

Decisi^onES 2025

Symposium on
Ecosystem Services,
Forest Management and
Decision Making



Porto Seguro

Jun 30th to Jul 4th BR

The goal of restoration was
to create a copy of the
natural ecosystem

Restoration rarely achieves ecosystem reference levels

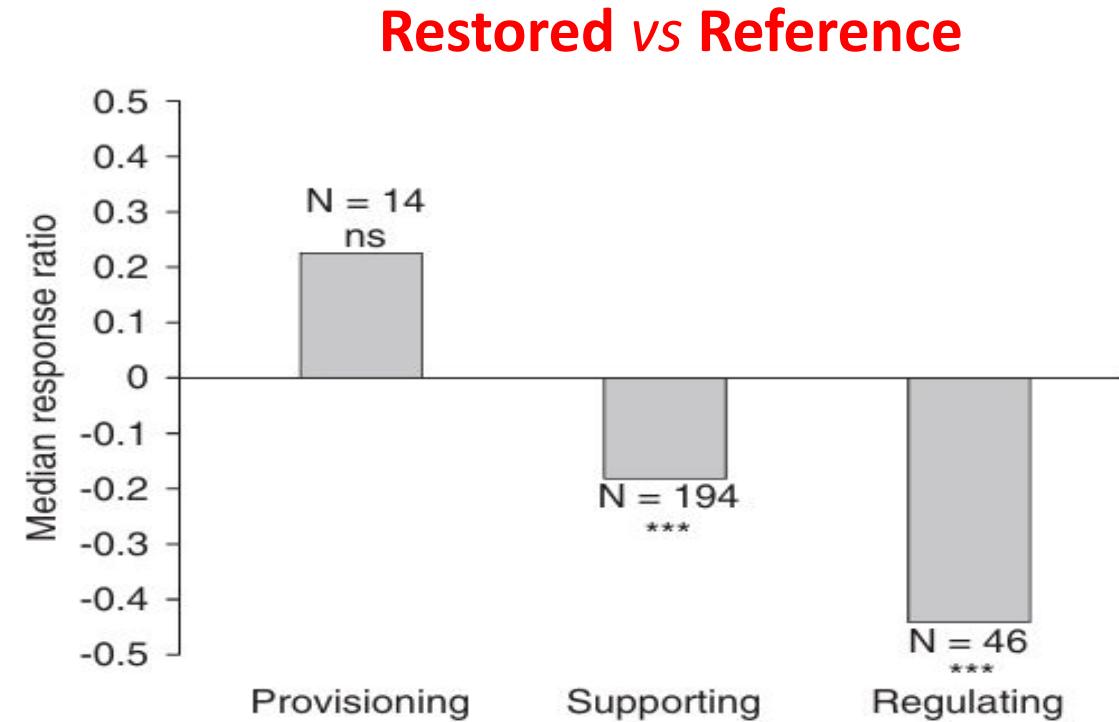
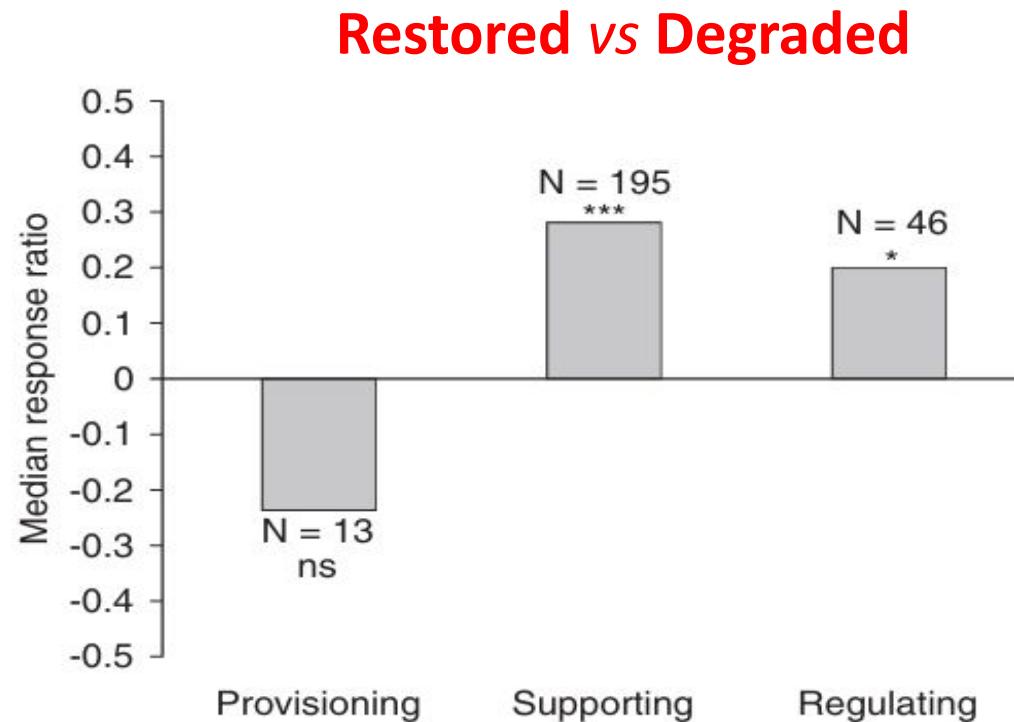


Figure. Response ratios of ecosystem services in restored ecosystems compared to degraded and reference ecosystems

Rey Benayas et. al 2009

Planting native trees in the Cerrado accelerates carbon stock in the biomass, but contribution to soil carbon is negligible

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Porto Seguro, Bahia
Julho, 2025



Legal framework and gap in savanna restoration

Native Vegetation Protection Law N°12.651/2012

Area located within a rural property, with the functions of:

- Assisting the conservation and rehabilitation of ecological processes,
- Ensuring the sustainable exploitation of natural resources,
- Promoting the conservation of biodiversity.

