Carbon storage in remnant trees and soils of grazing lands in Queensland

Hossein Ghadiri[A,C], Janet Hussein[A], Calvin Rose[A], Cyril Ciesiolka[B] and Caitlin Veraa[A]

[A] Griffith School of Environment, Griffith University, Kessels Rd, Nathan, 4111, Australia.
[B] Department of Natural Resources and Mines, Toowoomba, QLD, Australia
[C]Corresponding author. Email H.ghadiri@griffith.edu.au

Abstract
A large-scale research project was established in 2001 on a commercial grazing property in Queensland. Various aspects of grazing management at plot/catchment scales were studied for six years. This paper reports on the possible use of remnant trees in grazing lands as a carbon sequestration pathway in comparison to soil carbon. Trees growth was assessed using yearly height/girth measurement of 86 trees (*Eucalyptus dealbata)* in two plots. Some trees were harvested in 2001 and 2005 and the carbon (C) and nitrogen (N) concentrations measured on trunk, leaf and root samples. Total C and N were also measured in surface soil samples in 2001 and 2005. A Linear Mixed Effect model (LME) was developed from the growth data and used in combination with C concentration and tree density to predict C storage per hectare. Though there was no significant change in C storage in surface soil in the treed plots in the measurement period (2001-2005), there was a significant increase in C stored in the trees themselves. Although high tree densities are unrealistic for the entire grazing property, they may be appropriate for the less productive areas of land and could offset C emission from the rest of the grazing paddock.

Key Words
Carbon sequestration, *Eucalyptus dealbata* , trees in grazing lands, soil carbon.

Introduction
There has been much debate in recent years over the merit of keeping remnant trees in the grazing lands of Australia. Authorities have been trying to persuade graziers to keep more native trees on their lands because trees may help reduce compaction, erosion and soil loss while increasing nutrient retention and trees also provide shelter for the grazing animals (Bird *et al.* 1992). However, some graziers note the negative impacts of trees on the productivity of their lands and want to remove them.

In woodlands, the biomass of trees may store significantly more C than herbaceous plants (Young *et al.* 2005). Woodlands may also store more C than pasture and cropping systems, even when soil C values are added to the equation (Young *et al.* 2005). Additionally, C stocks of trees in grazed eucalypt woodlands in Queensland have been shown to increase with time (Burrows *et al.* 2002). This included C stocks in biomass from both live and dead trees, in both long and short-term studies. Increasing C stocks correlate with a reduction in emissions (Moore *et al.* 2001). This study suggested that with an increase in tree basal area in grazed woodlands of southwest Queensland, a decrease in emissions, or alternatively an increase in C storage, could be achieved. Peterson *et al.* (2003) also concluded that in farms which are predominantly used for grazing, the long term growth of tree plantations as C sinks successfully reduced overall on-farm emissions. Different types of grazing affect C storage as well. Grazing which was more productive emitted more greenhouse gases, when compared to less productive grazing under sheep (Moore *et al.* 2001). Some factors may increase the likelihood of tree growth and C storage such as grazing type (Burrows *et al.* 2002) and fire. However, while trees in grazing lands act as C sinks with an obvious environmental benefit, this can often mean that there is less land available for actual grazing and more stress on the remaining land which is grazed (Henry *et al.* 2005). Cook *et al.* (2005) suggested that only around 25% of the C sequestered by living trees is retained, while the remaining C is lost through leaves, twigs and bark to the ground below.

The objectives of this study were therefore to measure C storage within tree plots located within a time-controlled grazing area (TCG) in comparison to surface soils and to assess how this storage would vary with time and rainfall.

