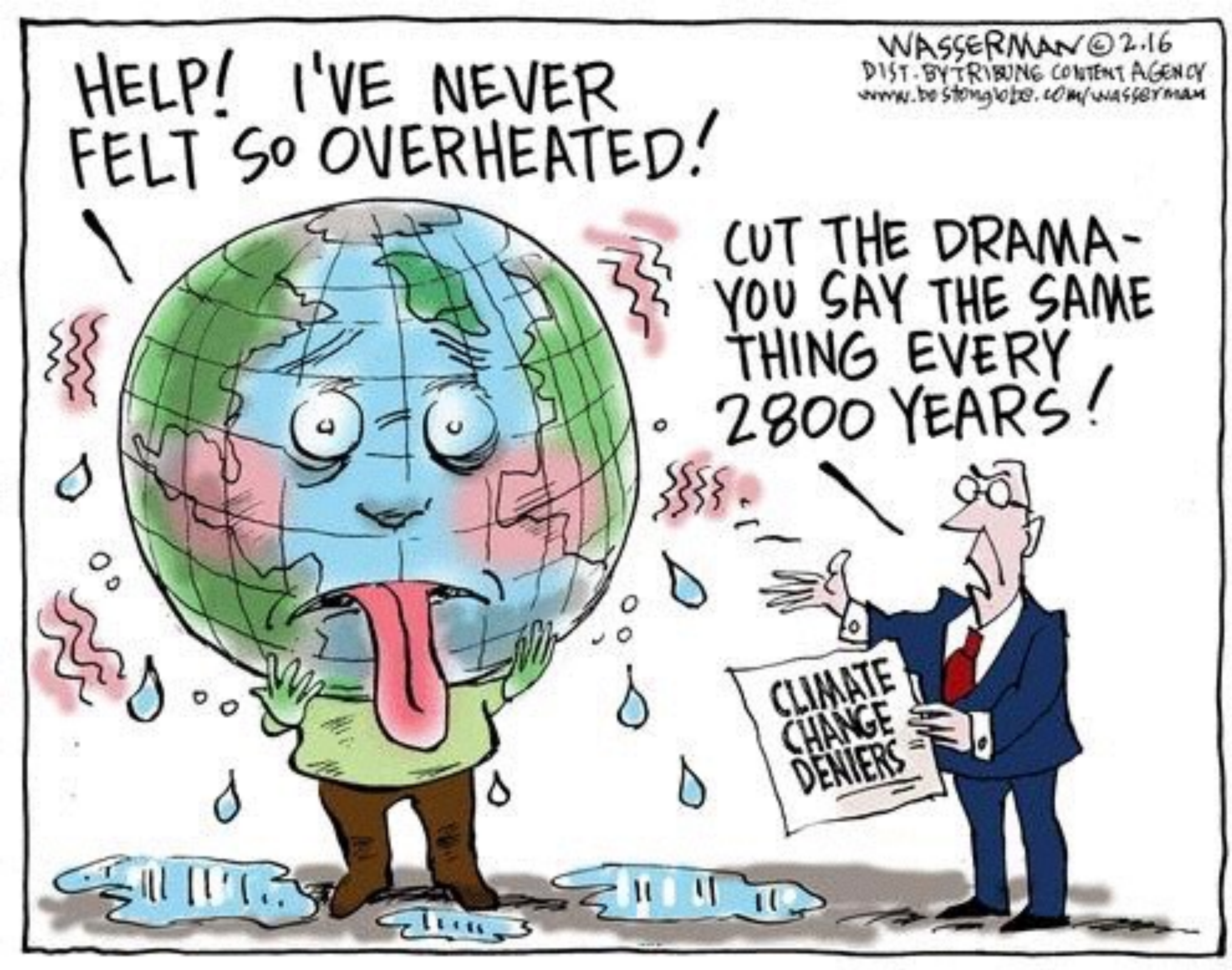
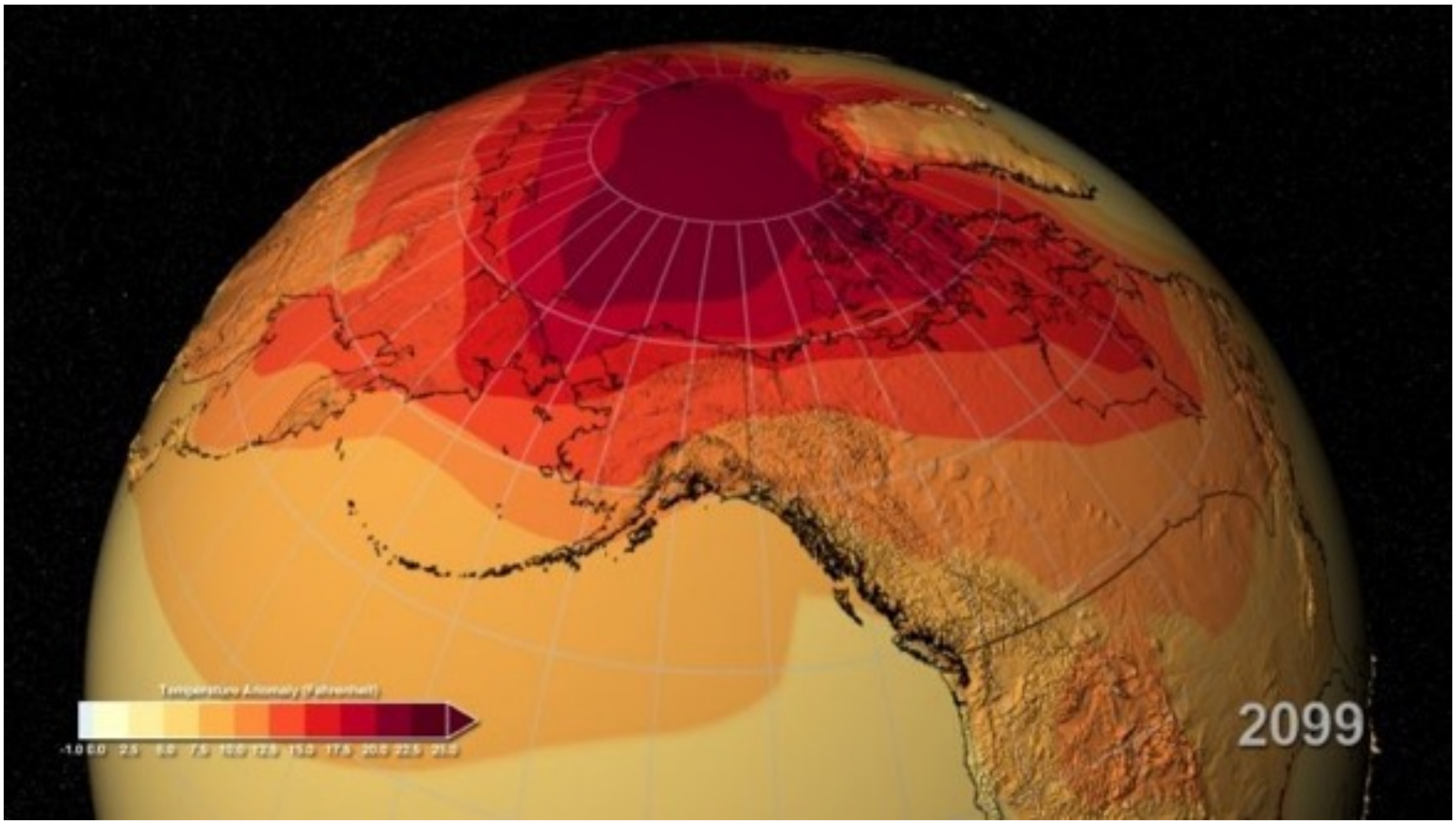
Il ruolo della sostanza organica nei processi di ripristino della qualità del suolo

Teodoro Miano

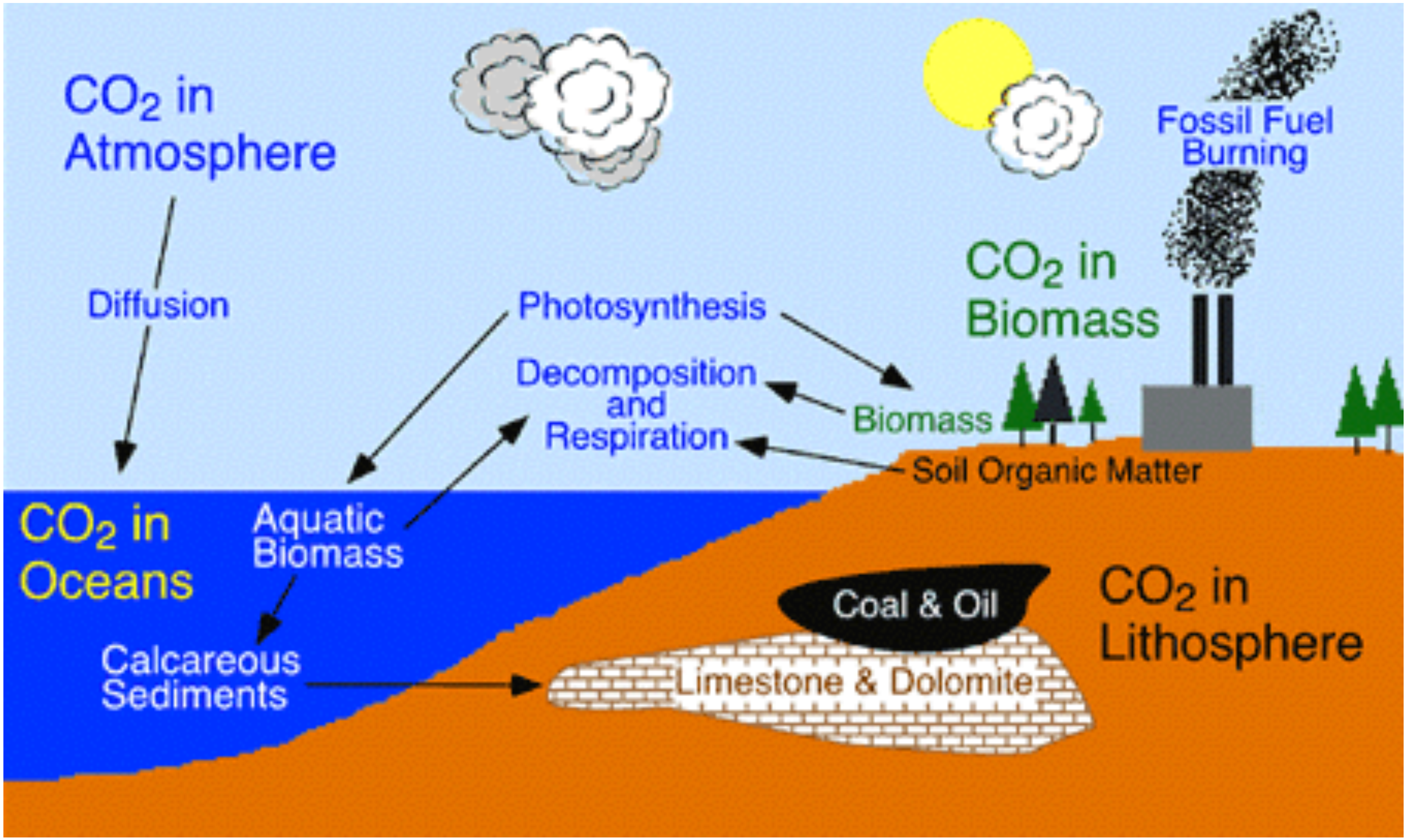
Università di Bari Aldo Moro

Climate change is defined as statistically significant variation in either state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing or to persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2001).


WASSERMAN © 2.16
DIST. BY TRIBUNE CONTENT AGENCY
www.bostonglobe.com/wasserman
HELP! I'VE NEVER FELT SO OVERHEATED!
CUT THE DRAMA- YOU SAY THE SAME THING EVERY 2800 YEARS!
CLIMATE CHANGE DENIERS


Temperature Anomaly (Fahrenheit)
2099


Positive proof of global warming.
18th Century
1900
1950
1970
1980
1990
2006


CO_2 in Atmosphere
Diffusion
Photosynthesis
Decomposition and Respiration
Fossil Fuel Burning
CO_2 in Biomass
Biomass
Soil Organic Matter
CO_2 in Oceans
Aquatic Biomass
Calcareous Sediments
Coal & Oil
Limestone & Dolomite
CO_2 in Lithosphere

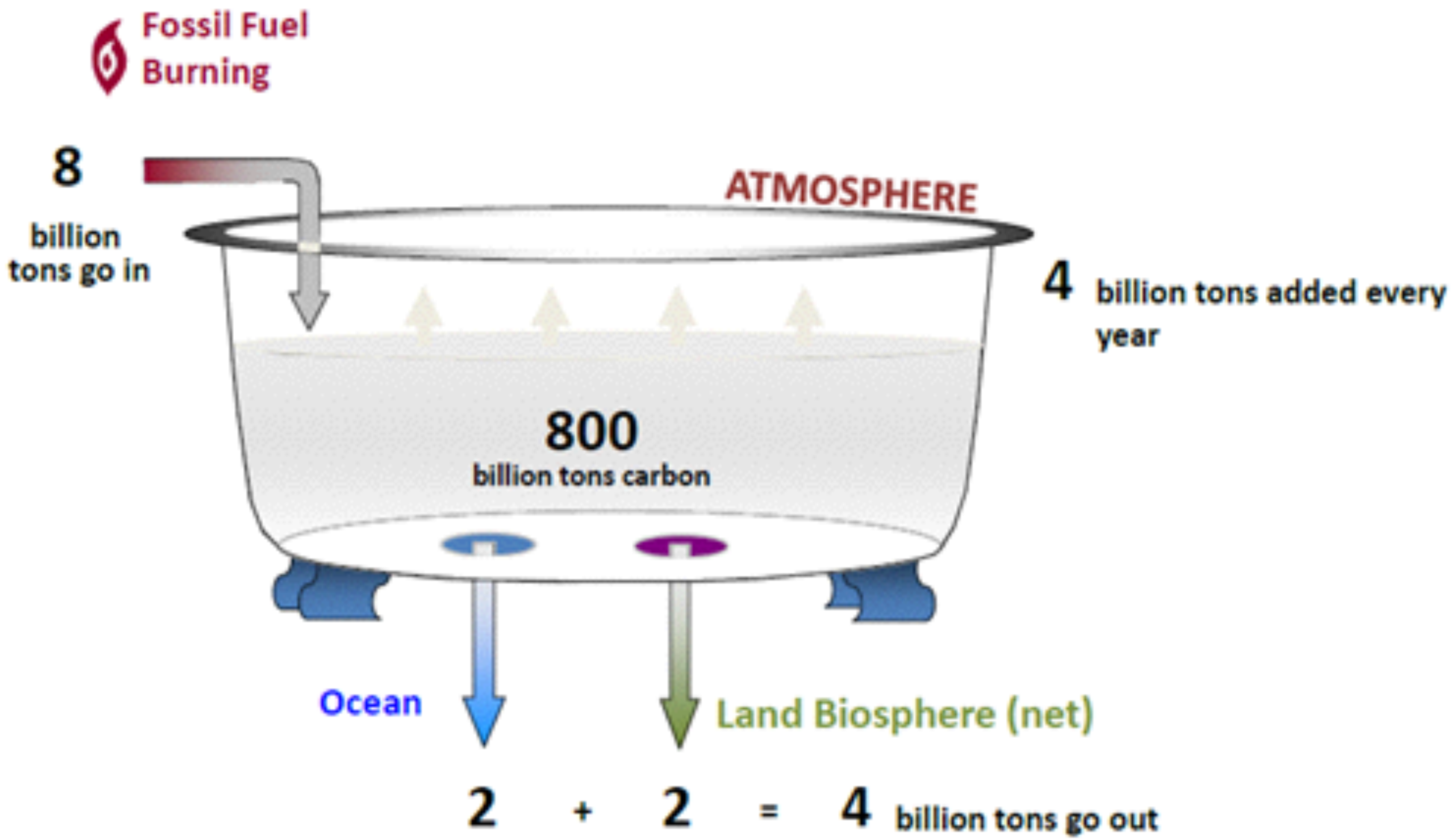
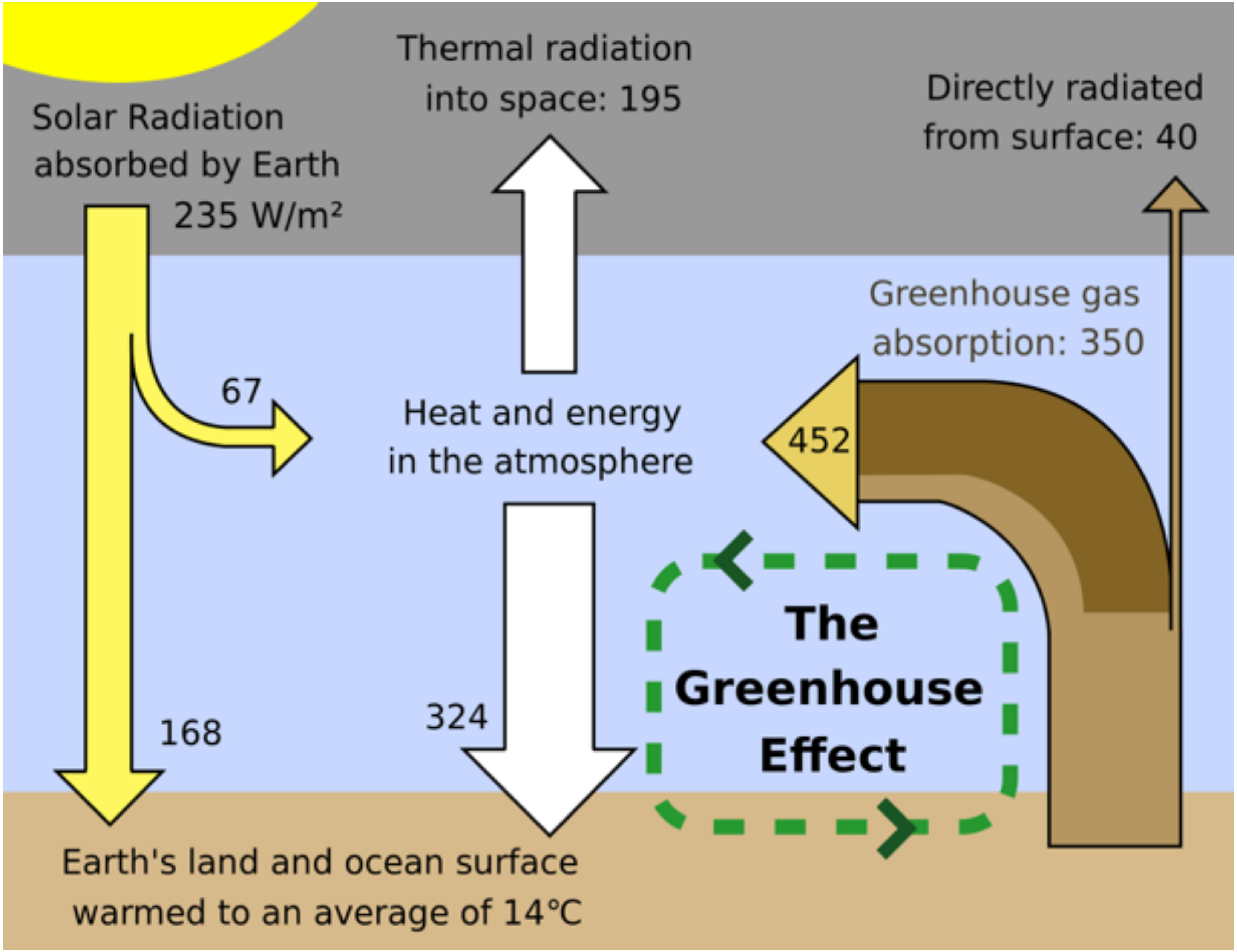
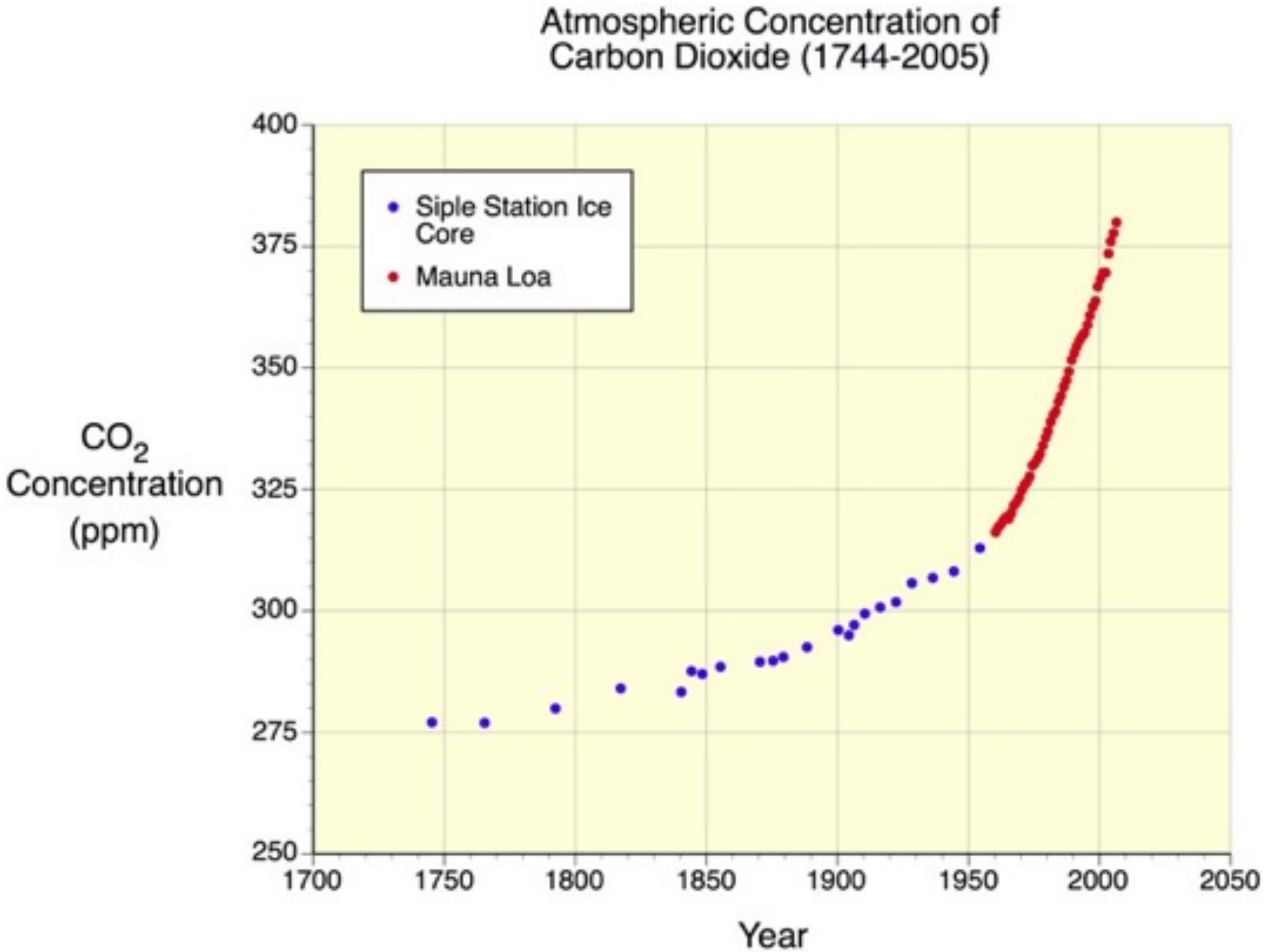
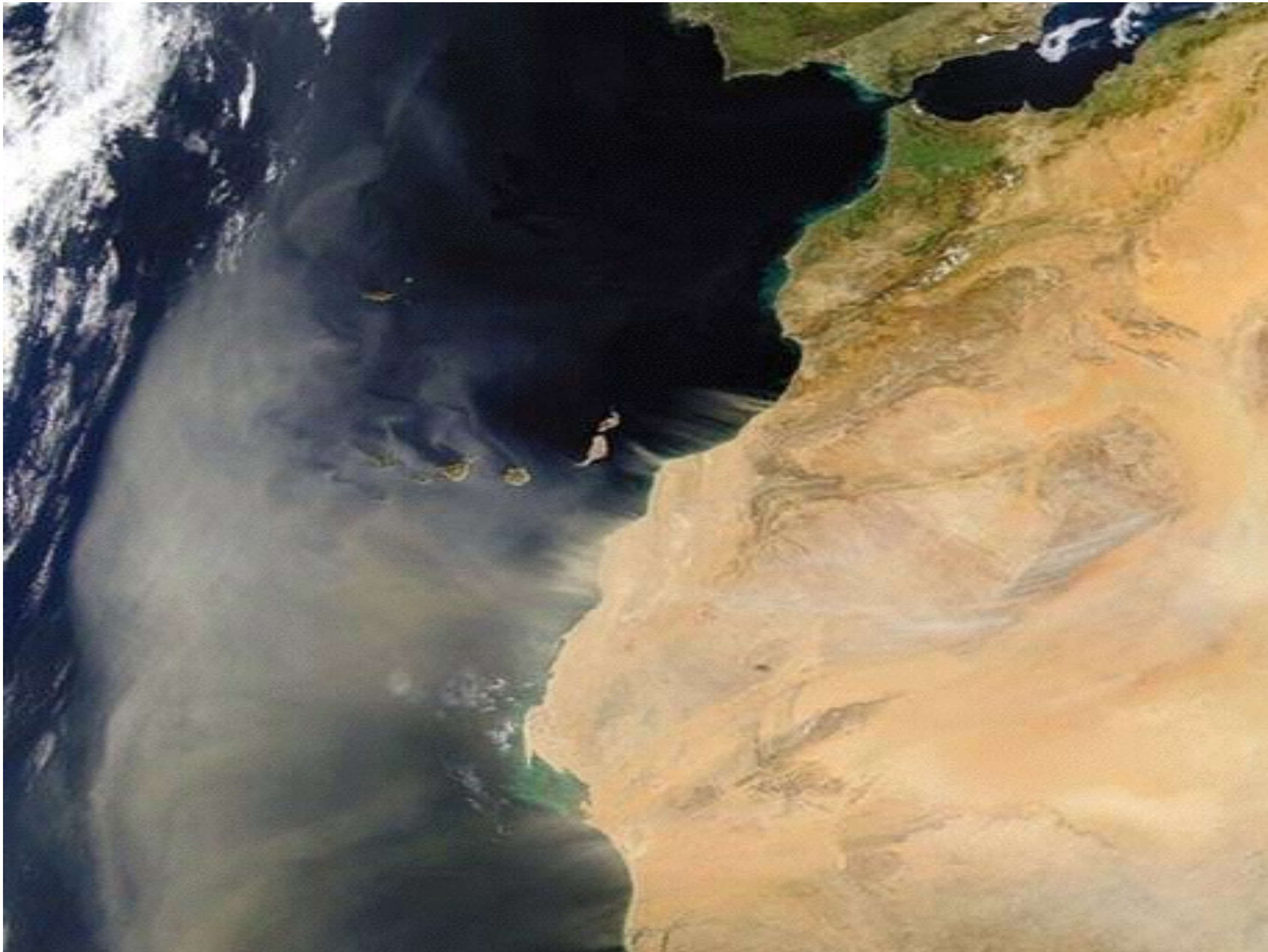


