Production of Sisal and Coconut Fibers: Potential Environmental Advantages of CO_2 Sequestration and Carbon Credit Sales

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Embrapa
MINISTÉRIO DA AGRICULTURA E PECUÁRIA
GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

Objectives:

- ✓ **Discuss:** the environmental advantages of sisal and coconut fibers;
- ✓ **Show:** the monetization potential of their carbon absorption capabilities aimed at payments for environmental services; and;
- ✓ **Estimate:** the possible revenues from carbon credits for the sector.

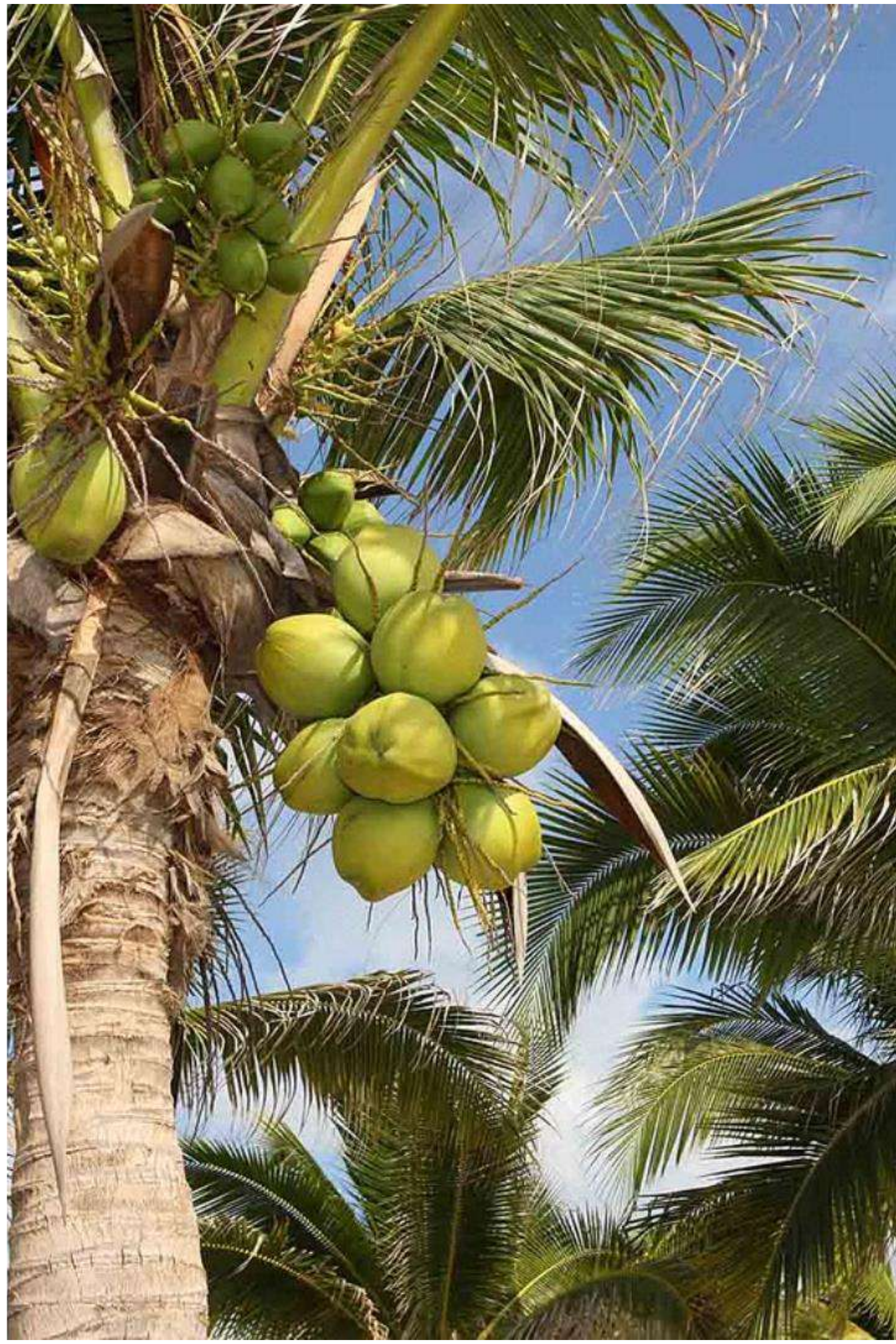
Content

Sisal and Coconut

Introduction to Sisal and Coconut in Brazil and the World;

1. Carbon is assimilated in compartments:
   - in the Sisal and Coconut plants;
   - in soils;
2. Carbon emissions;
3. Annual balance: Assimilation in the Plant and Soil annually – Annual expenses;
4. How Much is it Worth in Credit/Revenue per hectare?

5.Conclusion.



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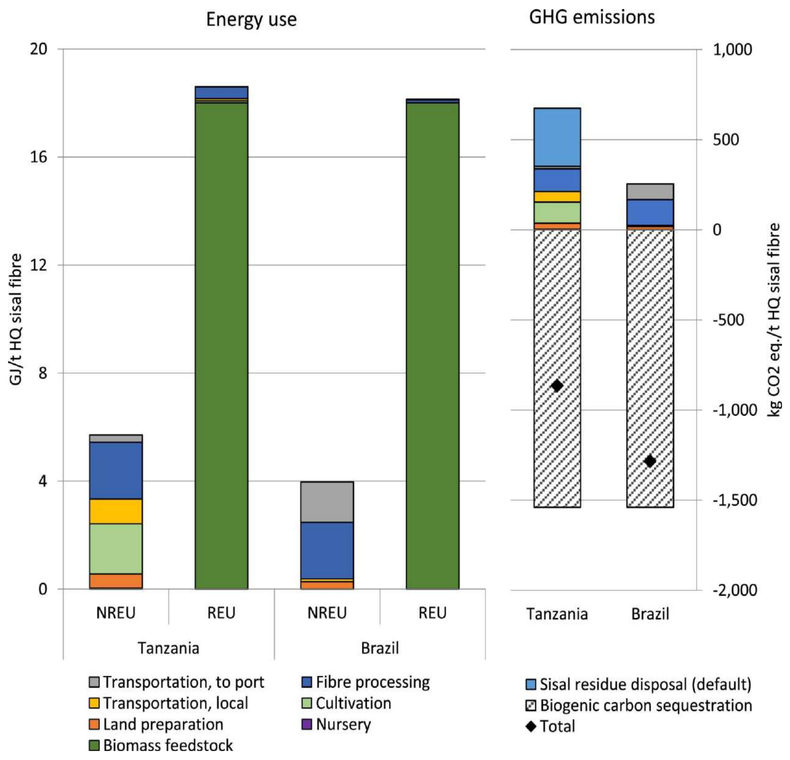
Sisal Environmental Advantages

Use land in the semi-arid region



Assimilate lots of carbon in sensitive environments

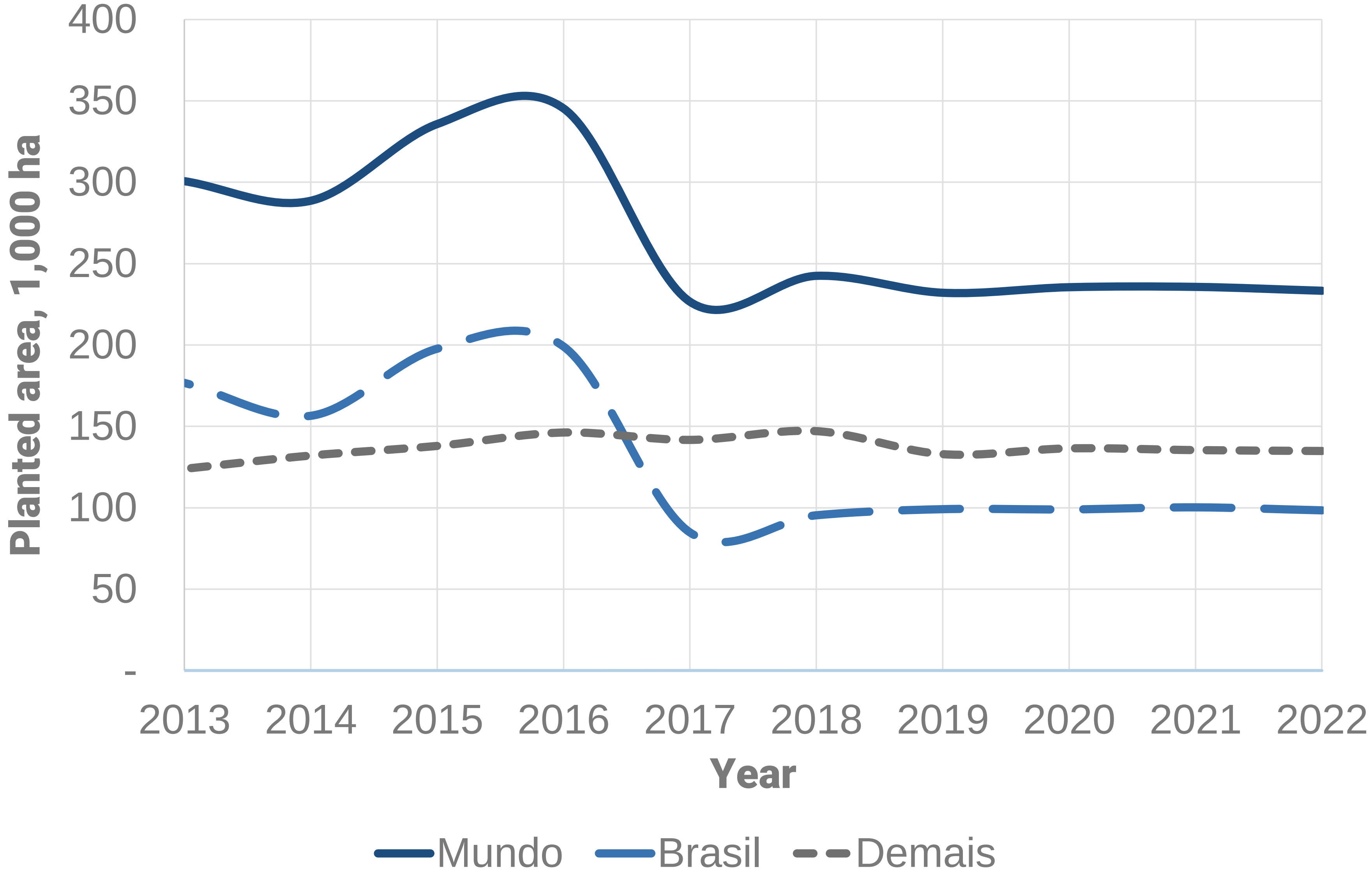
> 850 thousand jobs in Brazil and generates revenues of US$ 80 million/ year

Has wide industrial use as fiber

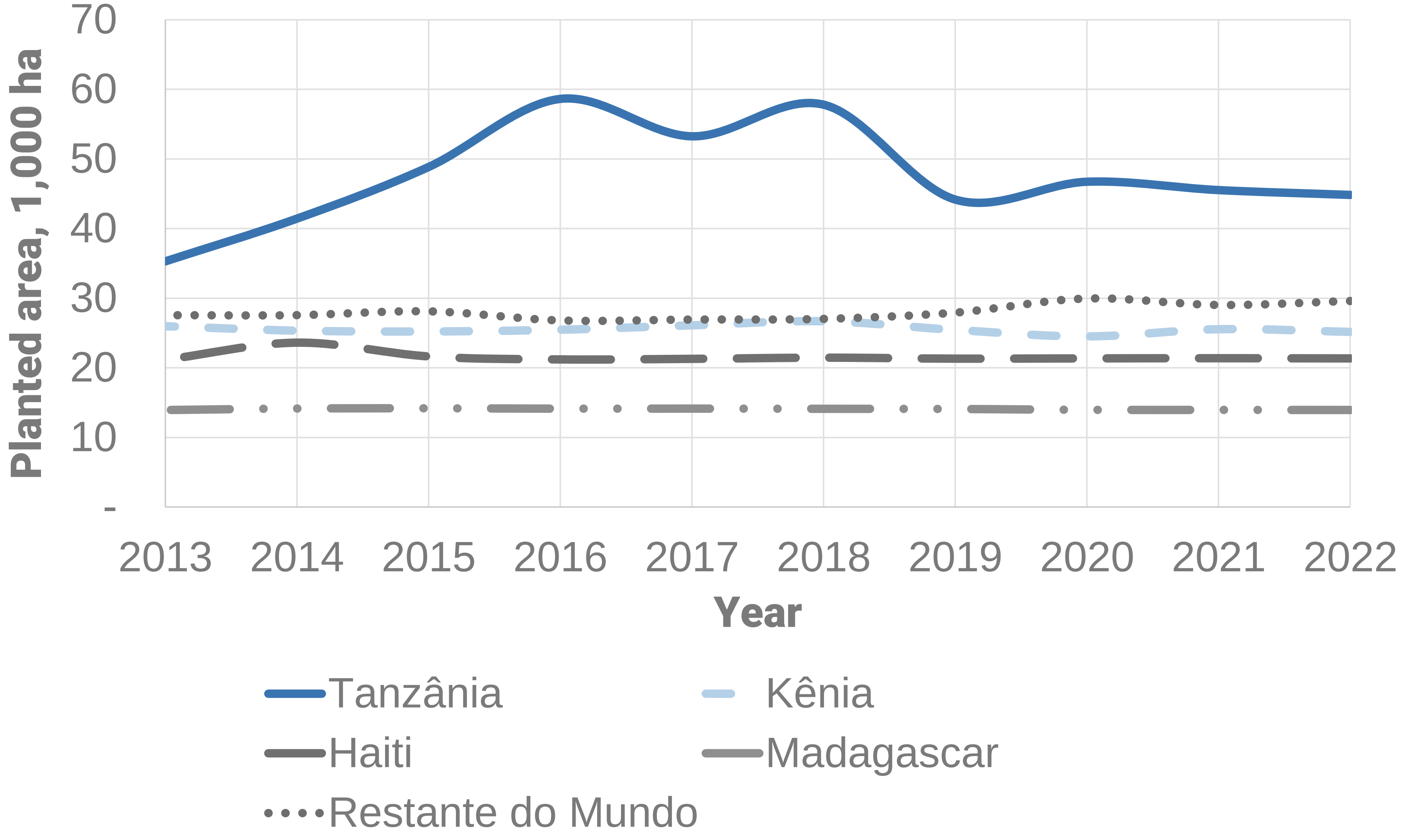
Harvested area with Sisal in Brazil and the World

Data FAOSTAT (2023, accessed on 08.05.2024)

Planted area 2013 a 2022

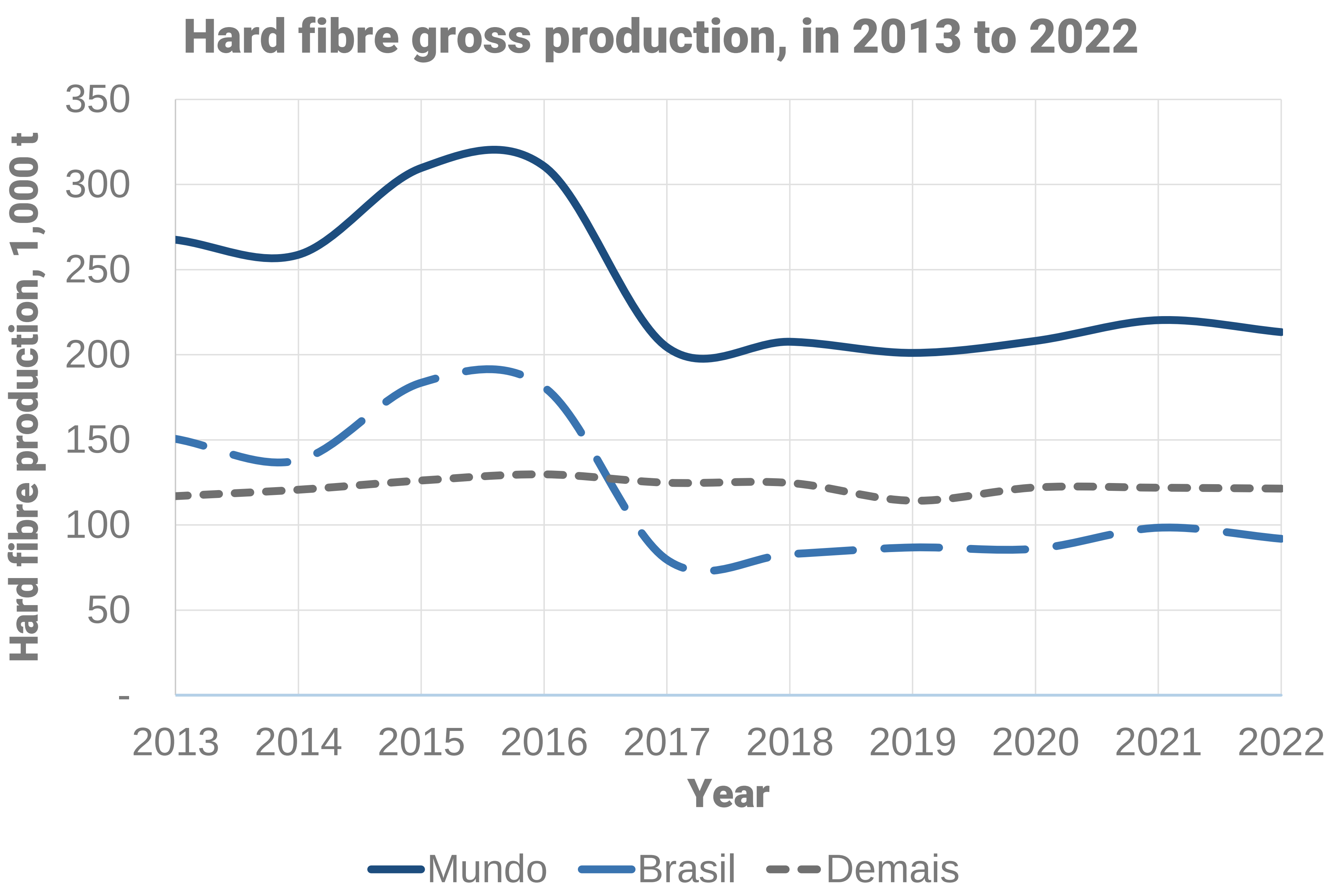


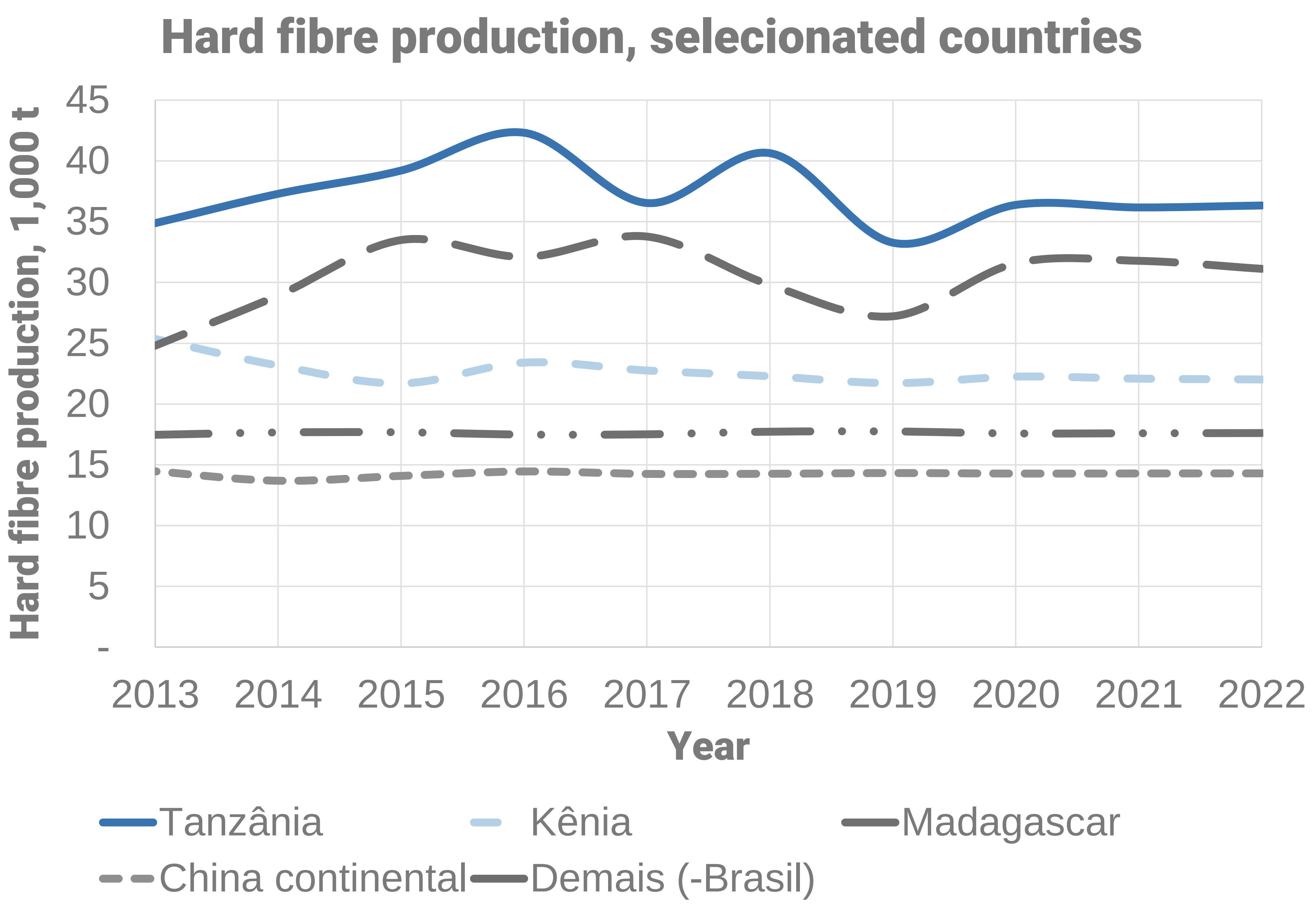
Planted area from 2nd to 5th higher world productor



