FUNCiTREE

REPORT

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FUNCiTREE – Final conference presentations

Session I: Ecological attributes and functions that support ecosystem services in agro-ecosystems

www.funcitree.nina.no

REFERENCE:
FUNCiTREE. Final Conference : «The role of functional diversity for ecosystem services in multi–functional agroforestry», Trondheim 23-25 May 2013

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COVER PICTURE:
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KEYWORDS:
Plant functional traits, ecosystem services, ecological functions, Bayesian networks

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Biological pest control - an ecosystem service provided by biodiversity at multiple spatial scales

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Funcitree, Trondheim, Norway, 2013-05-23

Outline of presentation

1. The value of biological control

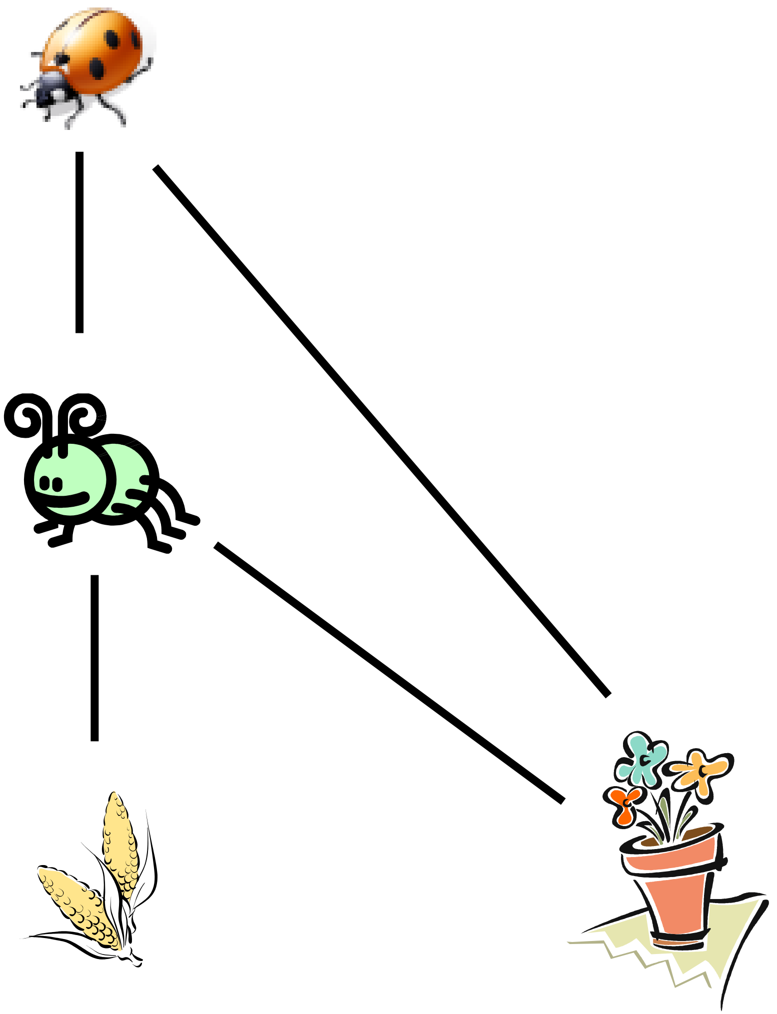
2. Effects of local management and landscape composition

4. What about agroforestry?

5. Biodiversity and biological control

6. The ’right’ kind of biodiversity

The ecosystem service biological control



Value of biological control

- $417 billion/year in the world

(Costanza et al. 1997, Nature)

- $4.49 billion/year in USA

(Losey and Vaughan 2006, Bioscience)

Value of biological control

	Conventional	Organic
Yield increase due to predation on cereal aphids by ground-living predators	15%	30%





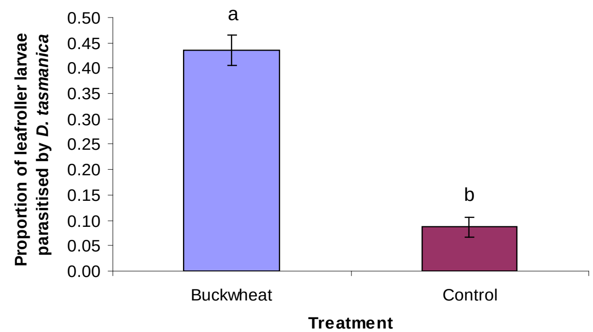

Östman et al. 2003. Ecol. Economics

Effects of local management

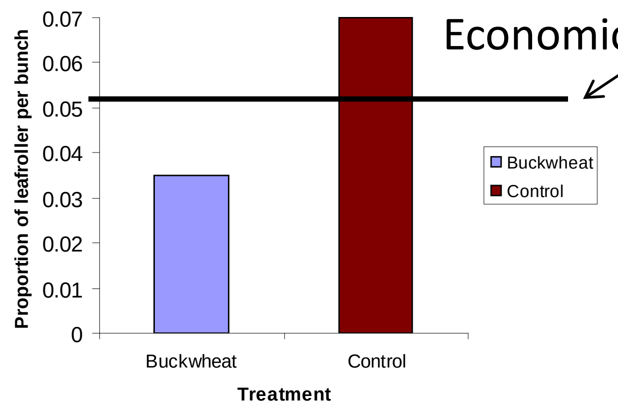
Flower-strips in NZ vineyards

Buckwheat, *Fagopyrum esculentum*

Leaf-roller parasitism



Abundance of leaf rollers



Economic threshold

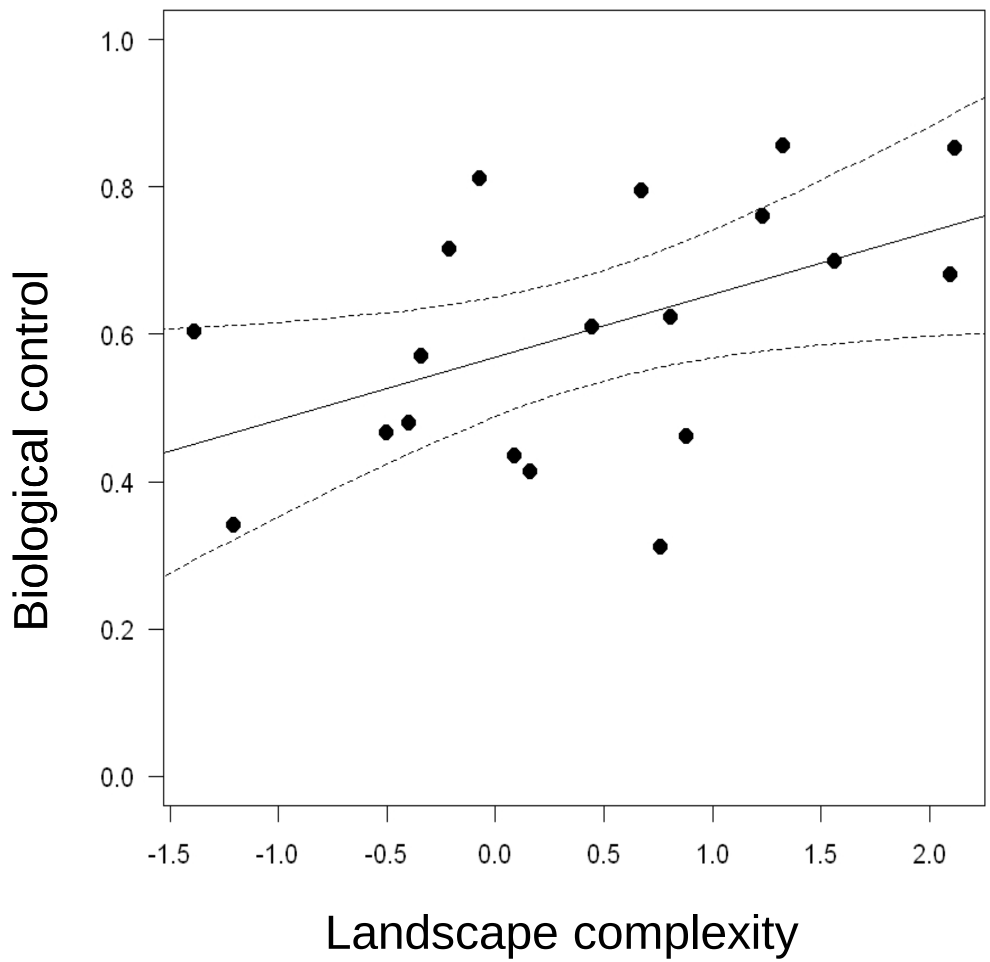
Effects of landscape composition

Predator exclusion cages

Biological control estimated in 19 different fields

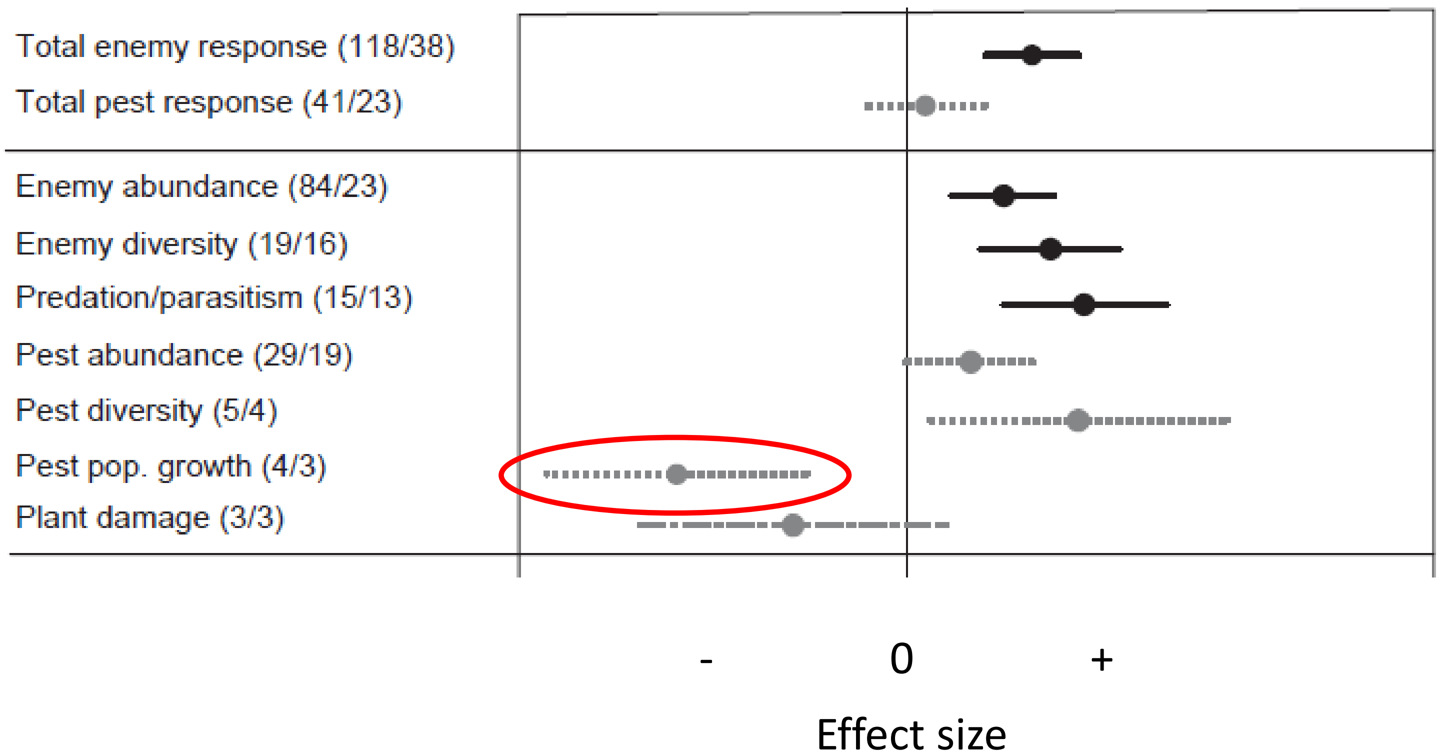
Potted plants with sentinel aphids

Biological control of cereal aphids more effective in complex landscapes



Rusch et al. 2013. J. Appl. Ecol.

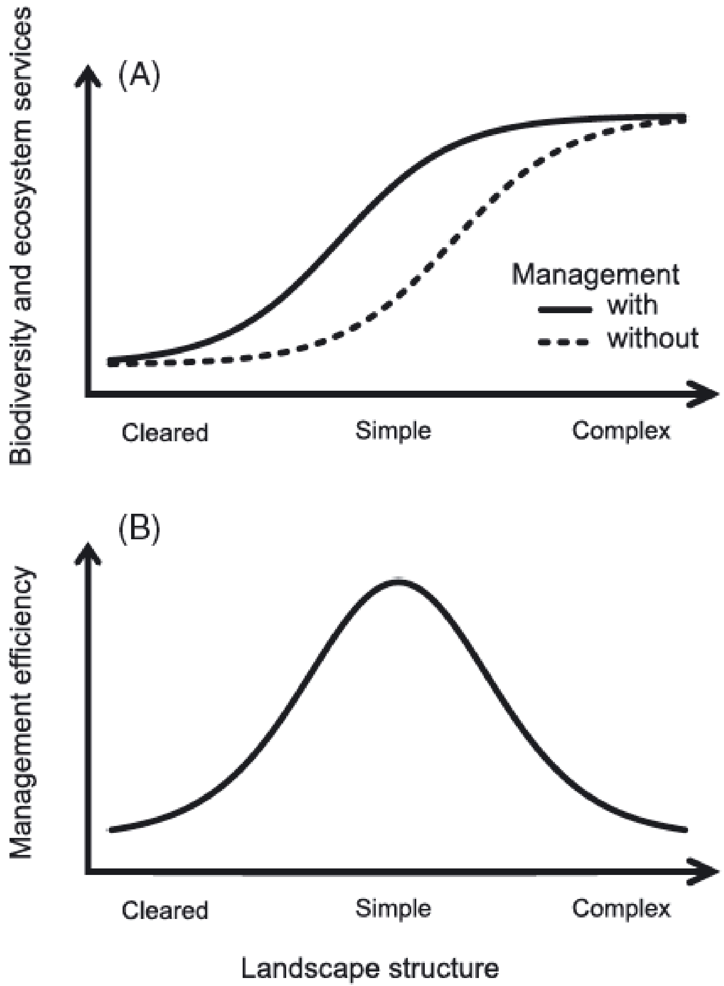
Review of the effect of landscape complexity



Chaplin-Kramer et al. 2011. Ecology Letters

Local management x landscape composition

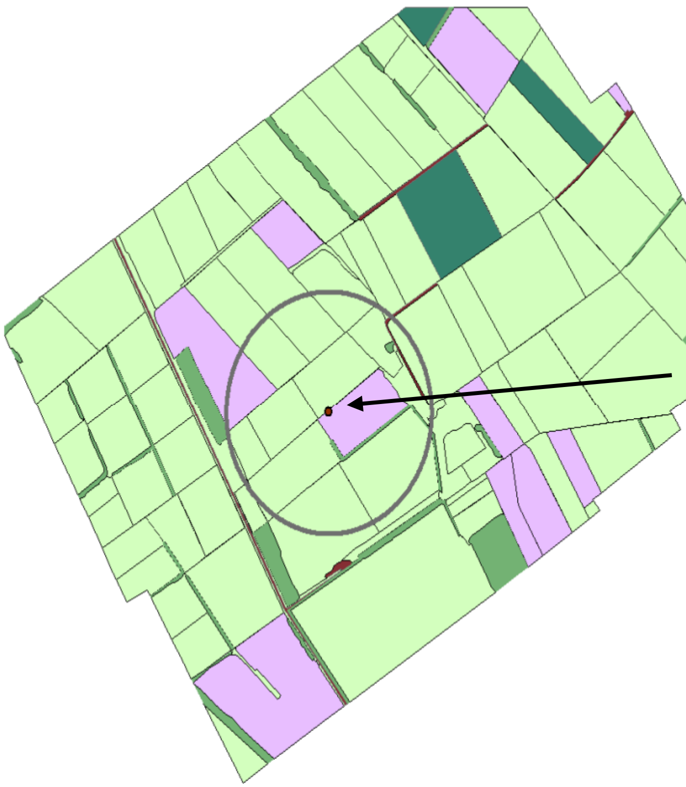
A hypothesis



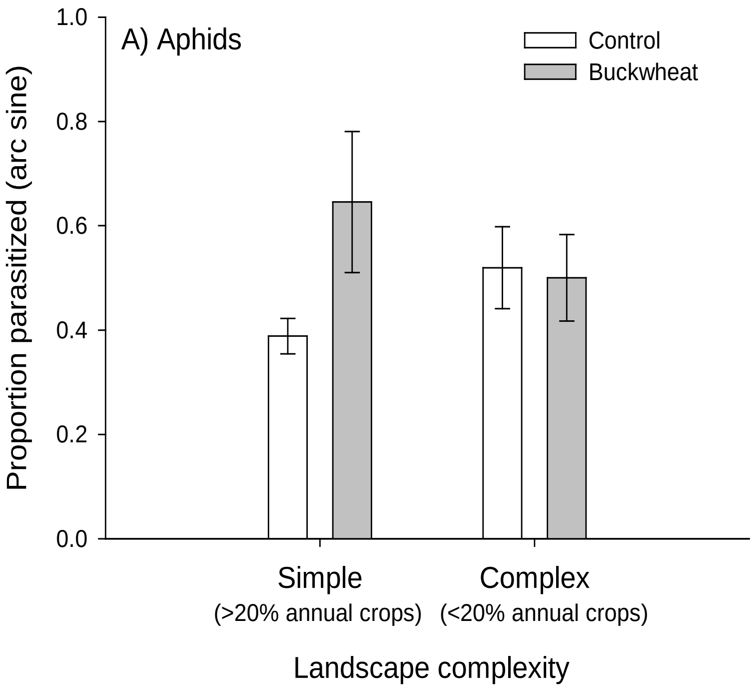
Tscharntke et al. 2012. Biological Reviews

Local management x landscape composition

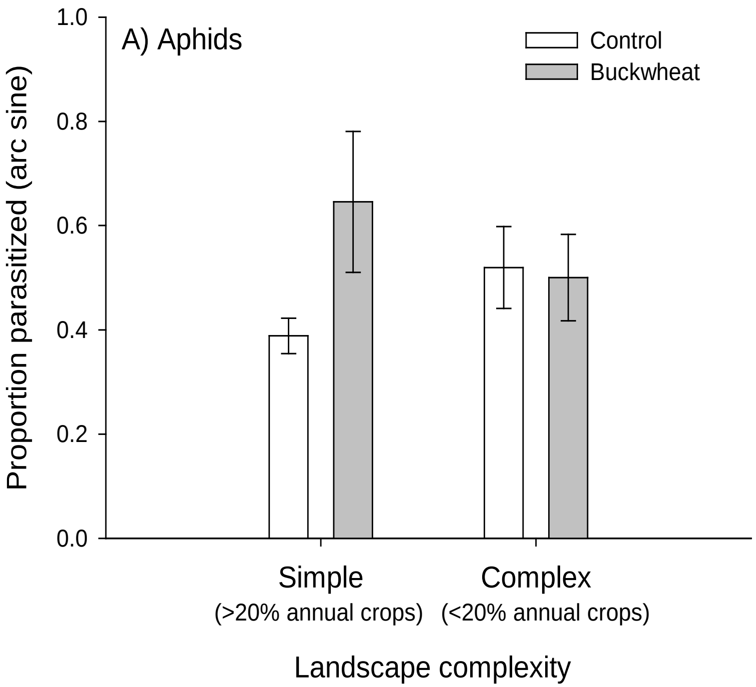
Flower strips in different landscapes

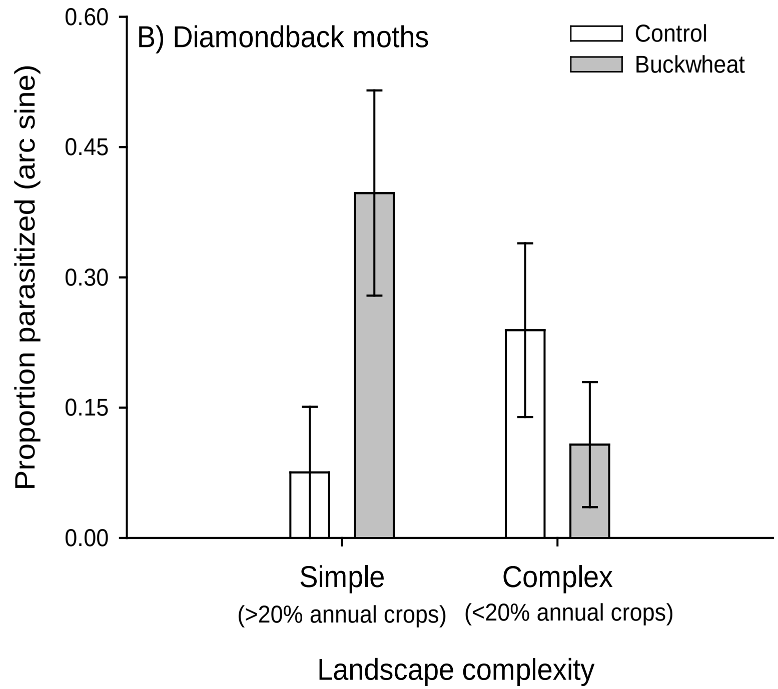


Flower strips increased parasitism in simple landscapes



Flower strips increased parasitism in simple landscapes





Review of the dependency of local management on landscape complexity

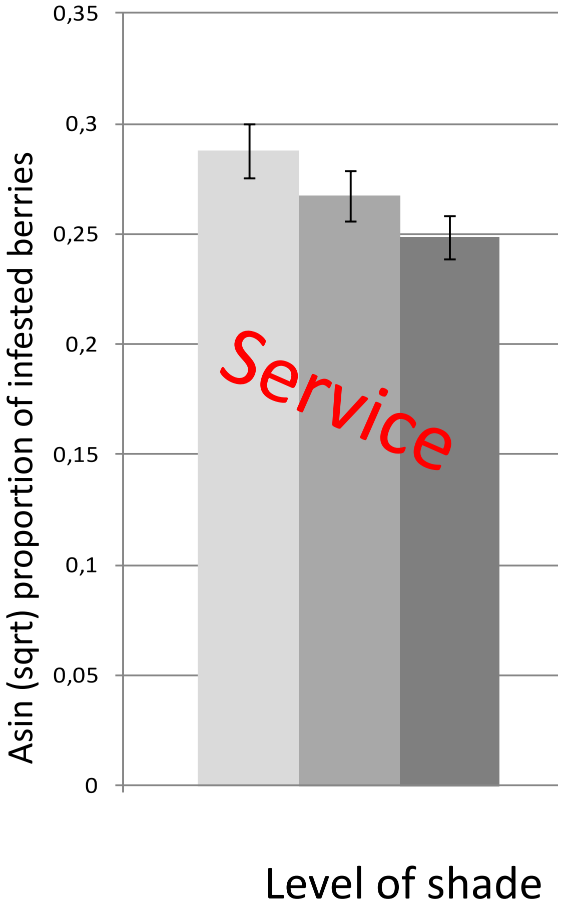
No interaction	Larger effect in simple landscape	Larger effect in complex landscapes
Östman et al. 2001 Purtauf et al. 2005 Roschewitz et al. 2005 Clough et al. 2007 Woltz et al. 2011 Midega et al. in prep	Thies and Tscharntke 1999 Schmidt et al. 2005 Haenke et al. 2009 Jonsson et al. in prep Backlund et al. in prep	Winqvist et al. 2011

What about agroforestry?