To the Cerrado:

- 35% (in the Legal Amazon) or
- 20% (in other regions of the country) of the property

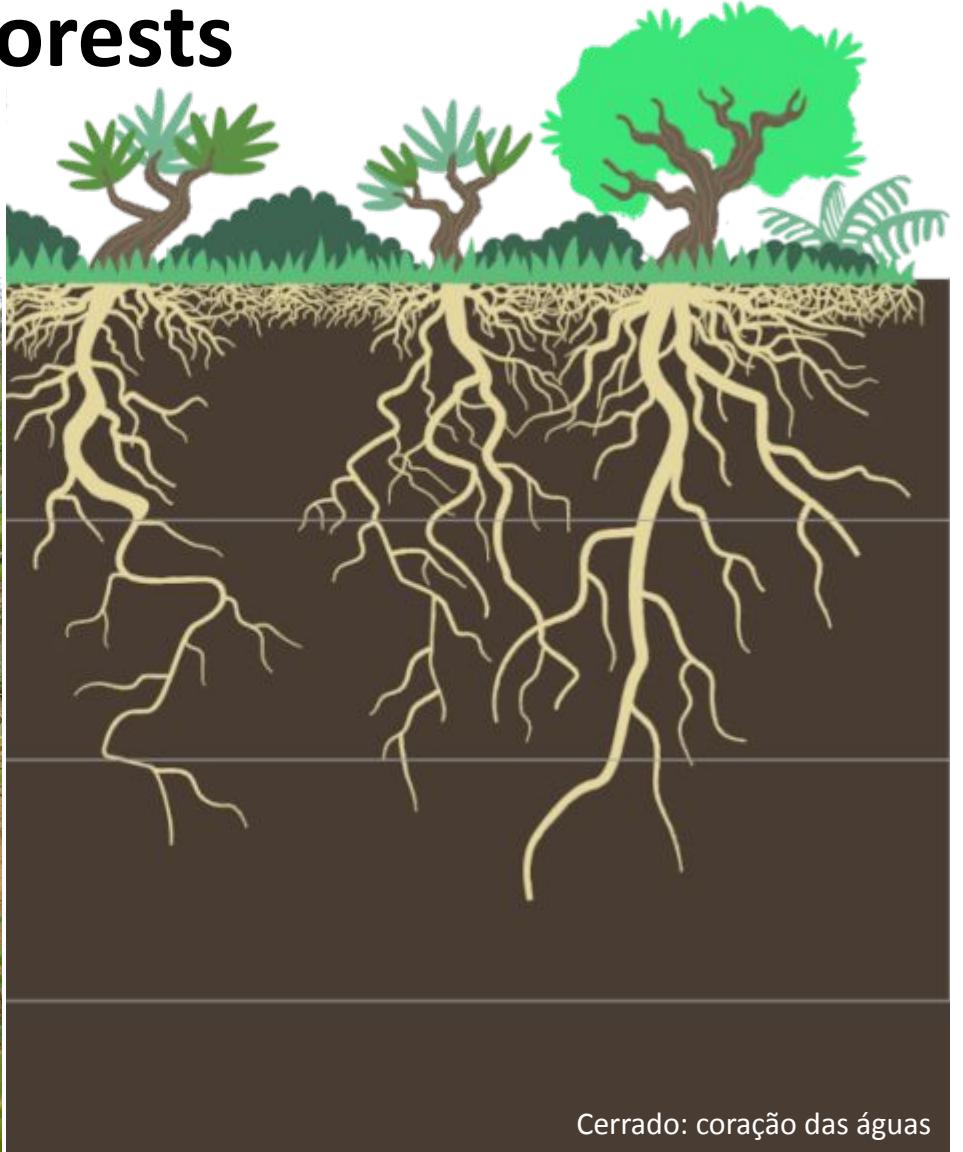
**Indicators of restoration success
come from forest ecosystems**

Typical forest indicators are commonly used in the restoration of the Cerrado (a savanna), for example:

Only the above-ground carbon stock without considering the below-ground carbon stock

Cerrado (savanna)

