III° International Course

Soil organic matter management: the relationship with cropping systems and cover crops Principles and keys for action

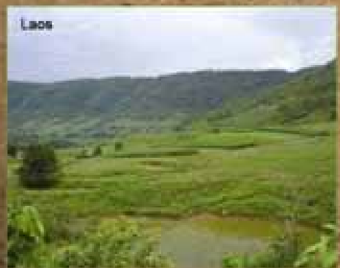
Realização

Universidade Estadual de Ponta Grossa
Departamento de Ciência do Solo e Engenharia Agrícola

Centre de Coopération Internationale en Recherche Agronomique pour le Développement

Apoio

Escritório de Assuntos Internacionais

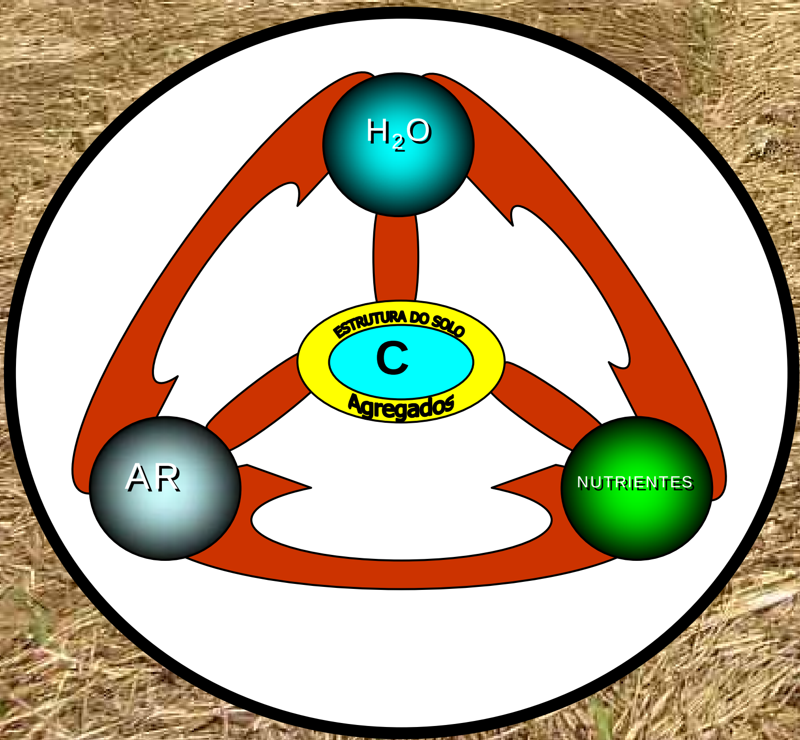


Ponta Grossa, November 03th to 20th, 2008

General Coordinator: Prof. Dr. João Carlos de Moraes Sá

UEPG The Soil Organic Matter Team

Our mission



UEPG The Soil Organic Matter Team

Our mission

Our research findings on soil organic matter dynamics provide some innovative concepts on soil organic C and N formation and storage.

We have developed procedures for particle size fraction of the soil organic matter. We understand that the two most labile fractions are more sensitive to environmental changes and management practices than the total soil organic matter.

The significance of these findings is that we will be better able to assess the long-term changes in soil organic matter as a result of climate, and management, and associate with cropping systems in no-till.

Outline

- ✓ The general overview in Conservation Tillage and cover crops
- ✓ The origin of Soil Organic Matter
- ✓ Chronological evolution of the the Soil Organic Matter study
- ✓ The crop residues and animal detritus transformation to the Soil Organic Matter
- ✓ The global carbon cycle
- ✓ The carbon pool’s


Soil Conservation tillage for
Sustainable Agriculture
General overview

Goiás (1988)

Lucien Seguy

Talking about soil profile and management

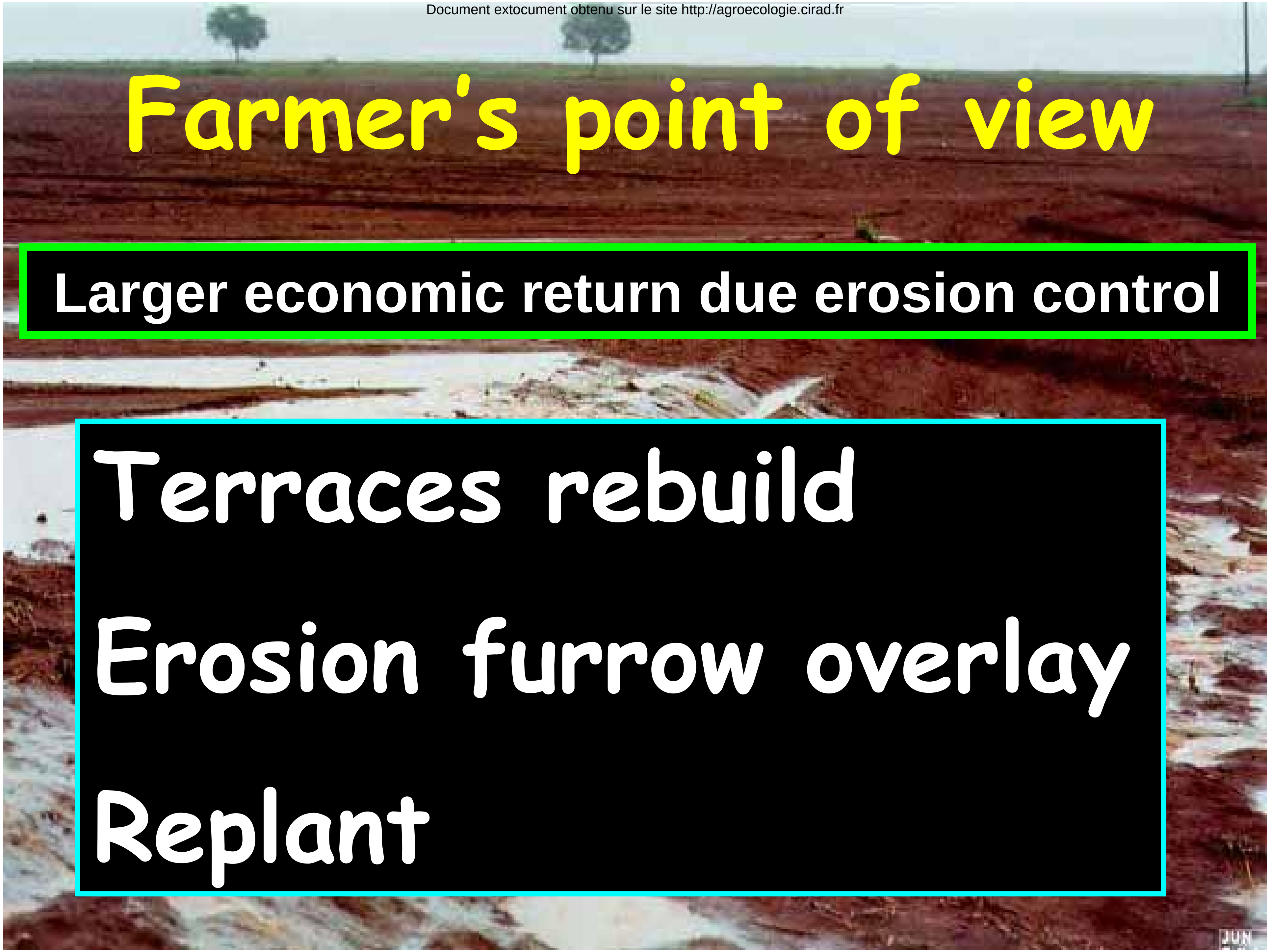

C losses by
conventional tillage
associate with
monoculture


The brazilian experience
and the reasons to
adopt No-tillage

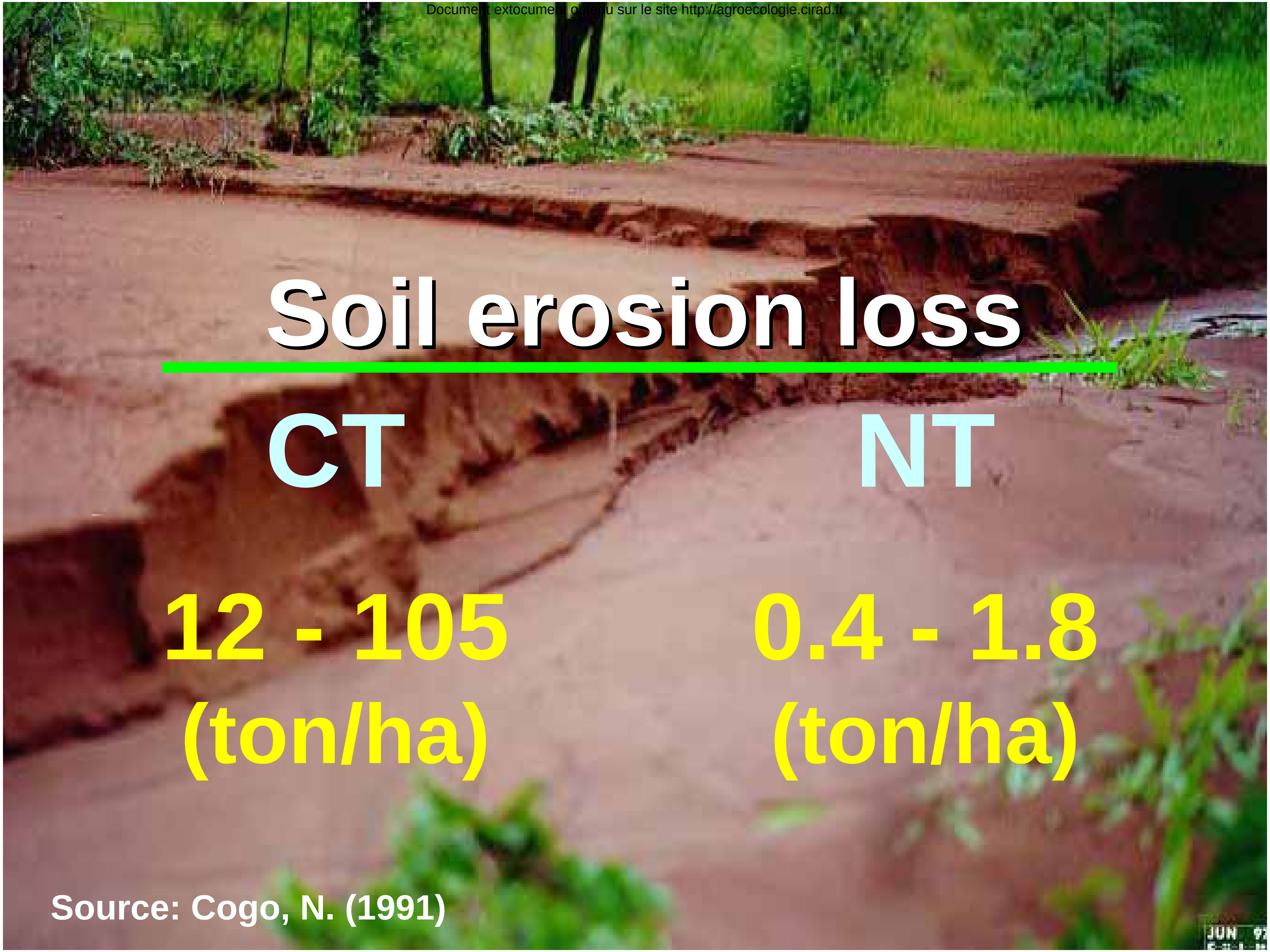
Why is no-tillage the key component of sustainable agricultural production ?

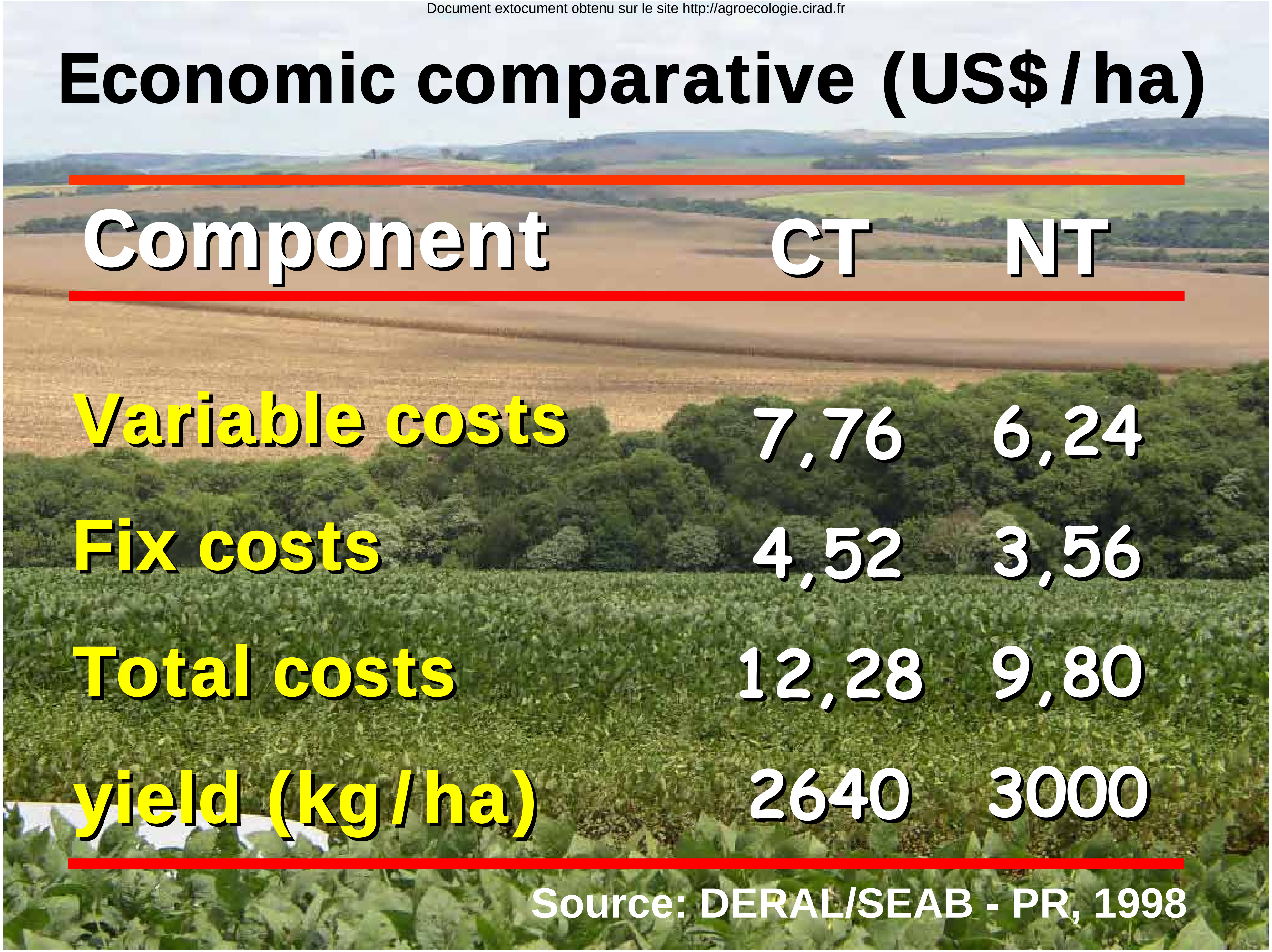
Farmer's point of view

- **Larger economic return due erosion control**
- **Cost planning**
- **Able to draw up a field program**


Farmer's point of view
Larger economic return due erosion control
Terraces rebuild
Erosion furrow overlay
Replant


Erosion soil loss in Brazil (1991)
= 1.3 billion ton/year
Source: Cogo, N., 1991


Soil erosion loss
CT
NT
12 - 105
(ton/ha)
0.4 - 1.8
(ton/ha)
Source: Cogo, N. (1991)

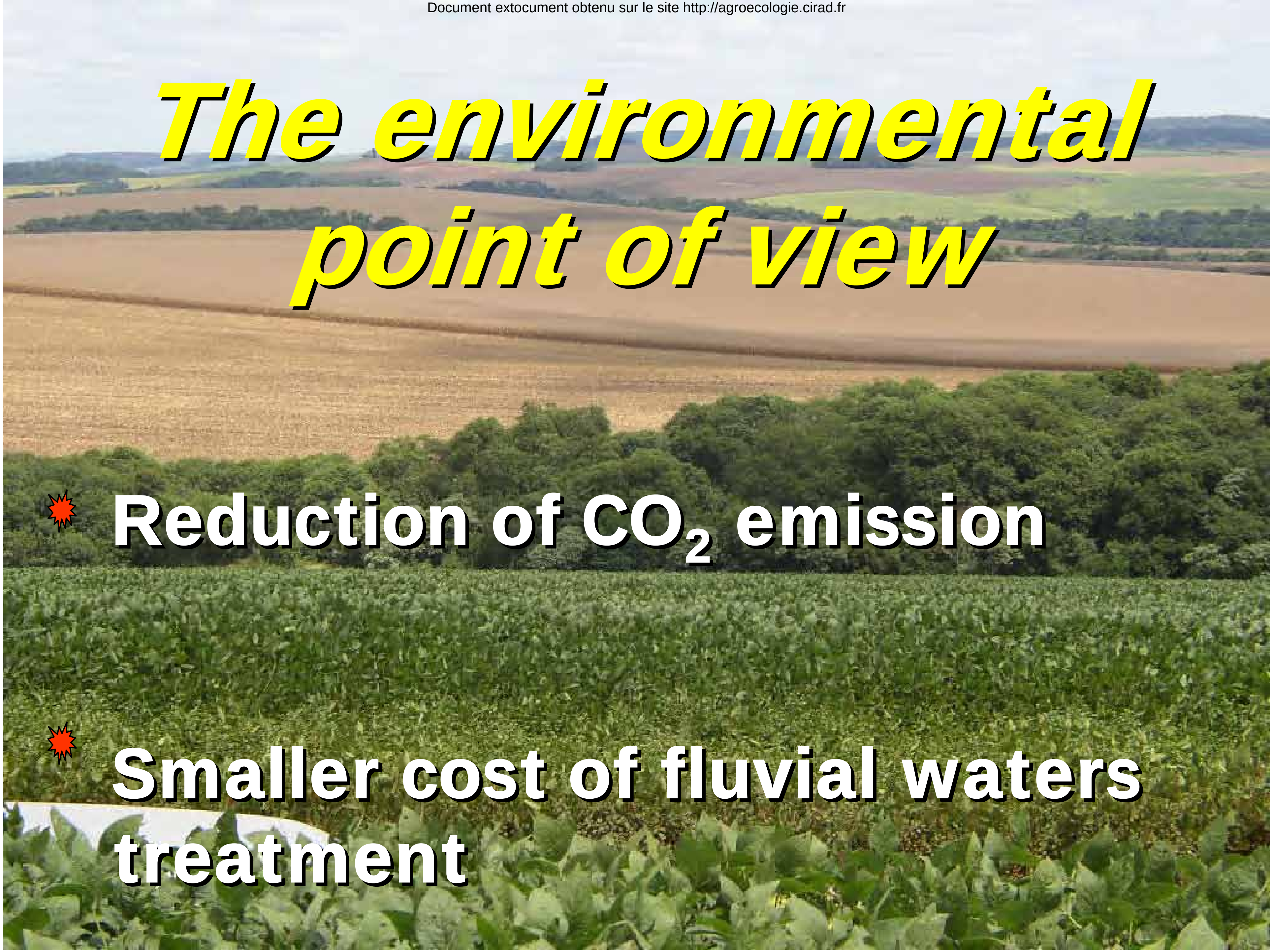


Economic comparative (US$/ha)

Component	CT	NT
Variable costs	7,76	6,24
Fix costs	4,52	3,56
Total costs	12,28	9,80
yield (kg/ha)	2640	3000

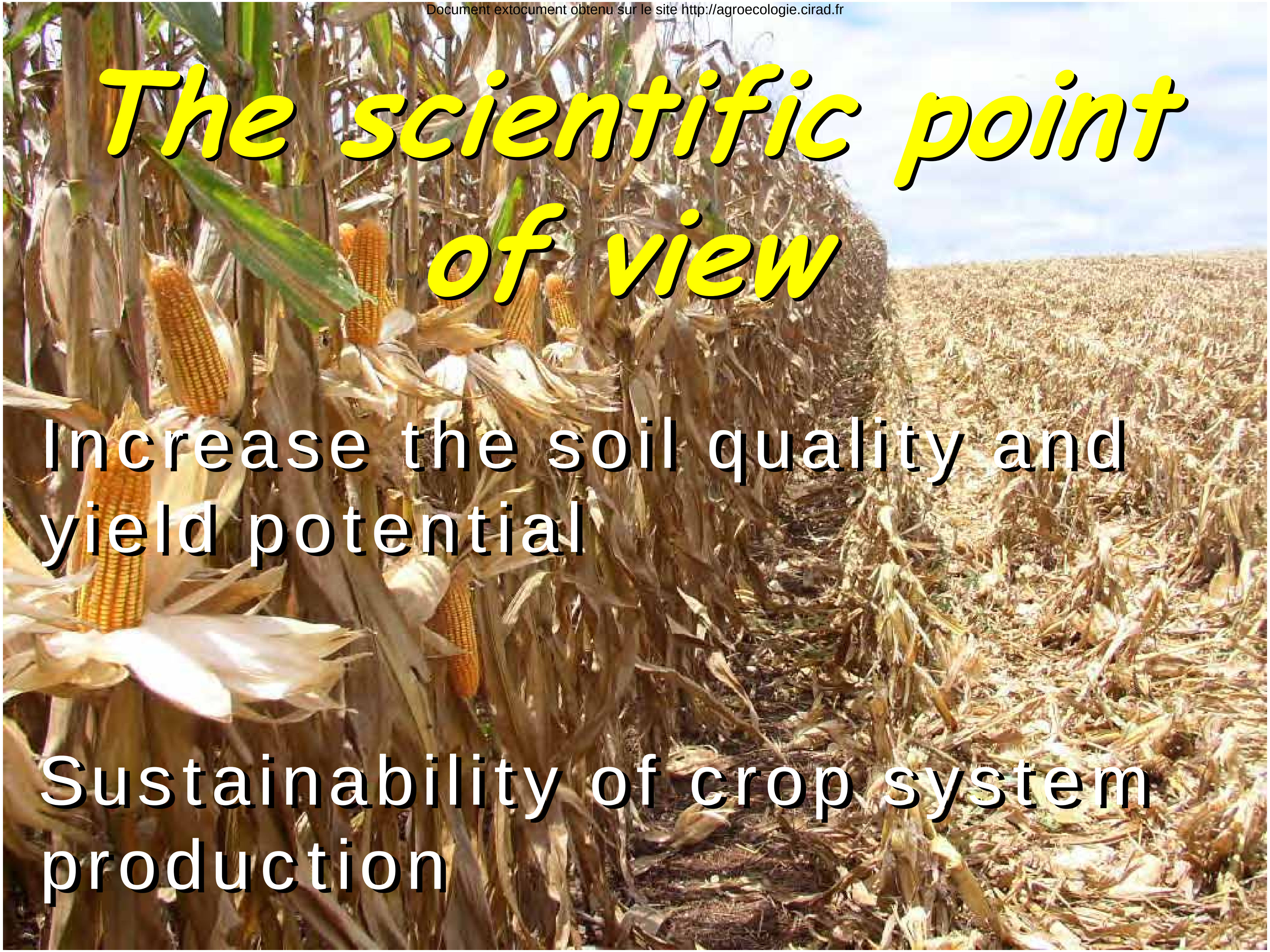
Source: DERAL/SEAB - PR, 1998


Money saved from ABC Foundation Farmer's - 140,000 ha (Paraná State) with soil fertility(1) and weed control(2) research program in no-tillage
Weed Control
Lime
N
P_2O_5
------------ x 1000 US$ --------
8,213.5
2,075.5
679.5
3,846.4
Total
14,814.9
(1) 1986 - 1996 (2) 1992 - 1996
US$ 105.8 / ha


