International Center for Tropical Agriculture
Since 1967 Science to cultivate change

RESEARCH PROGRAM ON Livestock

# Sustainable forage based livestock systems

**CLIFOOD SDG Graduate School**

*Hawassa*

*November 28, 2018*

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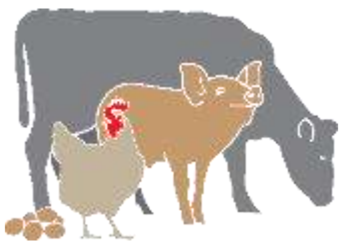
A CGIAR Research Center

*Peters et al., 2013*

# Why are Livestock and forages important: The facts



**17**
**BILLION**

The estimated total number of livestock worldwide

*(including cattle, sheep, goats, pigs, chickens, and about a dozen lesser known species, like guinea fowl, yaks, and camels).*

About two-thirds of the world's total agricultural area

**4.9 Bha**

is used to feed livestock, including

**3.3 Bha**
Of grazing land

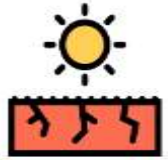
**25%**
Total crop area

The value of livestock as a global asset reaches

**USD3.1**
**TRILLION**

that accounts for some

**1.3 Billion** jobs



**~200 MHa**

In America Latina alone, have been **degraded by overgrazing and other unsustainable production practices.**

*This negative impact is similar in most areas used for feed 70% of sweet water to agriculture, 22% to livestock*

The annual contribution of livestock to climate change, which is about

**8.1 billion** $tCO_2eq$

**50%** Of total agricultural emissions

**15%** of all human-induced greenhouse gas emission

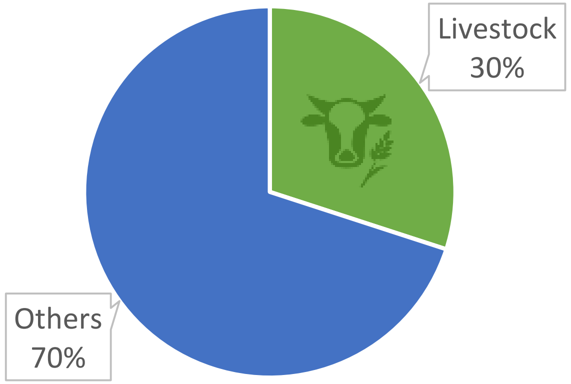
These includes emissions from deforestation to make way to pastures.

Grazed livestock systems are the world's single biggest land use. So, how they're managed – and especially how they're fed – is profoundly important for people and the planet

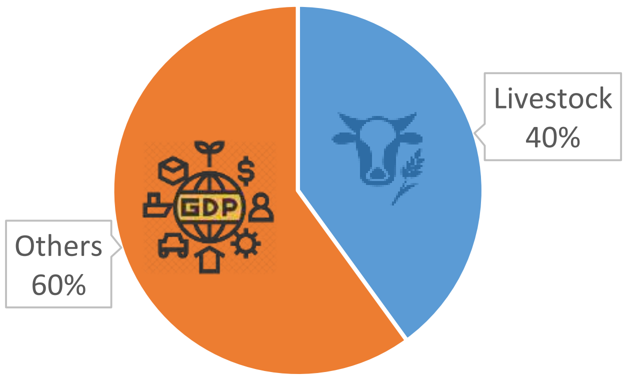
*Herrero et al., (2013)*

# Why is Livestock important: The facts

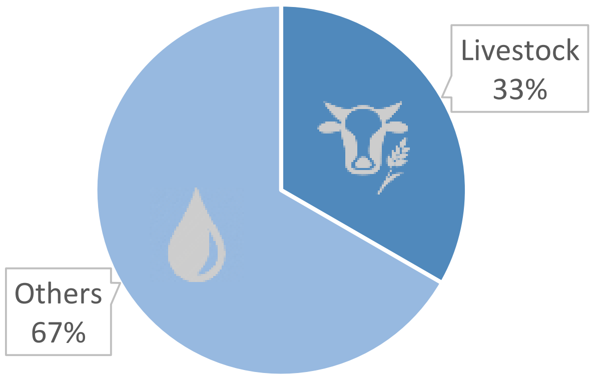
## Ice free land area



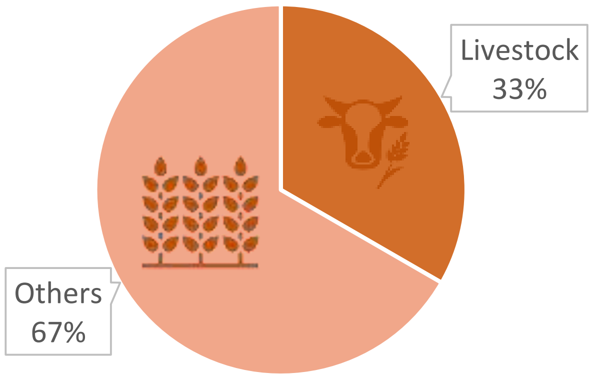

## Global agricultural GDP




## Global fresh water use



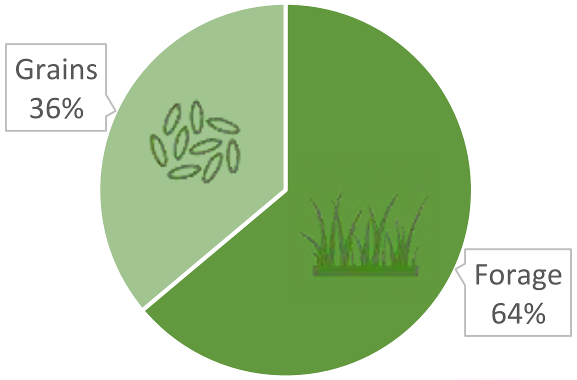

## Global crop land




Food for at least

**800** millions

People exposed to food insecurity

# Contributions of the livestock sector

## Livestock products make up

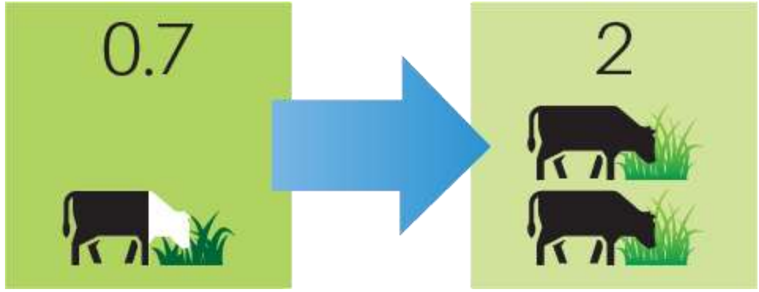
**17%**
of total human
calorie consumption

**33%**
of total human
protein consumption

with large deficits in
sub-Saharan Africa

Livestock are an important source of **soil nutrients** in Africa and other regions in particular where reliance on commercial fertilizer is low.

**Critical** for **first 1000** days of childhood development




Evidence that sustainable intensification of livestock production can **reduce GHG emissions** by sparing land from deforestation.

# Context

The **forage-based cattle sector plays a key role** in

**FOOD**
and nutrition security

**POVERTY**
Alleviation

But it is also associated with **causing negative environmental impacts**:

**EMISSIONS**
of greenhouse gases

**LAND**
degradation and deforestation

**WATER**
pollution and depletion

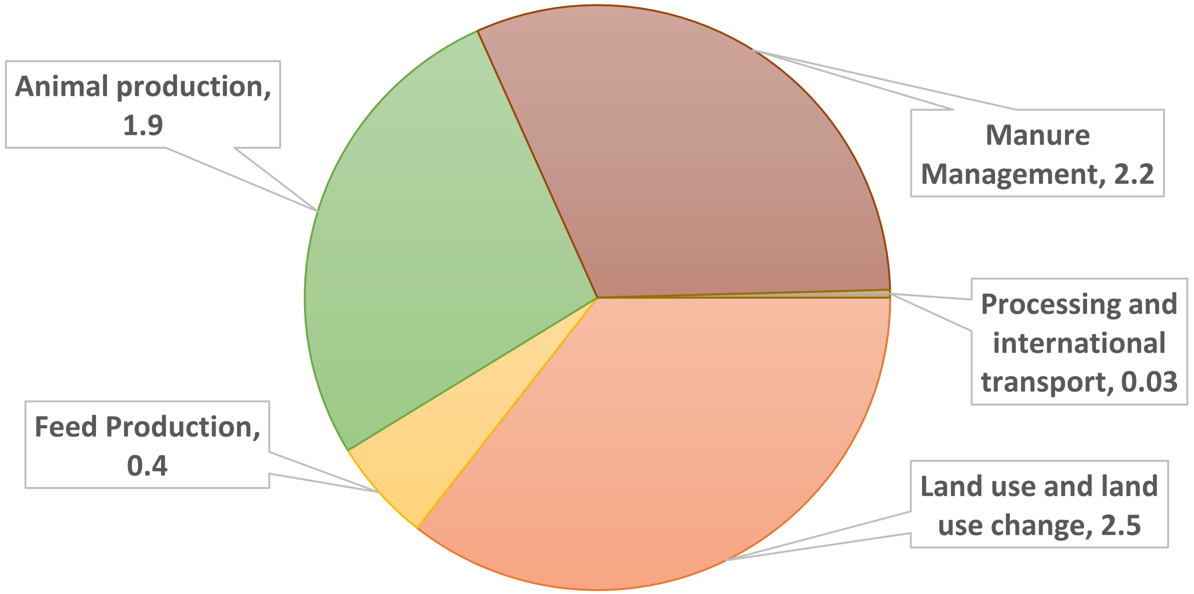
**DEFORESTATION**

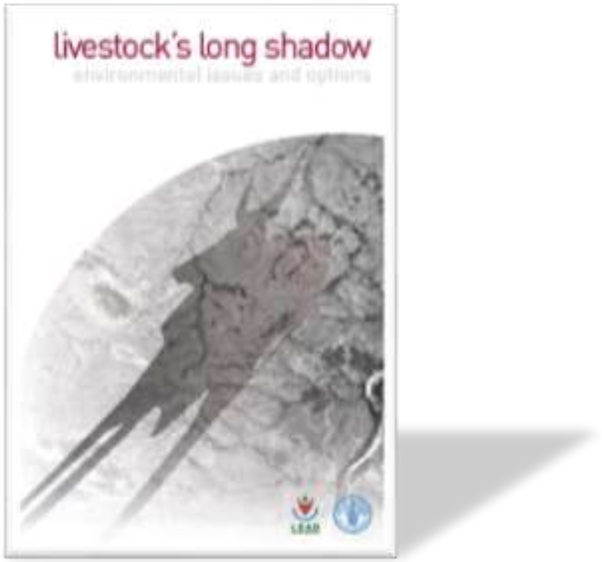
**BIODIVERSITY**
threatened

- ✓ **Improvements in animal feeding** and **sustainable intensification** are the most promising strategies for mitigating these impacts.
- ✓ The inclusion of **forage legumes in cattle production** systems has the potential to increase yield, efficiency and nutritional value of the forage, with less environmental impact.
- ✓ But **adoption and use by the producers remain limited** due to:
  - Economic factors
  - Lack of knowledge
  - Limited perceived benefits by the producer
  - Risk aversion and uncertainty.

# Livestock and climate change

- One of the top two or three most significant contributors to the most serious environmental problems.
- Should be a major policy focus when dealing with problems of land degradation, climate change and air pollution, water shortage and water pollution, and loss of biodiversity.
- Main sources of emissions (in Gt $CO_2$ eq):



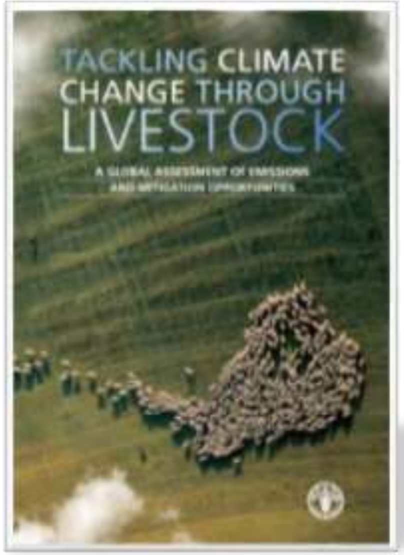

bit.ly/FAO-LivestockLongShadow

**Should we Abandon Livestock production?**

- Land use and land use change: 2.5 Gt $CO_2$ eq; including forest and other natural vegetation replaced by pasture and feed crop in the Neotropics.
- Feed Production: 0.4 $CO_2$ eq, including fossil fuel used in manufacturing chemical fertilizer for feed crops ($CO_2$) and chemical fertilizer application on feedcrops ($N_2O$, $NH_3$)
- Animal production: 1.9 Giga tonnes $CO_2$ eq, including enteric fermentation from ruminants ($CH_4$) and on-farm fossil fuel use ($CO_2$)
- Manure Management: 2.2 Giga tonnes $CO_2$ eq, mainly through manure storage, application and deposition ($CH_4$, $N_2O$, $NH_3$)
- Processing and international transport: 0.03 Giga tonnes $CO_2$ eq

# Victim, executioner and the solution! (2013)

- ✓ Responsible for 14.5 % of the anthropogenic emissions:
  - 44%: Production and feed processing
  - 38%: Enteric fermentation
  - 9%: Dung decomposition
  - 9%: Expansion of grasslands substituting forest
- ✓ Reductions in grasp: **<u>MANAGEMENT PRACTICES</u>** (and use of improved forages)
- ✓ Reduction of 30% of GHG (per unit of product)
- ✓ Key to reducing emissions: **<u>EFFICIENCY!</u>**
  - Better feed practices.
  - Waste management.
  - Energy saving and recycling along the supply chain.




fao.org/livestock-environment

Rao et al., 2015

There are **increasing global aspirations of achieving forest-based emissions reductions** (REDD+; Paris Agreement), landscape restoration (The Bonn Challenge) and biodiversity conservation (Aichi Targets) and <u>Livestock can be an important player</u>.

