# The role of environmental gradients and tree functional attributes on tree-understory interactions

Rusch, G. M., Armas, C., Diouf, M., Zapata, P., Fall, D., Casanoves, F., Diémé, J. S., Ibrahim, M., DeClerk, F., Pugnaire, F.I.



FUNCiTREE

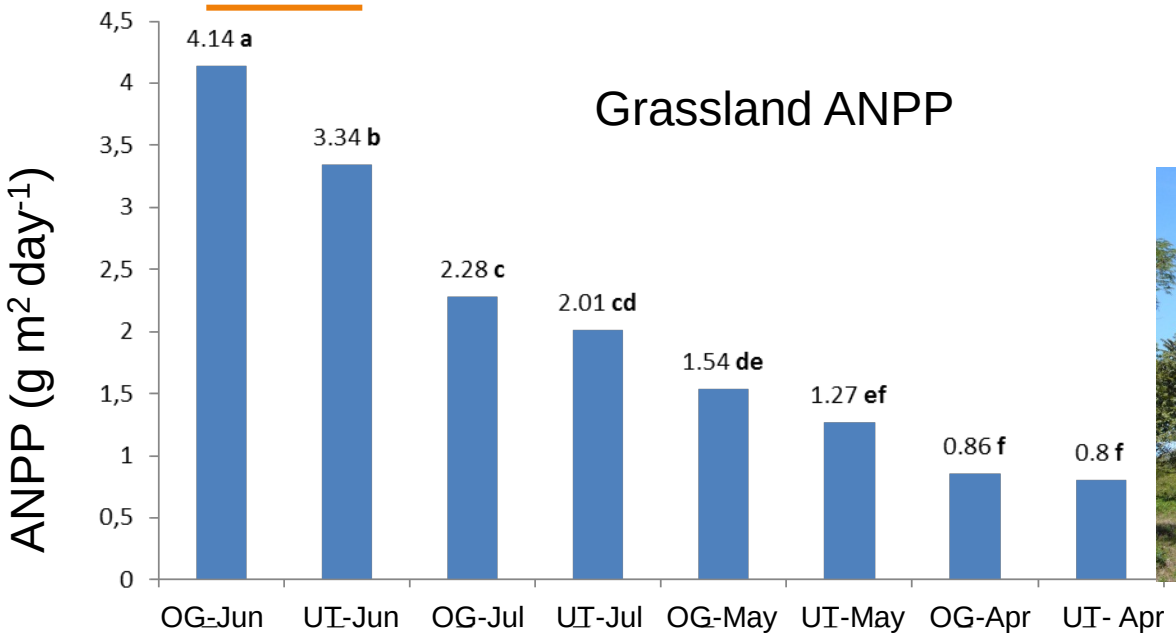
# Why tree-understorey interactions?

- Difference in size (height) => light interception, potential for asymmetric competition.
- Trees contribute significantly to soil formation (e.g. Casals et al. under revision).
- Microclimate (e.g. evaporation (Olivero 2010, soil temperature).

- Function important for farm production (ecosystem service – trade-offs).

# What we knew

- In Rivas, Nicaragua, grassland ANPP lower under trees (3 species) than in open, at peak.

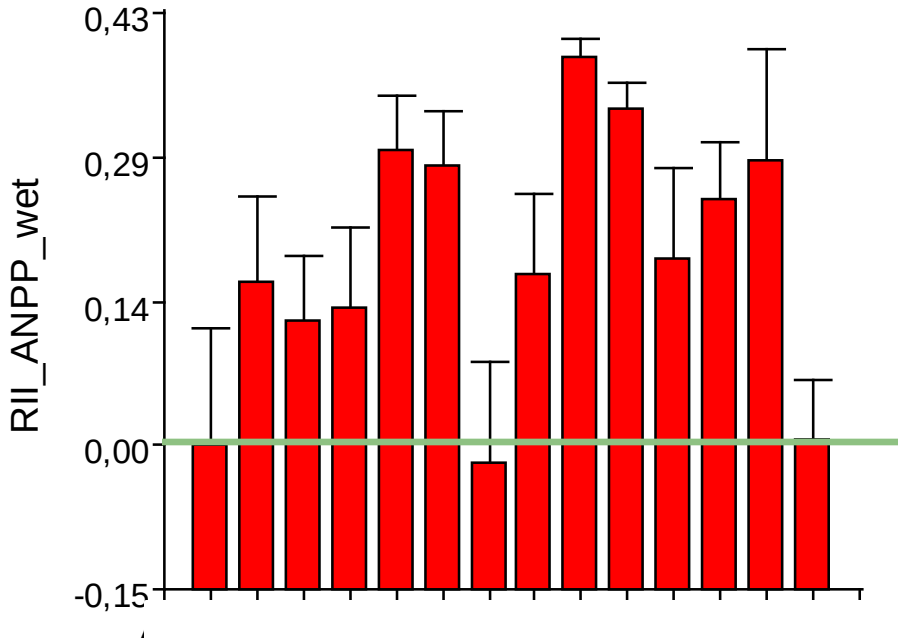



OG: Open grassland UT: Under tree

http://funcitree.nina.no/

FUNCiTREE

# What we knew




- In Potou, Senegal, the net effect of trees on grassland ANPP (RII_ANPP) was either neutral or positive. 14 species.

RII = 0 Neutral effect

# Interaction outcome x environment

- Both competition and facilitation occur among plants

- The relative importance of competition and facilitation tends to change with the environment  benign => harsh

# We asked:

- Whether the sign of the tree-grassland interaction function changed from negative to positive with site productivity.
- About the extent to which tree properties affect the net interaction balance.
- If the net effect of the tree was related to other beneficial functions (soil formation - fertility).

# Dataset

- A gradient of environmental conditions: soils and climate.
- 17 Species from Senegal and Nicaragua, n=5.

# Dataset



- ANPP wet season (Biomass accumulation during 3 months).
- Exclosures

# Dataset

- Paired sampling

- RII = Relative Interaction Index (Armas et al. 2004)

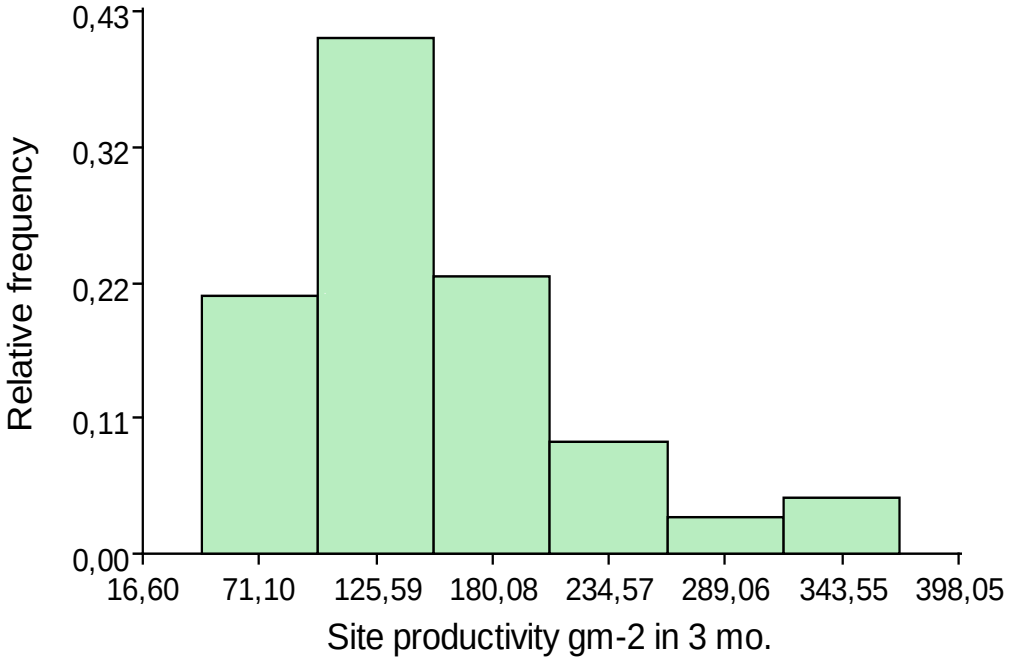
$$\frac{ANPP_{tree} - ANPP_{no\ tree}}{ANPP_{tree} + ANPP_{no\ tree}}$$

-1 +1

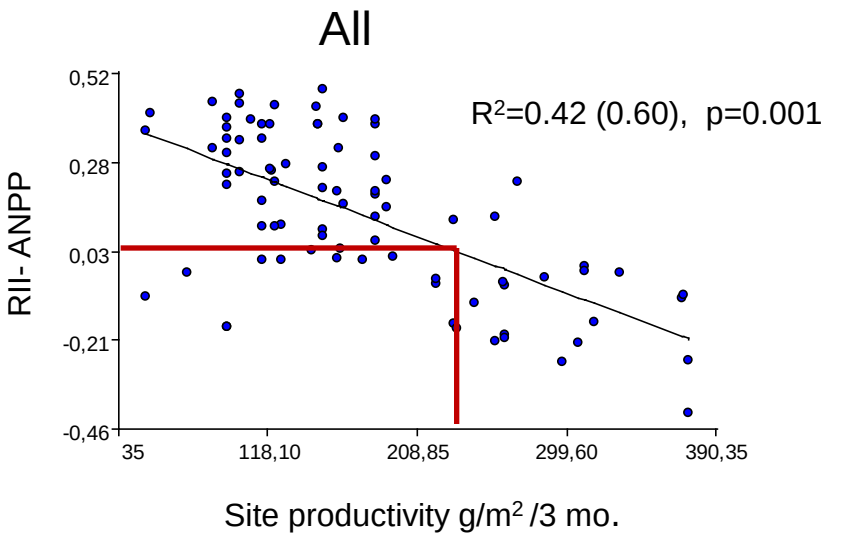
http://funcitree.nina.no/

# Dataset

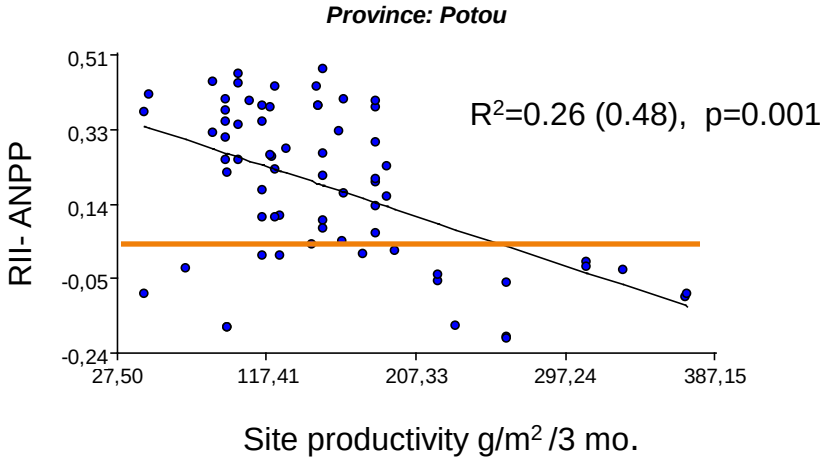
- ANPP of open grassland (control) as a proxy for «site productivity»

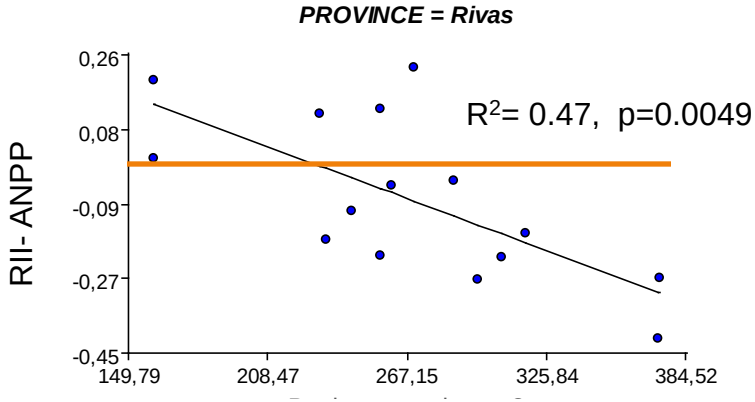


# Results



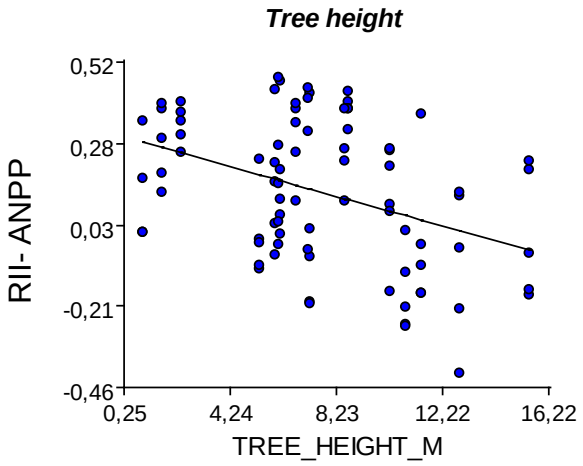

- Site productivity explained a large portion of tree net effect variatiability

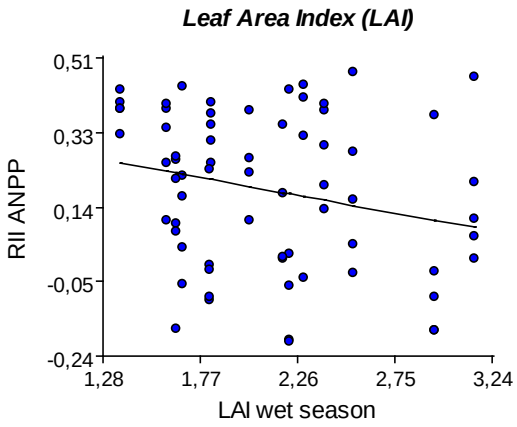


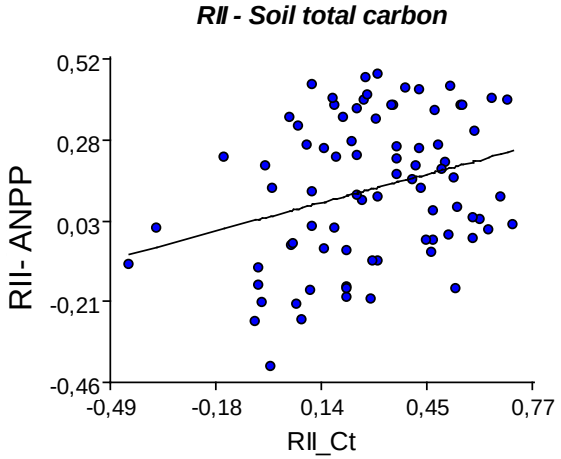



# Results

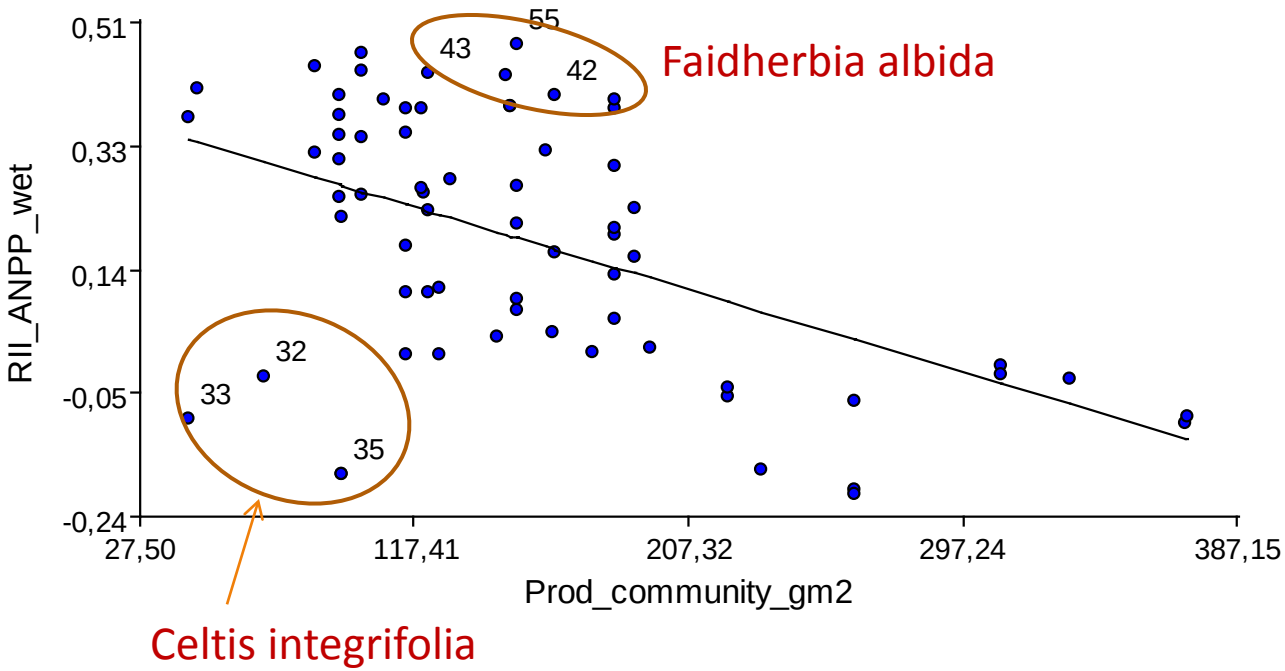
| Effect on RII - ANPP | | $R^2$ | p |
|---|---|---|---|
| Tree height | Riv+Pot | 0.15 | 0.0003 |
| LAI rainy season | Potou | 0.06 | 0.049 |
| | Rivas | 0.05 | 0.52 |
| RII – Soil total C | Riv+Pot | 0.09 | 0.008 |
| RII – Soil total N | Riv+Pot | 0.00 | 0.81 |
| Leaf N | Riv+Pot | 0.00 | 0.79 |



# Results




- Species-specific response.

# Concluding remarks

- Results reinforce evidence about different degrees of competition and facilitation along environmental gradients.

- Higher competition strength with high level of resources/favourable conditions for growth supported by:
  - (+) site productivity
  - (+) tree height (size)
  - (-) LAI

- Important for the design / planning of AFS.

# Concluding remarks

- Negative effects significant in the wet season: More relevant for crops than for pastures.

- Facilitation in early- or late rainy season could be important, but not detected.

# Concluding remarks

- Facilitation related to indirect effect of tree on soil formation (organic matter accumulation). No trade-off with this function.

- No association found with soil total N. Indicator may not be appropriate, but no association with leaf N nor legumes.

- Specific responses of particular trees important for planning, selection.


Thank you!