Fundamentally distinct from forests



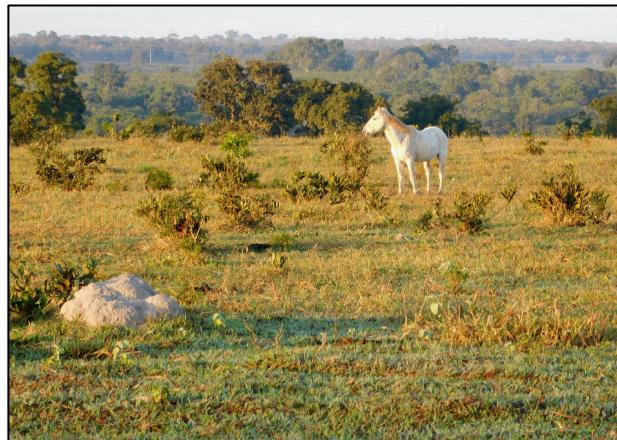
Cerrado: coração das águas

Cerrado restoration: resilience depends on land-use history

Silviculture



Pasture



**After these uses it
is possible to
restore the
structure and some
biodiversity**

=

**Restore the Carbon
levels of
pre-existing
vegetation**



Cerrado restoration: resilience varies according to land use history

Agriculture

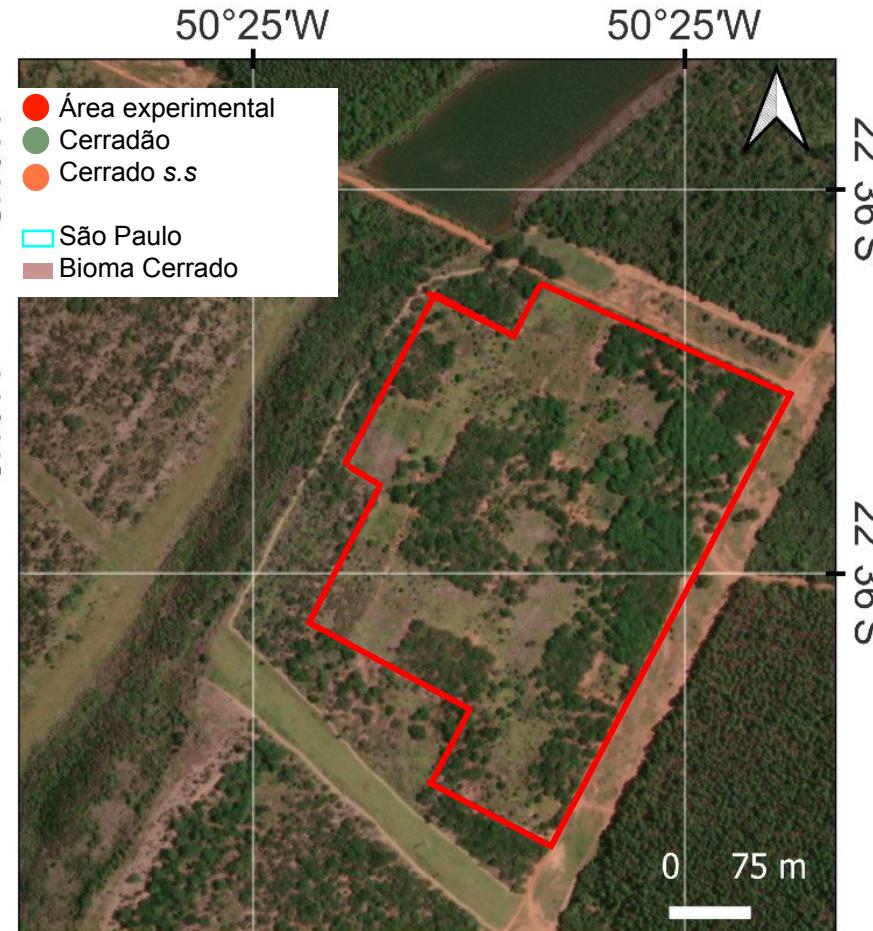
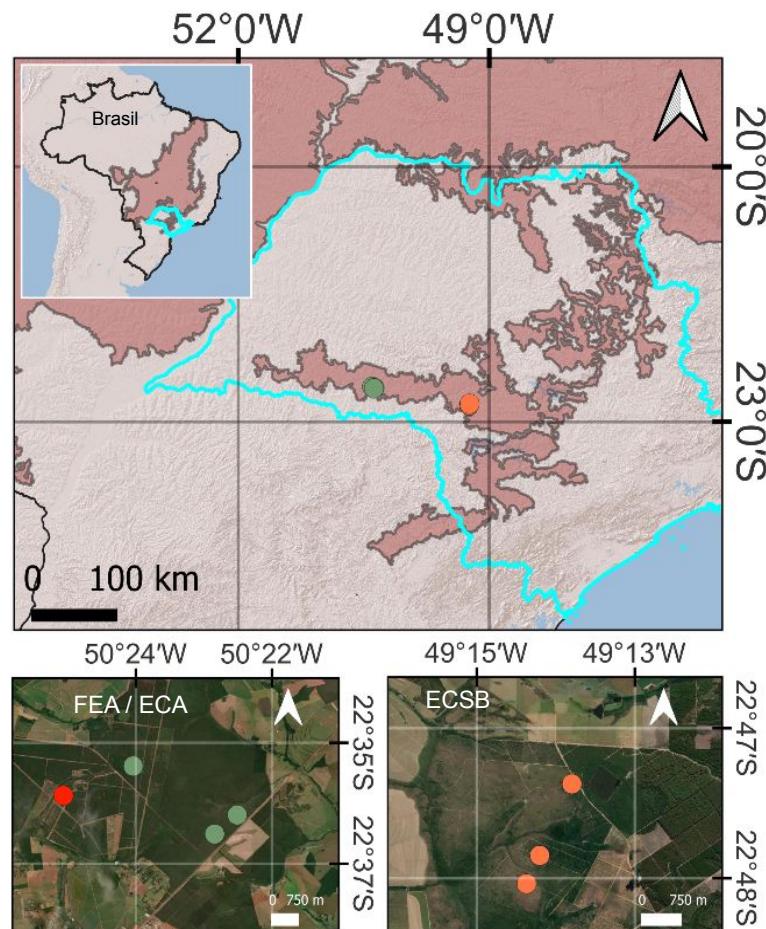


After this use, resilience is lost

Objective

Verify the effectiveness of seven restoration techniques on carbon stock in biomass (aerial and root) and soil

Study area - Assis State Forest (FEA), Assis - SP



**Experiment installed in
2015 - 17.5 ha**

History
**15 years of intensive
agriculture**

Original vegetation
Cerrado s.s

**7 treatments / 10
replicates arranged
randomly**
plots with 2.500 m^2

Restoration techniques were designed based on floristic and ecological knowledge of the regional Cerrado. They are:

Passive restoration (Control)



Taking advantage of
the **natural**
regeneration potential
of the Cerrado

Fruit Trees of the Cerrado



Native fruit species:

- araticum (*Annona crassiflora*)
- marolo (*Annona coriacea*)
- mangaba (*Hancornia speciosa*)
- pequi (*Caryocar brasiliense*)
- gabiroba (*Campomanesia adamantium*)

6.640 individuals
6m x 6m between trees
and 3 m x 1 m between
bushes

Nucleator trees



Species that help attract other plants. They have characteristics such as wide canopies:

- ingá (*Inga laurina*)
- jatobá (*Hymenaea stignocarpa*)
- mamona (*Mabea fistulifera*)
- massaranduba (*Pouteria ramiflora*)

623 individuals
with 5.5 m x 6.5 m
spacing

Conventional (available at nurseries)



Tree species available in nurseries:

- marolo (*Annona coriaceae*)
- massaranduba (*Pouteria ramiflora*)
- monjoleiro (*Senegalia polyphylla*)
- mulungu (*Erythrina mulungu*)
- murici (*Byrsonima sericea*)
- olho-de-cabra (*Ormosia arborea*)
- osso-de-burro (*Helietta apiculata*)
- jacaranda (*Machaerium aculeatum*)
- peito-de-pombo (*Tapirira guianensis*)
- pequi (*Caryocar brasiliense*)
- pindaíva (*Duguetia lanceolata*)

**4.000 individuals
with 3 m x 2 m spacing**

Generalists



Species that occur in the Cerrado and the regional Atlantic Forest:

- açoita-cavalo (*Luehea grandiflora*)
- almecegueira (*Protium heptaphyllum*)
- amaralinho (*Terminalia brasiliensis*)
- amendoim (*Platypodium elegans*)
- angico-vermelho (*Anadenanthera macrocarpa*)
- canela (*Ocotea corymbosa*)
- copaíba (*Copaifera langsdorffii*)
- dendaleiro (*Lafoensia pacari*)
- embaúba (*Cecropia pachystachya*)
- caqui (*Diospyros inconstans*)

2.489 individuals
with 3 m x 3 m spacing

Cerrado Specialists



Species that occur only in the Cerrado:

- angico (*Anadenanthera falcata*)
- carvalho (*Roupala brasiliensis*)
- lobeira (*Solanum lycocarpum*)
- gabiroba (*Campomanesia adamantium*)
- Ingá (*Inga laurina*)

2.489 individuals
with 3 m x 3 m spacing

Tachigali vulgaris



A native legume species,
fast-growing.

