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Linking measured CO_2 exchange by sugarcane crops and biomass production

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The problem

The advent of carbon trading and biofuel production highlight the need to document the carbon balances of Australia's cropping systems

- particularly true for sugarcane, a C4 plant with high carbon gains and biofuel potential

Modelling and soil sampling suggest that:

- whole crop removal, as in burnt cane or biofuel production, will deplete soil C
- trash retention will increase soil C (Vallis et al., Resende et al.)
- in both cases, likely changes in soil C are < 1 t C/ha/y

Can we measure such small changes?

- Traditional soil sampling error-prone and requires sampling periods > 10 years
- Could we determine gains or losses of soil C over a shorter term as the difference between the CO_2-C gained by the crop from the atmosphere and soil and litter respiration and the C in the crop biomass?

Approach

Make direct measurements of

- CO_2 exchange between the crop and the atmosphere, *A*
- CO_2 emitted from the soil surface through root respiration and litter breakdown, *S*
- Net gain of CO_2 = *A* + *S*

Estimate C in biomass from

- Tonnage of harvested cane delivered to mill, *H*
- Trash on the ground after harvest or trash burnt before harvest, *T*
- Root biomass, *R*
- Net biomass = *H* + *T* + *R*

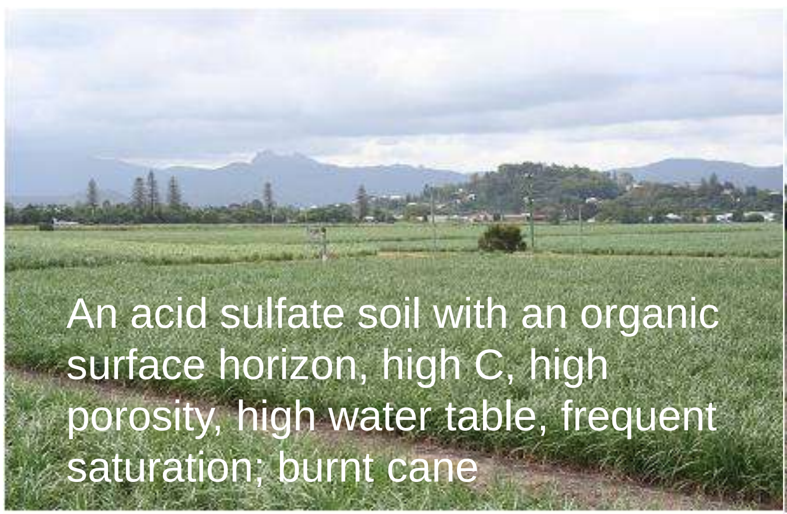
This approach tested with 2 crops:

- Murwillumbah, burnt cane, 1st ratoon crop on an acid sulfate soil
- Mackay, trash-blanketed 5th ratoon crop on Pioneer non-calcic brown soil

