Biochar:
Can it reduce pressure on the land?

Annette Cowie

National Centre for Rural Greenhouse Gas Research

NSW GOVERNMENT Industry & Investment

une University of New England

What is biochar?

Amazonian *Terra preta*

Terra preta (dark earth) soils
    High plant productivity
    High organic carbon
    – stable char (black carbon)

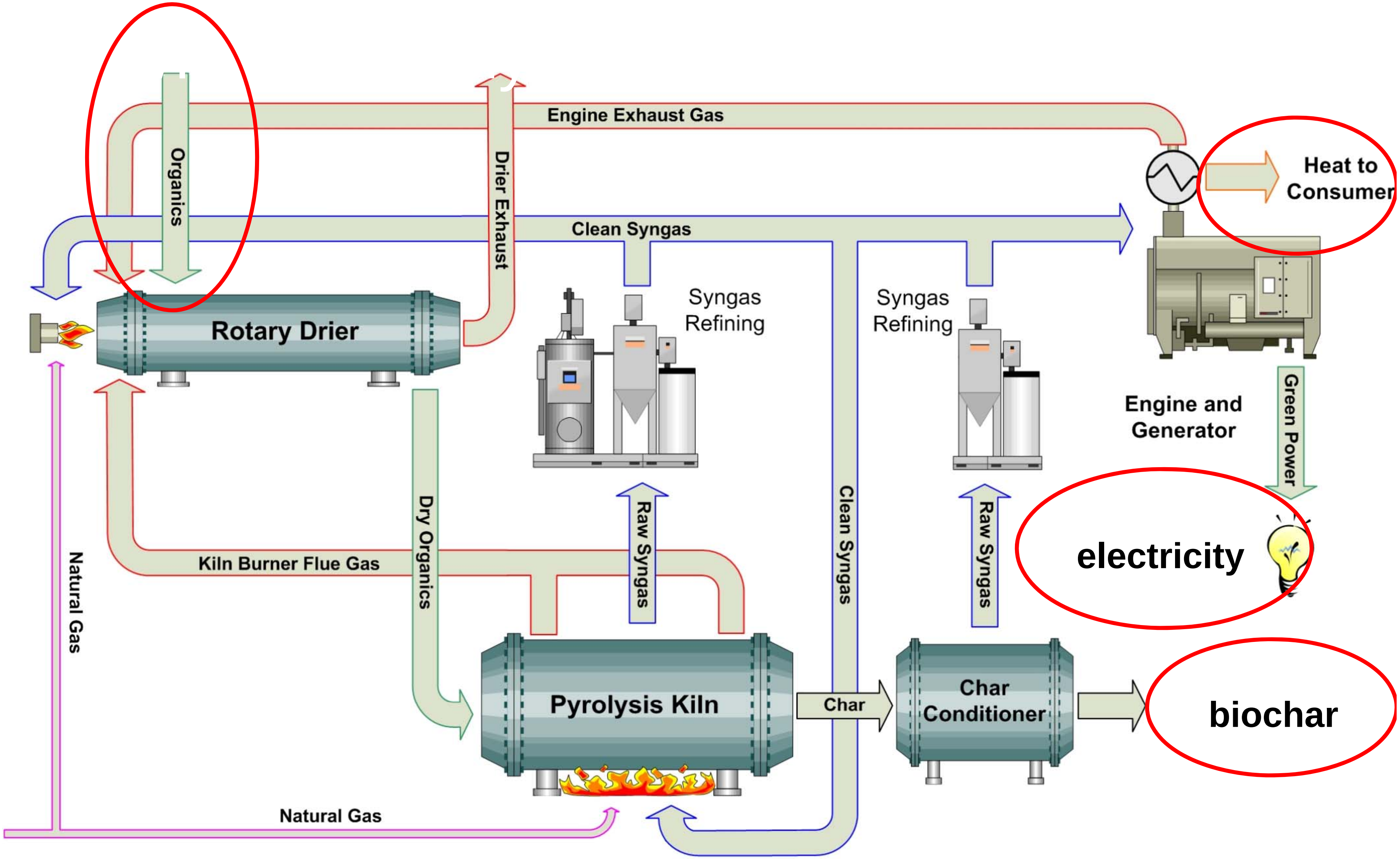
Source: www.biochar-international.org

Amazonian Terra preta

Recreate *Terra preta*?

