

# Decision tools to combine plant ecophysiology with practitioners' knowledge for multifunctional intercropping

*Visiting Research in Theme Trees at CIFOR-ICRAF*



**ICRAF**  
**Tree**  
**Theme**

**ILYAS SIDDIQUE**, Roeland Kindt, Lars Graudal,  
Ramni Jamnadass, John Innocent, Renata R. Lucas

- Applied Ecology Lab, Graduate Programs in Agroecosystems & Plant Genetic Resources, Federal University of Santa Catarina
- Agroecological Agroforestry Network of Southern Brazil
- Brazilian Association of Agroecology
- World Agroforestry CIFOR-ICRAF, Kenya
- University of Copenhagen, Denmark

**ILYSID@GMAIL.COM**    **@LEAPUFSC**  
**LEAP.UFSC.BR/ILYAS-EN**



## Produce:

- Diversity of foods, medicines, fodder, timber, fuel, green manure
- With minimal external inputs &

## Restore:

- Soil health,
- Biodiversity native to ecoregion, esp. threatened species,

**...at same time in same space,**

**...without spending long time**

**researching & planning.**



Sítio Flor de Ouro,  
Florianópolis, Brazil

## CHALLENGE:



[Introduction](#)[Select country](#)[Filter uses](#)[Filter climates](#)[Show species](#)[Summary tables](#)[Matching data](#)

## Select a country

The native distribution of tree species was obtained from GlobalTreeSearch on 8th May 2022. Note that the GlobalTreeSearch is being updated on a continuous basis (hence ideally you would verify online with this database) and also that this database provides a full list of tree species (not only the subset of useful species shown here).

Countries were assigned to continents and subcontinents based on the second edition of the World Geographical Scheme for recording Plant Distributions ( Brummit 2001 ). See the 'Methods' section for the few modifications we introduced to this scheme.

Where Plants of the World Online (POWO; Accessed October 2022 ) provided native distributions at a subnational level, it is possible to select a subset of species native to this subnational level.

Select a continent

Africa

Select a subcontinent

East Tropical Africa

Select a country

Kenya

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## Filter climate

Options provided below allow filtering species via the Tree Globally Observed Environmental Ranges (TreeGOER) database. See the TreeGOER manuscript or the metadata file from the [Zenodo archive](#) for details. Note that TreeGOER documents environmental ranges for 13,000 of the 14,000+ species available in GlobUNT.

### Bioclimatic zone of the planting site

You can filter species by global bioclimatic zones developed for the TreeGOER database. One method to obtain the CMI and Tmo10 zone of a selected planting site is via the [TreeGOER Global Zones atlas](#). Another method is to check the global [CitiesGOER database](#) that documents environmental ranges for 52,602 cities.

Select a CMI zone (TreeGOER database)

CMI.D (-0.5 ≤ CMI < -0.35; dry sub-humid)

Select a Tmo10 zone (TreeGOER database)

Tmo10.A (Tmo10 = 12; 'tropical')

You can also further filter species by the Climate zones as documented by the [World Checklist of Vascular Plants \(WCVP\)](#) (data were obtained from [WCVP version 10](#)). The same climate zone information is available from the [Plants of the World Online \(POWO\)](#).

Select the climate (WCVP/POWO: main biome)

(all)

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Metho



## Bioclimatic conditions at the planting site

If the user provides any of the bioclimatic conditions (these could correspond to future climates) at the planting site, a climate score will be calculated and shown for each species.

- Score = 3 means that in 'environmental space' the planting site occurs within the 25% - 75% species's range (as documented in the TreeGOER ) for all variables
- Score = 2 corresponds to the 5% - 95% species's range for all variables
- Score = 1 corresponds to the 0% - 100% species's range for all variables
- Score = 0 means that the planting site occurs outside the 0% - 100% species's range for some of the variables
- Score = -1 means that the species is not documented by TreeGOER

This scoring system corresponds to the BIOCLIM algorithm and was further inspired by a scoring and colouring system implemented in the BGCI Climate Assessment Tool (CAT) . (Note also that the downloaded file from the 'Show species' TAB can be directly loaded into the CAT, for example to compare results.)

One method to obtain baseline and future conditions at the planting site is via the global [CitiesGOER database](#) that documents environmental ranges for 52,602 cities.

BIO01 (mean annual temperature, degrees C)



BIO12 (total annual precipitation, mm)



## Key climatic variables:

- mean annual °C
- total precipitation
- Climatic Moisture Index
- months >10°C
- Growing Degree Days 5
- max. °C warmest mth
- min. °C coldest mth
- precip. wettest quarter
- precip. driest quarter
- mm max.climat.water deficit

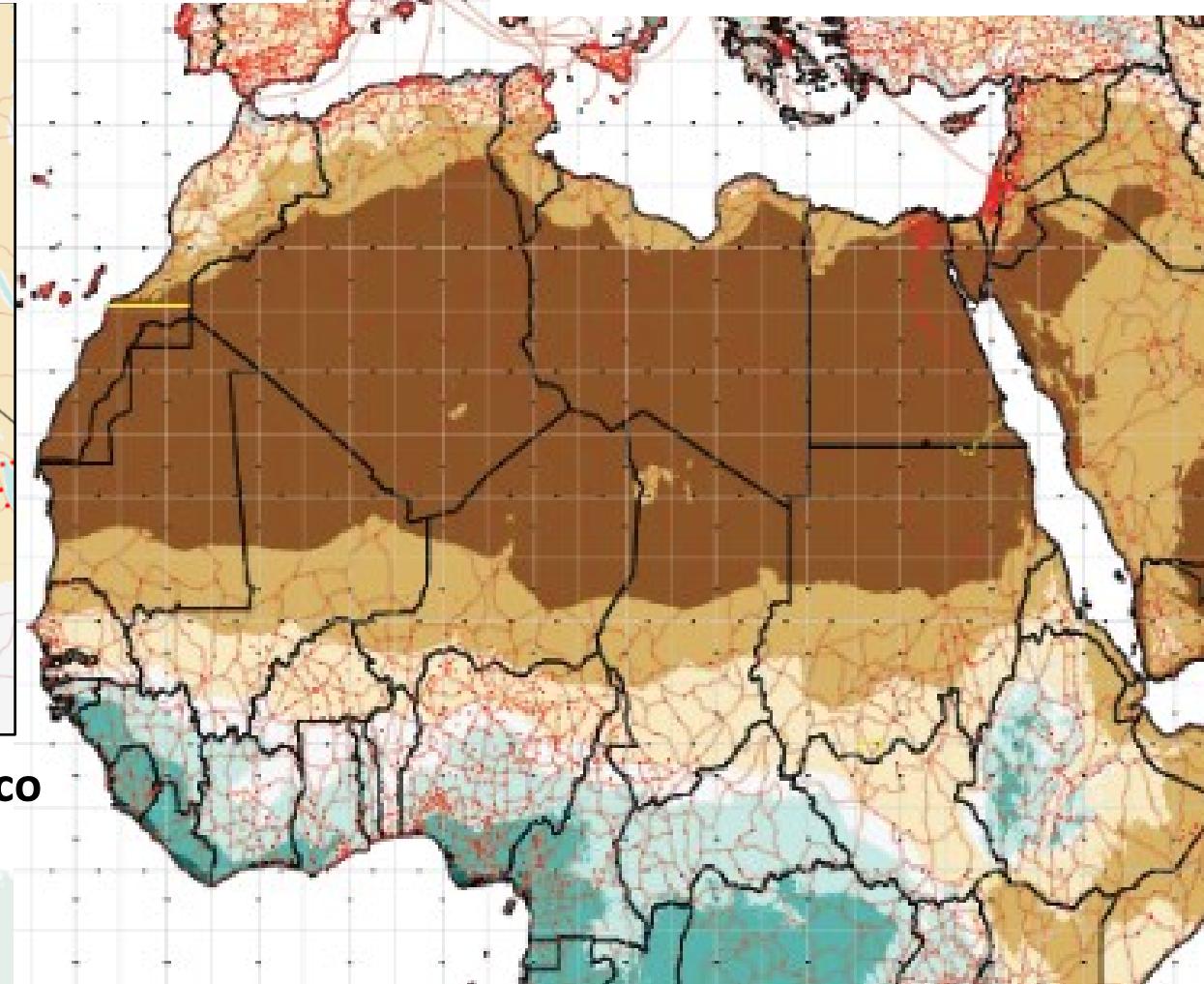
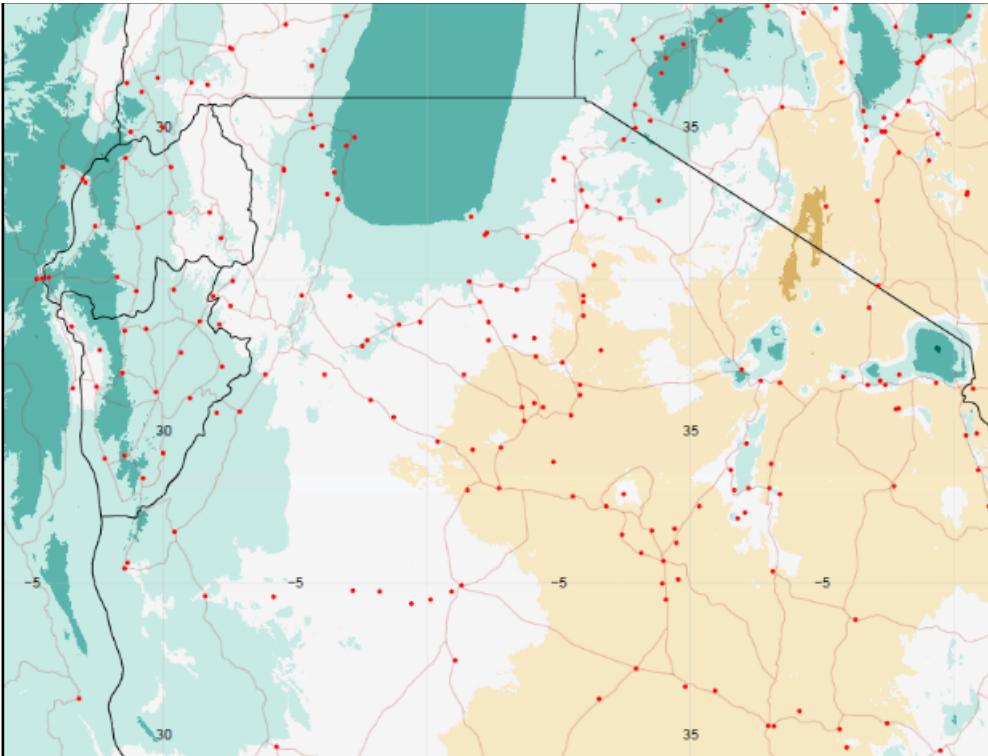
# Globally Observed Environmental Databases + Atlas

