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**CARBON SEQUESTRATION IN THE COMMUNITY  
RAINFOREST REFORESTATION PROGRAM (CRRP)**

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# CARBON SEQUESTRATION IN THE COMMUNITY RAINFOREST REFORESTATION PROGRAM (CRRP)

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**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<sub>2</sub> 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<sub>2</sub>. The direct financial cost of planting for this period was \$7.115m by Government Agencies. Given a \$5 per tonne of CO<sub>2</sub> sequestered (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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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 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<sub>2</sub> sequestration for the CRRP is undertaken. In the third section, an estimation of CO<sub>2</sub> 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<sub>2</sub> 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.

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## 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<sub>2</sub> 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<sup>3</sup> 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) <sup>a</sup> | Lambert (1979) <sup>b</sup> | Grierson et al. (1991) <sup>c</sup> | Maclaren and Wakelin (1991) <sup>d</sup> | Boardman <sup>e</sup> (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:

$$V = V_m e^{-be^{-kt}}$$

where  $V$  is the volume of biomass,  $V_m$  is the maximum or saturation level of  $V$  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, 1939). This would not differ with the tree species planted, however because of the lower density of trees in the CRRP,  $V_0$  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 (Vancley 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).

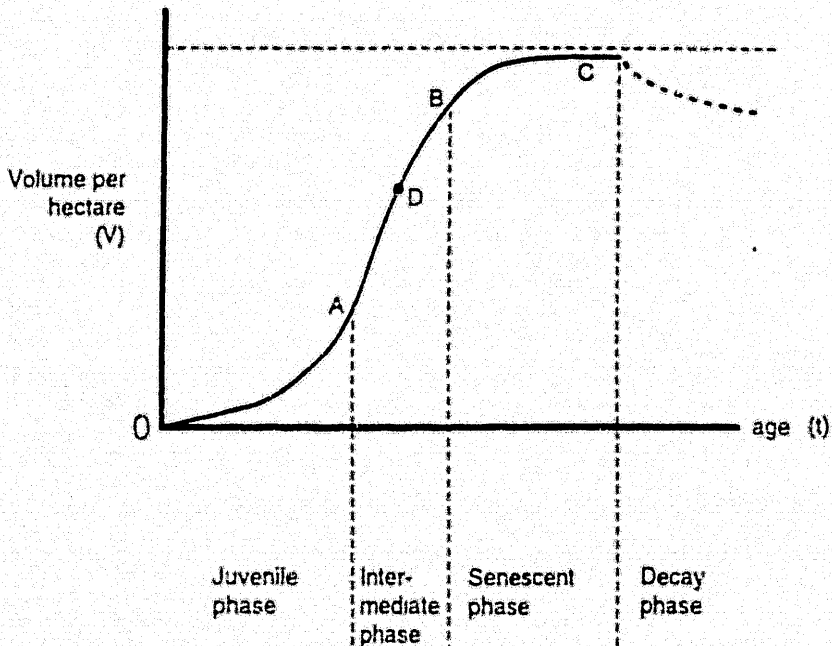
At any point in time the average stock of carbon sequestered per ha in a plantation estate that accords with this yield function is given by:

$$V_m \frac{\int_0^{t_n} e^{-be^{-kt}} dt}{t_n}$$

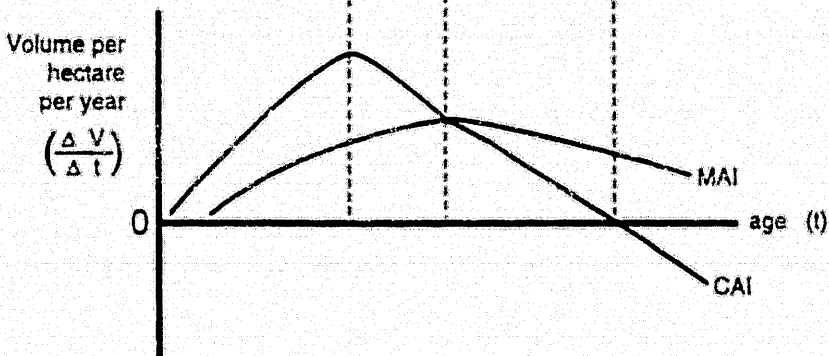
where  $t_n$  is the rotation period between successive harvest

Figure 1: Yield and Growth Curves

(a) Yield curve



(b) Growth curve



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 sequestered 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  $7.90\text{m}^3/\text{ha}/\text{yr}$ . 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  $20\text{m}^3$ .

Using this average MAI, after 35 years, the total volume of biomass would be  $315,832\text{m}^3$  above ground and  $63,166\text{m}^3$  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  $\text{m}^3$  (Turner, 1990). The amount of carbon sequestered 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<br>over 35 years (m <sup>3</sup> ) | Underground<br>biomass (m <sup>3</sup> ) | Carbon<br>sequestered<br>(tonne) per ha<br>over 35 years | Total Carbon<br>sequestered<br>(tonne) over 35<br>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<sup>3</sup>. The total amount of carbon sequestered 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<sub>2</sub> Emissions From Vehicles In North-Queensland

To compare the results obtained for carbon sequestration, we provide an estimate of CO<sub>2</sub> 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.<br>District/type | (a)<br>cars (a) | (b)<br>LVC | (c)<br>Rigid trucks | (d)<br>articulated<br>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   |
| Herbert                       | 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, TI, TIL, 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<sub>2</sub> emission from vehicles in the CRRP localities in 1993

|  | Cars   | LVC     | Rigid<br>Trucks | Articu.<br>Trucks | Energy<br>density<br>(Mjoule/l.) | CO <sub>2</sub><br>Emission<br>factors<br>(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            |                                  |  |
| <b>Fuel type</b>                       |        |         |                 |                   |                                  |  |
| <b>Petrol</b>                          | .728   | .728    | .108            | .001              | 34.2                             | 66.0   |
| <b>Diesel</b>                          | .198   | .198    | .857            | .996              | 38.6                             | 69.7   |
| <b>LPG</b>                             | .074   | .074    | .036            | .003              | 25.7                             | 59.4   |
| <b>CO<sub>2</sub>emissions tonnes)</b> |        |         |                 |                   | <b>Total</b>                     |  |
| <b>1993</b>                            | 86,438 | 174,399 | 58316           | 75,789            | 396,935                          |  |

Table 5 shows the total CO<sub>2</sub> emissions from vehicles in 1993 only. Emissions are almost three times the amount of CO<sub>2</sub> which will be absorbed over 35 years in the CRRP. Sequestration of CO<sub>2</sub> 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<sub>2</sub> emission, thus excluding all cars. The CO<sub>2</sub> 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<sub>2</sub> emissions from cars only with the results obtained from CO<sub>2</sub> sequestration in the CRRP.

## Conclusion

In this paper, the estimation of CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> emissions of vehicles in the study area. The results indicate that CO<sub>2</sub> 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<sub>2</sub> 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.

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# 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 | Pantehnicon  |
| 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 GRAP

OTHER SHIRES

Mulgrave

Other Shires