# Constraints

## Water scarcity

## Excess water

- Climate vulnerability
- Lack of resources
- Land competition, water, inputs

# LivestockPlus - the sustainable intensification of forage-based systems

Rao et al., 2015. DOI: 10.17138/TGFT(3)59-82

## Three innovative/ intensification processes:

**GENETIC**
Improved yield, quality, stress resistance

**ECOLOGICAL**
Better management of mixed crop-forage-tree-livestock systems

**SOCIOECONOMIC**
Better management of mixed crop-forage-tree-livestock systems

## Livelihood benefits:

**FOOD**
and nutrition security

**MANURE**
Organic fertilizers

**ADAPTATION**
To climate change

**INCOME**
generation

**POVERTY**
Alleviation

## Ecosystem services

- Resource use efficiency
- Restoration of degraded lands
- Reduced per unit animal GHGs
- Mitigation of climate change
- Biodiversity conservation
- Water flows and quality
- Reduced erosion & sedimentation
- Reduce pressure to the forest – Reduce deforestation

# Regions

**CENTRAL AMERICA**
Nicaragua

**SOUTH AMERICA**
Colombia
(Including strategic breeding and germplasm work)

**ASIA**
Vietnam

**AFRICA**
Kenya

# Conserving the world's largest collections of beans, cassava, and tropical forages

**37,987**
Bean accessions

**6,643**
Cassava accessions

**44,000**
Tropical forage accessions

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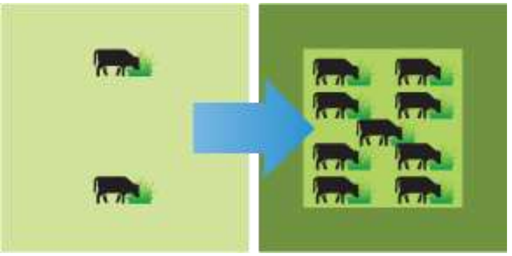
**Agrobiodiversity is key to maintaining ecosystems and providing adequate supplies of healthy, nutritious food in the face of climate change & environmental degradation.**

# Tropical Forages Breeding Program


Identify and produce **improved pastures** resistant to extreme conditions…

…that contribute to **increase animal (and crop) productivity**

and reduce **environmental impacts**…



…by **reducing the areas** required to respond to livestock demand


As well as reduce the **methane and nitrous oxide emissions**

# Sharping a reliable system to achieve genetic gain

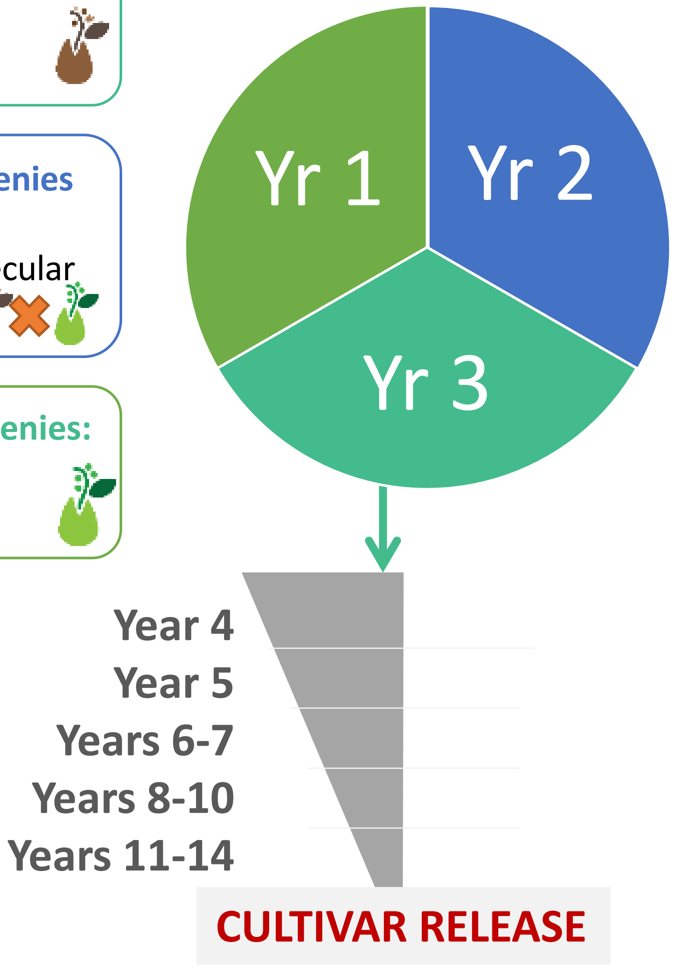
## Interspecific Breeding scheme in *Brachiaria*

*(Miles, 2007)*

**Recombination of sexual clones:**
30 **sexual clones** in 2 plots
(LAM & AF)

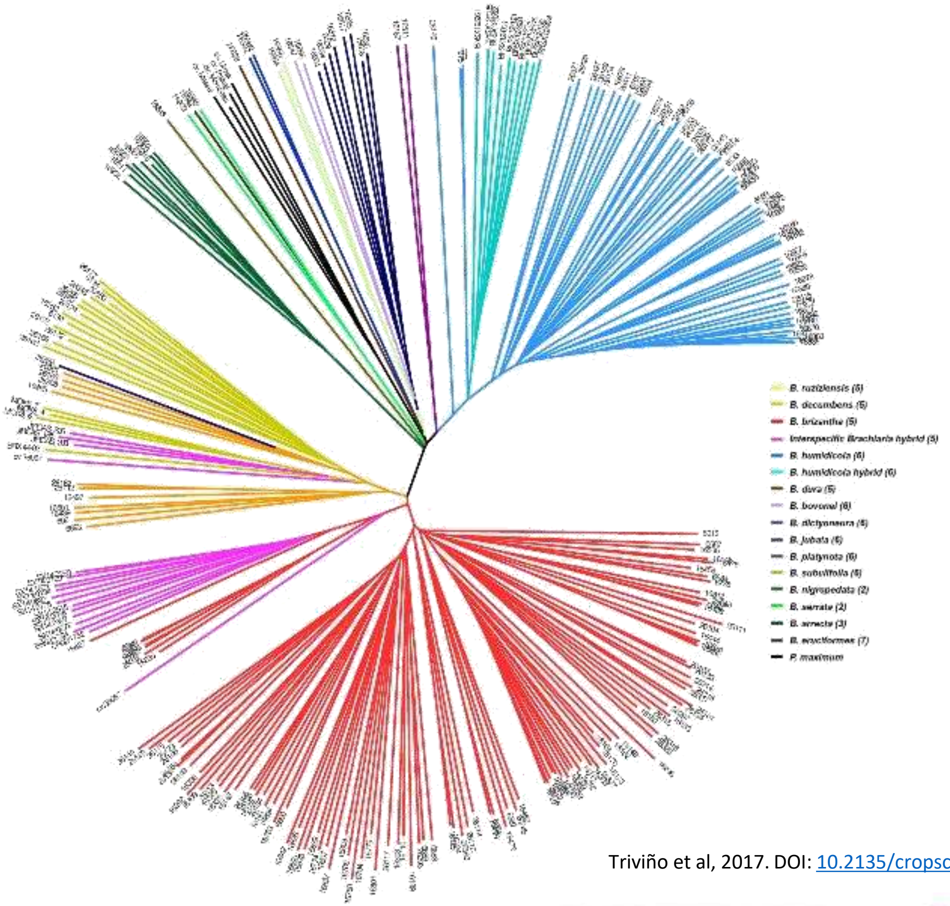
**Formation of testcross progenies SX x AP tester:**
4000 to be analyzed by molecular markers for **apomixes**

**Evaluation of testcross progenies:**
RCDB – 2 reps with 2000 **apomictic clones**




## Paving the way for the era of genomic selection

*(Worthington, 2013-2016)*




Triviño et al, 2017. DOI: 10.2135/cropsci2017.01.0045

# Current breeding programs

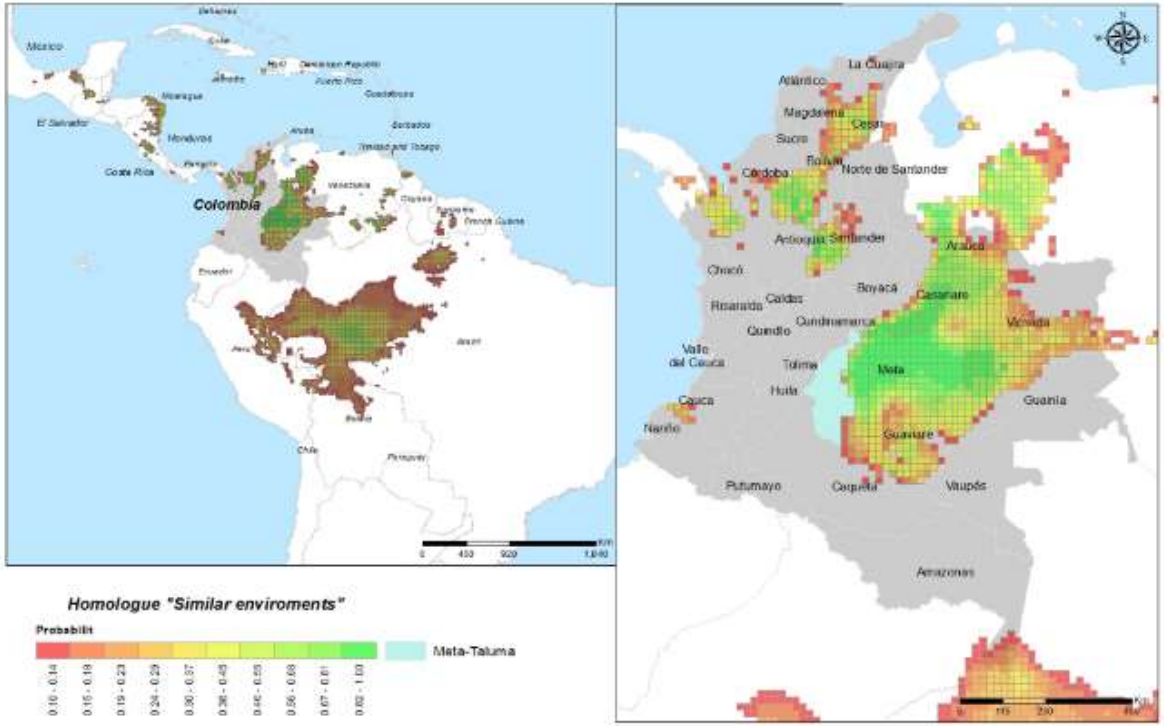
Interspecific – *Brachiaria decumbens / brizantha / ruziziensis*
1990

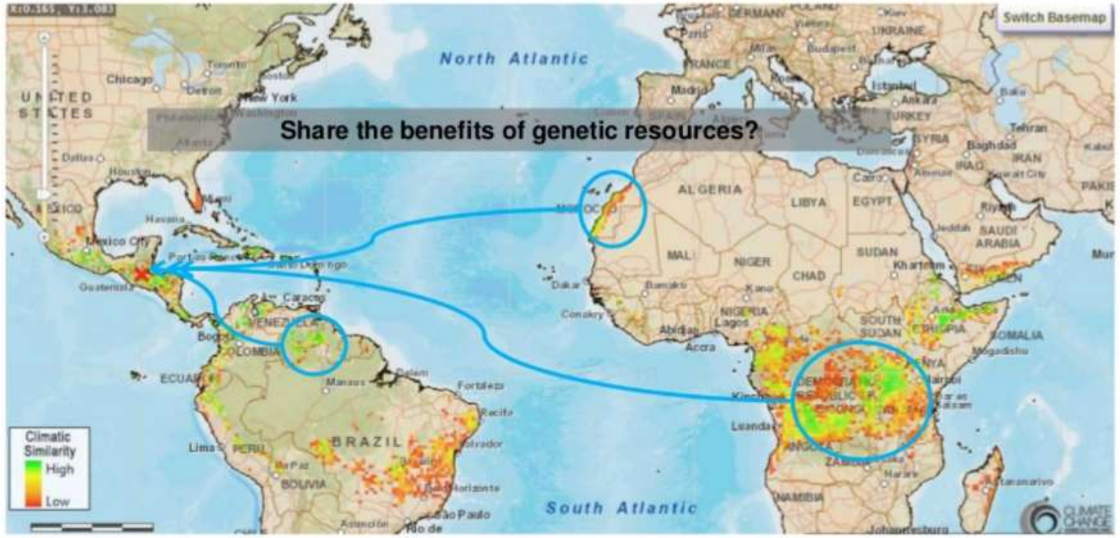
*Brachiaria humidicola*
2006

*Panicum maximum (syn. Megathyrsus maximus)*
2016

Focusing on guarantee effectiveness and therefore adoption, and launch products with optimum performance under **real farmers conditions**.