Sisal Production in Brazil and the World

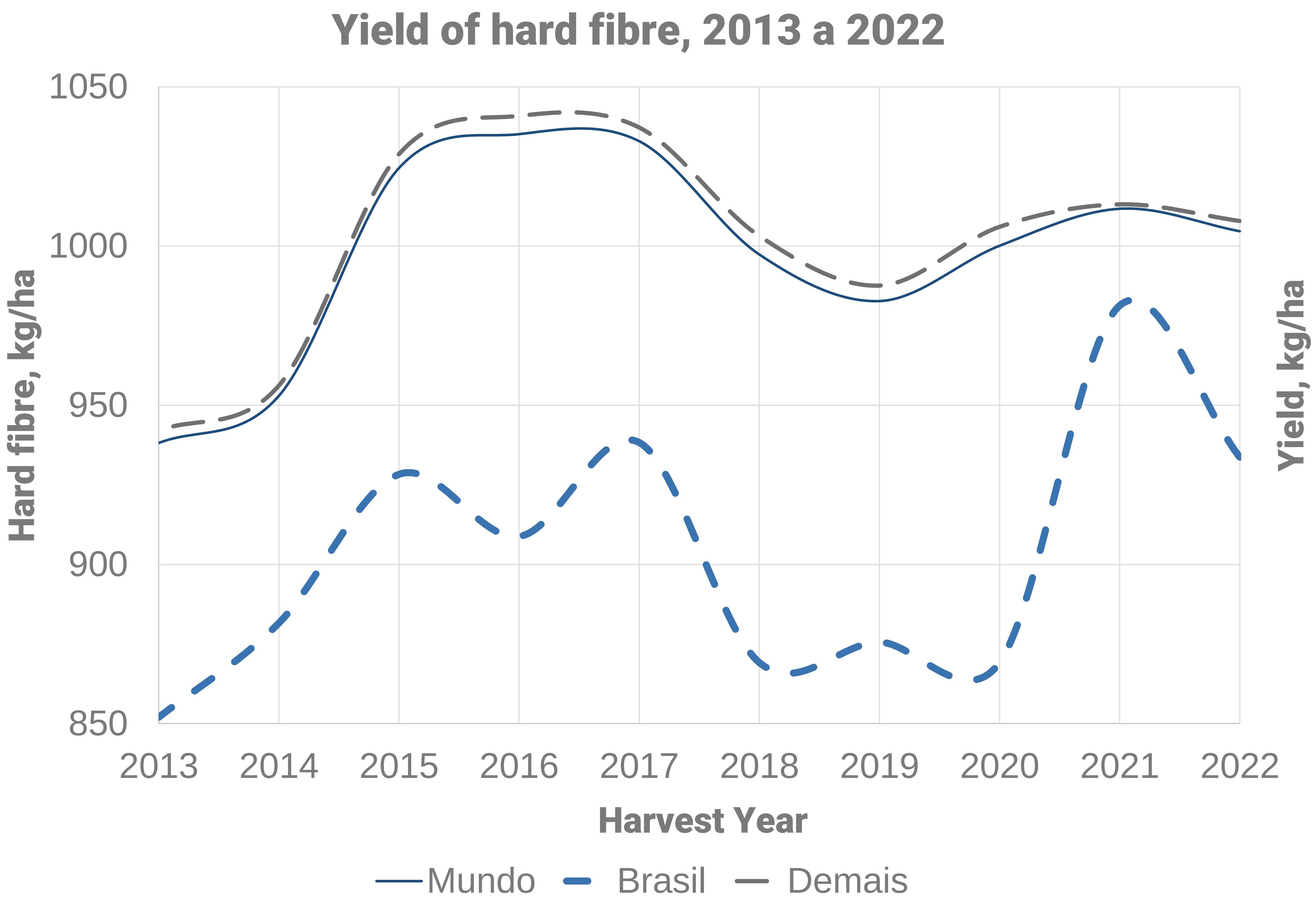
Data FAOSTAT (2023, accessed on 08.05.2024)

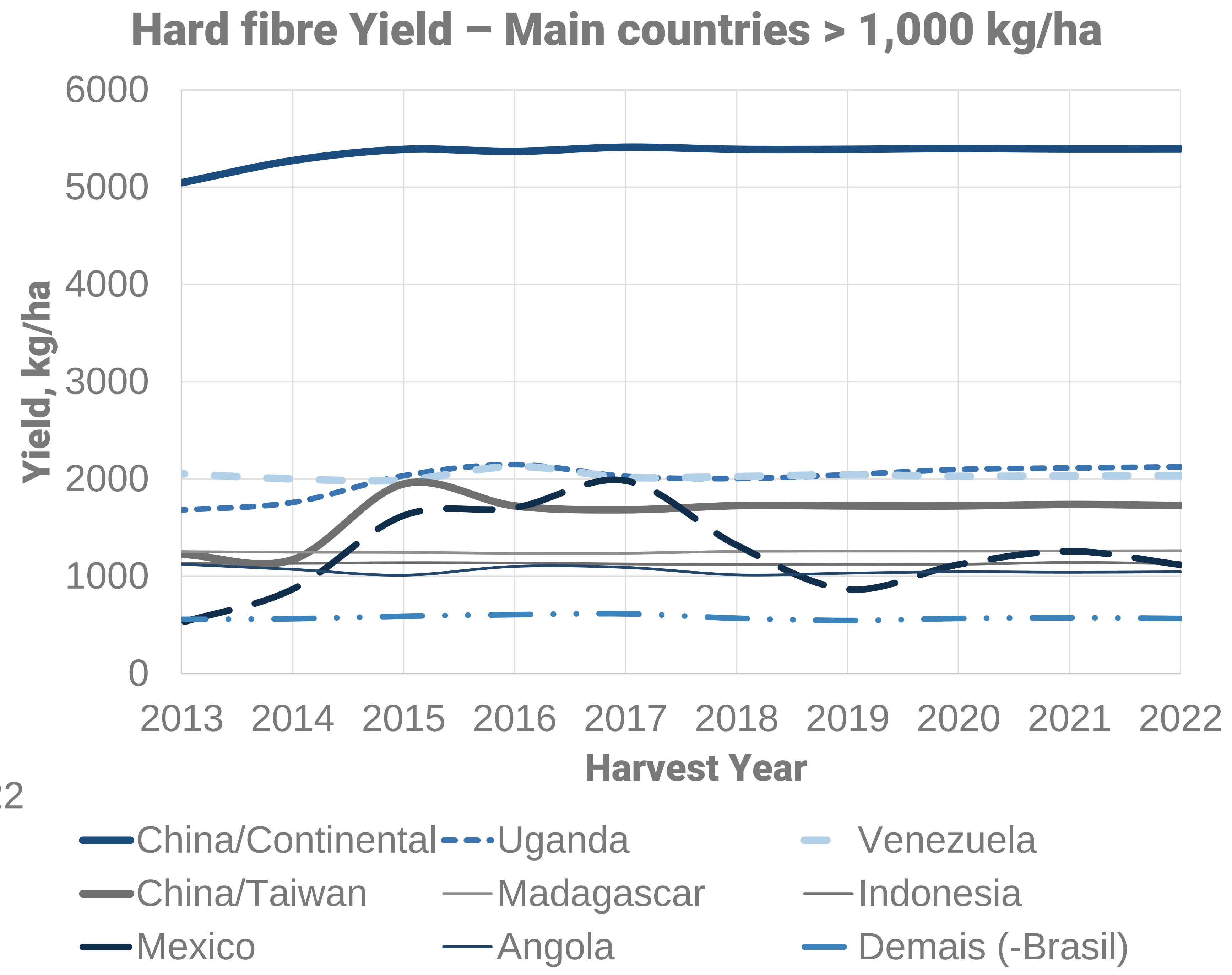




Sisal Productivity in Brazil and the World

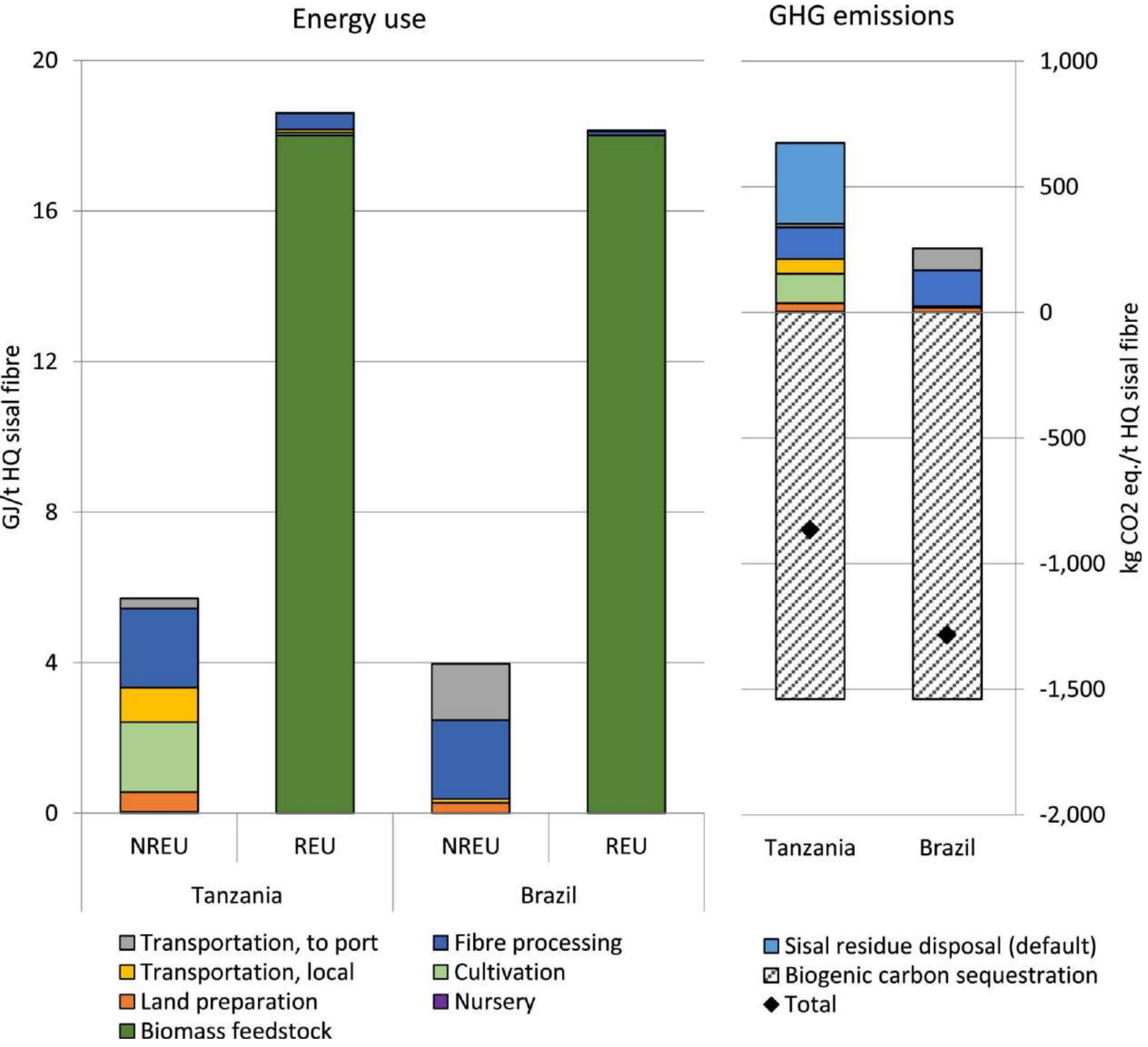
Data FAOSTAT (2023, accessed on 08.05.2024)





Use of Renewable Energies (REU) or not (NREU) and Greenhouse Gas Emissions (GEE) by Sisal

GEE emissions: Tanzania – 669 kg CO_2 eq / t Fiber; Brazil – 250 kg CO_2 eq/t Fiber produced. Biogenic sequestration for 1 t of Fiber = 1,539 kg CO_2 eq. PROBABLY UNDERESTIMATED!



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Life cycle assessment of sisal fibre – Exploring how local practices can influence environmental performance

Martijn L.M. Broeren, Stijn N.C. Dellaert [1], Benjamin Cok [2], Martin K. Patel [3], Ernst Worrell, Li Shen

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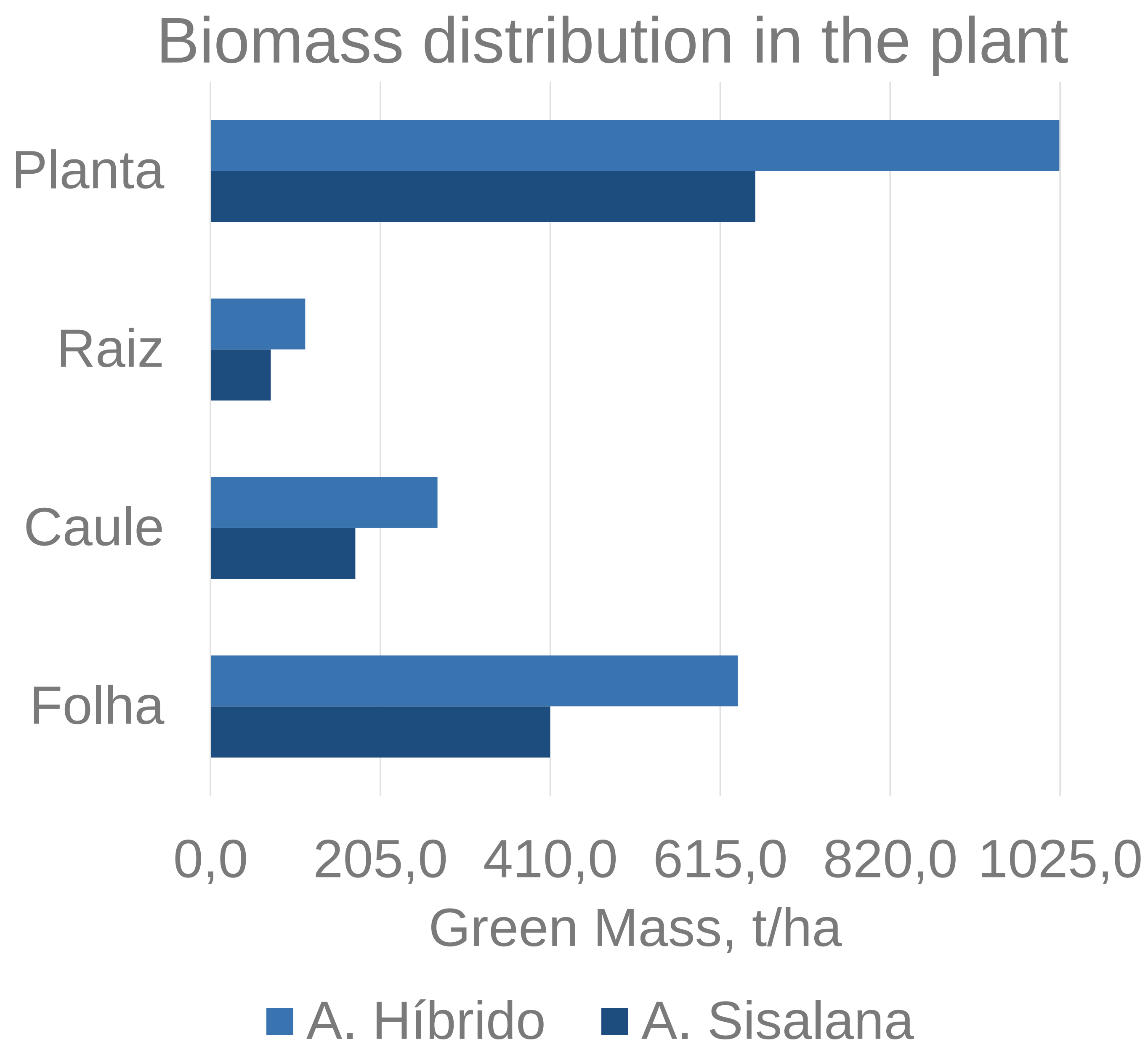
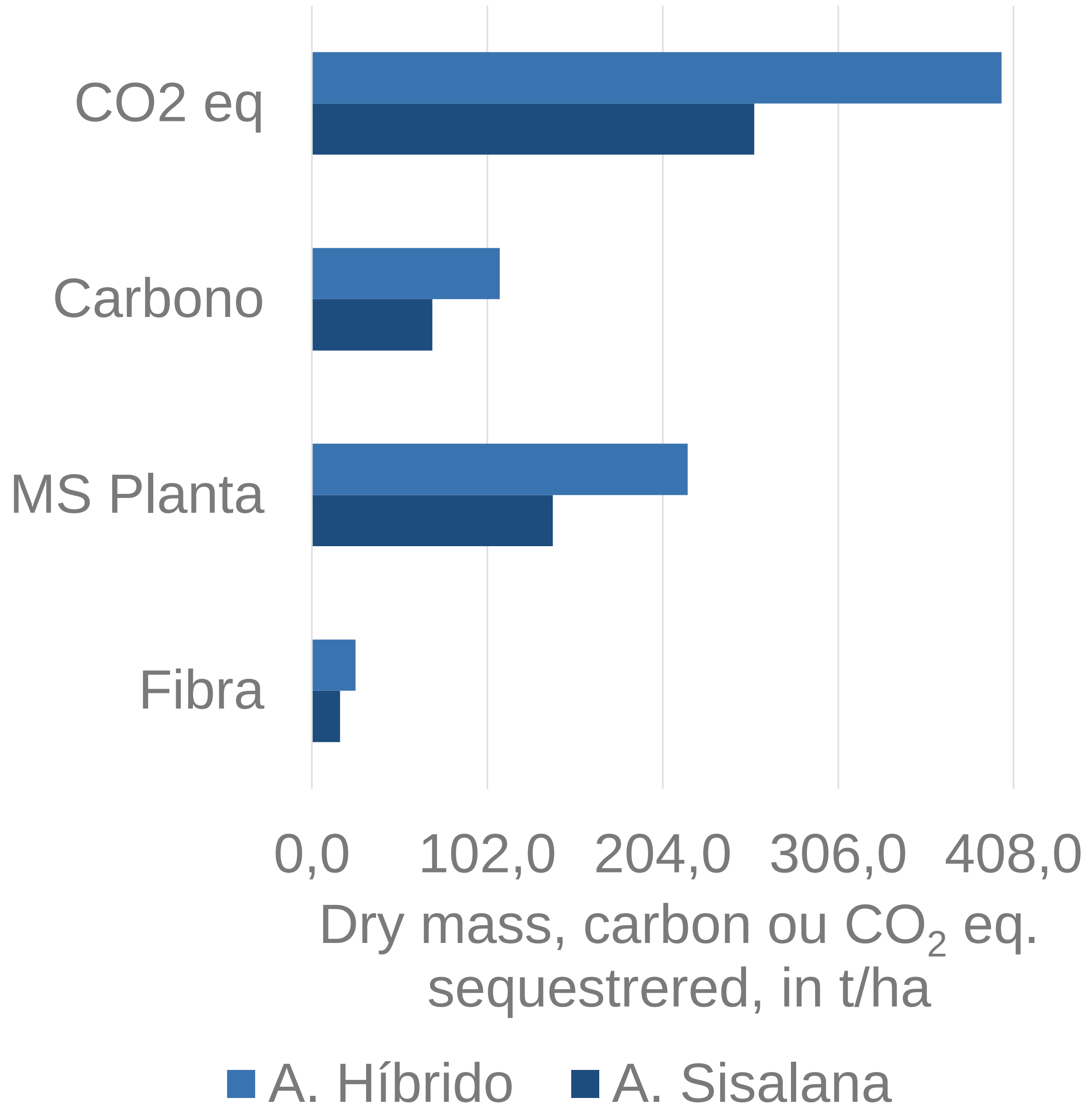
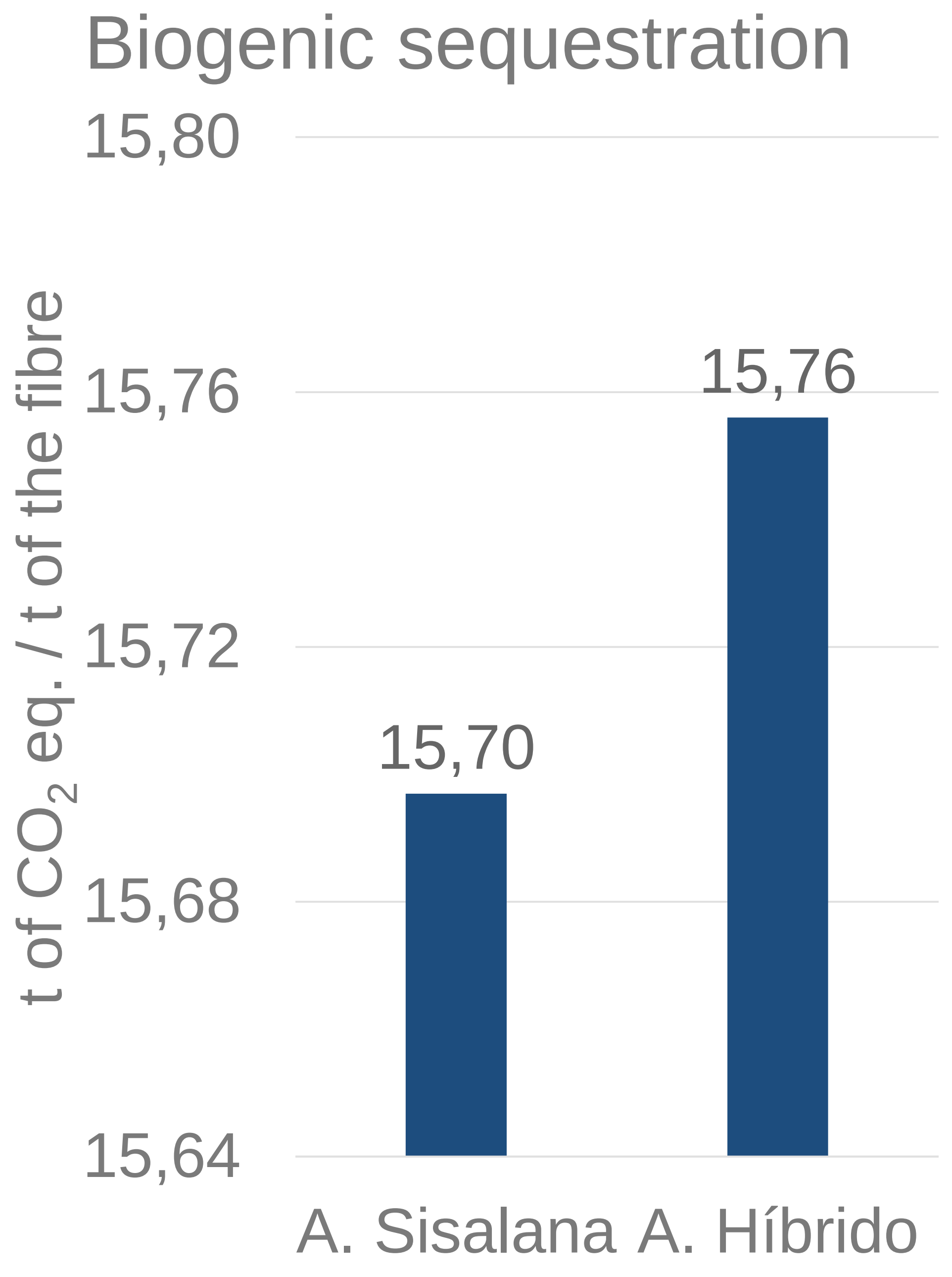
Received 14 November 2016, Revised 10 February 2017, Accepted 10 February 2017, Available online 12 February 2017, Version of Record 28 February 2017.