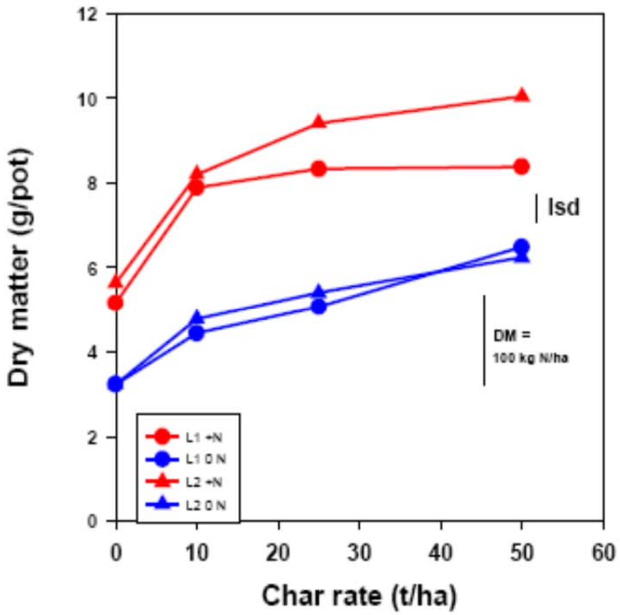
Pyrolysed biomass as a soil amendment

Source: Adriana Downie Pacific Pyrolysis



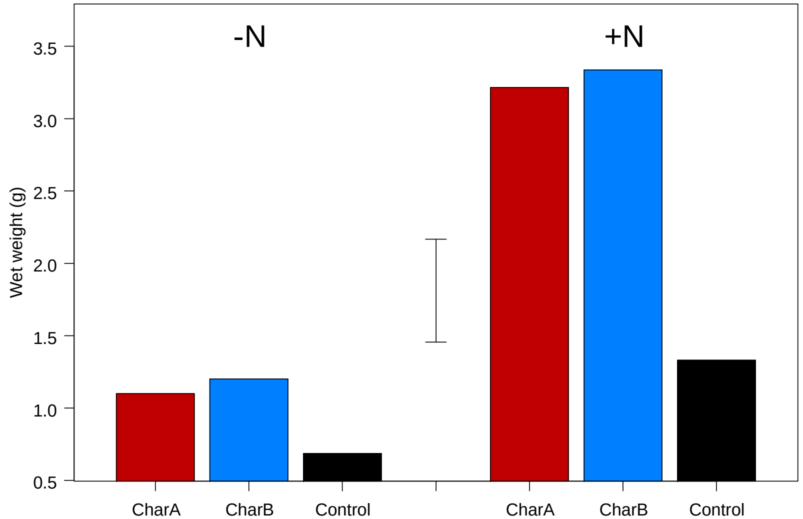
Slow pyrolysis process

PACIFIC PYROLYSIS



Poultry litter char applied to radish *Y. Chan 2007*

Paper sludge char applied to wheat *L. Van Zwieten 2007*



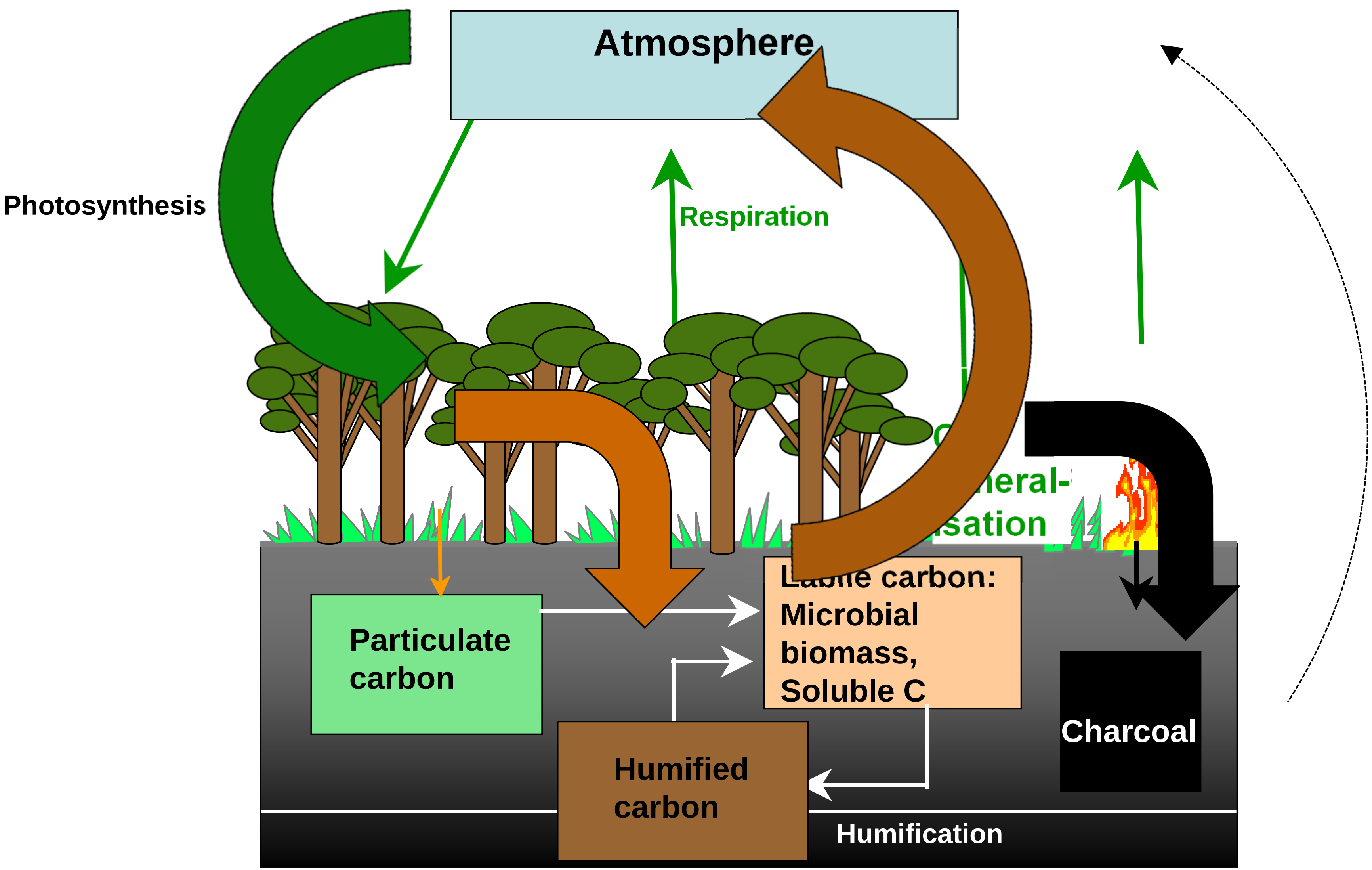
Source: L. Van Zwieten I&I NSW

Mitigation benefits of biochar

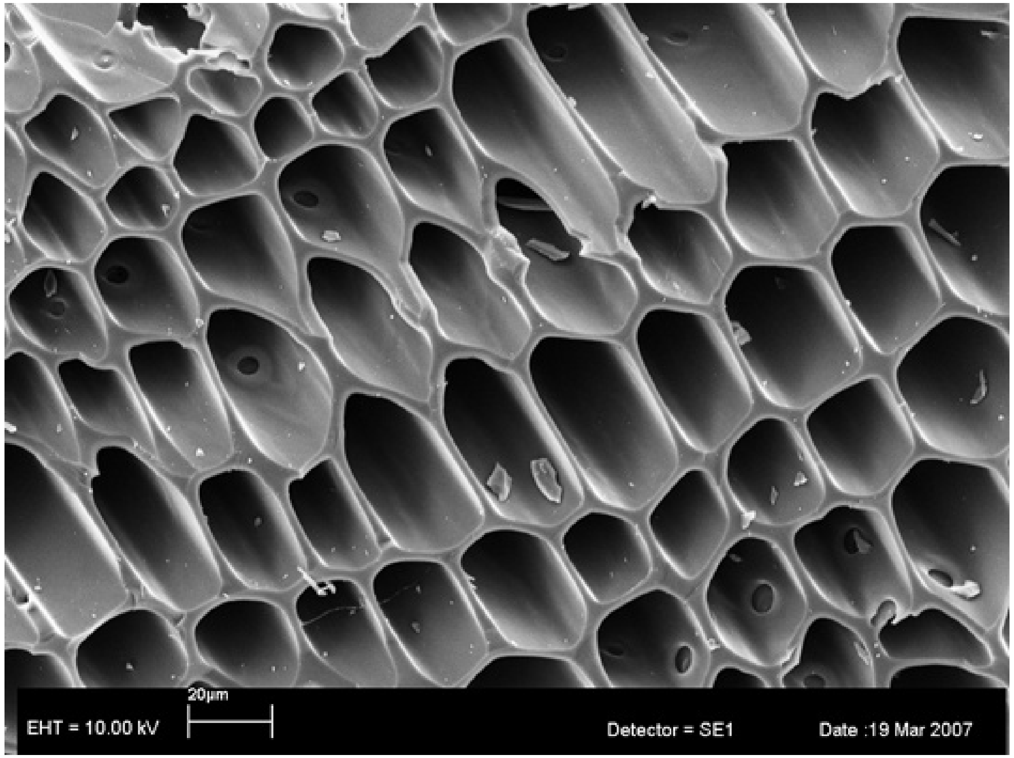
Reduced emissions from decay

- Char lasts in soil
  - Turnover time hundreds to thousands of years
  - Delays decay
  - Biochar as a carbon pump