Figure 6. A simplified depiction of the atmospheric carbon mass balance
(http://cmi.princeton.edu/wedges/pdfs/teachers_guide.pdf)

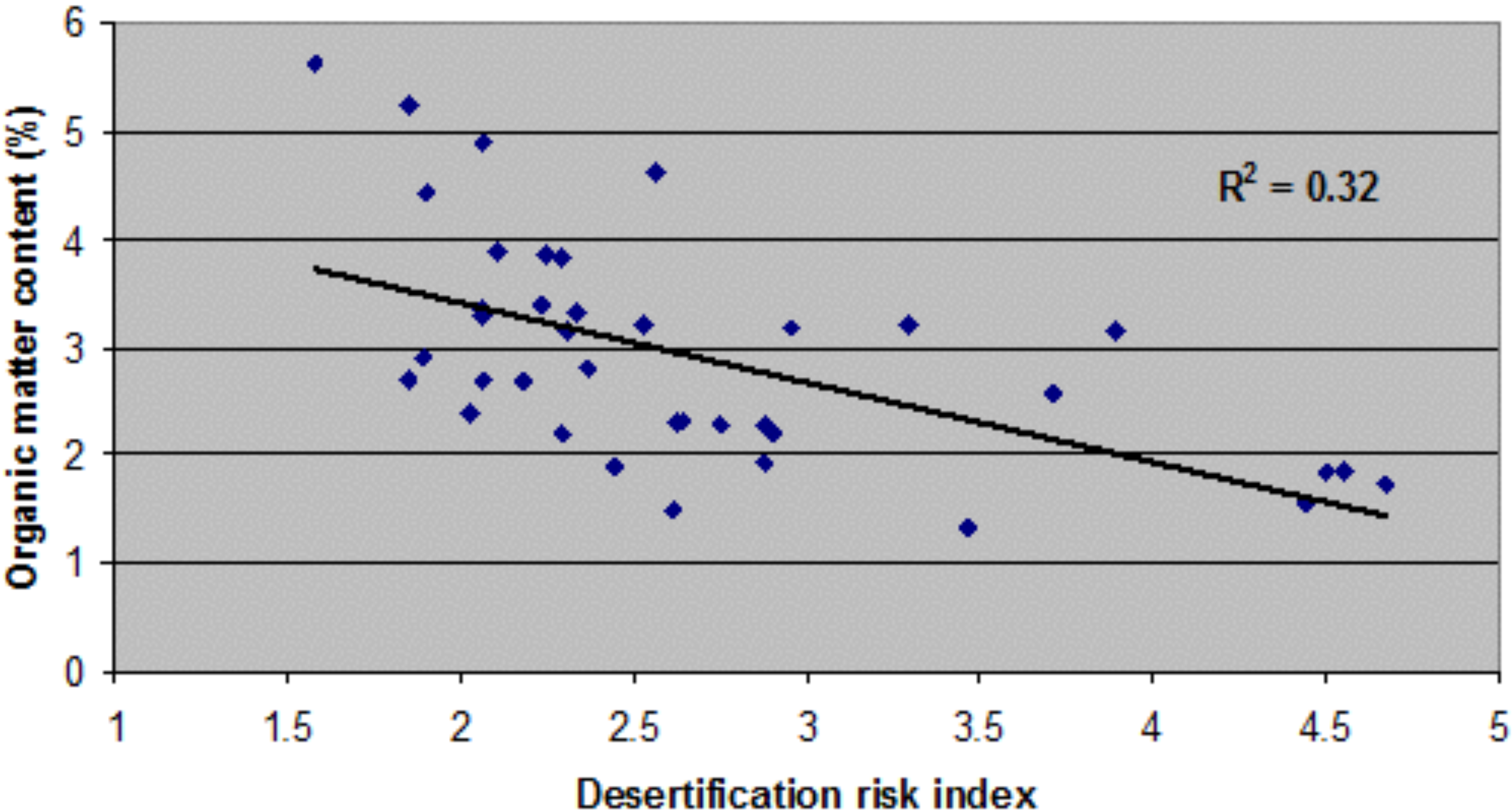

Thermal radiation
into space: 195
Directly radiated
from surface: 40
Solar Radiation
absorbed by Earth
235 W/m²
Greenhouse gas
absorption: 350
67
Heat and energy
in the atmosphere
452
The
Greenhouse
Effect
168
324
Earth's land and ocean surface
warmed to an average of 14°C



Atmospheric Concentration of
Carbon Dioxide (1744-2005)
Siple Station Ice Core
Mauna Loa
CO2 Concentration (ppm)
400
375
350
325
300
275
250
1700
1750
1800
1850
1900
1950
2000
2050
Year

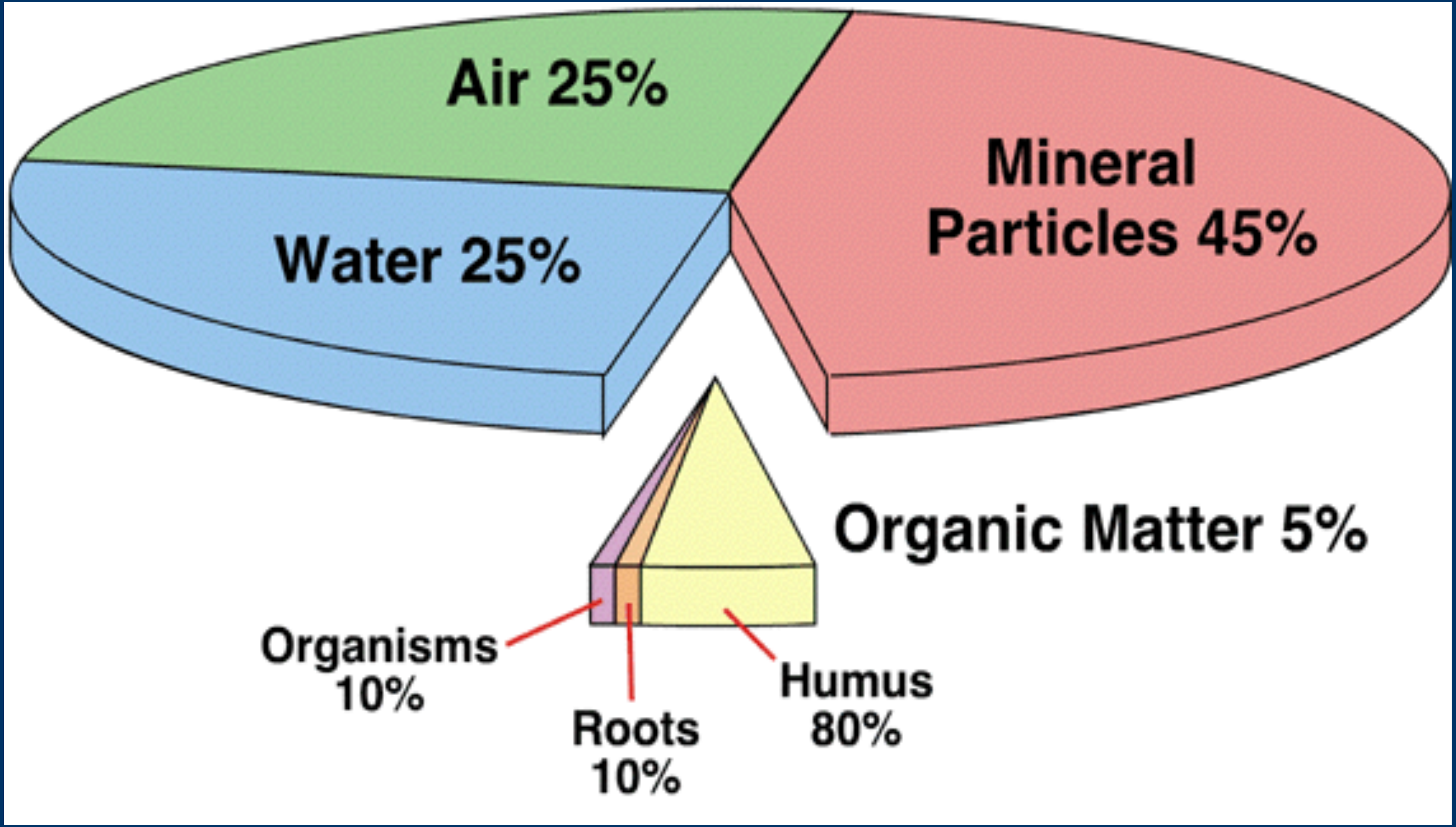



© China Foto Press / Barcroft Medi



Organic matter content (%)
Desertification risk index
$R^2 = 0.32$
0
1
2
3
4
5
6
1
1.5
2
2.5
3
3.5
4
4.5
5

Soil Components

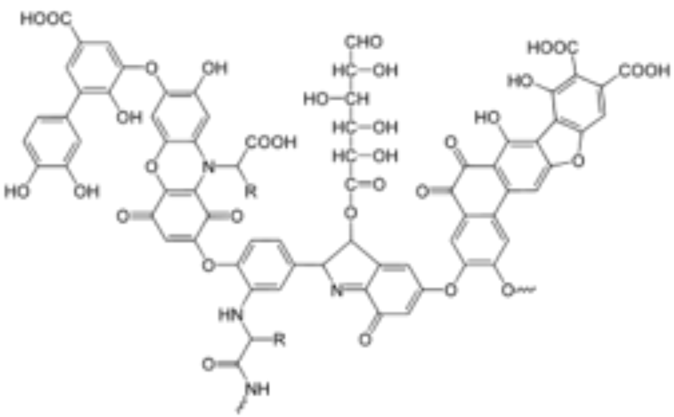


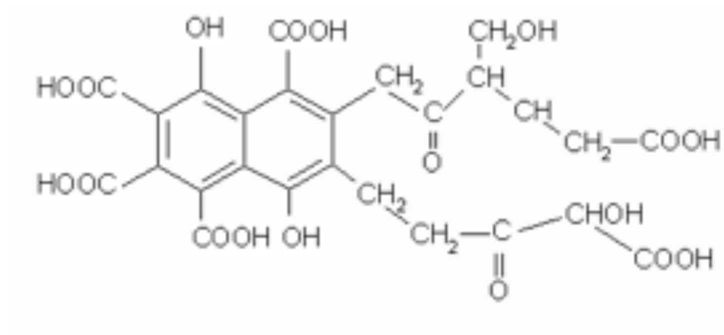
Biomolecules occurring in organisms and their preservation potential in terrestrial environments

Biomacromolecules	Occurrence	Preservation potential
Polysaccharides	All organisms	-/+
Proteins	All organisms	-/+
Nucleic acids	All organisms	-/+
Waxes	Vascular plants	+/++
Resins, ambers	Vascular plants	++/+++
Tannins/ph. Polymers	Vascular plants	++/+++
Melanins	All organisms	+++/++++
Lignins	Vascular plants	+++/++++
Sporopollenin	Vascular plants	++++
Algaenan	Algae	++++
Cutan	Vascular plants	++++
Suberan	Vascular plants	++++

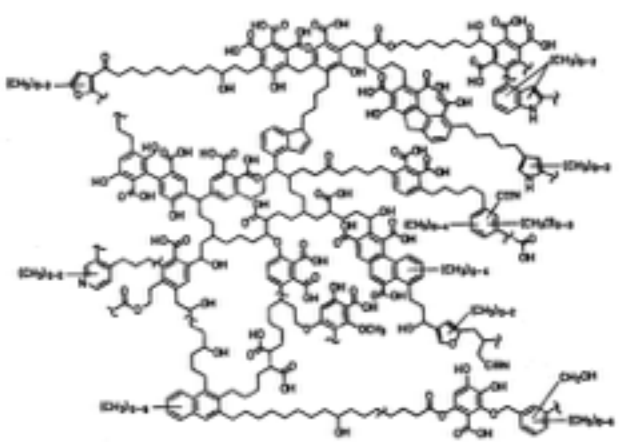
To Advance the Knowledge and Research of Natural Organic Matter in Soil and Water

