Is the grass greener on the other side?

Land Use and Land Cover Change and in Australian Savannas

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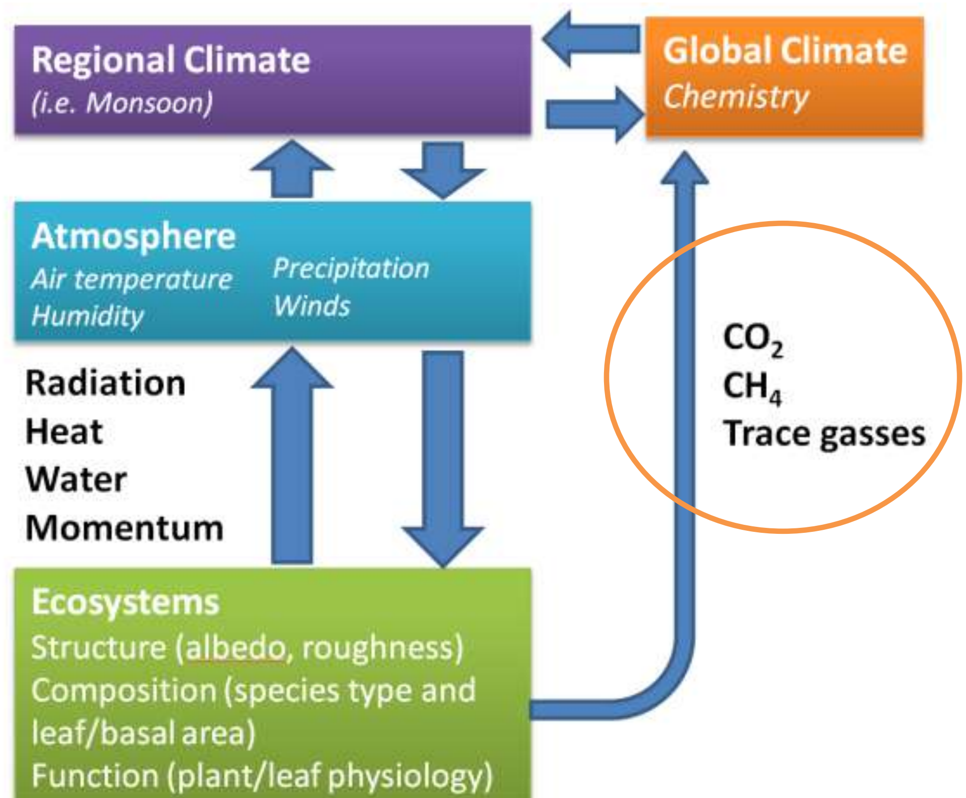
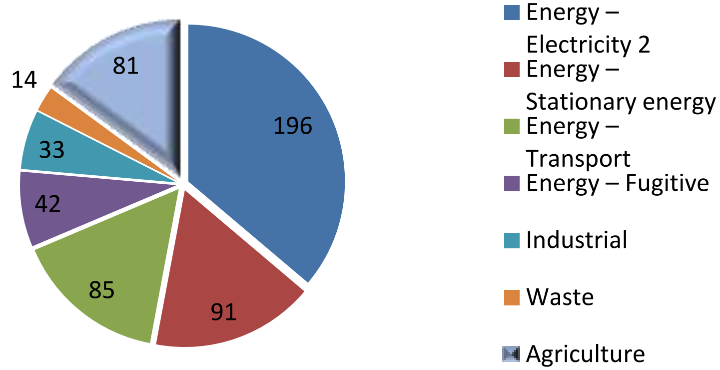
Introduction

- Tropical savanna ecosystems are a major contributor to global CO_2, N_2O & 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

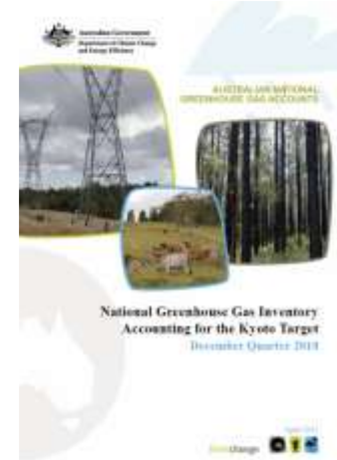


Research themes

- 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



Total 540 (Mt CO2-e)



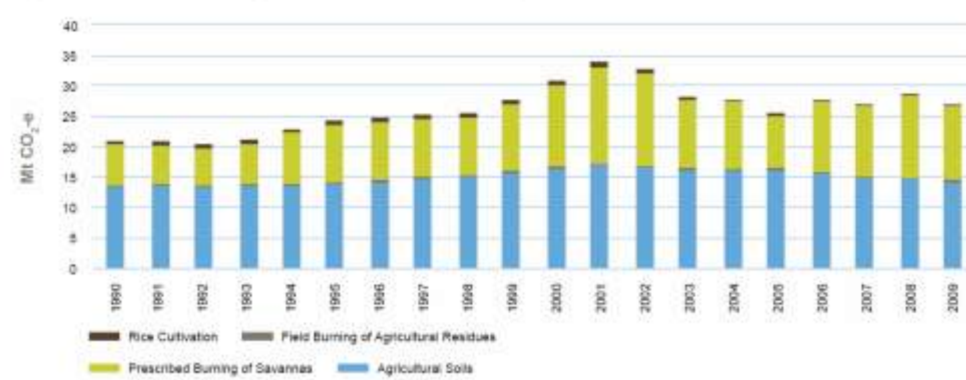
3.4 AGRICULTURE

Crops, Soil and Fire-Related Emissions

The estimated emissions from the other *Agriculture* sub-sectors in 2009 were:

- 0.05 Mt from *Rice cultivation*, a 90.6 per cent (0.4 Mt) decrease since 1990;
- 14.2 Mt from *Agricultural soils*, an 5.6 per cent (0.8 Mt) increase since 1990;
- 12.1 Mt from *Prescribed burning of savannas*, a 83.8 per cent (5.5 Mt) increase since 1990; and
- 0.3 Mt from *Field burning of agricultural residues*, a 5.9 per cent (0.02 Mt) increase since 1990.

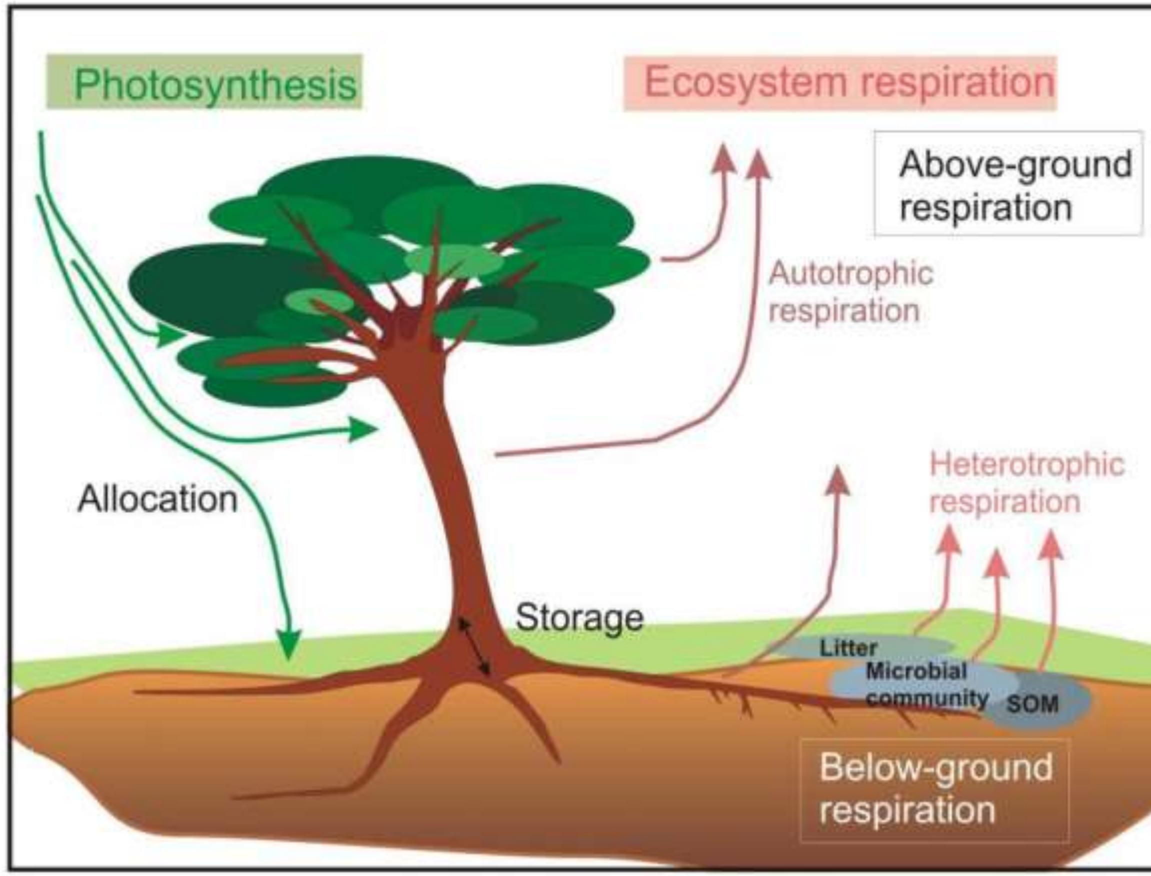
Figure 17: Trends in CO_2-e emissions from the crop, soil and fire related subsectors 1990 – 2009



