DecisionES 2025

Porto Seguro BR

Jun 30th to Jul 4th

Symposium on Ecosystem Services, Forest Management and Decision Making

AGRICULTURE AS AN OPTION FOR ADAPTATION AND MITIGATION OF GLOBAL CLIMATE CHANGE

Carlos Eduardo Cerri

CCARBON
CENTER FOR CARBON RESEARCH IN TROPICAL AGRICULTURE
UNIVERSITY OF SÃO PAULO

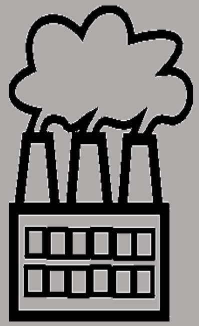
July 3, 2025


INTERNATIONAL ACTIONS AGAINST CLIMATE CHANGE
REDUCE EMISSIONS
INCREASE REMOVALS
TRANSPORTATIO N
ELECTRICITY
AGRICULTURE
INDUSTRY
VEGETATION
SOIL
CHALLENGE AND OPPORTUNITY TO COMBAT CLIMATE CHANGE

INTERNATIONAL ACTIONS AGAINST GLOBAL CLIMATE CHANGE

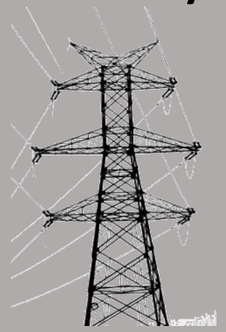
Reduce emissions

Industry



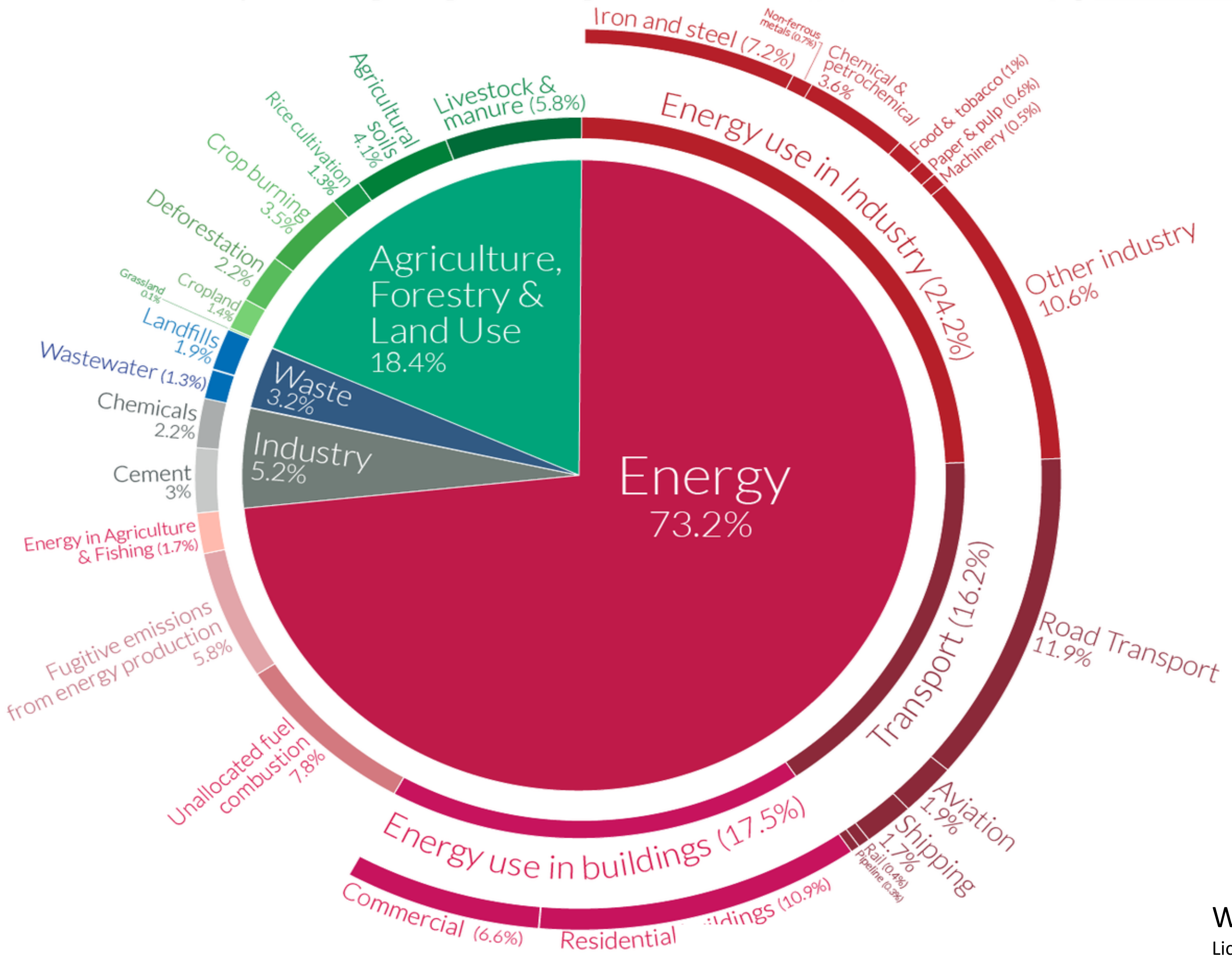
Transport

Electricity



Agriculture and LUC

Global Greenhouse Ga Emissions

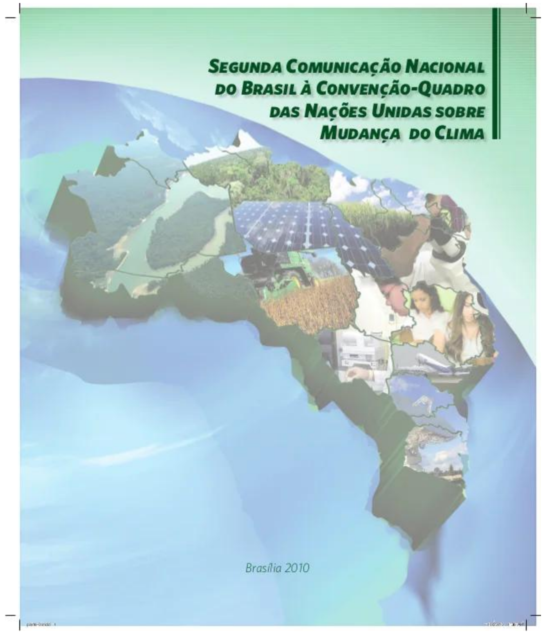


WRI, 2020

Greenhouse Gas Emissions: BRAZIL

National Inventory of Greenhouse Ga Emissions

2004



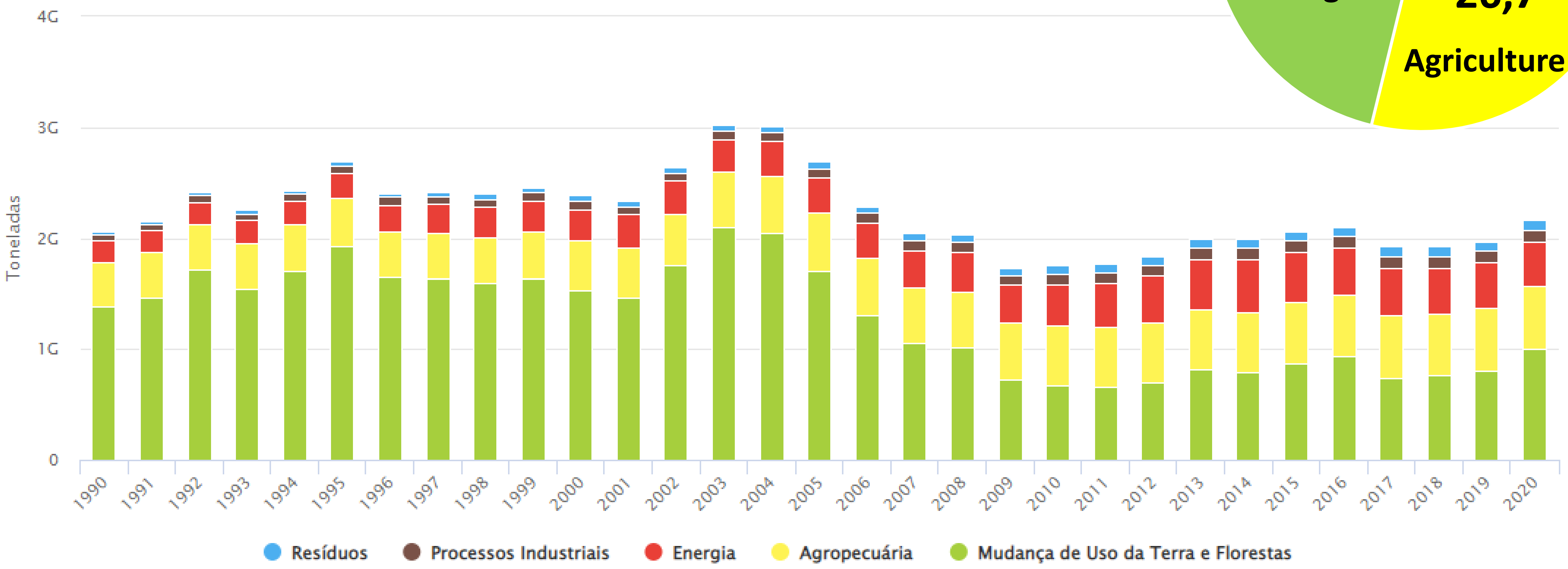
2010

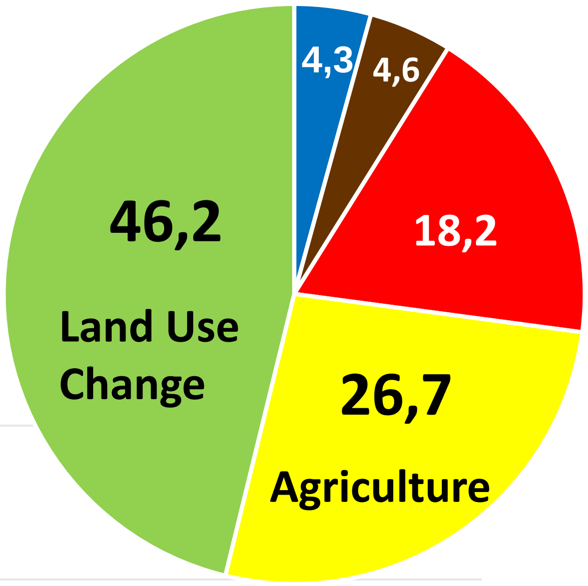
2015

2020

Greenhouse Gas Emissions: BRAZIL

Emissions per Sector (CO_2e) in 2020





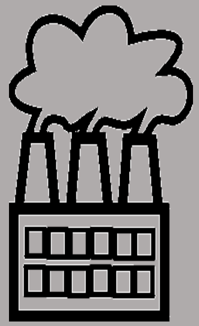
SEEG (2020)

INTERNATIONAL ACTIONS AGAINST GLOBAL CLIMATE CHANGE

Reduce emissions

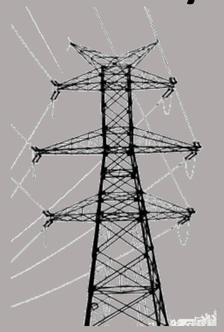
PRIORITY !

Industry

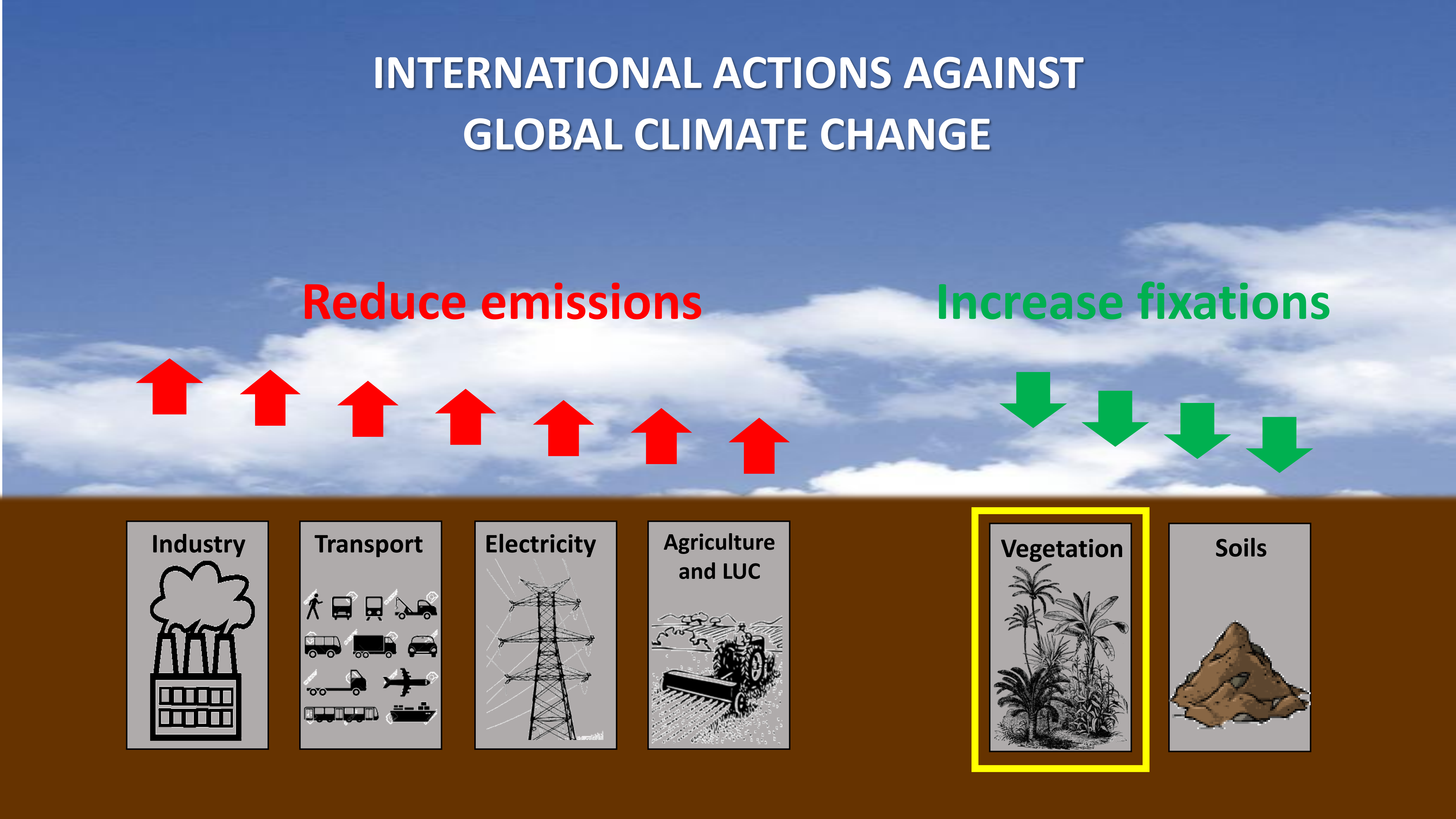


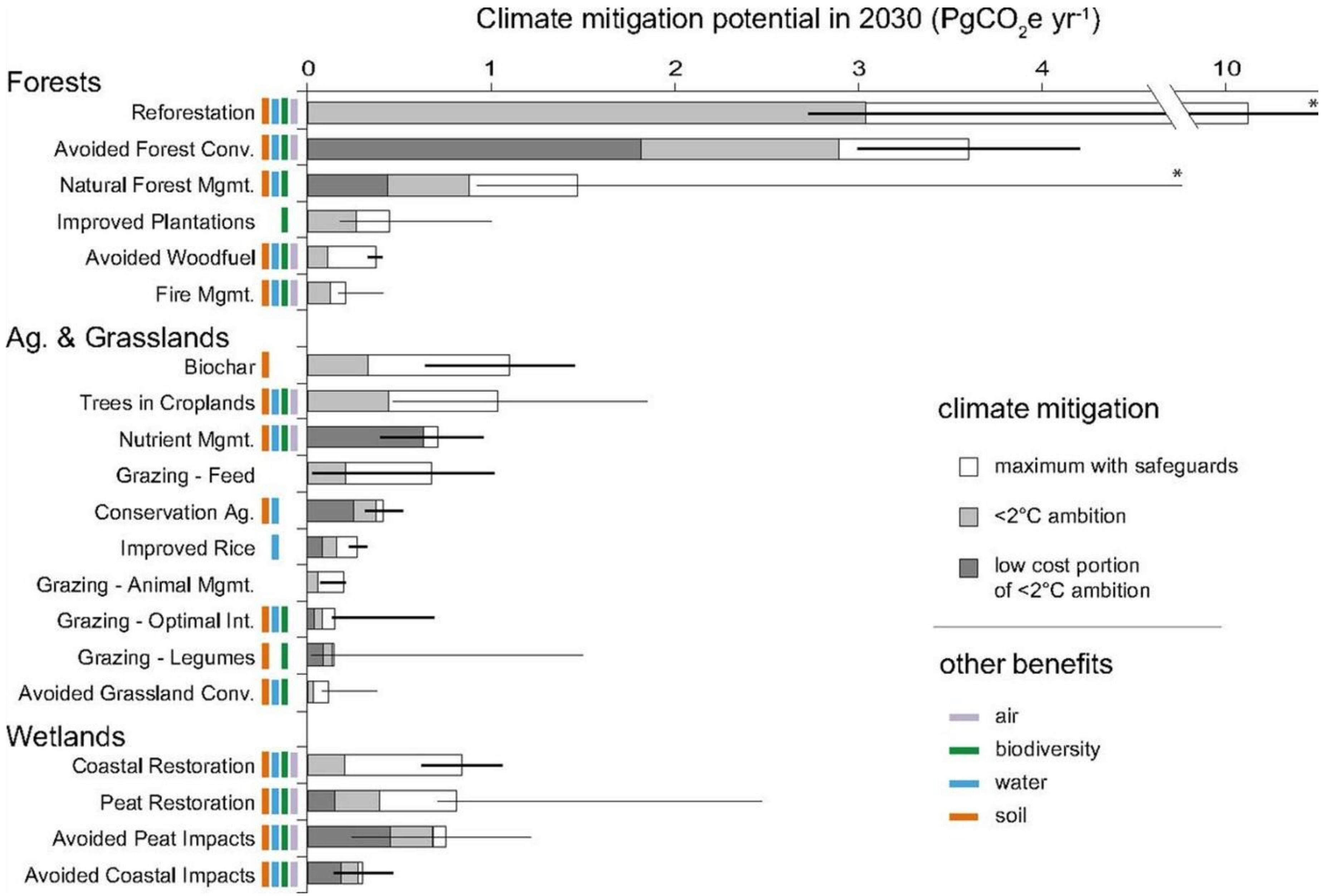
Transport

Electricity



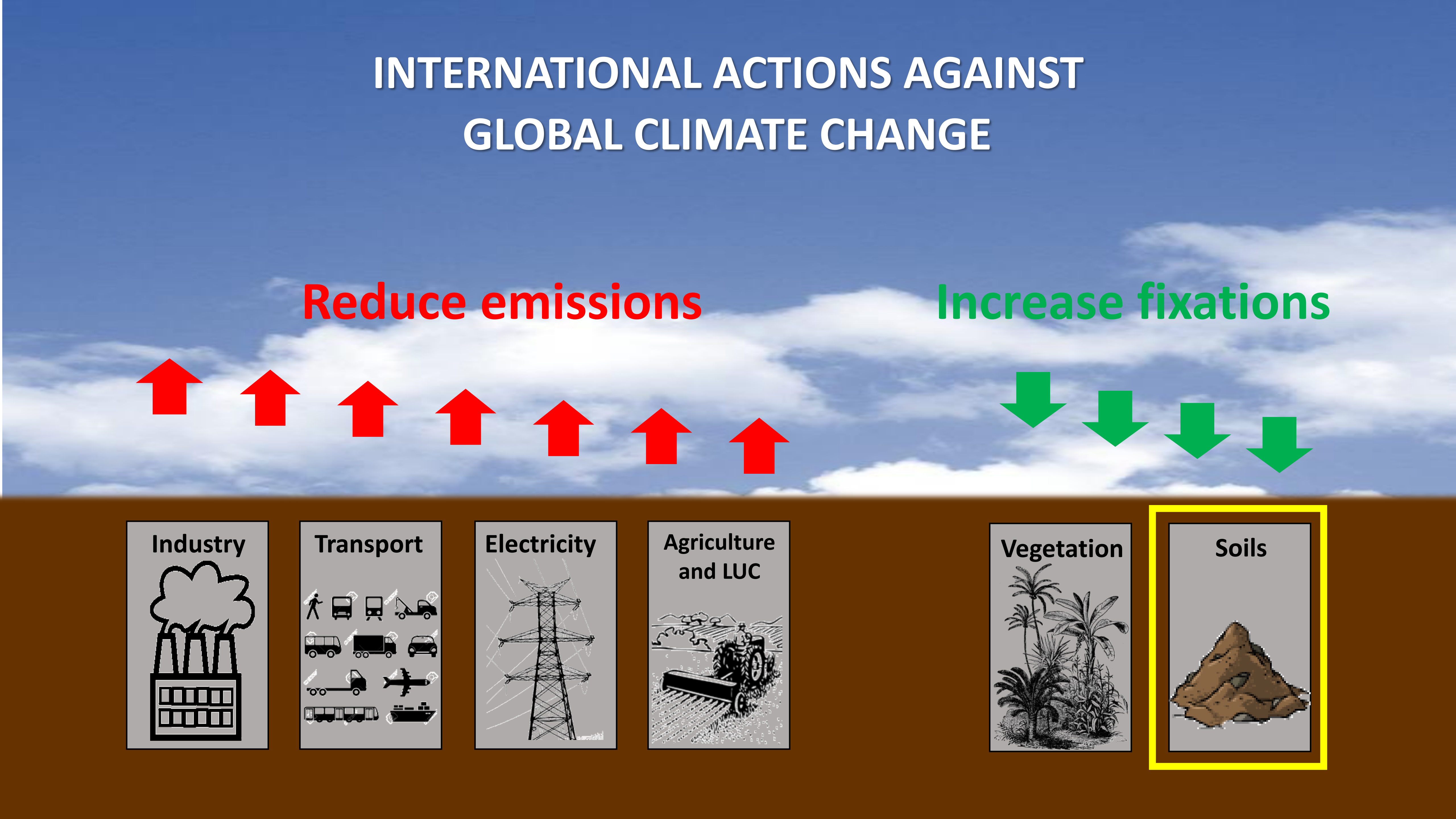
Agriculture and LUC


INTERNATIONAL ACTIONS AGAINST GLOBAL CLIMATE CHANGE
Reduce emissions
Increase fixations
Industry
Transport
Electricity
Agriculture and LUC
Vegetation
Soils



Fonte: Griscom, B. W. et al. *PNAS* **114**, 11645-11650 (2017).