# Soil carbon storage is promoted more by Jícaro than by Guácimo trees in silvopastoral systems in Nicaragua

Marcel Hoosbeek, Roy Remme, Andreas Nieuwenhuyse, Dalia Sánchez, Peter Buurman and Eef Velthorst

WAGENINGEN UNIVERSITY
WAGENINGEN UR

# Nicaragua

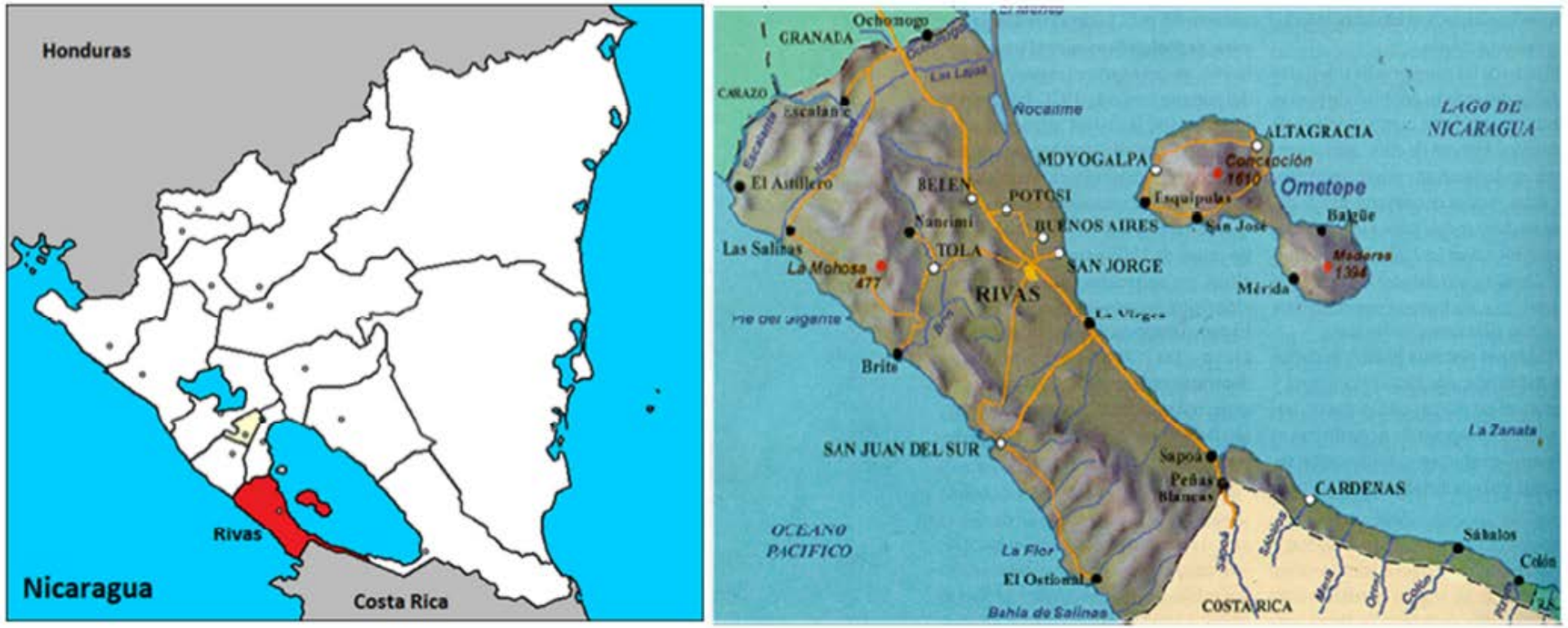
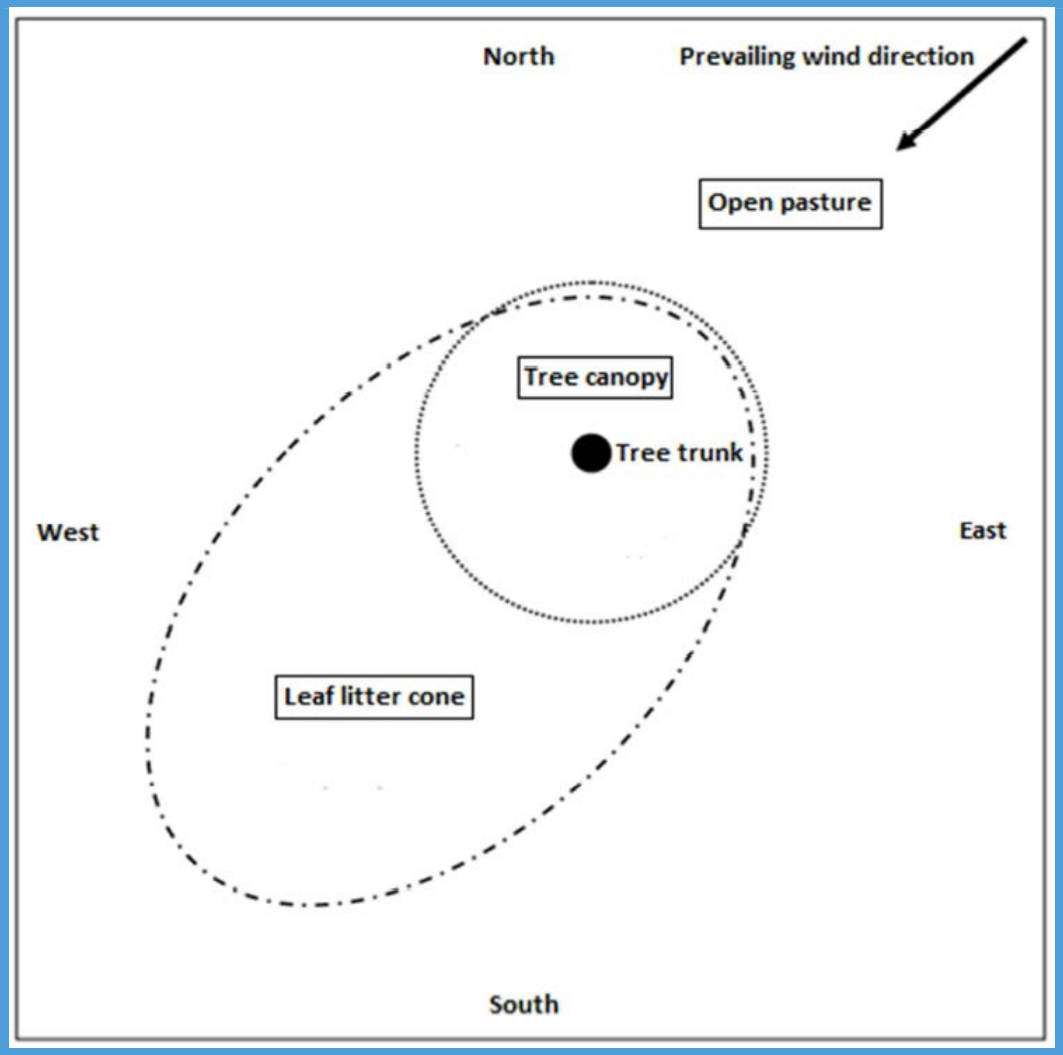



**Figure 1.1** Map of Nicaragua (left) and the department of Rivas (right). On the Nicaragua map the department of Rivas has been marked in red. Source Rivas map: Sánchez et al. 2010.

# Above ground litter deposition




3 locations:

1. pasture without tree litter
2. canopy with tree litter
3. pasture with tree litter

# Two tree species

*Guazuma ulmifolia*

“Guácimo”

*Crescentia alata*

“Jícaro”

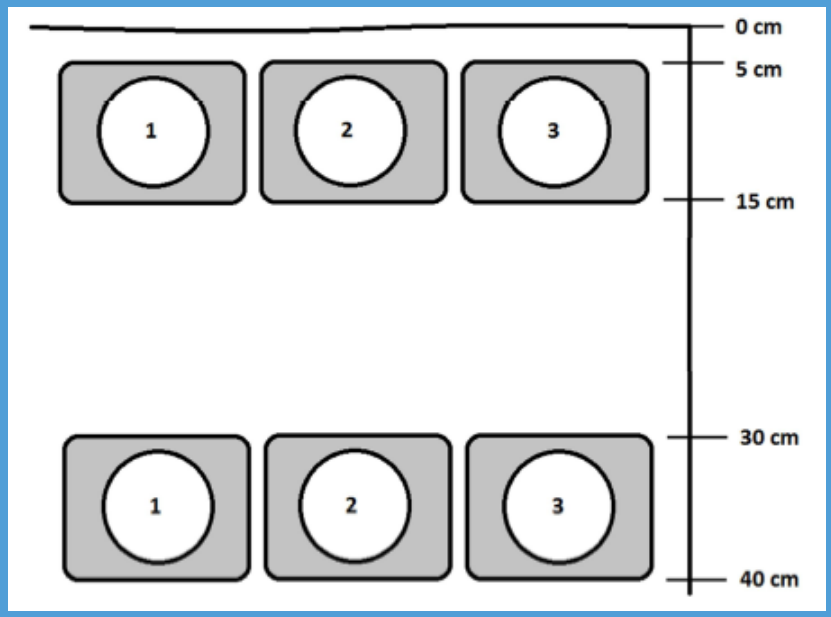
# Selected trees


- Yellow Guácimo
- Blue Jícaro

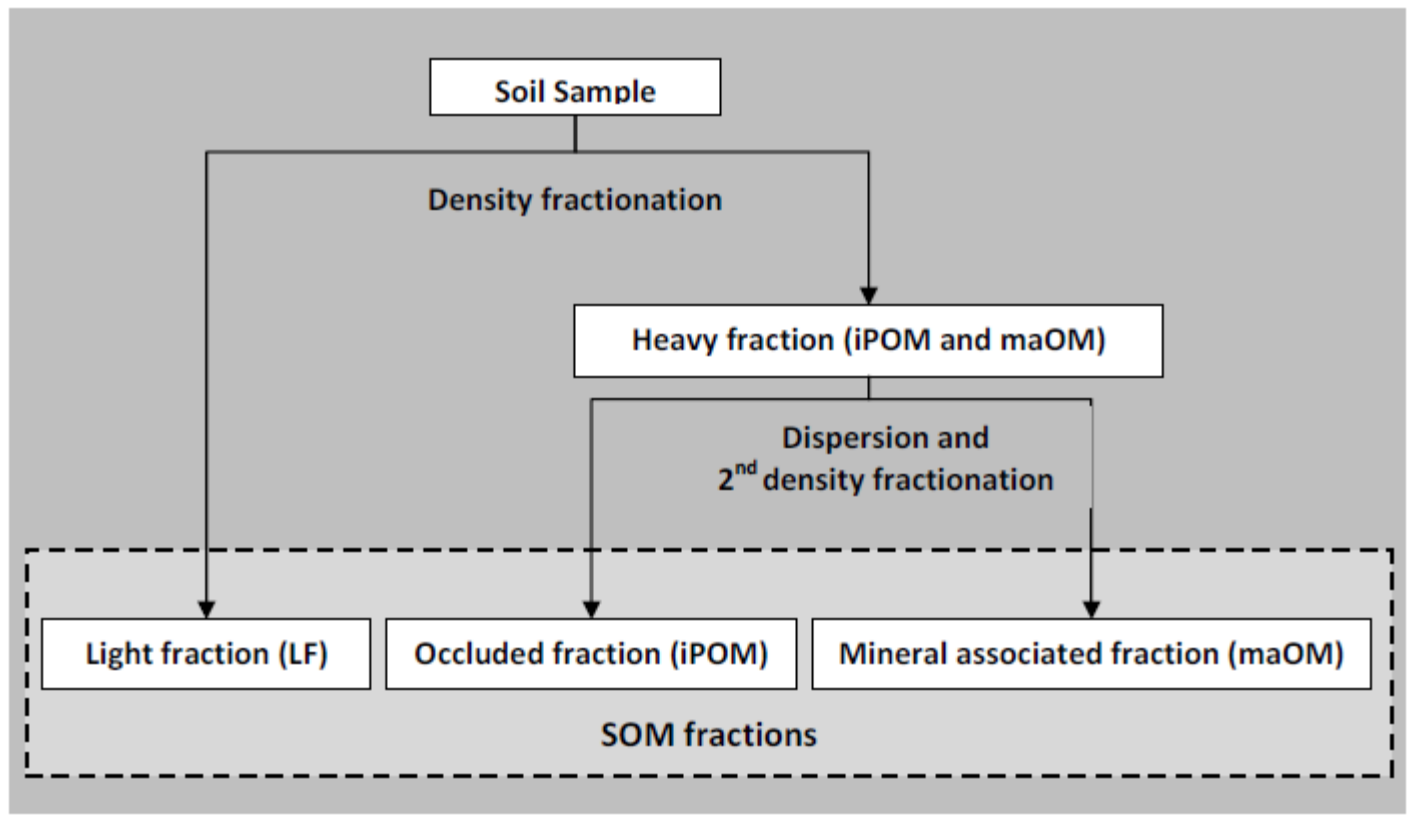
# Soils

- Haplusterts on central (flat) parts of alluvial fans
- (Vertic) Haplustolls on sloping parts of the alluvial fans

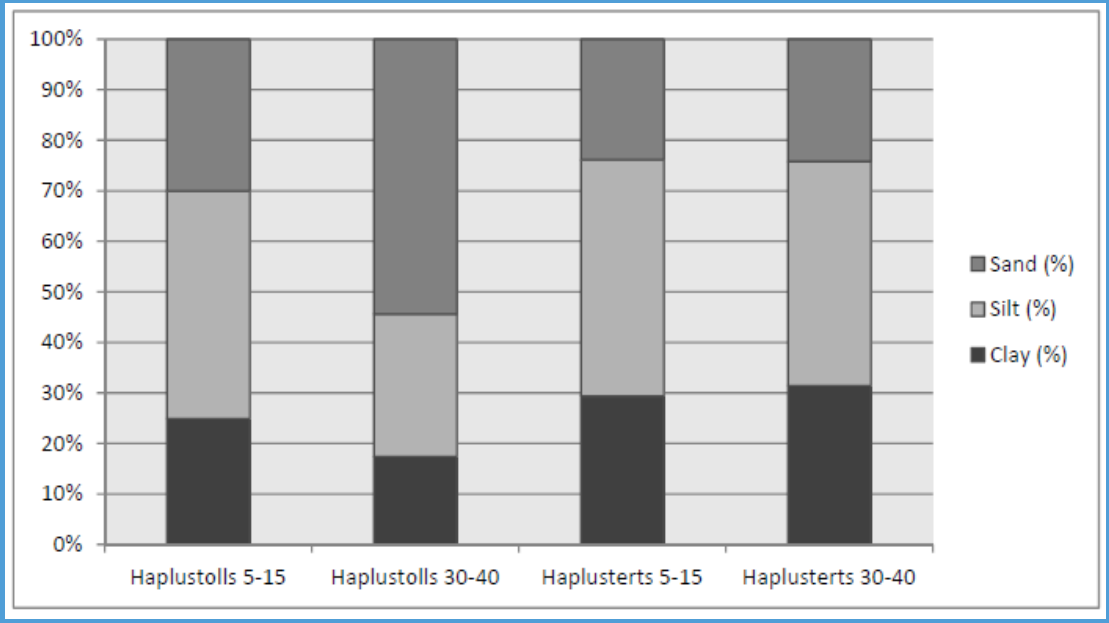
# Soil sampling



# Soil organic matter fractions



# Results – soil texture and bulk density




| Soil | Location | soil bulk density (g cm$^{-3}$) | s.e. |
|---|---|---|---|
| **Haplustoll** | pasture | 1.29 | 0.02 |
| | canopy | 1.30 | 0.02 |
| | leaf litter | 1.37 | 0.03 |
| **Haplustert** | pasture | 1.09 | 0.02 |
| | canopy | 1.43 | 0.05 |
| | leaf litter | 1.57 | 0.02 |

Soil bulk density was affected by

- soil type ($P=0.011$)
- tree species ($P<0.001$)
- location ($P<0.001$)

# Results – soil C N P (0 – 50 cm soil depth)

| Tree | Location | C (g m$^{-2}$) | s.e. | N (g m$^{-2}$) | s.e. | P (g m$^{-2}$) | s.e. |
|---|---|---|---|---|---|---|---|
| **Guácimo** | pasture | 7471 | 1135 | 597 | 85 | 24 | 4 |
| | canopy | 8073 | 1207 | 646 | 93 | 22 | 4 |
| | leaf litter | 9646 | 1741 | 766 | 113 | 25 | 3 |
| **Jícaro** | pasture | 8903 | 838 | 638 | 71 | 20 | 3 |
| | canopy | 13636 | 1378 | 1022 | 116 | 23 | 3 |
| | leaf litter | 12596 | 1362 | 874 | 106 | 25 | 3 |

- Soil C content was
  - higher in Vertisols ($P<0.001$)
  - lower in pasture ($P<0.001$)
  - lower in the sub-soil ($P<0.001$)
  - higher in the canopy and leaf litter zone of Jícaro with a significant tree species × location effect ($P=0.008$)
- Similar trends for soil N content as for soil C content.
- Soil P content higher in the Haplustolls ($P=0.053$) but was otherwise not affected.

# Results – C:N, C:P and N:P ratios

- Soil C:N, C:P and N:P were
  - higher in Vertisols ($P<0.001$)
  - not affected by location
- Soil C:P was higher under Jícaro ($P=0.023$)

# Results – SOM fractions

- Soil C present in the “free labile” and “occluded” fractions was only lower in the sub-soil ($P<0.001$), but otherwise not affected.
- The mineral associated C fraction was affected by
  - higher in Vertisols ($P<0.001$)
  - lower in pasture ($P<0.009$)
  - lower in the sub-soil ($P<0.001$)
  - higher in the canopy and leaf litter zone of Jícaro with a significant tree species × location effect ($P=0.029$)
- Nitrogen in soil fractions followed similar trends as for C.

# Results – soil respiration

- PP systems soil respiration system – EGM4
- August and October 2010 (rainy season)
- Soil respiration is
  - lowest under canopy ($P<0.001$)
  - highest in pasture with leaf litter (high substrate input)
  - higher under Guácimo ($P = 0.013$)
- Soil C and N fractions are strong predictors for soil respiration (rather than total soil C and N).

# Conclusions

- Soil C storage is higher
  - in Haplusterts (high clay % and impeded drainage)
  - under Jícaro
    - corresponds well with the observed higher respiration rates under Guácimo

- The observed species effect on C:P, but not on C:N, may indicate increased uptake of P under Jícaro and a possible growth limiting role of P.

# Conclusions - continued

- By looking at the free labile and occluded fractions, the early stages of soil C stabilisation processes seem not to be affected by tree species or location, or may be obscured by the rapid turn-over of organic matter and its high spatial variability.

- However, the most stable mineral associated fraction, which makes up ~ 89% of total soil C, is about one-and-a-half times larger under Jícaro than under Guácimo or pasture.
    - Carbon sequestration as an ecosystem service may therefore be promoted by the use of Jícaro in silvopastoral systems.