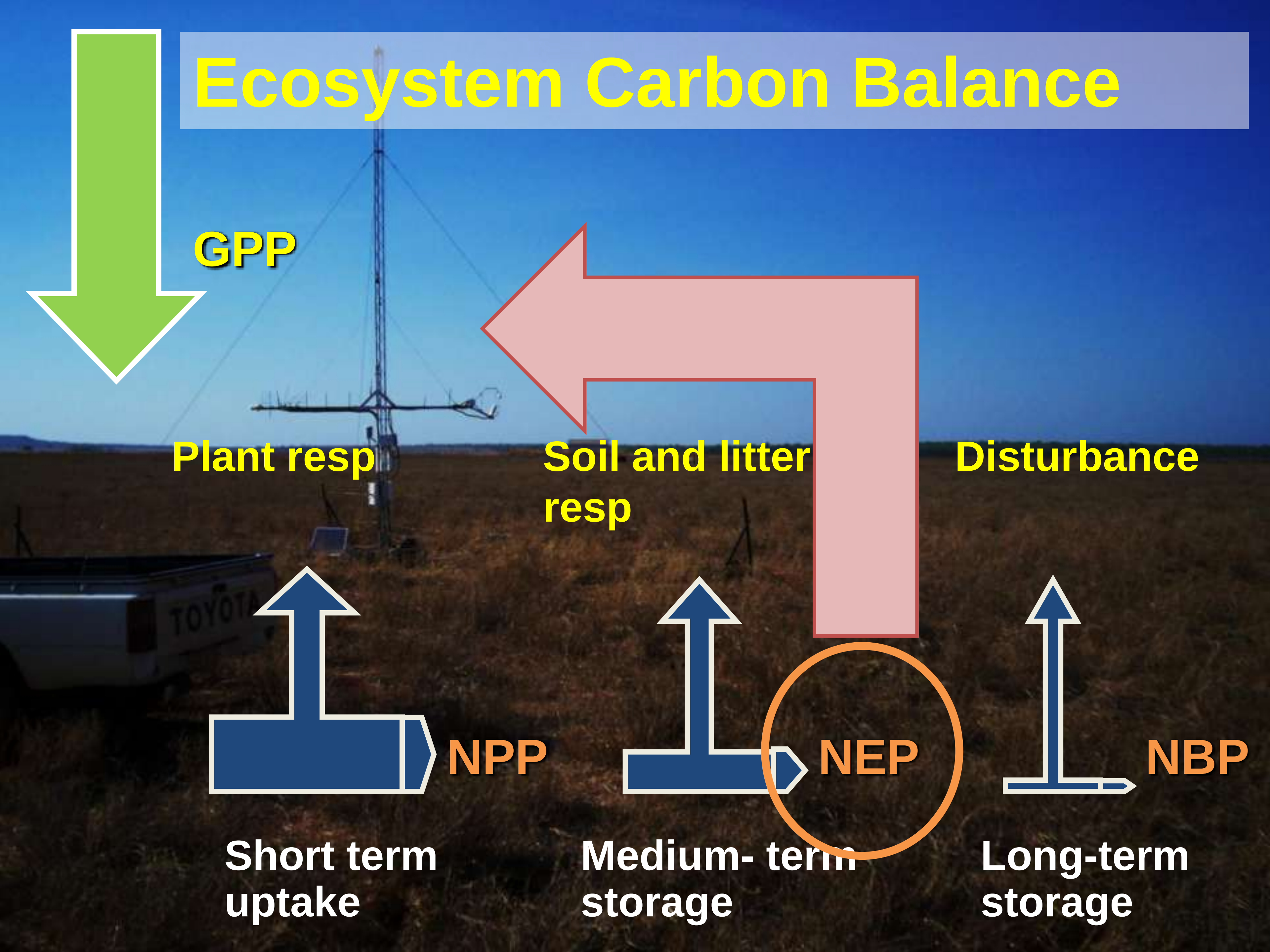
Australian national greenhouse accounts national Gas inventory APRIL 2011

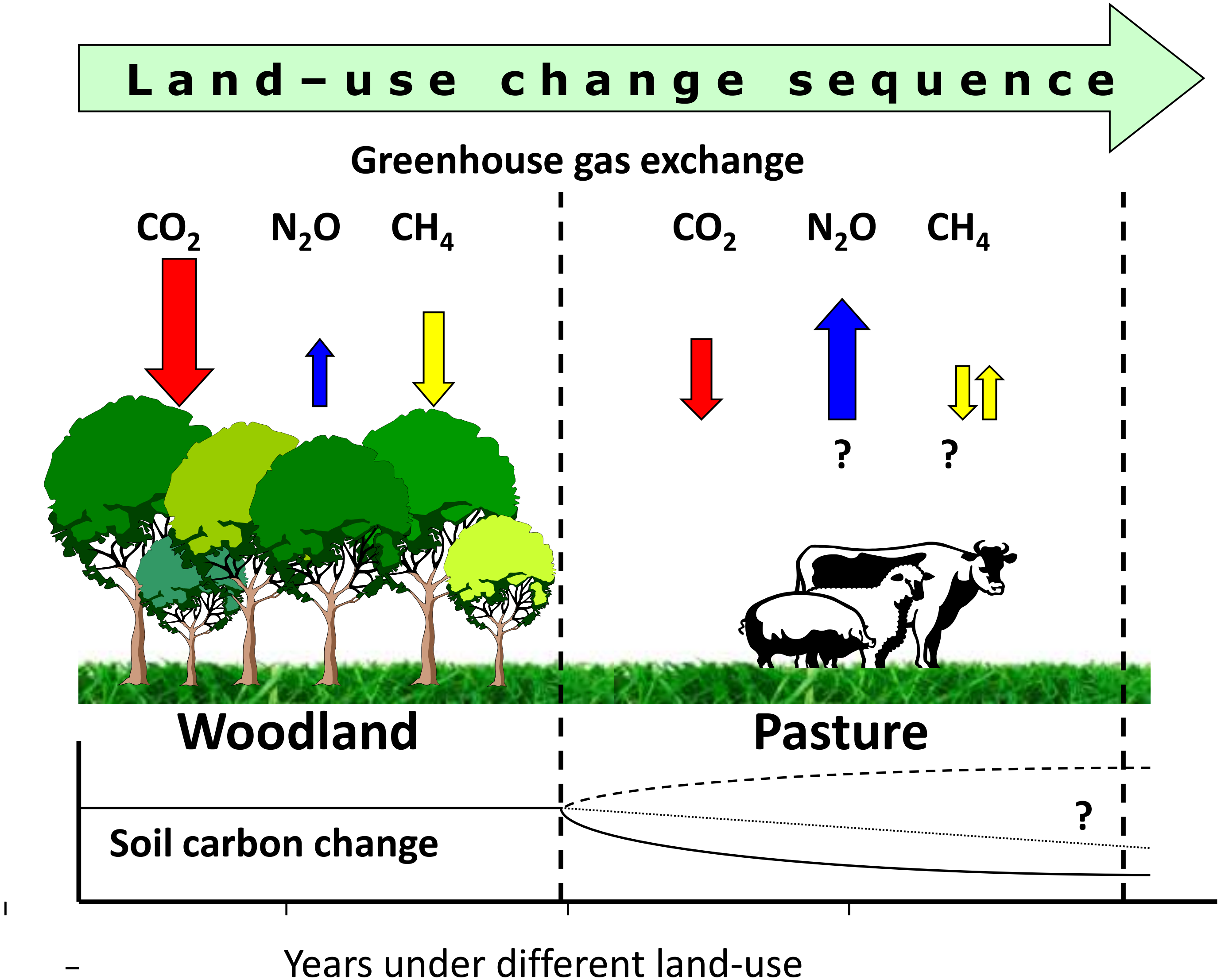
Understanding Carbon Dioxide Fluxes

- Canopy photosynthesis function of light, available water, nutrients, VPD, Leaf Area Index and CO_2 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
NEP
NBP
Short term uptake
Medium- term storage
Long-term storage
TOYOTA



Courtesy Stephen Livesley (Uni Melb)

Aims

GHG dynamics and nutrient cycling in north Australian savannas

CH_4, N_2O, CO_2

- Spatial and temporal variability
- Land use change
- Mechanisms controlling emissions
  Physical, chemical and biological soil properties
- Effect of Fire
- Contribution of termites