# Understanding conditions faced by the farmers



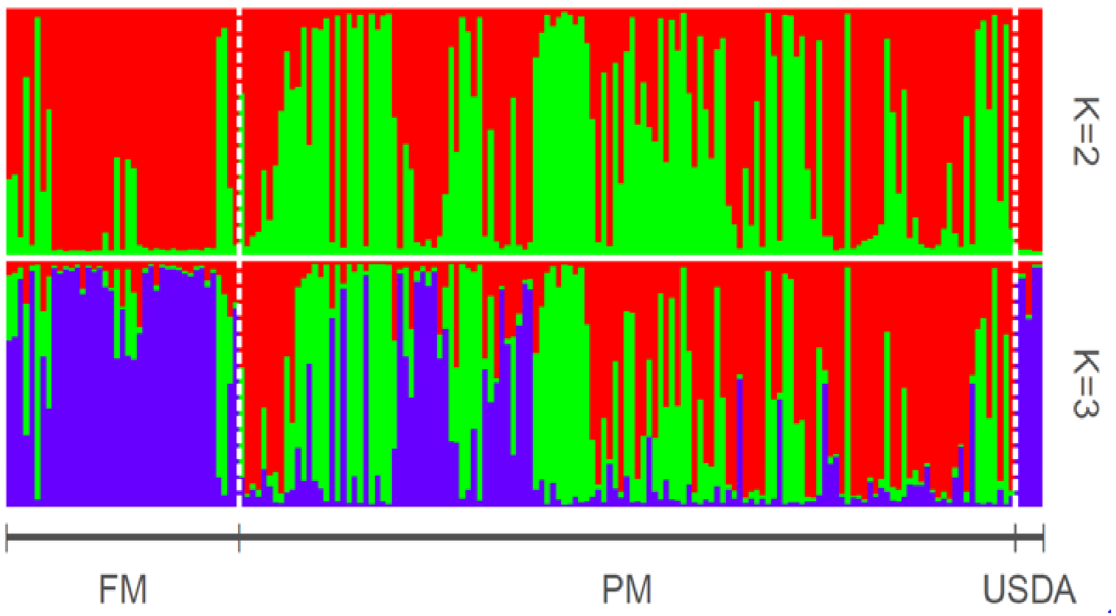

Arango and Jones, 2013

Use of **GIS** and **Foresight** tools to characterize the African (and soon Asian) target markets and its ideal representative testing environments

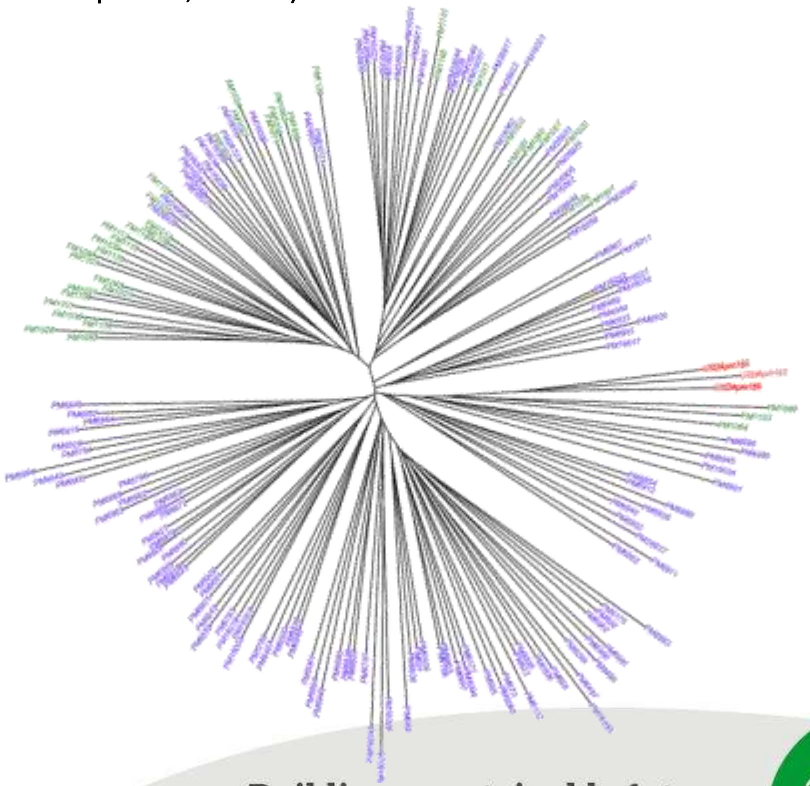
# Cluster 2 Highlights

## Development of forage genetic resources – Genotyping of *Panicum maximum* (syn. *Megathyrsus maximus*)

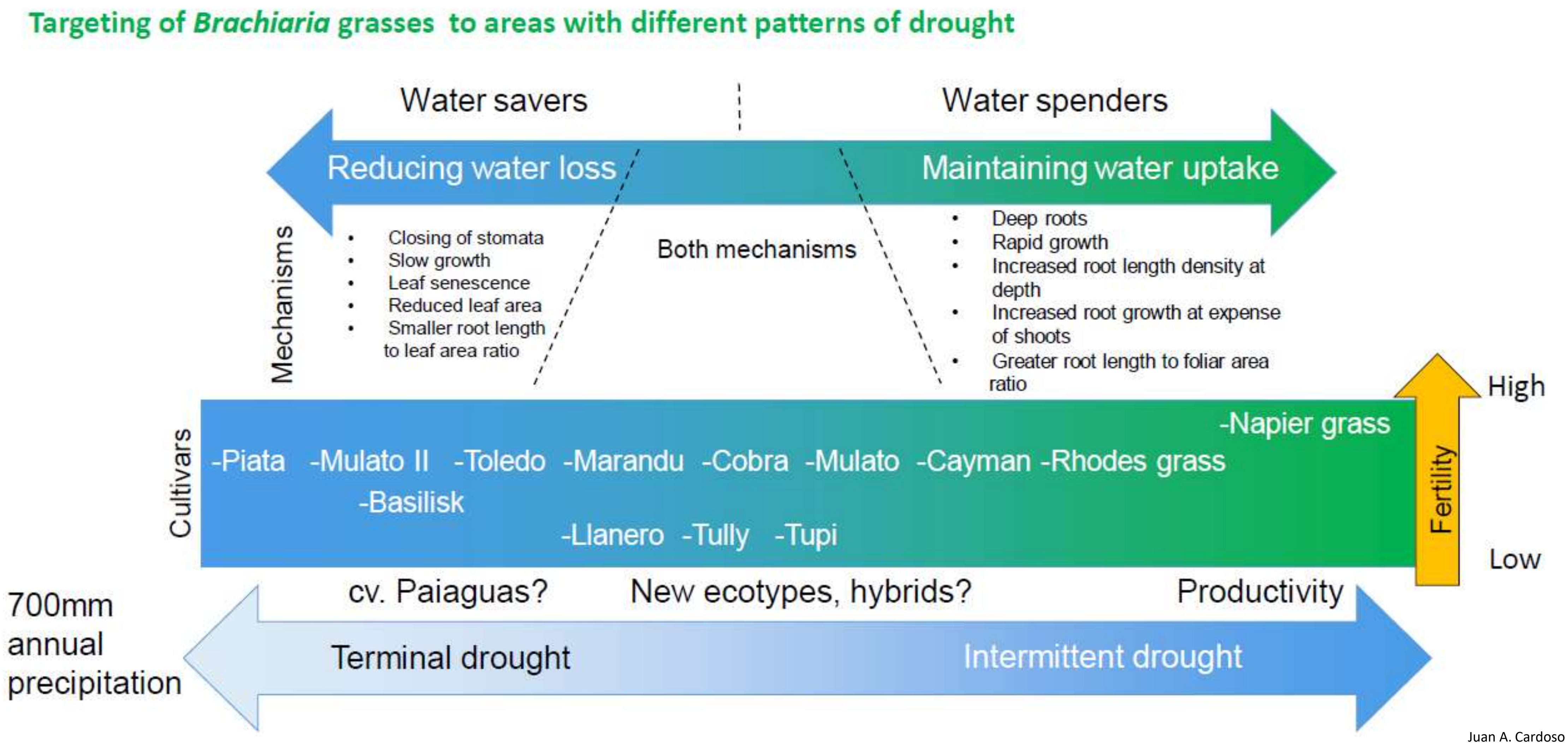
Analysis of the population structure for 183 accesions of *Panicum maximum* based on genotyping with SSR markers. Vertical bars indicate the relatedness coefficiet (Q) of each individual for each population and the colors are related with each *a priori* group (FM: Green, PM: Red y USDA: Blue).




*Neighbor Joining* tree for 183 accesions of *Panicum maximum* based on genotyping with SSR markers, according to the coeffitient of Gower y Legendre  (Ochiai, 1957). Color and prefix indicate the *a priori* group (FM: Hybrids, PM: Germplasm, USDA).

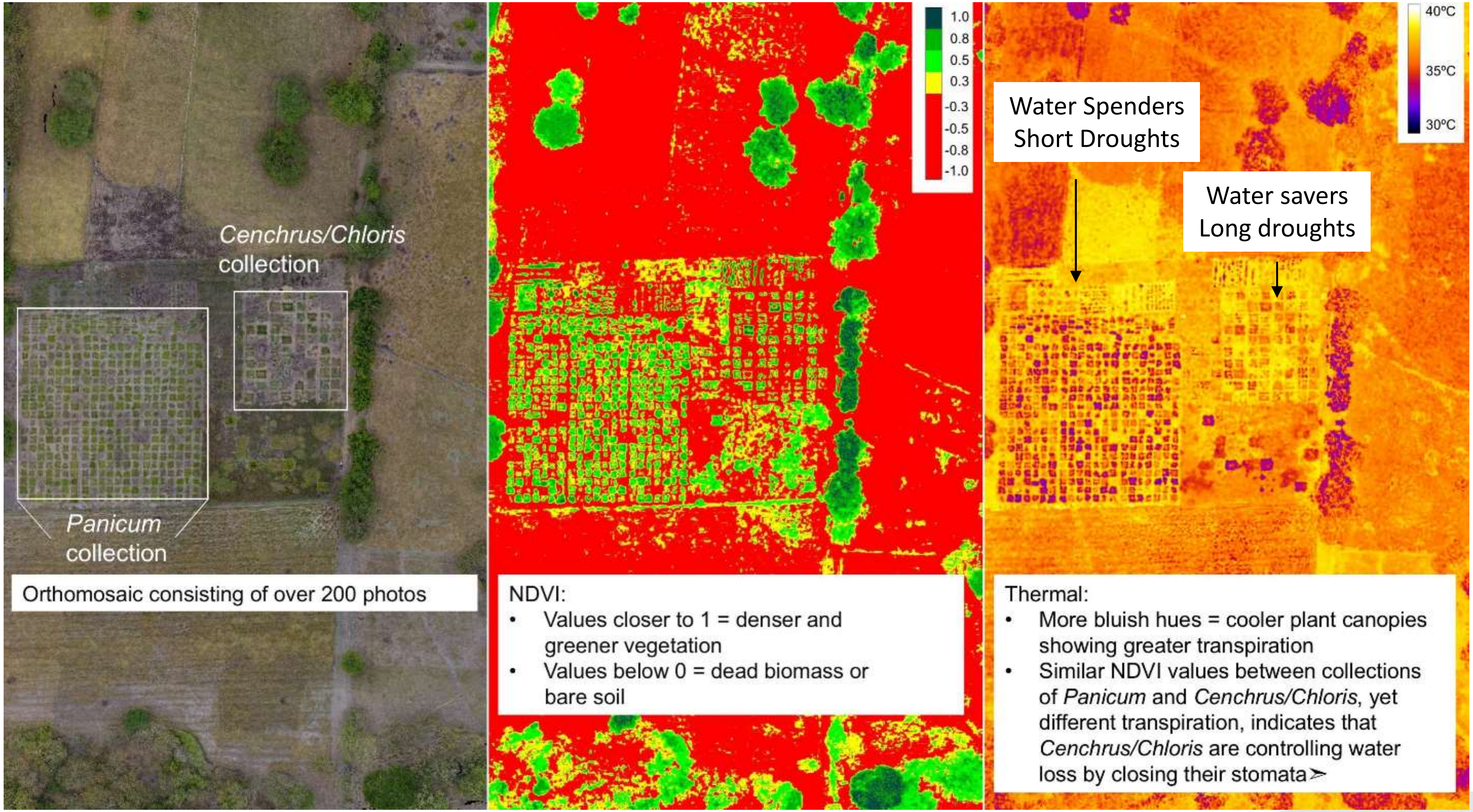


# Tropical grasses adapted to drought and low fertility




Juan A. Cardoso (CIAT), unpublished

# Water use efficiency: *Megathyrsus* vs. *Chloris* and *Cenchrus*



# Increase selection gain by reducing cycle time

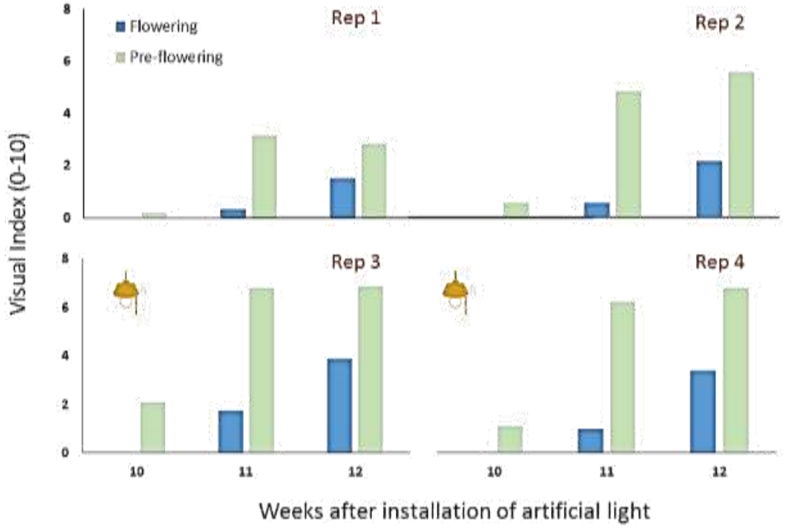
## Manage photoperiod to accelerate flowering

WEEK 1

WEEK 11

WEEK 14

WEEK 15




# Sustainable Forage Technologies

- ✓ Water and nutrient efficiency
- ✓ Recovery of degraded lands
- ✓ Silvopastoral systems
- ✓ Forage mixtures
- ✓ Fodder banks for cut and carrying
- ✓ Increase in productivity by ha,
  - ***kg/ha/year (of 100 to 1000 kg)***
- ✓ Increase in productivity per unit of area,
  - ***(from 0.6 to 4 UGG/ha)***

# Specific consideration

- ✓ Production = increased supply of forage based on dry matter
- ✓ Productivity = Kg meat and/or milk/ha/year
- ✓ Nutritive quality
- ✓ Efficient use of water
- ✓ Shade Tolerance
- ✓ Soil recovery
- ✓ Multipurpose uses

