CARBON, GREENHOUSE GASES, AND HOW WE MEASURE THEM

Mila Bristow
ENV101 Lecture 2015

Mila.Bristow@nt.gov.au

http://www.nt.gov.au/d/Primary_Industry/index.cfm?header=Action%20on%20the%20Ground

Quiz

1. What are greenhouse gases?
   A. Other words for inert gases
   B. Fuel used by farmers
   C. Vapours rising off greenhouses
   D. Heat-trapping atmospheric gases
2. What form does carbon travel in throughout the atmosphere?
3. Which of the following is **NOT** a ***source*** of carbon?
   A. Deep ocean
   B. Soil
   C. Marine life
   D. Land plants

Quiz - ANSWERS

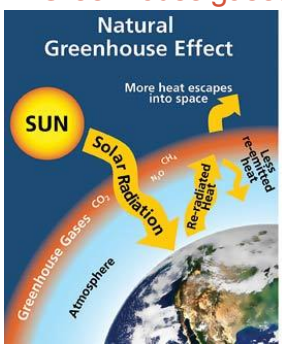
1. What are greenhouse gases?
   A. Other words for inert gases
   B. Fuel used by farmers
   C. Vapours rising off greenhouses
   D. **Heat-trapping atmospheric gases**
2. What form does carbon travel in throughout the atmosphere? **CO_2** or **carbon dioxide**
3. Which of the following is **NOT** a ***source*** of carbon?
   A. **Deep ocean**
   B. **Soil**
   C. **Marine life**
   D. **Land plants**

A B C D are all sources of Carbon

Outline for this lecture

- Greenhouse gases
- Carbon cycle
- Water cycle
- Plants, forests and agriculture – Carbon sequestration
- Land use change and GHG
- Applied examples of measuring GHG in land clearing experiment:
  - near real time GHG exchange using flux towers
  - manual chambers to measure soil non-CO_2 exchange
- Discussion

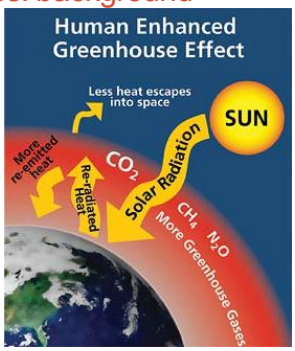
Greenhouse gases: background



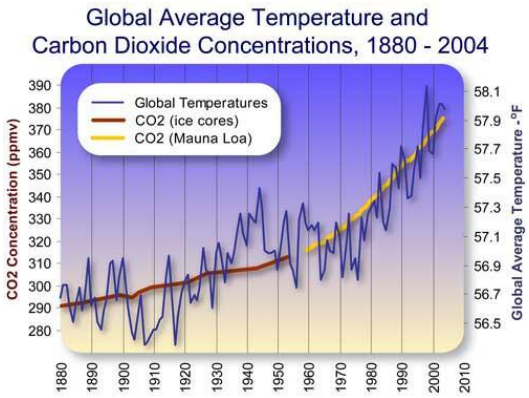
- Gases in the atmosphere that trap heat
- H_2O, CO_2, CH_4, N_2O, etc

Greenhouse gases: background

- burning of fossil fuels (coal, oil and natural gas)
- clearing of land (burning vegetation)
- Consensus this is changing the climate



[ClimateBits: Fast Carbon, SlowCarbon - YouTube]

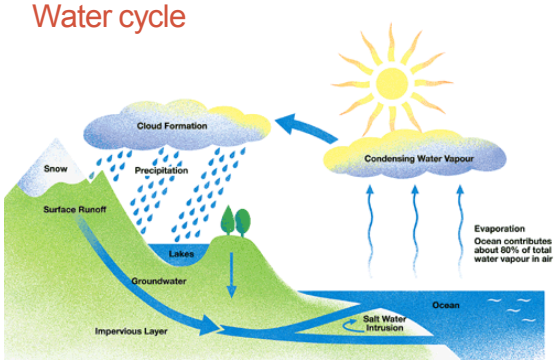


Climate Change Fuelling Wilder Weather

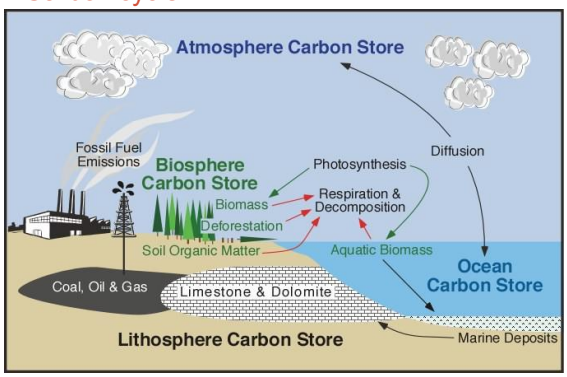
YouTube video: ClimateCommission
http://climatecommission.gov.au/

