# Soil carbon densities in the cropping areas of NSW with emphasis on the Red Soils of the Western Wheatbelt

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**Abstract**
Measurements of soil carbon densities for soils in the wheatbelt of NSW after clearing and under a range of management practices are presented. In the western part of the wheatbelt soil carbon densities to 30 cm depth (the Kyoto Standard) ranged from 28 to 40 t/ha in uncleared areas, to 20 to 25 t/ha in areas that had been cleared for long periods of time (> 20 years). In the more eastern part of the wheatbelt, measured soil carbon densities to 30 cm ranged from 100 t/ha in some uncleared areas with good grass cover, to 40 to 50 t/ha for pasture areas to 30 to 33 t/ha for cropped areas. . In the western part of the wheatbelt soil carbon densities to 100 cm depth ranged from 60 to 65 t/ha in uncleared areas to 50 to 55 t/ha in areas that had been cleared for long periods of time (> 20 years). No data was available for soil carbon densities to 100cm in the eastern part of the wheatbelt. Soil carbon density values for the western part of the NSW wheatbelt supported the use of 30 cm as a baseline for predicting soil carbon changes associated with changes in land use.

**Key Words**
Soil carbon densities, clearing, land management, NSW wheatbelt

**Introduction**
The size of carbon (C) stocks in ecosystems in NSW and the changes in C stocks as a consequence of changes in land use are critical components for the National Carbon Accounting System (NCAS) being developed by the Australian Greenhouse Office (AGO). The soil C stocks are one of the major components of these ecosystem C stocks (Rawson and Murphy 2000). This paper reports on soil C stocks and changes in soil C density following clearing of native vegetation for one of the major areas of current clearing in NSW. This covers a belt of land from Condobolin in the south to Walgett in the north. Our research project contributes to a national program of soil carbon flux estimation initiated by the AGO and using 10 paired sites in NSW in the regions where clearing for agriculture has occurred since 1970 (see Murphy *et al.* 2003). We provide data to estimate soil C densities under native vegetation and compare these with soil C levels following land clearing. Soil C density is also seen as a possible way of assessing soil quality for various purposes such as soil structural condition and fertility.

The results presented in the paper concentrate on the western parts of the wheat belt of NSW which is one of the areas most subject to clearing of native vegetation. The results compare uncleared and cleared land for the red earth soils (Red Kandosols) of the Cobar Peneplain for a range of periods of clearing (see Figure 1). The C densities are estimated to 30 cm as required by the Kyoto Protocol, but also to 100 cm.

Some estimates of soil C densities for cleared and uncleared land in more eastern parts of the wheat belt are included for comparison.

**Methods**
The methodology used conformed to the protocols set down for determining soil C densities by McKenzie *et al* (2000). However, there were several details in the methodology that were not addressed in McKenzie *et al. and* these are described fully in Murphy *et al.* 2003. The major difference related to the calculation of soil C densities to 30 cm. In Murphy *et al*., allowance is made for the effect of increased bulk density and soil settlement following clearing when estimating changes in soil C density to 30 cm.

A paired site approach was chosen to obtain data on relative C densities for cleared and uncleared land in order to obtain the maximum amount of information with available resources. To form a valid comparison, the members of a paired site were similar in all