# Agronomic Management of Forages

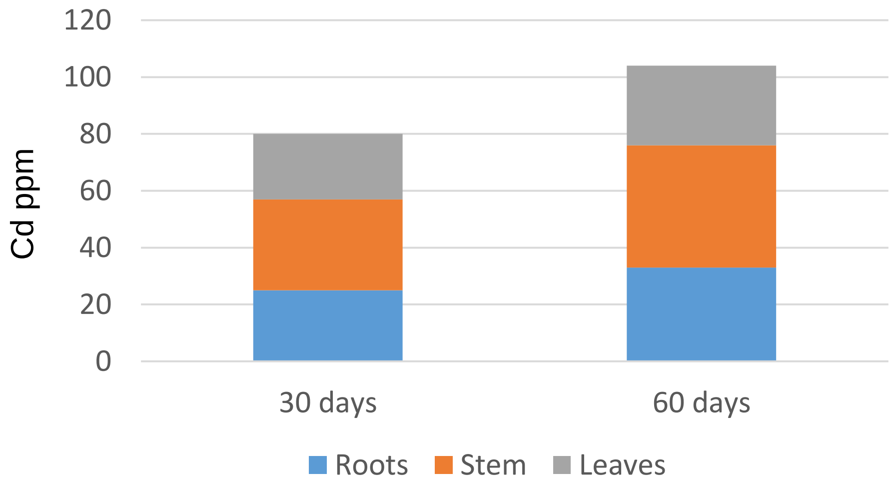
- Integration of improved forages
- Intensification by area unit and sustainability
- Division and rotation of pastures
- Definition of periods of occupation-recovery of the pasture
- Load Capacity (UGG)/ha

# Crop rotation with *B. ruziziensis*

# Forages Environmental Assessment

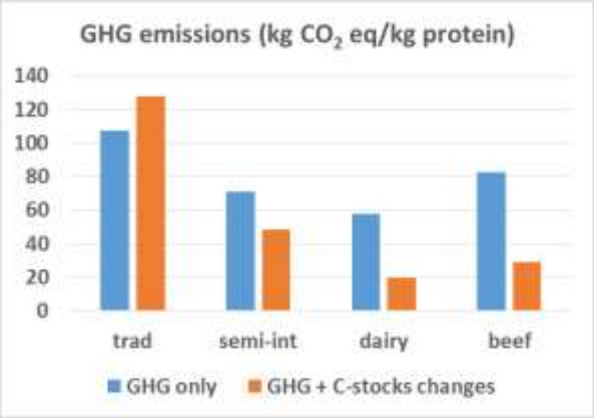
## Phytoextraction potential of cadmium by Napier grass (CIAT 26850)

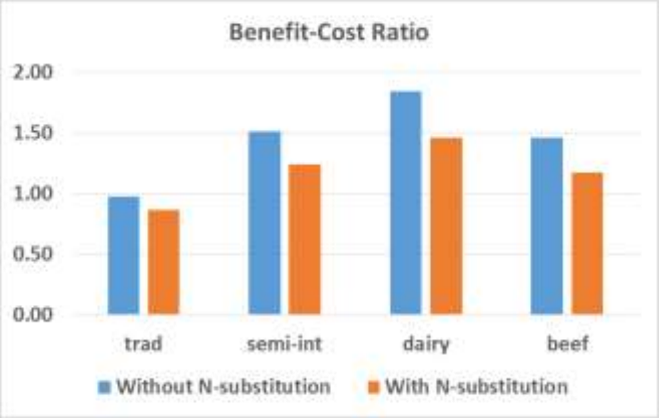
- Hydroponic study to test ability of Napier grass to uptake Cd
- Cadmium accumulated mostly in above ground tissue
- Nutrient disorders were symptoms associated with excess of cadmium, but only noticeable after ~40 days old plants
- > 90% of Cd could be recovered from shoot tissue by washing tissue on solutions of 0.5 N HCL




## Cleaned - ex-ante environmental impact assessment of livestock systems

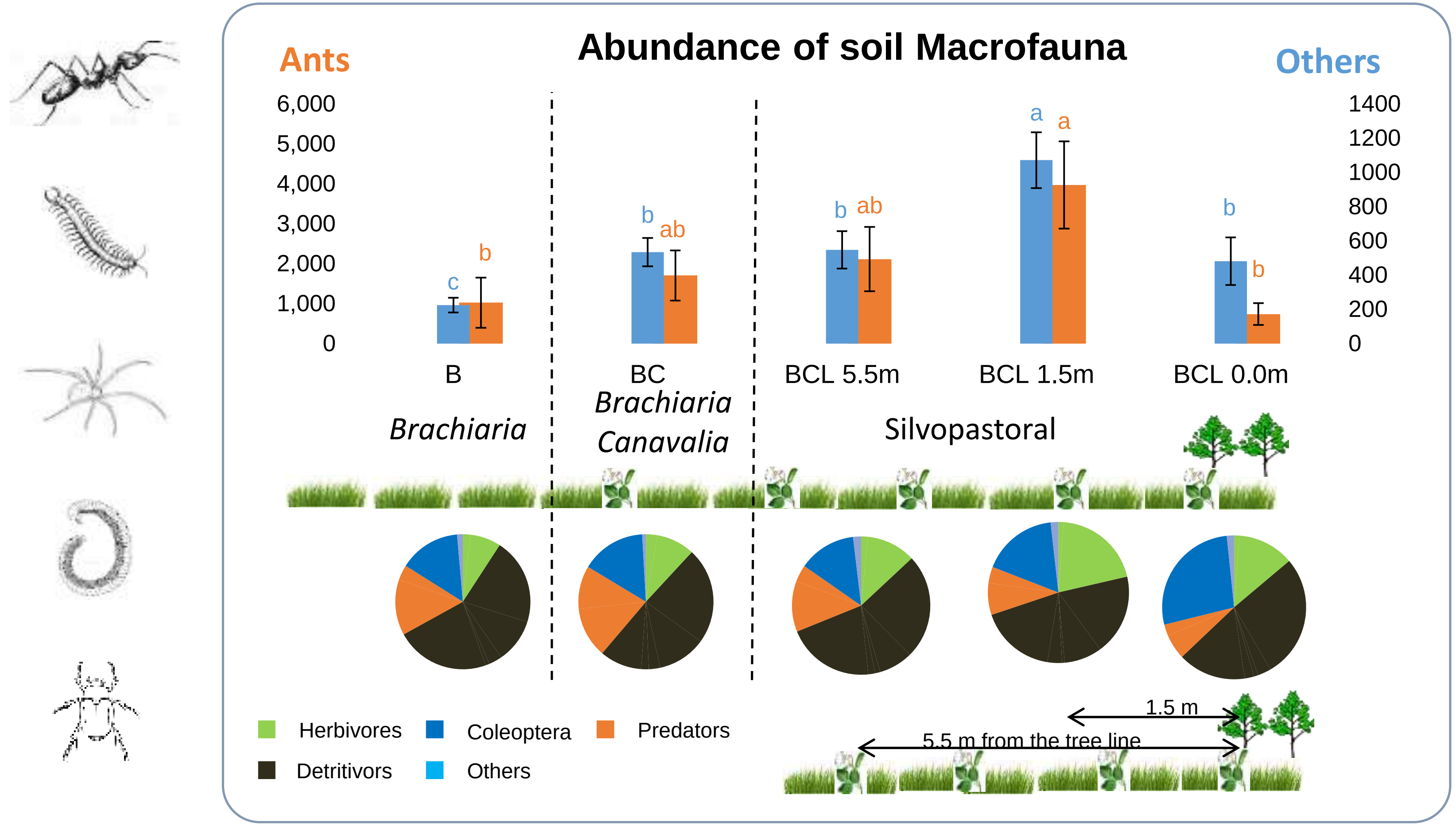
- Models (MS-Excel, R) – developed jointly by CIAT and ILRI
- CLEANED assesses greenhouse gas emissions, water use, carbon accumulation, soil erosion, nutrient balances, productivity, profitability at farm level
- Works in data-poor environments, farmers and other value chain actors provide feedback

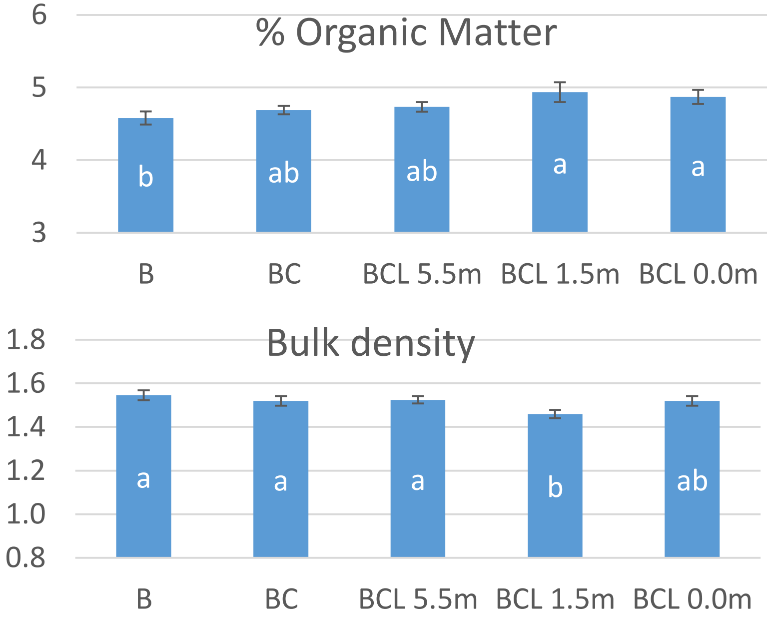


Vazquez et al., under preparation

# Ecosystem Services: Silvopastoral systems improve Soil Quality



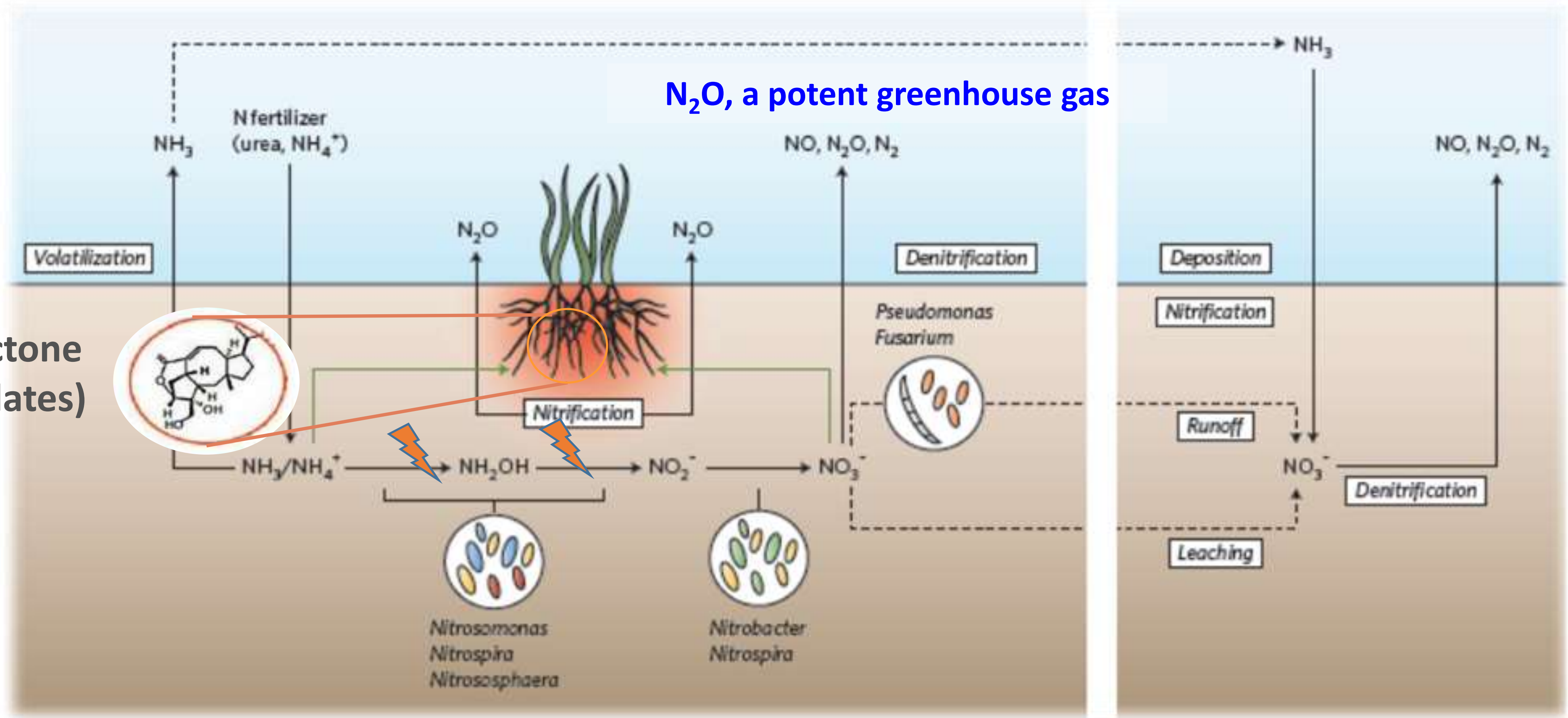

Biogenic Aggregate

- ✓ **The silvopastoral arrangement increased the abundance of soil macrofauna and improved soil structure.**
- ✓ **The biological activity of macrofauna and higher soil organic matter found in BCL treatment reduces soil compaction.**

# Ecosystem Services: Biological Nitrification Inhibition (BNI)

*Modified from: Devrim Coskun et al. 2017. Nature Plants 3, 17074*

Brachialactone (root exudates)




- **BNI where plant root systems produce nitrification inhibitors to suppress nitrifiers activity in soils to reduce $NO_3^-$ formation, facilitate $NH_4^+$ immobilization, plant uptake of $NH_4^+$ and reduction of $N_2O$ emissions.**
- **Is BNI ONLY PRESENT IN BRACHIARIA?**