Effects of agroforestry on two coffee pests in Uganda

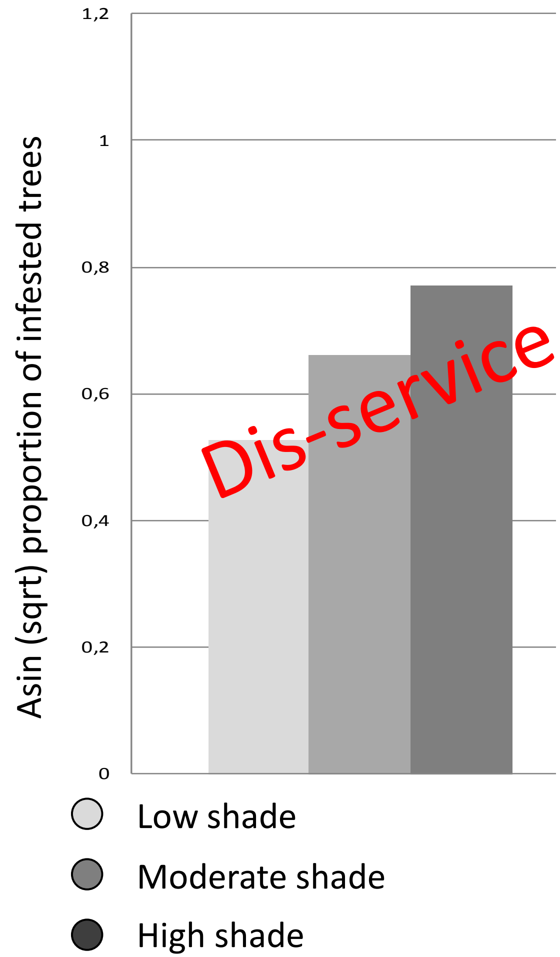
Coffee berry borer

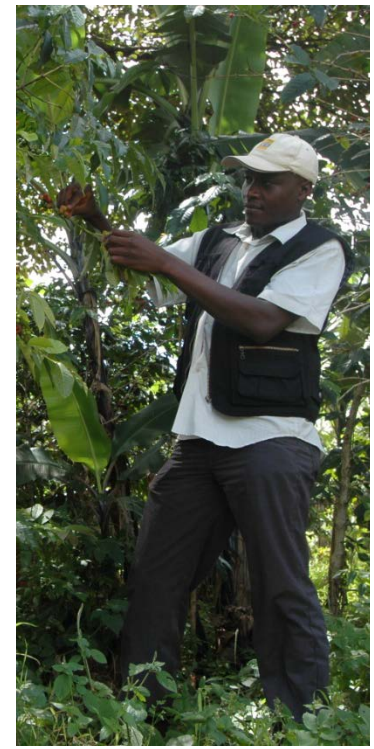
(*Hypothenemus hampei*)



White stem borer

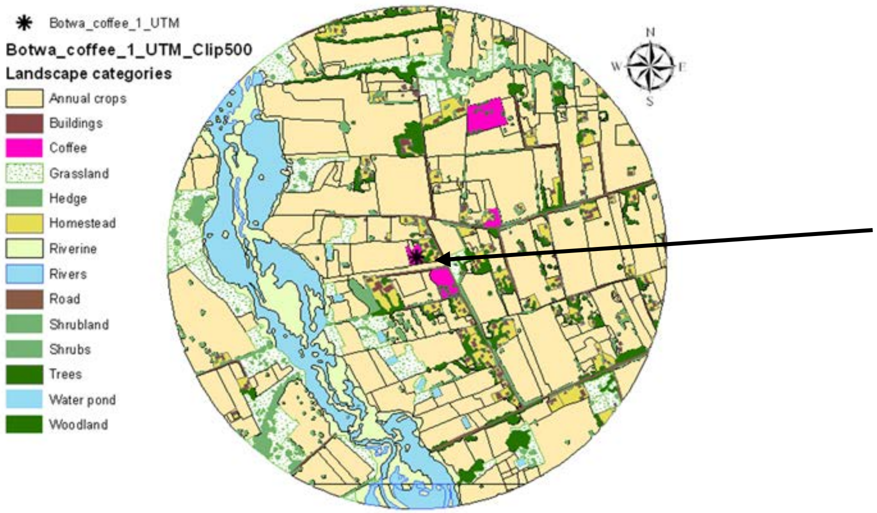
(*Monochamus leuconotus*)





Ijala Anthony Raphael

Shaded coffee plantations in landscapes with different cover of trees in W. Kenya

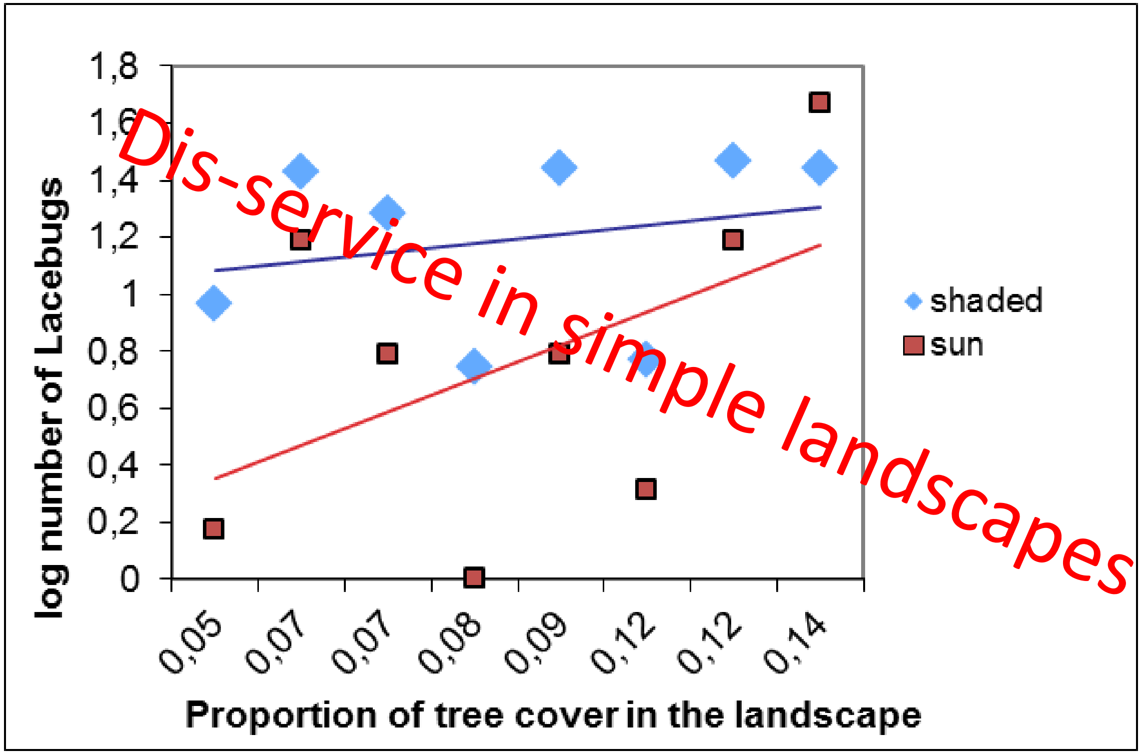


Shaded plantation

Sun-exposed plantation

Louise Malmberg & Nina Backlund (Msc-students)

The effect of local shade level on pest abundance depended on landscape composition



Local shade: **
Prop tree cover: NS
Local shade X prop tree cover : *

Biodiversity and biological control

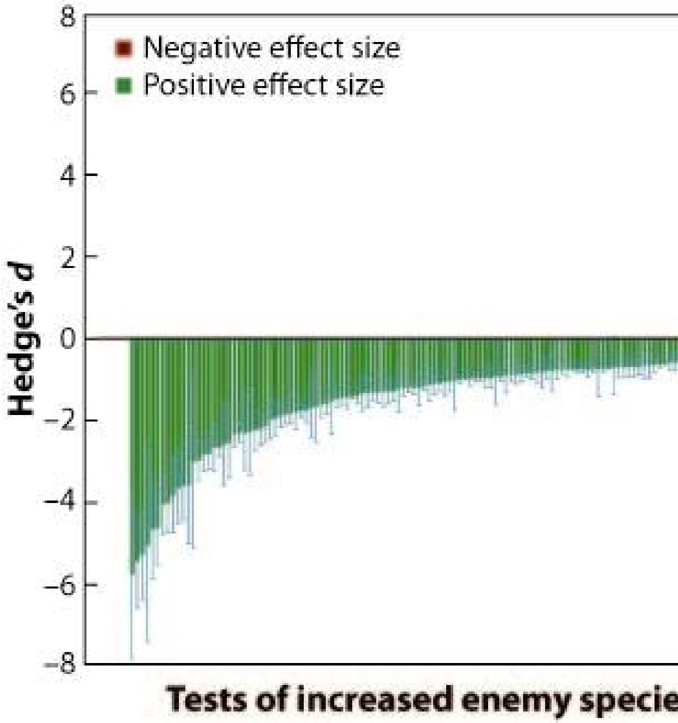
Agroforestry often increases biodiversity

(Perfecto *et al.* 2003; Tscharntke *et al.* 2011; Borkhataria *et al.* 2012)

- but effects on pests appear to vary.

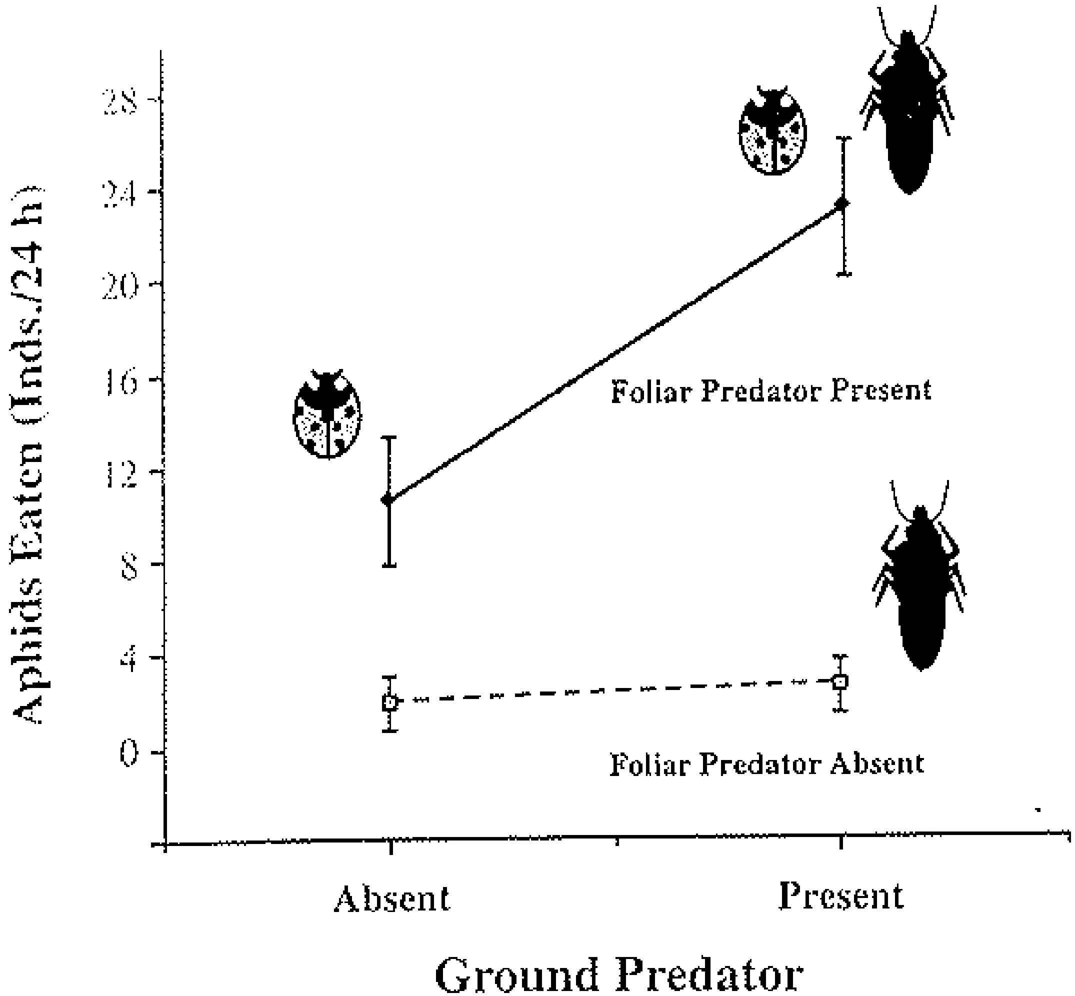
Biodiversity and biological control

Empirical studies of the effects of natural enemy diversity on biological control



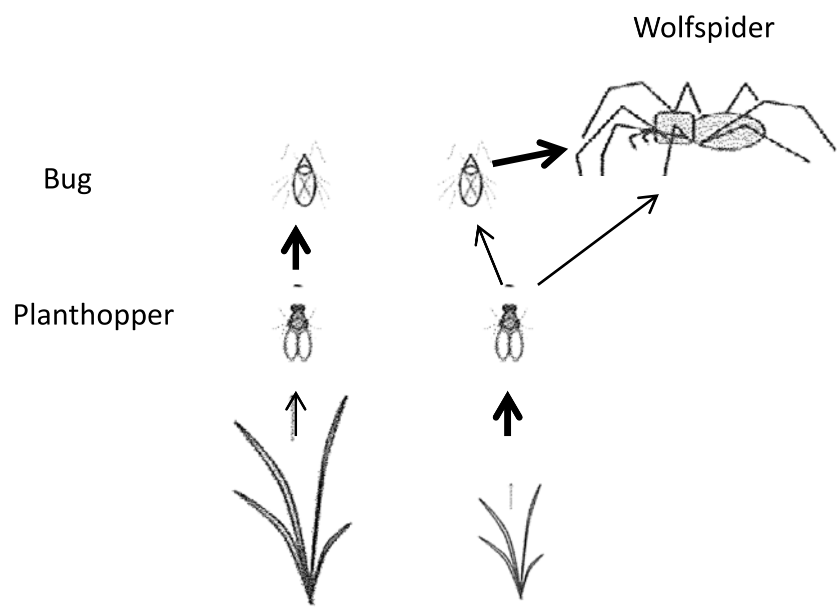
Letourneau DK, et al. 2009.
Annu. Rev. Ecol. Evol. Syst. 40:573–92

Positive effect of increasing enemy diversity - faciliation



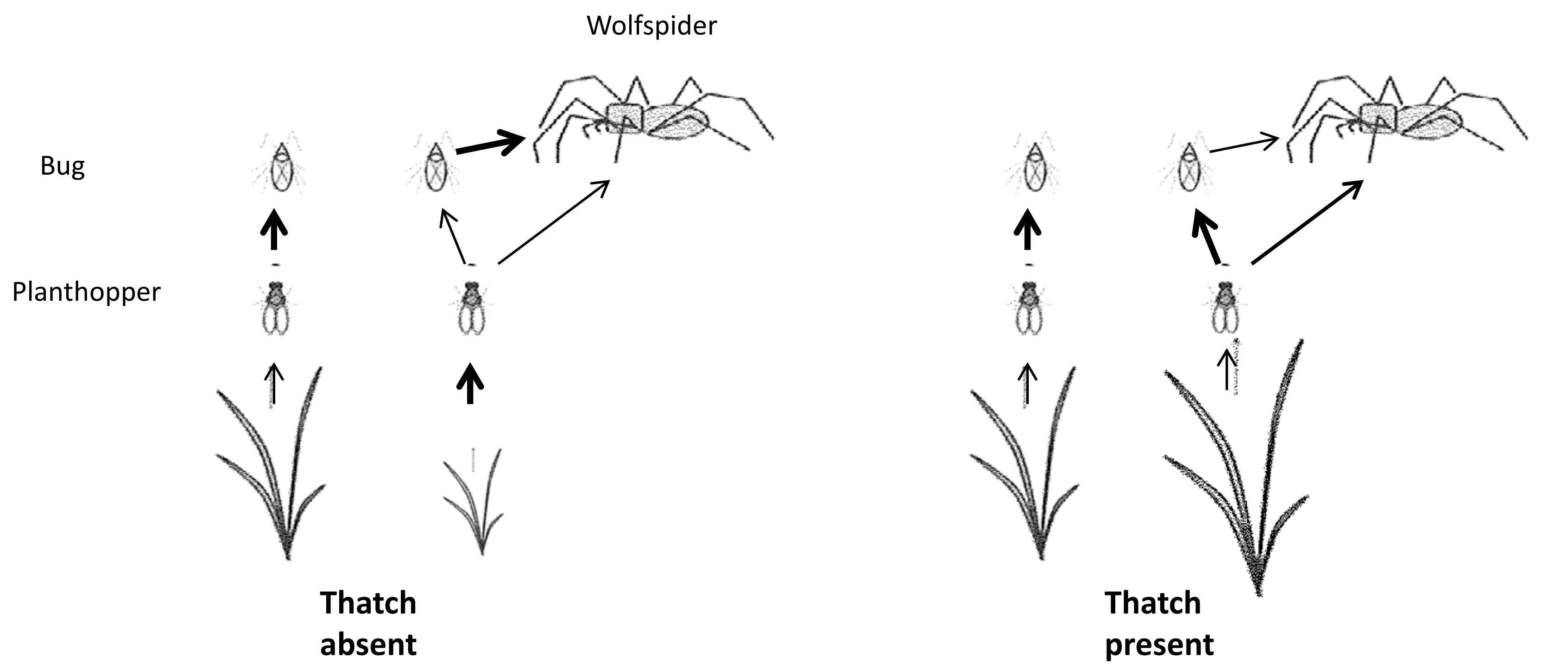
Losey & Denno 1998, Ecology

Negative effects of increasing predator diversity - intraguild predation



Finke & Denno 2004, Nature

Increasing habitat complexity may decrease intraguild predation

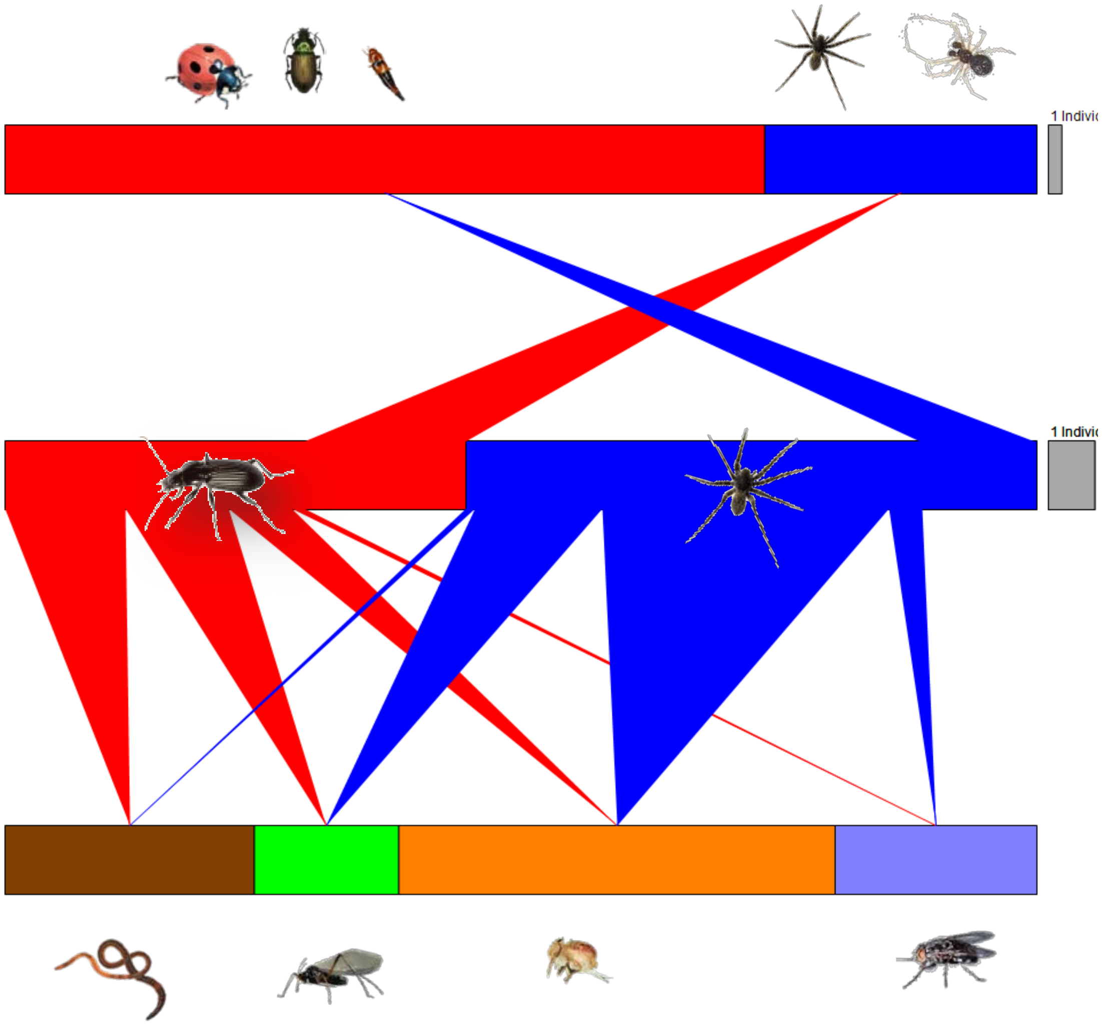


Finke & Denno 2006, Oecologia

Unravelling predator-prey foodwebs

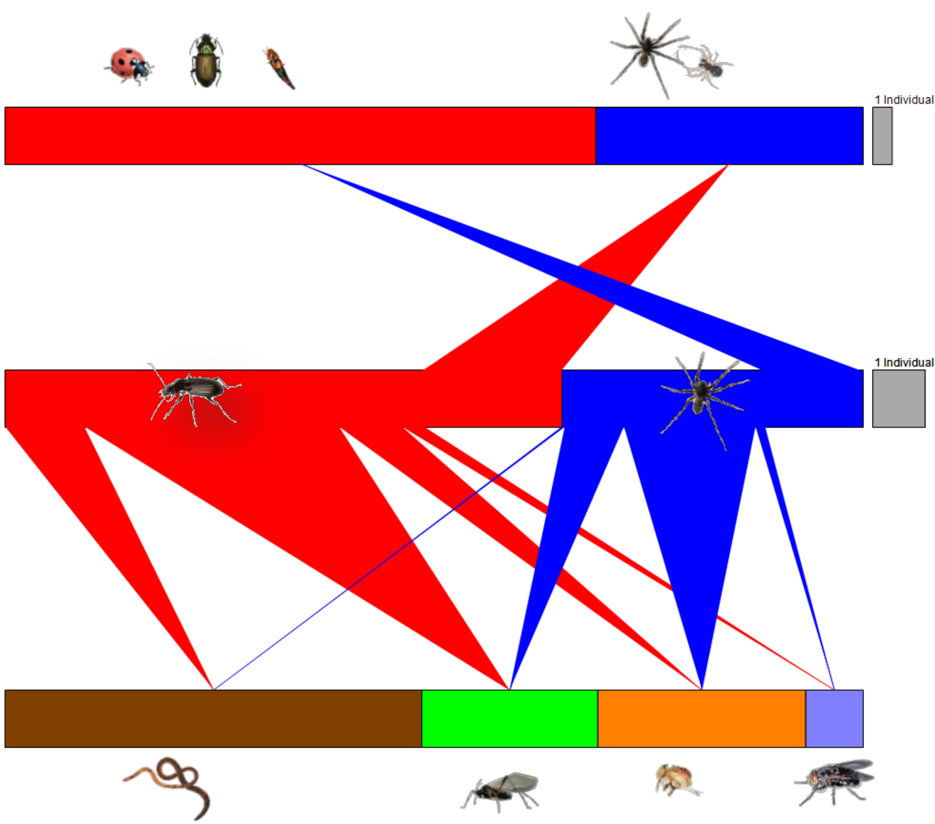
- Molecular gut-content analysis (MGCA) makes it feasible