Slide by Pedro Brancalion


INTERNATIONAL ACTIONS AGAINST GLOBAL CLIMATE CHANGE
Reduce emissions
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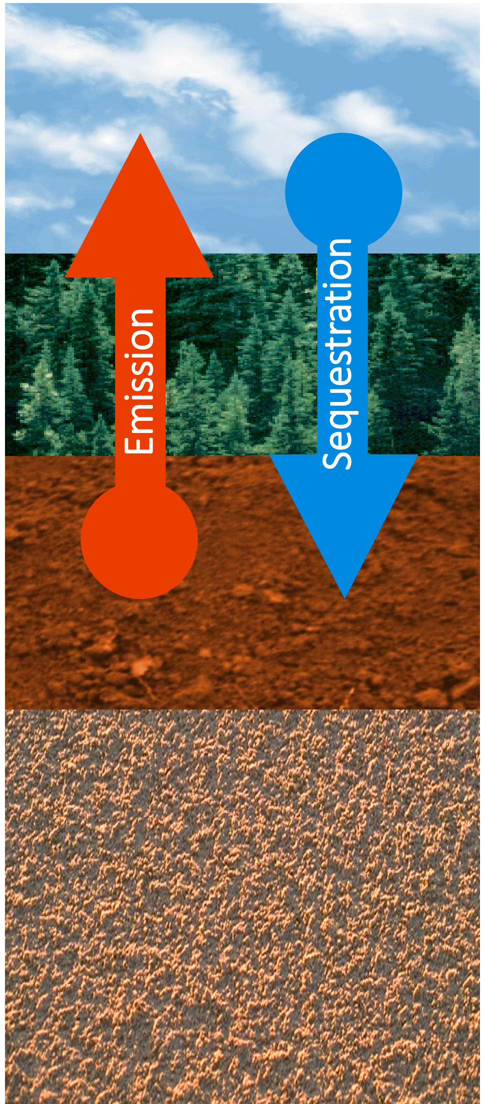
Vegetation
Soils

SOIL CARBON
as indicator

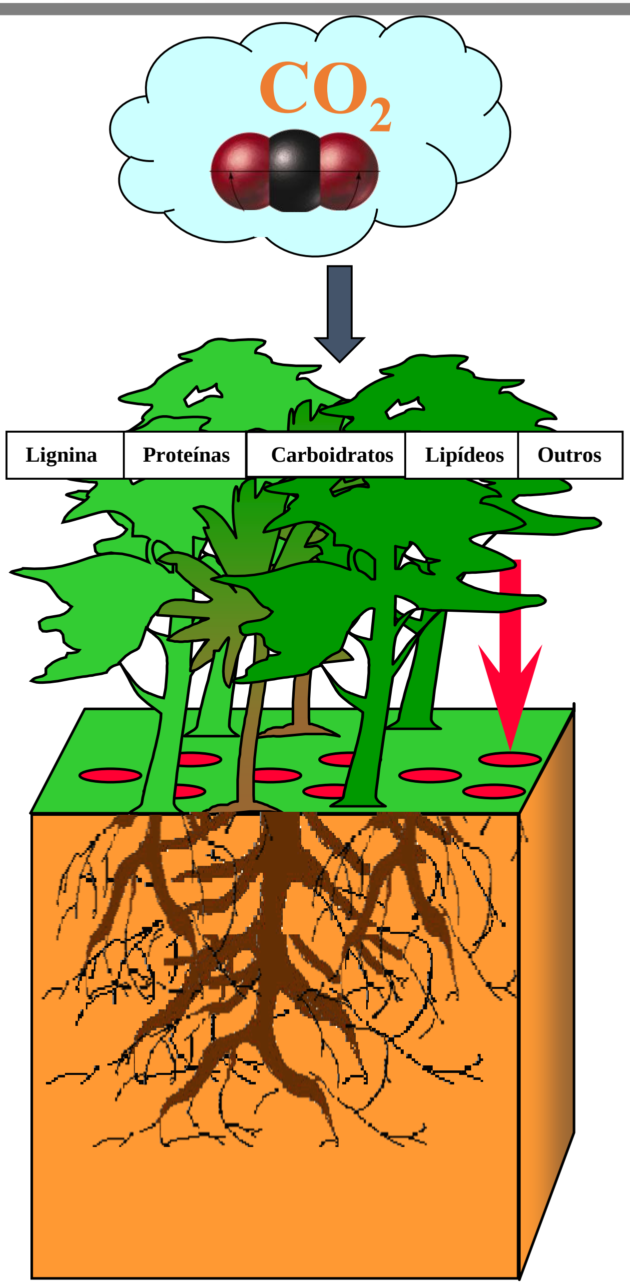
Importance of SOILS in the global carbon cycle

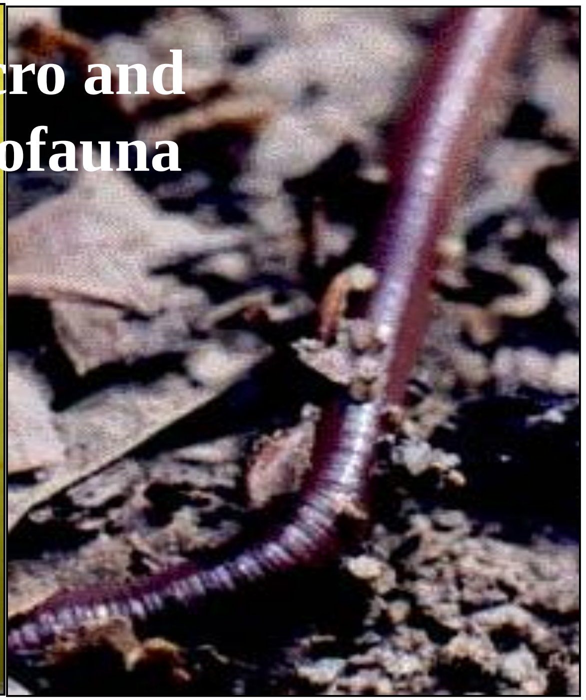


	Pg
Atmosphere	760 - △
Vegetation	470-655
Soil (0-30cm)	~800 + △
Soil (1m)	1500-2000

Values in Gt C (1Gt = 10^9 t = 1 Pg)