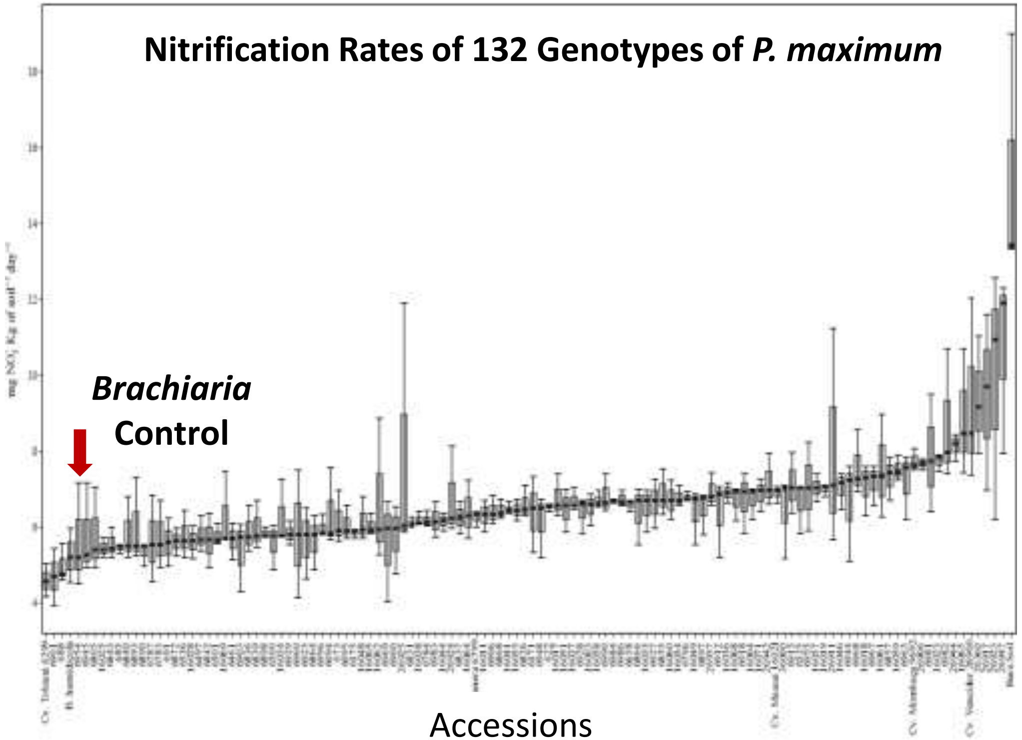
Villegas et al., under preparation

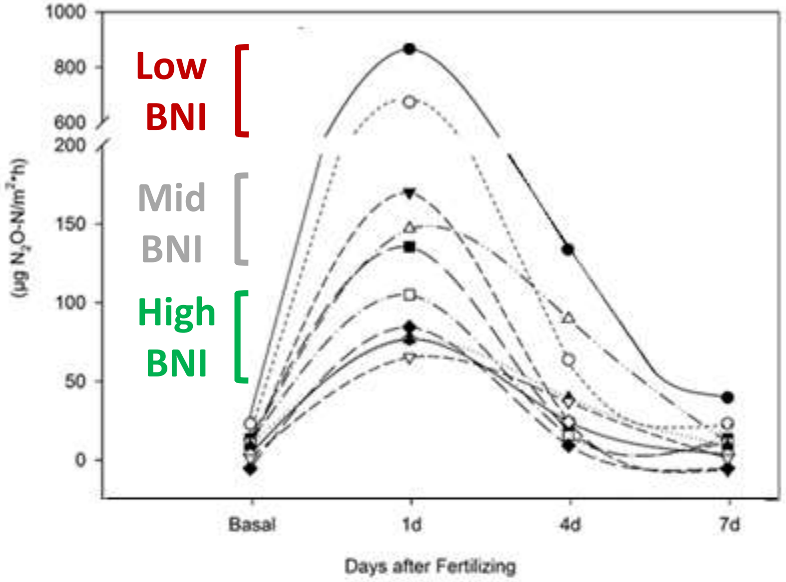
# BNI Potential of *Panicum maximum*

## Why Panicum? → Key for sustainable intensification (superior biomass and quality)

**Goal:** To evaluate the BNI potential of different *Panicum* genotypes for its implementation in a plant breeding

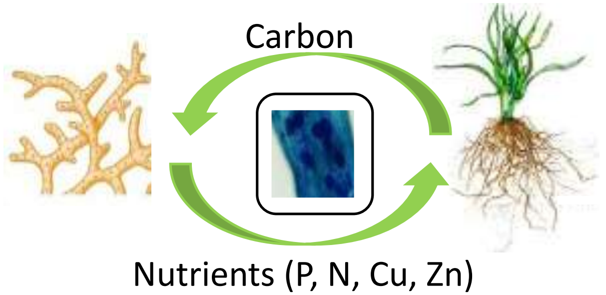
**132 *P. maximum* accessions**
**Bh CIAT 16888 (+)**
**Bare Soil (-)**

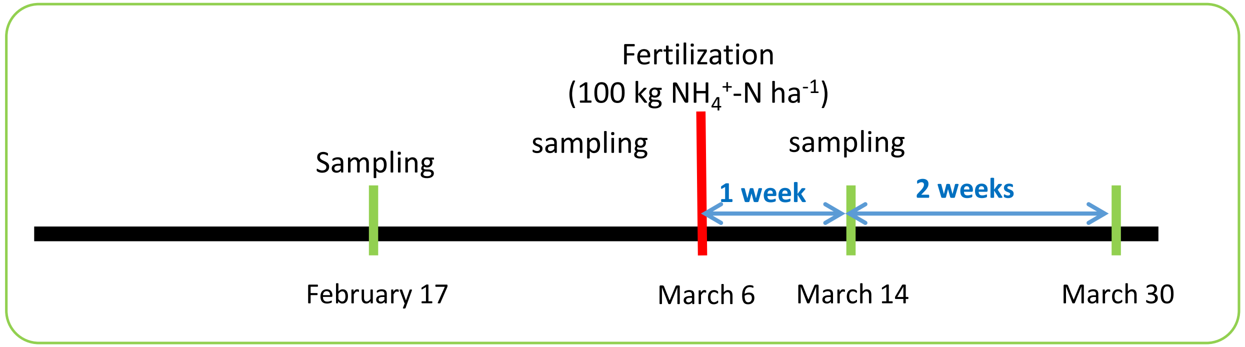


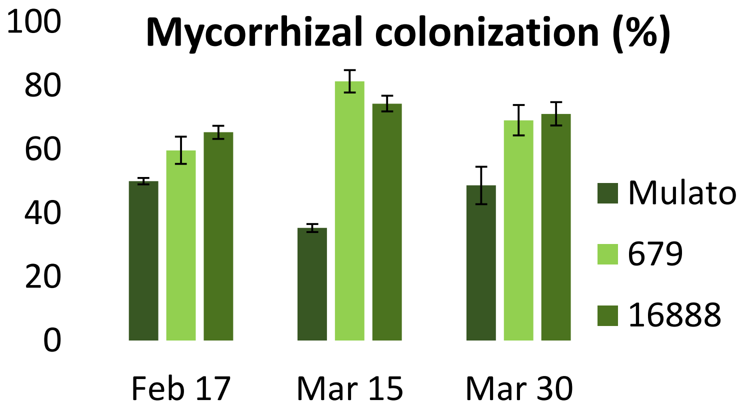




- ✓ ***Panicum* genotypes with higher BNI** capacity than ***Brachiaria*** were identified.
- ✓ **Achieving reduction of $N_2O$ emissions up to 84 % (vs. 55 % of Bh) compared to low BNI accessions.**
- ✓ **What about other important elements for plant nutrition such as P, Cu, Zn?**

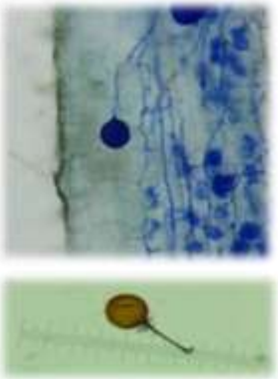
# Relationship between BNI – Mycorrhiza (plant-fungi symbiosis)

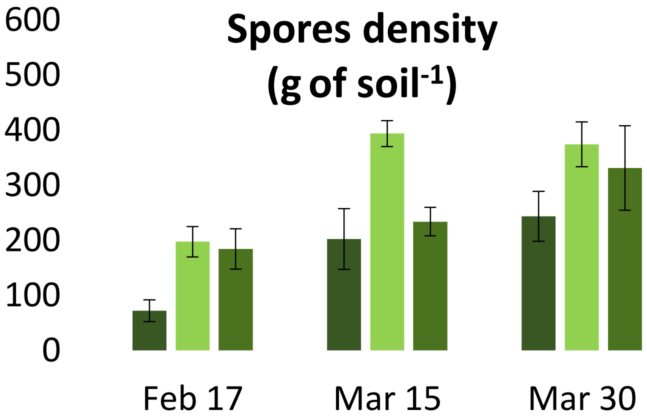



**Mulato**: Low BNI

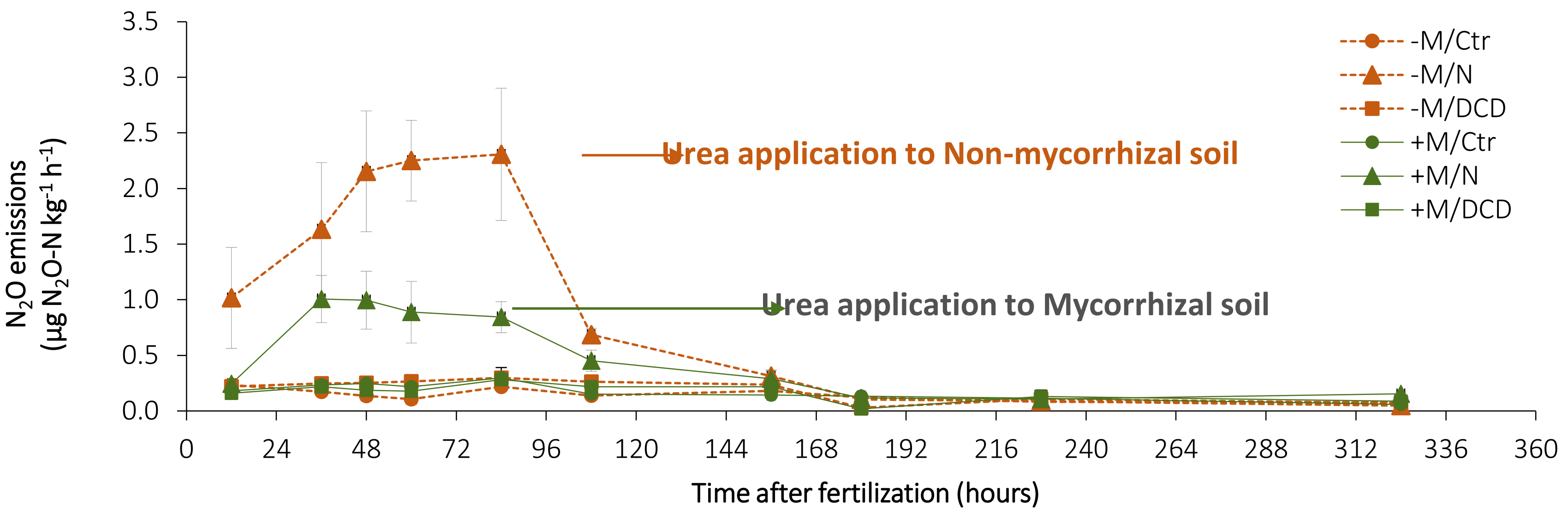


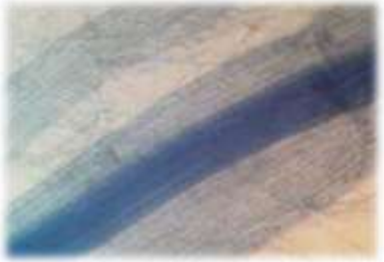



- ✓ **High BNI cultivars showed higher dependence on Mycorrhizal colonization.**
- ✓ **N application increased the Mycorrhizal colonization in soils.**
- ✓ **Possible role in ammonia uptake (that have low mobility in the soil) and reduced $N_2O$ emissions?**

