The Metropolitan Water Reclamation District of Greater Chicago

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OF THE 2010
M&R SEMINAR SERIES

BEFORE WE BEGIN

- SILENCE CELL PHONES & PAGERS
- QUESTION AND ANSWER SESSION WILL FOLLOW PRESENTATION
- SEMINAR SLIDES WILL BE POSTED ON MWRD WEBSITE AT (www. MWRD.org)
- Home Page → (Public Interest) → more public interest → M&R Seminar Series → 2010 Seminar Series

Greenhouse Gas (GHG) Accounting for the Metropolitan Water Reclamation District of Greater Chicago's Biosolids Management Program

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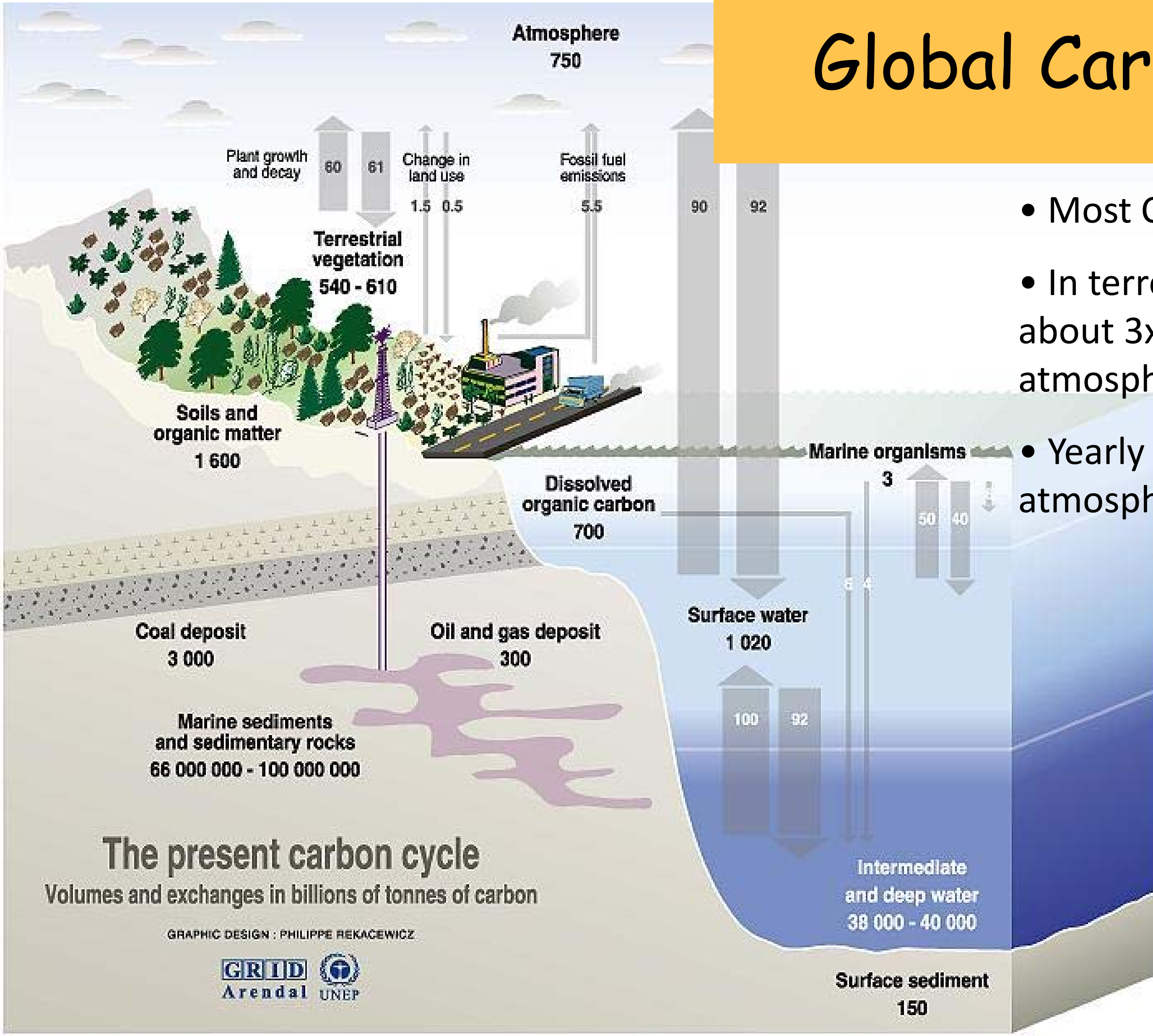
and

Guanglong Tian, MWRD

Global Carbon Cycle



Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

- Most C is in oceans and crust
- In terrestrial pools, soils store about 3x more carbon than atmosphere or biomass
- Yearly C emissions are ~1% of atmospheric pool

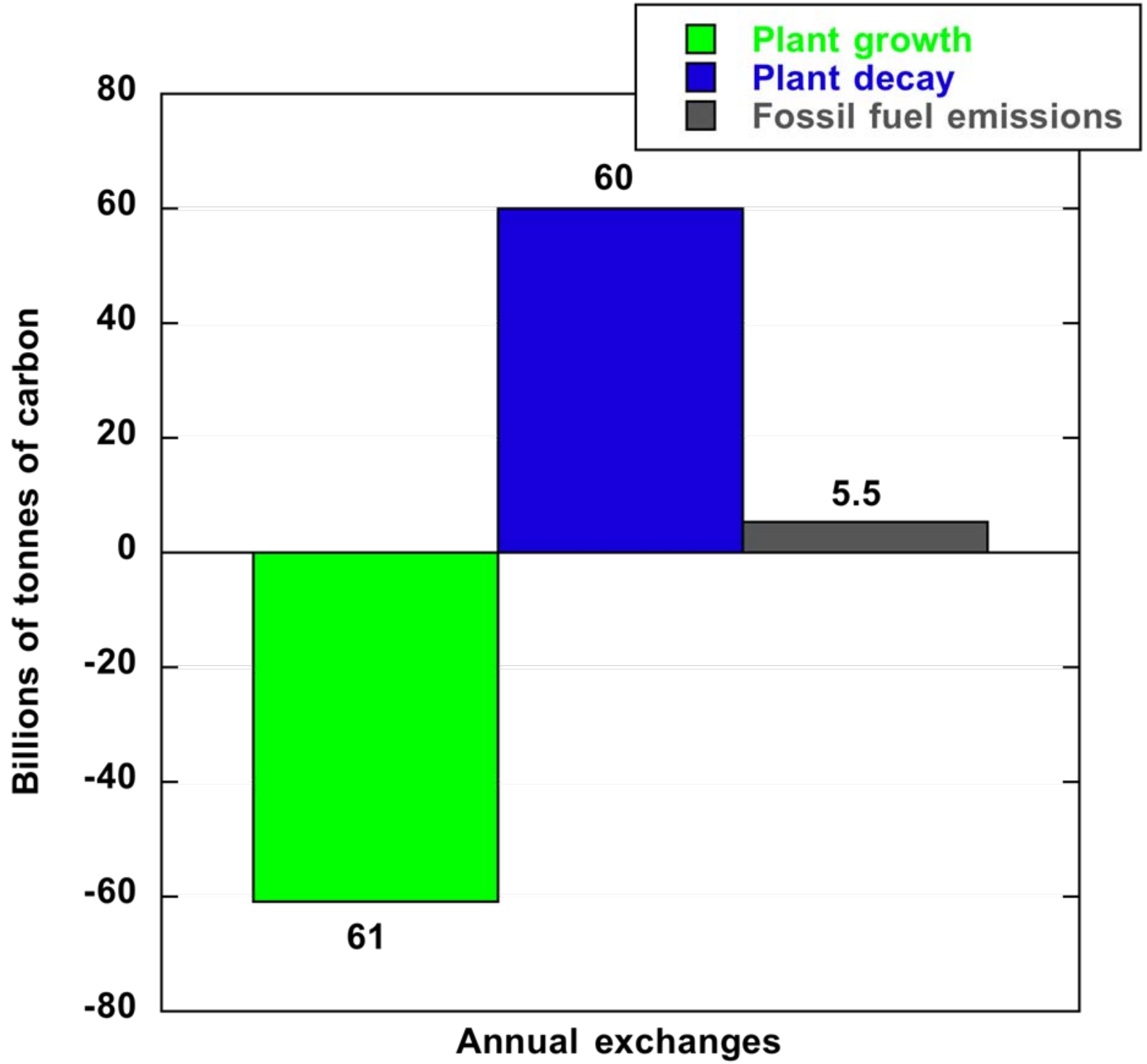
Short term carbon cycle- soils and plants

Energy from the sun is used to 'fix' atmospheric CO_2 via photosynthesis

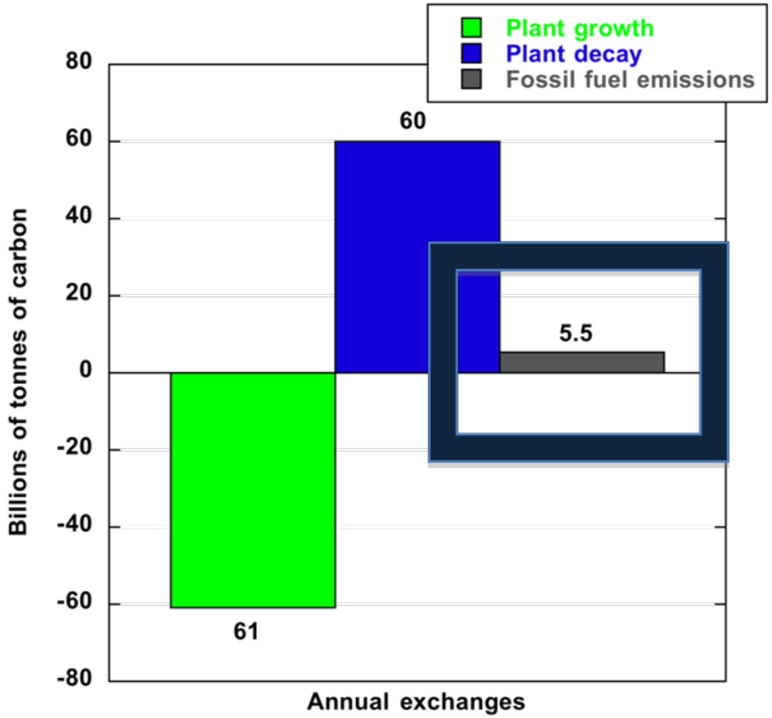
The fixed CO_2, in the form of plant matter is used as food by a wide range of animals including microorganisms

A portion of the carbon remains fixed (soil organic matter animal biomass) and the remainder decomposes aerobically and returns to the atmosphere as CO_2

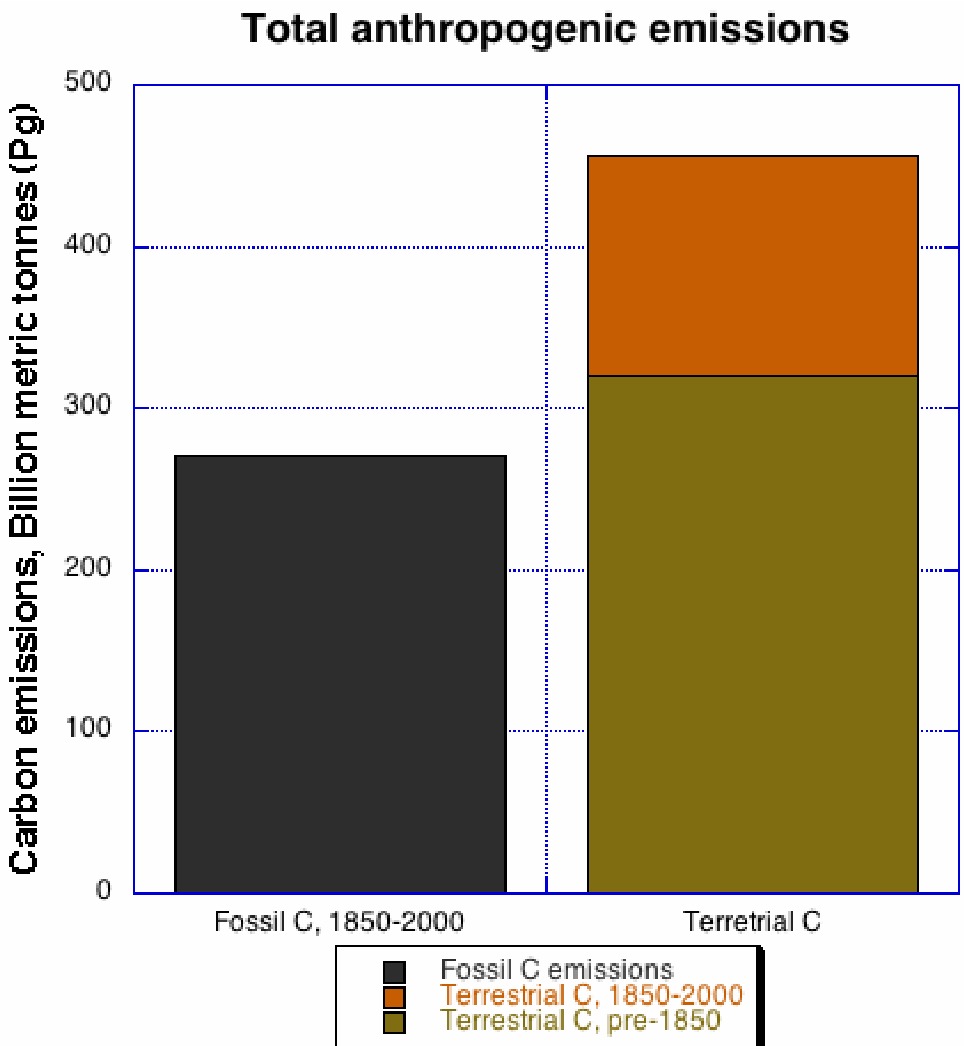
Magnitude of different cycles



Focus


Plant growth
Plant decay
Fossil fuel emissions
80
60
40
20
0
-20
-40
-60
-80
Billions of tonnes of carbon
60
61
5.5
Annual exchanges