Methods

Eddy-covariance towers

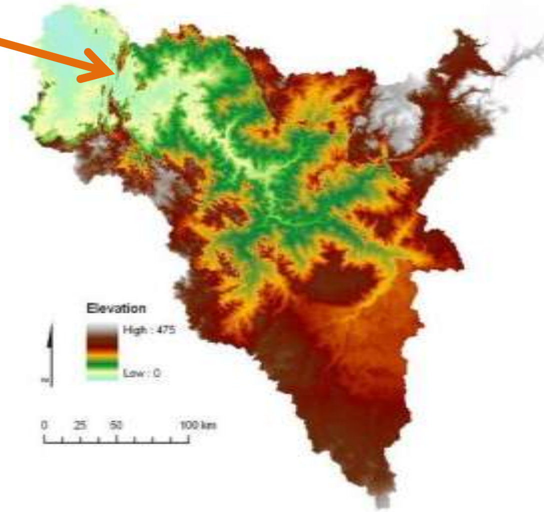
Automated trace gas system

Manual trace gas chambers

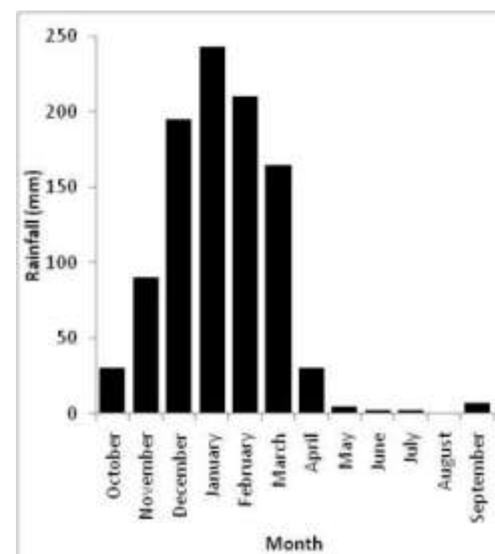
Soil nutrient and moisture

Modelling (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)

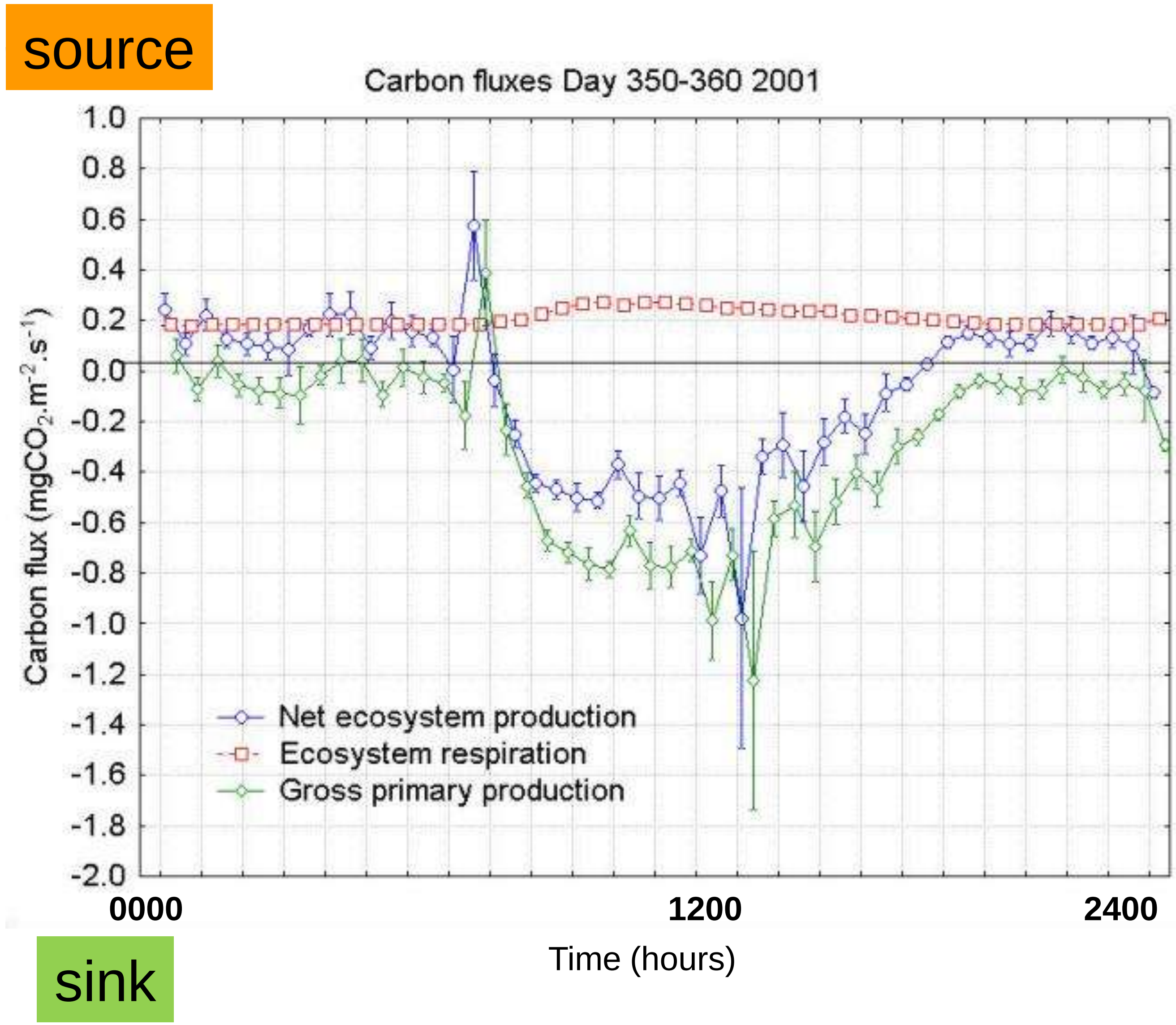


CO_2 exchange using flux towers

- 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)