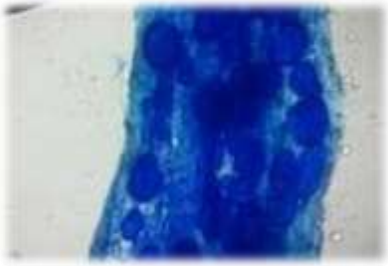
*Teutscherova et al., under review*

# Mycorrhizal association reduces $N_2O$ emissions



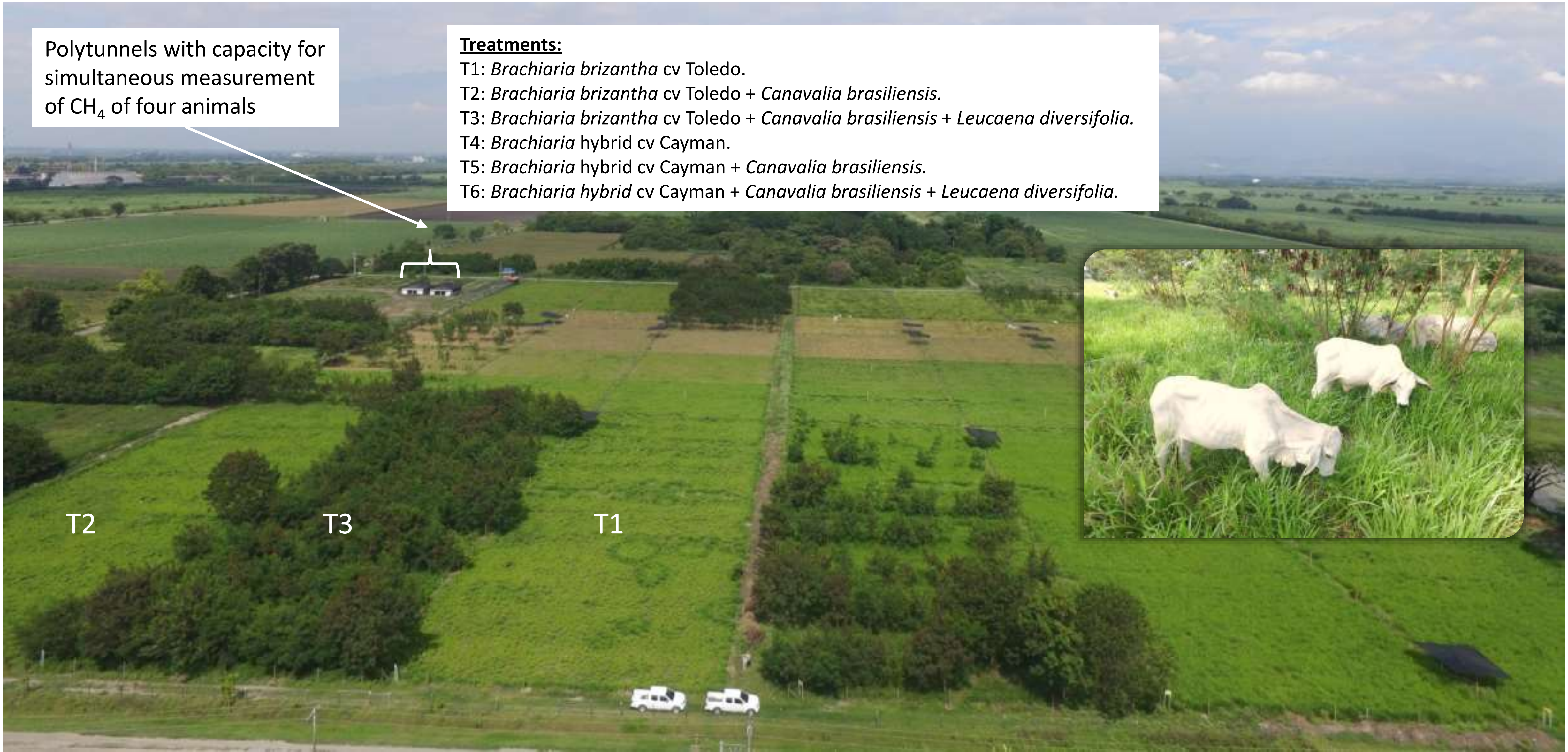
Control



Mycorrhizal fungal vesicles

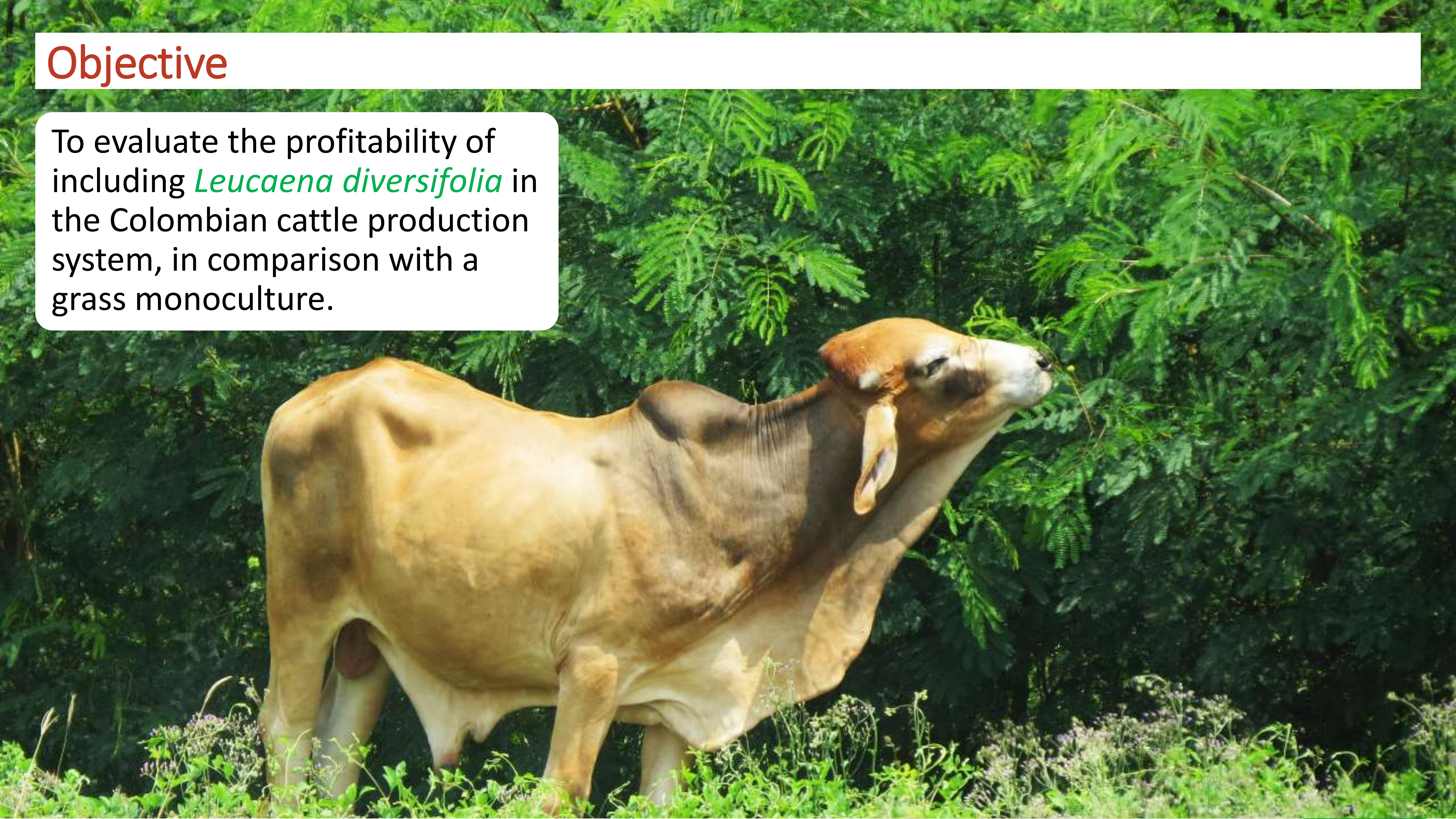
- ✓ Inoculation of native Mycorrhizal fungi to soil reduced $N_2O$ emissions after fertilization.
- ✓ Improved NUE by Brachiaria roots instead of $N_2O$ emissions.
- ✓ Nutrient immobilization to microbial biomass (including Mycorrhiza) could reduce negative effects of intensification.

# Field trial at CIAT HQ to test productive and environmental parameters with grass-legume combinations towards sustainable intensification



# Objective

To evaluate the profitability of including *Leucaena diversifolia* in the Colombian cattle production system, in comparison with a grass monoculture.



# Materials and methods

**Data source:** Monthly field measurements carried out by the International Center for Tropical Agriculture (CIAT) in Palmira, Valle del Cauca, Colombia, between August 2014 and August 2015.

**Evaluated diets:**

T1) *Brachiaria* hybrid cv. CIAT BR 02/1752 (Cayman) monoculture (100%)

T2) Cayman-*L. diversifolia* association in a proportion of 70:30% (2,000 *Leucaena diversifolia* plants/ha).

# Materials and methods

**Table 1:** Animal response data of T1 and T2

| Variable | T1 | | T2 | |
|---|---|---|---|---|
| | (Mean ± SD) | CV (%) | (Mean ± SD) | CV (%) |
| Carrying capacity (LSU/ha) | 3.36 | | 4.04 | |
| Weight gain (g/animal/d) | 440 ± 41 | 9.3 | 657 ± 73 | 11.2 |
| Animal productivity (kg/ha/y) | 723 ± 68* | | 1078 ± 120* | |
| Time to reach sales weight (months)[1] | 18 | | 12 | |

LSU: 450 kg/animal SD: standard deviation.

*Statistically different at 1% significance level P<0.01.

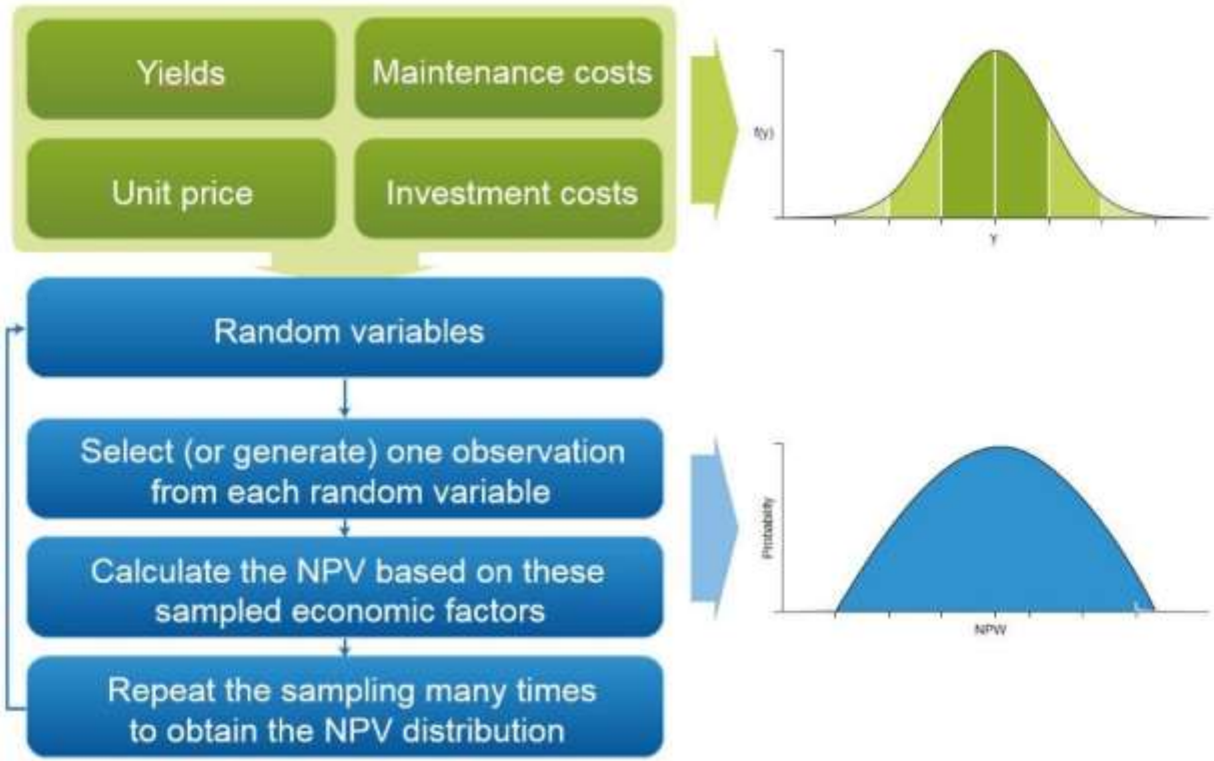
[1]Period of time required to bring a calf with an average weight of 200 kg to a sales weight of 450 kg.

# Materials and methods

## Economic, risk and sensitivity analyses

- A discounted cash flow model for the estimation of financial profitability indicators was developed.
- A quantitative risk analysis by running a Monte Carlo simulation was carried out.
- Three pasture persistence scenarios and the following variables were randomly combined:
  - ✓ Live weight gain per animal and year
  - ✓ Investment costs
  - ✓ Maintenance costs
  - ✓ Sales price per kg of live weight
  - ✓ Purchase price per kg of live weight.
- Sensitivity and scenario analyses were carried out to identify those variables with the strongest effects on the profitability indicators.

Scheme of a Monte Carlo simulation




Simulation made with **@RISK** Software

# Materials and methods

**Table 2.** Probability distributions for input variables, parameters and risk factors

| Variable | Treatment | Distribution | Parameters p1 | p2 | p3 | Distribution adjustment | Randomness |
|---|---|---|---|---|---|---|---|
| Live weight gain (kg/animal/y) | T1 | Pert (a,b,c) | 139 | 161 | 174 | Judgment of the researcher according to the availability of data and behavior of the variable according to literature (Gutiérrez et al. 2009). | Interaction between decision variables (e.g. type of feeding) and non-controlled ones (e.g. climatic conditions). |
| | T2 | | 205 | 239 | 268 | | |
| Sales price (US$/kg live weight)[1] | T1 & T2 | Lognormal (μ,σ) | 1.64 | 0.33 | | Based on the best historical data adjustment, using the Akaike information criterion (AIC; Akaike 1974). | Varies as a result of factors associated with the supply and demand of the market. |
| Purchase price (US$/kg live weight)[1] | T1 & T2 | Lognormal (μ,σ) | 1.36 | 0.22 | | | |
| Investment costs (US$/ha) | T1 | Triangular (a,b,c) | 586 | 689 | 794 | This distribution is recommended to specify situations that involve costs and investments. | Vary depending on the specific place where the establishment is made (e.g. the amount of tillage and level of fertilization is determined by soil characteristics and rainfall regime) (Rincón and Caicedo 2010). |
| | T2 | | 941 | 1,106 | 1,272 | | |
| Maintenance costs (US$/ha) | T1 | Triangular (a,b,c) | 134 | 148 | 163 | | |
| | | | 102 | 114 | 123 | | |

-Correlation factor between Sales price and purchase price: 0.89

# Results

**Table 2:** Summary of profitability indicators of the simulation model.

| Decision criteria | Indicator | | T1 | | | T2 | |
|---|---|---|---|---|---|---|---|
| **Scenarios** | | S1 | S2 | S3 | S4 | S5 | S6 |
| **NPV** | Mean[1] | (288) | (342) | (473) | 2,055 | 1,881 | 1,716 |
| | SD[2] | 447 | 434 | 404 | 697 | 673 | 651 |
| | CV | 1.55 | 1.26 | 0.85 | 0.34 | 0.36 | 0.38 |
| | CI (95%)[3] | (1,135)-558 | (1,165)-481 | (1,239)-292 | 743-3,389 | 610-3,172 | 484-2965 |
| **IRR** | Mean | 11% | 11% | 10% | 22% | 21% | 21% |
| | CI (95%) | 4%-15% | 4%-15% | 4%-14% | 16%-28% | 15%-28% | 15%-27% |
| **Benefit/Cost[4]** | Mean | 0.98 | 0.97 | 0.96 | 1.13 | 1.12 | 1.12 |
| | CI (95%) | 0.9-1.05 | 0.9-1.04 | 0.89-1.03 | 1.05-1.22 | 1.04-1.21 | 1.03-1.20 |
| **Payback period (years)** | Mean | 6 | 6 | 6 | 4 | 4 | 4 |
| | CI (95%) | 3-8 | 3-8 | 3-8 | 3-5 | 3-5 | 3-5 |
| **Minimum area (hectares)[5]** | Mean | 6.54 | | | 3.76 | | |

Scenarios were determined by considering three annual degradation rates that decrease the total forage supply and therefore the carrying capacity: for T1 at 1% (S1), 3% (S2) and 8% (S3), and for T2 at 1% (S4), 3% (S5), and 5% (S6), respectively. [1]Mean value of the VPN obtained in the simulation (5,000 iterations and confidence level of 95%); [2]SD: Standard deviation of the NPV with respect to the mean value; [3]CI: Minimum and maximum values in a 95% confidence interval; [4]Quotient between benefits and discounted costs; [5]Minimum area required for two basic Colombian salaries in hectares (1 CBS=US$279).