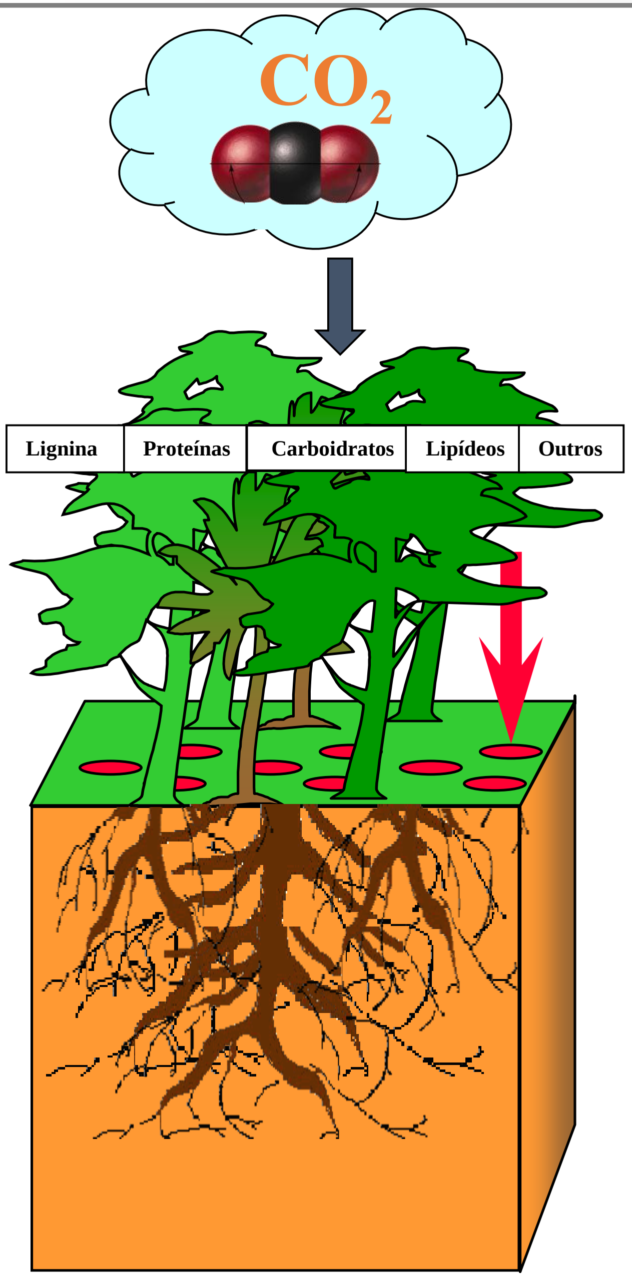
Soil Carbon Sequestration

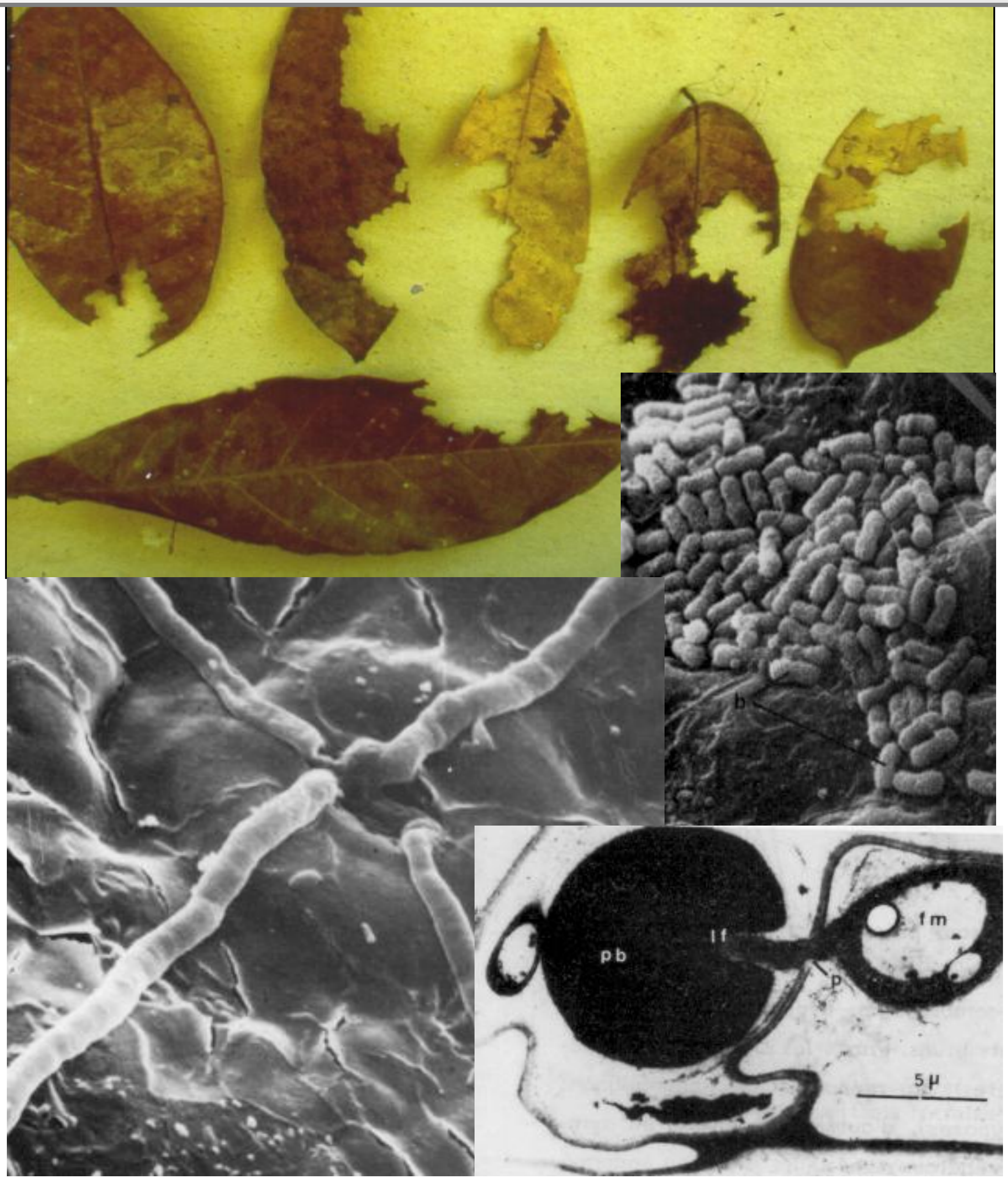




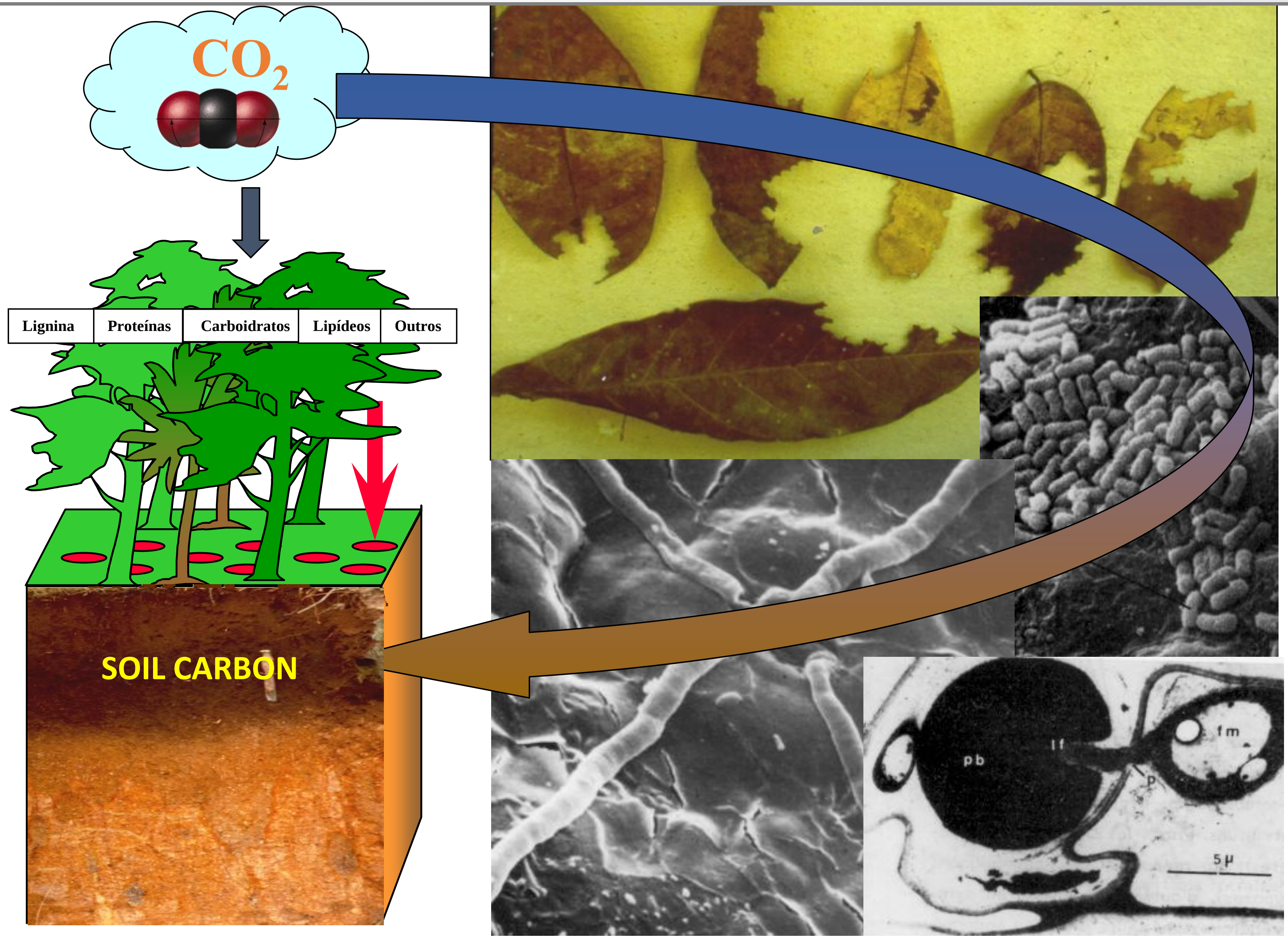
Macro and mesofauna

Soil Carbon Sequestration

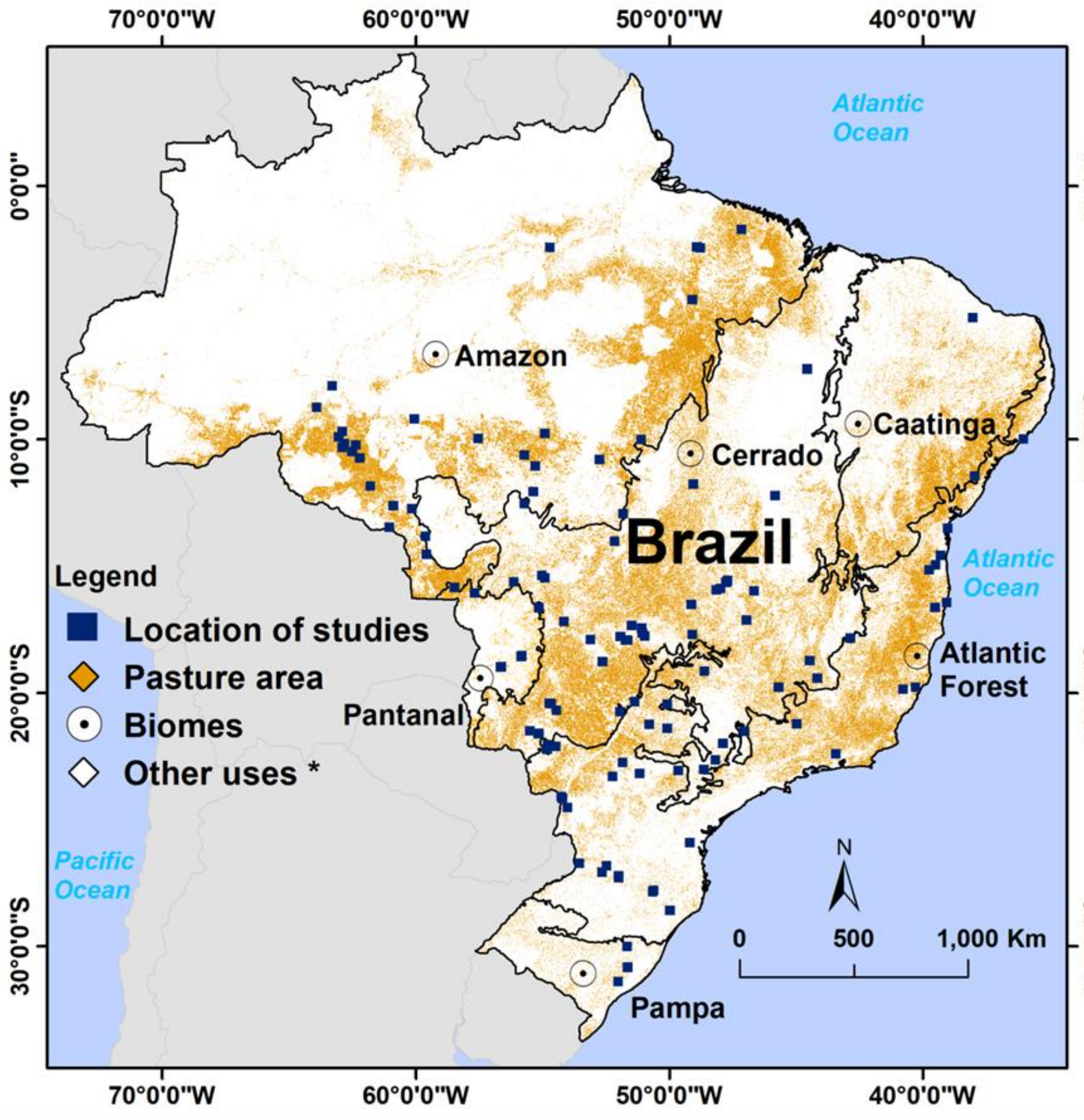




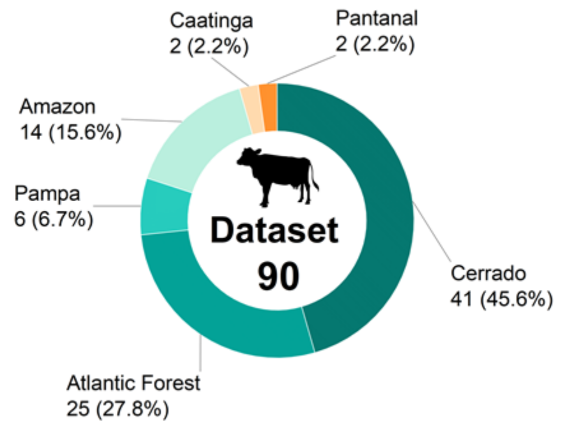
Soil Carbon Sequestration



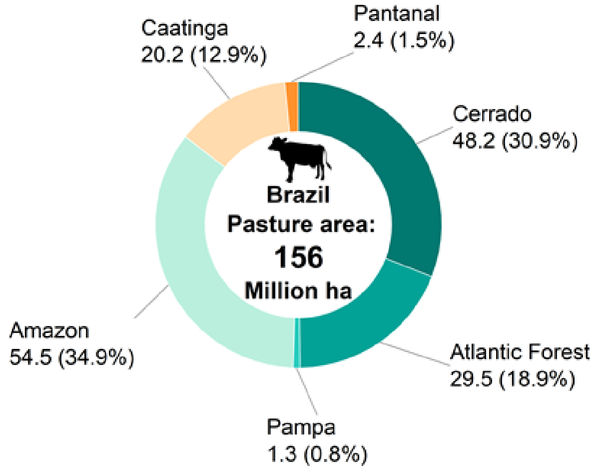
Pasture



70°0'0"W
60°0'0"W
50°0'0"W
40°0'0"W
0°0'0"
10°0'0"S
20°0'0"S
30°0'0"S
Atlantic Ocean
Amazon
Caatinga
Cerrado
Brazil
Atlantic Ocean
Atlantic Forest
Pantanal
Pampa
Pacific Ocean
Legend
Location of studies
Pasture area
Biomes
Other uses *
N
0
500
1,000 Km

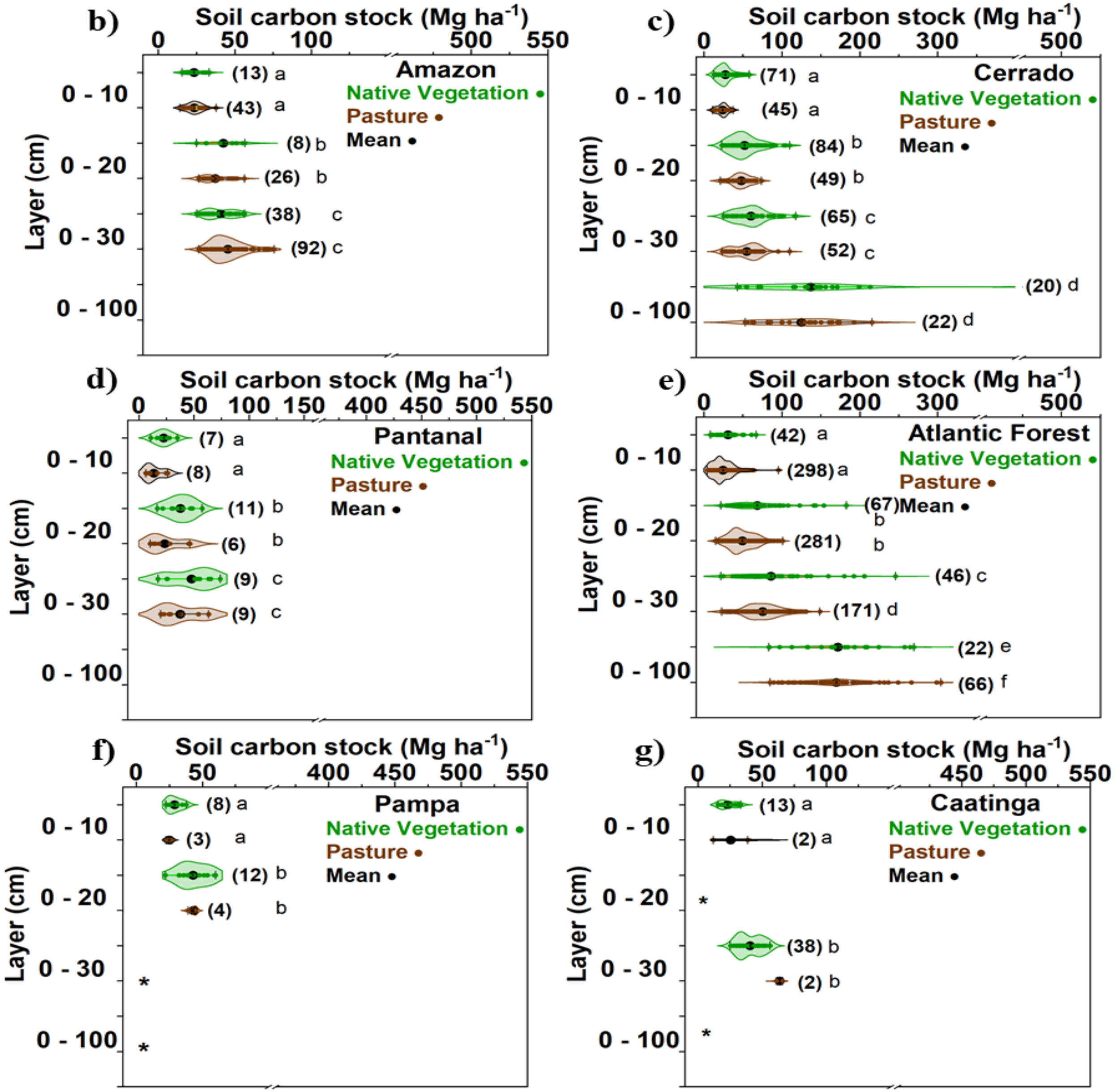


Caatinga
2 (2.2%)
Pantanal
2 (2.2%)
Amazon
14 (15.6%)
Pampa
6 (6.7%)
Dataset
90
Cerrado
41 (45.6%)
Atlantic Forest
25 (27.8%)

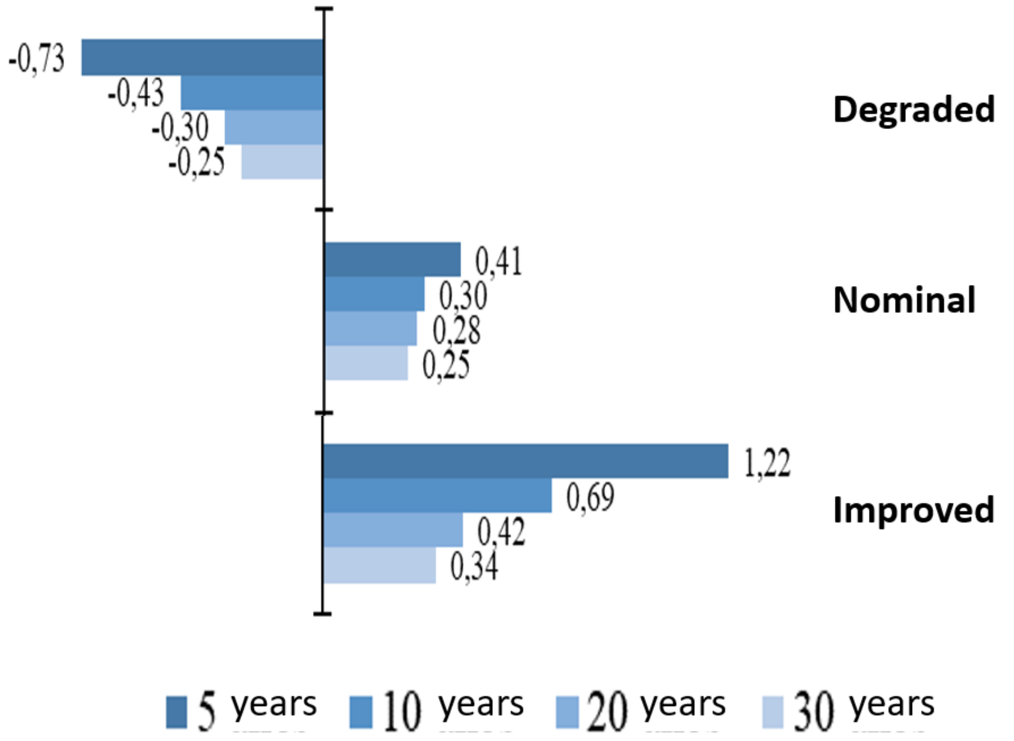


Caatinga
20.2 (12.9%)
Pantanal
2.4 (1.5%)
Cerrado
48.2 (30.9%)
Brazil
Pasture area:
156
Million ha
Amazon
54.5 (34.9%)
Atlantic Forest
29.5 (18.9%)
Pampa
1.3 (0.8%)

Pasture



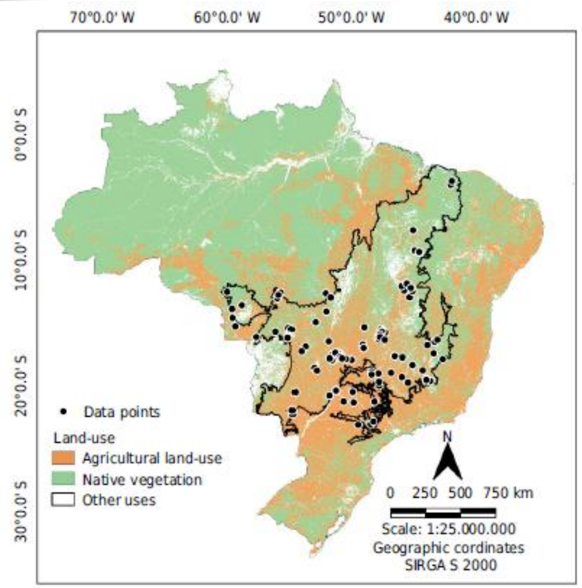
Rate of soil C stock changes
Mg ha^{-1} year^{-1}



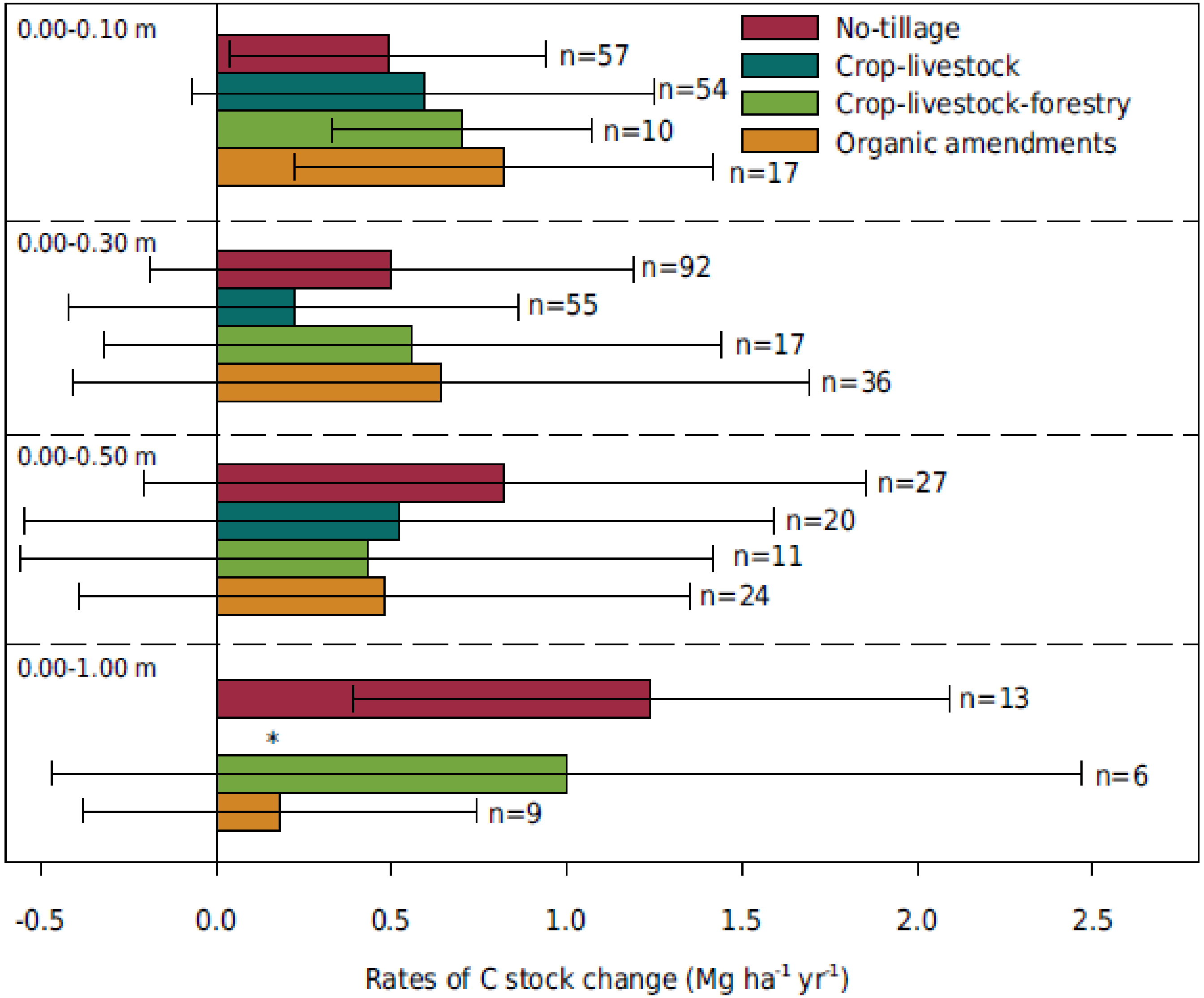
Soil C sequestration rates

conservation ag practices in Brazilian Cerrado

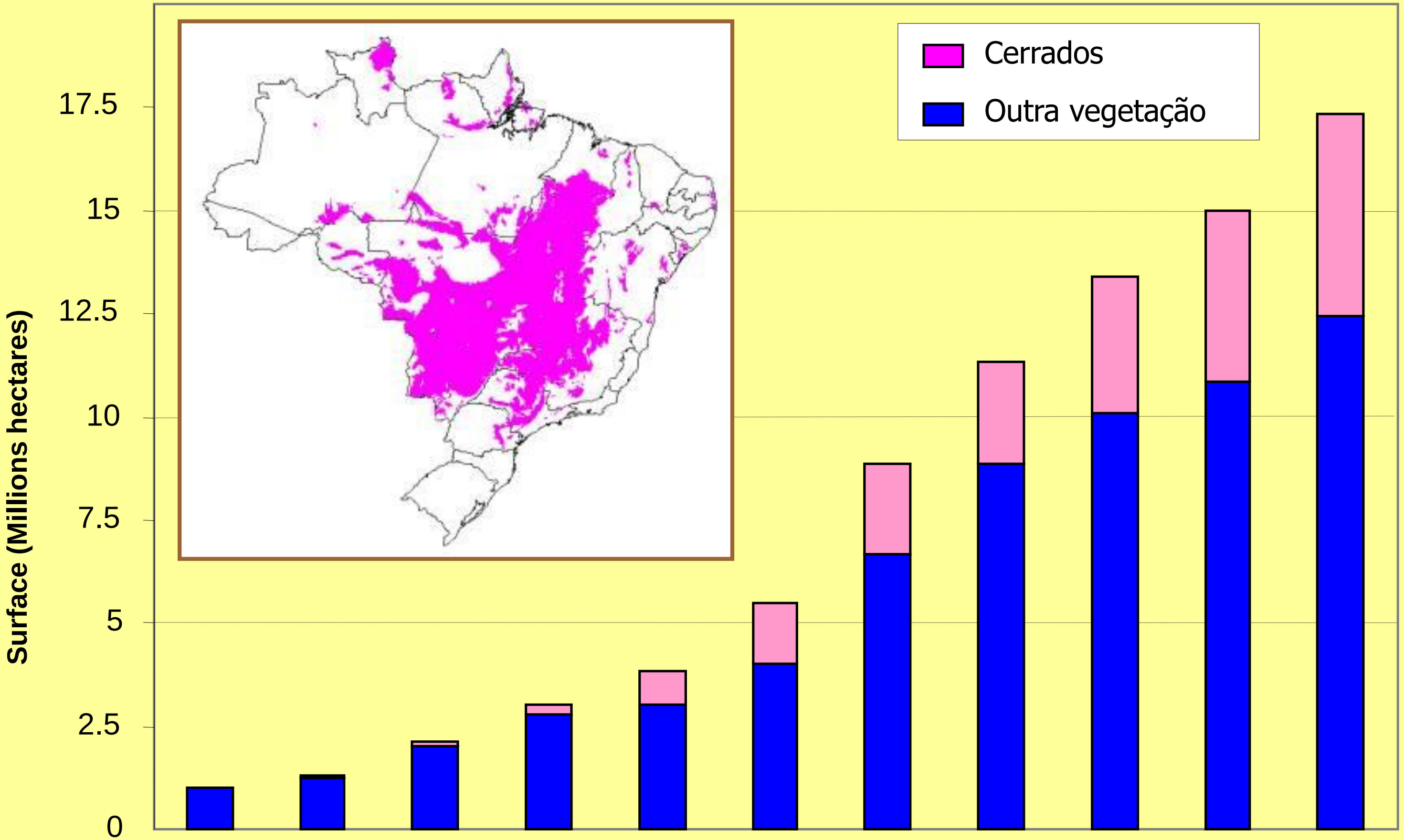
Climate-smart agriculture and soil C sequestration in Brazilian Cerrado: a systematic review



Oliveira et al. (2023)