Sites

Murwillumbah

MacKay



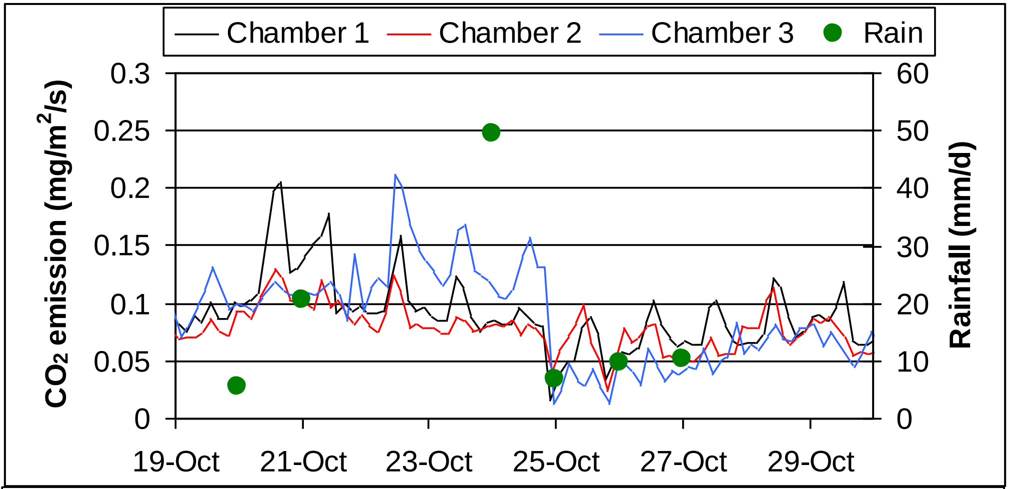
Measuring CO_2 exchange and evaporation

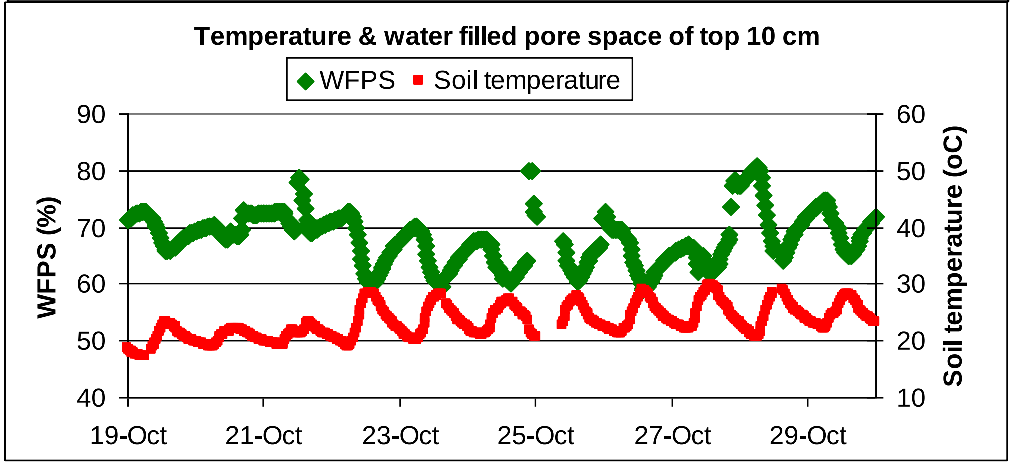
Automatic chambers for soil & litter CO_2

Air from chamber head space circulated through Fourier Transform Infrared Spectrometer (courtesy of UoW) and rate of increase in CO_2 concentration measured (along with CH_4 and N_2O emissions)