The environmental point of view
Reduction of CO_2 emission
Smaller cost of fluvial waters treatment

The society point of view

- Rural and urban areas integration
- Reduction of air pollution
- Reduction of breathing diseases index
- Improvement of the life quality



The scientific point of view

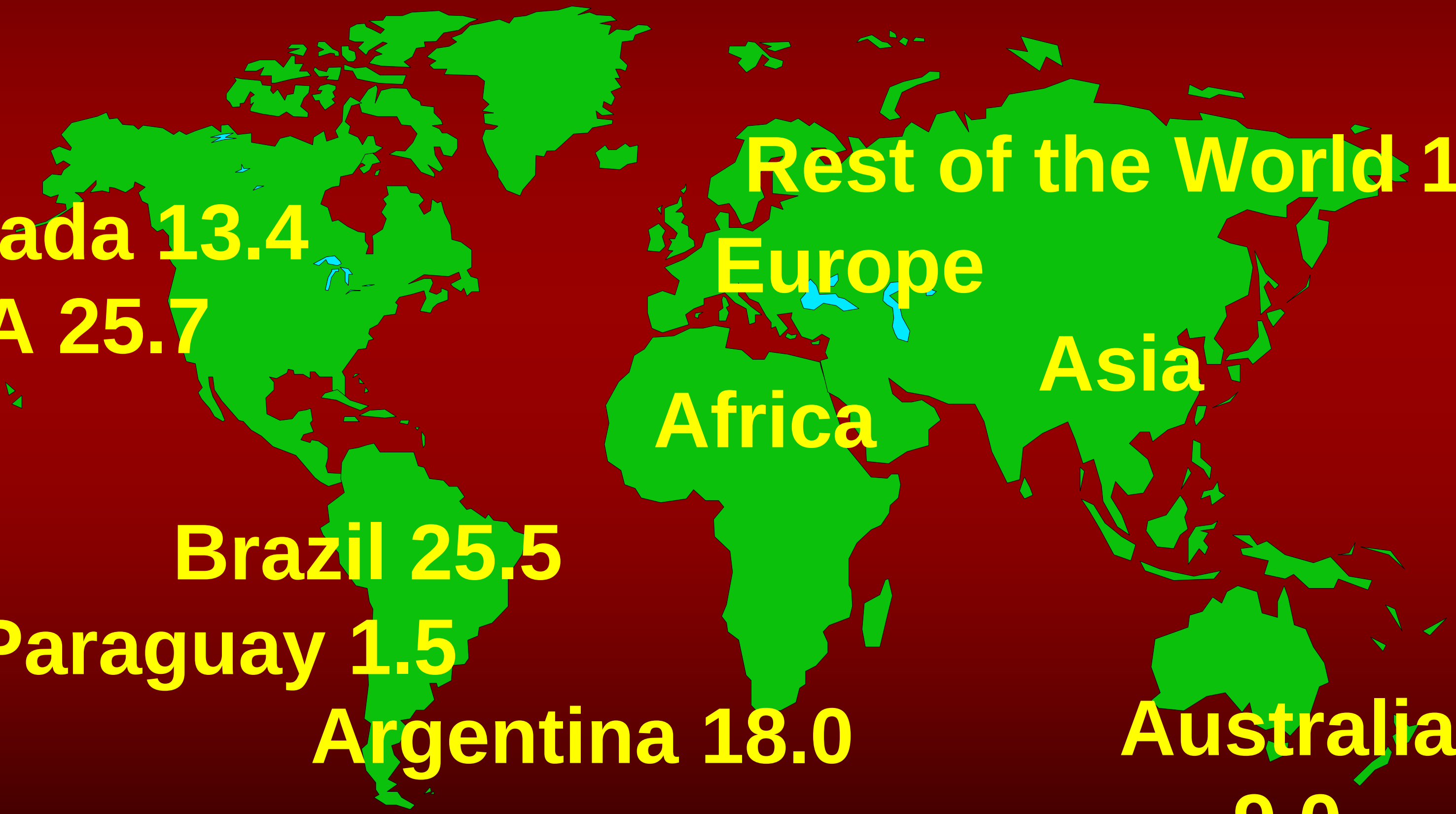
Increase the soil quality and yield potential

Sustainability of crop system production

World wide adoption of No-tillage 2006-07

(Million ha)

Total 95 Million ha



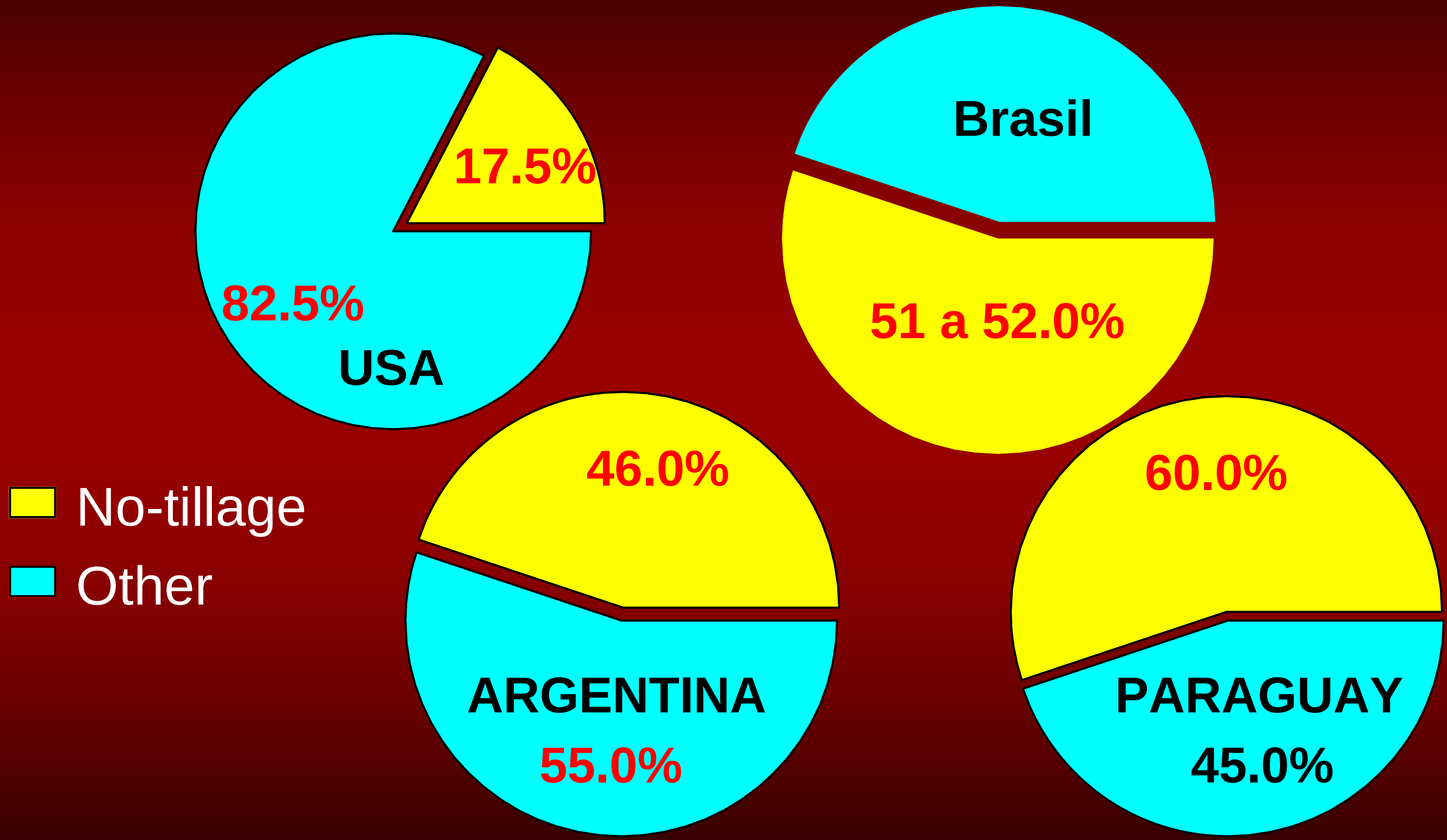
(Derpsch, 2005; and CAAPAS, 2008

84% of No-tillage is practiced in the Americas

(Total 95 Million ha)

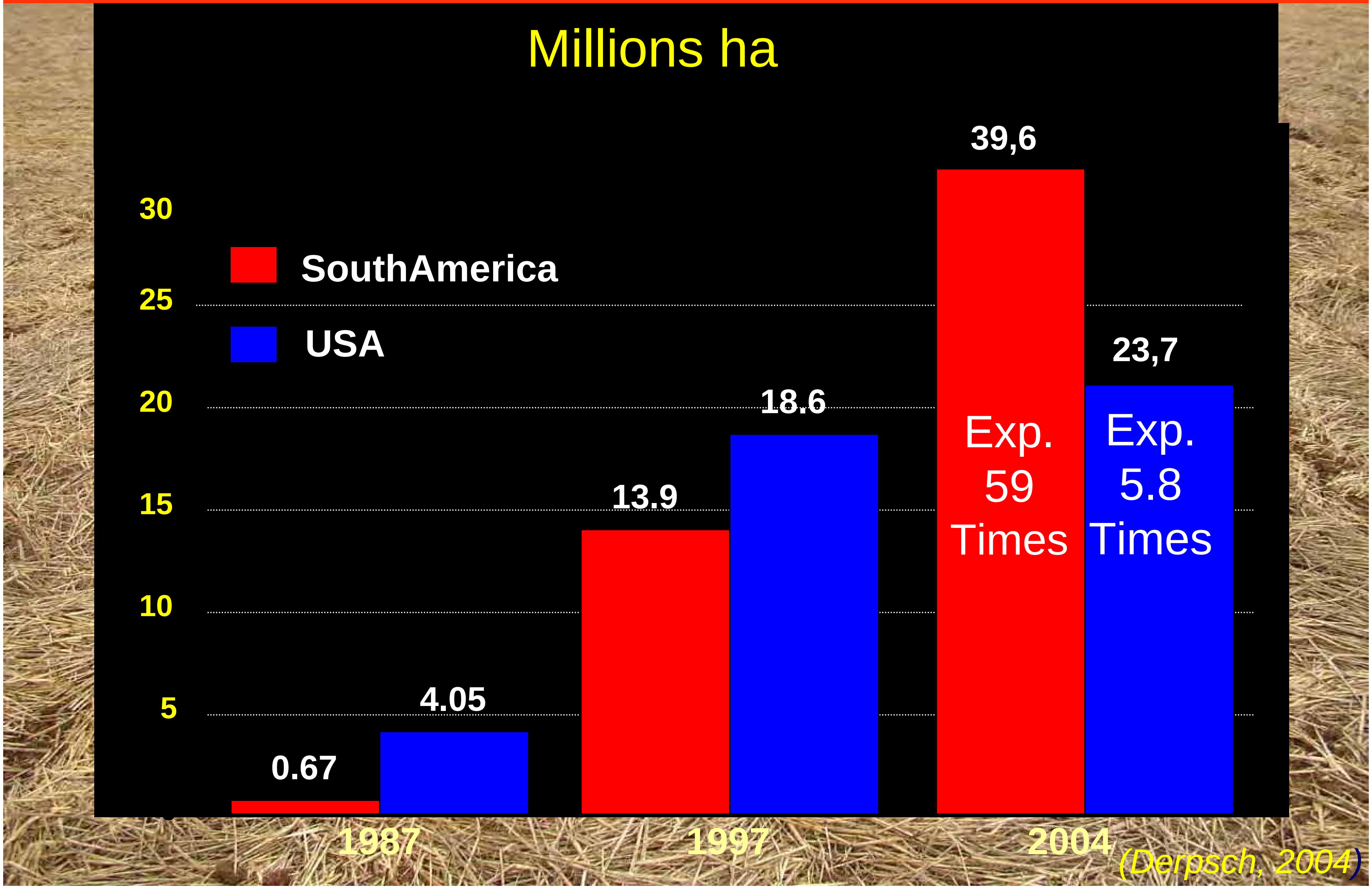
(Derpsch, 2005)

Percentage of No-till adoption in relation to total cultivated area



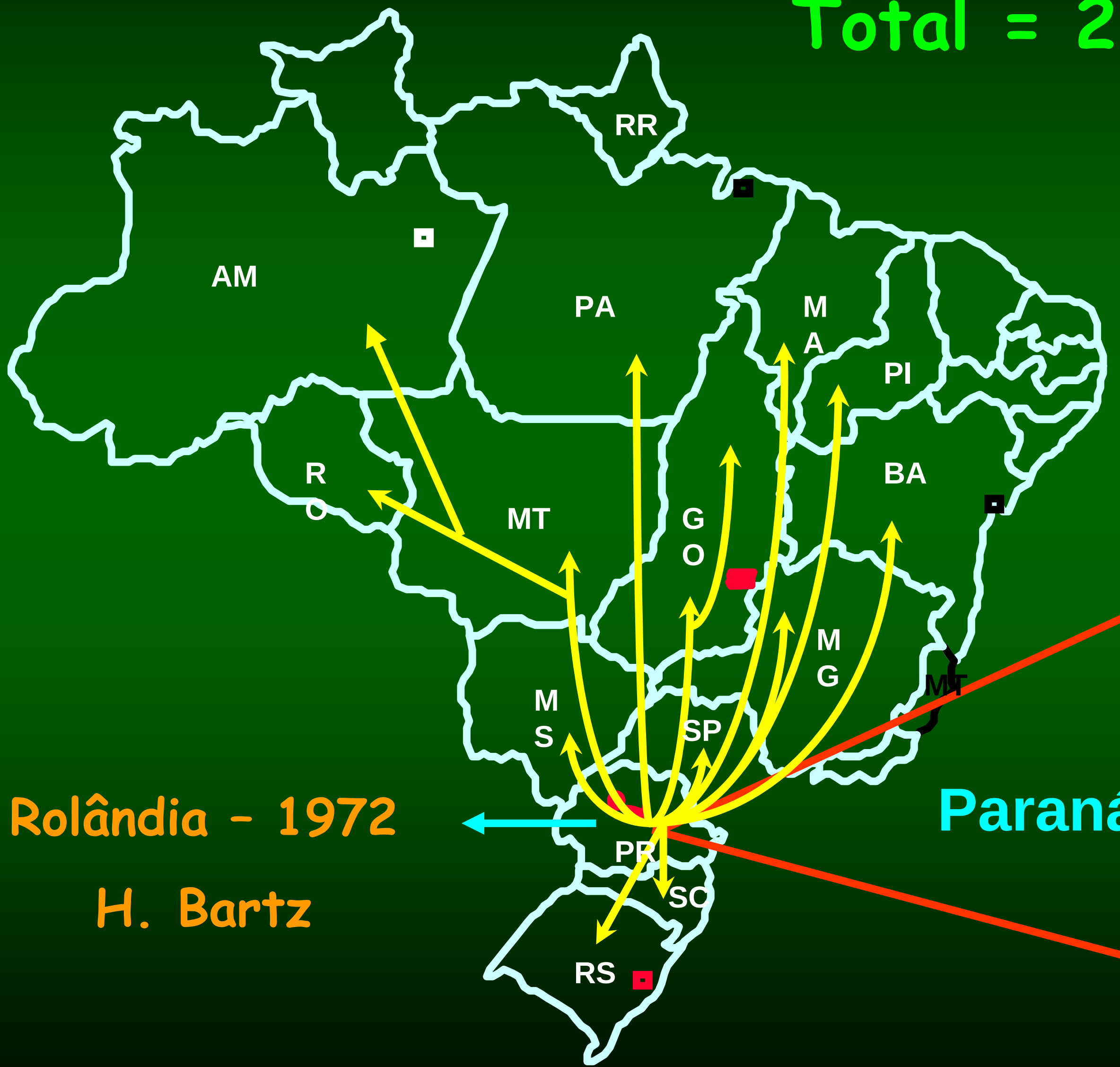
⇨ ***In Paraguay > 85% of mechanised agriculture is under no-tillage***

No-tillage increase in USA compared with SouthAmerica



No-tillage in Brazil

Total = 23.4 milllions ha



Rolândia – 1972

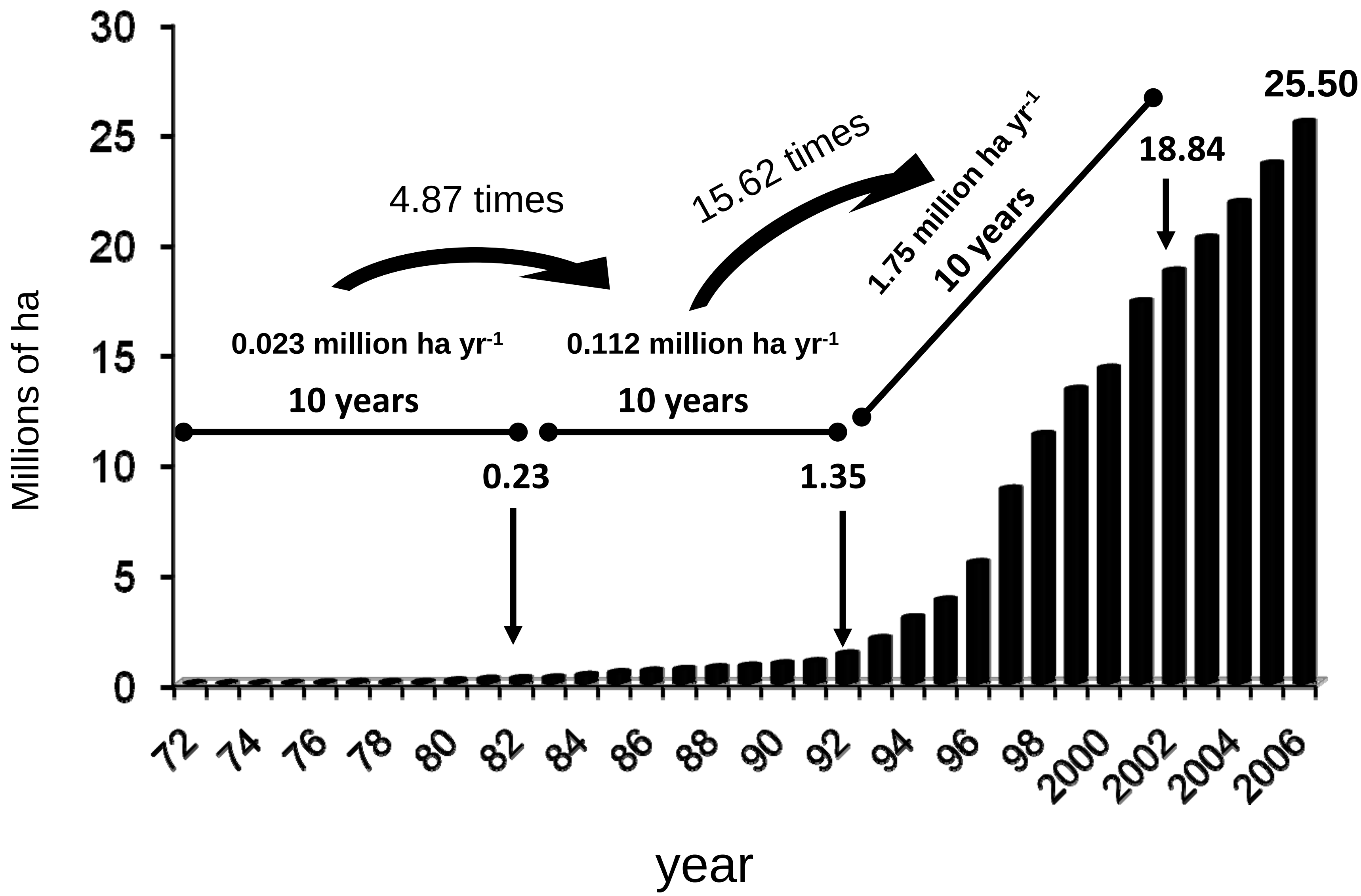
H. Bartz

Paraná

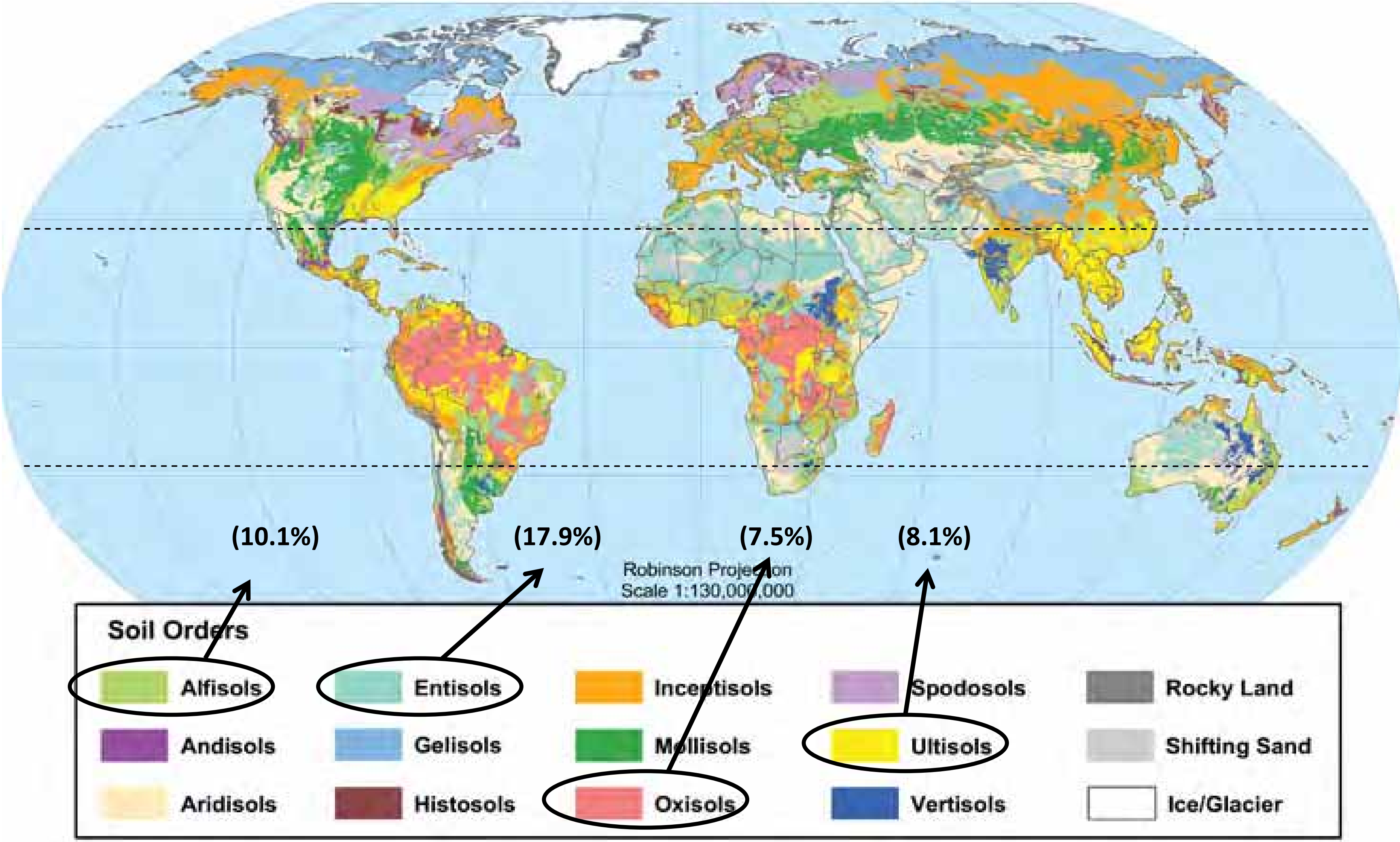
Ponta Grossa
Tibagi
Castro

Diffusion
Center

Expansion of No-till area in Brazil (1972 – 2006)