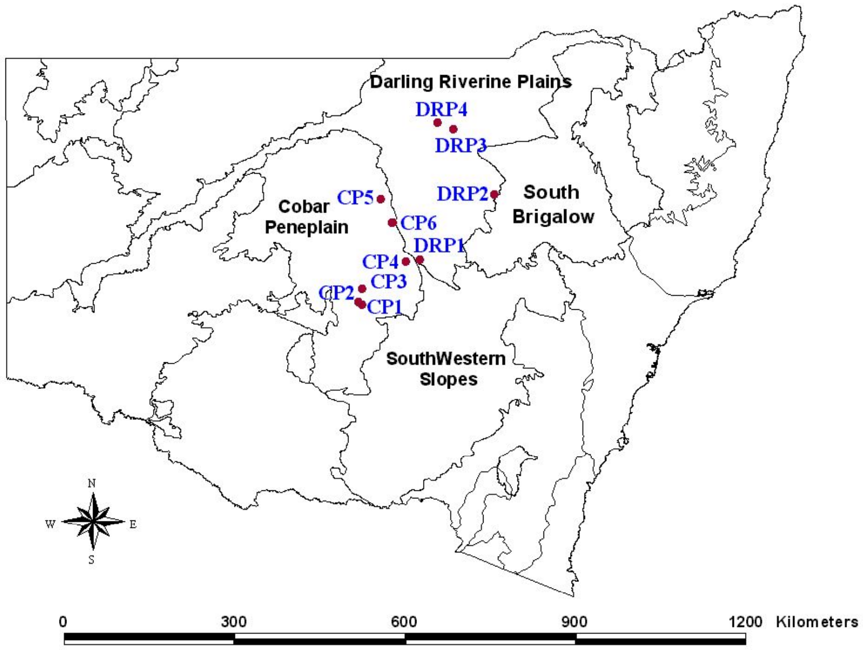


**Figure 1. Location of sites for soil C density measurements. IBRA Region boundaries are shown based on Thackway and Cresswell (1995). Red Kandosol soils are shown as the CP sites on the Cobar Peneplain .**

respects as possible except for the land use/cover change. The comparison was made on adjacent patches of land with identifiably different land use/cover with known history of use. The soil the slope, aspect and drainage were the same for each comparative site. Results indicated that Bimble Box (*E. populnea*)/ grass woodlands on the Cobar Peneplain were the main vegetation communities being cleared, so 6 of the 10 comparative sites were located in these communities.

Once a site was selected, 25 x 25 m quadrats were set up in the uncleared and cleared areas. These quadrats were located at least 50 to 60 m from the edge of the cleared area and were chosen to be representative of the cleared and uncleared areas. Areas avoided included logged areas and heavily grazed areas in uncleared areas and headlands and old wood heaps in cleared areas.

One length of the 25 m x 25 m quadrat was divided into 5 intervals to give 5 rows, and then each row was divided into 5 to give 25 cells per quadrat. Within each row one cell was selected at random for the soil core for C density measurements giving 5 cores per site. Dry matter and litter density measurements were made within these selected cells using a 50 cm x 50 cm plot. The 5 soil cores to be used for determining the soil C densities were taken from the 50 cm x 50 cm plots cleared for the dry matter and litter measurements.

At the centre of each quadrat, a soil core was taken using the Proline corer to a depth of 1300 mm. This soil core was stored in plastic drainpipe and brought back to the laboratory for general soil characterisation, including profile description and laboratory analysis. The methods and descriptions outlined by McDonald *et al* (1990). At each of the 5 selected cells, a 150 mm soil core was taken using a Proline Soil Corer with an internal split tube. The outside rotating auger was mounted on a bearing to minimise soil disturbance and to prevent rotation of the soil core. The core was removed from the ground and carefully placed on the rear tray of a vehicle. Care was taken not to disturb the soil surface. Note was taken of any obvious compaction and twisting. If this was observed the core was discarded and another taken. The depth of the hole was checked in relation to the soil core, and provided the soil was relatively dry, no compaction or twisting was recorded. The potential for this to occur was minimised by the large size of the core (150 mm in diameter).

Bulk densities were determined by cutting the soil core in the field at the depth intervals of 0 to 50 mm, 50 to 100 mm, 100 to 200 mm, 200 to 300 mm, 300 to 400 mm, 400 to 500 mm, 500 to 600 mm, 600 to

700 mm, 700 to 800 mm, 800 to 900 mm. This gave soil cylinders of known length and the diameter of the cutting bit of the Proline corer was used as the diameter of the core. It was approximately 150 mm, although the exact diameter of the cutting tip was used for calculations, and this was checked regularly in the field for any changes caused by wear. The wet weight of each cylinder of soil was determined using a field balance. This cylinder of soil was split into a subsample to be used for the determination for C percentage, and a smaller subsample placed in a watertight bottle to determine moisture content in the laboratory. Bulk density for each cylinder cut in the field for each depth interval was determined using the total wet weight for the soil cylinder and the moisture content. Each cylinder of soil for the depth intervals gave a large volume of soil and the soil was thoroughly mixed prior to subsampling for moisture content and for C determination.