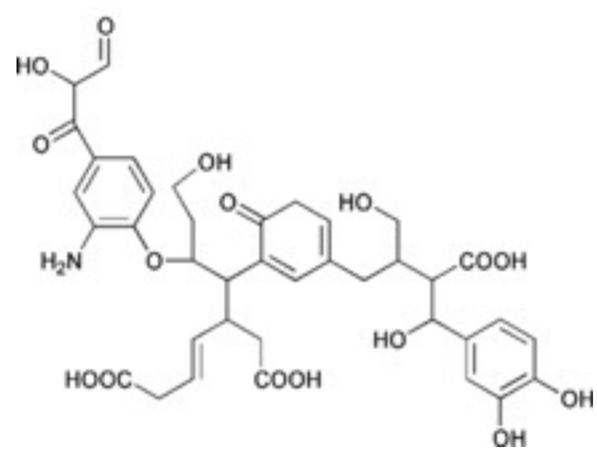
Stevenson, 1982





Model structure of fulvic acid

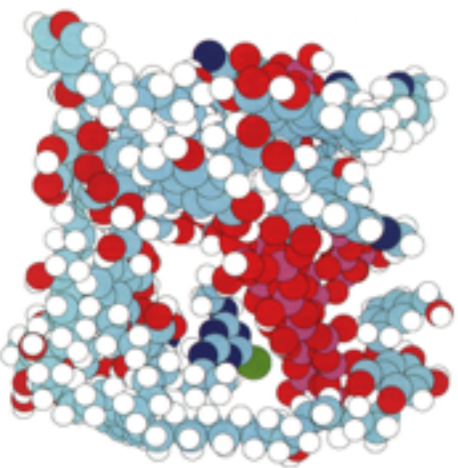


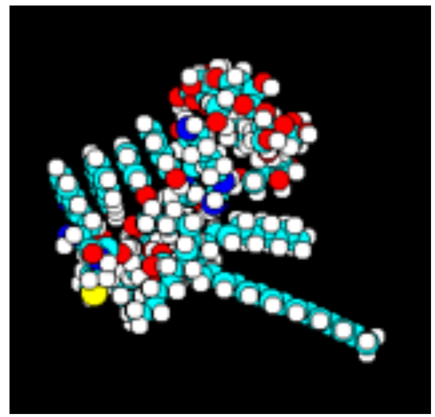


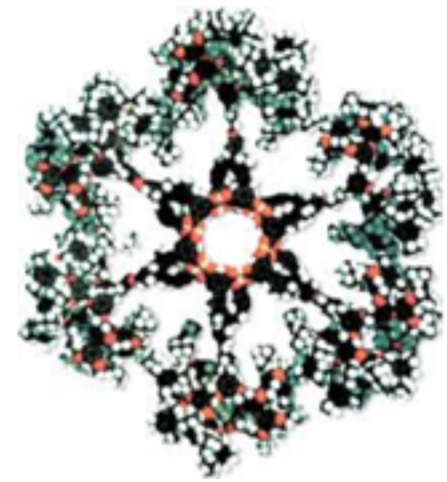
IHSS NATURAL ORGANIC MATTER RESEARCH

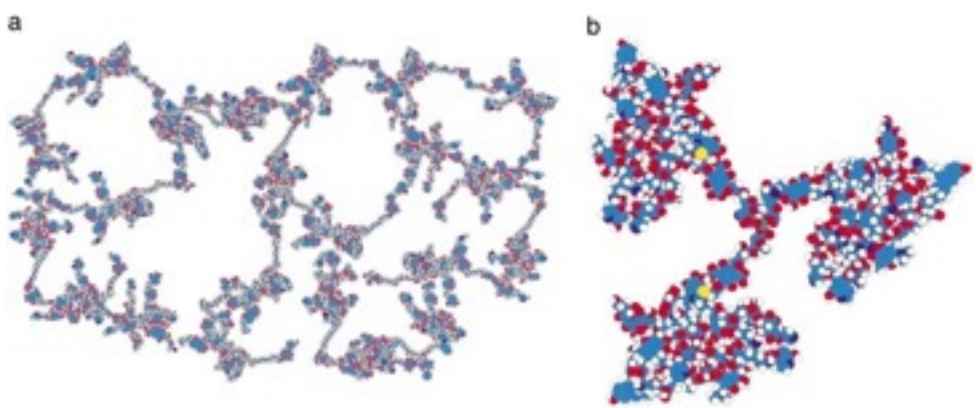
INTERNATIONAL HUMIC SUBSTANCES SOCIETY

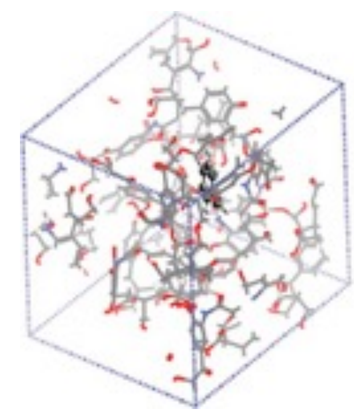
To Advance the Knowledge and Research of Natural Organic Matter in Soil and Water

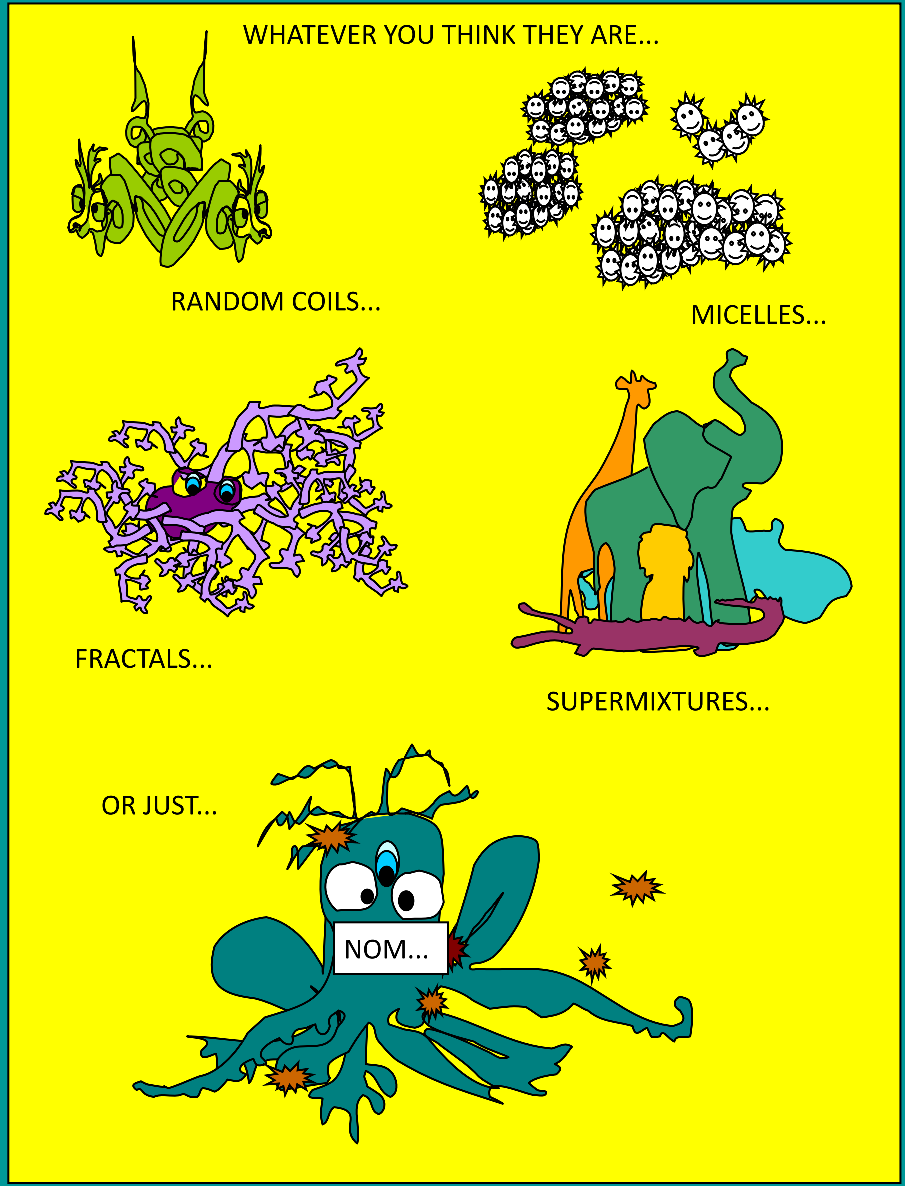






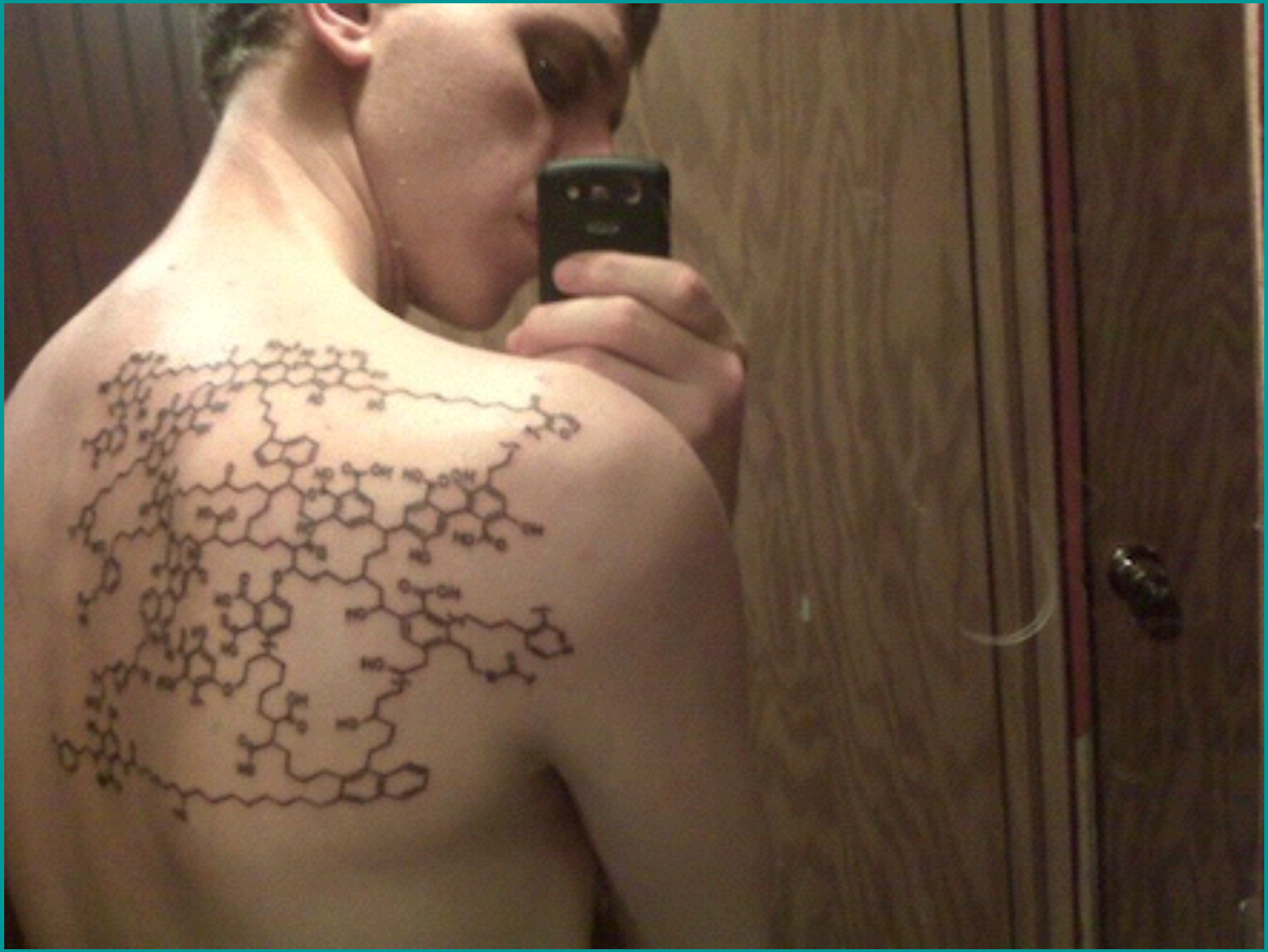




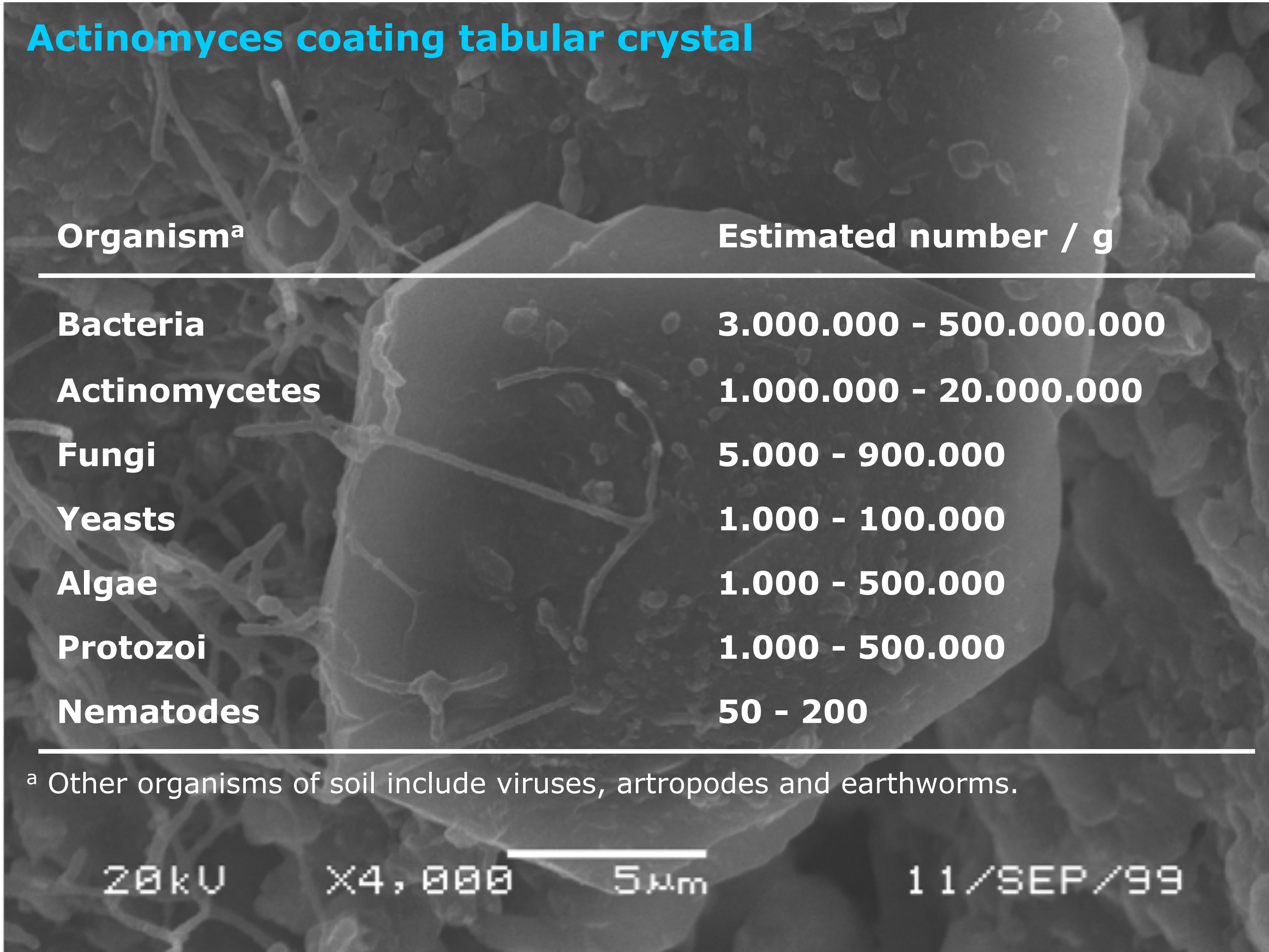

WHATEVER YOU THINK THEY ARE...
RANDOM COILS...
MICELLES...
FRACTALS...
SUPERMIXTURES...
OR JUST...
NOM...

Corey writes, "I got this tattoo as an homage **to the pain** of my graduate work. It's a model of fulvic acid which is a representation of natural organic matter in the soil.

I work with this molecule for my grad work and I figured I might as well get it etched into my skin so I can look at it and say, 'Well, at least it hurt less than grad school at Cornell".

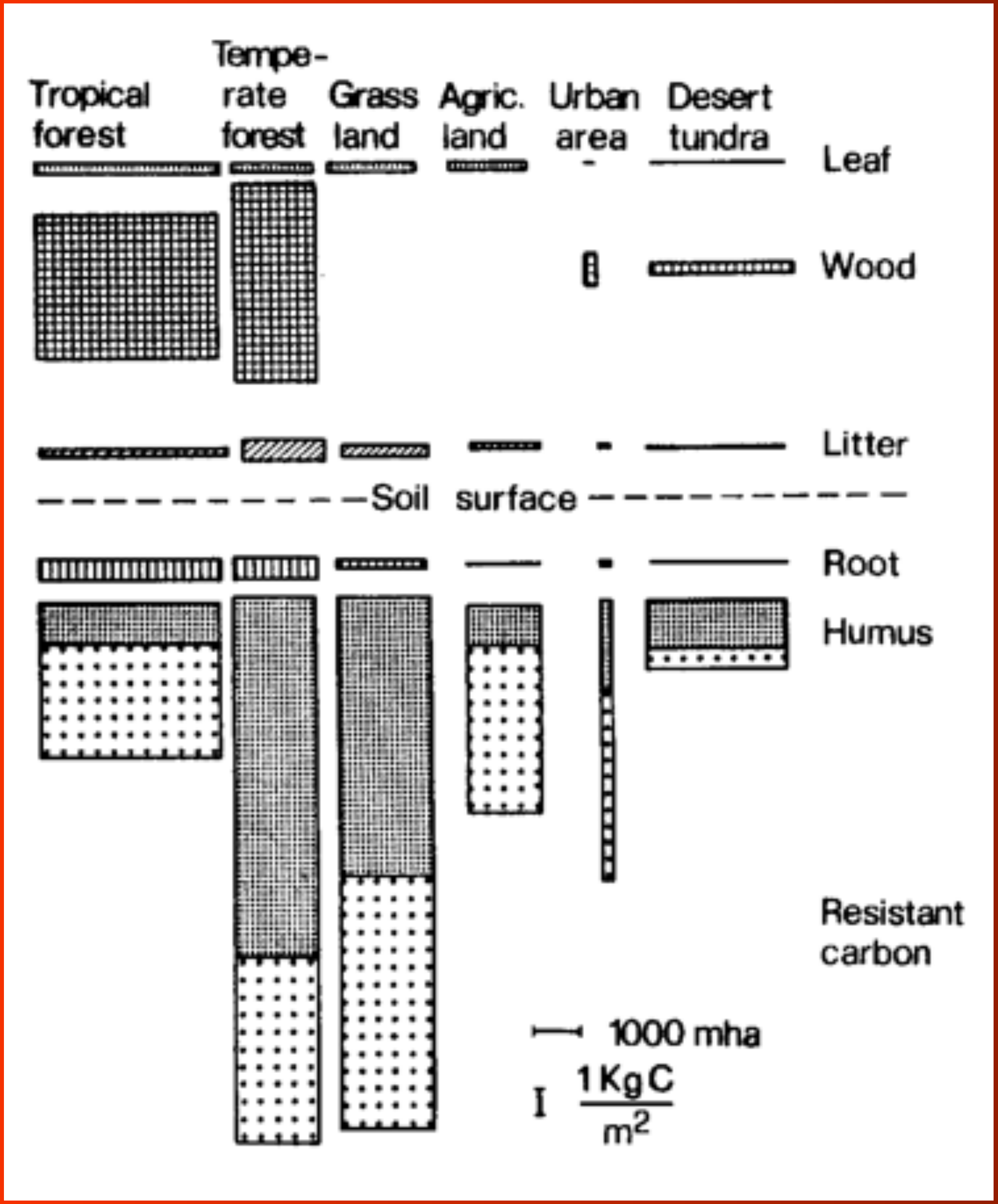


Actinomyces coating tabular crystal

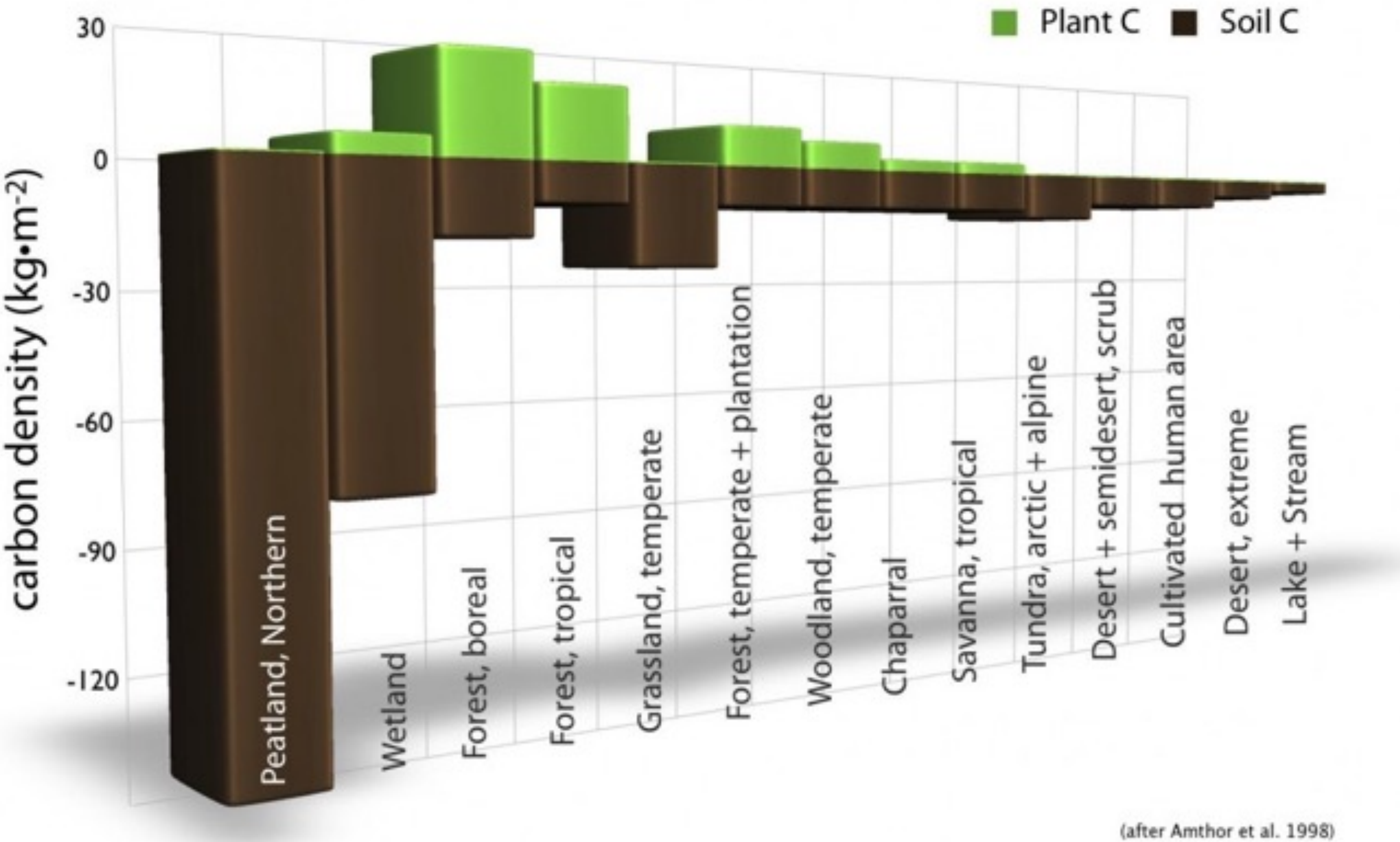


Organism[a]	Estimated number / g
Bacteria	3.000.000 - 500.000.000
Actinomycetes	1.000.000 - 20.000.000
Fungi	5.000 - 900.000
Yeasts	1.000 - 100.000
Algae	1.000 - 500.000
Protozoi	1.000 - 500.000
Nematodes	50 - 200

[a] Other organisms of soil include viruses, artropodes and earthworms.