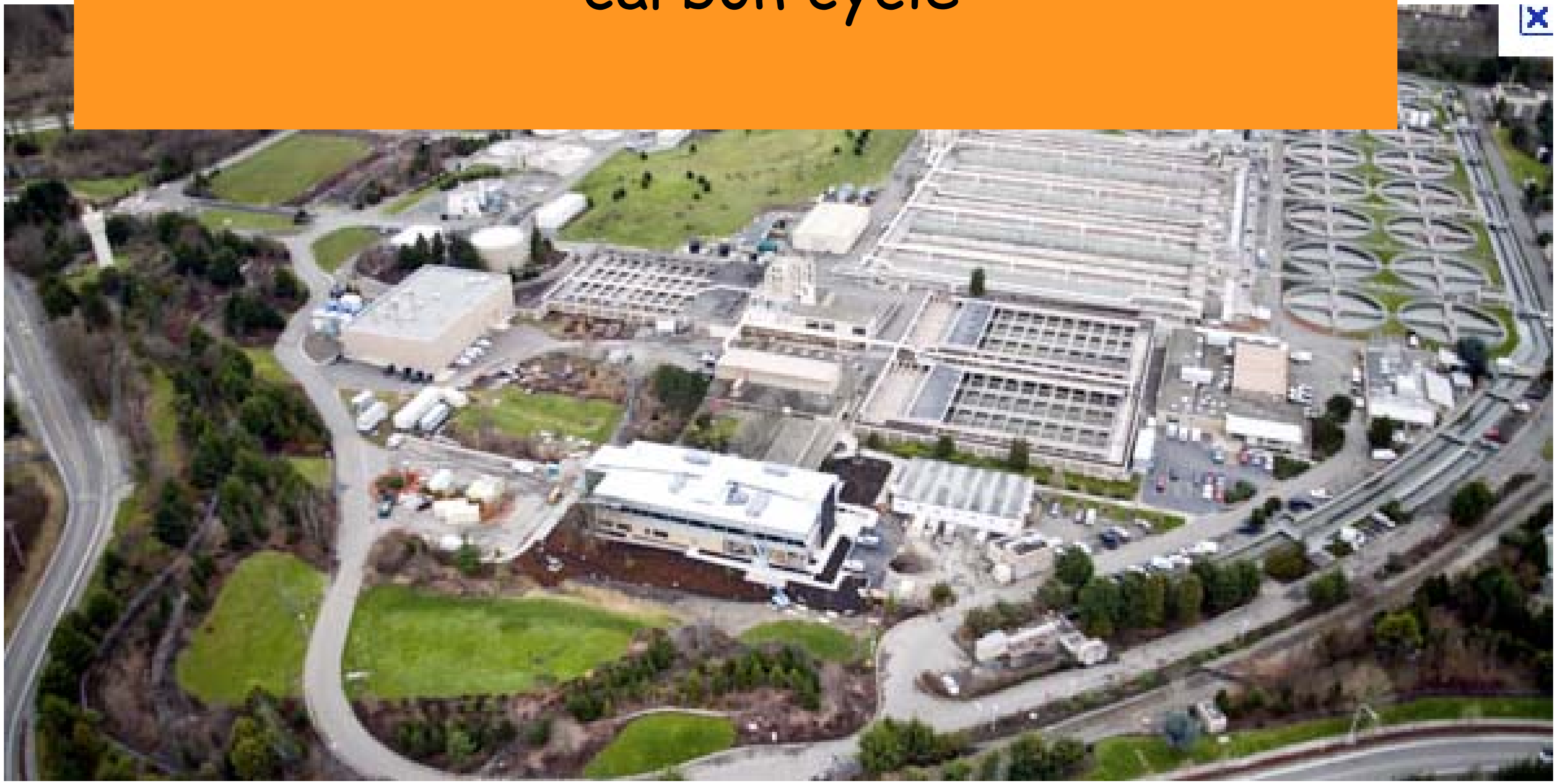
However, Land disturbance and Climate Change



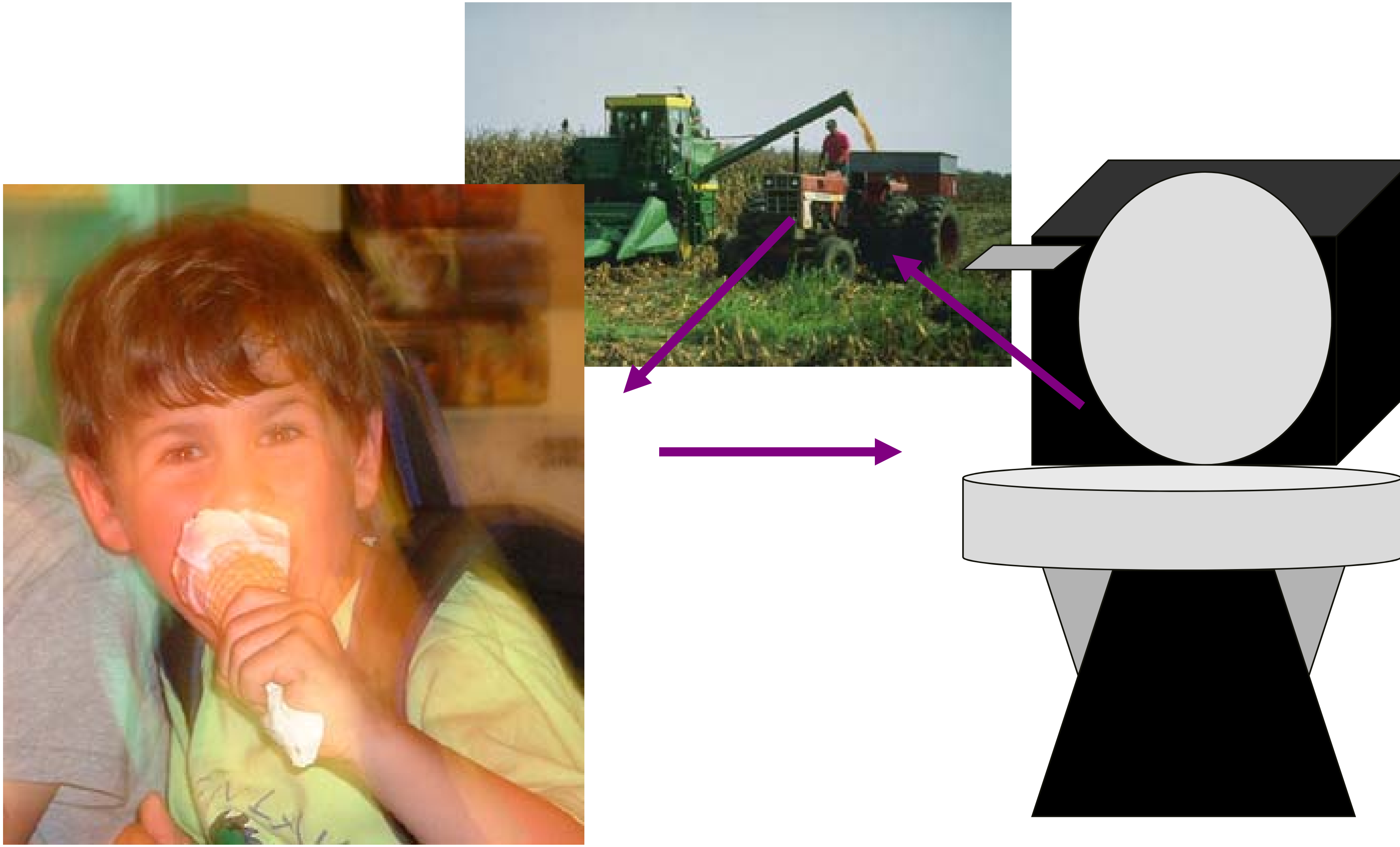
From Lal, 2004

Wastewater treatment

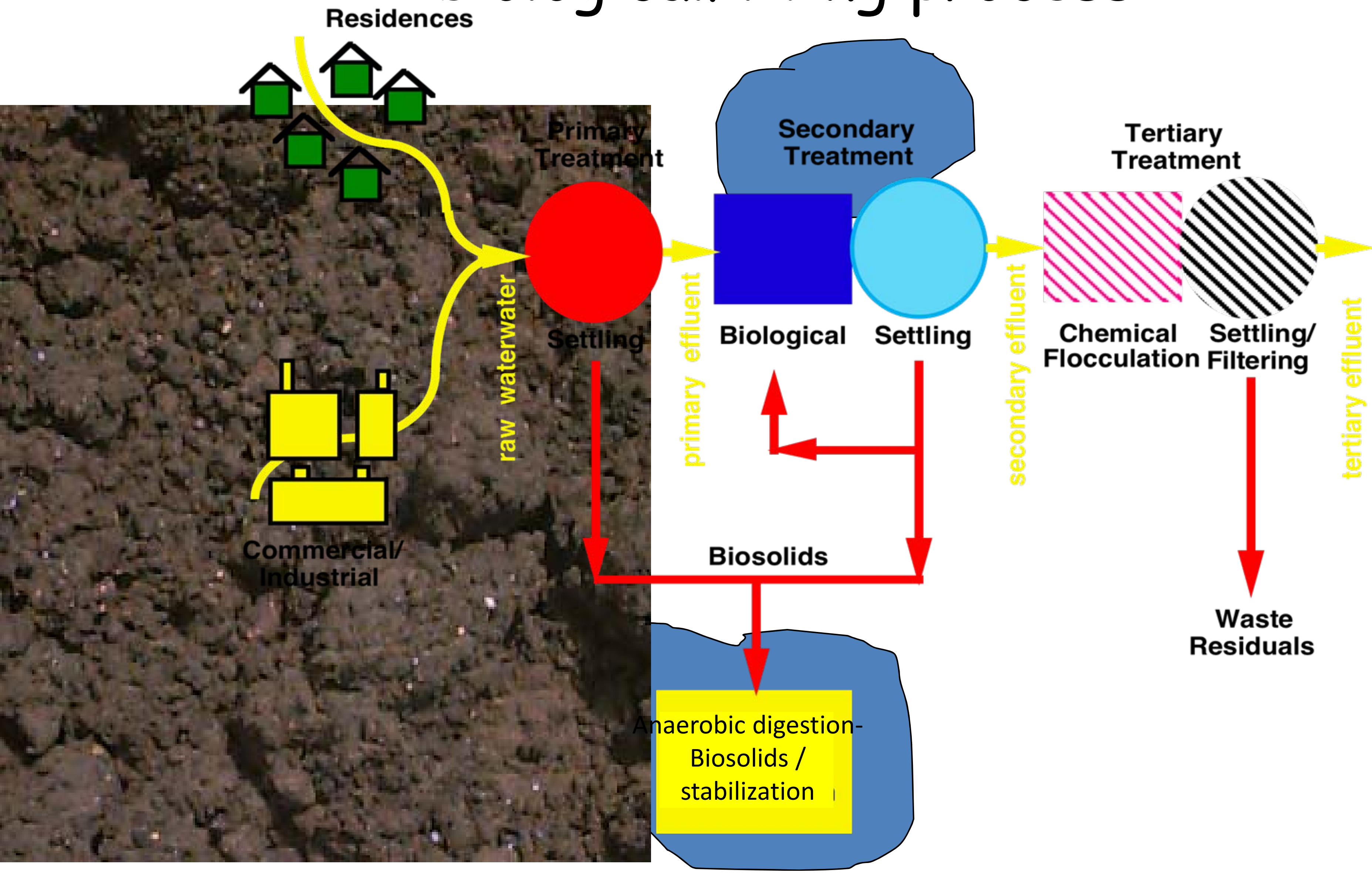
- A much more engineered system than the bear in the woods
- But basically part of the short term carbon cycle



The human version of the short term carbon cycle



Wastewater treatment-biological/living process

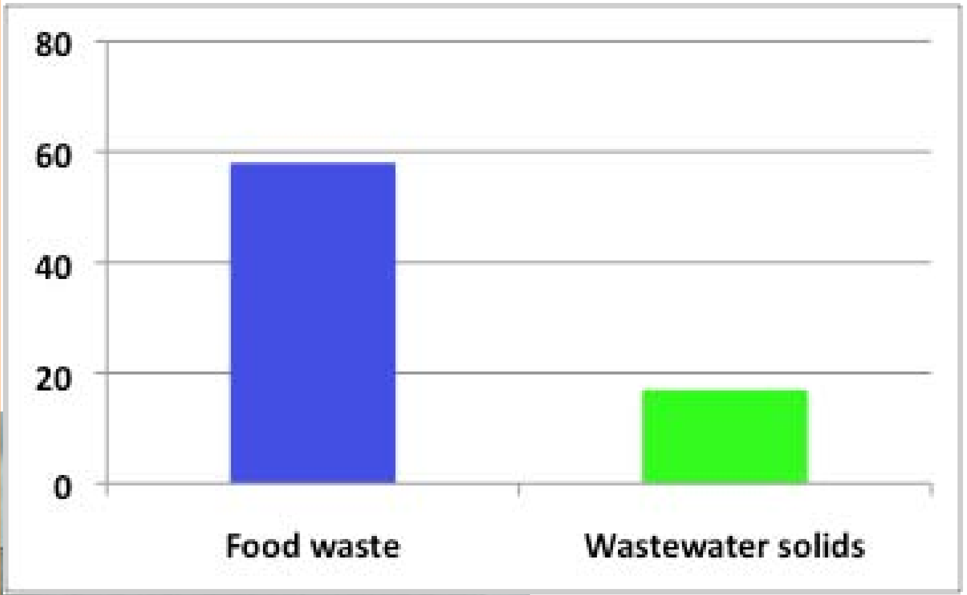


So for example

- Biological treatment is a natural process that is greatly expedited by pumping air
- Energy required for the air is a GHG debit