On return to the laboratory soil samples were immediately placed into a shade house for drying. This involved drying at normal air temperatures and largely by normal airflow. Once dried, samples were taken to the laboratory for crushing.
A sample splitter was used when preparing samples in the laboratory. When bulking, the amount of soil used from each depth was based on a weighted average of the bulk density of the soil in the top 30cm.

Major pieces of root material were removed from the soil samples prior to the determination of soil carbon percentage. About 30 minutes was assigned to this task. for samples with a large number of roots.

Soil C contents were determined by LECO furnace in the CSIRO laboratories in Adelaide. Soils with significant amounts of carbonate were crushed and the carbonate removed by acid treatment.

Soil C density (CD) for each depth was calculated by the equation:
CD (t/ha) = bulk density (t/m$^3$) x C content (% ) x depth (m) x 10 000.
As reviewed in Murphy *et al.* (2003), there are complications in estimating changes in soil C densities to 30 cm as a result of soil clearing because of soil settlement, but these are not considered in the current paper.

This paper concentrates on a visual presentation of the data, as the statistical analysis and details of methodology are presented in Murphy *et al*. (2003).

**Results**
*Soil C Densities in the Red Earth Soils (Red Kandosols) of the Western Wheat Belt of NSW*
Soil C densities per layer
The soil C densities per layer for different times since clearing are presented in Figures 1and 2. The largest losses in soil C are clearly from the top 10 cm. which supports the use of the 30 cm depth standard for estimating changes in soil C stores as proposed in the Kyoto Protocol. Generally the uncleared profile of soil C densities/cm of depth marks the highest values, except for the 3 and 90 year lines in the 10 to 30 cm depth range. The uncleared values are based on the mean of six sites and so are less affected by local variation associated with the location of individual trees and shrubs. The site where measurements were made 3 years after clearing would appear to be a site that had slightly higher soil C densities. This could be due to the inclusion of decaying tree roots or shrub roots within the samples taken from the site. This illustrates that some local variation can be present in soil C densities. The site where measurements were made 90 years after clearing has been a continuous pasture, and a lightly grazed pasture for the last 10 years, which explains the higher values compared to the cropped areas.

The decreases in soil C density/cm depth after clearing are shown in Figure 2. The site with 90 years since clearing is omitted as it was a pasture site. Although the major changes in soil density occur in the top 30 cm, there is clear evidence in this data that some changes in soil C density/cm continue below 30 cm.

