Comparing and predicting long-term trend of soil carbon at different land use systems in Red Ferrosol soils of Southeast Queensland

Tek Maraseni, Nicole Mathers, Ben Harms, Geoff Cockfield and Armando Apan

Email (First Author): maraseni@usq.edu.au
Introduction

- Forest clearing: a major environmental problem in Australia
  - Historical clearing – extensive cropping & grazing
  - Major source of greenhouse gas emissions
    - 735 Mt C emitted only due to loss of aboveground biomass since the European settlement
  - 12% of the total GHG emission in 1998
  - 80% of the total clearing is in Queensland from 1995-97
Introduction (Cont’d)

• Primary motivator of land clearing
  – Availability of cheap land
  – Agricultural profit (immediate by increased profit and long-term by increased land value)
  – Attitude: clearing was viewed as development (vigorous regrowth of eucalypts and others)
  – Incentives (loans or land grants, tax break)
  – R&D (new bread, new practices, clearing technology)
  – New infrastructure (road/rail access to markets)
  – Market forces (both in boom and bust)
Introduction (Cont’d)

• **Changing scenario**
  
  – Pressure on farmers: increasing expenditure & decreasing prices
    
    • Effect: Shift in land use from cultivation to grazed pasture in 1980s in unproductive cropping land
  
  – Recently, Govt is encouraging hardwood plantations on the degraded ex-cultivated and pasture areas
    
    • Forest clearing rate has decreased
    • Average plantation rate has increased
    • People are encouraged for hardwood plantation
Growing popularity of *Corymbia citriodora* (spotted gum) as a hardwood plantation in South East Queensland?

- Diminished supply from native forests, but its demand is increasing by 2-3 percent every year
- Early age performance is encouraging
- Preliminary results of genetic improvement program are promising
- Highly valued nationally and internationally
Introduction (Cont’d)

– Recent policies

• Tree clearing laws and Land Act

• The Vision 2020: targeted national plantation estate of about 3 million ha by 2020

• Federal-State partnership: SEQRFA Program

• The QLD Govt has approved a $30m plan for hardwood plantation (mainly spotted gum) in SEQ

• The long-term viability of the plan is still questionable
Introduction (Cont’d)

• Research assumption and research boundary:
  – Economic viability is a major driver for plantation
  – Major limiting factor for agricultural crop is soil moisture (mean monthly rainfall > evaporation)
  – High rainfall and non-degraded soil area are not viable
  – SEQRFA area where farmers get incentive for plantation could help a lot
  – Spotted gum is highly demanding species for plantation
  – If C Trading is considered, plantation could be competitive in low rainfall, rain-fed & degraded soil (Red Ferrosols) area of SEQRFA
Objectives

- To find the optimum rotation age of spotted gum and then compare the economic benefit of different land use systems incorporating both C and tangible values (part of PhD thesis)

- Objectives of the paper:
  - to compare soil C under different land use systems; and
  - to predict the long-term trend of soil C in different land uses in the red Ferrosols of SEQ
Figure: Red Ferrosol soil area of Australia

Source: www.grdc.com.au
Research area: South Burnett district

A: Mat. Spotted gum
B: Pasture, cultivation, native scrub & spotted gum plantation

Figure: Location of SBD in Australia (upper) & the study areas in the SBD (lower)
Land uses analysed for the study

Pastureland

Mature spotted gum

Scrubland

Cultivated land

Koli, Finland
Figure: Timeline of land use change in the study site

Timeline was used to triangulate soil C in different land use system
Research Method

(a) **Soil sampling:** Main core: 110 cm depth, adjacent cores: 30 cm
(sample: 0-5, 5-10, 10-20, 20-30, 30-50, 50-70, 70-90 & 90-110 cm depths)
Figure: Soil sample taking with hydraulically operated soil rig
(b) Surface litter and POM sampling
Marked 5 m radius plot, rank litter light, medium & heavy, found area of each type, randomly selected 2 quadrats of 50 cm × 50 cm from each (Fresh weight (kg/ha) = \(\sum (A_i \times W_i \times 20,000)\))
(c) Presentation of results

- Due to differences in bulk density between land-uses, soil C comparisons based on cumulative depth may be misleading.

- Therefore, all calculations are referred to a fixed dry mass of soil per unit ground area.