Global Soil Regions

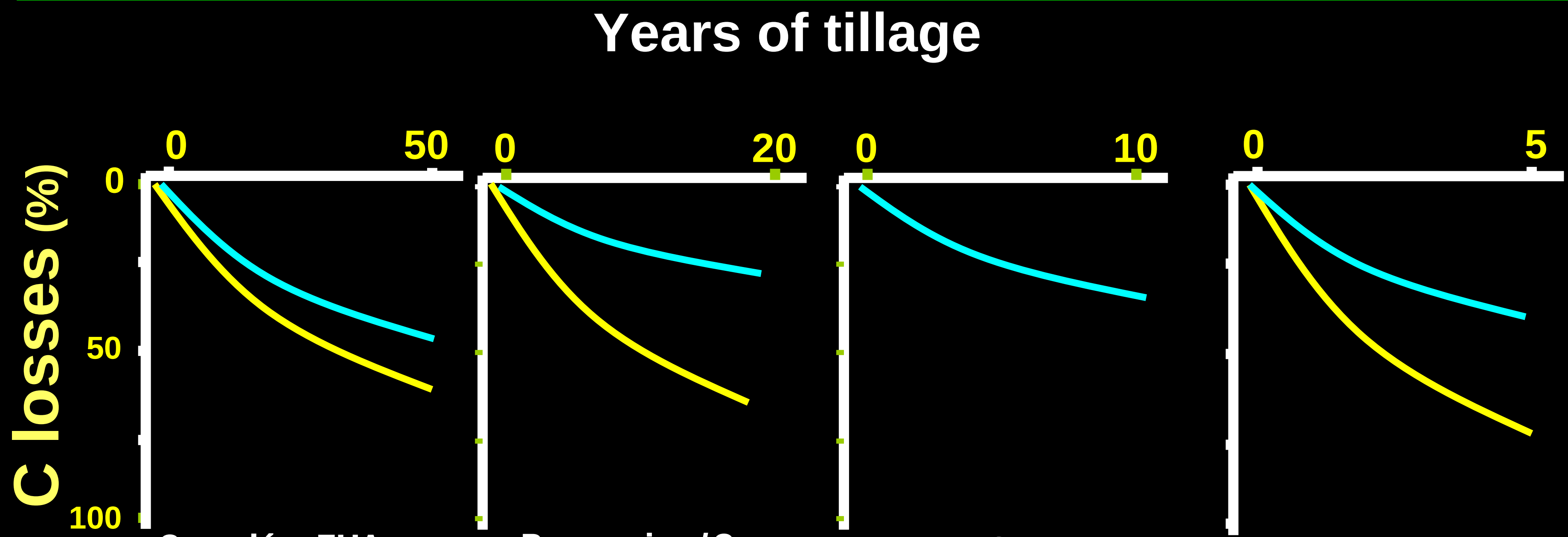


USDA NRCS US Department of Agriculture Natural Resources Conservation Service

Soil Survey Division
World Soil Resources
soils.usda.gov/use/worldsoils

November 2005

Impact of conventional tillage associate with monoculture in C losses intemperate, sub-tropical and tropical areas



Canadá – EUA
48 a 58 %
(Wheat)

Campbell & Souster, 1982; Mann, 1985

Latitude 42° N

Pergamino/C. Sarmiento-ARG
24-60 % (Wheat)

Michelena, 1989; Casas, 1998

Latitude 32° S

Ponta Grossa - PR
35 % (Soybean)

Sá et al., 2001

Latitude 25° S

Cerrado – GO; MT
35 a 69 %
(Soybean)

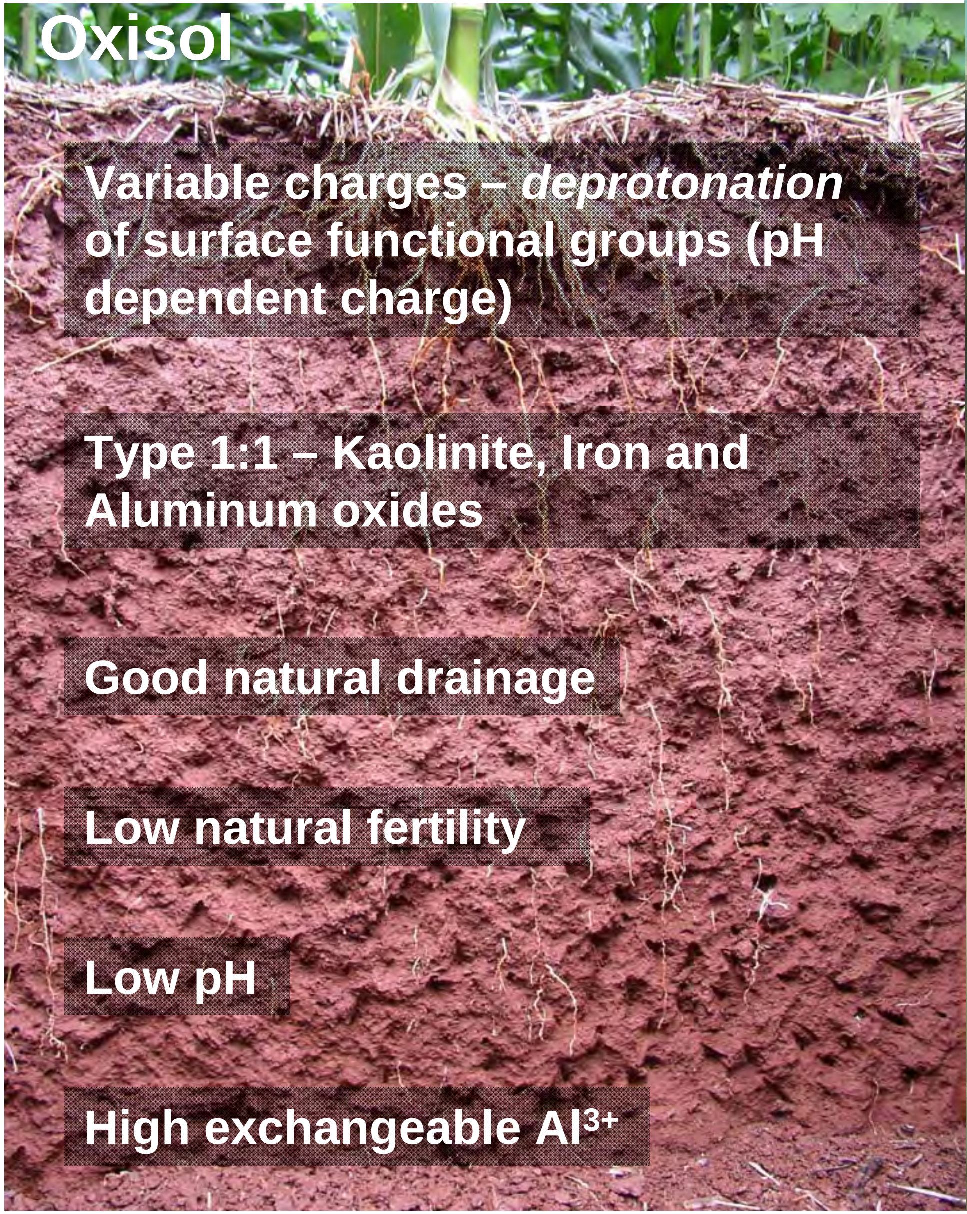
Resck, 1998

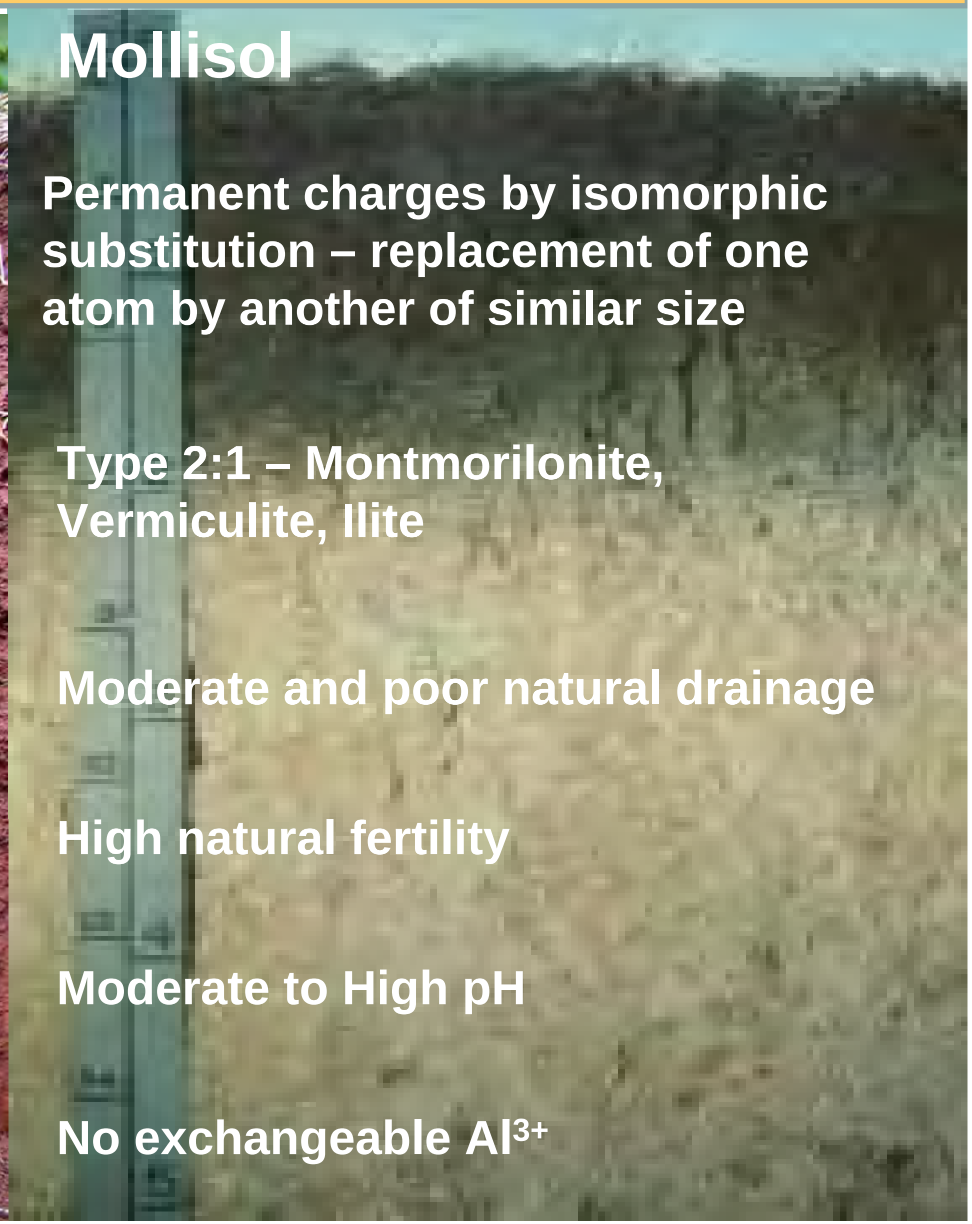
Seguy & Bouzinac, 2002

Latitude 13 a 16° S

0,96 a 1,2% aa | 1,2 a 3,0% aa | 3,5% aa | 7 a 13,8 % aa

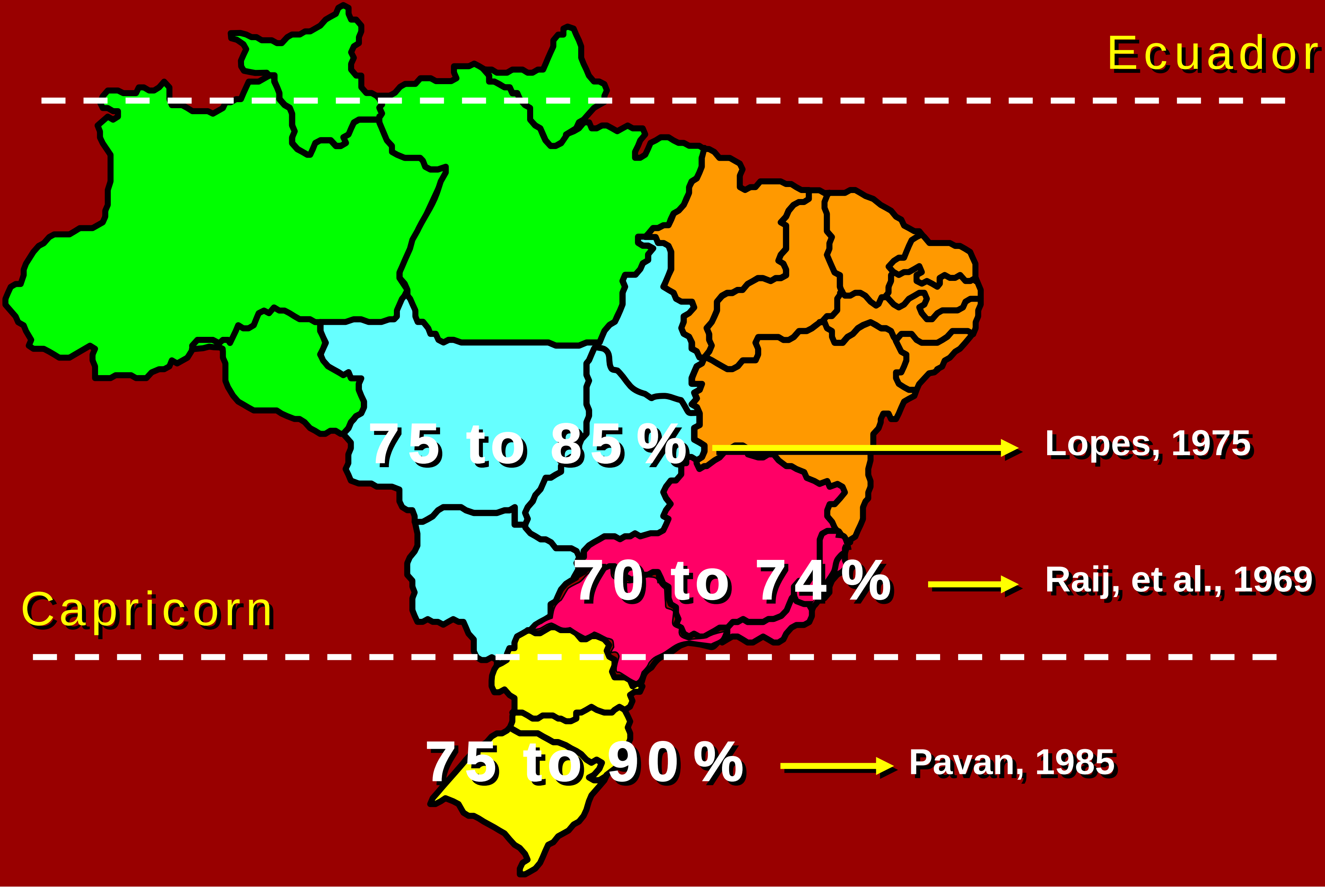
Main differences – Tropical and Temperate soils





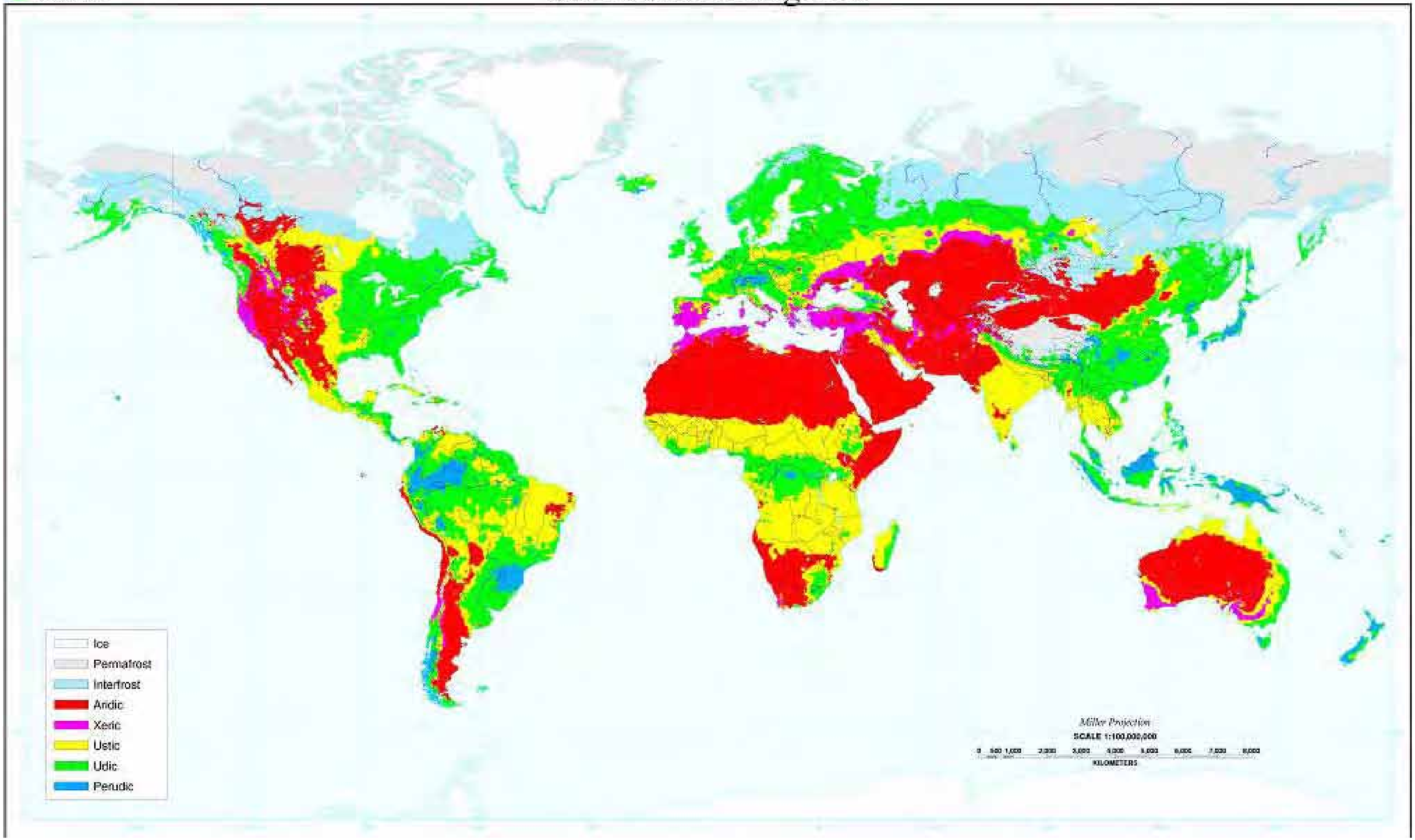
Oxisol	Mollisol
Variable charges – *deprotonation* of surface functional groups (pH dependent charge)	Permanent charges by isomorphic substitution – replacement of one atom by another of similar size
Type 1:1 – Kaolinite, Iron and Aluminum oxides	Type 2:1 – Montmorilonite, Vermiculite, Ilite
Good natural drainage	Moderate and poor natural drainage
Low natural fertility	High natural fertility
Low pH	Moderate to High pH
High exchangeable Al^{3+}	No exchangeable Al^{3+}

% of the CEC due to the soil organic matter in Brazilian soils



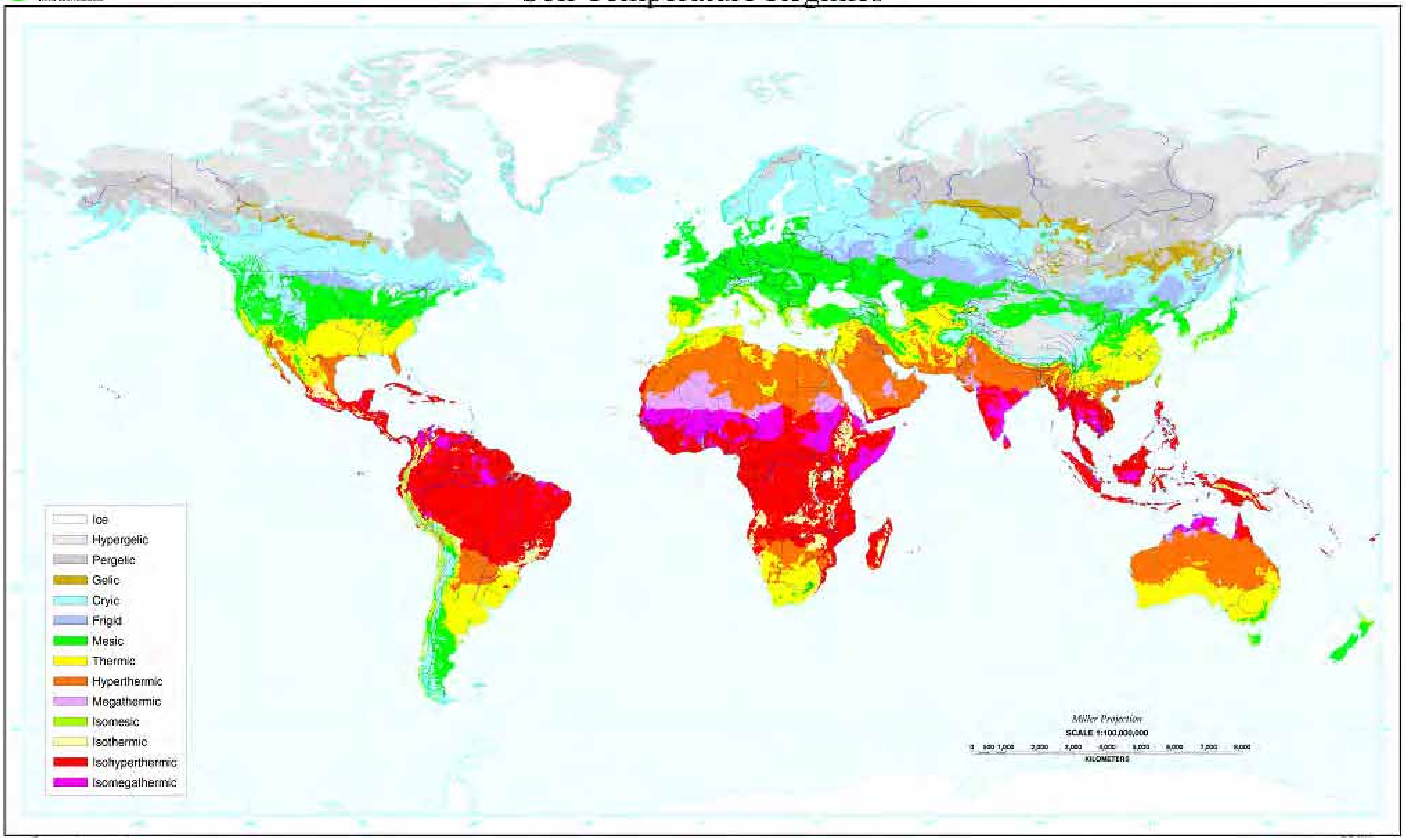
U.S. Dept. of Agriculture
Natural Resources Conservation Service
Soil Survey Division
World Soil Resources