Above-crop CO_2 exchange and evaporation measured by eddy covariance

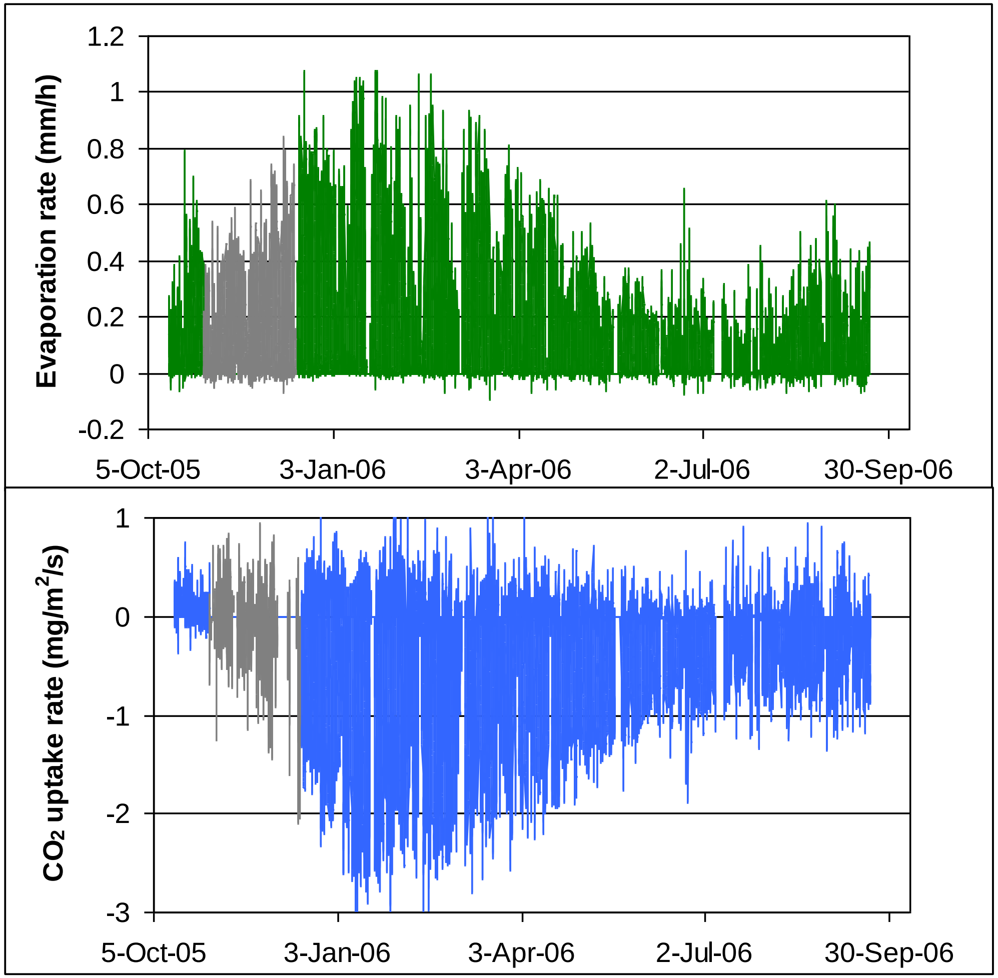
Automatic chamber measurements of CO_2 emissions from soil surface at Murwillumbah





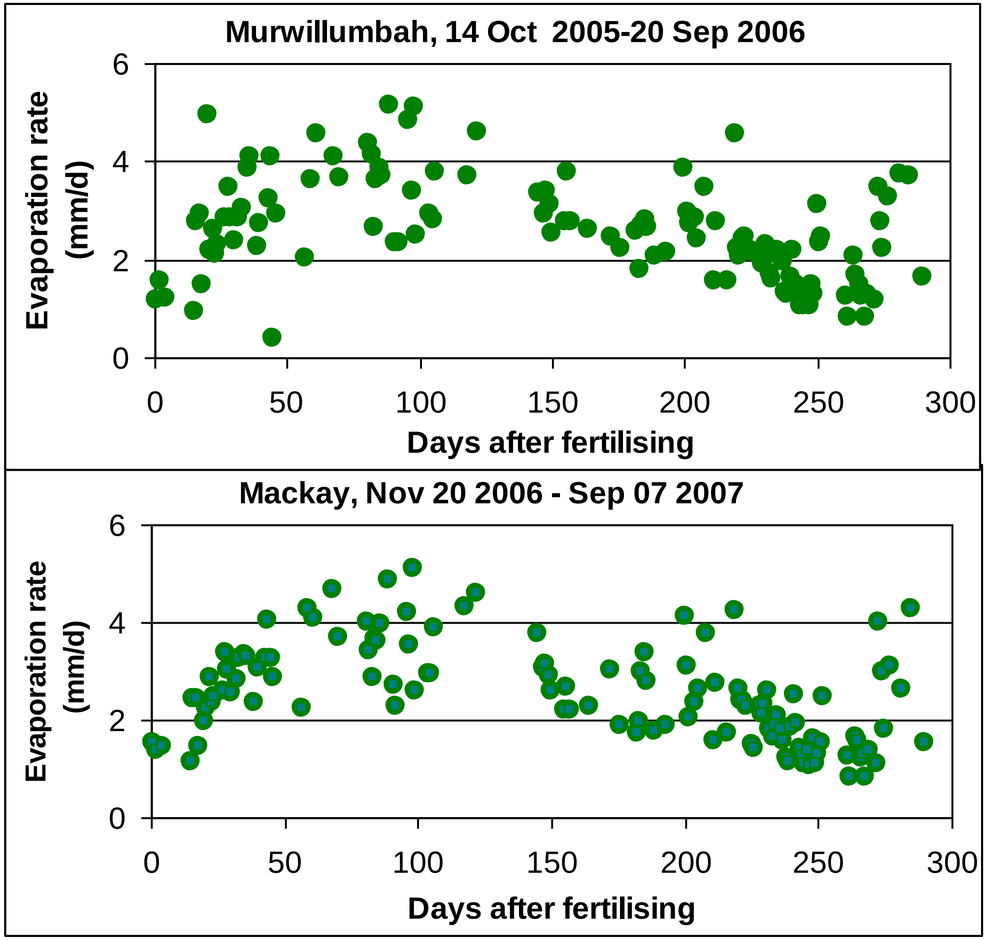
- 6 chambers multiplexed for continuous measurements
- 2 chambers on one side of plant row, 2 on other side, 2 in middle of inter-row
- Chamber lids normally open, but closed in turn for 30 min every 3 hours and build up in CO_2 concentration monitored
- The diurnal cycle in emission rate may result from diurnal changes in temperature-dependent biological activity and in gas diffusion rate caused by changes in the water filled pore space