Anaerobic digestion- Can be a significant source of credits

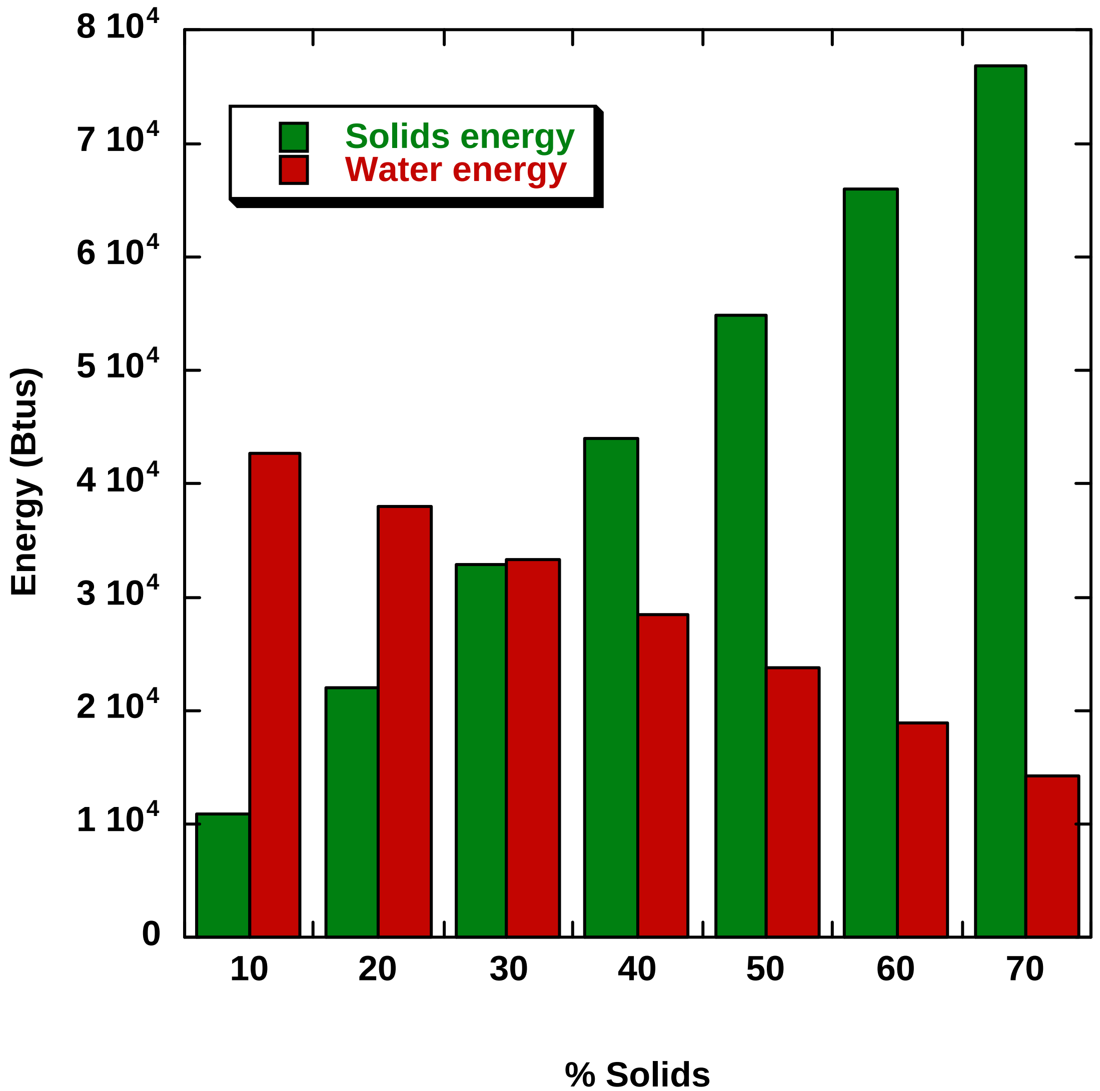
- 2260 kWh dry Mg biosolids
- Co-digestion will significantly increase this



Biosolids

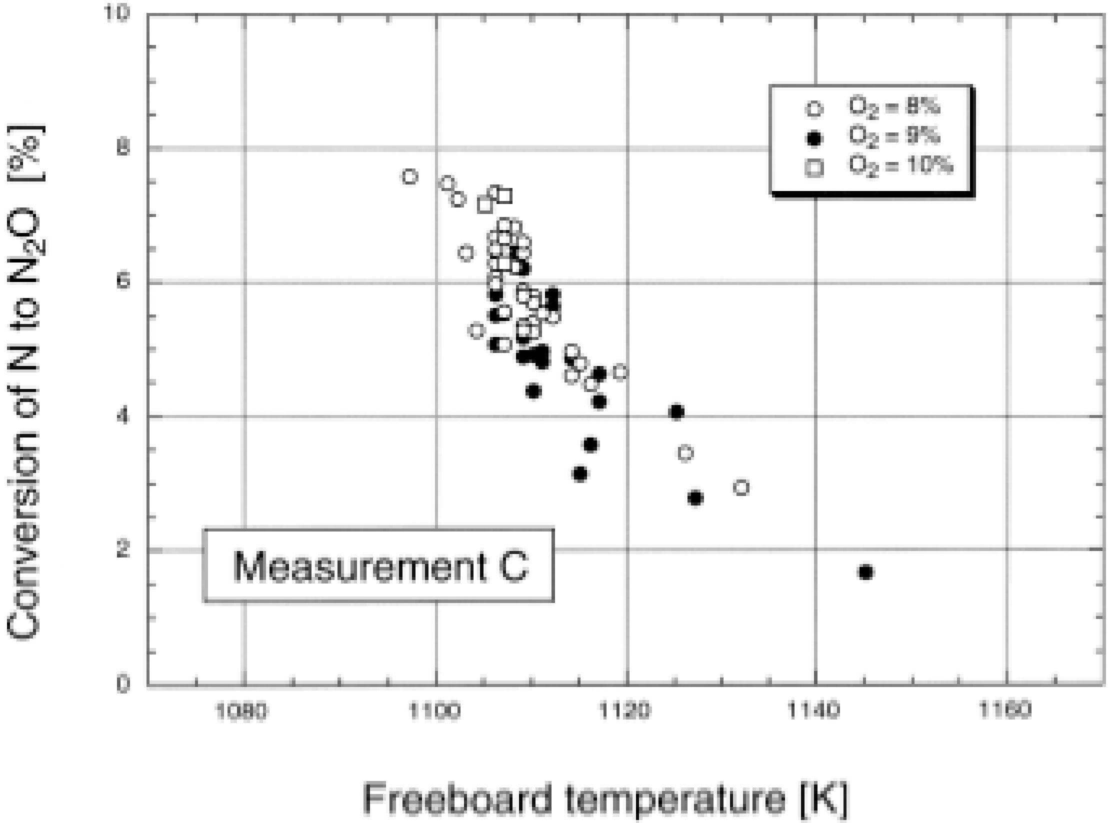
- Can impact the carbon cycle:
- By making or using energy
- By replacing products that require energy to produce
- By replacing products that emit GHGs
- By emitting gasses other than CO2
- By sequestering carbon

Combustion: potential source of credits
(Metcalf and Eddy, 100% efficiency)

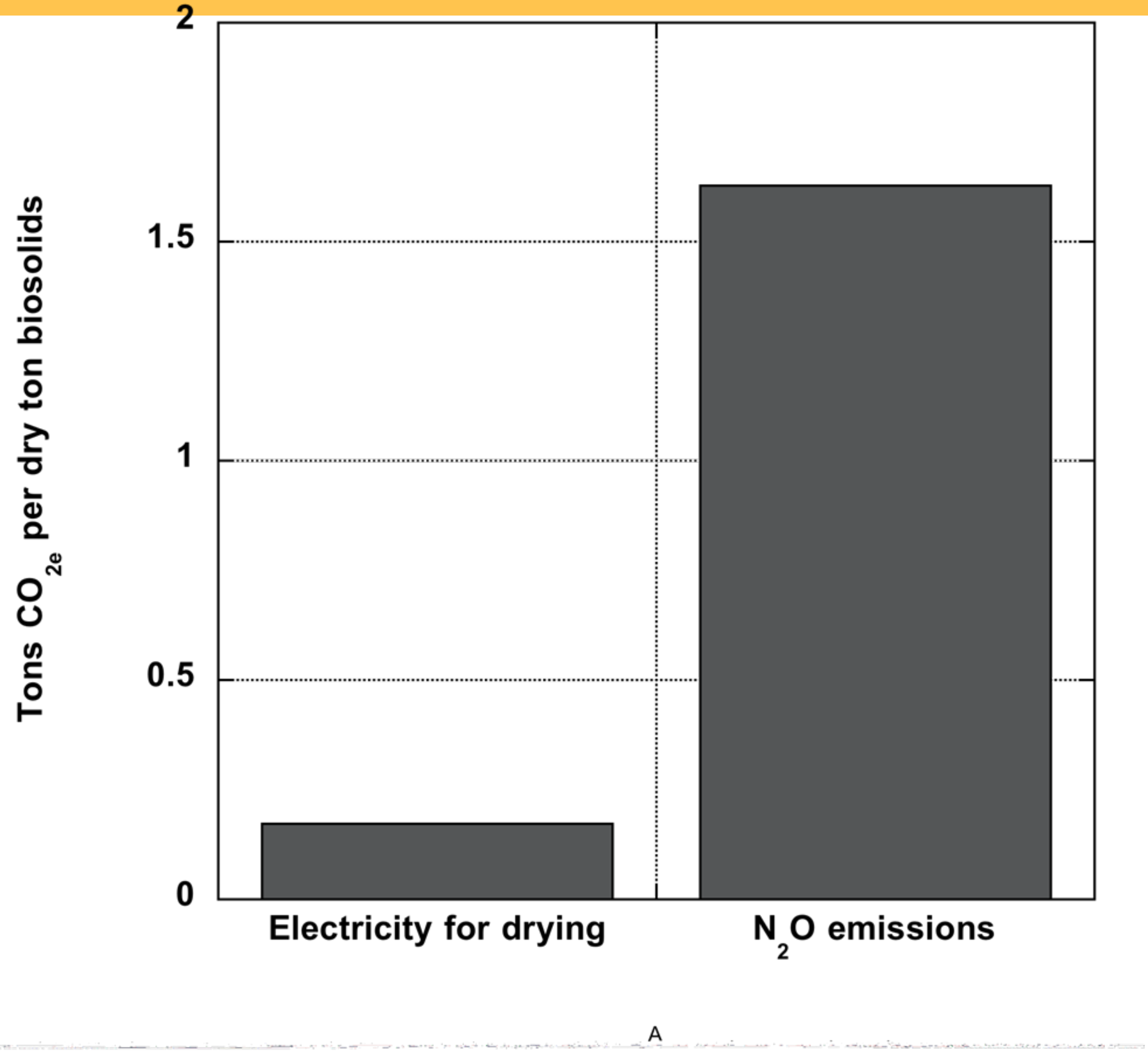


Gasses other than CO_2 can have a huge impact
CH_4-21-23 x CO_2 N_2O 296 x CO_2

Emissions of 1.5-6.4 kg N_2O per dry Mg biosolids
0.44 – 1.9 Mg CO_{2eq} per dry Mg
(Suzuki et al., 2003)



So for one fluidized bed mono-combustion facility



Biosolids GHG spreadsheet calculator tool

- Funded by the CCME
- Andrew Carpenter, Northern Tilth
- Ned Beecher, NEBRA

Spreadsheet

- Storage
- Conditioning/ thickening
- Aerobic/anaerobic digestion
- Landfill disposal
- De-watering
- Thermal drying
- Alkaline stabilization
- Combustion
- Land application
- Transportation

Combustion (incineration, thermal oxidation)

Unit Processes & Inputs	Inputs & Daily Emissions	Default Input (Optional)
Solids Input (to incinerator)		
Quantity (Mg/day-wet)	100	
Solids content (%)	25.0%	
Quantity (Mg/day-dry)	25.0	
Is sludge digested prior to incineration?	no	no
Total nitrogen (%-dry weight)	4.0%	4.0%
Total phosphorus (%-dry weight)	1.5%	1.5%
TVS(%-dry weight)	70.0%	70.0%
Type of incinerator	Fluidized Bed	Fluidized Bed
Recovered energy to electricity (%)	0%	
Recovered energy as heat (%)	75%	
Disposition of ash - Is it used to replace phosphorus fertilizer or in cement or brick?	none	none
Is a urea-based selective noncatalytic reduction emissions system being used?	no	no
Average high (freeboard) temperature of combustion (°C)	850	850
Energy Balance		
Energy requirements of the incinerator-evaporating water (BtU/day)		319,888,238
Energy potential of sludge (Btu/day)		544,994,775
Fuel Use		
Natural gas needed to evaporate water in sludge (m^3/day)		8,821
Avoided gas use from recovered energy (m^3/day)		9,017
Net natural gas used (m^3/day)	-196	-196
CO_2 emissions from natural gas used (Mg/day)	-0.37	
Electricity Use		
Electricity requirements of incinerator (kWh/day)		5,000
Electricity generated (kWh/day)		0
Net Electricity used (kWh/day)	5,000	5,000
CO_2 emissions from electricity used (Mg/day)	0.91	
Methane Emissions		
CO_2 emissions equivalents from released methane (Mg/day)	0.03	
Nitrous Oxide Emissions		
N_2O emitted during incineration (Mg/day)	0.064	0.064
N_2O emission adjustment for SNCR based on urea (Mg/day)	0.000	
N_2O emission adjustment for moisture content of sludge (Mg/day)	-0.032	
CO_2 emissions equivalents from released N_2O (Mg/day)	9.92	
Cement Replacement Value		
CO_2 replacement value from cement manufacture (Mg CO_2/day)	0.00	
Fertilizer Off-set Credits		
From phosphorus applied to soil (Mg CO_2/day)	0.00	
Biomass Combustion		
CO_2 Emissions equivalents from burning sludge (Mg/day)	35.93	
CO_2 equivalents (Mg/year)	**3,825**	
Scope 1	3,494	
Scope 2	331	
Scopes 1 & 2	3,825	