Total organic carbon in soil is estimated around 2-3 · 10^{12} t, that is 3 to 4 times the atmospheric C and 5 to 6 times the C of terrestrial biomass.



(after Amthor et al. 1998)

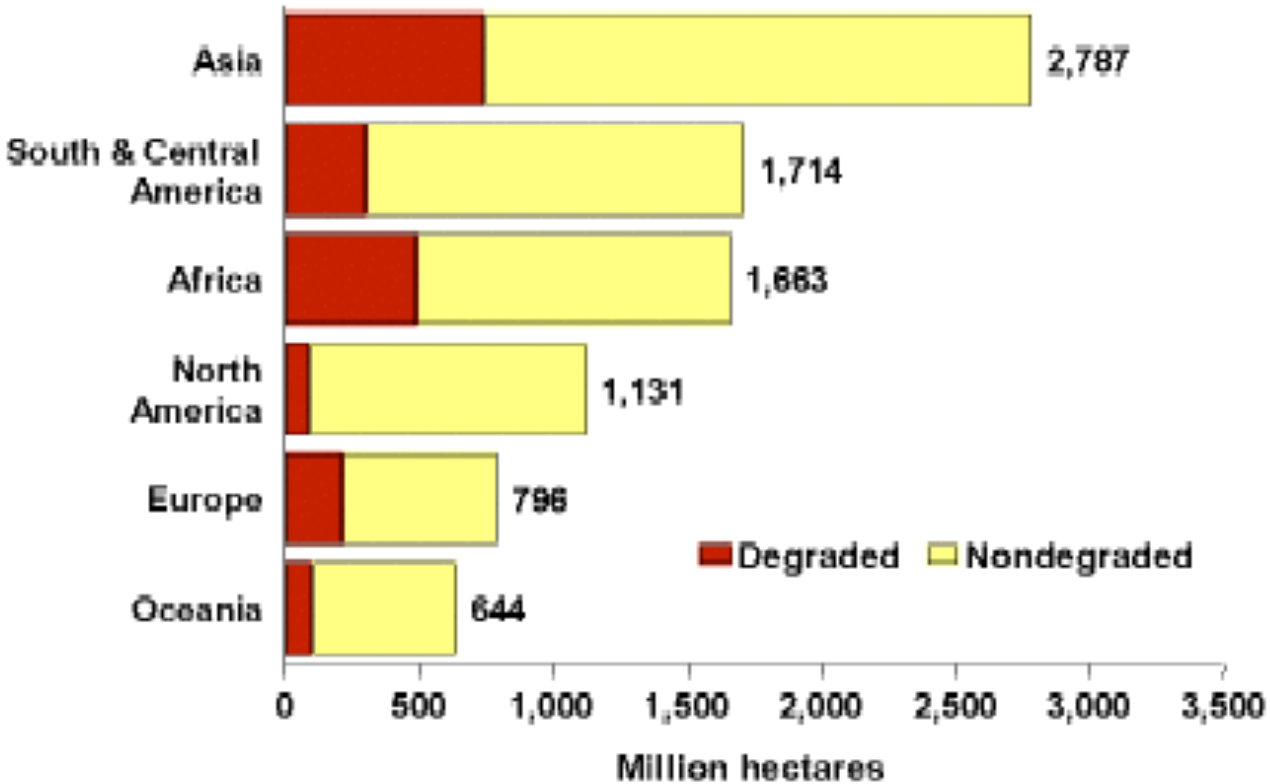
General properties of SOM in the Soil

Property	Remarks
Colour	Dark colour of soils, warming
Water retention	Up to 20 times in weight, drying and shrinking
Mineral associations	Cements, aggregates, structure. Gas exchanges
Water solubility	Very limited. Little OM is lost by leaching

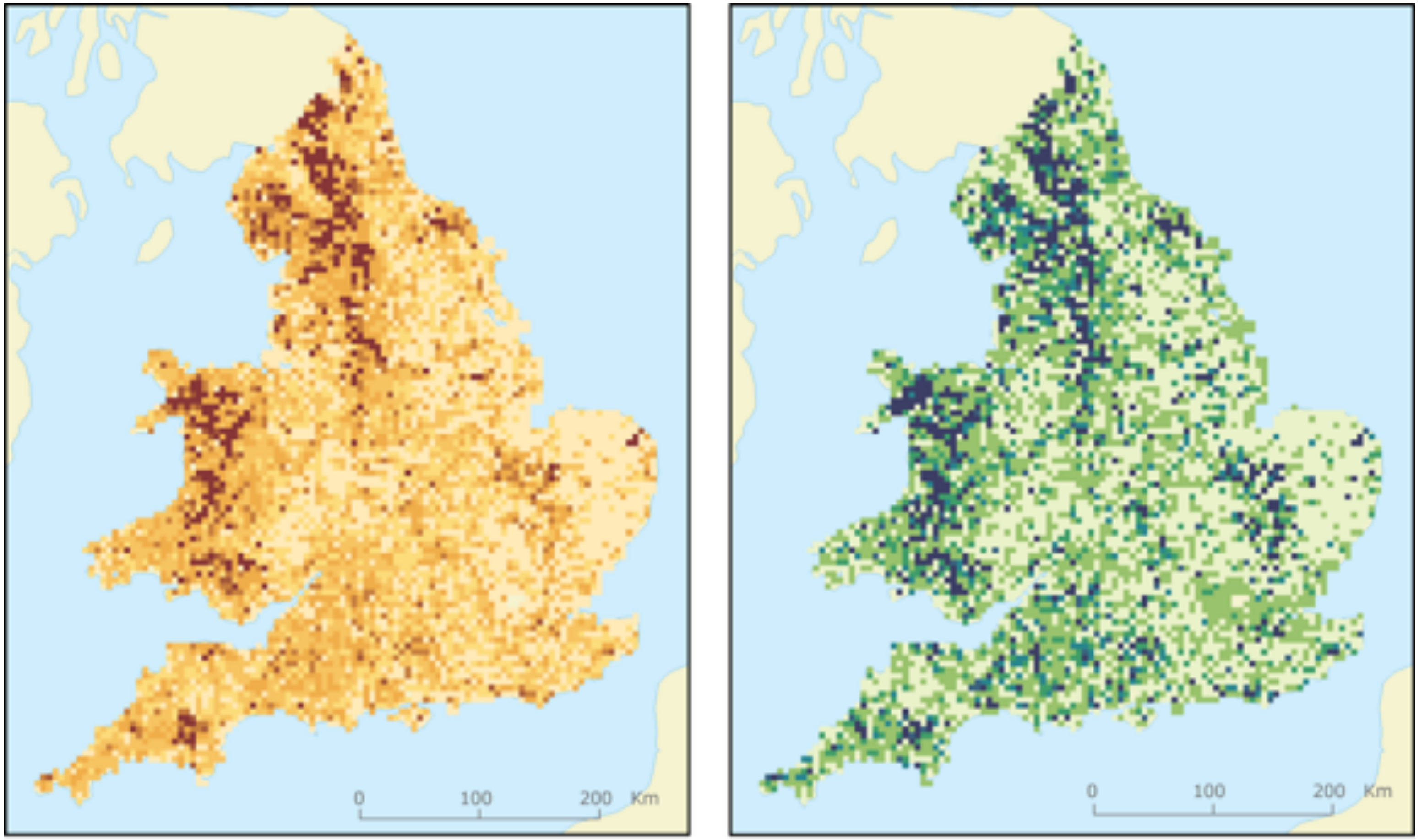
General properties of SOM in the Soil

Property	Remarks
Mineralization	Source of macro- and micro-nutrients for plants
Cation exchange	20 to 70% of soil CEC
Chelation	Stable complexes with polyvalent cations
Buffer action	Uniform pH in soil
Xenobiotic assoc.	Bioactivity, persistence and biodegradability

Global estimates of soil degradation



Source: S. Scherr, *Soil degradation: A threat to developing-country food security in 2020?* (Washington, D.C.: IFPRI, 1999).



Change in soil organic carbon contents across England and Wales between 1978 and 2003

Left: carbon contents in the original samplings (1978–1983)

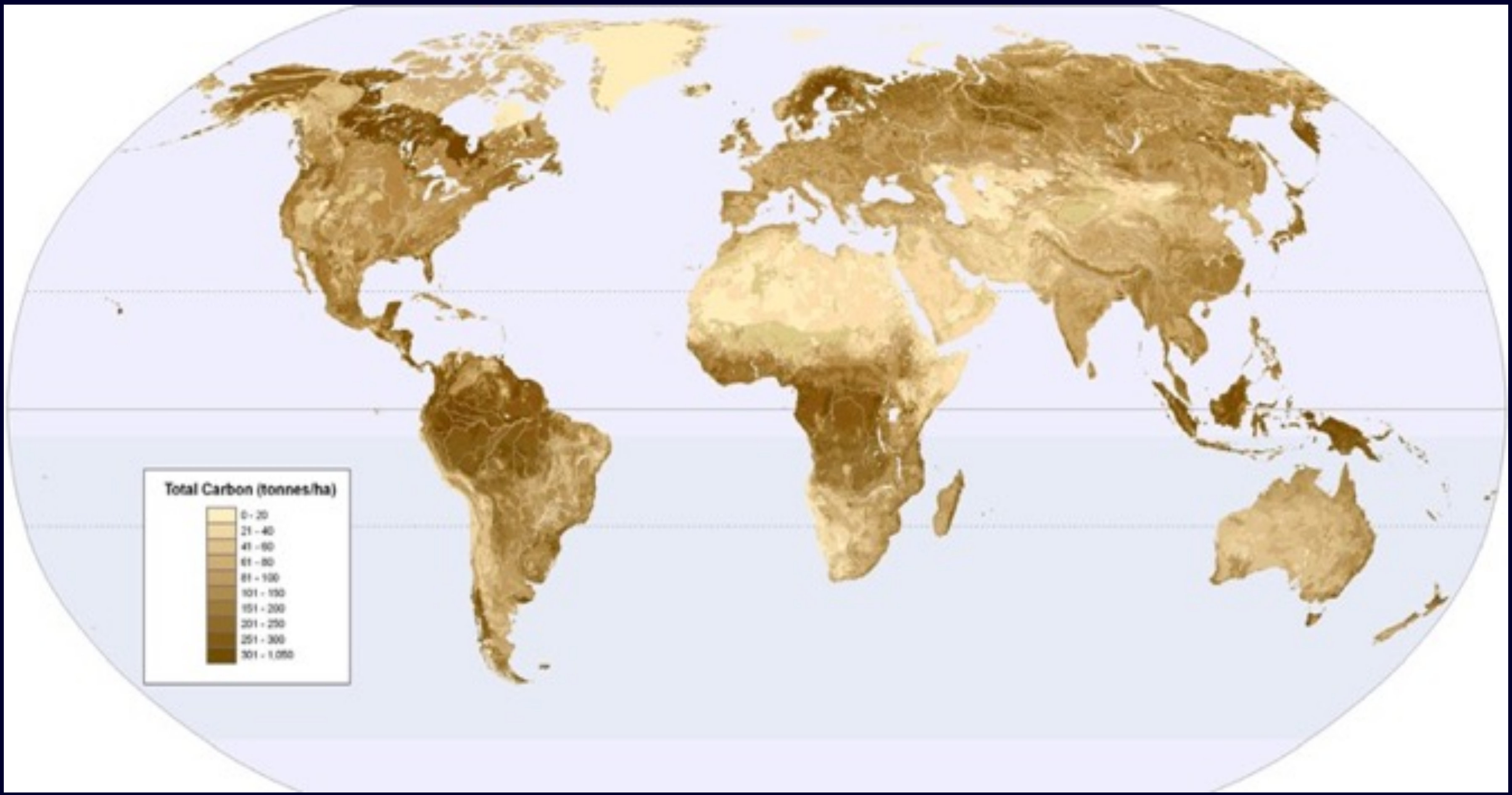
Right: rates of change calculated from the change over the different sampling intervals (1994–2003)

Original C_{org} (g/kg)

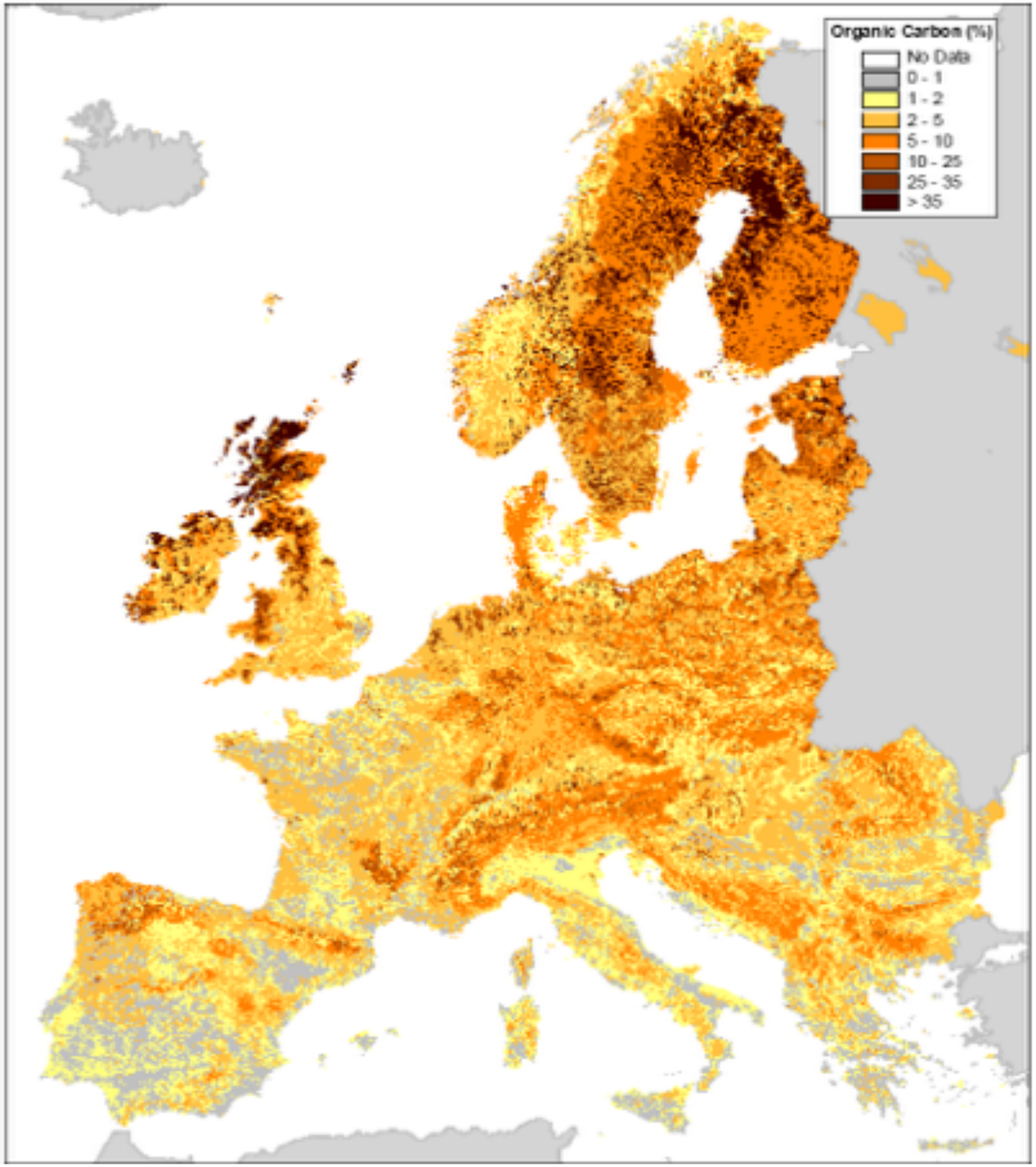
< 20 | 20–30 | 30–50 | 50–100 | 100–200 | 200–300 | > 300

Rate of change (g/kg/yr)

< -2.0 | -2.0 to -1.5 | -1.5 to -1.0 | -1.0 to -0.5 | -0.5 to 0.0 | > 0.0



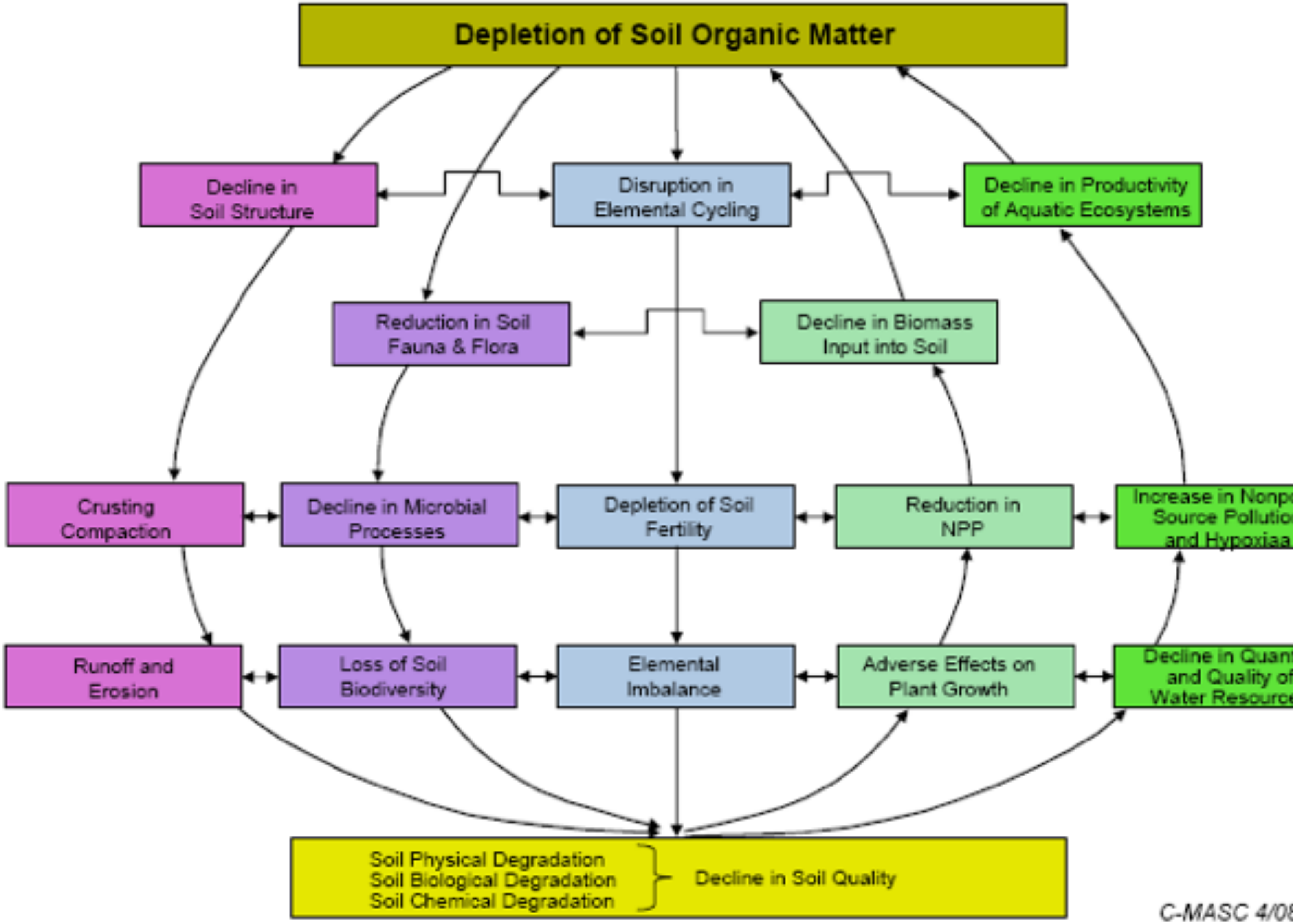
(Scharlemann et al., 2011 - UNEP WCMC Updated Global Carbon Map. United Nations Environment Programme - World Conservation Monitoring Centre)