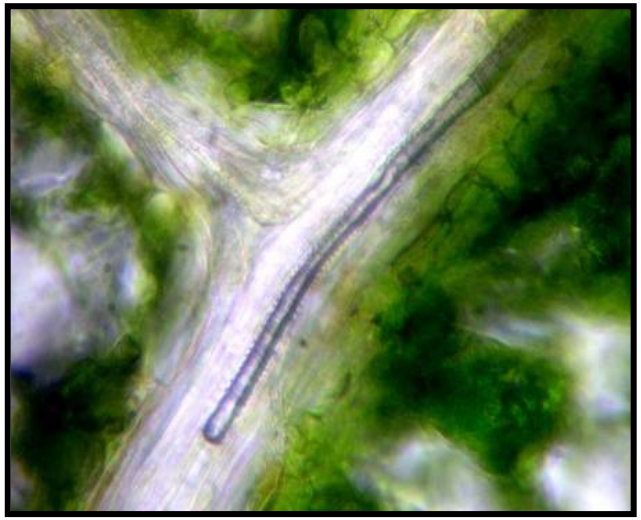
# Thank you

# Is resistance to xylem cavitation a relevant trait for dry season forage production?

Ariane Cosiaux, Philippe Thaler,
Mayecor Diouf and S. Delzon

# Functions and traits

- Can we relate physiological functions, characterized by physiological traits, to agroforestry functions, defined by farmers?
- Can we relate these physiological traits to morphological traits that are easier to assess?



# Forage trees during the dry season in the Sahel

Risky business!

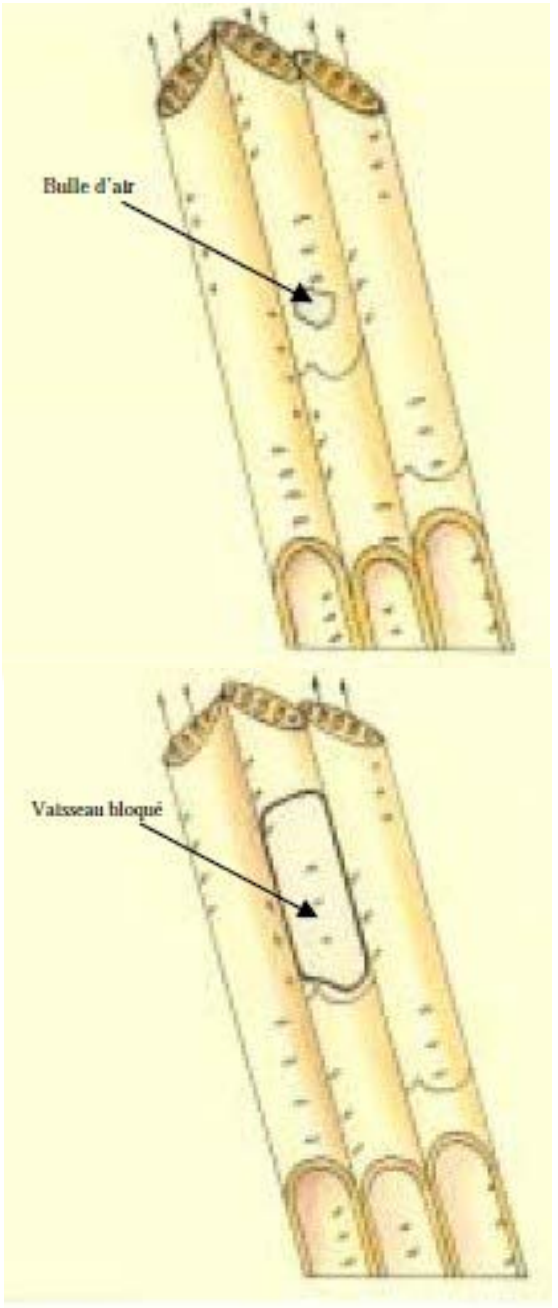
- Keep active leaves under high evaporative demand
- Huge tension induced in the vessels along the soil-tree-air pathway
- High risk of vessel cavitation

# What is xylem cavitation and embolims?

When the vessels are submitted to excessive tension (due to high difference in water potential between soil and air)

1. Vacuum occurs (cavitation)
2. Vacuum is filled by air (embolism)
3. Air bubbles expand and impede sap flow

– Drop in the conductivity of the vessels (K)
– Leaves and other tissues are no more watered
– Leaf fall, dieback...

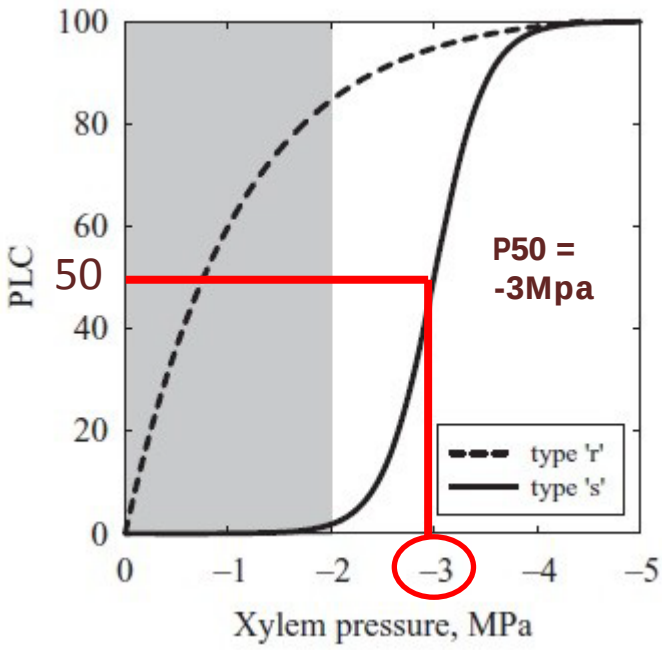


# How do we measure it?
# The vulnerability curve

Application of increasing tension (negative pressure) to branch segments by several methods

1. Dehydration (Sperry et al. 1988)
2. Air injection (Cochard et al. 1992)
3. Centrifugation (Cochard et al. 2005)

– Determination of percentage loss of conductivity (PLC)
– Validation of the curve shape (S)
– Determination of P50. The tension inducing 50% loss of conductivity




Cochard et al. 2010

- **Relationships between sensitivity to xylem cavitation, morphological traits and resistance to drought of AF species in Senegal**

- Water transport in xylem is vulnerable, as it has to sustain high tension
  - Risk of embolism or cavitation

- Anatomy plays a central role

- Structural traits of xylem determine functionnal limits or the safety margins of plants

*(Global convergence in the vulnerability of forests to drought*

Choat et al, Nature 2012).

# Hypotheses and objectives

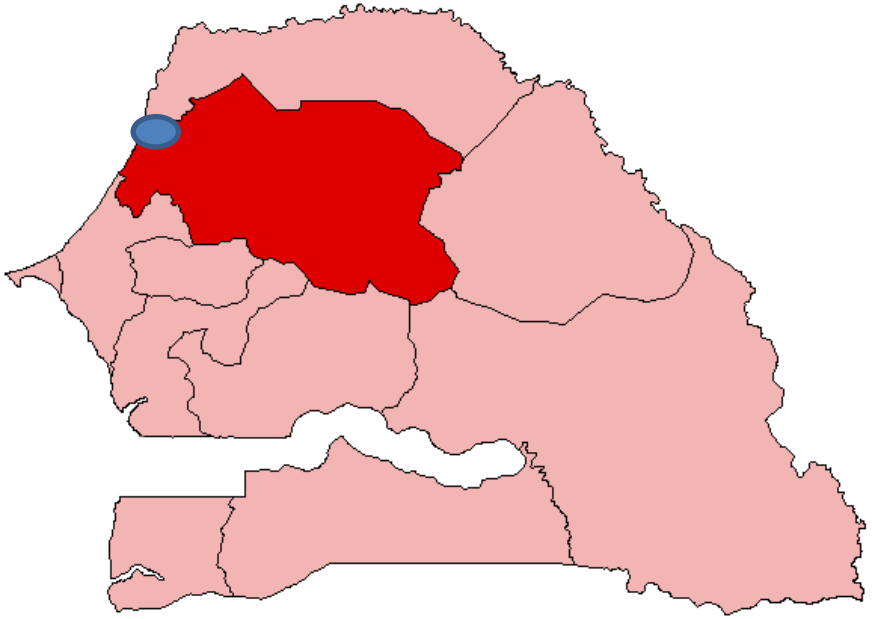
- Resistance to cavitation is a relevant trait to select woody species for fodder production during the dry season.

- This physiological trait can be related to morphological traits that are easier to assess

There is little available information on the resistance to cavitation of sahel trees and shrubs

- Specific objective: assess the feasibility of the centrifugation method Cavitron (Cochard et al. 2005) to measure this trait on ten sahelian woody species

# Study area -Senegal

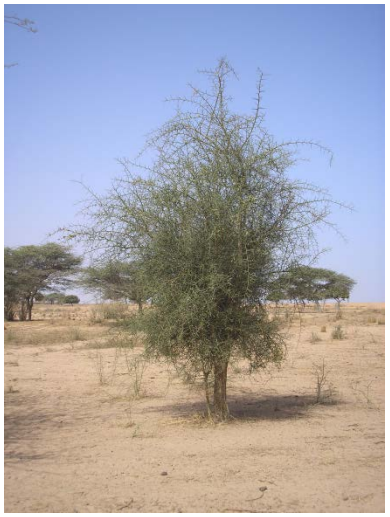


## Leona rural community, Potou, region of Louga.

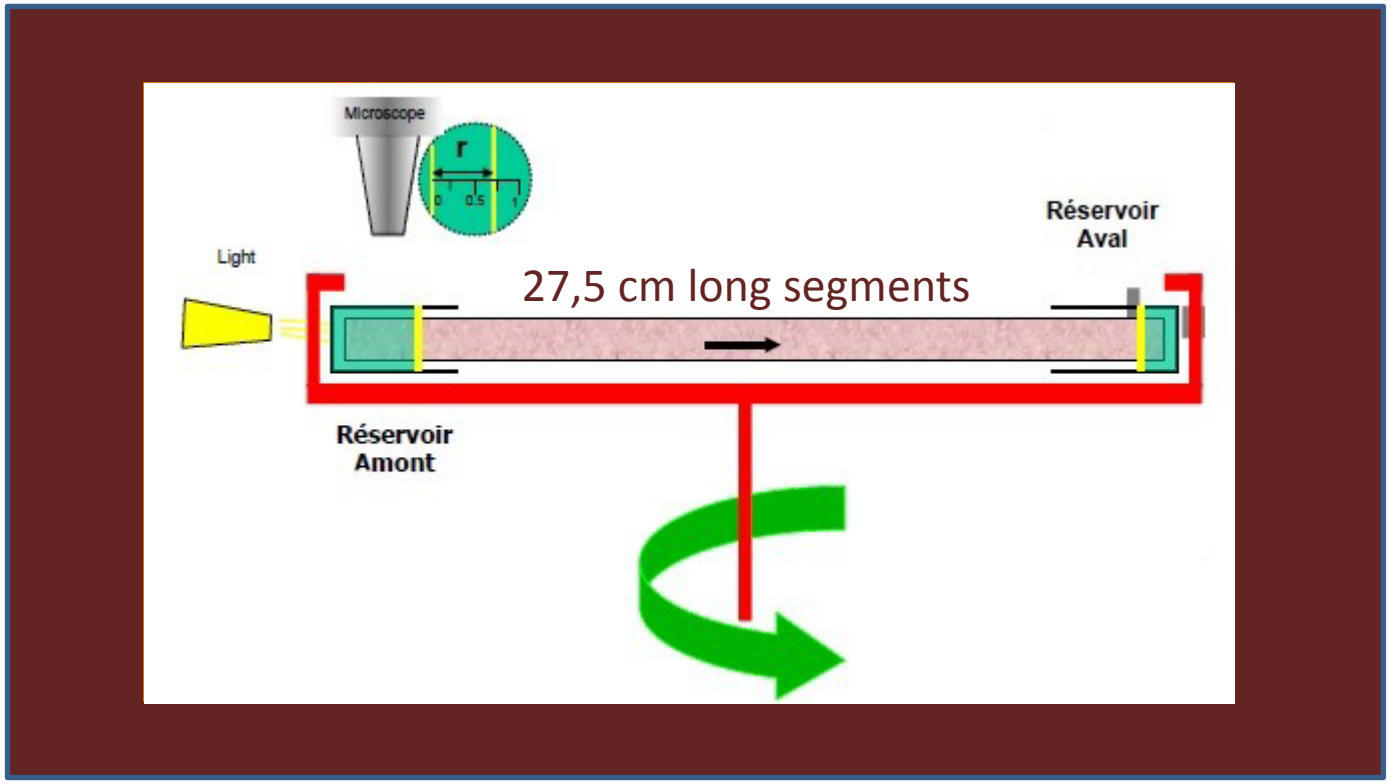
- Long dry season from October to June.
- Mean monthly temperatures from 23,6 to 30,3°C.
- Mean annual rainfall : 290 mm (1982-2005).

# Ten woody species

| Famille | Genre | espèce | FC | F | intérêt fourrager | n |
|---|---|---|---|---|---|---|
| Fabacées | *Acacia* | *tortilis* subsp. *raddiana* (Savi) Brenan | a | sc | +++ | 6 |
| Bombacacées | *Adansonia* | *digitata* L. | a | c | +++ | 6 |
| Balanitacées | *Balanites* | *aegyptiaca* (L.) Del. | a | sc | ++ | 6 |
| Capparacées | *Boscia* | *senegalensis* (Pers.) Lal. Ex Poir. | ab | p | +/- | 6 |
| Ulmacées | *Celtis* | *integrifolia* Lam. | a | p | ++ | 6 |
| Fabacées | *Faidherbia* | *albida* (Del.) Chev. | a | c | +++ | 6 |
| Fabacées | *Prosopis* | *juliflora* (Sw.) DC. | a | p | + | 6 |
| Anacardiacées | *Sclerocarya* | *birrea*(A. Rich) Hochst. | a | c | +/- | 6 |
| Fabacées | *Tamarindus* | *indica* L. | a | p | +/- | 7 |
| Rhamnacées | *Ziziphus* | *mauritiana* Lam. | ab | c | ++ | 6 |



# The Cavitron methodology

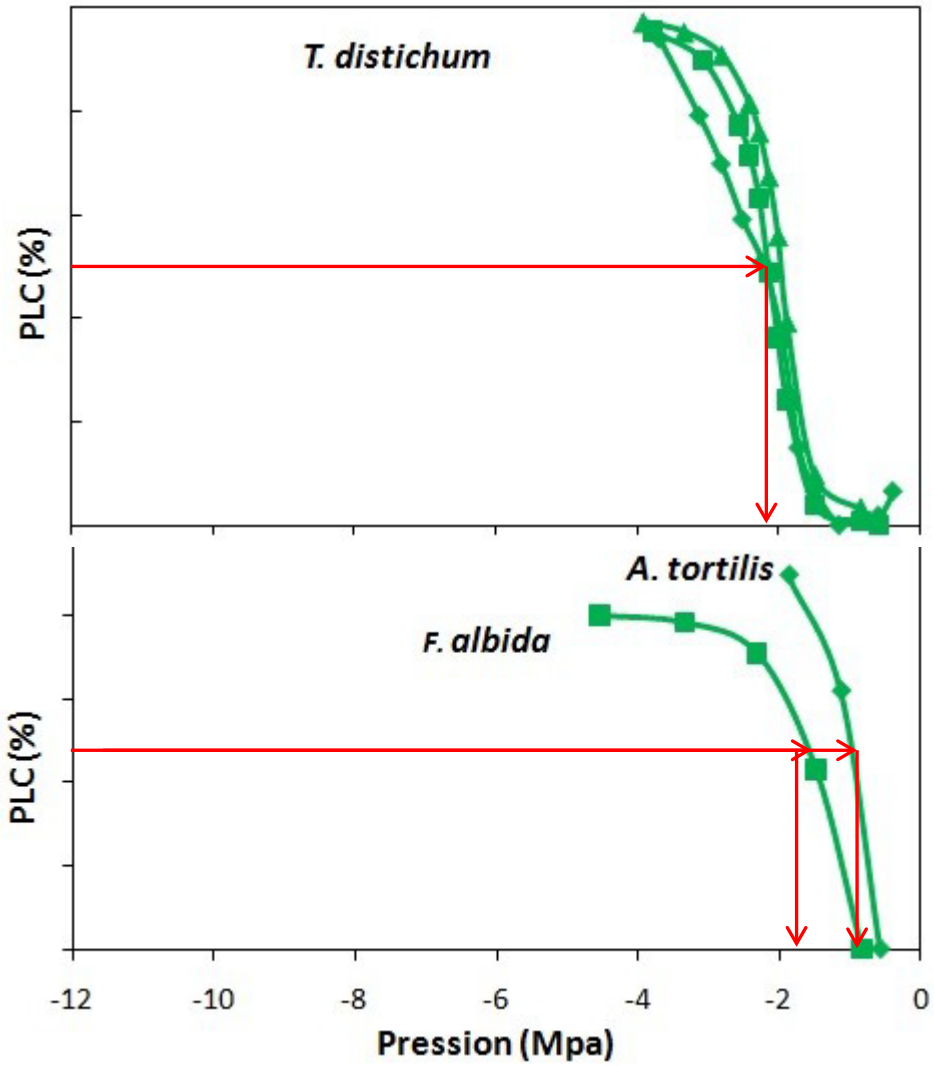



Centrifuge force

➢ Negative pressure (tension)

➢ Effect on conductivity (*K*) measured by the displacement of water between the 2 tanks

# Results

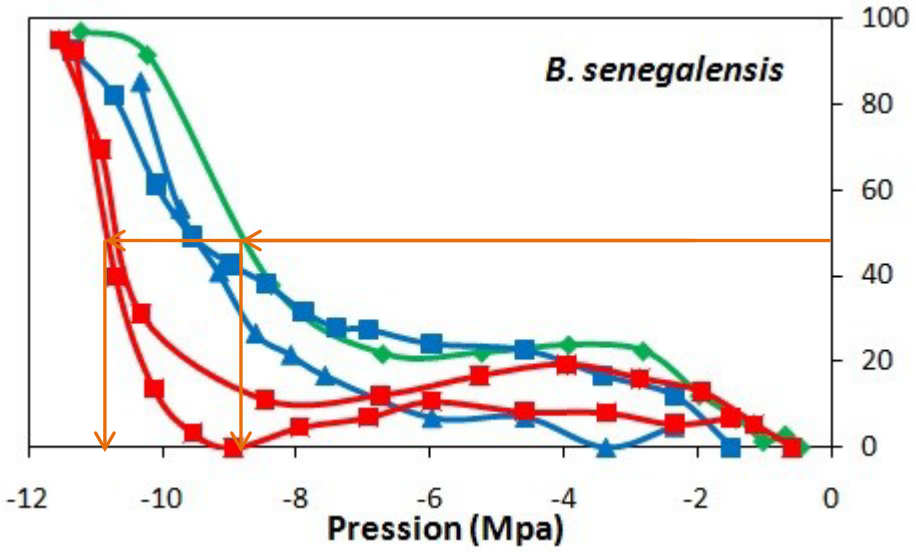



Extremely high P50 on most species,
around -2 Mpa for *T. distichum* and *F. albida*
around -1 Mpa for *A. tortilis*

That would mean that this species are very sensitive to cavitation and would suffer from embolism under moderate water stress

Actually, the shape of the curves, 'R' type, indicates a problem with the measurement.