Soil C sequestration rates

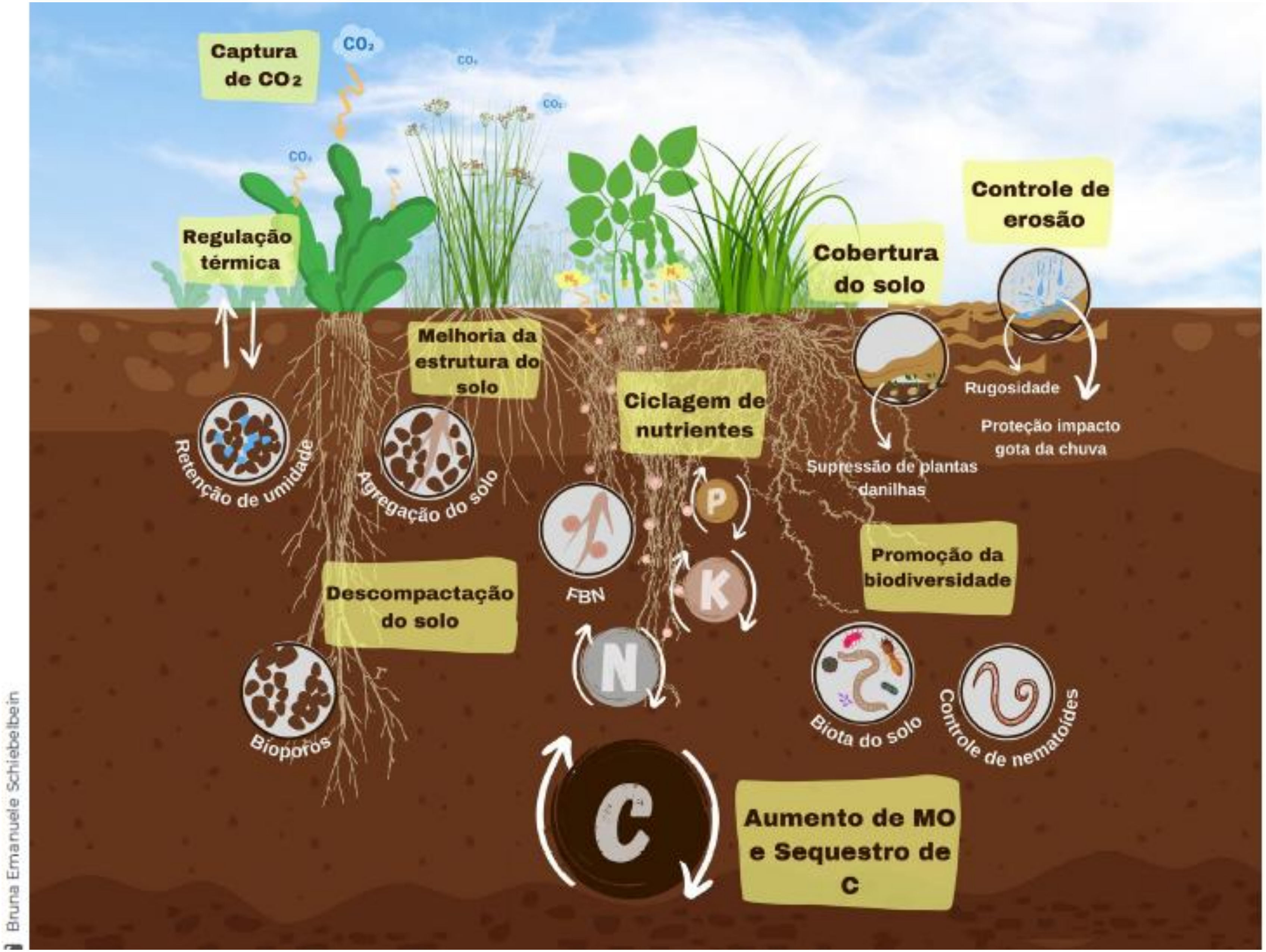


Conventional → No-tillage
1.1 Million ha per year

NO-TILLAGE

Presently
~30 M ha:
Sequestration rate
0.5 Mg ha^{-1} yr^{-1}

~15 Mt C yr^{-1}



Cherubin et al. 2024

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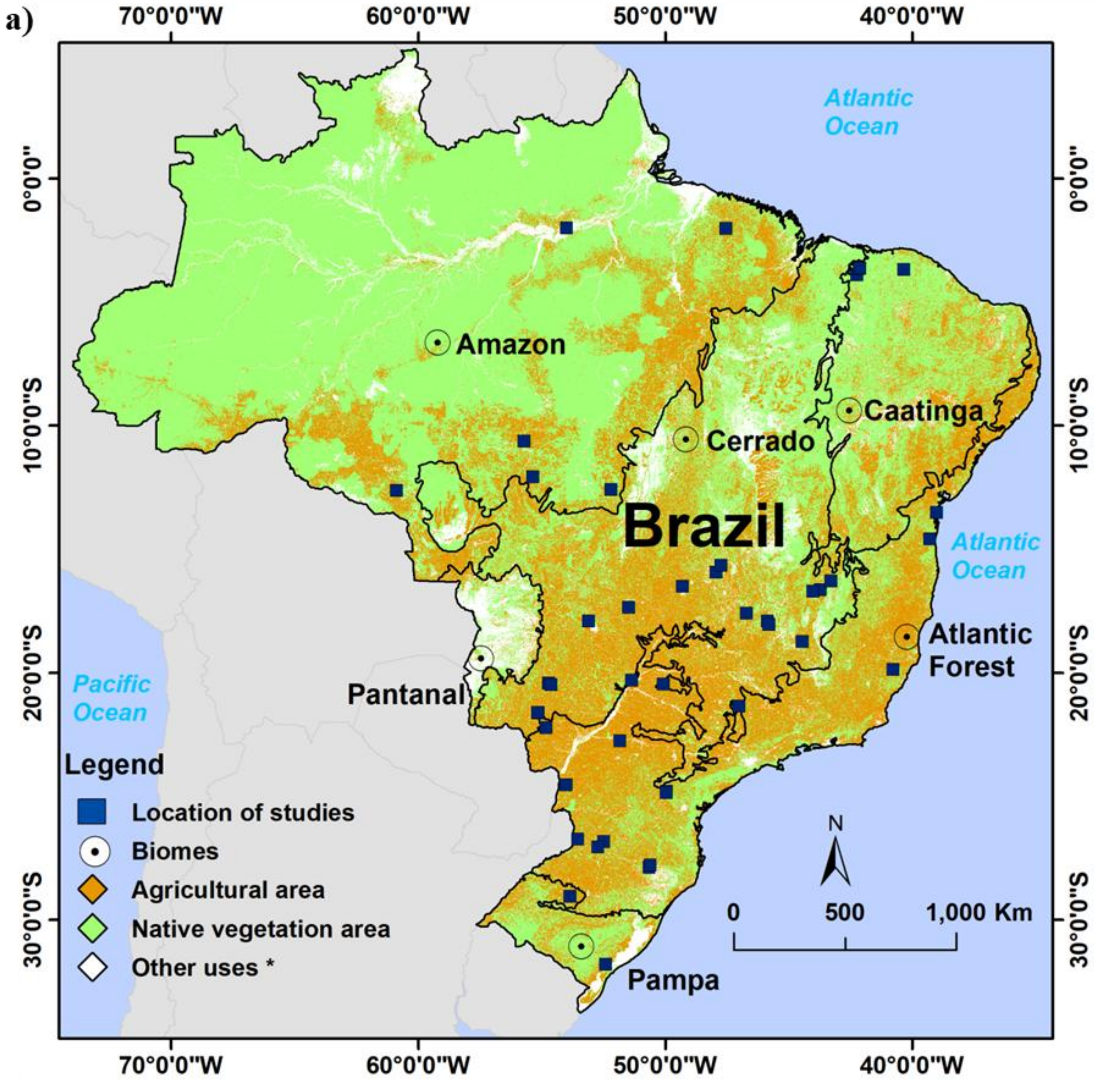
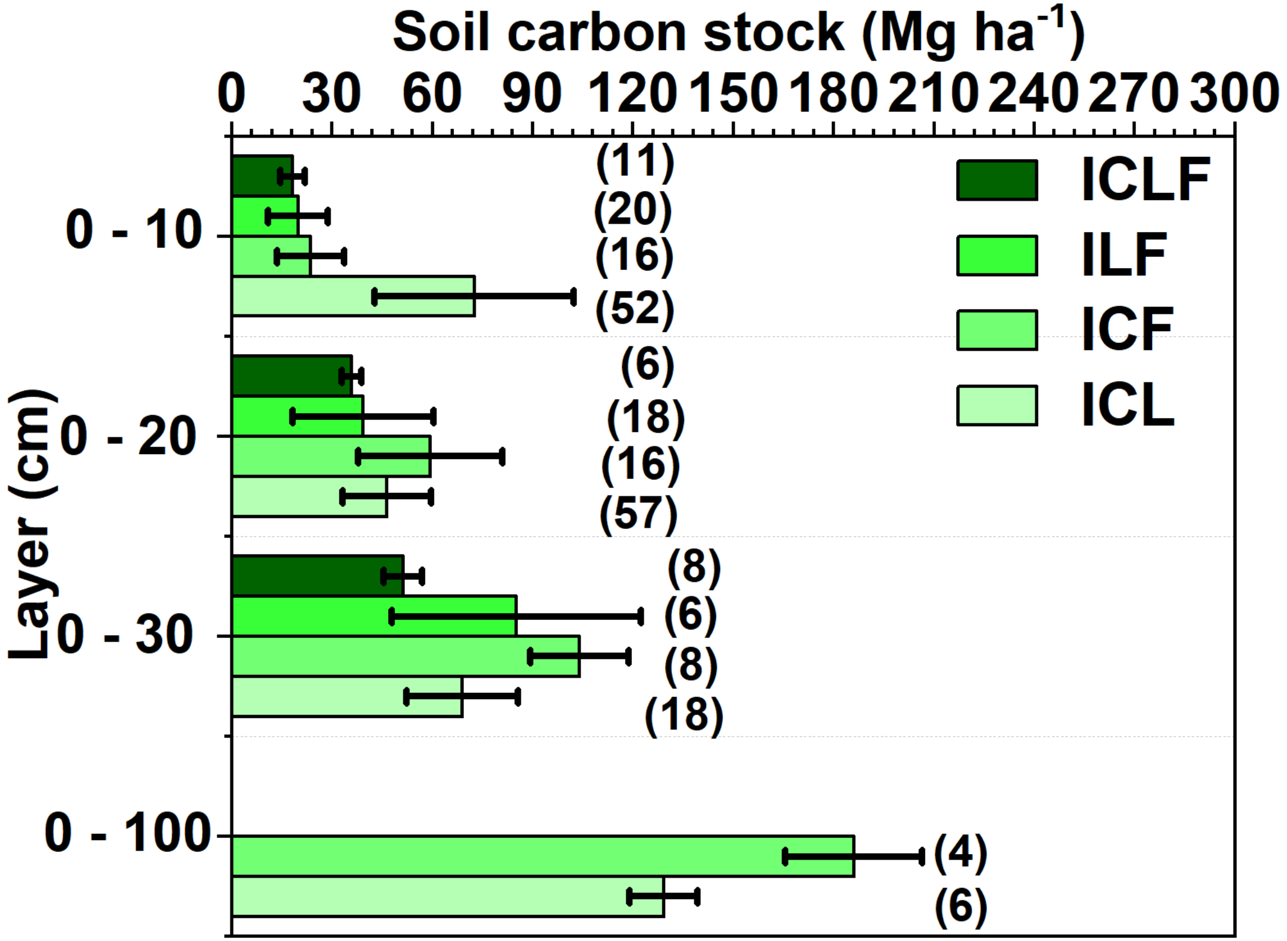
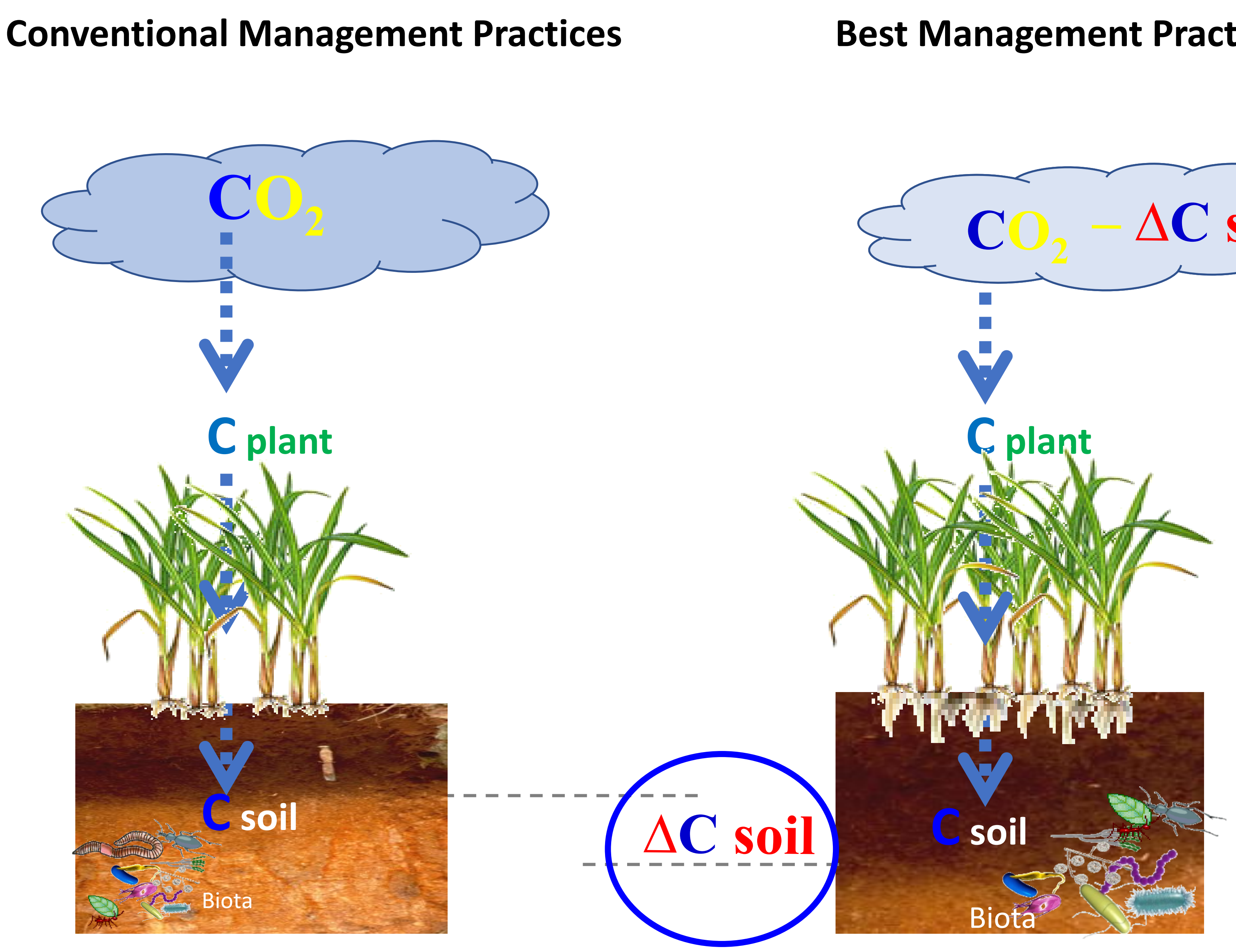
Soil C stocks in Integrated Agricultural Systems



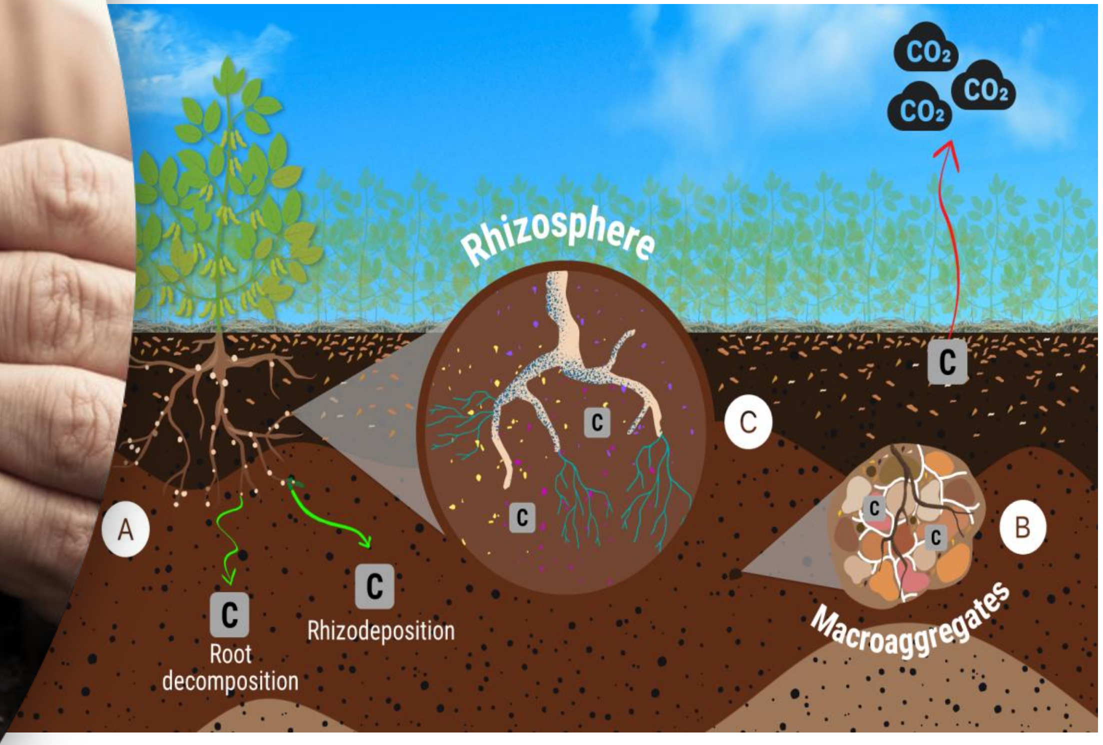


Vilella et al., 2022



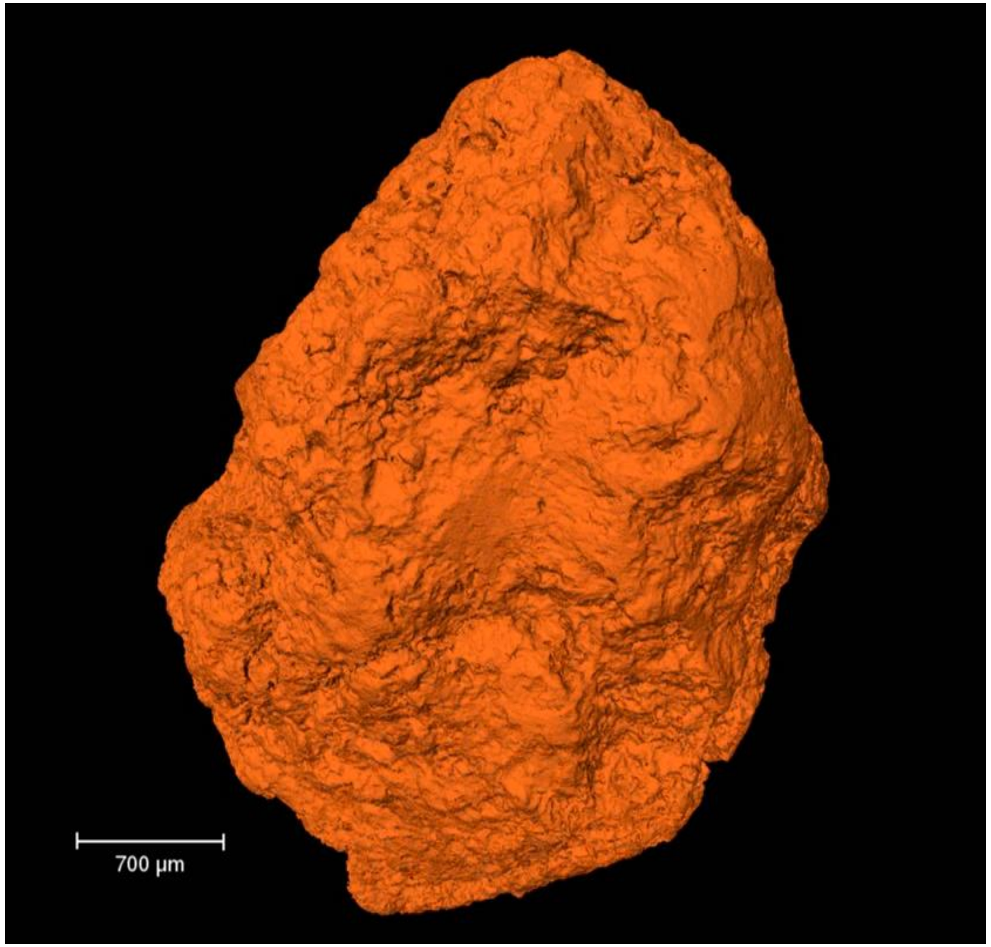
Conventional Management Practices
Best Management Practices
CO_2
$CO_2 - \Delta C$ soil
C plant
C plant
C soil
C soil
Biota
Biota
ΔC soil