Relazione tra il contenuto in
SO nei suoli ed il clima

Carbonio organico (%)
nell'orizzonte superficiale
(0-30 cm) dei suoli europei

Adverse Impacts of Depletion of Soil Organic Matter on Soil Quality and Ancillary Ecosystem Services



Journal of Environmental Management 144 (2014) 83–87

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Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

ELSEVIER

Short communication

Dynamics and climate change mitigation potential of soil organic carbon sequestration

CrossMark

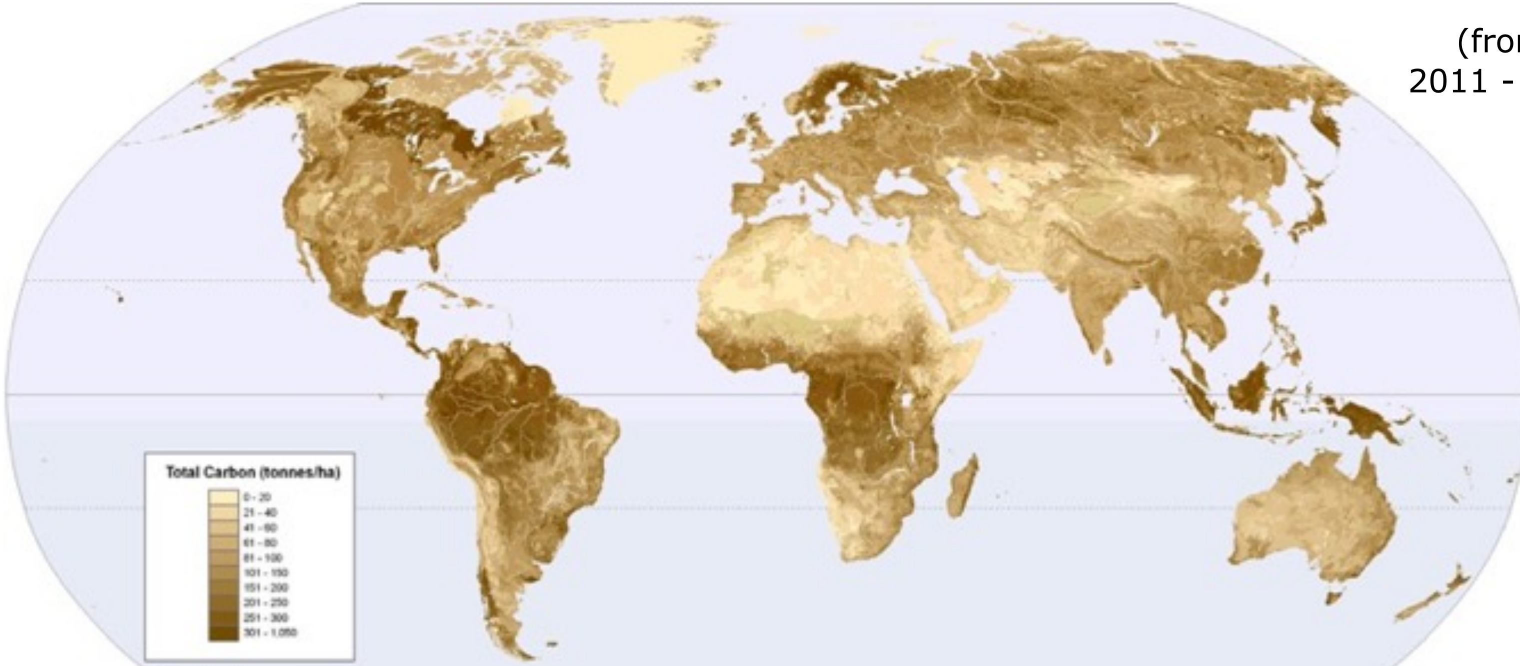
Rolf Sommer*, Deborah Bossio

International Center for Tropical Agriculture (CIAT), ICIPE Duduville Campus, Kasarani, P.O. Box 823-00621, Nairobi, Kenya

Assessing Soil Organic Carbon sequestration and its climate change (CC) mitigation potential at global scale.

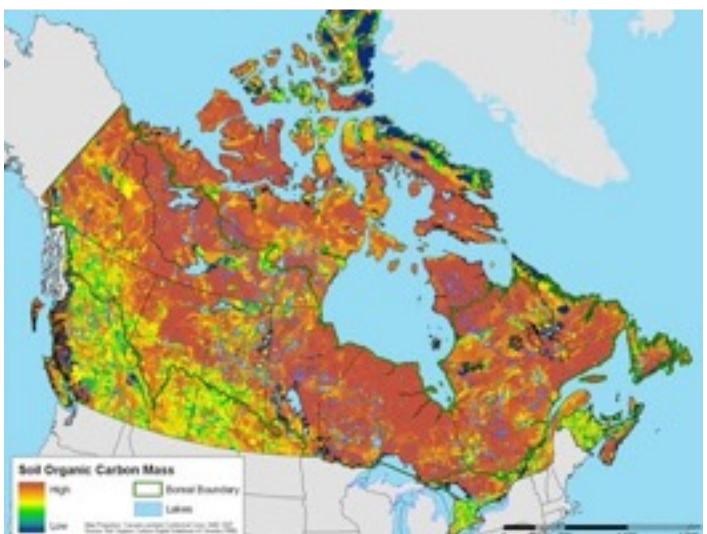
Adopting **SOC sequestration measures** at global scale takes time. Given a Global adoption of soils as C sink, SOC will increase only till a new equilibrium is reached.

The combination of the 2 processes into a model predicts that C stored in soils at global level from 2014 to 2100 ranges **ONLY between 1.9-3.9 %** of the *total anthropogenic emissions* in the remaining 86 years. Really limited mitigation potential.



(from *Scharlemann et al.*, 2011 - UNEP WCMC Updated Global Carbon Map)

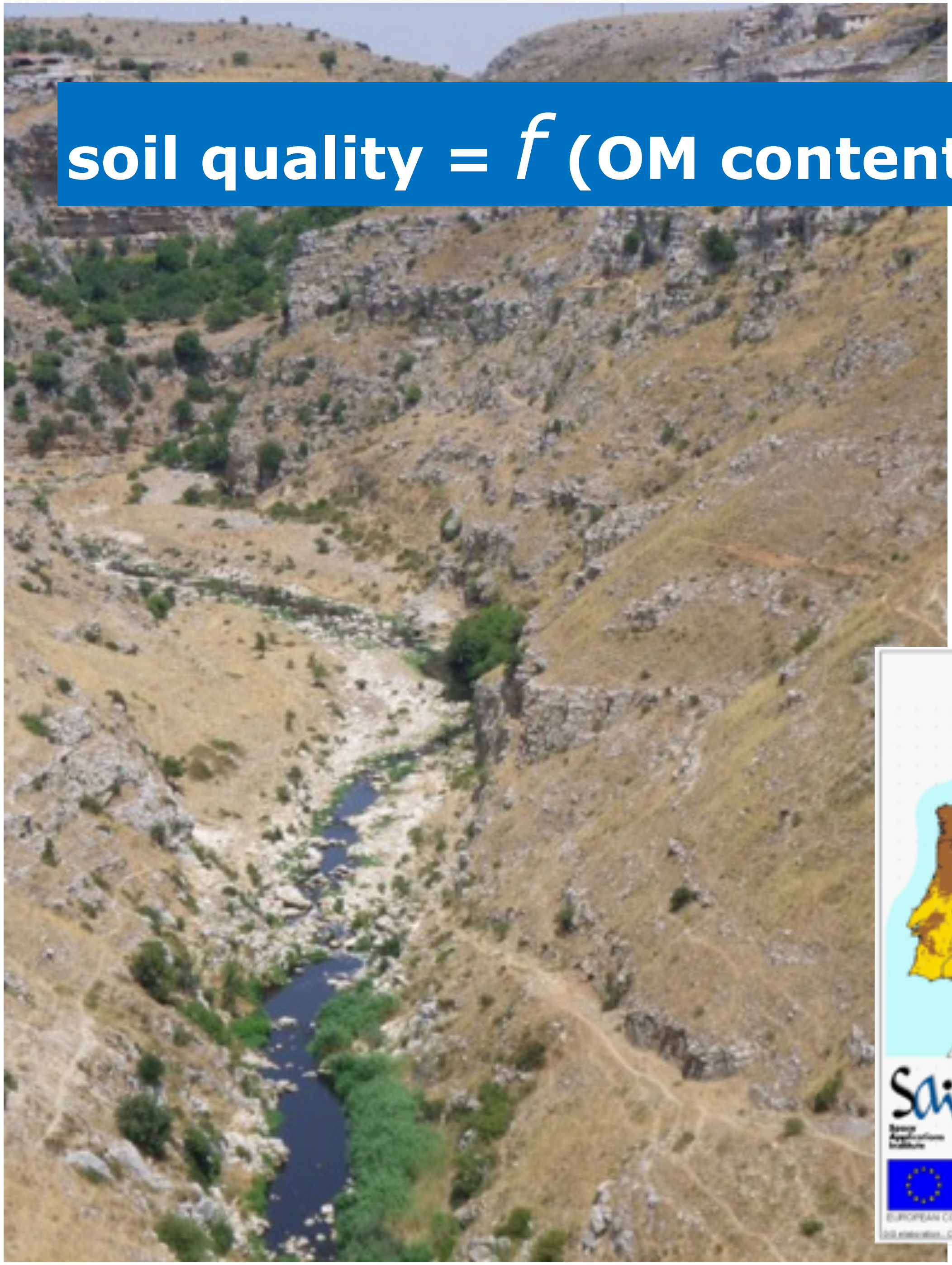
OM = *f* (climate)$_{\text{time, vegetation, topography, parental material, ... human activity}}$

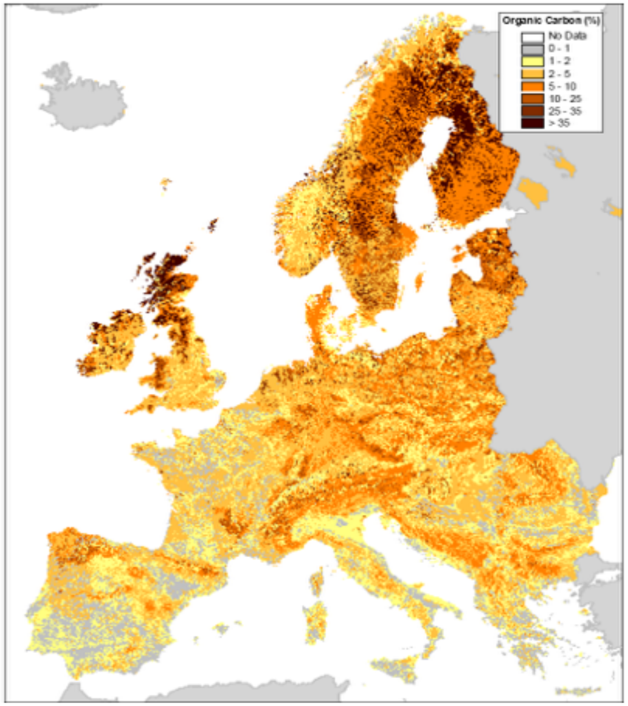


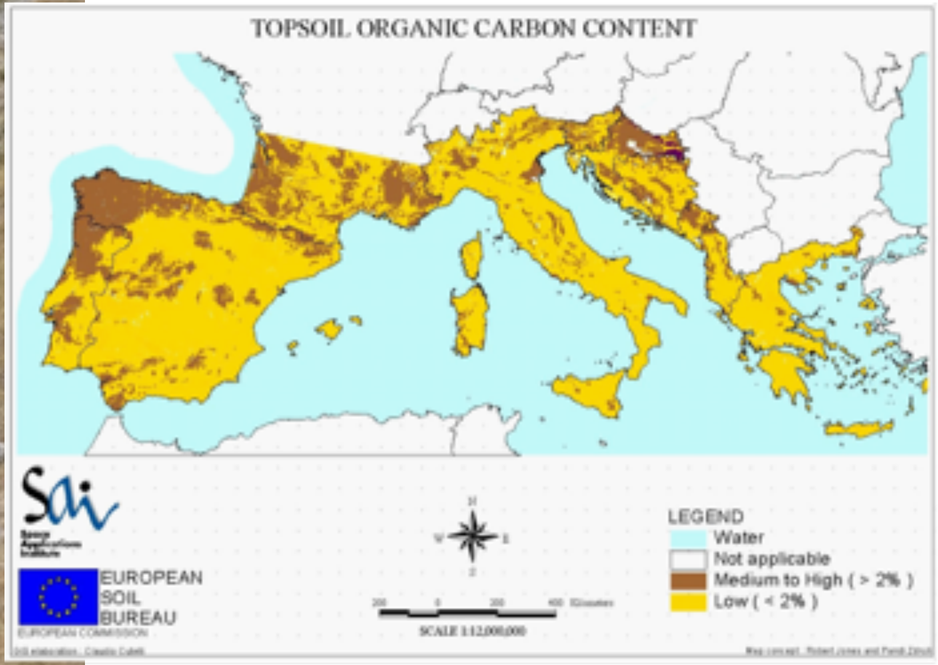
Jones et al., 2004 - The map of organic carbon in topsoils in Europe, Version September 2003. European Soil Bureau Research Report No.17, EUR 21209 EN.

(Source: http://newswatch.nationalgeographic.com/2009/11/12/boreal_forest_protection/)

soil quality = f (OM content)







SOIL QUALITY ?

Environment International 36 (2010) 609–622

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review

Soil quality assessment under emerging regulatory requirements

James Bone [a], Martin Head [a], Declan Barraclough [b], Michael Archer [b,c], Catherine Scheib [d], Dee Flight [d], Nikolaos Voulvoulis [a,*]

Development of the definition of soil quality.

Soil quality definition	Year	Reference
The sustained capability of a soil to accept, store and recycle water, nutrients and energy	1984	Anderson and Gregorich (1984)
The state of existence of soil relative to a standard, or in terms of a degree of excellence	1991	Larson and Pierce (1991)
The capacity of a soil to function, within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health	1994	Doran and Parkin (1994)
Ability of soil to perform or function according to its potential, and changes over time due to human use and management or to unusual events.	1995	Mausbach and Tugel (1995)
The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation	1997	Karlen et al. (1997a)
Encompassing an indefinite (open) set of tangible or dispositional attributes of the soil. These attributes may be substituted for or supplemented by other attributes without needing to change the term. Therefore it is a vessel to contain what is assigned to it. The attributes assigned to the term will differ among soil and the various demands, because the term is influences by value judgements	2000	Patzel et al. (2000)

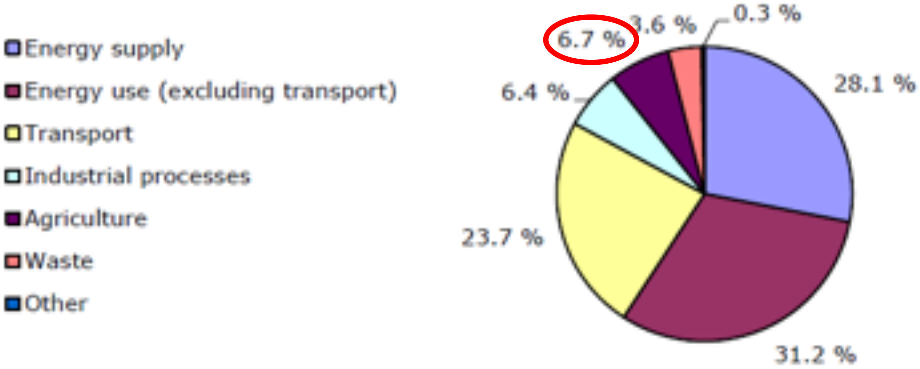
uman, animal and plant health

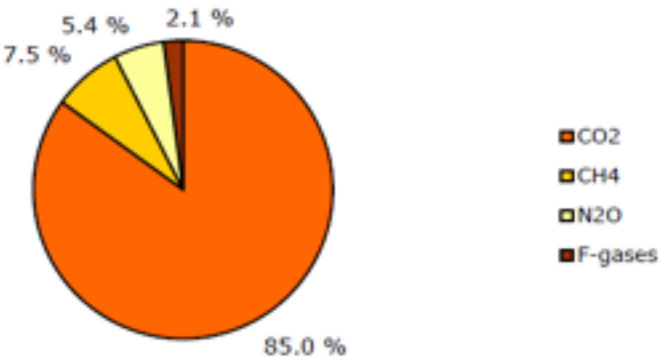
Soil (OM) conservation *vs.* agriculture …

C sink

C source

Share of GHG emissions by main source and by gas in 2010





(Source: http://www.eea.europa.eu/publications/ghg-trends-and-projections-2012)

What we do
(… or could do!!!)