http://www.youtube.com/watch?v=MNdF-eVRWX4

Water cycle

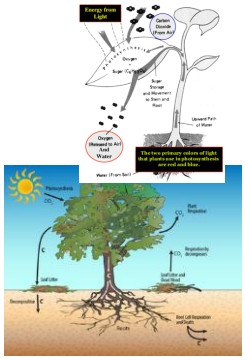


Carbon cycle



Carbon in terrestrial systems

- Plants sequester (absorb or remove from the atmosphere) and store atmospheric CO_2
- Store C in live & dead tissues
- C to groundwater, rivers and oceans
- C to soils, sediments & fossil fuels
- C released to atmosphere through respiration, decomposition, burning fossil fuels, deforestation, etc.

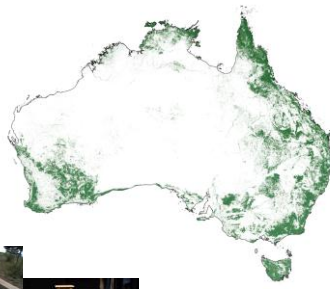


Carbon in forests

- Forests cover > 4 billion hectares (~31% of the earth's surface)
- Forest ecosystems store ~ 650 billion t C
  - 44% in live (standing) biomass
  - 11% in dead (rotting/decomposing) necromass
  - 45% in soils
- and absorb 8.5 billion tCO_2 per yr from the atmosphere

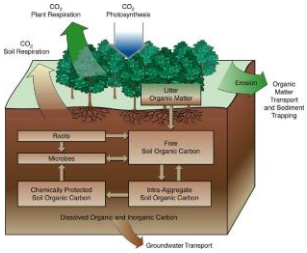
Carbon in forests

149 M ha forest in Australia
- 2 M are plantations
- <10% native forest harvested



Carbon in soils

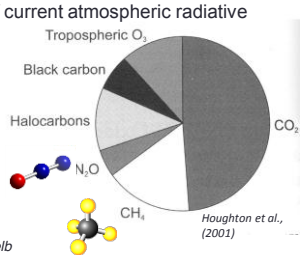
- soils store ~ 75% of terrestrial C
- 2 to 3 times the amount stored in living plants and animals
- Soil management effects soil C



C cycle and non-CO_2

- Non-CO_2 gases are not typically included in C budgets, as sources and sinks are not well understood.
- **CO_2** represents < 50% of current atmospheric radiative forcing.

Methane (CH_4) and **Nitrous oxide** (N_2O) are responsible for ~25% of current atmospheric radiative forcing.



Houghton et al., (2001)

Slide courtesy of S.J. Livesley, Uni Melb

C cycle and non-CO_2

- **Global warming potential** (**GW**) radiative forcing of CO_2, based (and persistence in atmosphere.

	Pre-ind.	Current	*GWP*
CO_2	280	398	1

- **Carbon dioxide equivalents** (**CO_2-e**), normalise all gases to that of CO_2 using their GWP.

Slide courtesy of S.J. Livesley, Uni Melb

Outline for this lecture

- Greenhouse gases
- Carbon cycle
- Water cycle
- Plants, forests and agriculture – Carbon sequestration
- Land use change & GHG
- Applied examples of measuring GHG in land clearing experiment:
  - near real time GHG exchange using flux towers
  - manual chambers to measure soil non-CO_2 exchange
- Discussion

What is land use change?

- Converting from one land use to another:
  - Forest ⟶ agricultural land
  - Grazing pasture ⟶ cropping land
  - Dryland farming ⟶ irrigated farming

Why are we interested?