TreeGOER: 48,129 tree spp & 51 variables <https://zenodo.org/record/8411069>

CitiesGOER: 52,602 Cities with Pop  $\geq$  5000 <https://zenodo.org/record/8318468>



- ... (dark brown)
- arid (light orange)
- semi-arid (light green)
- dry sub-humid (medium green)
- humid (teal)
- per-humid (dark teal)
- ... (dark teal)



+Camadas opcionais: Months  $> 10^{\circ}\text{C}$ , Máx. déficit climático de água, 8 propriedades químicas e físicas do solo



[www.worldagroforestry.org/tree-knowledge](http://www.worldagroforestry.org/tree-knowledge)



Resilient Landscapes

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## Select uses

By checking these boxes, species will be shortlisted that were documented in the World Checklist of Useful Plant Species to provide that particular use. The last category corresponds to a list of 830 tree species prioritized for planting in the tropics and subtropics.

Selecting several boxes will result in species being filtered for each of the selected categories.

- Animal Food (AF)
- Environmental Uses (EU)
- Fuel (FU)
- Gene Sources (GS)
- Human Food (HF)
- Invertebrate Food (IF)
- Materials, excluding fuels (MA)
- Human and veterinary Medicines (ME)
- Poisons (PO)
- Social Uses (SU)
- A priority list for planting in tropics and subtropics (TOP830+)

# GlobalUsefulNativeTrees (GlobUNT)

<https://patspo.shinyapps.io/GlobalUsefulTrees>

CIFOR-ICRAF and Botanic Gardens Conservation International (BGCI) version v.2023.11

Introduction Select country Filter uses Filter climates Show species Summary tables Matching details Methods Credits

Show 200 entries

Search:

Species Family Countries Switchboard Taxonomy CABI.ISC POWO Seed.Information

<i>Acca sellowiana</i>	Myrtaceae	3	<a href="#">Acca sellowiana</a>	wfo-0000281732		<i>Feijoa sellowiana</i>	<a href="#">Acca sellowiana</a>
<i>Alibertia edulis</i>	Rubiaceae	20	<a href="#">Alibertia edulis</a>	wfo-0000941730		<i>Alibertia edulis</i>	<a href="#">Alibertia edulis</a>
<i>Allophylus edulis</i>	Sapindaceae	6	<a href="#">Allophylus edulis</a>	wfo-0000526658		<i>Allophylus edulis</i>	
<i>Allophylus membranifolius</i>	Sapindaceae	1	<a href="#">Allophylus edulis</a>	wfo-0000526658		<i>Allophylus edulis</i>	
<i>Allophylus puberulus</i>	Sapindaceae	1	<a href="#">Allophylus edulis</a>	wfo-0000526658		<i>Allophylus edulis</i>	
<i>Anacardium humile</i>	Anacardiaceae	3	<a href="#">Anacardium humile</a>	wfo-0000533060		<i>Anacardium humile</i>	
<i>Annona crassiflora</i>	Annonaceae	2	<a href="#">Annona crassiflora</a>	wfo-0000537725		<i>Annona crassiflora</i>	
<i>Annona glabra</i>	Annonaceae	52	<a href="#">Annona glabra</a>	wfo-0000537770	cabicompendium.5811	<i>Annona glabra</i>	<a href="#">Annona glabra</a>
<i>Annona montana</i>	Annonaceae	39	<a href="#">Annona montana</a>	wfo-0000537842		<i>Annona montana</i>	<a href="#">Annona montana</a>
<i>Annona mucosa</i>	Annonaceae	39	<a href="#">Annona mucosa</a>	wfo-0000537847		<i>Annona mucosa</i>	<a href="#">Annona reticulata</a>
<i>Araucaria angustifolia</i>	Araucariaceae	3	<a href="#">Araucaria angustifolia</a>	wfo-0000260143		<i>Araucaria angustifolia</i>	<a href="#">Araucaria angustifolia</a>
<i>Byrsinima crassifolia</i>	Malpighiaceae	24	<a href="#">Byrsinima</a>	wfo-0000576794		<i>Byrsinima crassifolia</i>	<a href="#">Byrsinima aff. crassifolia</a>
<i>Campomanesia guazumifolia</i>	Myrtaceae	1	<a href="#">Extinto</a>			<i>Campomanesia guazumifolia</i>	
<i>Campomanesia</i>	Myrtaceae	1	<a href="#">Ameaçado</a>			<i>Campomanesia</i>	
			<b>EX</b>	<b>EW</b>			
			<b>CR</b>	<b>EN</b>	<b>VU</b>		
			<b>NT</b>	<b>LC</b>			
				<b>RED LIST</b>			



Direct HYPERLINKs to:



SOCIETY FOR  
ECOLOGICAL  
RESTORATION



Plants of the  
World Online

→ Seed storage & mass



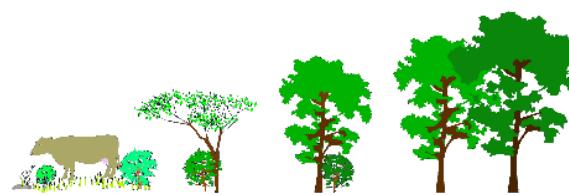
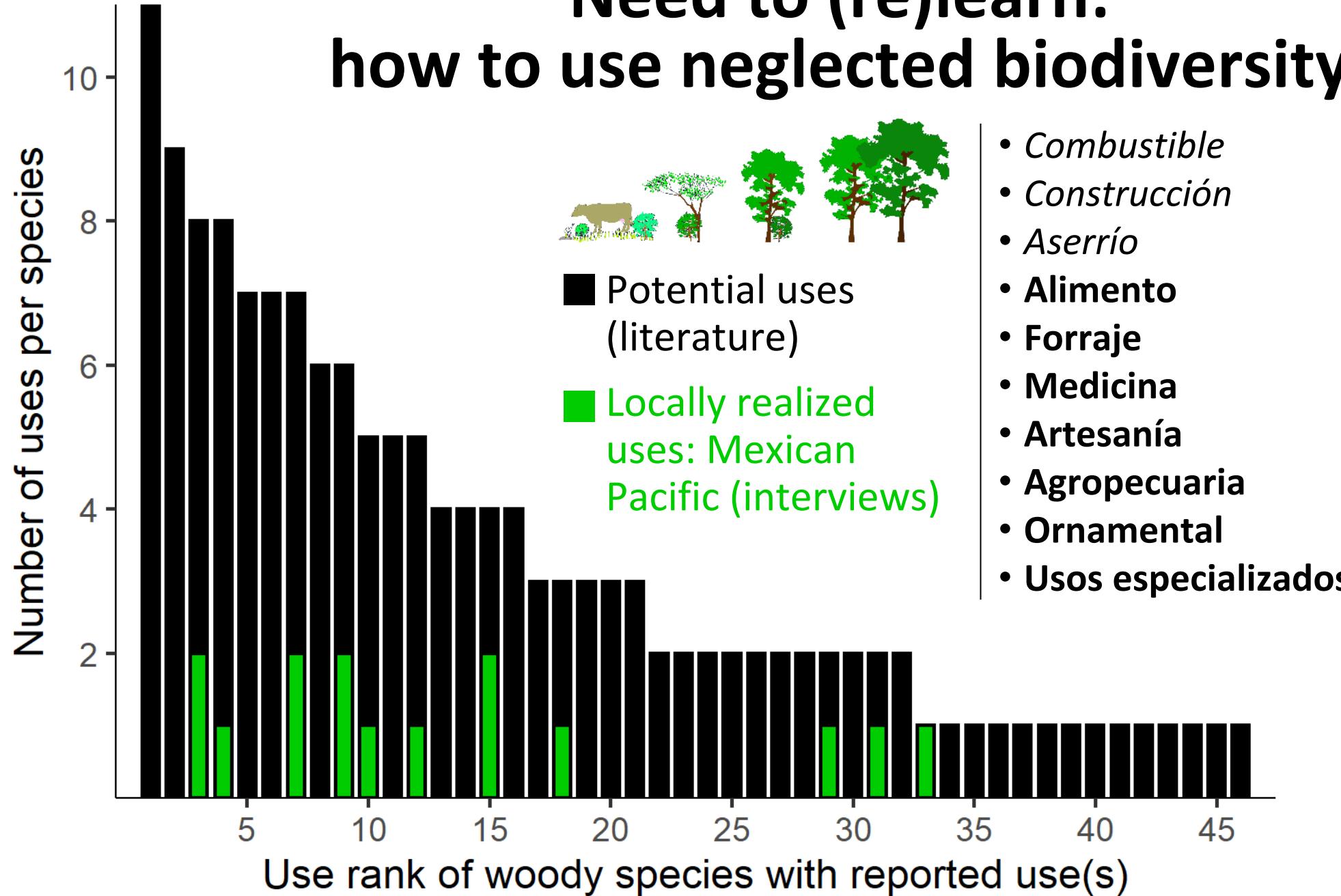
→ All local floras



Detailed seed  
sources,  
propagation,  
planting,  
management  
guidelines,  
etc

Kindt et al. 2023. GlobUNT Sci Rep

# Need to (re)learn: how to use neglected biodiversity



■ Potential uses  
(literature)  
■ Locally realized  
uses: Mexican  
Pacific (interviews)

- Combustible
- Construcción
- Aserrío
- Alimento
- Forraje
- Medicina
- Artesanía
- Agropecuaria
- Ornamental
- Usos especializados



Siddique et al. 2021  
*For. Ecol. Manage.*

Datos: Godínez/  
Pérez/ BADEPLAM

After knowing which trees are right for each place...