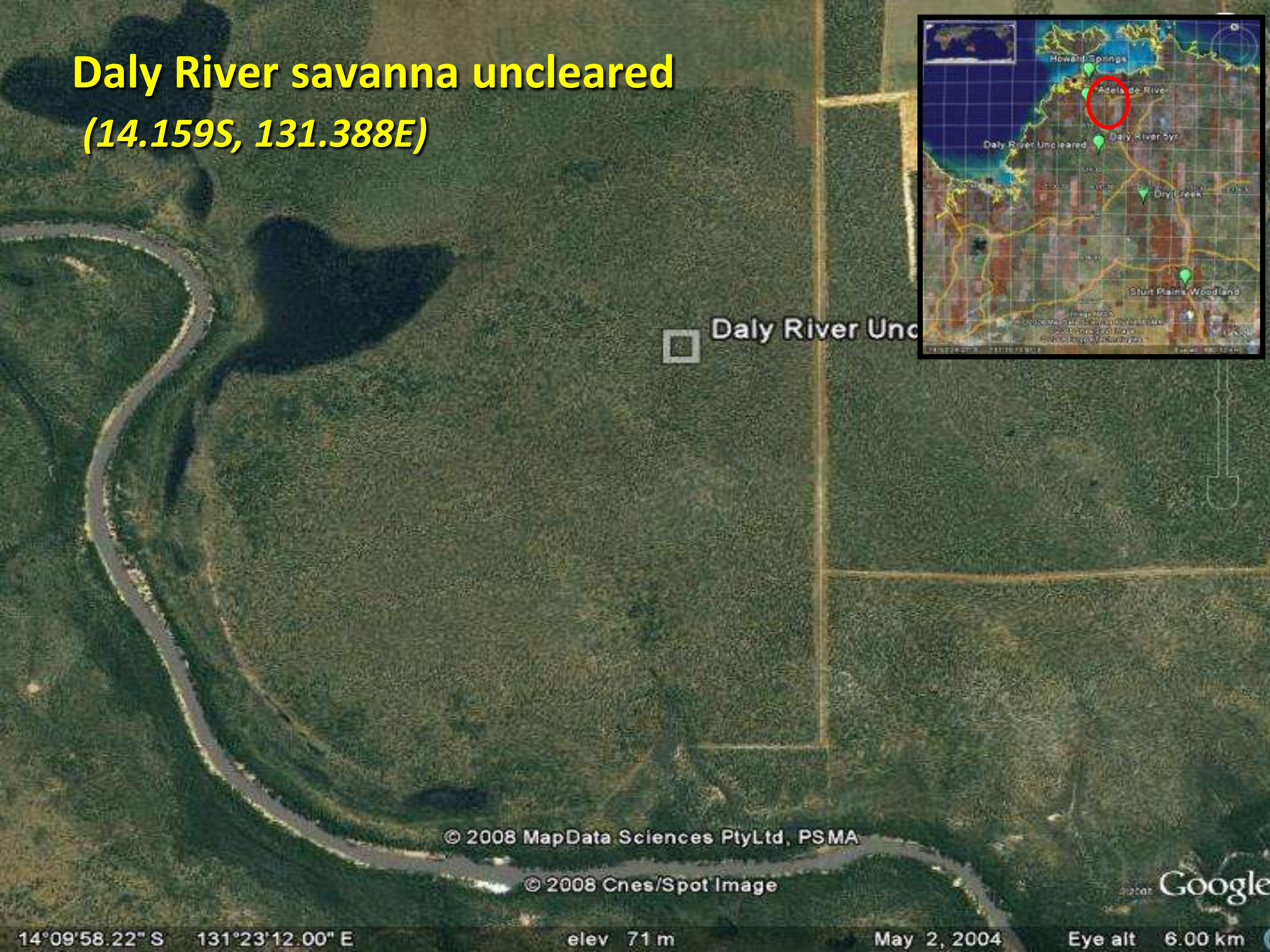
Net Ecosystem Production

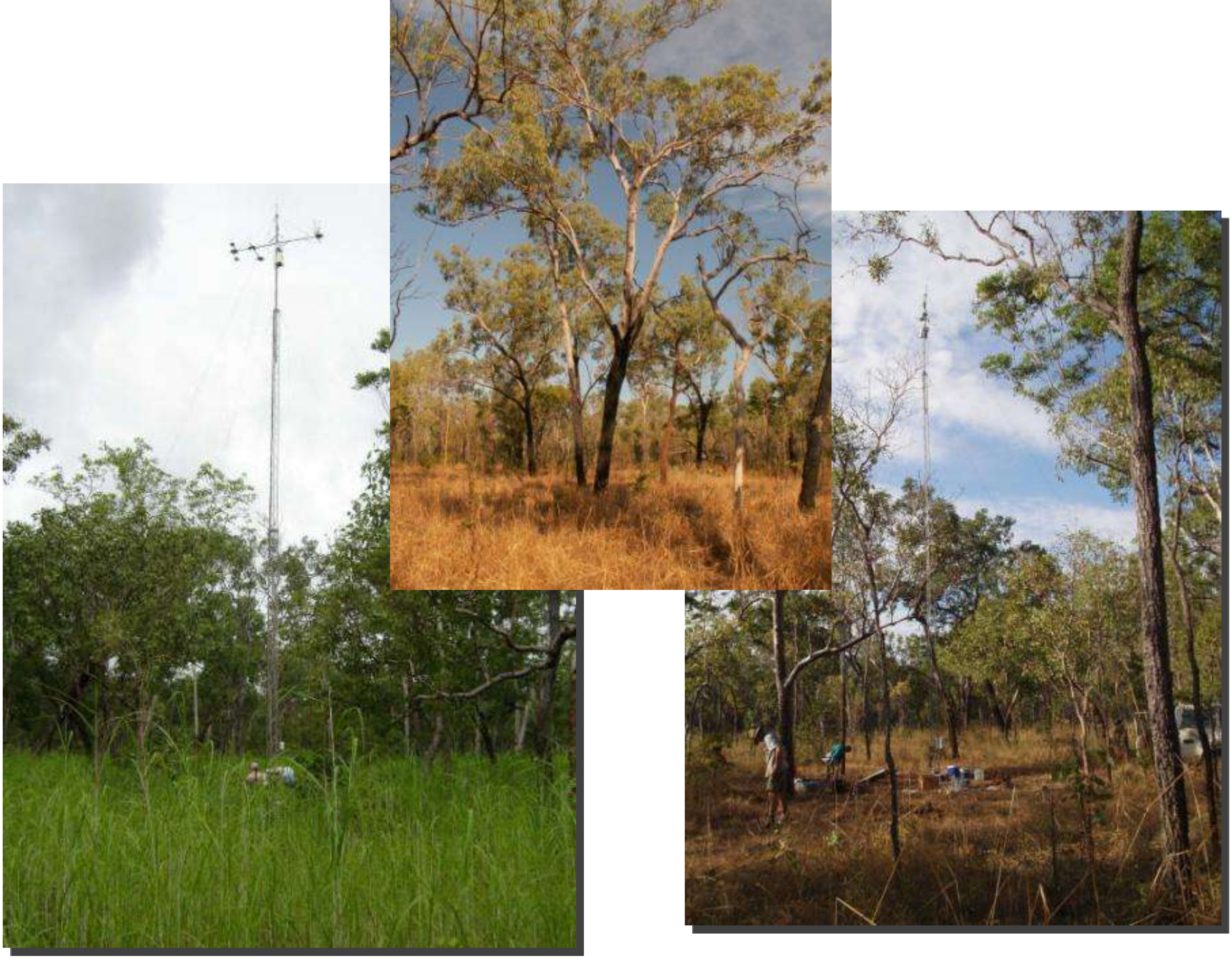
- Eddy covariance measurements of NEP
- Neural network model for ecosystem respiration (R_e)
- NEP = GPP – R_e
- Uncertainties in methodologies



Daly River savanna uncleared

(14.159S, 131.388E)





Daly River regrowth site

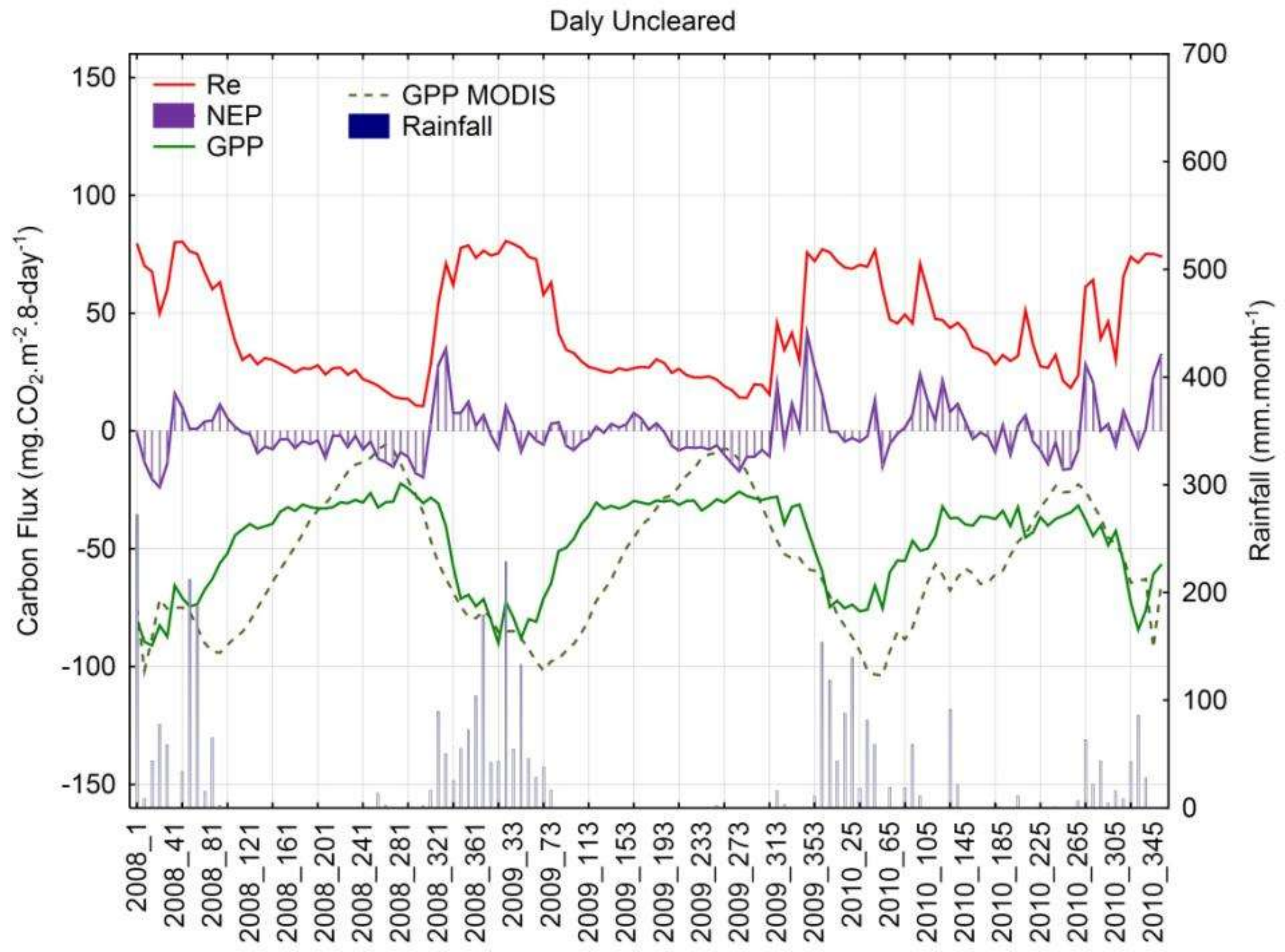
(14°07'50.16"S, 131°22'58.08"E)