Soil organic carbon protection



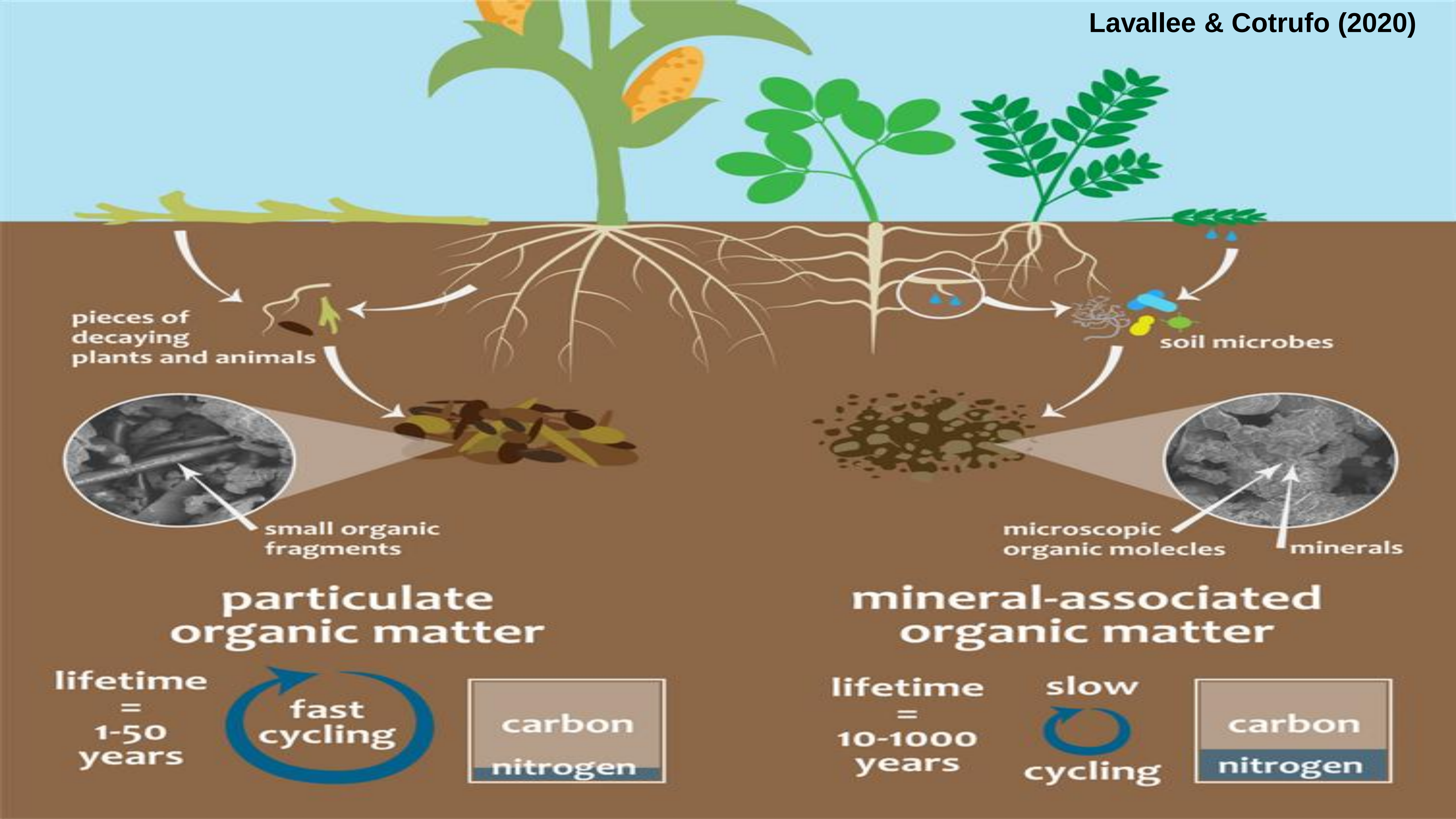
Carvalho et al. (2023)

Synchrotron radiation



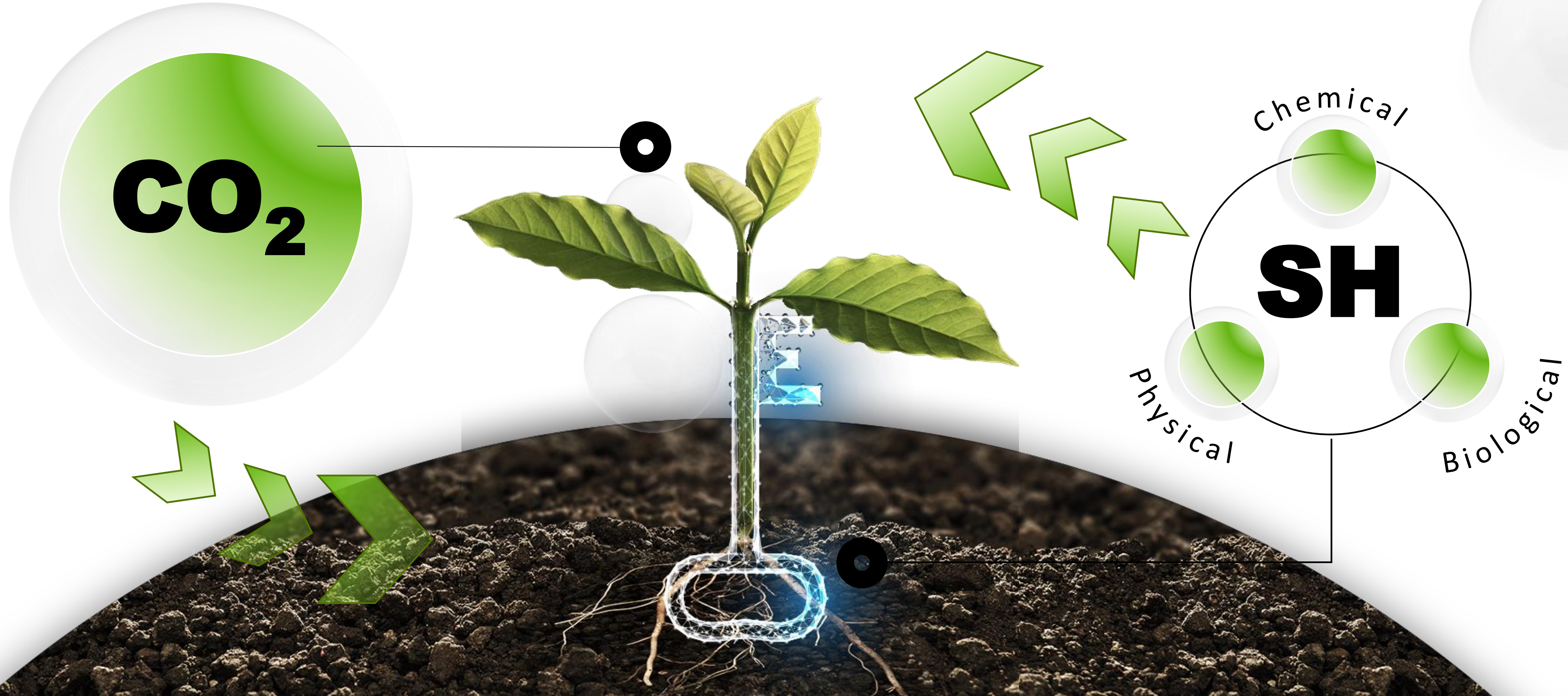
Oliveira et al. (2023)

Lavallee & Cotrufo (2020)



Relationship between soil C sequestration and soil health

...INTENSIFICATION & DIVERSIFICATION



BRAZILIAN

SOIL HEALTH

PARTNERSHIP

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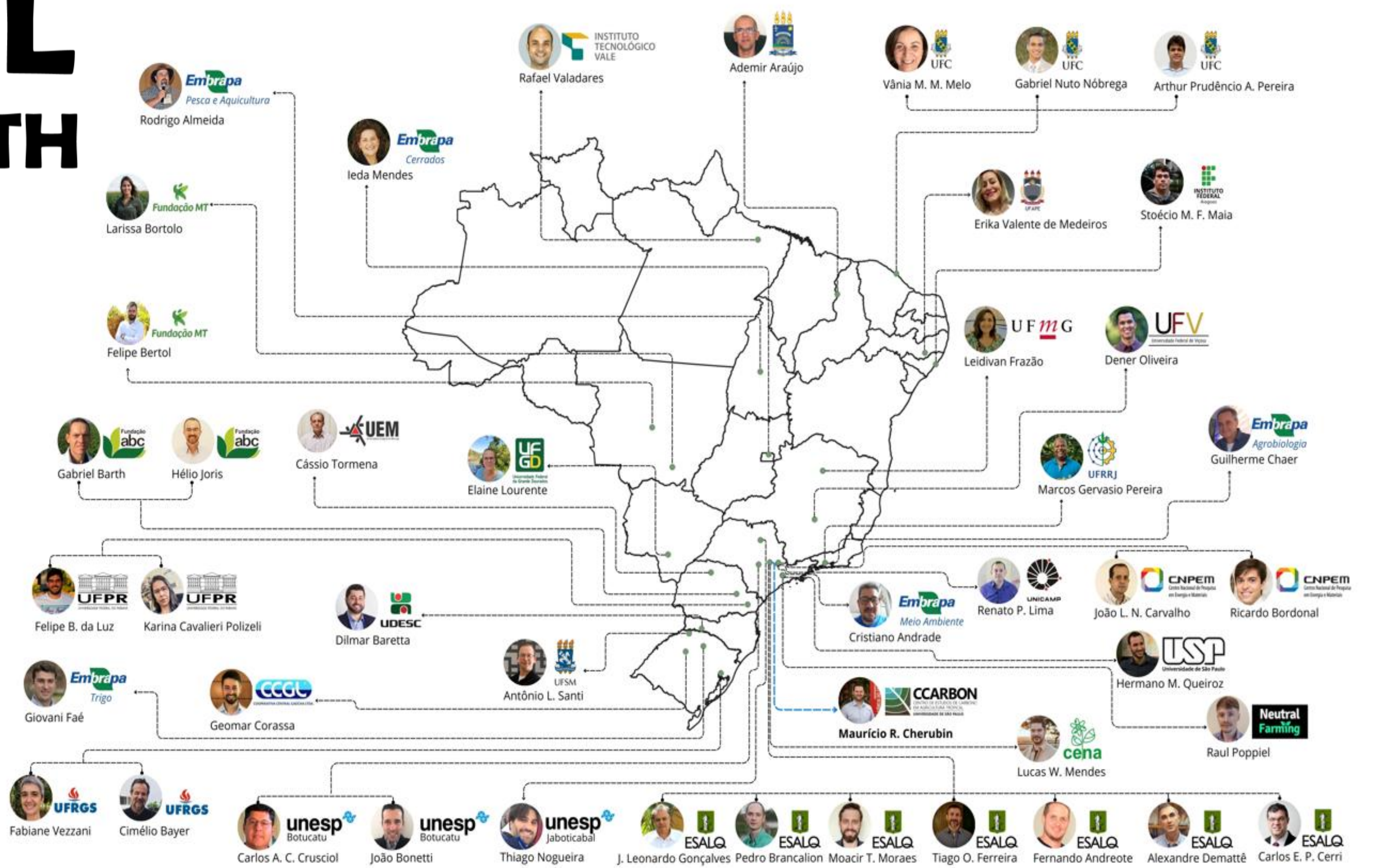
+50 researchers

Promoting a national soil health agenda, enabling connections between scientists, farmers and stakeholders



SCAN ME

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INPI INSTITUTO NACIONAL DA PROPRIEDADE INDUSTRIAL

30/07/2024 870240064465 16:23

29409162317910882

Pedido nacional de Invenção, Modelo de Utilidade, Certificado de Adição de Invenção e entrada na fase nacional do PCT

Número do Processo: BR 10 2024 015629 3

Dados do Depositante (71)

Depositante 1 de 1

Nome ou Razão Social:	UNIVERSIDADE DE SÃO PAULO - USP
Tipo de Pessoa:	Pessoa Jurídica
CPF/CNPJ:	63025530000104
Nacionalidade:	Brasileira
Qualificação Jurídica:	Instituição de Ensino e Pesquisa
Endereço:	Rua da Reitoria, 374 - Butantã
Cidade:	São Paulo
Estado:	SP
CEP:	05508220
País:	Brasil
Telefone:	(11) 3091.4474
Fax:	
Email:	pidireto@usp.br

KIT SOHMA

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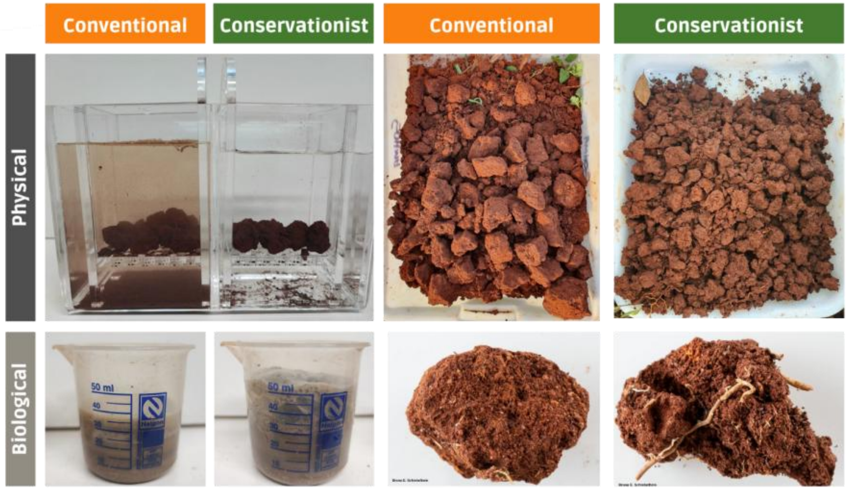
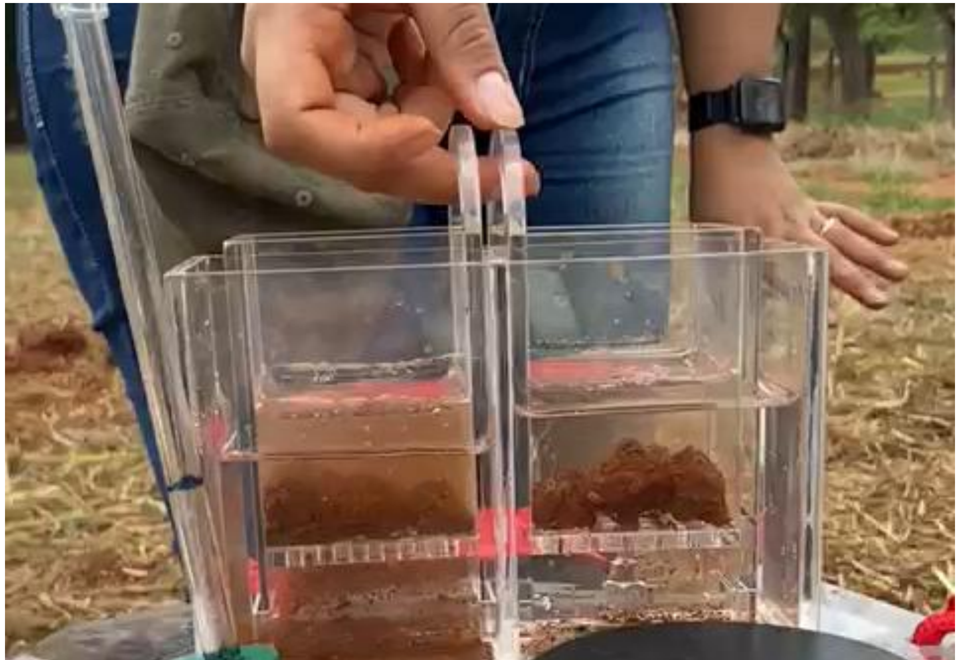
UNIVERSITY OF SÃO PAULO

SOHMA KIT
SOIL HEALTH

Indicators

Physical	Infiltration Test
	Aggregate stability
	Soil structure
Chemical	pH
Biological	Biological activity
	Macrofauna evaluation
	Aggregate visual separation





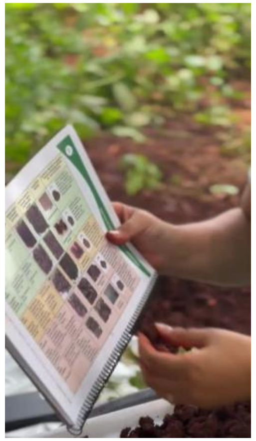
1

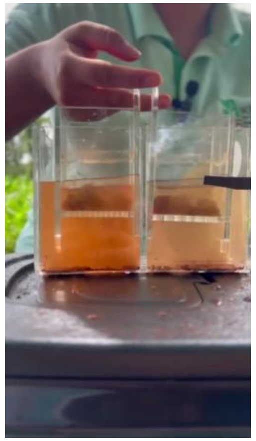

KIT SOHMA
SAÚDE DO SOLO

SCAN ME

2


KIT SOHMA
SAÚDE DO SOLO





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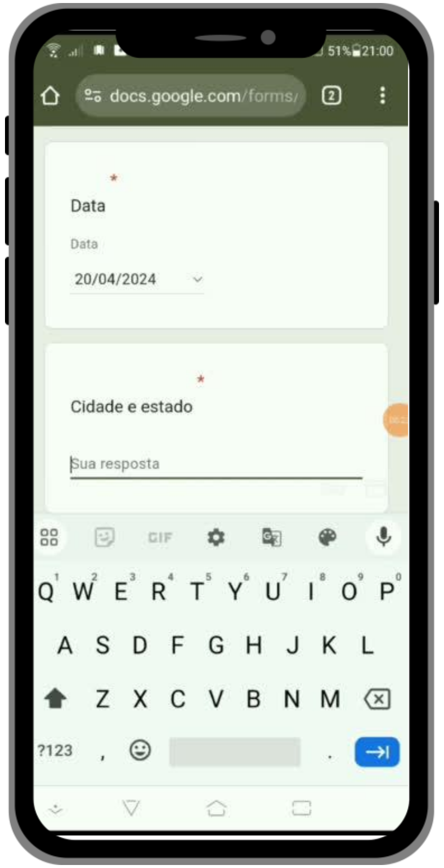
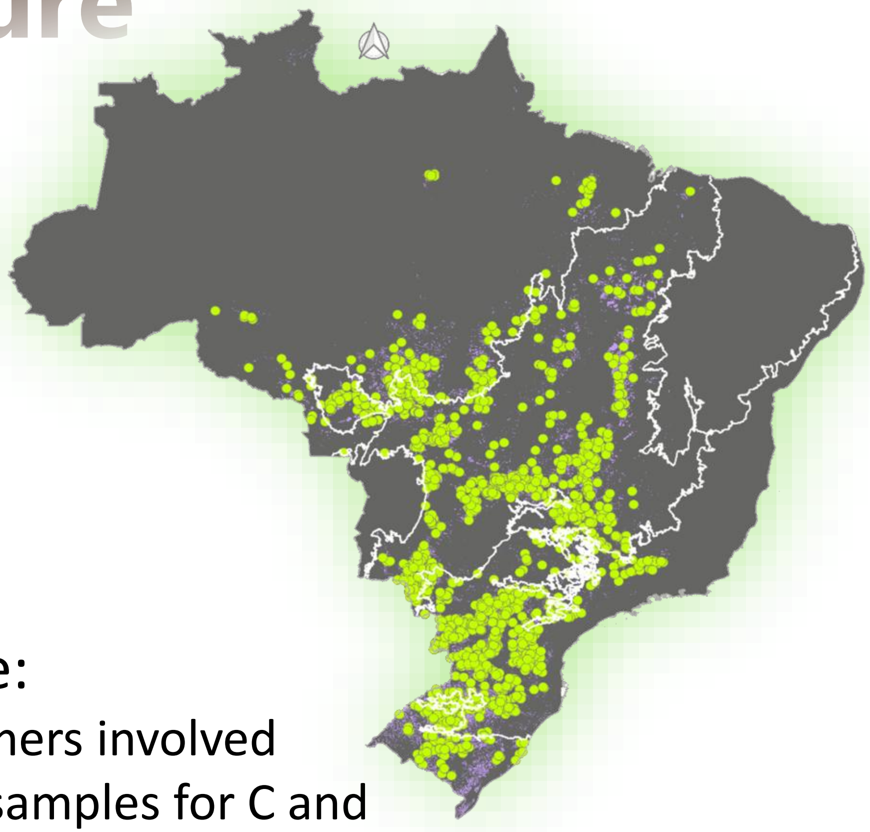

docs.google.com/forms/
Data
Data
20/04/2024
Cidade e estado
Sua resposta

Carbon balance and soil health assessment in annual cropping systems under regenerative agriculture



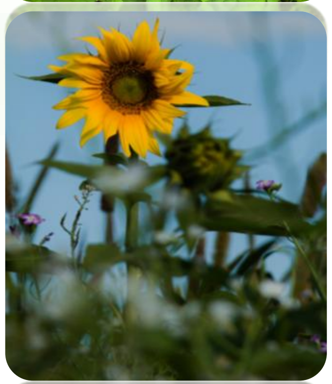
Objective:

To support scientifically a carbon farming program by evaluating cropping system biodiversification options (using cover crops) to quantify C stocks, GHG emissions and soil health indicators (on-farm and lab) across the country.