First – not discussed
Drying- Centrifuge

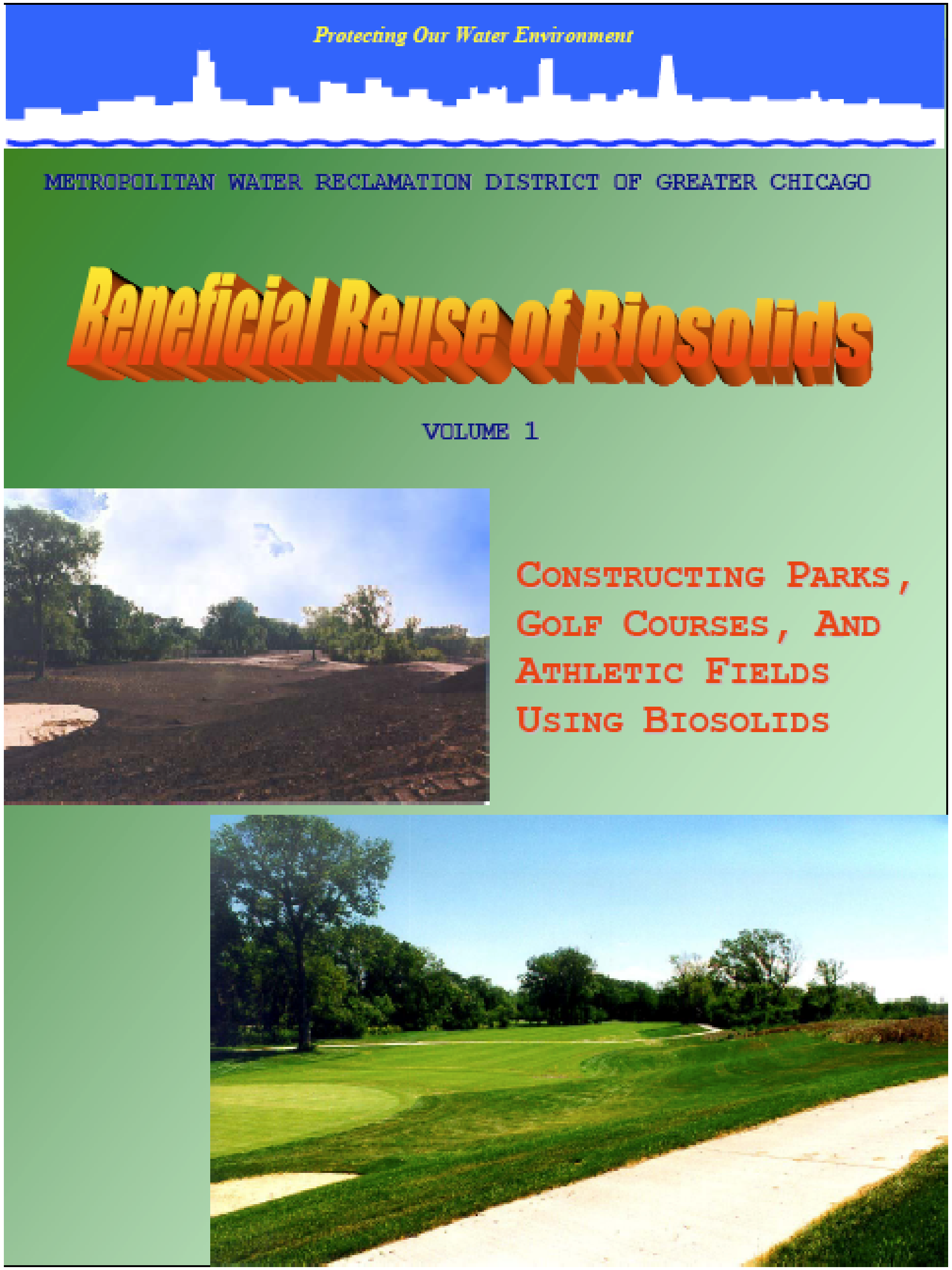
- Centrifuge
- Higher % solids
- Much higher energy use
- 0.04-0.2 kWh/m^3 wet
- Higher emissions from energy use

- Belt filter press
- Lower % solids
- Much lower energy use
- 0.004-0.01 kWh/m^3 wet

Polymer

- 23 Mg CO_2 per Mg polymer
- Average use of 5 kg per dry Mg biosolids
- 110 kg CO_2 per dry Mg biosolids to aid in dewatering

Applied the tool to calculate GHG balance for MWRD's biosolids program



MWRD Program

- Focus on biosolids
- Data from 2 years
  - 2001,2008
- Debits
- Credits
- Unknowns

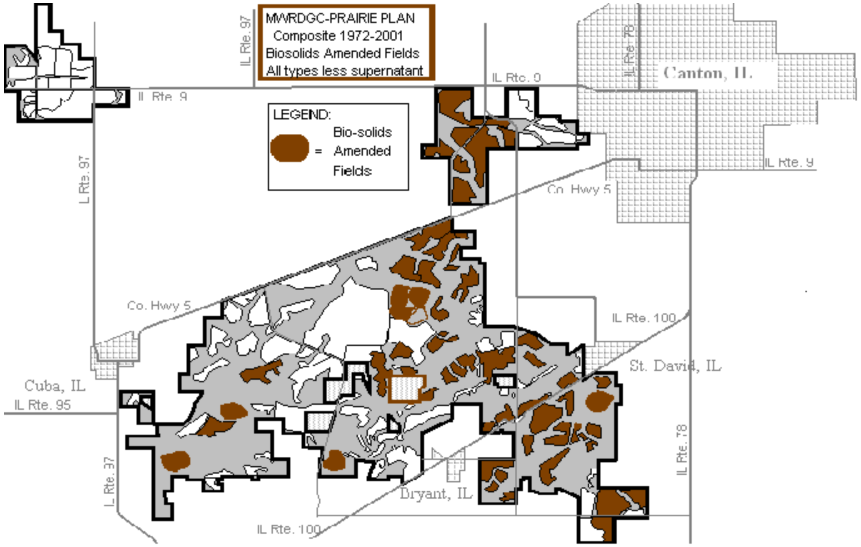
Where biosolids went

Biosolids Use	2001	2008
Class B Dewatered cake		
Farmland Fertilizer	128,100	97,100
Landfill Daily Cover	35,700	26,500
Class A Air-Dried		
Urban Reclamation	3,100	20,000
Mineland Reclamation	22,000	0
Landfill Final Cover	1,500	46,500
Landfill Co-Disposal	12,700	2,000
Total	203,100	192,100

Chemical and physical characteristics of biosolids

	Air-Dried		Dewatered Cake	
	2001	**2008**	**2001**	**2008**
Total Solids (%)	70.2	71.3	25.9	25.3
Total Volatile Solids (%)	35.4	38.1	54.2	52.5
Total Kjeldahl N (%)	1.87	2.22	4.29	4.18
NH_4^+ - N (%)	0.40	0.20	0.43	0.54
NO_3^-- N (%)	0.044	0.031	ND	0.007
Total P (%)	2.20	2.13	2.52	1.94
Bulk Density (g cm^{-3})	0.68	ND	0.52	ND

Fulton County biosolids land reclamation



Strip-mined land

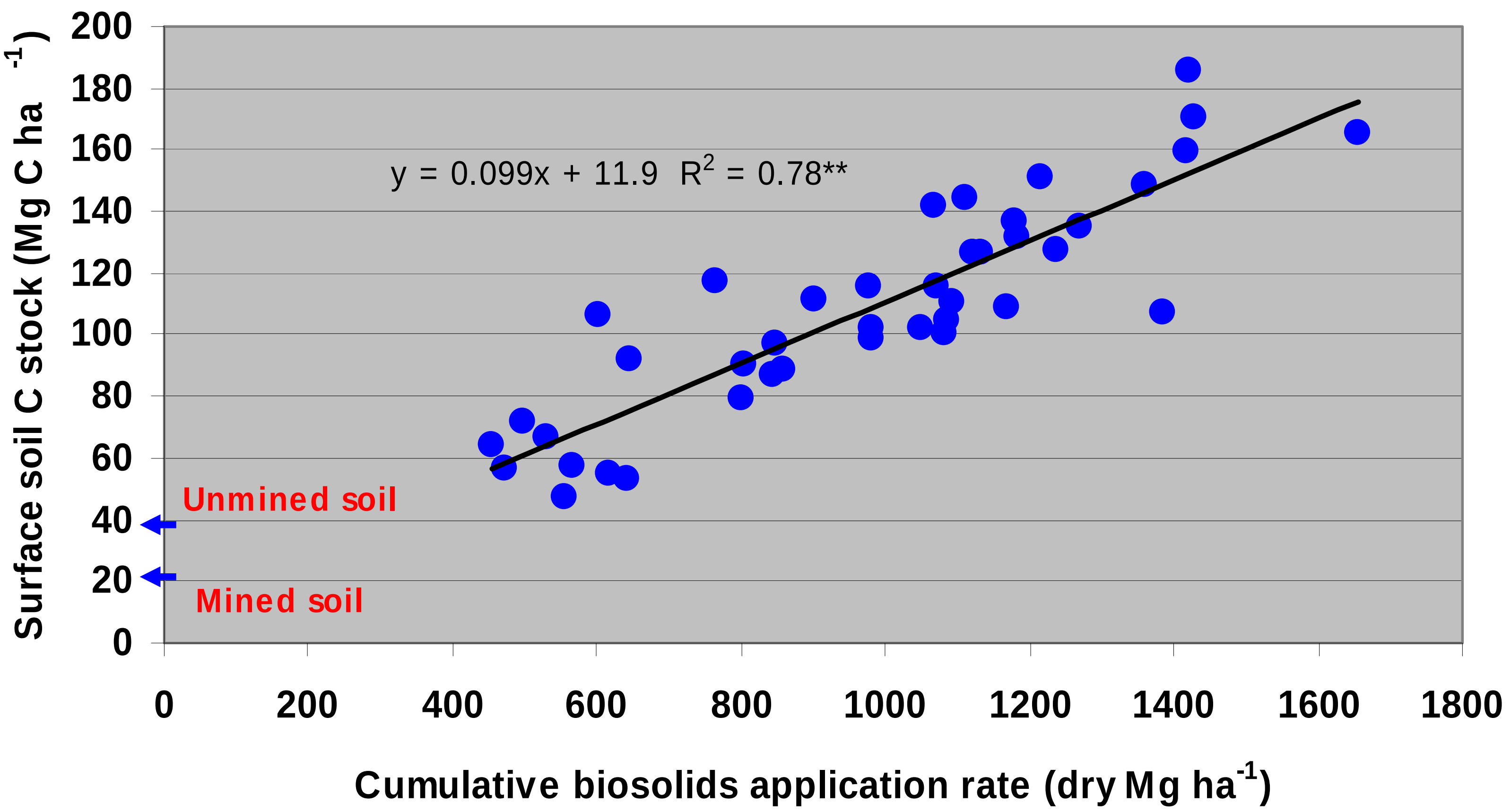
1973

From liquid to dewatered and air-dried biosolids (1972-2004)

Biosolids-amended land (2009)

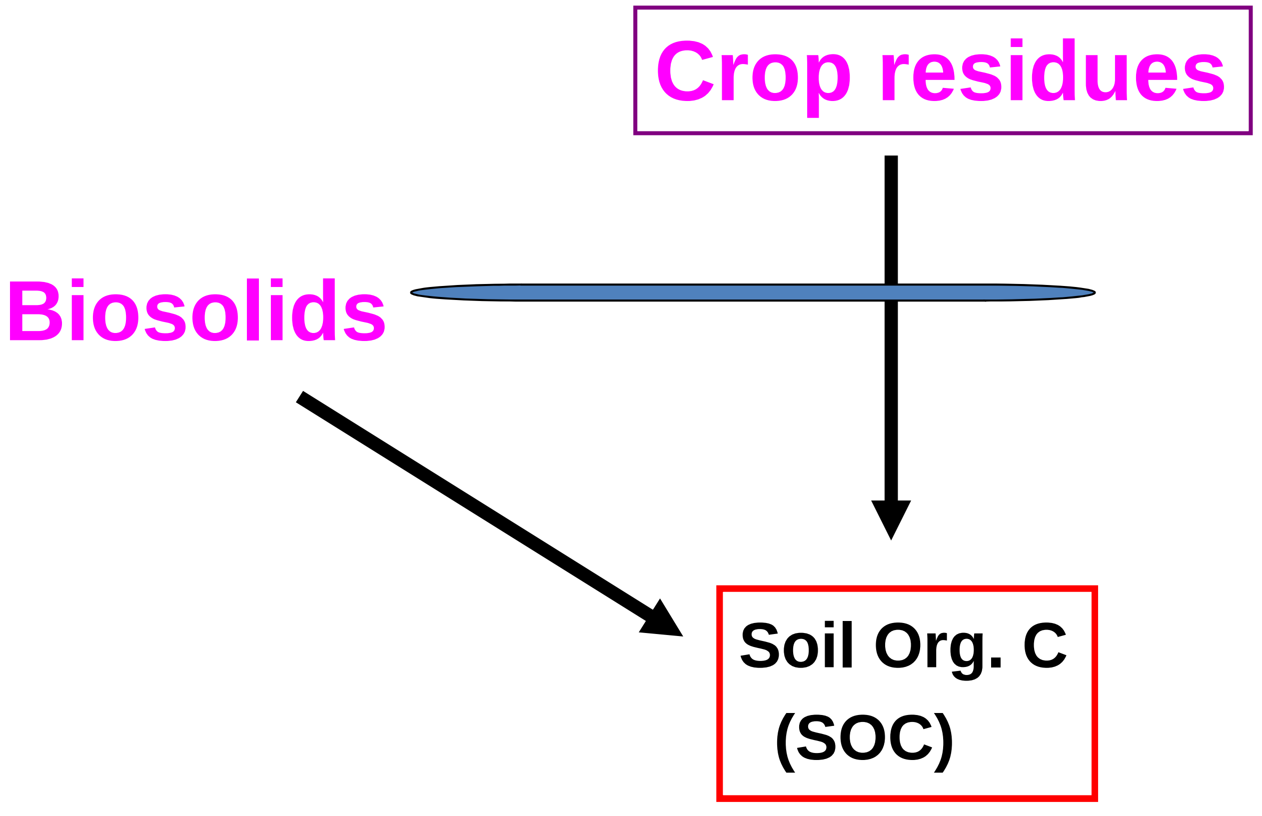
Biosolids build up Soil Org. C

Soil organic C response to biosolids



Tian et al. 2009. JEQ 38: 61-74.