- Usually involve manipulation C stores: soils and vegetation

Greenhouse gases: Agricultural sources

Source	Emissions Mt CO_2-e		Change in emissions (%) 1990-2005
	1990	2005	
Enteric fermentation	63.9	58.7	-8.1
Manure management	2.07	3.4	66.3
Rice cultivation	0.49	0.22	-56.0
Agricultural soils (non-CO_2 gases)	14.4	16.6	15.2
Savanna burning	6.6	8.7	30.9
Agricultural residue burning	0.29	0.35	20.6
TOTAL	**87.7**	**87.9**	**0.2**

[1] emissions from livestock manure in intensive industries e.g. piggeries (50%), feedlots (30%) and dairies (20%)

Source: AGO 2007 quoted by M Keogh 2007

Background

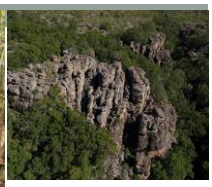
Background

February 14, 2013

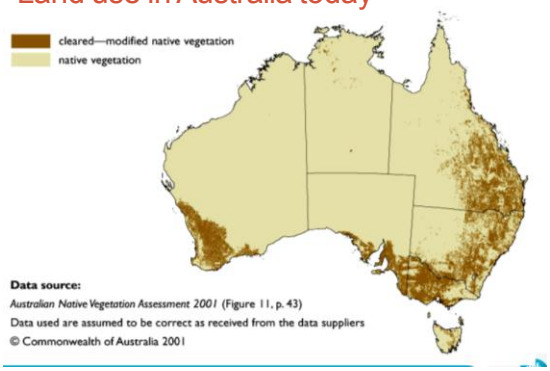
North Australian water resources

The North – the NT bit

- 30% of the population is Aboriginal
- Youngest demographic in Australia – media
- Economy
  - Agricultural commodities → $195 million
  - Tourism spend → $1.5 billion
  - Mining commodities → $7.3 billion

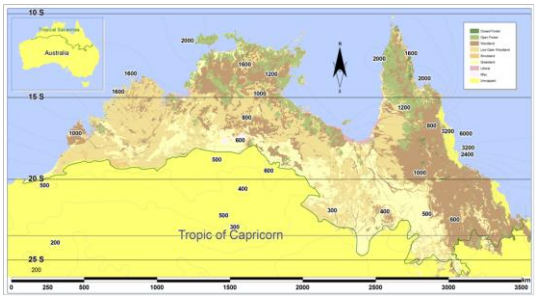


Land use in Australia today



Landscapes of north Australia

- Tropical savanna woodland and open-forests dominate the north



Landscapes of north Australia climate

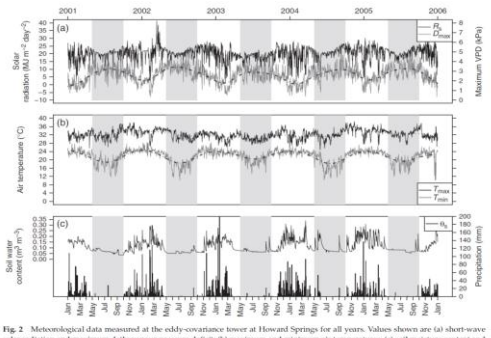
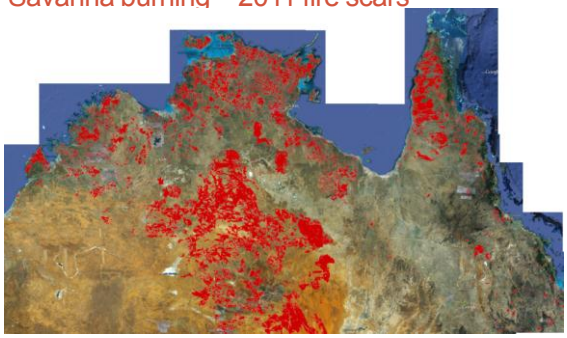


Fig. 2 Meteorological data measured at the eddy-covariance tower at Howard Springs for all years. Values shown are (a) short-wave solar radiation and maximum daily vapour pressure deficit; (b) maximum and minimum air temperatures; (c) soil moisture content and rainfall (vertical bars).

North Australian landscapes
Savanna burning – 2011 fire scars



Fires Tropical Savannas

Project aims

Evaluate the impacts of LUC on ecosystem GHG exchange

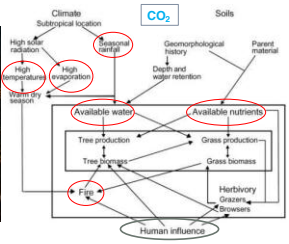
Evaluate the impacts of LUC on soil C and N stocks and processes at long time scales

Evaluate the impacts of plantation afforestation on water resources

Assess different LUC scenarios and implications for ecosystem service provision

Climate change and savanna landscapes

- How will climate change affect these landscapes?
  - Savanna structure and productivity shaped by climate and fire interactions
  - Reduce or increase productivity (sink)? Or no change?