Predator-prey foodwebs based on MGCA

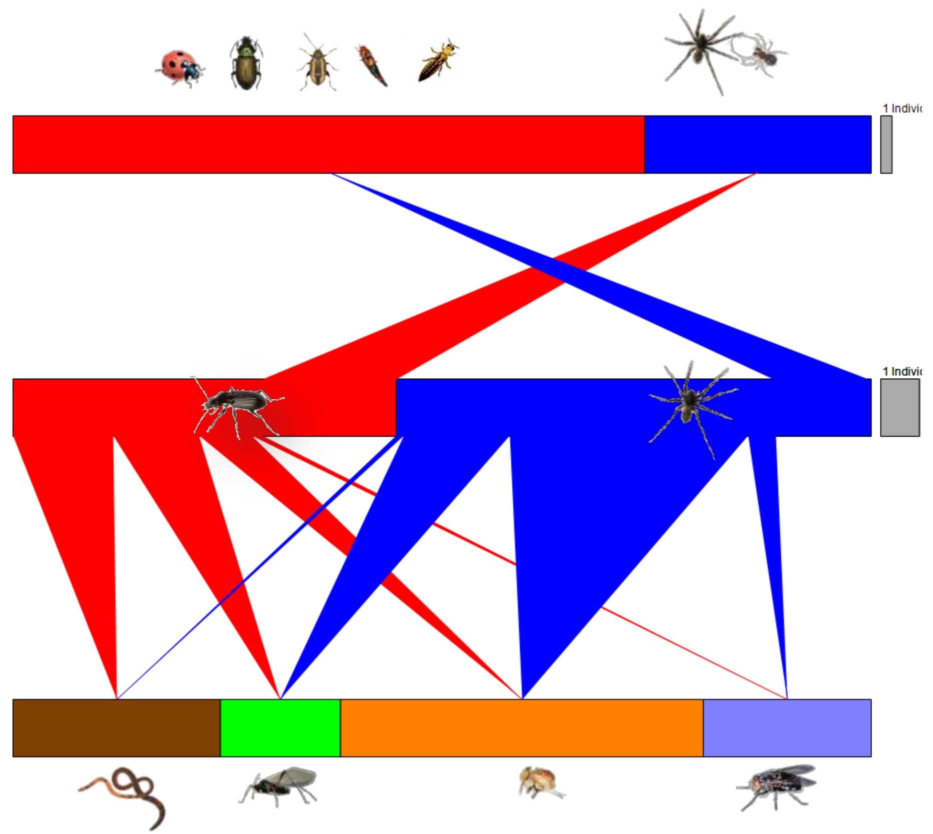


Comparing foodwebs

Conventional



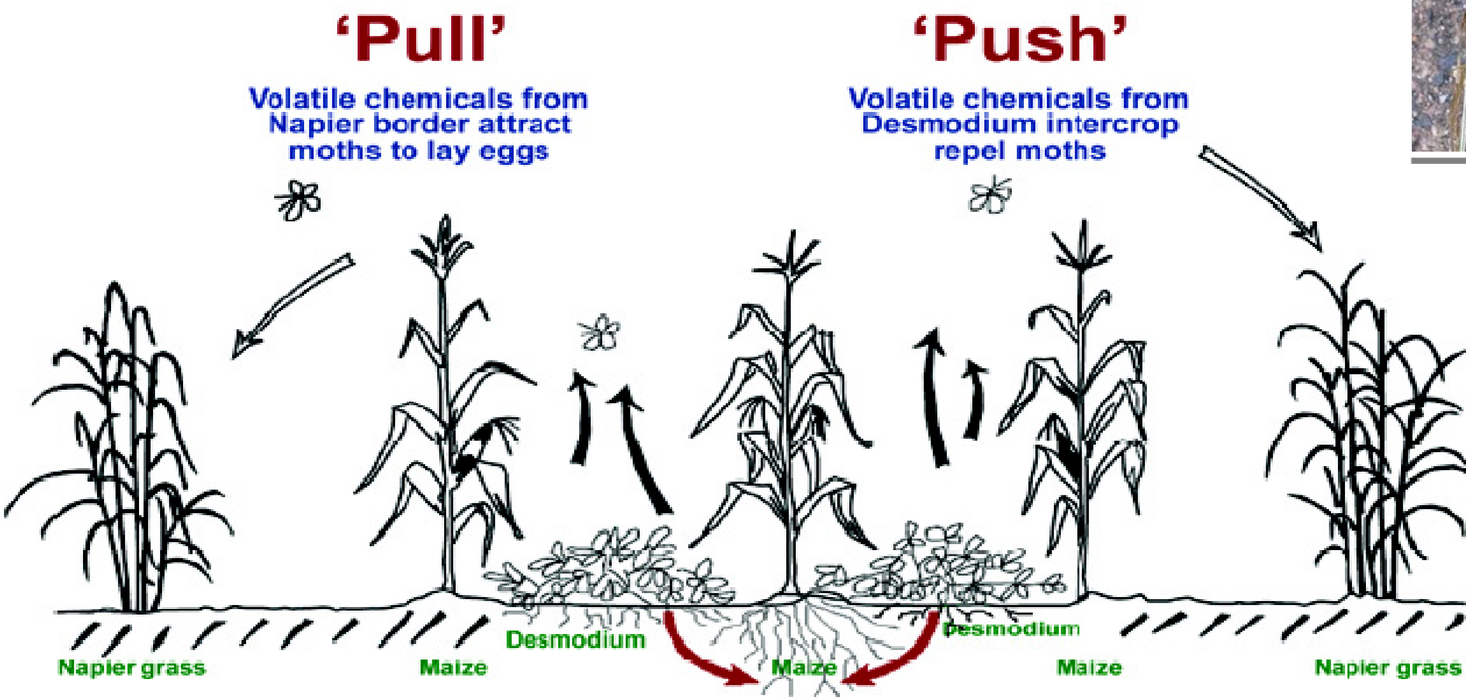
Organic



Adding the ’right’ kind of biodiversity

’Push-pull’ – a success story

’Push-pull’ for stemborer and striga control



Chemicals (isoflavones) secreted by desmodium roots inhibit attachment of striga to maize roots and cause suicidal germination of striga seed in soil

Khan et al. 2008. Biol. Control

Effects of ’push-pull’.

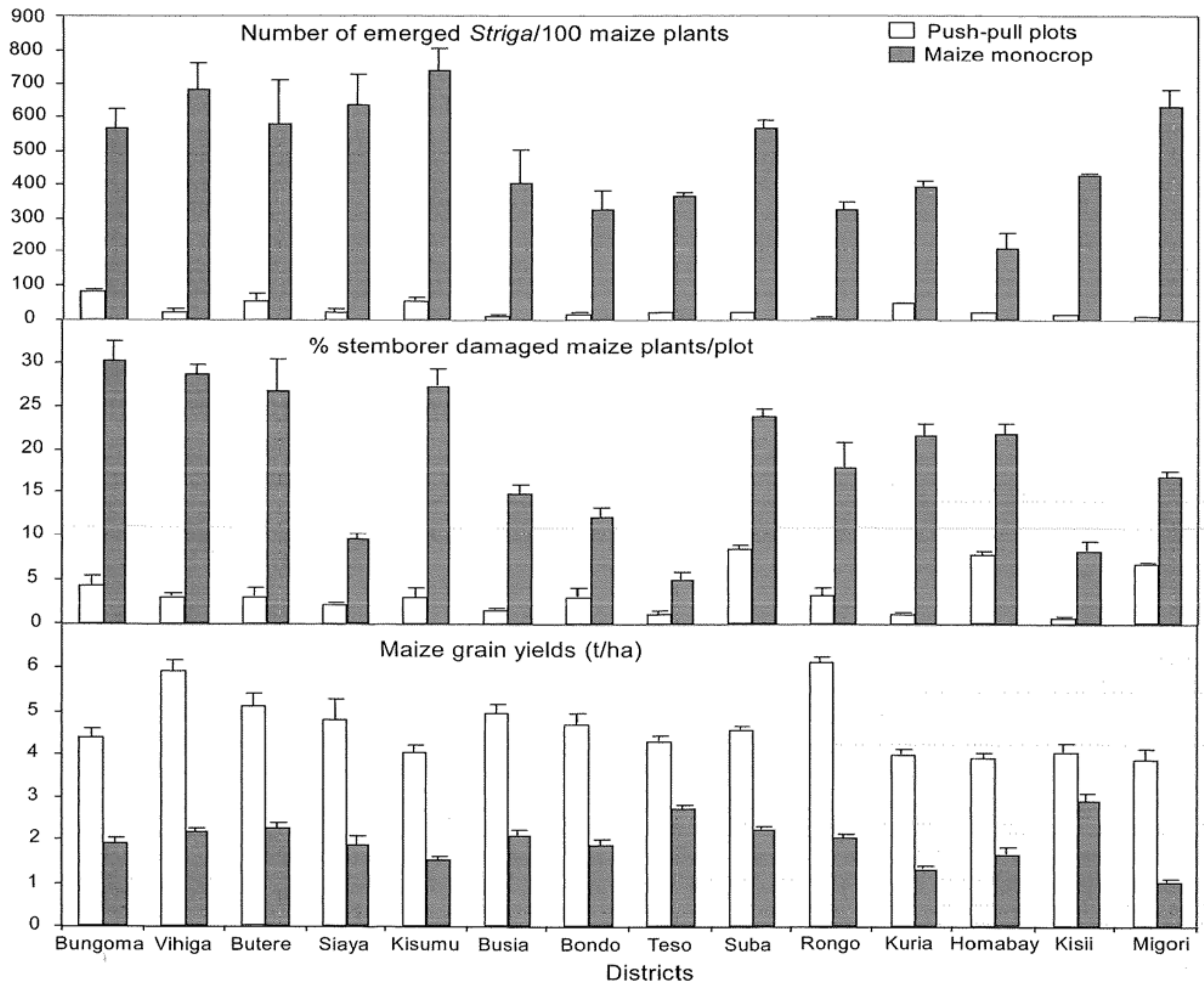


Figure 16.3 Mean number of emerged *Striga hermonthica* per plot, proportion of stemborer-damaged plants per plot, and average maize grain yields (t/ha) from maize monocrop and push–pull plots in different districts in western Kenya. Means represent data averages from 30 farmers' fields per district over two cropping seasons (long and short rains 2009). In all districts, mean number of *S. hermonthica* emerged per 100 maize plants and percent stemborer damaged maize plants were significantly higher in the maize monocrop than push–pull plots while maize grain yields were significantly higher in the push–pull plots ($p < 0.0001$).

Adoption of 'push-pull'

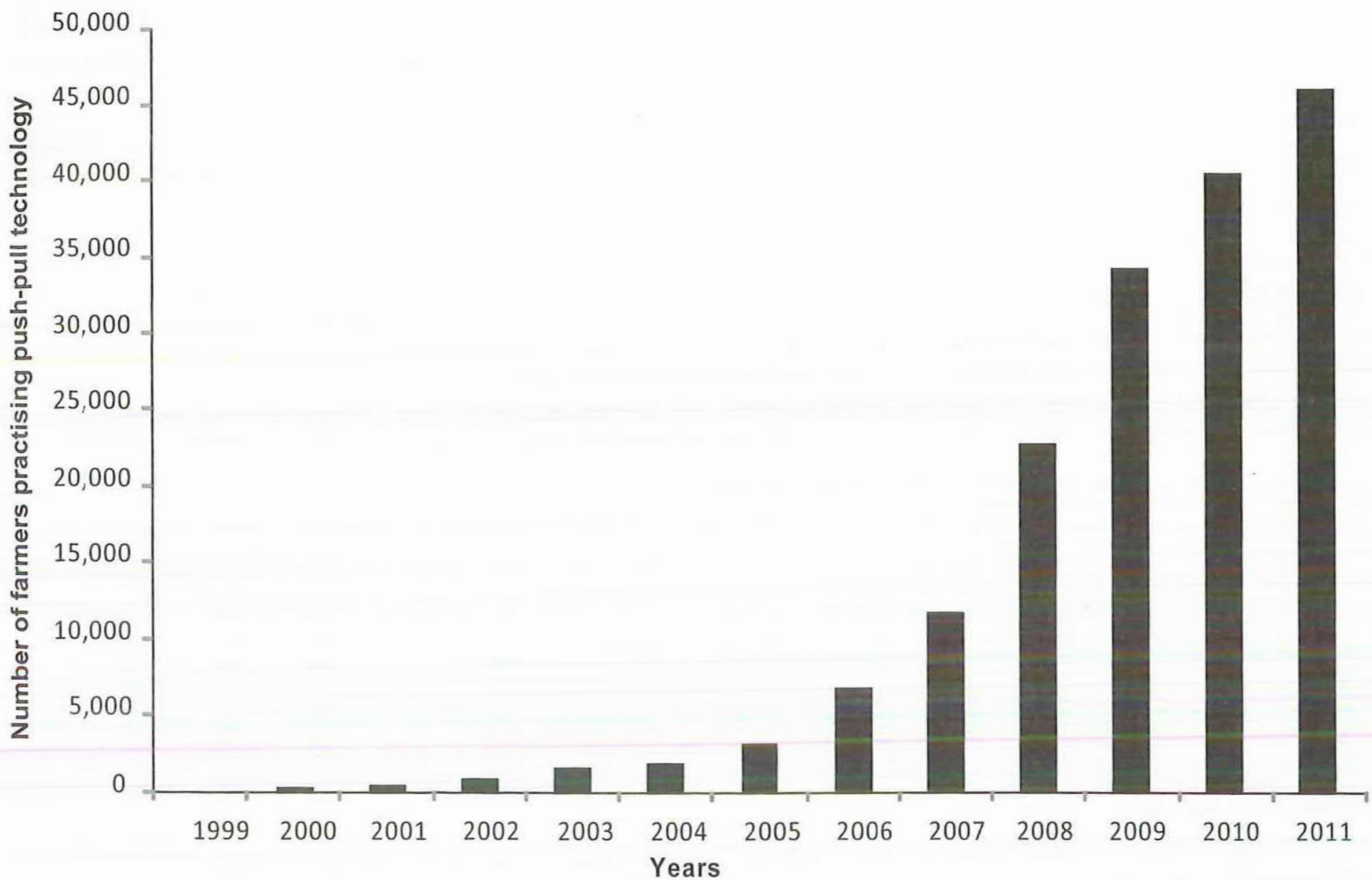


Figure 16.4 Number of farmers who have progressively adopted the push–pull technology from 1997 to June 2011 in East Africa (1997–2011).

Summary

1. Both local and landscape management influence biological pest control

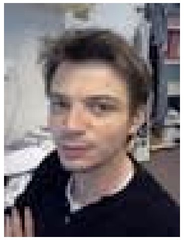
2. Agroforestry increases biodiversity, but effects on pest control are variable

3. A good understanding of food-web interactions and species biology allows selecting the ’right’ biodiversity in habitat management

SLU

Acknowledgements











biodiversa

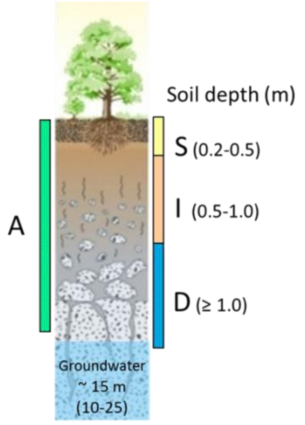
formas

Forskningsrådet Formas

SLU

Bio-Protection

Unraveling plant resource use strategies in dry tropical agroforestry ecosystems (AFs) using stable isotopic signal



Central America

Sahel - West Africa

Cristina Armas (EEZA-CSIC), F. Casanoves (CATIE), J. S. Diémé (EEZA-CSIC & ISRA), M. Diouf (ISRA), D. Fall (ISRA), I. Prieto (EEZA-CSIC) L. Rocha (NINA), D. Sánchez (CATIE), J. I. Querejeta (CEBAS-CSIC), F. A. DeClerck (CATIE), F. I. Pugnaire (EEZA-CSIC) & G. M. Rusch (NINA)

Plant resource use strategies in dry tropical AFs

- Water limited habitats: heterogeneous conditions and pulsed resource availability
- Plant responses are strongly influenced by their water use strategies.
- Coexisting plant species may adopt contrasting resource use strategies through differences in key traits.

FUNCiTREE goal: Portfolio of tree species whose functional, cultural, ecological, and production traits are known, taking into consideration traits related to **drought tolerance and water use efficiency**.

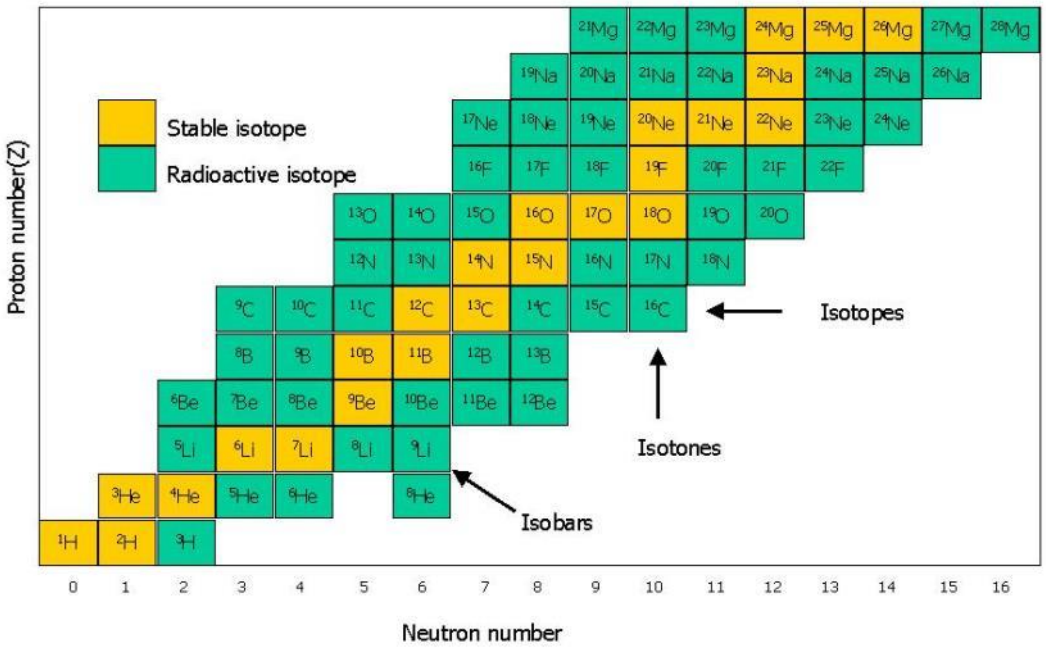
Analysis of **stable isotopic composition** of xylem water and leaf tissues of AFs species coupled with soil /possible water sources. Insights on plant water sources and resource use efficiency.

Jacobsen et al. (2008), Moreno-Gutiérrez et al (2012), West et al. (2012)

Stable isotopes

Isotopes: atoms of the <u>same element</u> that have the same number of protons and electrons but <u>differ in the number of neutrons</u>. They have the same atomic number but <u>different mass</u> number (protons + neutrons)

Stable isotopes: their nuclei do not decay by spitting out radiation



Abundance (%)	
^{16}O ~ 99.76	^{18}O ~ 0.20
^{1}H ~ 99.98	^{2}H ~ 0.01
^{12}C ~ 98.98	^{13}C ~ 1.11
^{14}N ~ 99.63	^{15}N ~ 0.36

http://isesecol.blogspot.com.es/p/isotopos.html

Natural abundance. Isotope composition (δ): per thousand (‰) deviation in the proportion of the heavy to light isotope of an element (R_{sample}) relative to an international reference standard ($R_{standard}$)

$$\delta^{XX}E = 1000 \cdot \left(\frac{R_{sample}}{R_{standard}} - 1 \right), ‰$$

$$R = \frac{^{18}O}{^{16}O}$$

R denotes the ratio of the heavy to light isotope (e. g., $^{2}H/^{1}H$; $^{18}O/^{16}O$)

e.g. $\delta^{18}O$ of groundwater in:

Rivas = -7.03 ± 0.36 (-7.85 to -6.49)

Potou = -4.42 ± 0.36 (-5.60 to -1.10)

Dawson et al. (2002)

Isotopes analyzed in FUNCiTREE

Isotope signature	Material	Related to
$\delta^{18}O$ and $\delta^{2}H$ of H_2O	Stem, soil, well water & rain	Plant water sources
$\delta^{13}C$	Leaf	Plant intrinsic Water Use Efficiency ($\delta^{13}C \sim \frac{c_i}{c_a} \sim WUE_i = \frac{A}{g_s}$) only C_3
$\delta^{18}O$ & $\Delta^{18}O$	Leaf	Stomatal conductance ($\Delta^{18}O \sim \frac{e_a}{e_i} \sim g_s$)
$\delta^{15}N$	Leaf	N sources and N use efficiency

Dawson et al. (2002), Barbour (2007), Querejeta et al. (2006, 2007, 2008), Moreno-Gutiérrez (2011, 2012)

Field sites

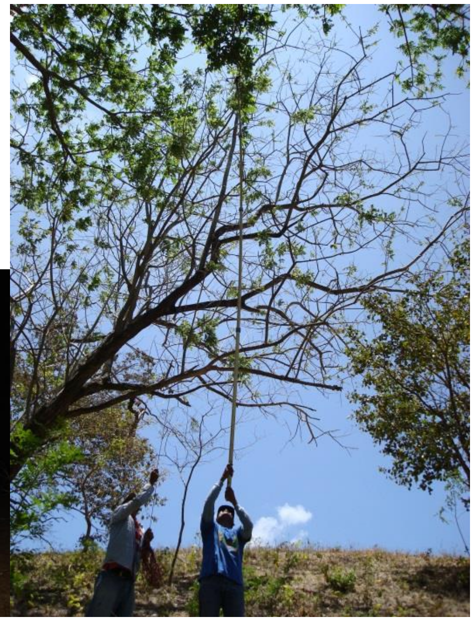
	Rivas (Nicaragua)	Segou (Mali)	Potou (Senegal)
Rainfall (mm)	1300	635	250
Rainy season	May-Oct(Nov)	May-Oct	July-Sep(Oct)
T (ºC)	26.4 (24-30)	27.9 (22-35)	27 (21-32)
Aquifer (depth; m)	10 - 22	1 - ?	1 - 35

~21 species x site; 2 seasons; n = 6 [1-6] trees x species x season

Sánchez and DeClerck (2012)

Sampling

Plants { Leaves ($\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$)
Xylem sap ($\delta^{2}H$, $\delta^{18}O$): stems or roots



Soil water at different depths ($\delta^{2}H$, $\delta^{18}O$)

Water Rain, dew, groundwater or wells ($\delta^{2}H$, $\delta^{18}O$)

Freezer//Oven → SIRFER lab (USA)

cryogenic vacuum extraction line →

Mass Spectrometer →

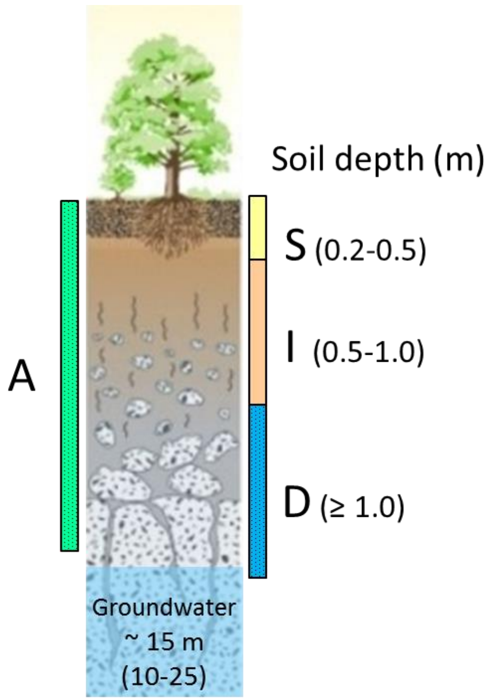
$$\delta = \frac{(R_{sample} - R_{standard})}{R_{standard}} \times 1000 \ [‰]$$

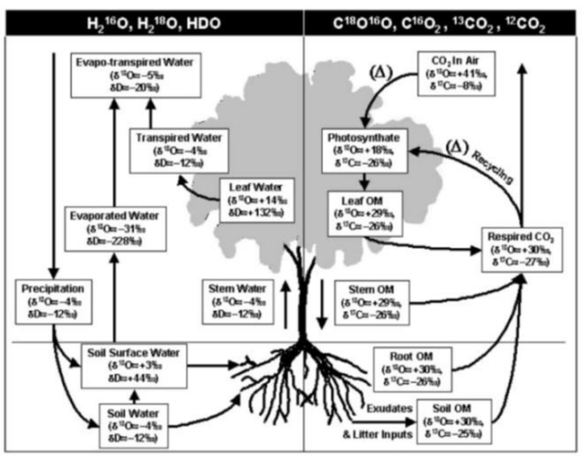
Plant water sources

Assumption: During water uptake plants do not change the isotope signal of source water

Matching the isotipc signature in δ^2H, $\delta^{18}O$ of plants (xylem sap) with:

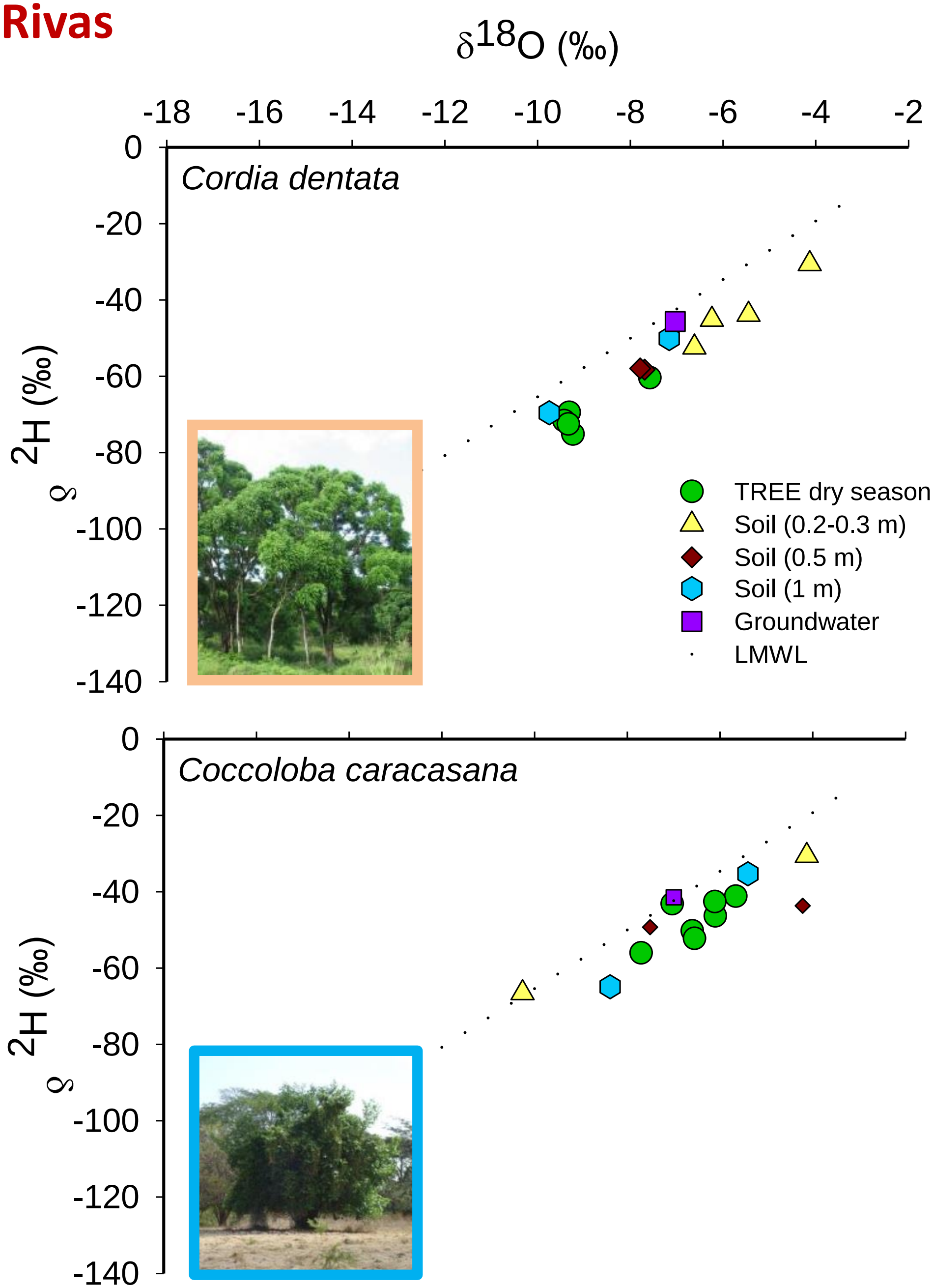
- soil water (different depths: 0.25, 0.5, 1 m)
- other possible water sources (rain and groundwater)

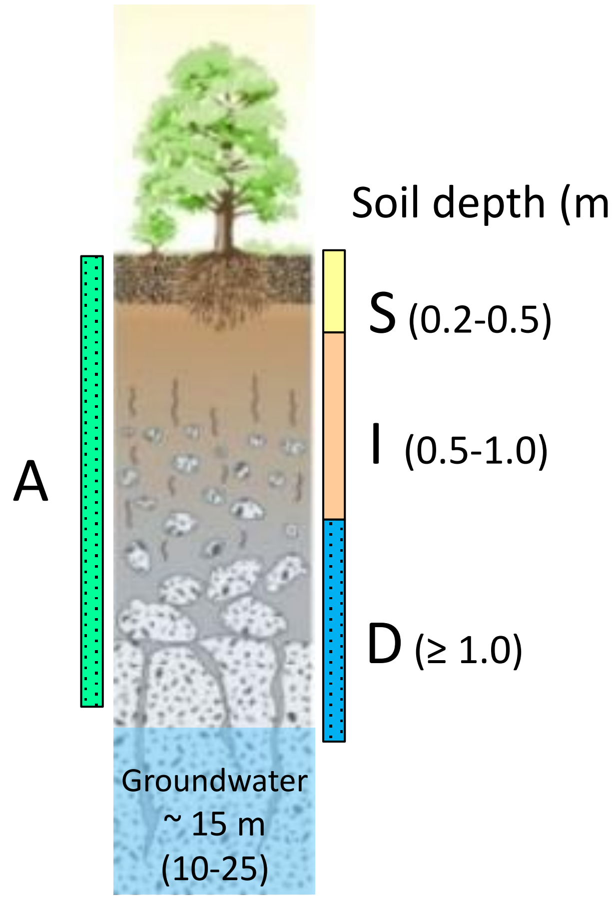




Dawson et al. (2002)

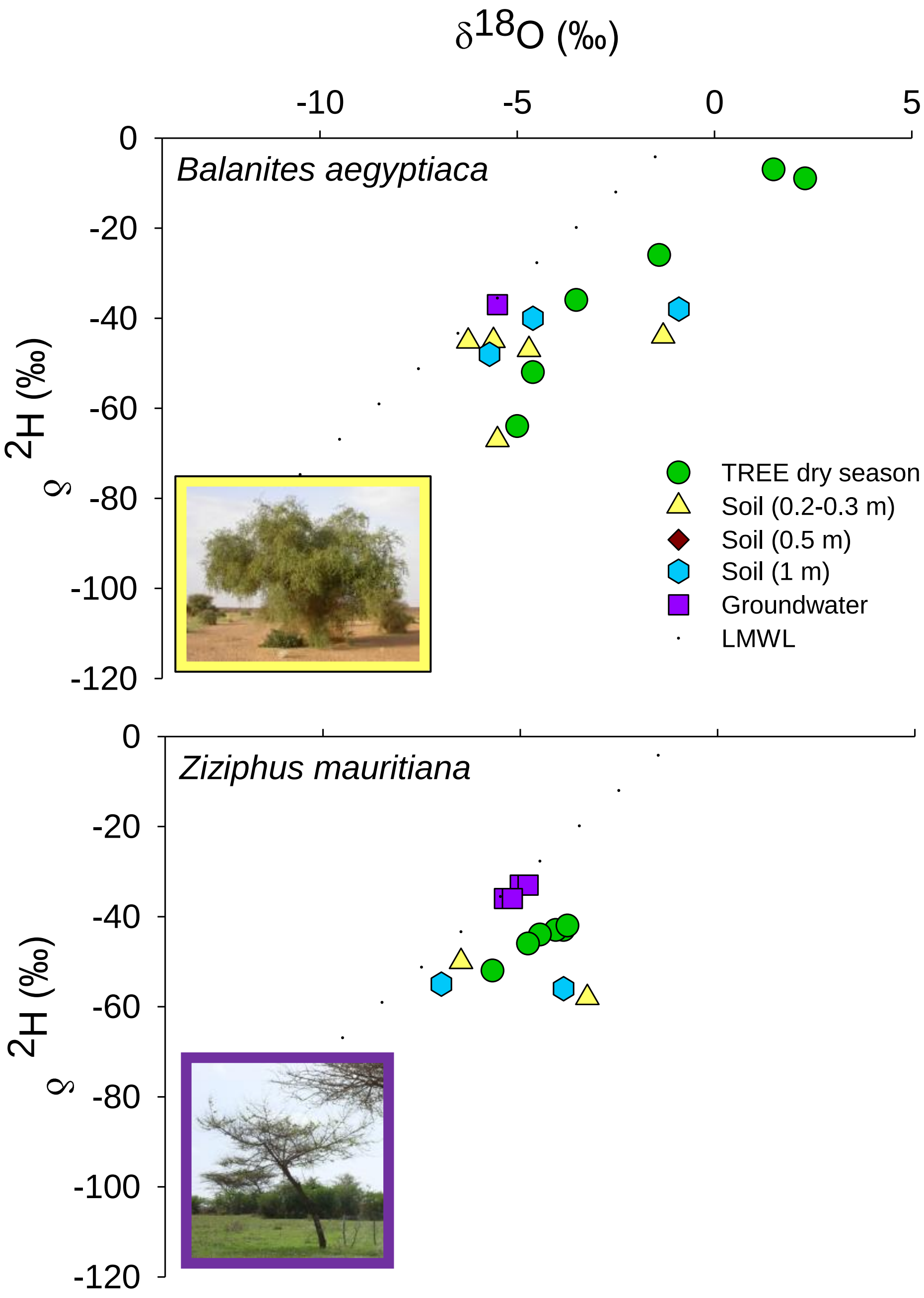
Rivas

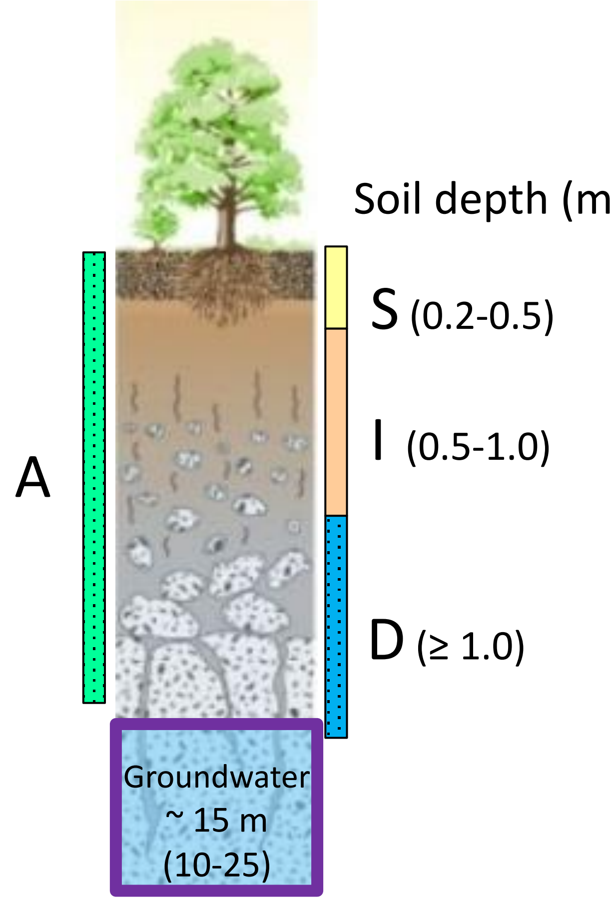




Rivas (Nicaragua)

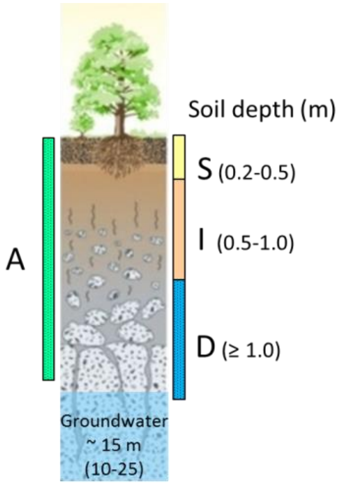
Potou

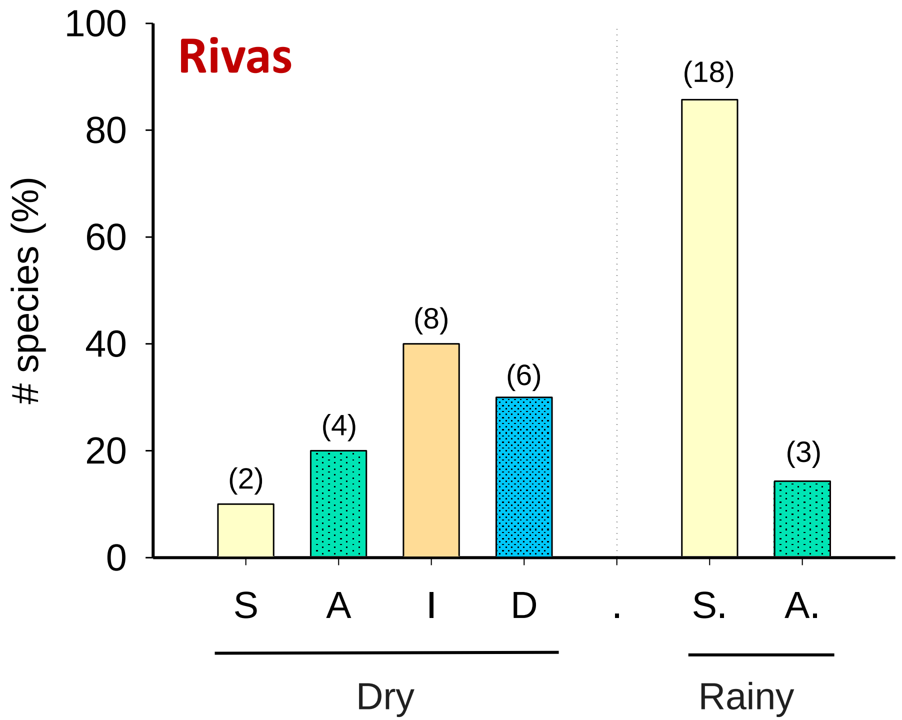




Potou (Senegal)

Water Sources





Dry season

S: Karwinskia calderonii, Spondias purpurea

I: *Byrsonima crassifolia, Cordia alliodora, C. dentata, Guazuma ulmifolia, Simarouba amara, Spondias mombin, Swietenia humilis, Tabebuia rosea*

A: *Albizia saman, Cassia grandis, Crescentia alata, Gliricidia sepium*

D: *Albizia niopoides, Ceiba pentandra, Coccoloba caracasana, Enterolobium cyclocarpum, Mangifera indica, Myrospermum frutescens*

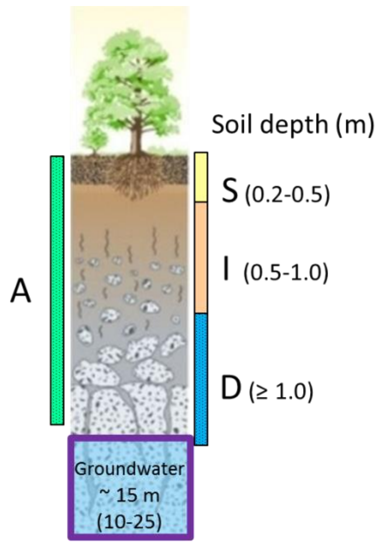
Rainy season

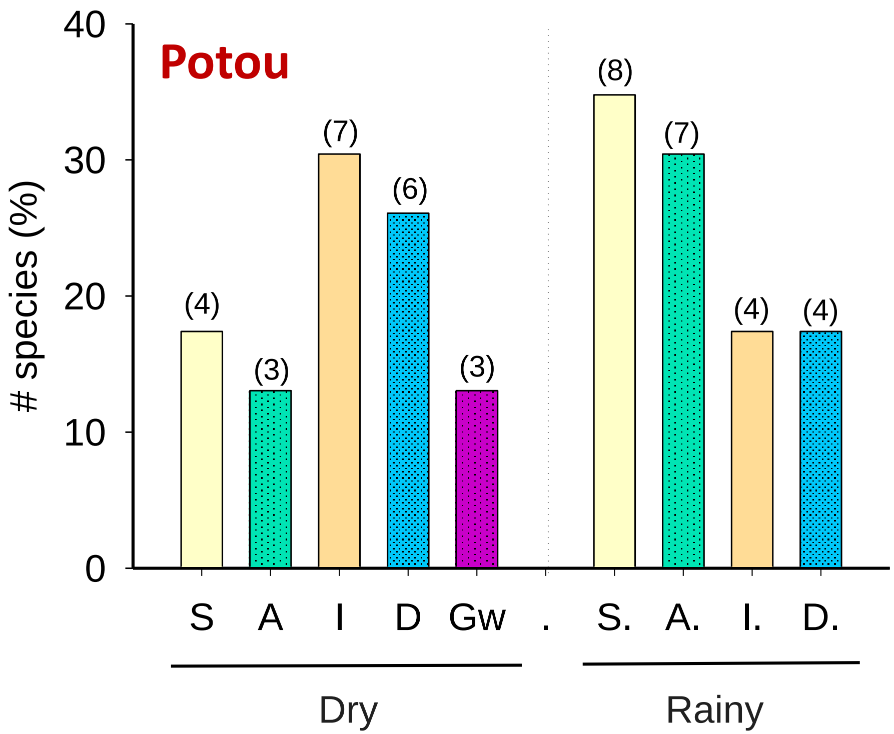
S: All (except sp A)

A: *Ceiba pentandra, Myrospermum frutescens, Spondias mombin*

All species changed water sources between seasons except *Spondias purpurea*

Water Sources





Dry season

S: *Crateva religiosa, Faidherbia albida, Piliostigma reticulatum* (low n)

I: *Acacia seyal, Acacia tortilis, Annona senegalensis, Boscia senegalensis, Combretum glutinosum, Prosopis juliflora, Sclerocarya birrea, Balanites aegyptiaca*

A: *Acacia senegal, Neocarya macrophylla, Tamarindus indica*

D: *Acacia nilotica, Adansonia digitata, Aphania senegalensis, Bauhinia rufescens, Celtis integrifolia, Maytenus senegalensis* (D to Gr)

Gr: *Cordia sinensis, Tamarix senegalensis, Ziziphus mauritiana*

Rainy season: 65% sp changed water sources between seasons.

Common changes (dry to wet)
* Deep to A profile
* Intermediate to surface
* Groundwater to A/D

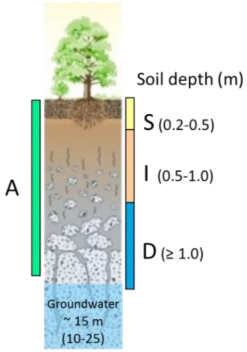
Plant intrinsic water use efficiency (WUE_i)

In C_3 species:

$$\delta^{13}C \sim \frac{c_i}{c_a} \sim WUE_i = \frac{A}{g_s}$$

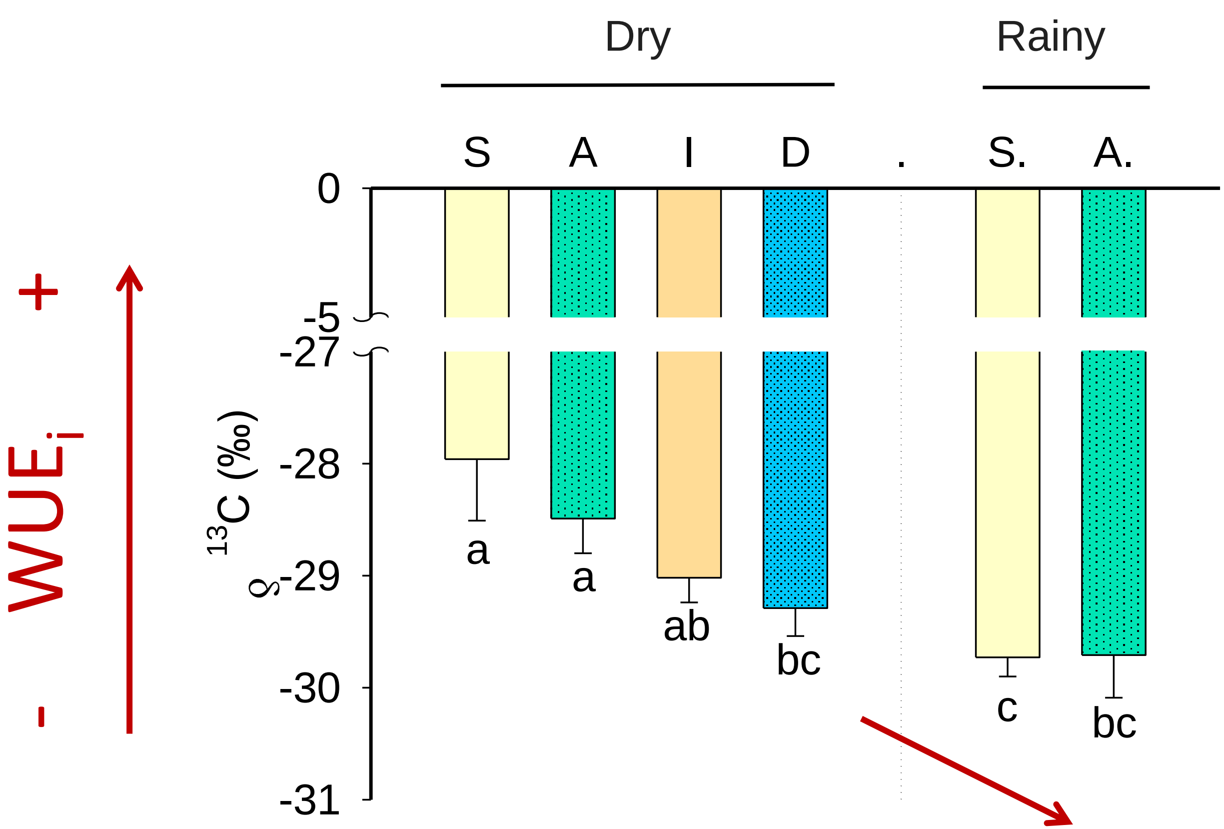
$\sim WUE = \frac{A}{E}$, VPD (~)

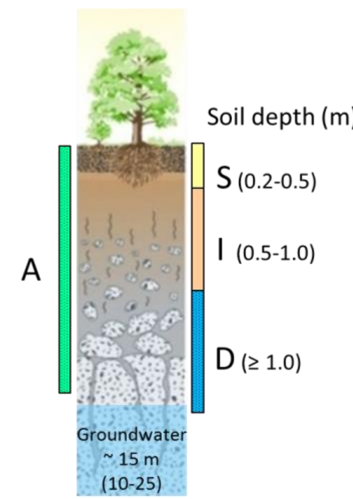
Species WUE_i among seasons, water uptake strategies and leaf phenology



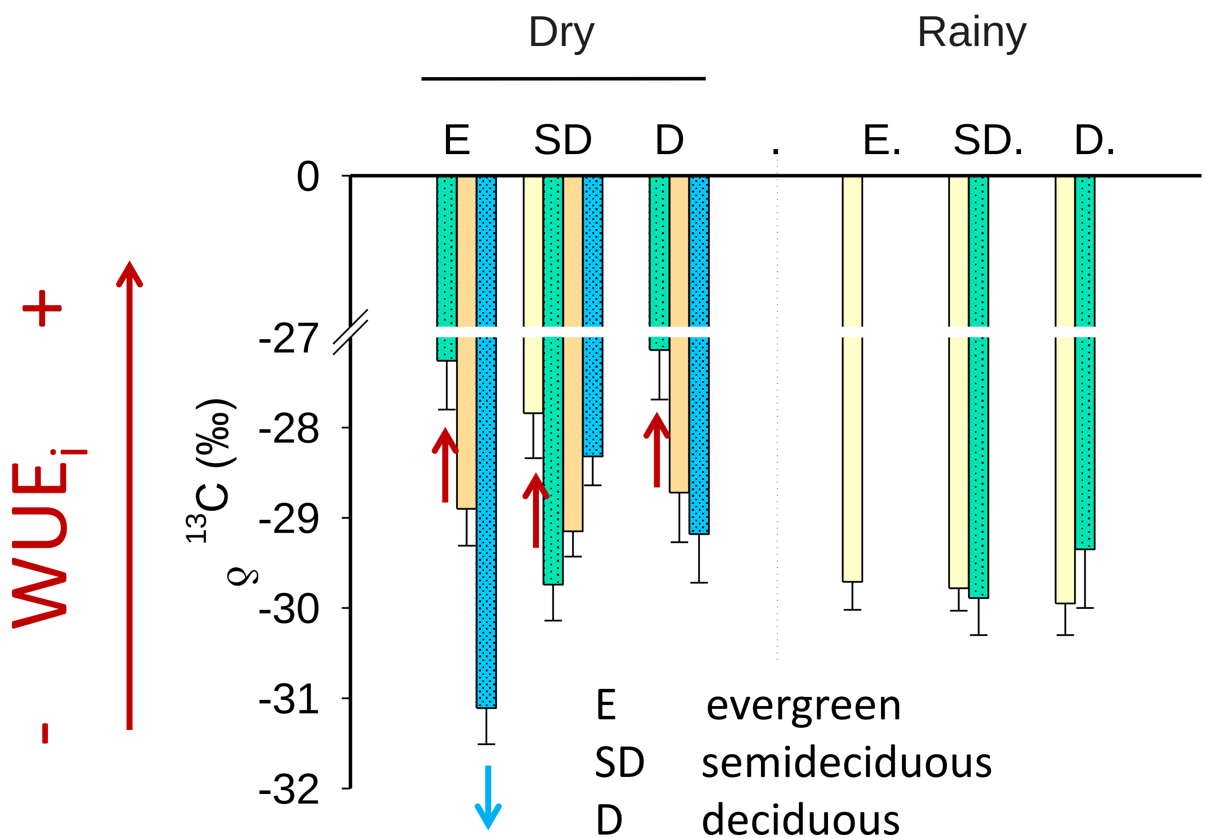
Farquhar et al. (1989), Dawson et al. (2002), Klein et al. (2005)

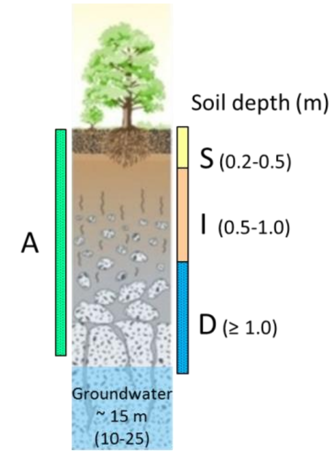
Rivas - Nicaragua





Rivas





Lowest WUE = evergreen sp. uptaking deep water (*Coccoloba caracasana, Mangifera indica).* Both changed water sources between seasons (deep to superficial)

Highest WUE = No clear trend with phenology. *Gliricidia sepium* (D) & *Crescentia alata* (E); *Enterolobium cyclocarpum* (E), *Spondias purpurea, Swietenia macrophylla* (SD).