Whole of season eddy covariance measurements of evaporation rate and CO_2 exchange at Murwillumbah



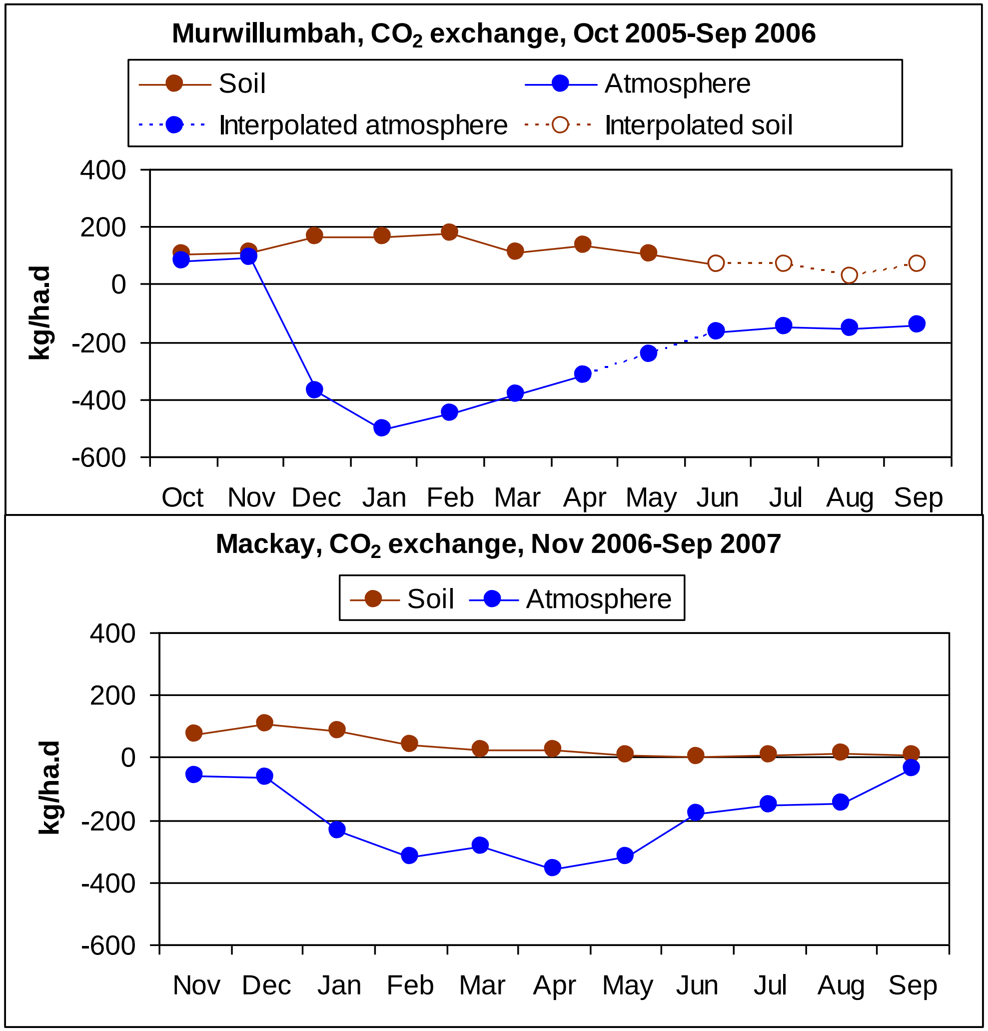
- Measurements made in continuous 30-min runs. Grey lines indicate periods when alternative instruments used
- Evaporation rate and CO_2 uptake rate increase as crop grows, decline in winter and increase again in spring
- Gaps in data due to instrument failure, filtering for unfavourable weather and low turbulence. Gaps filled by linear interpolation