Daly River savanna Regowth

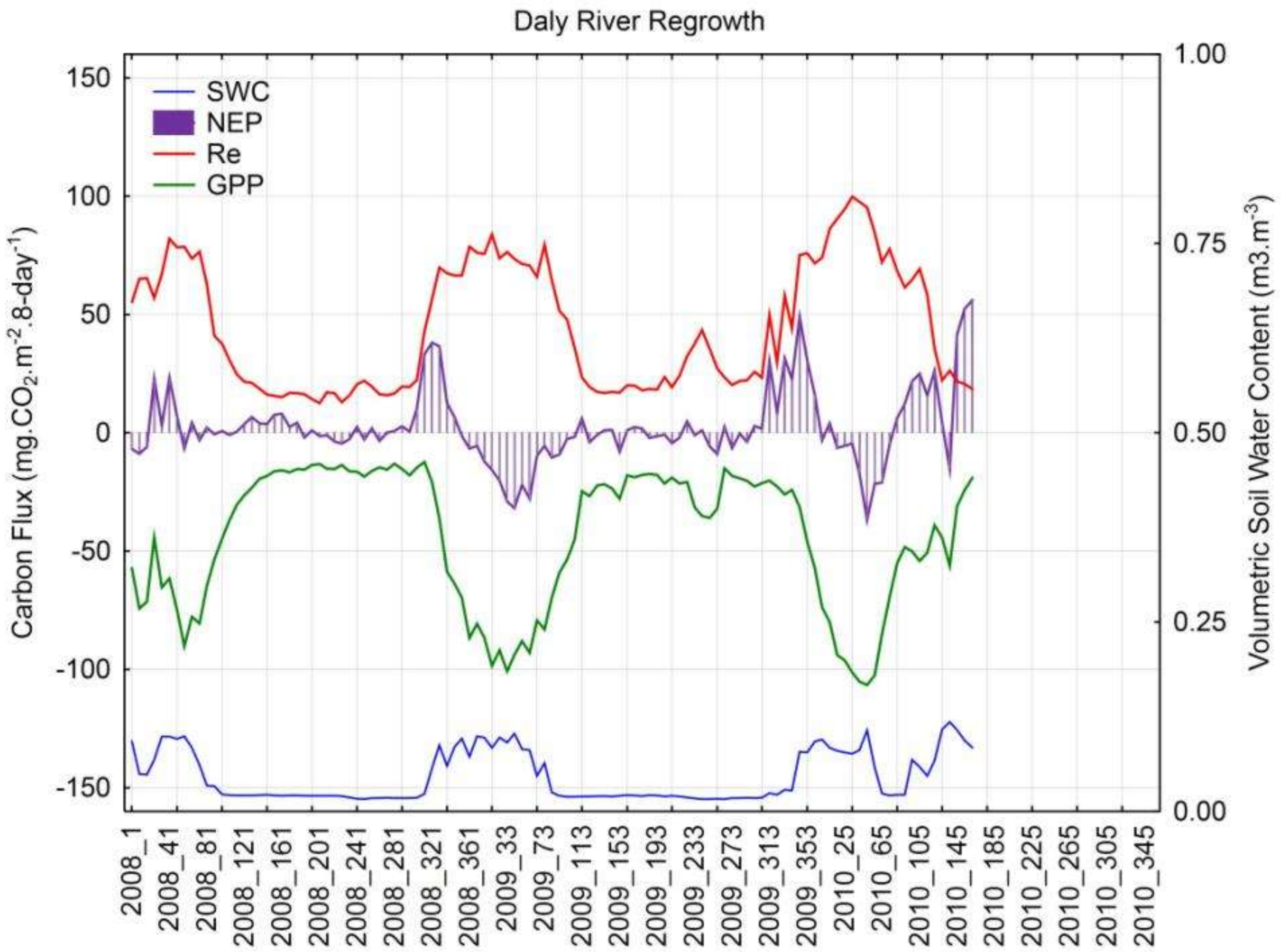
Daly River Pasture site

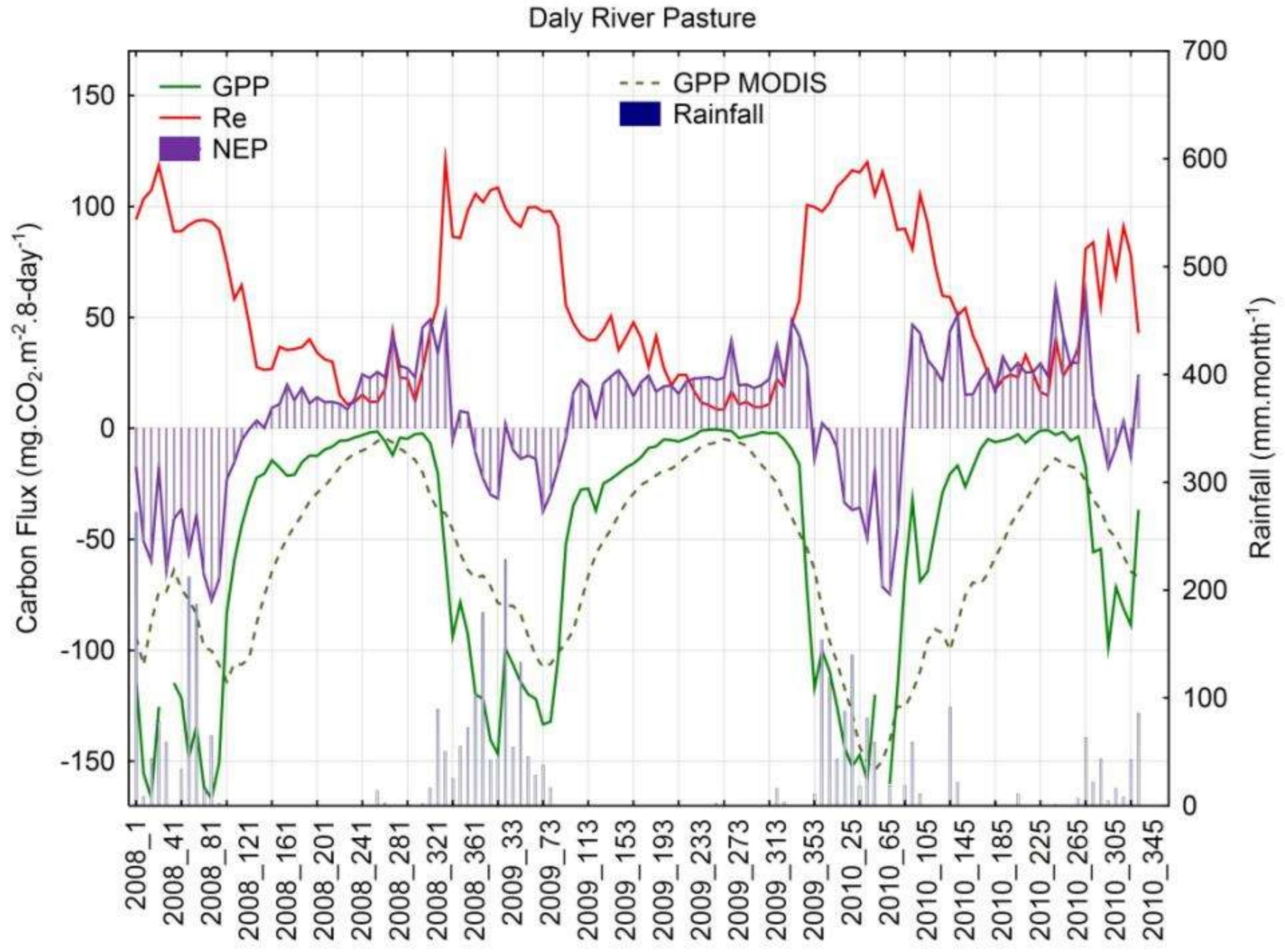
(14◦3'47.88"S 131◦19'5.16"E)