*$\alpha$ -diversity*

**...How do we combine compatible species to be intercropped in the same space (*agroforestry system*), minimizing competition?**



# Need to diversify range of spp, incl rare & threatened

...Avoid repeating standard recipe combinations of the same cosmopolitan spp

→ Versatile Decision Support Tools need to help combine intercrops from the most suited species for a particular context/project (envtl conditions & socioecon demands)



Intercropping for food, medicine, fibre, timber, fuel...

Stratification:

# Agroforest Restoration

Stack, save, facilitate, fund



Emergent  
High  
Mid  
Low

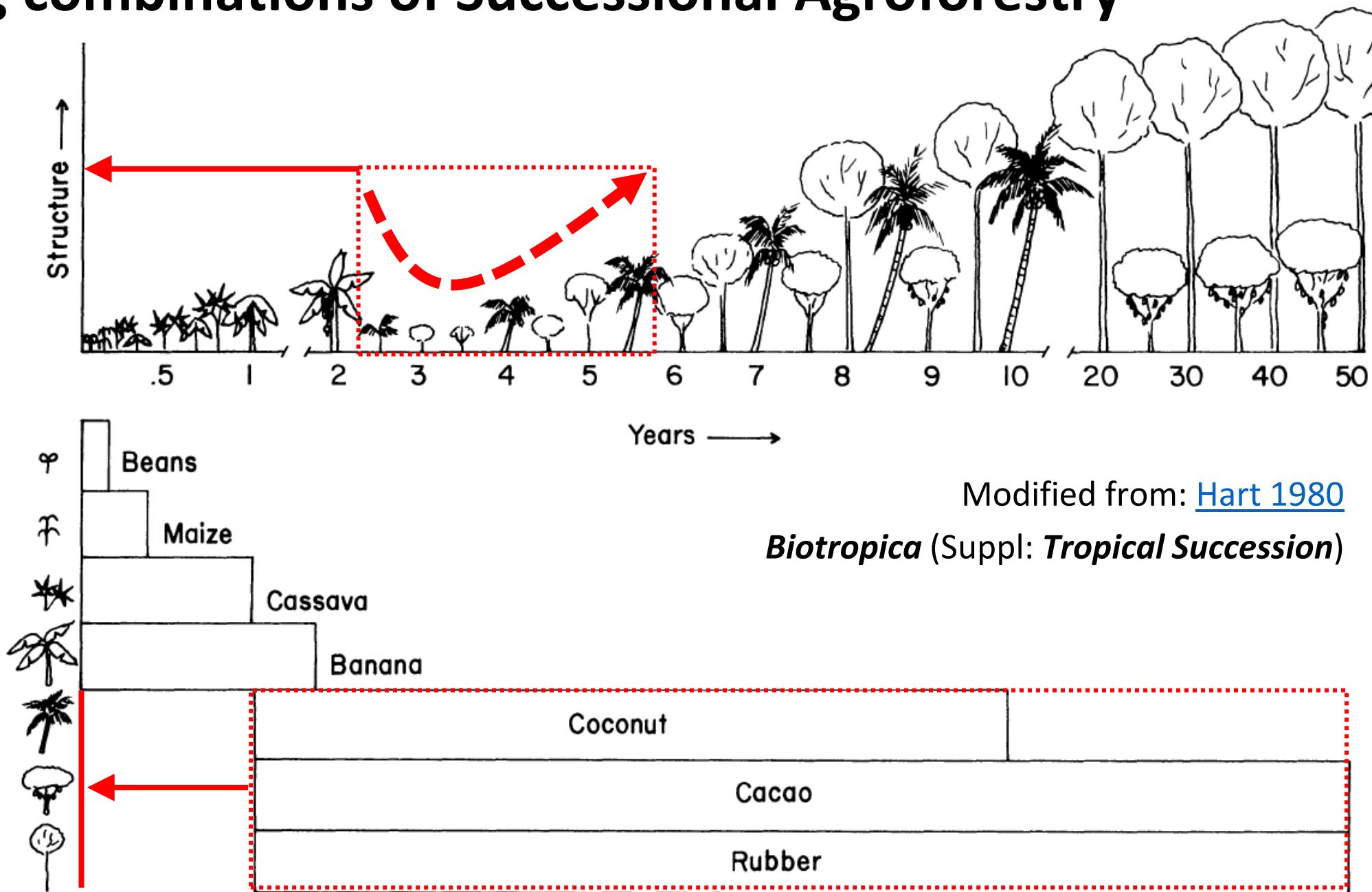


Crops with increasing shade tolerance

# Intercropping combinations of Successional Agroforestry

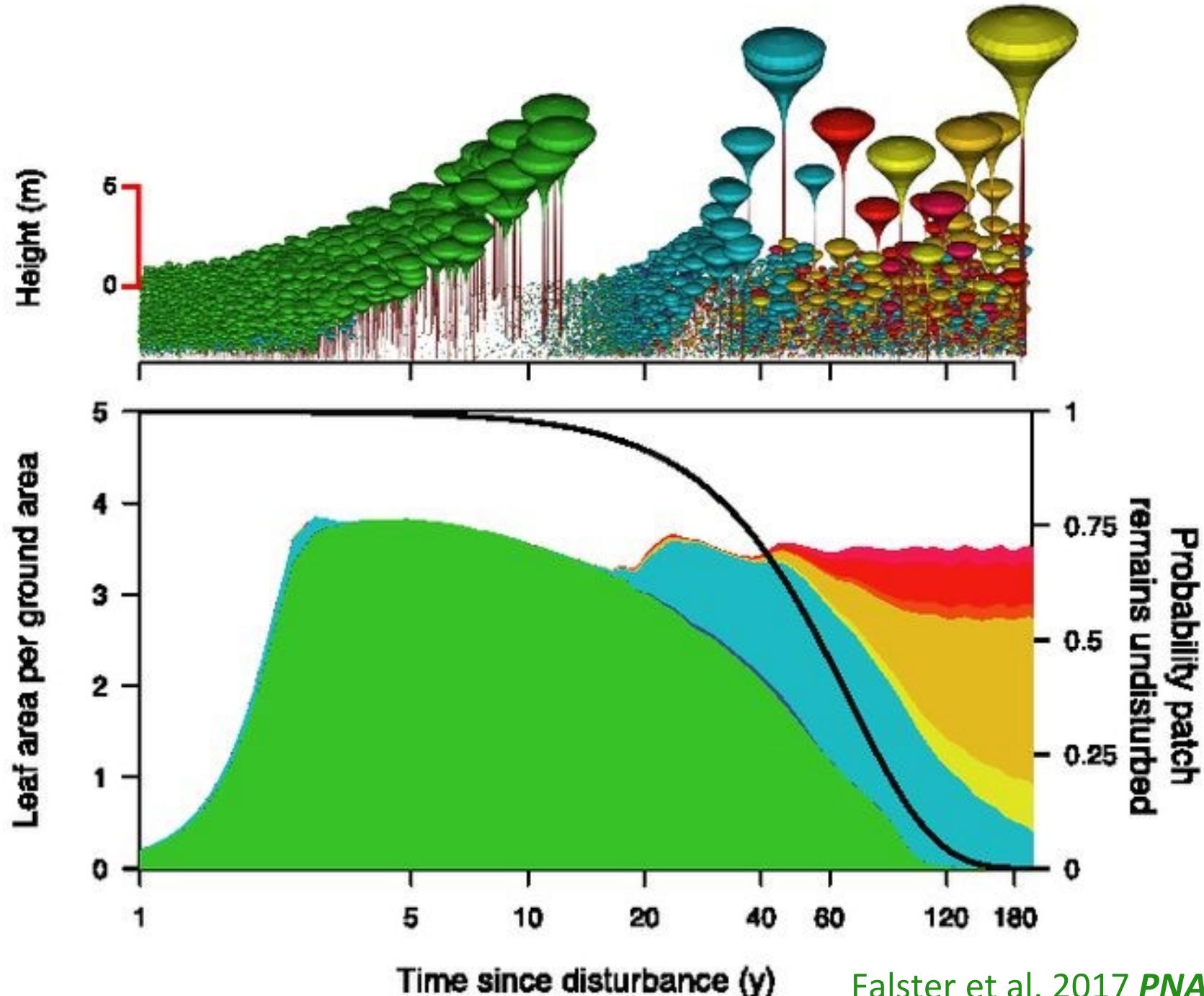
...ideally include  
pioneer & late-  
successional  
trees already  
with short-lived  
annuals