Soil Moisture Regimes



U.S. Dept. of Agriculture
Natural Resources Conservation Service
Soil Survey Division
World Soil Resources

Soil Temperature Regimes



U.S. Department of Agriculture
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Soil Survey Division
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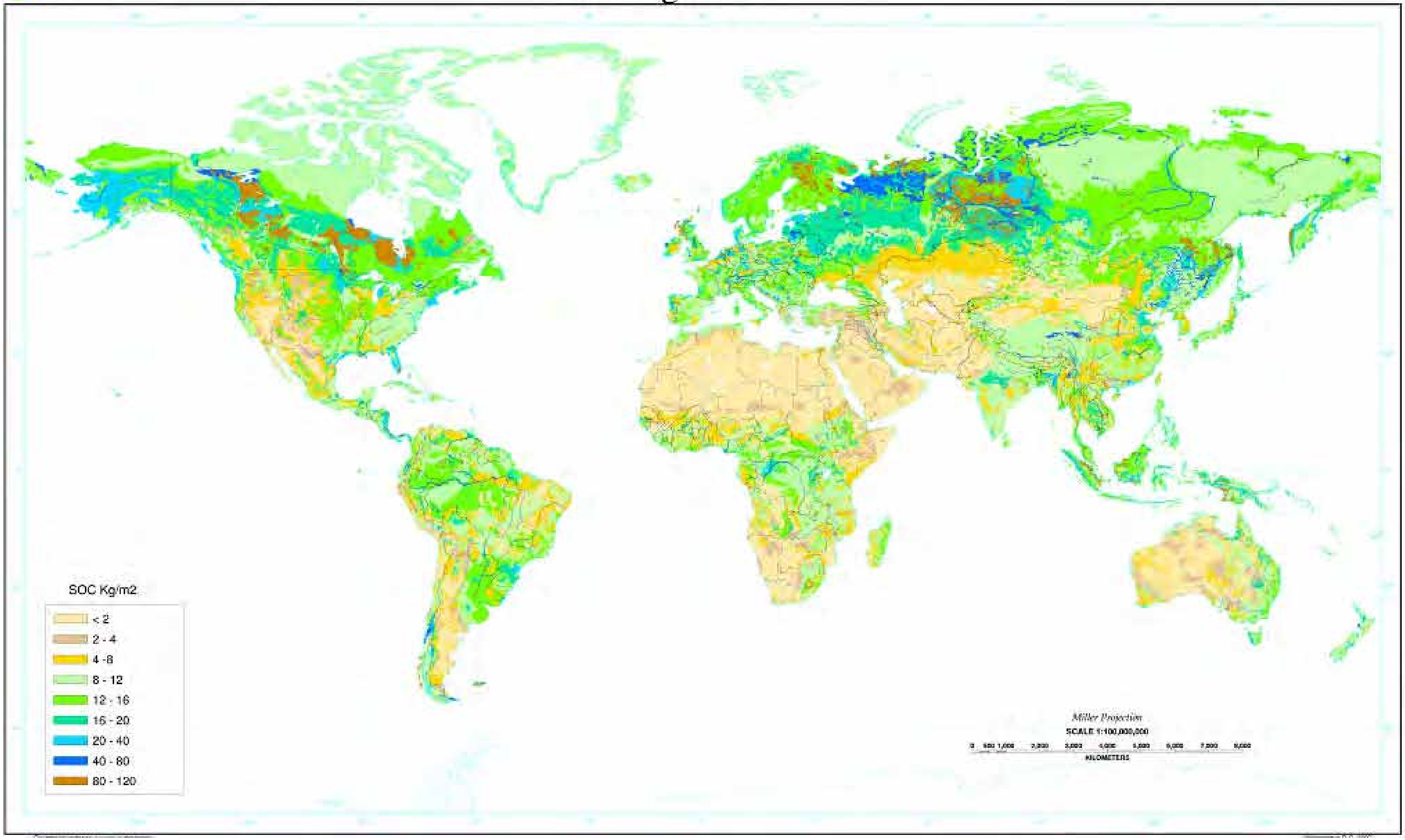
Soil Organic Carbon



Tillage type definitions (www2.ctic.purdue.edu/Core4/CT/Definitions.html)

Conventional-till or intensive-till - Full width tillage which disturbs all of the soil surface and is performed prior to and/or during planting. There is less than 15 percent residue cover after planting. Generally involves plowing or intensive (numerous) tillage trips.

Reduced-till (15-30% residue)- Full-width tillage which involving one or more tillage trips which disturbs all of the soil surface and is performed prior to and/or during planting. There is 15-30 percent residue cover after planting

Conservation Tillage Types (30 percent or more crop residue left, after planting)

Any tillage and planting system that covers 30 percent or more of the soil surface with crop residue, after planting, to reduce soil erosion by water.

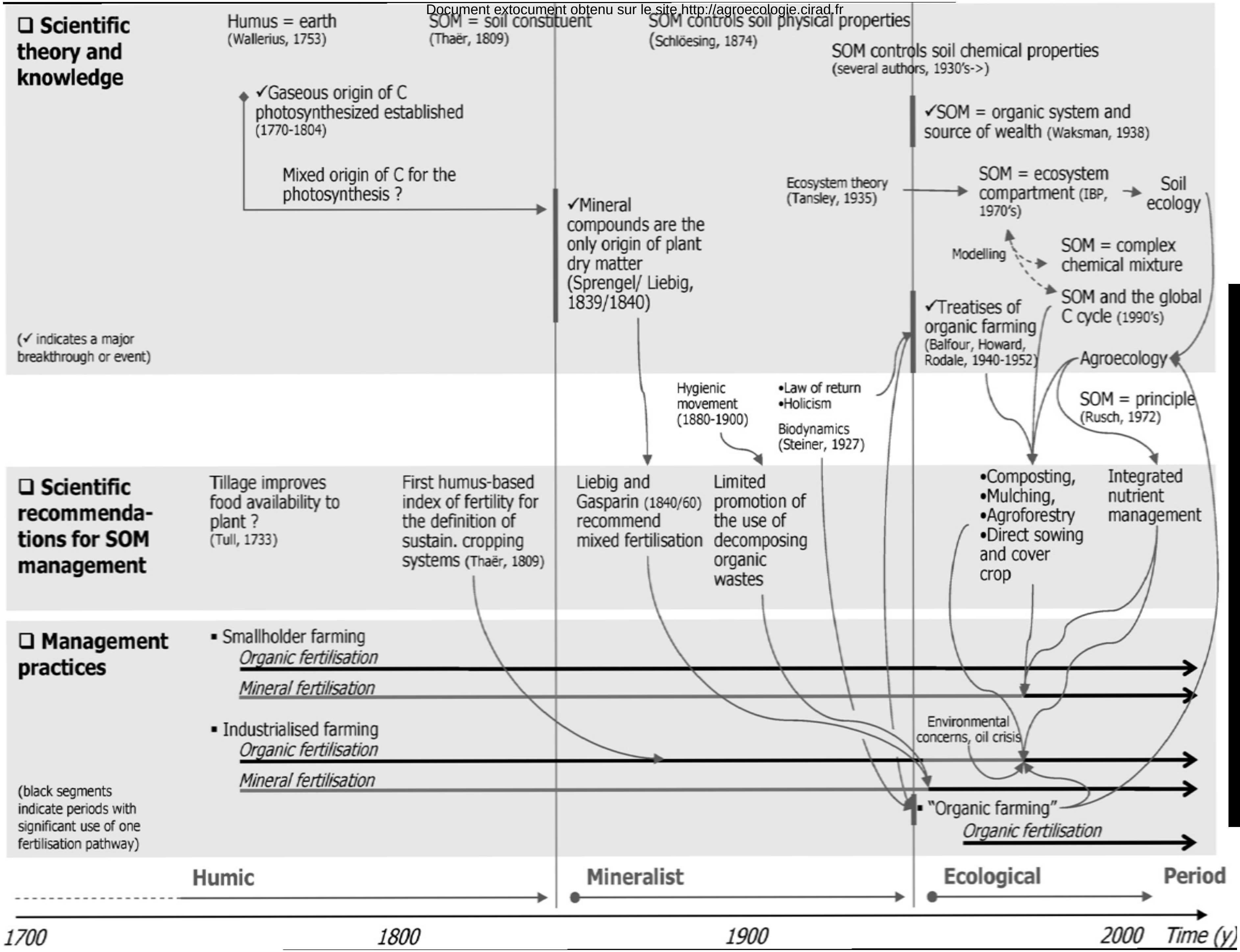
Ridge-till - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width. Planting is completed on the ridge and usually involves the removal of the top of the ridge. Planting is completed with sweeps, disk openers, coulters, or row cleaners. *Residue is left on the surface between ridges*.

Mulch-till – Full-width tillage involving one or more tillage trips which disturbs all of the soil surface and is done prior to and/or during planting. Tillage tools such as chisels, field cultivators, disks, sweeps or blades are used.

No-till/strip-till - The soil is left undisturbed from harvest to planting except for strips up to 1/3 of the row width (strips may involve only residue disturbance or may include soil disturbance). Planting or drilling is accomplished using disc openers, coulter(s), row cleaners, in-row chisels or roto-tillers. Other common terms used to describe No-till include direct seeding, slot planting, zero-till, row-till, and slot-till.

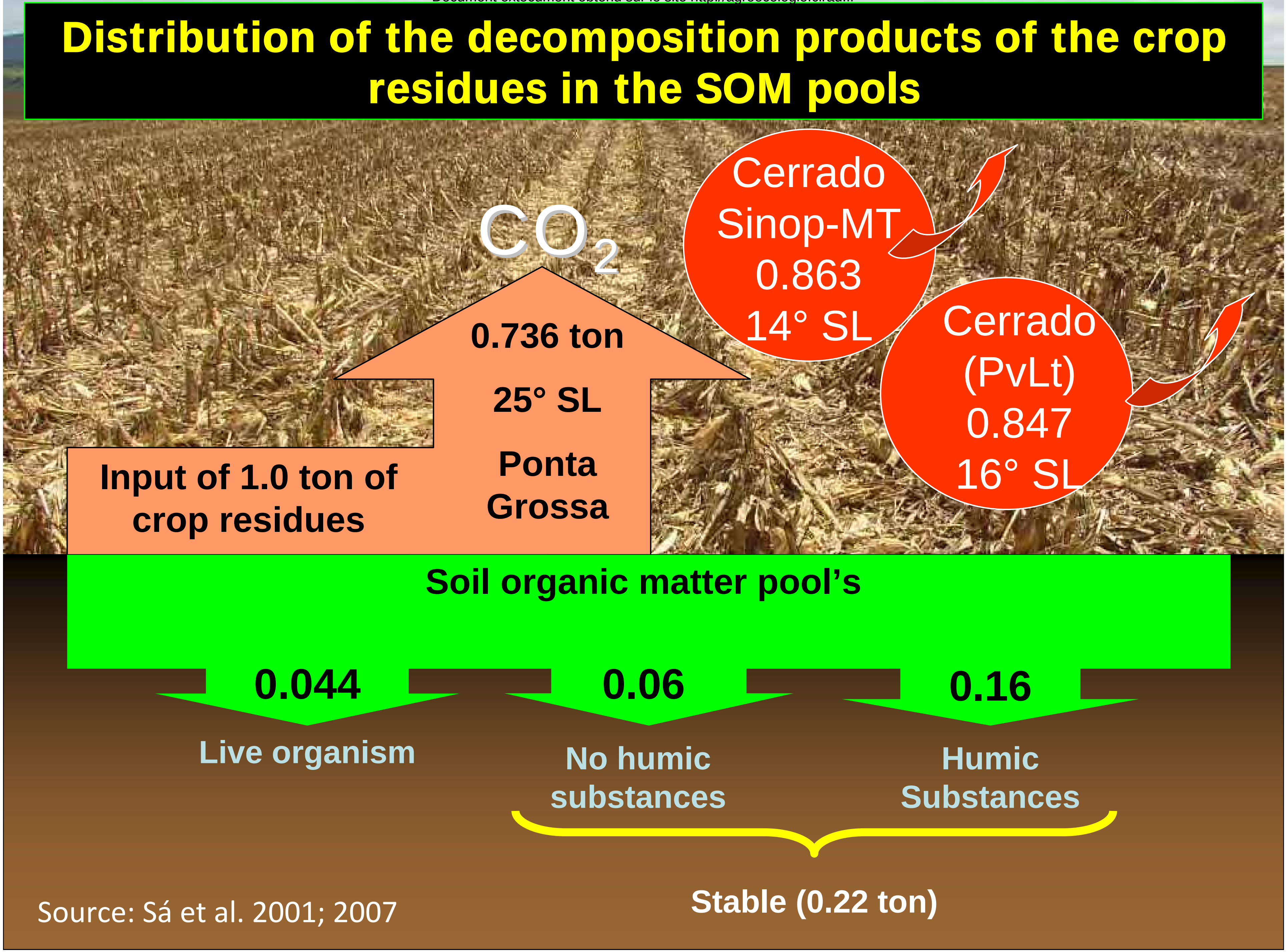
Time		
1995 - today	C and N from crop residues, Microbial biomass, Green houses gases and C balance and C Sequestration	Focus on SOM pools afected by tillage and cropping systems and environment
1975 - 1995	Aggregates models, Particle size fractions, C and N cycling and models	
1955 - 1975	Methodology and tecnics of ^{13}C NMR e EPR	Identification of chemical groups and humus struture and models
1935 - 1955	Models and functioning of humus struture (Chemical methods – Fractioning of humic substances)	
1850 - 1935	Organic compounds characterization	Chemistry development
- 1850	SOM benefits to the soil attributes	The first papers

Schnitzer, 1978 and 1998; Jenkinson, 1976; Cerri, 1986; Parton et al., 1987; Jastrow, 1998

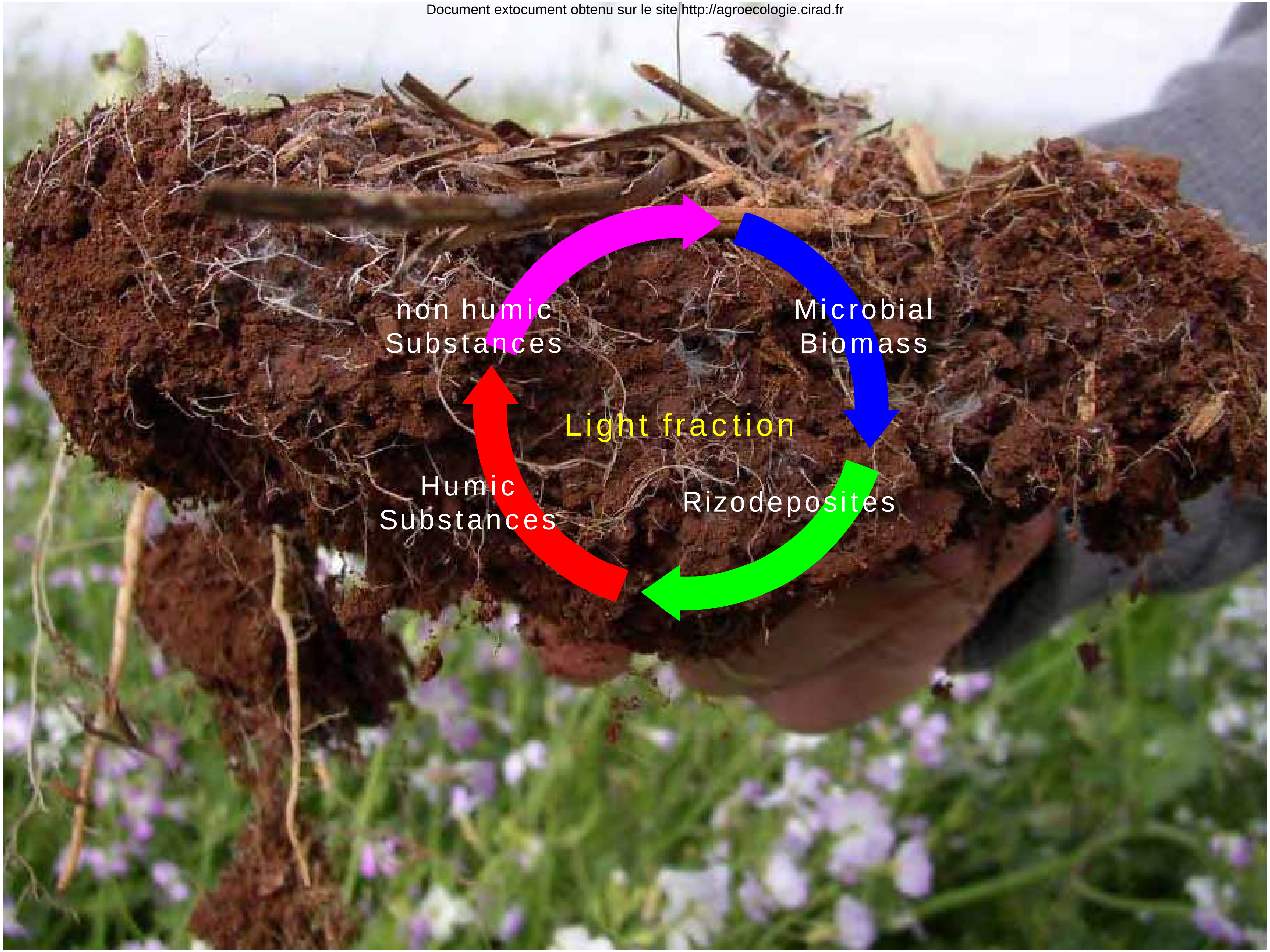


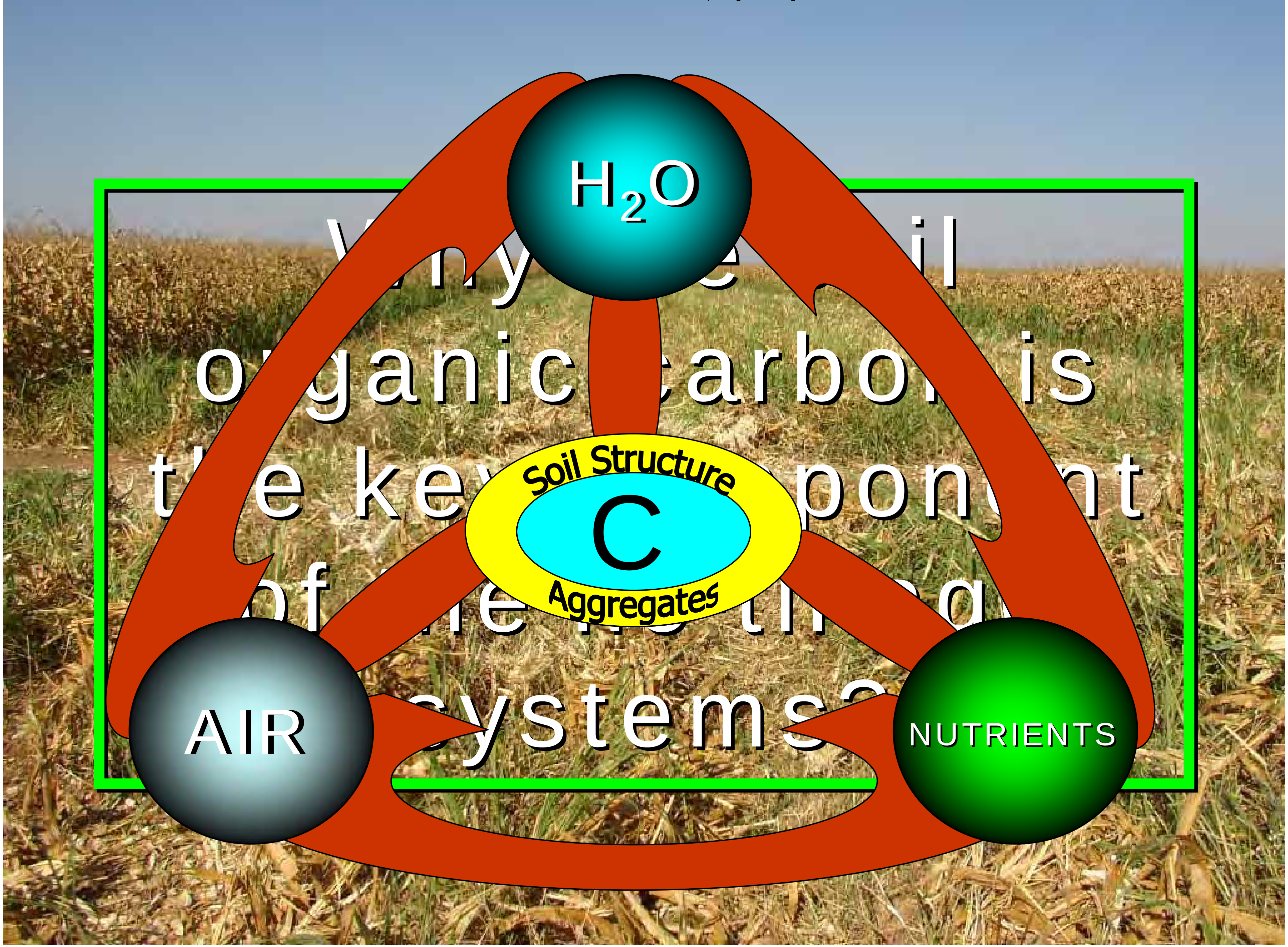
Manlay et al., 2007. Agric. Ecosys. Envir., 119:217-233.