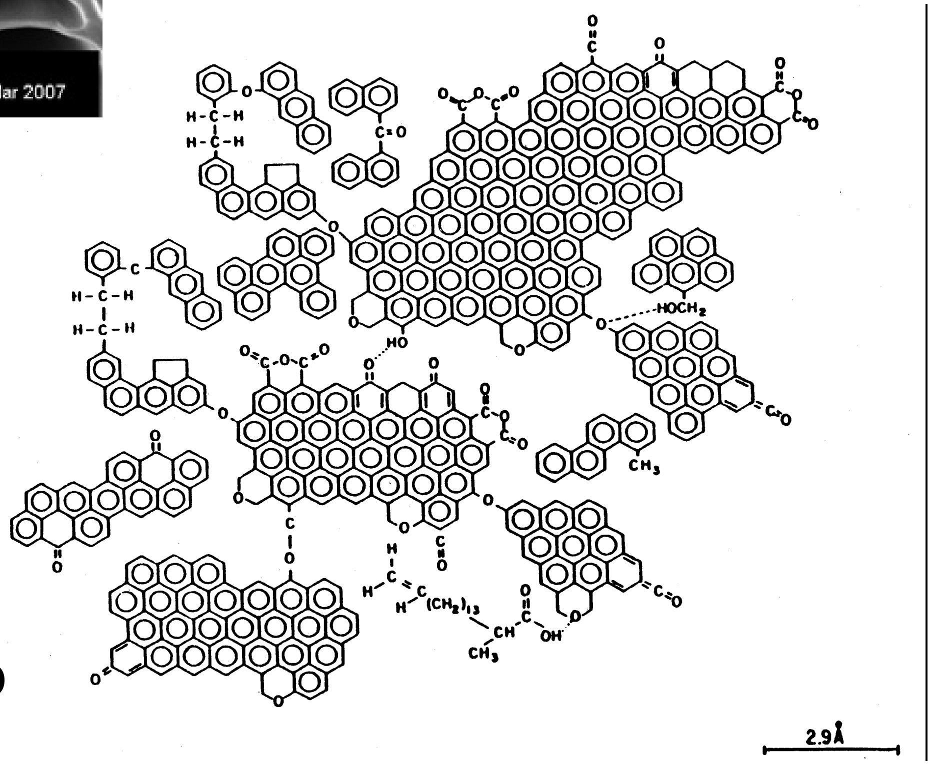
Terrestrial Carbon Cycle



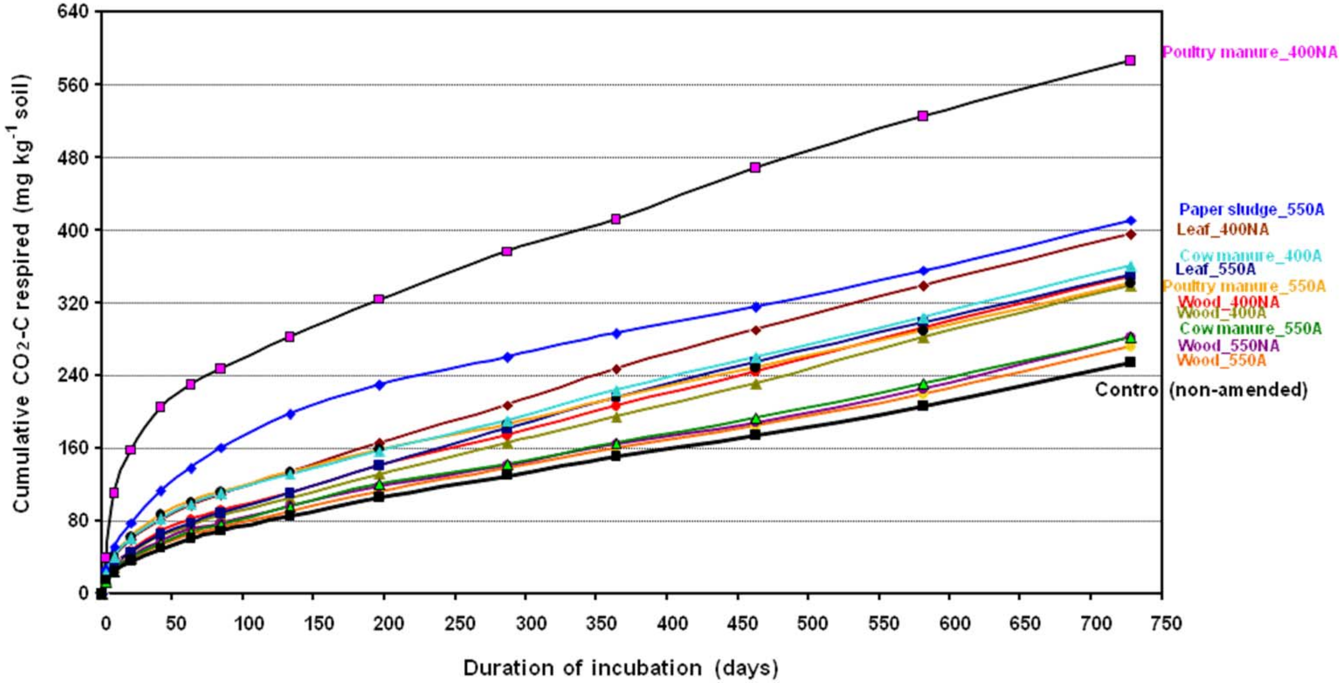
After J. Skjemstad, CRC Greenhouse Accounting



Source: S. Joseph UNSW



Source: E Krull CSIRO



Char-carbon **turnover rate** estimated as **130 -1800 years**

Affected by

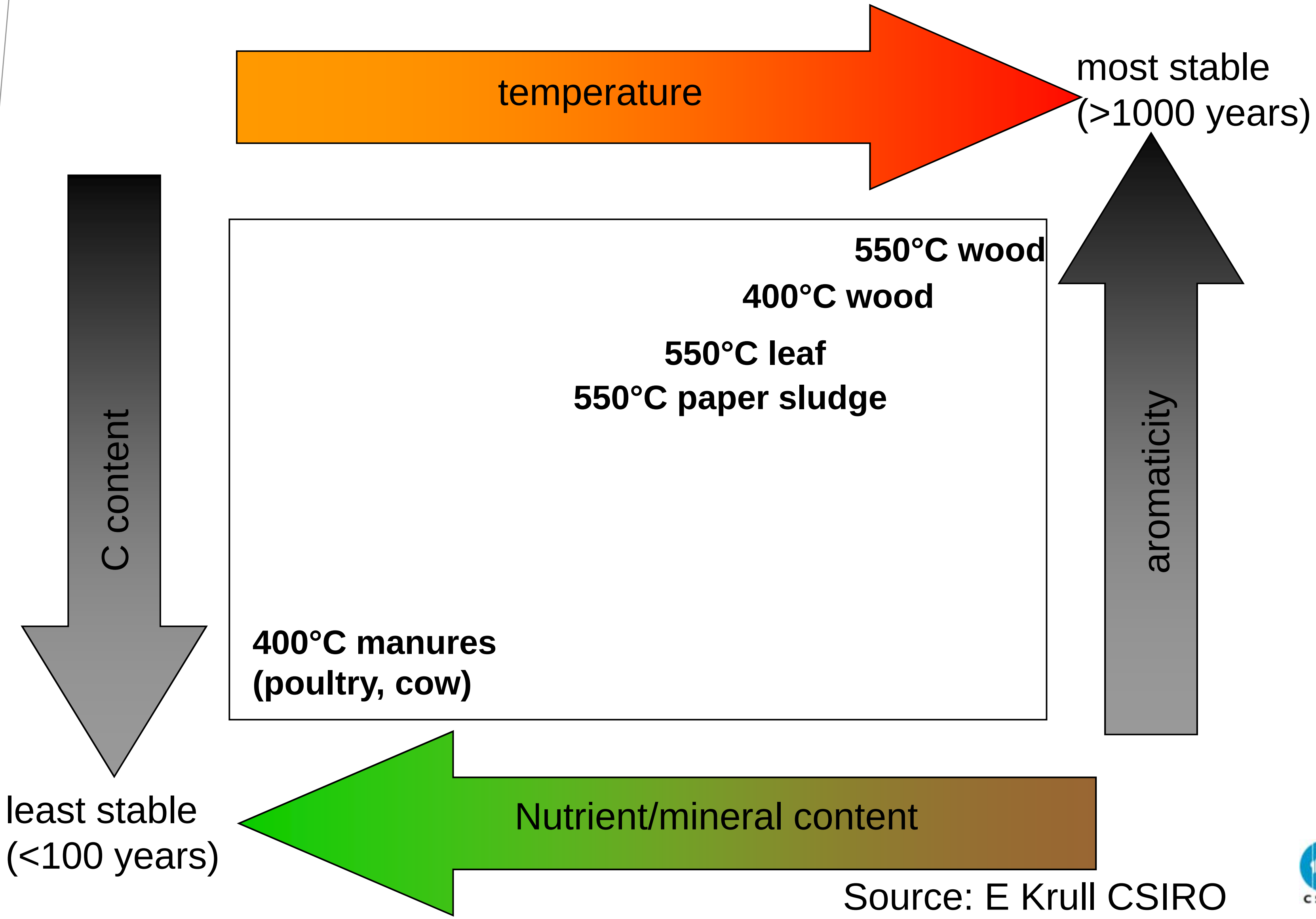
•feedstock

•pyrolysis conditions

BP Singh 2007

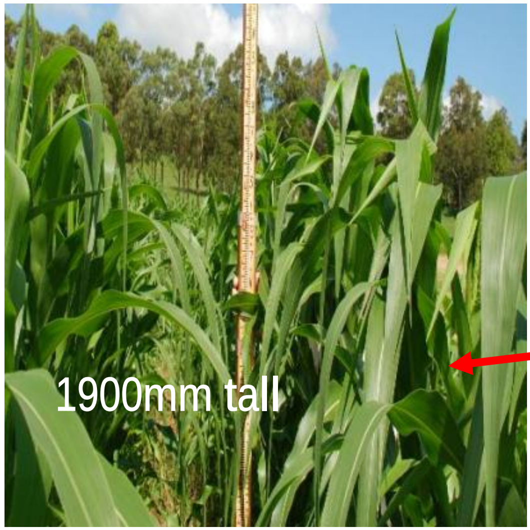
Source: BP Singh DPI NSW

Why are there differences between chars?



Source: E Krull CSIRO

Increased plant growth



Poultry biochar rate t/ha	Maize 07/08 weight of cobs (t/ha)	Faba bean 2008 dry bean (t/ha)	Maize 08/09 weight of cobs (t/ha)
0	16.2	2.4	19.6
5	17.9	4.2	22.5
10	26.7	4.6	22.6
20	28.4	5.5	22.3
50	32.9	5.6	24.2