→ avoid collapse  
in biomass &  
productivity after  
removal of semi-  
perennial crops,  
but this requires  
**careful planning**



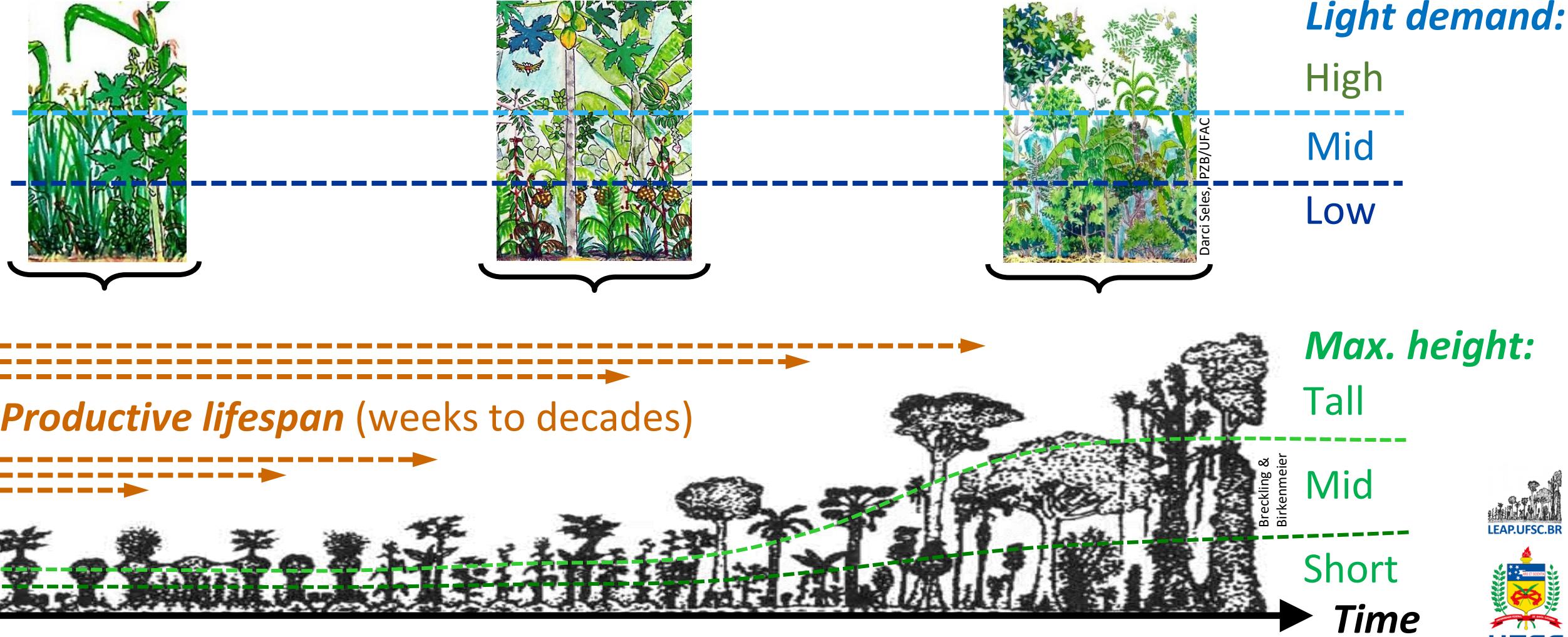
# Natural forest succession:

- Pioneers crowd out other group's growth
- Upper strata overcrowded
- At sudden pioneer death forest biomass & productivity drops, resilience vulnerable



# Which traits predict intercrop compatibility?

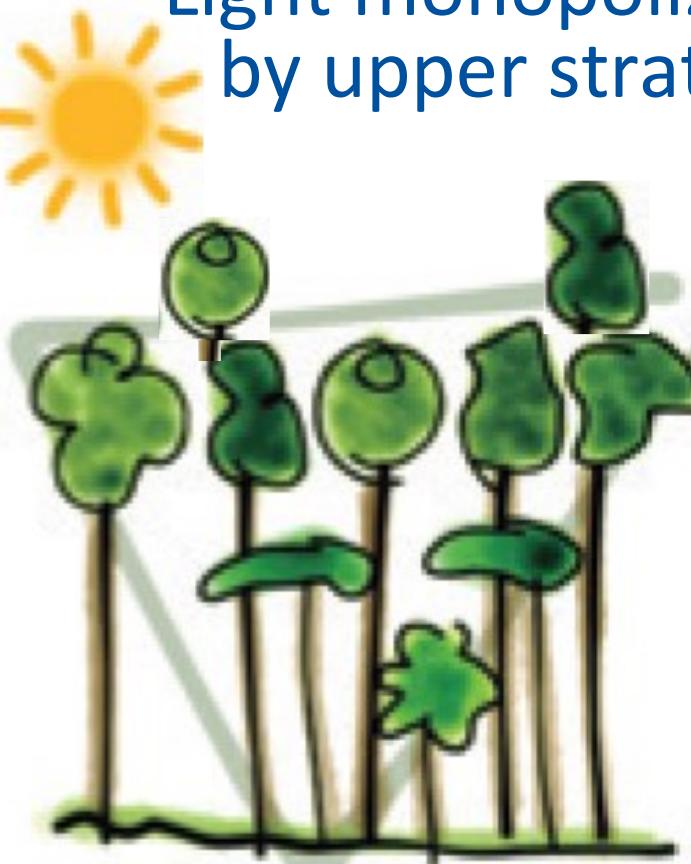
- ✓ Integrate >1 niche dimension → better prediction
- ✓ Already used by (experienced) practitioners
- ✓ Available for 100s-1000s of agroforestry plants