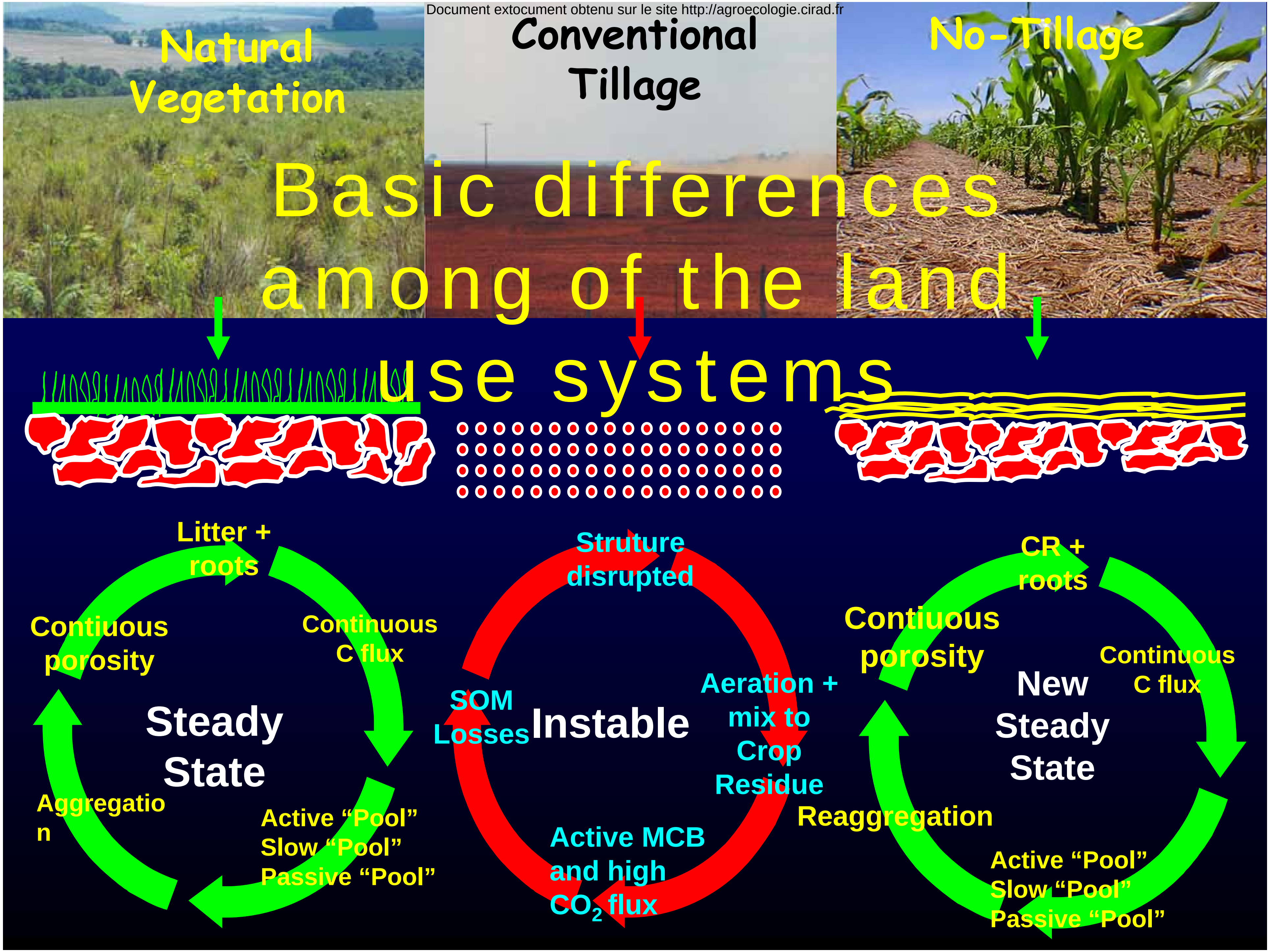
Understanding the soil organic matter in a no-tillage


Distribution of the decomposition products of the crop residues in the SOM pools
CO_2
0.736 ton
25° SL
Ponta Grossa
Input of 1.0 ton of crop residues
Cerrado Sinop-MT 0.863 14° SL
Cerrado (PvLt) 0.847 16° SL
Soil organic matter pool's
0.044
Live organism
0.06
No humic substances
0.16
Humic Substances
Stable (0.22 ton)
Source: Sá et al. 2001; 2007

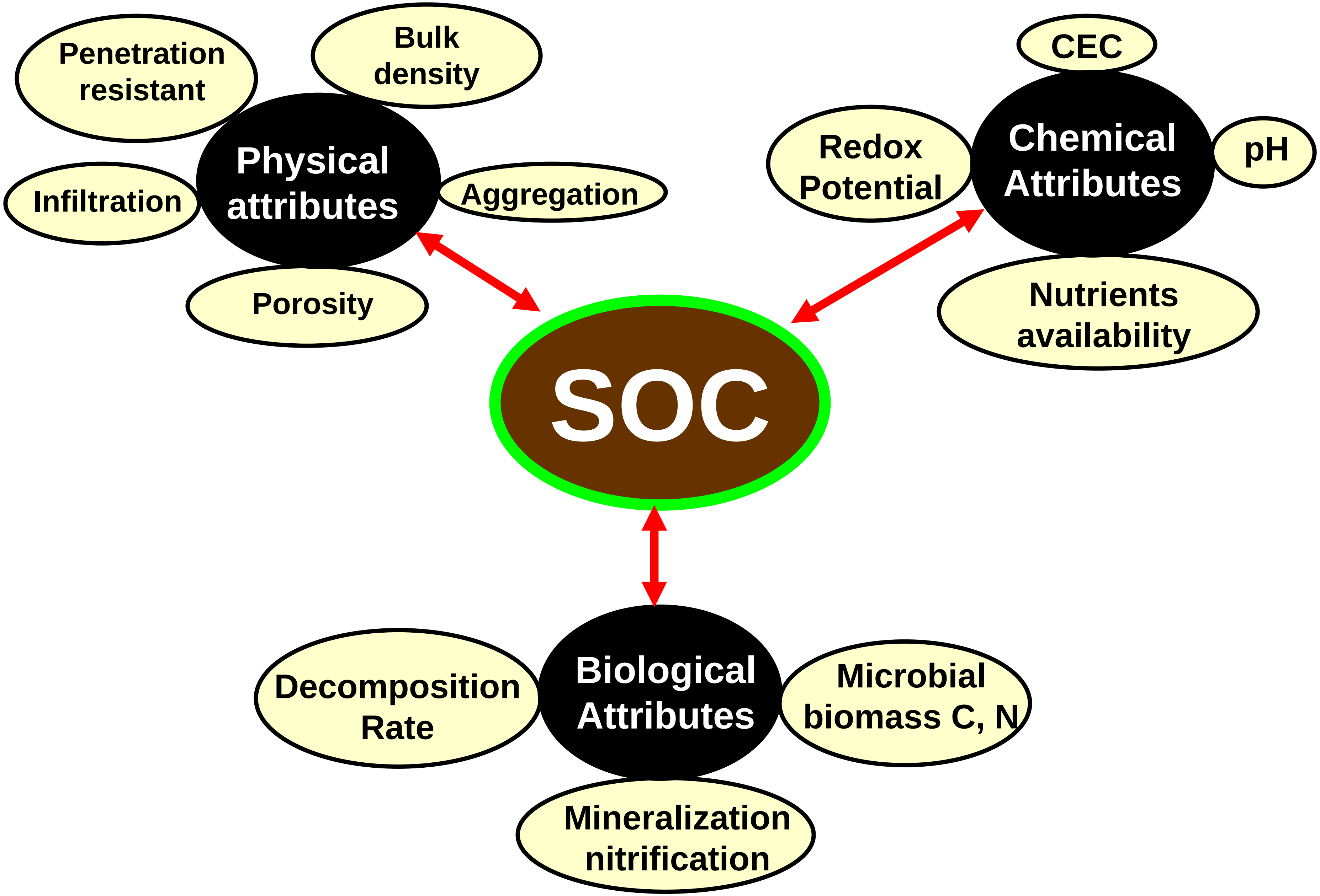

“To understand the soil organic matter in no-tillage system you have to think as a crop residue”


non humic
Substances
Microbial
Biomass
Light fraction
Humic
Substances
Rizodeposites


H_2O
Soil Structure
C
Aggregates
AIR
NUTRIENTS


Natural Vegetation
Conventional Tillage
No-Tillage
Basic differences among of the land use systems
Litter + roots
Contiuous porosity
Continuous C flux
Steady State
Aggregation
Active "Pool"
Slow "Pool"
Passive "Pool"
Struture disrupted
SOM Losses
Instable
Aeration + mix to Crop Residue
Active MCB and high CO_2 flux
CR + roots
Contiuous porosity
New Steady State
Continuous C flux
Reaggregation
Active "Pool"
Slow "Pool"
Passive "Pool"

SOC and Soil attributes interactions



1990 - today	C and N from crop residues, Microbial biomass, Green houses gases and C balance and C Sequestration	Focus on SOM pools afected by tillage and cropping systems
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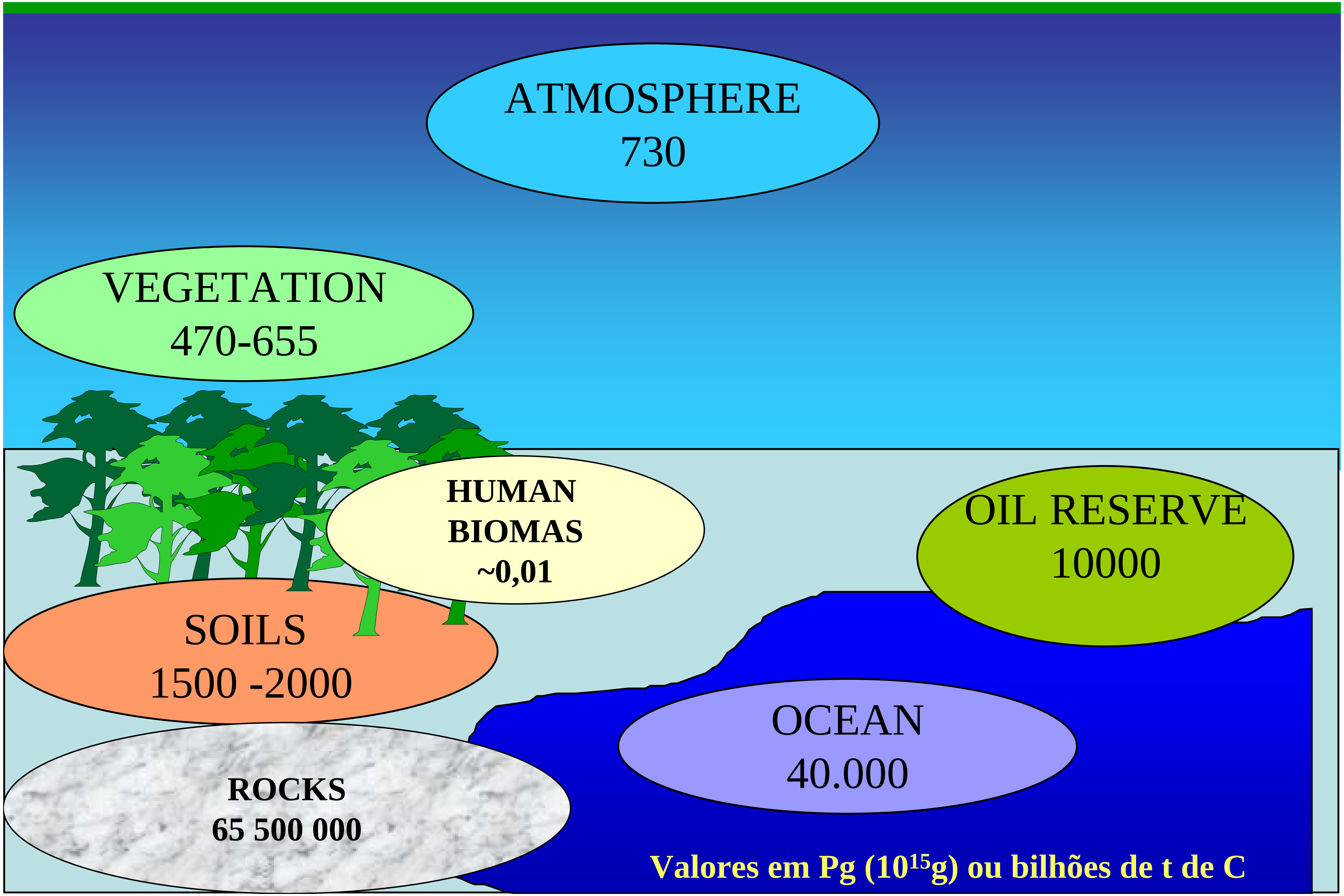
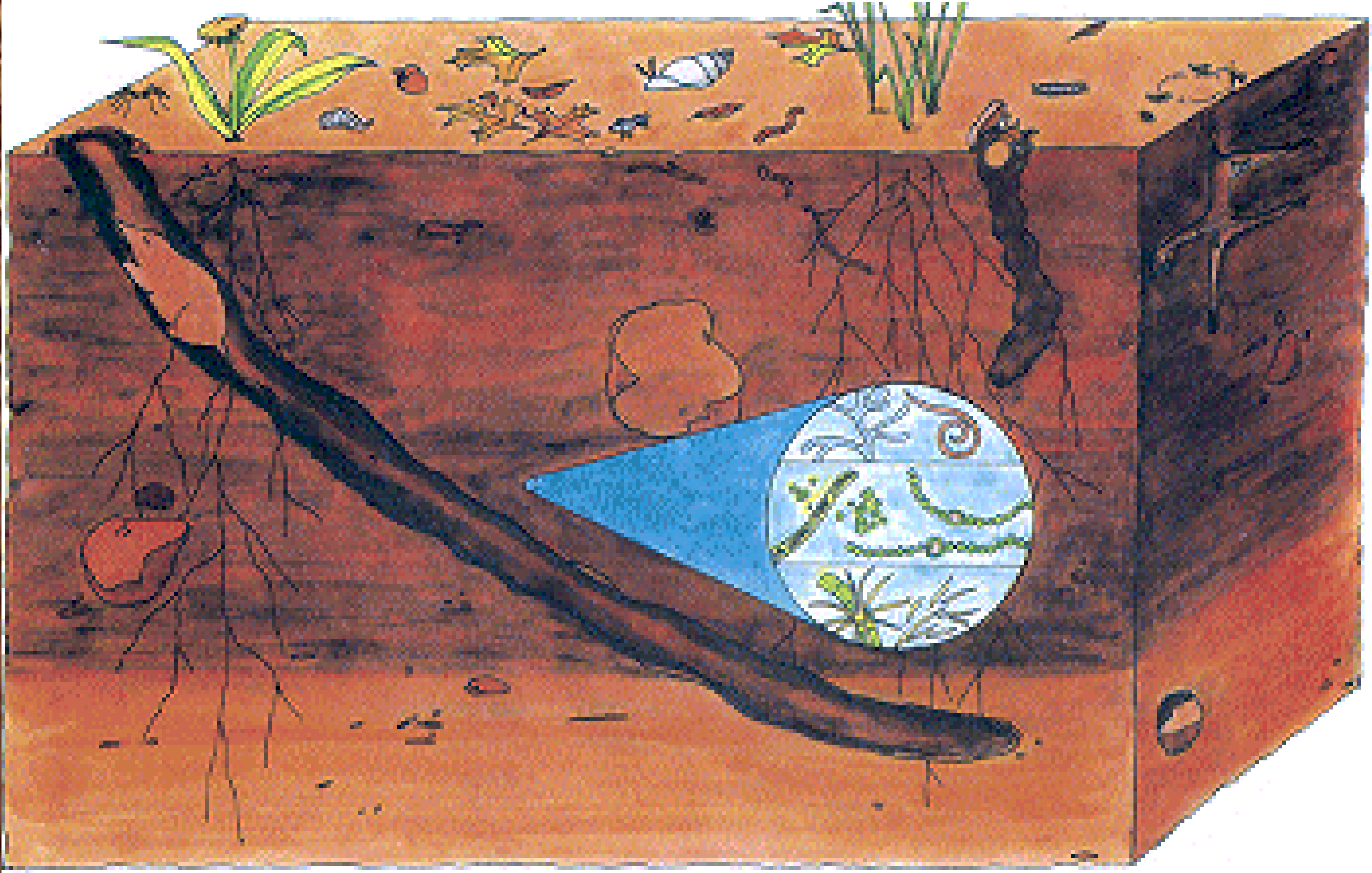
Time

Schnitzer, 1978 and 1998; Jenkinson, 1976; Cerri, 1986; Parton et al., 1987; Jastrow, 1998