Daily evaporation, both sites



- The average daily evaporation rate at Murwillumbah was 3.75 mm/d, 11% higher than at Mackay, 3.32 mm/d
- Total seasonal evaporation was 1281 mm over 342 days at Murwillumbah and 970 mm over 292 days at Mackay

CO_2 sources: soil and atmosphere



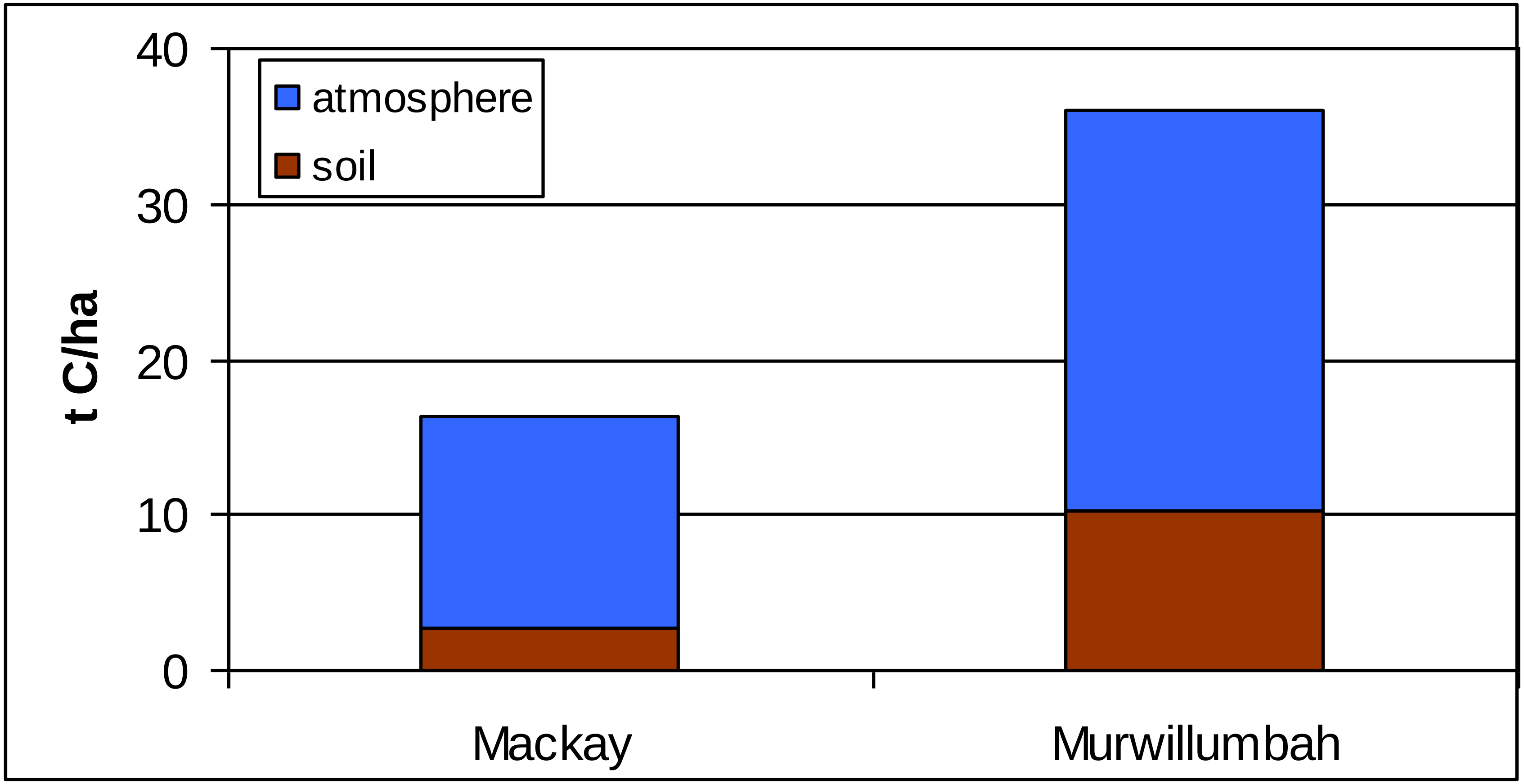
Soil emissions much greater at Murwillumbah