Distribution of Dry Matter and Carbon Sequestration in the Sisal Plant in a 10-Year Cycle



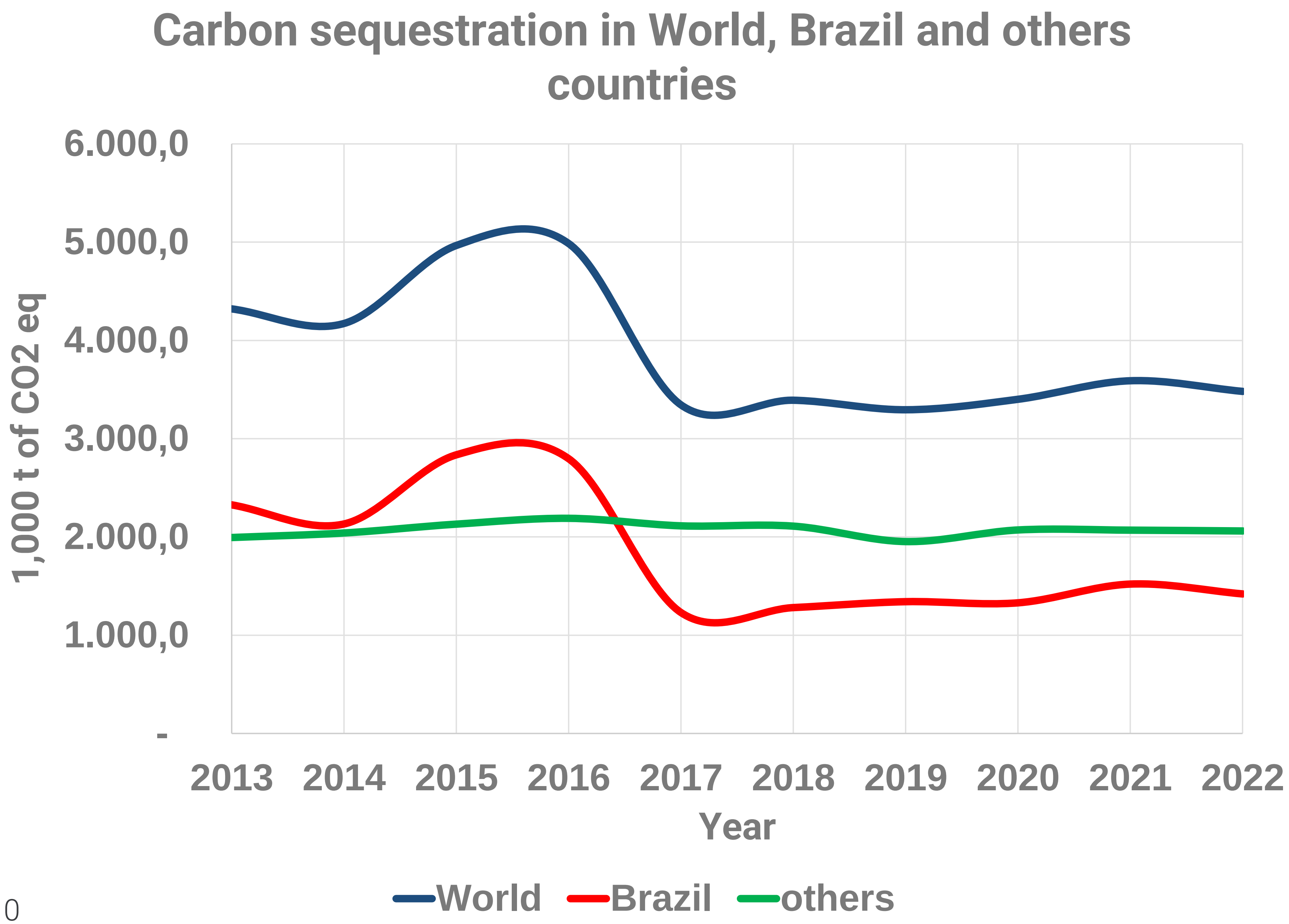


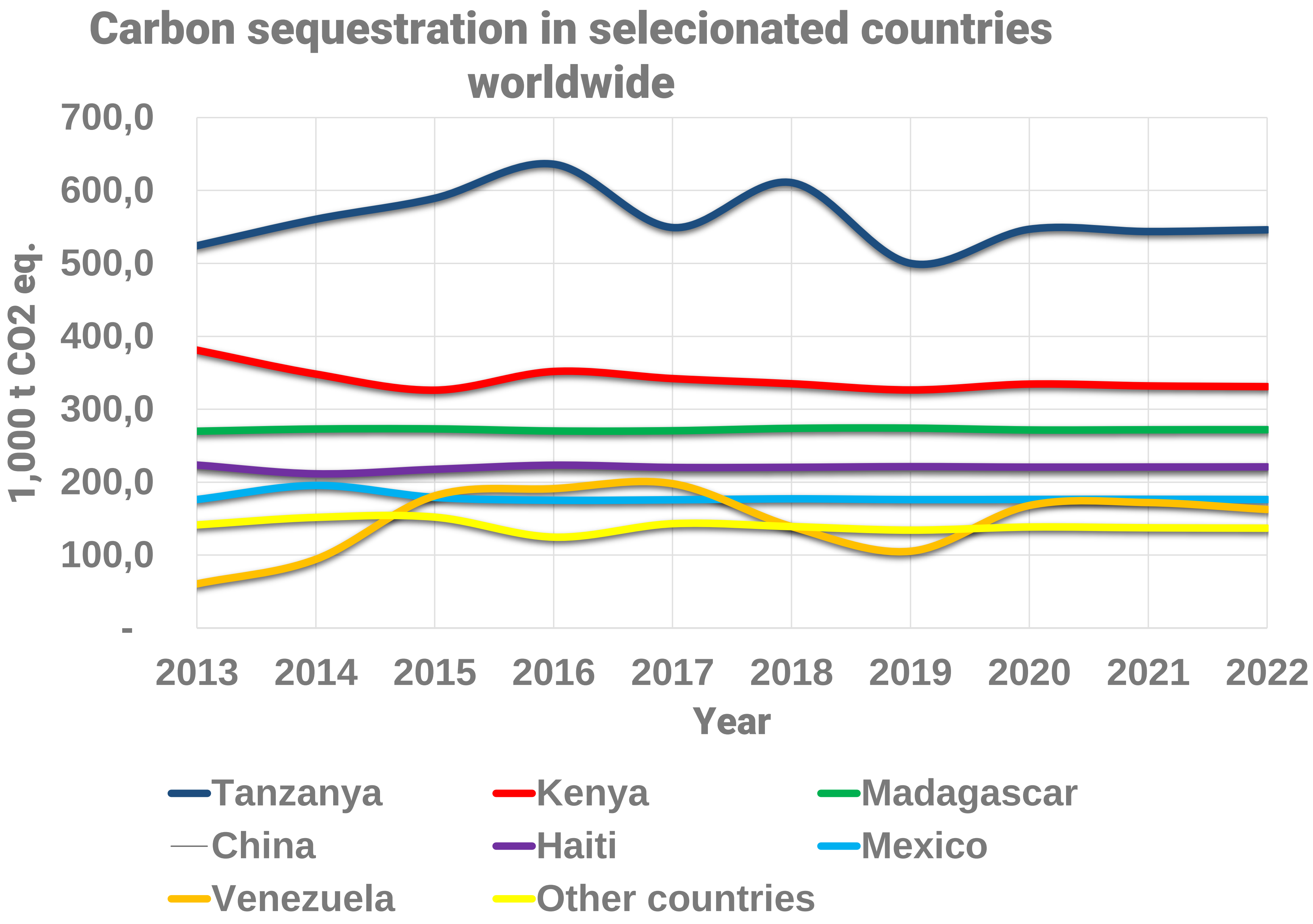


Carbon Sequestration Estimates in Sisal Cultivation in Brazil and the World, in rate about 15.45 or 15.03 t CO_2 eq./ha/ano

Estimated from FAOSTAT Data (2023), Broeren et al. (2017) and other sources.

Understimated:
Tanzania, Kenya and China = 870 kg CO2 eq./t Fibra
Brazil and Other countries = 1,289 kg CO2 eq./t Fibra





Concentration of Agave Fiber Production in Brazil

< 62% area

> 160% productivity

Planted area, production and productivity of sisal produced in Brazil in 2002 and 2022

Brazil and Federation Units	Planted area, ha		Production fiber t/year		Productivity t/ha	
	2012	2022	2012	2022	2012	2022
Brasil	**258964**	**98795**	**89128**	**91923**	**358**	**934**
Ceará	485	29	1015	57	2093	1966
Rio Grande do Norte	842	-	566	-	672	-
Paraíba	9604	4943	7969	3942	830	856
Bahia	**248033**	**93823**	**79578**	**87924**	**335**	**937**

Fonte: IBGE - Produção Agrícola Municipal (2024)
https://sidra.ibge.gov.br/tabela/5457#resultado

How to increase the economic potential of this culture?

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Total CO_2 Equivalent Sequestration (t)

Estimated from IBGE (2022) and Broeren et al. (2017).

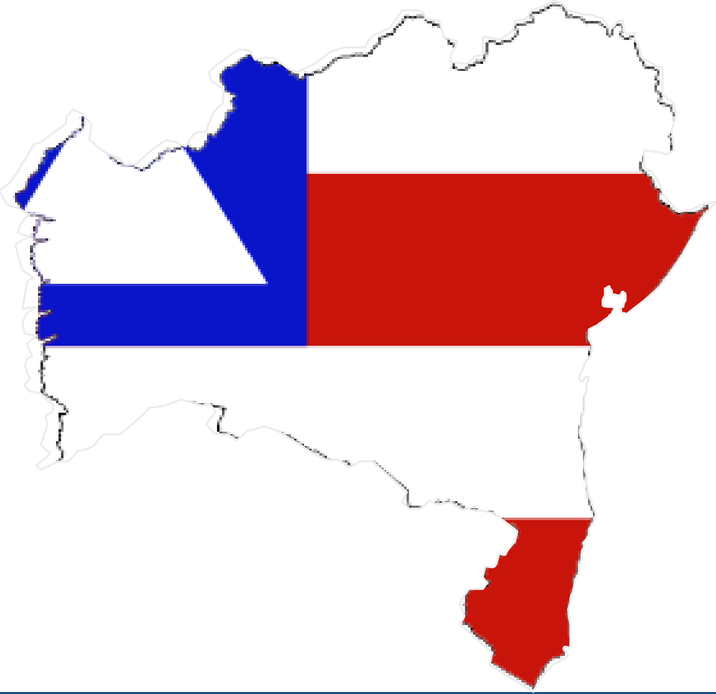
Credit carbon seller in market: US$ 5.00 to 20.00 by t CO_2 eq.

Price for Petroleum to 85 US$/barrel = US$ 209.77 / t CO_2 eq.

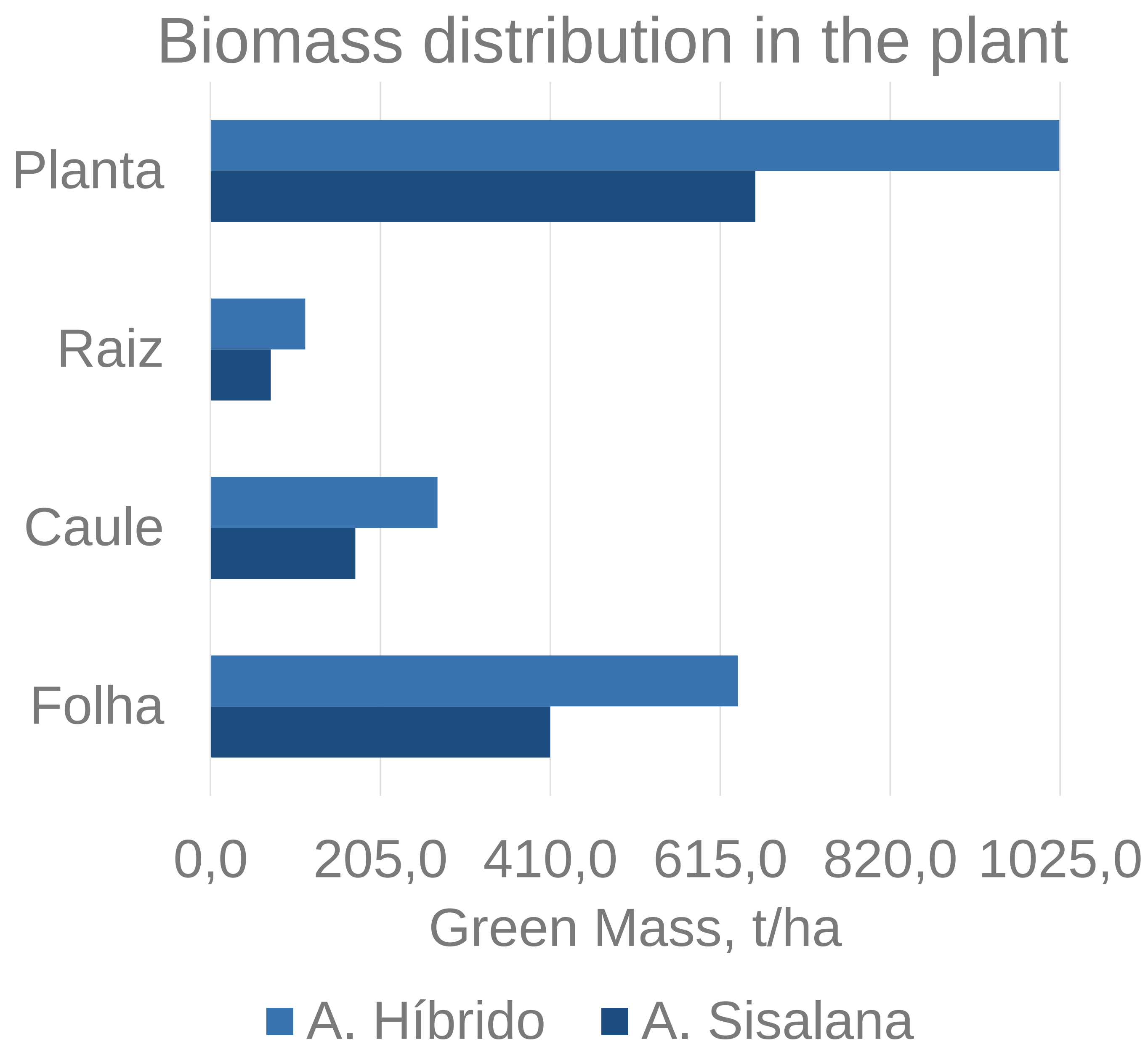
Brasil	Ceará	Paraíba	Bahia
			
1,420,210 t	881 t	60,904 t	1,358,426 t

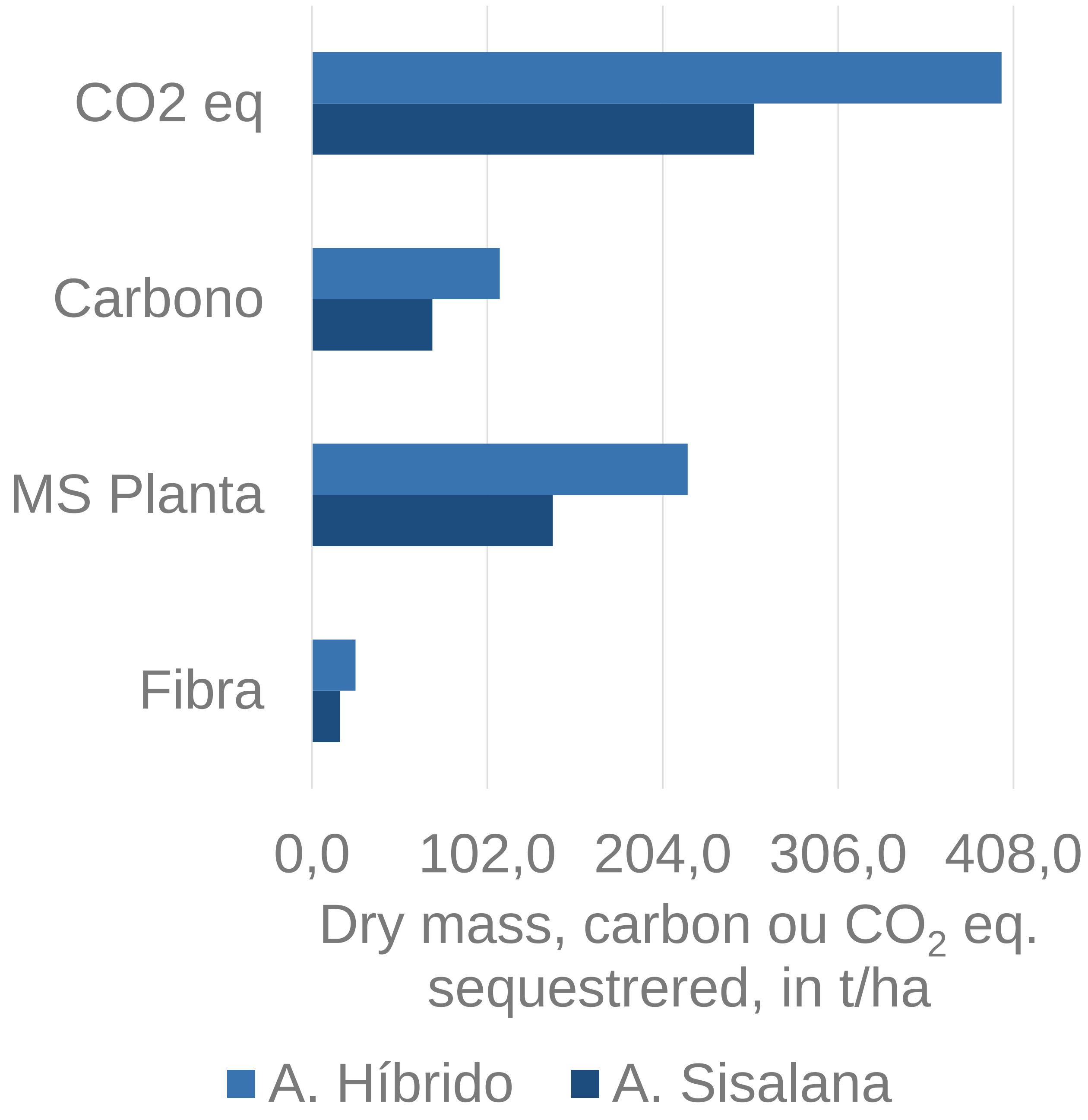
Average CO_2 Equivalent Sequestration (kg/ha)

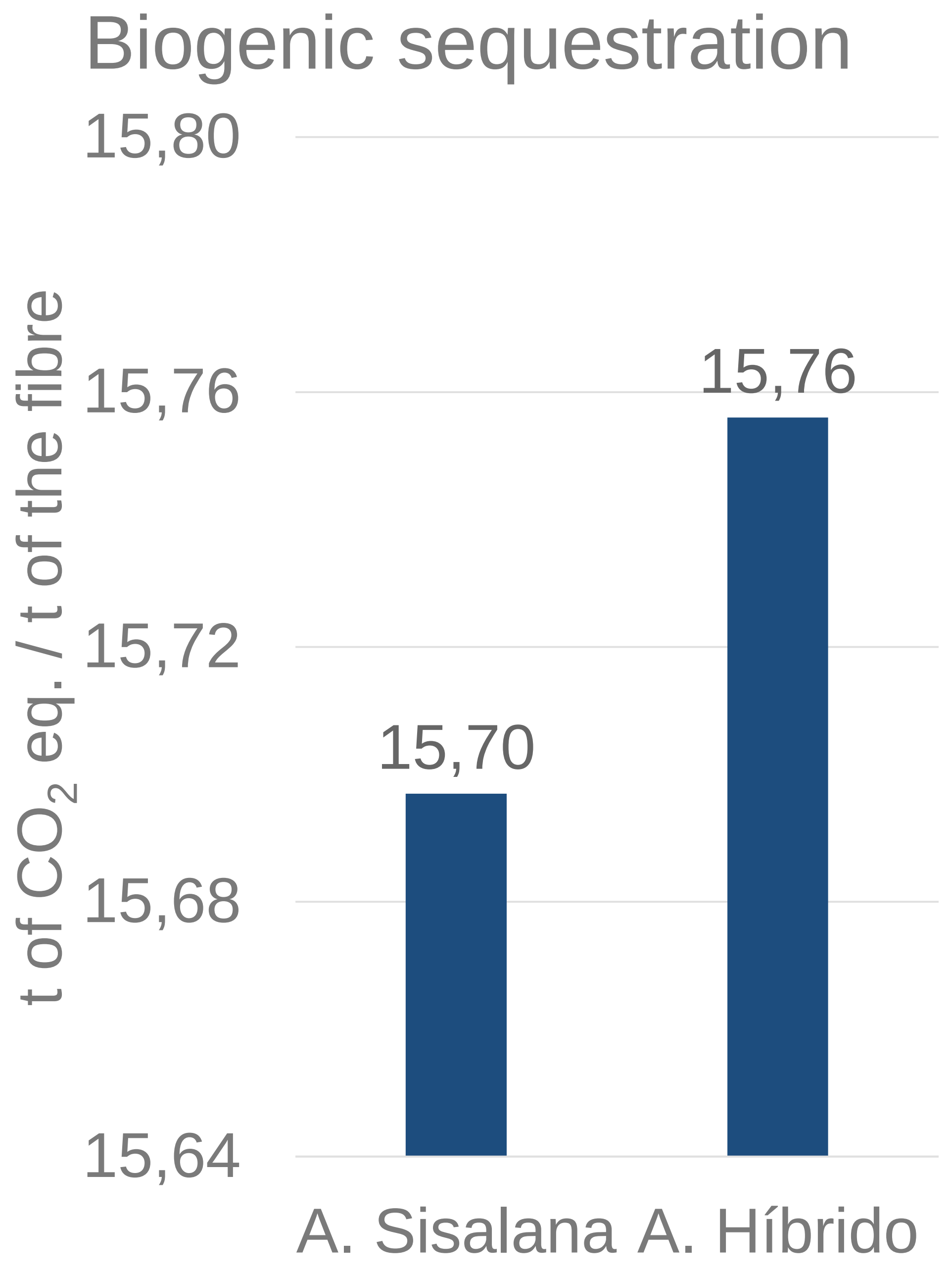
Estimated from IBGE (2022) e estimated from several sources.