# Unmanaged — Structure — Managed

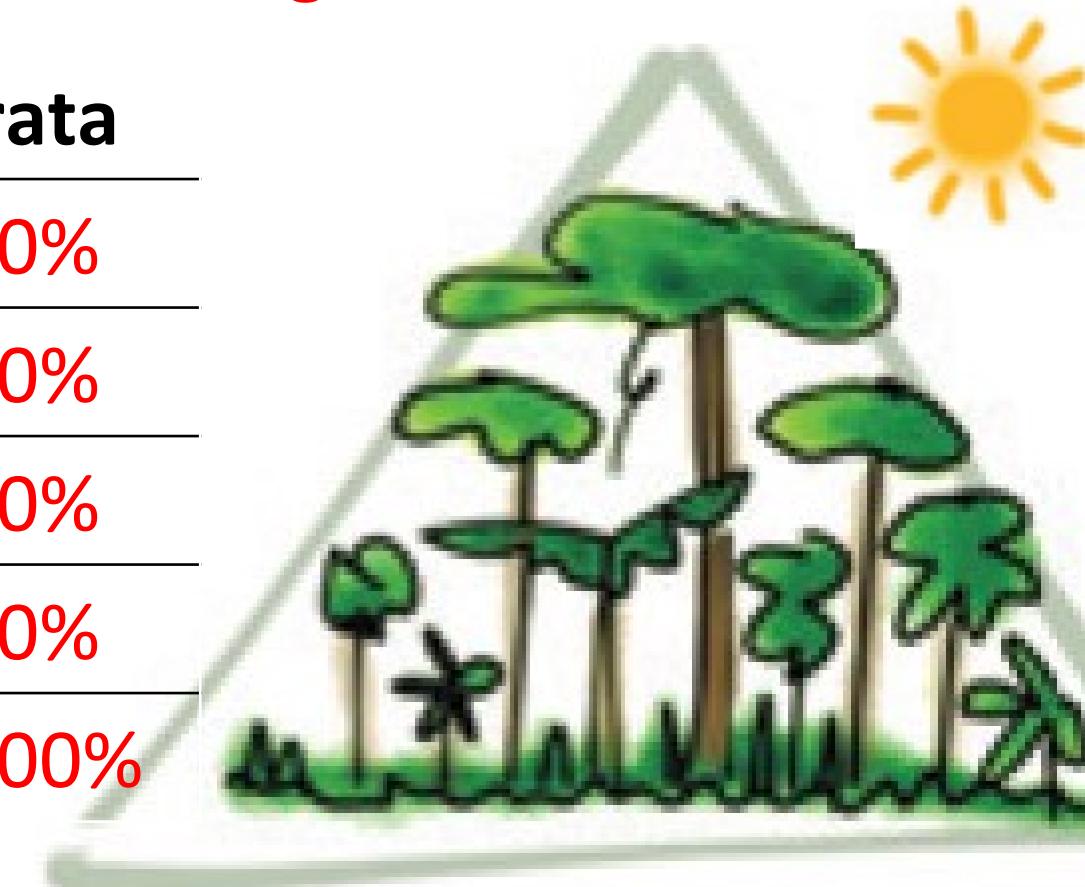
## Mature natural forest

Light monopolized  
by upper strata



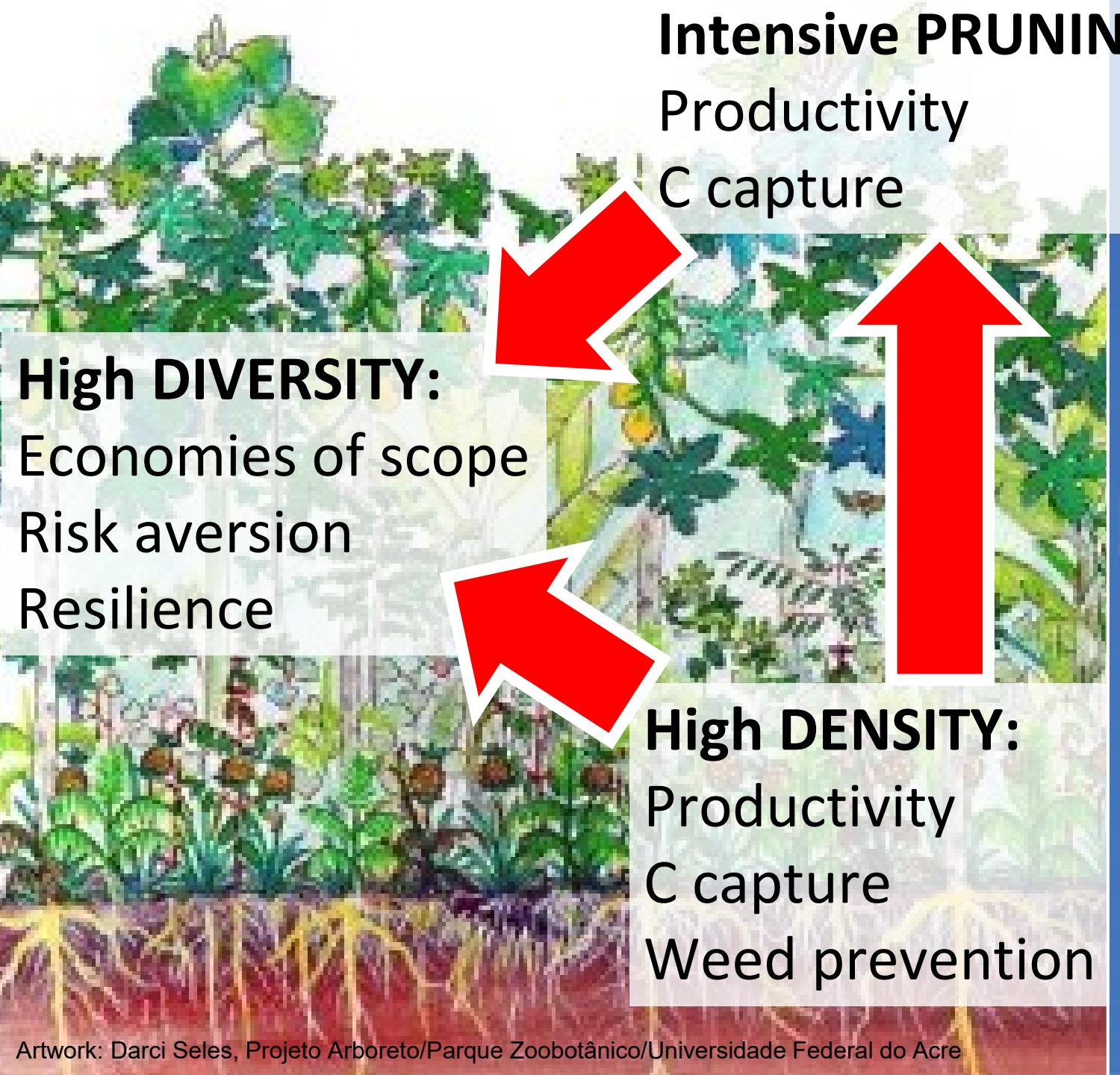
## Agroforest with pruning & slashing

Light reaches all strata

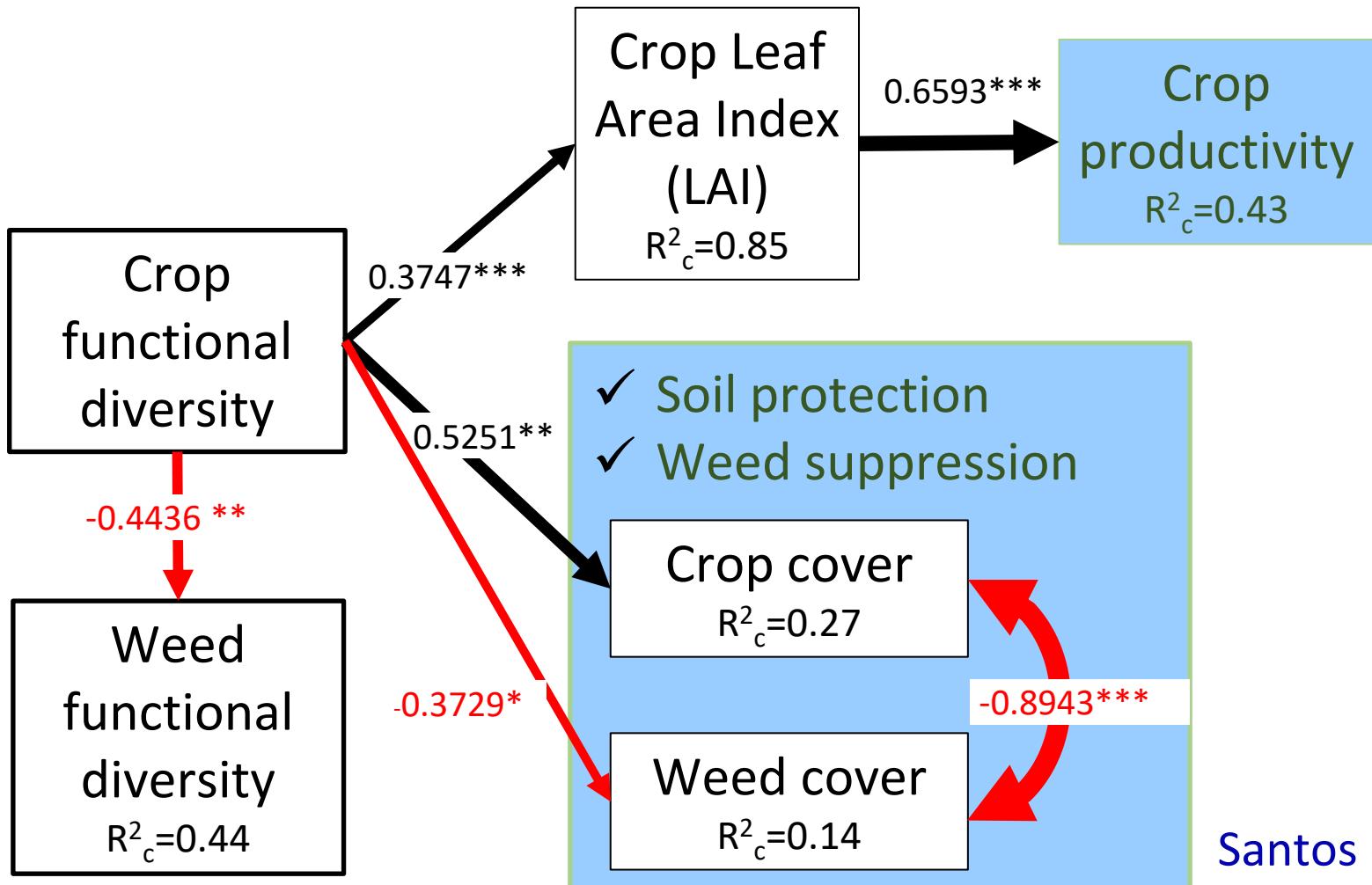


### Occupancy per Strata

~25%	Emergent	20%
~40%	High	40%
~20%	Medium	60%
~10%	Low	80%
~5%	Ground	100%



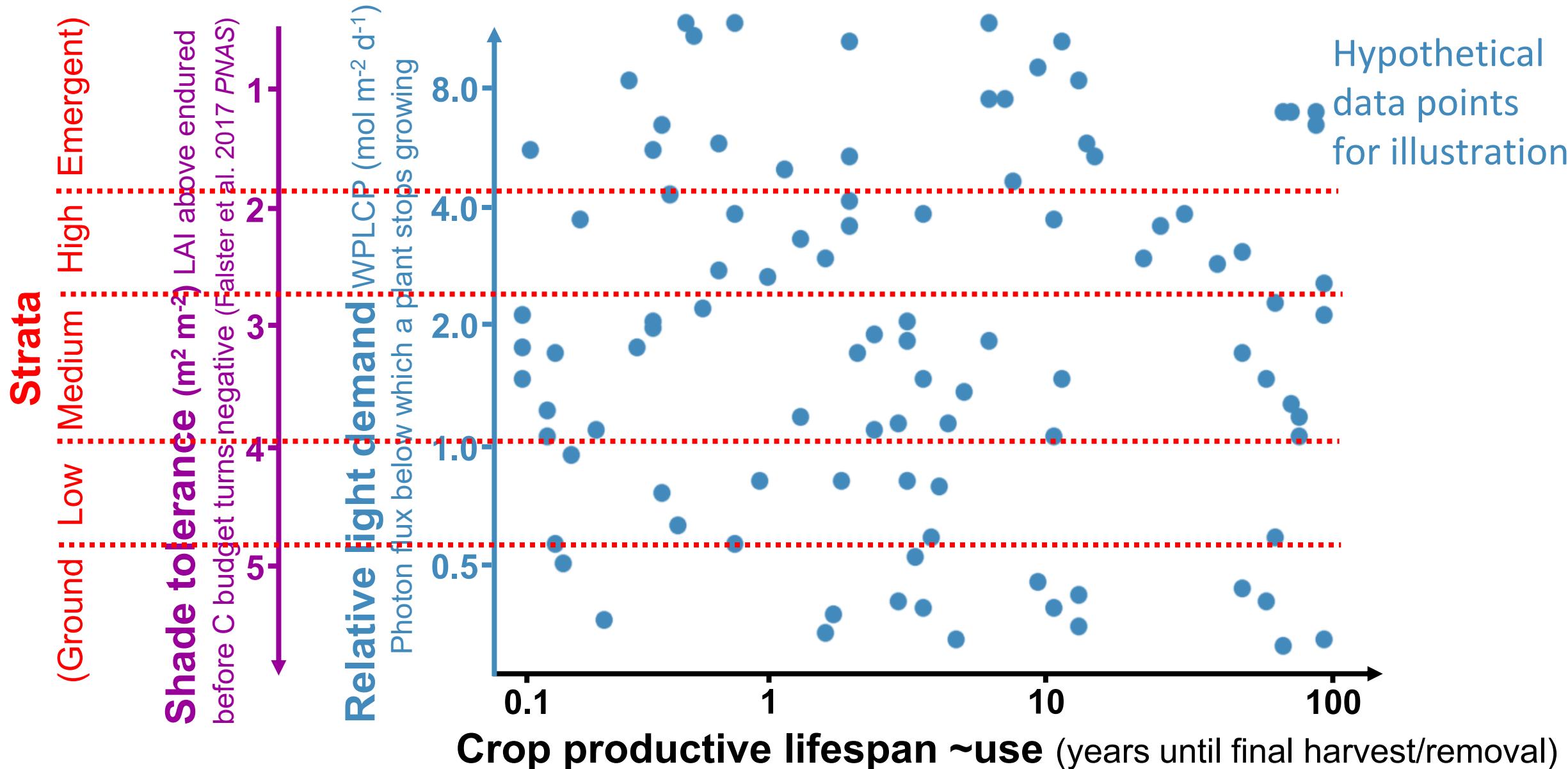