Uptake from atmosphere also much greater at Murwillumbah

Greater soil emissions at Murwillumbah understandable because of higher soil C, but greater uptake by plants unexpected

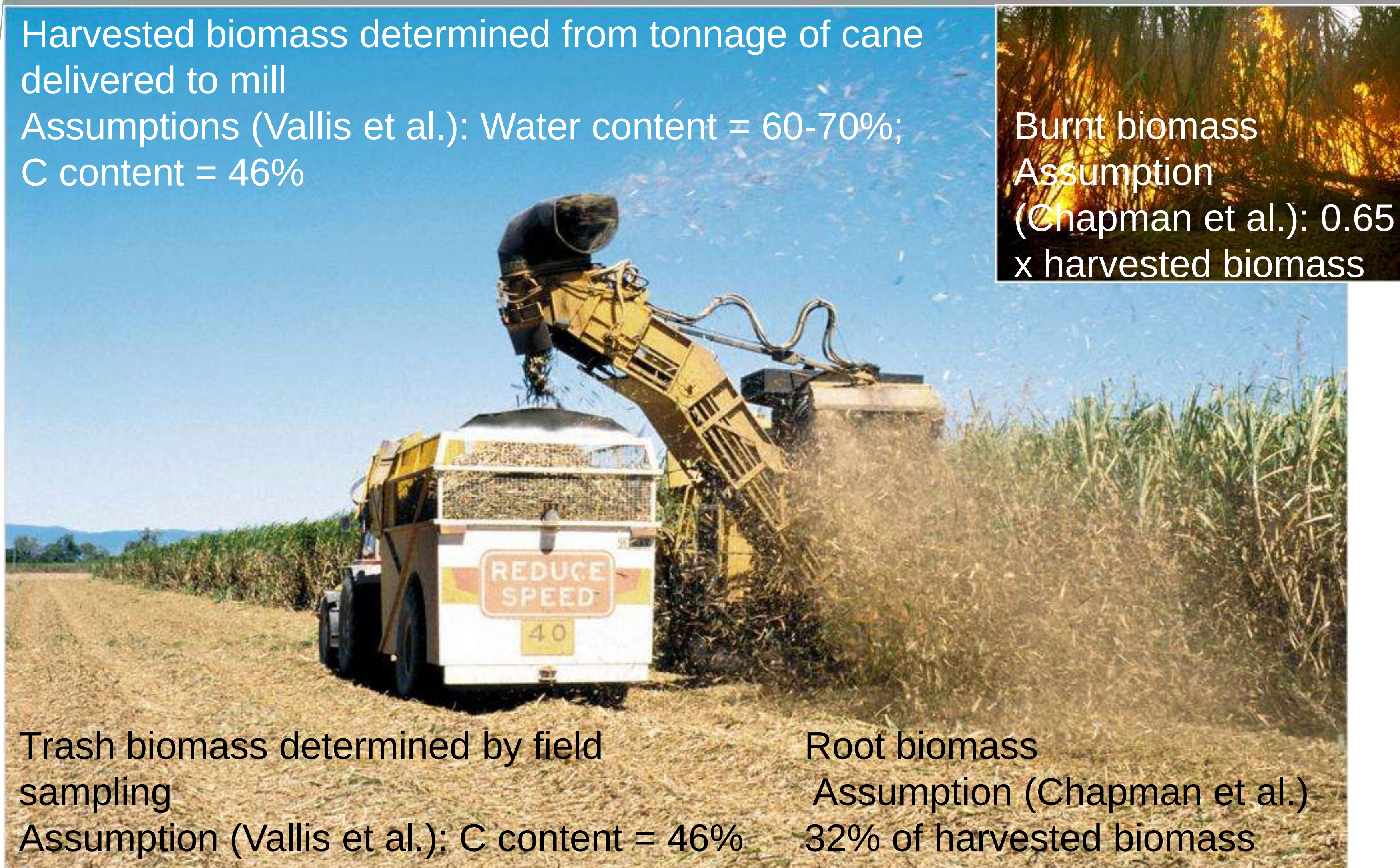
- perhaps due to age differences?