- As an alternative to the standard depth of 30 cm & 1 m, soil C in the top 0.4 t and 1.2 t dry soil m\(^{-2}\) is adopted.
Research Methods (Cont’d)

(d) Chemical Analysis (total C, N & δ\textsuperscript{13}C & δ\textsuperscript{15}N)
   – Isoprime IRMS coupled to a Eurovector elemental analyser (Isoprime-EuroEA 3000)

(e) Estimation of soil C using the ROTHC soil model

(f) Statistical test for validation (field estimation = RothC estimation)
   – Correlation test
   – Independent t-test
   – Paired t-test
Results

(a) Total C (%)
### Results (Cont’d)

(b) Cumulative soil C (t ha⁻¹) under different land uses

<table>
<thead>
<tr>
<th>Land uses</th>
<th>Cumulative Soil C to 0.4 t m⁻²</th>
<th>Cumulative Soil C to 1.2 t m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivation</td>
<td>38</td>
<td>72</td>
</tr>
<tr>
<td>Pasture</td>
<td>74</td>
<td>145</td>
</tr>
<tr>
<td>Native Scrub</td>
<td>85</td>
<td>178</td>
</tr>
<tr>
<td>Mat. Spotted Gum</td>
<td>202</td>
<td>267</td>
</tr>
</tbody>
</table>
## Results (Cont’d)

(c) Total C (t ha⁻¹) content under different land use systems

<table>
<thead>
<tr>
<th>Land use types</th>
<th>POM</th>
<th>Surface litter</th>
<th>Soil C</th>
<th>Total C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivation</td>
<td>0</td>
<td>0</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Pasture</td>
<td>0</td>
<td>1.01</td>
<td>145</td>
<td>146</td>
</tr>
<tr>
<td>Native scrub</td>
<td>4.18</td>
<td>46.46</td>
<td>178</td>
<td>228.6</td>
</tr>
<tr>
<td>Mature spotted gum</td>
<td>8.12</td>
<td>6.21</td>
<td>267</td>
<td>281.3</td>
</tr>
</tbody>
</table>
(d) Long-term prediction of total soil C: extrapolation of past trend
(e) Long term prediction of total soil C: RothC model

Cumulative soil carbon to 1.2 t/m² (t/ha)

- Cultivation
- Pasture
(f) Comparison of two results

- The estimated annual rate of soil C loss under cultivation from 1950-2005 was 2.1% (~ \textit{ROTHC} predicted value)
  - Independent t-test (p>0.05): (\mu_1=\mu_2)
  - Correlation test (r = 0.99, p=0.000)
  - Paired t-test (p<0.001), indicating (\mu_D \neq 0). It means these two set of predicted values are not same. Annual rate of soil C loss is different in different periods.
    - Loss by 4.4% from 1950-1955
    - Loss by 2.4% from 1955-1965
    - Loss by 1.8% from 1965-2000
    - Loss by 1.48% from 2000 and onwards
(f) Comparison of two results (cont’d)

- The estimated annual rate of soil C gain under pasture from 1983-2005 was 1.1% (~ ROTHC predicted value)
  - Independent t-test (p>0.05): (µ₁=µ₂)
  - Correlation test (r = 0.98, p=0.000)
  - Paired t-test (p<0.001) indicated µD ≠ 0
    - Increase by 3.74% from 1983-1988
    - Increase by 0.90% from 1988-2000
    - From 2001 to 2025 increase by 0.45%

- The estimated annual rate of soil C gain under mat spotted gum from 1950-2005 was +1.4 (need to be tested by ROTHC)
Conclusion

– Demonstrated how a timeline of land use change might be useful to predict soil C trends using a minimum number of land use systems

– Planting spotted gum on ex-agricultural land has considerable potential for sequestering soil C.
Implication of the study

• The result applies only to Red Ferrosol soils in the SEQ environment.

• Although the rate of loss (2.1%) of soil C in cultivation & rate of gain in pasture is very high (1.1) in the long run, for the valuation of soil C, current rate should be used.

• Annual loss by 1.48% in cultivation & annual gain by 0.45% in pastureland.
Implication of the study (Cont’d)

• MSG was studied for proxy value of soil C for new SG plantation under the SEQRFA program

• New plantations are a silvipastoral, including legumes (soil C>normal). But many things to be considered before transferring research benefit:
  – The MSG forest was planted in pastureland & nobody knows for how long the pasture was there
  – The crown cover of MSG is well maintained all the time
  – The soil C under the MSG could not accurately reflect the plantations over 50 years as the agri. land would never return to original condition

• Proposed soil C scenarios for the further analysis: 10%, 20% and 30% lower than the actual rate.