# High *crop functional diversity* increases crop cover, suppresses weeds & boosts productivity



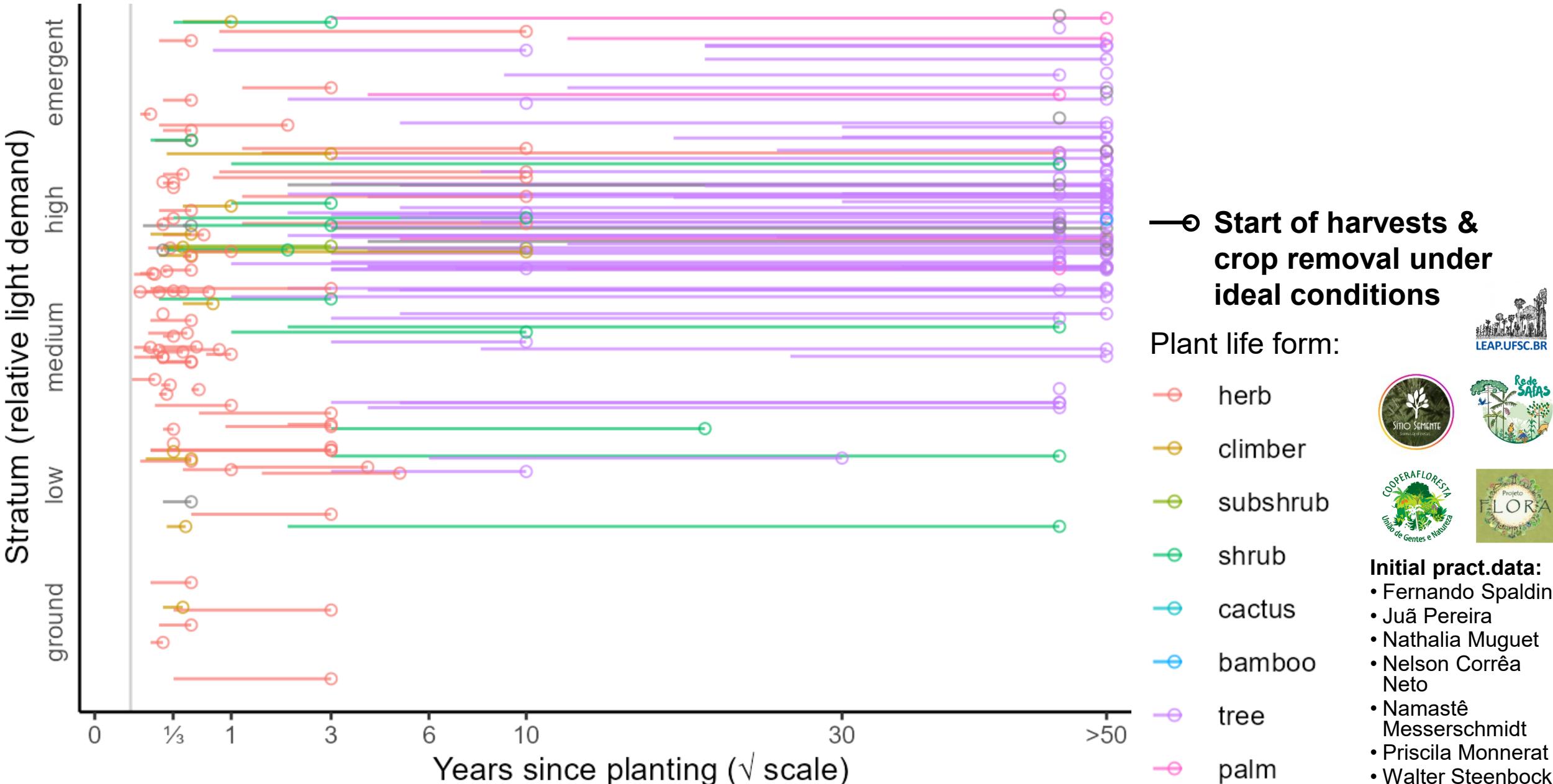
1<sup>st</sup> year of long-term agroecological experiment in permanent field plots



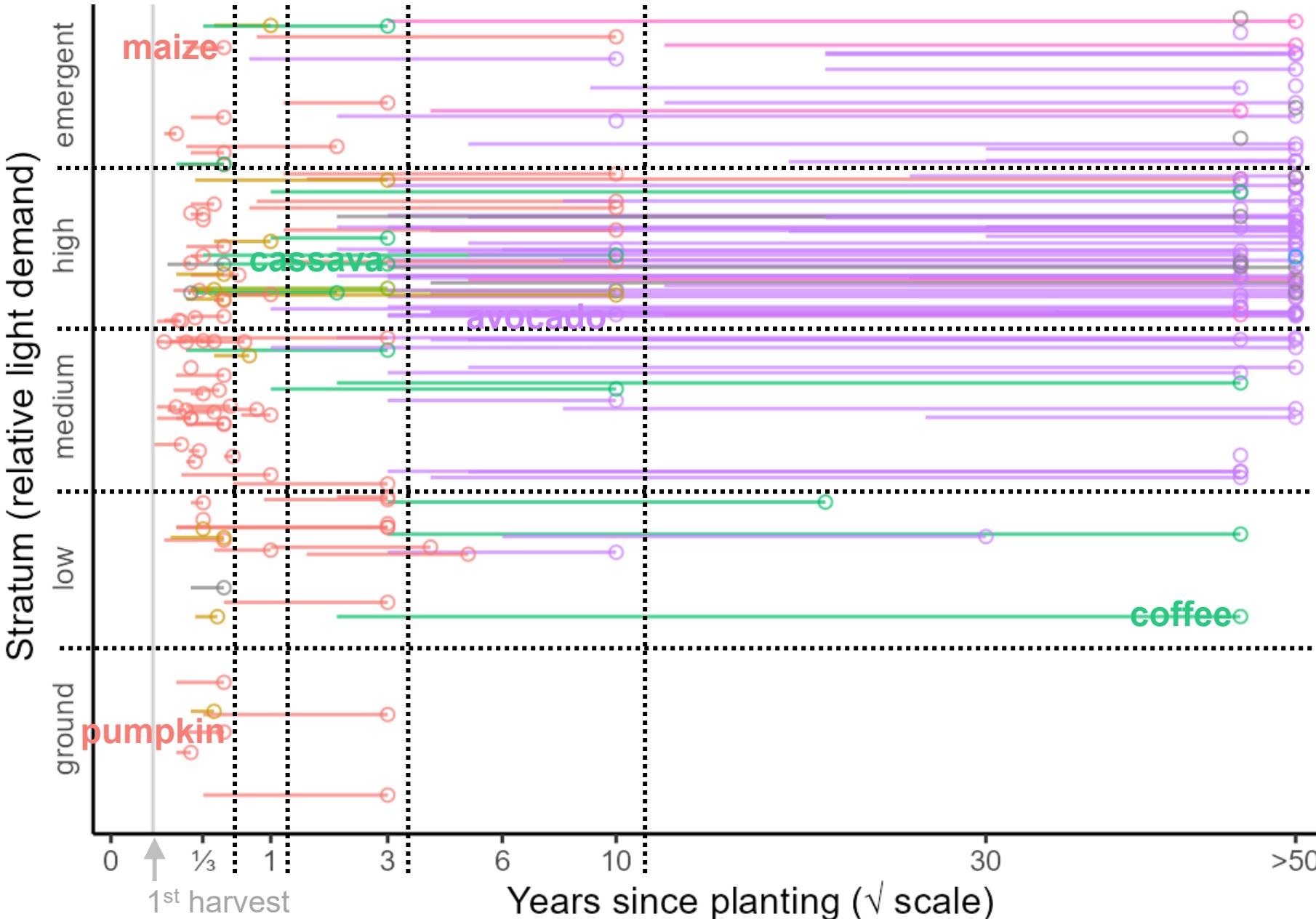
# Translating non-intuitive jargon & math-heavy ecophysiological traits into broad management categories already widely used by agroforest practitioners