Daly River Pasture site

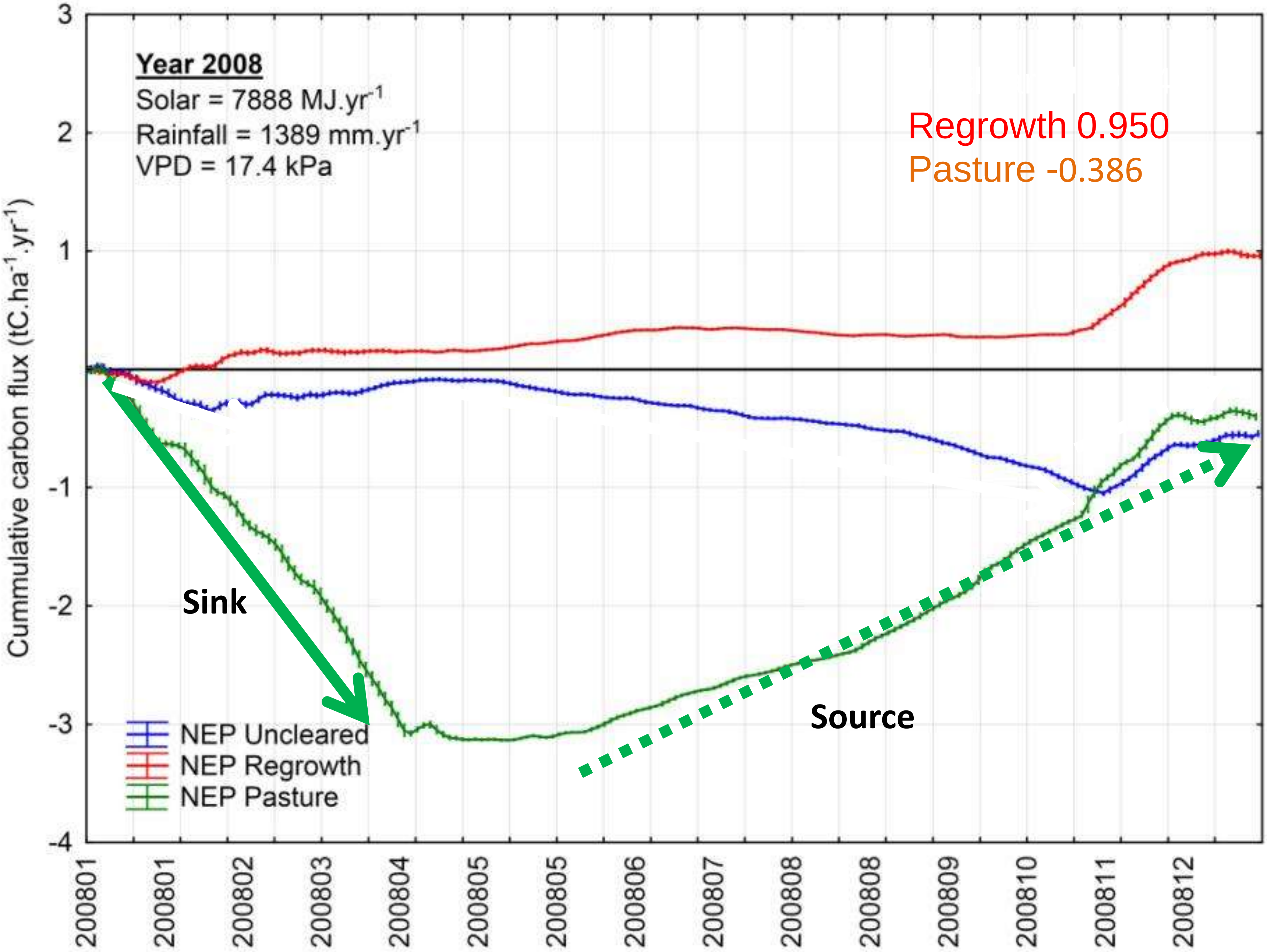


Daly Uncleared
Re
NEP
GPP
GPP MODIS
Rainfall
Carbon Flux (mg.CO$_2$.m^{-2}.8-day^{-1})
Rainfall (mm.month^{-1})
150
100
50
0
-50
-100
-150
700
600
500
400
300
200
100
0
2008_1
2008_41
2008_81
2008_121
2008_161
2008_201
2008_241
2008_281
2008_321
2008_361
2009_33
2009_73
2009_113
2009_153
2009_193
2009_233
2009_273
2009_313
2009_353
2010_25
2010_65
2010_105
2010_145
2010_185
2010_225
2010_265
2010_305
2010_345

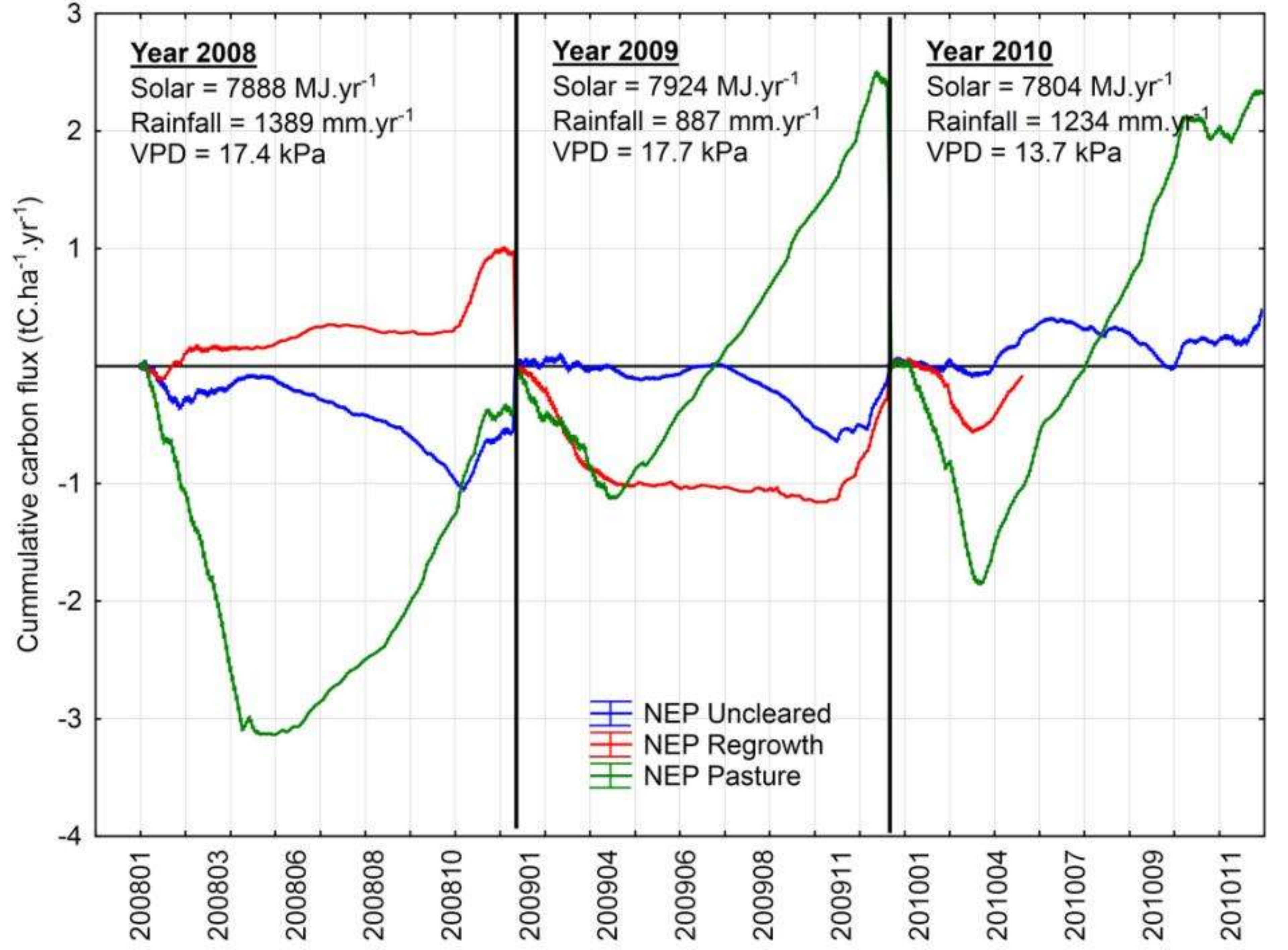

Daly River Regrowth
SWC
NEP
Re
GPP
150
100
50
0
-50
-100
-150
Carbon Flux (mg.CO2.m-2.8-day-1)
1.00
0.75
0.50
0.25
0.00
Volumetric Soil Water Content (m3.m-3)
2008_1
2008_41
2008_81
2008_121
2008_161
2008_201
2008_241
2008_281
2008_321
2008_361
2009_33
2009_73
2009_113
2009_153
2009_193
2009_233
2009_273
2009_313
2009_353
2010_25
2010_65
2010_105
2010_145
2010_185
2010_225
2010_265
2010_305
2010_345



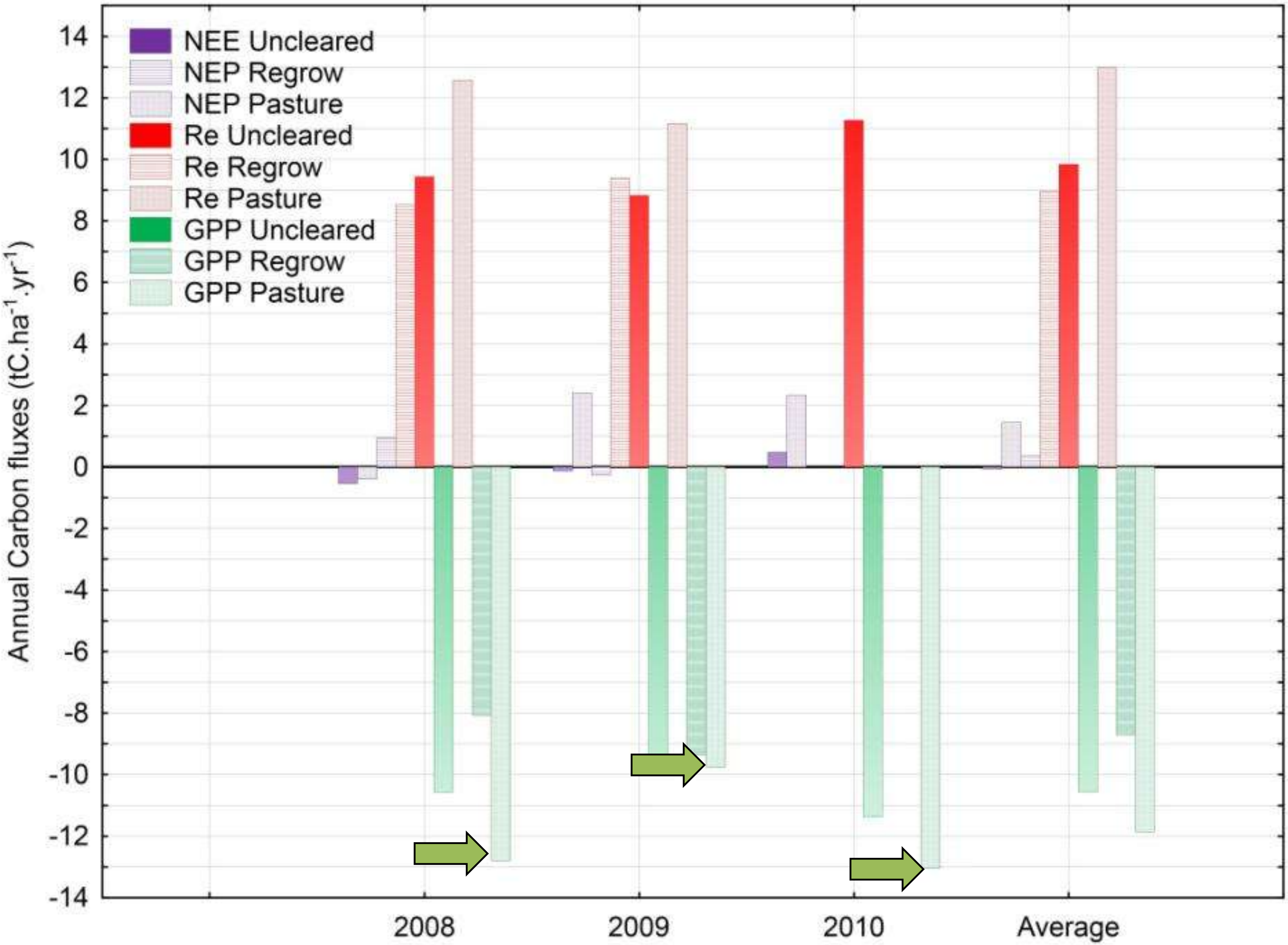
Daly River Pasture
GPP
Re
NEP
GPP MODIS
Rainfall
Carbon Flux (mg.CO$_2$.m^{-2}.8-day^{-1})
Rainfall (mm.month^{-1})
150
100
50
0
-50
-100
-150
700
600
500
400
300
200
100
0
2008_1
2008_41
2008_81
2008_121
2008_161
2008_201
2008_241
2008_281
2008_321
2008_361
2009_33
2009_73
2009_113
2009_153
2009_193
2009_233
2009_273
2009_313
2009_353
2010_25
2010_65
2010_105
2010_145
2010_185
2010_225
2010_265
2010_305
2010_345