Biosolids-amended soil

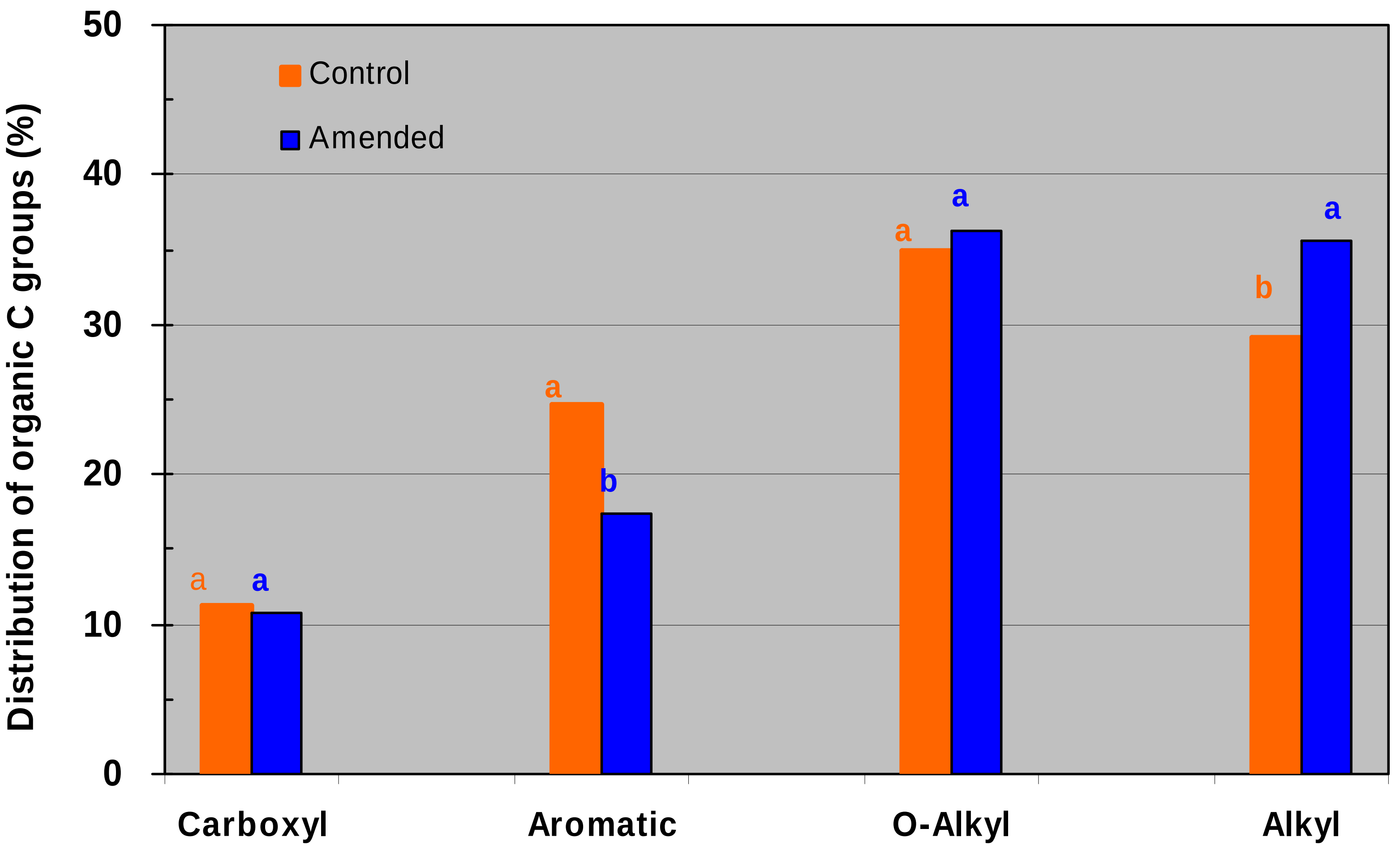


H1: direct addition to stable SOC

Biosolids high in Alkyl C, mainly microbial transformation of O-alkyl to Alkyl during the aeration.

- O-alkyl C: easily decomposable
- Alkyl C: resistant to decomposition

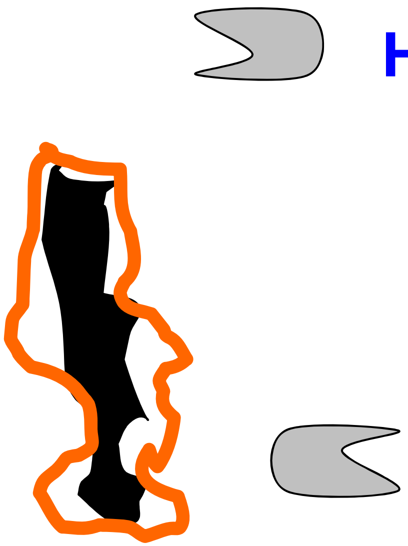
Carbon functional groups of humic acids in FC soils detected by Nuclear Magnetic Resonance (NMR)



H2: Biosolids Fe/Al reduces the oxidation of crop residue-derived SOC

- **$Fe(OH)_n^+$**
- **$R\text{-}COO^-$**
- **Fe-soil organic matter complexes**
  - **Co-precipitation (Schwertmann et al. 2005)**
  - **Adsorption (Kaiser et al. 2007)**

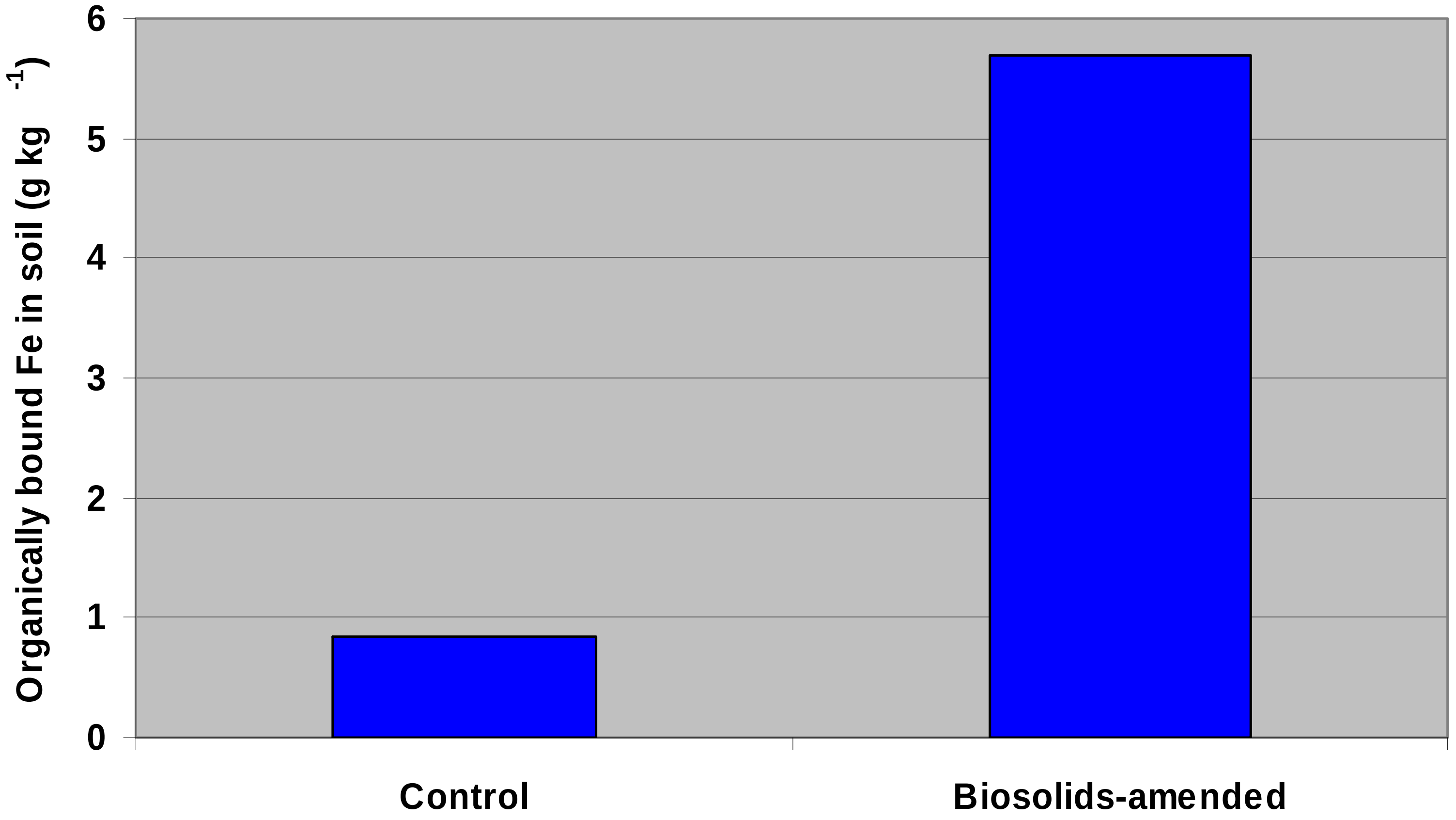
Fe $(OH)_n$ coating decreases the access of biota to SOC



Hey, that's good stuff. I will take it

Yuck! I don't want it

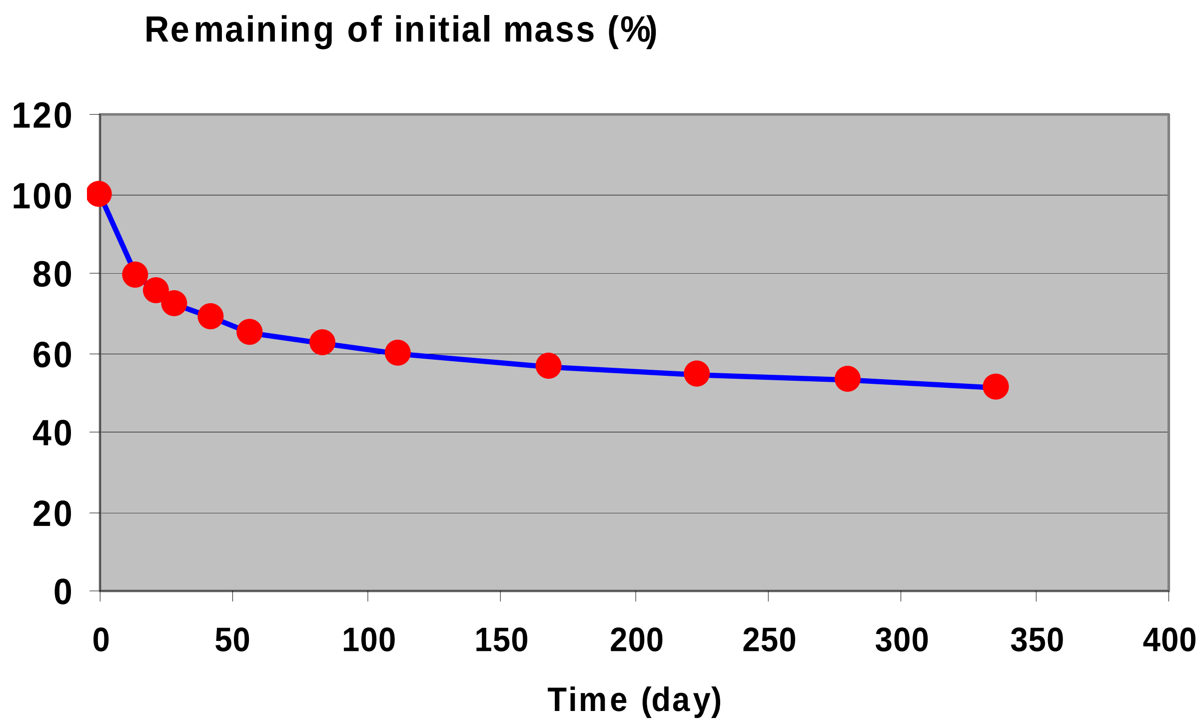
Organically bound Fe in FC soils



Track the Biosolids C Remaining

- **Exponential decay model: $y = a_1e^{-k1t} + a_2e^{-k2t} + a_3e^{-k3t}$**
- **Fractions: labile (k_1), slow (k_2), recalcitrant (k_3)**

Terry et al. 1979. JEQ 8: 342-347.