# Management traits already used by practitioners to design intercrops



# Management traits already used by practitioners to design intercrops



—○ Start of harvests & crop removal under ideal conditions

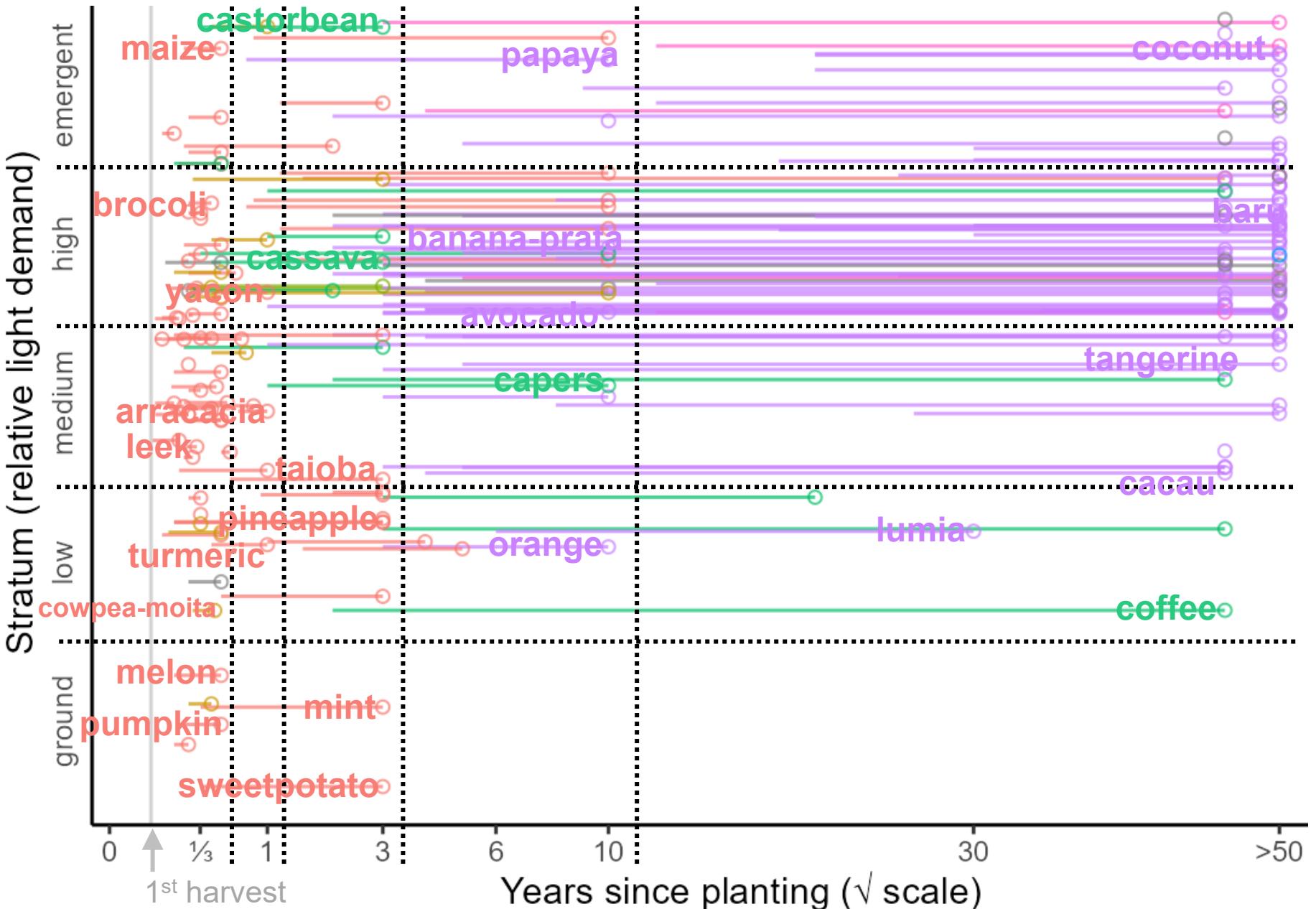
Plant life form:



## Initial pract.data:

- Fernando Spalding
- Juã Pereira
- Nathalia Muguet
- Nelson Corrêa Neto
- Namastê Messerschmidt
- Priscila Monnerat
- Walter Steenbock

# Management traits already used by practitioners to design intercrops



Pick *non-overlapping* species to add to main crop (density recommended for monoculture)

—● Start of harvests & crop removal under ideal conditions



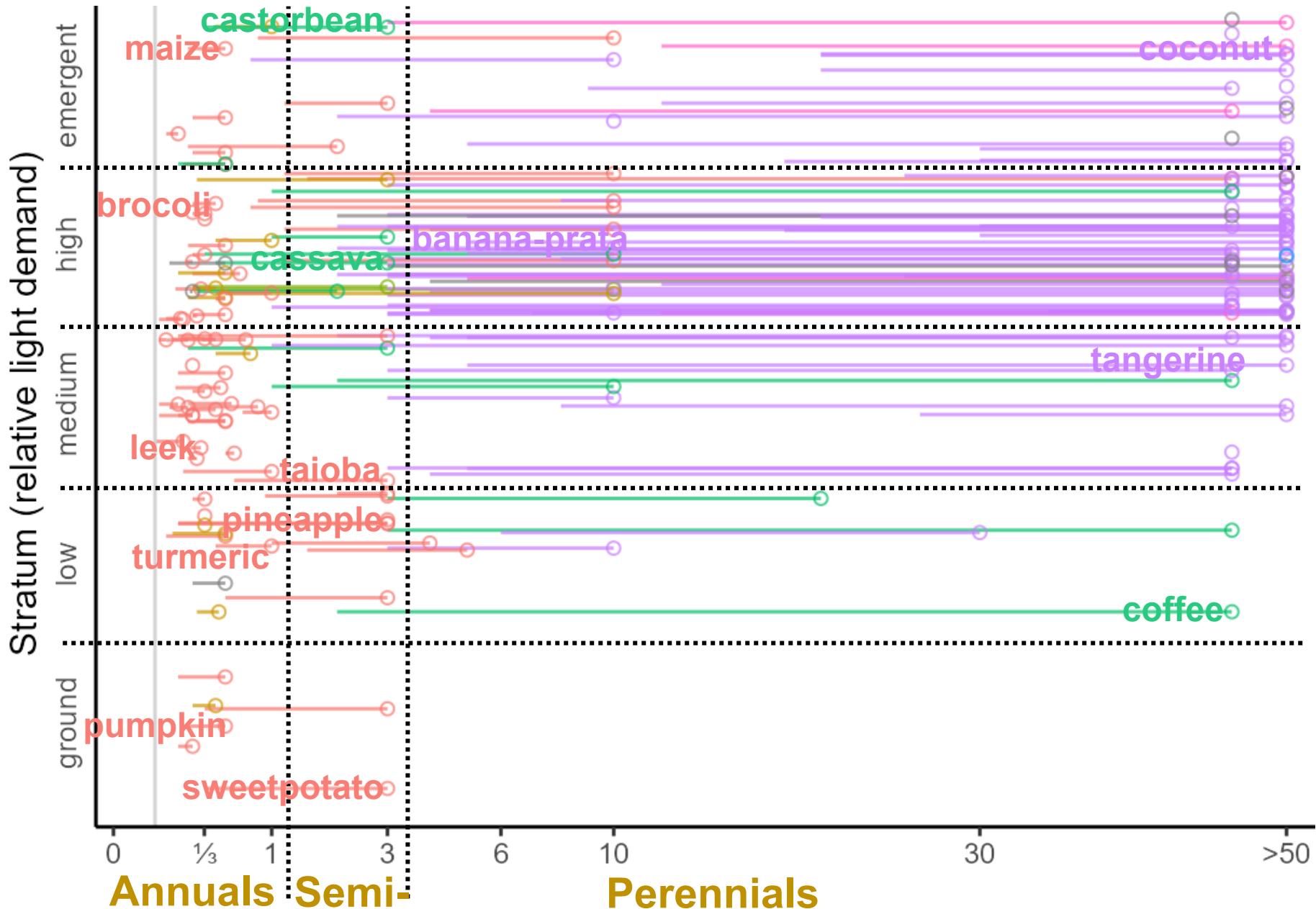
Plant life form:



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# Users can reduce nº categories to complexity manageable in their context



Pick *non-overlapping* species to add to main crop (density recommended for monoculture)