Brasil	Ceará	Paraíba	Bahia
			
14,430 kg	30,375 kg	13,225 kg	14,477 kg

Distribution of Dry Matter and Carbon Sequestration in the Sisal Plant in a 10-Year Cycle







Where is the carbon sequestered??

- **In the Plant:**

Roots, stem, leaves, suckers, inflorescence, and bulb

- **In the Soil:**

Soil organic matter (fulvic, humic acids, and humin) and microbial biomass of the soil and soil air

- **In the Production System (volunteer plants and intercropped plants)**

Crop options for > carbon sequestration

Strategies to increase carbon sequestration:

1. Invest in technology for more productive and sustainable sisal crops;

2. Use Integrated Production Systems:
Perennial Crops – Annual;
Crops – Livestock;
Crops – Livestock – Forests.

3. Invest in the full use of the sisal plant and its consorts.

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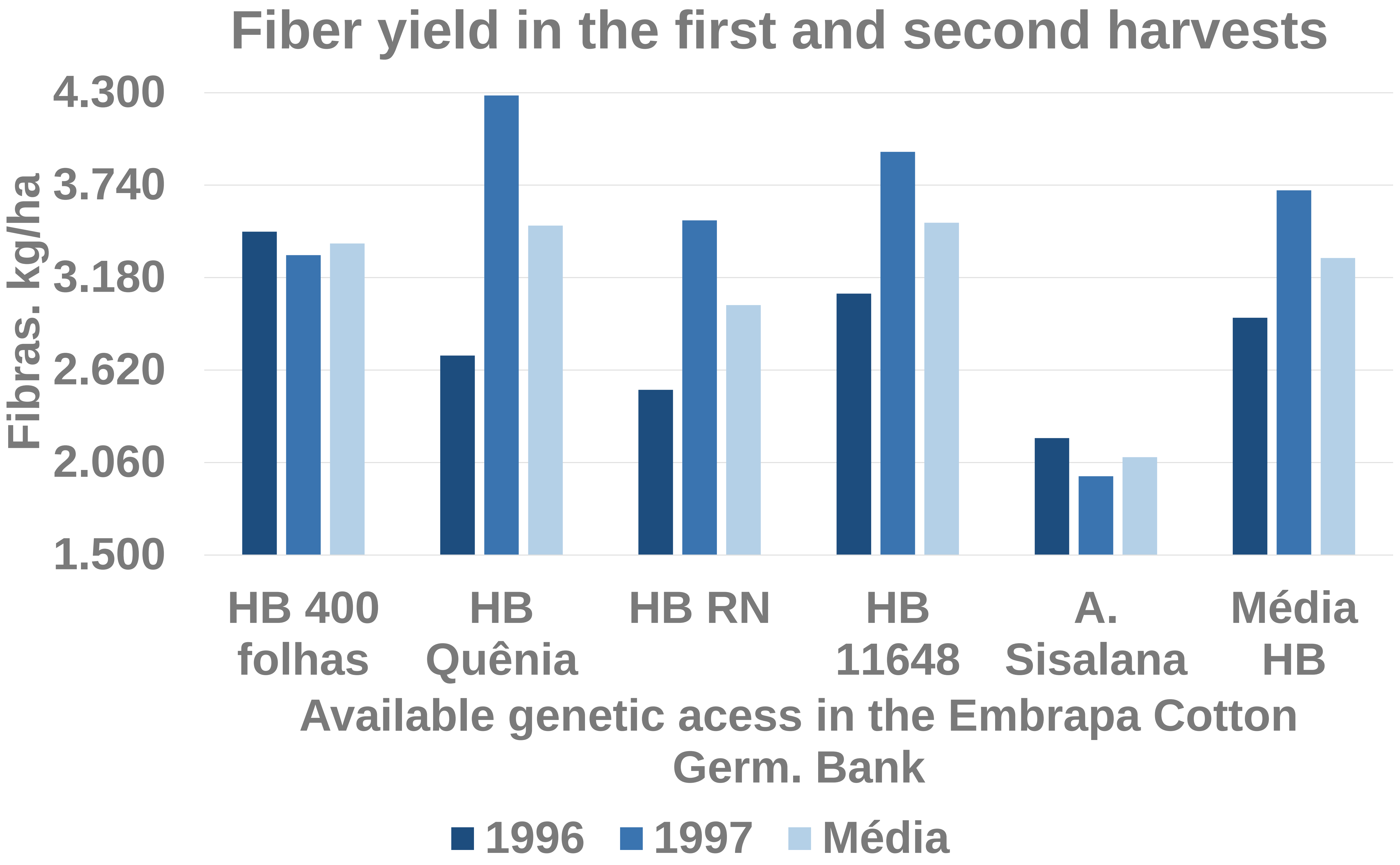
Potential of Available Germplasm to Increase Productivity and Carbon Sequestration

Adapted Data from Silva and Beltrão (1999), in Monteiro – PB.

...of Agave accessions using quantitative biometrical and physiological features.



Challenge: FULL UTILIZATION OF THE PLANT
Economic viability with the utilization of defibering residue and co-productss

Foto: Tarcísio Marcos S. Gondim

Leaf sisal:
- ✓ Fiber - 5% (only 4% - Commonly Usable);
- ✓ Mucilage – 15% and
- ✓ Juice – 80%.

Defibration residues represent:
- ✓ 1% residual fiber;
- ✓ 15% mucilage: organic fertilizer or animal feed;
- ✓ 80% juice: Biopharmaceuticals and bioinsecticides.

PLANT:

Bioenergy: briquettes, ethanol, methane gas, and bioelectricity.

Other products: fructose, syrups, inulin, concentrated sweets, baked goods, and fruit sauces, each made with different parts of the agave plant (leaves, "pineapple," inflorescence, etc.)

Slides adapted from Dr. Tarcísio Gondim

How to increase the economic potential of this culture?

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Sisal: A productive chain


Cultivation


Harvest


Defibering


Rotary screening

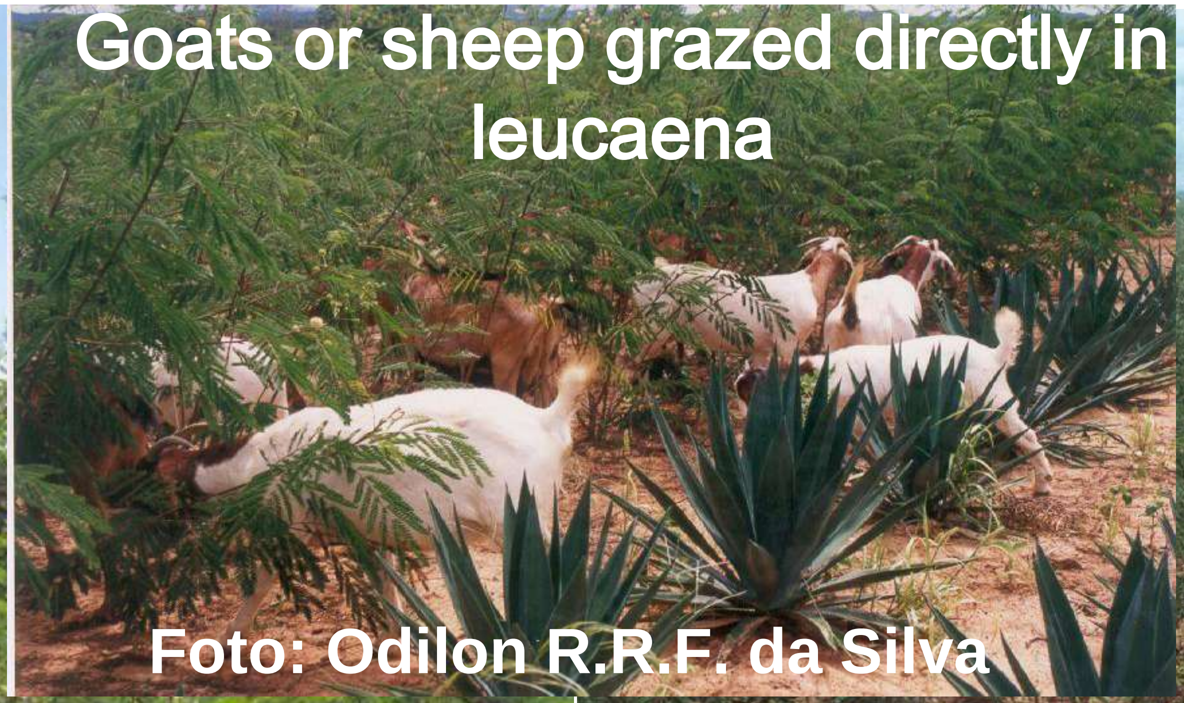

Mucilage


Animal food


Haying or silage

Slides adaptados from Dr. Tarcísio Gondim

Consortium of Sisal and Leucaena (Alley Crops or Protein Banks))



Sisal in double rows + Leucaena

Sisal in simple rows + Leucaena

Advantages:

- Integration with consortium areas Sisal + Buffel Grass + agave residue silage;
- Meat and milk production.

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Consortium of Sisal and Buffel Grass

Productivity:

Green mass: 11,500 kg/ha
Dry mass: 2,875 kg/ha
Carbon: 1,438 kg/ha
CO_2 eq: 5,276 kg/ha

Foto: Orozimbo RRF da

Sisal in single rows + buffel grass

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Consortium of sisal and sesame

Consortium of Sisal and Sesame

Sisal in single or double rows:

4 m x 1 m or 5 m x 1 m

4 m x 1 m x 1 m or 5 m x 1m x 1 m

Sesame:

Non-branched: 0.8 m x 0.1 m – Var. BRS Anahir;

Branched: 1.0 m x 0.2 m – Var. BRS Seda

- ✓ *Production: 400 kg/ha of sesame BRS Seda (branched)*
- ✓ *4,465 kg/ha of MS, 2,233 kg/ha Carbon*
- ✓ *8,187 kg/ha of CO_2 eq.*

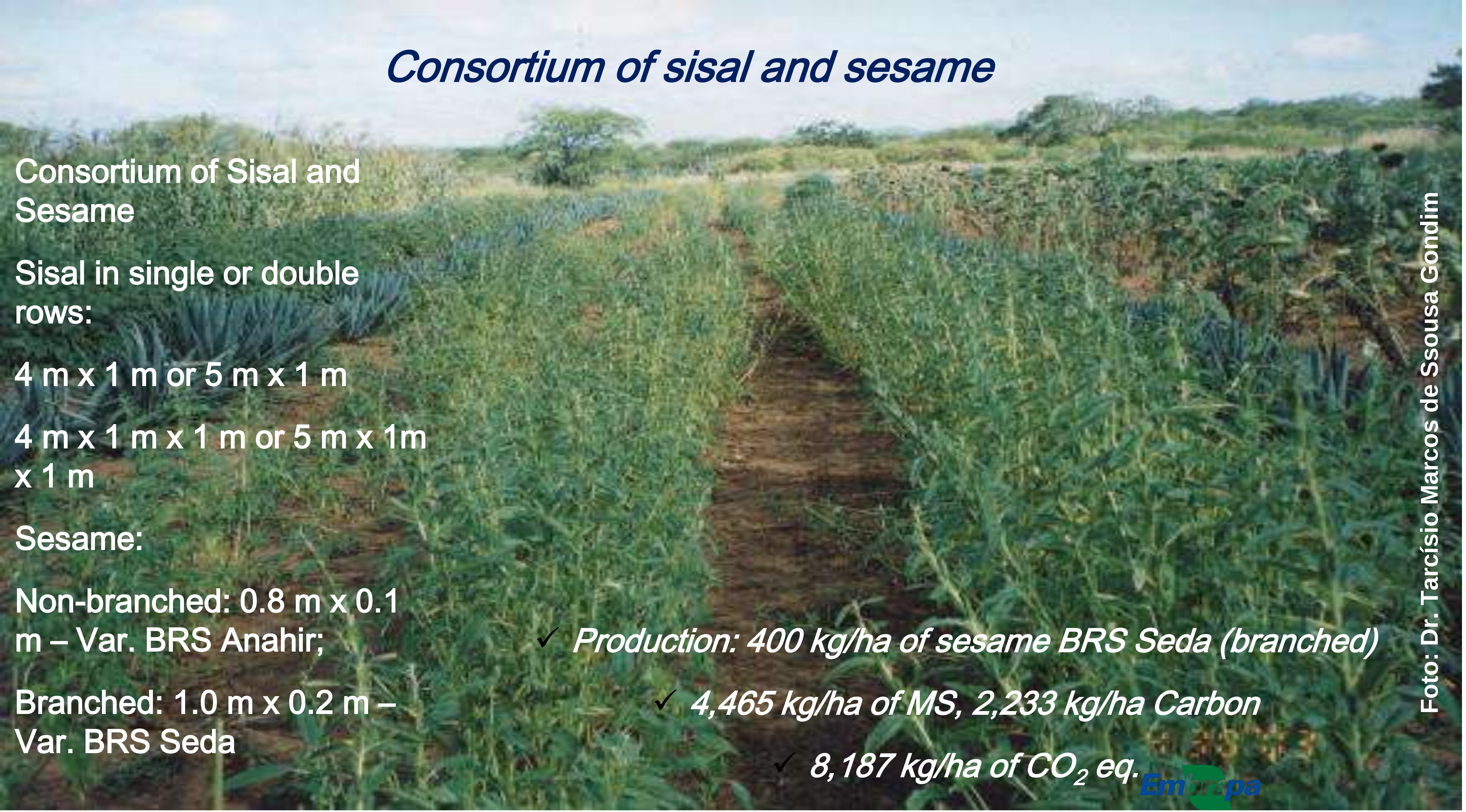
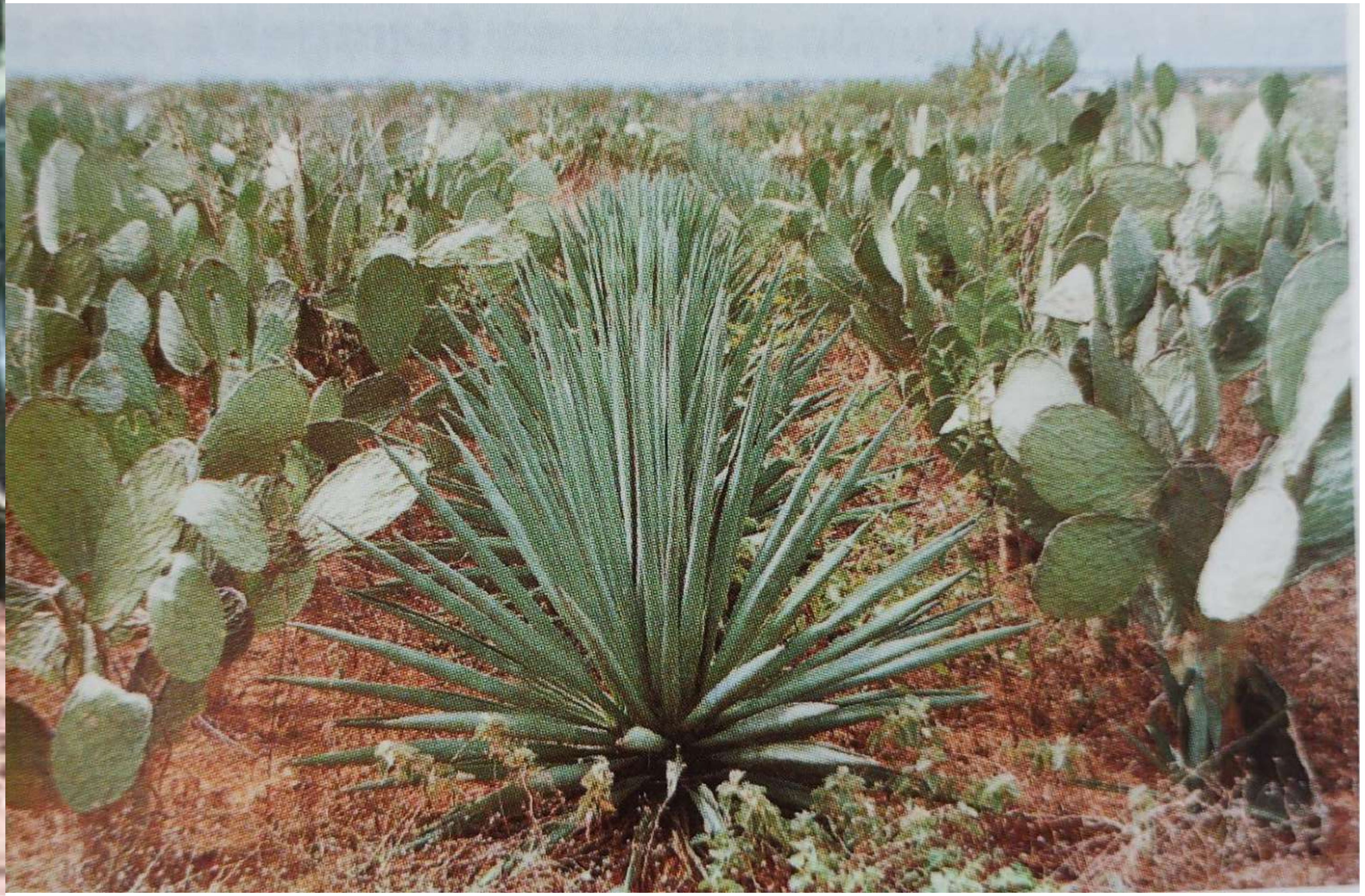


Foto: Dr. Tarcísio Marcos de Ssousa Gondim

Sisal and Cactus Pear Consortium



Consortium of Sisal and Cactus Pear
Sisal in double rows:
with 4 m x 1 m x 1 m or 5 m x 1m x 1 m
Cactus Pear:
Var. Redonda or Gigante with 10 m x 0.25 m; and
Var. Miúda with 10 m x 2 m

Production: 41.5 t/ha/year of Cactus Pear

Sequestration of 1,077 kg/ha/year of Carbon or 3,952 kg/ha/year of CO_2 eq..

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Sisal and Cowpea Beans Consortium

Average Bean Production = 600 kg/ha

Sequestration of 230 kg/ha of C and 842 kg CO_2 eq/ha. Borges et al. (2011)

Bean grains = 876 kg/ha with A. Hybrid or = 683 kg/ha with A. sisalana (Silva & Beltrão 1999).

Sequestration of 335/262 kg/ha of C and 1,229/961 kg CO_2 eq/ha. Borges et al. (2011)

Sisal and corn consortium

Corn grains = 1,348 kg/ha (Silva & Beltrão, 1999).

Sequestration of 1,296 kg/ha of C and 4,757 kg CO_2 eq/ha.
Monteiro et al. (1998)

Machines for sisal leaf defibering in small and medium-sized farms in Brazil

Mobile sisal leaf shredder set with generator, machine and tractor for moving in the field along the carriers. COSIBRA

Slides adapted from Dr. Tarcísio Gondim

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DSF VIII
02

FAUSTINO VIII machine for removing fibre from sisal leaves.

FAUSTINO VIII machine for removing fibre from sisal leaves.

DESFIBRADORA FAUSTINO
IX EM FUNCIONAMENTO:

Organic Fertilization with Sisal Residue

Direct use of sisal residue, after fibre recovery.
Include the short fibre and juice – 10 to 20 kg/plant.