Ecological research

Does this ecosystem ***absorb*** more carbon than it releases?

Or ***release*** more carbon than it absorbs?

Sink

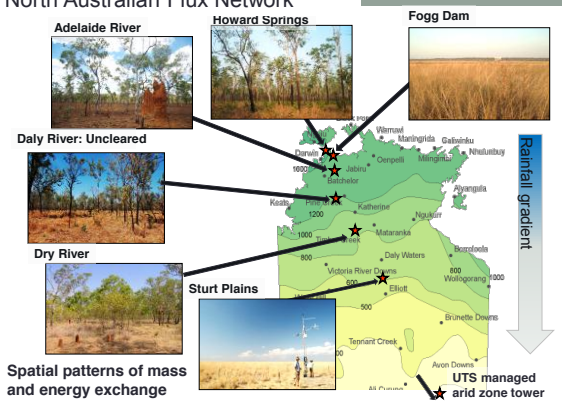
CO_2

Source

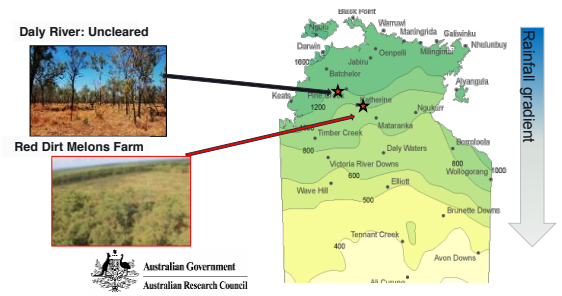
Red Dirt Melons farm

What are the impacts of LUC on ecosystem GHG exchange?

North Australian Flux Network



North Australian Flux Network



Eddy covariance (flux tower) system

- Measures:
  - energy
  - ET
  - CO_2
- calculate GPP
- scale up to annual sink/source

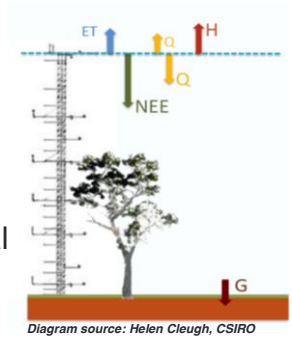


Diagram source: Helen Cleugh, CSIRO

Flux towers

Flux towers

Measuring standing biomass

- Need to know stocks as well as fluxes
- How much biomass in the savanna?

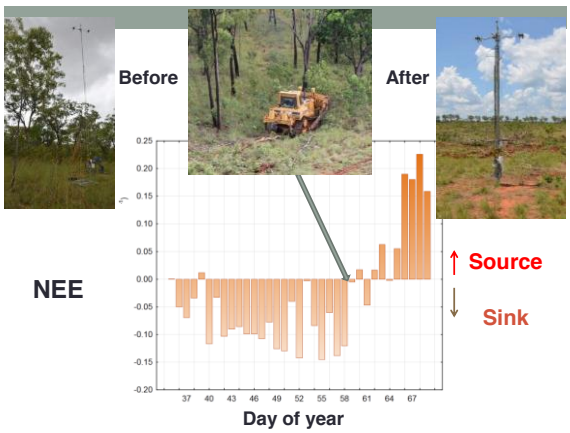
Land use change and soil

What are the impacts of LUC on soil C and N stocks and processes at long time scales?

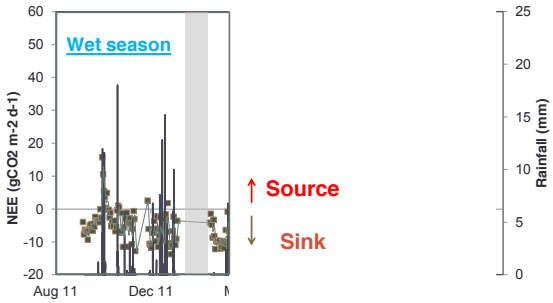
- Temporal and spatial sampling
- Replicated cleared and uncleared plots
- NO_3, NH_4 pool size and net nitrification
- Soil gas diffusivity

non-CO_2 fluxes, soil C & N stocks and process?

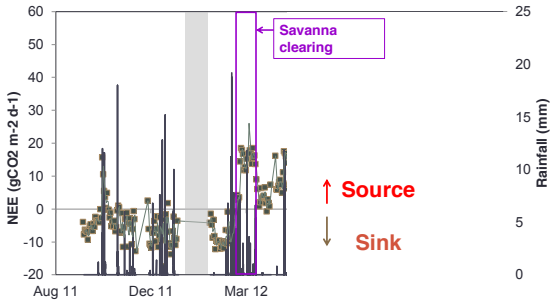
How is forest converted to farm land?