Methods
Site details
The land at Currajong Station is used for sheep and cattle grazing, without the use of fertilizers and other inputs. The Station is located in the Inglewood shire in Queensland, Australia (28º 33' S and 151º 33' E) at

~675 m above sea level. Currajong has average maximum and minimum temperatures of 24ºC and 10ºC respectively and the average yearly rainfall is 691 mm. A large scale multi-faceted research project was established in 2001 on the Station and run for 6 years (Sanjari, 2009). The project examined the effect of different types of grazing (time controlled and continuous) on vegetation production, soil properties and runoff water quality. Within the TCG catchments, two areas of high tree density were chosen for this study. The tree areas comprised both grazed and non-grazed (fenced-off) areas. The trees were *Eucalyptus dealbata,* which germinated around 1987. Trees were located in plot I which was on sloping land (12%) and 800 m^2 in area (density 0.135 trees/m^2) and in plot II (slope 23%) with an area of 362 m^2 (density 0.221 trees/m^2). Plot I initially contained 112 trees, but 108 trees were counted in 2006, while plot 2 contained 91 trees on first count, but by 2006 this had dropped to 80 trees. Tree density was therefore higher in plot 2. Shrubs were not included in this study, though they were present within these plots.

Geology at the site comprises part of the Warroo land system, generally referred to as Traprock. This is a complex mixture of highly deformed sandstone, mudstone, inter-bedded conglomerate, limestone and volcanic. The soils are shallow to moderately deep with a hard setting brown to dark clay loams.

Tree height/girth measurements
Tree height/girths were measured for 116 trees, in 2001, 2003, 2004 and 2005 in Plot 1. However, there were some missing data, so only trees with a full set of data (86) were used for subsequent statistical analysis. For tree height, tall trees were measured using a clinometers located at 6.0 m from the tree using the following formula: Height of tree = $(\tan \theta \times 6m) + 0.9m$. Shorter trees were simply measured using a rigid tape measure. Tree girths were measured at both 0.5 m and 1.3 m height above ground.

Tree and soil sampling
Trees were harvested from plot 1 for chemical analysis (3 trees in 2001 and in 2005). To avoid decimating tree numbers in plot 1, extra trees were harvested in plot 2 (3 in 2001 and 5 in 2005). The harvested trees spanned a range of heights. Trees were cut up on site before being transported to the laboratory. Samples were subsequently separated into trunk, root and leaf components and were then dried and ground to<0.4 mm. Soil samples (0-10 cm depth) were also collected from treed and non-treed plots within the TCG catchment in 2001 and 2005. The samples from treed plots were taken in both grazed and non-grazed areas.

Chemical analysis
Total carbon (C) and nitrogen (N) contents of the tree and soil samples in 2005, and for the soil samples in 2001, were determined in triplicate for each sample by Dumas combustion using a Leco analyser. However, for the tree samples in 2001, the nitrogen was determined using the Kjedahl method. Data from

Results and discussion
Total carbon in the soil
There were no significant differences in total soil C between 2001 and 2005 and no significant differences between total soil C in treed and non-treed areas or between grazed and ungrazed treed areas (Table 1). Likewise no significant differences were found for total soil N.

Table 1. Amounts of carbon and nitrogen in surface soil samples (0-10 cm) in 2001 and 2005.

	Total C (mg/kg)		Significance	Total N (mg/kg)		Significance
	2001	2005		2001	2005	
Trees present	40637	40350	NS	2778	2609	NS
Trees absent	26540	28763	NS	1875	1988	NS
Significance	NS	NS		NS	NS	
Treed grazed	41225	42982	NS	2849	2663	NS
Treed ungrazed	40050	37718	NS	2708	2554	NS
Significance	NS	NS		NS	NS	

NS = no significant differences between values in the same column or row at P==0.05

The C:N ratios were ~15 throughout. The total C stored in the top 0.1 m of soil in the treed area equates to 48.2 and 47.8 t/ha in 2001 and 2005 respectively using an average bulk density of 1185 kg/m^3 (Sanjari 2009) and a soil volume of 1000 m^3 (0.1 m depth x 10000 m^2 per ha). Sanjari (2009) measured soil organic carbon (SOC) in the surface soil in the open TCG pasture to be ~26 ton/ha in 2001 and ~28 ton/ha in 2006. Herbage contributed another ~1 900 and 2500 ton//ha while litter contributed ~1600 and 2000 ton/ha in 2001 and 2005 respectively.

© 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World

1 – 6 August 2010, Brisbane, Australia. Published on DVD.