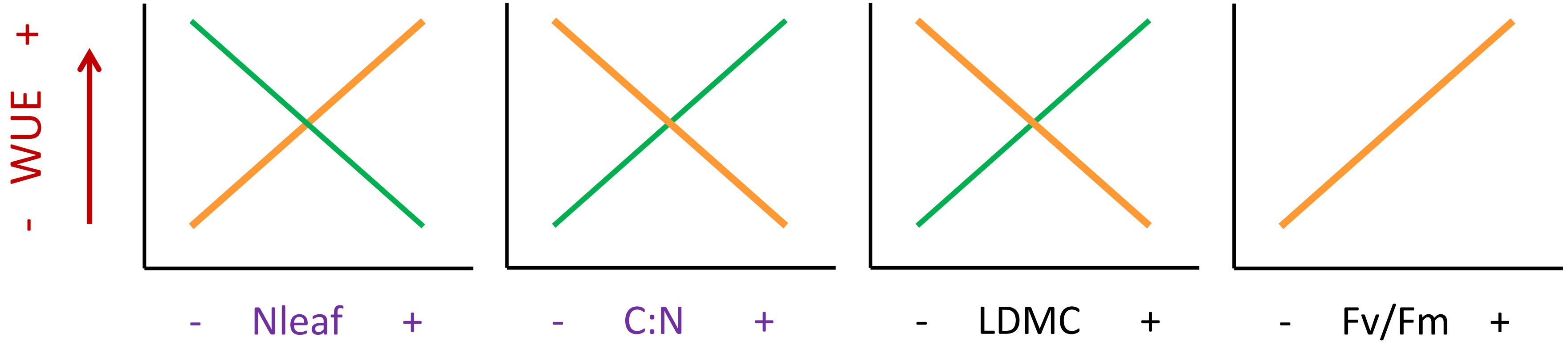
WUE *vs.* other plant physiological responses

Rivas

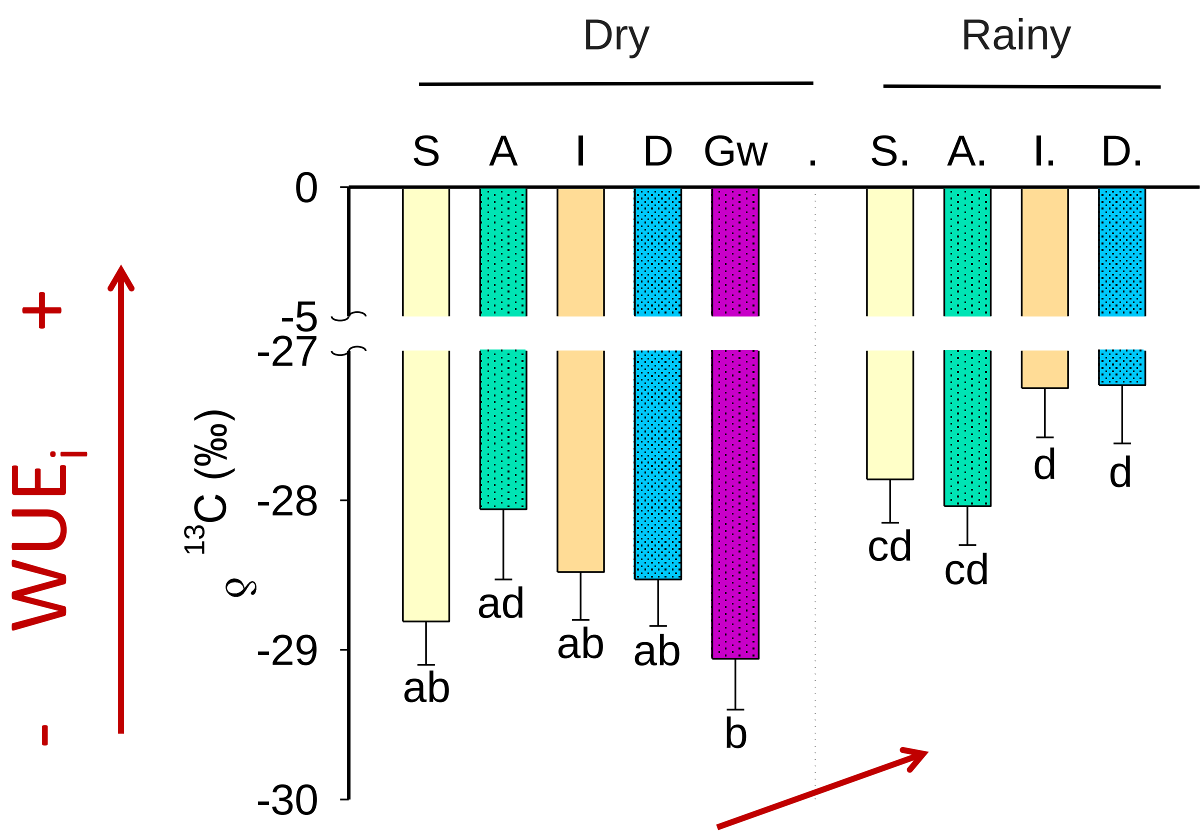
Dry

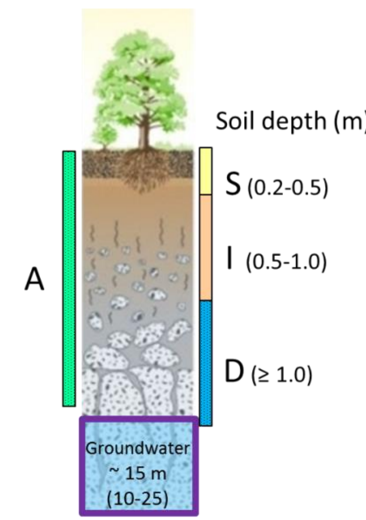
vs

Rainy

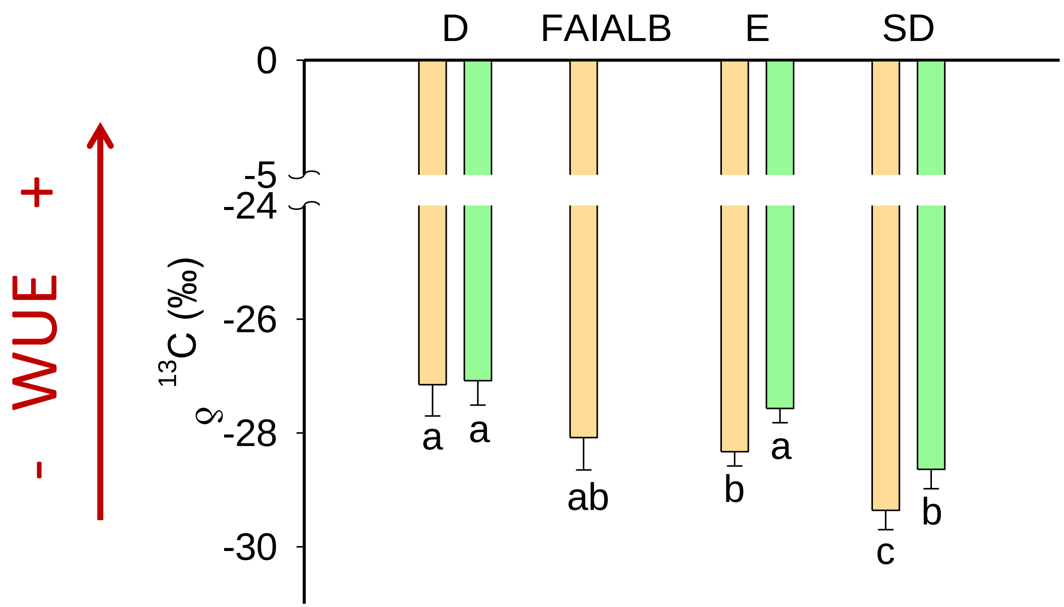


WUE$_i$ in Potou (Senegal)





Potou

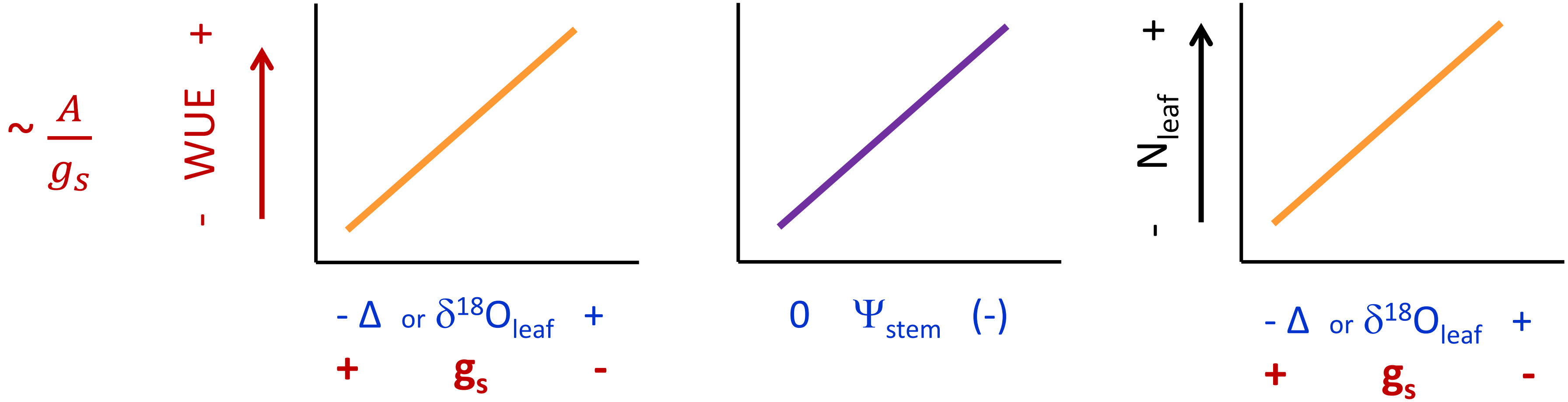


D deciduous
E evergreen
FAIALB *Faidherbia albida*
SD semideciduous

WUE *vs.* other water related responses

$$\Delta^{18}O = \delta^{18}O_{leaf} - \delta^{18}O_{source\ water\ (stem)}$$

$$\Delta^{18}O \sim \frac{e_a}{e_i} \sim g_s \quad \text{(but not} \sim \text{A)}$$



Potou

Barbour (2007), Farquhar et al. (2007) , Moreno-Gutiérrez et al. (2012)

Unraveling water use strategies of trees in dry AFs

- Coexisting woody species in dry AFs displayed contrasting water use strategies.

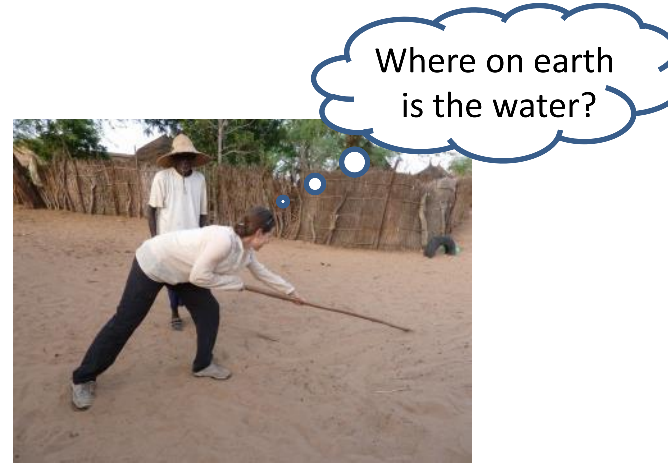
- During dry spells trees mainly relied on soil water stored at intermediate to deep soil profiles, and changed water sources to shallower soil profiles during rainy season.

- Trees WUE was related to their source of water (in Nicaragua). Trees relying on deep or more permanent water sources displayed lowest WUE values while those that had to withstand pulsed resource availability (shallow soils) displayed highest WUE (Nicaragua).

- Increased WUE was mainly controlled by decreasing stomatal conductance (and E) as water availability became more erratic.

- Stable carbon and oxygen isotope compositions ($\delta^{13}C$, $\delta^{18}O$, $\Delta^{18}O$) of coexisting woody species reflect the functional diversity of plant water use strategies in AFs.

FUNCiTREE



CATIE: Dalia Sánchez, Cipriano Rivera, Fabio Guerrero, and Iván Prieto (CSIC), Lester Rocha (NINA)

Moussa Sylla (IER), Graciela Rusch (NINA) and Mayécor Diouf, Dioumacor Fall, Joseph S. Diémé (ISRA/CNRF)

Fernando Casanoves and Fabrice De Clerck (CATIE), Nacho Querejeta (CEBAS-CSIC), Francisco I. Pugnaire (CSIC-EEZA)

AND SOON…….

……. RESULTS FROM SEGOU (IER/CRRA)

……. TO BE CONTINUED

RESPONSE TO DROUGHT OF SAHELIAN TREE SPECIES IN THE NORTHWEST SEMIARID AREA OF SENEGAL

Joseph S. Diémé1*, Mayécor Diouf2, Cristina Armas1, Graciela Rusch3 and Francisco I. Pugnaire1

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2 Centre National de Recherches Forestieres (CNRF)/ISRA - Senegal

3 Norwegian Institute for Nature Research (NINA) – Norway

***Email: josadi@eeza.csic.es**

INTRODUCTION

- ❑ Water is the most limiting ecological resource for most tree
- ❑ Decline soil water content → trees become more stressed and begin to react to resource availability changes
- ❑ Plant attributes and functional traits are related to the environnemental conditions they have to withstand and thus can be used to assess species tolerance to stress

INTRODUCTION

- The utilisation of functional groups is an important method in current ecological research

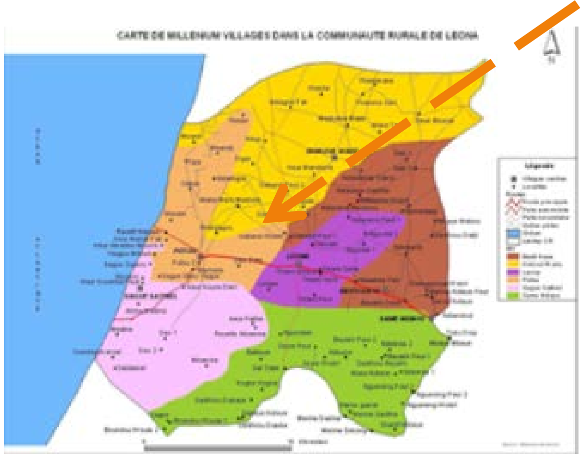
- There has been a large effort to characterise funcional groups with simple robust parameters of structural and functional traits

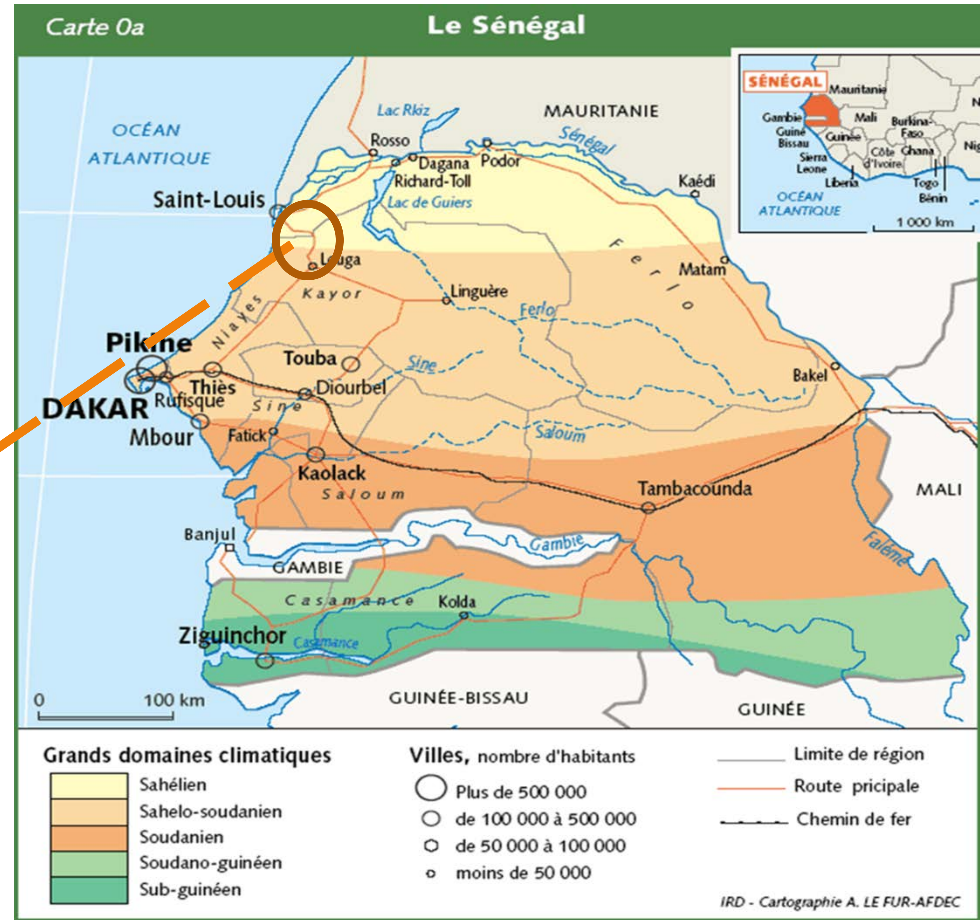
- To evaluate possible impacts of funcional groups on ecosystem water relations, physiological traits that are important for these processes can be characterised

OBJECTIVE

To understand the physiological strategies that developed the woody species regarding soil and climate conditions and classify them into different functional groups

MATERIALS AND METHODS





Measurements

Species (Niayes and Dieri): *Acacia tortilis, Adansonia digitata, Balanites aegyptiaca, Combretum glutinosum, Celtis integrifolia, Faidherbia albida, Neocarya macrophyla, Sclerocarya birrea* and *Tamarindus indica*.

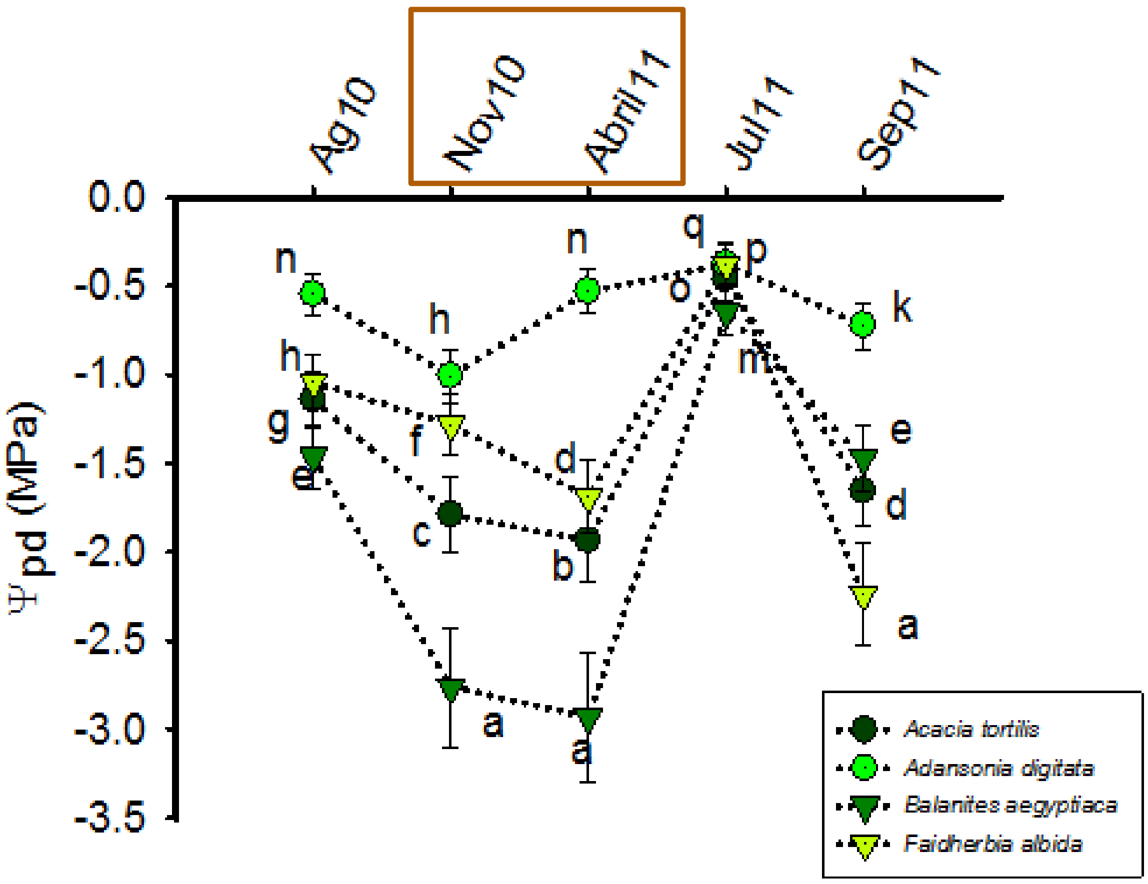
Measures (July 2010 – September 2011)

Functional traits

Relative Water Content (RWC) (%)
Specific Leaf Area (SLA) (m^2/kg)
Leaf Area Index (LAI)
Predawn water potential (MPA)

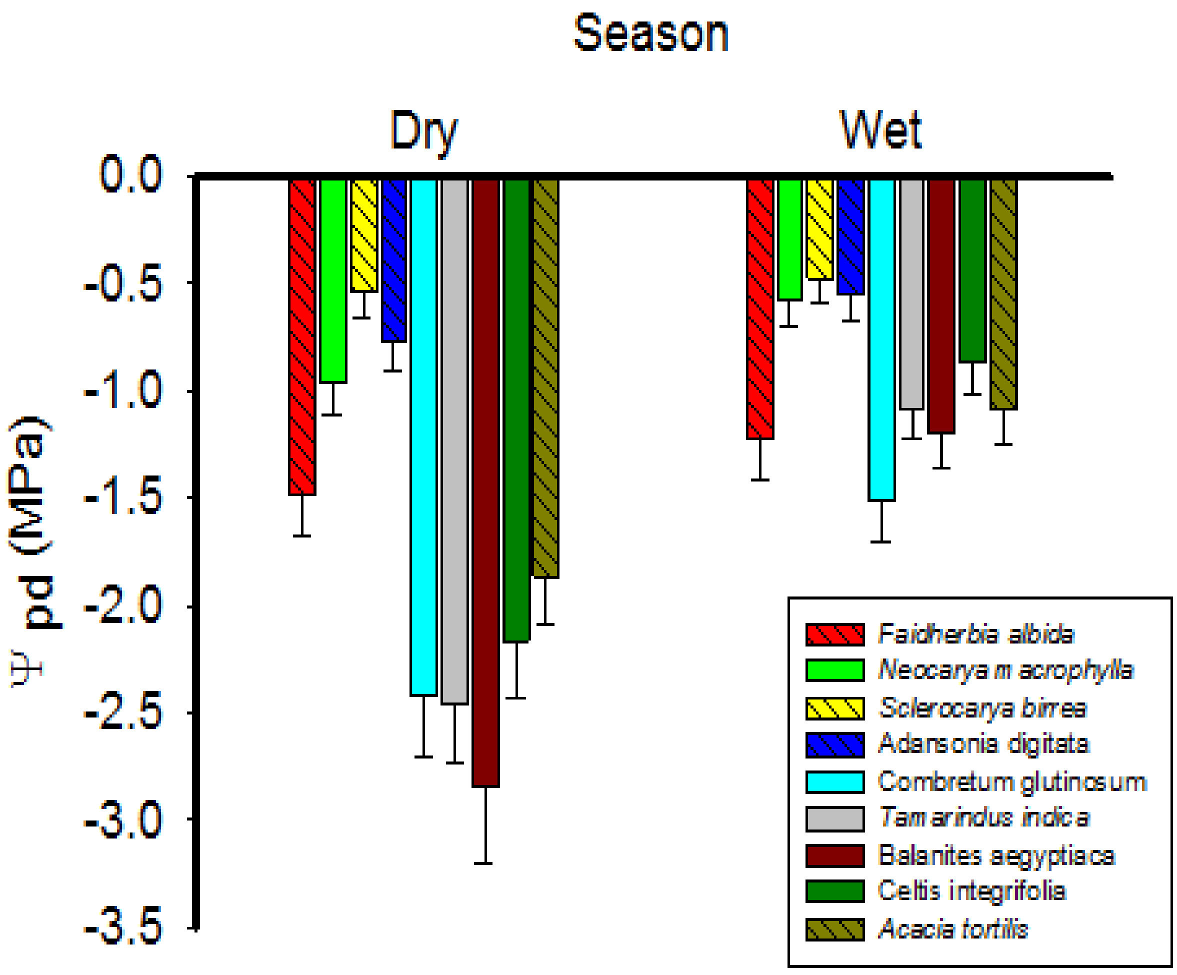
Protocols: Cornelissen *et al.* (2003); Knevel *et al.* 2005