# Results




Very low P50 in *Boscia senegalensis* (from -8 to – 10.5 Mpa)

This species is resistant to cavitation and can maintain sapflow under high water stress

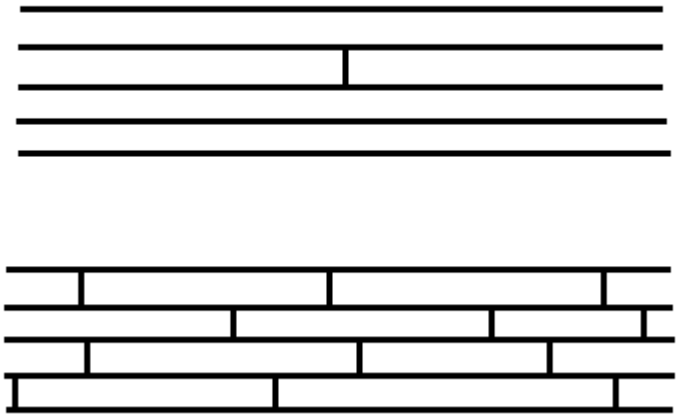
Only with this species we obtained the right 'S' type curves.

# Comparison of measured P50 and minimum observed base leaf water potential

| Species | Min base Leaf potential | P50 |
|---|---|---|
| Acacia tortilis (radiana) | -3.0 | -1.1 |
| Balanite aegyptiaca | -4.4 | -3.1 |
| Boscia senegalensis | -6.5 | -9.7 |
| Celtis integrifolia | -3.3 | |
| Faidherbia albida | -3.8 | -1.9 |
| Prosopis juliflora | -4.1 | |
| Sclerocaria birrea | -1.6 | -1.5 |
| Tamarindus indica | -4.1 | -3.6 |
| Ziziphus mauritania | -3.6 | -1.3 |
| Adansonia digitata | -1.3 | |

Most the species are actually able to function under lower water potential (higher water stress) than P50.
The method overestimates the sensitivity to cavitation, except in *Boscia senegalensis.*

# Why such problem?
# The vessel length issue



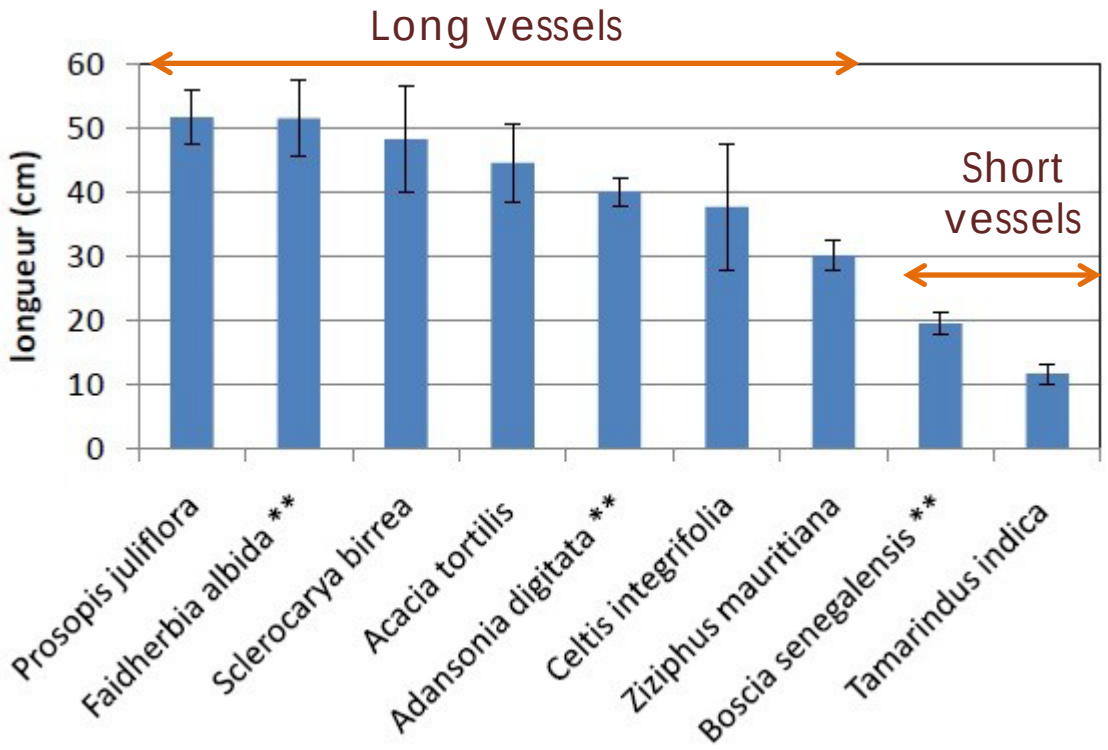
Long vessels

Short vessels

Xylem vessels are segmented by pits. When the vessel length is longer than the Cavitron rotor, most vessels are open (cut) and filled by air during installation.

- artificial early loss of conductivity
- R type curves

# Why such problem?
# Most the studied species had long vessels




Branch segment length corresponding to about 10 open vessels (proxy of mean vessel length)

# Prospects

➢ The Cavitron Method is not adapted to most the studied species and more generally it is know questioned for most angiosperms, which have long vessels.

➢ Old method by dehydratation (Sperry et al. 1988).

➢ Measurement of native embolism rate as related to water potential

➢ Mesurements of other traits correlated to resistance to cavitation.

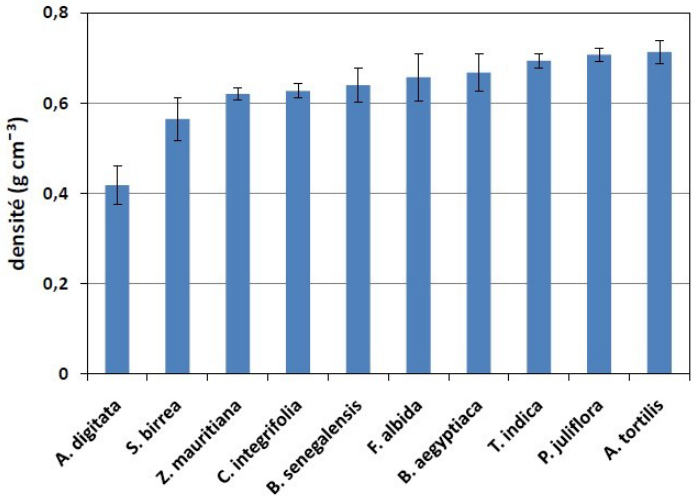
# Prospects

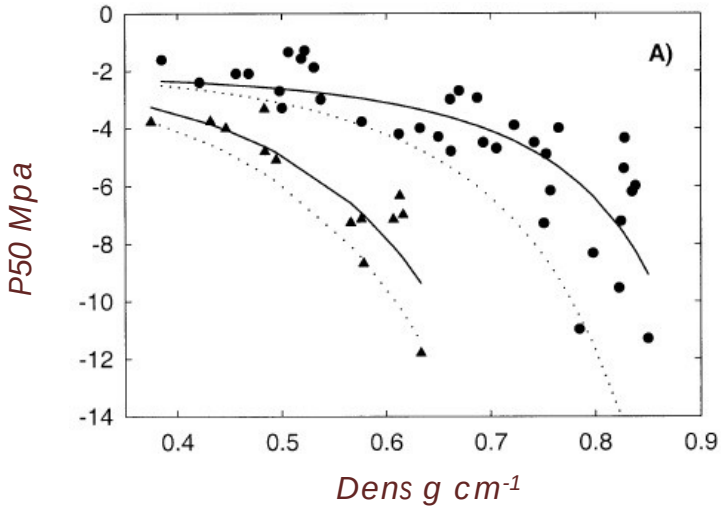
➢ A proxy to P50: wood density.

According to the measured density, we expect:

-6 Mpa < P50 < - 2 Mpa

➢ Wood anatomy : characterization of vessel pathways (density, surface, structure).
To be performed in 2013 on anatomical slices prepared by UCAD, Dakar




Relationship between wood density and *P50* (Hacke et al. 2001)

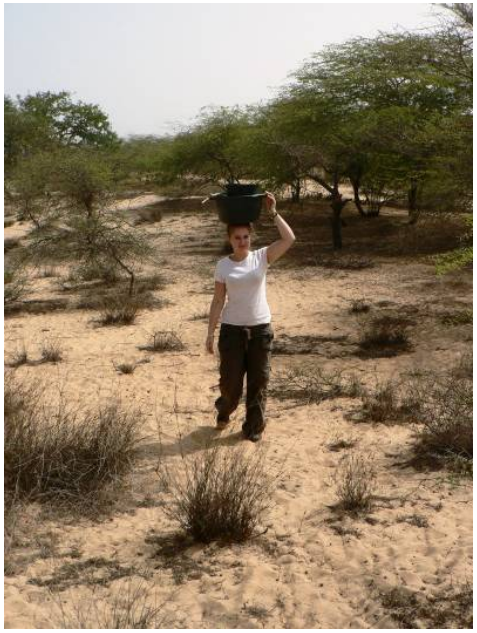
# Prospects

Possible paper:

Methodological limits to the measurement of hydraulic traits of Sahel trees.

P Thaler, A Cosiaux, S Delzon and M Diouf

# Merci pour votre attention



# FORAGE INTAKE OF TREE SPECIES ON RANGELANDS:

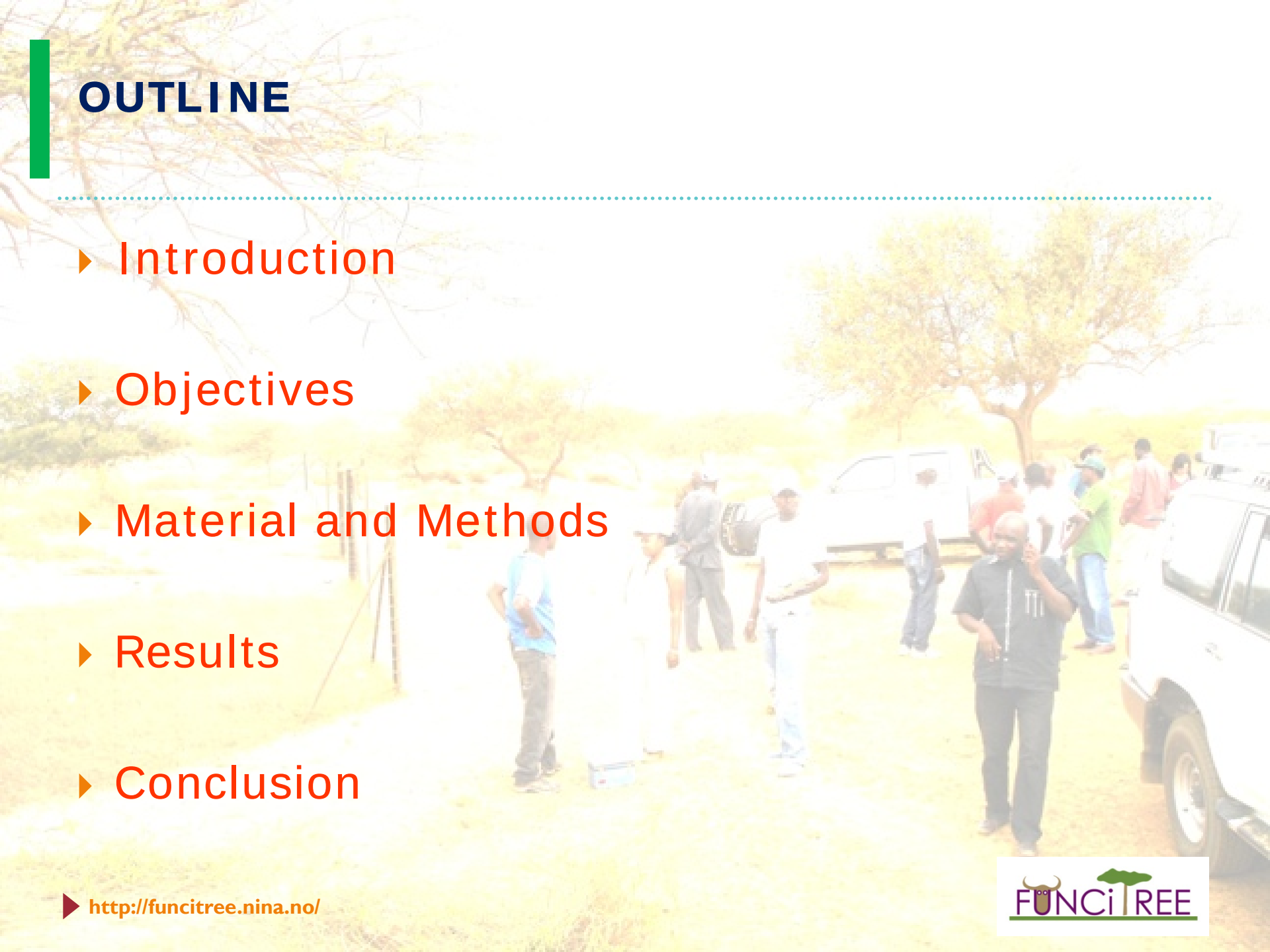
## A relative value as a combination of resource availability, species traits and ruminant behavior

**FUNCITREE – WP4**

**V.HEISLEN, M.MEURET, H.GUERIN,**
**E.H.TRAORE, A.ICKOWICZ,**

# OUTLINE

- Introduction
- Objectives
- Material and Methods
- Results
- Conclusion



# INTRODUCTION

- In dry areas, tree and shrubs play a major role in ruminant feeding during dry season (quantity, quality) (10 to 90%)
- Appetability of forage trees and shrubs species is variable and related to available forage
- Some individuals are very much browsed while others are not
- How to manage tree and shrub contribution to feeding ?

# OBJECTIVES

## General objective:

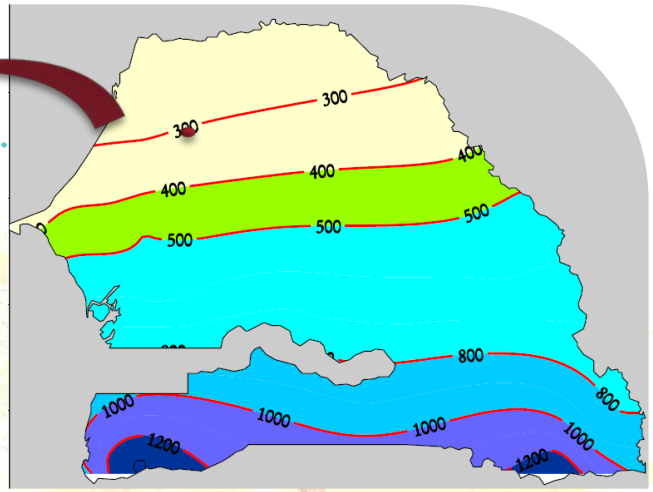
Describe functional traits related to forage value of trees and shrubs through study of ruminant feeding behavior

## Specific objectives:

- Describe the feeding system of ruminant in study site
- Estimate tree and shrub contribution to the ruminant diet
- Identify trees and shrubs functional traits that explain forage value

# MATERIAL AND METHODS

- Senegal
  - Louga Region
    - Communauté Rurale de Léona




*Niayes zone*

*Dieri zone*

# MATERIAL AND METHODS

- 3 cattle herd

| gradient agro-éco | Ouest ⟵ Est ***Niayes Dieri*** | | | |
|---|---|---|---|---|
| spécificité pastorale | présence de *Niayes* | pression pastorale et anthropique importante | faible pression foncière dominante sylvo-pastorale | |
| Ruminant | bovin | bovin | bovin | ov./caprin |
| conduite | extensive | intensifiée →distribution de concentré | extensive | extensive |
| effectif | 46 | 25 | 40 | 60 |
| nb. de suivi | **6** | **4** | **7** | 3 |

- Survey period : ⟶ Dry season: april to july
- Frequence of surveys: ⟶ 5-20 days
- Survey duration: ⟶ 1-2 days/herd

http://funcitree.nina.no/

# MATERIAL AND METHODS

## « Herd – Rangeland » level :

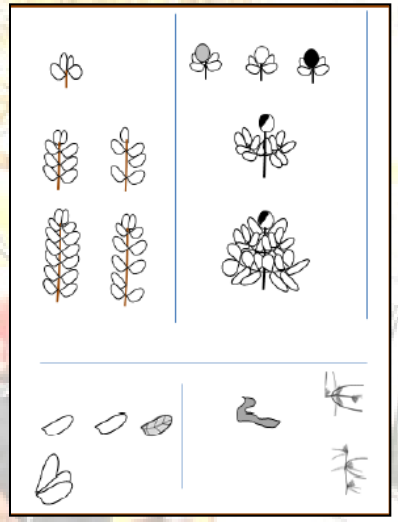
- Tree cover description
- Herd activities:
  - % of tree intake by herd
  - other activities

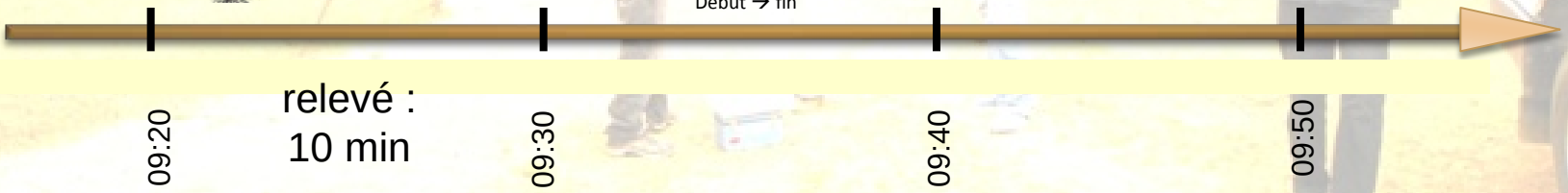
## « Animal – Plant » level :

→ PIL observation

→ Intake rate by catégory of forage

***Grid for coding bites***




- **Intake time on trees (PIL)**

http://funcitree.nina.no/

# RESULTS : INTAKE BEHAVIOR

# RESULTS : FORAGE TREE AVAILABILITY IN DRY SEASON

**Dominant species**
**N= 5**

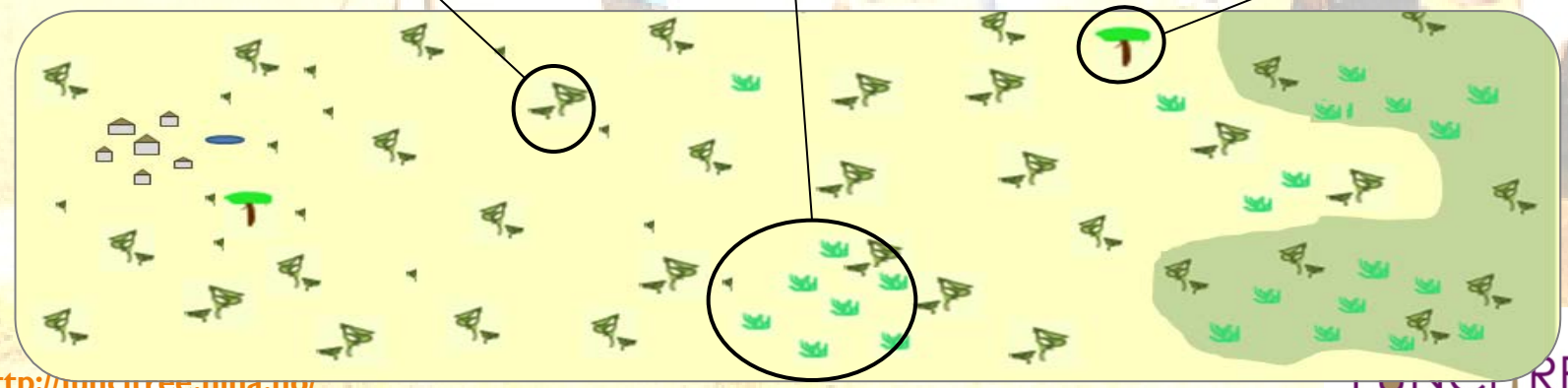
*Balanites* aegyptiaca
*Acacia tortilis*
*Faidherbia albida*
*Acacia senegal*
*Combretum glutinosum*

**Localised species**
**N= 4**

*Boscia senegalensis*
*Guiera senegalensis*
*Maytenus senegalensis*
*Prosopis juliflora*

**Isolated species**
**N= 16**

*Zizyphus mauritiana*
*Cassia sieberiana*
*Celtis intergrifolia*
*Bauhinia rufescens*
*Pilostigma reticulatum*
*Neocarya macrophylla*
*Commiphora africana*
*Sclerocarya birrea*
*Tamarindus indica*
*Adansonia digitata*, . . .