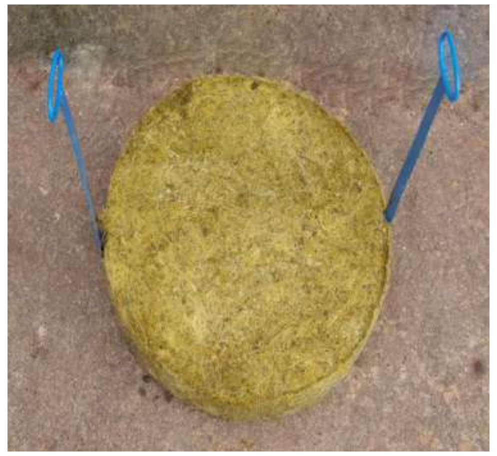



Liquid Fraction of Sisal – "Odilon" Extractor Press

15% mucilage or pulp, 80% juice, and 1% fibers of different sizes



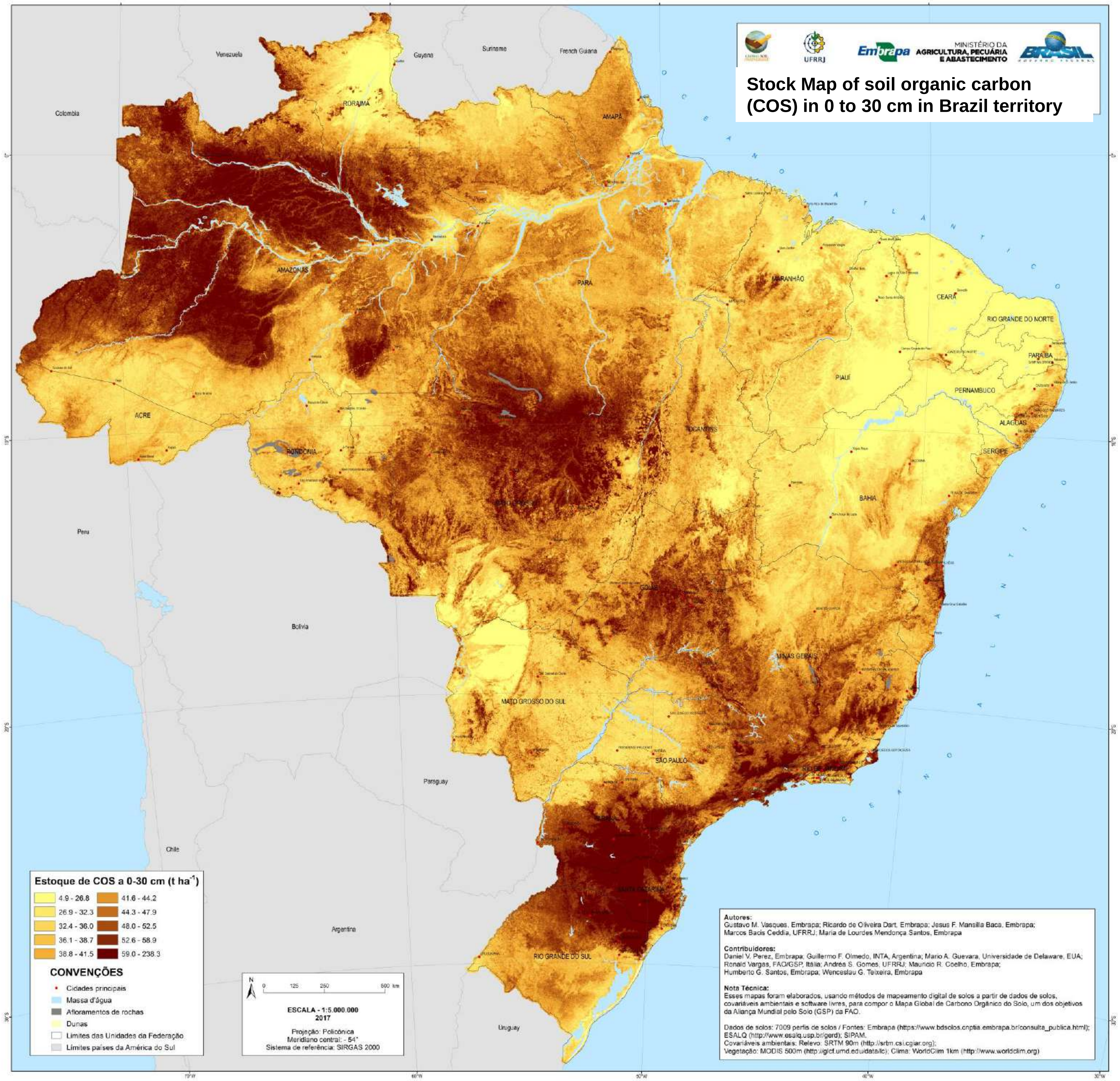


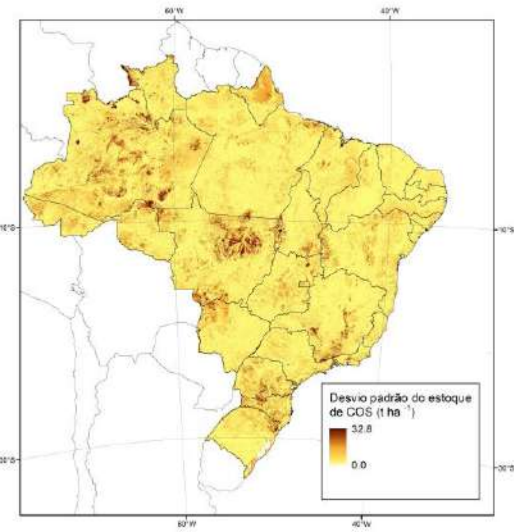



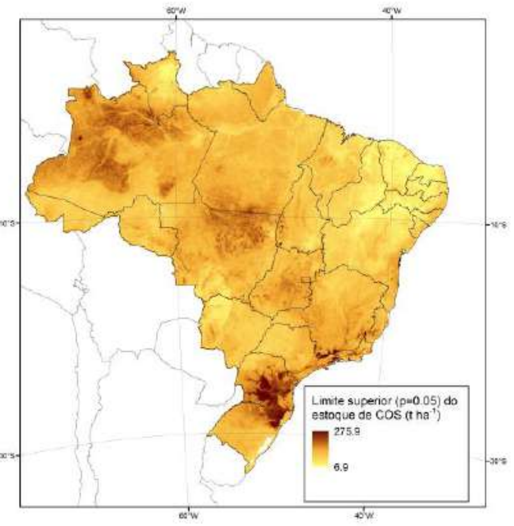

Bioinseticida da fração líquida (suco)

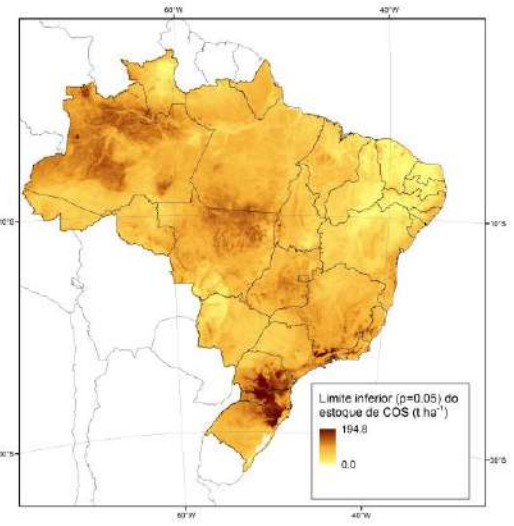

500 a 800 L of “juice” per day


Soil Compartment: CO_2 Sequestration









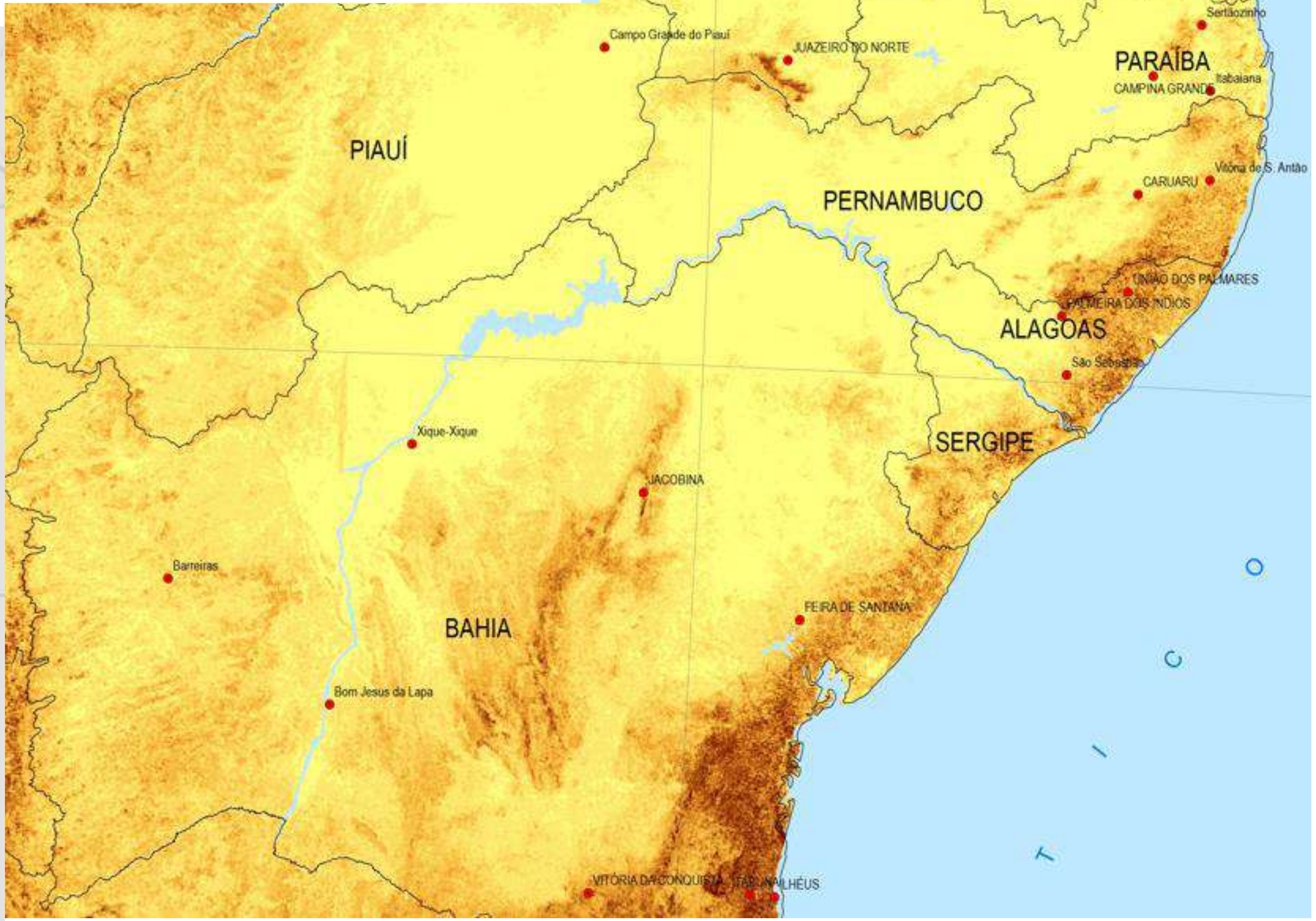
Stock map of soil organic carbon (SOC) in 0 to 30 cm in Brazil territory

Stock of SOC in 0 to 30 cm, t/ha

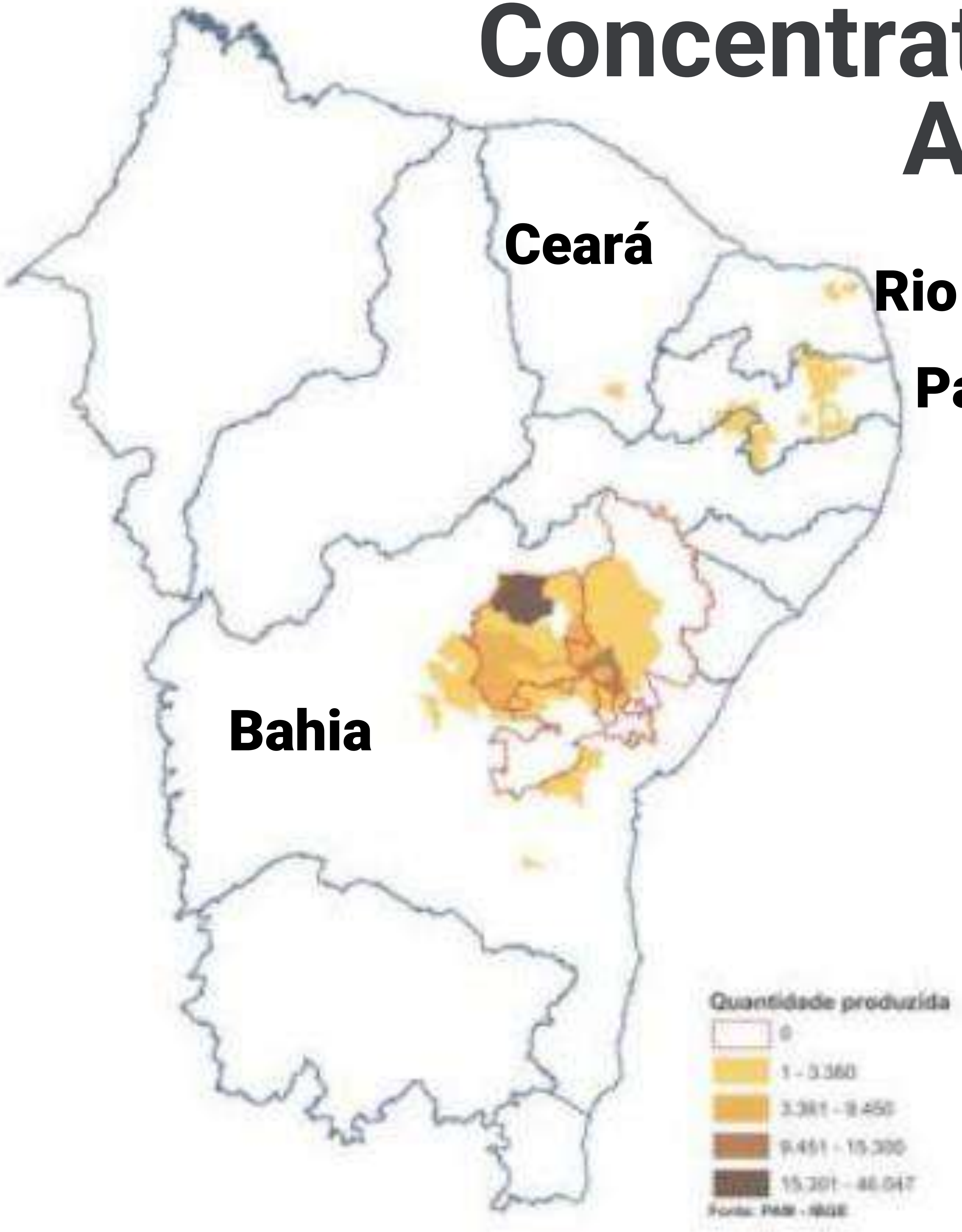
4.9 - 26.8	41.6 - 44.2
26.9 - 32.3	44.3 - 47.9
32.4 - 36.0	48.0 - 52.5
36.1 - 38.7	52.6 - 58.9
38.8 - 41.5	59.0 - 238.3

CONVENÇÕES

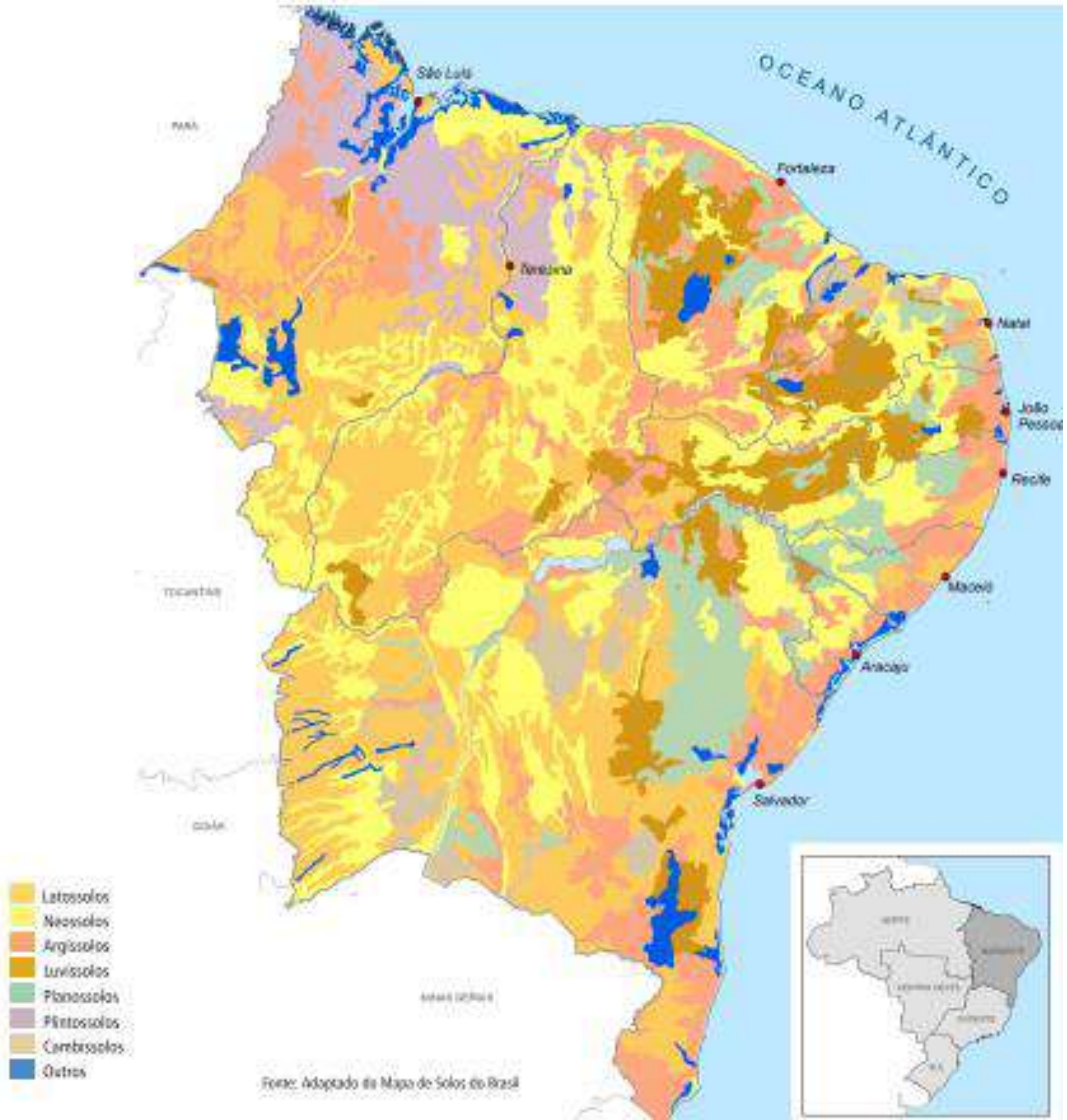
- Cidades principais
- Massa d'água
- Afloramentos de rochas
- Dunas
- Limites das Unidades da Federação
- Límites países da América do Sul



Concentration of Sisal Producing Areas in Brazil



The culture prefers soils of medium texture; fertile; not subject to waterlogging; not compacted or densely packed and deep..