- **k adjusted to Fulton county climate conditions using ratio derived from Gilmour and Gilmour. 1980. JEQ 9: 194-199.**

Biosolids C remaining equation

$$y = [0.35 - (55 - Vs)/55]C_{BS}e^{-0.0222t} + [0.52 + 0.8*(55-Vs)/55]\,C_{BS}e^{-0.000381t} + [0.13 + 0.2*(55 - Vs)/55]C_{BS}e^{-0.0000448t}$$

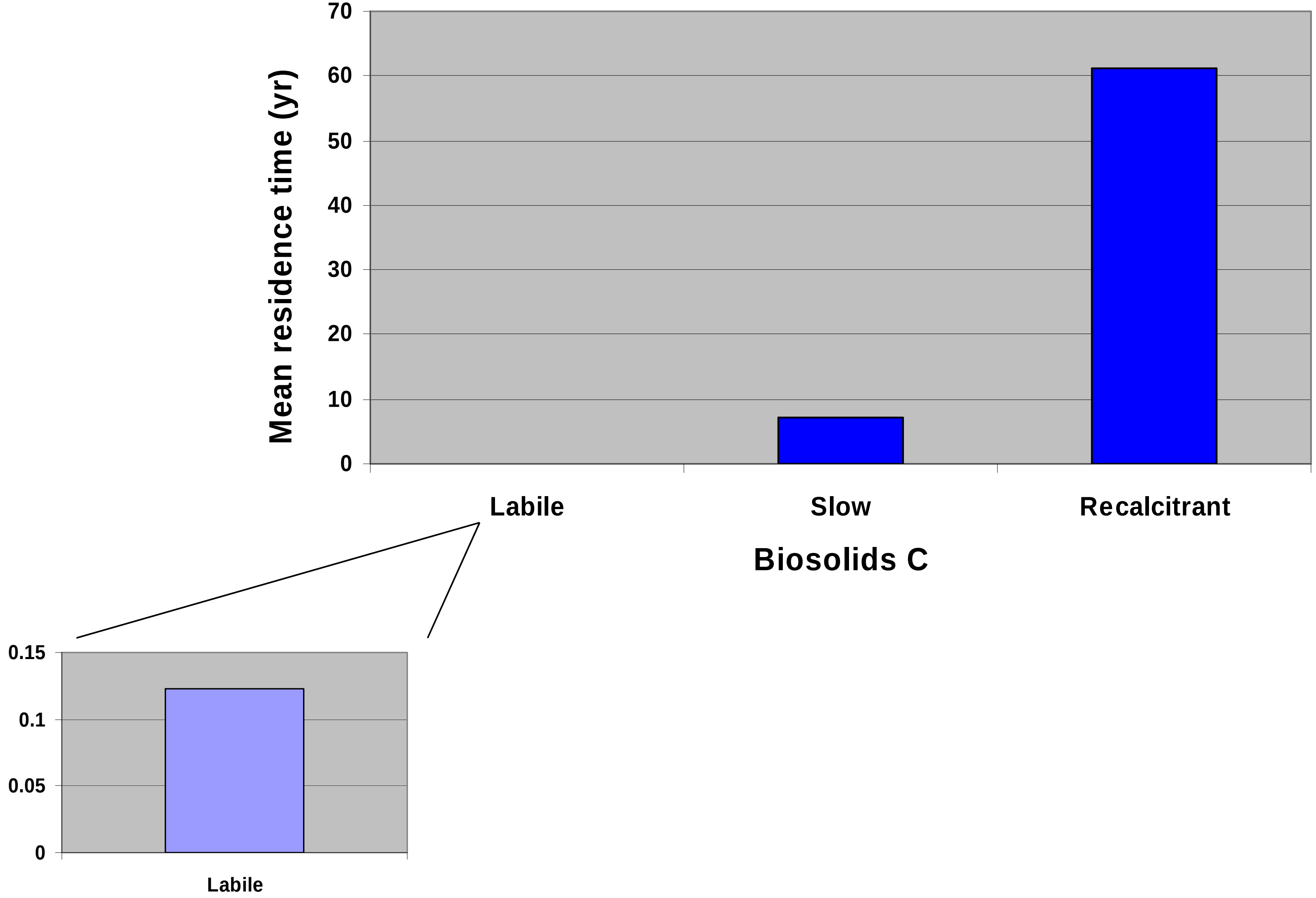
y = remaining biosolids C in soil (Mg C ha^{-1})

Vs = volatile solids in biosolids (%)

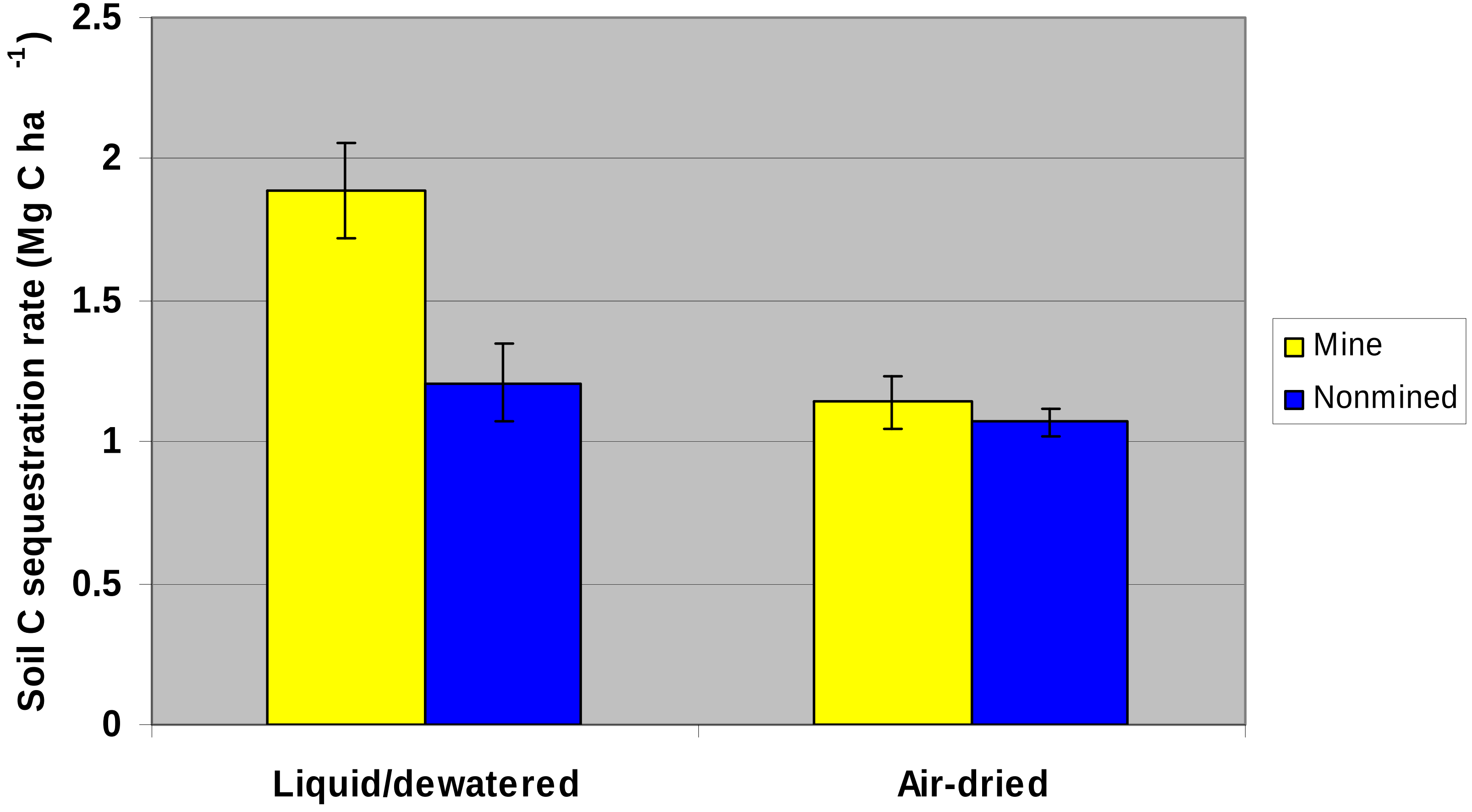
C_{BS} = C input from applied biosolids (Mg C ha^{-1})

t = time (day)

Mean residence time of biosolids C



Soil C sequestration rate at Fulton county ($Mg\ C\ ha^{-1}$, 22.4 DT biosolids)



We used recalcitrant C fraction as undecomposable biosolids C

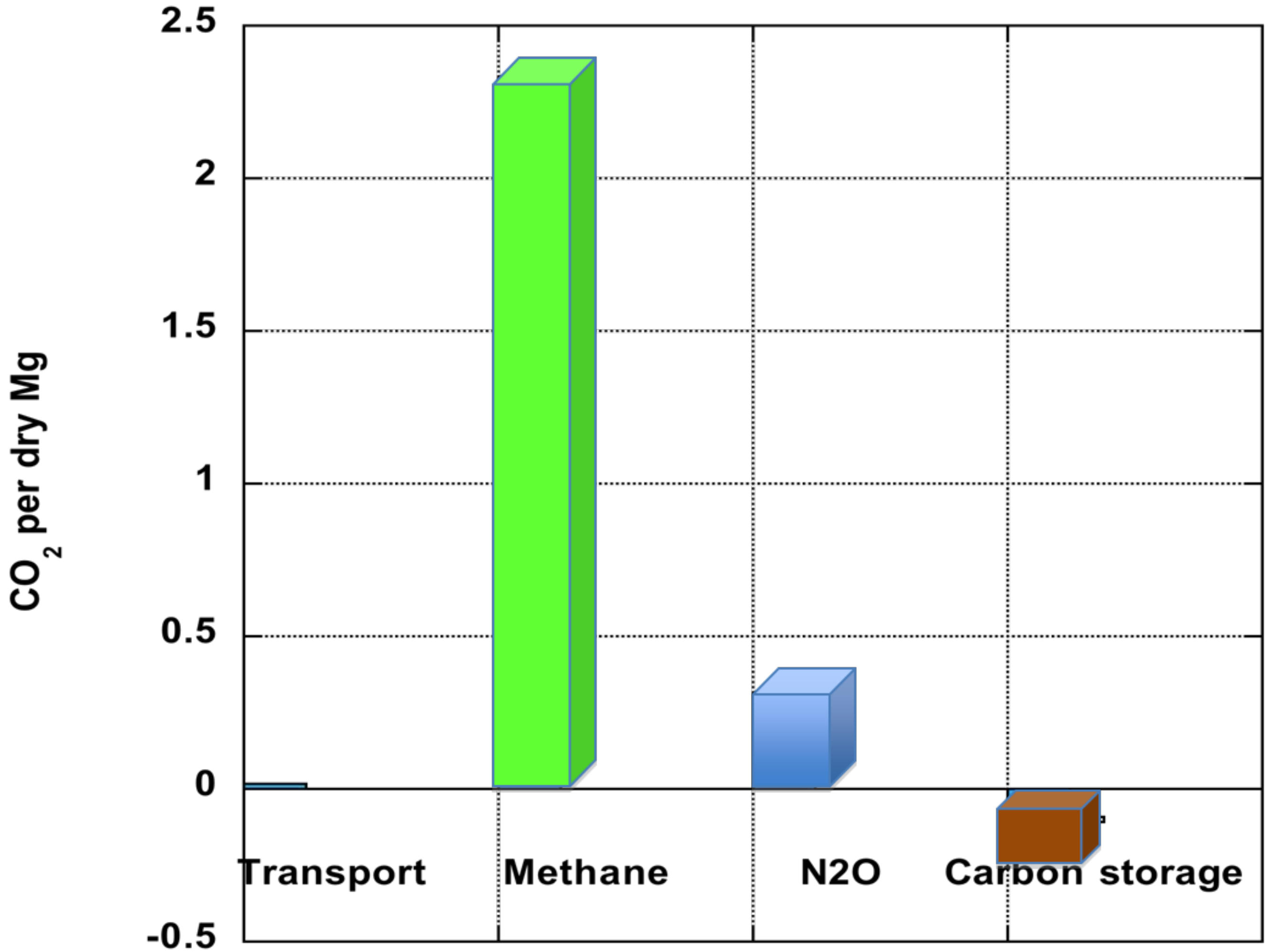
- **Liquid (vs = 55%)** — $f_u = 0.13$
- **Dewatered cake (vs = 52.5%),** — $f_u = 0.14$
- **Air-dried (vs = 35.8%)** — $f_u = 0.2$