2.489 seedlings
with 3 m x 3 m spacing

Regional reference ecosystems

Cerrado *sensu stricto*



Historical vegetation,
a savanna

Cerradão



Vegetation after fire suppression,
a forest

Data collection - C stock in biomass

50x50m (border)

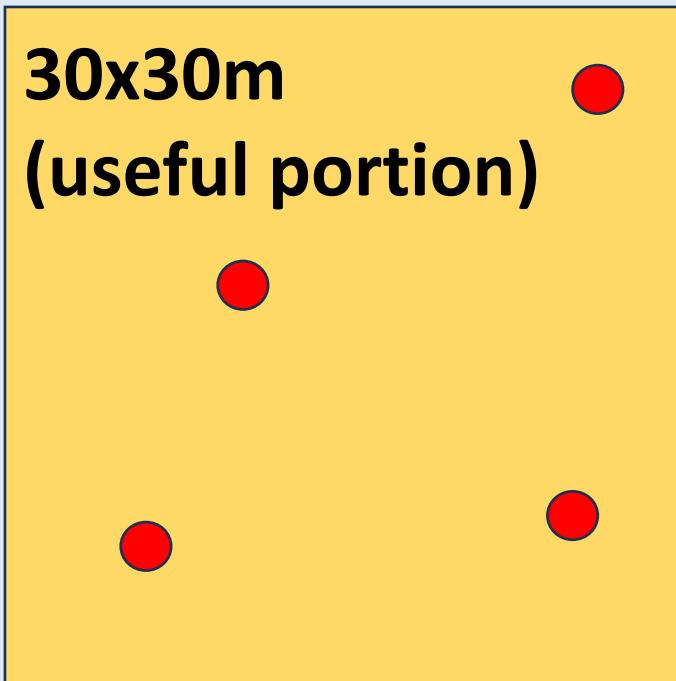
**30x30m
(useful portion)**

- i) We measured all individuals with DBH \geq 5cm
- ii) We estimated the biomass per plot using an allometric equation that includes root and aerial part biomass (Pinheiro, 2008)
- iii) We estimated the carbon stock using the conversion factor of 0.5 kg C of biomass (Mg/ha)

Data collection - Soil C stock

50x50m (border)

**30x30m
(useful portion)**



- i) We collected composite samples down to 1 meter, in five layers (at depths 0–20, 20–40, 40–60, 60–80 and 80–100 cm)
- ii) Soil was analyzed in the lab
- iii) Carbon stock was estimated using the Ellert and Bettany (1995) equation

Data analysis

Carbon stock in biomass and soil

We used a generalized linear model, followed by Tukey's test, to compare treatments. We then compared them graphically with the values of reference ecosystems.

Results and discussion- C stock in biomass

Assessment at age nine

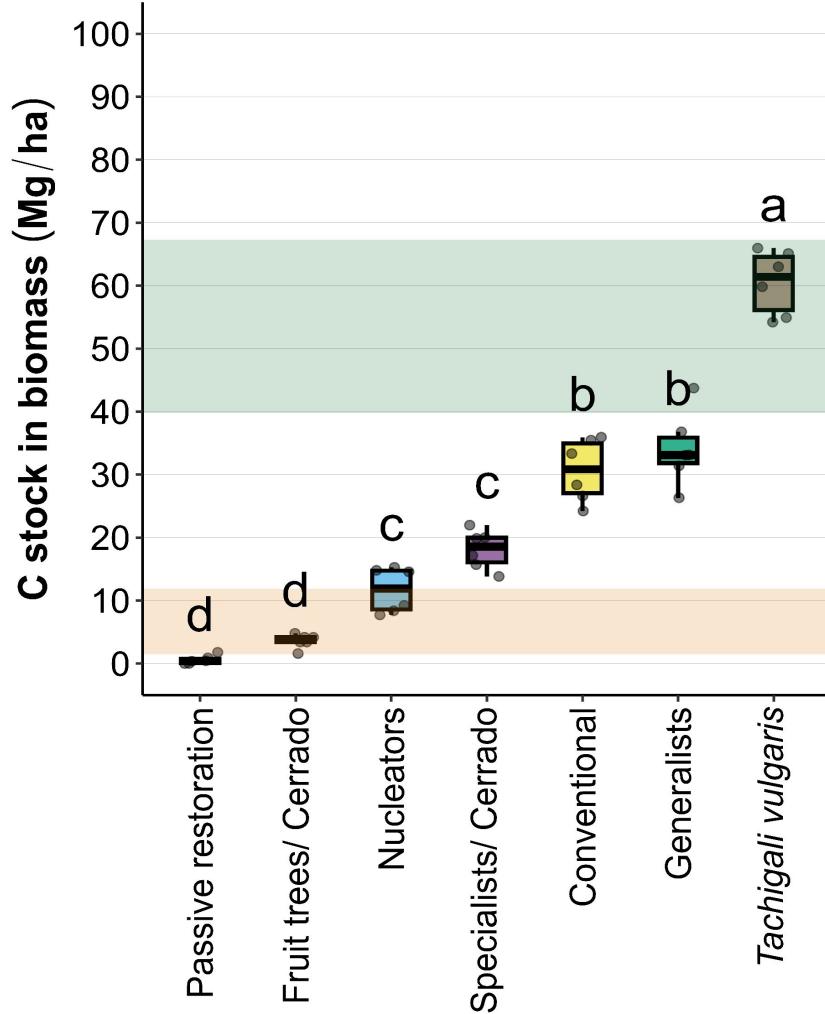
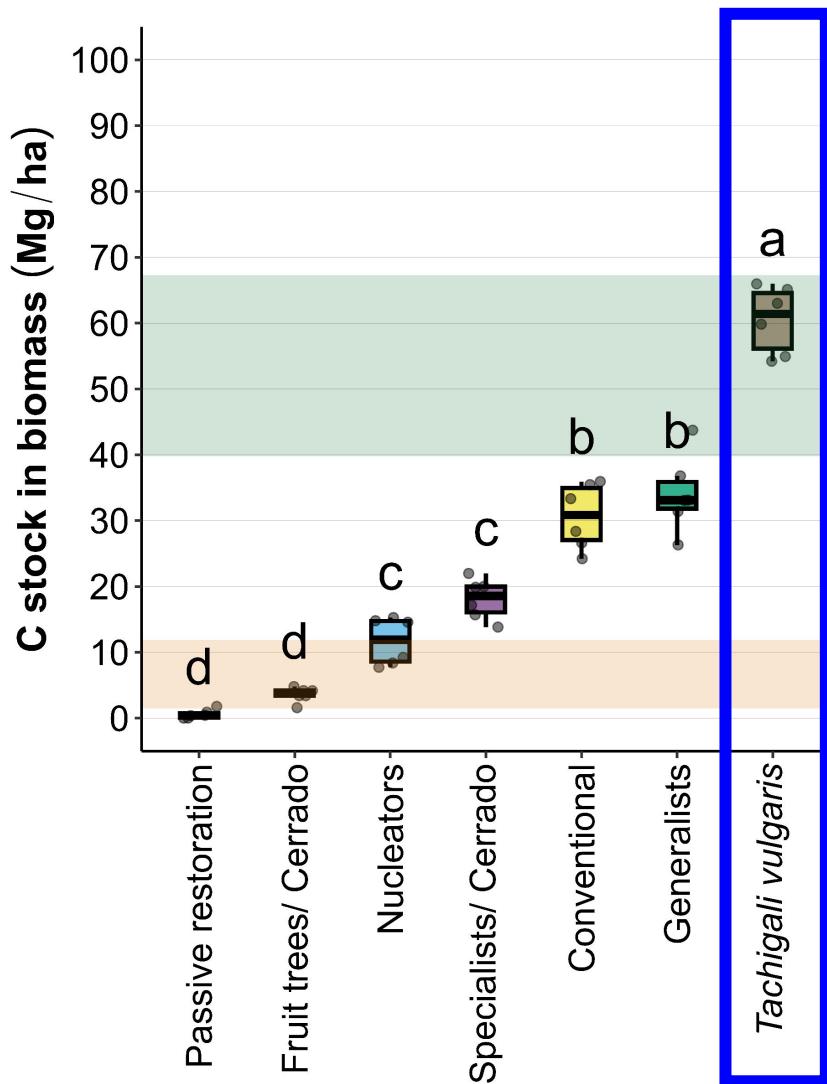