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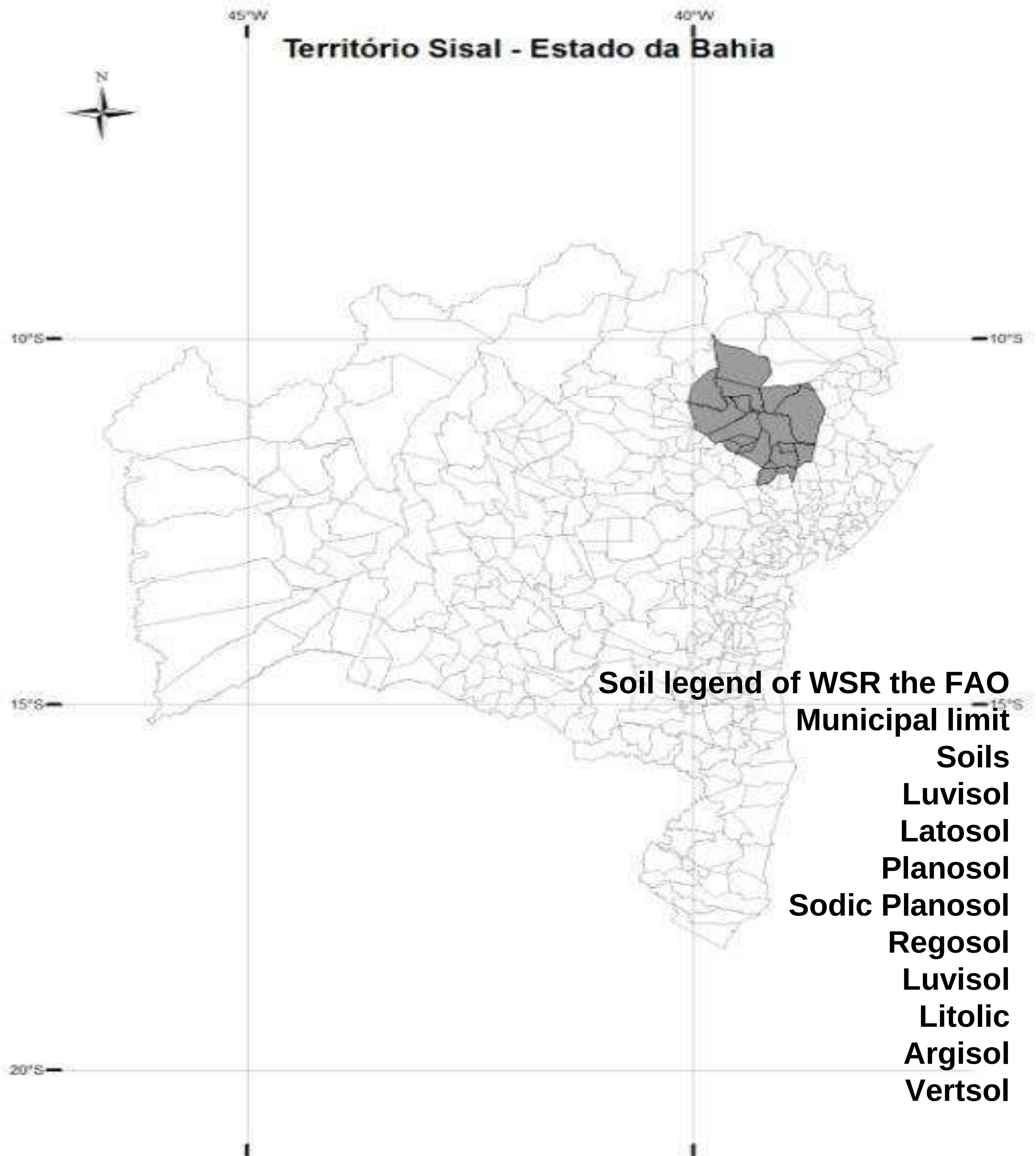
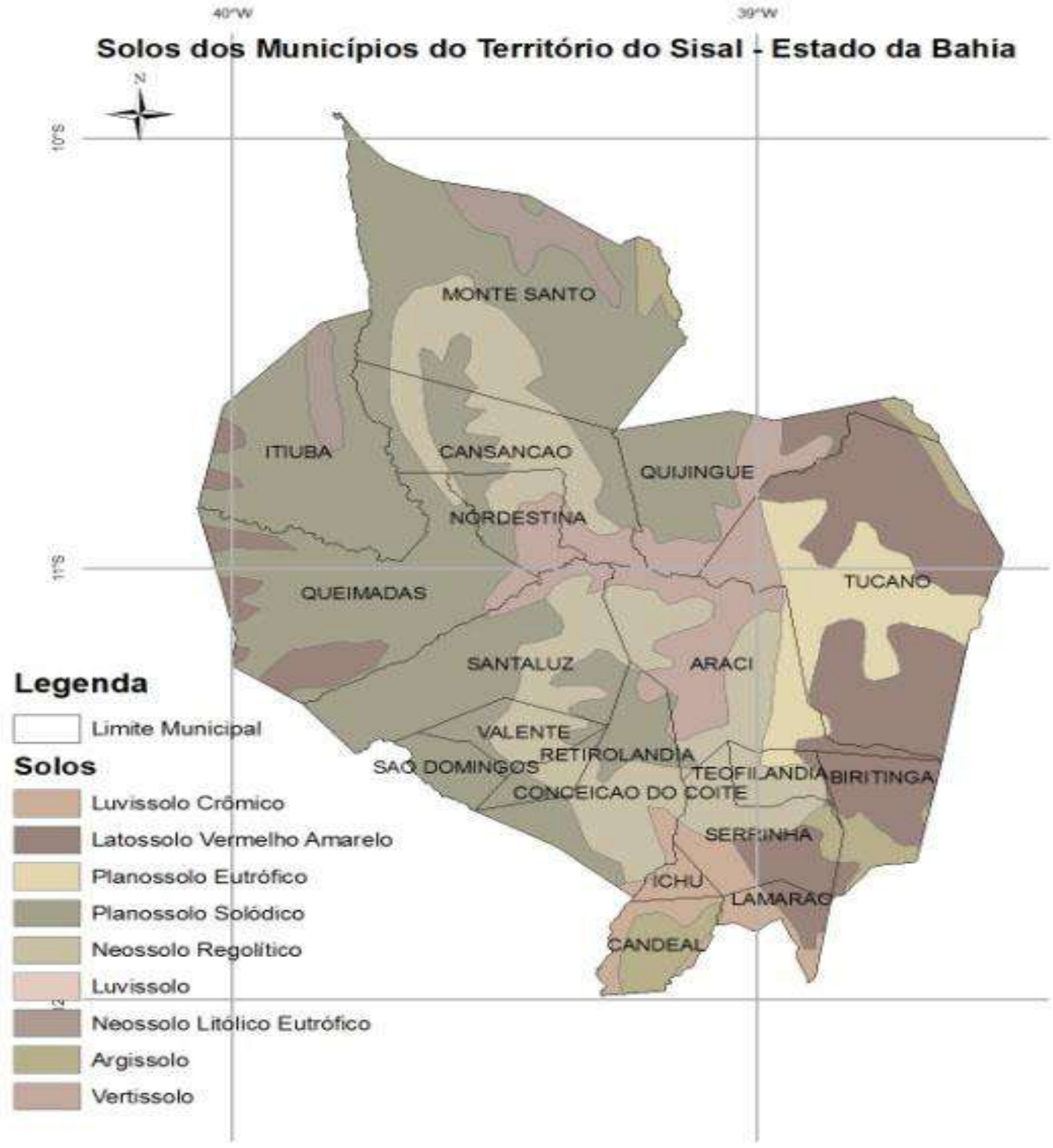
Soils for Sisal Cultivation

The culture prefers soils of medium texture; fertile; not subject to waterlogging; not compacted or densely packed and deep..

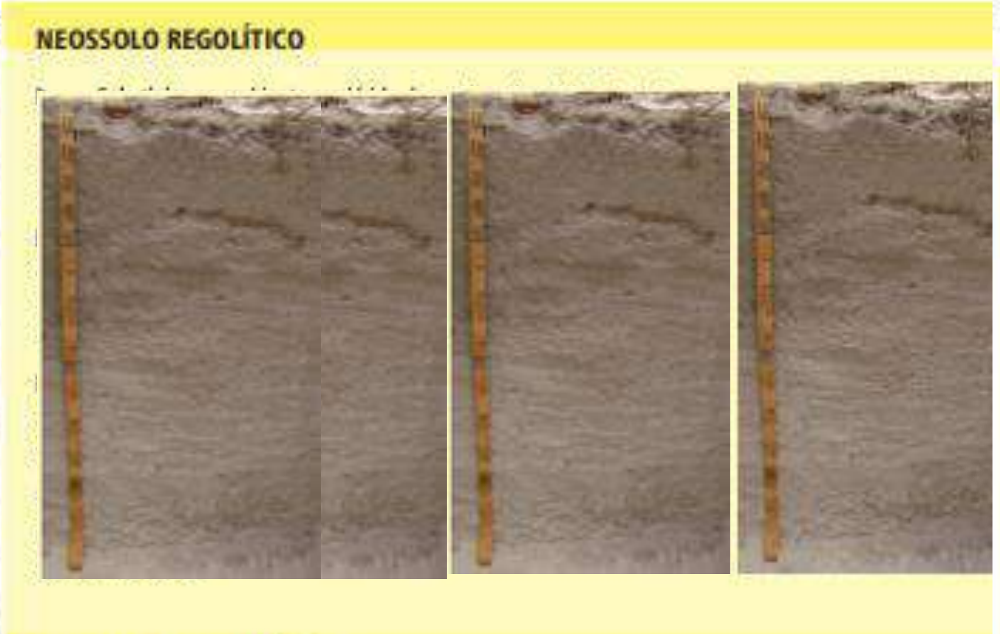


Soil legend of WSR the FAO
Municipal limit
Soils
Luvisol
Latosol
Planosol
Sodic Planosol
Regosol
Luvisol
Litolic
Argisol
Vertsol



Typic Soils Cultivated with Sisal in BA: low amount of Carbon Sequestered

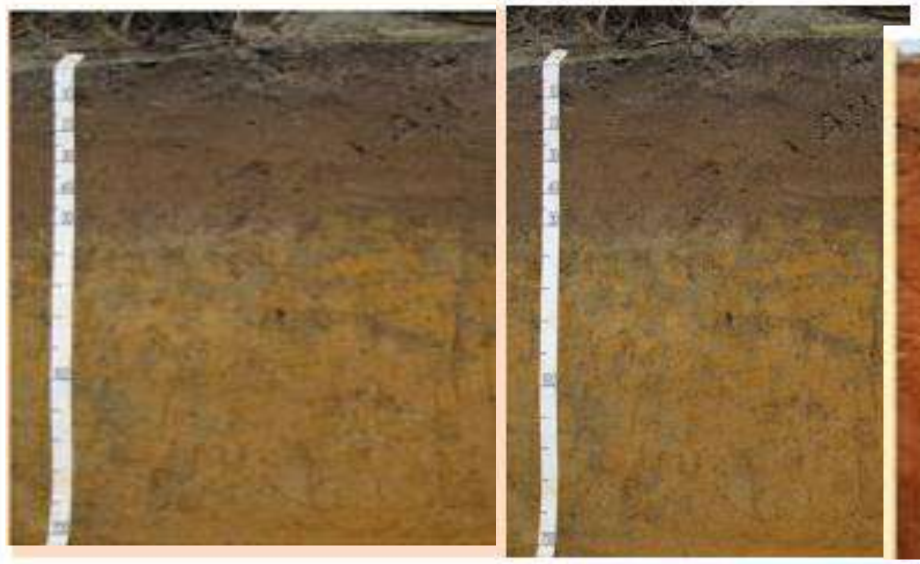
Planosols

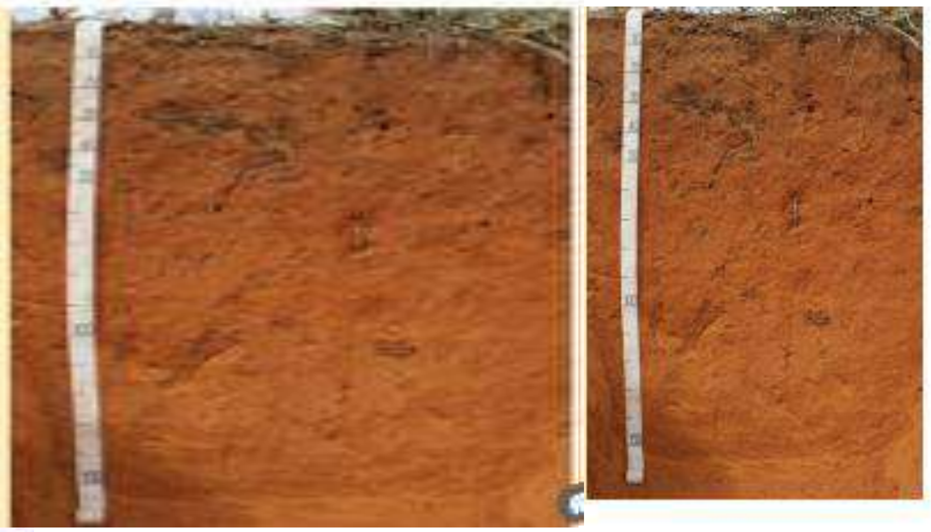


Regolitic and Quartzarenic Neosols

Litolic Neosol

Typic Soils Cultivated with Sisal in BA: medium amount of Carbon Sequestered





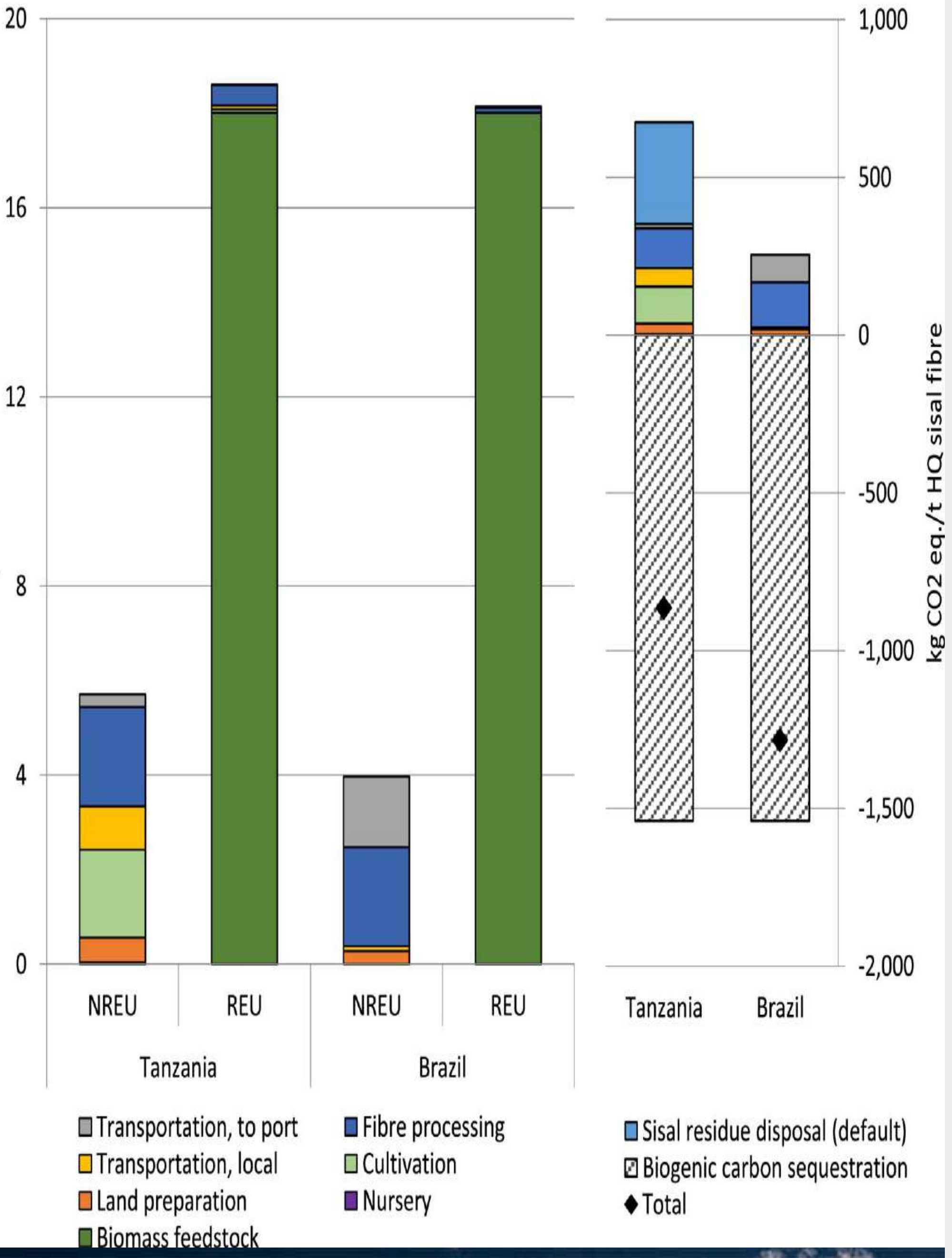
Luvisol

Argisol

Latosol

Carbon Expenditure and Sequestration in Sisal Production until the Fiber is Delivered to the Port

Adapted from Broeren et al. (2017) and other researchers



Total carbon sequestrated

1,539 kg CO_2 eq./t fibra

Mensured by Dry Matter accumulated in total plant

~ 15,700 kg CO_2 eq/t fibra

Total expenditure of 250 kg CO2 eq./t Fiber in Brazil; In Tanzania, it reaches 669 kg CO2 eq/t Fiber.

Expenditure in fibre recovery

132.5 kg CO_2 eq./t Fibra

53%

Expense in transport to the port

95 kg CO_2 eq./t Fibra

38%

Spend on soil preparation

22.5 kg CO_2 eq./t Fibra

9%

Annual Balance: Annual Sequestration in the Plant and Soil – Annual Expenditure:

Data in kg CO_2 eq. to produce 1 t of sisal fiber.

Biogenic sequestered

1,539

Pela Dry Matter

15,700

Emissão de CO2 ou Gases GEE

BR - 250

TZ - 669

Annual balance Brazil and most coutries in the world

15,450

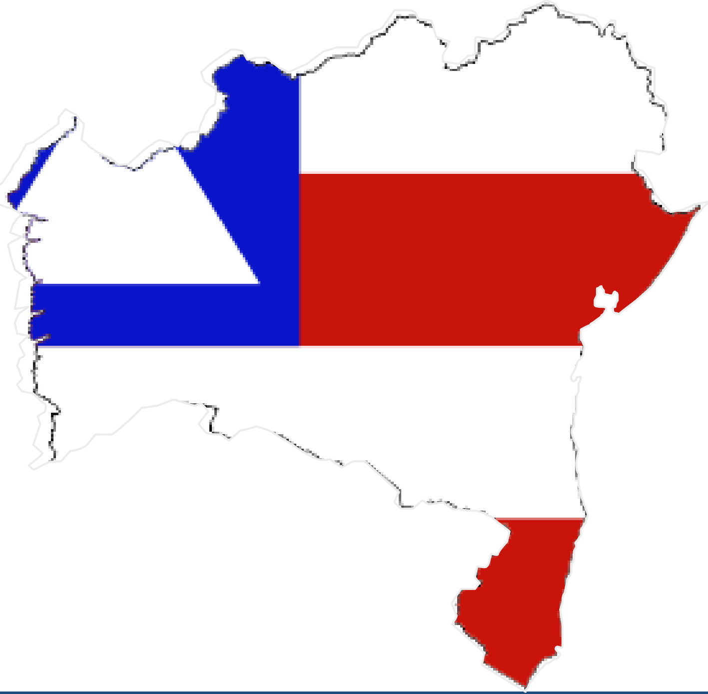
Tanzanya, Kenya, Mexico and China

15,031

Various agricultural practices can change this situation, including the better use of defibering residues for gas and energy production.

How Much is it Worth in Credit/Revenue from the Sale of Sequestered CO2: US$ 10,00/t CO_2 eq.; US$/ha

Estimated from IBGE Data (2022). Curiosity: US$/t CO_2 eq in petroleum: 209.77 (for US$ 85,00/barrels)

Brasil	Ceará	Paraíba	Bahia
			
US$/ha 144.30	US$/ha 303.75	US$/ha 132.25	US$/ha 144.77

Estimated by Dry Matter Produced in total plant, by Ferreira, G.B. (2024) – Carbon Sequestered: 15,450 kg CO_2 eq/t de fibra.

Average CO_2 Equivalent Sequestration (kg/ha) in selected countries around the world

Estimated from IBGE (2022), FAO (2022) and others sources.

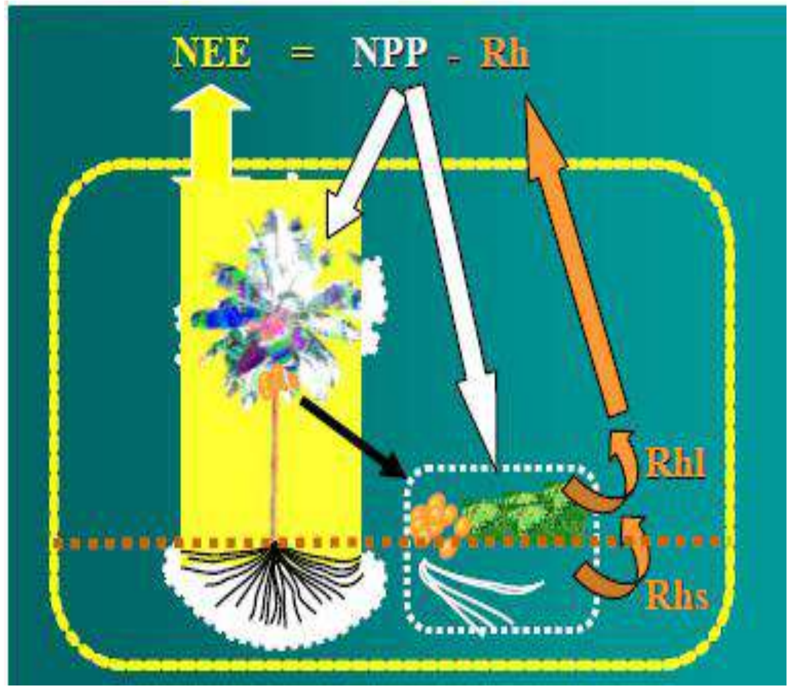
Chi	Uga	Ven	Mad	Ind	Mex	Ang	Ken	Tan	Others
810.53	319.38	305.82	189.82	169.88	168.11	157.27	131.49	121.78	85.15

Conclusions

- The Sisal culture sequesters CO_2 and conserves soil and water;
- It can accumulate > 400 t/ha of CO_2 in the entire plant, 15.7 t CO_2 eq/t of fibers harvested during its cycle about 10 years.
- In intercropped and integrated systems with animal husbandry, carbon sequestration is greater.
- It is essential to utilize the co-products of sisal and the entire plant for the sustainability of the culture.

1. Coconut environmental advantages;
2. Introduction to coconut in Brazil and the World;
3. Carbon assimilation:
4. Carbon emissions;
5. Annual balance;
6. Conclusion.