RESULTS (1 / 5)



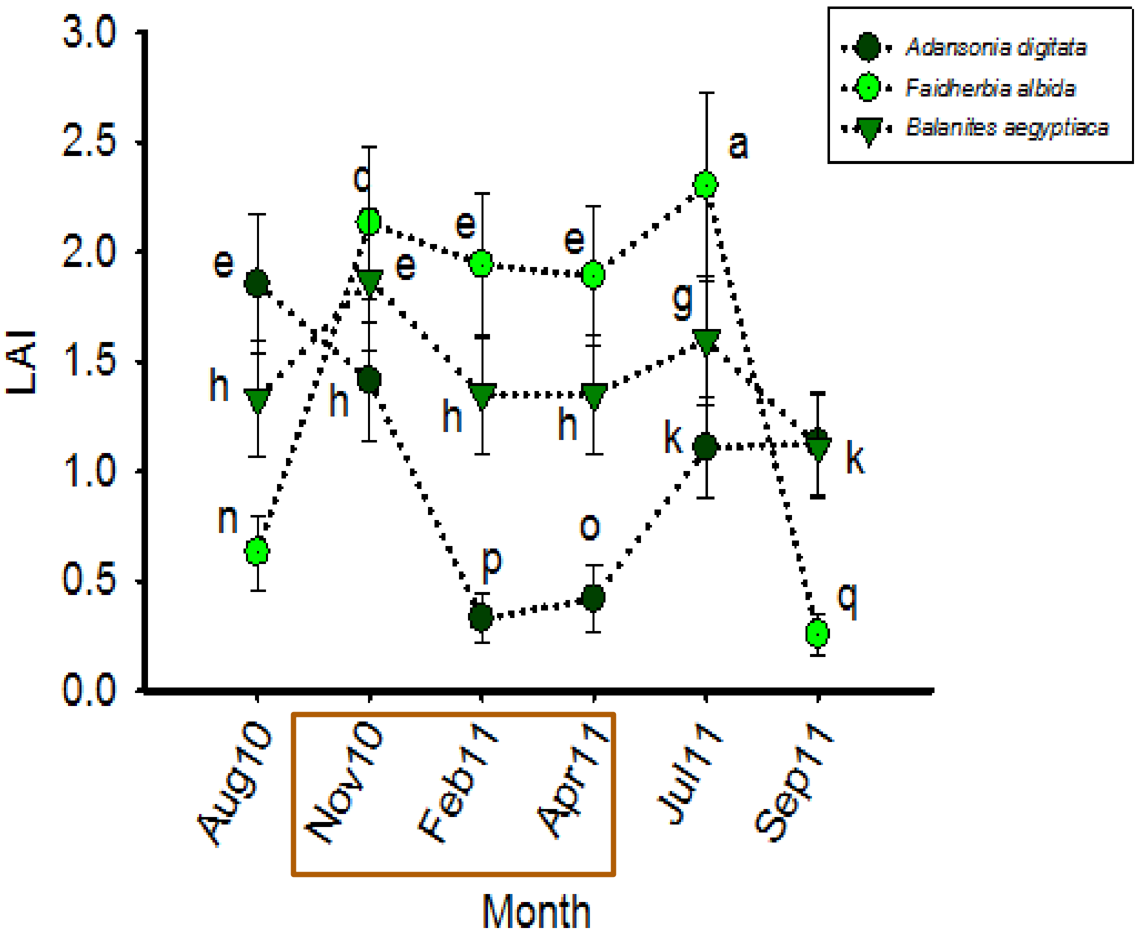
Predawn leaf water potential varied according to the season, being higher in the wet than in the dry season. Species like *Adansonia digitata* showed relatively stable values while *Balanites aegyptiaca* showed strong seasonal changes.

RESULTS (2 / 5)



This behaviour is linked to the phenology, as, *Adansonia digitata* is a drough-deciduous species while *Balanites aegyptiaca* is evergreen. Water potential patterns should also reflect rooting depth of the different species.

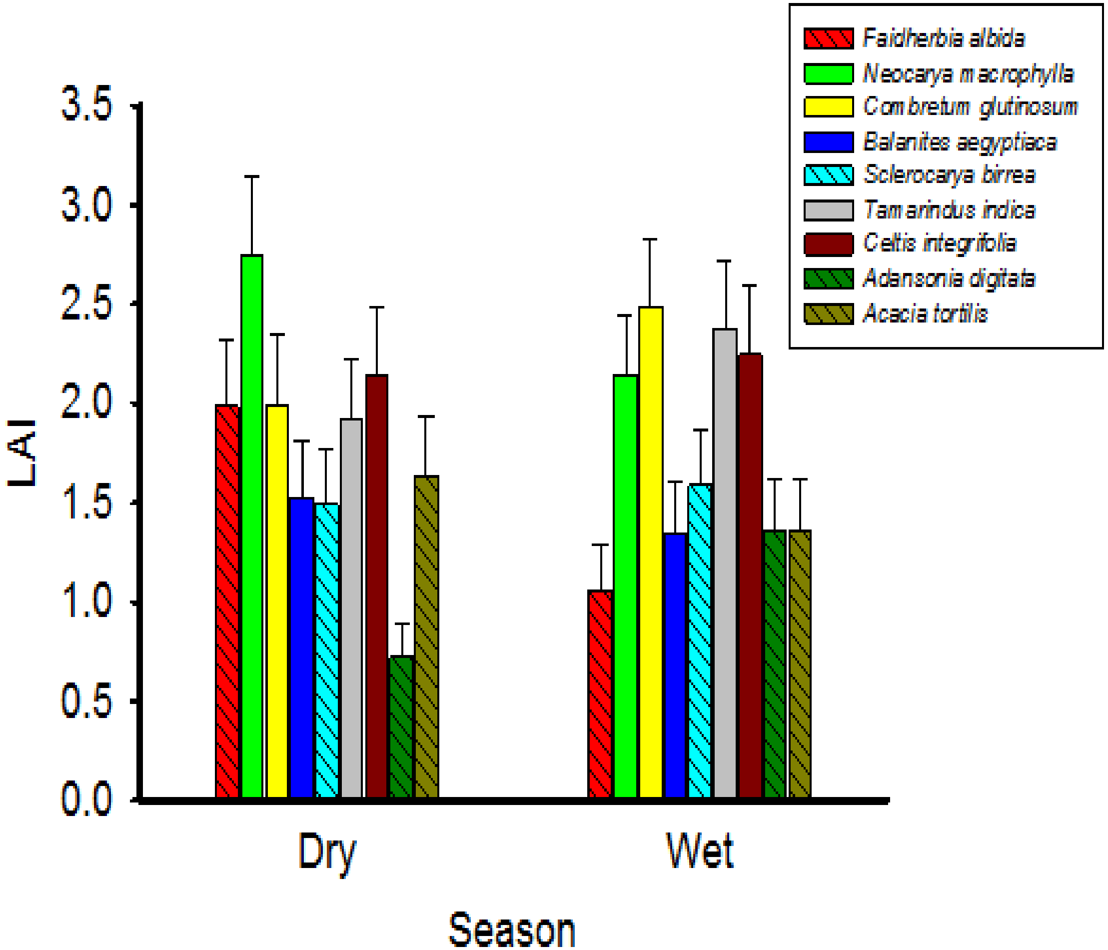
RESULTS (3 / 5)



LAI of dry season deciduous species (e.g., *Adansonia digitata*) was lower than LAI of evergreen species (*Balanites aegyptiaca*) during the dry season.

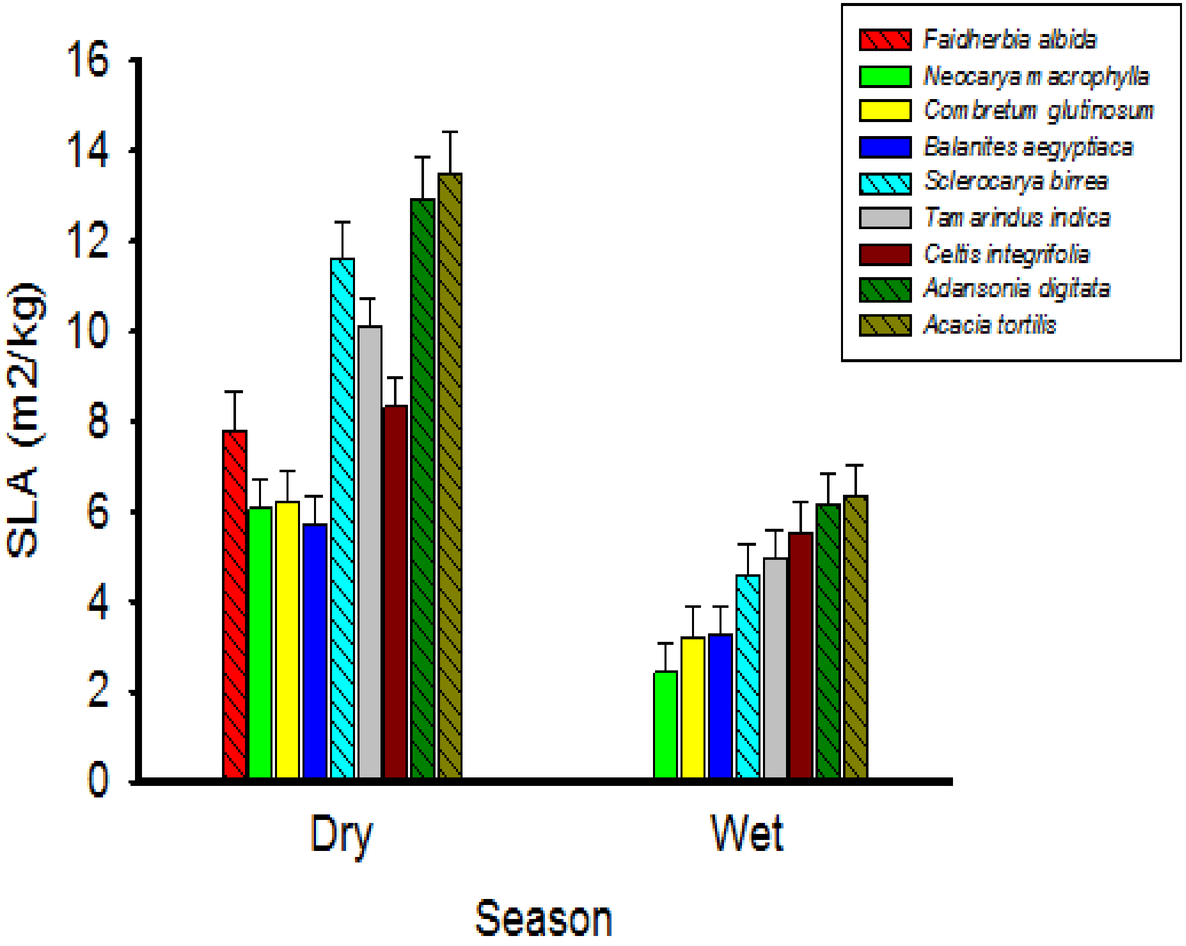
FUNCiTREE

RESULTS (4 / 5)



LAI was below 5 for all species in the two seasons, but was higher in perennial than in deciduous species except for *Balanites aegyptiaca*. Dry season deciduous species had a greater LAI during the wet season and wet season deciduous species (*Faidherbia albida*) had higher LAI in the dry season.

RESULTS (5 / 5)



SLA was larger in the dry season than in the wet season, perhaps because it was measured on newly developed leaves while in the wet season it was measured on leaves developed in the dry season. Overall, SLA was higher in dry season deciduous species.

CONCLUSION

Differences in water relations and behaviour of the different species reflect different strategies depending on the season. Although most species shared similar strategies, there were significant differences among them which will allow us to classify them in different functional groups.


MERCI POUR VOTRE AIMABLE ATTENTION
THANK YOU
DIOKO NDIAL
DIEURE DIEUF
MUCHAS GRACIAS

Responses of agro-forestry species to water availability in seasonally dry climates and their effect on understory vegetation

F.I. Pugnaire[1], C. Armas[1], M. Diouf[2], J.S. Dieme[1], F. Casanoves[3], D. Fall[2] and G.M. Rusch[4]

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2. Institut Sénégalais de Recherches Agricoles (ISRA), Senegal
3. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica
4. Norwegian Institute for Nature Research (NINA), Norway

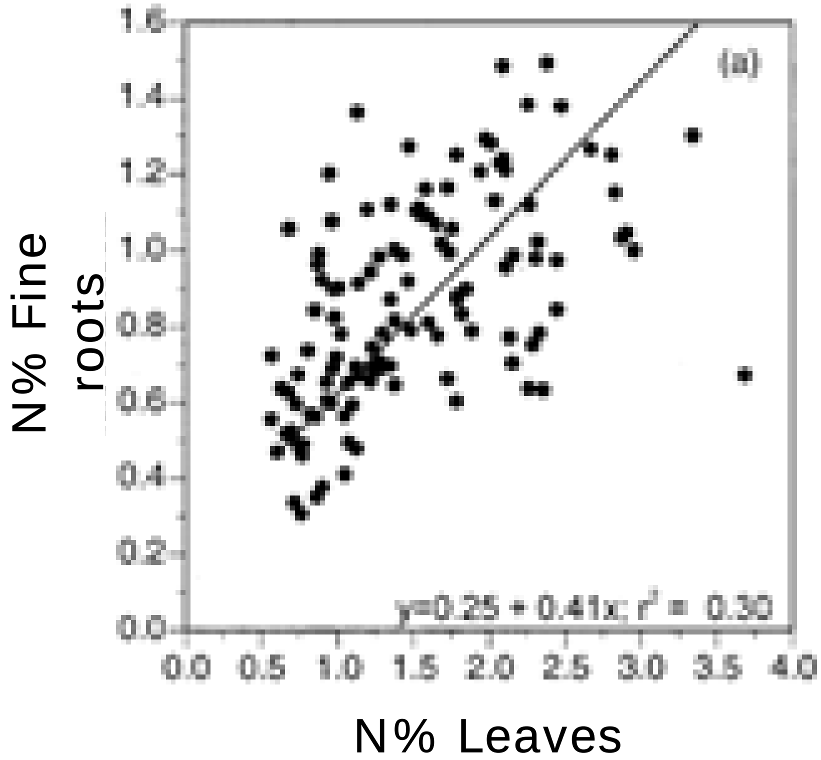
Objective: improve performance of agro-forestry systems

- ❑ Identify tree species suitable for dry and marginal areas

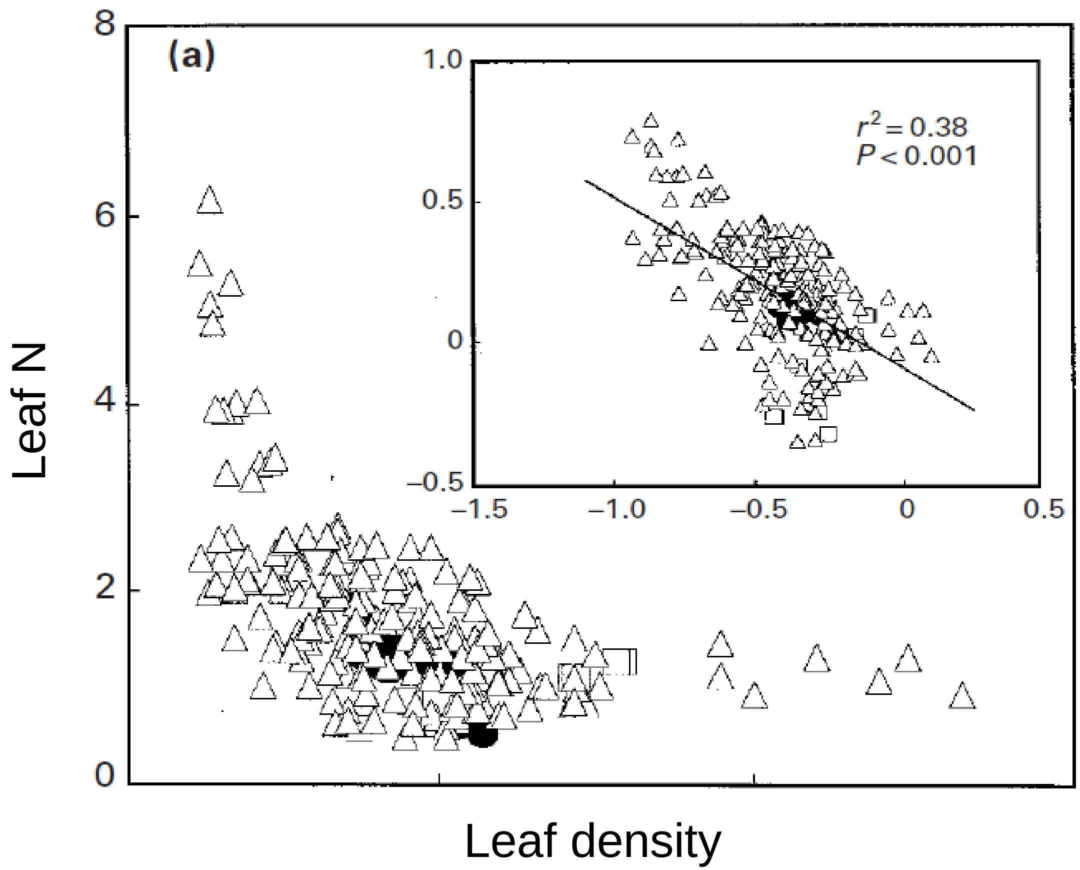
- ❑ Tree responses to drought

    - Adaptations
    - Effects on soil & biological communities
    - Understory vegetation
    - Affected by livestock

There are many relationsips among plant traits



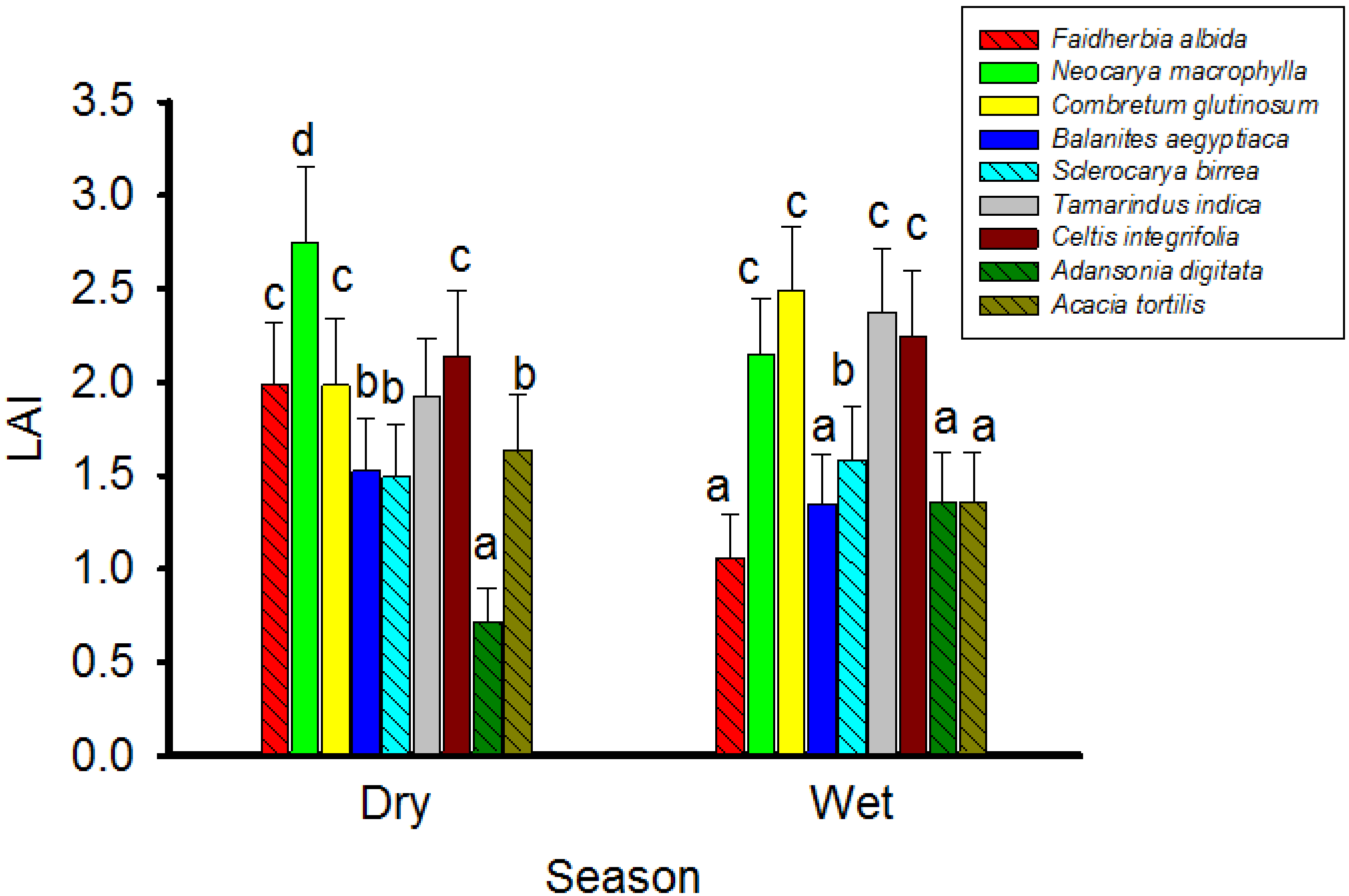
Craine 2008



Niinimets 1999

Expected trait convergence (Kraft et al. 2008)

But relationships are sometimes contradictory and not universal. Niinimets 1999



Contrasting responses to water shortage

- Different strategies

OBJECTIVE

To explore relationships between tree functional traits and understory productivity