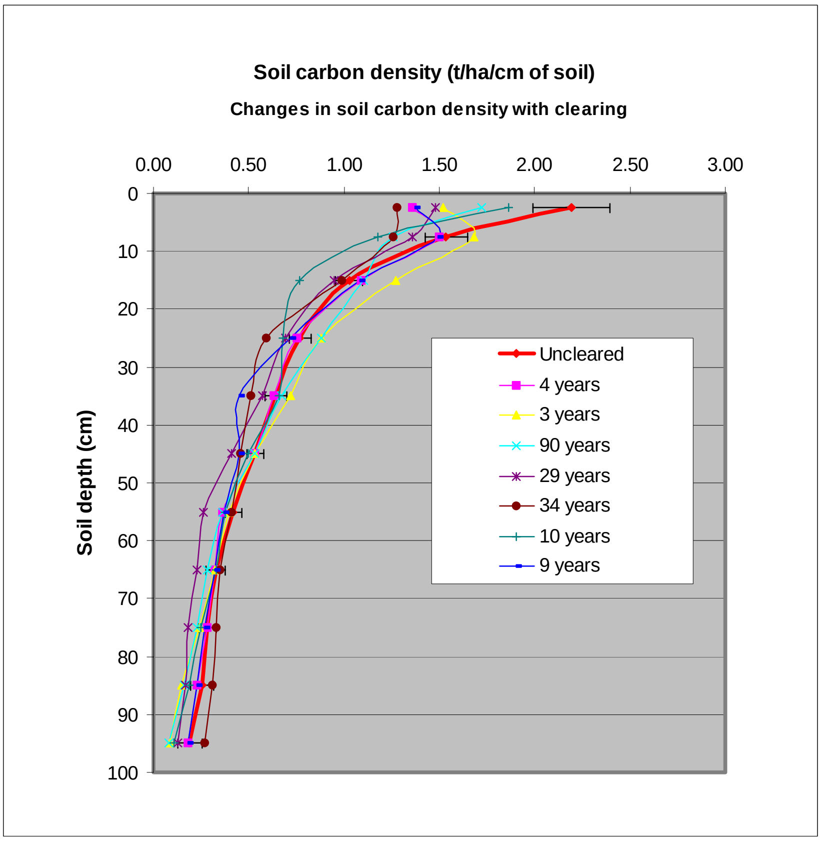


**Figure 1. Soil C densities per layer compared to years since clearing – profile changes**

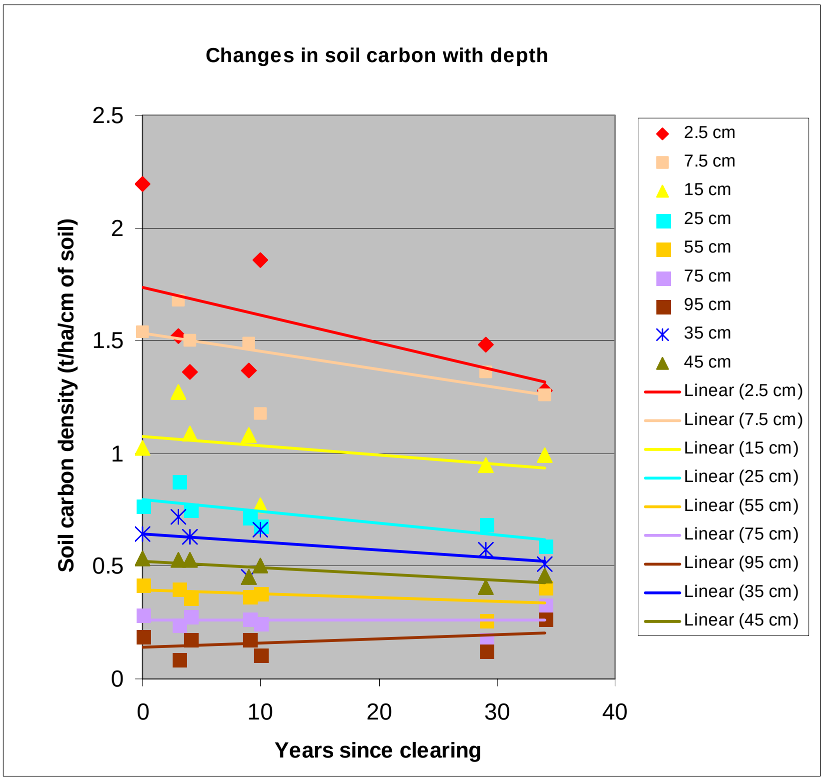


**Figure 2 Soil C densities per layer compared to years since clearing – changes with individual layers**

*Total soil C densities with depth – soil C stores*

The changes in total soil C stores with depth are shown in Figures 3 and 4. Soil C densities to 30 cm that is the standard depth for the Kyoto Protocol, change on average from about 30 t/ha in uncleared land to 20 t/ha after clearing. The results show that total soil C stores to 100 cm are in the vicinity of 60 t/ha and that they decline to about 50 t/ha after clearing. The differences in soil C density after clearing are the same when measured at 30 cm and 100 cm. The trend lines for depths below 30 cm are clearly close to parallel (see Figure 4). These results would indicate that soil C changes occur largely in the shallower depths above 30 cm. The results show that on average about 10 t/ha of soil C is lost to the atmosphere as a consequence of clearing, which is equivalent to about 37 tonnes of C dioxide.