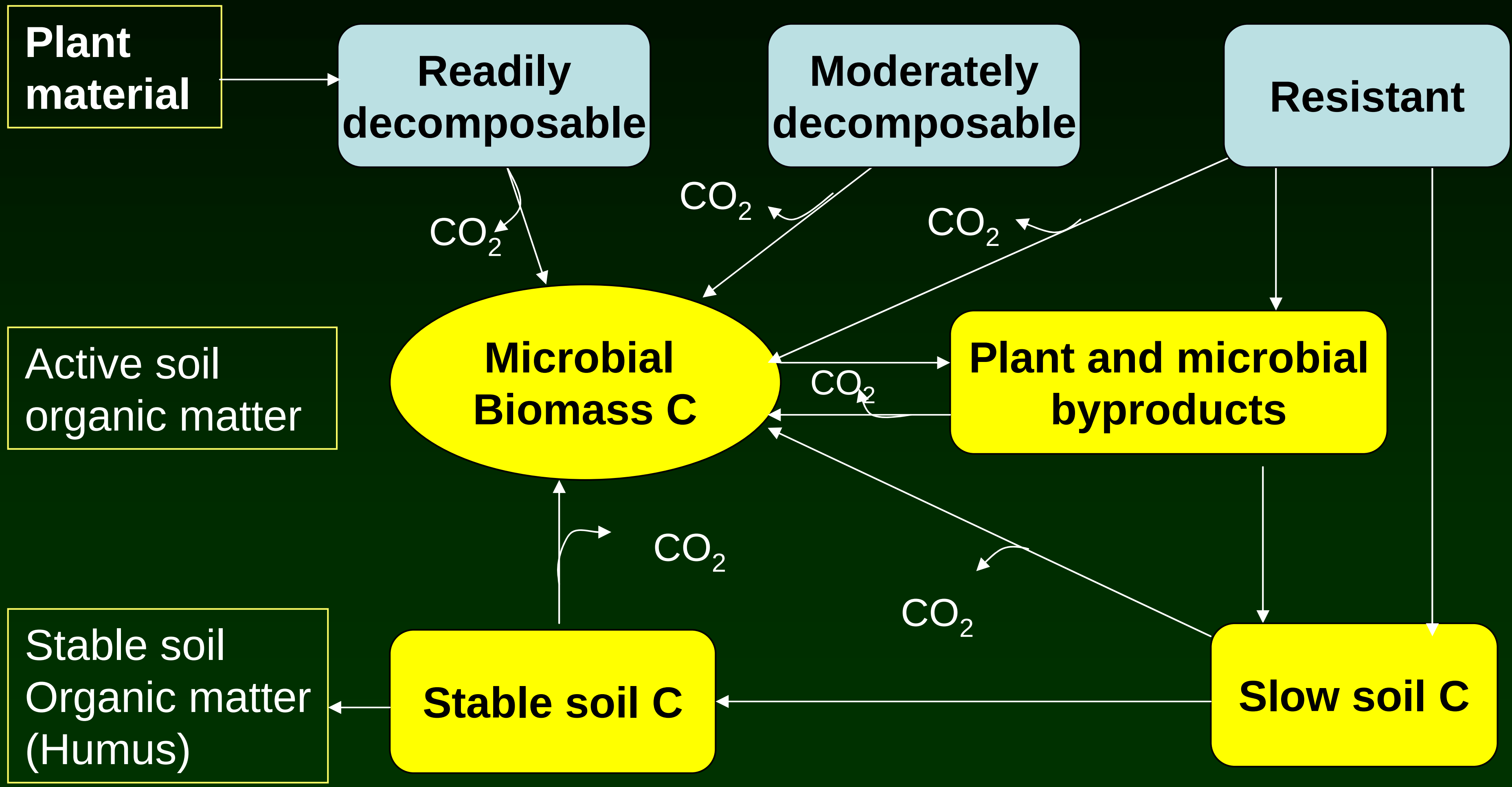
The carbon pools



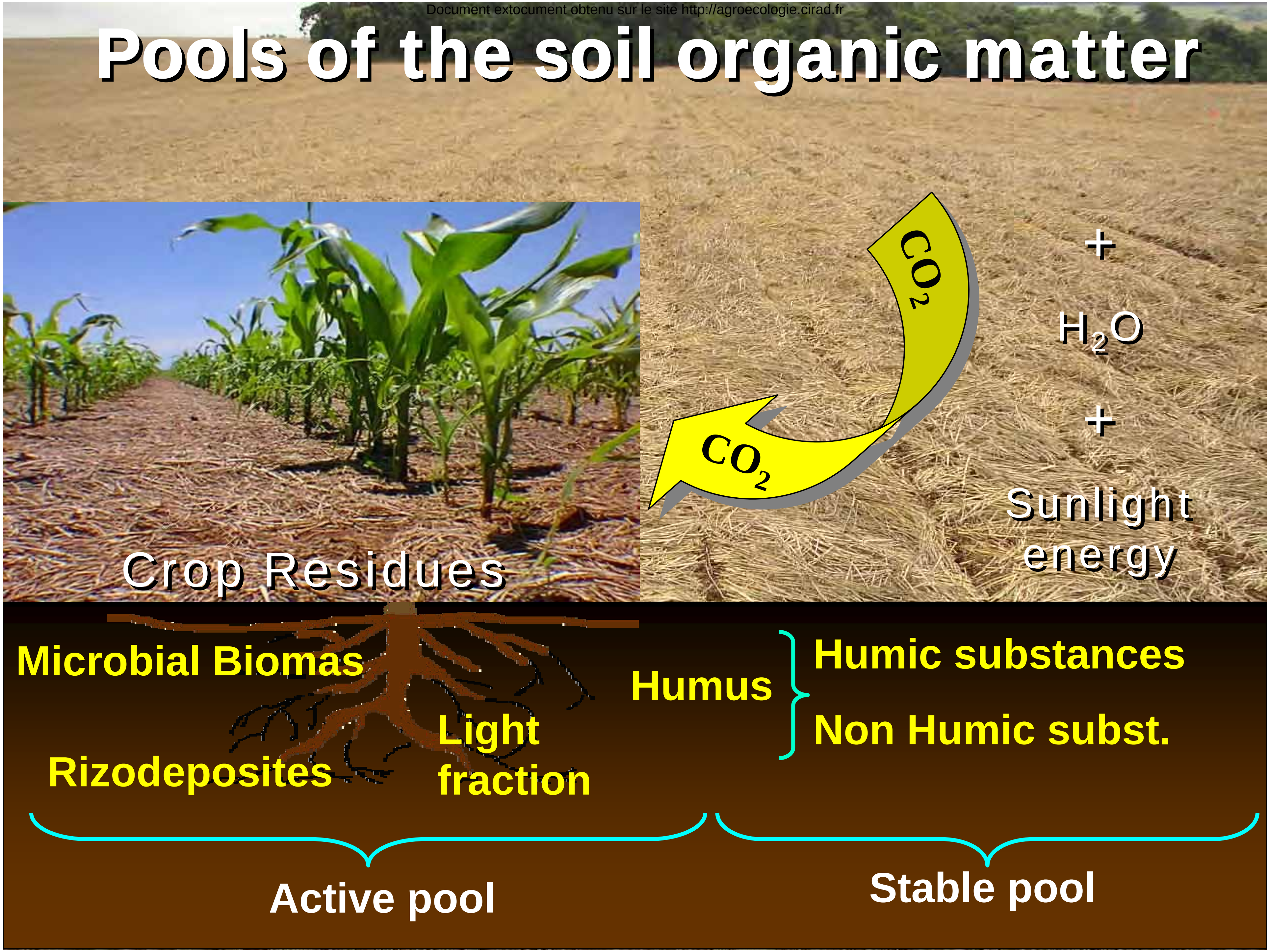
The soil ecosystem

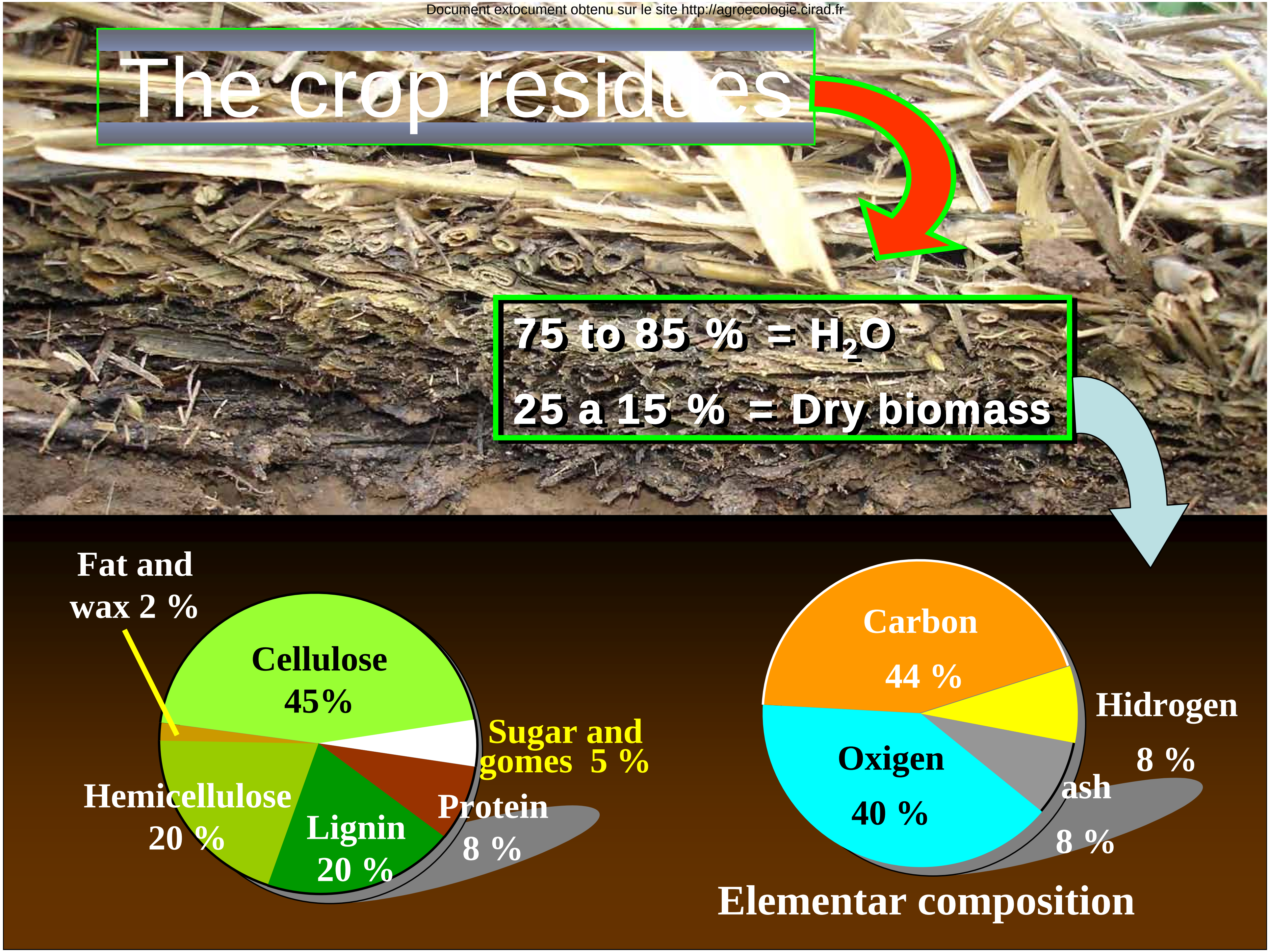


Carbon Input and Output

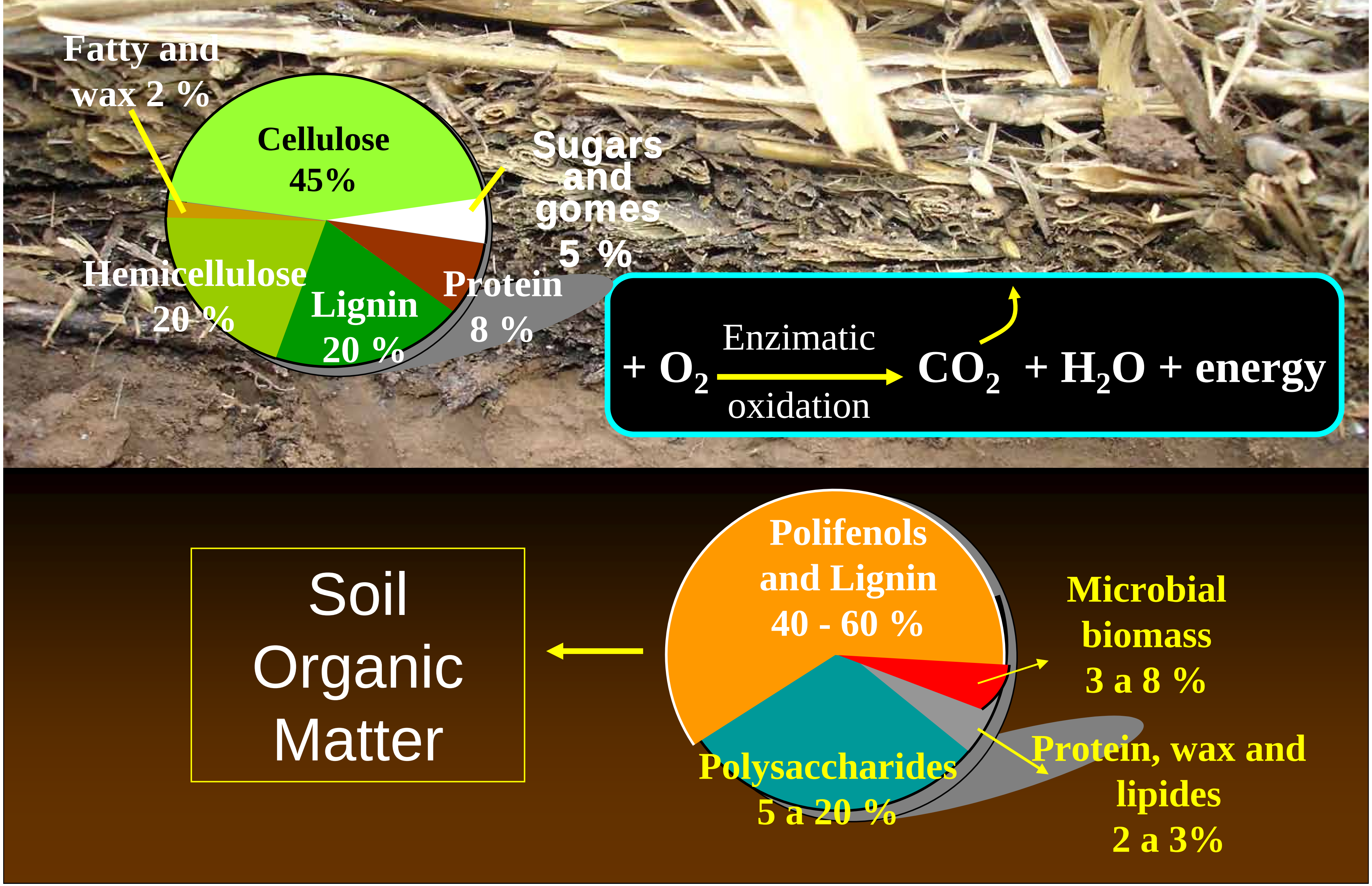


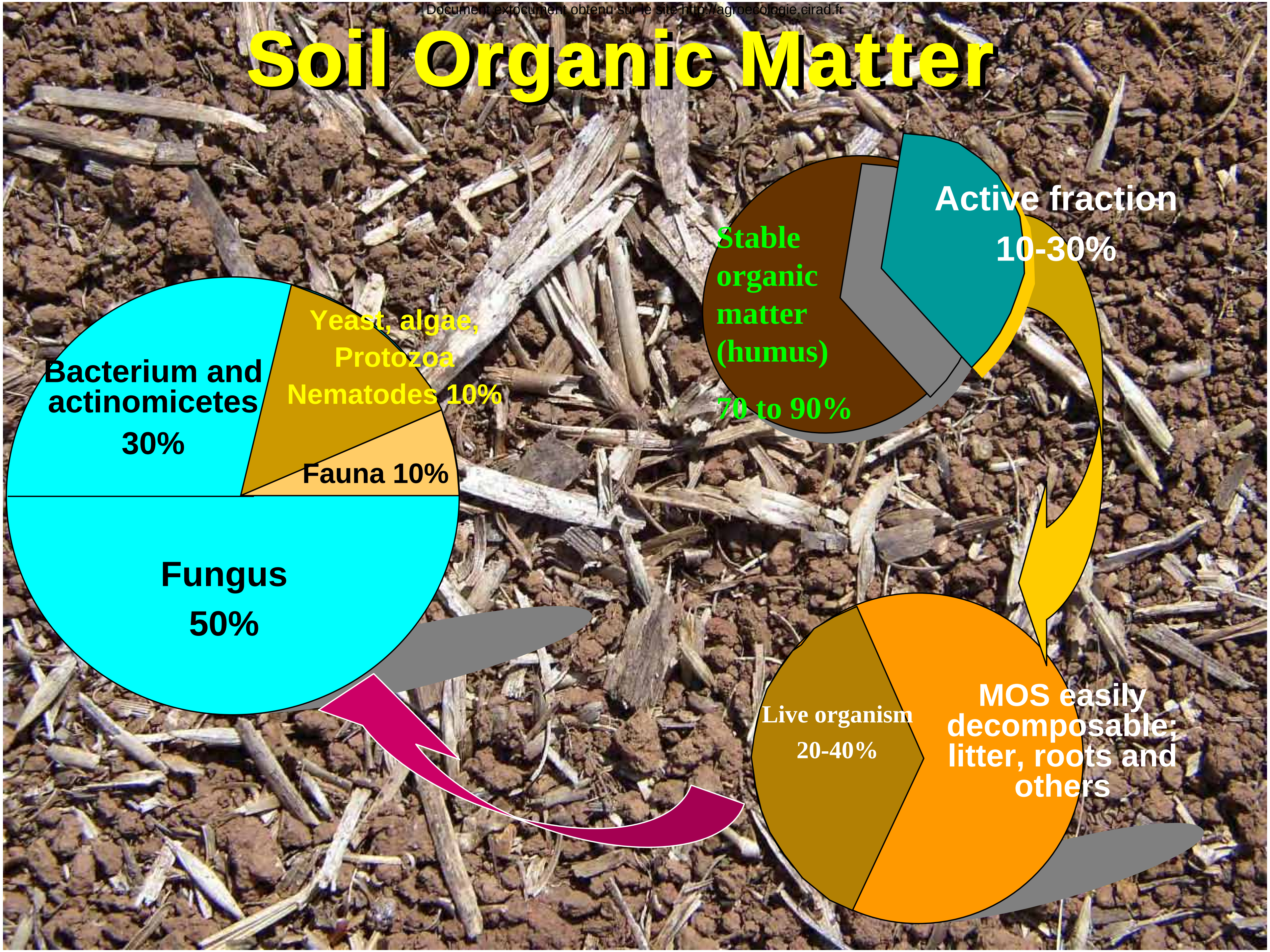

How is the organic matter formed under no-tilage soils?
Which are the soil organic matter pools?


Pools of the soil organic matter
CO2
CO2
+
H2O
+
Sunlight energy
Crop Residues
Microbial Biomas
Rizodeposites
Light fraction
Humus
Humic substances
Non Humic subst.
Active pool
Stable pool

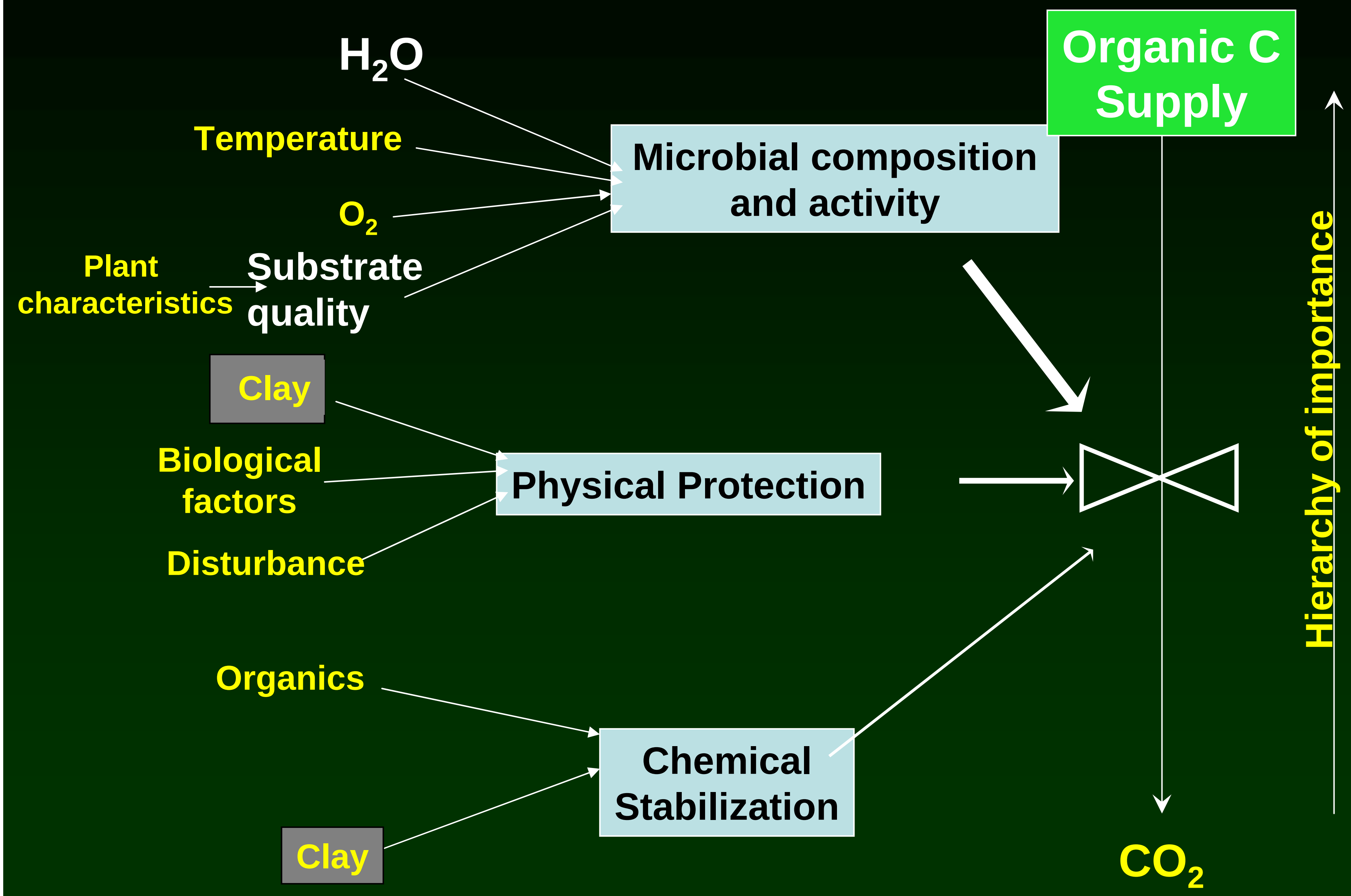

The crop residues
75 to 85 % = H_2O
25 a 15 % = Dry biomass
Fat and wax 2 %
Cellulose 45%
Sugar and gomes 5 %
Hemicellulose 20 %
Lignin 20 %
Protein 8 %
Carbon 44 %
Hidrogen 8 %
Oxigen 40 %
ash 8 %
Elementar composition