Landfill- Class B
Disposal and daily cover

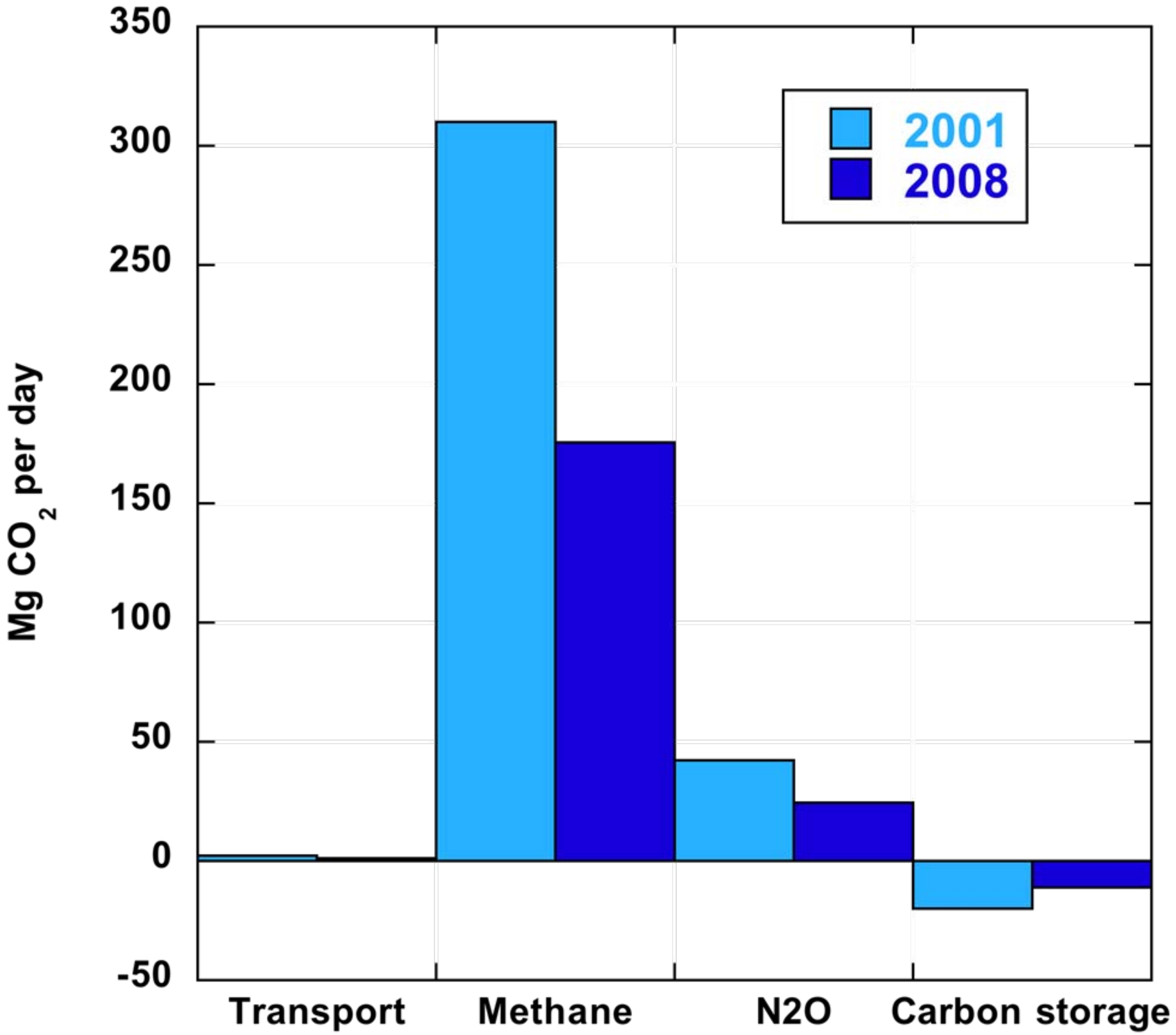
- Credits
  - Carbon storage

- Debits
  - Transport
  - Methane emissions
  - Nitrous oxide emissions

Landfill emissions



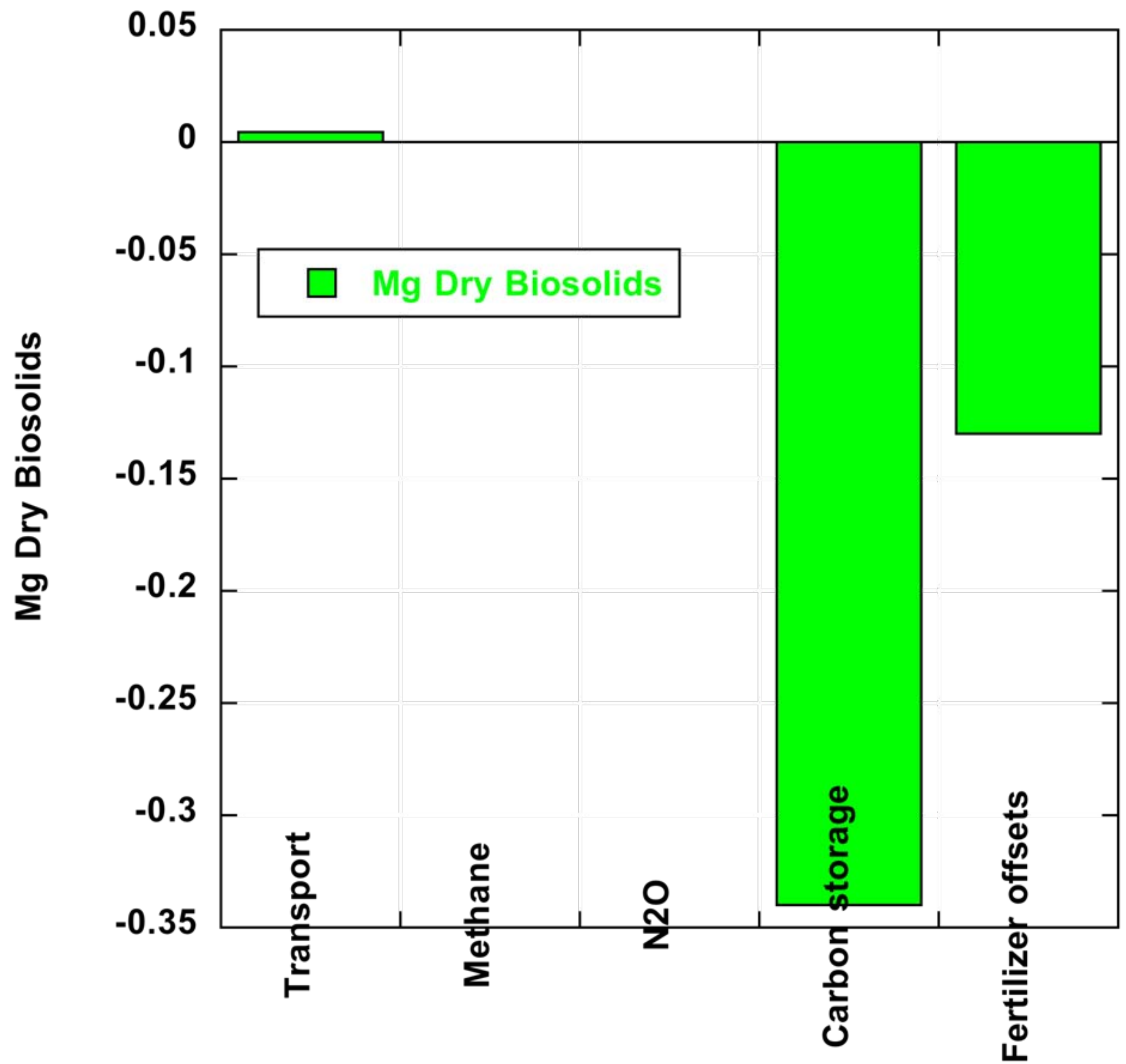
Landfill emissions



Landfill- Final cover

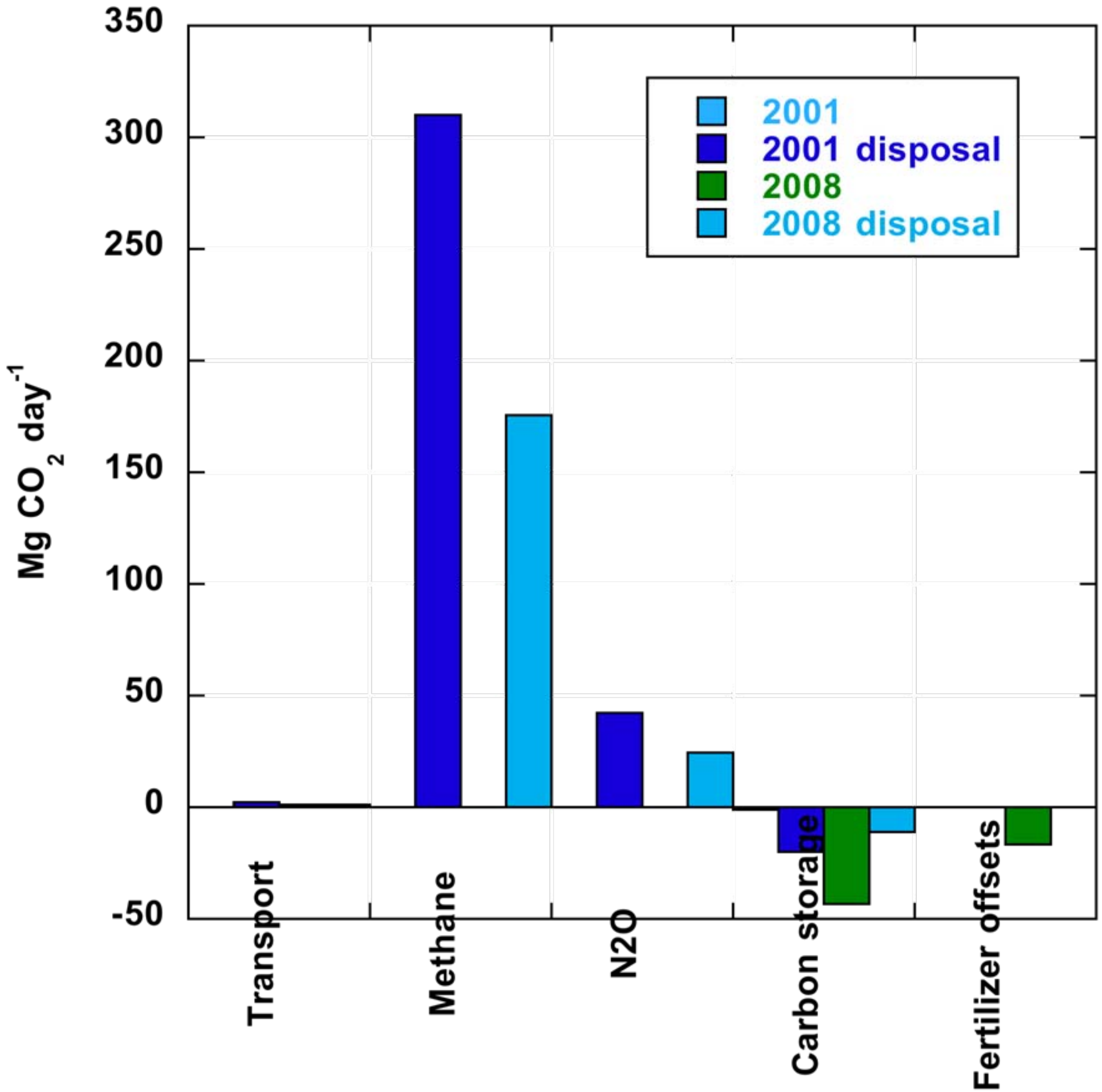
- Class A dry material
  - Used at final surface
  - Used as a soil material

Different picture



2001 versus 2008

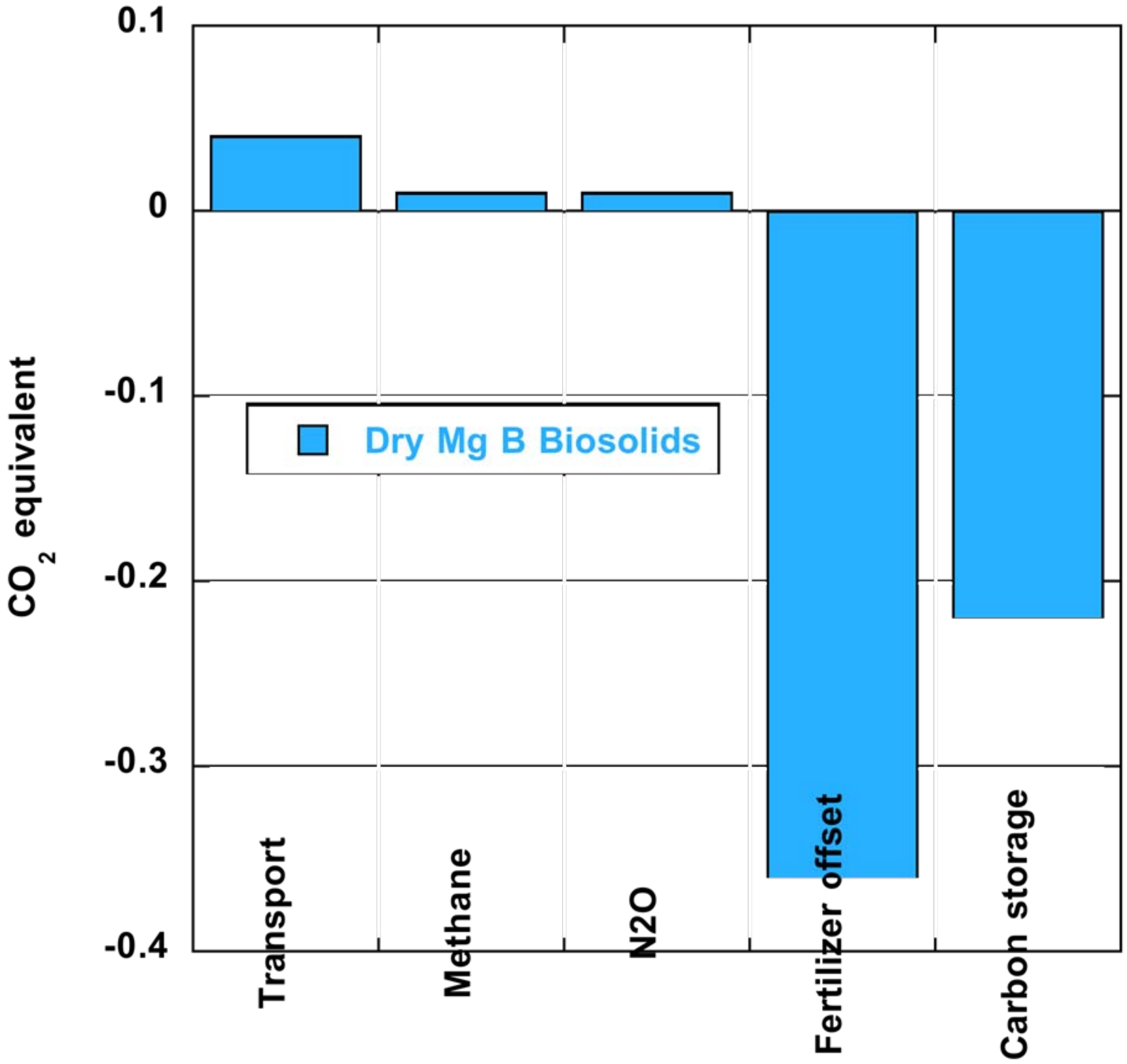
- CH_4 and N_2O debits are highly significant
- Transport minimal
- Credit potential for final cover



Agricultural use

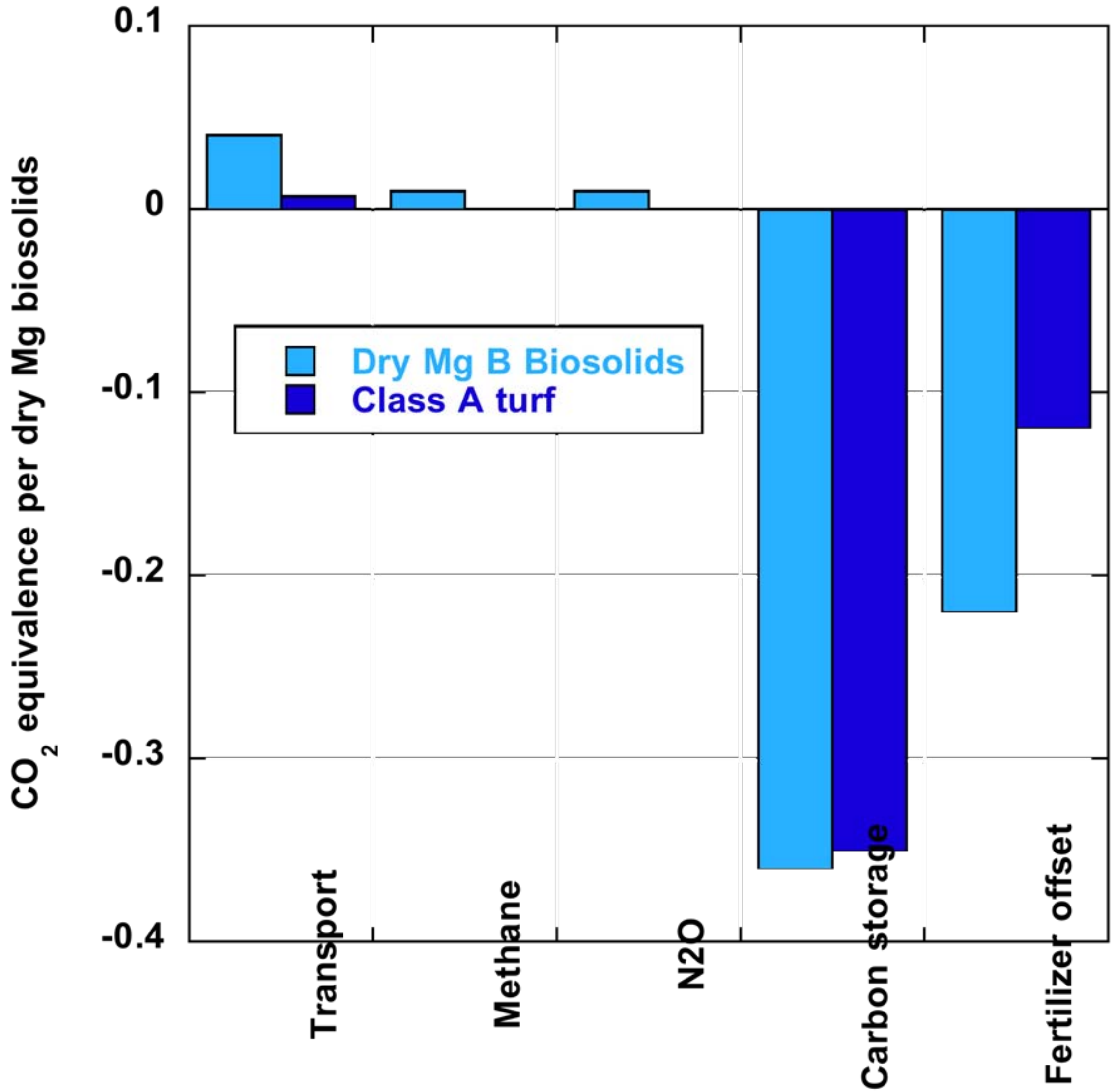
- Benefits
  - Fertilizer offsets
  - Soil carbon storage
- Debits
  - Transport
  - N_2O?