Figure. Comparison of carbon stocks (Mg/ha) in living biomass (shoots and roots) between treatments. The orange and green bands indicate, respectively, the C stocks of the cerrado s.s and cerradão (reference ecosystems). Different letters indicate a significant difference ($p<0.05$) between treatments. The box plot is limited by the first and third quartiles, the horizontal line is the median and the vertical line represents the dispersion of the data. The points are outliers.

Results and discussion- C stock in biomass



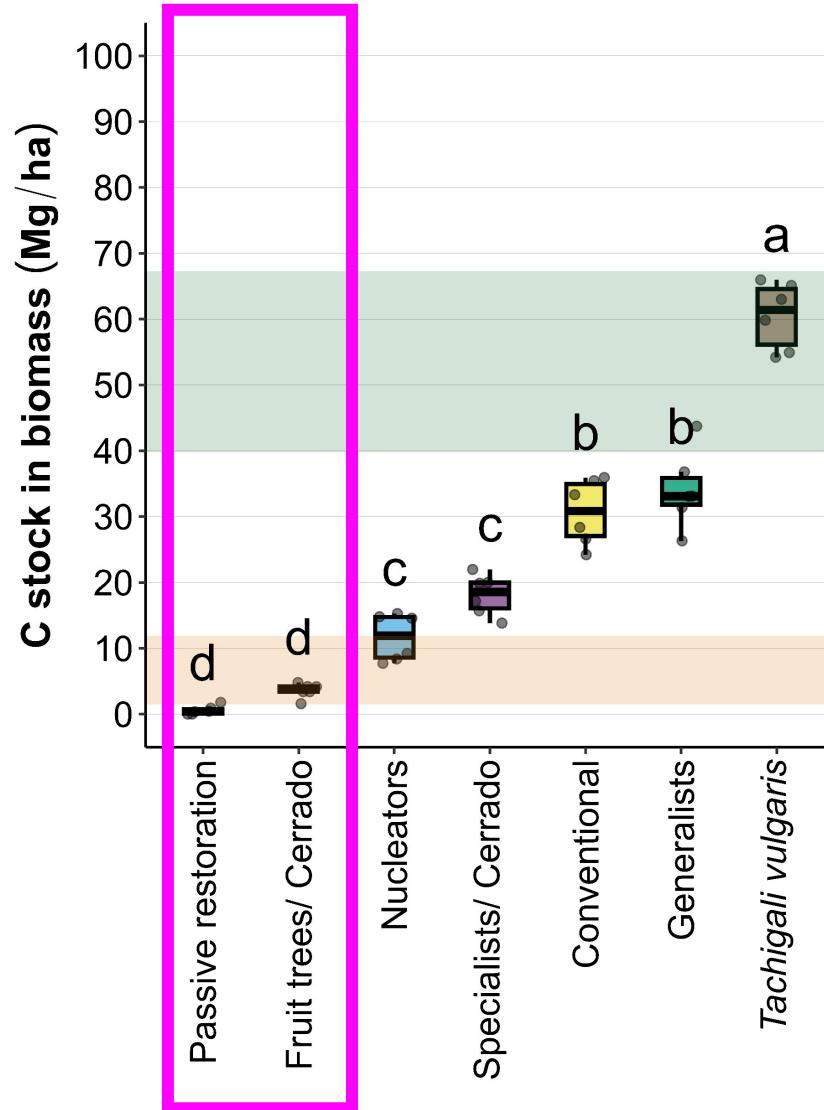
Largest Carbon Stock



Planting of *Tachigali vulgaris*

Figure. Comparison of carbon stocks (Mg/ha) in living biomass (shoots and roots) between treatments. The orange and green bands indicate, respectively, the C stocks of the cerrado s.s and cerradão (reference ecosystems). Different letters indicate a significant difference ($p<0.05$) between treatments. The box plot is limited by the first and third quartiles, the horizontal line is the median and the vertical line represents the dispersion of the data. The points are outliers.