Total carbon in the trees

Height and girth measurements from the 86 trees were plotted versus the year and growth models were developed using LMEs (Table2).

Table 2. Tree growth models using data from 86 trees.

Tree height = H (m)	H = 2.00 + 0.68 * years of growth after 2000 (0.099) (0.028)	(1)
Tree girth at 1.3 m = G (mm)	G = 50.91 + 30.81 * years after 2000 (3.18) (193)	(2)

- Figures in brackets represent the std error for the values

Chemical analysis of the tree components (Table 3) indicated the predominance of Total C compared to N. Total C and N were significantly higher ($P<0.05$) in the leaves compared to stems and roots. There were significant differences in C levels ($P<0.01$) between 2001 and 2005 for all the tree components.

Table 3. Mean concentrations of carbon and nitrogen in tree samples in 2001 and 2005.

Year	Parameter (mg/kg)	Roots	Trunks	Leaves
2001	Total C	500 167	499 000	543 833
2005		425 114	435 448	484 901
2001	Kjeldhal N	3.314	3.193	12.485
2005	Total N	2.605	2.975	14.895

Using pooled allometric equations from a study in northern NSW by Specht and West (2003), tree measurements (Table 2) were then used to predict biomass of the trees as $W= aD^b$ where W = oven-dry biomass (kg), a = 0.355, D (cm) = diameter at 1.3 m height and b =2.00 (girth was first converted to diameter). Using the calculated biomasses, the C concentrations and tree densities in the two plots, C storage per hectare was then calculated (Table 4) and thus used to predict C stored in the trees over time (Figure 1).

Table 4. Estimated total biomass values and carbon storage of trees with time in two plots.

Year	Average girth at 1.3 m (cm)	Total biomass (kg/tree)	Total Carbon content (kg/tree)[A]	Carbon Plot 1 (t/ha)	Carbon Plot 2 (t/ha)
2000	5.1	0.93	0.45	0.63	1.1
2001	8.2	2.4	1.2	1.7	2.7
2002	11	4.6	2.2	3.0	4.8
2003	14	7.4	3.6	4.8	7.9
2004	17	11	5.3	7.1	12
2005	20	15	6.8	9.1	16
2006	24	20	9.6	13	21

[A]Actual C contents used in 2001 and 2005. For other years, calculation assumes an average C content for all tree parts over both years of 481 411 mg/kg (= 48.14% derived from Table 3).

Figure 1 indicates an exponential increase in C storage in the two tree plots with time. Plot 2 had a greater tree density than plot 1 which gave rise to greater C storage. Some of this C storage would be decreased by leaf/twig fall and root die-back during the year which would in turn be affected by moisture conditions in the area. However, overall carbon storage in the trees did not seem to be affected by variations in annual rainfall (Figure 1) which ranged from ~510 to 760 mm/yr during the years of measurement. This is in contrast to C storage in litter and herbage at Currajong (Sanjari, 2009) which was affected by rainfall, decreasing in dry years. Carbon stored in the top 10 cm of soil exceeded tree C in both years, but tree C would exceed this by 2020 at the current rate of increase or if tree density increased. However, C levels for lower soil horizons were not assessed for this study and these would increase the overall soil C storage. Nevertheless, it is likely that the soil C levels will remain somewhat static compared to tree-stored C, particularly that stored within the trunks and larger branches. Mean values for C density in Victorian forests were found to be between 18.0 and 250.0 t C /ha (Grierson *et al.*1992) while Miehle *et al.* (2006) also predicted C density in a number of *Eucalyptus globulus* plots through use of a model. That study returned predicted values of between 22 and 106 t C / ha for trees aged at 6 years old. Burrows *et al.* (2002) noted that above-ground C stocks in live and standing dead woody plants in eucalypt woodlands gave a mean net above-ground annual C increment for all 57 sites of 0.53 t C /ha. y. The annual C increments are higher for this study (>0.7 t/ha.yr – see Table 4) but they include root material as well.