Source: L. Van Zwieten DPI NSW

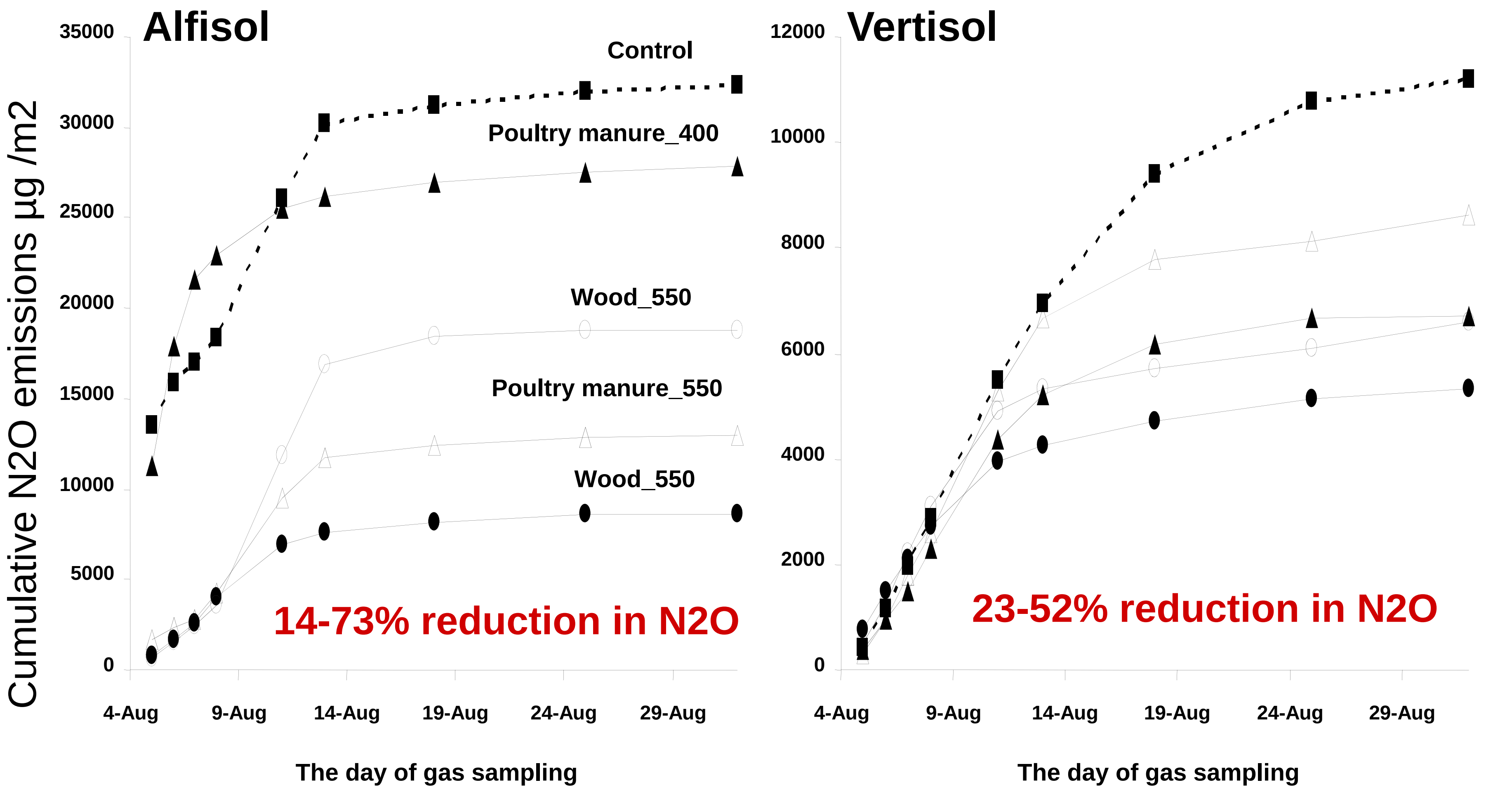
Reduced emissions due to fertiliser manufacture

- Reduced nutrient leaching
- Build soil N in microbial biomass
- Increase P availability
- Fertiliser requirements reduced
- Less nitrogen fertiliser manufactured

Reduced emissions from fertiliser application

- Nitrous oxide is released when N fertiliser applied
  - powerful greenhouse gas – GWP 298 cf CO_2
- Nitrous oxide emission varies with temperature, moisture

Biochar can reduce soil N_2O emissions



BP Singh et al. 2010 (JEQ)

Enhanced soil carbon

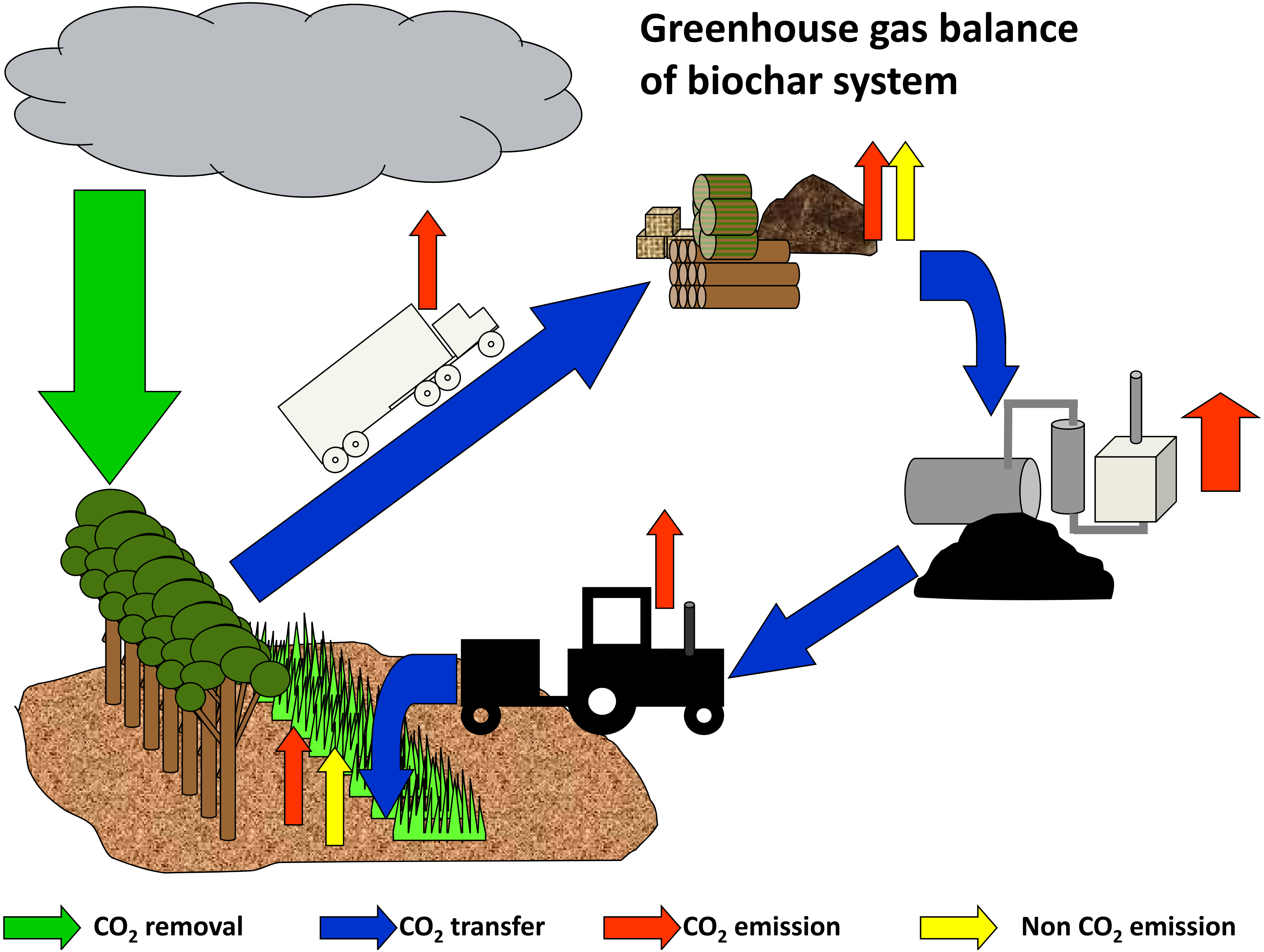
- Stimulates microbial activity
- OM/mineral/char interactions protect soil OM