Results and discussion- C stock in biomass



Lower Carbon Stock - - Structurally Open



Control
(Passive restoration)



Fruit trees of the Cerrado

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Results and discussion- C stock in biomass

In low-resilience areas, if the goal is rapid carbon sequestration, we recommend dense planting with fast-growing native species.

Passive restoration has been very slow, confirming the legacy of agriculture.

Results and discussion- Soil C stock

Assessment at age nine

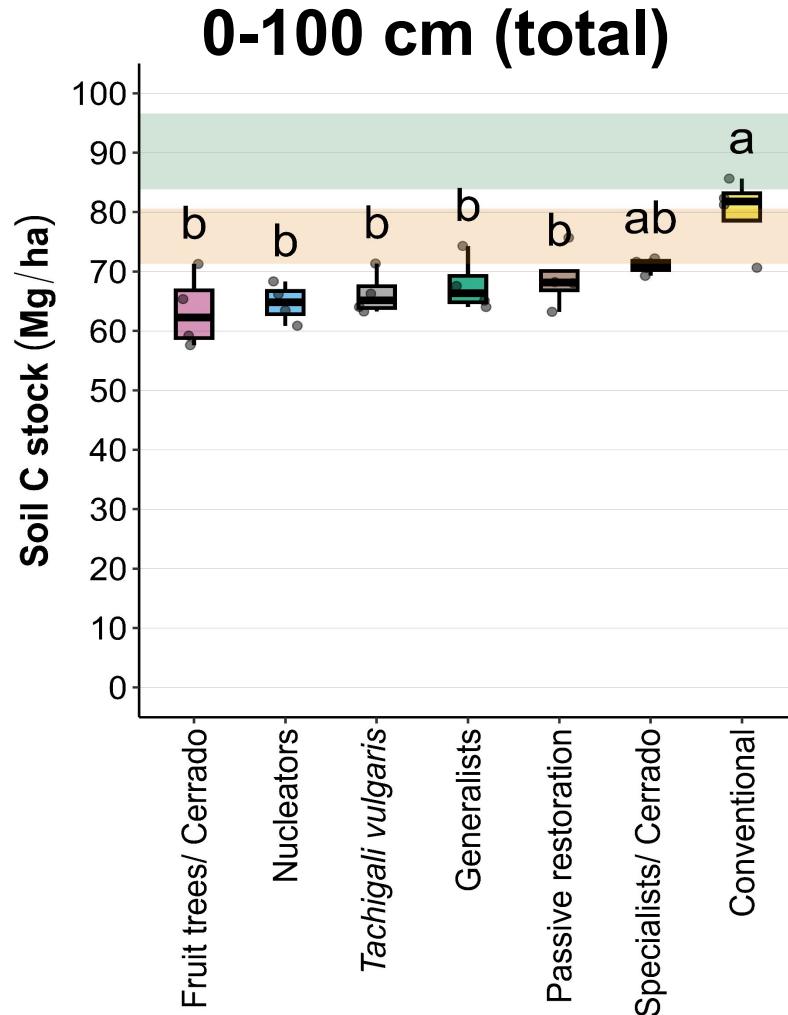
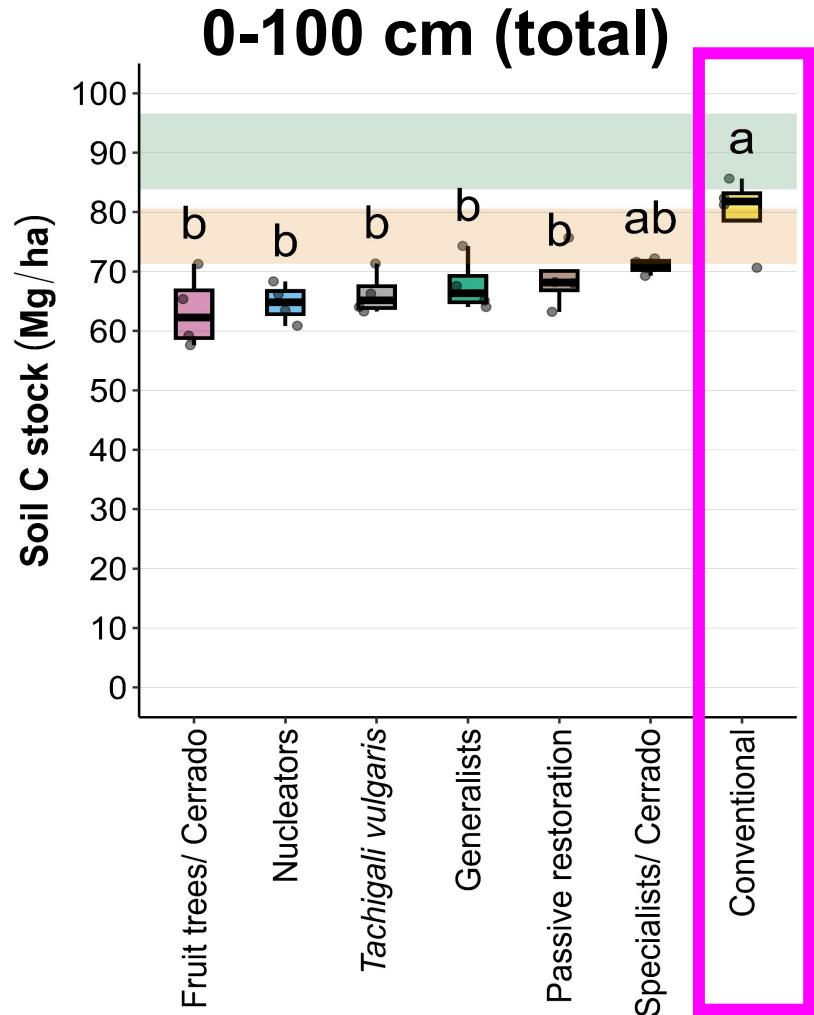


Figure. Comparison of carbon stocks (Mg/ha) at depths of 0-100 cm (total: sum of all depths) between treatments. The orange and green bands indicate, respectively, the C stocks of the cerrado s.s and cerradão (reference ecosystems). Different letters indicate a significant difference ($p<0.05$) between treatments. The box-plot box is limited by the first and third quartiles, the horizontal line is the median and the vertical line represents the dispersion of the data. The points are outliers.