*Soil C Densities in the Red Soils (Red Chromosols and Red Kandosols of the Eastern Wheatbelt of NSW*

There is not the same level of comprehensive data on soil C densities to 1m depth in the eastern parts of the wheatbelt of NSW. However, a series of soil profiles were measured for a range of soils in the eastern wheatbelt to 30 cm (Geeves *et al.* (1995) and Valzano *et al*. 2003). Measurements included bulk densities and soil C percentages using the LECO furnace. A summary of the results is presented in Table 1.

Although the data is limited, there is a clear reduction in soil C densities with tillage. Overall soil C densities appear to be 5 to 10 t/ha higher than the soil C densities in the western parts of the NSW wheatbelt. This is expected given the lower rainfall in the western areas. An important factor to consider is that the grazing and direct drill management practices had large standard errors, so predictions are more difficult to make for these practices. One explanation is that the actual soil C densities under these practices depends very much on how the practices are implemented (see Lawrie *et al.* 2000).

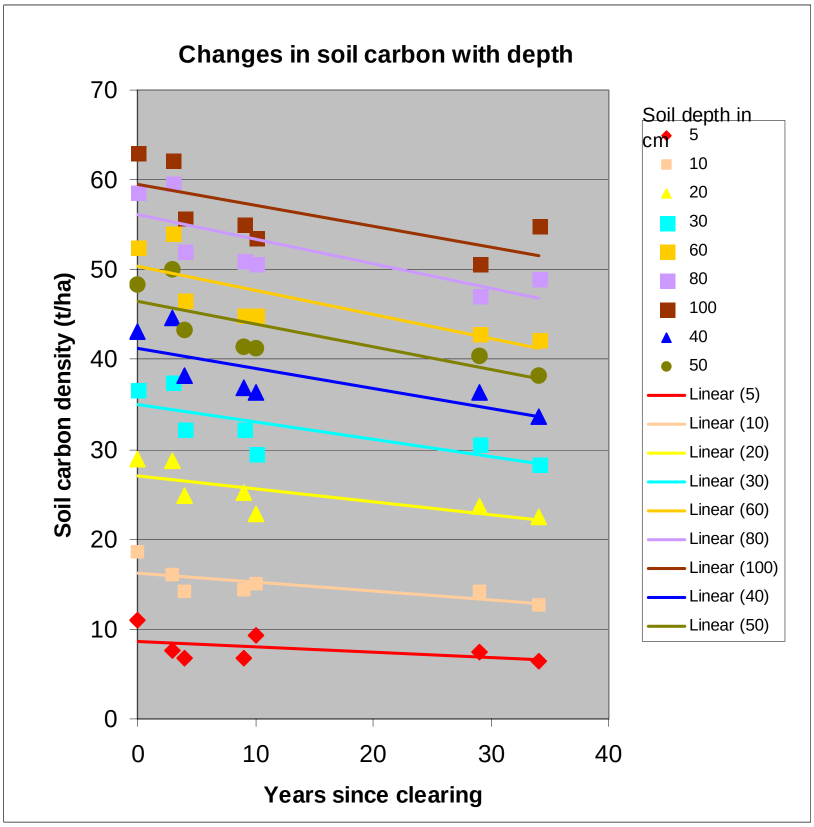


**Figure 3. Changes in soil C densities with clearing – profiles to 100 cm.**

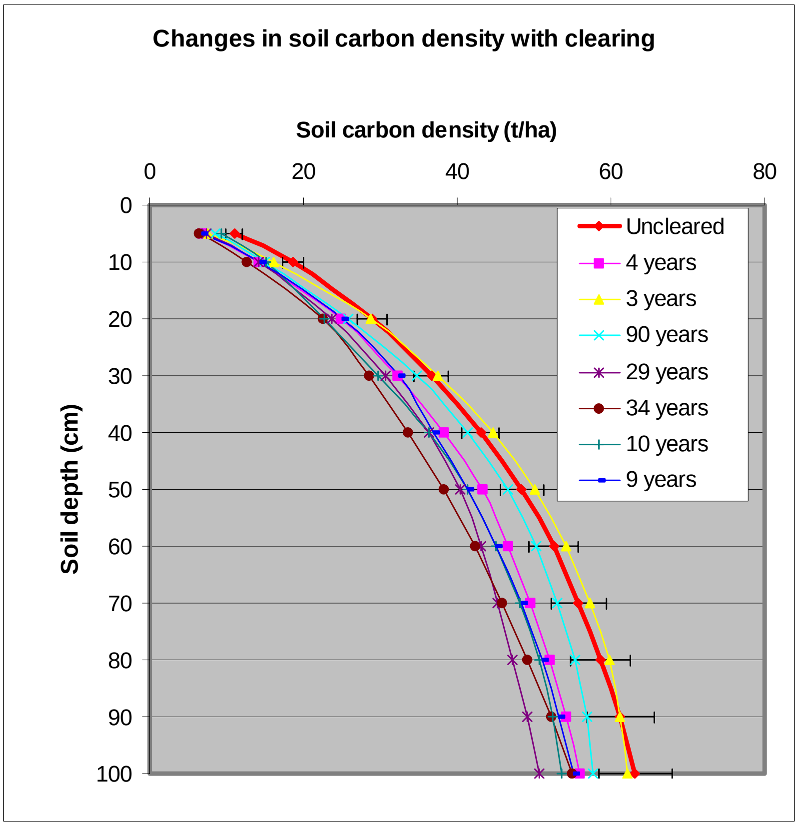


**Figure 4. Changes in soil C density with depth in relation to years since clearing**

**Table 1. Measured soil C densities to 30 cm in the red soils (Red Chromosols and Red Kandosols) in the eastern wheatbelt of NSW (Geeves *et al.* 1995 and Valzano et al. 2003).**

| General Management Practice | Mean soil C density to 30 cm (t/ha) | standard error | number of paddocks |
|---|---|---|---|