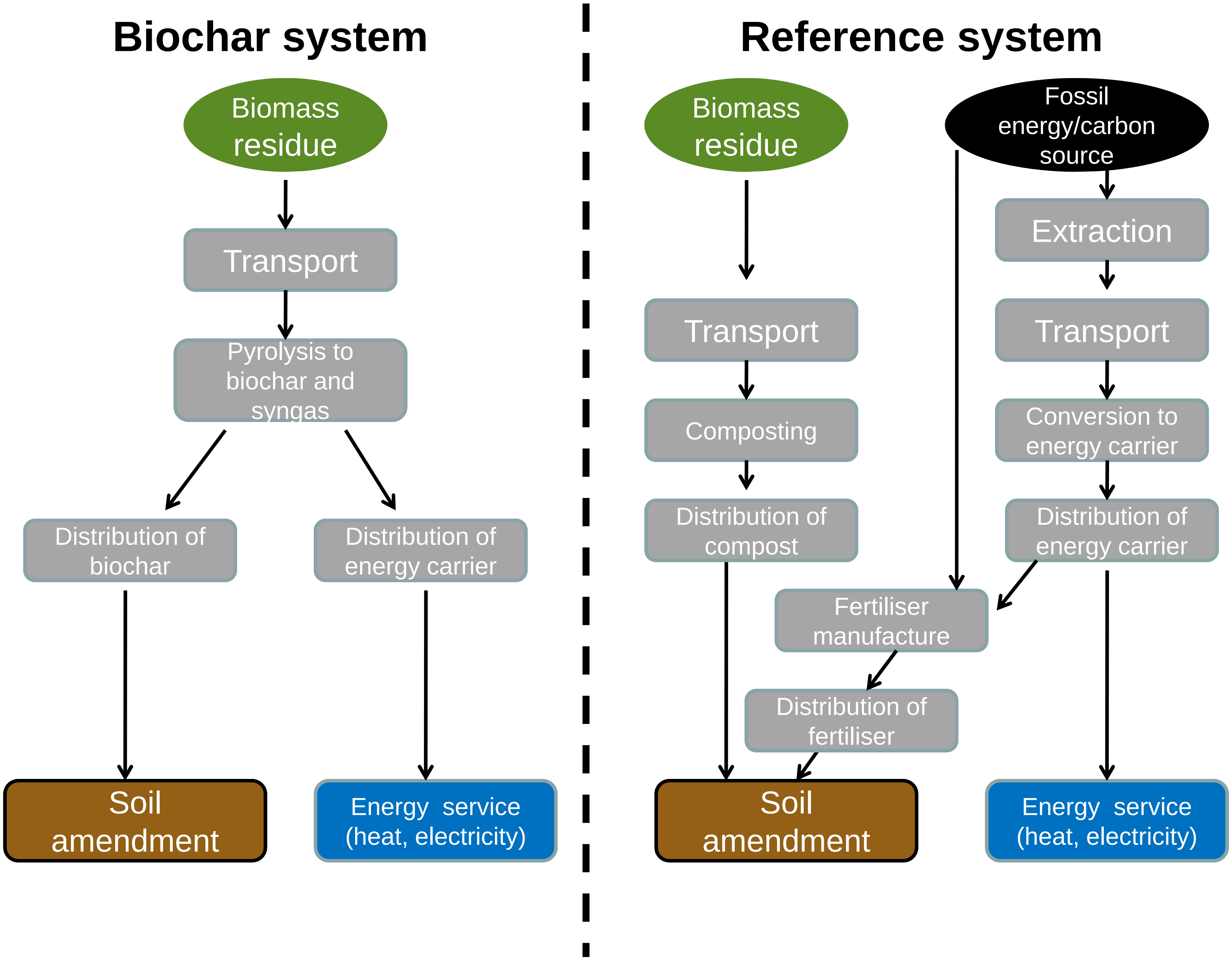
Avoided emissions from waste

- In landfill, biomass decomposes anaerobically, releasing methane
- GWP of methane is 25 cf CO_2
- Utilisation for char avoids methane from landfill/composting
- Animal manures release methane and nitrous oxide
- Utilisation for char avoids these emissions

Renewable energy

- Pyrolysis produces syngas
  - heat
  - electricity
- Avoids emissions from fossil fuel energy sources


Greenhouse gas balance
of biochar system
CO_2 removal
CO_2 transfer
CO_2 emission
Non CO_2 emission


Biochar system
Biomass residue
Transport
Pyrolysis to biochar and syngas
Distribution of biochar
Distribution of energy carrier
Soil amendment
Energy service (heat, electricity)
Reference system
Biomass residue
Fossil energy/carbon source
Extraction
Transport
Transport
Composting
Conversion to energy carrier
Distribution of compost
Distribution of energy carrier
Fertiliser manufacture
Distribution of fertiliser
Soil amendment
Energy service (heat, electricity)

Quantifying climate change benefit

- Emissions reduction for whole system, across life cycle, compared with reference “business as usual” baseline
- Same system boundary, same service
- Consider
  - all GHGs: N_2O, CH_4
  - C Stock change in biomass and soil
  - Fuel use: Construction, start-up
- Units:
  - CO2e saved/ unit biomass used for biochar
  - CO2e saved/ ha used to grow biomass
  - CO2e saved/ unit product output

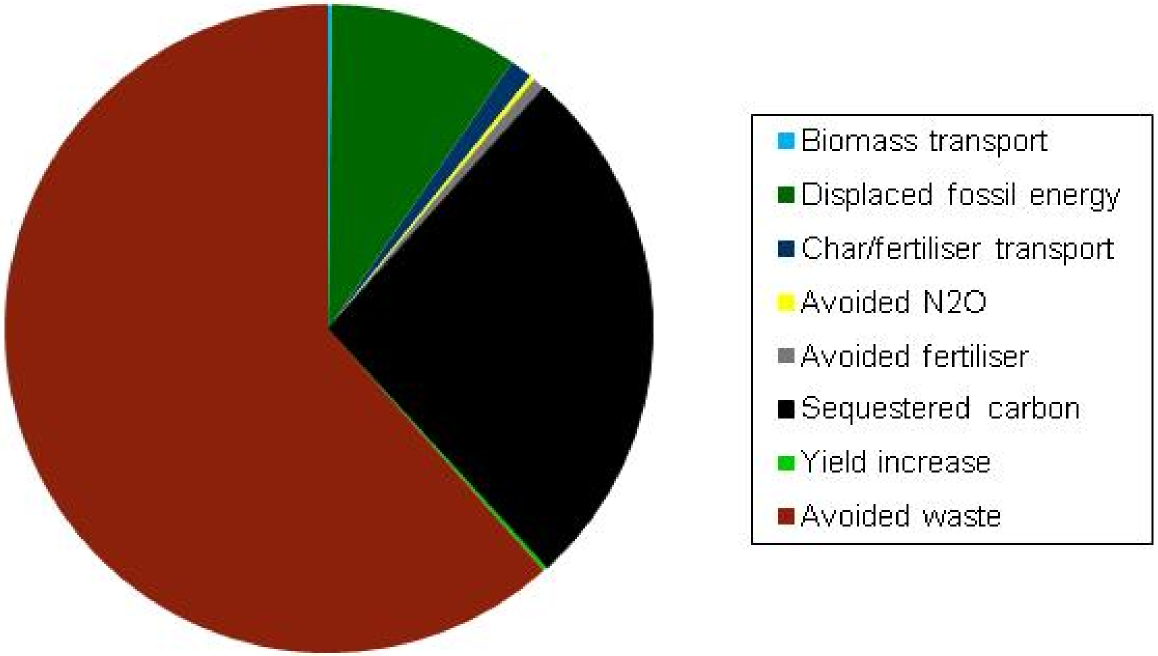
Quantifying climate change benefits of a biochar system

- Compare project with reference
- System boundary
  - All greenhouse gases CO2 and non-CO2
  - Deliver equivalent service (area fertilised, electricity produced)
- Consider whole system life cycle
  - Direct and indirect emissions
- Include C stock change in biomass, soil
- Express as emissions reduction per unit limiting resource (biomass, land area)
- Result is specific to each situation

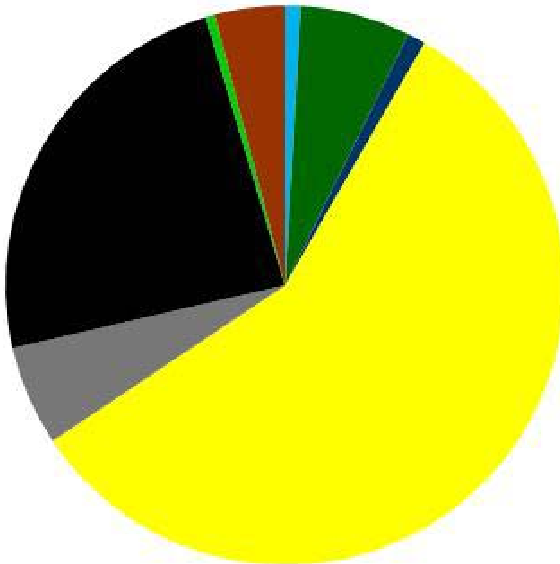
GHG mitigation benefits of biochar

- Long term carbon storage in soil ie avoided decomposition
- Avoided fossil fuel emissions due to use of syngas as renewable energy
- Avoided emissions from N fertiliser manufacture
- Reduced nitrous oxide emissions from soil
- Avoided methane and nitrous oxide emissions due to avoided decay of residues
- Increased plant growth
- Increased soil organic matter
- Reduced fuel use in cultivation