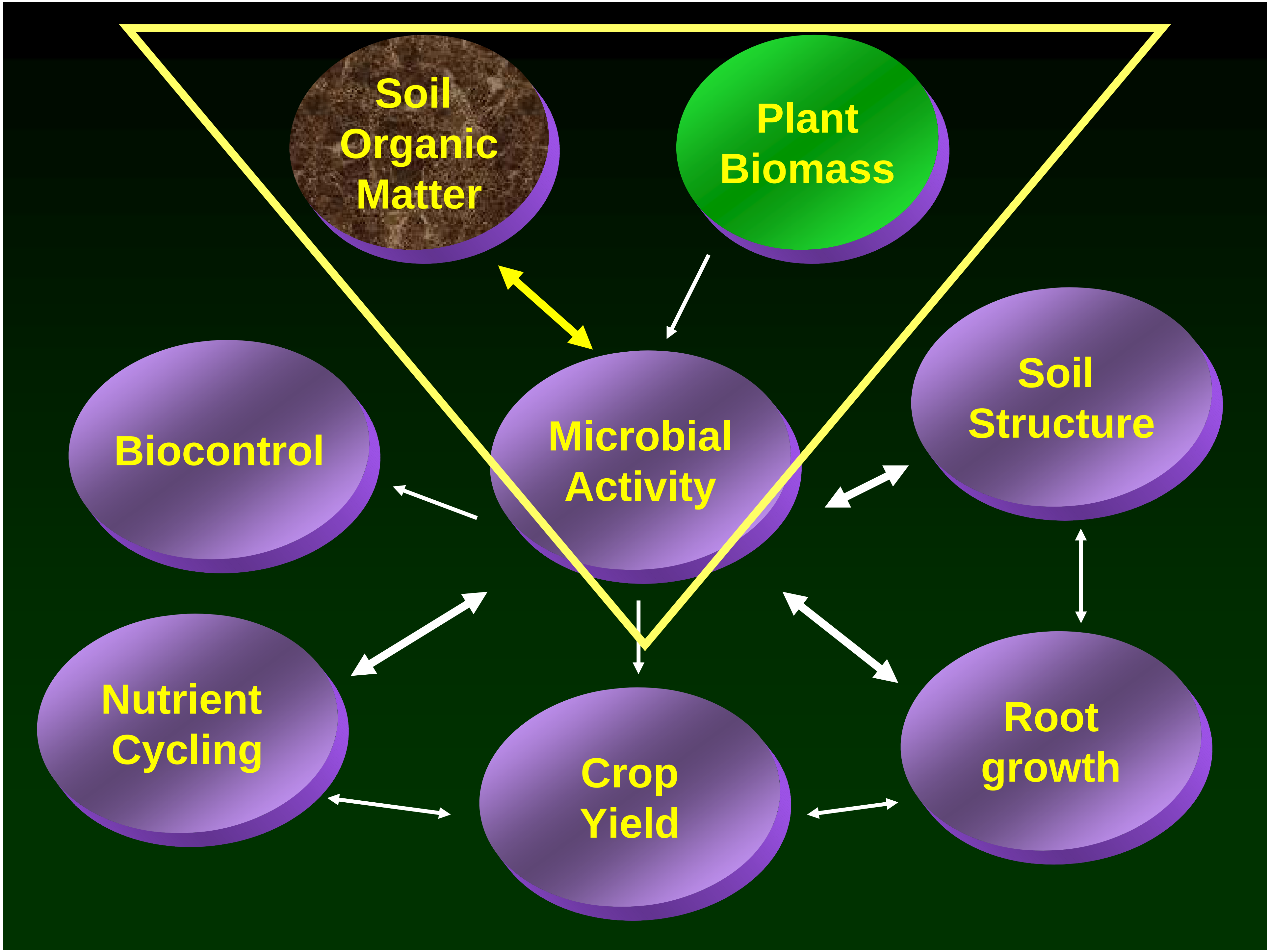
Carbon Pathway in the soil

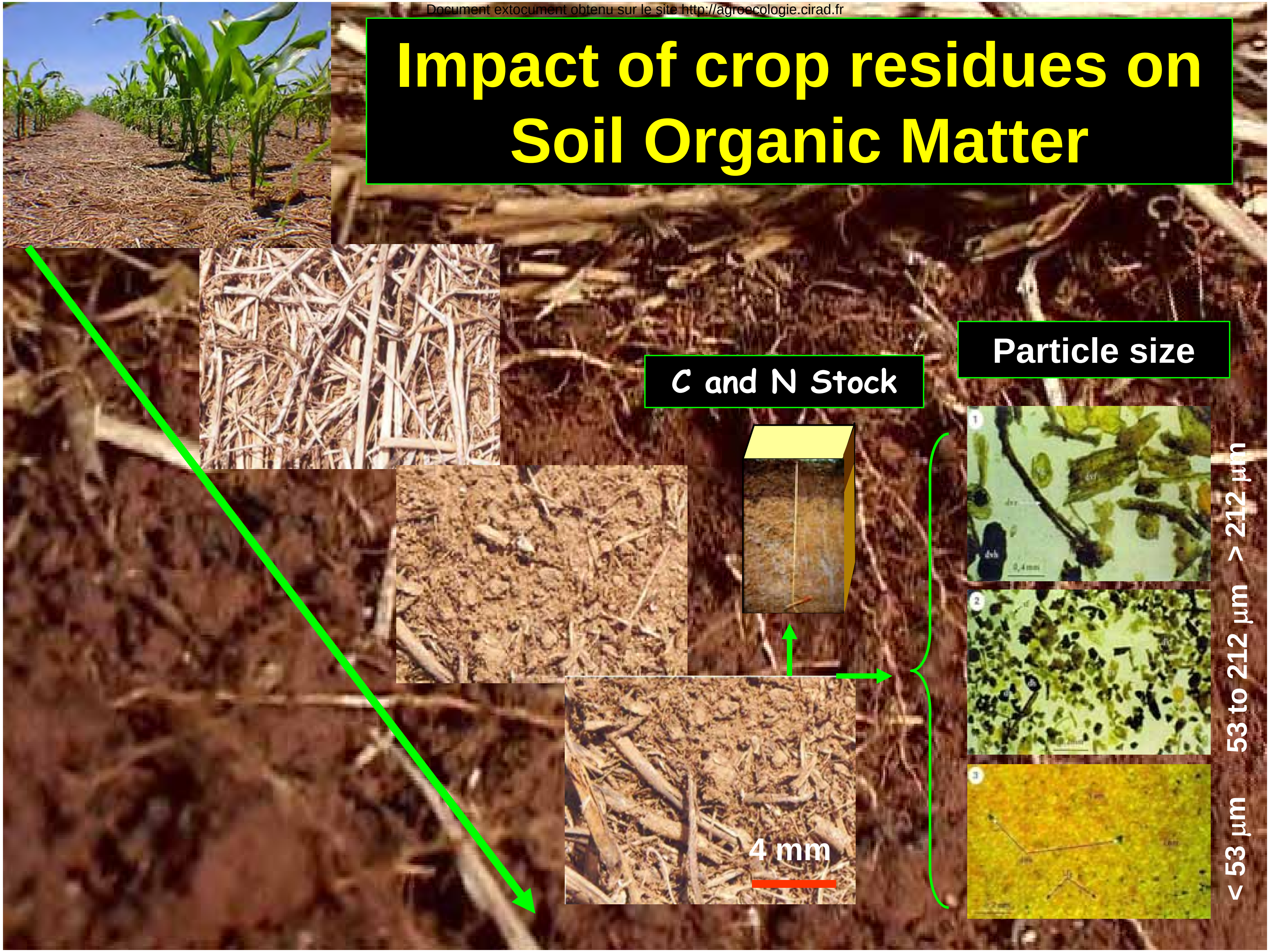


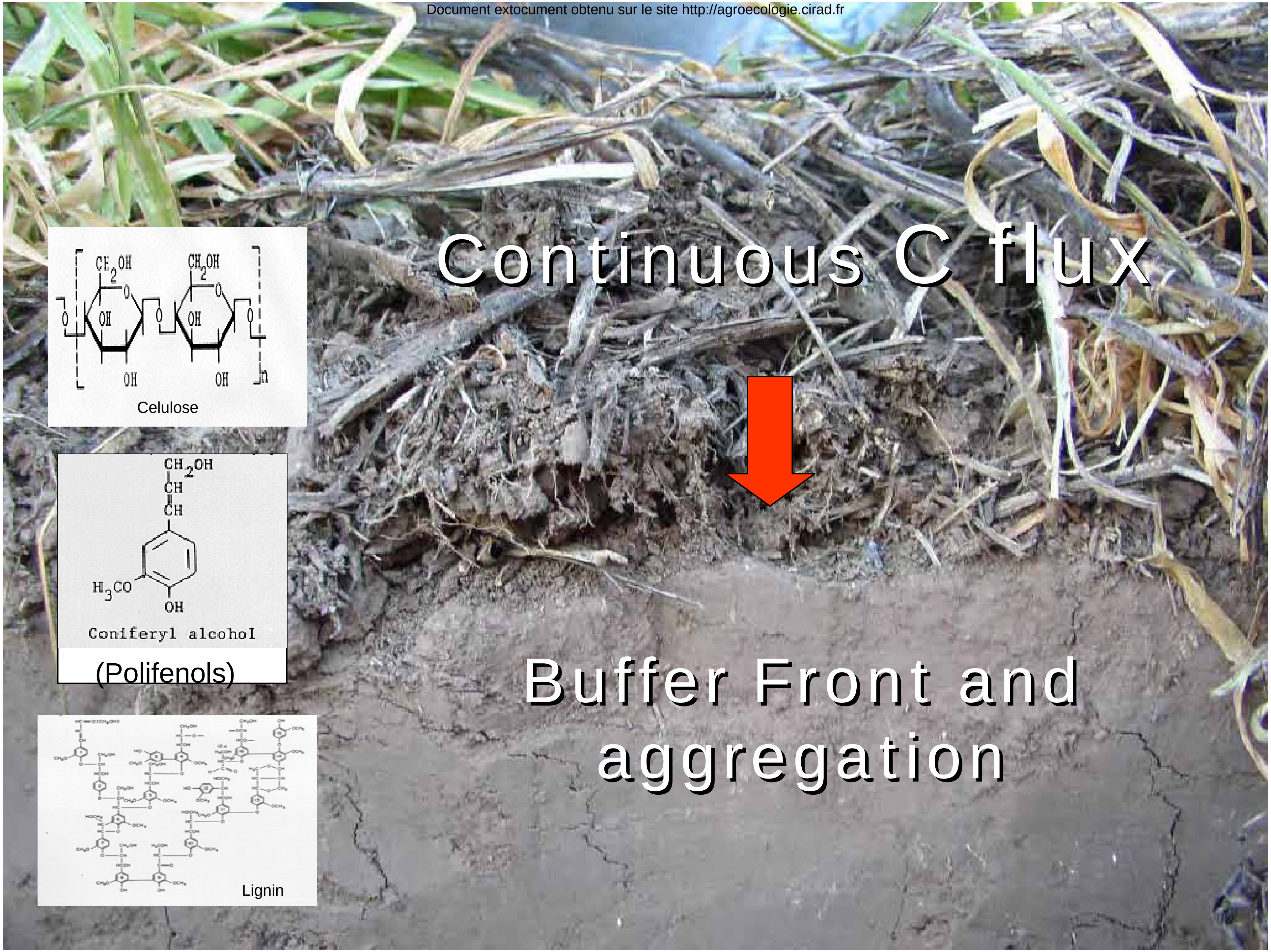

Soil Organic Matter
Active fraction
10-30%
Stable organic matter (humus)
70 to 90%
Bacterium and actinomicetes
30%
Yeast, algae, Protozoa Nematodes 10%
Fauna 10%
Fungus
50%
Live organism
20-40%
MOS easily decomposable: litter, roots and others

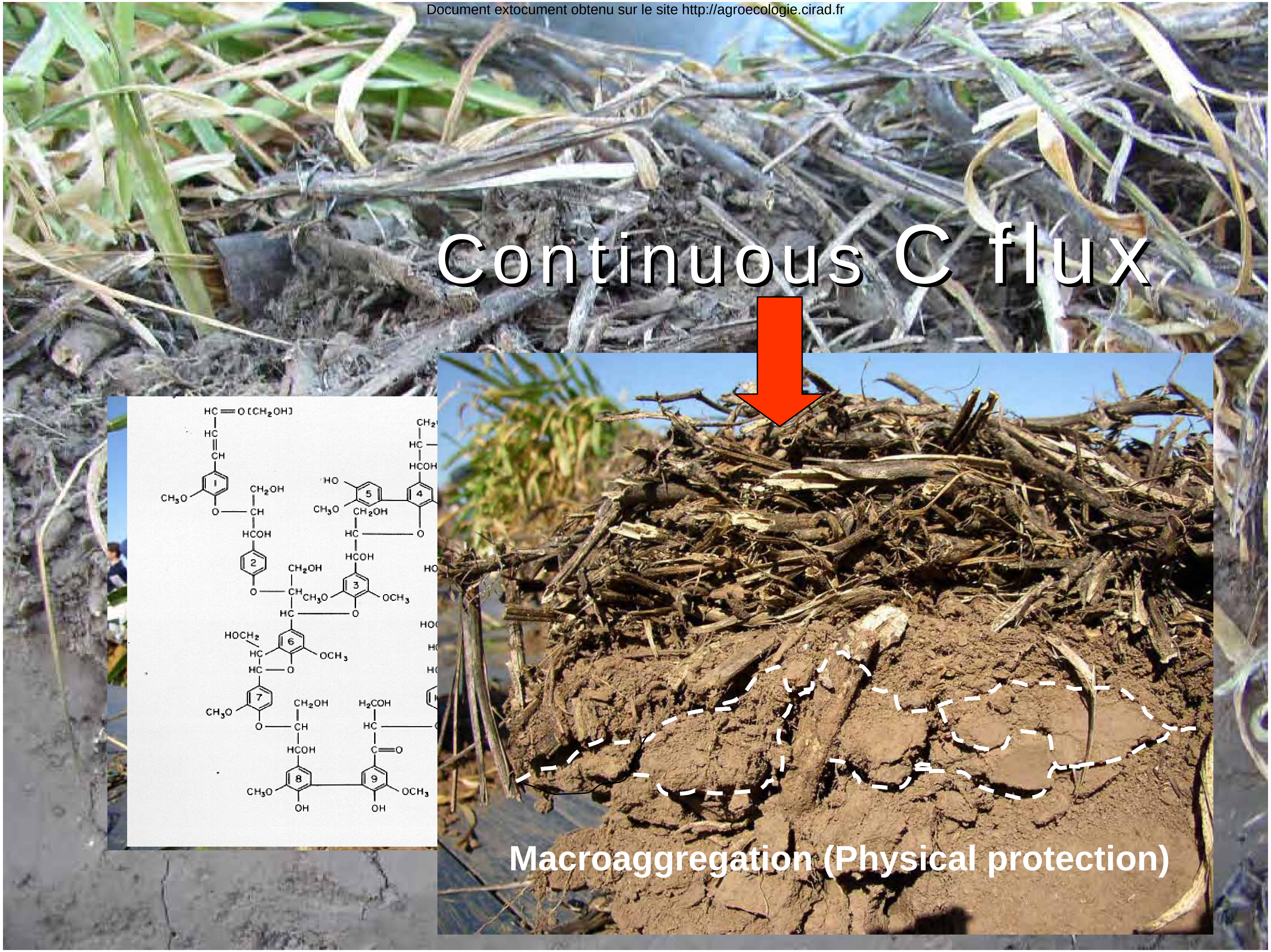
Conservation of Soil Carbon

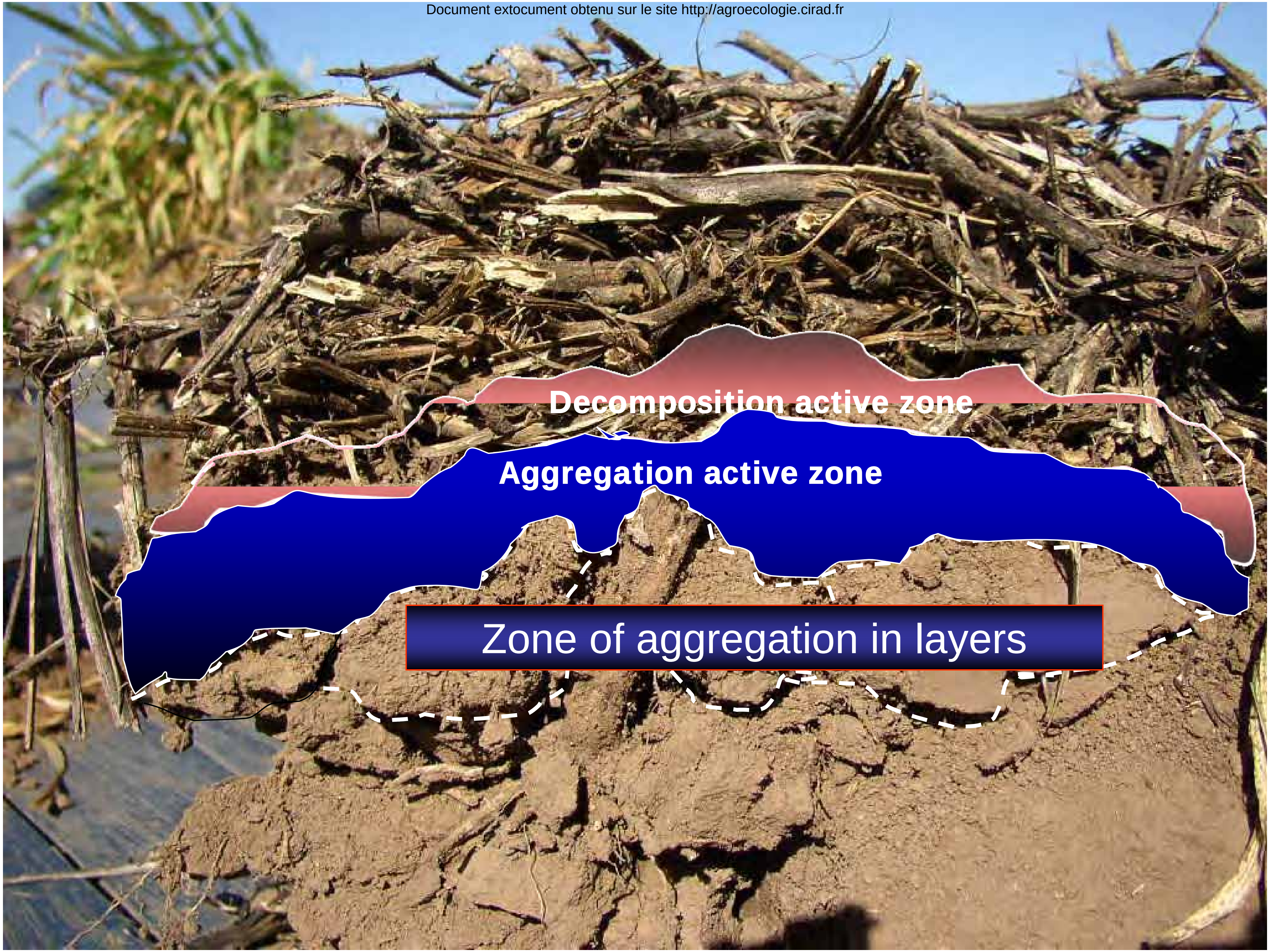


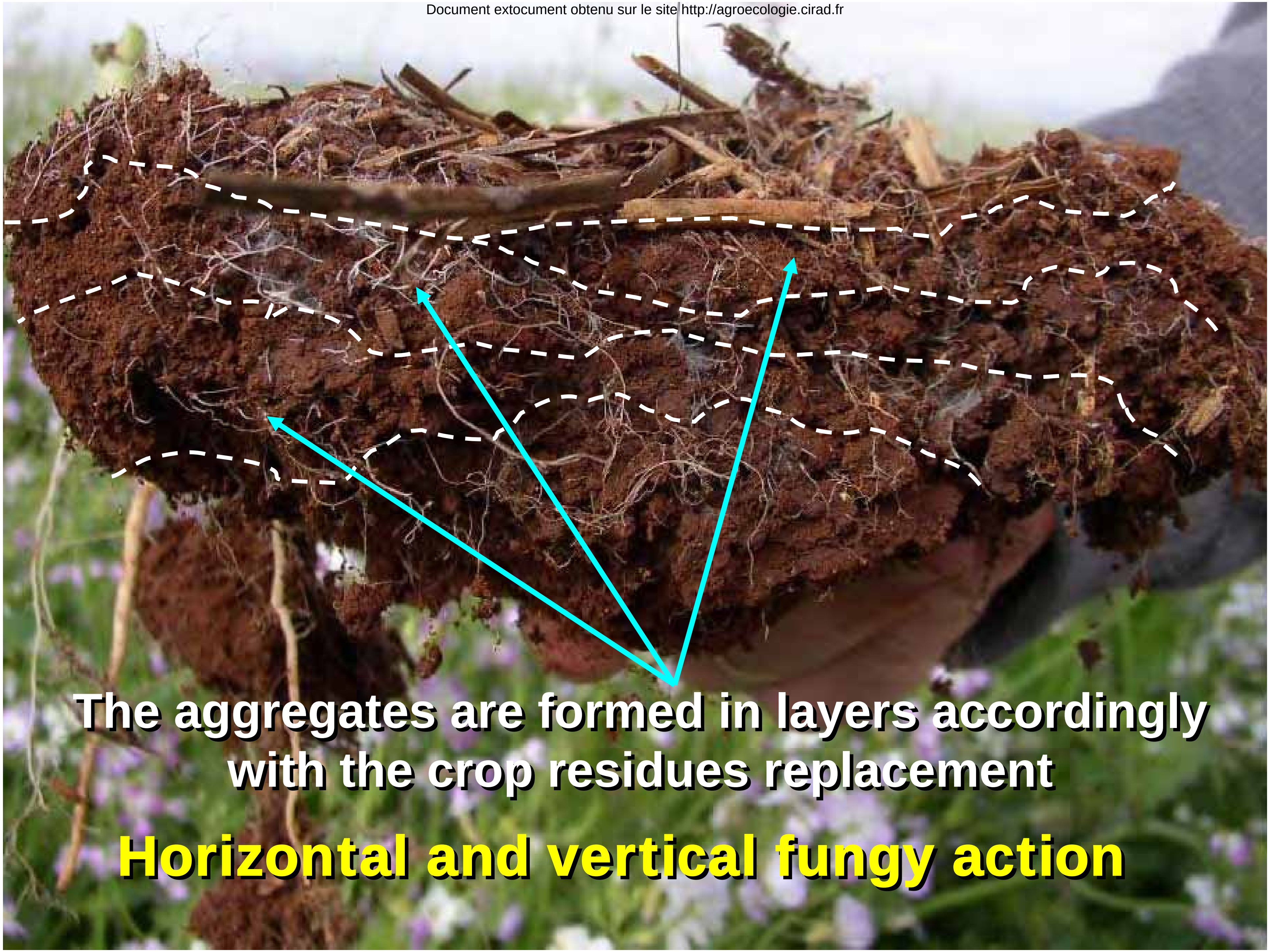

Soil Organic Matter
Plant Biomass
Microbial Activity
Biocontrol
Soil Structure
Nutrient Cycling
Crop Yield
Root growth


Impact of crop residues on
Soil Organic Matter
C and N Stock
Particle size
4 mm
> 212 µm
53 to 212 µm
< 53 µm


Continuous C flux
Celulose
Coniferyl alcohol
(Polifenols)
Buffer Front and aggregation
Lignin


Continuous C flux
Macroaggregation (Physical protection)


Decomposition active zone
Aggregation active zone
Zone of aggregation in layers


The aggregates are formed in layers accordingly with the crop residues replacement
Horizontal and vertical fungy action

Soil organic carbon on the soil profile

CT	Depth	NT
27 g kg^{-1}	5 cm	55 g kg^{-1}
25 g kg^{-1}	10 cm	43 g kg^{-1}
23 g kg^{-1}	15 cm	32 g kg^{-1}
19 g kg^{-1}	25 cm	19 g kg^{-1}
12 g kg^{-1}	40 cm	11 g kg^{-1}
8 g kg^{-1}	50 cm	8 g kg^{-1}

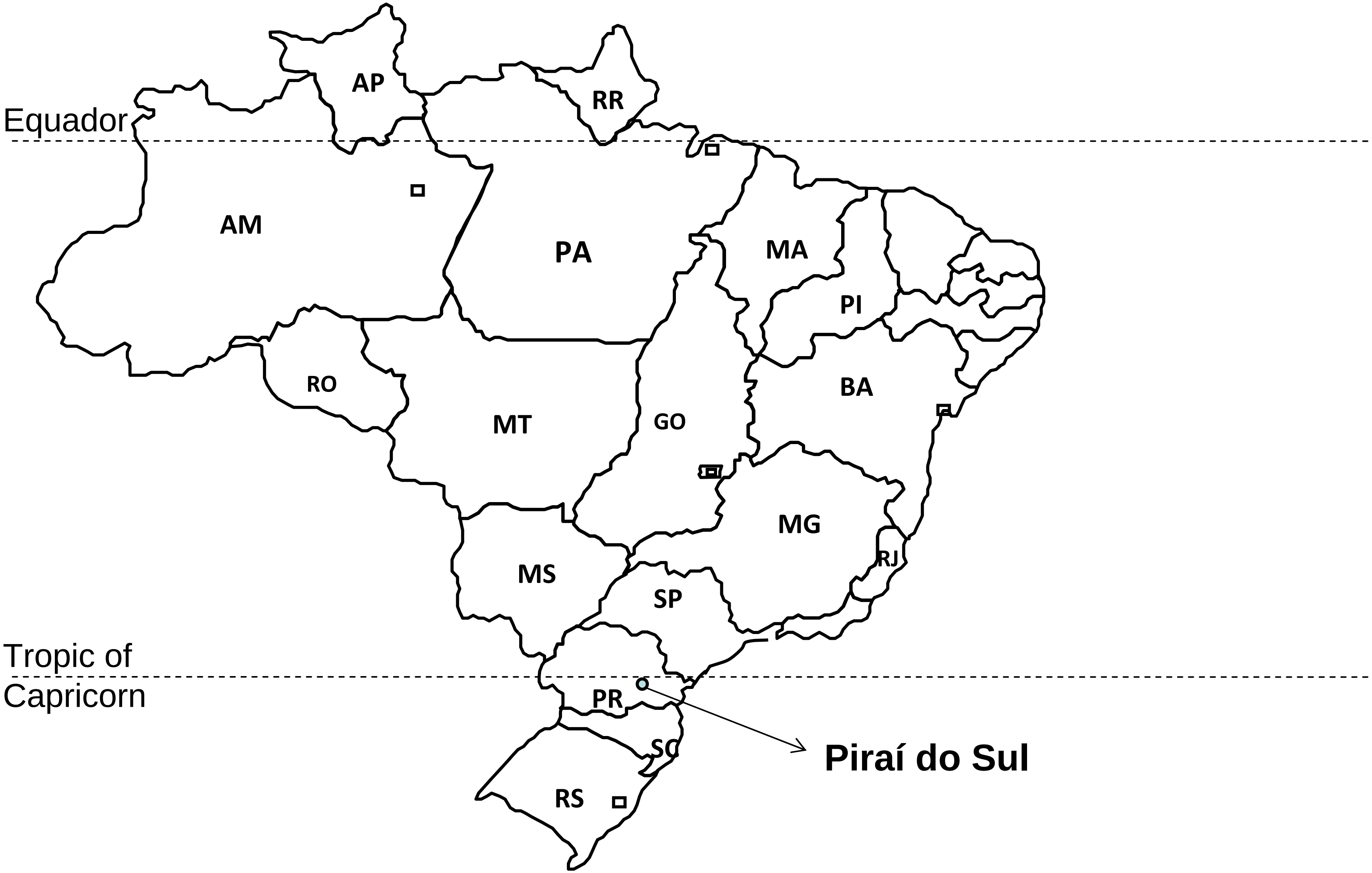
CT

NT

Source: Sá, 2007


“The challenge in the tropics is to manage the decomposition rate of the crop

Crop residues decomposition (oats + remaining residues) during the corn development (Piraí do Sul, 910 m ASL, 25 °SL, 2003-04, Oxisol (62% of clay)