| Woodland | 109 | 12 | 3 |
| Light grazing | 51.3 | 17 | 3 |
| Heavy grazing | 43.6 | 6.4 | 3 |
| Direct drill type cropping practices | 33.5 | 6.7 | 11 |
| Traditional tillage type cropping practices | 31.8 | 3.8 | 9 |

## Conclusion

The results relate to the following:

1. The C densities in the major areas of clearing in NSW are estimated to 30 cm as required by the Kyoto Protocol, but also to 100 cm. Soil C densities are of the order of 20 to 40 t/ha to 30 cm, and 40 to 60 t/ha to 100cm.
2. Results indicate that losses of the order of 10t/ha are common as a consequence of clearing on the Red Kandosol soils in the western parts of the NSW wheatbelt.
3. The results support to a large degree the use of the 30 cm depth standard proposed for C accounting for land use changes in the Kyoto Protocols. However, there are some indications that there maybe a small underestimate of changes in soil C stores because small changes in soil C were detected at depths below 30 cm.
4. Soil C densities in the eastern part of the wheatbelt of NSW are higher than those in the west. Soil C densities are in the vicinity of 30 to 35 t/ha in cropped areas, 40 to 50 t/ha in grazed areas, and up to 100 t/ha in uncleared areas.
5. Further analysis of this data and other published is required to confirm these conclusions.
6. These data on soil carbon densities for different land management practices can be used to calculate the likely changes in soil carbon stocks for NSW that are associated with land clearing and changes in land management practices. The area of land under each land use or land management practice is required to estimate soil carbon stocks for NSW.

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