Factors contributing to mitigation

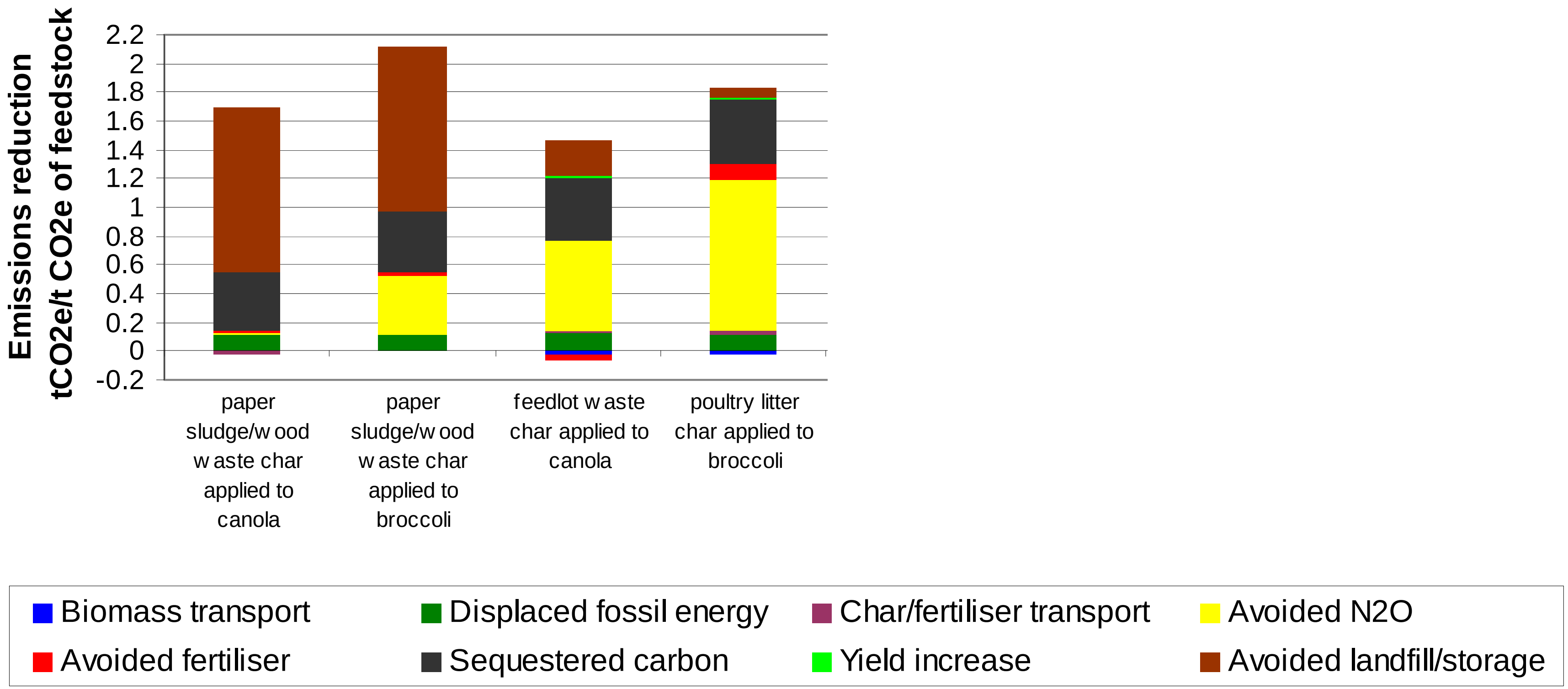


Greenwaste biochar applied to canola



Poultry litter biochar applied to broccoli

Life cycle emissions reduction

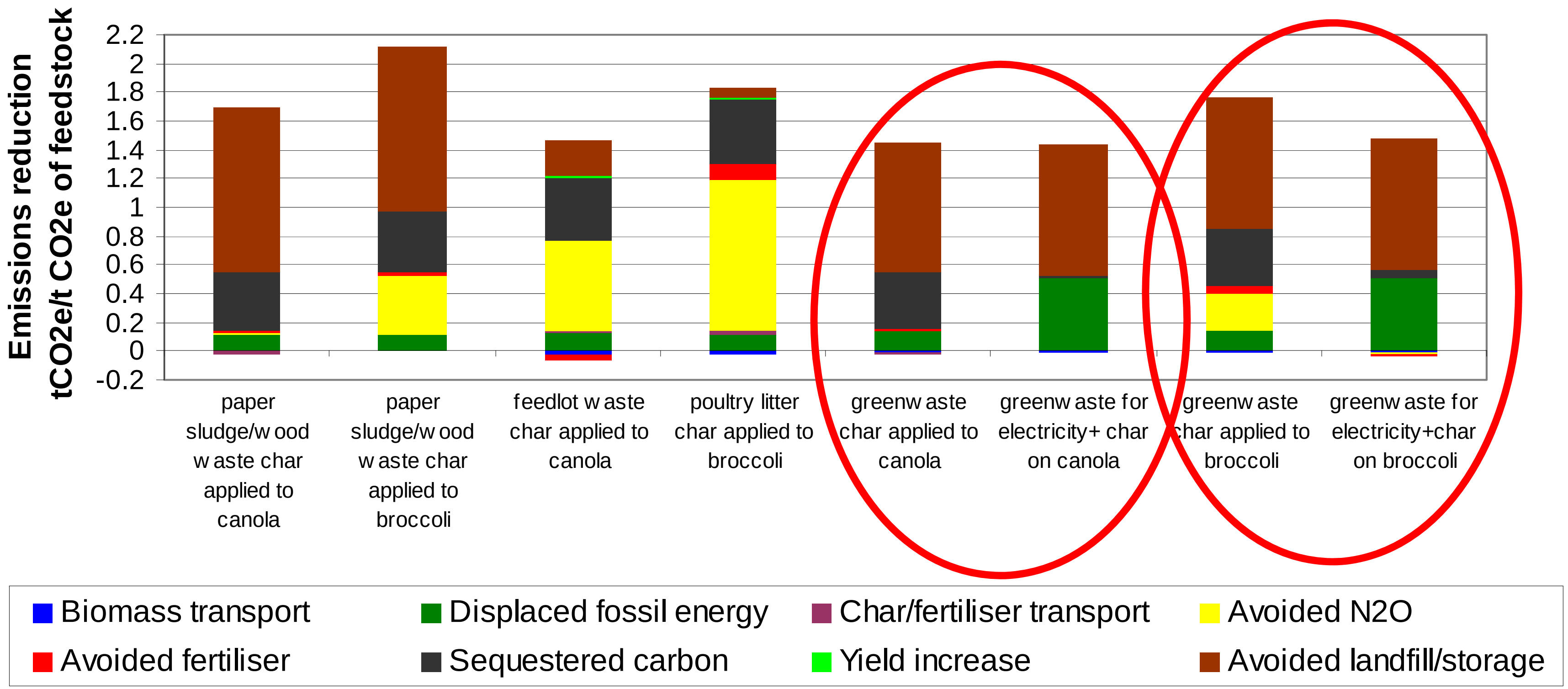


1.1-2.7 tCO_2e/t feedstock

1.3-5.9 tCO_2e/t feedstock Gaunt and Cowie 2009

0.8-0.9 tCO_2e/t feedstock Roberts et al 2010 (-0.04-0.44 for purpose-grown)

Life cycle emissions reduction – including energy options



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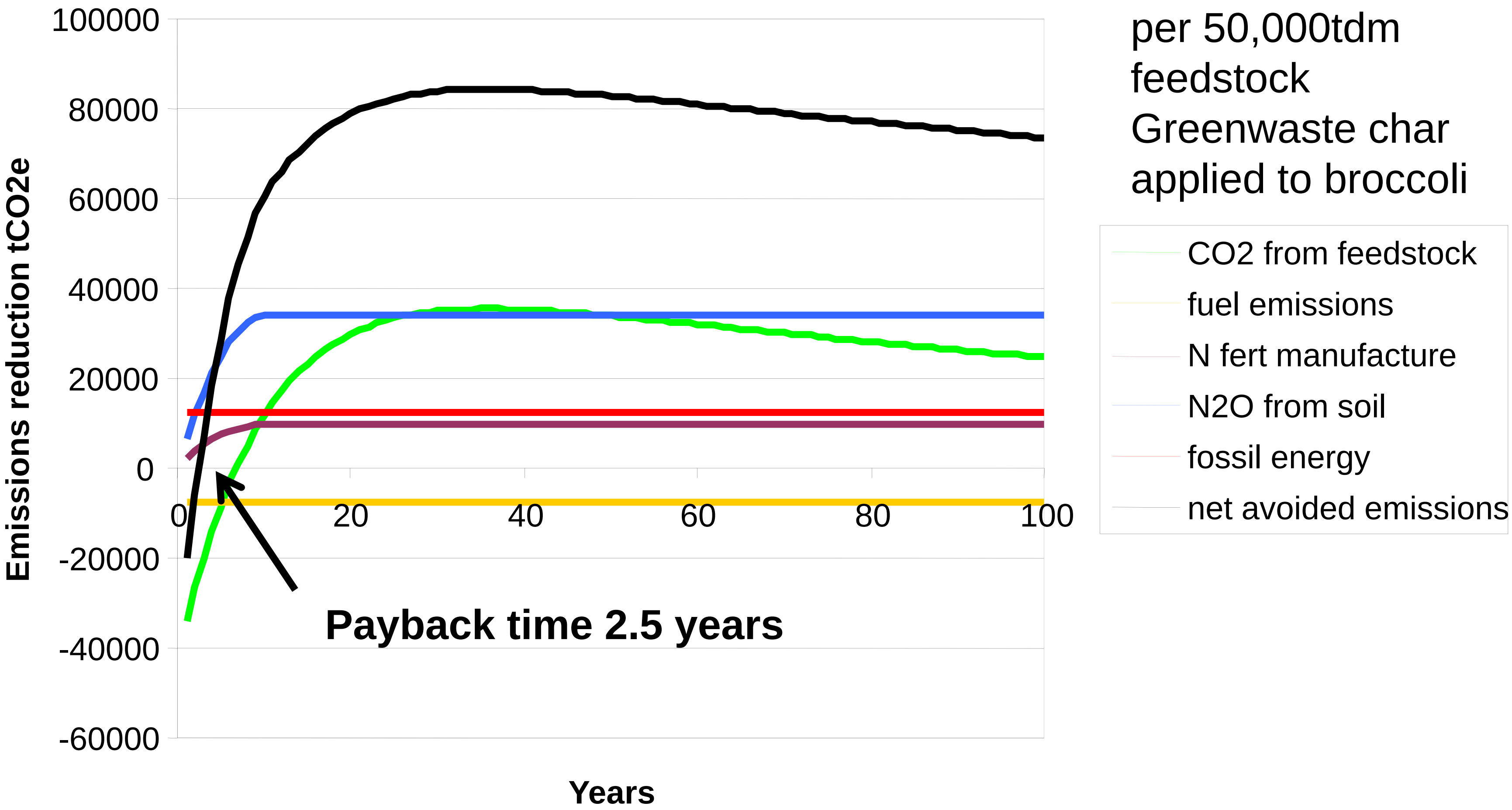
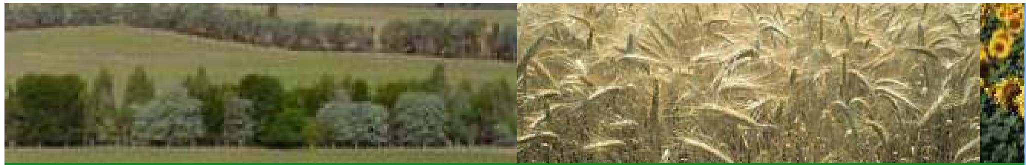
The time dimension