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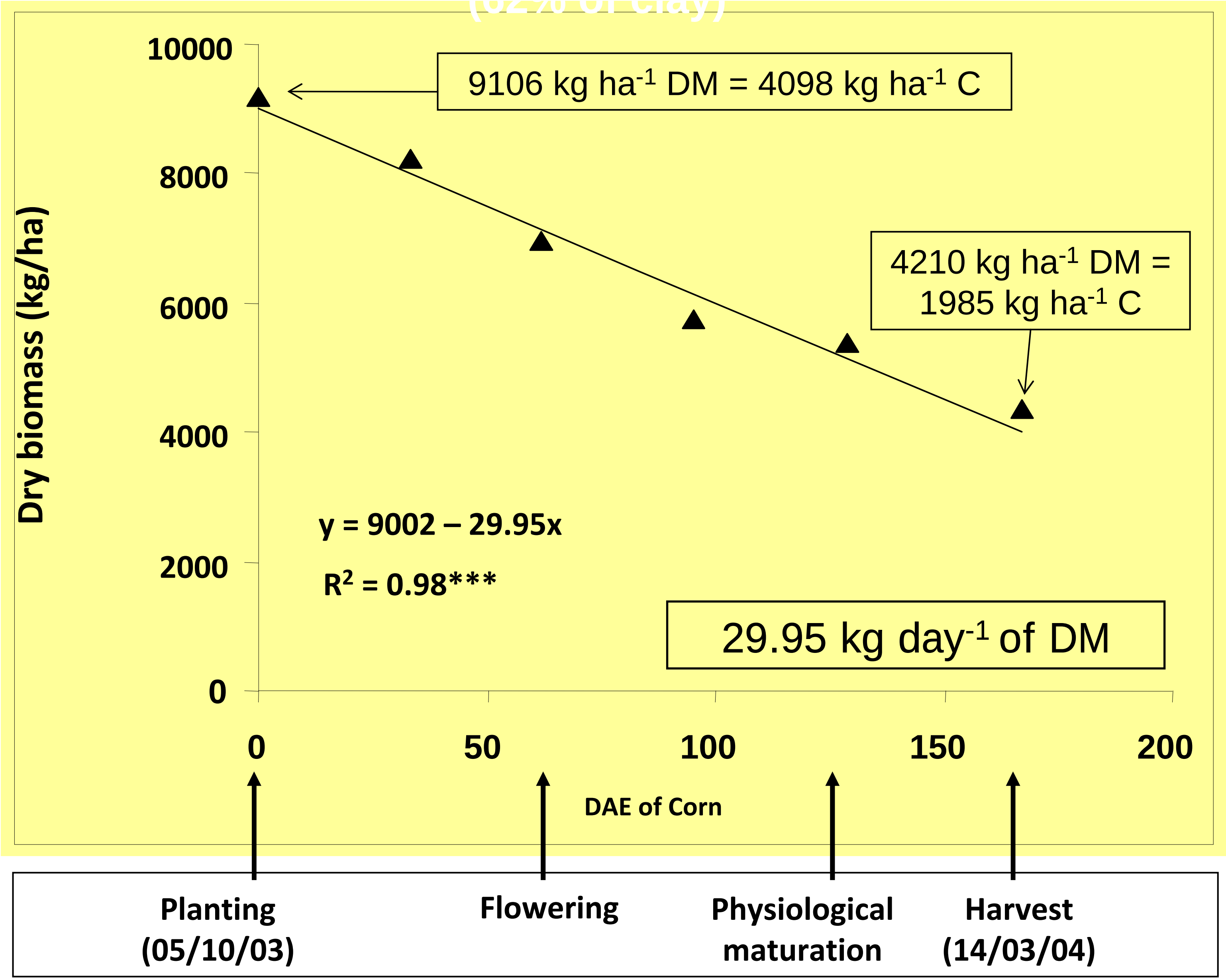
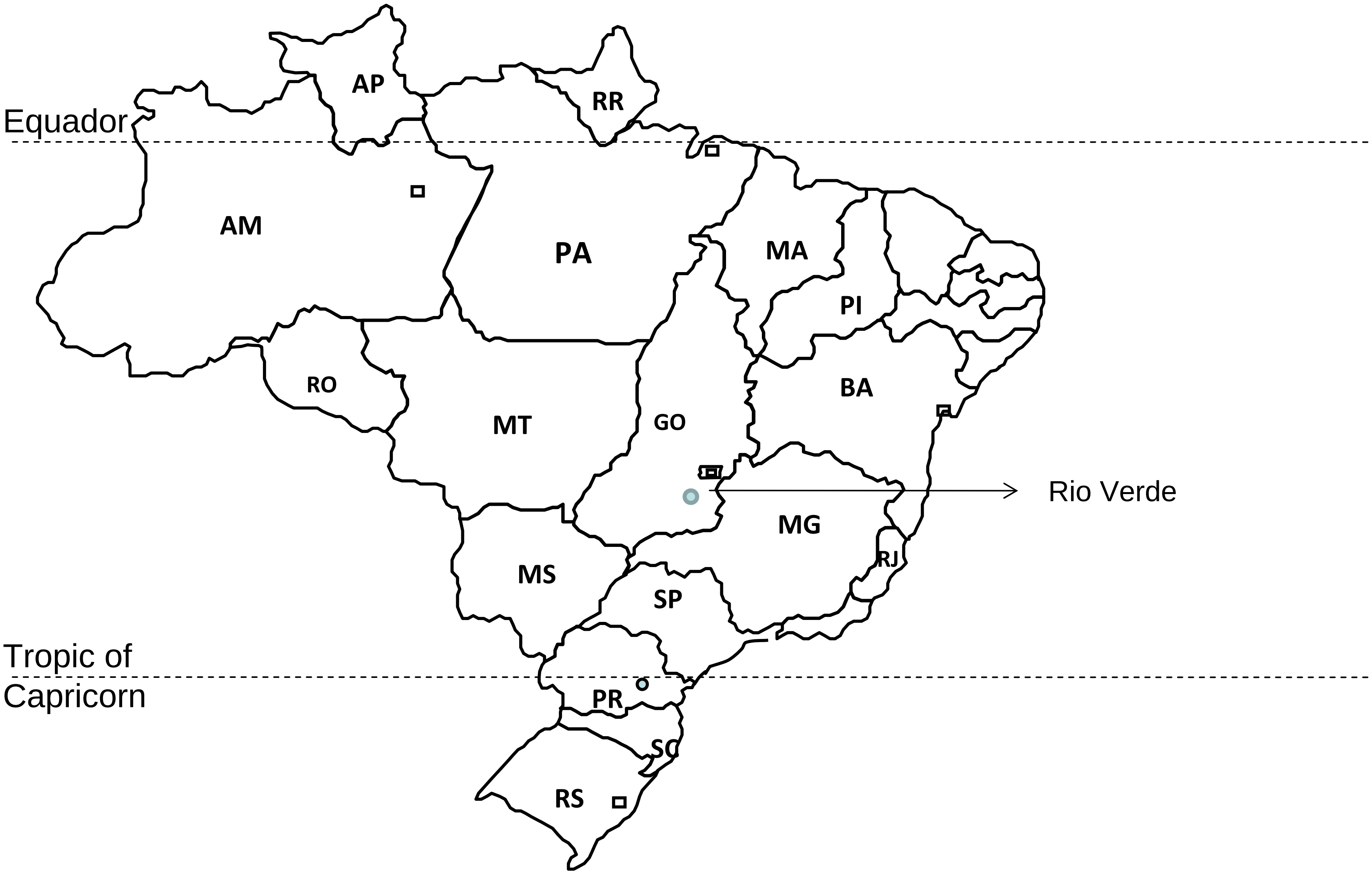
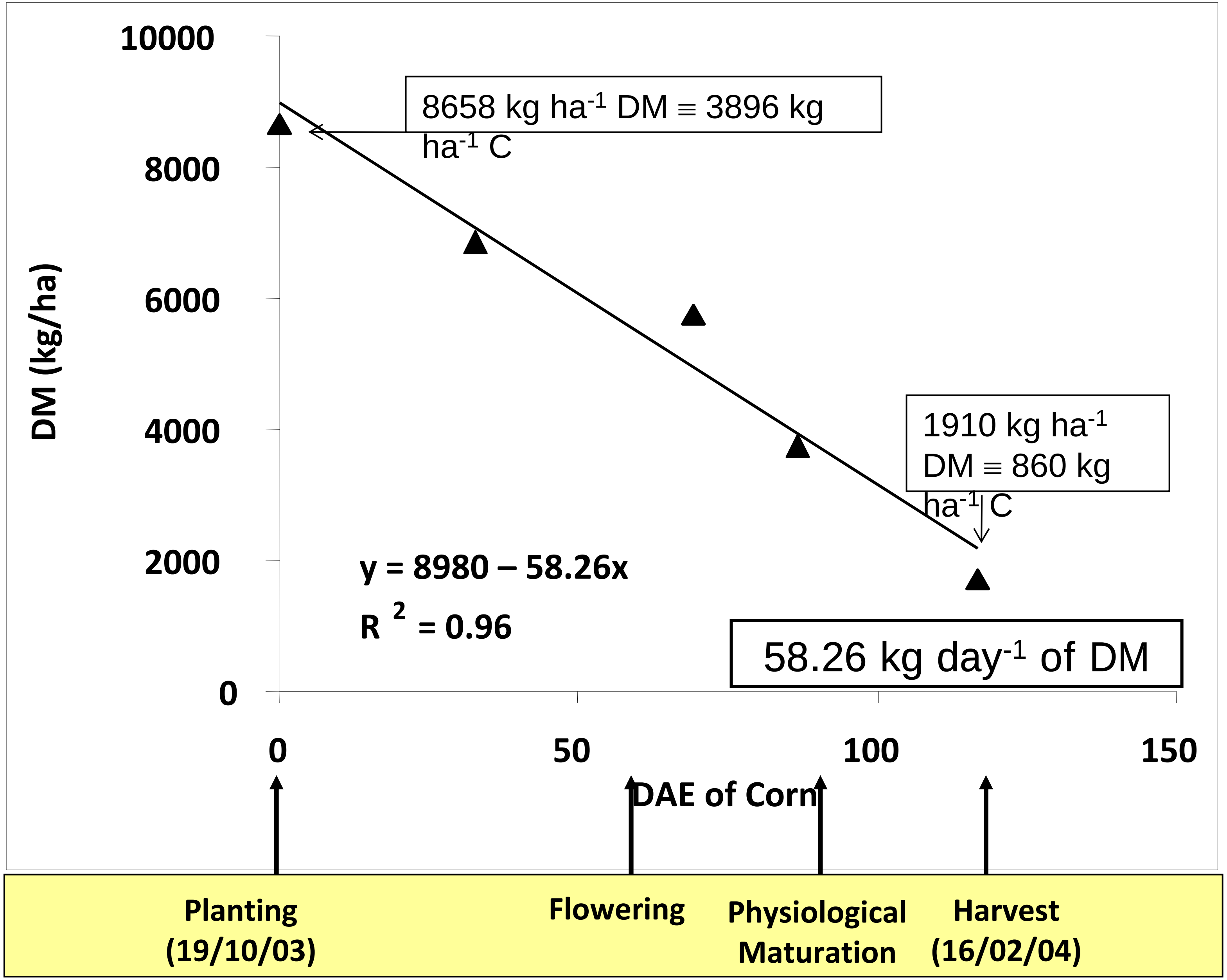


Source: Sá, et al, 2004

Crop residues decopmposition (Brachiaria *decumbens*) during the corn development (Rio Verde, 880 m ASL, Latitude ≅ 16° S, 2003-04, Oxisol (65% of clay)

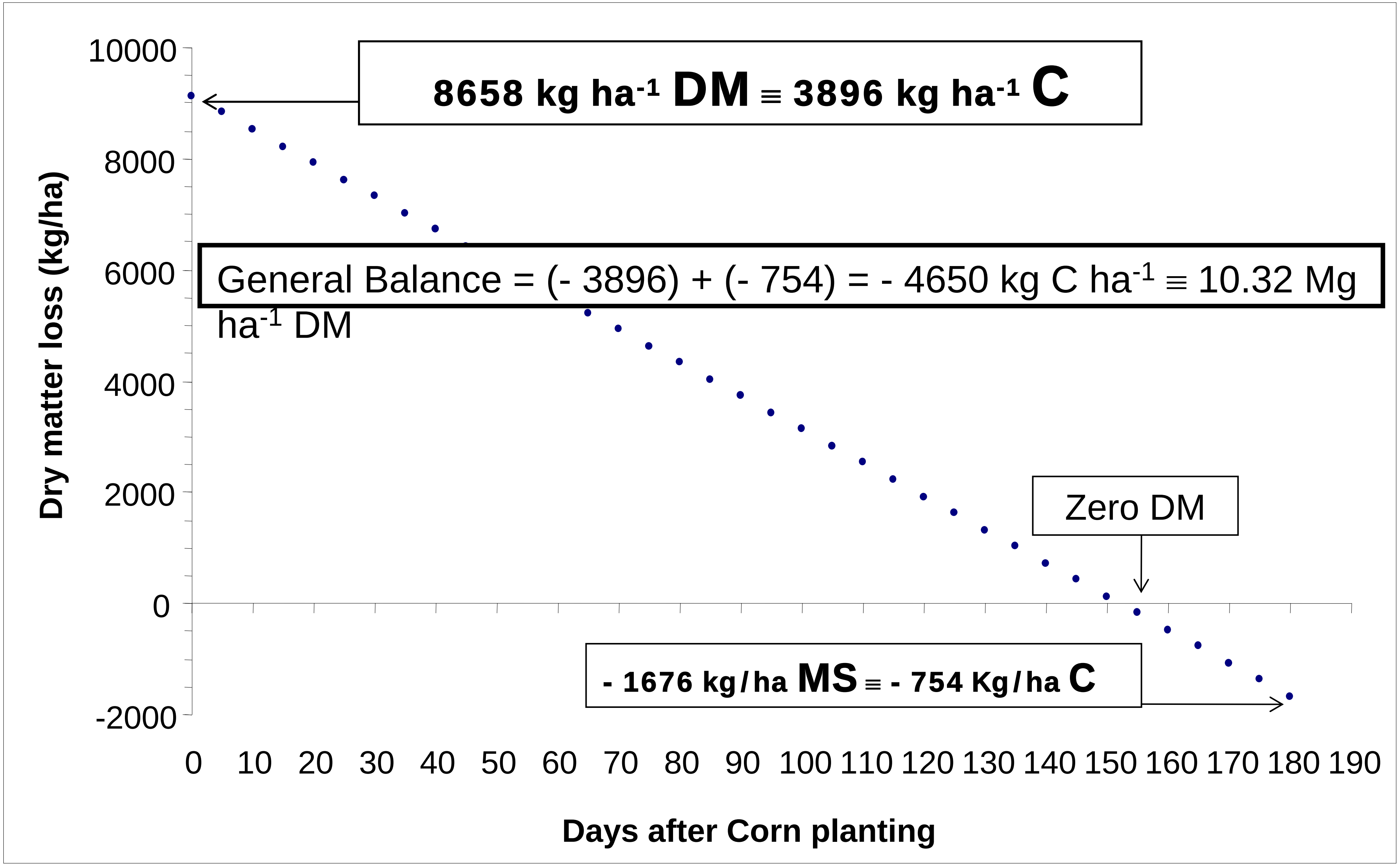


Crop residues (Brachiaria *decumbens*) decomposition during the **corn** development Rio Verde, 880 m ASL, Latitude ≅ 16° S, 2003-04, Oxisol

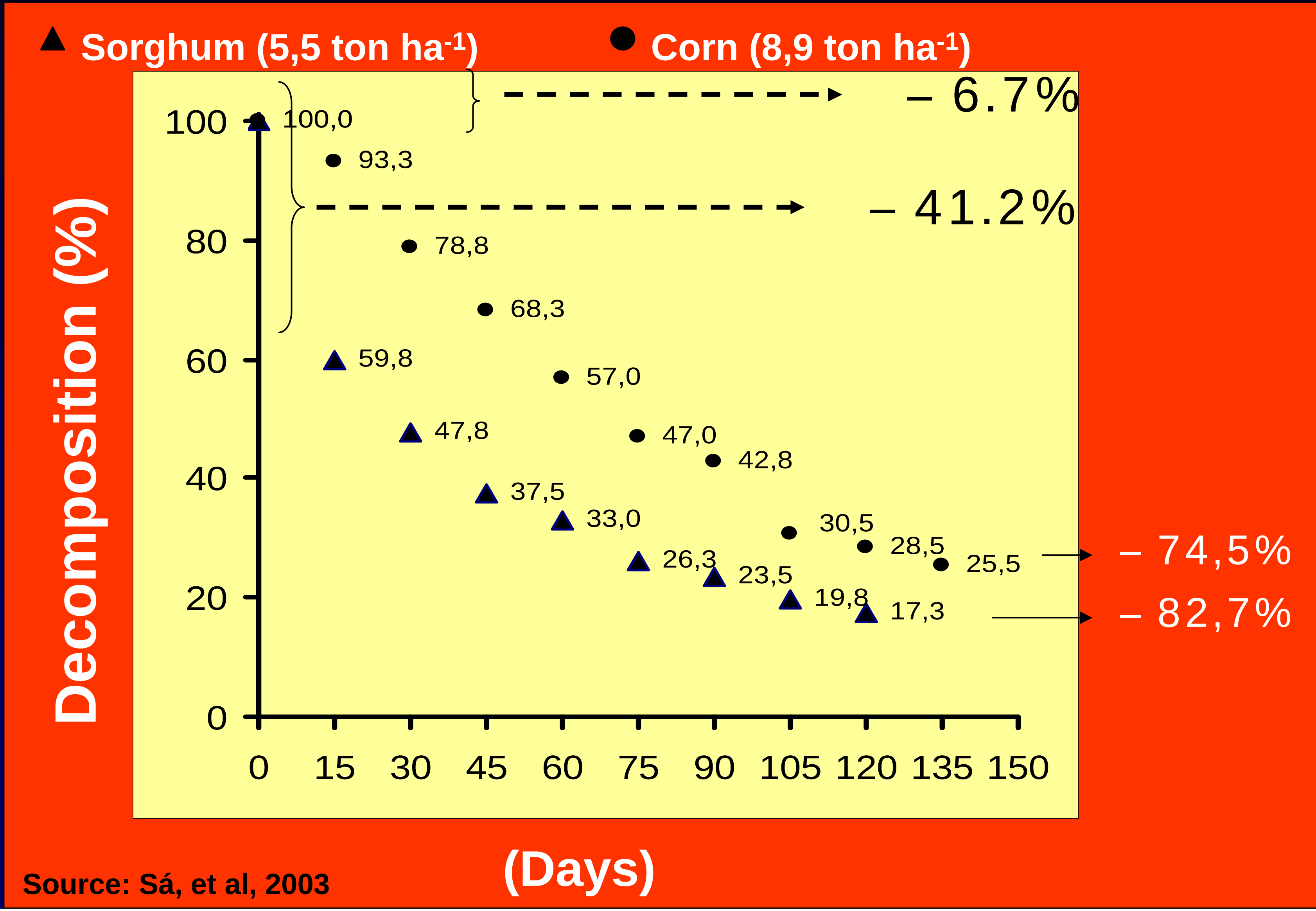


Source: Sá, et al, 2004

Amount of crop residues to maintain the C equilibrium in the soil



Decomposition of corn and sorghum crop residues in tropical zone (Primavera do Leste – MT, 610m, 17° SL, 2002)

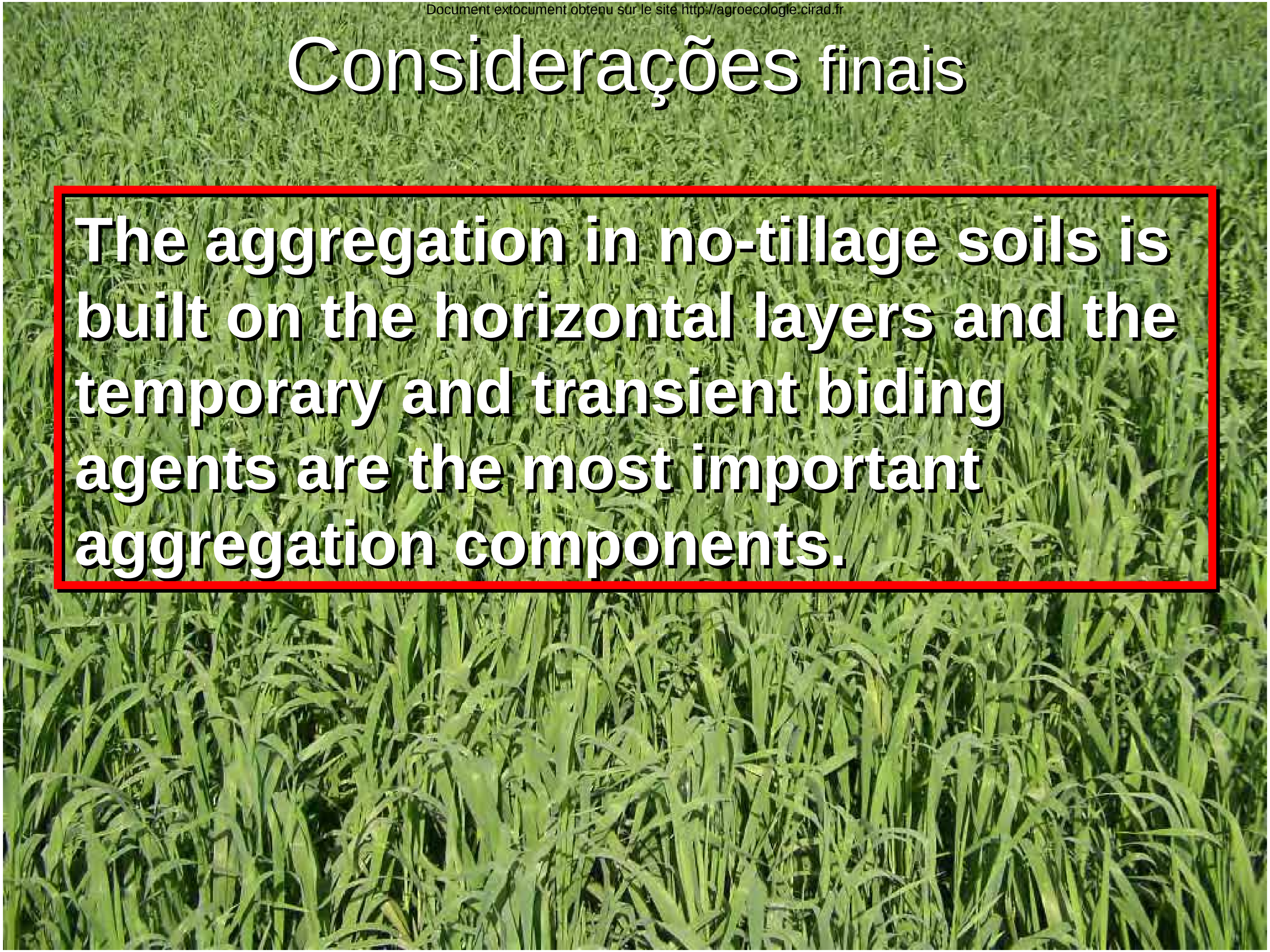


Source: Sá, et al, 2003

Final comments

The SOM have two main pool's represented by active and stable pool

The continuous C flux and the C changes in the active pool is the pathway to enhance the stable SOM pool



Considerações finais

The aggregation in no-tillage soils is built on the horizontal layers and the temporary and transient biding agents are the most important aggregation components.