Database:

~2000 farmers involved

~100,000 samples for C and supporting indicators



Challenges for soil carbon measuring, reporting and verification

frontiers | Frontiers in Sustainable Food Systems

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EDITED BY
Edward Wilczewski,
Bydgoszcz University of Science and Technology, Poland

REVIEWED BY
Serkan Ates,
Oregon State University, United States
BorisĐurđević Durdevic,
University of Osijek, Croatia

*CORRESPONDENCE
Carlos Eduardo Pellegrino Cerri
cepcerri@usp.br

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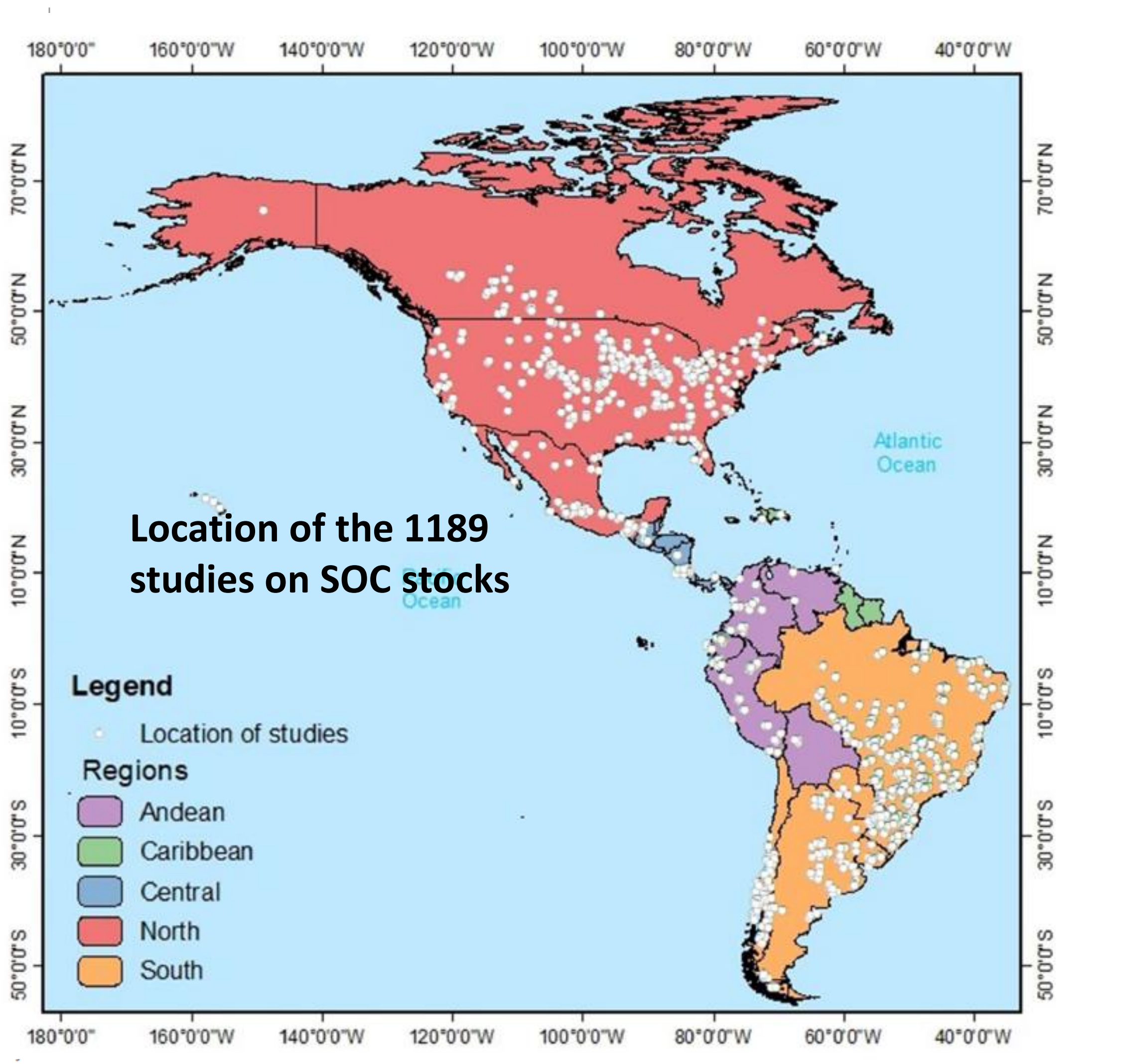
Carbon farming
of the Americas

Carlos Eduardo Pellegrino Cer
Maurício Roberto Cherubin[1,2],
Jorge Luiz Locatelli[1], Martha L
Federico Villarreal[3], Francisco
Muhammad Akbar Ibrahim[3] ar

[1]Department of Soil Science, Luiz de Queiroz C
Paulo, Brazil, [2]Center for Carbon Research in Tr
Paulo, São Paulo, Brazil, [3]Inter-American Institut
Rica, [4]CFAES Rattan Lal Center for Carbon Mana
and Natural Resources, The Ohio State Universit

Soil represents Earth's largest terrestria
sink of C from the atmosphere. Howeve
practices (BMPs) to increase soil C seq
emissions in agroecosystems remains
on soil C sink capacity is important f
be monitored, an essential step to pr
potential. This study brings an overview
in the Americas and presents the cu
Additionally, it estimates the large-scale
in the region. Results indicated that s
literature. Despite that, from a total o
in the systematic literature review, on
only 4.6% measured soil C for the 0–3
and South America regions. Literature
related to BMPs (e.g., cover cropping)
Estimates revealed that upscaling of B
Mha) of the Americas can lead to soil
20 years, offsetting ~39% of agricultu
Results suggest that efforts should be
system on soil C dynamics on the c
availability is low (e.g., Central, Caribl
available degraded area for the contin
BMPs adoption for Central, Andean, and
encountered in our analysis. Thus, it is
may be associated with the obtained
of BMPs across the Americas suggest
the atmosphere and represents a glob
mitigation and adaptation.

KEYWORDS
soil C sequestration, climate mitigation,
adaptation, soil health, soil organic matt



Living Soils of the Americas

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IN TROPICAL AGRICULTURE
UNIVERSITY OF SÃO PAULO

frontiers | Frontiers in Sustainable Food Systems

TYPE Systematic Review
PUBLISHED 19 November 2024
DOI 10.3389/fsufs.2024.1481005

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*CORRESPONDENCE
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✉ cepcerri@usp.br

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Carbon farming in the living soils of the Americas

Carlos Eduardo Pellegrino Cerri[1,2]*, Maurício Roberto Cherubin[1,2], João Marcos Villela[1], Jorge Luiz Locatelli[1], Martha Lustosa Carvalho[1], Federico Villarreal[3], Francisco Fujita de Castro Mello[3], Muhammad Akbar Ibrahim[3] and Rattan Lal[4]

[1]Department of Soil Science, Luiz de Queiroz College of Agriculture, University of São Paulo, São Paulo, Brazil, [2]Center for Carbon Research in Tropical Agriculture (CCARBON), University of São Paulo, São Paulo, Brazil, [3]Inter-American Institute for Cooperation on Agriculture, San José, Costa Rica, [4]CFAES Rattan Lal Center for Carbon Management and Sequestration, School of Environment and Natural Resources, The Ohio State University, Columbus, OH, United States

be monitored, an essential step to properly estimate large-scale C sequestration potential. This study brings an overview of thousands of research articles conducted in the Americas and presents the current state-of-the-art on soil C research. Additionally, it estimates the large-scale BMPs adoption impact over soil C dynamics in the region. Results indicated that soil C-related terms are widely cited in the literature. Despite that, from a total of ~13 thousand research articles recovered in the systematic literature review, only 9.2% evaluated soil C (at any depth), and only 4.6% measured soil C for the 0–30 cm soil layer, mostly conducted in North and South America regions. Literature review showed a low occurrence of terms related to BMPs (e.g., cover cropping), suggesting a research gap on the subject. Estimates revealed that upscaling of BMPs over 30% of agricultural land area (334 Mha) of the Americas can lead to soil C sequestration of 13.1 (±7.1) Pg CO_2eq over 20 years, offsetting ~39% of agricultural GHG emissions over the same period. Results suggest that efforts should be made to monitor the impact of cropping

Challenges for soil carbon measuring, reporting and verification

Living Soils of the Americas

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cepcerri@usp.br

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Carbon farming in the living soils of the Americas

Carlos Eduardo Pellegrino Cerri[1,2]*, Maurício Roberto Cherubin[1,2], João Marcos Villela[1], Jorge Luiz Locatelli[1], Martha Lustosa Carvalho[1], Federico Villarreal[3], Francisco Fujita de Castro Mello[3], Muhammad Akbar Ibrahim[3] and Rattan Lal[4]

[1]Department of Soil Science, Luiz de Queiroz College of Agriculture, University of São Paulo, São Paulo, Brazil, [2]Center for Carbon Research in Tropical Agriculture (CCARBON), University of São Paulo, São Paulo, Brazil, [3]Inter-American Institute for Cooperation on Agriculture, San José, Costa Rica, [4]CFAES Rattan Lal Center for Carbon Management and Sequestration, School of Environment and Natural Resources, The Ohio State University, Columbus, OH, United States

Soil represents Earth's largest terrestrial reservoir of carbon (C) and is an important sink of C from the atmosphere. However, the potential of adopting best management practices (BMPs) to increase soil C sequestration and offset greenhouse gas (GHG) emissions in agroecosystems remains unclear. Synthesizing available information on soil C sink capacity is important for identifying priority areas and systems to be monitored, an essential step to properly estimate large-scale C sequestration potential. This study brings an overview of thousands of research articles conducted in the Americas and presents the current state-of-the-art on soil C research. Additionally, it estimates the large-scale BMPs adoption impact over soil C dynamics in the region. Results indicated that soil C-related terms are widely cited in the literature. Despite that, from a total of ~13 thousand research articles recovered in the systematic literature review, only 9.2% evaluated soil C (at any depth), and only 4.6% measured soil C for the 0–30 cm soil layer, mostly conducted in North and South America regions. Literature review showed a low occurrence of terms related to BMPs (e.g., cover cropping), suggesting a research gap on the subject. Estimates revealed that upscaling of BMPs over 30% of agricultural land area (334 Mha) of the Americas can lead to soil C sequestration of 13.1 (±7.1) Pg CO_2eq over 20 years, offsetting ~39% of agricultural GHG emissions over the same period. Results suggest that efforts should be made to monitor the impact of cropping system on soil C dynamics on the continents, especially in regions where data availability is low (e.g., Central, Caribbean, and Andean regions). Estimating the available degraded area for the continent and the soil C sequestration rates under BMPs adoption for Central, Andean, and Caribbean regions were major shortcomings encountered in our analysis. Thus, it is expected that some degree of uncertainty may be associated with the obtained results. Despite these limitations, upscaling of BMPs across the Americas suggests having great potential for C removal from the atmosphere and represents a global positive impact in terms of climate change mitigation and adaptation.

KEYWORDS
soil C sequestration, climate mitigation, greenhouse gas, agriculture, climate adaptation, soil health, soil organic matter, food systems

BMPs	Region	Mean SOC Accumulation Rate (Mg ha^{-1} year^{-1})
Improved pastures	North	0.25
	Central	0.25
	Caribbean	0.25*
	South	0.48
	Andes	1.03
Conservation agriculture	North	0.42
	Central	0.35
	Caribbean	0.35*
	South	0.67
	Andes	0.42
Integrated agricultural systems	North	0.87
	Central	1.16
	Caribbean	1.16*
	South	0.79
	Andes	1.08

Challenges for soil carbon measuring, reporting and verification

frontiers | Frontiers in Sustainable Food Systems

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EDITED BY
Edward Wilczewski,
Bydgoszcz University of Science and Technology, Poland

REVIEWED BY
Serkan Ates,
Oregon State University, United States
BorisĐurđević Durdevic,
University of Osijek, Croatia

*CORRESPONDENCE
Carlos Eduardo Pellegrino Cerri
cepcerri@usp.br

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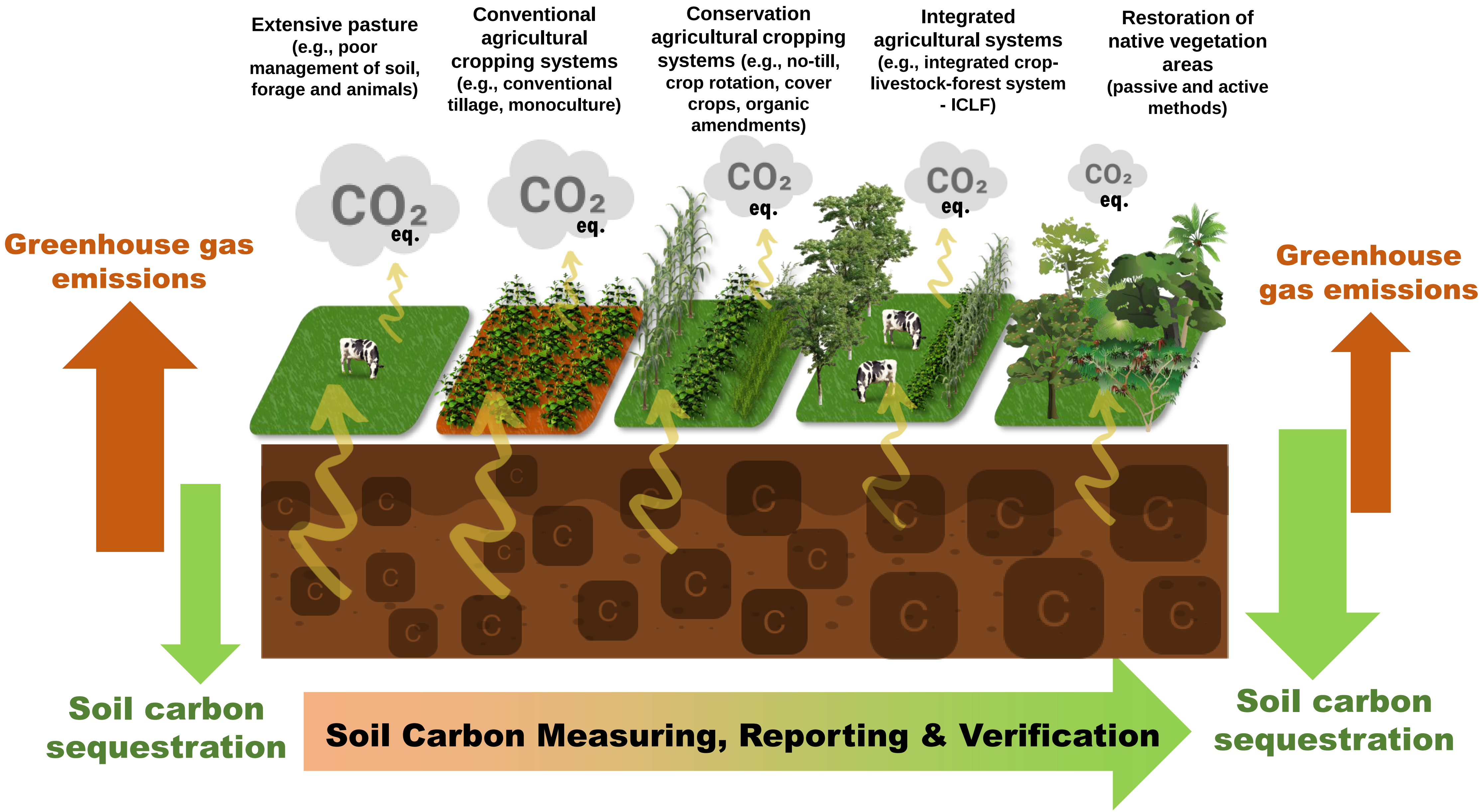
KEYWORDS
soil C sequestration, climate mitigation, greenhouse gas, agriculture, climate adaptation, soil health, soil organic matter, food systems

Estimates revealed that upscaling of best management practices (no-tillage; pasture reclamation and integrated systems) over 30% of agricultural land area (334 Mha) of the Americas can lead to soil C sequestration of 13.1 (±7.1) Pg CO_2eq over 20 years, **offsetting ~39% of agricultural GHG emissions** over the same period.

Pathways for enhancing soil carbon sequestration through intensification and diversification of agricultural systems in Brazil



Studies to evaluate the CARBON BALANCE in intensified agricultural systems

EQUATION

Carbon balance

=

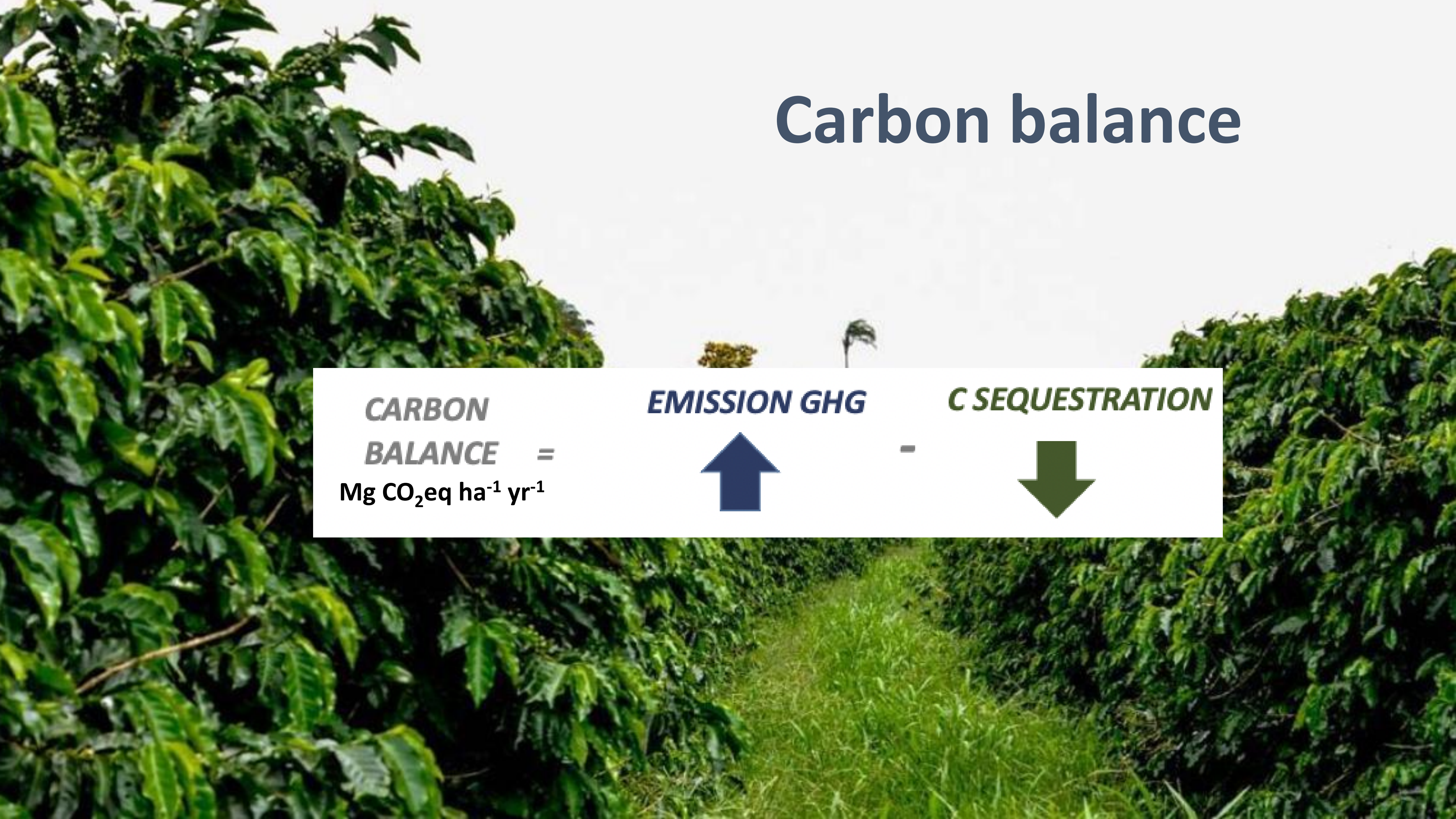
Inputs

(Δ C accumulation)

Losses

(GHG emissions)

CARBON BALANCE IN COFFEE PRODUCTION
with the adoption of best management practices