FUNCiTREE

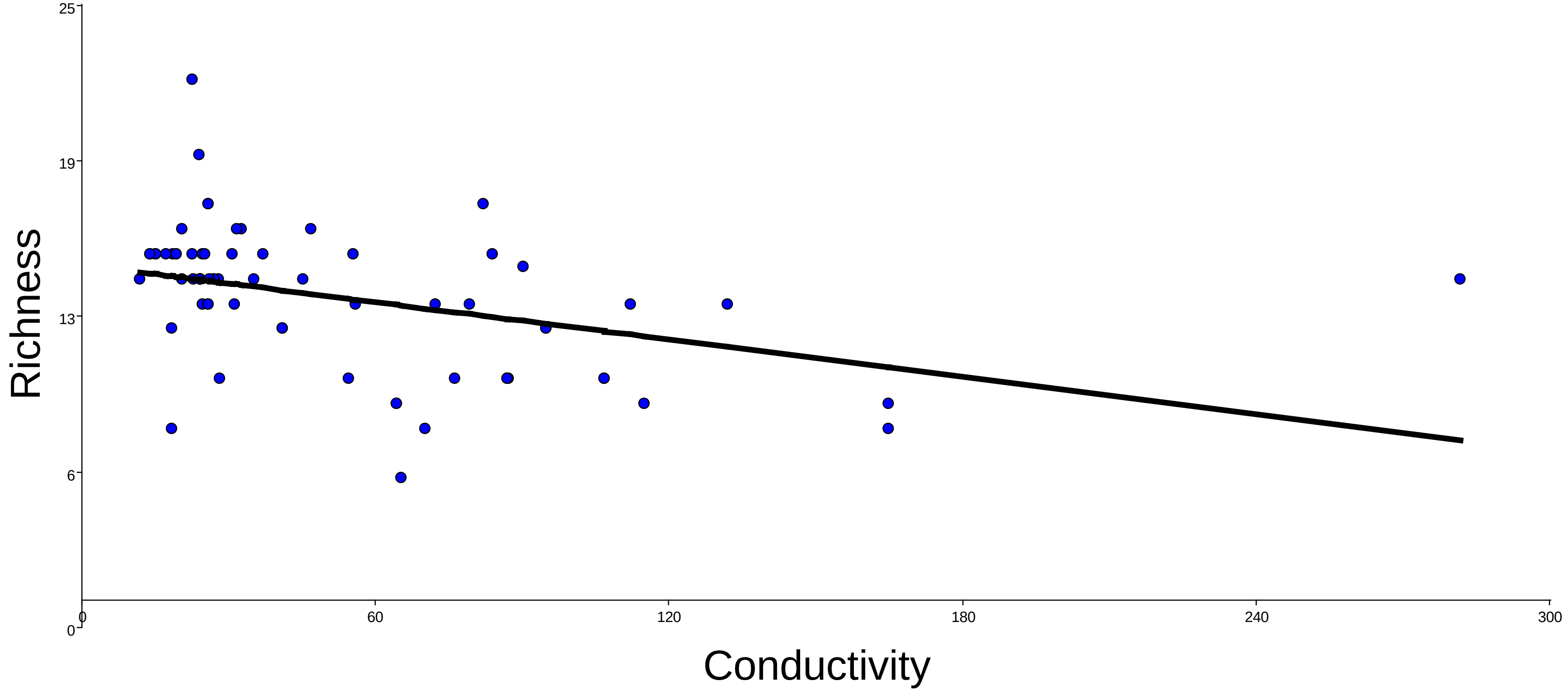
FIELD SITE


Carte 0a
Le Sénégal
OCÉAN ATLANTIQUE
MAURITANIE
Lac Rkiz
Rosso
Dagana
Podor
Richard-Toll
Lac de Guiers
Sénégal
Kaédi
Saint-Louis
Louga
Kayor
Niayes
Linguère
Ferlo
Matam
Pikine
Touba
Thiès
Diourbel
Sine
DAKAR
Rufisque
Mbour
Fatick
Kaolack
Saloum
Bakel
Tambacounda
MALI
Banjul
GAMBIE
Gambie
Falémé
Casamance
Kolda
Ziguinchor
GUINÉE-BISSAU
GUINÉE
0
100 km
SÉNÉGAL
Mauritanie
Gambie
Guiné Bissau
Mali
Guinée
Sierra Leone
Liberia
Burkina-Faso
Côte d'Ivoire
Ghana
Togo
Bénin
OCÉAN ATLANTIQUE
1 000 km
Grands domaines climatiques
Sahélien
Sahelo-soudanien
Soudanien
Soudano-guinéen
Sub-guinéen
Villes, nombre d'habitants
Plus de 500 000
de 100 000 à 500 000
de 50 000 à 100 000
moins de 50 000
Limite de région
Route pricipale
Chemin de fer
IRD - Cartographie A. LE FUR-AFDEC

Significant differences among sites

- species richness
- grass productivity
- nutrient availability
- pH
- soil salinity
- mycorrhizal fungi

The less salinity, the more species

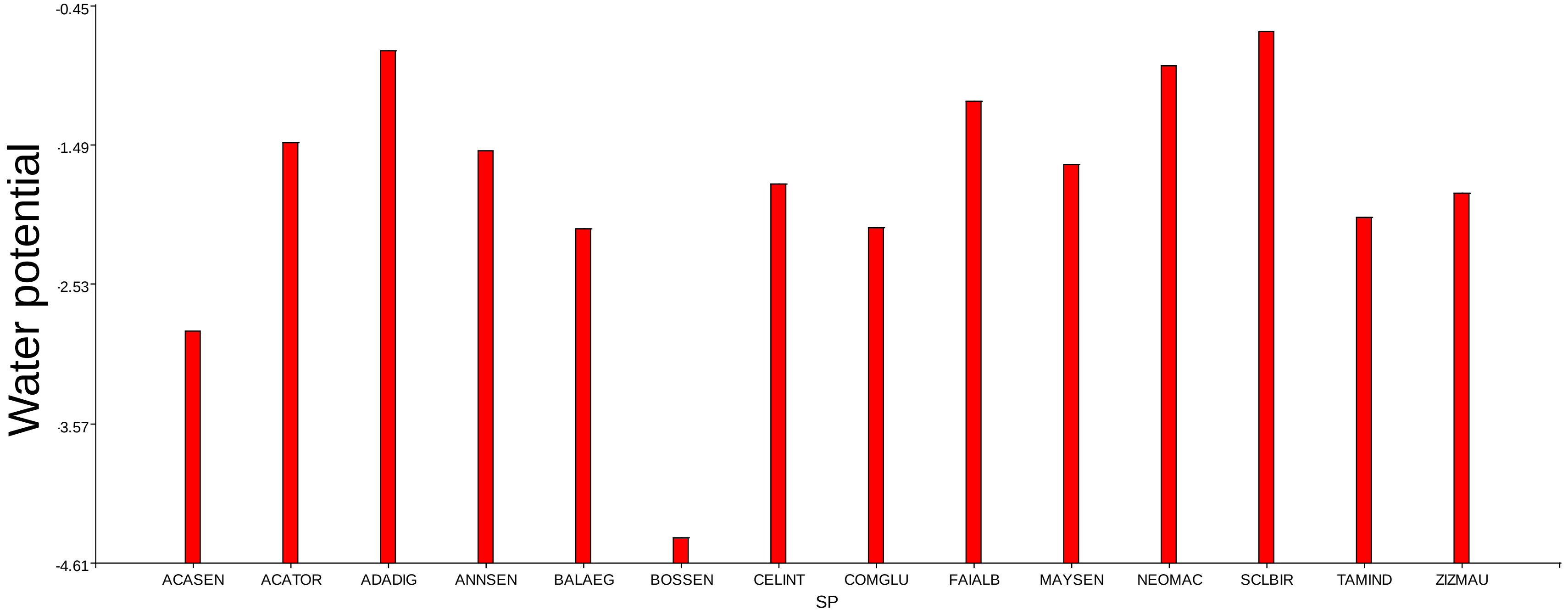


Several physiological traits are associated to tree size

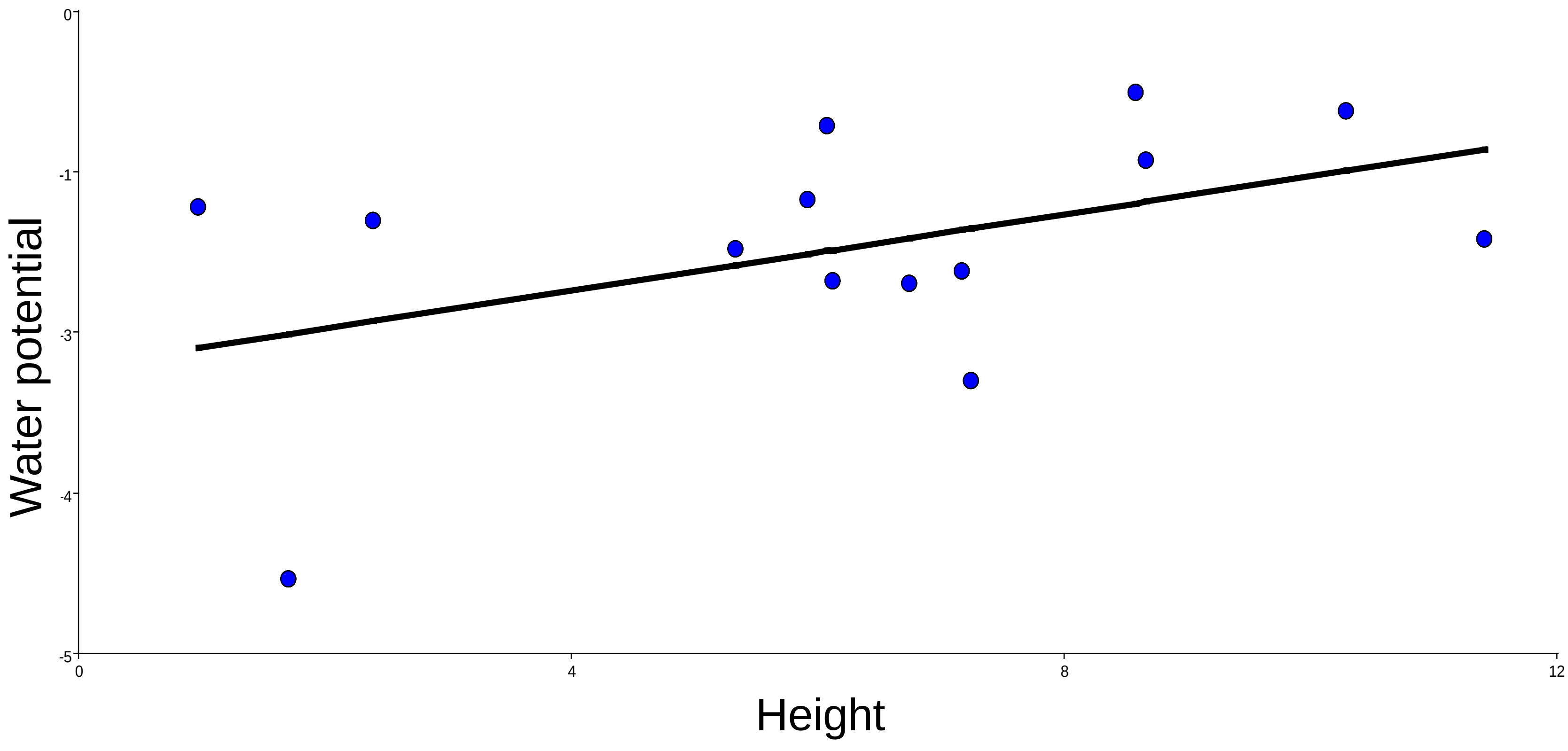
- Ψ_{pd} (in wet and dry seasons)
- SLA
- RWC
- WUE
- and related measurements.

- And $\delta^{15}N$, D_2O, and ^{18}O

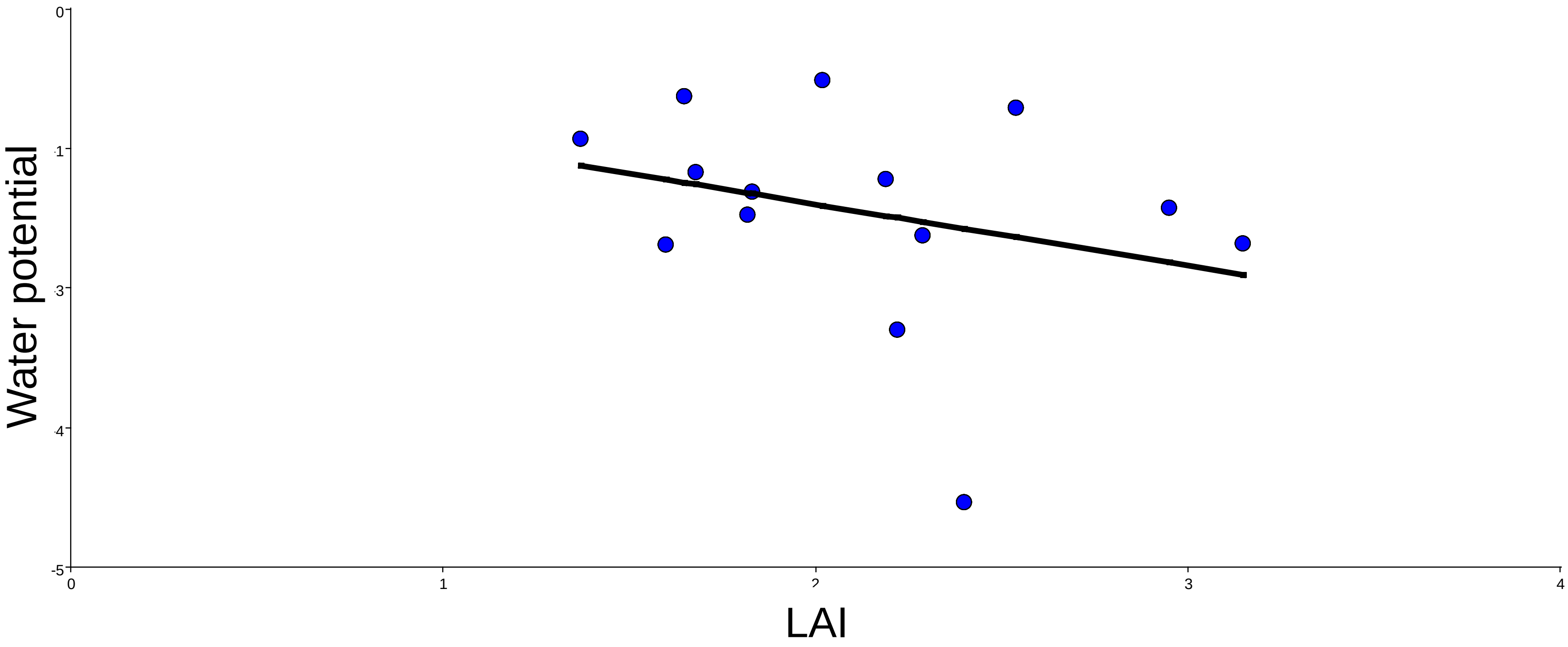
Water potential is species-specific



Larger tress have higher Ψ_{pd}

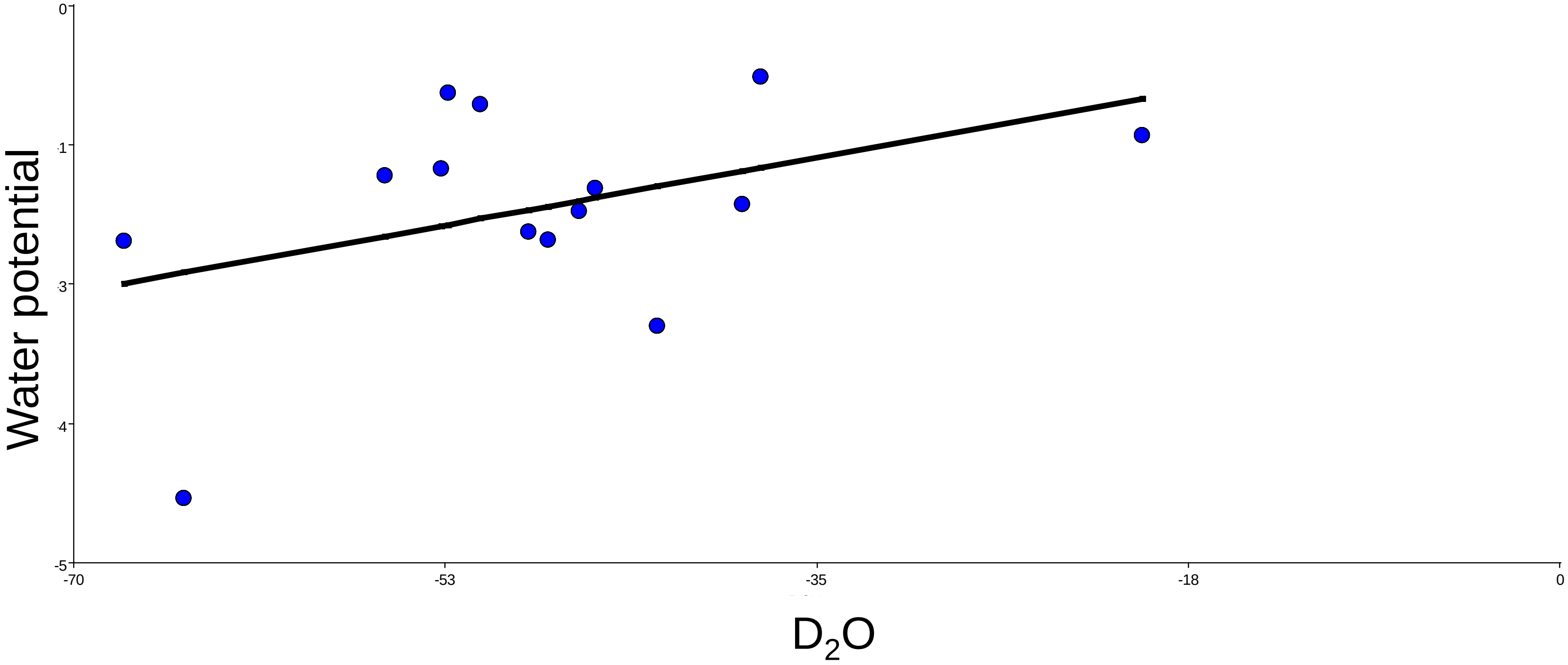


Trees with high LAI (dense foliage) show lower Ψ_{pd}

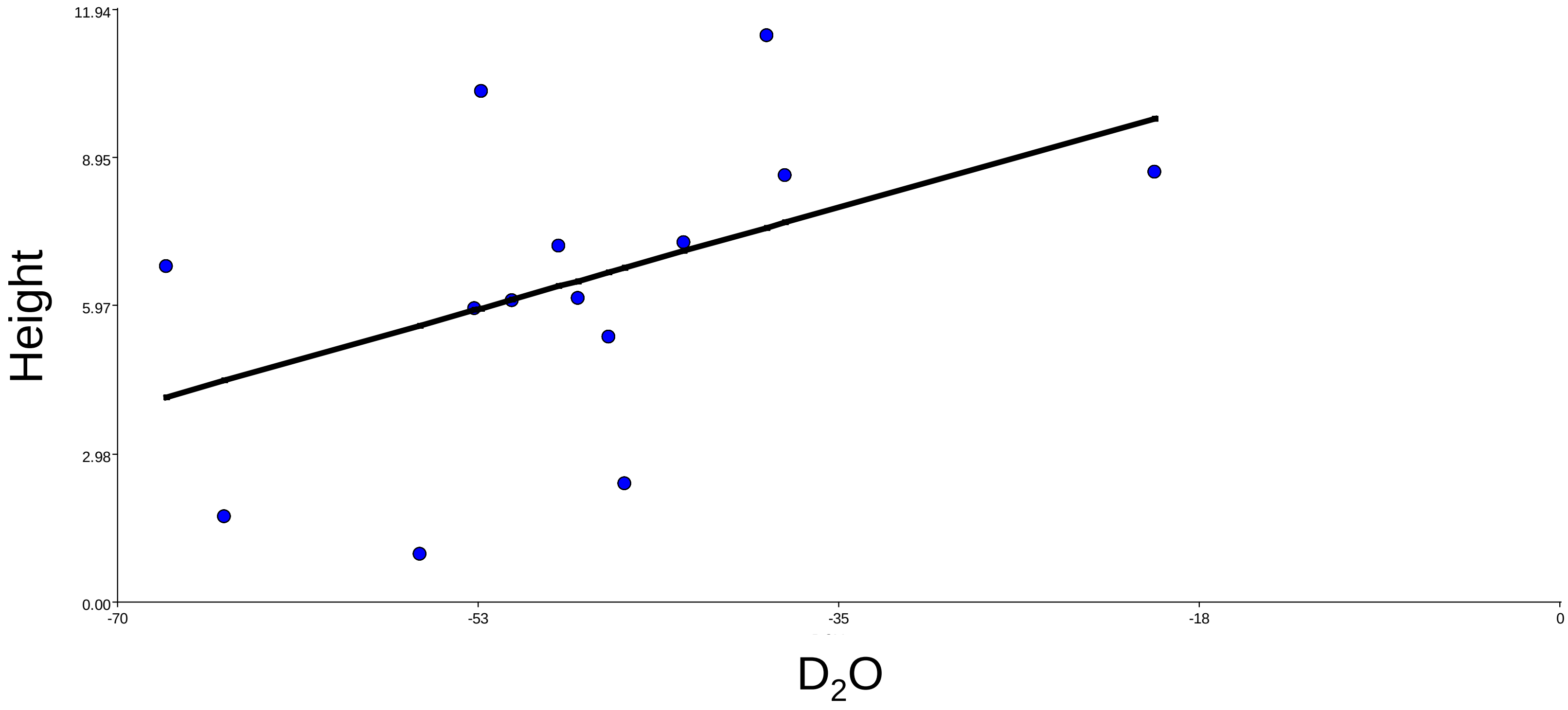


http://funcitree.nina.no/

Water potential is linked to deuterium

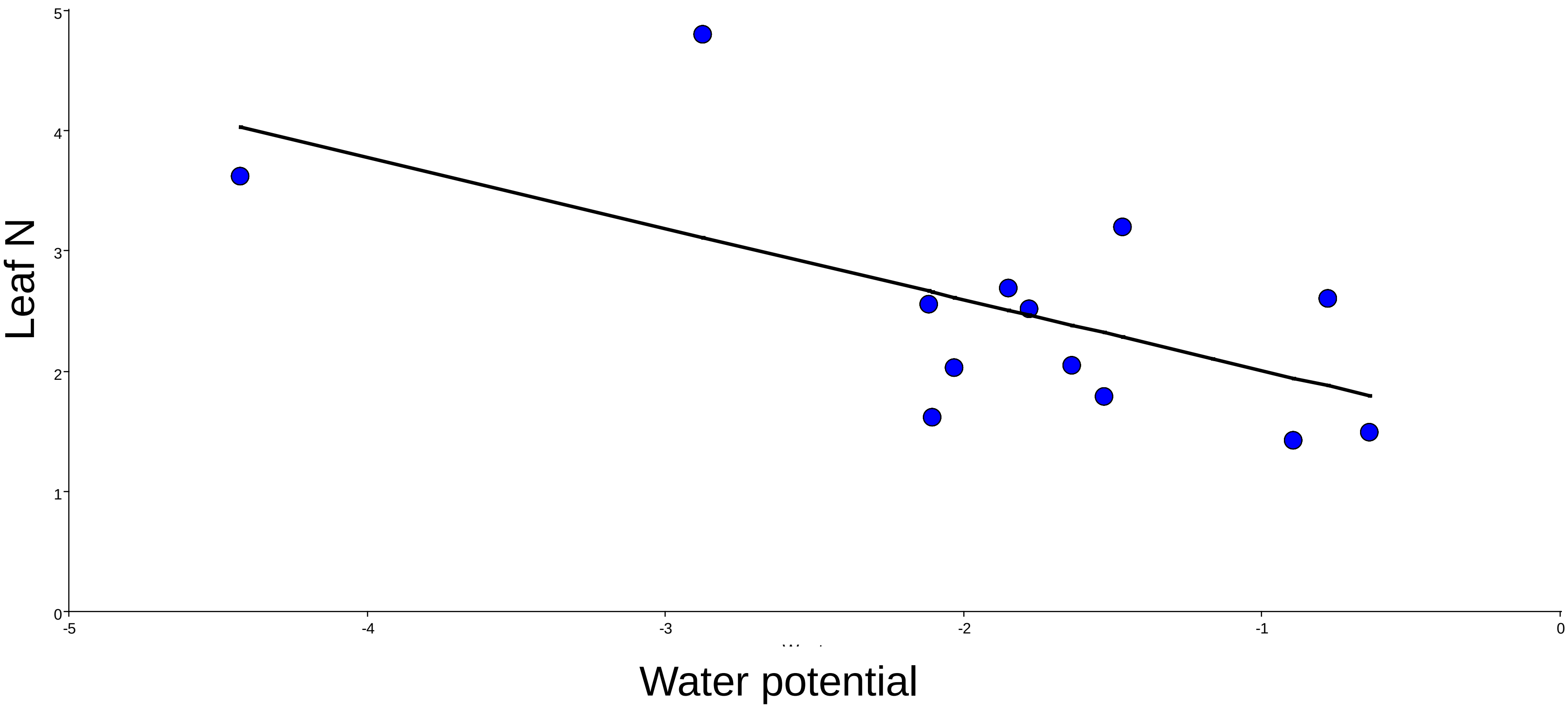


Deuterium increases with tree size



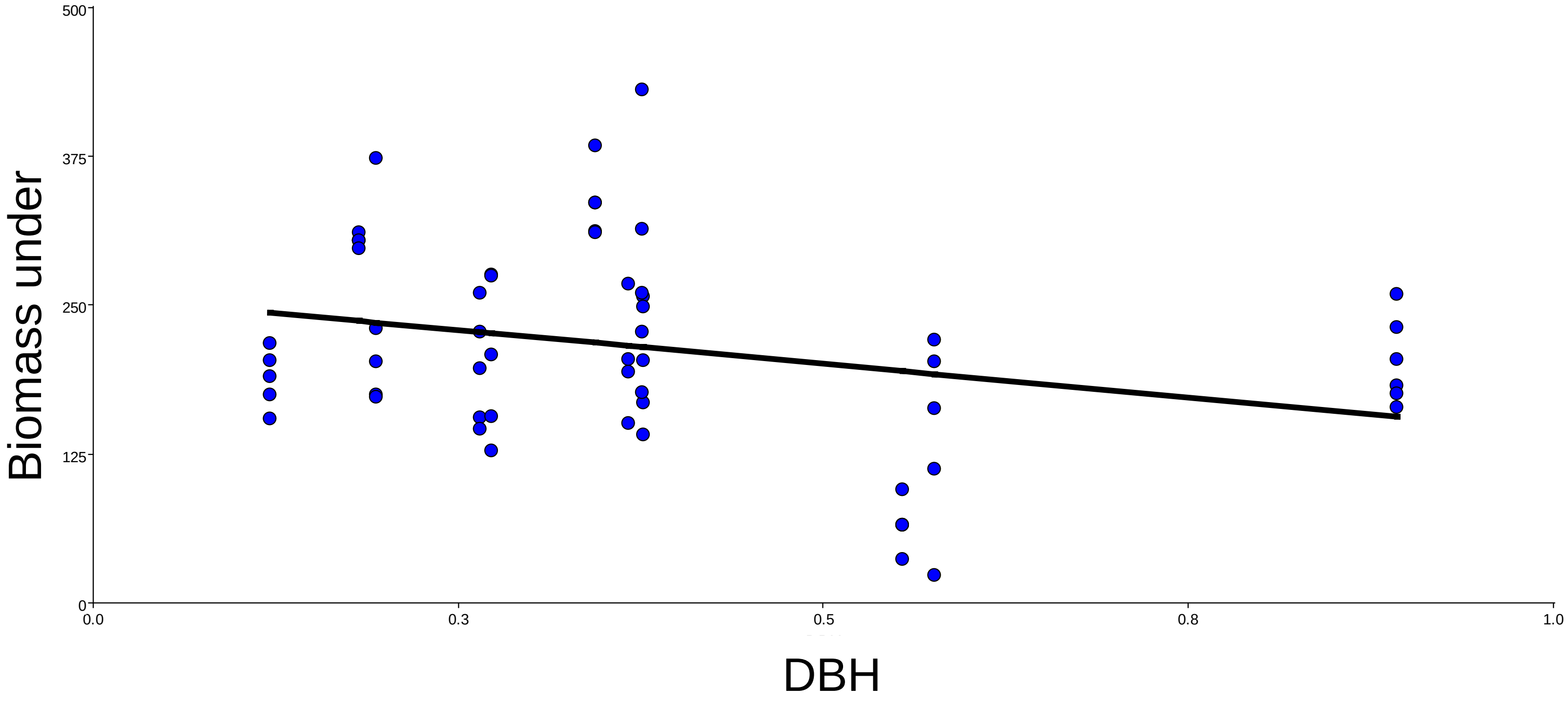
http://funcitree.nina.no/

Leaf N is negatively correlated with water availability (wet season)