# Results

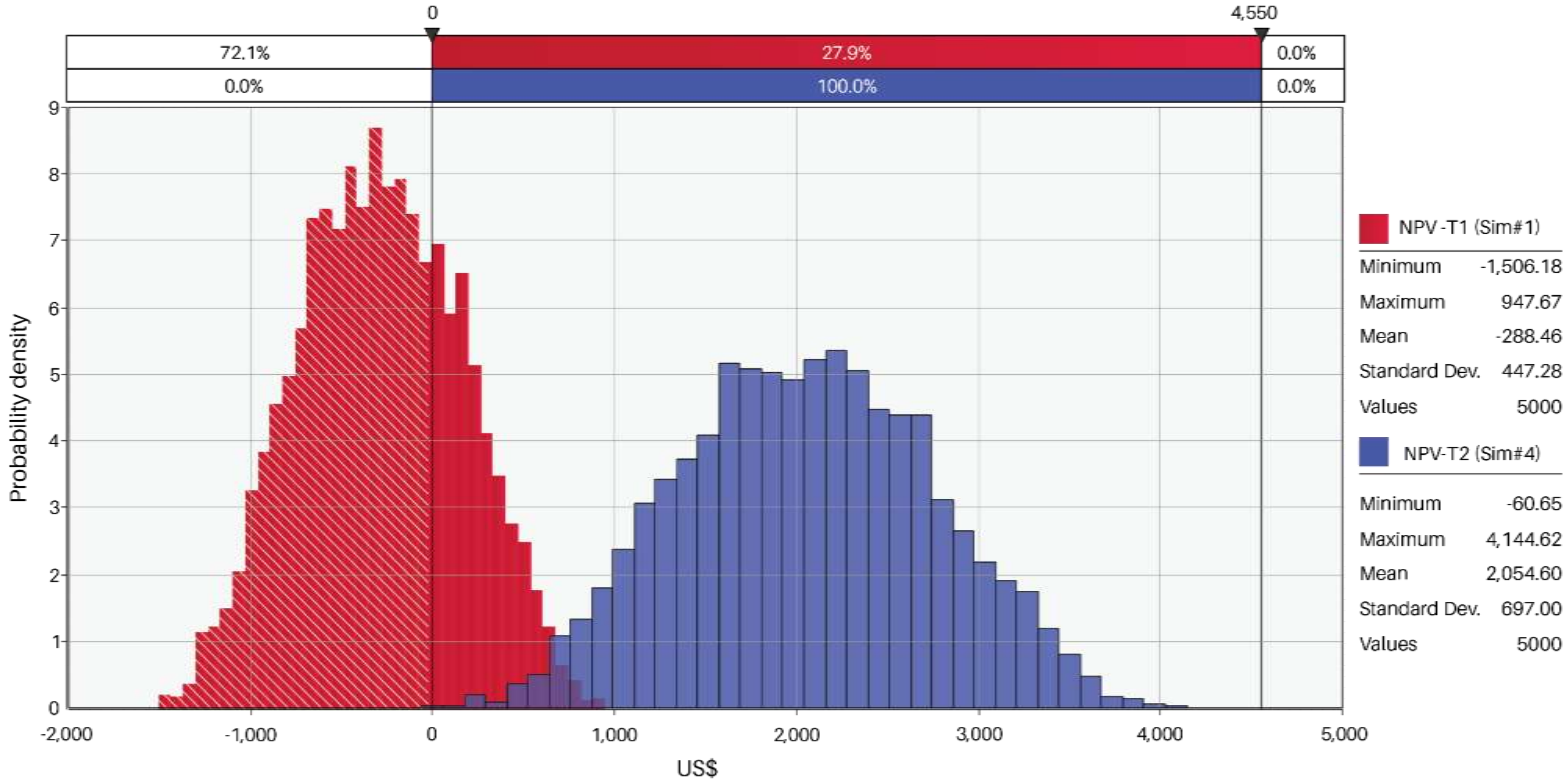



**Figure 1:** Probability and accumulative density distributions for the NPV for T1 and T2.

# Results

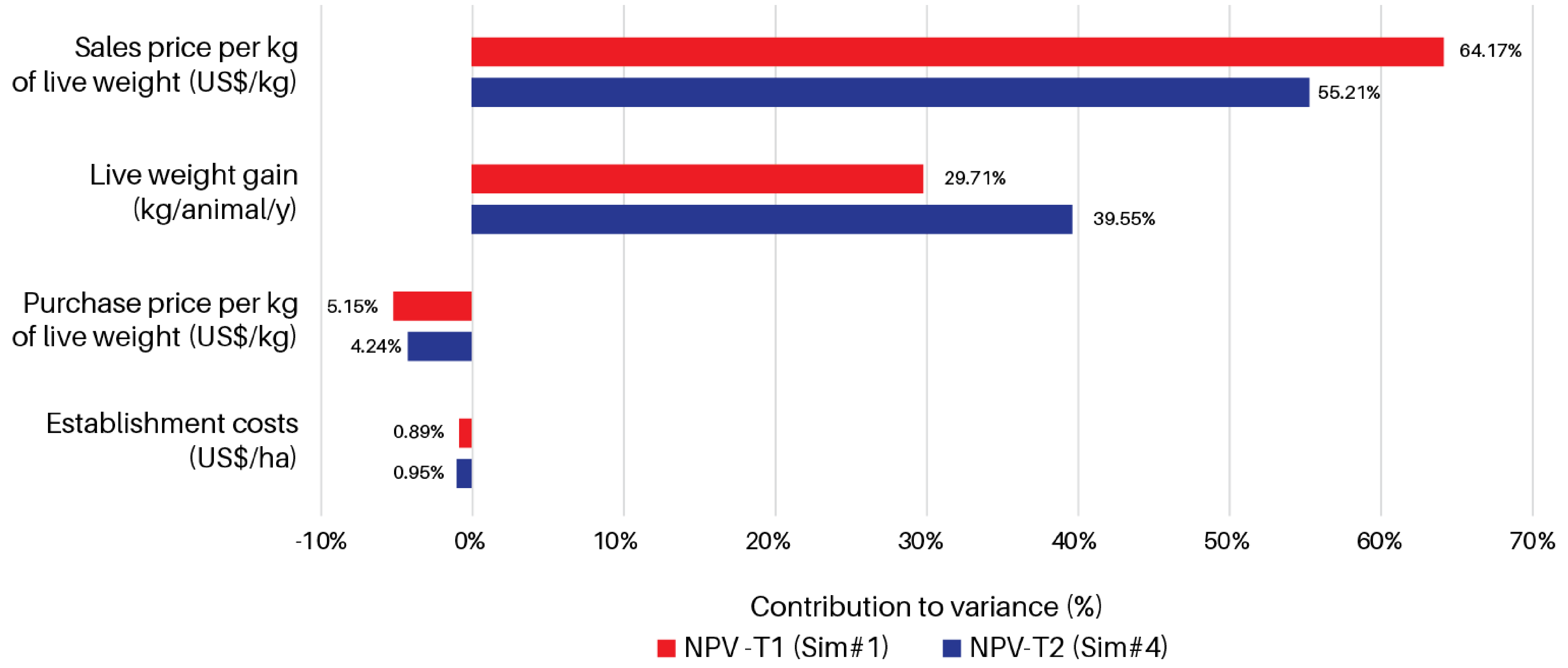
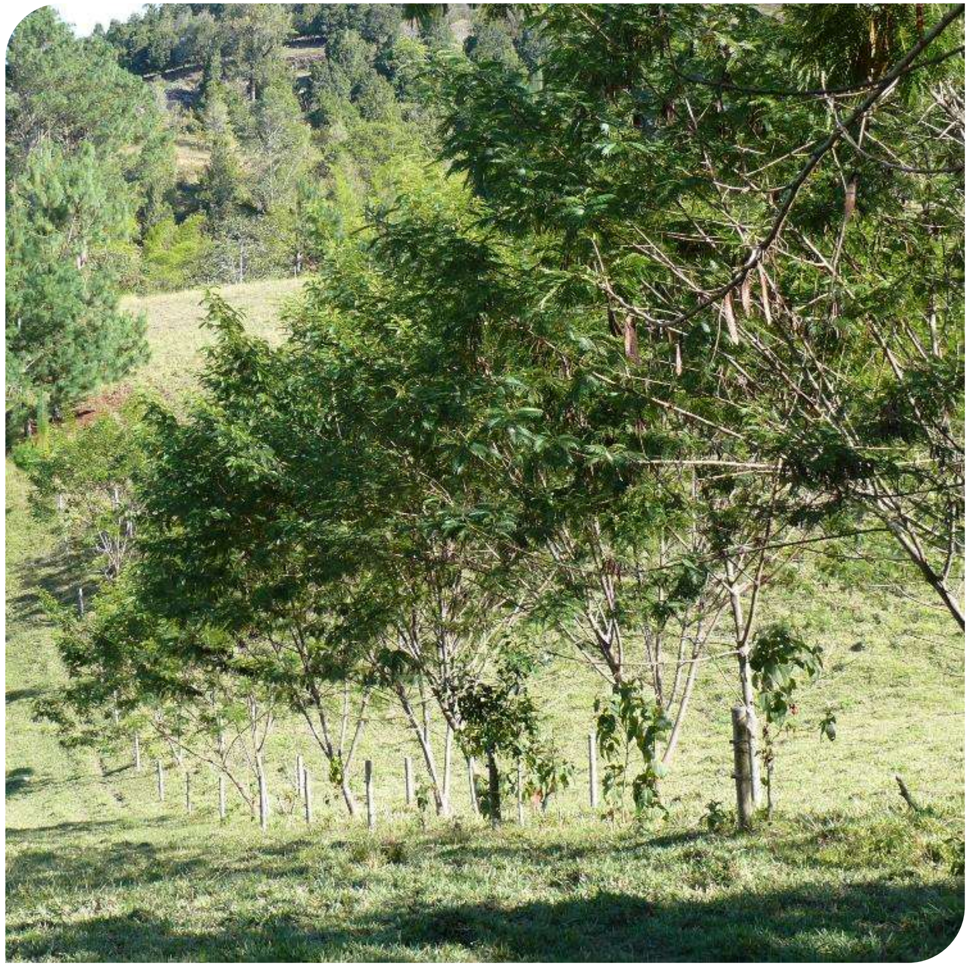



**Figure 2.** Multiple tornado graph displaying the contributions of random input variables to the variance of the NPV for T1 and T2.

# Summary of Leucaena assessment

- *L. diversifolia* has significant potential to **increase animal productivity and profitability**, under different scenarios of animal productivity and market conditions, which is conducive to the **sustainable intensification of meat production** in grazing systems.
- The inclusion of *L. diversifolia* comes along with a **reduction of the risk of economic loss** and less variance to changes in critical variables.
- This is key to encourage adoption, since farmers, being naturally rather risk adverse, will **most likely favor technologies with a relatively lower variance**.



# Conclusions

- The establishment of grass-legume associations should be accompanied by **specific training and extension programs** that overcome the lack of knowledge and experience in the use of tropical forage legumes.
- This will **reduce uncertainties associated with technology adoption** and increase adoption rates.
- The **access to and structure of necessary financial resources** (e.g. credits) needs to be improved in order to provide the required framework for technology adoption.