# RESULTS : HERD CIRCUITS



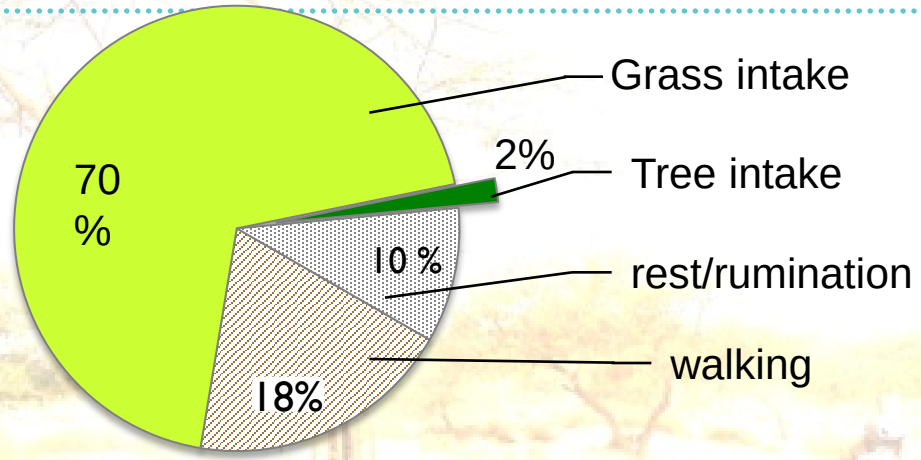



http://funcitree.nina.no/

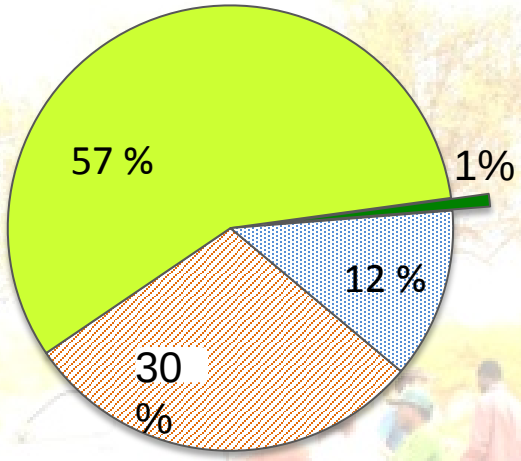
FUNCiTREE

# RESULTS : SHARE BETWEEN ACTIVITIES

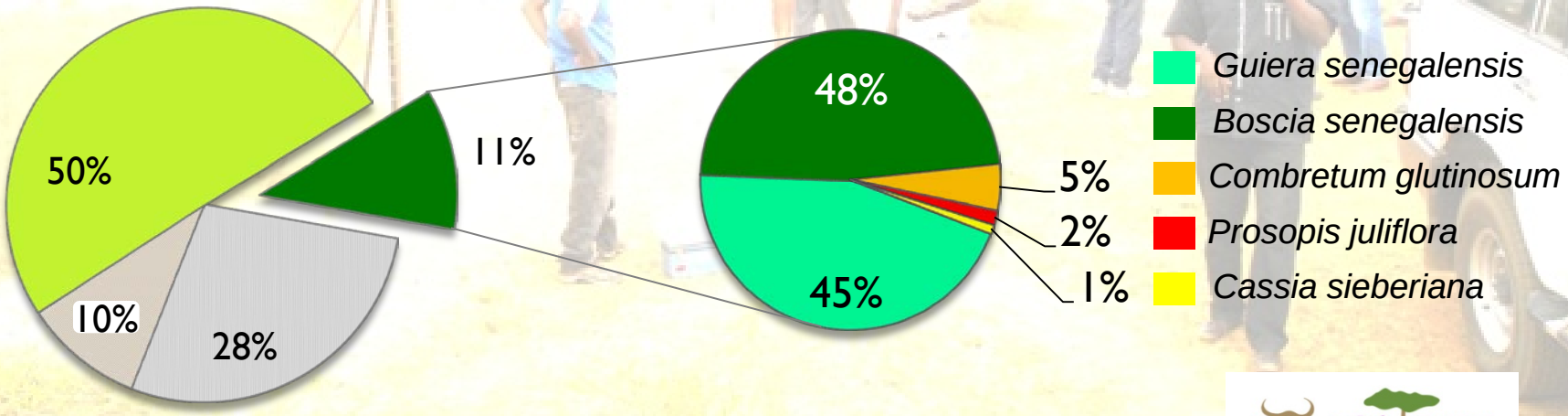
o « *Niayes* » Herd




o « Intensified-*Dieri* » Herd

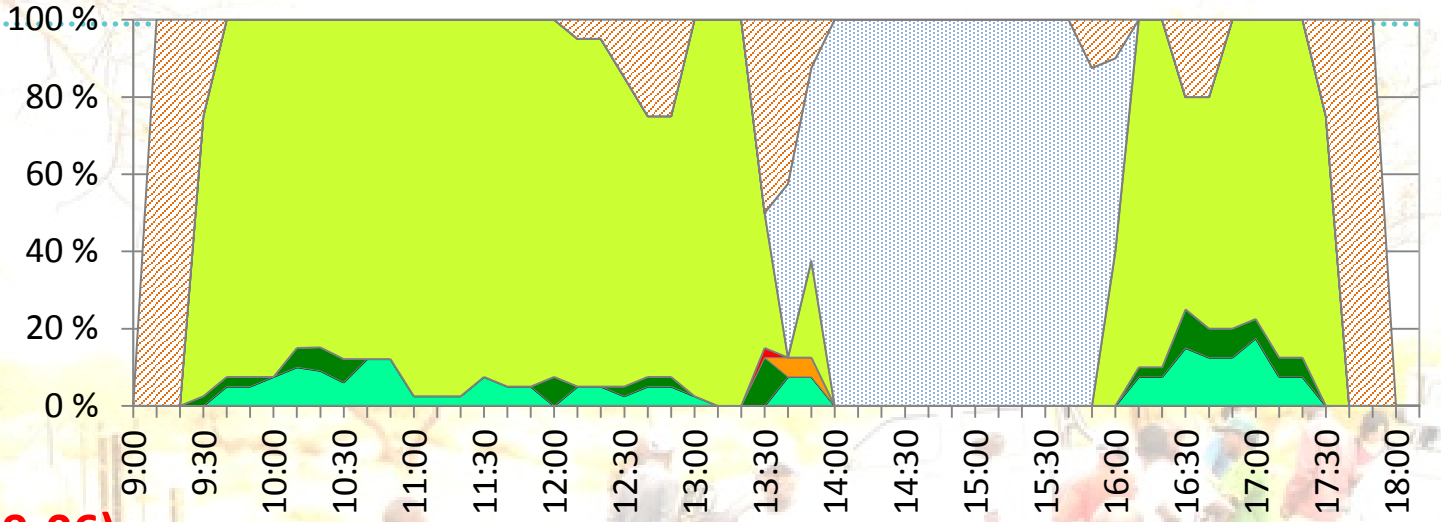



o « Extensive-*Dieri* » Herd

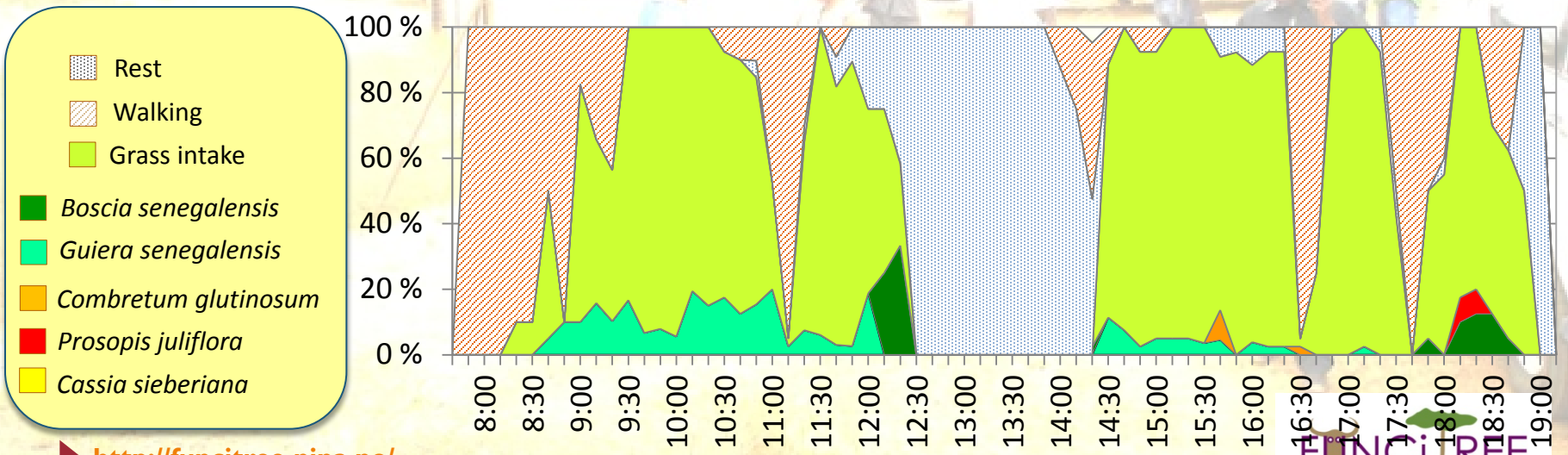


# RESULTS : HERD ACTIVITIES

## April (24-04)




## Mid-june (19-06)




http://funcitree.nina.no/

FUNCiTREE

# RESULTS: INTAKE RATE ESTIMATES

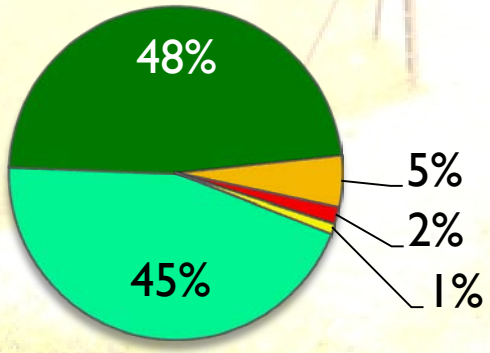
- Type and mass of bite (PA) known
- nb of PA per PIL
- Duration of PIL


nPA_1 + nPA_2

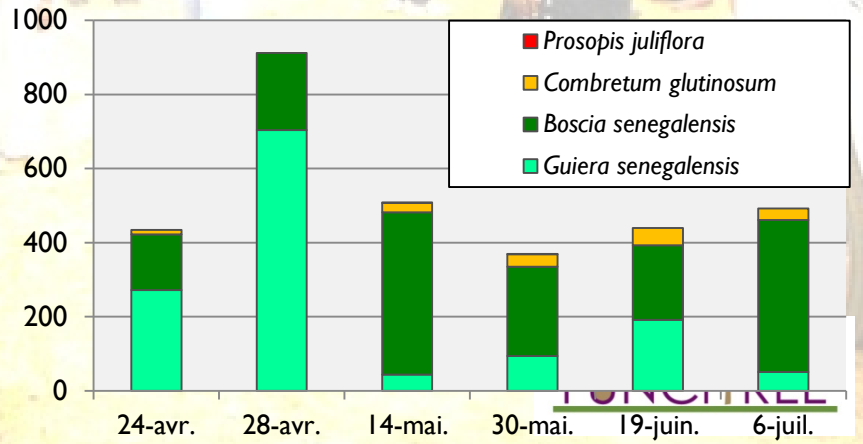
**Estimates of intake rates (g DM / min)**

| | |
|---|---|
| *Guiera se.* | 11 g DM/min |
| *Boscia se.* | 12 g DM/min |
| *Combretum se.* | 15 g DM/min |
| *Prosopis ju.* | 3 g DM/min |

- Proportion of time spent




- Estimates of daily intake (g DM/day)

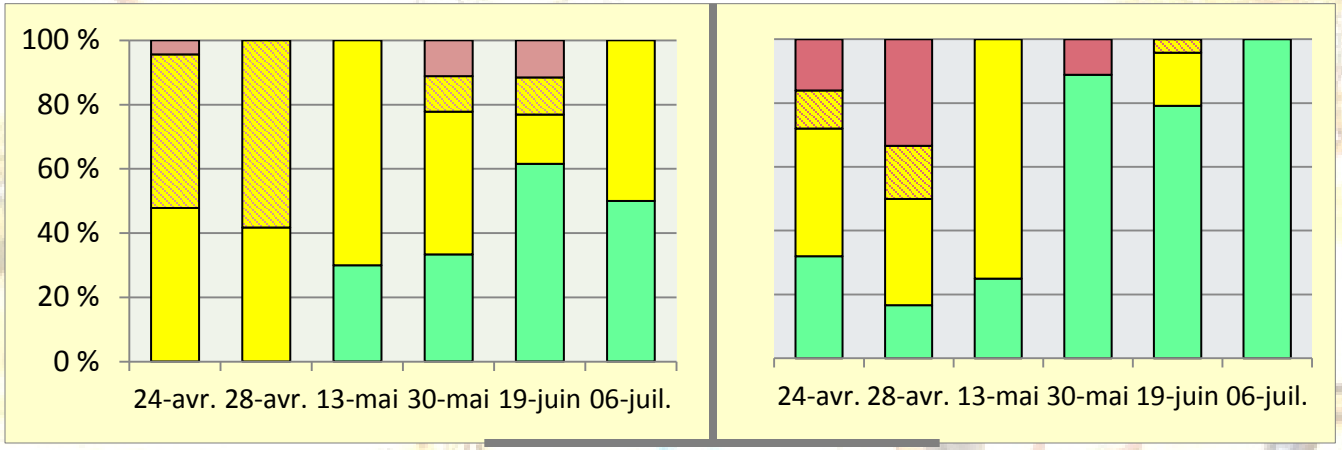



http://funcitree.nina.no/

# RESULTS: INFLUENCE OF PHENOLOGICAL TRAITS

## *Guiera senegalensis :*

**Phenology stage of browsed trees** *vs* **Phenological stage of local population**




- Preference for fruits
- Flowers not browsed

## *Boscia senegalensis :*

Only fructification phase

- *Reject fruits*
- *Leaves browsed*

http://funcitree.nina.no/

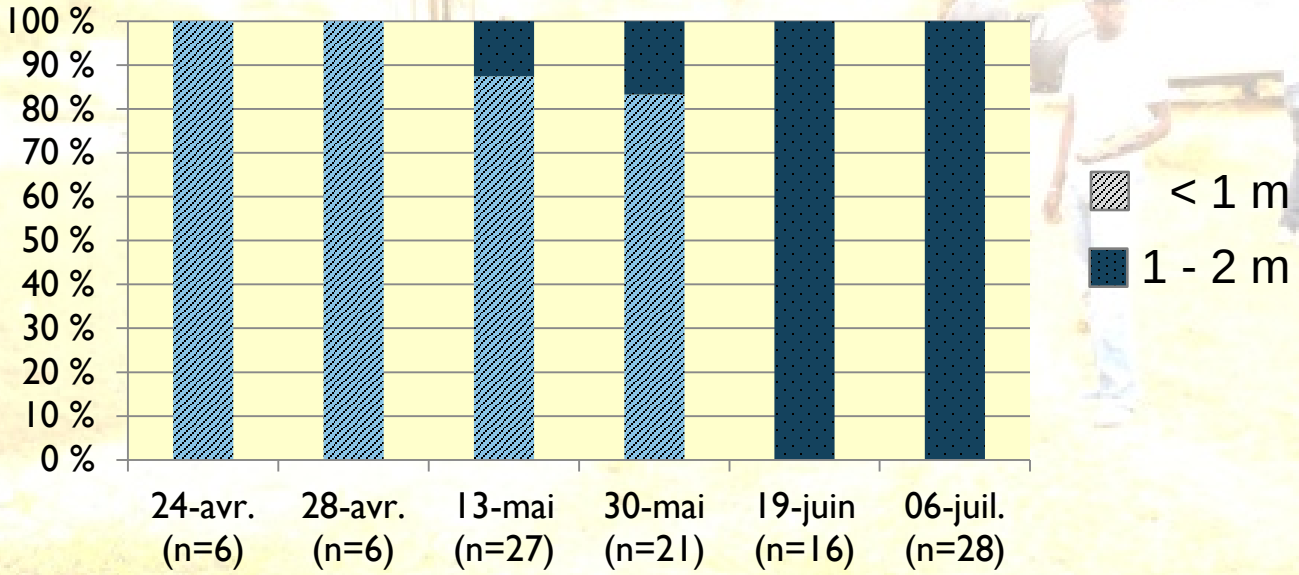
# RESULTS: INFLUENCE OF HEIGHT

## *Guiera senegalensis :*

*No preference*

## *Boscia senegalensis :*

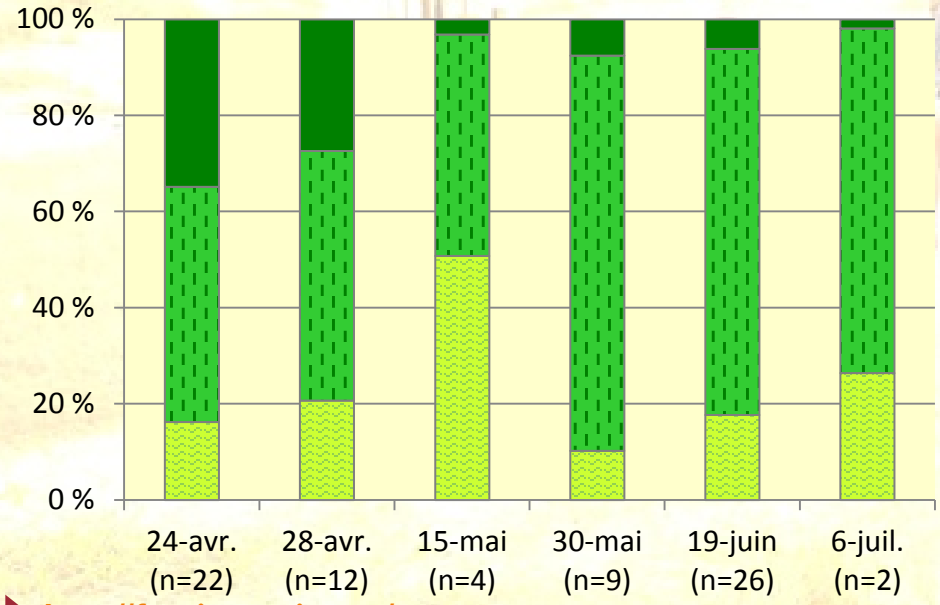
Feeding behavior vary with shrub heigth




# RESULTS: STRUCTURE OF BITES

## *Guiera senegalensis :*

| type de prise | description | Masse (g MS) |
|---|---|---|
| **Prise feuille** | feuille uniquement | 0,08 - 0,23 |
| **Prise rameau** | tige peu lignifiée + feuille ; matériel végétal frais | 0,15 - 0,74 |
| **apex** | structure dense, composée de plusieurs rameaux ; pouvant porter fleur et fruit | **2,30 - 2,55** |