CO_2 contributions from atmosphere and soil



Coefficients of variation for net C gains of each crop estimated to be between 2 and 4 t C/ha

Estimating biomass: assumptions



Harvested biomass determined from tonnage of cane delivered to mill

Assumptions (Vallis et al.): Water content = 60-70%; C content = 46%

Burnt biomass

Assumption (Chapman et al.): 0.65 x harvested biomass

Trash biomass determined by field sampling

Assumption (Vallis et al.): C content = 46%

Root biomass

Assumption (Chapman et al.) 32% of harvested biomass

CO_2 exchange and biomass C (t C/ha)

	Mackay		Murwillumbah	
Net CO_2 exchange	**17**		**36**	
	Moisture		Moisture	
Biomass components	60%	70%	60%	70%
Harvested cane	11	8	18	14
Trash	4	4	1	1
Roots	4	3	6	4
Burnt			12	9
Total biomass	**19**	**15**	**37**	**28**

- Changing cane moisture from 60 to 70% decreases biomass by 23%
- Changing stalk fraction of biomass by 10% (Inman-Barber et al) changes estimate by 1 t C/ha
- Reducing C content of biomass to 43% (Kingston) reduces estimate by 1-2 t C/ha
- **Even so, there is near balance between measured CO_2-C and biomass-C**

Conclusions

- Measurement errors for CO_2 exchange are around 10%
- Measurement errors for mill data are perhaps about the same
- Many assumptions have been made in regard to biomass properties
- They might change estimates of biomass-C by a further 10%
- Resende et al. measured changes in soil C over 16 years of trash retention with coefficients of variation between 13 and 30%
- Modelling and long-term sampling indicate annual gains in soil C of around 0.2 t C/ha (Vallis et al., Resende et al.) with gains of about twice that for the first 20 years of trash retention
- We conclude that measurement errors on a field scale are presently too large to employ our proposed difference technique; the errors in each of the terms in the calculation are at least equal to and mostly greater than the expected change in soil C
- **Verifying predicted or claimed changes in soil C stocks in the short term seems beyond our present measurement capabilities**

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Thank you