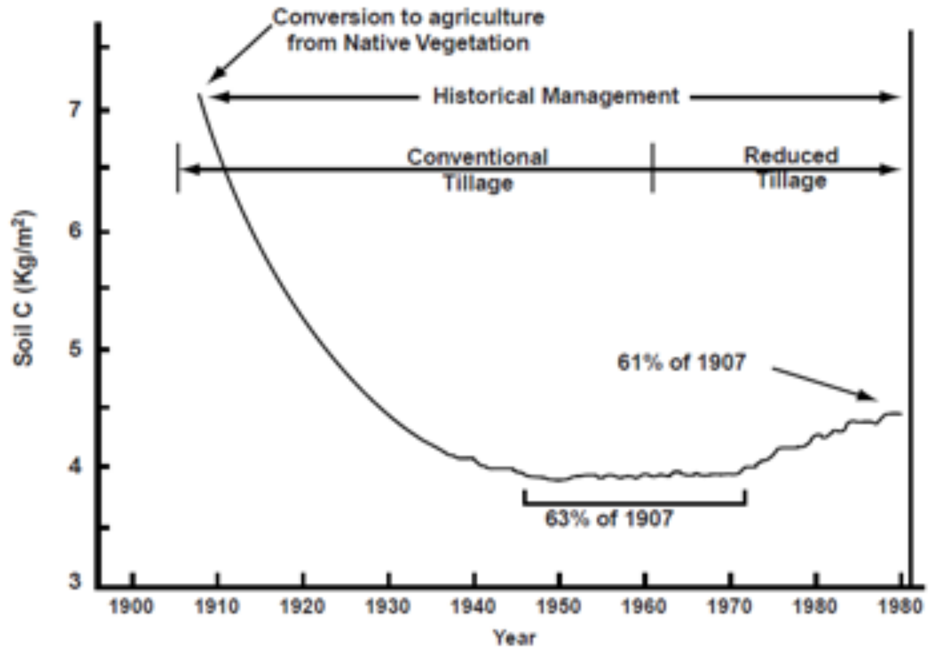
Sustainable agriculture

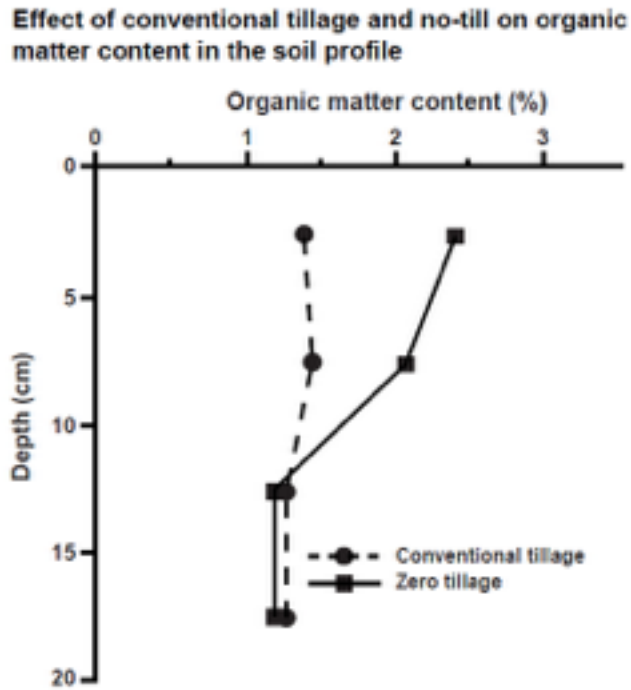
=

Soil Organic Matter

REDUCE PLOWINGS

Simulated total soil carbon changes (0 to 20 cm depth) from 1907 to 1990 for the central U.S. corn belt (from Smith, 1999)





Tillage effects on soil organic C with depth: 14 yrs continuous corn, Mg C/ha/cm (from *Huggins et al.*, 2007)

Depth	No-till	Plow	
0-7.5	4.49	3.89	**
7.5-15	4.94	4.66	
15-30	3.51	3.17	
30-45	2.45	1.48	**
0-45 (Mg/ha)	160	133	**

Soil C sequestration rates for 15 years (Mg C/ha/y) (from *Nicoloso et al.*, 2008)

Depth (cm)	Fertilizer N Tilled	Fertilizer N No-till	Manure N Tilled	Manure N No-till
0-5	0.161	0.351	0.393	1.182
0-15	0.254	0.497	0.792	1.402
0-30	0.336	0.717	0.839	1.387
0-60	0.146	1.325	0.733	1.141

INCREASE OM IN SOILS

C Sequestration

Biomass C in forest
- species selection
- site preparation
- nutrient and stand management

Wetland Management
- water table management
- sediment control
- plant biodiversity

Soil C farming
- erosion control
- conservation tillage
- cover cropping
- manuring
- agro-forestry
- controlled grazing
- biochar

Biofuel plantations
- species selection
- soil type
- composting by-products

Technological options for C sequestration in terrestrial ecosystems

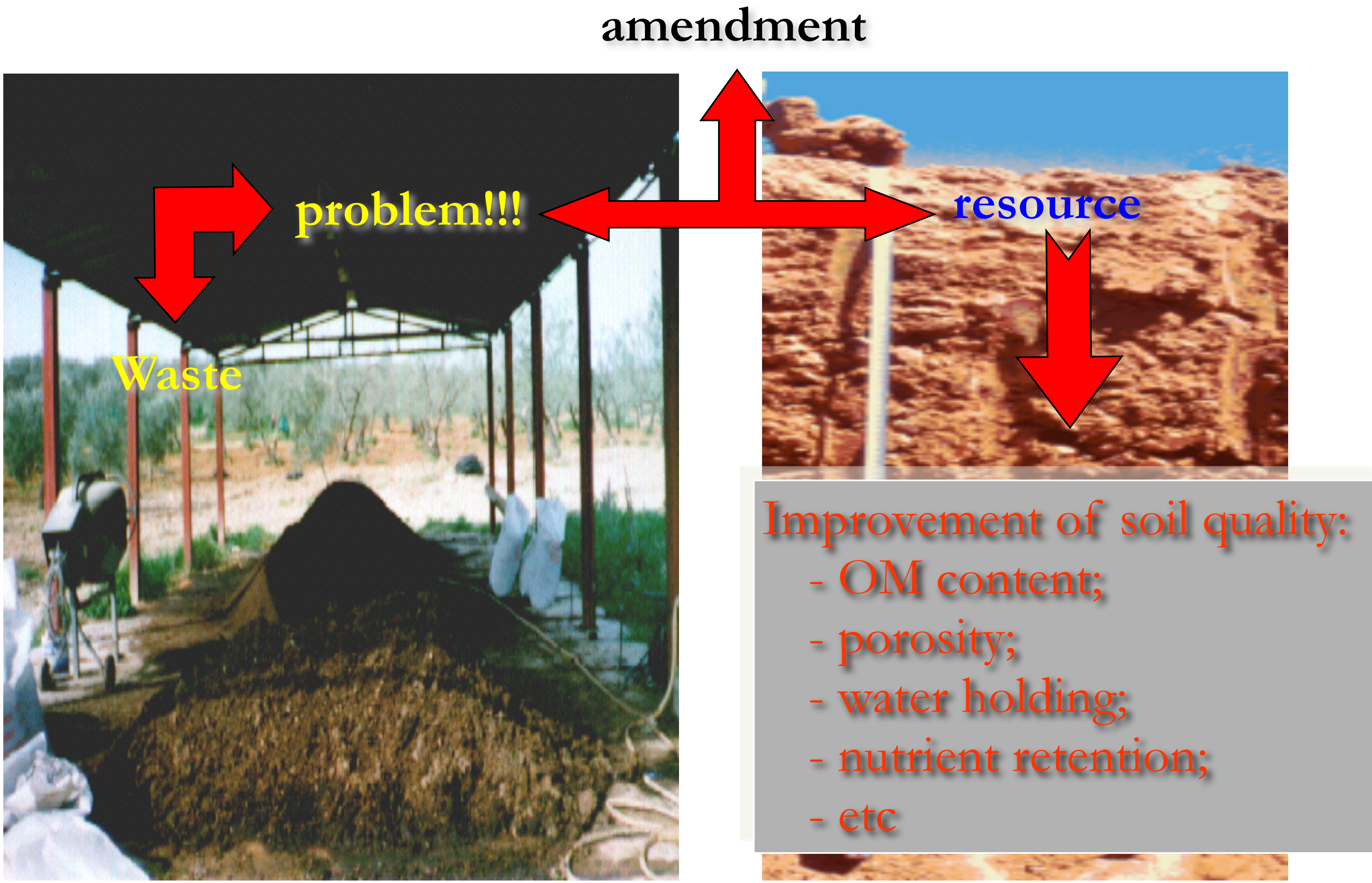
Cover crops

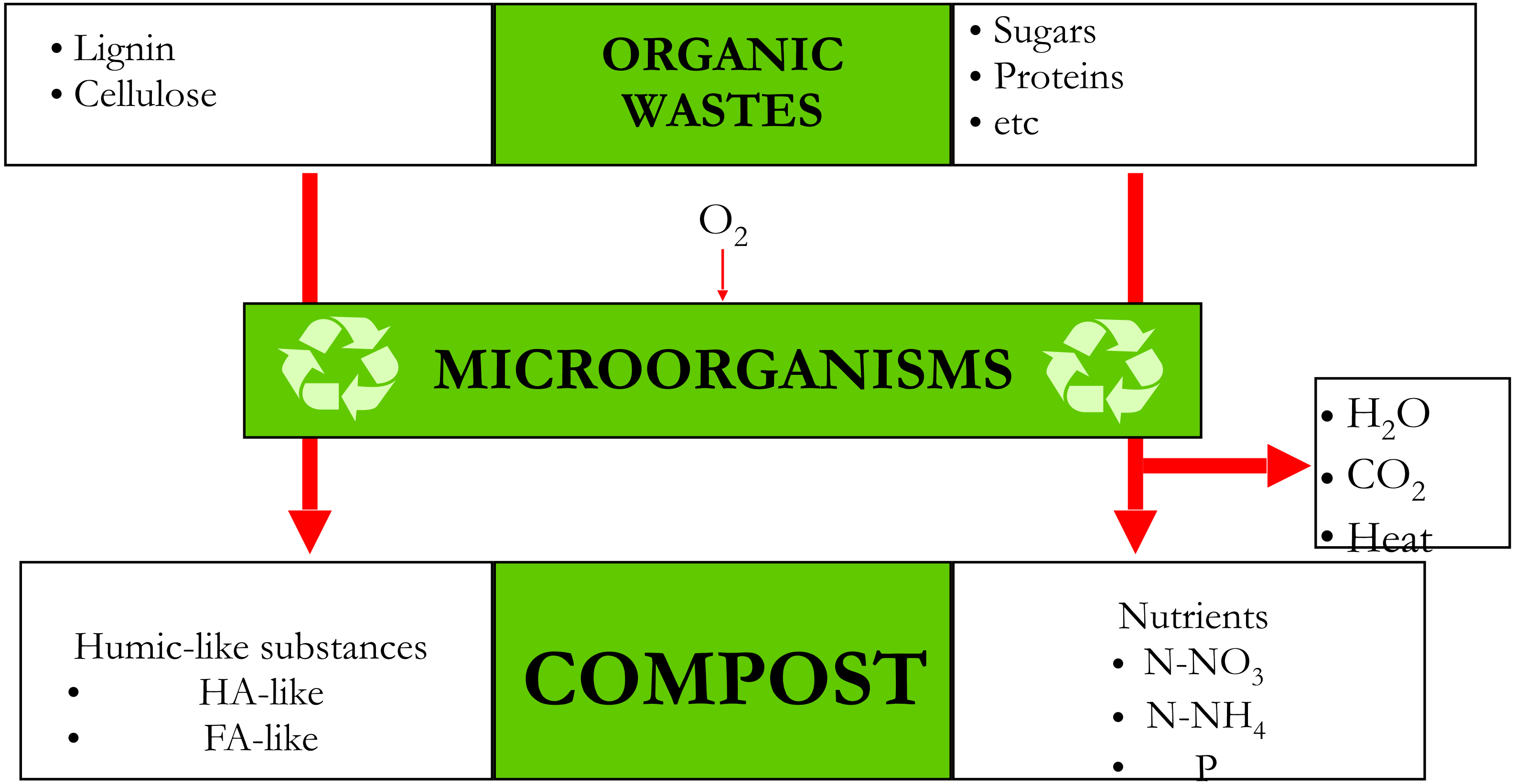
Bio-fuel plantations

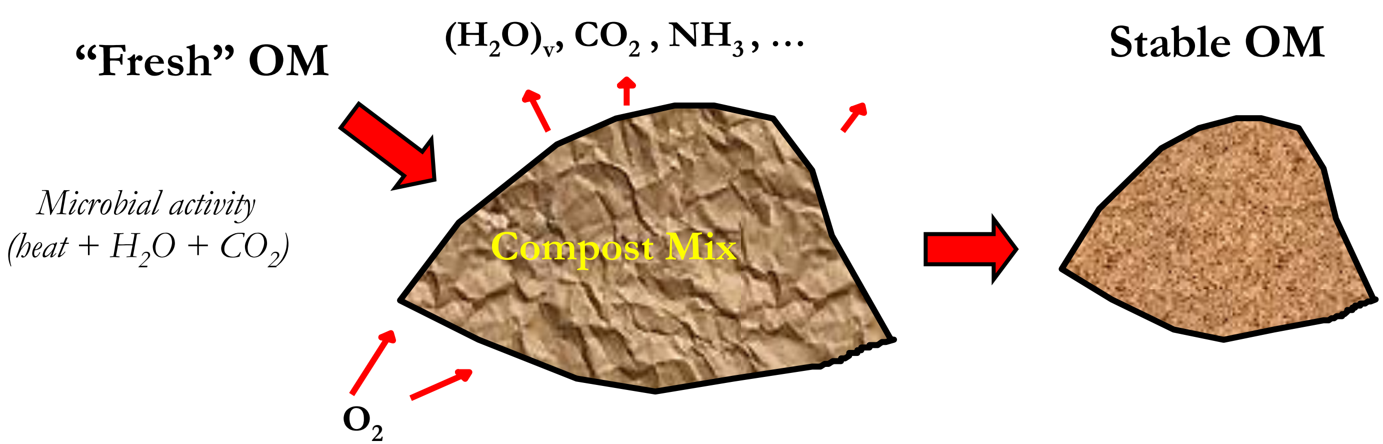
(nofood species; e.g., *Arundo donax*, *Miscanthus*)

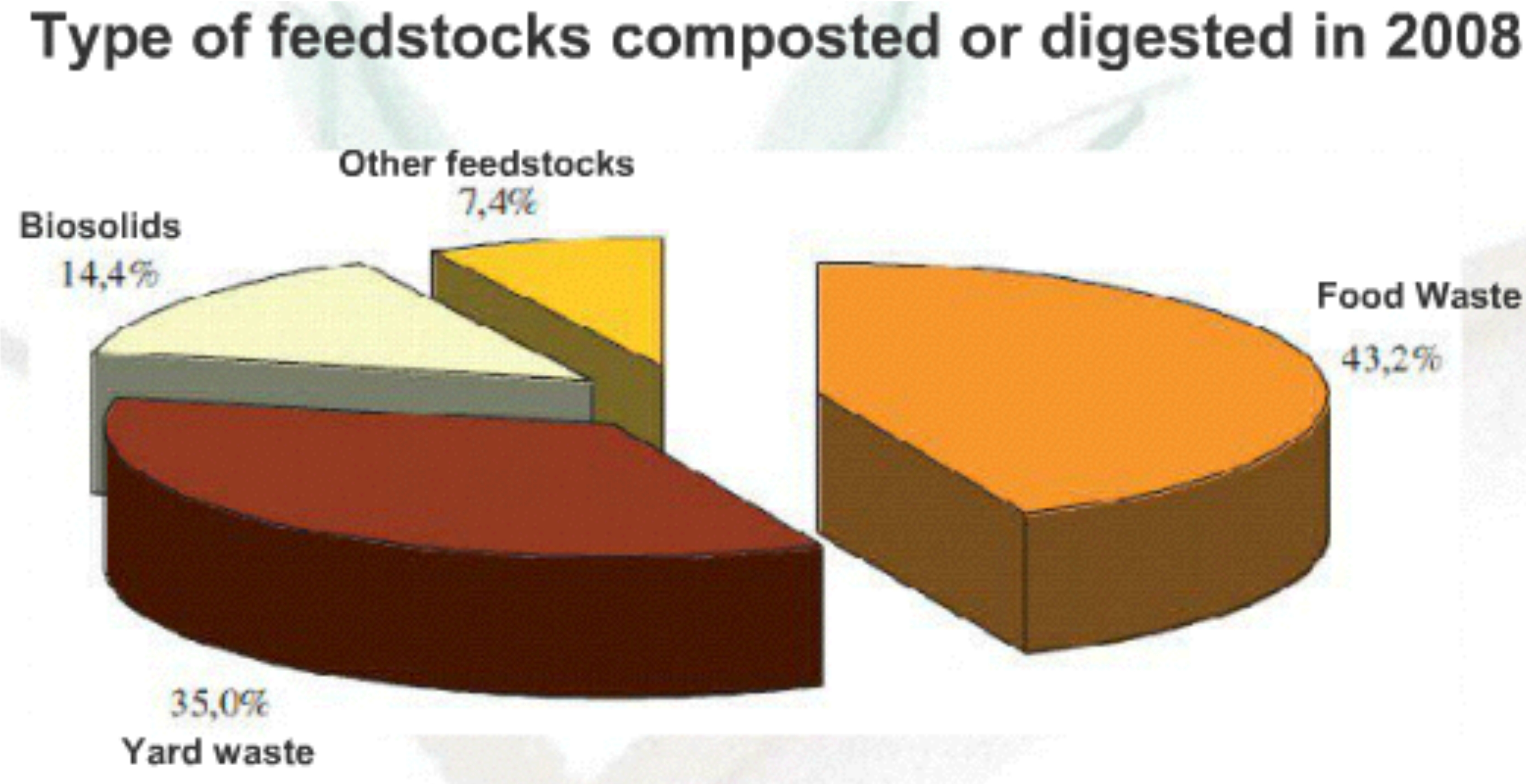
Utilization of farm residues
(high C/N ratio)

… Correct and "safe" use of organic wastes: composting



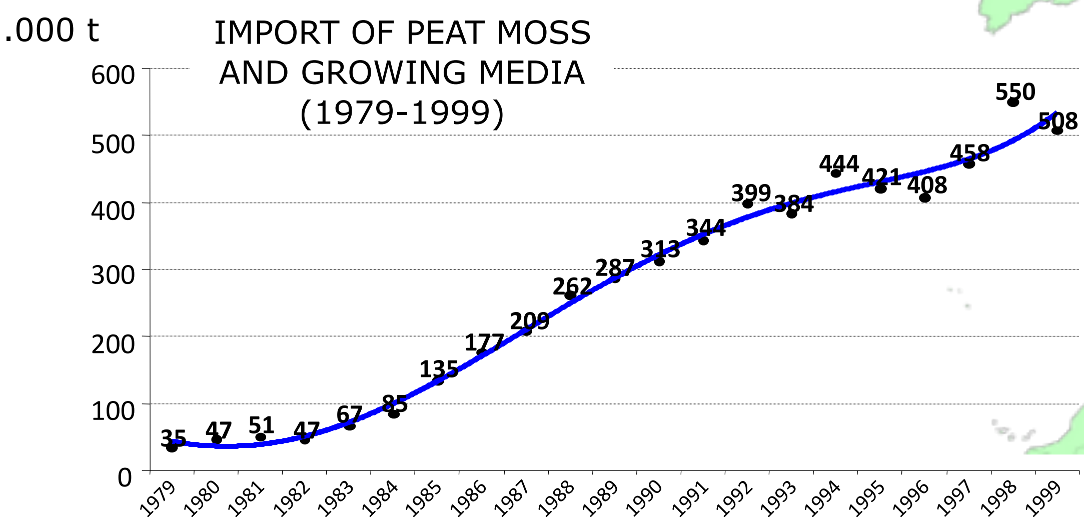

• Lignin
• Cellulose
ORGANIC WASTES
• Sugars
• Proteins
• etc
O_2
MICROORGANISMS
• H_2O
• CO_2
• Heat
Humic-like substances
• HA-like
• FA-like
COMPOST
Nutrients
• $N\text{-}NO_3$
• $N\text{-}NH_4$
• P


"Fresh" OM
$(H_2O)_v$, CO_2 , NH_3 , …
Stable OM
Microbial activity
(heat + H_2O + CO_2)
Compost Mix
O_2



(Source: ISPRA – Waste report 2009)

Organic waste treated in Italy in 2006: *ca.* 3,200,000 t
(source: Rapporto Rifiuti APAT-ONR 2007)



Compost *vs.* peat

	Peat moss	Optimal growing media	Green compost	Biowaste compost
Bulk density (g cm^{-3})	0.06-0.1	0.15-0.50	0.35	0.40
Total porosity (% vol:vol)	>96	>85	82.3	81.3
Air capacity (% vol:vol)	45-50	20-30	28.9	29.9
Available water (% vol:vol)	24-40	24-40	13.8	15.7
pH	2.5-3.5	4.5-6	7.8	8.1
EC (mS m^{-1})	200-1600	<2100	980	3730
CEC (meq l^{-1})	148.1	100-1000	236.7	173.5

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Can we build better compost? Use of waste drywall to enhance plant growth on reclamation sites

M. Anne Naeth*, Sarah R. Wilkinson

Department of Renewable Resources, Room 751 General Services Building, University of Alberta, Edmonton, Alberta, T6G 2H1 Canada

In agricultural soil and clean fill, biosolids composts with 15% coarse and 18% ground drywall improved native grass response, particularly biomass, relative to biosolids compost without drywall. Drywall manure composts reduced native grass response relative to manure compost without drywall.

Greenhouse research shows that **drywall composts have potential as soil amendments for reclamation**, especially to **low quality soils**. Drywall waste added to biosolids or manure during composting had no detrimental effects on H. vulgare, A. trachycaulum and F. saximontana.

Drywall biosolids compost enhanced native grass response, particularly biomass. Response of native grasses to drywall manure composts were less favourable than to manure compost without drywall. High electrical conductivity in drywall manure compost may prevent its use in reclamation.

Compost rate significantly affected plant biomass in agricultural soil and reduced performance of native species at highest application rates suggesting a threshold beyond which conditions are compromised for revegetation. Grinding drywall does not significantly improve plant performance and use of coarse drywall would eliminate the need for specialized equipment and resources.

Drywall composts are appropriate soil amendments for establishment of native and non native plant species on reclamation sites but substrate properties and plant species tolerances will need to be considered in developing the drywall composts.

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Almond tree and organic fertilization for soil quality improvement in southern Italy

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Evaluate soil quality under different practices of bio-physical amelioration which involve the soil-plant system (<u>almond trees</u>) and <u>microorganism-manure</u> (Pantanello farm).

Two types of fertilization (mineral and organic) and three slope gradients (0, 2 and 6%), in order to evaluate the effects of management practices in resisting soil erosion.

The organic treatment affected soil microbiological and physicochemical properties by increasing soil nutrient availability, microbial activity, and improving soil structure.