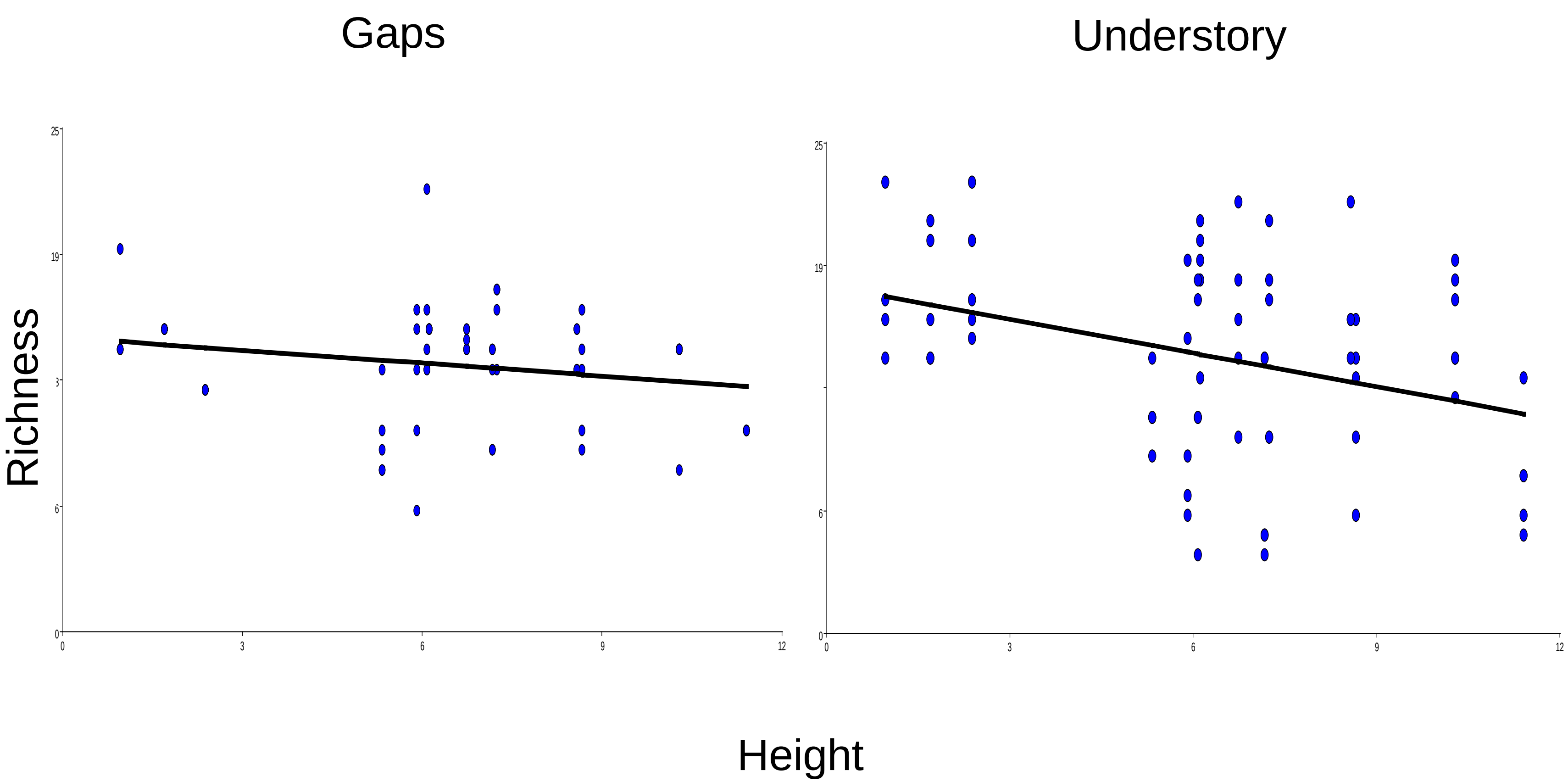


Tree attributes have an impact on understory vegetation

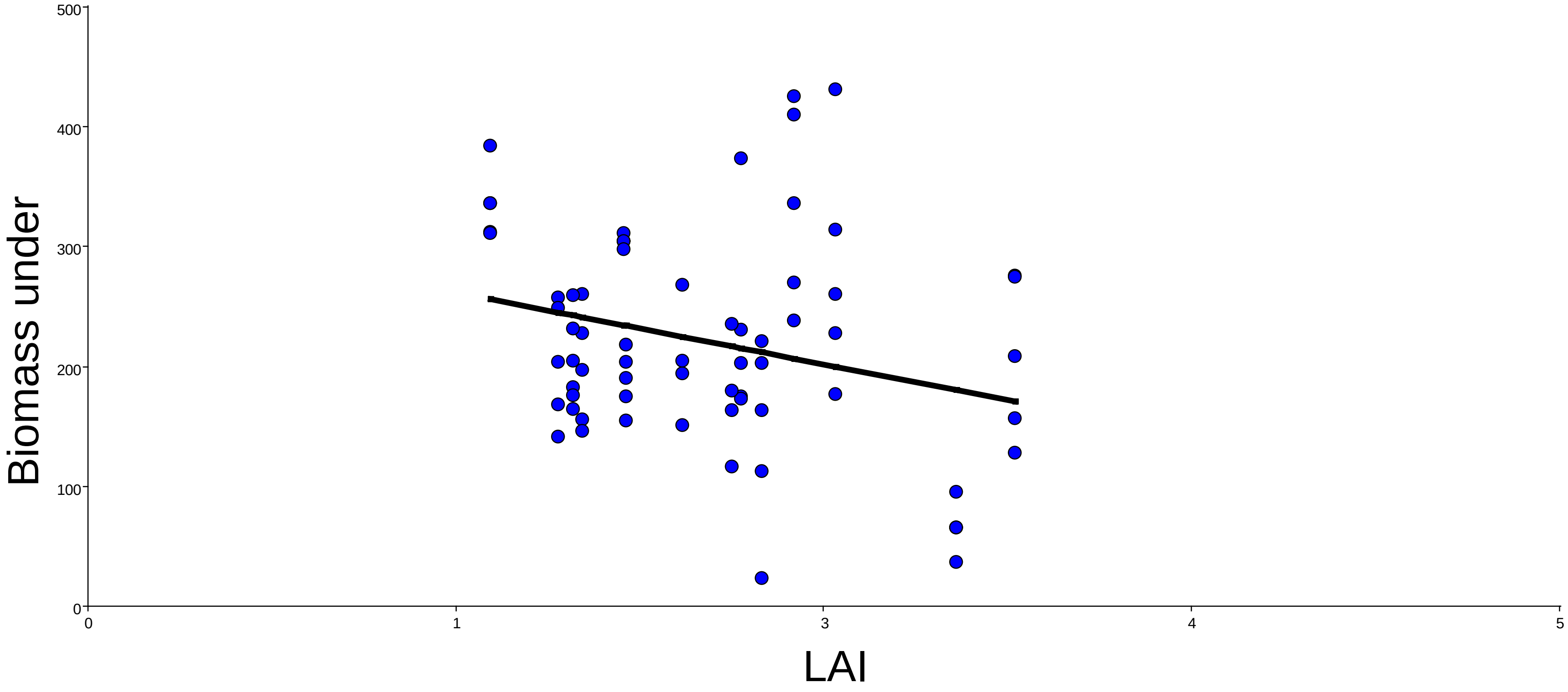
Trunk diameter and height negatively influenced understory biomass and cover



Taller trees have fewer species in the understory



Trees with dense foliage show less grass productivity and understory cover



http://funcitree.nina.no/

CONCLUSIONS

There are site-specific differences

Different tree species have different access to resources

Affect understory productivity in different ways

Providing tools for improvement of agro-forestry systems


Thanks!

Mixed model approaches to analyze unbalanced paired data

Fernando Casanoves

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Context

- Quantifying the ecosystem services provided by tree species in agroforestry systems
- Studying the tree effect in the context of climate change

Sampling design

Photo: Graciela Rush

Sampling design

Photo: Graciela Rush

Context

- Analyze tree effect on:
  - Productivity
  - Soil properties
  - Animal behavior
  - Grass biodiversity
  - Grass functional traits, etc.
- Assumption:
  - Before tree presence paired plots were similar (confounding)

Common methods

- Paired T test
- Relative Interaction Index (RII; Armas *et al.* 2004)
- Use mean differences in a ANOVA

- Limitations:
- If there are missing values for a given pair, all the information is lost

Mixed model frame

- Use maximum likelihood (ML) or restricted maximum likelihood (REML) estimators
- Provides criteria to select the best model

- AIC
- BIC
- Likelihood ratio test (LRT)
- R squared

Advantages

- Can work with missing data
- Support unbalanced treatments
- Provides the correct degree of freedom (avoid pseudoreplication)
- Multi-factor analysis can be performed
- Covariates can be included (ANCOVA)
- Allow modeling complex sampling designs (distances, cardinal points)

Advantages

- They allow modeling:
  - Heterogeneous variances
  - Random effects
  - Repeated measures
  - Spatial correlation
  - Regression with treatments
  - Different covariance structures

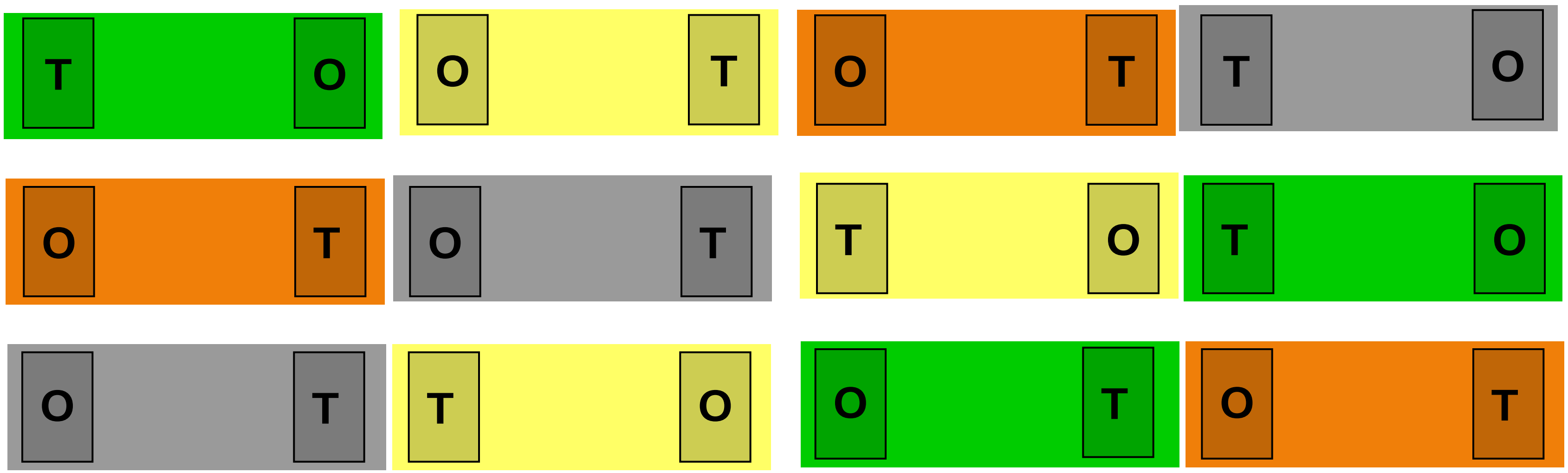
Alternative methods

- Disadvantages:

- Sampling design in all trees, sites, treatments etc. should be the same
- In this context RII alternative is better
- Advanced knowledge of statistics is needed

Sampling design scheme

- 4 species
- 3 replicates
- 2 positions (under the tree and open area)



ANOVA table

Source of variation	Degrees of freedom
Species	3
Error A (species)	8 (11-3)
Position	1
Species × Position	3
Error B	8
Total (corrected by mean)	23

The use of Split-plot design avoid pseudoreplication

Considerations

- Using paired T test, one for species, statistical power is poor
- By using all species in a T test, hypothesis of differences among species can not be tested
- Using mean differences we can perform hypothesis test for species (12 differences), but it is impossible to test the interaction between factors (Species × Position)

Example 1

- 3 species (A, B and C)
- 4 replicates by species
- 12 sampling units for tree
- 2 positions (under the tree and open area)
- Interest in the Species x Position effect
- 24 sampling units for position

Example 1

Trees

Case	Species	Tree	Position	Response
1	A	1	open	2030
2	A	1	shade	1900
3	A	2	open	2215
4	A	2	shade	1960
5	A	3	open	1870
6	A	3	shade	1650
7	A	4	open	1950
8	A	4	shade	1900
9	B	5	open	2050
10	B	5	shade	1720
11	B	6	open	2100
12	B	6	shade	1870
13	B	7	open	2245
14	B	7	shade	1905
15	B	8	open	2080
16	B	8	shade	1745

Real | Records: 24*4 | n = 4

Example 1

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1
24	233.31	240.43	-108.65	44.54	0.63	0.97

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testing (Type III SS)**

	numDF	denDF	F-value	p-value
(Intercept)	1	9	4549.04	<0.0001
Species	2	9	2.53	0.1344
Position	1	9	72.28	<0.0001
Species:Position	2	9	25.47	0.0002

Example 1

Trees

Case	Species	Tree	Position	Response
1	A	1	open	2030
2	A	1	shade	1900
3	A	2	open	2215
4	A	2	shade	1960
5	A	3	open	1870
(6)	A	3	shade	1650
7	A	4	open	1950
8	A	4	shade	1900
9	B	5	open	2050
(10)	B	5	shade	1720
11	B	6	open	2100
12	B	6	shade	1870
(13)	B	7	open	2245
14	B	7	shade	1905
15	B	8	open	2080
16	B	8	shade	1745

Categorical | Records: 24= [21 + (3)]*4

Example 1

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1
21	197.54	203.20	-90.77	50.02	0.58	0.94

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testing (Type III SS)**

	numDF	denDF	F-value	p-value
(Intercept)	1	9	6361.69	<0.0001
Species	2	9	3.15	0.0920
Position	1	6	29.68	0.0016
Species:Position	2	6	11.23	0.0094

Example 1

- **Fit measurements**

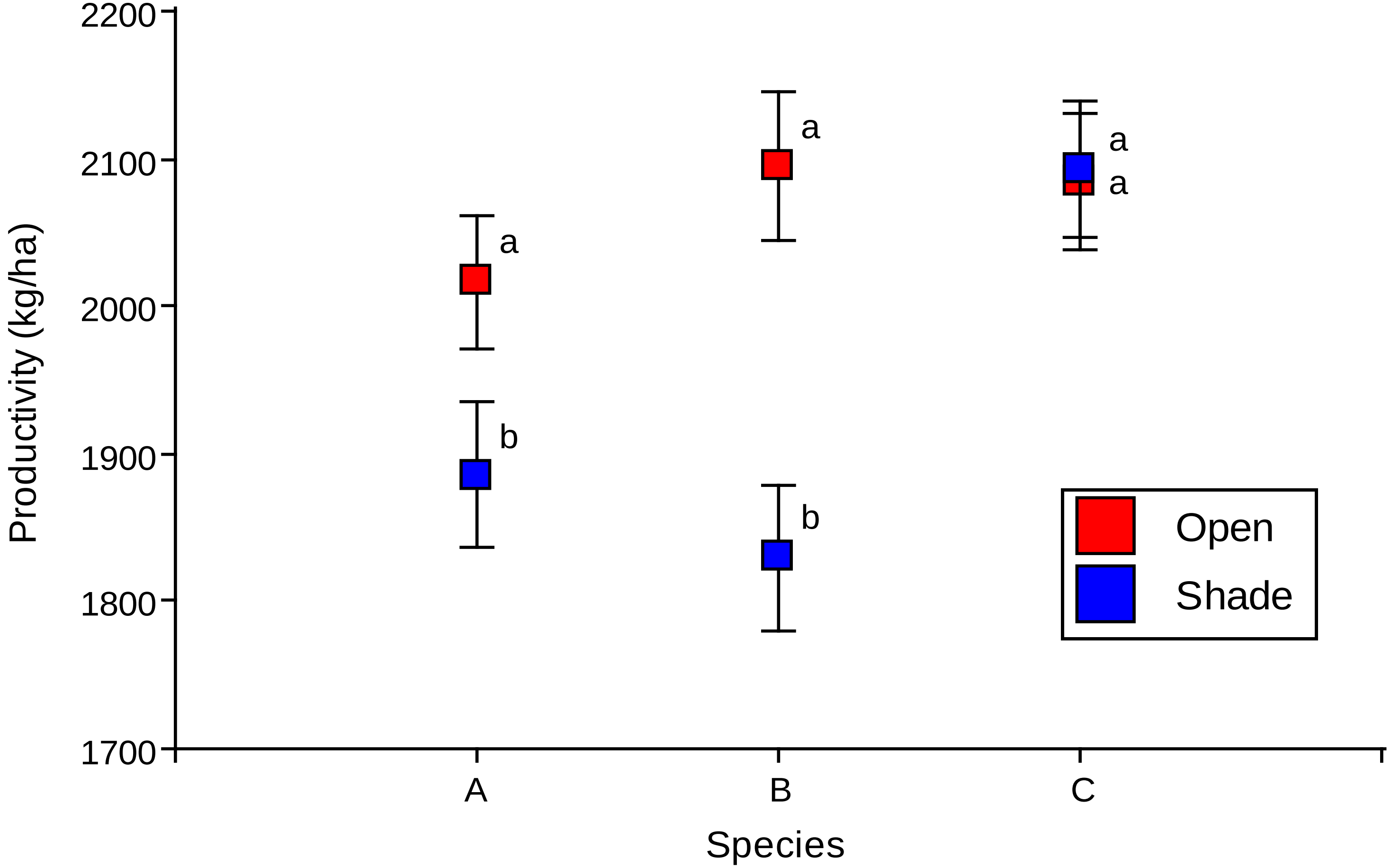
N	AIC	BIC	logLik	Sigma	R2_0	R2_1
21	197.54	203.20	-90.77	50.02	0.58	0.94

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testing (Type III SS)**

	numDF	denDF	F-value	p-value
(Intercept)	1	9	6361.69	<0.0001
Species	2	9	3.15	0.0920
Position	1	6	29.68	0.0016
Species:Position	2	6	11.23	0.0094

Example 1



2200
2100
2000
1900
1800
1700
Productivity (kg/ha)
a
a
a
a
b
b
Open
Shade
A
B
C
Species

Example 2

- Data from FUNCITREE (Potou, Senegal)
- 84 trees
- 2 positions
- 4 covariates
- Response variable productivity

Example 2

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1
104	948.19	1014.18	-446.09	54.11	0.69	0.70

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testingmodel.003_Biomass_gm2_REML**

	numDF	denDF	F-value	p-value
(Intercept)	1	41	4.26	0.0454
Species	10	37	11.57	<0.0001
Position	1	41	0.02	0.8834
TREE_HEIGHT	1	37	1.94	0.1721
DBH_M	1	37	4.52	0.0401
LAI_wet	1	37	0.06	0.8006
WUE_13C	1	37	1.19	0.2816
Species:Position	10	41	1.26	0.2822

Example 2 (without 6 observations)

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1
98	883.22	946.97	-413.61	55.44	0.68	0.68

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testingmodel.005_Biomass_gm2_REML**

	numDF	denDF	F-value	p-value
(Intercept)	1	37	5.33	0.0267
Species	10	37	10.51	<0.0001
Position	1	35	0.02	0.8863
TREE_HEIGHT	1	37	3.31	0.0770
DBH_M	1	37	5.80	0.0211
LAI_wet	1	37	0.21	0.6506
WUE_13C	1	37	1.85	0.1824
Species:Position	10	35	0.99	0.4683

Example 3

- 2 sites
- 1 species
- 2 positions
- 6 trees
- 6 repeated measures in time
- Unbalanced in time
- Loosing 6 data

Example 3

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1
70	254.59	302.13	-101.29	1.68	0.84	0.84

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testing (Type III SS)**

	numDF	denDF	F-value	p-value
(Intercept)	1	42	1653.88	<0.0001
Site	1	4	2.44	0.1932
Position	1	42	60.85	<0.0001
Month	5	42	23.01	<0.0001
Site:Position	1	42	0.62	0.4357
Site:Month	5	42	1.85	0.1230
Position:Month	5	42	1.59	0.1828
Site:Position:Month	5	42	0.84	0.5323

Example 3

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1	R2_2
70	256.58	305.95	-101.29	1.67	0.84	0.84	0.84

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testing (Type III SS)**

	numDF	denDF	F-value	p-value
(Intercept)	1	38	1654.22	<0.0001
Site	1	4	2.45	0.1927
Position	1	4	56.67	0.0017
Month	5	38	23.20	<0.0001
Site:Position	1	4	0.58	0.4887
Site:Month	5	38	1.87	0.1234
Position:Month	5	38	1.61	0.1817
Site:Position:Month	5	38	0.84	0.5303

Example 3

- **Fit measurements**

N	AIC	BIC	logLik	Sigma	R2_0	R2_1	R2_2
64	230.53	276.13	-88.27	1.64	0.84	0.85	0.85

- *Smaller AIC and BIC is better*

- **Marginal hypothesis testing (Type III SS)**

	numDF	denDF	F-value	p-value
(Intercept)	1	32	1158.50	<0.0001
Site	1	4	0.85	0.4075
Position	1	4	60.65	0.0015
Month	5	32	18.38	<0.0001
Site:Position	1	4	1.90	0.2405
Site:Month	5	32	2.26	0.0724
Position:Month	5	32	2.31	0.0670
Site:Position:Month	5	32	0.52	0.7584

Final remarks

- Availability of software to perform the analysis
- More statistical power
- Extract more information of the data set
- The most important:
  - Is modern
  - Is fashion
  - Prevents troubles with editors!

Thank you, merci, gracias, takk !