Year 2008
Solar = 7888 MJ.yr-1
Rainfall = 1389 mm.yr-1
VPD = 17.4 kPa
Regrowth 0.950
Pasture -0.386
Cummulative carbon flux (tC.ha-1.yr-1)
3
2
1
-1
-2
-3
-4
Sink
Source
NEP Uncleared
NEP Regrowth
NEP Pasture
200801
200801
200802
200803
200804
200805
200805
200806
200807
200808
200808
200809
200810
200811
200812



Year 2008
Solar = 7888 MJ.yr-1
Rainfall = 1389 mm.yr-1
VPD = 17.4 kPa
Year 2009
Solar = 7924 MJ.yr-1
Rainfall = 887 mm.yr-1
VPD = 17.7 kPa
Year 2010
Solar = 7804 MJ.yr-1
Rainfall = 1234 mm.yr-1
VPD = 13.7 kPa
Cummulative carbon flux (tC.ha-1.yr-1)
3
2
1
-1
-2
-3
-4
NEP Uncleared
NEP Regrowth
NEP Pasture
200801
200803
200806
200808
200810
200901
200904
200906
200908
200911
201001
201004
201007
201009
201011



NEE Uncleared
NEP Regrow
NEP Pasture
Re Uncleared
Re Regrow
Re Pasture
GPP Uncleared
GPP Regrow
GPP Pasture
Annual Carbon fluxes ($tC.ha^{-1}.yr^{-1}$)
14
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-14
2008
2009
2010
Average

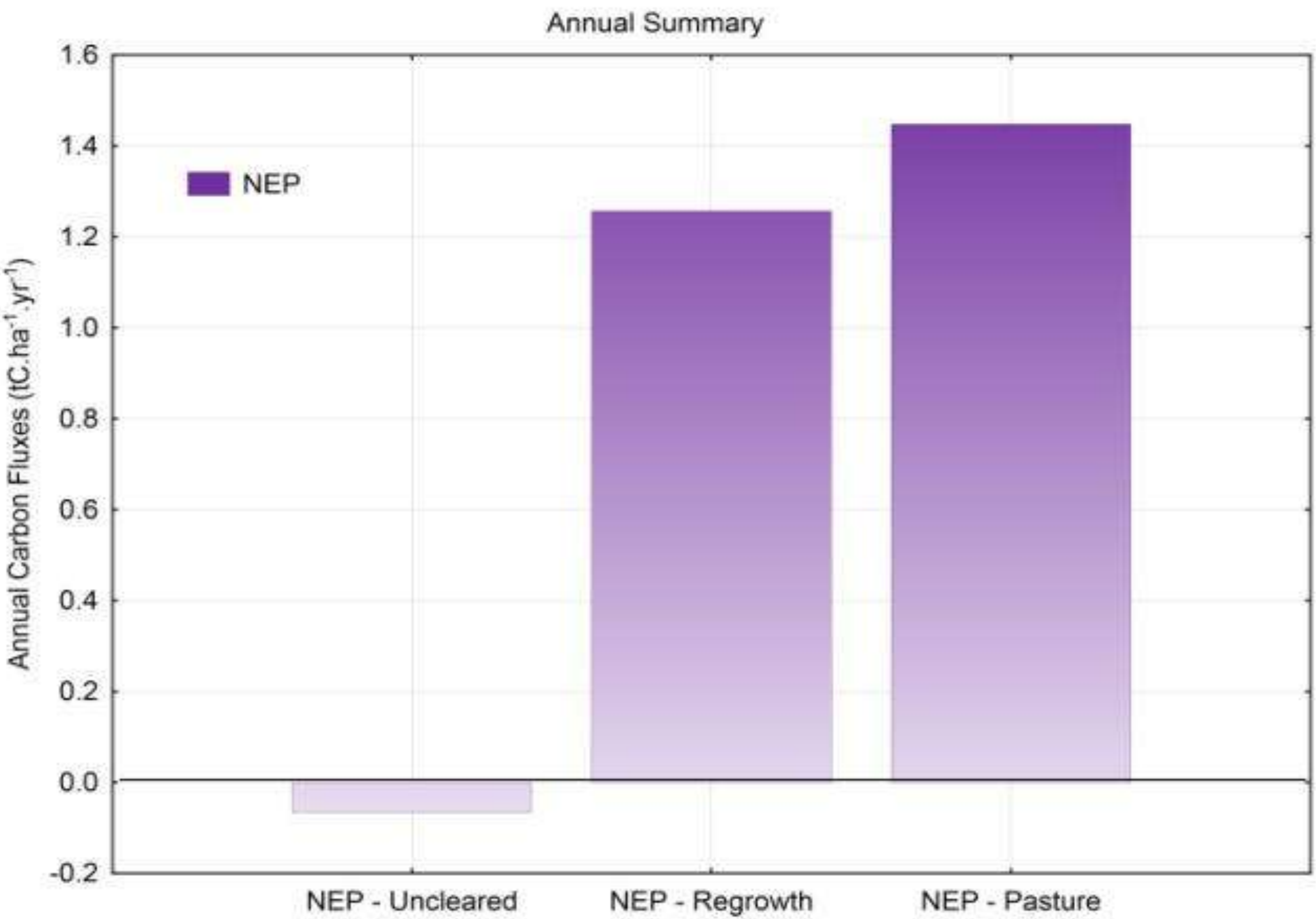

Annual Summary
NEP
Annual Carbon Fluxes (tC.ha-1.yr-1)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
NEP - Uncleared
NEP - Regrowth
NEP - Pasture

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

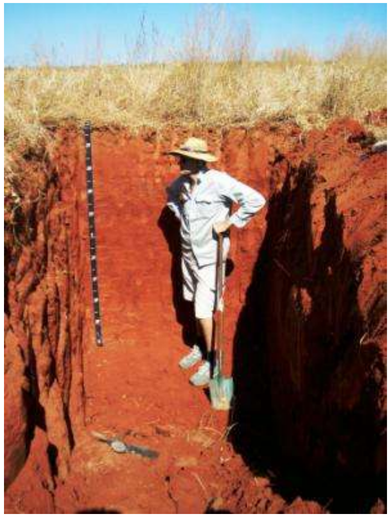
Country	**Station**	**NEE [tCha-1yr-1]**	**Year**	**Type of Vegetation**
Brazil	Cortiguacu	-1.66	2000	Pasture
Brazil	Fazenda Rio de Janeiro	No Data	2003	Pasture
Brazil	Santarem	-3.87	Dec 2000-Nov 2001	Pasture
Brazil	Santarem	6.88	Nov 2001-Dec 2001	Bare Soil