Agriculture- Class B



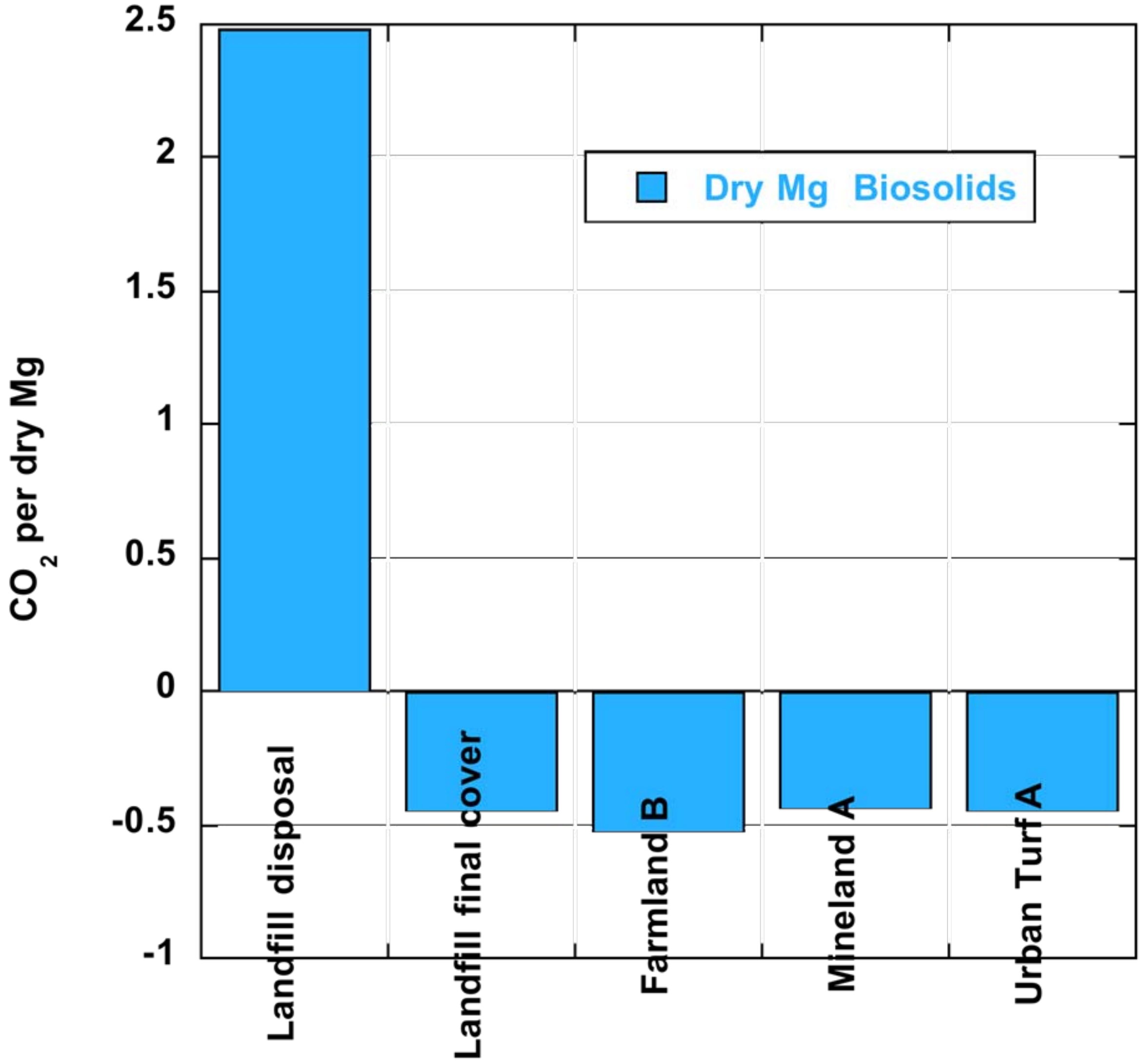
Class A urban versus Class B ag

6 of one….



0.1
0
-0.1
-0.2
-0.3
-0.4
CO2 equivalence per dry Mg biosolids
Dry Mg B Biosolids
Class A turf
Transport
Methane
N2O
Carbon storage
Fertilizer offset

End use options- GHG emissions



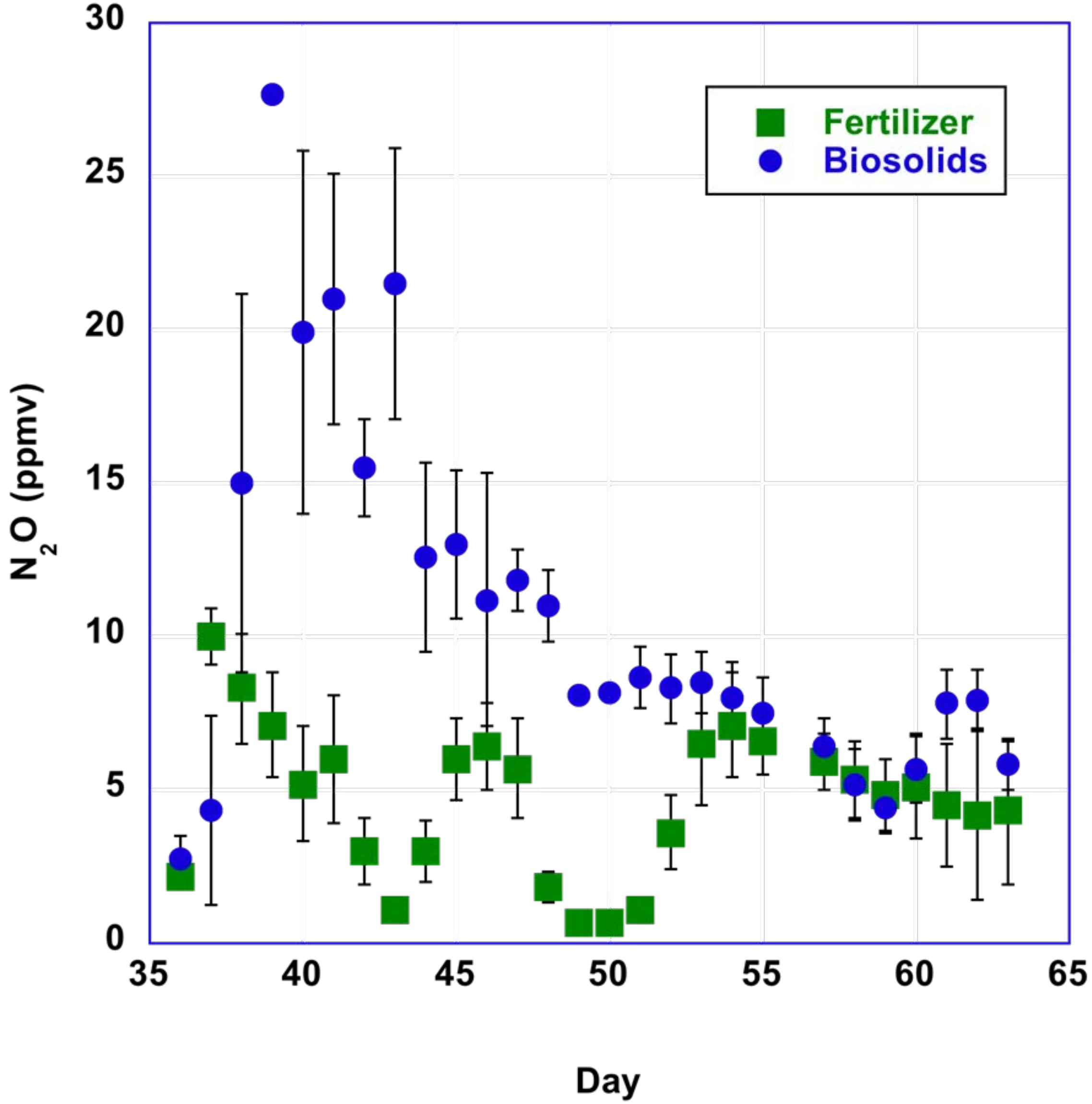
Uncertainties

- CH_4 likely to be minimal in an aerobic soil environment
- N_2O currently treated to be equivalent to fertilizer emissions
  - Increase in N_2O could result in a significant debit

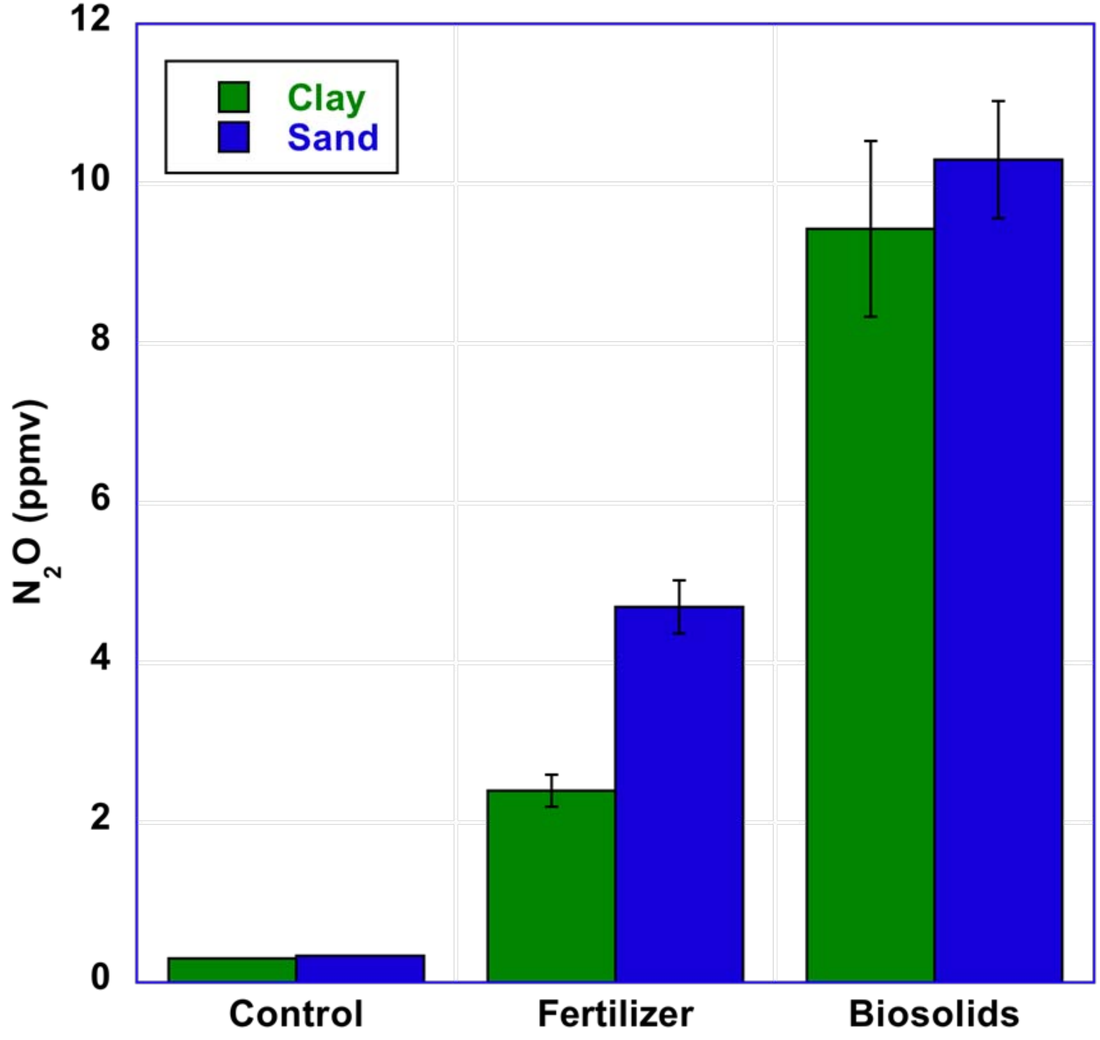
Preliminary studies

- Biosolids added to turf in the greenhouse
- Surface application of Class A cake
- Sandy soil
- Clay soil

Higher N_2O from biosolids



Higher N_2O from biosolids



Drying beds

- 50% of the total N is lost
- 20 kg per dry Mg
- If 10% is lost as N_2O
- Debit of 600 kg per dry Mg biosolids

Conclusions

- Biosolids can be a significant source of GHG credits
- Transport is of minimal importance
- Quantifying C sequestration is important
- Understanding and minimizing fugitive gas emissions is critical