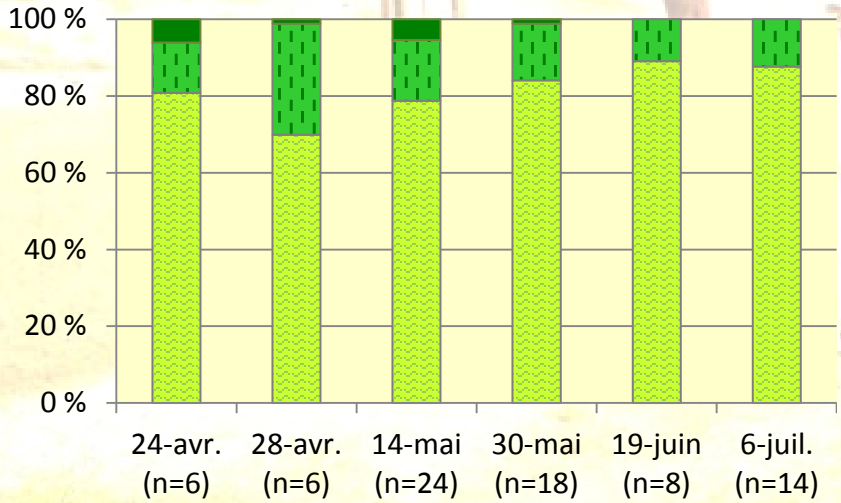



http://funcitree.nina.no/

# RESULTS: STRUCTURE OF BITES

## *Boscia senegalensis :*

| type de prise | description | masse (g MS) |
|---|---|---|
| Prise feuille | feuille uniquement | 0,18 - 1,68 |
| Prise rameau | section de tige portant des feuilles | **2,10** |
| Prise apex | section de « partie terminale » composée de petites feuilles | 0,82 |

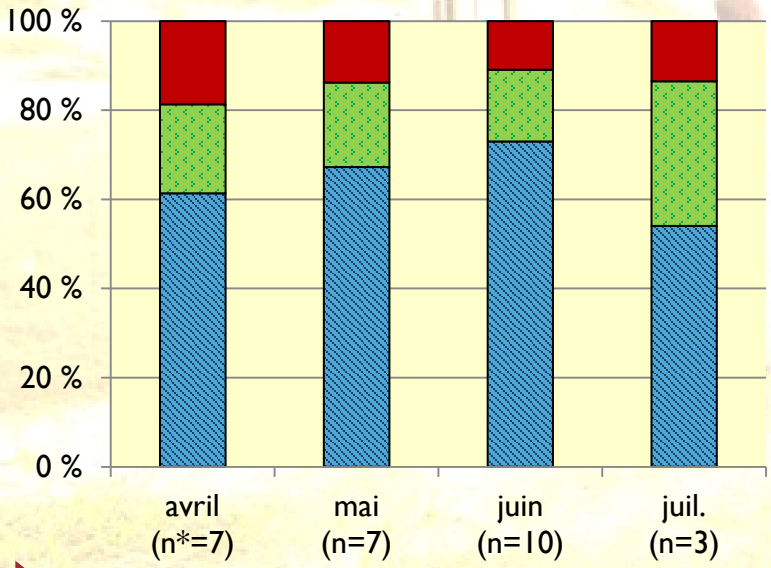




http://funcitree.nina.no/

# RESULTS: STRUCTURE OF BITES

## *Combretum glutinosum :*

| type de prise | description | code | masse (g) |
|---|---|---|---|
| Prise Clip | feuille âgées, coriaces, couleur vert-grisâtre | Clip V | 0,86 |
| | feuille jeunes, souples, couleur vert claire. | Clip J | 0,90 |
| Prise twig | section terminale des tiges, composée d'une section de tige & portant des jeunes feuilles couleur vert-rouge. | Ram 5 (~5cm) | **3,5** |
| | | Ram 10 (8-10cm) | **6,25** |




PA type twig

PA type Clip V (young leave)

PA type Clip J (old leave)

http://funcitree.nina.no/

# RESULTS: FUNCTIONAL INTERPRETATION

+ abondance & leaves availability

-

Structure & leaves prehension

*Combretum glutinosum*

*Guiera senegalensis*

*Boscia senegalensis*

*Prosopis juliflora*

**Feeding selection on rangelands**

Always browsed when met

Not always browsed when met

**Intake rate**

***Guiera se. & Boscia se.***
Small leaves
Open structure
Good prehension

*medium*

**Group A** :

*Guiera se.*
*Boscia se.*

***Combretum gl.***
Big leaves
Good prehension
Chemical repelent

*high*

***Prosopis ju.***
Sparse leaves
Spines: low prehension

*low*

**Group B :**

*Combretum gl.*
*Prosopis ju.*

http://funcitree.nina.no/

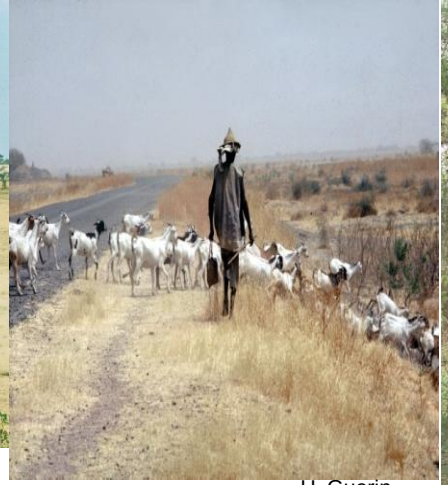
FUNCiTREE

# CONCLUSION

- Forage value of trees depend on other forage resource availability
- According to season, phenogical traits have some influence in ruminant browsing behavior and intake rate
- Morphological traits (height, structure) might be linked with other traits (chemical) that influence browsing
- A diversity of tree species allow to provide tree forage in a regular basis as they are complementary (phenology)

I;Touré

V. Heislen



H. Guerin

B. Toutain

# Fodder function of trees and shrubs for domestic ruminants in african arid areas. Characterization with mutidimensional traits

**Guerin H. [1], Ickowicz A.[1],**

Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France.

**Corresponding author/presenter**: Hubert Guerin ; hubert.guerin@cirad.fr

cirad

http://funcitree.nina.no/

FUNCiTREE

# Introduction
# Diversity of contexts focused on Western an Central Africa


- Projects in partnership *
- Sylvo-pastoral sahalian
- Agro-sylvo pastoral sahalo sudanian
- Agro-sylvo-pastoral guinean
- **ISRA Sénégal, IER Mali, CNRA Ivory Coast, IRAD Cameroon, LRVZ Chad, U. Hohenheim Germany, UA Gembloux-Libramont Belgium*

8 sites between 9° and 16 °Lat
300 to 700 mm rains during 3 to 6 months
200 species common in sahelo-sudanian west africa
In general 20 to 30 significative species by site



FUNCiTREE

# FODDER FUNCTION

- **I  What means fodder function ?**
- uses, effects on ruminants, nutritional interpretation
- **II Building of knowledge**
- Traditional knowledge  -Scientific knowledge –Integration
- **III : Analytical approach of fodder function : terms and chaining**
- Resource in its context –Animal resource interaction
- **IV : Comparisons and relative value**
- According  contexts ; tree species ; animal species
- **V Impact of fodder function on resources**
- **CONCLUSION : Which use of knowledge ?**

# I What means fodder function ?

## I.1 Diversity of fodder uses,

### Spontaneous Direct Intake

- Browsing on trees and shrubs

B.Toutain

- Gleaning on soil :
- dried leaves (*Calotropis procera*),
- flowers –
- pods (*Acacia sp.)*
- fruits (*Sclerocarya birrea*)

# I What means fodder function ?

## I.1 Diversity of fodder uses,

### Spontaneous Direct Intake

- Browsing on trees and shrubs

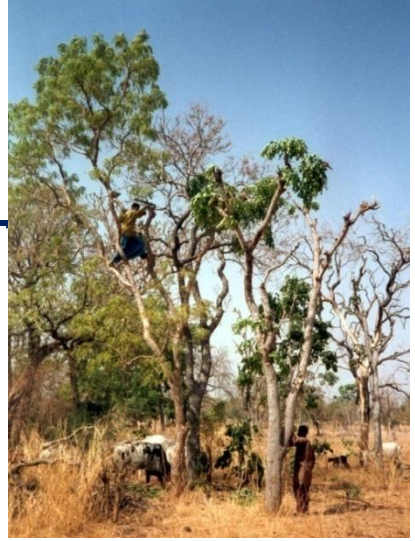
B.Toutain

- Gleaning on soil :
- dried leaves (*Calotropis procera*),
- flowers –
- pods (*Acacia sp.)*
- fruits (*Sclerocarya birrea*)

C. Cossalter

B. Toutain

# I.1 Diversity of fodder uses



## Assisted browsing

- Herding on ranges : palatable shrubby areas

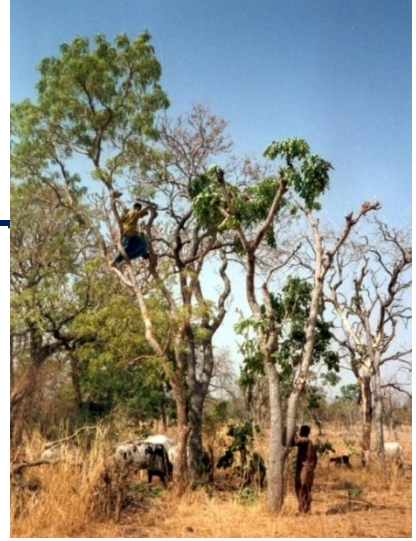
- Pollarding (i.e.*Pterocarpus sp.*)
- Pruning (i.e. *Adansonia digitata*)
- Cropping, selling in market and foraging in stabulation

http://

# I.1 Diversity of fodder uses

## Assisted browsing

- Herding on ranges : palatable shrubby areas



S. Petit

- Pollarding (i.e.*Pterocarpus sp.*)
- Pruning (i.e. *Adansonia digitata*)
- Cropping, selling in market and foraging in stabulation

M. Arbonnier

D. Louppe

D. Louppe

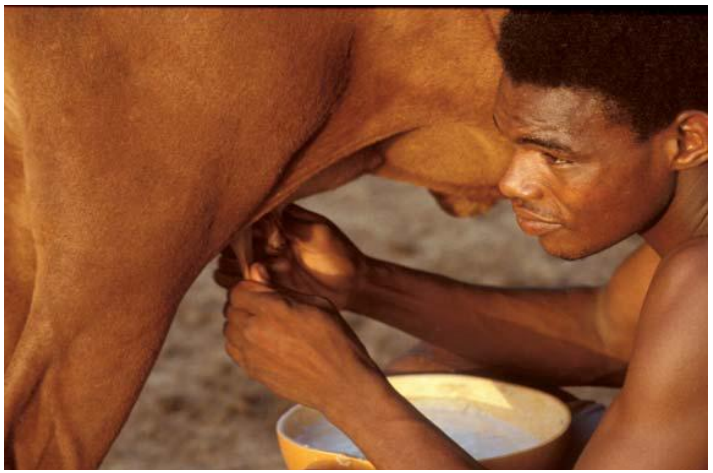
H. Guerin

http://funcitree.nina.no/

# I What means fodder function ?

## I.2 Maintenance and animal production

- **Nutritional status** - end of dry season
- **Survival -drought**
- **Growth**
- **Reproduction**
- **Milking** :
- **Weaning**
- **Fattening**
- **Medicine**



D. Barriere

V. Heislen

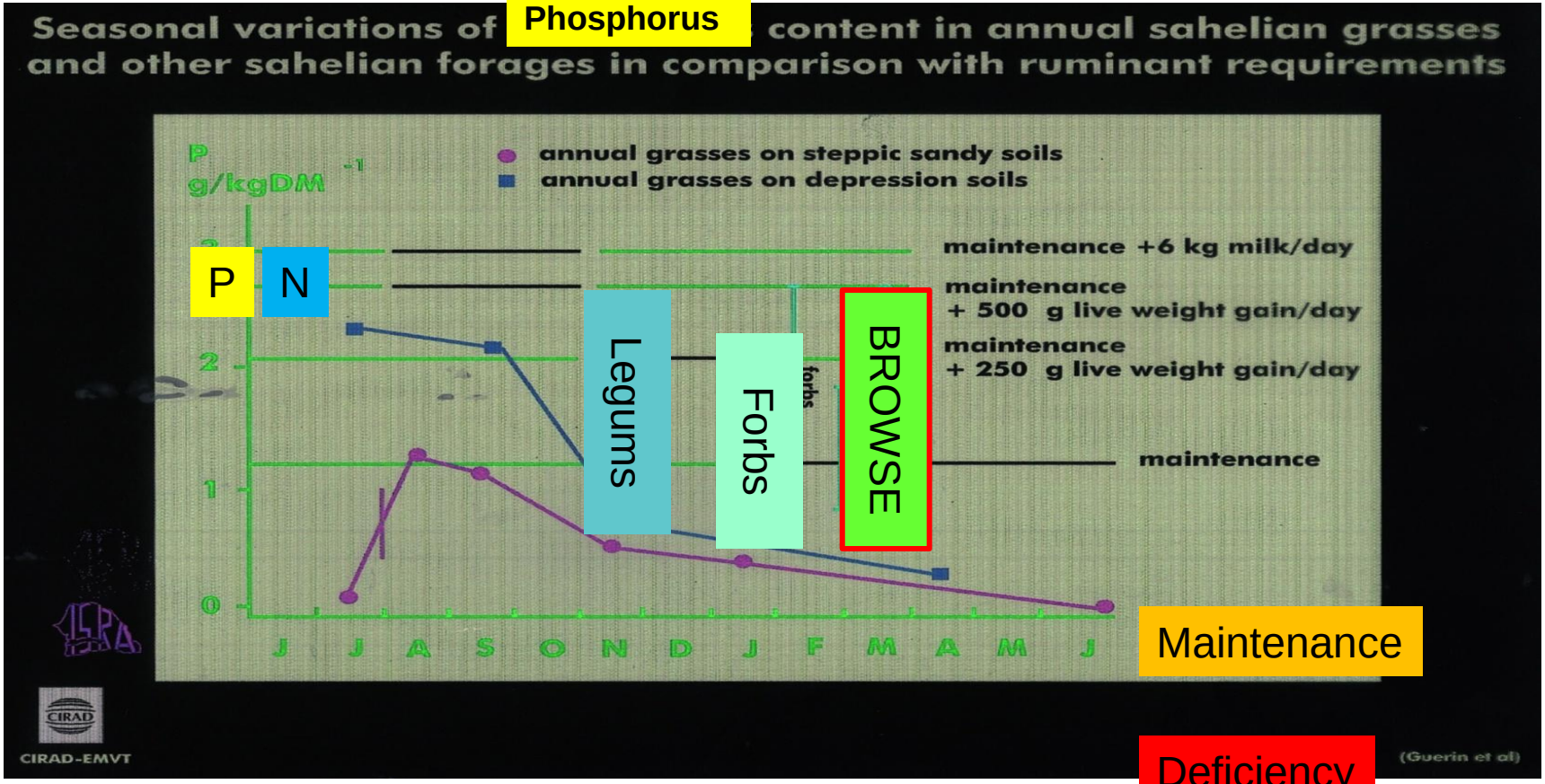
# I What means fodder function ?
## Physiologist and animal scientist points of view

- Nutritional Context –
- rare rough poor herbaceous biomass :
  - Nitrogen and minerals deficiencies
  - Low digestibility, low intake, low energy intaked

D. Friot

Nitrogen

Phosphorus




**two steps of supplementation** :

1 - rumen microbial flora :

digestion of fiber - intake stimulation

2 - animal metabolism :

meet nutritional requirements (protein,energy, minerals)

# II Building of knowledge and definition of traits

## II.1 Traditional local knowledge and practices

- - characterization of ranges by trees resource
- - rights on land and resources
- - mobilities
- - sustainables local uses
- - protection and renewal

- *BUT … global changes and increasing local pressure*

Maerua crassifolia
No prunning
Toubous - Chad


Engraving

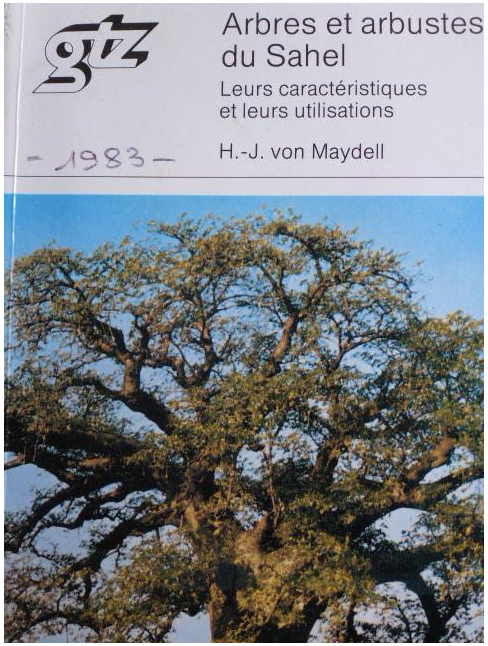
*One tree ies and an ethnic territorial history page disappears (Yosko 1998)*

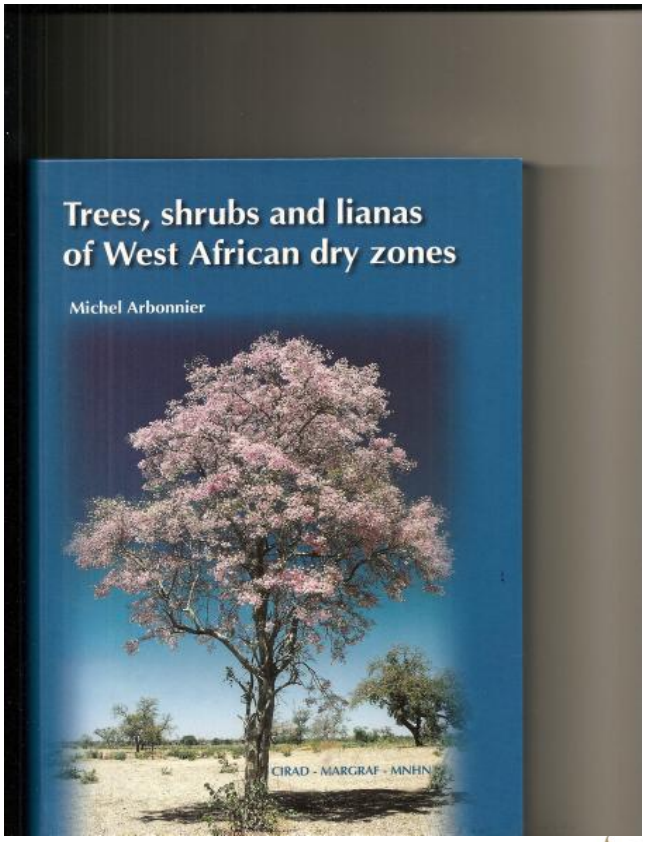
## II Building of knowledge and definition of traits
### II.2 Ecological and multidisciplinary descriptive approaches (60-80…)

BOTANISTS –ANTHROPOLOGIST-PASTORALISTS -FORESTERS

SYNTESIS of KNOWLEDGE

, von MYDELL, ARBONNIER, .