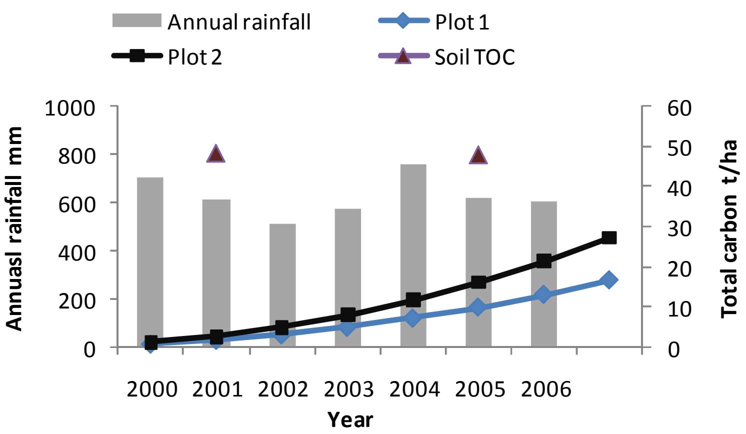

Figure 1. Carbon storage in trees and surface soils as a function of time.

Conclusion

Carbon storage in remnant trees in a TCG zone increased exponentially with time between 2001 and 2005 but remained less than soil surface C which did not change over the same period. Annual rainfall appeared to have little impact on this increase possibly because the trees are conservative in their water use. Further research including measurements of stored soil and root C at depth may help to establish whether graziers can earn ongoing income for sequestering C by returning non-productive parts of their lands to eucalypts.

Acknowledgements

Thanks to Scott Byrnes for analysis of soils and vegetation samples, Ahmed Mahmoodabadi for assistance in tree sampling, and the National Heritage Trust for funding.

References

Bird PR, Bicknell D, Bulman PA, Burke SJA, Leys JF, Parker JN, van der Sommen FJ, Voller P (1992) The role of shelter in Australia for protecting soils, plants and livestock. *Agroforestry Systems* **20**, 59-86

Burrows WH, Henry BK, Back PV, Hoffmann MB, Tait L J, Anderson ER, Menke N, Danaher T, Carter JO, McKeon GM (2002) Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. *Global Change Biology* **8,** 769-784.

Cook GD, Liedloff AC, Eager RW, Chen X, Williams RJ, O'Grady AP, Hutley LB (2005) The estimation of carbon budgets of frequently burnt tree stands in savannas of northern Australia, using allometric analysis and isotopic discrimination. *Australian Journal of Botany* **53,** 621-630.

Grierson, PF, Adams MA, Attiwill PM (1992) Estimates of Carbon Storage in the Above-ground Biomass of Victoria's Forests. *Australian Journal of Botany,* **40,** 631-640.

Henry B, Mitchell C, Cowie A, Woldring O, Carter J (2005) A regional interpretation of rules and good practice for greenhouse accounting: Australian savanna systems. *Australian J. of Botany* **53,** 589-605.

Miehle P, Livesly SJ, Feikema PM., Li C, Arndt SK (2006) Assessing productivity and carbon sequestration capacity of *Eucalyptus globulus* plantations using the process model Forest-DNDC: Calibration and validation. *Ecological Modelling* **192**, 83-94.

Moore JL, Howden SM, McKeon GM, Carter JO, Scanlan JC (2001) The dynamics of grazed woodlands in southwest Queensland, Australia and their effect on greenhouse gas emissions. *Env. Inter.* **27**, 147-153.

Sanjari G (2009) Evaluating the Impacts of Time Controlled and Continuous Grazing Systems on Soil Properties, Surface Hydrology and Pasture Production in South-East Queensland. PhD Thesis, Griffith School of Environment, Griffith University.

Specht,A, West PW (2003) Estimation of biomass and sequestered carbon on farm forest plantations in northern New South Wales, Australia. *Biomass and Bioenergy* **25**, 363-379.

Young R, Wilson BR, McLeod M, Alston C (2005) Carbon storage in the soils and vegetation of contrasting land uses in northern New South Wales, Australia. *Australian Journal of Soil Research* **43**, 21-31.