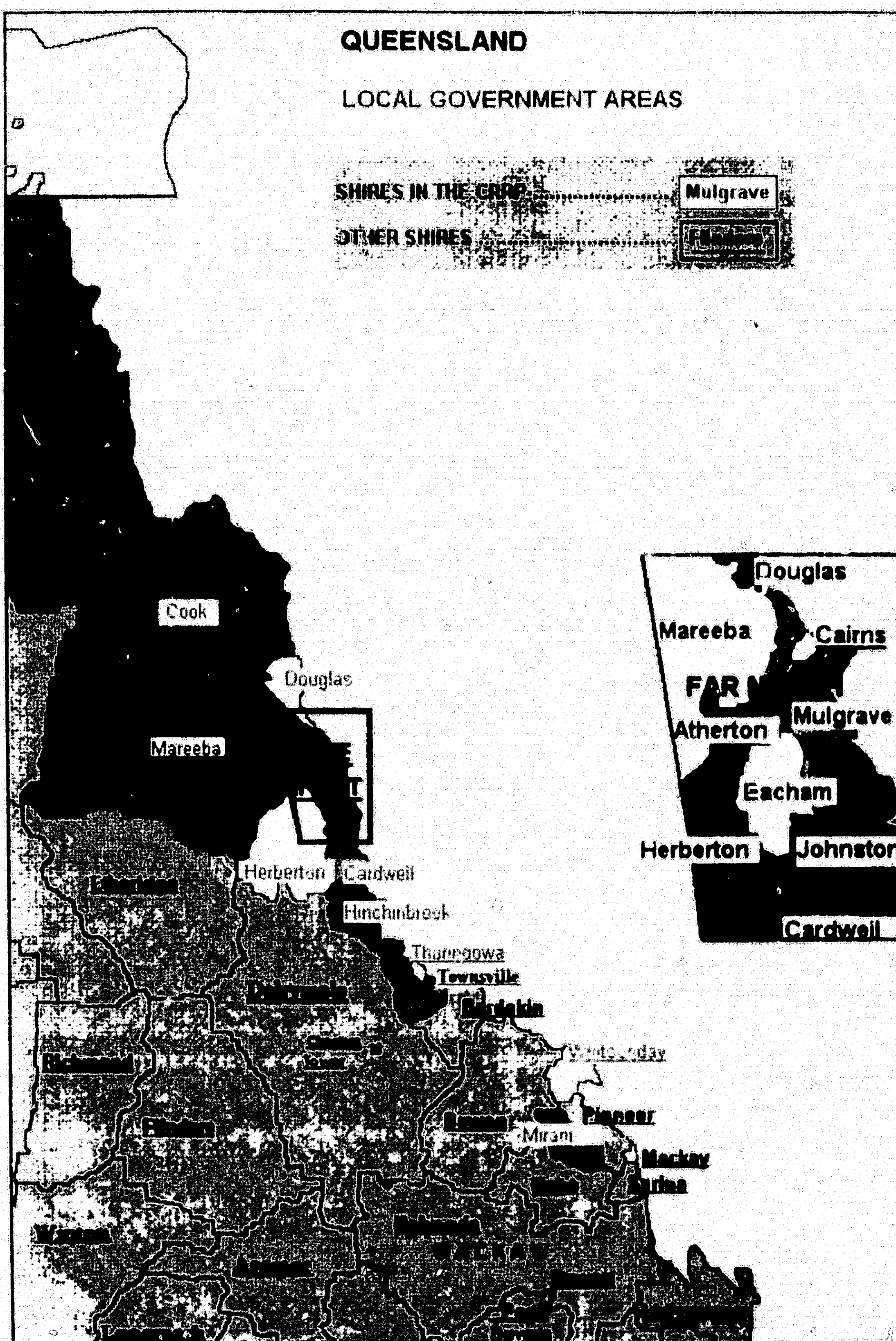
TABLE A

QUEENSLAND VEHICLES ON REGISTER

BODY TYPE DESCRIPTION

CH	Hearse
CS	Sedan
CSR	Car Street Rod
CSW	Station Wagon
P	Panel Van
PSR	Panel Van Street Rod
PB	Light Bus
PBS	Panel Van (School Bus)
U	Utility Truck
UCA	Utility Caravan
USR	Utility Street Rod
UTL	Utility Tow Truck (Licensed)
UTT	Utility Tow Truck
UTU	Utility Towing Unit
T	Trucks
TCC	Cab and Chassis
TCM	Concrete (Agitator Truck)
TT	Tow Truck
TTL	Tow Truck (Licensed)
VAN	Van
VPA	Pantechnicon
VRF	Refrigerated Van
B	Bus
BCA	Caravan (Truck Type)
BS	School Bus
BST	Truck or Van School Bus
BT	Bus Truck
BNA	Articulated Bus (Banana Bus)
RTU	Towing Unit
RTT	Truck Tractor
RRT	Road Train
RBD	B Double
MBH	Backhoe (Specially Constructed)
MBT	Mobile Boring Plant (Truck Mounted)
MCC	Mobile Crane Carrier
MCD	Mobile Crane Dolly
MCR	Mobile Crane (Specially Constructed)
MCT	Mobile Crane (Truck Mounted)
MDT	Dumper Truck
MEL	Endloader (Specially Constructed)
MEM	Miscellaneous Mobile Machinery and Equipment (Specially Constructed)
MET	Miscellaneous Mobile Machinery and Equipment (Truck Mounted)
MFK	Forklift (Specially Constructed)
MST	Straddle Truck

PPL	Limited Use Permit Plates
HTE	Tractor
SCR	Side Car
SIC	Invalid Chair
SMP	Moped Motor Cycle
SOL	Motor Cycle
STY	Tricycle
DBT	Boat Trailer
DCA	Caravan Trailer
DCB	Cane Bin Trailer
DEM	Machinery or Equipment Trailer
DLL	Low Loader
DOL	Dolly Trailer
DSB	Semi Trailer Bus
DSC	Caravan Semi Trailer
DTJ	Timber Jinker
DTR	Trailer
DTS	Semi Trailer
DMH	Mobile Home Trailer
DCC	Multiple Car Carrier Trailer
DMC	Trailer Towed by Motor Cycle
DFT	Farm Trailer
DHF	Drawn Horse Float
DOG	Dog Trailer
LDR	Dealer
AMB	Ambulance
R	Recreational Vehicle


QUEENSLAND
LOCAL GOVERNMENT AREAS
SHIRES IN THE CRRP
Mulgrave
OTHER SHIRES
Cook
Douglas
Mareeba
Herberton
Cardwell
Hinchinbrook
Townsville
Burdekin
Pioneer
Mirani
Mackay
Douglas
Mareeba
Cairns
Atherton
Mulgrave
Eacham
Herberton
Cardwell