Coconut environmental advantages



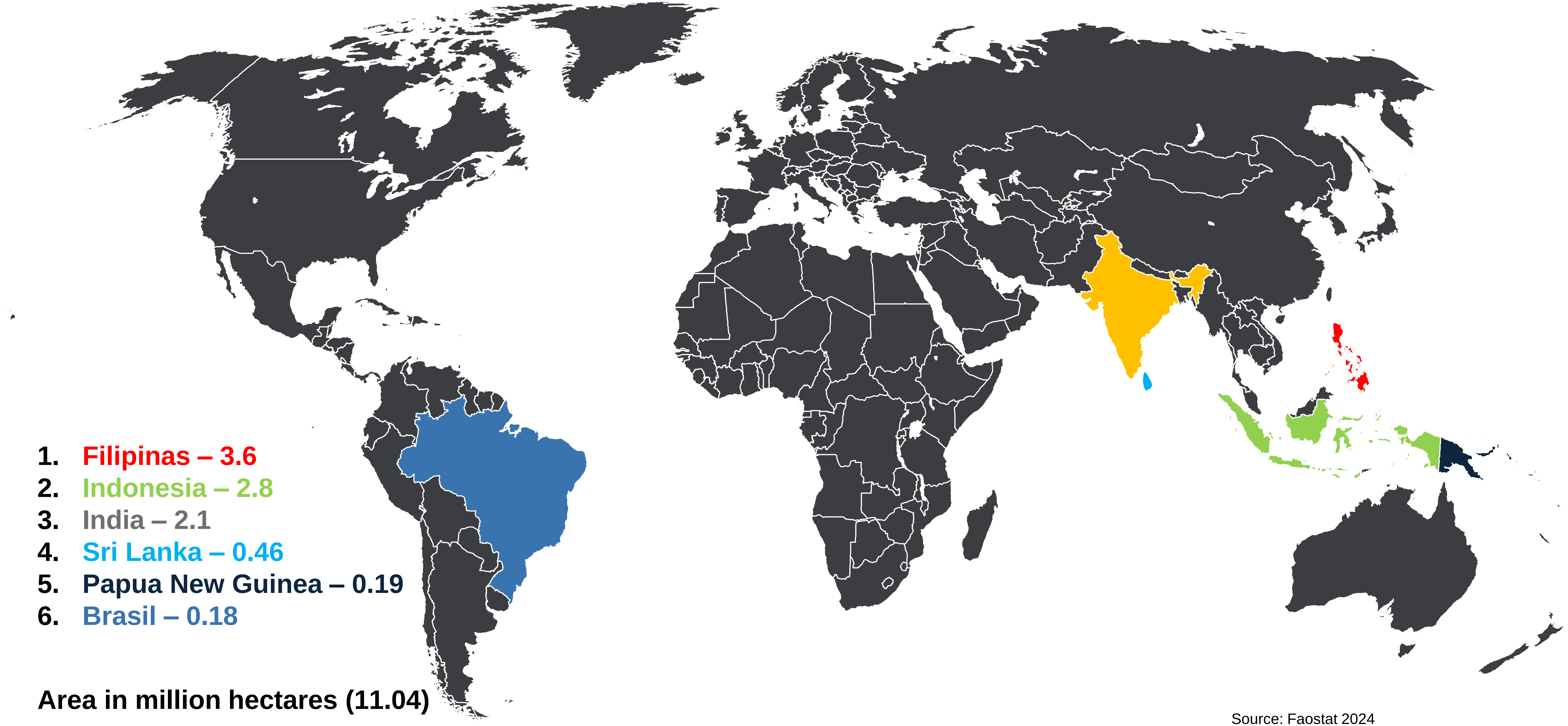
Carbon Sequestration

Soil Conservation

Crop Diversification

Efficient use of resources

Coconut harvested area

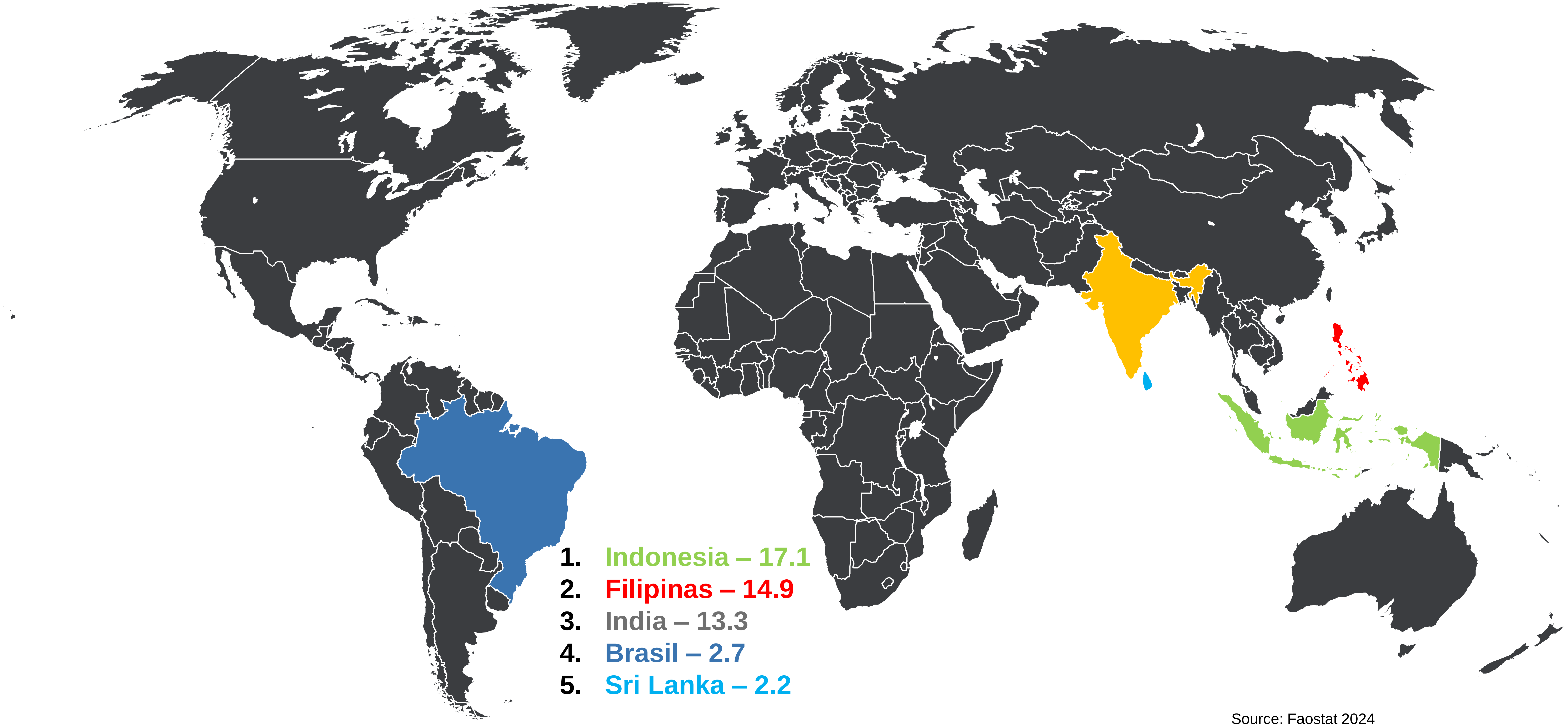


1. Filipinas – 3.6
2. Indonesia – 2.8
3. India – 2.1
4. Sri Lanka – 0.46
5. Papua New Guinea – 0.19
6. Brasil – 0.18

Area in million hectares (11.04)

Source: Faostat 2024

The top 5 coconut producing countries



1. Indonesia – 17.1
2. Filipinas – 14.9
3. India – 13.3
4. Brasil – 2.7
5. Sri Lanka – 2.2

Production in million tonnes (62)

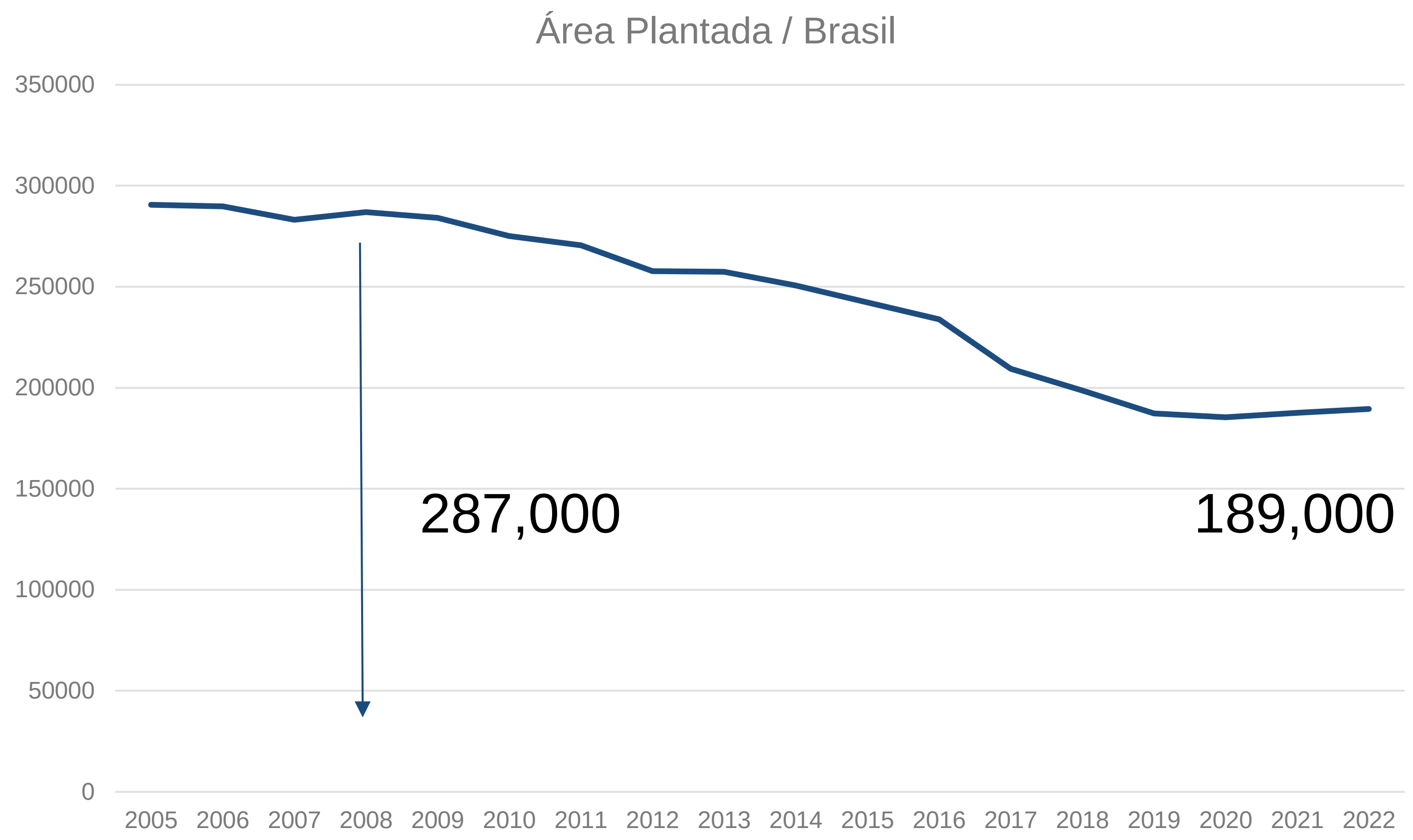
Source: Faostat 2024

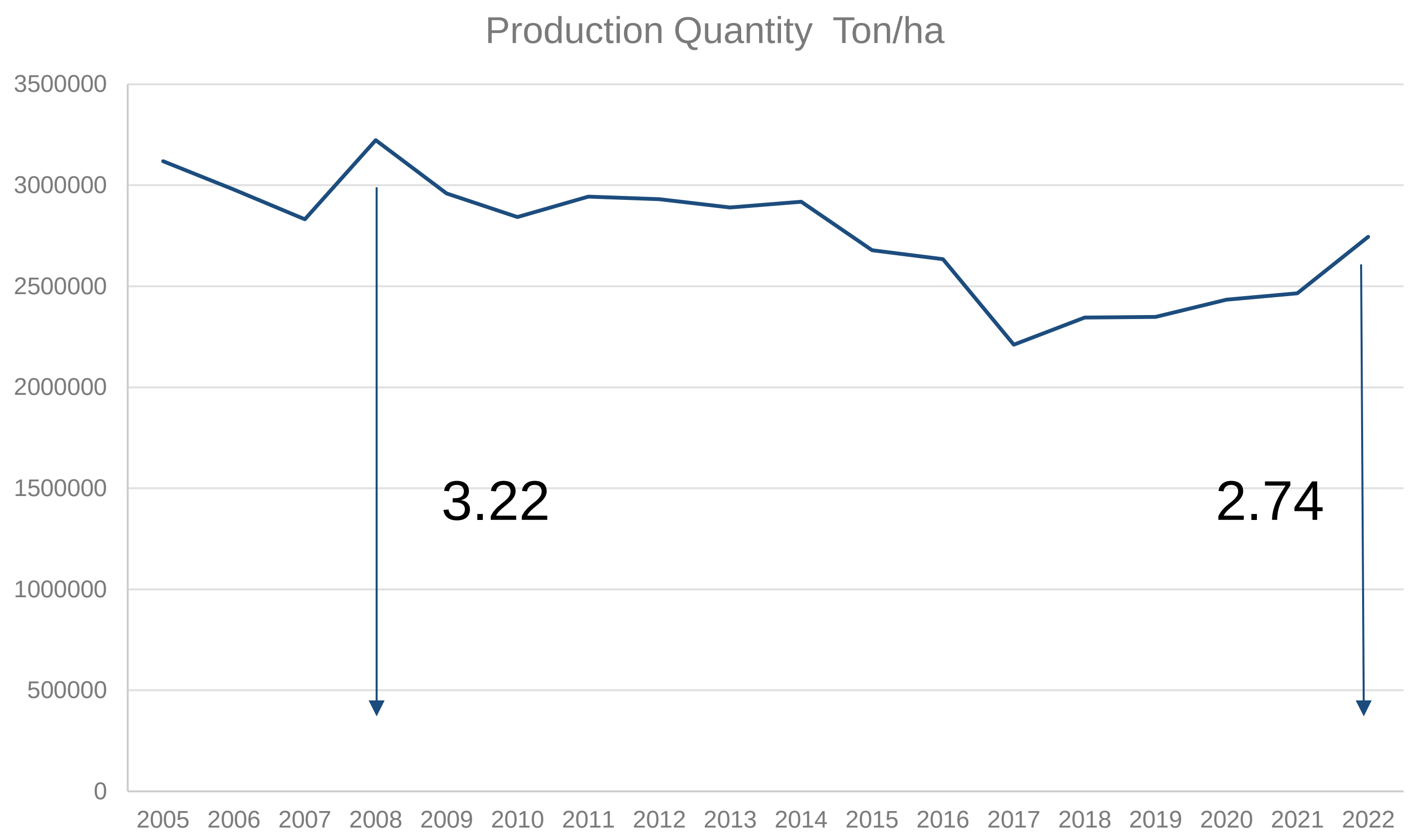
Evolution of coconut cultivation (2005 – 2022)

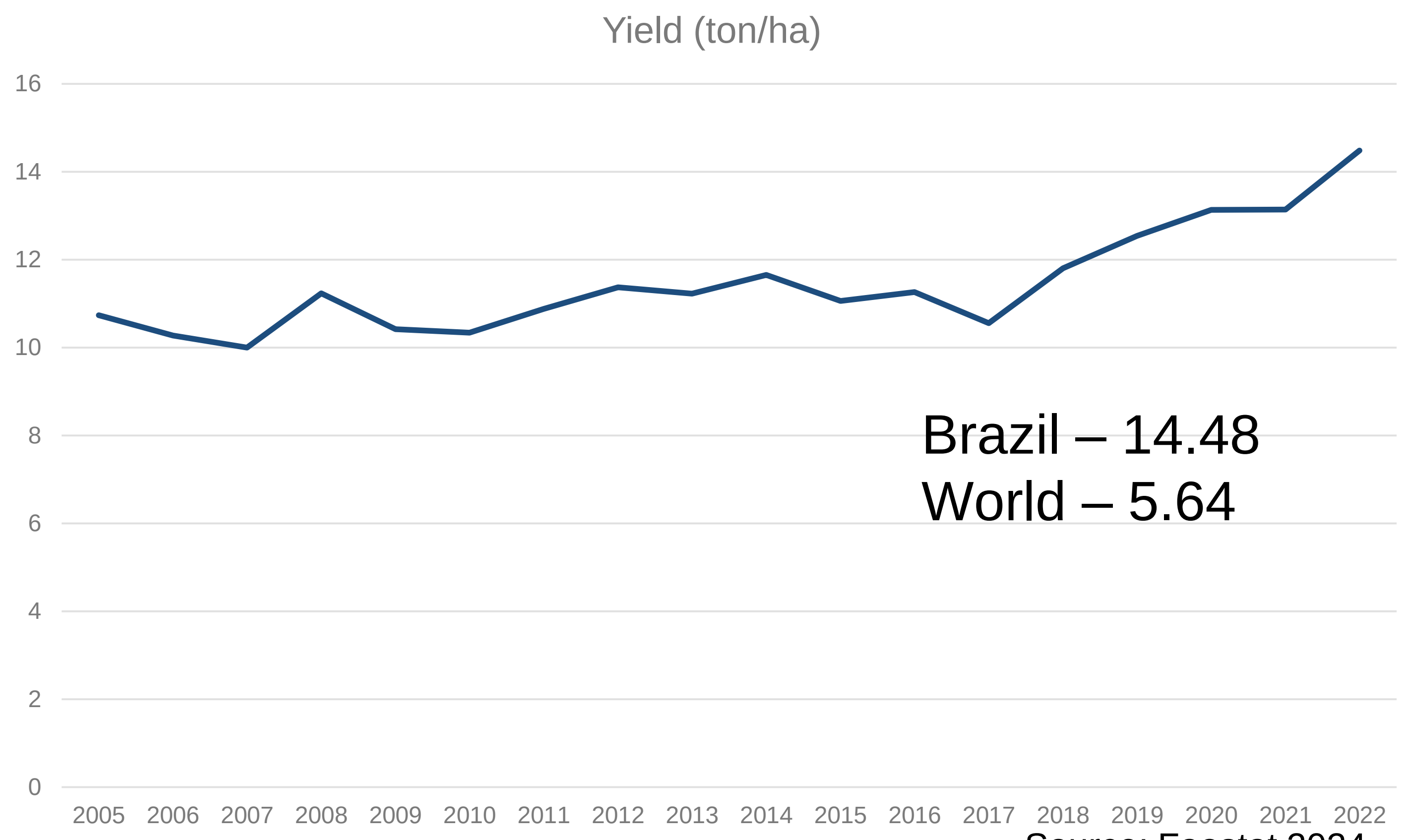
Reduction of cultivated area

Reduction in production

Increased productivity

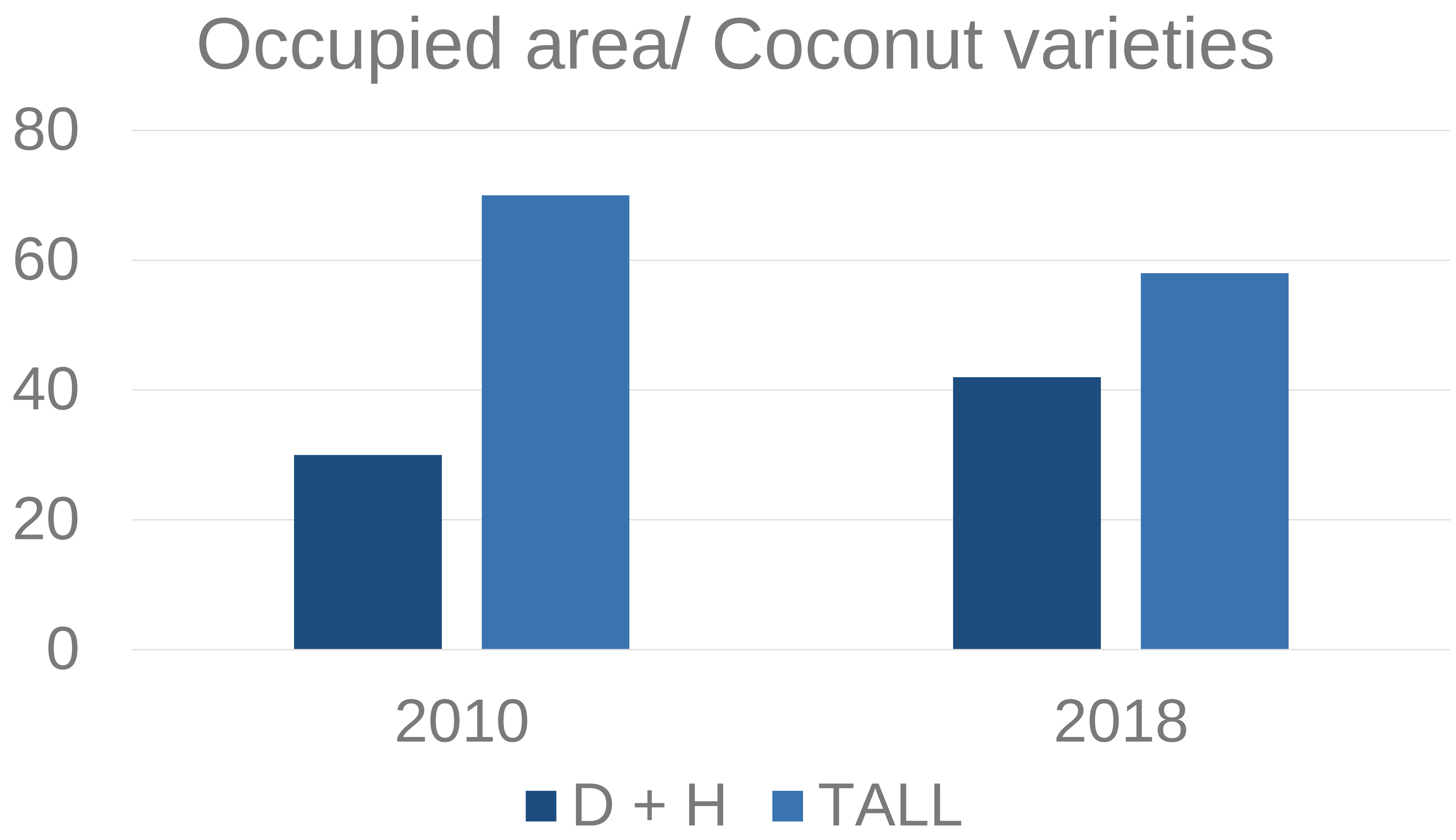






Source: Faostat 2024

Distribution of coconut plantations by varieties in Brazil



WANDERLEY & LOPES (2010); SINDCOCO (2018)

Dwarf + Hybrid 12% ↑

Tall 12% ↓

- Greater acceptance by the consumer market of fresh coconut
- The processing industry has also demonstrated a preference for more productive and adapted cultivars

ESTIMATE OF TOTAL NATIONAL CARBON SEQUESTRATED

The quantification of carbon stock in coconut plantations is complex due to variations in crop conditions and age of the plantations.