Results and discussion- Soil C stock

Assessment at age nine

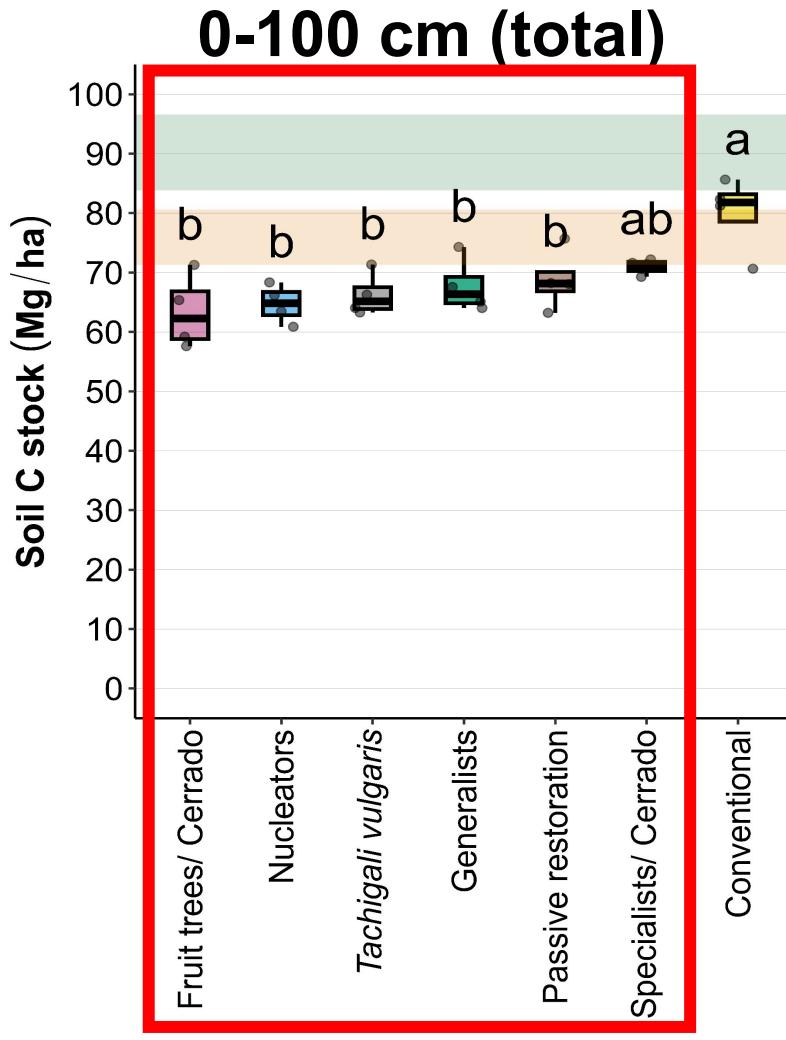


Conventional
(available in nurseries)

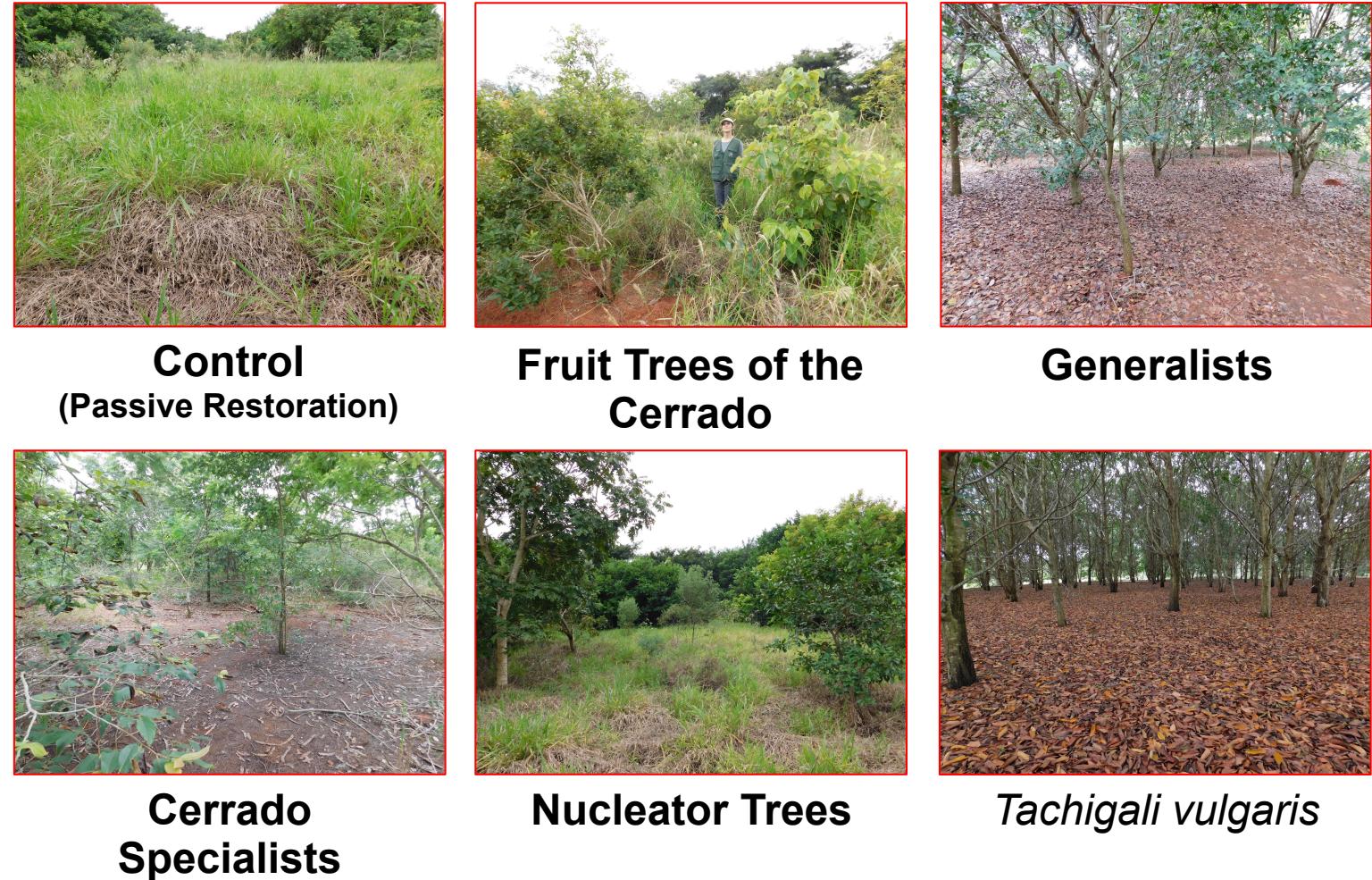
**Planting
at higher
density**

Figure. Comparison of carbon stocks (Mg/ha) at depths of 0-100 cm (total: sum of all depths) between treatments. The orange and green bands indicate, respectively, the C stocks of the cerrado s.s and cerradão (reference ecosystems). Different letters indicate a significant difference ($p<0.05$) between treatments. The box-plot box is limited by the first and third quartiles, the horizontal line is the median and the vertical line represents the dispersion of the data. The points are outliers.