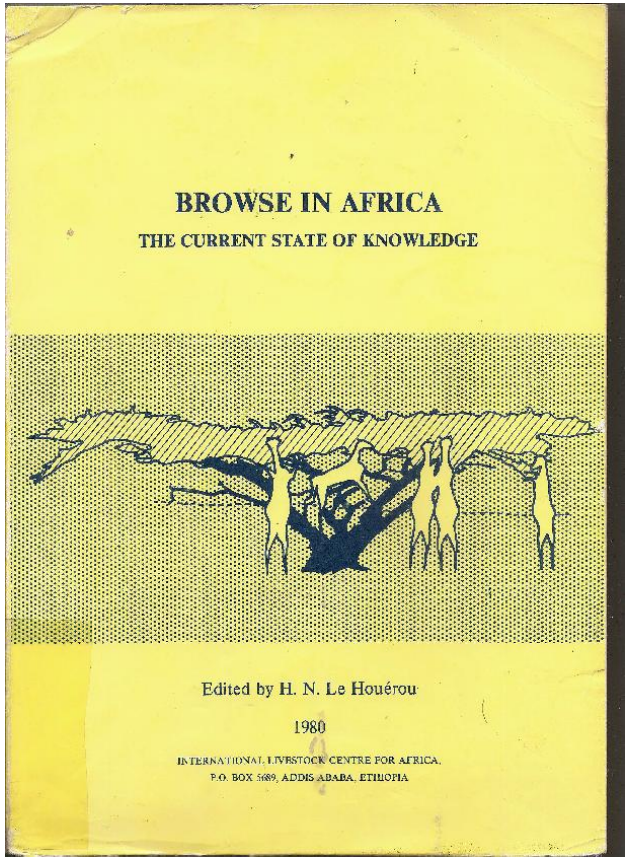
# II Building of knowledge and definition of traits

## II.3 Analytical quantitative AND interdisciplinary systemic approaches (80-00…)

- ***After sahalian droughts,***
  - Browse in africa – Addis Ababa 1980 –Le Houerou ed.
  - Synthesis of knowledge and needs of reserarch

  ***Increase of funded research projects***

- - ecology, productivity and nutrient contents
- - assess plane fodder balances on ranges,
- Increase of interdisciplanarity : foresters, pastoralists, animal scientists
- -
- *Australian, American ranching experience supported (expertise and literature*




http://funcitree.nina.no/

FUNCiTREE

*BUT around 2000  Depression of research on pastoralism*

- Linked to emergence *of controversies :*

- *- livestock and local deforestation*
- *- livestock and global environment*

- *AND*

- *Arid arid areas neglected by development policies : low competivity for development fund*

## II Building of knowledge and definition of traits and new research questions

II.3 Ecological and socio-economical integrated approaches

- XXI Century :
- Two priorities :
  - climate change
  - Development of african agriculture (World bank)

New more integrated diciplinary approaches :

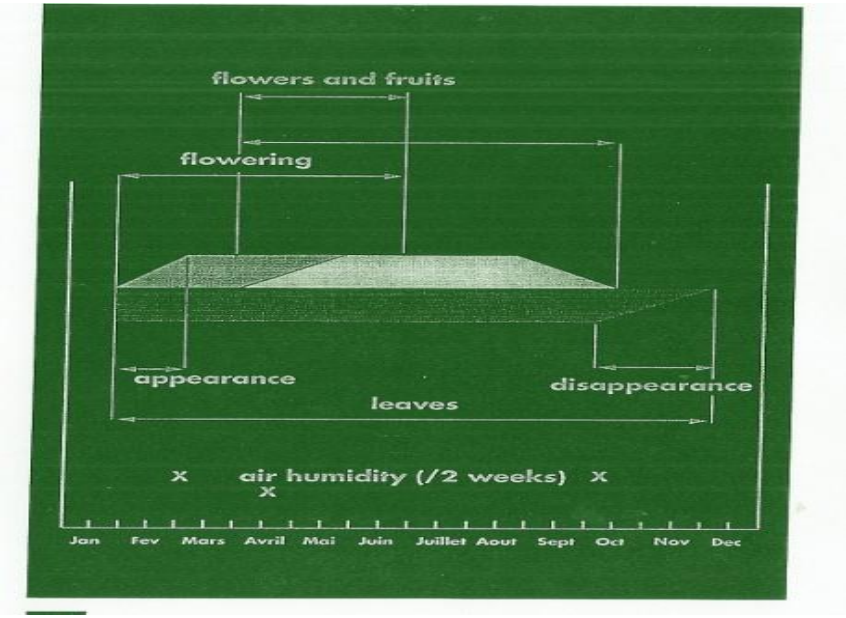
- multi-functionality of agro-sylvo-pastoral territories and resources
- stakeholders local knowledge
- i.e pastoralist organizations and others users
- Integration with support of modeling (i.e. FUNCITREE ambition)
-

# III : ANALYTICAL approach (80-00) of fodder function : sequence of terms.
# Description and prediction –Variability
# III.1 Availability of forage

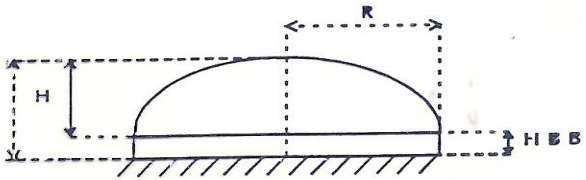
- **Trees demography and cover** :
- field surveys ------aerial photographies ----- remote sensing

**Phenology**,

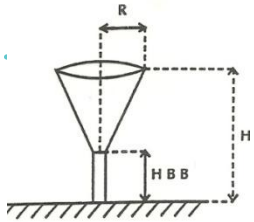
- Stages and categories : leaves and reproduction organs
- **Variability** : species, seasons, topography, soil and water, years, ?
- **Priority** : its synchronisation to animal needs



**Biomass Productivity (/tree, /ha):**
**-maximal available : rainy season, adjusted to phenology, geometric models**

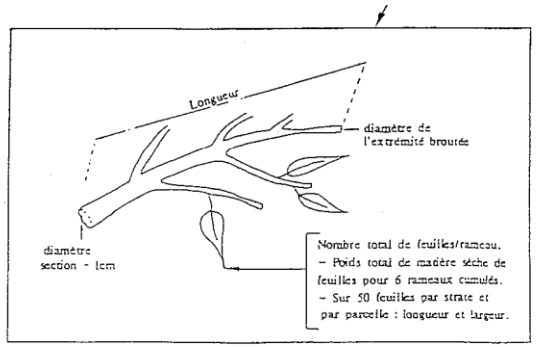


Salvadora persica

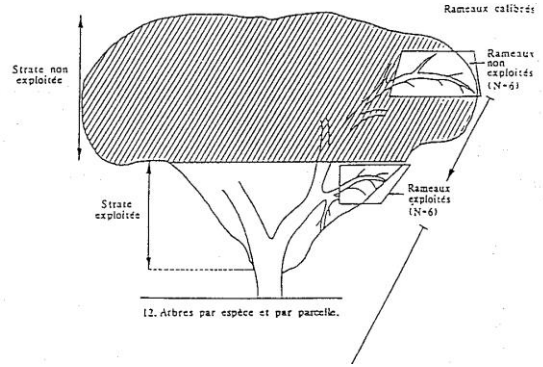


Acacia raddiana
Acacia senegal
Acacia seyal
Acacia laeta
Leptadenia pyrotechnica
Calotropis procera
Ziziphus mauritiana

**-relative : representaive calibrated twigs**




**Accessibility** :
- shape, size and density of crown


# II : ANALYTICAL approach

## III .1 Availabilty :Descriptors of Resource and relation with diet

***: contrasts between criteria***

| | | SYNTHETIC NUTRITIVE VALUE | % RESOURCE | | |
|---|---|---|---|---|---|
| | | | % trees | % area | % biomass |
| THORNY | Acacia senegal | See below | 6 | 18 | 0,1 |
| | Balanites aegyptiaca | | 6 | 12 | 1 |
| NOT THORNY | Boscia senegalensis | | 45 | 8 | 26 |
| | Calotropis procera | | 18 | 4 | 3 |
| | Savadora persica | | 6 | 35 | 69 |

High

Medium

Low

# Nutritive value
# Representative sampling
# Forage or fecal material

Chemical Analysis

- Digestibility in vitro, enzymatic, in situ
- Digestibility in vivo
- NIRS Near Infrared Reflectance Spectrometry

- **AIM : Models for prediction** of
  - digestible energy
  - digestible nitrogen contents

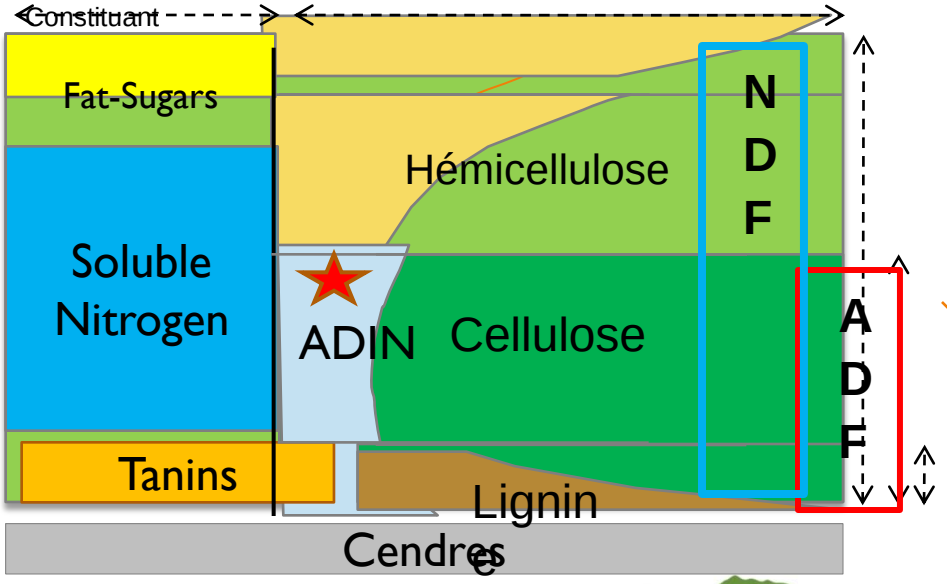
http://funcitree.nina.no/

D. Friot

# ANALYTICAL approach of nutritive value example : chemical Nutritive value

- **Chemical**
- Nitrogen and fiber
- Total nitrogen
- Fibers

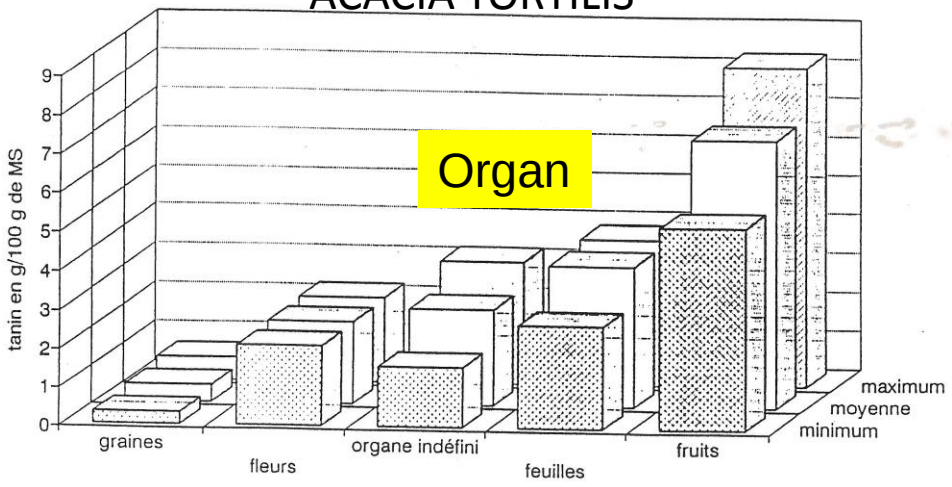
- i.e. NDF : NEUTRAL DETERGENT FIBER
  - ADF : ACID DETERGENT FIBER
  - **ADIN : Acid Detergent Insoluble NITROGEN**
- Tanins



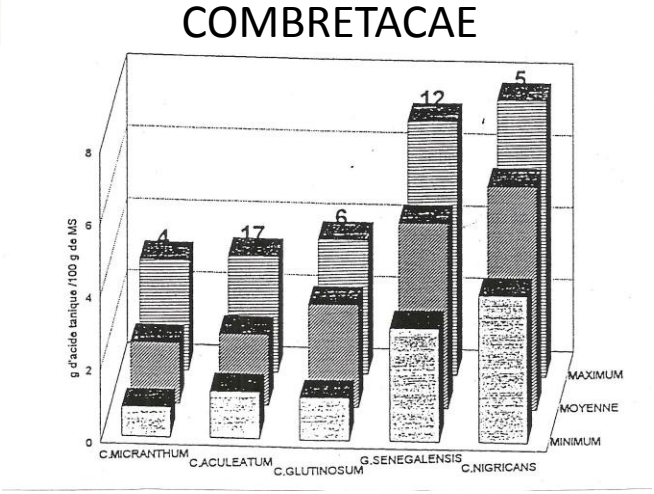
# TANIN CONTENT OF ACACIA species, and *ACACIA TOTILIS* organs

ACACIA SP. -LEAVES


ACACIA TORTILIS




COMBRETACAE



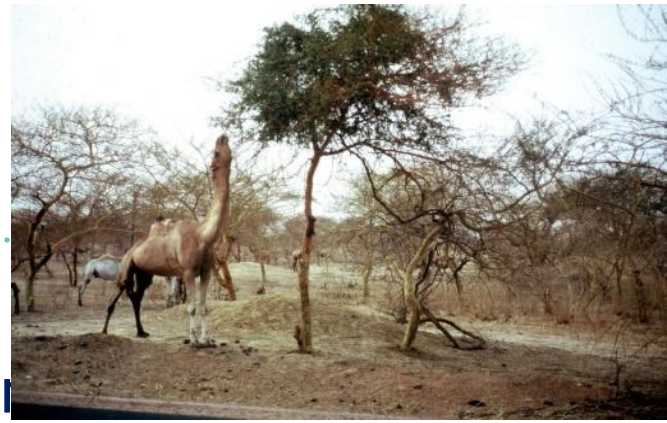

FUNCiTREE

# IV COMPARISONS OF NUTRITIVE VALUE according chemicals analysys and enzymatic degradability of lignous forage *: contrasts between criteria*

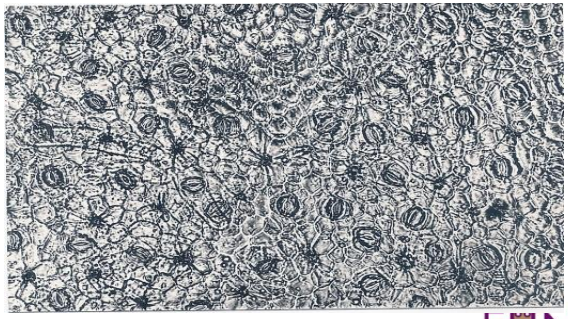
| Nutritive value | Chemical criter |
|---|---|
| High | Good |
| Medium | Medium |
| Low | Bad |

| | | PROTEIN VALUE | | | ENERGY VALUE | ANTINUTRITIONAL | | SYNTHESIS |
|---|---|---|---|---|---|---|---|---|
| | | CRUDE PROTEIN | CP degrad | N in ADF -% Total N | OM degrad | LIGNIN | TANINS | |
| MIMOSACEAE | Acacia seyal | 14 | 62 | 7 | 73 | 4 | 6,6 | |
| | Acacia senegal | 23 | | 7 | 77 | 6 | 0 | |
| | Acacia nilotica | 12 | 67 | 10 | 79 | 6 | 2,6 | |
| | Acacia tortilis | 15 | 51 | 15 | 51 | 10 | 1,4 | |
| | | | | | | | | |
| OTHER THORNIES | Balanites aegyptiaca | 14 | 77 | 10 | 72 | 10 | 0,1 | |
| | Bauhinia rufescens | 13 | 51 | 15 | 51 | 9 | 3,8 | |
| | Ziziphus mauritiana | 12 | 63 | 18 | 56 | 9 | 2,4 | |
| | | | | | | | | |
| COMBRETACEAE | Combretum aculeatum | 12 | 76 | 15 | 55 | 8 | 1,7 | |
| | Combretum glutinosum | 10 | 58 | 12 | 51 | 8 | 3,2 | |
| | Combretum micranthum | 14 | | 12 | 56 | 12 | 3,4 | |
| | Guiera senegalensis | 11 | 27 | 28 | 31 | 16 | 4,2 | |
| | | | | | | | | |
| OTHER | Adansonia digitata | 9 | 48 | 28 | 52 | 11 | 4 | |
| | Boscia senegalensis | 20 | 86 | 5 | 58 | 10 | 0 | |
| | Calotropis procera | 15 | 90 | 5 | 90 | 7 | 0 | |
| | Piliostigma reticulatum | 10 | 58 | 36 | 28 | 20 | 2,2 | |
| | Sclerocarya birrea | 9 | 15 | 29 | 42 | 11 | | |

