Is the grass greener on the other side?

Land Use and Land Cover Change and in Australian Savannas

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Introduction

- Tropical savanna ecosystems are a major contributor to global CO$_2$, N$_2$O & CH$_4$
- Increasing pressure to develop agriculture - deep-rooted native trees replaced with shallow rooted pasture species
- The Daly River catchment of northern Australia has large areas of cleared native savanna vegetation for pasture. NOW change to hardwood species.
- Understanding impacts a key to sustainable management
  - What is the impact of Land Use and Land Cover Change (LULCC) on climate (GHG) and hydrological processes (ET) across the catchment?
  - Today look at total GHG budget
Research themes

• Link to climate change policy
  – Research needed to improved understanding of savanna carbon stocks and flows
    • Vegetation and soil derived emissions and sinks
    • Fire derived GHG emissions (WALFA et al.)
  • Carbon Farming
    – Total savanna GHG balance required

• Scientific basis for verification essential
Understanding Carbon Dioxide Fluxes

- Canopy photosynthesis function of light, available water, nutrients, VPD, Leaf Area Index and CO₂ concentration.
- Strongly climate modified
- Autotrophic respiration depends on photosynthesis and temperature
- Heterotrophic respiration dependant on water and modified by temperature
- Short and long term exchanges which are modified by LULCC
- Other GHGs too!

(Trumbore et al. 2006)
Ecosystem Carbon Balance

GPP

Plant resp

Soil and litter resp

Disturbance

NPP

Short term uptake

Medium-term storage

NEP

Long-term storage

NBP
Land-use change sequence

Greenhouse gas exchange

CO₂  N₂O  CH₄

Woodland

Soil carbon change

Pasture

Years under different land-use

Courtesy Stephen Livesley (Uni Melb)
Aims

GHG dynamics and nutrient cycling in north Australian savannas

$\text{CH}_4, \text{N}_2\text{O}, \text{CO}_2$

Spatial and temporal variability

Effect of Fire

Land use change

Contribution of termites

Mechanisms controlling emissions
Physical, chemical and biological soil properties

Methods

Eddy-covariance towers
Automated trace gas system
Manual trace gas chambers
Soil nutrient and moisture Modelling ($\text{NCAT, DNDC}$)
Study Area

- Daly River catchment covers approx 53,000 sq. km and 200 km south of Darwin
- Rainfall dominated by short, intense wet season, decreases from north west (~1400mm) to south east (~700mm)
- Savanna vegetation (tree/grass), with varying structural attributes
- Low relief catchment (0-475m), with skeletal, uniform sands, earths, texture contrast and cracking clay soils
- 4-8% of catchment suitable for agriculture (earth soils)
CO$_2$ exchange using flux towers

- The only method of *directly* determining fluxes.
- Non-invasive
- Measures at whole ecosystem level above canopy
- Gives Net Ecosystem Exchange (~NEE) of CO$_2$
- Can calculate Gross Primary Production and Ecosystem Respiration
- Also measures evapotranspiration and energy
- Most accurate method but is complex.
- Hourly measurements continuously over years (scale up to annual sink/source)
- Complementary to other techniques (top-down and bottom-up)
Net Ecosystem Production

- Eddy covariance measurements of NEP
- Neural network model for ecosystem respiration ($R_e$)
- NEP = GPP – $R_e$
- Uncertainties in methodologies
Daly River savanna uncleared
(14.159S, 131.388E)
Daly River regrowth site
(14°07’50.16”S, 131°22’58.08”E)
Daly River savanna Regrowth
Daly River Pasture site

\(14^\circ 3'47.88''S \ 131^\circ 19'5.16''E\)
Daly River Pasture site
Year 2008
Solar = 7888 MJ yr\(^{-1}\)
Rainfall = 1389 mm yr\(^{-1}\)
VPD = 17.4 kPa

Regrowth 0.950
Pasture -0.386
Table 3: Annual NEE for pastures and cultivated field (Priante-Filhou et al. 2004; Santos et al. 2004; Sakai et al. 2004)

<table>
<thead>
<tr>
<th>Country</th>
<th>Station</th>
<th>NEE [tCha-1yr-1]</th>
<th>Year</th>
<th>Type of Vegetation</th>
</tr>
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<tbody>
<tr>
<td>Brazil</td>
<td>Cortiguacu</td>
<td>-1.66</td>
<td>2000</td>
<td>Pasture</td>
</tr>
<tr>
<td>Brazil</td>
<td>Fazenda Rio de Janeiro</td>
<td>No Data</td>
<td>2003</td>
<td>Pasture</td>
</tr>
<tr>
<td>Brazil</td>
<td>Santarem</td>
<td>-3.87</td>
<td>Dec 2000-Nov 2001</td>
<td>Pasture</td>
</tr>
<tr>
<td>Brazil</td>
<td>Santarem</td>
<td>6.88</td>
<td>Nov 2001-Dec 2001</td>
<td>Bare Soil</td>
</tr>
</tbody>
</table>
## Vegetation carbon pools (t C ha\(^{-1}\))

<table>
<thead>
<tr>
<th></th>
<th>Savanna</th>
<th></th>
<th>Regrowth</th>
<th></th>
<th>Pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overstory</td>
<td>Understory</td>
<td>Overstory</td>
<td>Understory</td>
<td></td>
</tr>
<tr>
<td>AGB</td>
<td>31.1</td>
<td>2.15</td>
<td>1.4</td>
<td>2.45</td>
<td>1.5</td>
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<tr>
<td>BGB</td>
<td>28.7</td>
<td>~0.5</td>
<td>1.3</td>
<td>~0.5</td>
<td>?</td>
</tr>
</tbody>
</table>
• Total soil column mineral organic C higher at Pasture site
• 28 years old but in trajectory from clearing to equilibrium.

![Soil sequestration rate – improved pastures](image)

0.37 t C ha\(^{-1}\) y\(^{-1}\)
N$_2$O and CH$_4$ fluxes represent <1% of soil GHG flux in CO$_2$-e terms
Carbon fluxes vary on different time scales

- Annual NEP (source or sink?). Inter-annual variability due to grass productivity – related to growing season. Climate change.
- Woody savanna less variable and small sink.
- Dry season irrigation led to greater N$_2$O emissions in pasture soils than uncleared savanna but similar reductions in soil CH$_4$ uptake.
- N$_2$O fluxes were minimal and uncleared savanna soil was a constant CH$_4$ sink.
- Soil GHG emissions are dominated by CO$_2$.
- LULCC from savanna to pasture increased soil GHG emissions.
- Changes in stocks must be taken in context of LULCC and succession. Need longitudinal data.