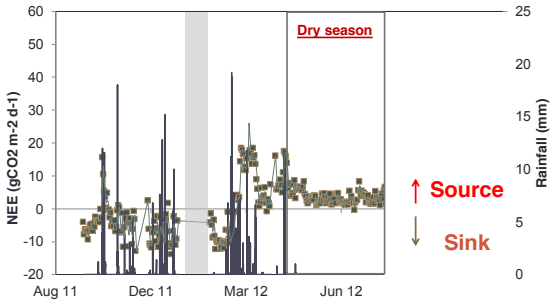
Clearing site: source/sink dynamics



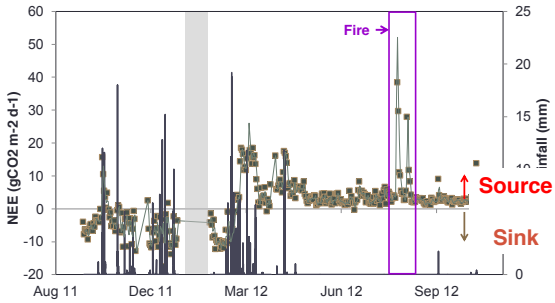
Clearing site: source/sink dynamics



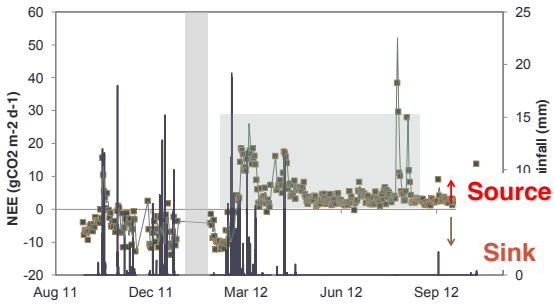
Clearing site: source/sink dynamics



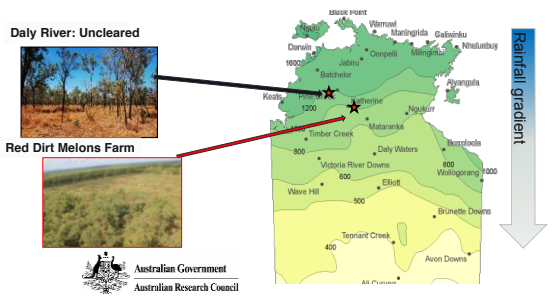
Clearing site: source/sink dynamics



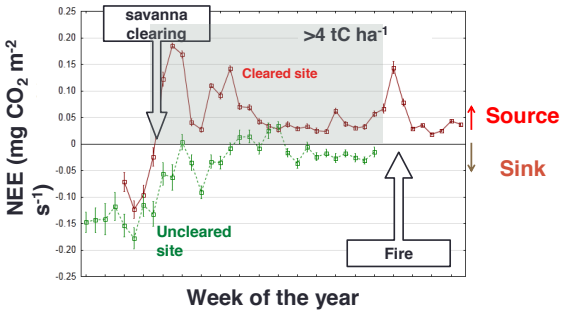
Clearing site: source/sink dynamics



North Australian Flux Network



Uncleared + Clearing site



Learnt so far…

- Ecosystems can be source of CO_2 (from land to atmosphere) or a sink
- Source /sink dynamics can change with season
- Clearing savanna leads to source of CO_2
  - Shifting savanna ecosystem from expected sink to a source

GHG emissions from burning debris

- Fuel curing over dry season 2012
- Burning late dry season to maximise consumption for site preparation to melons
- Emissions estimated for fire event using NCAS default emissions factors
- Assumptions
  - all AGB consumed
  - 90% of BGB consumed
  - Fine roots ignored, no soil C loss, no CWD included, no decay of coarse roots

The site today

CO_2 from clearing: comparing cleared and uncleared tower sites

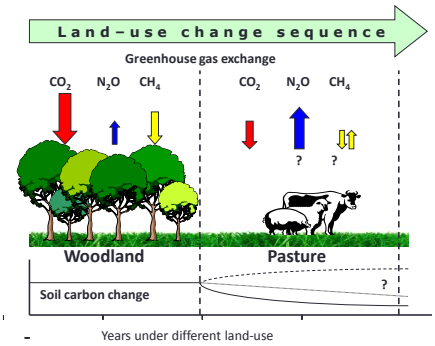
- Total net emissions (all GHG, flux tower + burn) = +165.1 Mg CO_2-e ha^{-1}
- equivalent to MANY decades years of carbon sequestration