Emissions reduction per 50,000tdm feedstock Greenwaste char applied to broccoli



Available biomass

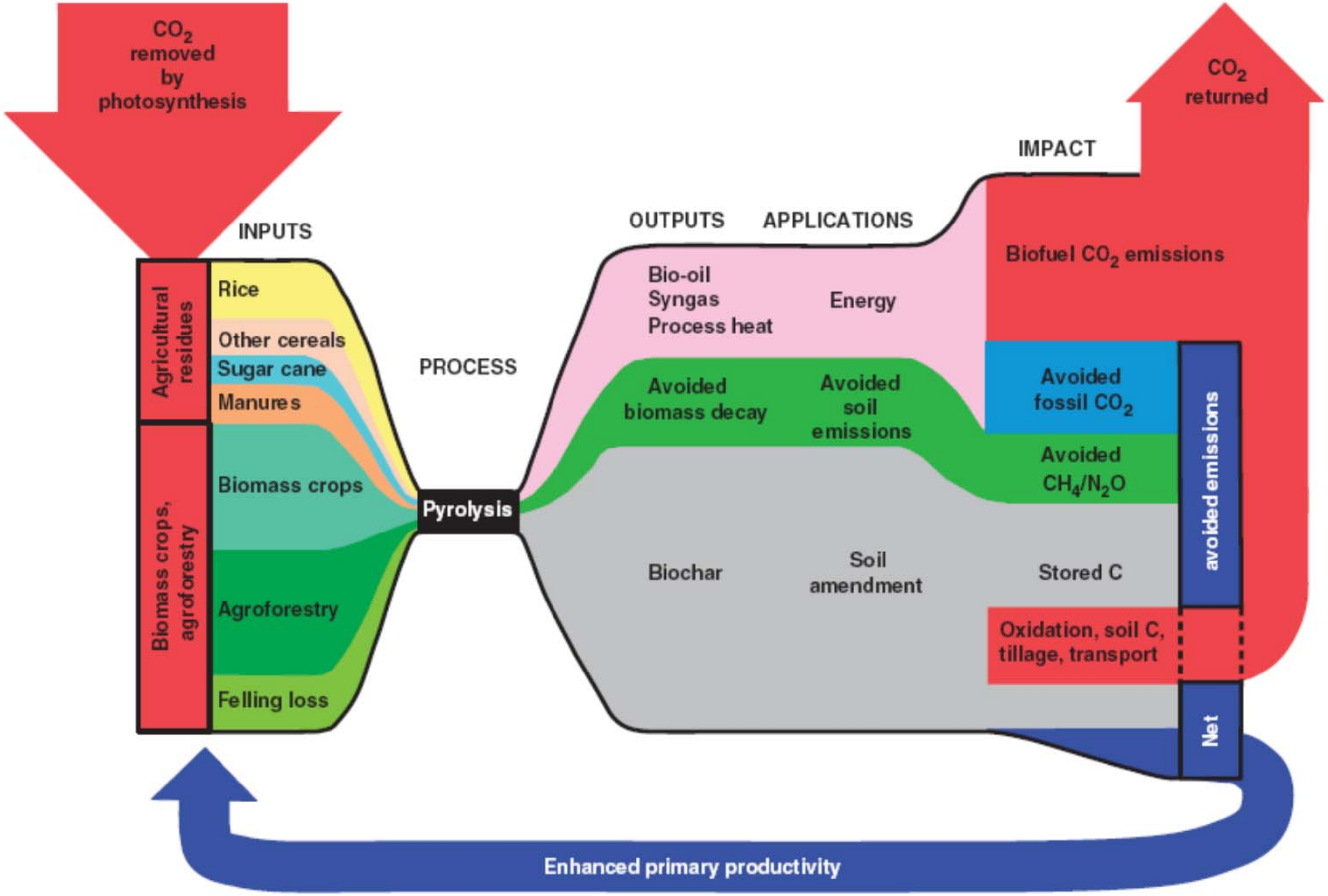
- "Wastes"
  - Urban green waste
  - Feedlot manure, poultry litter
  - Bagasse, sugar cane tops
  - Biosolids
  - Sawmill residues



Available biomass

- Forest harvest residues
- Crop stubble?
- Purpose-grown crops
  - Oil mallee

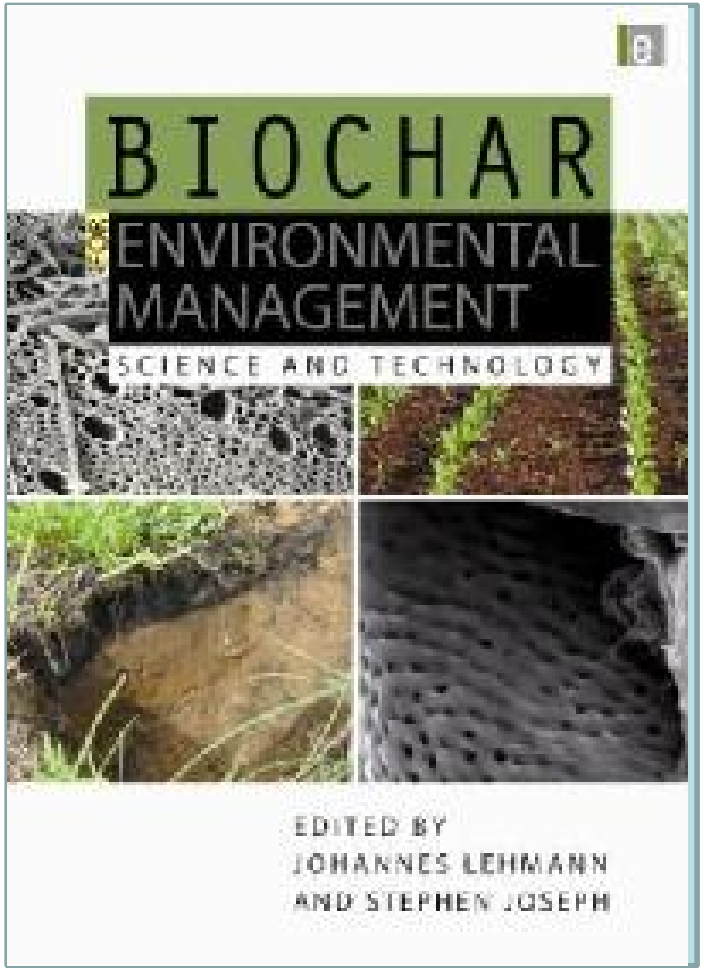
Potential mitigation through biochar - global



Woolf et al 2010 Total mitigation predicted: 1.8Gt CO2-e pa =12% current emissions

Integration with bioenergy

- Syngas from pyrolysis – heat, electricity, biofuel
- Pyrolysis of residues unsuited to energy applications
  “contaminated” – high ash
  high moisture
- Pyroysis of residues from biofuel production
- Biochar for remediation of degraded land and to enhance land productivity so
  - produce more biomass for energy
  - increase resilience to climate change