# Scaling of Tropical Forages

## East Africa

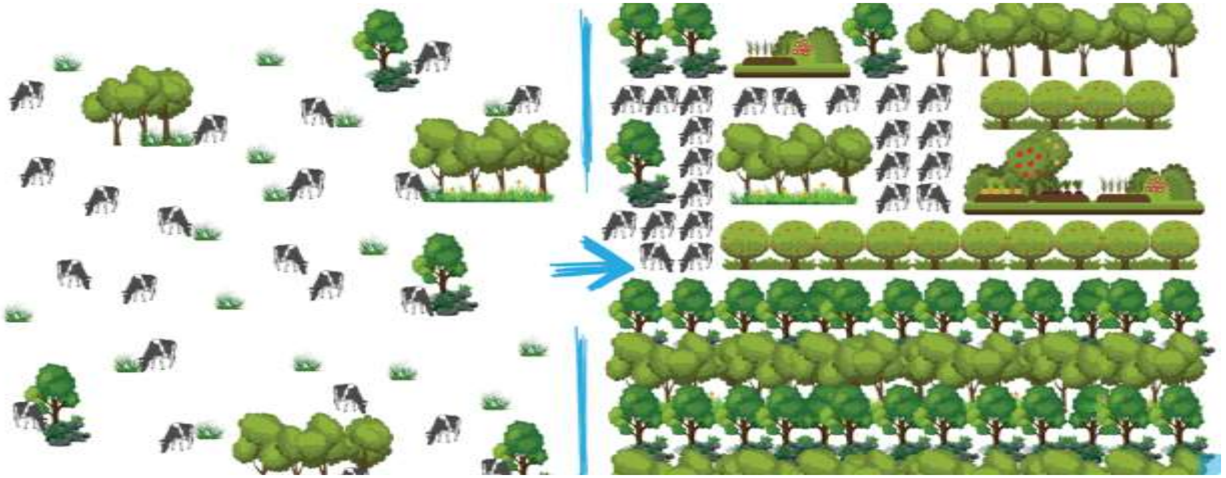
- Demo plots
- Field days
- 'Trade fairs'
- Fact sheets
- Close interaction with private sector e.g. seed suppliers and dairy cooperatives

## Colombia

ganso.com.co

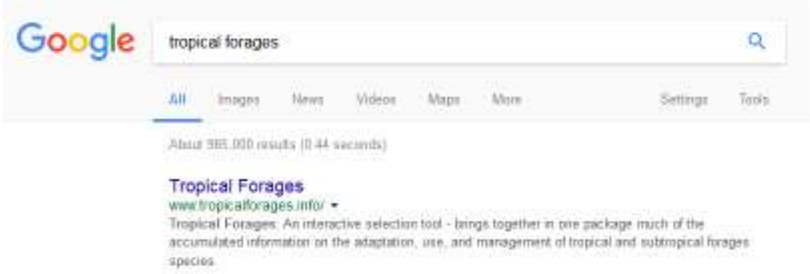
### GANSO's farm level business model

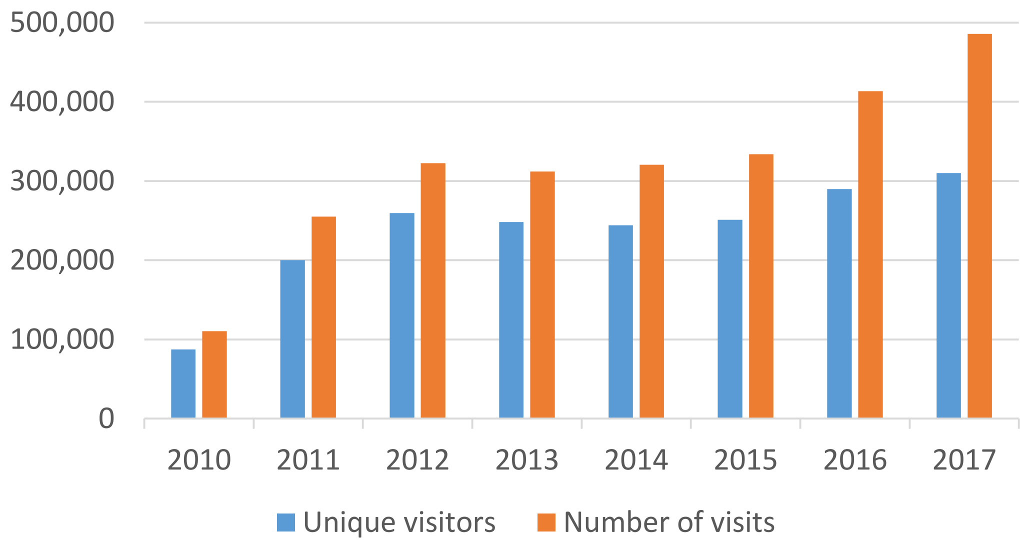
- Support farms with extensive cattle operations to transition to an intensified system with improved pasture management boosting productivity and reducing land use
- a) Intensification of cattle operations; b) Diversification of production; c) Restoration and conservation



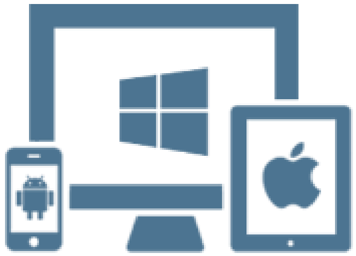
# Tropical Forages Selection Knowledge Tool Update

- #1 Result in Web search engines
- Among the most frequented on web site of CIAT; almost 500,000 annual visits
- Preeminent source of information on tropical forages




*Update content*



*Access through mobile devices*

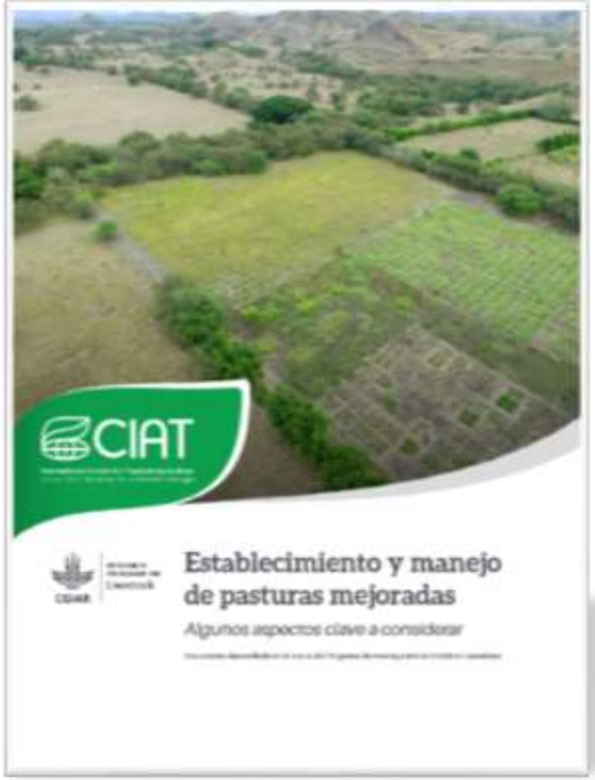
*Incorporating Advances in IT +*


*Automatic translation in +90 languages*

**Partners:** CIAT, ILRI, IDENTIC

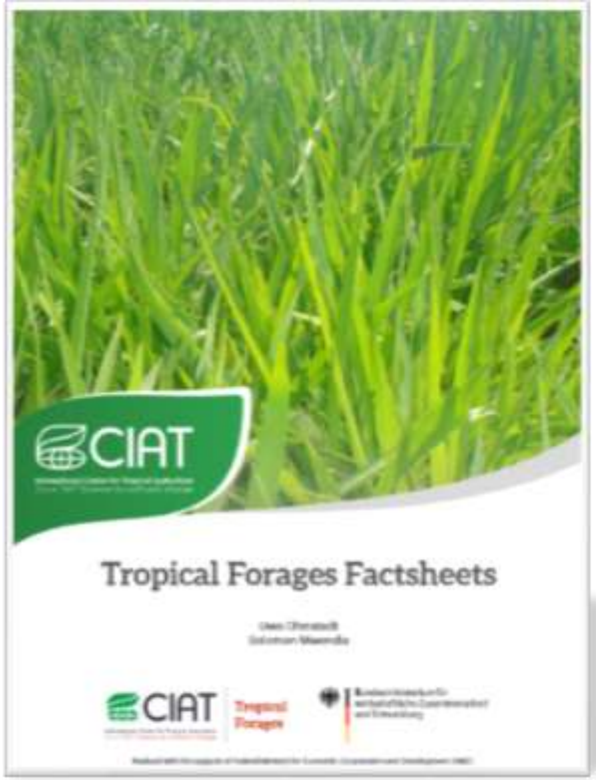
# Capacity building

**Training manual** for producers and extensionists: Establishment and management of improved pastures




hdl.handle.net/10568/96261

**10 Factsheets** on tropical forages for East African producers and extensionists

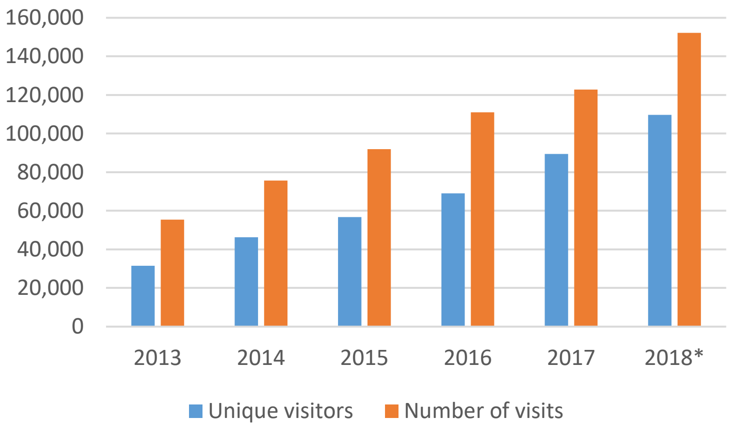


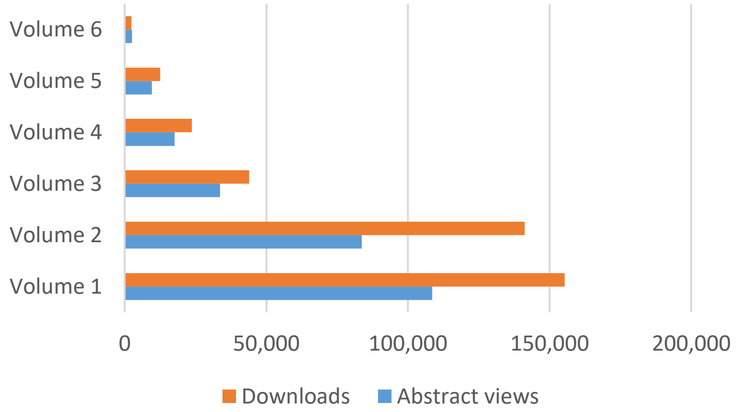

hdl.handle.net/10568/93394

# Tropical Grasslands-Forrajes Tropicales Online Journal

ISSN: 2346-3775 www.tropicalgrasslands.info

- An international, open access, bilingual, peer-reviewed online journal
- SHERPA/RoMEO green journal [+]
- Released in 2012 as the result of a merger of the former journals **Tropical Grasslands**, and **Pasturas Tropicales**
- 198 papers published so far, 115 in special issues and 83 in regular issues
- Indexed in the major abstract and citation databases for peer-reviewed literature





Impact Factor (2017): 0.389
Scopus CiteScore2017: 0.44
SciMago Journal Rank (2017): 0.188

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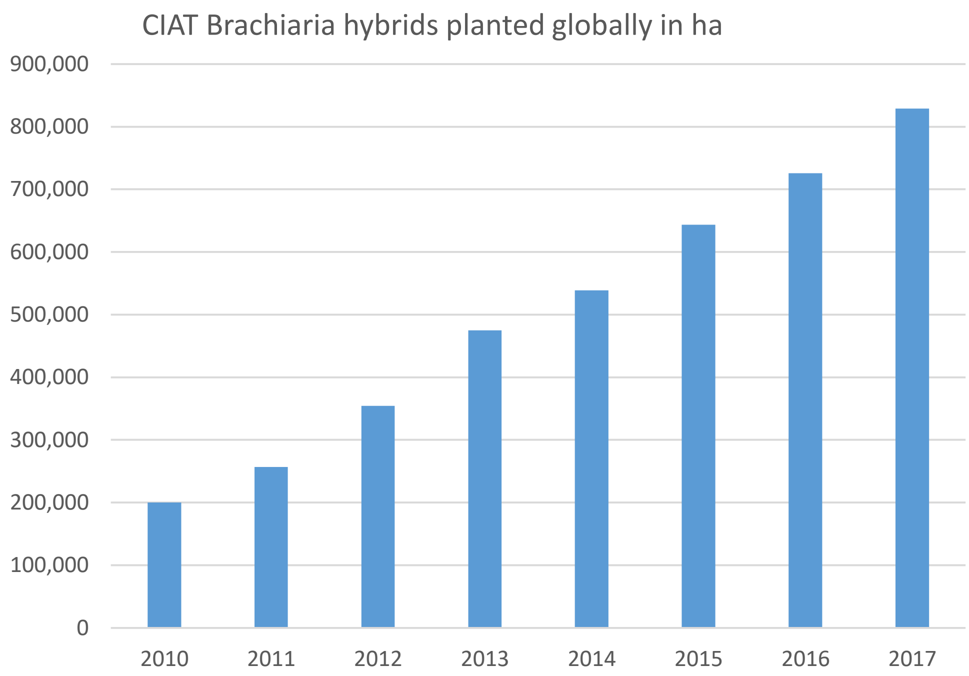
# Commercial releases of forage hybrids

CIAT has released more than **200** advanced genotypes, out of those

**Four** are already commercialized, and
**Four** are in development and adaptation.


Mulato Brachiaria híbrido

**Mulato**, the first commercial Brachiaria hybrid (released in **2001**) was bred by CIAT.




Hybrids has been a success in the market, reaching a total area of **828,638** ha*

*Estimated by seed sales, assuming 7 kilos of seed per hectare (2017)

Farmers adopt improved forages options package - management practices and adequate germplasm – to improve productivity and lower environmental footprint.

Data, tools, approaches and recommendations on efficient and environmentally friendly resource management practices in mixed crop livestock systems.


Recommendations on sustainable intensifications of crop-livestock systems, environ- mental impacts of livestock production, and on diets: Policy analysis, technical evidence for policy formulation, modeling and foresight.

Innovations for efficient and sustain- able value chains (germplasm, data on prices/ supply/ demands/ actors, value chain optimization, management practices, business models, extension approaches and financial mechanism).

# Thank you!

**Acknowledgements**

This work was done as part of the CGIAR Research Program on Livestock. We thank all donors that globally support our work through their contributions to the CGIAR system.

CGIAR

RESEARCH PROGRAM ON Livestock

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