Learnt so far…

- Ecosystems can be source of CO_2 (from land to atmosphere) or a sink
- Source /sink dynamics can change with season
- Clearing savanna leads to source of CO_2
  - Shifting savanna ecosystem from expected sink to a source
- Burning vegetation releases CO_2 at greater rate than disturbance(s) from clearing

Slide courtesy of S.J. Livesley, Uni Melb



Soil impacts of LUC

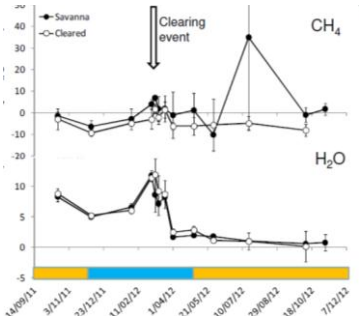
LUC savanna to pasture can:

- Increase soil bulk density (less diffusion)
- Increase/decrease soil fertility (N/P)
- Increase/decrease soil moisture (transpiration)
- Change soil pH or salinity
- Change soil temperature
- Change soil organic matter (C) content

Grover *et al.* (2012) *Biogeosciences* 9, 423-437.
Livesley *et al.* (2011) *Agricultural and Forest Meterology* 151, 1440-1452.

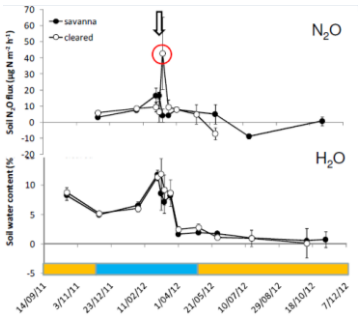
Soil CH_4 and N_2O fluxes

Soil methane flux in relation to soil moisture change



Soil CH_4 and N_2O fluxes

Soil nitrous oxide flux in relation to soil moisture change



Learnt so far…

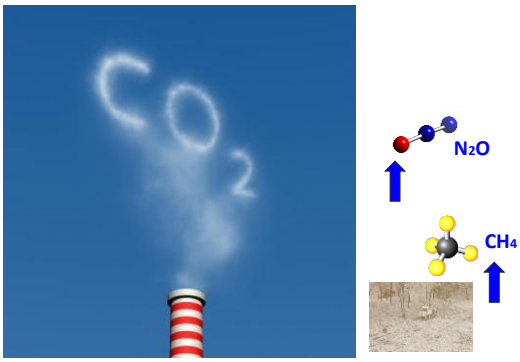
- Savanna soil can switch from being a weak CH_4 sink to a weak CH_4 source, due to soil water and termites.
- Soil moisture drives majority of soil CH_4 and N_2O flux.
- Savanna clearing had little impact on soil CH_4 exchange.
- Savanna soil was a weak N_2O source (~5 mg N m^{-2} h^{-1})
- Clearing led to small, short-lived pulse in soil N_2O flux.
- Negligible in comparison to soil and vegetation C losses.

Savanna ecosystems are a **major** exchange of **global GHG**

Flux towers critical tool to understand ecosystem change....

to this....

to this...



Terrestrial (fringe) stores of carbon

And if you thought land clearing in savannas was interesting, think about clearing **mangroves** and coastal vegetation… the **largest stores of C** there are in 'terrestrial' systems

(hint…Google: Blue Carbon)

Potential useful links/references

- http://epa.gov/climatestudents/basics/today/carbon-dioxide.html
- http://www.climatechange.gov.au
- http://www.science.org.au/policy/climatechange.html
- http://www.abc.net.au/news/2012-09-24/blue-carbon/4277608

Understanding GHG emissions from NT agriculture

- The Australian Government's *Securing a Clean Energy Future* plan, released in July 2011, contains four basic elements:
1. introducing a carbon price;
2. promoting innovation and investment in renewable energy;
3. encouraging energy efficiency; and
4. creating opportunities in the land sector to cut carbon pollution.

- The land sector elements are about creating opportunities on the land whilst addressing carbon pollution.

These days you'll find me:

- NT Government

http://www.nt.gov.au/d/Primary_Industry/index.cfm?header=Action%20on%20the%20Ground