The consistently **higher values of hydrolytic enzyme activities** often observed in the presence of plants and on the 0 and 2% slopes, suggested the stimulation of nutrient cycles by tree roots, which improve the conditions for soil microorganisms in carrying out their metabolic activity**. In the 6% slope** and, in particular, in the mineral fertilizer treatment, **soil metabolism was lower** as suggested by the dehydrogenase activity which was 50% lower than that found in the 0 and 2% slopes (related to a slowdown in the nutrient cycling and organic carbon metabolism). However, on this slope, in both mineral and organic treatments, **a significant stimulation of hydrolytic enzyme activities** and an improvement of soil structure were observed with plants compared to the control soil.

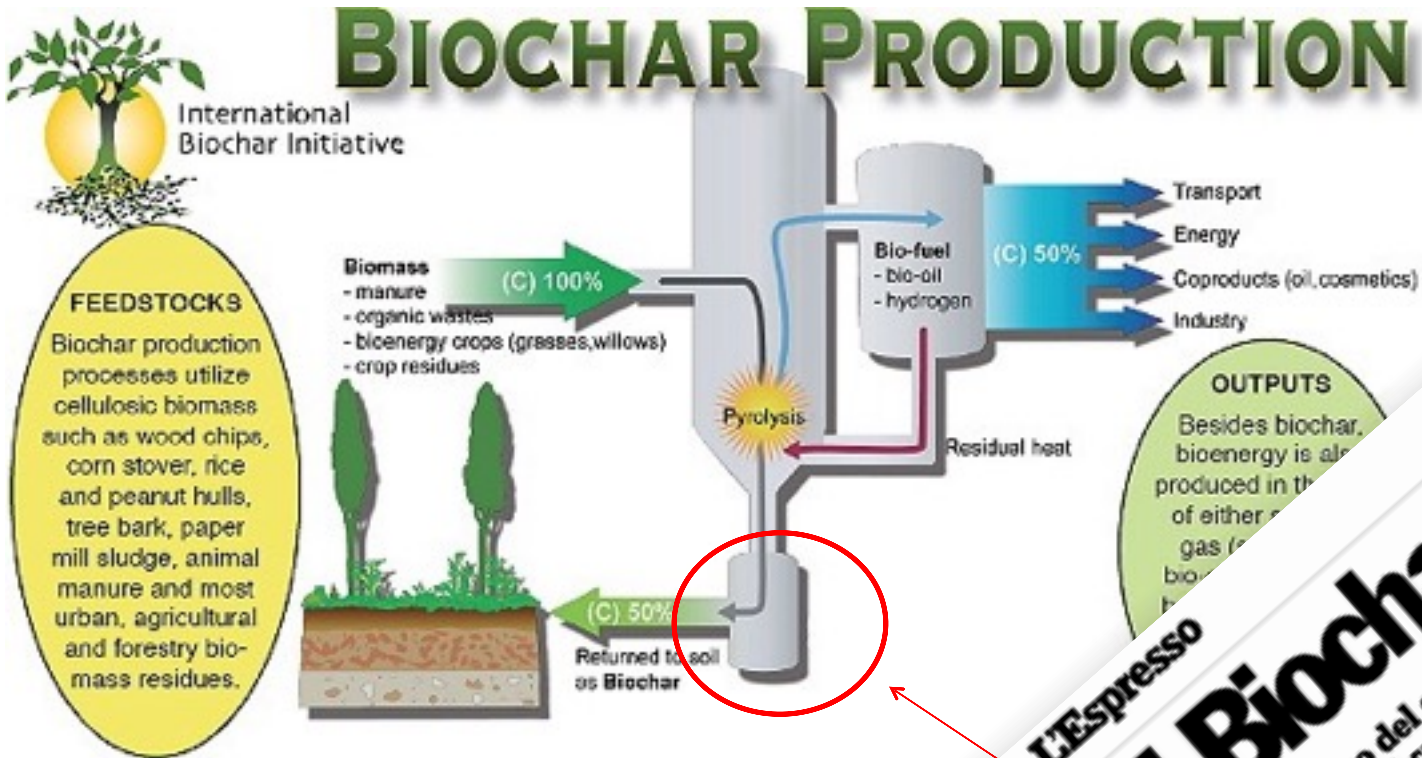
The **combination of organic fertilization and almond trees** resulted effective, also in the highest slope, in mitigating the degradation processes through the improvement of chemico-nutritional, biochemical and physical soil properties

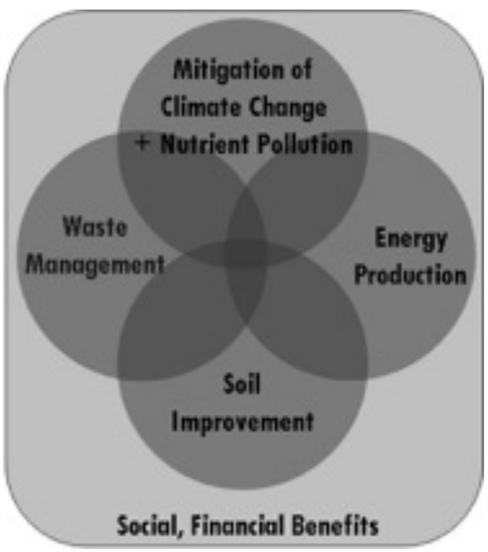
… Correct and "safe" use of organic wastes: olive mill wastewaters

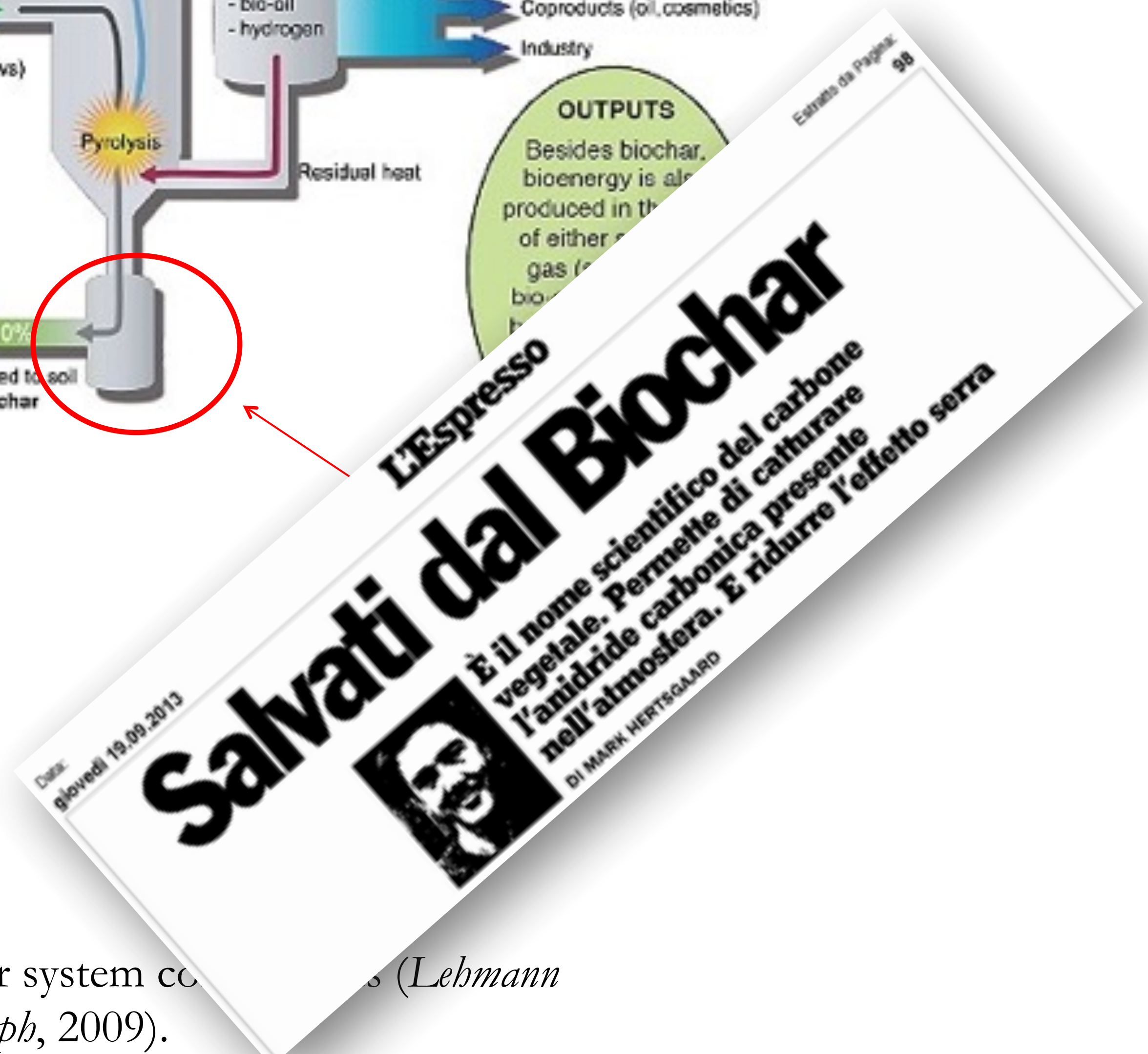
Traditional Mills

- Dark-brown color
- pH between 4.8 and 5.5
- Residual dry matter content, 10-17%:
  - 85-88% of the residual dry matter is composed of OM
  - 12-15% of the residual dry matter is inorganic materials (very rich in P and K)

… *Correct and "safe" use of organic wastes: biochar(s)*



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L'Espresso

Salvati dal Biochar

È il nome scientifico del carbone vegetale. Permette di catturare l'anidride carbonica presente nell'atmosfera. E ridurre l'effetto serra

DI MARK HERTSGAARD

Biochar system co… s (*Lehmann and Joseph*, 2009).

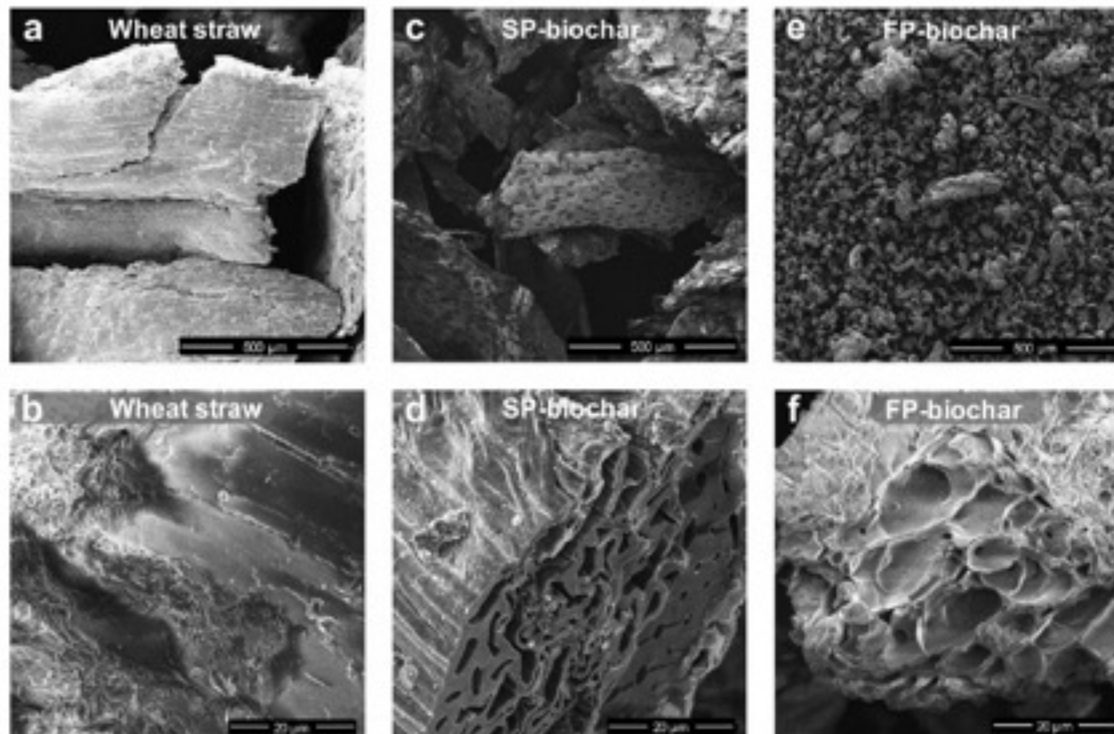
Table 2. Some chemical properties of biochars in different experiments

Biomass for producing biochar	Production (°C)	pH	C (g kg^{-1})	N (g kg^{-1})	P (m kg^{-1})	K (m kg^{-1})	Ca (m kg^{-1})	Mg (m kg^{-1})	CEC (cmol kg^{-1})
Corn residue	350	5.9	675	9.3	–	1040	270	–	610
Corn residue	600	6.7	790	8.2	–	670	310	–	215
Green waste	450	9.4	360	1.8	–	21[a)]	0.4[a)]	0.6[a)]	24
Wheat straw	350–550	9.5	467	5.9	–	2600	1000	600	–
Cow manure	500	9.2	34	1.5	8140	0.1[a)]	2.1[a)]	1.4[a)]	5
Wood residue	–	7.5	870	3.1	48[b)]	3.1[a)]	4.4[a)]	0.3[a)]	11
Wood	–	9.2	729	7.6	30[b)]	464	331	49	112
Hardwood	450	9.8	761	6.8	–	–	–	–	–
Pecan shell	700	7.5	834	3.4	263	415	3640	698	
Bamboo	600	8.2	681	8.7	–	–	–	–	–

a) Exchangeable nutrients (cmol kg^{-1}).
b) Available nutrients.

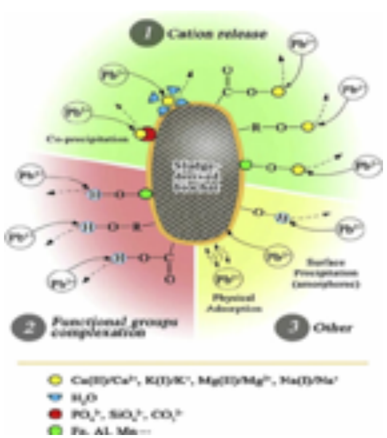
(from *Xu et al.*, 2012)

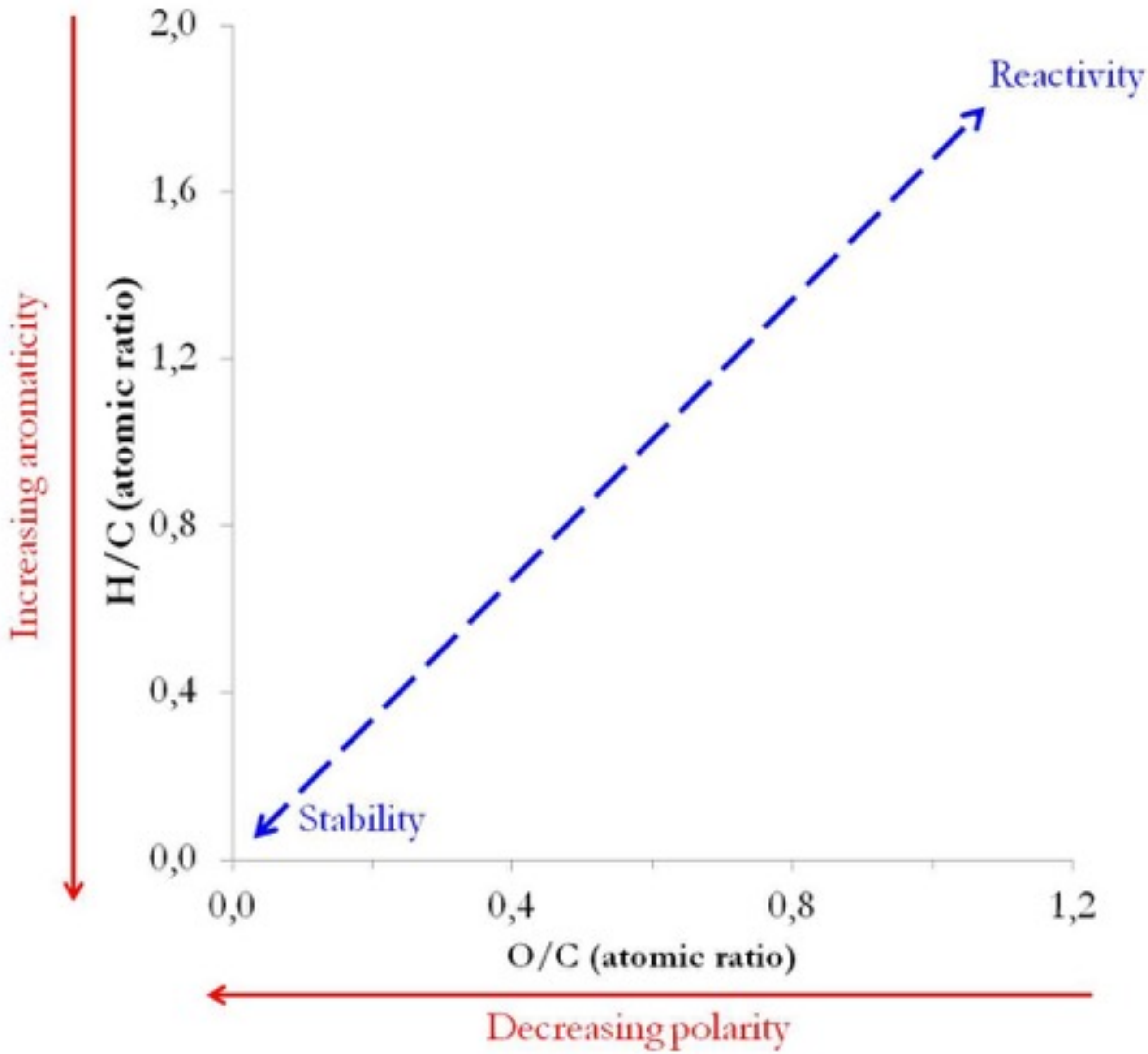
Biochar features are extremely variable, depending on …



Can biochar substitute natural OM?

How stable is biochar?





Can biochar replace soil organic matter **always** and **everywhere**?

… still several open questions !!!

Definition ?

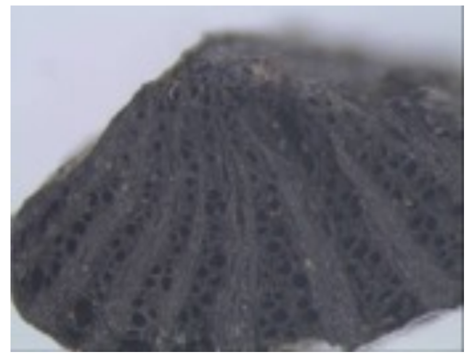
Structure ?

Stability ?

Toxicology (PAH) ?

…

Surface ?



Porosity ?

Hydrophobicity ?

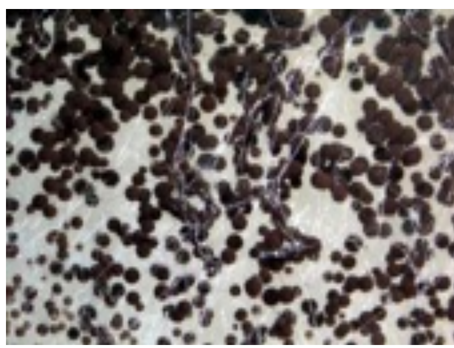
Mineral interaction ?

…

GHG-emission ?

Soil flora and fauna ?

Pathogens ?



…

Biodiversity ?

C storage?

Soil fertility ?

Plant yield ?

Nutrients (N cycle) ?

Erosion ?

Temperature ?

…

Soil water ?

Food Policy 36 (2011) S33–S39

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Sequestering carbon in soils of agro-ecosystems ☆

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Soils of the world's agroecosystems are depleted of their soil organic carbon (SOC) pool by 25–75% depending on climate, soil type, and historic management.

Soils with severe depletion of their SOC pool have low agronomic yield and low use efficiency of added input. Conversion to a restorative land use and adoption of **recommended management practices (RMP)**, can enhance the SOC pool, improve soil quality, increase agronomic productivity, advance global food security, enhance soil resilience to adapt to extreme climatic events, and mitigate climate change by off-setting fossil fuel emissions.

The strategy is to create positive soil C and nutrient budgets through adoption of **no-till farming** with mulch, use of cover crops, integrated nutrient management including biofertilizers, water conservation, and harvesting, and improving soil structure and tilth.

Thus, the objective of this article is to describe potential and challenges of C sequestration in soils of the world’s agroecosystems.