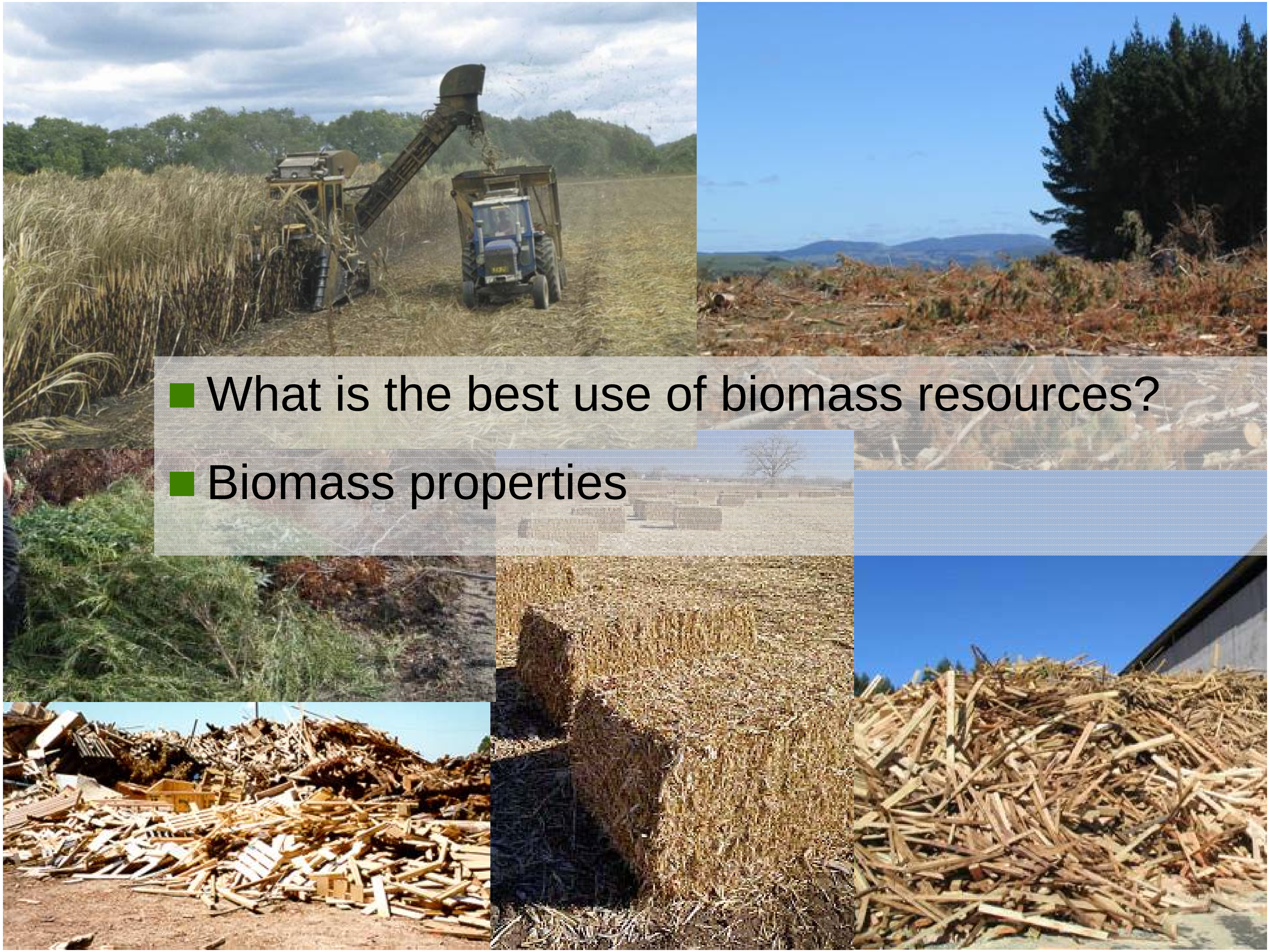


Biochar for Environmental Management
Science and Technology
Edited by
Johannes Lehmann and Stephen Joseph

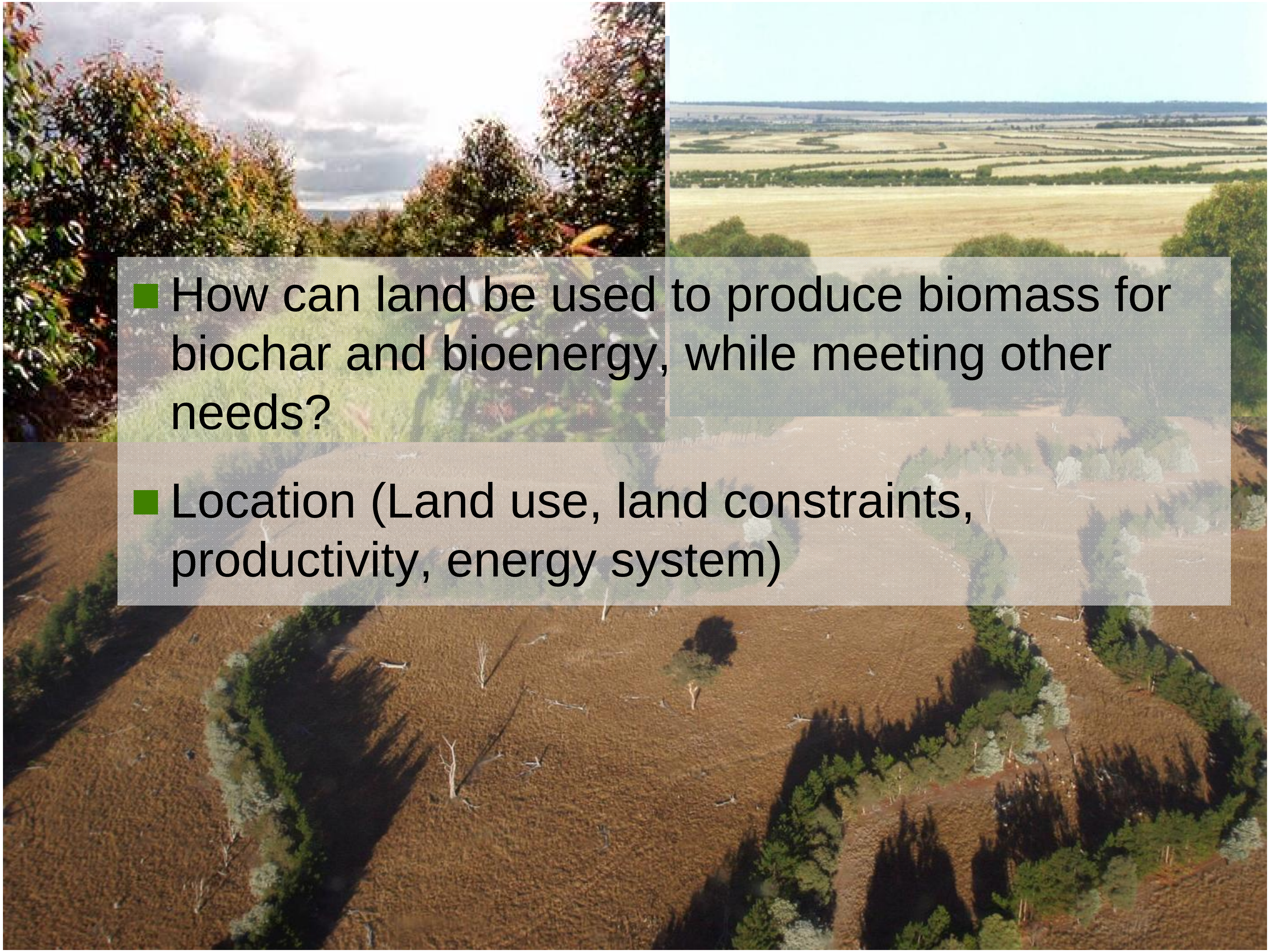
Earthscan 2009

International Biochar Initiative
www.biochar-international.org

ANZ Biochar Researchers' Network
www.anzbiochar.org/



- What is the best use of biomass resources?
- Biomass properties



- How can land be used to produce biomass for biochar and bioenergy, while meeting other needs?
- Location (Land use, land constraints, productivity, energy system)

Conclusion

- Biochar systems based on residues, where syngas used to displace fossil fuel can deliver net reduction in GHG emissions
- Major contribution to mitigation from OM stabilisation, avoided N_2O and CH_4, displaced fossil fuels
- Least benefit from manure biochars (less stable)
- Benefit can be greater than if used for energy alone
- Assumptions need further testing
- Biochar can be integrated with bioenergy
  - greater mitigation in some cases
  - sustainable land management
  - adaptation to climate change

Thank you

annette.cowie@une.edu.au

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University of New England

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