Carbon balance

CARBON BALANCE = EMISSION GHG - C SEQUESTRATION

Mg CO_2eq ha^{-1} yr^{-1}

Carbon Balance

N Fertilizer Urea

Pesticides/ agrochemicals

Fuel

Eletricity

Liming

CARBON BALANCE = **EMISSION GHG** ↑ - **C SEQUESTRATION** ↓

Mg $CO_2eq\ ha^{-1}\ yr^{-1}$

C Plant Biomass

C Soil

Carbon Balance

N Fertilizer Urea

Pesticides/ agrochemicals

Fuel

Eletricity

Liming

CARBON BALANCE = EMISSION GHG - C SEQUESTRATION

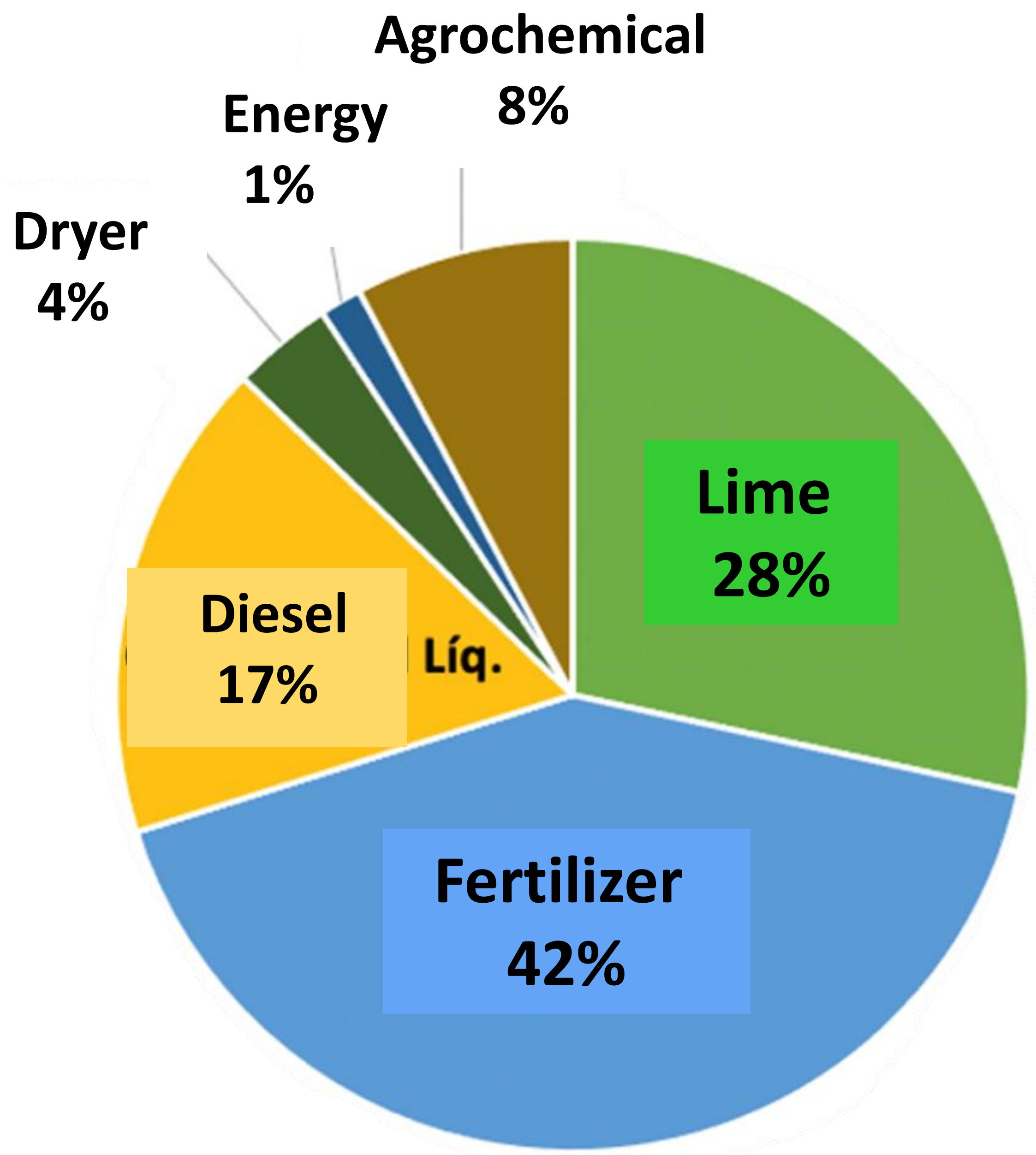
$Mg\ CO_2eq\ ha^{-1}\ yr^{-1}$

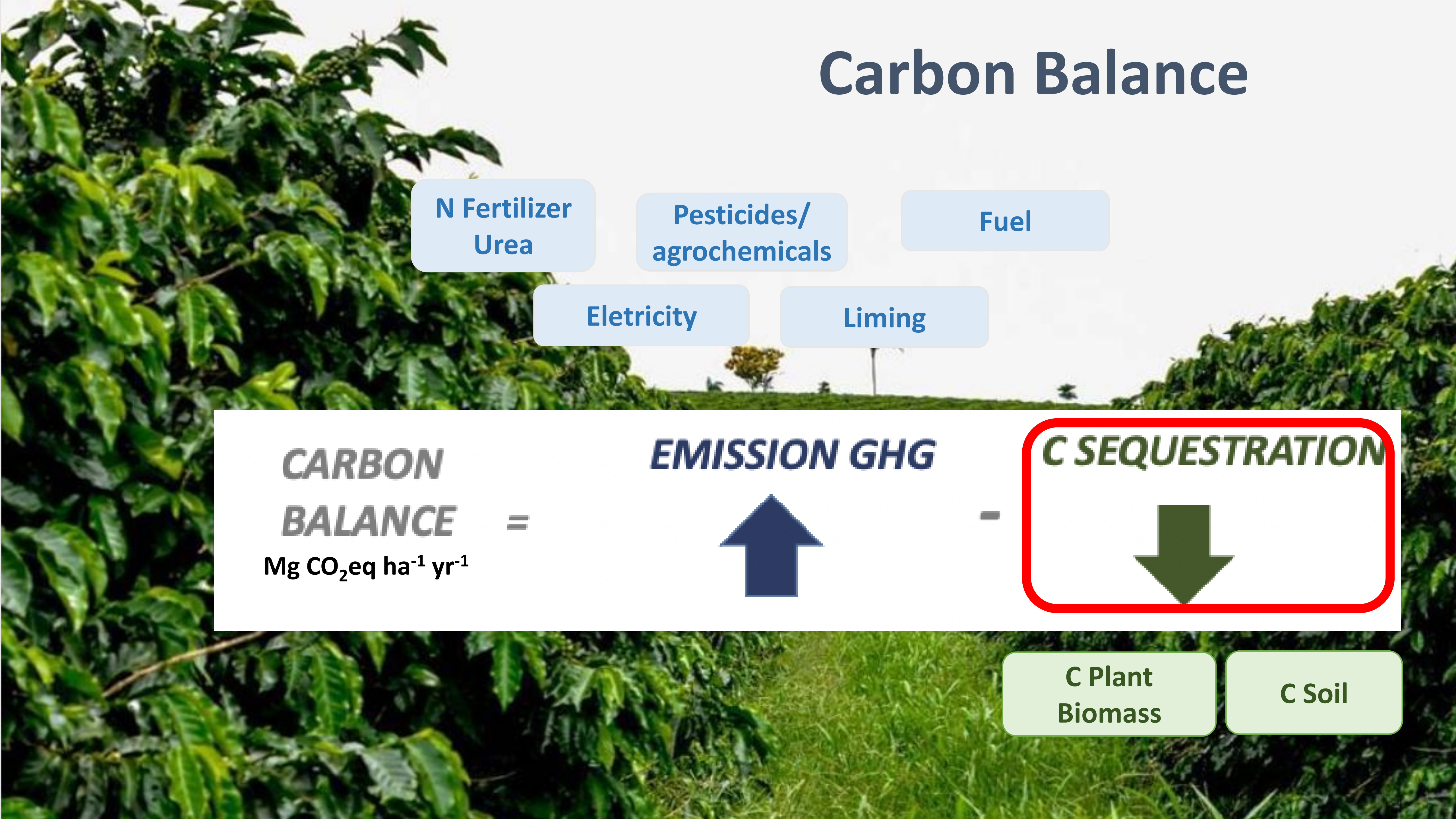
C Plant Biomass

C Soil

Greenhouse Gas emission estimates

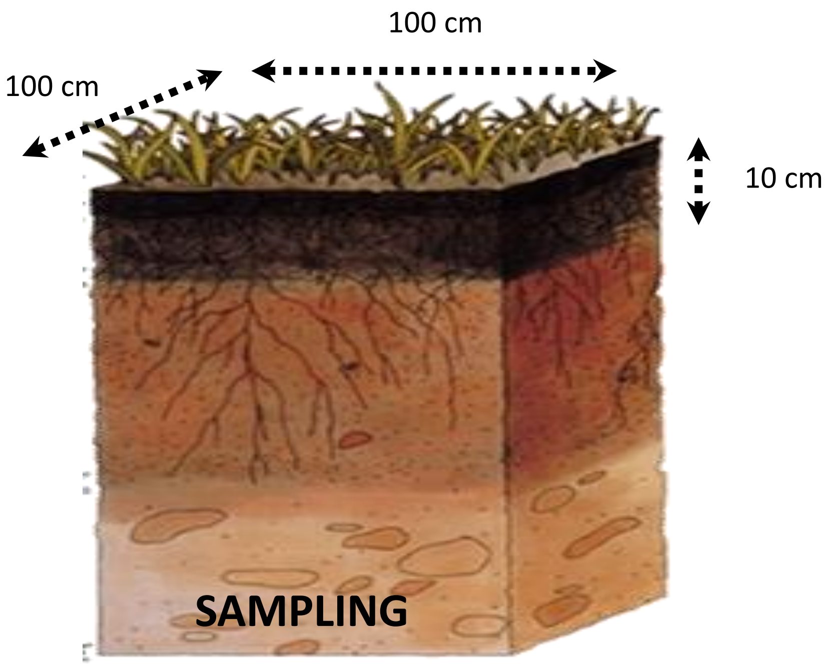
Average (40 farms):
1.74 Mg CO_2eq ha^{-1} yr^{-1}

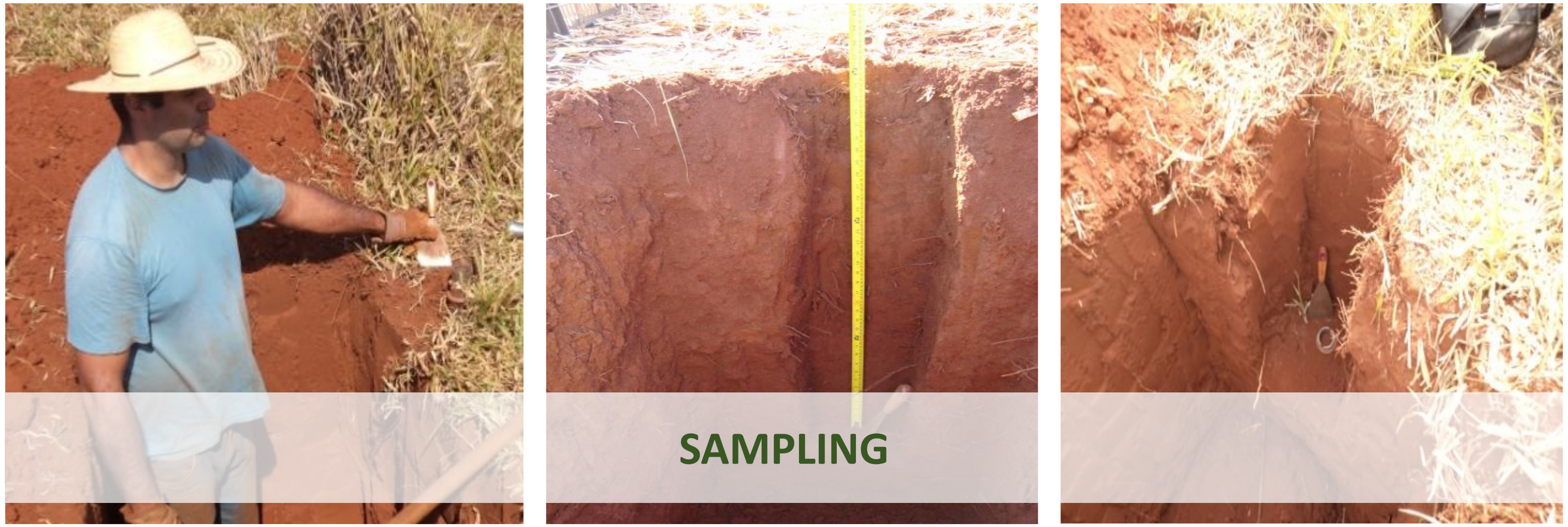



Carbon Balance
N Fertilizer Urea
Pesticides/ agrochemicals
Fuel
Eletricity
Liming
CARBON BALANCE =
Mg CO_2eq ha^{-1} yr^{-1}
EMISSION GHG
-
C SEQUESTRATION
C Plant Biomass
C Soil


Cerrado
Matas de
Minas
Sul de Minas

SOIL CARBON STOCKS





Stock = C content x Bulk Density x Layer

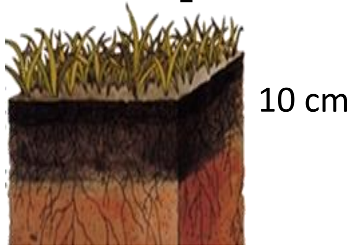
kg C m^{-2}

or

Mg C ha^{-1}

% C

$$d = \frac{m}{V}$$



SOIL CARBON STOCKS

Carbon quantification by dry combustion

PLANT CARBON STOCKS



$$\text{Stock}_i = \textbf{Content}_i \times \textbf{DMt}$$

kg C kg^{-1}
or
Kg C plant^{-1}

% Carbon

Biomass Dry Mass (g plant^{-1})

PLANT CARBON STOCKS

Carbon quantification by dry combustion

Carbon Balance

N Fertilizer Urea

Pesticides/ agrochemicals

Fuel

Eletricity

Liming

CARBON BALANCE = EMISSION GHG - C SEQUESTRATION

Mg CO_2eq ha^{-1} yr^{-1}

1.74 - 12.25

C Plant 5.96

C Soil 6.29

Carbon Balance

N Fertilizer Urea

Pesticides/ agrochemicals

Fuel

Eletricity

Liming

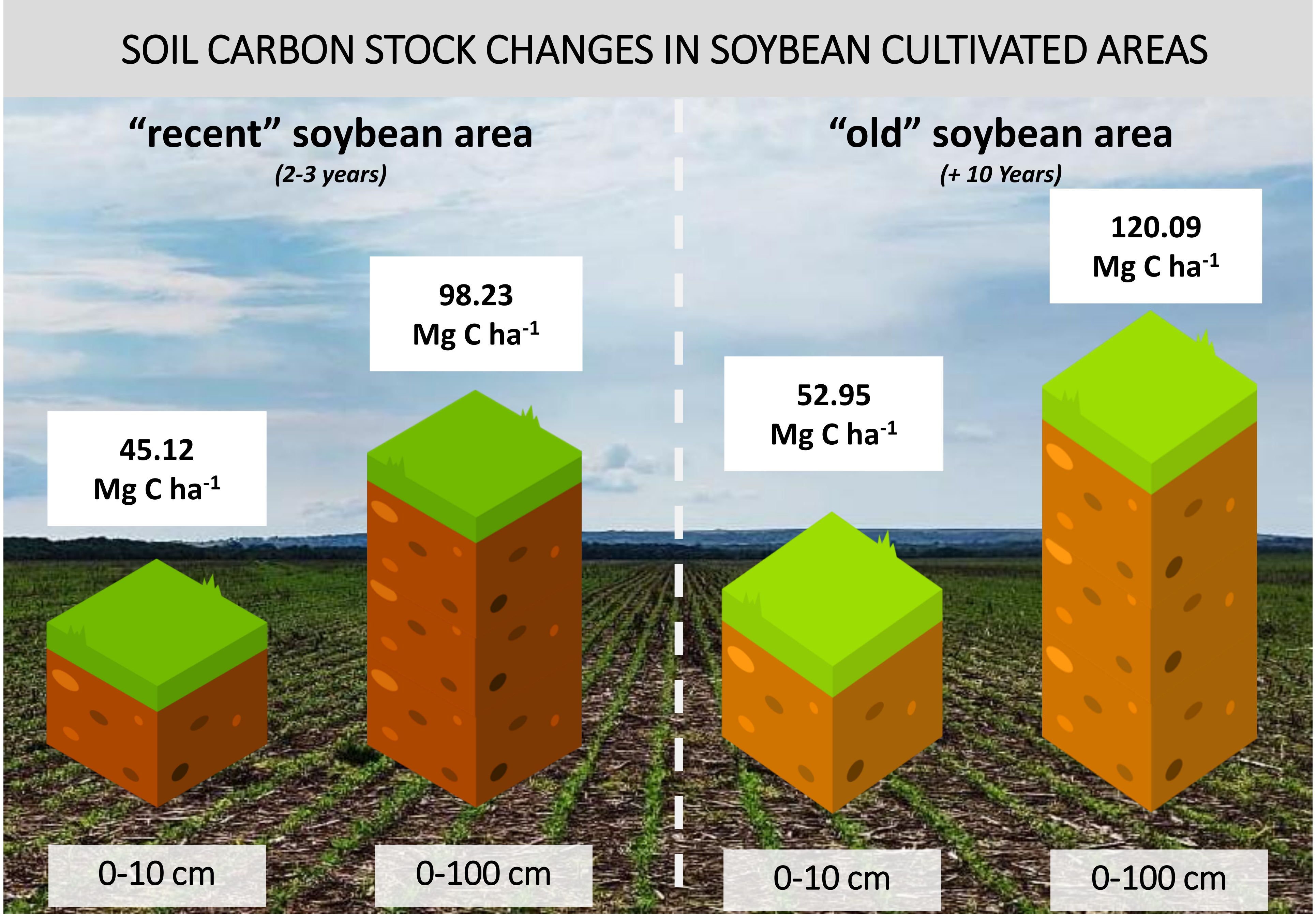
CARBON BALANCE = EMISSION GHG − C SEQUESTRATION

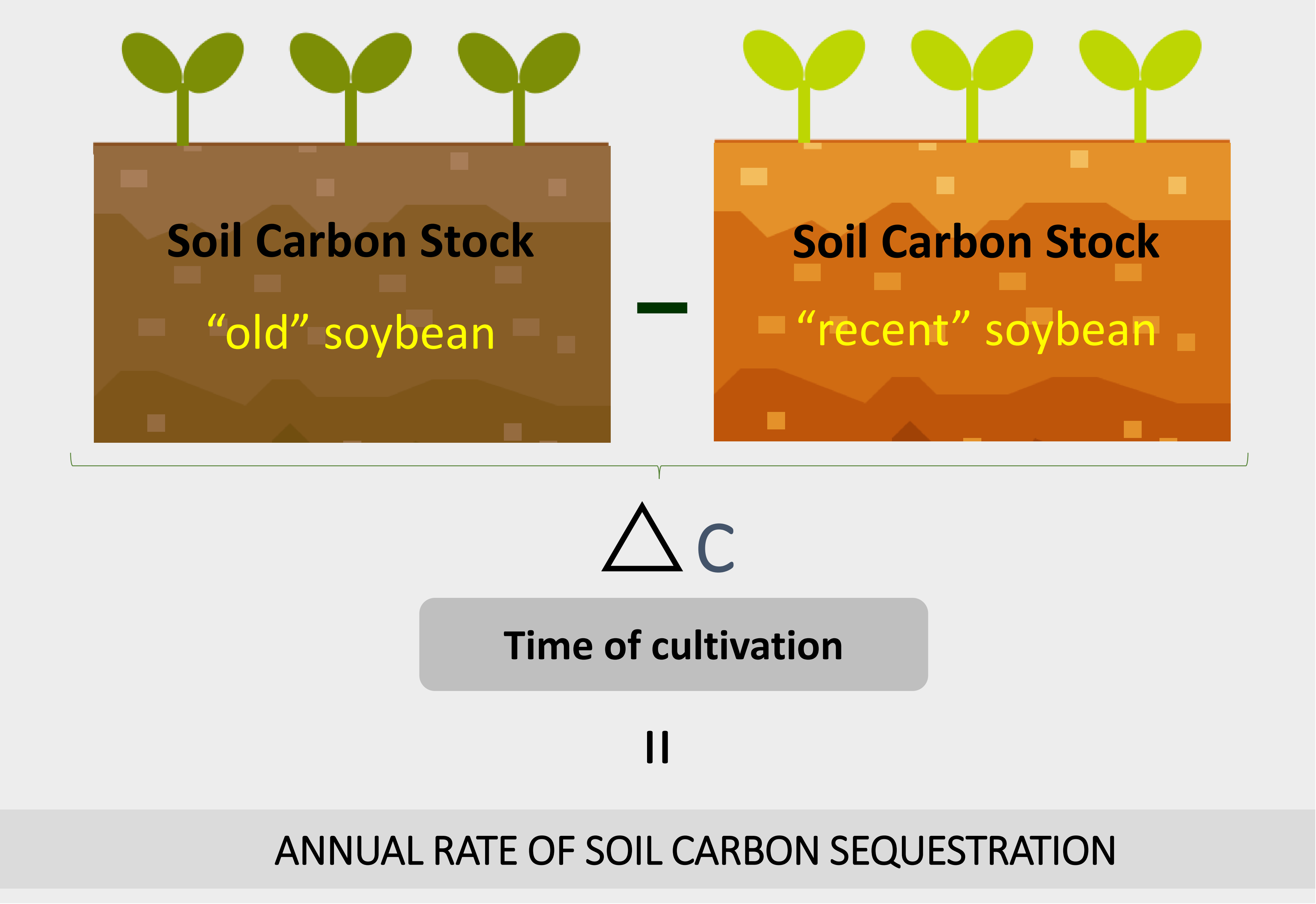
$Mg\ CO_2eq\ ha^{-1}\ yr^{-1}$

-10.5

CARBON BALANCE IN SOYBEAN CULTIVATION with the adoption of best management practices