The strategy is to increase **soil resilience**, enhance adaptation to extreme events, and mitigate climate change by off-setting emissions through soil C sequestration.

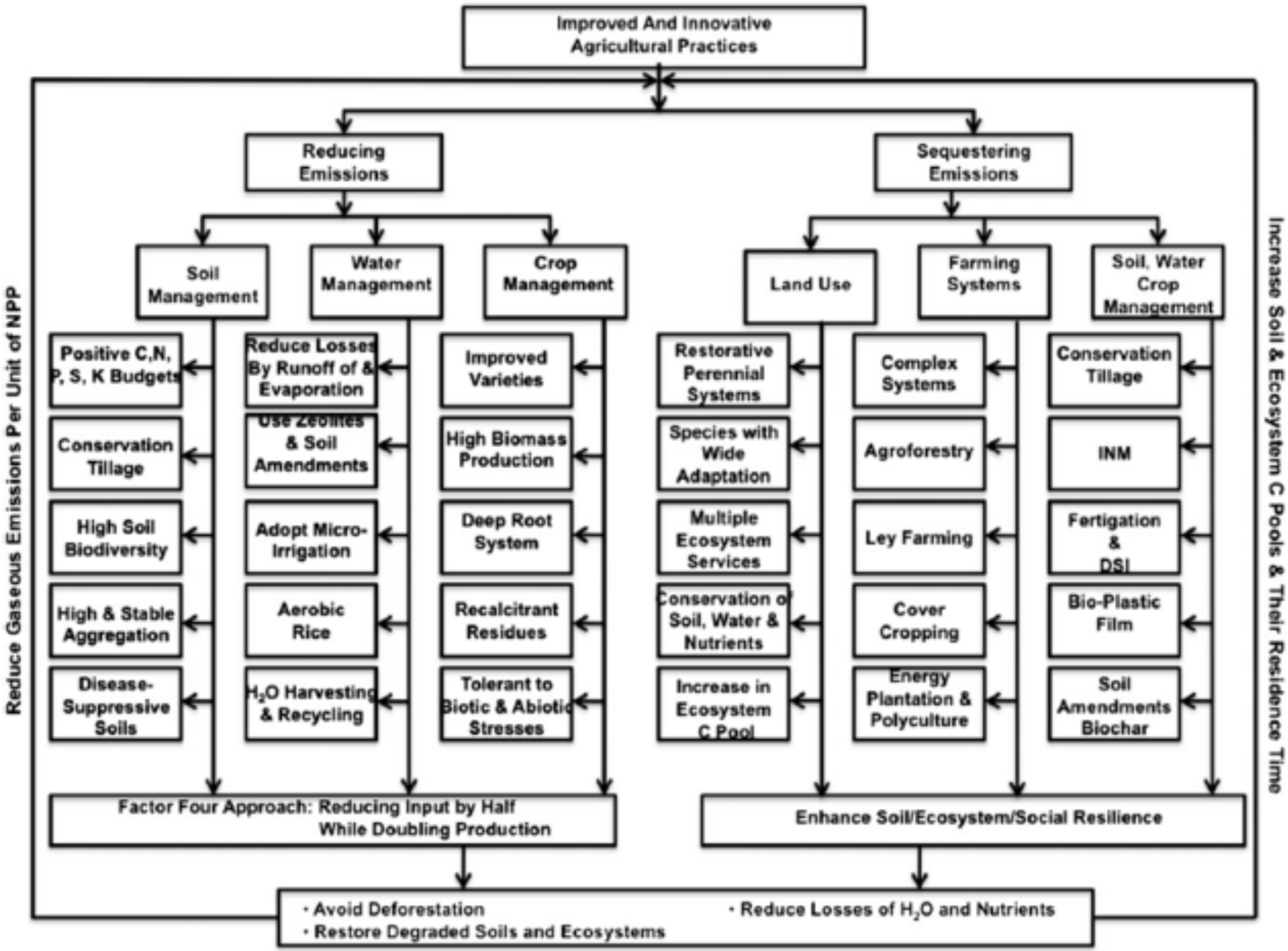

Fig. 2. Technological options to reducing emissions and sequestering emissions from agricultural ecosystems. It is a flow chart with multiple rectangular boxes. It is black and white.

The technical potential of carbon (C) sequestration in soils of the agroecosystems is **1.2–3.1 billion tons C/yr**.
Improvement in **soil quality**, by increase in the SOC pool of 1 ton C/ha/yr in the root zone, can increase annual food production in developing countries by 24–32 million t of food grains and 6–10 million t of roots and tubers.

Table 1
Technical potential of soil carbon sequestration in agroecosystems (Modified from Lal, 2004a, 2010a–d).

Agroecosystem	Land area (million ha)	Technical Potential (billion tons C/yr)
Croplands	1350	0.4–1.2
Savanna and grasslands	2900	0.3–0.5
Salt affected soils	955	0.3–0.7
Desertification control	3500	0.2–0.7
Total		1.2–3.1

Descriptions of agricultural recommended management practices (RMPs) for mitigation of climate change.

Table 3
Potential increase in food grains production in developing countries through adoption of RMPs which improve soil quality because of increase in SOC pool (Lal, 2006a).

Crop	Total increase in food grain production (million tons/yr)			
	Africa	Asia	Latin America	Total
Wheat	0.2–0.4	2.9–4.9	0.5–0.6	3.6–5.9
Maize	0.8–1.3	4.1–8.2	4.5–6.9	9.4–16.4
Rice	0.1–0.2	4.1–6.9	0.2–0.3	4.7–7.4
Sorghum	1.7–2.6	1.3–1.8	0.4–0.6	3.4–5.0
Millet	0.6–1.0	0.4–0.7	0.01–0.01	1.0–1.8
Beans	0.1–0.2	0.4–0.7	0.3–0.5	0.8–1.4
Soybeans	0.02–0.03	0.3–0.5	0.7–1.2	1.0–1.7
Total	3.5–5.7	13.5–23.7	6.6–10.1	23.6–39.5 (32 ± 11)

Soils are an important sink of CO_2 and CH_4 through conversion to a restorative land use and adoption of RMPs which create positive C and elemental (N, P, S, K) budgets.

Recarbonizing the pedosphere with a C sink capacity of > 2 billion tons C/yr for 25–50 years can have a strong impact on the global carbon cycle. Increasing the C pool of the pedosphere by 10% over the 21st century (+250 billion tons) can create a drawdown of 110 ppm of atmospheric CO2 abundance.

Being the foundation of agrarian societies, **soil restoration through sustainable management** is the engine of economic development, eliminating poverty, enhancing political stability and transforming rural communities in developing countries. Trading C credits would create another income stream for farmers.

If soils are not restored, crops will fail even if rains do not; hunger will perpetuate even with emphasis on biotechnology and genetically modified crops; civil strife and political instability will plague the developing world even with sermons on human rights and democratic ideals; and humanity will suffer even with great scientific strides.

The role of organic amendments in soil reclamation: A review

Francis J. Larney[1] and Denis A. Angers[2]

[1]Agriculture and Agri-Food Canada, 5403 1st Avenue S., Lethbridge, Alberta, Canada T1J 4B1; and [2]Agriculture and Agri-Food Canada, 2560 Boul. Hochelaga, Québec, Québec, Canada G1V 2J3.
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Larney, F. J. and Angers, D. A. 2012. **The role of organic amendments in soil reclamation: A review**. Can. J. Soil Sci. **92**: 19–38. A basic tenet of sustainable soil management is that current human activities are not detrimental to future

Humans have been **recycling organic matter** (livestock manure, human waste) through soils for centuries, with beneficial effects on soil fertility and crop yield (enhancing chemical, physical and biological properties of degraded soils), **so the idea is not new**.

However, organic amendments are often negatively viewed as **waste products with undesirable features** (odour, excessive N and P, HMs, pathogens, toxins, etc.), potentially transportable to surface or ground waters by runoff or leaching. Many view such amendment practices as **merely using soil as a dumping ground** for agricultural or industrial waste products.

Soils are resilient and can benefit from diverting these products from increasingly burdened landfill sites.

Table 1. Mean elemental content and C:N ratio of organic amendments commonly used in land reclamation

Amendment	Carbon	Nitrogen	Phosphorus	C:N ratio
	(g kg^{-1}, dry wt.)			
Beef feedlot manure				
Fresh (Larney et al. 2003a)	292	16.5	5.6	17.7
Compost (Larney et al. 2003a)	196	17.4	3.4	11.3
Pig manure (Zanuzzi et al. 2009)	320	21.7	ND[z]	14.7
Alfalfa hay (Larney et al. 2003a)	449	23.8	0.2	18.9
Wheat straw (Larney et al. 2003a)	453	8.6	0.6	52.6
Paper deinking sludge (Fierro et al. 1999)	382	3.4	0.3	112.4
Sewage sludge (Zanuzzi et al. 2009)	340	50.5	ND	6.7

[z]ND, not determined.

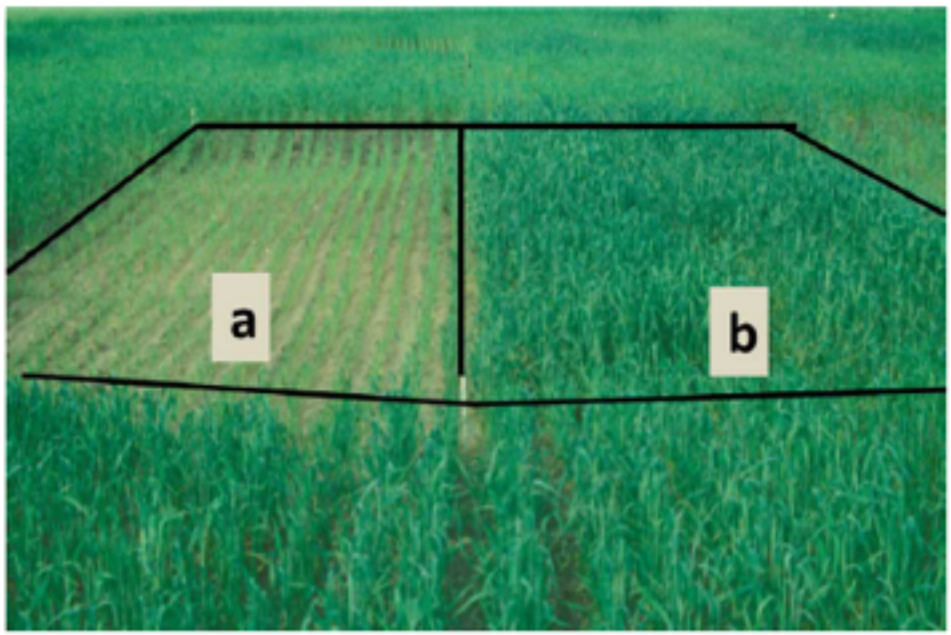

Fig. 2. Productivity of spring wheat plots (3×10 m) following 20 cm of topsoil removal at Hill Spring, Alberta, July 17, 1991. (a) Check treatment (no amendment); (b) Manure treatment (75 Mg ha^{-1}, wet wt. cattle manure). See Larney et al. (2000b) for further details, including crop yields.

Table 2. Ranking of 20 topsoil replacement depth × amendment treatments in the order of highest to lowest reclamation capacity, at three well sites in south central Alberta[z]

Ranking	Topsoil replacement depth (%)	Amendment	Reclamation capacity (%)[y]
1	100	Compost	119 (±5)[x]
2	150	Manure	113 (±6)
3	150	Compost	112 (±5)
4	150	Alfalfa	110 (±8)
5	50	Compost	109 (±7)
6	50	Manure	108 (±7)
7	100	Manure	107 (±3)
8	100	Alfalfa	107 (±6)
9	150	Check	103 (±5)
10	100	Check	100 (±0)[w]
11	50	Alfalfa	100 (±8)
12	0	Manure	99 (±6)
13	0	Compost	95 (±5)
14	150	Straw	94 (±4)
15	0	Alfalfa	91 (±6)
16	50	Check	90 (±3)
17	100	Straw	85 (±4)
18	0	Check	83 (±4)
19	50	Straw	79 (±6)
20	0	Straw	64 (±5)

[z]From Larney et al. (2003a).
[y]Based on biomass yields (10 site years) or grain yields (2 site years).
[x]Standard error of the mean in parentheses.
[w]100% topsoil replacement depth – check = baseline treatment set at 100%.

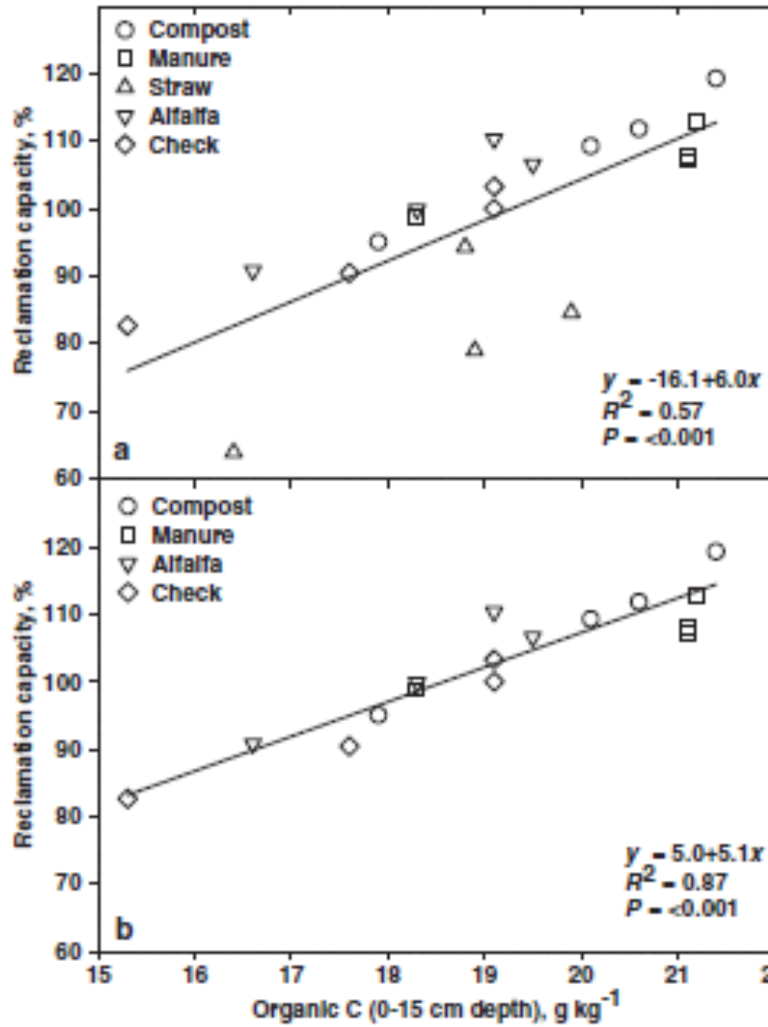

Fig. 3. Relationship between soil organic carbon (0 to 15 cm depth, average of three well sites, fall 2000) and reclamation capacity (Table 2) using (a) all 20 topsoil replacement depths × amendment treatments; (b) 16 topsoil replacement depths × amendment treatments (straw amendment omitted). Adapted from Larney et al. (2005) using re-analyzed soil organic carbon data.

More decomposable organic amendments may have more intense but shorter-term effects, while recalcitrant materials may be less intense but longer lasting. **However, in reclamation, no one solution fits all**, and research should be carried out to test various organic amendments in as many soils, climates and end land uses as possible.

Future research on the role of organic amendments in land reclamation could focus on:

- Single high rates of organic amendments vs. repeated low rates over several years.
- Soil overloading with nutrients or contaminants especially as it relates to water quality.
- Nutrient dynamics, such as P release and immobilization.
- Soil genesis mechanism following organic amendment incorporation, such as creation of new organomineral complexes.
- Economic analyses on long distance transport of organic amendments for reclamation purposes.
- Life cycle analyses, carbon footprints and overall impacts on greenhouse gas emissions from utilization of organic amendments in reclamation.

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REGULAR ARTICLE

Long-term effects of organic amendments on the recovery of plant and soil microbial communities following disturbance in the Canadian boreal forest

Aria S. Hahn · Sylvie A. Quideau

The use of forest floor material (FFM) as an organic amendment resulted in a greater percent cover of upland vegetation and placed the soil microbial community on a faster trajectory towards ecosystem recovery than did the use of a peat amendment. The soil microbial composition within the reclaimed sites exhibited a greater response to changes in moisture than did the soil microbial communities from natural sites.

Importance of native organic matter and vegetation for reconstructing soils.

The use of **Forest Floor Material** as a soil organic amendment has been shown to be advantageous in terms of native upland forest vegetation establishment and survival when reclaiming sites in northeastern Alberta.

The use of FFM also promoted the development of soil microbial communities more similar to those found on natural forest stands than did the use of organic materials salvaged from surrounding peatlands.

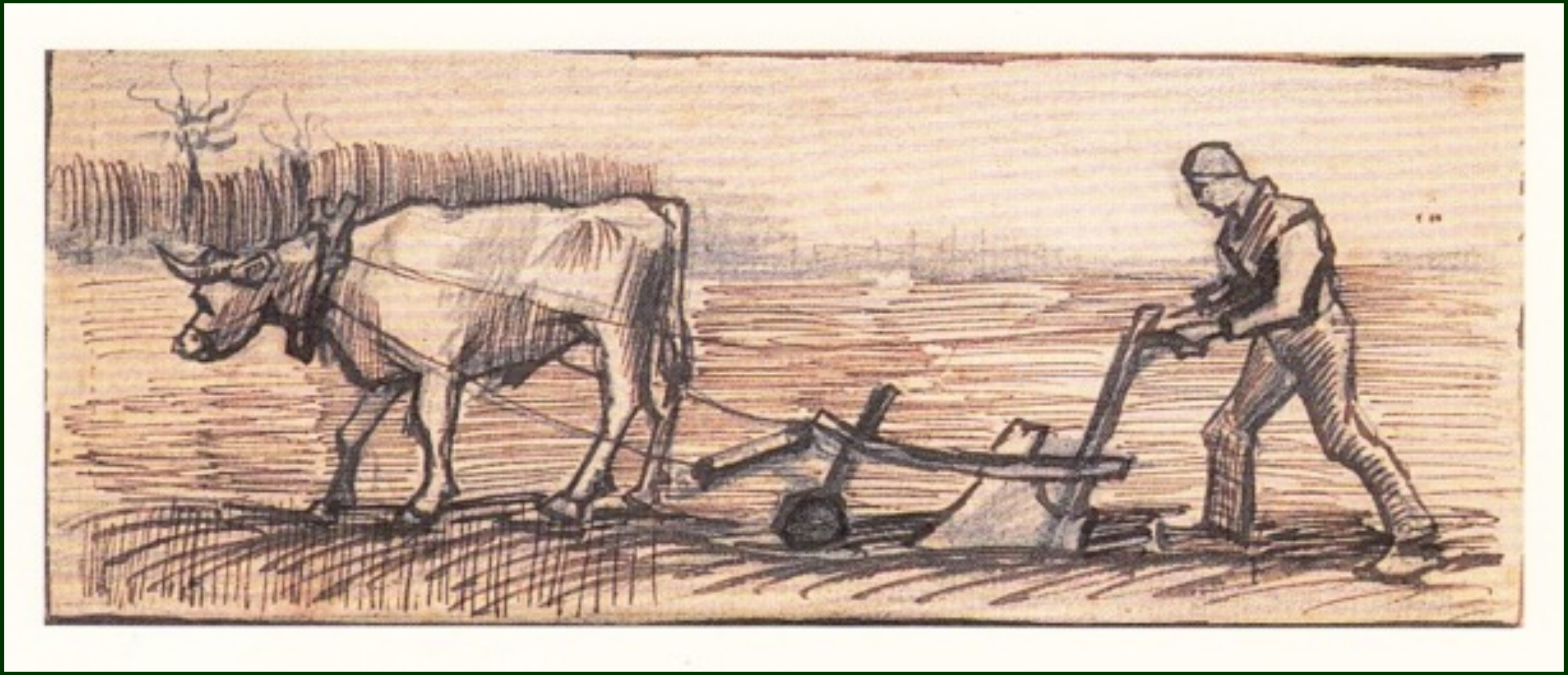
Thus, the accelerated development of the "natural" soil microbial communities may be linked to the similarities in plant communities found between these plots and the natural forest reference stand.

BUT the time needed to reach ecosystem recovery at these sites will extend well beyond a decade, or alternatively, suggests that soil microbial composition may never return to pre-disturbance composition.

Political stability and global peace are threatened because of soil degradation, food insecurity, and desperateness. The time to act is now.

(Lal, 2008)

Università degli Studi di Bari Aldo Moro



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