Results and discussion- Soil C stock



These restaurant techniques don't care about soil carbon stock



Results and discussion- Soil C stock

Assessment at age nine

Over the typical 20-year timeframe of carbon projects, we should not expect large soil carbon gains from forest plantations in low-resilience areas of the Cerrado.

Conclusion

Planting native trees in the Cerrado accelerates carbon stock in biomass, but contribution to soil carbon is insignificant.

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Restore forests where forests once stood!

Restore savannas where savannas once stood!

**Restore grasslands where grasslands once
stood!**

Acknowledgements



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Planting native trees in the Cerrado accelerates carbon stock in the biomass, but contribution to soil carbon is negligible

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Thank you!

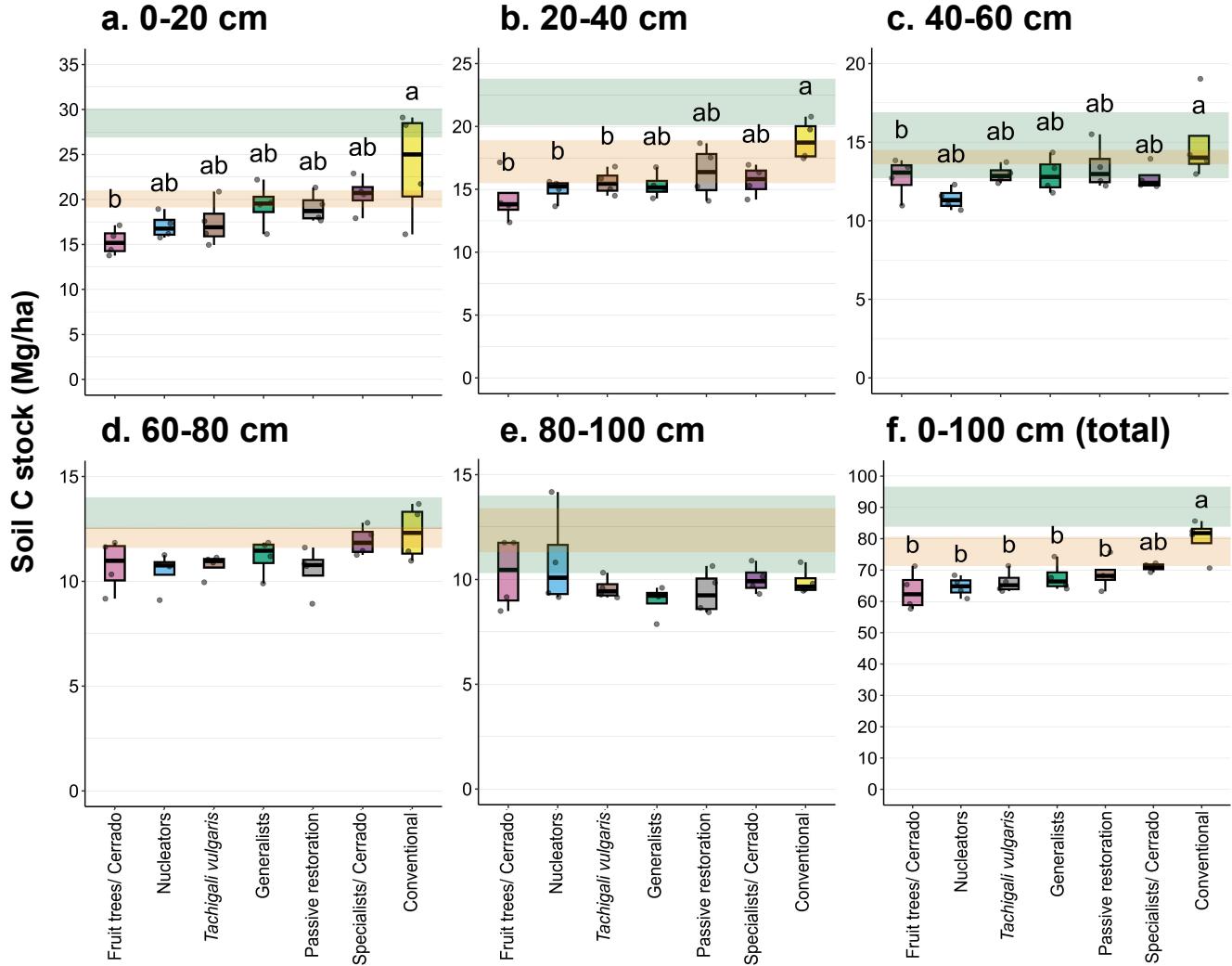
mvbx293@gmail.com

Laboratory

<https://labecologiahidrologia.weebly.com/>



Results and discussion- Soil C stock



Planting at
higher
density

Conventional
(available in nurseries)

Figure. Comparison of carbon stocks (Mg/ha) at depths of (a) 0-20 cm, (b) 20-40 cm, (c) 40-60 cm, (d) 60-80 cm, (e) 80-100 and (f) 0-100 cm (total: sum of all depths) between treatments. The orange and green bands indicate, respectively, the C stocks of the cerrado s.s and cerradão (reference ecosystems). Different letters indicate a significant difference ($p<0.05$) between treatments. The box-plot box is limited by the first and third quartiles, the horizontal line is the median and the vertical line represents the dispersion of the data. The points are outliers.

Seven Cerrado restoration techniques



Control
(Passive Restoration)



Conventional
(available at nurseries)



**Fruit Trees of the
Cerrado**



Generalists



Cerrado Specialists



Nucleator Trees



Tachigali vulgaris