# Palatibility and intake

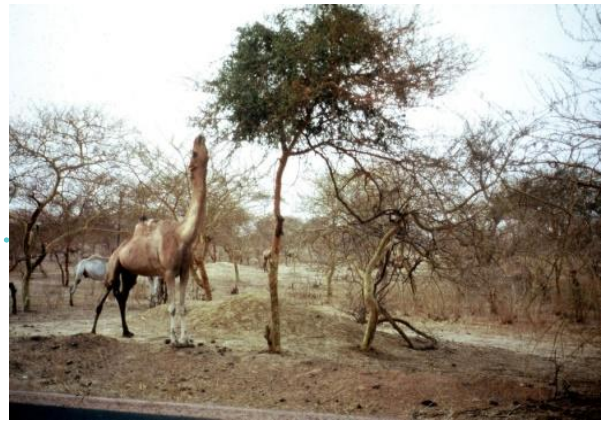


- Damage on trees
- Animal behavior : **from** time spe on species **to** counting bites and measure of intake rate (g/mn)
- Cafetaria test (Nelson Perez - 2011) and in pen measures
- Fecal material
- (plants indigestible epididermis)



# Palatibility and intake

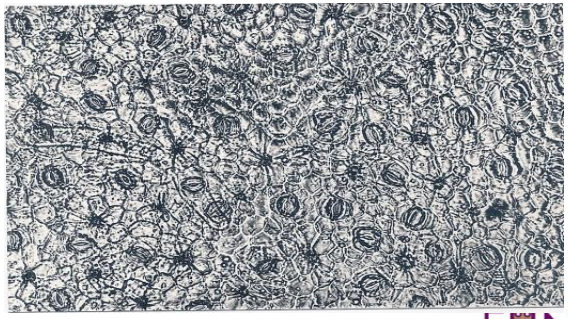
- Damage on trees
- Animal behavior : **from** time spent on species **to** counting bites and measure of intake rate (g/mn)
- Cafetaria test (Nelson Perez - 2011) and in pen measures
- Fecal material
- (plants indigestible epididermis)



A. Ickowicz

D. Friot

D. Friot



*Calotropis procera* epididermis
H. Planton

http://funcitree.nina.no/

FUNCiTREE

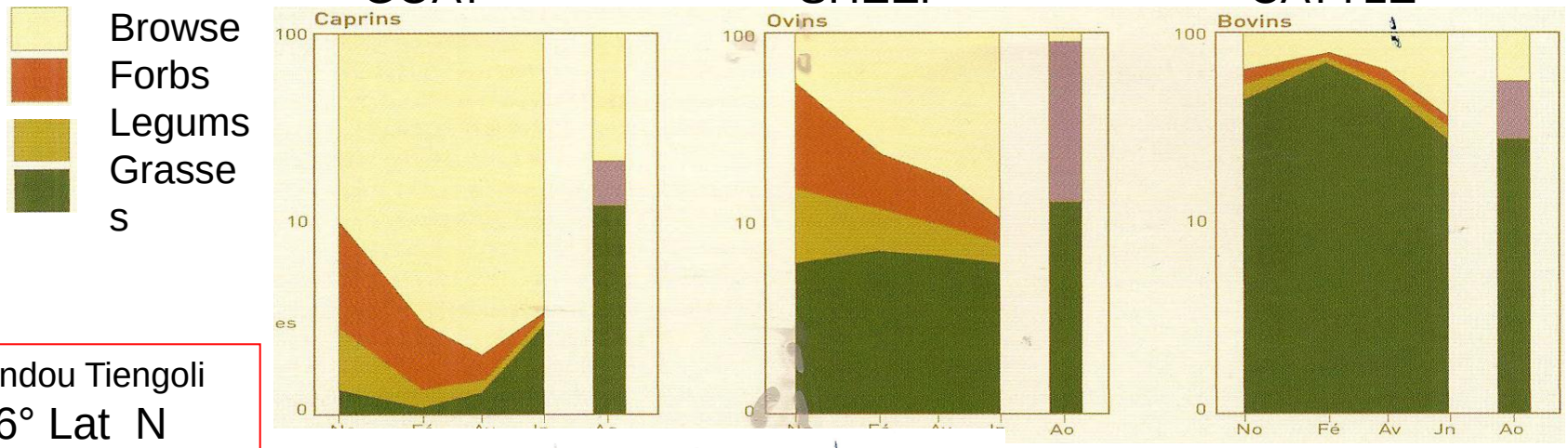
# Descriptors of Resource and relation with diet

| | Availability | Chemical criter |
|---|---|---|
| | Nutritive value | |
| | Palatibilty | |
| | High | Good |
| | Medium | Medium |
| | Low | Bad |

| | | SYNTHETIC NUTRITIVE VALUE | % RESOURCE | | | % DIET | | |
|---|---|---|---|---|---|---|---|---|
| | | | % trees | % area | % biomass | Cattle | Sheep | Goat |
| THORNY | Acacia senegal | | 6 | 18 | 0,1 | 0 | 12 | 19 |
| | Balanites aegyptiaca | | 6 | 12 | 1 | 0 | 4 | 3 |
| NOT THORNY | Boscia senegalensis | | 45 | 8 | 26 | 33 | 0 | 1 |
| | Calotropis procera | | 18 | 4 | 3 | 7 | 57 | 48 |
| | Savadora persica | | 6 | 35 | 69 | 16 | 12 | 11 |

# Example of complementarity between ruminant species

## to exploit browse resource (*mixed grazing* )




Vindou Tiengoli
16° Lat N
Senegal

| | % of the stand (100 subjects/ha) | % of the browsed part of the diet | | |
|---|---|---|---|---|
| | | Cattle | Sheep | Goats |
| Combretaceae | 7 | 29 | 12 | 9 |
| Thorny shrubs and trees | 39 | 2 | 31 | 47 |
| Other shrubs and trees | 54 | 69 | 57 | 44 |

COMBRETACAE
Combretum sp.
Guiera senegalensis

Thorny species :
Acacia sp.
Balanites aegyptiaca
Ziziphus mauritiana

Other species
Sclerocaria birrea

http:

## RESOURCE (% of trees **-%T**)

## CONTRIBUTION TO DIET (Cattle – **C**, Sheep- **S**, Goat-**G**)

| Availability | Chemical criter |
|---|---|
| Nutritive value | criter |
| Palatibilty | |
| High | Good |
| Medium | Medium |
| Low | Bad |

| | | SYNTHETIC NUTRITIVE VALUE | VINDOU 16° | | | | LOUGA 15°30 | | DOLI 14°45 | | | THYSSE 13°45 | | | | BACHOUM 3 13° | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % T | C | S | G | %T | C | % T | C | S | % T | C | S | G | % T | C | S | G |
| | Acacia macrostachya | | | | | | | | | | | 2 | 6 | 2 | 4 | | | | |
| | Acacia seyal - | | 0,5 | | 3 | 4 | | | | | | | | | | | | | |
| MIMOSACEAE | Acacia senegal | | 2 | 0 | 3 | 7 | | | | | | | | | | 6 | 0 | 12 | 19 |
| | Acacia nilotica | | | | | | | | | | | | | | | | | | |
| | Acacia tortilis | | 1 | | | 1 | | | | | | | | | | | | | |
| | Faidherbia albida | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | Balanites aegyptiaca | | 26 | | 23 | 36 | | | | | | | | | | 6 | 0 | 4 | 3 |
| OTHER THORNY | Bauhinia rufescens Lam. | | * | | | | | | | | | | | | | | | | |
| | Ziziphus mauritiana Lam. | | 0,3 | | * | * | | | | | | 1 | 0 | 1 | 4 | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | Combretum glutinosum | | 4 | 0 | 0 | 0 | | ** | 9 | 0~30 | | 41 | 17 | 11 | 13 | | | | |
| | Combretum micranthum | | | | | | | | | | | 4 | 1 | 1 | 1 | | | | |
| | Combretum nigricans | | | | | | | | 2 | | | 13 | 17 | 12 | 12 | | | | |
| | Guiera senegalensis | | 1 | 28 | 12 | 8 | | *** | 85 | 50~80 | | 1 | 4 | 1 | 1 | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | Adansonia digitata | | | 7 | 3 | 1 | | | | | | | | | | | | | |
| | Boscia senegalensis | | 11 | 35 | 15 | 7 | | * | | | | | | | | 45 | 33 | 0 | 1 |
| | Calotropis procera | | 26 | 7 | 12 | 11 | | | | | | | | | | 18 | 7 | 57 | 48 |
| OTHER FAMILIES | Ferethia apodentera | | | | | * | | | | | | 8 | 3 | 12 | 7 | | | | |
| | Icacina senegalensis | | | | | | | | | | | 11 | 1 | 0 | 0 | | | | |
| | Neocarya macrophylla | | | | | | | | | | | 5 | 0 | 0 | 0 | | | | |
| | Savadora persica | | | | | | | | | | | | | | | 6 | 16 | 12 | 11 |
| | Sclerocarya birrea | | 21 | 21 | 18 | 14 | | | | | | | | | | | | | |

Hierarchies of fooder uses in dets depending of fodder value, resource context (other resources) and animal species

NUTRITIVE VALUE,

RESOURCE (% of trees **-%T**)

CONTRIBUTION TO DIET (Cattle – **C**, Sheep-**S**, Goat-**G**)

| Availability | Chemical criter |
|---|---|
| Nutritive value | criter |
| Palatibilty | |
| High | Good |
| Medium | Medium |
| Low | Bad |

| | | SYNTHETIC NUTRITIVE VALUE | VINDOU 16° | | | | LOUGA 15°30 | | DOLI 14°45 | | | THYSSE 13°45 | | | | BACHOUM 3 13° | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % T | C | S | G | %T | C | % T | C | S | % T | C | S | G | % T | C | S | G |
| | Acacia macrostachya | | | | | | | | | | | 2 | 6 | 2 | 4 | | | | |
| MIMOSACEAE | Acacia seyal - | | 0,5 | | 3 | 4 | | | | | | | | | | | | | |
| | Acacia senegal | | 2 | 0 | 3 | 7 | | | | | | | | | | 6 | 0 | 12 | 19 |
| | Acacia nilotica | | | | | | | | | | | | | | | | | | |
| | Acacia tortilis | | 1 | | | 1 | | | | | | | | | | | | | |
| | Faidherbia albida | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | Balanites aegyptiaca | | 26 | | 23 | 36 | | | | | | | | | | 6 | 0 | 4 | 3 |
| | Bauhinia rufescens Lam. | | * | | | | | | | | | | | | | | | | |
| OTHER THORNY | Ziziphus mauritiana Lam. | | 0,3 | | * | * | | | | | | 1 | 0 | 1 | 4 | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | Combretum glutinosum | | 4 | 0 | 0 | 0 | | ** | 9 | 0~30 | | 41 | 17 | 11 | 13 | | | | |
| | Combretum micranthum | | | | | | | | | | | 4 | 1 | 1 | 1 | | | | |
| | Combretum nigricans | | | | | | | | 2 | | | 13 | 17 | 12 | 12 | | | | |
| | Guiera senegalensis | | 1 | 28 | 12 | 8 | | *** | 85 | 50~80 | | 1 | 4 | 1 | 1 | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | Adansonia digitata | | | 7 | 3 | 1 | | | | | | | | | | | | | |
| | Boscia senegalensis | | 11 | 35 | 15 | 7 | | * | | | | | | | | 45 | 33 | 0 | 1 |
| | Calotropis procera | | 26 | 7 | 12 | 11 | | | | | | | | | | 18 | 7 | 57 | 48 |
| OTHER FAMILIES | Ferethia apodentera | | | | | * | | | | | | 8 | 3 | 12 | 7 | | | | |
| | Icacina senegalensis | | | | | | | | | | | 11 | 1 | 0 | 0 | | | | |
| | Neocarya macrophylla | | | | | | | | | | | 5 | 0 | 0 | 0 | | | | |
| | Savadora persica | | | | | | | | | | | | | | | 6 | 16 | 12 | 11 |
| | Sclerocarya birrea | | 21 | 21 | 18 | 14 | | | | | | | | | | | | | |

Hierarchies of fooder uses in diets depend beyond of nutritive value, resource context (other resources) and animal species



FUNCiTREE

# V Impact of fodder function on resource

- climate change ?
- Zoo anthropogenic factors :
  - overbrowsing
- - breaking branches (*Acacia sp.)*
- *W*ood utilisation

  *(equipping wells i.e.)*
- cultures

Von Maydell

B. Toutain

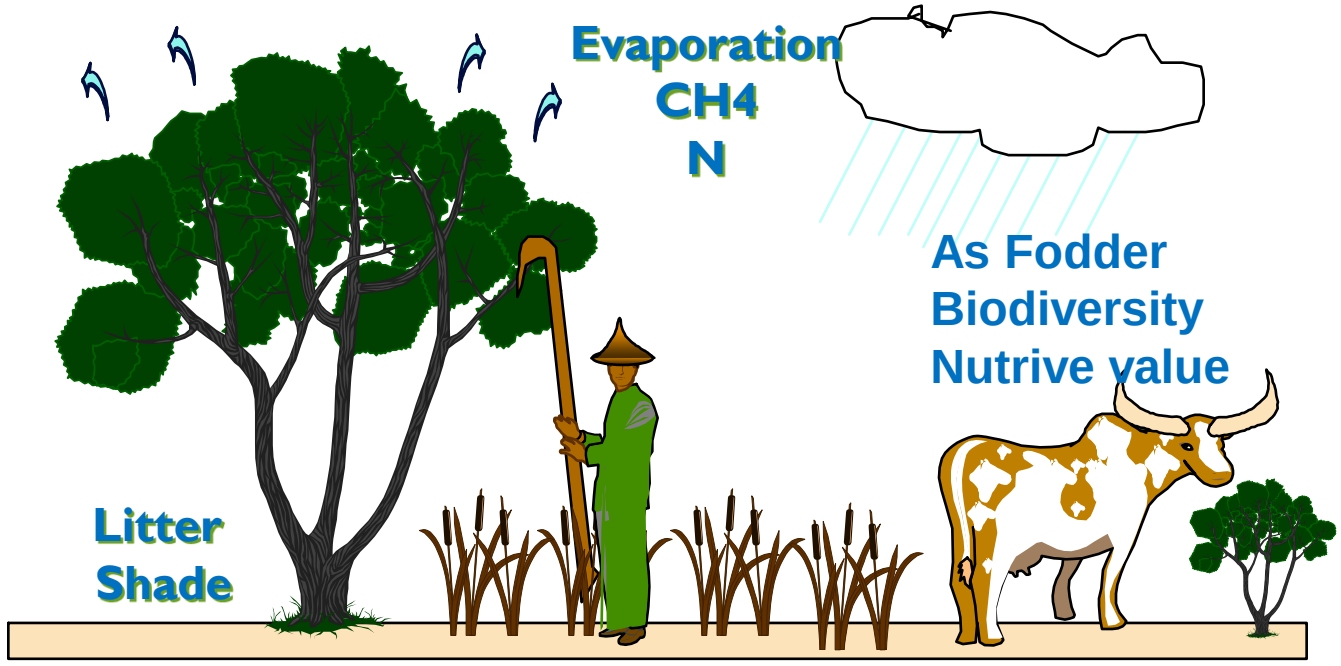
FUNCiTREE

# V Impact of fodder function on resource

- **Risks for sustainability of resource**
  - Absence of *reproduction*
  - Decreasing species until *extinction*
  - Invader species and *encroachment*
- **Adaptative traits**
  - *Resprouting* after browsing (*C. Skarpe*)
  - Reaction to branch cutting : *suckering*
  - Conservation of seeds, *zoochory*
  - Vegetative regeneration natural or assisted (*R.Peltier*)

# TREES and LIVESTOCK INTERACTIONS FOR ECOSYSTEMS SERVICES

*FIELD and LANDSCAPE scales*



# CONCLUSIONS : how evaluate and manage fodder function of trees ?

- Analytical approaches to understand but not for decision
- Consider specificities of context to understand variability of fodder function
- Favour sustainable biodiversity more than quantity and even quality
- Integrate analytical traits for a global appraisal discussed with stakeholders
- Return to stakeholders knowledge, and practices  including mobilities
- Promote concertation

Intake of overbrowsed « *bonzai* » species

***Small is beautiful***

**Concertation**

http://funcitree.nina.no/

Living hedges –Bauhinia rufescens –D. Louppe

**Innovation**

Intake of Azadirachta indica

**Unusual is opportunity**

FUNCiTREE

# CONCLUSIONS : how evaluate and manage fodder function of trees ?

- Analytical approaches to understand but not for decision
- Consider specificities of context to understand variability of fodder function
- Favour sustainable biodiversity more than quantity and even quality
- Integrate analytical traits for a global appraisal discussed with stakeholders
- Return to stakeholders knowledge, and practices  including mobilities
- Promote concertation

***Small is beautiful***

**Unusual is opportunity**

**Concertation**

http://funcitree.nina.no/

**Innovation**

FUNCiTREE


THANK YOU !
SEE YOU SOON ?

FUNCiTREE

**Functional Diversity:**
**An ecological framework for sustainable and adaptable agro-forestry systems in landscapes of semi-arid ecoregions.**

Based on the principles of functional ecology, FUNCiTREE addresses the provision of multiple services of silvopastoral systems (SPS) in semi-arid regions in Africa and Central America. FUNCiTREE aims to provide farmers in the regions with a portfolio of regionally suitable tree species that are capable of providing multiple services. The project integrates theories and concepts from agroforestry and ecological science and will provide a scientifically based model for the design of modernized SPS.

NINA (Norway): The leading research center in Norway on applied ecology, emphasizing the interaction between human society, natural resources and biodiversity

CATIE (Costa Rica): A regional research and education centre about agricultural sustainability, environmental protection and poverty eradication

WUR (The Netherlands): Internationally leading university in agricultural Almeria has a focus on organism responses to drought, ecological interactions, biodiversity conservation, desertification, and soil science

**CIRAD** (France): Research on agro-ecosystems for international sustainable development, environmental, and climate research

CSIC (Spain): Research at the Arid Zones Research Station,

ISRA (Senegal): Priority areas relate to agronomic, animal and forest production, and rural economy

IER (Mali): The leading research centre in Mali on agriculture and agro-ecosystems.

**www.funcitree.nina.no**