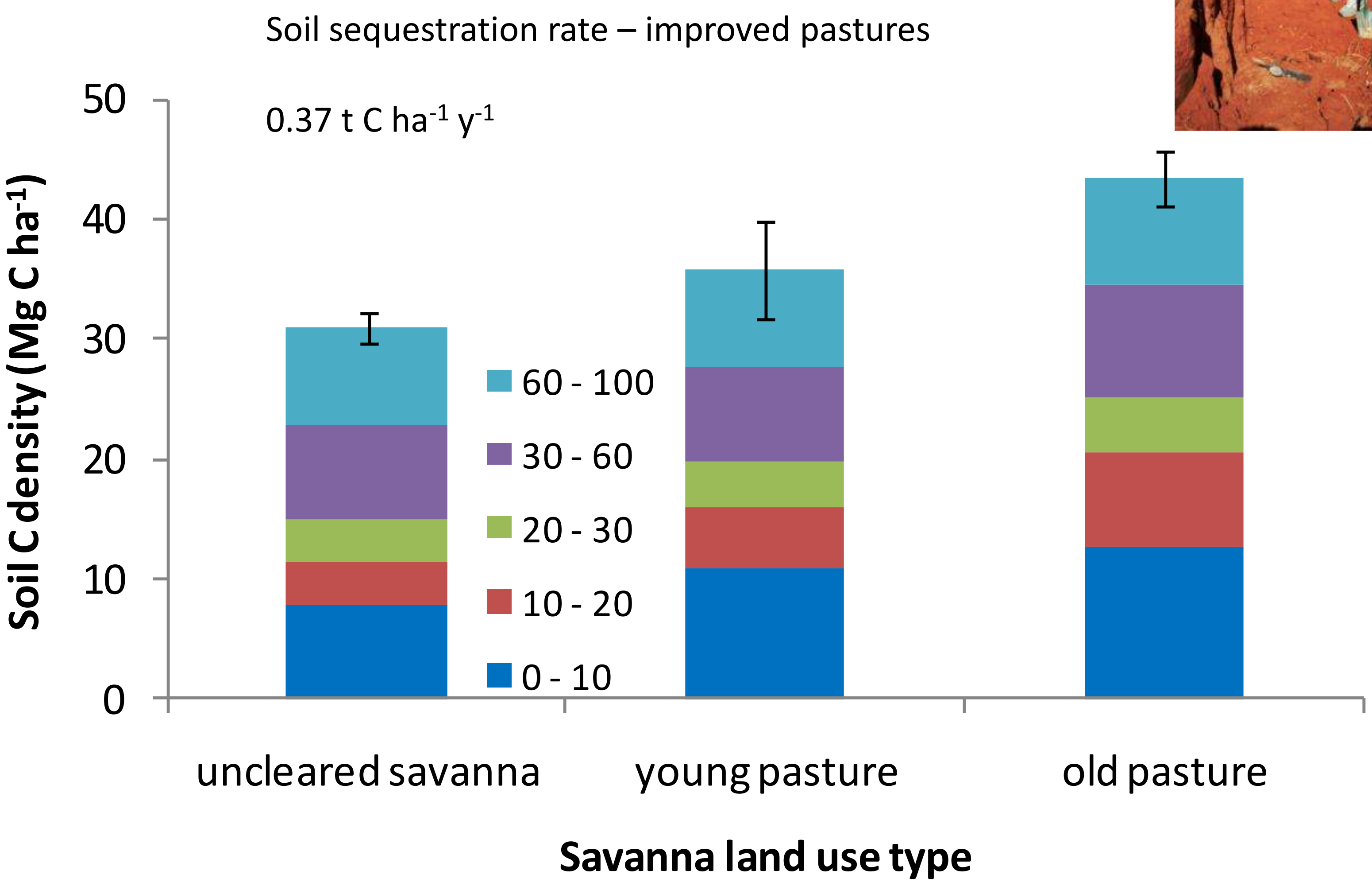
Spiess - Carbon budgets of tropical ecosystems using eddy covariance measurements

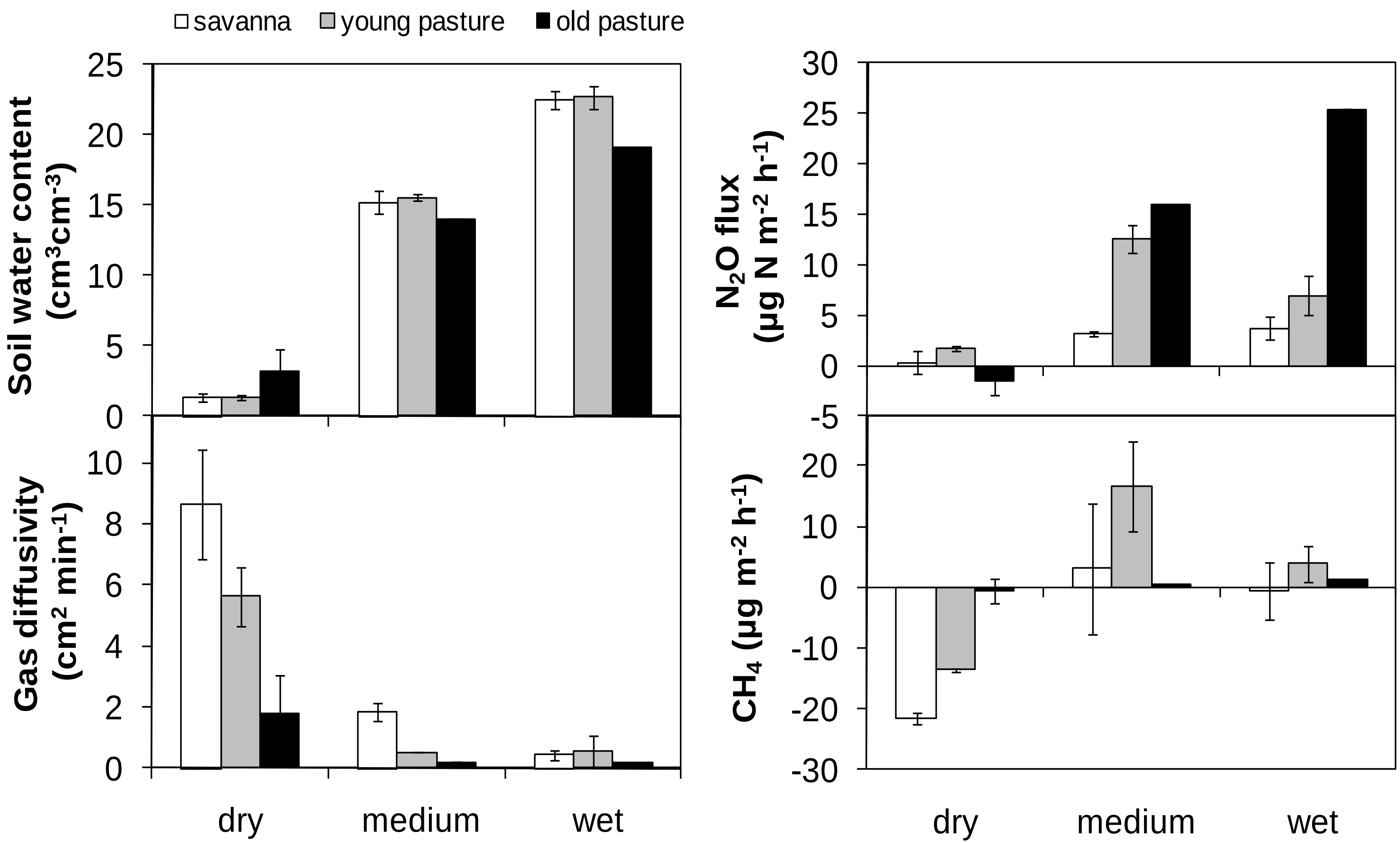
Vegetation carbon pools (t C ha^{-1})

	Savanna		Regrowth		Pasture
	Overstory	Understory	Overstory	Understory	
AGB	31.1	2.15	1.4	2.45	1.5
BGB	28.7	~0.5	1.3	~0.5	?

- Total soil column mineral organic C higher at Pasture site
- 28 years old but in trajectory from clearing to equilibrium.






savanna
young pasture
old pasture
Soil water content
(cm3cm-3)
25
20
15
10
5
0
N2O flux
(µg N m-2 h-1)
30
25
20
15
10
5
0
-5
Gas diffusivity
(cm2 min-1)
10
8
6
4
2
0
CH4 (µg m-2 h-1)
20
10
0
-10
-20
-30
dry
medium
wet
dry
medium
wet

Sources only

	Carbon flux as CO_2			N_2O			CH_4		
	savanna	*young pasture*	*old pasture*	*savanna*	*young pasture*	*old pasture*	*savanna*	*young pasture*	*old pasture*
Transition	3.34	4.53	5.95	0.00	0.01	0.06	-0.42	-0.25	0.09
Wet	8.54	12.28	8.76	0.03	0.03	0.03	-0.16	-0.11	2.55
Dry	2.66	3.15	3.79	-0.02	0.00	-0.02	-0.97	-0.70	-0.12
Annual sums	14.55	19.96	18.50	0.02	0.05	0.07	-1.55	-1.06	2.52
Annual CO_2-e	**53.35**	**73.19**	**67.84**	**0.01**	**0.02**	**0.03**	**-0.05**	**-0.03**	**0.08**

N_2O and CH_4 fluxes represent <1% of soil GHG flux in CO_2-e terms

Summary

- 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.
  - NBP? Small accumulation soil C? Need longer term measurements.
- Dry season irrigation led to greater N_2O emissions in pasture soils than uncleared savanna but similar reductions in soil CH_4 uptake.
- N_2O 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.