SOIL CARBON STOCK CHANGES IN SOYBEAN CULTIVATED AREAS


SOIL CARBON STOCK CHANGES IN SOYBEAN CULTIVATED AREAS
“recent” soybean area
(2-3 years)
“old” soybean area
(+ 10 Years)
45.12 Mg C ha-1
98.23 Mg C ha-1
52.95 Mg C ha-1
120.09 Mg C ha-1
0-10 cm
0-100 cm
0-10 cm
0-100 cm


Soil Carbon Stock
“old” soybean
–
Soil Carbon Stock
“recent” soybean
△C
Time of cultivation
=
ANNUAL RATE OF SOIL CARBON SEQUESTRATION

CARBON BALANCE

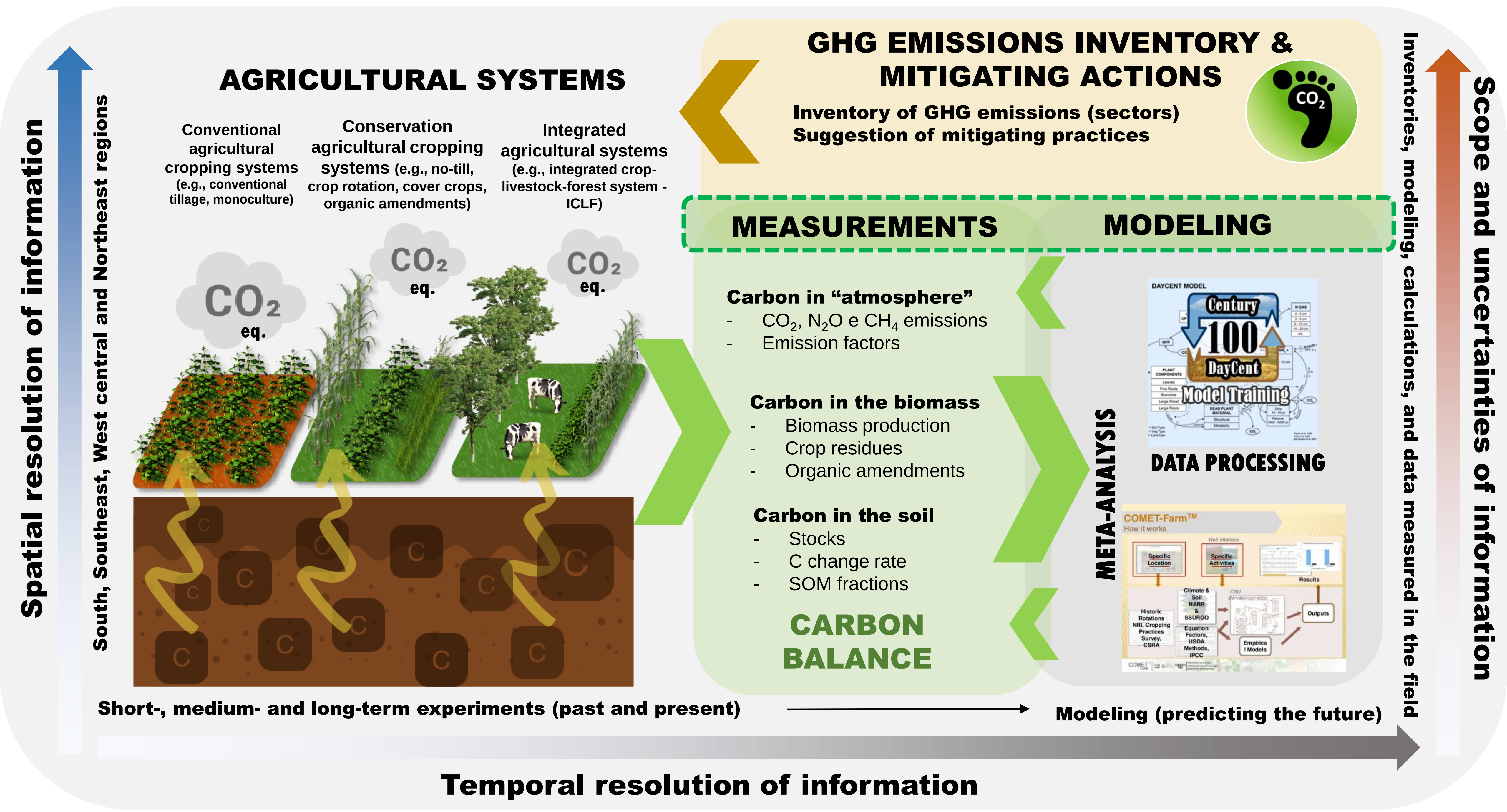
CARBON BALANCE

CARBON BALANCE

CARBON BALANCE

CARBON BALANCE **-1.27** = GHG EMISSIONS **0.57** − SOIL C SEQUESTRATION **2.24**

Mg C ha^{-1}



AGRICULTURAL SYSTEMS
Conventional agricultural cropping systems (e.g., conventional tillage, monoculture)
Conservation agricultural cropping systems (e.g., no-till, crop rotation, cover crops, organic amendments)
Integrated agricultural systems (e.g., integrated crop-livestock-forest system - ICLF)
CO_2 eq.
CO_2 eq.
CO_2 eq.
C
GHG EMISSIONS INVENTORY & MITIGATING ACTIONS
Inventory of GHG emissions (sectors)
Suggestion of mitigating practices
CO_2
MEASUREMENTS
MODELING
Carbon in "atmosphere"
- CO_2, N_2O e CH_4 emissions
- Emission factors
Carbon in the biomass
- Biomass production
- Crop residues
- Organic amendments
Carbon in the soil
- Stocks
- C change rate
- SOM fractions
CARBON BALANCE
META-ANALYSIS
DAYCENT MODEL
Century
100
DayCent
Model Training
DATA PROCESSING
COMET-Farm™
How it works
Specific Location
Specific Activities
Results
Historic Rotations NRI, Cropping Practices Survey, CSRA
Climate & Soil NARR & SSURGO
Equation Factors, USDA Methods, IPCC
Empirical Models
Outputs
Spatial resolution of information
South, Southeast, West central and Northeast regions
Short-, medium- and long-term experiments (past and present)
Modeling (predicting the future)
Temporal resolution of information
Inventories, modeling, calculations, and data measured in the field
Scope and uncertainties of information

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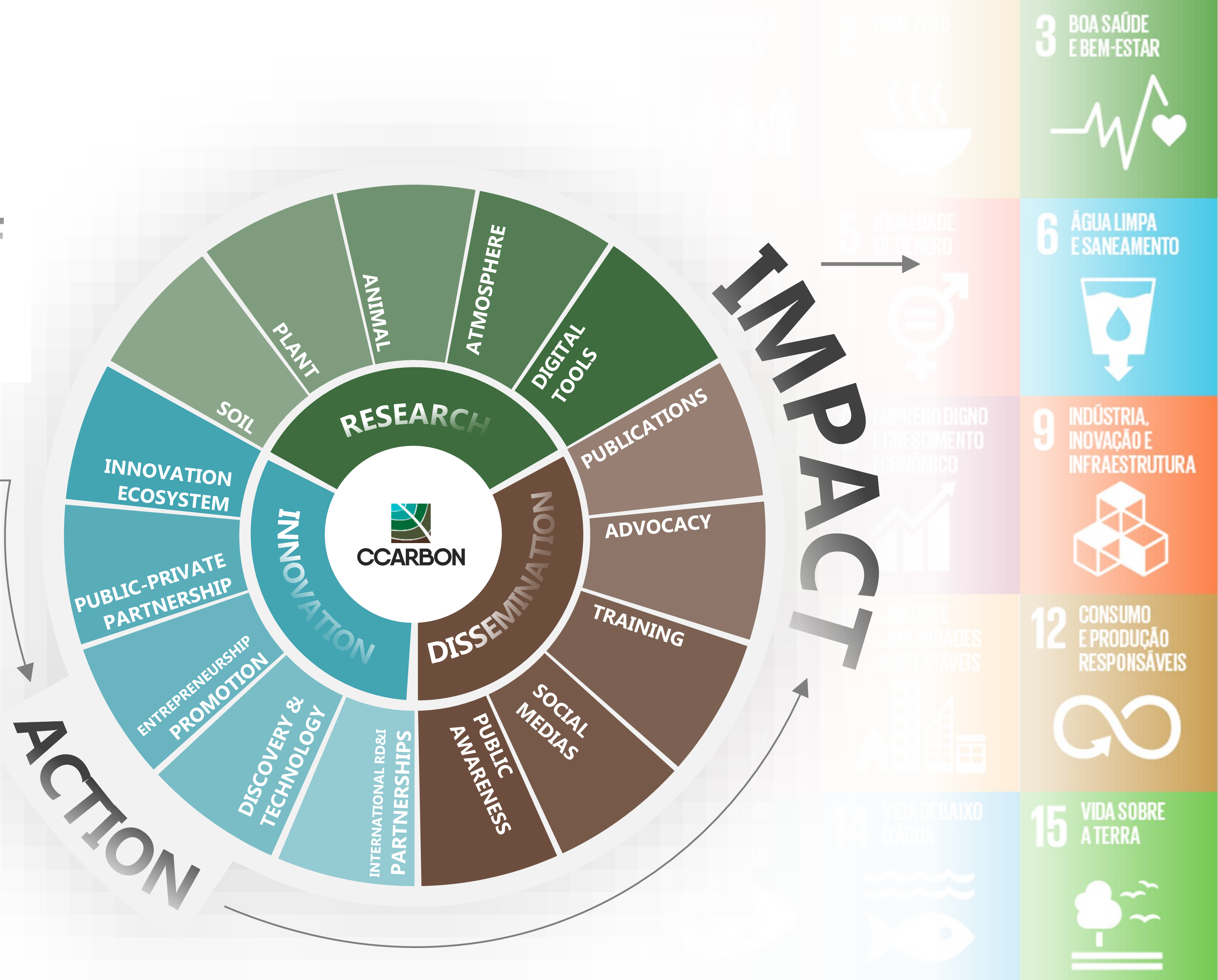
SUMMARY OF CCARBON'S ACTION STRATEGY

CHALLENGES

- Climate Change Mitigation
- Food Security
- Low-Carbon Economy
- Social Development



SUMMARY OF CCARBON'S ACTION STRATEGY

DISSEMINATION

PUBLICATIONS
- Encouraging publications in scientific journals
- Publication of a book
- Publication of semi-annual technical bulletins

ADVOCACY
- Annual remote meeting between university and competent bodies
- General booklet for municipalities disseminating good practices

TRAINING
- Webinars and
- Online Panels
- Podcasts
- E-books/Booklets

SOCIAL MEDIAS
- Online course/training for technicians
- Online Field Day
- Benchmarking between farmers and professionals
- Symposium
- with experts

PUBLIC AWARENESS
- Documentary production
  In-person event "Carbon Week"
- Event in an odd years about "Carbon Balance in the Soil-Plant-Animal-Atmosphere"
- Monthly releases
- Creation of informative website

INTERNATIONAL PARTNERSHIPS

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SUMMARY OF CCARBON'S ACTION STRATEGY

INNOVATION.

INTERNATIONAL RD&I PARTNERSHIPS
- Agrifood 5 (A5) Alliance
- C-MASC-OSU
- IICA

DISCOVERY & TECHNOLOGY
- New products & processes
- New software

ENTREPRENEURSHIP PROMOTION
- Startups
- Companies

PUBLIC-PRIVATE PARTNERSHIP
- Co-working in RD&I
- Private co-funding
- Institutional relationship with stakeholders

INNOVATION ECOSYSTEM
- Ceres Hub
- AUSPIN
- Embrapii_Esalq
- AgTech Valley

SOIL

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SUMMARY OF CCARBON'S ACTION STRATEGY

RESEARCH

SOIL
- Soil C management
- Soil fertility
- Soil biodiversity
- Soil conservation & restoration
- Soil health & ES

PLANT
- Agri-food systems
- Crop management
- Plant protection
- Plant breeding
- Ecological restoration
- Forestry

ANIMAL
- Pasture management
- Waste management
- Feed additives
- Rumen microbiota
- Animal performance

ATMOSPHERE
- GHG emissions
- National inventories
- Agricultural zoning
- Climate projections
- Water management

DIGITAL TOOLS
- Precision Ag
- Modelling tools
- New methodologies
- Geotechnologies

PUBLICATIONS

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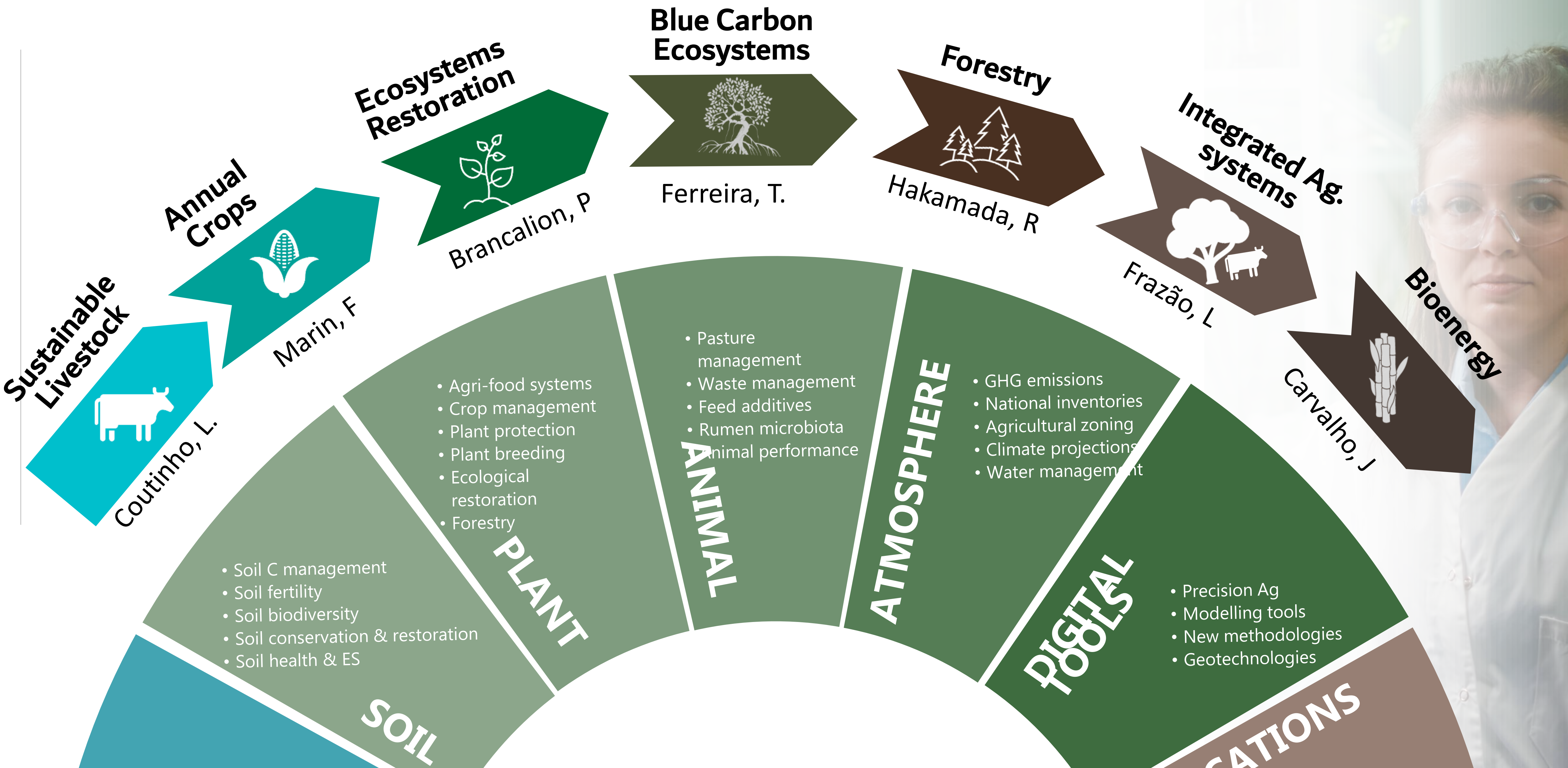
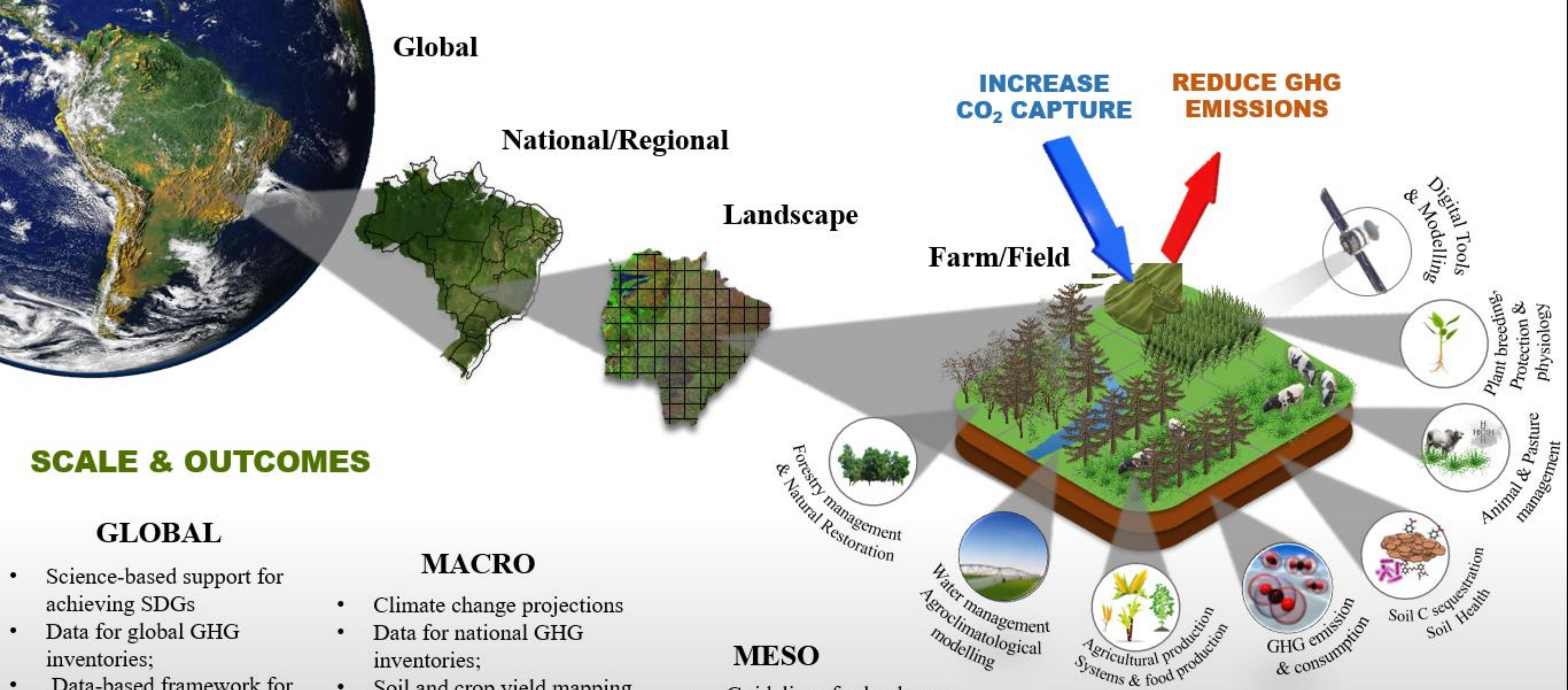
Sectorial Research Chains





GLOBAL

- Science-based support for achieving SDGs
- Data for global GHG inventories;
- Data-based framework for C markets
- Technology and knowledge transfer for tropical regions

MACRO

- Climate change projections
- Data for national GHG inventories;
- Soil and crop yield mapping
- Technology and knowledge transfer/dissemination
- Science-based support for achieving NDCs, sectorial programs and public policies

MESO

- Guidelines for landscape management;
- Best management practices
- MRV protocols
- Natural restoration plan
- Technology and knowledge validation

MICRO / MOLECULAR

- Understanding of processes and mechanisms to increase C sequestration in tropical agriculture
- Research, Development and Innovation
- Data collection & knowledge generation

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DecisiOnES 2025

Porto Seguro

Jun 30th to Jul 4th BR

Symposium on Ecosystem Services, Forest Management and Decision Making

AGRICULTURE AS AN OPTION FOR ADAPTATION AND MITIGATION OF GLOBAL CLIMATE CHANGE

Carlos Eduardo Cerri

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UNIVERSITY OF SÃO PAULO

July 3, 2025