—○ Start of harvests & crop removal under ideal conditions

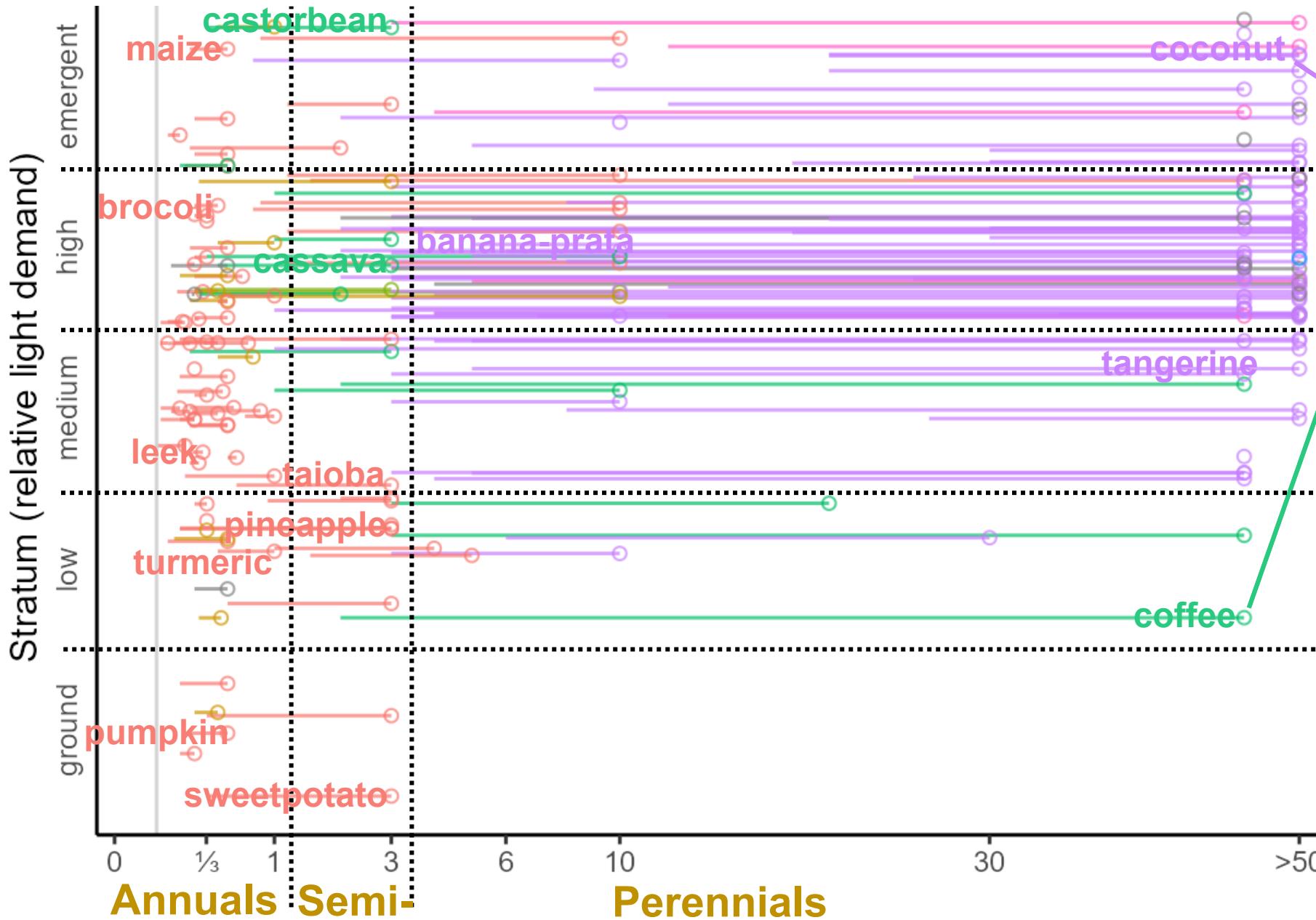


Plant life form:



- herb
- climber
- subshrub
- shrub
- cactus
- bamboo
- tree
- palm

# Users can reduce nº categories to complexity manageable in their context



Direct  
**Hyperlinks** to:



...for detailed  
seed sources,  
propagation,  
planting, mgmt  
guidelines, etc



Practitioners'  
management trait:  
*% Resprouting  
capacity*  
*\* % canopy pruned*

**Citizen Science**  
sourcing of practical  
trait data & decision  
tool visualization

**Practical data  
visualization**



**MySQL database  
structure that can  
adapt & evolve**

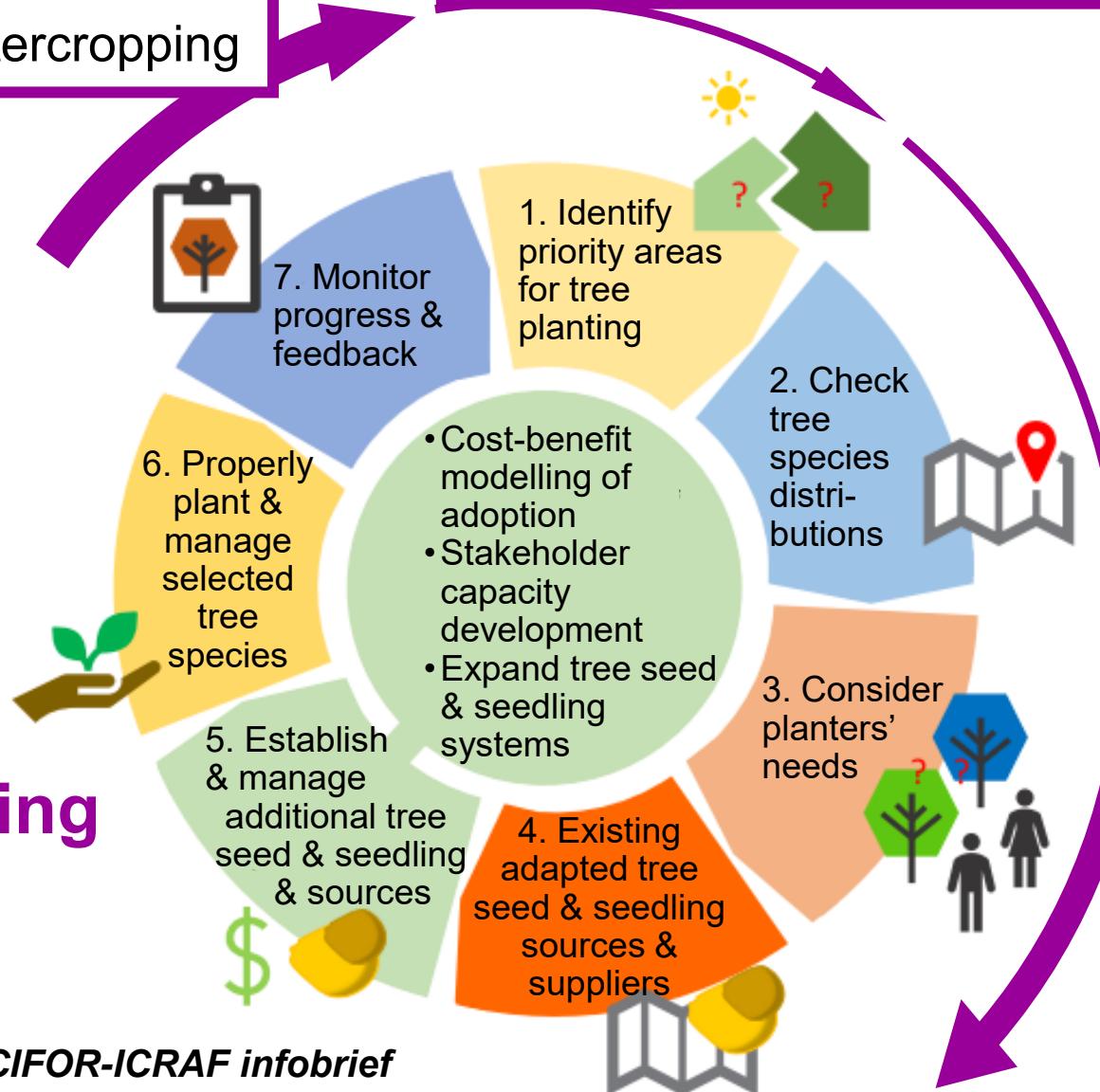
**Periodical  
updates to  
database**

**Practitioners +  
Collaborators  
contribute data**

**db Curators check  
authenticity &  
validity**

7. Interactive visualization of practitioners' experience with plant management traits to inform agroforest intercropping

# Integrating practitioners' ways of expressing agroforestry knowledge for practical decision making for CAPTD:



Black: Kindt et al. 2023 CIFOR-ICRAF infobrief

Purple: UFSC+ICRAF Tree Theme collaboration

Not just to predict in a statistical sense, but to **imagine how**  
different crops & trees occupy different spaces & niches,  
how dynamic over time

*Planning  
tool & game*

*Magnet  
components  
allow to simulate  
growth & pruning*



*Creator:  
Jefferson  
Mota*

[agroflorestinha.com.br](http://agroflorestinha.com.br)



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**...Not only planning challenge:** Also save labor on heavy, repetitive tasks: slashing, chopping, transferring biomass



Foto+sistema:  
Anderson Munarini

..to free up labor  
on fine-tuning, manual  
tasks: pruning, harvesting,  
planting

# How to organize diversity in space and time that is compatible with small-scale mechanization



# Social organization to make access to mechanization viable

Cooperatives, associations, social movements & NGOs through projects, social credit, hire or lending through local government, etc



Examples: [Projetos Flora](#) , [Agroflorestar](#) , [Tecnologia Social SAFA](#) [mst.org.br](#)

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- Applied Ecology Lab, Graduate Programs in Agroecosystems & Plant Genetic Resources, Federal University of Santa Catarina
- World Agroforestry CIFOR-ICRAF, Kenya
- University of Copenhagen, Denmark
- Agroecological Agroforestry Network of Southern Brazil
- WG Agroecosystem Management, Brazilian Association of Agroecology

**LEAP.UFSC.BR/ILYAS  
ILYSID@GMAIL.COM  
@LEAPUFSC**



**ICRAF Tree Theme**

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