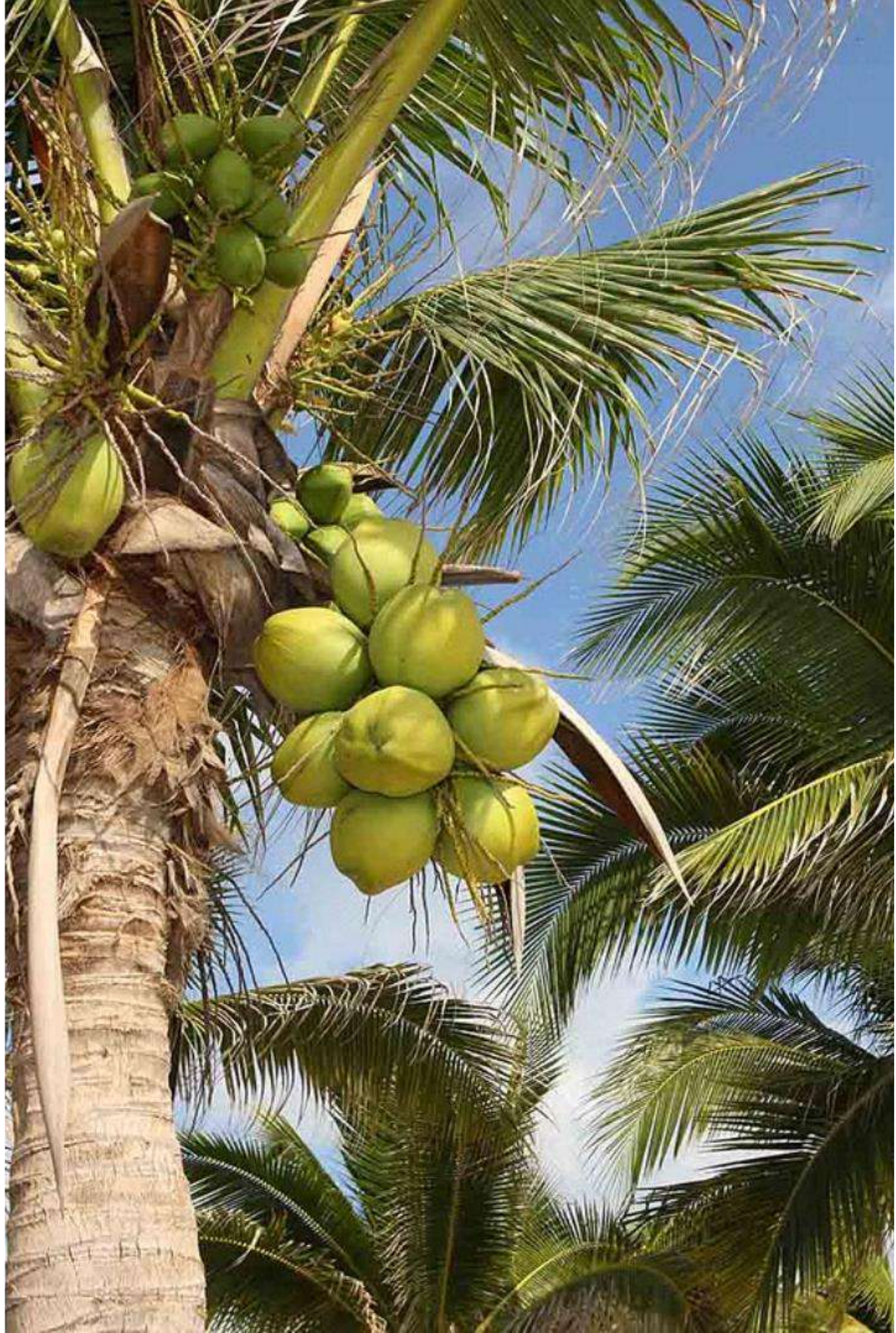
Recent studies estimate that coconut trees can remove between 22.0 and 36.7 tons of CO_2-eq per hectare/year, depending on the cultivation system adopted.

Irrigated dwarf coconut cultivation has a carbon sequestration potential of up to 28.6 tons of CO_2-eq per hectare/year.

CARBON SEQUESTRATION IN THE COCONUT TREE

Annual net assimilation of CO_2-eq ha^{-1} $year^{-1}$ (tons) in different plant organs and the total of irrigated green dwarf coconut trees, in a commercial production area		
Organ	CO_2-eq ha^{-1} $year^{-1}$	Partial Contribution (%)
Stem	2.0	7.1
Leaves	8.7	30.4
Fruits	17.5	61.1
Roots	0.4	1.4
Total	28.6	100.0

Adapted from Fernandes et.al.; 2022



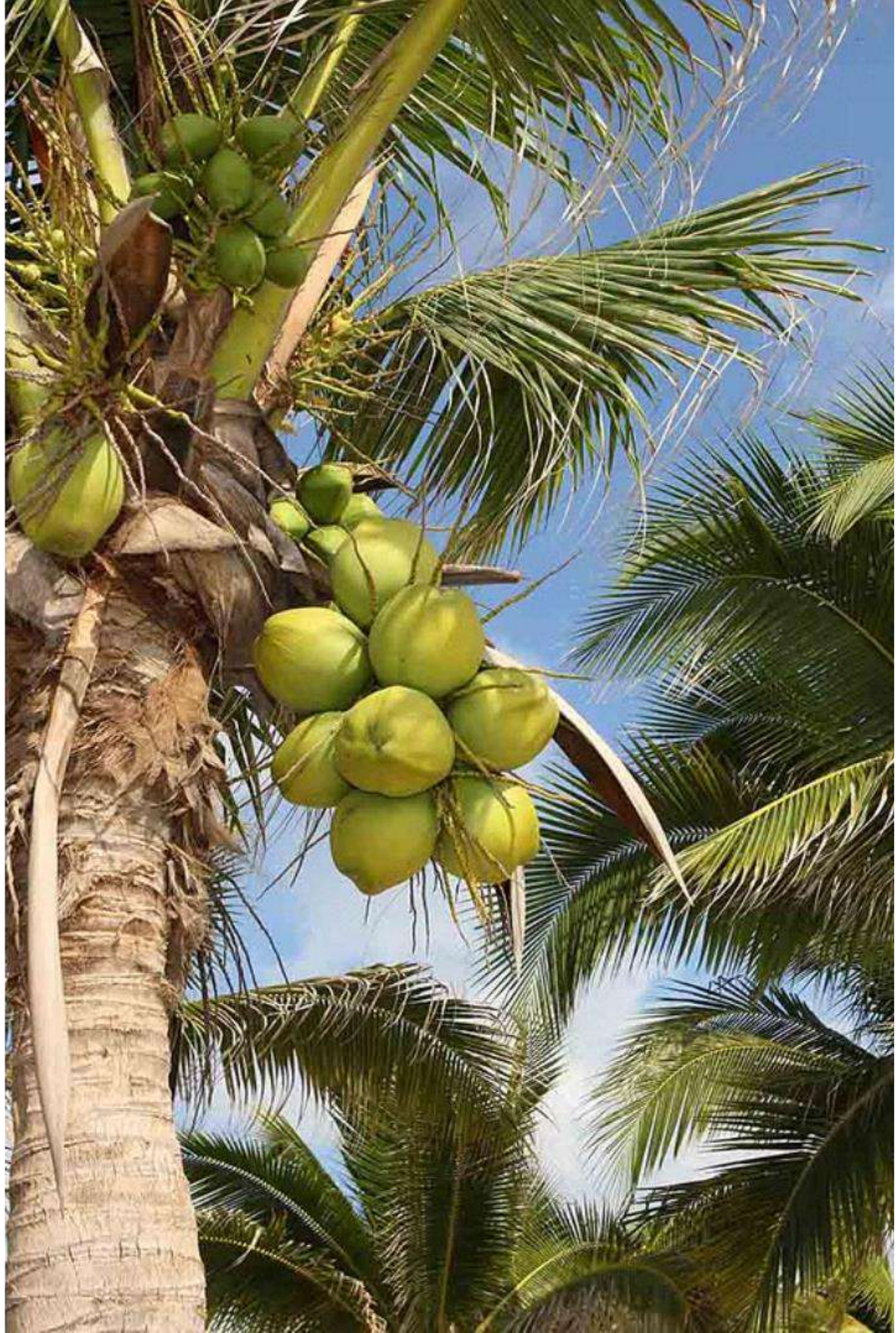
CARBON STOCK IN THE COCONUT TREE

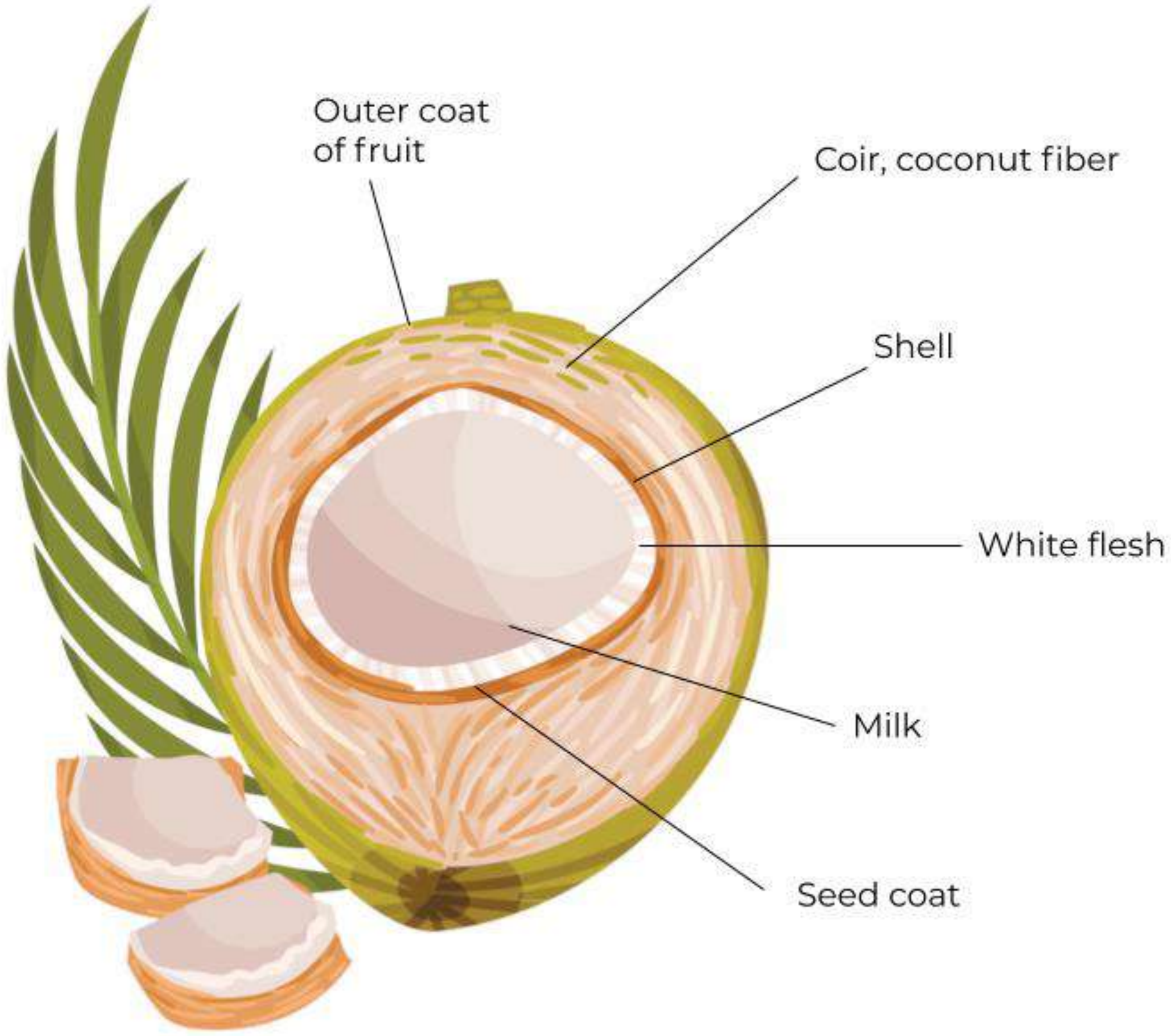
Determining the carbon stock of coconut trees in Brazil is complex due to variations in growing conditions, plantation age and other factors.

Quantification of C stocks (ton of CO_2-eq ha^{-1}) in live biomass and fruit and leaf residues per hectare of irrigated green dwarf coconut trees, aged 9 and 22 years

Component	Stem	Leaves	Fruits	Leaf Insertion	Roots	Total ton of CO_2-eq
9 years						
Live Biomass	20.0	14.9	4.4	6.4	9.1	54.9
Residues (in equilibrium condition)	-	5.5	31.4	-	-	36.9
Total	20.0	20.5	35.8	6.4	9.1	91.8
22 years						
Live Biomass	47.4	14.9	4.4	6.4	14.6	87.7
Residues (in equilibrium condition)	-	5.5	31.4	-	-	36.9
Total	47.4	20.5	35.8	6.4	14.6	124.6

Adapted from Fernandes et.al.; 2022

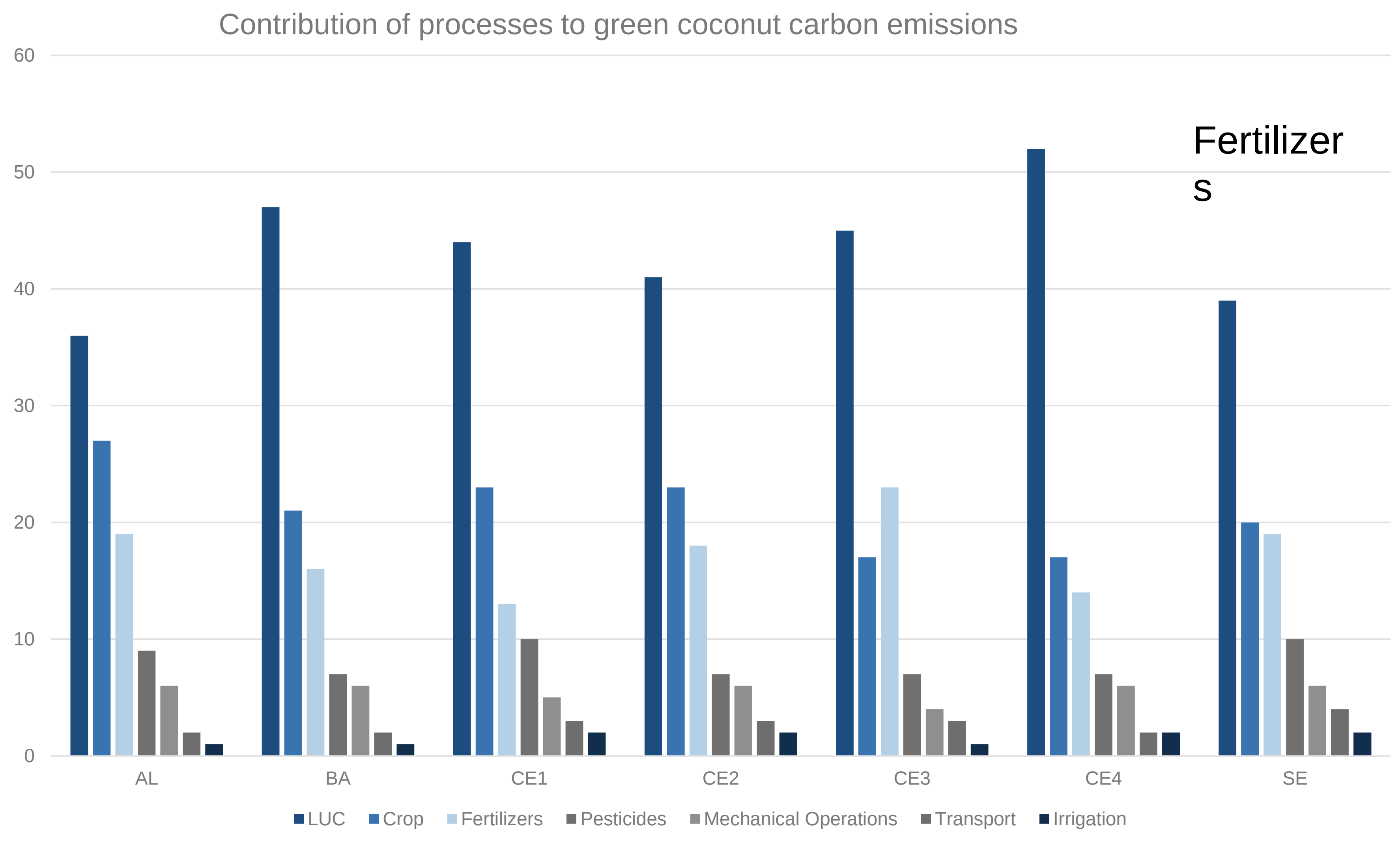


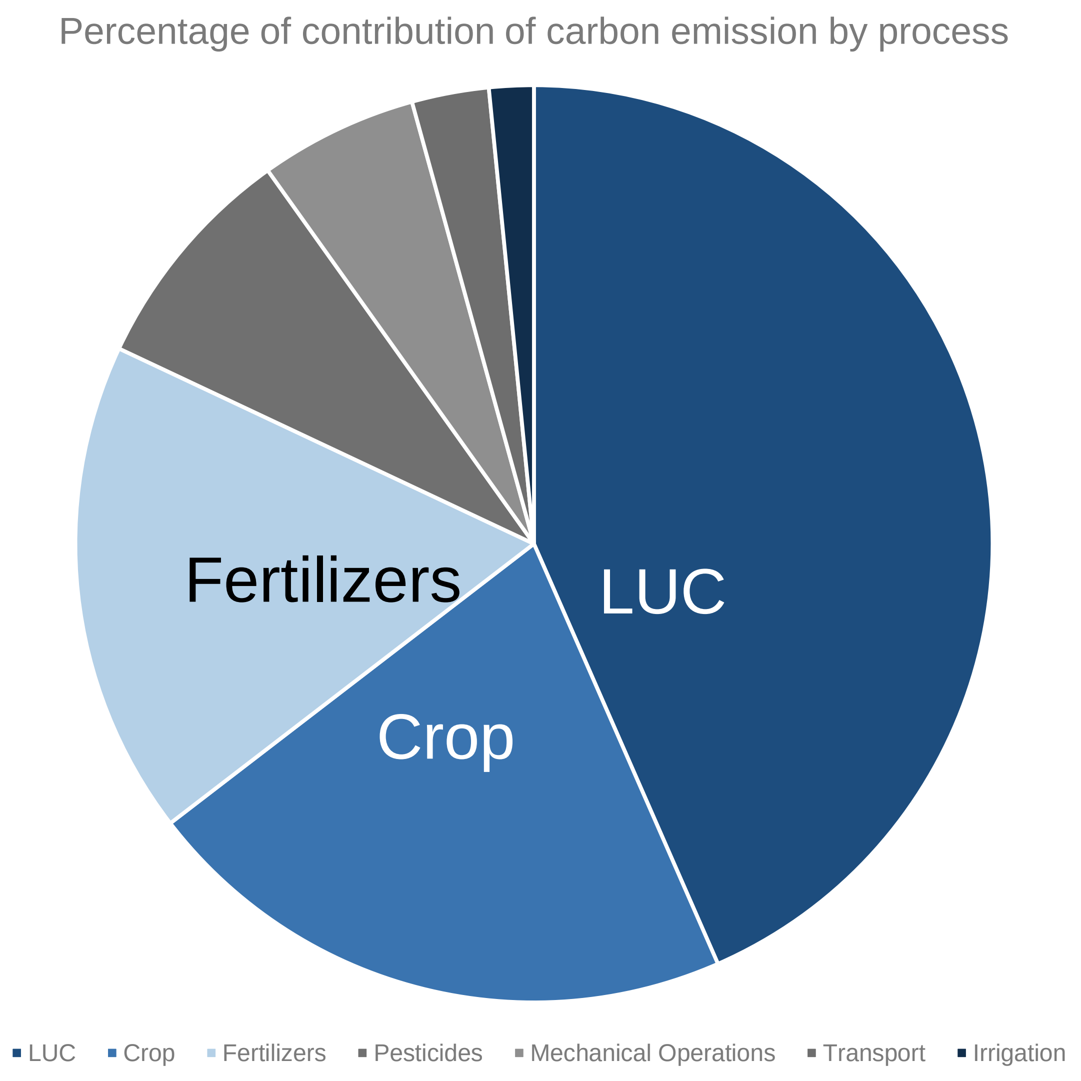

Outer coat
of fruit
Coir, coconut fiber
Shell
White flesh
Milk
Seed coat


COCO GRILL
100% NATURAL
CARVÃO
DE FIBRA DE COCO
3horas
ACESO


GOLDEN
mix
SUBSTRATO
PARA PLANTAS
FIBRA DE COCO
PARA USO AGRÍCOLA E FLORESTAL
GRUPO
SOCOCO
AMAFIBRA
CONTEÚDO 107 Litros

Analysis of Carbon Emissions Contributions in Green Coconut Farms





AL: 1.67 ton/ha CO_2-eq	CE3: 5.26 ton/ha CO_2-eq
BA: 2,69 ton/ha CO_2-eq	CE4: 2.36 ton/ha CO_2-eq
CE1: 1,93 ton/ha CO_2-eq	SE: 1.97 ton/ha CO_2-eq
CE2: 2.22 ton/ha CO_2-eq	

Source: Sampaio et al. 2021

Net Carbon Balance in Coconut Plantations by year

- PER HECTARE

Assimilation	Emissions	Net Carbon Balance
28,628 ton/ha CO_2 eq	1.67 ton/ha CO_2 eq 5.26 ton/ha CO_2 eq	26.94 ton/ha CO_2 eq 23.37 ton/ha CO_2 eq

- IN THE TOTAL AREA

Assimilation	Emissions	Net Carbon Balance
5,410,692 ton CO_2 eq	315,630 ton CO_2 eq 992,250 ton CO_2 eq	5,095,662 ton CO_2 eq 4,418,442 ton CO_2 eq

CONCLUSIONS

Annual Net Carbon Assimilation: 5.4 million tons of CO_2-eq/year. If revenue to US$ 10.00/t CO_2 eq., the Ambiental service value is US$ 54 bilhões/year!
This represents the net carbon sequestration in different plant organs of the coconut tree in commercial areas.

Potential at Historical Peak: 8.21 million tons of CO_2-eq/year. Revenue carbon credit in US$ 82.1 billion/year!

Integrated Systems: Adoption of ILPF (Integrated Crop-Livestock-Forest), ILP (Integrated Crop-Livestock), ILF (Integrated Livestock-Forest), and IPF (Integrated Production Systems) can increases soil carbon stock (can increase carbon sequestration from 0.5 to 1.5 tons of CO_2-eq per hectare per year.

Estimates from various studies indicate a positive net balance per hectare.
Demonstrates the effectiveness of green coconut cultivation in contributing to carbon sequestration and climate change mitigation.

Planting coconut trees is one of the cost effective and durable ways to overcome the current increase in atmospheric carbon dioxide. Due to its high productivity the coconut tree directs majority of its photosynthetic output towards its leaves, fruits, peduncle and fine roots. Most of these are perishable and are decomposed by microbes to convert them into soil organic matter. Coconut plantation could act like a tropical evergreen broad leaf forest, which has got high potential to sequester carbon. At the present system of coconut farming with better management strategies and with suitable intercropping the coconut plantations can be effectively considered as a potential C sequestration source to mitigate the climate change problems.

Thank you very much!

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